DOCUMENT RESUME

ED 221 757 CE 034 084

TITLE Graphics Specialist, 6-1. Military Curriculum Materials for Vocational and Technical Education.
INSTITUTION Air Force School of Applied Aerospace Sciences, Lowry AFB, CO.; Ohio State Univ., Columbus. National Center for Research in Vocational Education.
SPONS AGENCY Office of Education (DHEW), Washington, D.C.
PUB DATE 78
NOTE 563p.; For a related document see CE 034 085.

EDRS PRICE MF02/PC23 Plus Postage.
DESCRIPTORS Behavioral Objectives; Criterion Referenced Tests; *Drafting; *Graphic Arts; Military Personnel; Military Training; Postsecondary Education; *Reprography; Secondary Education; *Technical Education; *Technical Illustration
IDENTIFIERS *Drawing; Military Curriculum Project

ABSTRACT

This military-developed text consists of five volumes of instructional materials for use in training graphics specialists. Covered in the individual volumes are the following topics: fundamentals of graphics (graphic equipment and material, fundamentals of lettering, and techniques of line and tone media); applied basic drafting techniques (geometric and graphic construction, section views, dimensioning, and projections); applied basic drafting techniques (machine drawings, intersections and developments, and structural drafting); basic drawing (basic form, layout and composition, human form, cartoons and caricatures, and landscapes); and drawing and production (perspective, visual communication, and reproduction methods and processes). The volumes are divided into several chapters. Each chapter is organized around criterion-based learning objectives accompanied by readings, criterion test items, and answers to the items. Also provided is a volume review exercise with questions keyed to the objectives. (MN)

MILITARY CURRICULUM MATERIALS

The military-developed curriculum materials in this course package were selected by the National Center for Research in Vocational Education Military Curriculum Project for dissemination to the six regional Curriculum Coordination Centers and other instructional materials agencies. The purpose of disseminating these courses was to make curriculum materials developed by the military more accessible to vocational educators in the civilian setting.

The course materials were acquired, evaluated by project staff and practitioners in the field, and prepared for dissemination. Materials which were specific to the military were deleted, copyrighted materials were either omitted or approval for their use was obtained. These course packages contain curriculum resource materials which can be adapted to support vocational instruction and curriculum development.

The National Center Mission Statement

The National Center for Research in Vocational Education's mission is to increase the ability of diverse agencies, institutions, and organizations to solve educational problems relating to individual career planning, preparation, and progression. The National Center fulfills its mission by:

- Generating knowledge through research
- Developing educational programs and products
- Evaluating individual program needs and outcomes
- Installing educational programs and products
- Operating information systems and services
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FOR FURTHER INFORMATION ABOUT
Military Curriculum Materials
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The National Center for Research in Vocational Education
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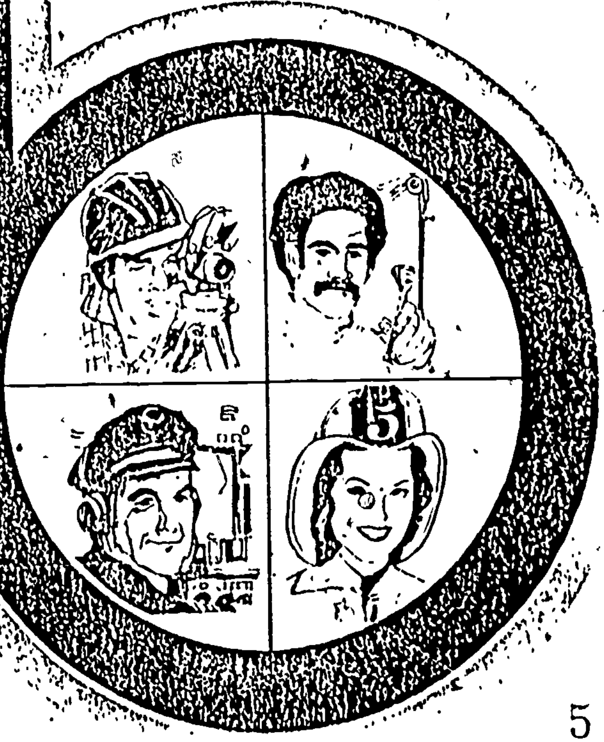
Military Curriculum Materials for Vocational and Technical Education

Information and Field Services Division

The National Center for Research in Vocational Education



Military Curriculum Materials Dissemination Is . . .

an activity to increase the accessibility of military-developed curriculum materials to vocational and technical educators.

This project, funded by the U.S. Office of Education, includes the identification and acquisition of curriculum materials in print form from the Coast Guard, Air Force, Army, Marine Corps and Navy.

Access to military curriculum materials is provided through a "Joint Memorandum of Understanding" between the U.S. Office of Education and the Department of Defense.

The acquired materials are reviewed by staff and subject matter specialists, and courses deemed applicable to vocational and technical education are selected for dissemination.

The National Center for Research in Vocational Education is the U.S. Office of Education's designated representative to acquire the materials and conduct the project activities.

Project Staff:

Wesley E. Budke, Ph.D., Director
National Center Clearinghouse

Shirley A. Chase, Ph.D.
Project Director

What Materials Are Available?

One hundred twenty courses on microfiche (thirteen in paper form) and descriptions of each have been provided to the vocational Curriculum Coordination Centers and other instructional materials agencies for dissemination.

Course materials include programmed instruction, curriculum outlines, instructor guides, student workbooks and technical manuals.

The 120 courses represent the following sixteen vocational subject areas:

- Agriculture
- Aviation
- Building & Construction Trades
- Clerical Occupations
- Communications
- Drafting
- Electronics
- Engine Mechanics
- Food Service
- Health
- Heating & Air Conditioning
- Machine Shop
- Management & Supervision
- Meteorology & Navigation
- Photography
- Public Service

The number of courses and the subject areas represented will expand as additional materials with application to vocational and technical education are identified and selected for dissemination.

How Can These Materials Be Obtained?

Contact the Curriculum Coordination Center in your region for information on obtaining materials (e.g., availability and cost). They will respond to your request directly or refer you to an instructional materials agency closer to you.

CURRICULUM COORDINATION CENTERS

EAST CENTRAL
Rebecca S. Douglass
Director
100 North First Street
Springfield, IL 62777
217/782-0759

NORTHWEST
William Daniels
Director
Building 17
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MIDWEST
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1515 West Sixth Ave.
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Mississippi State, MS 39762
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GRAPHICS SPECIALIST

Table of Contents

Developed by:

United States Air Force

Development and Review Dates

February 1976

Occupational Area:

Drafting

Cost:

Print Pages

544

Availability:

Military Curriculum Project, The Center for Vocational Education, 1960 Kenny Rd., Columbus, OH 43210

Suggested Background:

None

Target Audiences:

Grades 10-adult

Organization of Materials:

Criterion objectives, text, criterion test items and answers; volume review exercises and supplementary materials

Type of Instruction

Individualized and self-paced

Type of Materials			No. of Pages:	Average Completion Time:
Volume 1	–	*Fundamentals of Graphics*	87	Flexible
		Volume Review Exercise	10	
Volume 2	–	*Applied Basic Drafting Techniques (Part I)*	106	Flexible
		Volume Review Exercise	9	
Volume 3	–	*Applied Basic Drafting Techniques (Part II)*	142	Flexible
		Volume Review Exercise	12	
Volume 4	–	*Basic Drawing*	43	Flexible
		Volume Review Exercise	6	
		Supplementary Material	23	
Volume 5	–	*Drawing and Production*	79	Flexible
		Volume Review Exercise	8	

Supplementary Materials Required:

None

Expires July 1, 1978

Course Description

This course was designed to upgrade an Apprentice (semi-skilled) Graphics person to a Specialist (skilled) Graphics person. The course covers basic drafting techniques, drawing and production. The duties of a Graphics Specialist are as follows.

- Plans and prepares graphics and drawings
- Operates special graphic equipment
- Prepares medical illustrations
- Supervises graphics personnel

This course is divided into five volumes each containing several chapters. Each chapter is organized around criterion learning objectives accompanied by readings, criterion test items, and answers to the items. A volume review exercise with questions keyed to the objectives is also available, but the answers are not included. Some of the chapters were deleted because they referred to specific military procedures or organizations.

Volume 1 — *Fundamentals of Graphics* provides an overview of graphic equipment and material, the fundamentals of lettering, and the techniques of line and tone media. Three chapters dealing with career ladder progression, security, and supervision and training were deleted.

Volume 2 — *Applied Basic Drafting Techniques (Part I)* discusses geometric and graphic construction, section views, dimensioning, and projections.

Volume 3 — *Applied Basic Drafting Techniques (Part II)* covers machine drawings, intersections and developments, and structural drafting.

Volume 4 — *Basic Drawing* explains basic form, layout and composition, human form, cartoons and caricatures, and landscapes. A supplement containing foldouts for study accompanies this volume.

Volume 5 — *Drawing and Production* discusses perspective, visual communication, and reproduction methods and processes.

This course is designed to go beyond the basic drafting techniques and provide the student with experience in drawing, composition, and reproduction techniques. It is designed for student self-study and evaluation, but would be best used in conjunction with a studio or on the job learning situation

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CDC 23151

GRAPHICS SPECIALIST

(AFSC 23151)

Volume 1

Fundamentals of Graphics

Extension Course Institute

Air University

PREPARED BY
DEPARTMENT OF AEROSPACE PHOTOGRAPHY TRAINING
USAF SCHOOL OF APPLIED AEROSPACE SCIENCES (ATC)
LOWRY AIR FORCE BASE, COLORADO

EXTENSION COURSE INSTITUTE, GUNTER AIR FORCE STATION, ALABAMA

THIS PUBLICATION HAS BEEN REVIEWED AND APPROVED BY COMPETENT PERSONNEL
OF THE PREPARING COMMAND IN ACCORDANCE WITH CURRENT DIRECTIVES
ON DOCTRINE, POLICY, ESSENTIALITY, PROPRIETY, AND QUALITY.

Preface

YOUR TRAINING consists of obtaining information and developing the skills to become a graphics specialist. This information can be obtained by studying this Career Development Course (CDC), which covers fundamentals, principles, theory, and concepts associated with the graphics specialty. This CDC is composed of five volumes and a supplement designed to bring you to the 5 skill level. Intensive study of these volumes provide the necessary information to reach the 5 skill level. A CDC cannot provide the necessary drawing practice that is required to reach any skill level, so time must be provided by your trainer.

The behavioral objectives contained herein are designed to help you understand what the subjects are all about. Studying the text and achieving the objectives will give you the fundamental knowledge needed to perform as a graphics specialist. Guided by the behavioral objectives, answer all of the exercises for each chapter. Then, refer to the answer section in the back of the volume and check your answers.

If you have questions on the accuracy or currency of the subject matter of this text, or recommendations for its improvement, send them to Tech Tng Cen/TTOC, Lowry AFB CO 80230.

If you have questions on course enrollment or administration, or on any of ECI's instructional aids (Your Key to Career Development, Behavioral Objective Exercises, Volume Review Exercise, and Course Examination), consult your education officer, training officer, or NCO, as appropriate. If he can't answer your questions, send them to ECI, Gunter AFS AL 36118, preferably on ECI Form 17, Student Request for Assistance.

This volume is valued at 21 hours (7 points).

Material in this volume is technically accurate, adequate, and current as of November 1974.

Contents

MODIFICATIONS

Pages 1-43 of this publication has (have) been deleted in adapting this material for inclusion in the "Trial Implementation of a Model System to Provide Military Curriculum Materials for Use in Vocational and Technical Education." Deleted material involves extensive use of military forms, procedures, systems, etc. and was not considered appropriate for use in vocational and technical education.

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Equipment and Material (Basic)

MANY OF THE problems of today are caused by a "Lack of Communication." Word languages are highly sophisticated systems of communication, but they are still inadequate in many instances, especially when describing physical things. Drawing is a graphic language that communicates in the universal tongue of art. It is a language that expresses and conveys ideas of shape, size, and construction. As with any form of communication, the tools of the trade are your most important asset. The use and care of this eqiupment is vital to the graphics specialist, for it is his voice in the universal language of art.

4-1. Care of Equipment

Equipment care is the first order of business with any graphics specialist. Equipment well cared for denotes a person who does or has the potential of doing exceptional work. Few workers can do a good job with poor or badly misused equipment, and the graphics specialist is no exception. Giving a poor craftsman the best equipment in the world will not appreciably improve his work. A good craftsman, however, will usually produce better work if his equipment is well cared for.

035. State the rules for proper equipment care.

Rules to Observe. These rules are:

(1) Have a place for each piece of equipment and keep it there when not in use.

(2) Keep all instruments used to dispense ink or other liquid media CLEAN.

(3) Never expose any pointed equipment to the possibility of point damage.

(4) Never use any instrument for any purpose except that for which it was designed.

Each instrument and piece of equipment was designed to do a particular job. Learn what that job is, and use your tools accordingly. Most good equipment can be kept clean with mere soap and water, although some equipment may require special solvents for cleaning.

Exercise (035):

1. List two of the four rules for equipment care.

4-2. Use of Equipment

As was stated before, most instruments and pieces of equipment are designed for a specific purpose in a particular place. So let's begin this discussion with the place where the equipment is to be used.

036. Identify the elements to be considered for a well organized work area.

Your Work Area. Your work area is usually very simple. All that is needed is a drawing table, a drawing chair or stool, and a tabouret for storing materials and drawings. For the best results, you should arrange your equipment for maximum comfort. Some of the things that will contribute to that are ventilation and lighting.

Ventilation. Your area should be well ventilated. If the room is stuffy you may become drowsy, hot and tired, and irritable. These feelings invariably show up in your work, so keep the temperature slightly cool, and the feeling will be COOL.

Lighting. Since you use your eyes almost

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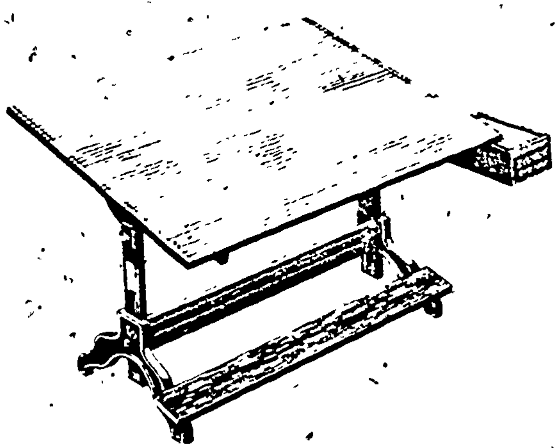

Figure 4-1. Drawing table.

constantly on work which must be accurately and carefully executed, you want your working area to be well lighted. Natural light is best but this situation is rare. For best results the light source should come over your left shoulder and from the left-front, if you are right-handed; or over the right shoulder, right-front, if you are left-handed. This eliminates shadows cast by drawing instruments and your hand. Avoid glaring lights and reflections, as they contribute to eyestrain.

Drawing table and chair or stool. Your drawing table, similar to the one shown in figure 4-1, should be adjustable in both height and tilt of the top. Adjust the height of the table so that if you desire to work in a standing position, you can do so without stooping or holding your arms in a slightly raised position. The table top may be left flat or inclined according to your preference. Your chair or stool should be high enough so you can see the whole drawing board, but not so high that you have to lean over uncomfortably to draw. By shifting your body or head slightly you should be able to look directly at any point on a drawing sheet of average size. That is, your line of sight should be approximately perpendicular to the drawing surface.

Placement of equipment. Before you begin to draw, arrange your equipment in an orderly manner. Place each article so that you can reach it easily, but will not hit it when you use the T-square or drafting machine and triangle. Keep your tools in their proper places when you are not using them; good tools are expensive and easily damaged. A systematic arrangement is timesaving and efficient and decreases the likelihood of accidentally dropping or pushing something off the table.

Exercises (036):

1. What elements make up a work area?

2. If you are right-handed, you should arrange your work area so that the light comes from what direction?

3. Why is it usually more convenient to use a high stool and a drawing table adjusted to a high level, rather than a conventional chair and a drawing table adjusted at a low level?

4. Why should you arrange your drawing equipment in an orderly manner and keep everything within easy reach of your working position?

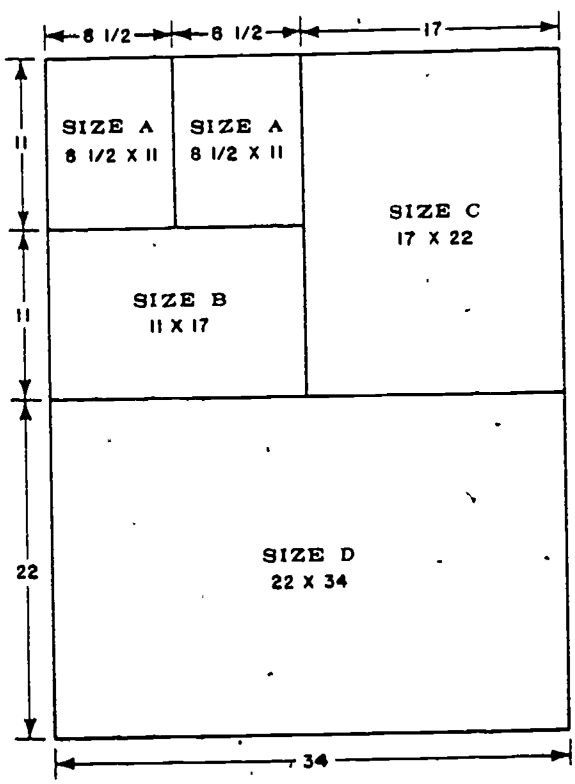

Figure 4-2. Standard sizes for drawings.

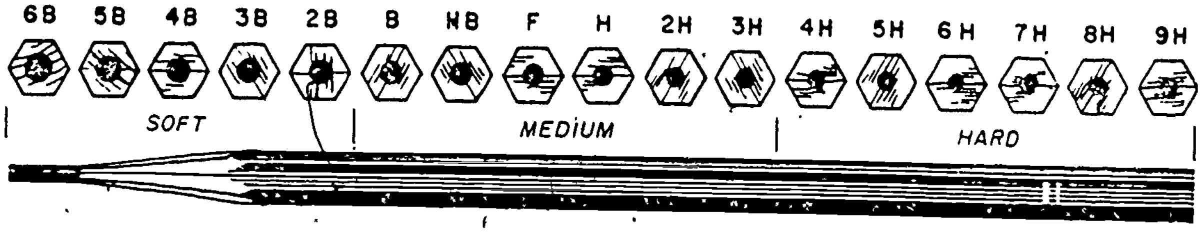

Figure 4-3. Grades of drawing pencils.

4-3. Basic Materials

The basic materials used by the graphics specialist in the preparation of art work contain such items as paper, pencils, erasers, pen and ink, brushes, and other such devices.

037. Explain the features of drawing paper, drawing board, and paper sizes.

Drawing Paper. Drawing paper is one of the key ingredients for most illustrations. It is the surface upon which most drawings are made initially. Drawing paper is made in a variety of qualities for various purposes. It may be hot or cold pressed which determines the surface finish, and can be purchased in both rolls and sheets. Most drawing paper is chemically treated so that the colors will remain true even if constantly exposed to harsh light.

In general, paper should have sufficient grain to take pencil or ink, and a hard surface so that the pencil will not groove it or that ink will not bleed. Drawing paper must also have good erasing qualities so that when an erasure does occur, the surface of the paper is still smooth and hard enough to be redrawn upon.

The Air Force maintains drawing paper standards. These sizes are based on the ordinary commercial letter page dimensions of 8½ x 11 inches as shown in figure 4-2. This 8½ x 11 inch size can be filed in a standard letter size filing cabinet. As you can see in figure 4-2, a 44- x 34-inch drawing can be folded into the 8½- x 11-inch size by always folding the long side in the middle.

Other drawing papers and drawing boards can be identified by their trade names, but they all serve the same purpose. The ultimate purpose of any drawing surface is to supply the artist with a vehicle which he or she can express ideas in any media or technique that is available. In many cases, drawing paper and drawing boards are manufactured for specific media or technique.

Tracing Paper. Tracing paper is just what the name implies—it is a natural (translucent) or transparent paper used to trace all or parts of drawings and blueprints when reproduction is not possible from the original. Tracing paper varies widely in color, thickness, and surface qualities. Therefore, the grade of pencil or ink techniques must be adjusted to suit the paper. All paper has a front and a back. Most of the time the two sides are the same, but with drawing paper you have to be careful. Drawing paper may have a smooth and a textured side, or a white and an off-white side; the front side is usually white or smooth.

Exercises (037):

1. Why must a drawing paper have good erasing qualities?

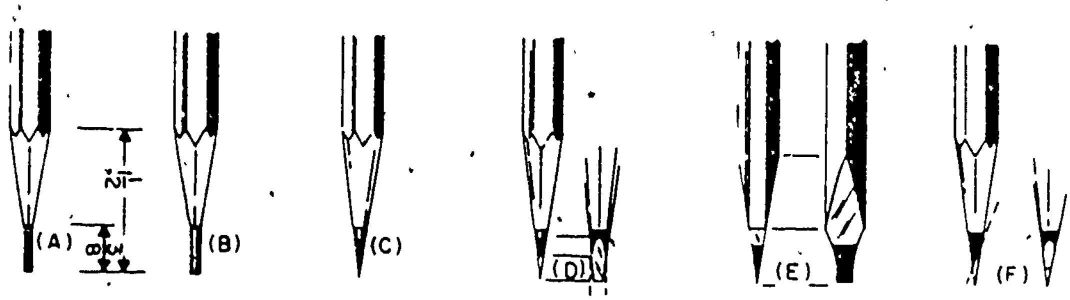

Figure 4-4. Various pencil point shapes.

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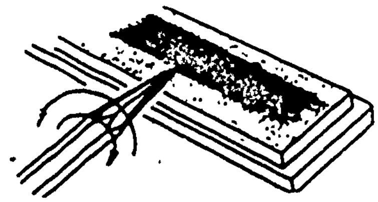

Figure 4-5. Sanding pad.

2. Why does the Air Force have size standards for drawing paper?

3. What is tracing paper?

038. List characteristics of drawing pencils.

Drawing Pencils. The selection of a grade of pencil lead is to some extent a matter of personal preference. Special pencils are used for drawing, as illustrated in figure 4-3. There are 18 grades of pencil leads, 17 of which are shown in figure 4-3. Leads are divided into three general categories: hard, medium, and soft. The breakdown is as follows:

9H to 4H	hard
3H, 2H, F, and HB	medium
B to 7B	soft

In general, the soft leads are used more for illustrative-type drawings, shading, and making tonal drawings in shades of gray. Medium leads are used primarily for general-purpose technical drafting, tracing, and lettering. Hard leads are for graphs, charts, or diagrams requiring a high degree of accuracy.

More important than the quality of the pencil is the condition of the point. The proper shape for a pencil point is shown in figure 4-4. The tapered wood portion should be from 7/8 inch to 1½ inches long, and 3/8 inch of lead should be exposed, as shown in part A. This can be done with a sharp knife or razor blade, or by a special pencil sharpener which cuts away only the wood leaving the point, as shown in part B. After using either of these methods, the lead should be brought to a point by means of a file or sandpaper. Three different points are commonly used. For a conical point, as shown in part C, the pencil should be rotated slowly while you rub it back and forth on the file or sandpaper (see fig. 4-5). The pencil should be inclined to the direction of motion. To produce the wedge point, shown at E in figure 4-4, the opposite sides are rubbed down. Some artists prefer the screwdriver point shown at D. This point requires additional sanding at the corners of the wedge. The elliptical or bevel point, item F, is made by sanding the lead entirely on one side.

Each type of point is useful and has certain advantages. The wedge point is used for drawing straight lines, since it does not wear down so rapidly. Its use, however, is limited to drawing straight lines. The conical point is used for general-purpose work and for lettering where a thin uniform line is required. The bevel or elliptical point is recommended for use in the compass, as it has the same advantages there as the wedge point has for drawing straight lines. The soft lead pencils with beveled points are often used for shading. Since drawing pencils wear away rapidly, you should always keep a sandpaper pad handy to resharpen the lead.

The disadvantage of using an ordinary drawing pencil is that you must take time to sharpen it, and as it becomes shorter, it is more difficult to handle. Semiautomatic or mechanical pencils, shown in figure 4-6, do not have these disadvantages. Equipped with a chuck to clamp and hold the lead, they can be

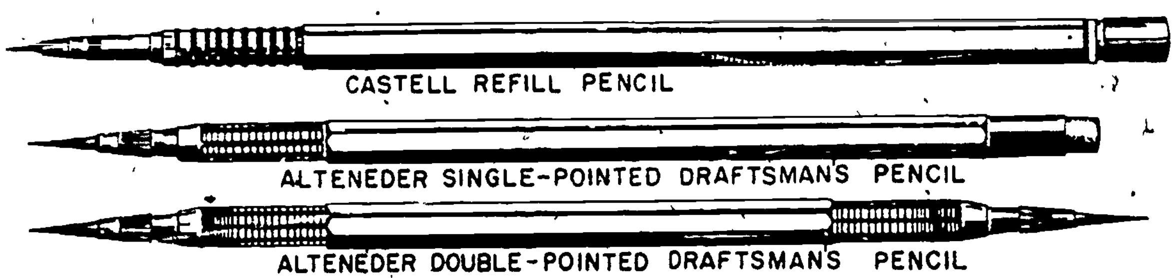

Figure 4-6. Mechanical pencils.

quickly adjusted, the point sanded as the lead of a wooden pencil, and they maintain their length. In addition, the entire lead can be used.

Exercises (038):

1. What are the three general categories of lead for a drawing pencil?

2. What are the three different pencil point types?

3. What is one of the outstanding disadvantages that a wooden drawing pencil possesses?

039. State the primary features of ruby erasers and kneaded erasers.

Erasing Equipment. Erasers and other erasing equipment are important tools of the graphics specialist. Many drawings can be saved by a good job of erasing. Figure 4-7 shows some of the erasing tools a specialist uses. Probably the most important of these is the red ruby eraser. It is designed primarily for pencil corrections, but can also be used to remove ink. It will not destroy the surface of the paper if used properly, and this is especially important when you need to re-ink lines in the erased area. If the surface of the paper is damaged, the ink, when it is reapplied, will bleed or spread and ruin the drawing. Sometimes you can repair a damaged area by burnishing the area with a metal instrument or your fingernail.

Pencil erasers have an advantage over those you hold in your fingers, since there is less chance of getting oil from your hand on the erasing surface. This is also true of the electric eraser which has an additional advantage of saving time, especially when considerable erasing is required. Oil on the erasing surface, as you probably already know, will cause smudging.

When erasing in an area containing many lines that are close together, you will find an erasing shield very useful. By placing the shield over the area so that the line which you want to erase shows through the appropriate opening in the shield, you can erase the line without fear of damaging nearby lines.

An art gum eraser is generally used to clean up large areas. This cleanup job should be done before inking, because erasing over inked lines will destroy the luster of the ink. Deep black lines made with a soft pencil cannot be erased successfully with art gum, since soft pencil lines smudge very easily. It is

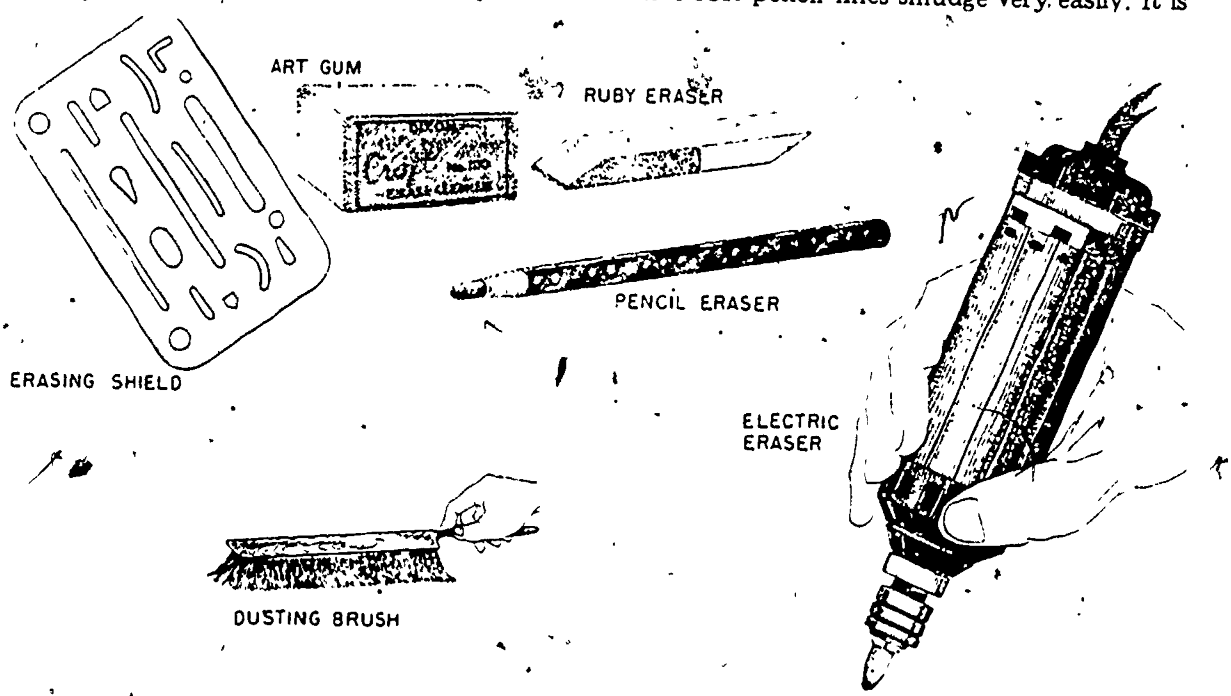

Figure 4-7. Erasing equipment.

far better to keep the drawing clean than to try to clean it with art gum after it has been soiled. The following suggestions, if observed, will help to keep the drawing clean:

- When moving the T-square, bear down on the head so that the blade is raised slightly from the paper.
- Your hands are always somewhat oily—keep them off the paper.
- Use a hard pencil for layout work.
- Pick up the triangles rather than slide them.
- When finishing a drawing with a soft pencil, cover all areas, except the one on which you are working, with a clean sheet of paper.
- Blow graphite particles, which flake off the soft pencil, from the sheet.
- Use a brush or soft cloth to brush erasing crumbs off the sheet rather than using the flat of your hand.
- Use a hard, smooth-surfaced paper if this is suitable for the type of drawing being made.

Many specialists also use kneaded erasers. These erasers are made from synthetic rubber or plastic and may be kneaded into a fine point, or any shape that is advantageous to the specialist. They have the advantage of leaving few, if any, crumbs on the drawing, and can be used to pick up graphite dust rather than to rub it off. The kneading tends to incorporate the dust particles and cleans the eraser at the same time.

An electric erasing machine is a timesaver when there is much erasing to be done. The erasing machine is very difficult to use on paper without damaging the surface. Its hard eraser tip, which rotates very rapidly, will bite into most surfaces with any undue pressure.

An eraser shield is a small plate of thin spring steel with holes of various shapes. The holes in the shield make it possible to remove unwanted lines while leaving other work untouched. Also, the sharp edge of the metal cuts away the smudged exterior of the eraser, permitting a clean eraser tip to always be on the drawing surface.

In addition to art gum erasers, cleaning compounds include pulverized gum eraser particles which may be squeezed from a plastic bottle or from a cloth bag. The granules sift through the bag as it is rubbed over the drawing. The eraser pad is also excellent for precleaning, to prevent later soil buildup.

Exercises (039):

1. What feature of the ruby eraser makes it an important piece of erasing equipment?

2. What features does the kneaded eraser possess that makes it unique?

040. Tell what drawing ink is, and tell which kinds will not reproduce photographically.

Ink. Drawing ink is finely ground carbon in suspension, with gum arabic added to make the mixture cohesive and waterproof. Nonwaterproof ink flows more freely but smudges easier than waterproof ink. Ink can be procured in almost any color, but most are not adequate for reproduction. Light blue and white *will not* reproduce on photo, photolithographic diazo equipment. Since ink dries quickly, you should keep the stopper in the bottle except when filling the pen or drawing instrument. This cuts down on

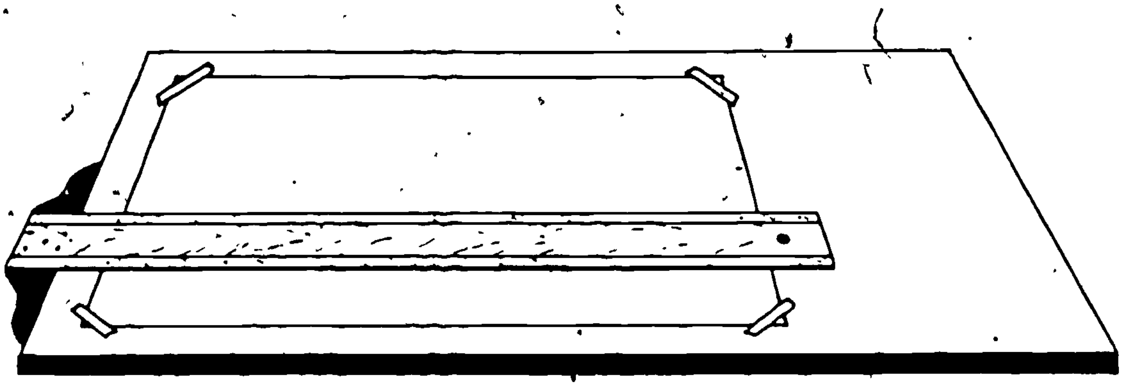

Figure 4-8. Drawing board and T-square.

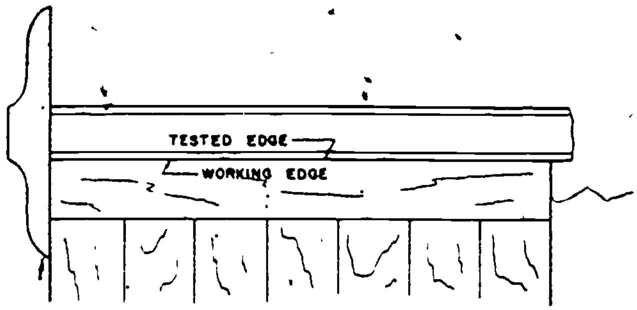

Figure 4-9. Checking working edge of drawing board.

evaporation. Thickened ink is extremely hard to work with; if this does happen, thin it with a few drops of water.

Exercises (040):

1. Drawing ink is made from what?

2. Which two drawing inks will not reproduce photographically?

041. List the graphic materials and tools that are absolutely essential to general illustrating.

Tools. The basic tools used by a graphic specialist consist of a drawing board, T-square, triangles, protractor, scales, irregular curves, and instrument set. The basic materials used are pencils, paper or board, erasers, and inks. There are other tools and equipment that have special uses. We will discuss these pieces of equipment when we discuss the particular technique.

Drawing board. The surface on which a graphics specialist places his drawing paper may be a table top or a separate board. In either case, the working surface must be flat. It should be made of well seasoned, clear white pine or basswood cleated together to prevent warping. The working edge, which is the edge contacted by the head of a T-square (see fig. 4-8), must be straight.

You can check the straightness of the working edge by placing a straightedge against it and observing whether or not the straightedge touches the working edge at all points. Figure 4-9 shows how this is done,

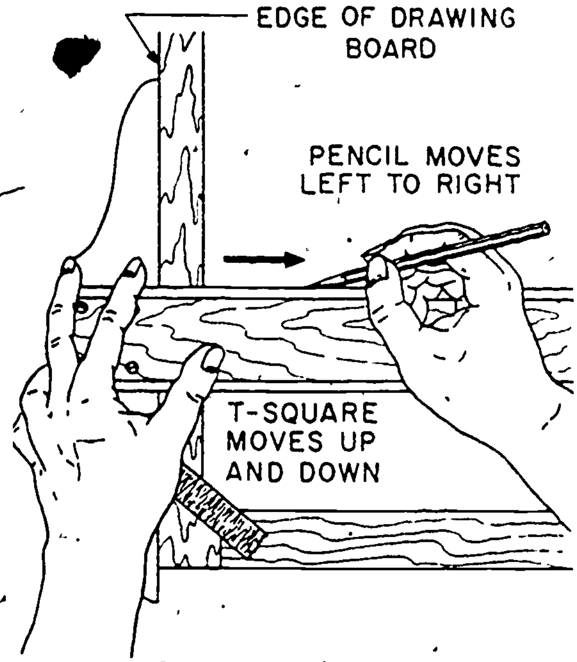

Figure 4-10. Drawing a horizontal line.

using the tested edge of a T-square which has been found true.

T-square. This tool gets its name from its shape, which you probably observed when looking at figures 4-8 and 4-9. It consists of a blade attached at one end to a shorter crosspie[illegible]alled the head. As you can see, the head is [illegible]nted under the blade so that it will fit against the edge of the drawing board while the blade rests on the surface of the board.

The T-square is used for drawing horizontal lines, as shown in figure 4-10. To use the T-square for this purpose, first apply pressure to the head to hold it in contact with the working edge of the board. This keeps the working edge of the blade perpendicular to the working edge of the board. Next, slide the T-square up or down to position its working edge slightly below the point through which you want to draw the line. Then hold the head of the T-square against the edge of the board as you move the pencil along the

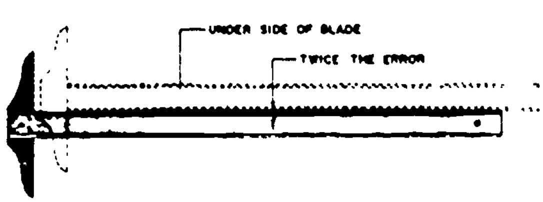

Figure 4-11. Testing a T-square.

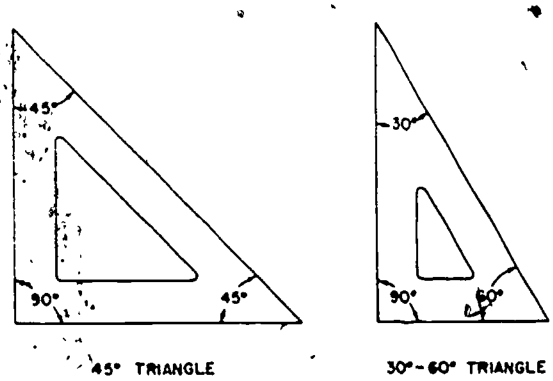

Figure 4-12. Standard triangles.

working edge of the T-square. Draw the line with the pencil tilted in the direction of movement at an angle of approximately 60° from the surface of the paper. Rotate the pencil between your fingers as you draw the line so that the lead wears evenly and produces a line having the same thickness throughout its length. Of course, to draw a straight line, the working edges of the T-square must be straight and perpendicular to each other. Let us see how these conditions are checked.

To test the working edge of the head, see if the T-square "rocks" when the head is placed against an edge of something you know is straight, such as the working edge of a drawing board which has been checked and found true. If the working edge of the T-square is not straight, remove the head and sand the edge until it tests straight. When you replace the blade on the head, you should use furniture glue in addition to the screws.

To test the working edge of the blade, draw a sharp line very carefully with a hard pencil, using the entire length of the working edge; then turn the T-square over, as shown in figure 4-11, and draw the line again along the same edge. If the edge is straight, the two lines will coincide (appear as one); otherwise, the space between the lines will be twice the error of the blade.

It is difficult to correct a crooked T-square blade. If the error is considerable, it may be necessary to discard the T-square and obtain another. However, if the error is slight, you may be able to straighten the edge by sanding it with fine sandpaper wrapped around a block of wood.

You can check to see if the head and blade of a T-square are perpendicular to each other by using the 90° angle of a triangle, which you know is true. If they are not perpendicular, you will probably be better off if you discard the T-square and obtain a new one.

Here are some of the rules about the care of a T-square:

- Never use the blade as a guide for a knife when cutting paper.
- To keep the T-square true, always hang it up by the hole located in the end of the blade or lay it on a flat surface.
- Be careful not to drop a T-square, as you might knock it out of alignment.
- Never use the lower edge of the blade.

Exercises (041):

1. List two of the basic materials and four of the basic tools essential to general illustrating.

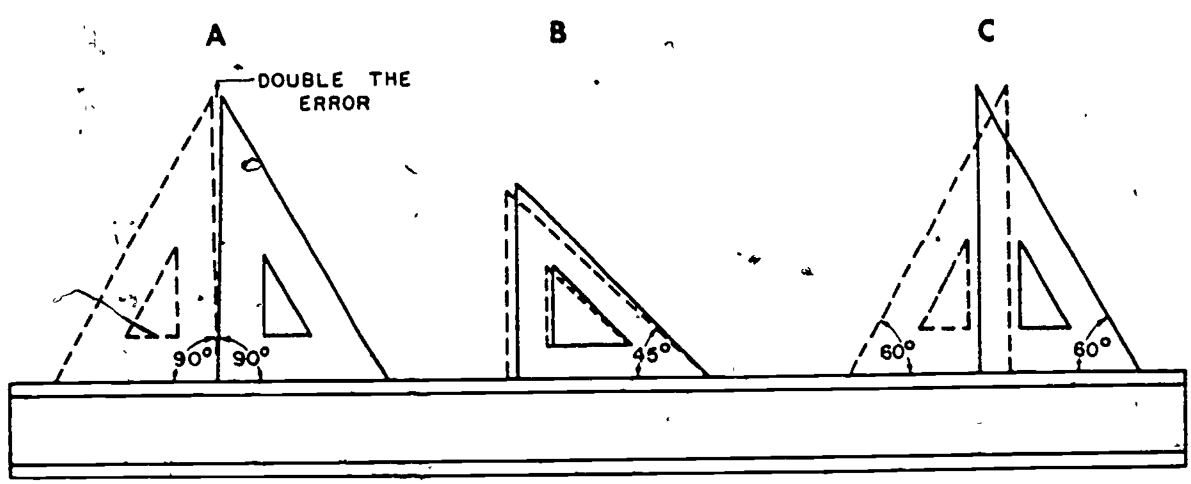

Figure 4-13. Testing triangles.

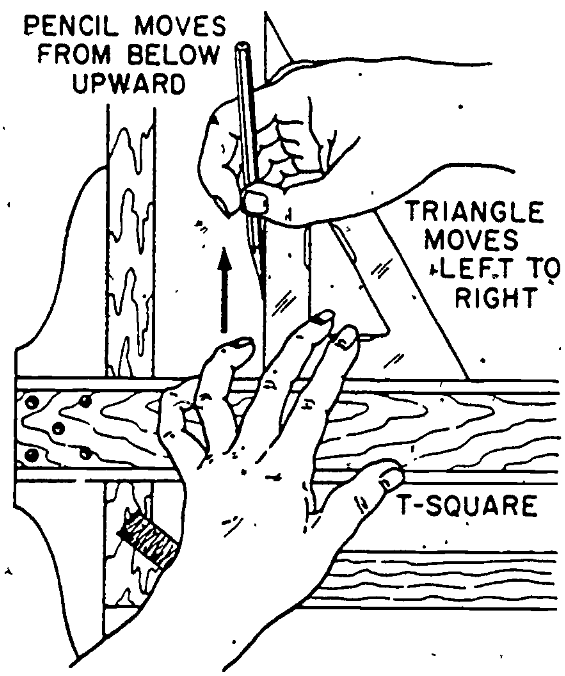

Figure 4-14. Drawing a vertical line.

2. Of what material should a well-constructed drawing board be made? Why?

3. How can the working edge of the T-square be checked?

042. State the functions of the triangle and protractor.

Triangles. Right-angle triangles are used in conjunction with the T-square or straightedge to draw vertical or inclined lines. The two standard types, as shown in figure 4-12, have acute angles of 45°-45° and 30°-60°. Triangles are made of transparent plastic so that lines of the drawing may be seen through them. Like a T-square, to be functional, triangles must be accurate. The edges of triangles can be tested for straightness by the same two-point method used to test the

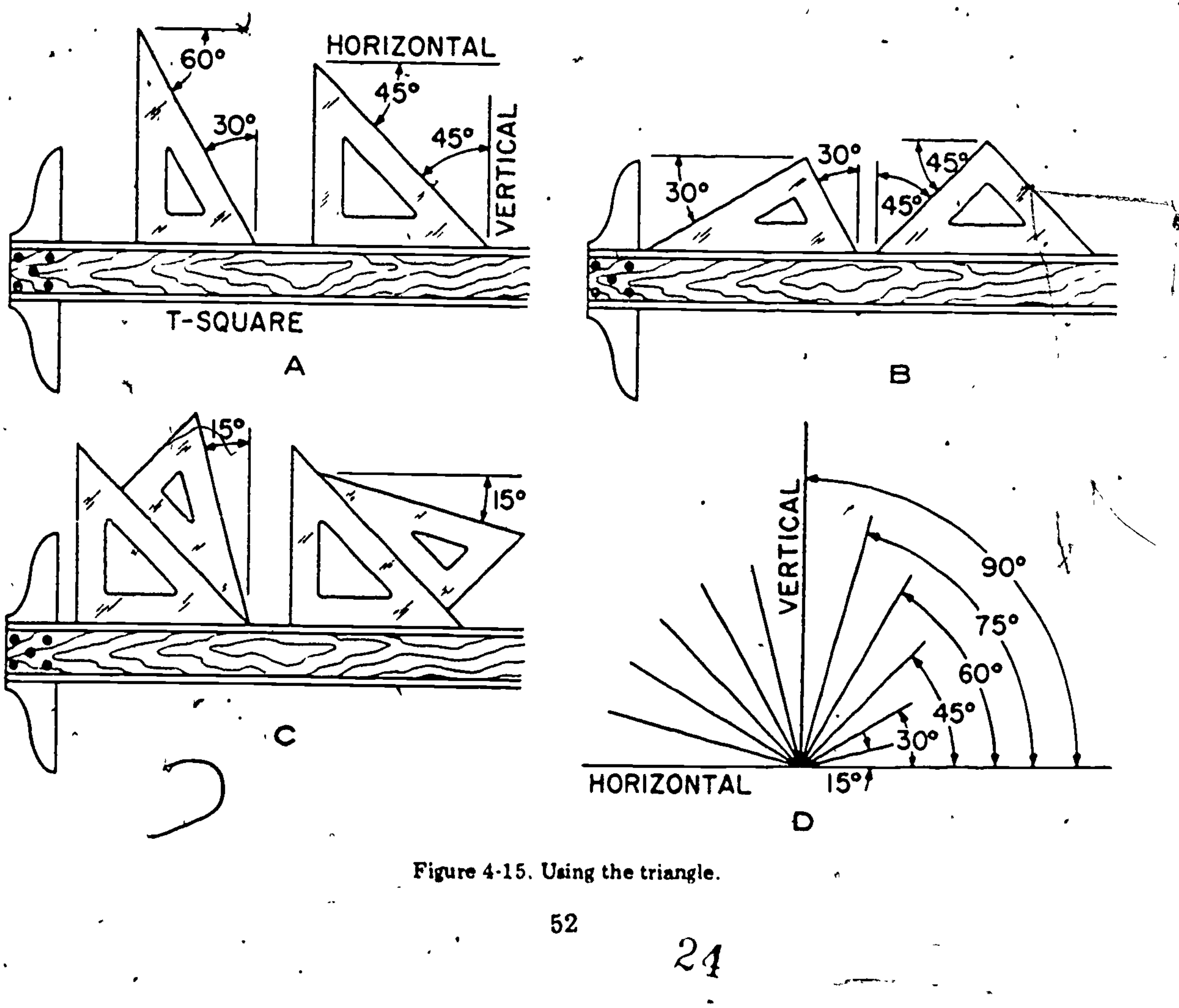

Figure 4-15. Using the triangle.

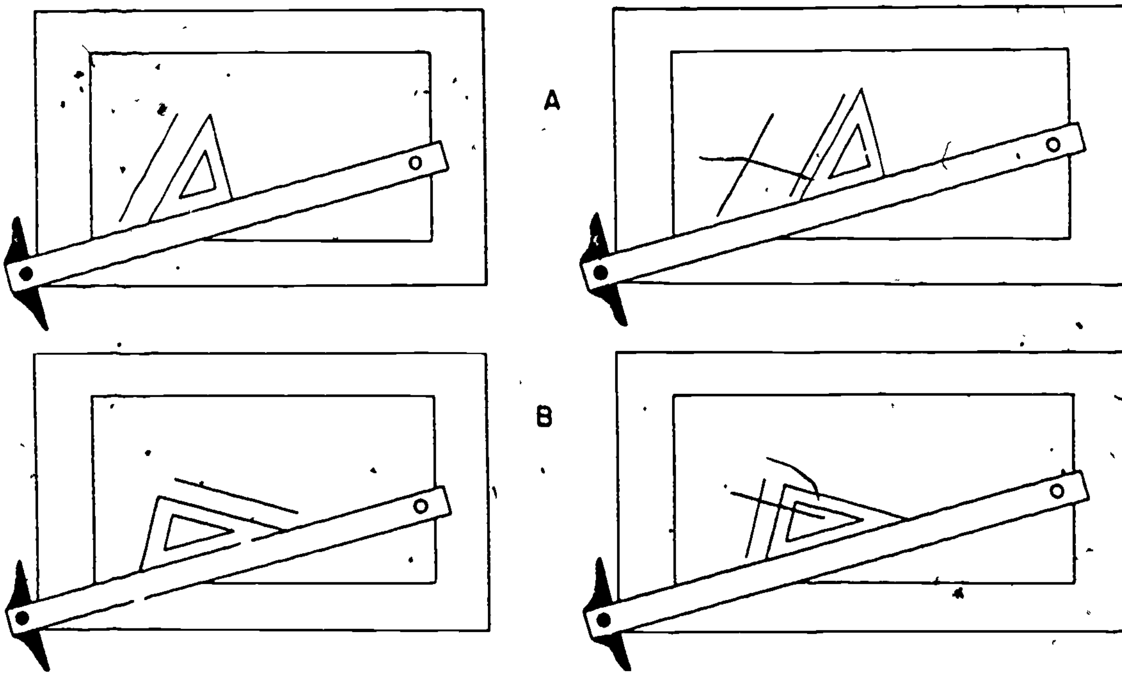

Figure 4-16. Drawing parallel and perpendicular lines.

working edge of the T-square. Figure 4-13 shows how to check the angles of the triangles.

To check the 90° angle on either triangle, set the triangle against the working edge of a T-square and draw a vertical line through a given point. Then without moving the T-square, turn the triangle over to position it (see dotted outline in fig. 4-13,A) and draw a second line through the same point using the same edge. If the two lines coincide or are very close together, the triangle is usable.

The 45° angles may be tested by drawing a line at a 45° angle to the horizontal and then checking the opposite angle to see if the edge coincides with the pencil line. This process is shown in figure 4-13,B.

You can test the 60° angle by drawing an equilateral triangle as shown in figure 4-13,C. If the triangle has equal sides, the 60° angle is correct. Of course if both 90° and 60° angles are correct, the 30° angle will be correct also since the sum of the angles of a triangle is 180°.

The method used to draw vertical lines is shown in figure 4-14. Notice that the left hand not only applies pressure to hold the T-square in position so that the head is against the working edge of the drawing board, but is also used to hold the triangle against the working edge of the T-square. The right hand moves the pencil along the triangle with an upward motion.

You can use triangles singly, as shown in parts A and B of figure 4-15, to draw lines at angles of 30°, 45°, 60°, and 90° with the horizontal. You can use them in combination, as shown in part C, to draw lines at angles of 15° and 75° with the horizontal. Part D shows the lines that can be drawn with 30°-60° and 45° triangles. Since all lines should be drawn from left to right (if you are right-handed), lines sloping downward from left to right will be drawn with a downward motion; those sloping upward from left to right will be drawn with an upward motion. This procedure allows you to see your work better.

When a line must be drawn between two points, a triangle may be used for a straightedge in place of a T-square. As with a T-square, you should be careful not to let the triangle slip when using it as a straightedge. The alignment of the edge of the triangle with the two points may be simplified by using the following procedure:

- Place the tip of your pencil on the point which is higher for drawing vertical lines, or on the point which is farther to the right for drawing horizontal and inclined lines.
- Move the triangle up against the pencil.
- Using the pencil as a fulcrum, pivot the triangle to align its edge with the second point.

Perhaps the most important use of the

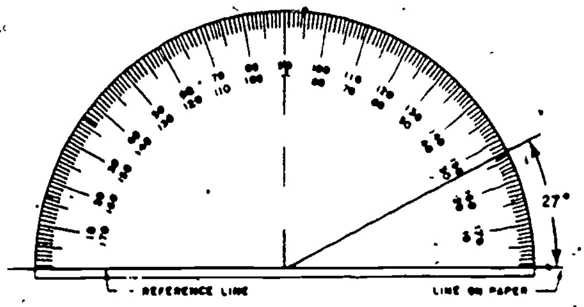

Figure 4-17. Using a protractor.

triangle, T-square combination, is to draw lines parallel or perpendicular to a given line. Figure 4-16 shows the two steps of these procedures. The procedure of drawing parallel lines is shown in part A, and the procedure of drawing perpendicular lines is shown in part B. In each of these procedures, the first step consists of placing the triangle against the T-square and moving them as one until the edge of the triangle is aligned with the given line. Then in the next step, while holding the T-square stationary, you slide the triangle along the working edge of the T-square until the edge of the triangle is aligned with the point through which you wish to draw the parallel or perpendicular line. Naturally, you use the same edge of the triangle to draw parallel lines as you used to align the two instruments in the first step, and you use the edge of the triangle that is perpendicular to that edge when you draw perpendicular lines.

Protractor. A protractor is used for setting off and measuring angles, including those obtained by using the T-square and triangles. Ordinarily, a transparent plastic protractor 6 inches wide is sufficient. Such a protractor is shown in figure 4-17. Notice that the circumference is marked twice with a scale running from 0° through 180° in each direction. Having 0° starting points at opposite ends of the diameter makes the protractor easier to use and read in any position on the drawing board.

To make accurate measurements with a protractor, draw the baseline of the angle so that it extends beyond both zero points of the protractor. The center point of the protractor must be aligned directly over the apex of the angle to be measured or drawn. In laying out an angle, make a light pencil mark on the drawing opposite the appropriate degree mark. Then draw a line from the apex through the pencil "*tick*" mark to complete the angle.

Exercises (042):

1. What are the two types of triangles?

2. What is the primary function of the triangle?

3. What is the function of the protractor?

043. Tell how each type of scale is used.

Scales. Although you are probably more familiar with the term "ruler," "scale" is the correct term to use for a straightedge that is graduated for measuring purposes. Scales are made with a variety of graduations to meet the requirements of many different kinds of work. For convenience, scales are classified according to their most common uses. Thus we have scales for mechanical engineers, civil engineers, and architects. A graphics specialist will find each of these types of scale convient for certain types of work.

Mechanical engineer's scales are divided and numbered so that fractions of inches represent inches. The most common ranges are ⅛, ¼, ½, and 1 inch to the inch. These scales are known as the size scales because the designated reduction also represents the ratio of size. For example, on the ⅛ scale, 1 inch

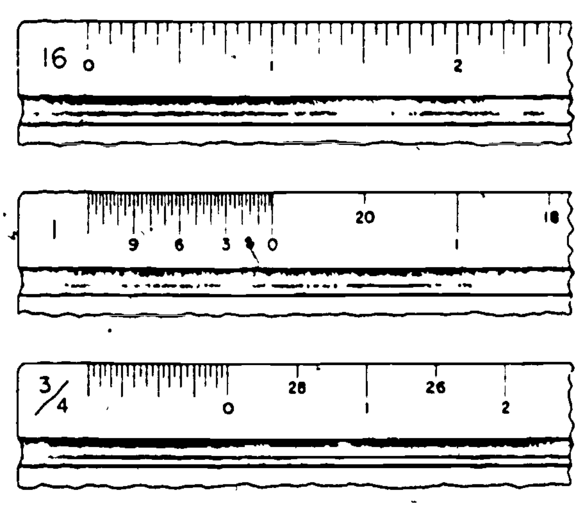

Figure 4-18. Sample sections of architect's scale.

is represented by each 1/8 of an inch of the scale. These scales are almost always "full divided"; that is, the smallest divisions run throughout the entire length. They are often graduated with the marked divisions numbered from right to left, as well as from left to right. Mechanical engineer's scales are used chiefly for drawing machine parts and small structures where the drawing size is never less than one-eighth the size of the actual object.

Civil engineer's scales are divided into decimals with 10, 20, 30, 40, 50, 60, and 80 divisions to the inch. Such scales are usually fill divided and sometimes numbered both from left to right and right to left. They are used chiefly for plotting and drawing maps, although they are convenient for any work where divisions of the inch in tenths is required.

Architect's scales are divided into proportional divisions representing feet and inches, and are used to make scaled-down drawings. These scales have unit divisions of 3/32, 1/8, 3/16, 1/4, 3/8, 1/2, 3/4, 1, 1½, and 3 inches. Each unit represents 1 foot. They are usually "open divided," that is, the units representing feet are shown along the entire length, but only the end units are subdivided into fractions representing inches. Three samples are shown in figure 4-18.

We are all familiar with the top scale (12-inch ruler). We were introduced to it during our early school days. It is divided into 12 inches, and these units are further divided into 16 equal parts. If you use this scale to make a scaled-down drawing of an object, you must calculate the lengths that you require. In some cases this may be difficult. If you were using the scale, 1 inch equals 1 foot, you would have little or no trouble finding the measurement representing 5 feet 3 inches, because 3 inches equals ¼ foot and is represented by ¼ of an inch on the scale. You merely mark off 5¼ inches for your measurement. However, suppose that you wanted to find the scale measurement of 5 feet 4 inches. This is not so easy. When you convert 4 inches into feet, you get ⅓ foot. Since ⅓ foot is represented by ⅓ inch on the scale and since there is no division at this point, you must estimate or mechanically divide the distance to obtain the measurement. Let us see how much easier it is to use the scale shown in the center of figure 4-18.

The numeral 1 located at the end of the scale identifies this scale as the 1 inch equals 1 foot scale. Notice that the zero index is located 1 inch in from the end of the scale.

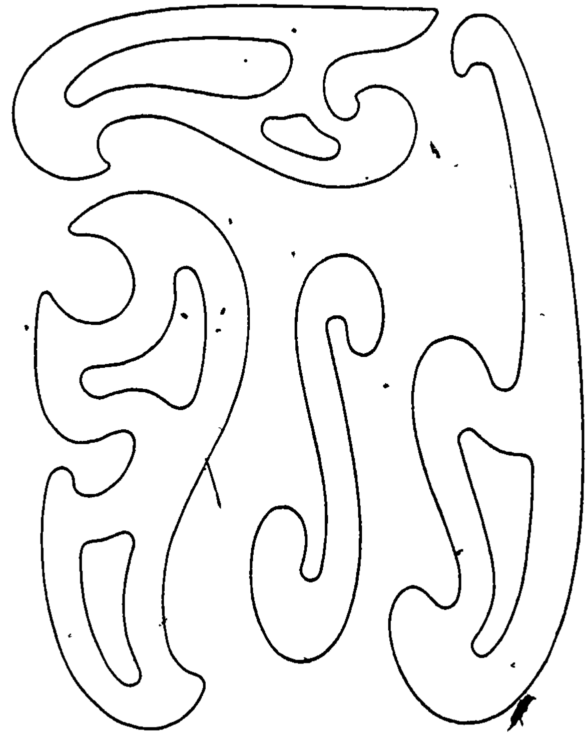

Figure 4-19. Irregular curves.

The major divisions are numbered 1 through 10. (Only the numeral 1 appears on the section of the scale shown. The numerals 20 and 18 are part of the 1/2 scale, which is read from the other end of the scale.) The section of the scale to the left of the zero index is divided into 12 major divisions which represent inches. This is the section of the scale that makes measuring in inches easy.

To obtain the scaled measurement representing 5 feet 4 inches, all you have to do is place the unit division 5 at the right end of your measurement and mark the left end at a point opposite the fourth major division to the left of the zero index. This is more accurate than estimating and much easier than dividing the distance, isn't it? In fact, with this scale you can make measurements down to 1/4 inch directly on the scale.

The bottom scale shown in figure 4-18 is used in the same way. On this scale 3/4 inch represents 1 foot. Let us see if you can determine where you would mark the two ends of a measurement representing 2 feet 9 inches. If you selected the unit 2 division for the right end of your measurement and the third major division to the left of the zero index for the left end of your measurement, you are correct. If you did not get the measurement right, you should study the scale again.

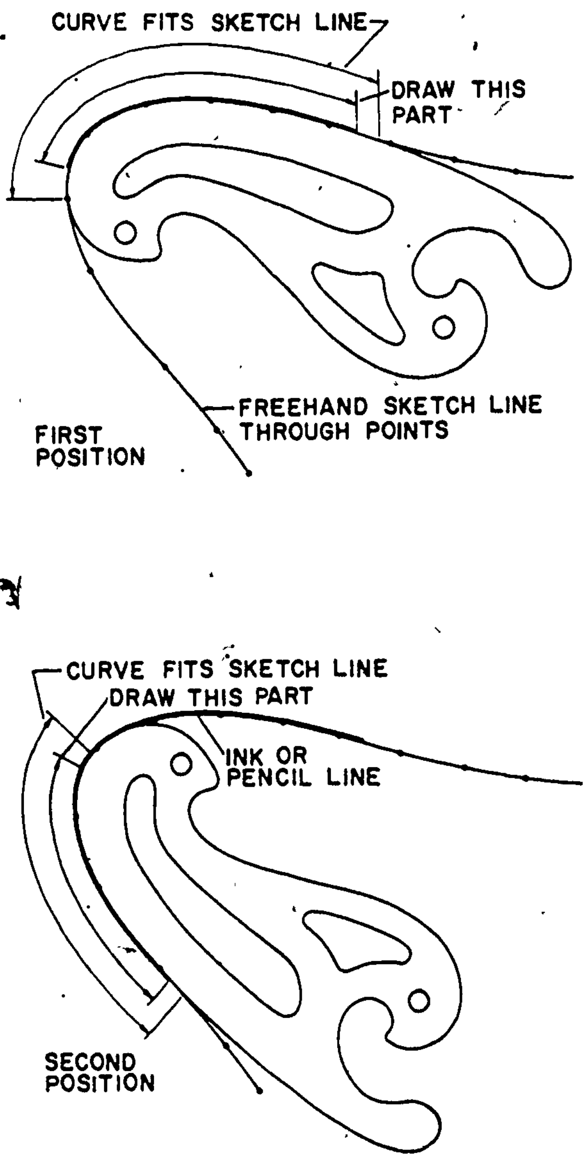

Figure 4-20. Using an irregular curve.

Exercises (043):

1. What are the different types of scales?

2. How is each scale used?

044. State the purpose of an irregular curve.

Irregular curves. These curves are used to draw curved lines which are not segments of circles. They are made of metal or of transparent plastic and come in various shapes, some of which are shown in figure 4-19. The patterns for these curves are laid out in ellipses and spirals or other mathematical curves in various combinations.

Figure 4-20 shows how an irregular curve is used to draw a smooth line through predetermined points. After the points are plotted, a light pencil line should be sketched to connect the points with a smooth flowing line. Then apply the curve to it, selecting the part of the curve which most nearly matches a portion of the line. The curve should match the line at a minimum of three consecutive points. When selecting the part of the line to be used, be sure to place the short radius portion of the line to be drawn. In drawing the part of the line matched by the curve, always stop a little short of the distance in which the guide and line seem to coincide. After drawing this portion, shift the curve to find another place that will coincide with the continuation of the line. Avoid abrupt changes in curvature by arranging the curve to coincide for a short distance with the part of the line already drawn. Thus, the lines drawn coincide at each junction and create a smooth curve.

When using the irregular curve as a guide for inking a curved line, hold the ruling pen so that it is tilted slightly in the direction of movement and is in a plane perpendicular to the paper. In this position, both blades of the pen will touch the paper at points just off the center of their curved tips. As you move the pen along the edge of the curve, rotate it slowly between your fingers or turn your hand to keep the blades parallel to the edge of the curve.

Exercise (044):

1. What is the purpose of an irregular curve?

4-4. Mechanical Drawing Instruments

Drawing instruments may be purchased singly, or as a set. The advantage of buying your instruments in the set is that the case is designed as a single, safe storage place. An average set of instruments usually consists of a ruling pen, compass, divider, and bow instruments. In addition, there are attachments for the compass, an extension bar, and extra needles in case of breakage.

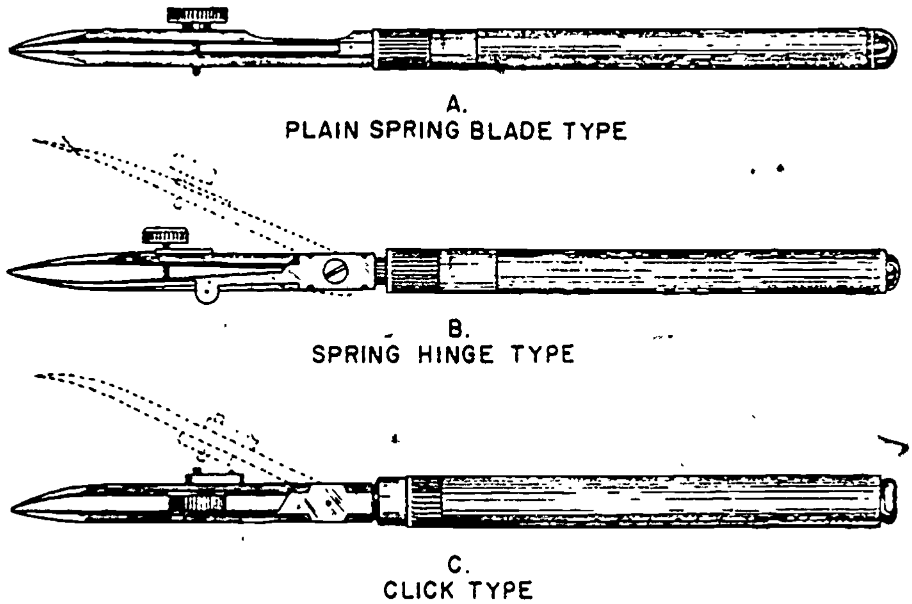

Figure 4-21. Ruling pens.

The purpose of the following paragraphs is to make clear the proper methods for handling the various pieces of a drawing set, what to look for in selecting them, how to care for them, and how to keep them in proper working order.

045. Describe the use and care of the ruling pens.

Ruling Pens. A ruling pen consists of two steel blades attached to a handle. It is used to make straight ink lines of uniform thickness. The standard ruling pen, shown in figure 4-21,A, has an adjustable spring blade. A screw running through a hole in the adjustable blade screws into the stationary blade and is used to adjust the gap between the ends of the blades, which are called nibs. The width of the gap determines the thickness of the line that the pen will produce. Never tighten the screw far enough to bring the blades tightly together, as you might bend the nibs and ruin the pen. The adjusting device also allows you to open the blade so that you can clean inside the nibs. Before you put the pen away, you should loosen the screw to relieve the spring tension.

The two other types of ruling pens, shown in figure 4-21,B and 4-21,C, have hinged blades which allow the pens to be opened, cleaned, and snapped back in place without changing the width of the setting. These types of blades are very handy when you have a great deal of inking to do.

The spring pressure of the blades should be positive but not too strong, or it will cause the threads on the adjusting screw to wear out rapidly. Don't buy a pen with undue friction on this screw.

Ruling pens are supplied with two general types of points. The wide-pointed pens are called detail pens, but they are no more useful for this purpose than any other. They serve best for drawing long, heavy lines since they hold more ink. Pens of any one type are

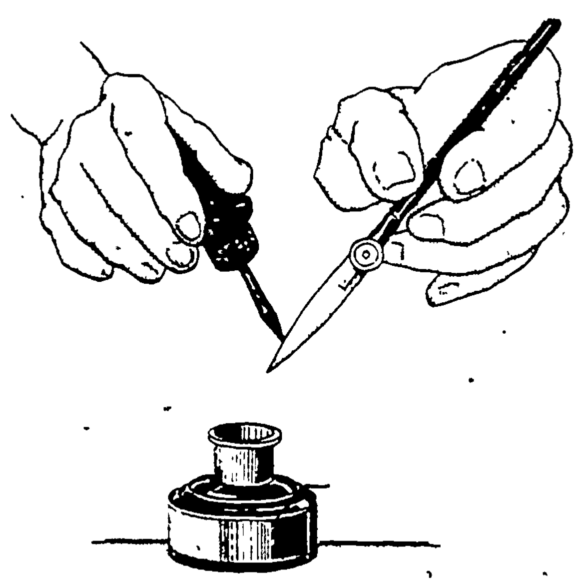

Figure 4-22. Filling a ruling pen.

specified by overall length. When buying a single pen, you should purchase one that suits your hand.

A ruling pen should be filled by placing the quill, which is in the stopper of the ink bottle, between the nibs of the pen and letting the ink run into the pen, as shown in figure 4-22. The ink should not stand more than 1/4 inch high in the pen, as the weight of a higher column will frequently cause the ink to run out and make a blot. After filling a pen, you should always make a test line on a piece of scratch paper. Be sure the ink flows properly and the width of the line is correct before you ink a line on a drawing.

The ruling pen should be held in the same manner as the drawing pencil. As shown in parts (a) and (b) of figure 4-23, the pen

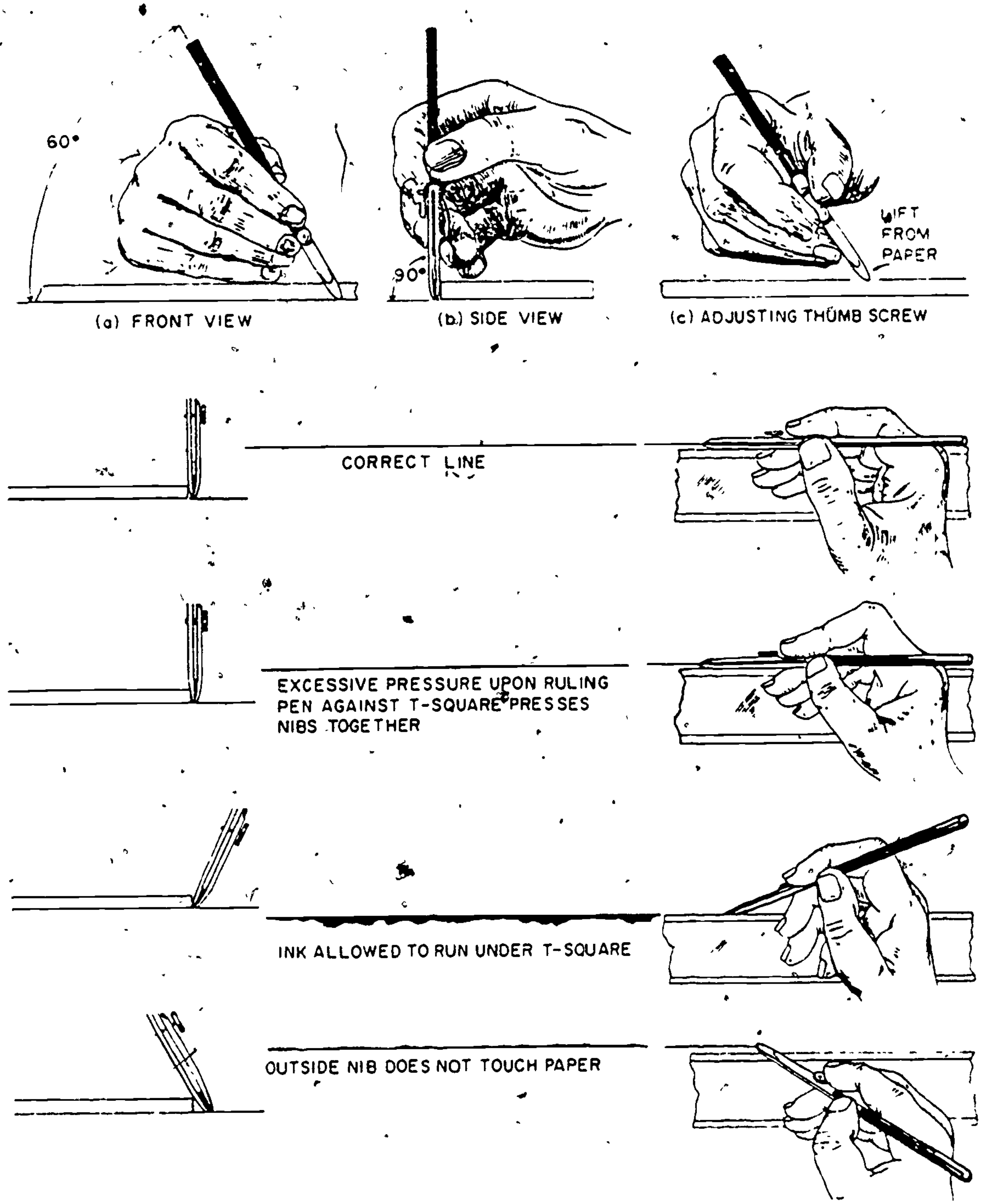

Figure 4-23. Using a ruling pen.

perpendicular to the paper, and when the compass is held in a vertical position, the pen just touches the paper. Once you have adjusted the needle point, leave it in that position. When you change the pen attachment for a pencil attachment, adjust only the lead point. You use the same relationship as for the pen attachment.

The lead for the compass should be of the same grade as that used in pencil work. This means that you should keep several lead points on hand to suit the varieties of pencil used. You can sharpen the lead to a bevel point by sanding the outside edge (see fig. 4-27). Sanding the outside edge of the lead permits you to sharpen the point without disturbing the compass setting even when the compass is set for drawing very small circles. With the bevel on the outside, the point of lead is nearer the needlepoint, thus permitting you to draw smaller circles.

When drawing small circles, you may leave the legs of the compass straight; but for large circles, bend the legs, as shown in part A of figure 4-28. The amount of bend depends on the size of the circle. Adjust the legs so that both nibs of the inking pen touch the paper when you hold the compass perpendicular to the paper. Notice that the leg containing the needle point is also perpendicular to the paper. In this position the needle point will not wear an unsightly hole when you draw several concentric circles. It is best to draw a circle with a clockwise movement and to go around the circle only once when inking. However, to secure a good black pencil line, you may find it necessary to go over the circle several times.

For drawing circles larger than the compass will accommodate, you may add the extension bar attachment, as shown in part B of figure 4-28 or you use a beam compass, as shown in part C. A beam compass consists of a bar, or beam, of metal 18 to 70 inches long, a steel needle point, and a pen or pencil point. You can slide the needle point and pen or pencil point along the bar to any desired position and then tighten them against the bar

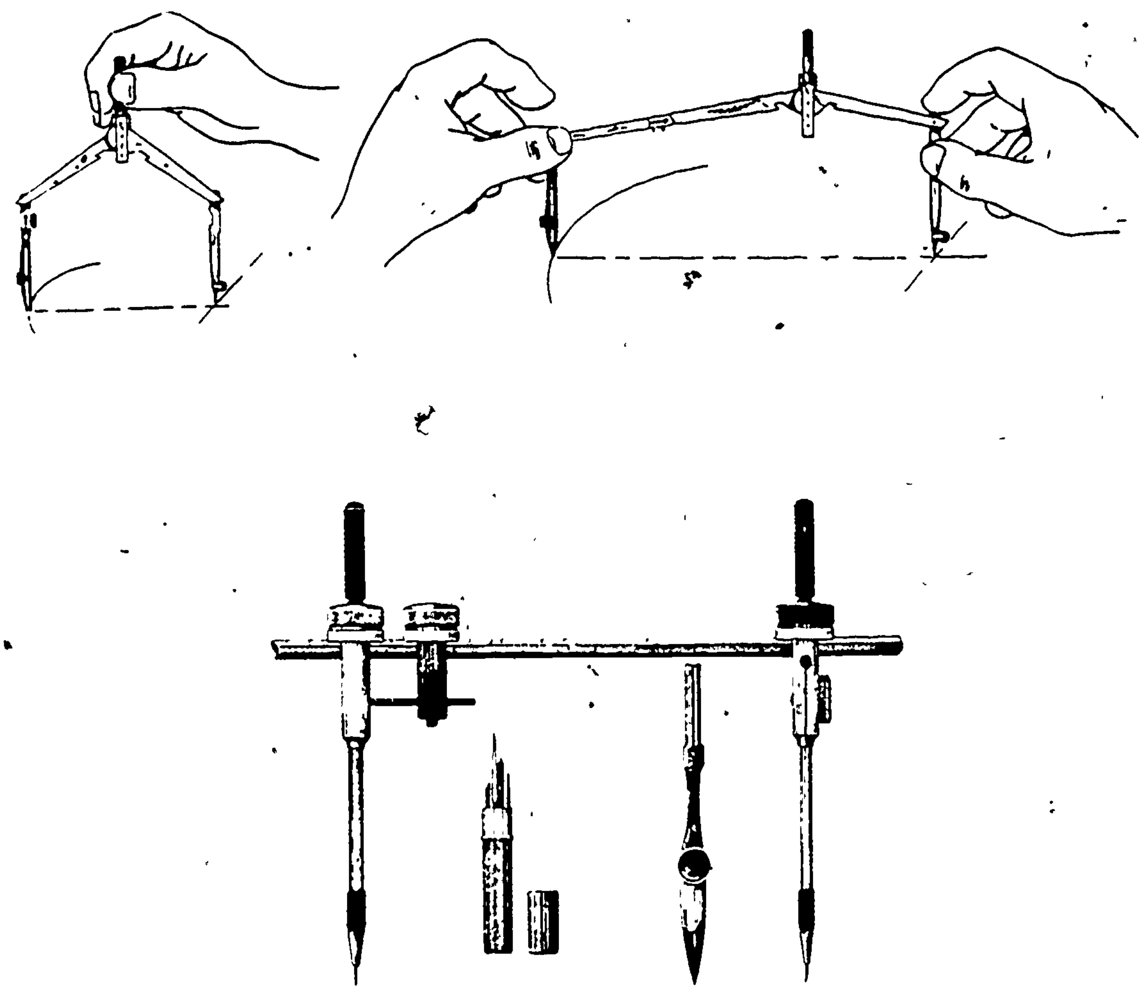

Figure 4-28. Extension bar compass and beam compass.

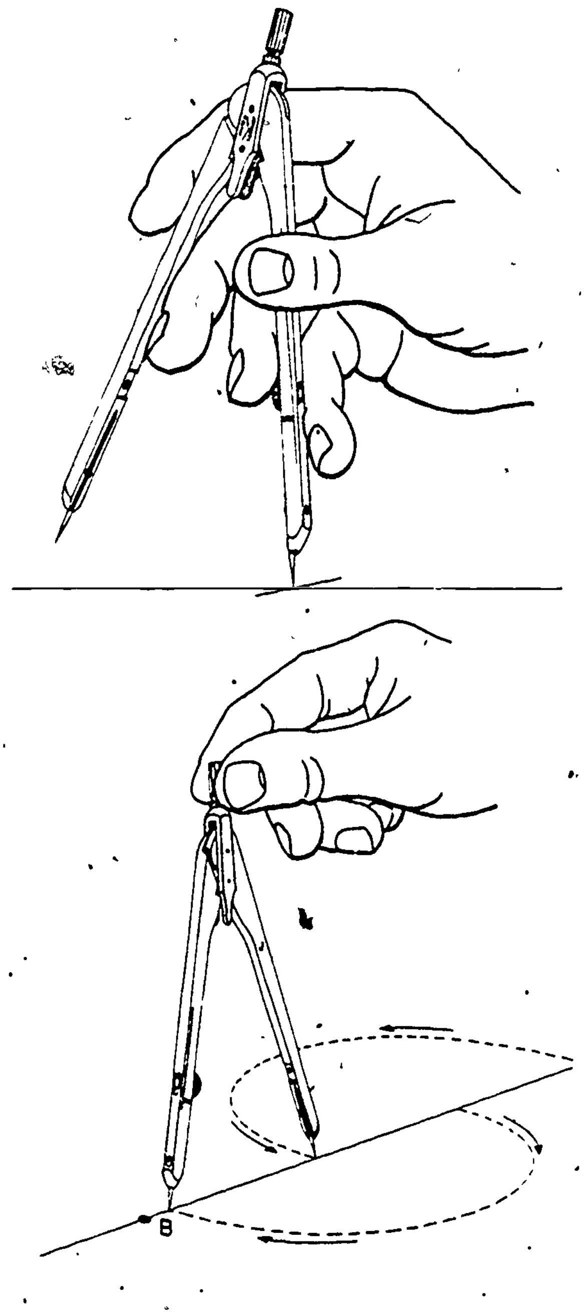

Figure 4-29. Adjusting and using the divider.

with thumbscrews. Using the extended compass and beam compass requires more skill than handling a regular compass since both hands must be employed, one to hold the needle at the center and the other to move the pencil or pen point.

Dividers. Dividers are used chiefly for transferring distances and occasionally for dividing spaces into equal parts. They are similar to compasses except that both legs have needle points (see fig. 4-29).

To set the divider, hold it in one hand. Then, if the distance to be set permits, hold it as shown in the top illustration. This permits you to increase the span by applying the pressure with your middle and ring fingers and to decrease the span by applying pressure with your thumb and index finger. If the distance is small, remove your fingers from inside the divider and close down the legs to the proper measurement by applying pressure with your thumb and fingers. A screw on one of the legs provides for a fine adjustment. To test dividers, close the legs and check to see if the two points come together in line with the legs.

To transfer a measurement from one drawing to another or from an object to a drawing, set the divider to the correct measurement and transfer the measurement to the drawing by pricking the drawing surface very slightly with the points of the divider. To step off a series of equal measurements, set the divider to the desired measurement and step off this measurement as many times as desired by swinging the divider first clockwise and then counterclockwise, as shown in the lower illustration of figure 4-29. Alternately reversing the swing permits you to maintain your grip on the divider.

You can use dividers to divide a measurement into a number of equal parts by the trial and error method. The principle of this method is shown in the bottom portion of figure 4-29. If you want to divide the distance between points A and B into three equal parts, start by estimating one-third of the distance. Then set the divider for this distance; place one point of the divider on point A, and step off three spaces along the line between points A and B. Be careful to prick the paper as lightly as possible. If the point of the divider coincides with point B, you have accomplished your objective. The two prick holes mark the division points of the line A-B. You may want to back and make these holes slightly larger or mark them with a pencil to complete the operation.

If the point of the divider falls short of point B, as shown in figure 4-29, or overshoots it, you can use the distance of the undershoot or overshoot to determine approximately how much to change the setting of the divider for the next trial operation. In the above example, since you are dividing the distance between points A and B into three equal spaces, and the first trial setting was too small, increase the span of the divider by one-third the distance between the final position of the divider and

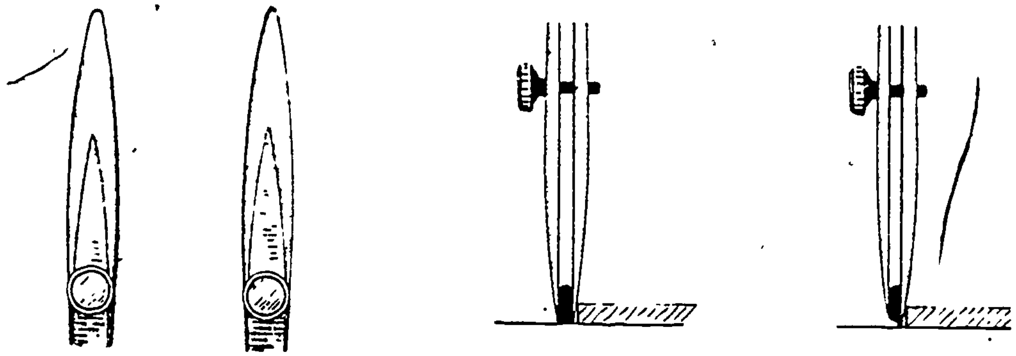

Figure 4-24. Correct and faulty ruling pen nibs.

should be slightly inclined in the direction of motion and in a plane perpendicular to the paper through the line being drawn. You should take great care to get and to keep the pen in the correct position, since only a slight deviation is necessary to bring disastrous results.

The four illustrations in the lower portion of figure 4-23 show the results of correct and incorrect manipulation of the ruling pen. The correct position of the pen and the resulting correct line are shown in the top illustration. Shown next is the result to applying too much pressure against the straightedge. As you can see, this forces the nibs together and thus reduces the thickness of the line. When the ink comes in contact with the straightedge and paper at the same time, it runs under the straightedge and blots the drawing, as shown in the third illustration. The same thing will occur if you leave ink on the outside of the nib and it touches the straightedge. When the pen is held, as shown in the bottom illustration, the outside nib of the ruling pen does not touch the paper and a ragged line is produced.

To draw a long line, you should use a steady, even arm movement. Your little finger and ring finger should rest on and slide along the straightedge to help keep the angle of inclination constant. Just before you reach the end of the line, stop your arm and two guiding fingers and, without stopping the motion of the pen, finish the line with a finger movement. Draw short lines with this finger movement alone. When you reach the end of the line, quickly lift the pen from the paper and move the straightedge away from the line.

The quality of a line produced by a ruling pen depends not only on the manipulation of the pen but also on the condition of the point. Even the best pens seldom come from the manufacturer properly pointed. Therefore, you should learn to sharpen and shape the nibs. The correct shape is shown in part A of figure 4-24. Notice that it is not very pointed. A pointed tip produces a very high capillary action. This is the action by which the surface of a liquid is depressed or elevated as it comes into contact with a solid. This action holds the inkwell away from the

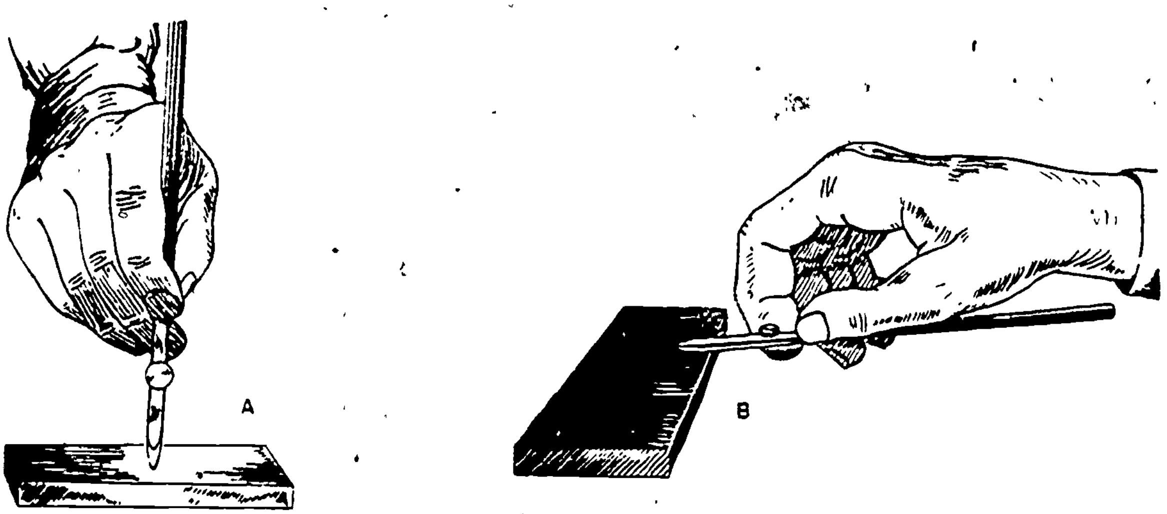

Figure 4-25. Equalizing the nibs and sharpening the ruling pen.

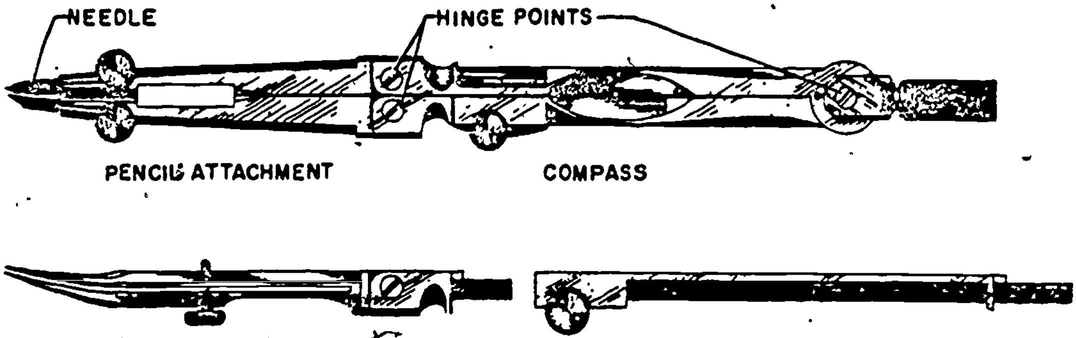

Figure 4-26. Standard compass with attachments.

point of the pen. A point of this type will not permit the ink to start, even on a broad line.

The equality in the length of the nibs is another condition that will affect the flow of ink. Before the ink will flow properly, both nibs must be equal in length, as shown in part C of figure 4-24. Part D of figure 4-24 shows what happens if one nib is longer than the other. Notice that the ink does not touch the paper and therefore doesn't flow.

After a few months of steady service, a good point will wear, producing a flat spot on the side that contacts the paper, as shown in figure 4-24,B. All three defects—sharp points, unequal length of nibs, and flattened points—can be corrected by proper honing on a finegrained oilstone.

The process of shaping the nibs of a ruling pen consists of two operations. The first operation consists of honing them to an even length and then rounding them off so that the end has a parabolic shape. This can be done by carefully closing the nibs of the pen and then rubbing the nibs over an oilstone, as shown in part A of figure 4-25. While rubbing the nibs over the stone, keep the pen in a plane perpendicular to the surface of the stone and rock it back and forth in the direction of motion. The second operation is that of sharpening the nibs. This must be done by grinding entirely from the outside, as shown in part B, until the edges of the nibs do not show any shiny flat spots when viewed edgewise. A magnifying glass is useful in making this examination. Exercise care in this operation to make the nibs equal in length and not so sharp that they cut the drawing paper. Under no circumstances should you attempt to sharpen the pen by honing the inside of the nibs. Sharpening it this way ruins the pen.

Exercises (045):

1. Why shouldn't the blades on a ruling pen ever be brought tightly together?

2. The wide-pointed ruling pen is called a ________ pen.

3. What are the three common defects of used ruling pens?

046. List the measuring instruments of a mechanical drawing set.

Compass. The large compass (see fig. 4-26) is one of the most important instruments in a drawing kit. It should be adjusted before it is used for the first time and then maintained in that condition. As you can see, one leg is arranged to hold either a pencil attachment or a pen attachment. You should insert the pen attachment first and then adjust the needle point so that it is about 1/32 of an inch longer than the pen. Thus, when the needle point sinks into the paper, the pen is

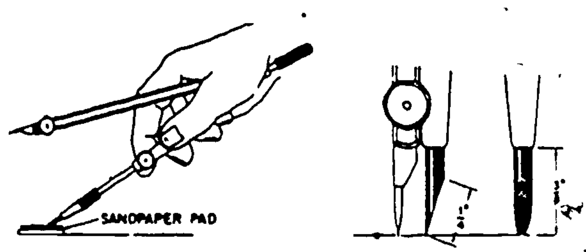

Figure 4-27. Sharpening and adjusting the compass lead.

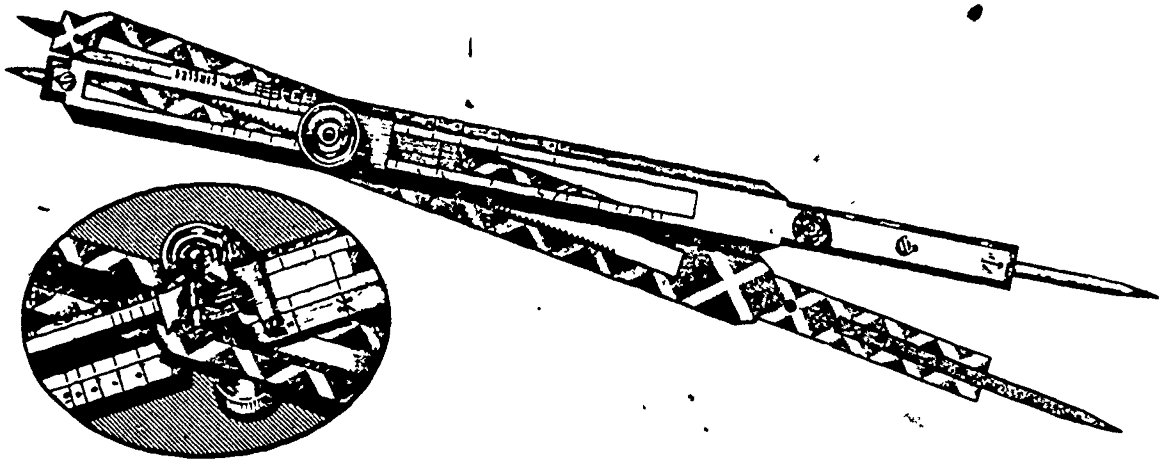

Figure 4-30. Proportional divider.

point B. By repeating this trial operation, you will find the right setting.

Proportional divider. An easier method of dividing the line shown in figure 4-29 includes the use of a proportional divider (see fig. 4-30). This type of divider consists of two legs which are held together by a movable pivot section and which have a needle point on each end. The movable pivot section allows you to adjust the divider so that the span of the short needle points has a desired ratio to the span of the long needle points. The enlarged detail of this section shows how this is done. Notice that the knob on the underside of the bottom leg is geared to a rack on the inside of this leg. As you turn the knob, the pivot section slides along the inside of both legs. You can set the divider for a desired ratio by aligning the index mark on the movable slide with the graduation marks on the top leg. The divider illustrated in the enlarged detail of figure 4-30 is set with the index mark aligned with the 2/5 graduation mark. Therefore, the span of short needles will be two units when the span of the long needles is five units. After setting the divider for a certain ratio, lock the pivot point by tightening the locking nut on the face of the upper leg. This setting and locking operation is done with the legs of the divider closed. After locking the pivot point, you are ready to use the divider.

Now let us see how you would use the proportional divider to divide the distance between points A and B of figure 4-29. Since you want to divide the distance into three equal parts, you must first set the divider for a ratio of 3 to 1. You do this by setting the index mark opposite the indicating mark 3 and tightening the locking nut. Next, you spread the legs of the divider until the long needle points will touch points A and B. Finally, you reverse the ends of the divider and step off the distances which divide line A-B, using the short needle points.

Notice that the proportional dividers shown in figure 4-30 are graduated for dividing circles as well as lines. To use them for this purpose, you set the right end of the index mark to the graduation line corresponding to the number of divisions desired. Then set the span of the long needles equal to the radius of the circle to be divided. Now you can use the short needle end of the divider to step off the divisions along the circumference of the circle.

Bow instruments. A mechanical drawing set usually contains three bow instruments—a bow pen, bow pencil, and bow divider. Bow pens and pencils are used for drawing circles and circular arcs with smaller than 1 inch radii. Bow dividers, like regular dividers, are

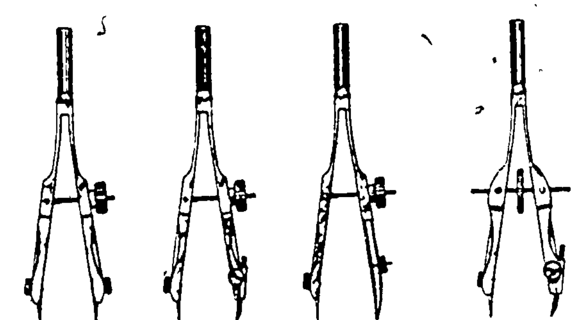

Figure 4-31. Bow instruments.

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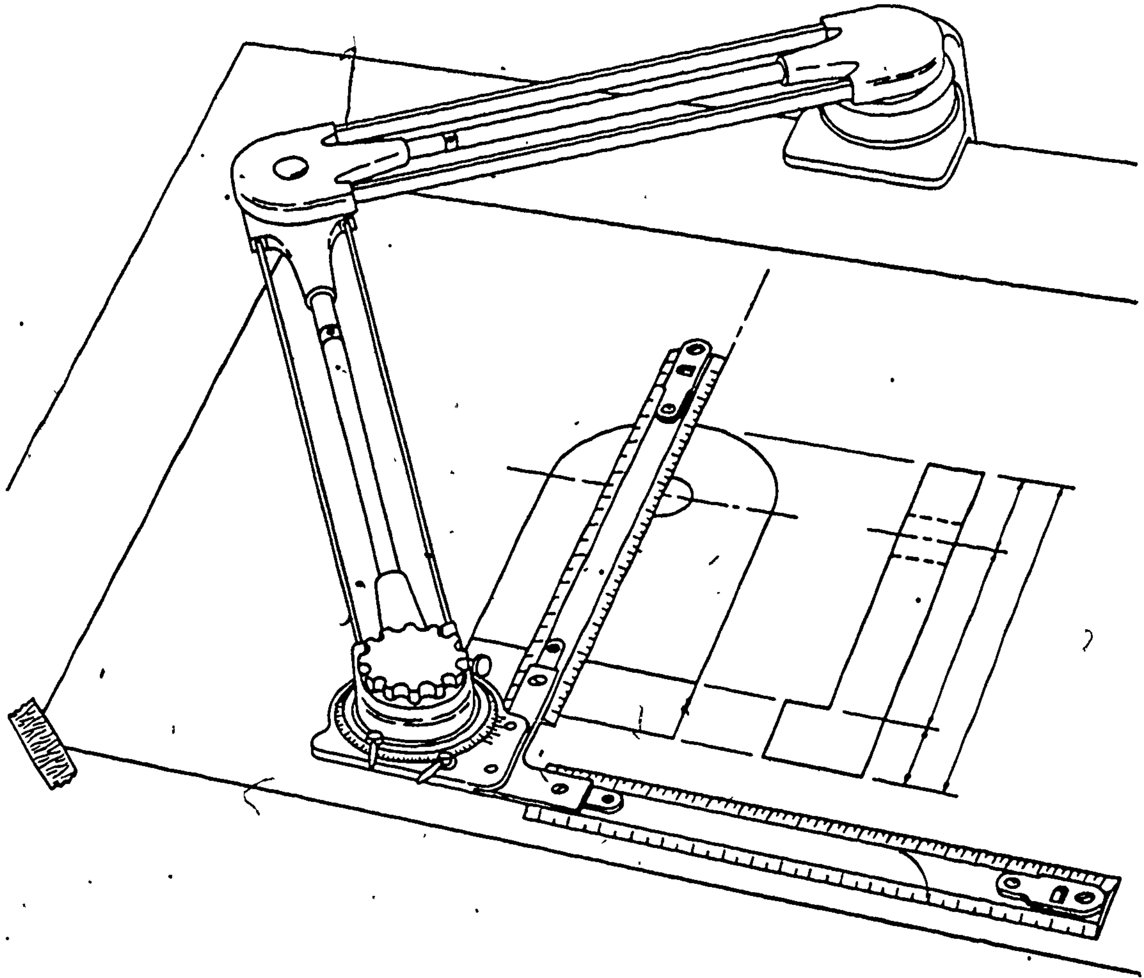

Figure 4-32. Drafting machine.

used for transferring measurements and dividing lines into equal parts but on a much smaller scale.

There are two types of bow instruments in general use. If the adjusting screw is on the side of the instrument, as shown in part A of figure 4-31, the instrument is called a side bow. If the adjusting screw is in the center, as shown in part B, the instrument is called a center bow. Both of these instruments are used in the same manner as the compasses and dividers previously described.

As you can see in figure 4-31, side bow instruments are merely small instruments which have a thumbscrew acting against the spring tension of the legs. The screw threads on these instruments are delicate; therefore, do not force them. You can decrease the wear on the threads by holding the legs together lightly as you turn the adjusting screw. This applies only to the side bow instruments. You should keep the threads of both types of instruments free from rust and dirt.

Exercises (046):

1. List the two types of measuring instruments of the drawing set.

2. What are proportional dividers?

3. How many bow instruments does a mechanical drawing set contain?

047. State the advantage of a drafting machine.

Drafting Machine. The drafting machine, or parallel motion protractor as it is sometimes called, is one of the most useful and timesaving devices that you will use. You can use it in place of a T-square, triangle, scale, and protractor. As you can see in figure 4-32, the drafting machine is attached to the top edge of the drawing table with the straightedges resting on the surface of the drawing table or paper. The controlling head of the machine provides a means of adjusting and locking the straightedges at any desired angle. The supporting links are arranged so that the straightedges always remain at the desired angle no matter where they are moved on the board. Thus, when the long blade is set to a horizontal position, it will remain horizontal regardless of the position of the control head on the drawing table. Interchangeable straightedges marked with standard scale divisions permit you to use the drawing machine for many types of drawing.

Since the various parts of the drafting machine are metal, the accurate relationship of one part to another is not subject to change. However, they do have certain inherent faults. Unless the metal straightedges are pressed firmly against the drawing by placing one hand at the center of straightedge, the blade will flex or "swing" slightly when moderate pressure is applied to the free end. The links or bands which control the position of the straightedges must be adjusted properly to eliminate the possibility of introducing error from this source. When using the drafting machine to attain speed, you must take great care not to gain speed at the cost of accuracy.

Exercise (047):

1. What is the advantage of a drafting machine?

CHAPTER 5

Fundamentals of Lettering

THE THOUGHTS or ideas the graphics specialist wishes to pass on to someone else are seldom conveyed by illustrations alone. Most illustrations are accompanied by some form of written word. The words may take the form of a title, which usually tells something about the illustration, or they may be included as an integral part of the illustration. You can see this by looking at the advertisements in any magazine or newspaper. Illustrations used by the Air Force are not exceptions. This means that you as a graphics specialist must be able to letter as well as illustrate. In fact, you will find that a fair illustration with good lettering is more effective than a good illustration with poor lettering. In other words, the lettering can make or break an illustration. We might say also that being able to letter well can be the difference between a good graphics specialist and a poor one. One thing for sure, if you learn to letter well, you will be of great value to any graphics organization regardless of your other qualifications.

Lettering, like drawing, is an art. As in other arts, you must spend many hours studying and practicing to acquire the necessary knowledges and skills. This course cannot help you develop your skill. You must gain that by continuous practice. It can, however, present helpful information on the fundamentals of lettering. From this chapter, you should learn the basic principles of lettering, how each letter is formed, what constitutes good spacing, how to obtain good spacing, how to letter by hand and by using mechanical lettering equipment, and how to use prepared lettering. Let us start with lettering fundamentals.

5-1. Fundamentals of Lettering

Lettering produced by hand without mechanical lettering aids of any kind has a quality that cannot be obtained by any other means. It takes on the personality of the individual letterer as well as the character of the instrument used to produce it.

The ability to letter well can be acquired only by continued and careful practice. Anyone with muscular control of his fingers can acquire this ability if he will practice faithfully and intelligently and take the trouble to observe carefully the shapes of the letters, the sequence of strokes used to make the letters, and the rules for letter composition.

048. Name the styles most used in modern lettering, and tell how printing affects lettering.

Origin of the Alphabet. The alphabet we use today had its origin in ancient hieroglyphics. After being developed by the Egyptians into a cursive form, it was adopted by the Phoenicians, who produced an alphabet of 22 letters. This alphabet was transmitted in the course of time to the Greeks and by them to the Romans. Each of these civilizations made changes in the alphabet due in part to the kinds of tools and materials they used in recording their writings. The Roman capital alphabet finally evolved and has come down to us practically unchanged. Except for small letters, which were added to the Roman alphabet by the master printers of Venice after printing had been invented in Germany in the 15th century, most newspapers, magazines, and books of today use letters which differ very little from those carved on Roman architecture over 2000 years ago. The success and durability of the Roman alphabet can be attributed to the fact that the letters are based on well-defined principles and geometric truths—the circle, ellipse, vertical lines, horizontal lines, and diagonal lines being the elements.

Styles of Lettering. Through the centuries, writing styles and even the basic letter forms were changed and modified due to the materials used and the tendency of men to try to find easier ways of doing something. Printing imposed certain changes toward a more mechanically perfected letter form. This began a trend toward simplicity and ease of construction.

Text. The first type faces were simply copies of the manuscript lettering of the period. The Gutenberg Bible, the first printed book, was printed in an angular, northern block letter. A number of type faces based on the old block-letter or text alphabets, such as the German Text and Old English Text, are still used. For those of us who are accustomed to simpler styles, the text style of lettering is quite difficult to read. Therefore, we seldom use this style for blocks of copy. Text lettering is used often for formal and decorative purposes on certificates, formal announcements, diplomas, etc.

Gothic. In this style all parts of the letters are of equal width. When the width of the strokes can be made with a single stroke of a lettering pen, pencil, or brush, the style of letter is called *single-stroke* Gothic. When the outline of a letter is drawn and the area between is filled in, the style is called filled-in or built-up Gothic.

Roman. The style of alphabets in which the letters are produced by thick and thin strokes is classified as Roman. The thick and thin strokes of this style give variety and letter characteristics which are easy to read; therefore, Roman style lettering is widely used. In fact, most books, magazines, newspapers, and other written means of communication use this style of print..

Each of the three styles of lettering may be further subdivided into capital letters, or uppercase, and small letters, or lowercase. The terms "lowercase" and "uppercase" evolved from the printing trade. Before the advent of modern printing, printers had to hand set their type. They used a letter case with compartments to keep the different letters of a font (complete set of type) separated from each other. The small letters of a font were kept in the lower part of the letter case and the capital letters were kept in the upper part of the case. Thus, lowercase and uppercase became common usage for small and capital letters.

The printers and manuscript writers of Italy added another characteristic to the style of lettering. They used a slanting stroke instead of a vertical stroke in their letter design. This distinguishing characteristic resulted in the adoption of the term "italic" for all letters having this characteristic slant.

Styles of letters can also be distinguished by their general proportions. Although there is no standard for the proportions of letters, there are certain fundamental points in design and certain characteristics of individual letters that you must learn before you attempt to compose letters into words and sentences. Not only do the widths of letters in any alphabet vary, from I, the narrowest, to W, the widest, but different alphabets vary as a whole. Styles narrow in their proportion of width to height are called *compressed* or *condensed* and are used when space is limited. Styles wider than normal are called *extended* lettering.

The proportion of the thickness of stem to the height varies widely, ranging from 1/3 to 1/20. Letters with heavy stems are called *boldface*, and those with thin stems are called *lightface*. Thus, besides the three main items used to designate any style of letter (basic form, uppercase or lowercase, and vertical or slant), terms such as single-stroke or filled-in, condensed or extended, and boldface or lightface are also used.

Exercises (048):

1. What are the styles of lettering most used today?

2. What changes did printing have on lettering styles?

3. Letter styles narrow in their proportions of width to height are called __________ or ________ letters.

4. Styles wider than normal are called __________ lettering.

049. Define letter nomenclature.

Letter Nomenclature. Before we go further into lettering fundamentals, we should go

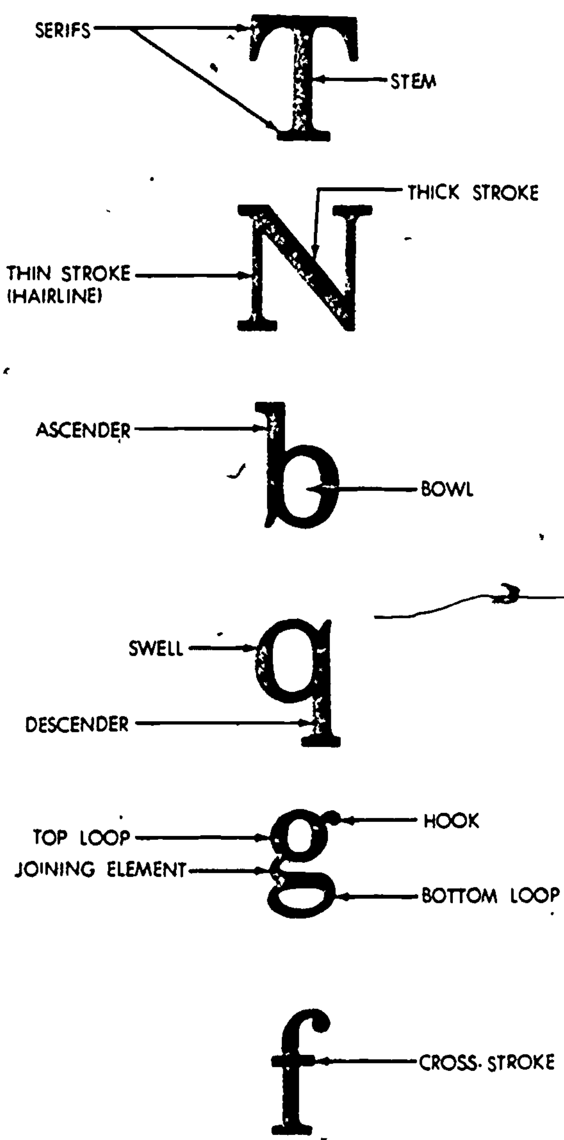

Figure 5-1. Letter nomenclature.

over the names of the various parts of letters. This will give us a common language to use in discussing lettering principles. The different parts of letters are designated in figure 5-1. You are probably familiar with some of these names, but let us go over them to make sure that you know all of them.

The two parts, *serif* and *stem*, shown on the top letter, should be familiar names. The *serif* is a thin, short finishing stroke at the top and bottom of letters made with straight vertical or horizontal strokes. Serifs are a characteristic of Roman letters. The *stem* of a letter is the name for the straight vertical line that is used as a basis for most letters of the alphabet.

The next letter of figure 5-1 shows two names that are often used to describe parts of letters. When a broad nibbed pen is used to construct letters, it is usually held so that the nib is parallel with the line of lettering. Therefore, when a downward stroke is made, the part of the letter produced is a *thick stroke*. Naturally, a thin stroke is produced when the pen is moved horizontally or is turned so that the nib is moved edgewise down the paper as in the construction of the letter N. Sometimes we refer to the thin stroke as a *hairline*.

The next two letters in figure 5-1 are quite similar, so we can discuss their nomenclature together. The stem of a lowercase letter that extends above the body of the letter is called the *ascender*, and the portion of a lowercase letter that extends below the body is called the *descender*. The combination of the ascender or descender and the body of a letter is the same height as a capital letter. The white area inside of a letter made with a curved stroke is called the *bowl* or the *counter* of the letter. The curved portion of such letters is called the *swell*. The swell is often made slightly wider than the stem because it is thick only at one point, and appears thinner than the stem when made the same thickness. This is apparent in figure 5-1 where the swell is the same thickness as the stem.

Now let us look at the last two letters in figure 5-1. As you can see, the letter "g" has many additional parts with different names. However, the names are self-explanatory and need no further explanation. The final part of letters shown in the figure is the cross-stroke. This is the thin horizontal stroke of the lowercase letters f and t and capital letters A and T. Sometimes it is used to refer to the horizontal strokes of the capital letters E and F.

Exercises (049):

1. What is letter nomenclature?

2. Serifs are characteristic of what type letter?

3. What is the curved outer portion of a lowercase letter called?

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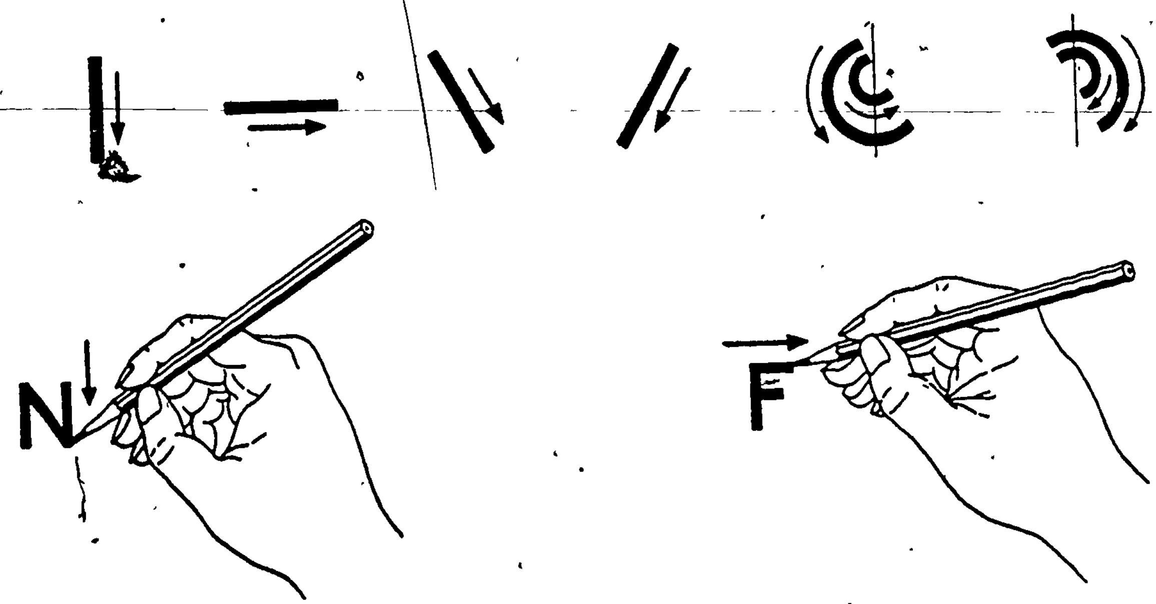

Figure 5-2. Basic lettering strokes.

5-2. Letter Formation

There are three necessary steps in learning to letter. You must know the proportions and forms of the letters, the order of the strokes used to produce each letter, and composition—the spacing of letters and words.

050. List the two elements and the six basic strokes of lettering.

Elements of Letters. The letters of the alphabet are composed of two simple elements, with a few variations due to the shape of certain letters. The first of these elements is called the stem of the letter and is made with a single downward stroke. The second element is called the round or oval and is made with one or two strokes, depending upon the size of the letter being made. The basic strokes used to produce these elements are shown in figure 5-2.

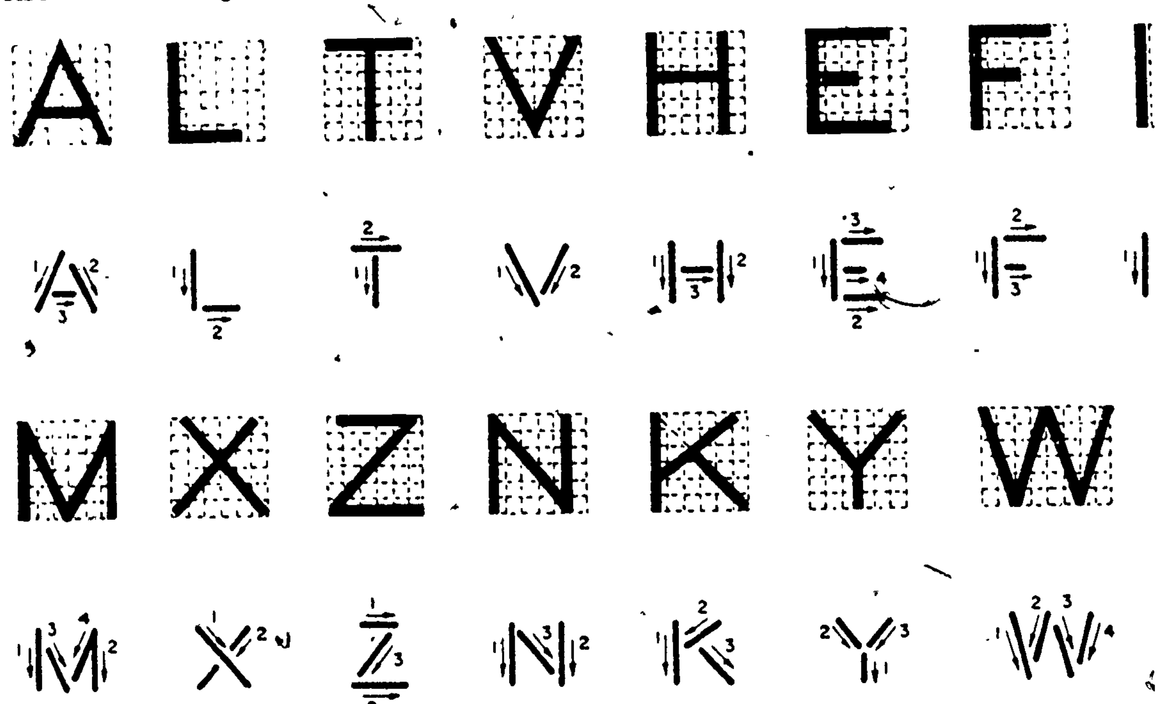

Figure 5-3. Vertical straight line capitals.

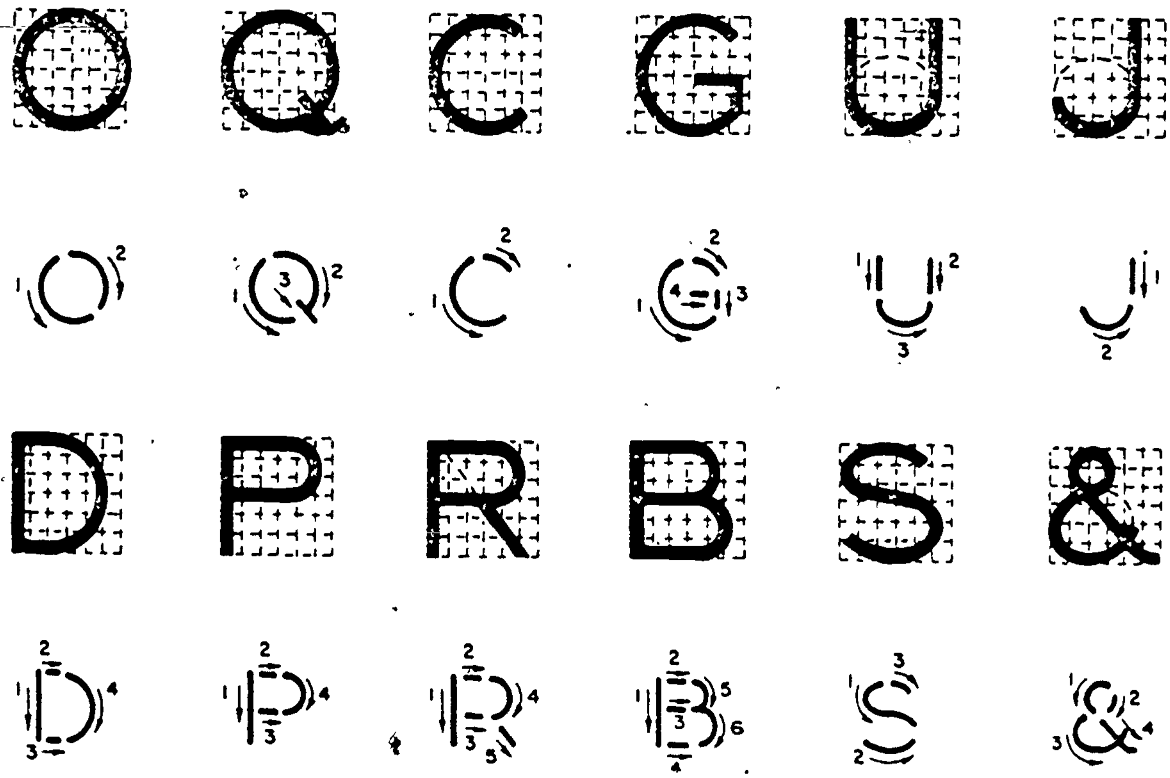

Figure 5-4. Curved, and curved/straight line combinations capitals.

Stems. The straight lines, vertical or slant, which form a part of more than four-fifths of all the letters of the alphabet, are called the stems. This term does not apply to those horizontal straight lines which form a part of such letters as A, E, F, and H. The following rules are applicable in forming all stems:

- The stems are uniform in weight or thickness and have uniform height. When using a pen to produce letters, the width of the stroke is determined by the kind and size of the pen being used rather than the amount of pressure applied to the pen.
- The stems are perfectly straight without hooks or curls at either end.
- The slopes of the stems are uniform and parallel to each other throughout any piece of lettering.

Rounds or ovals. The second element in lettering is a perfect circle or a perfect ellipse with a well-determined ratio between its major and minor axes. A good proportion for width to height is 5 to 6. That is, the width of a parallelogram inclosing the ellipse should be five-sixths the height. The ellipse should touch the four sides of the parallelogram at their midpoints. These proportions give what is termed a standard vertical or slant oval which, when properly combined with the stem, produces the normal or standard letter.

Combination of stem and oval. When you have mastered the technique of the individual elements, it becomes a simple task to combine the elements to form such letters as a, b, d, n, r, and u. The secret of success lies chiefly in remembering that the stem becomes one side of the parallelogram. In making the stem tangent to the ellipse remember that they must coincide with each other, but in no case should the thickness of the letter at the point of tangency be permitted to become greater than the thickness of the stem.

Capital Letters. In learning the form of each letter and the sequence of stroke used to make each letter, let us begin with the capital letters that are made entirely of straight lines. These letters are shown in figure 5-3. Notice that, except for the W and the I, the letters have been placed within a parallelogram which is divided into six equal spaces both horizontally and vertically. The letter I being the basic vertical stroke makes it possible for you to determine the width of each letter at a glance. The strokes with arrows beneath each letter show the direction and order of strokes used to make each letter. As you can see, the

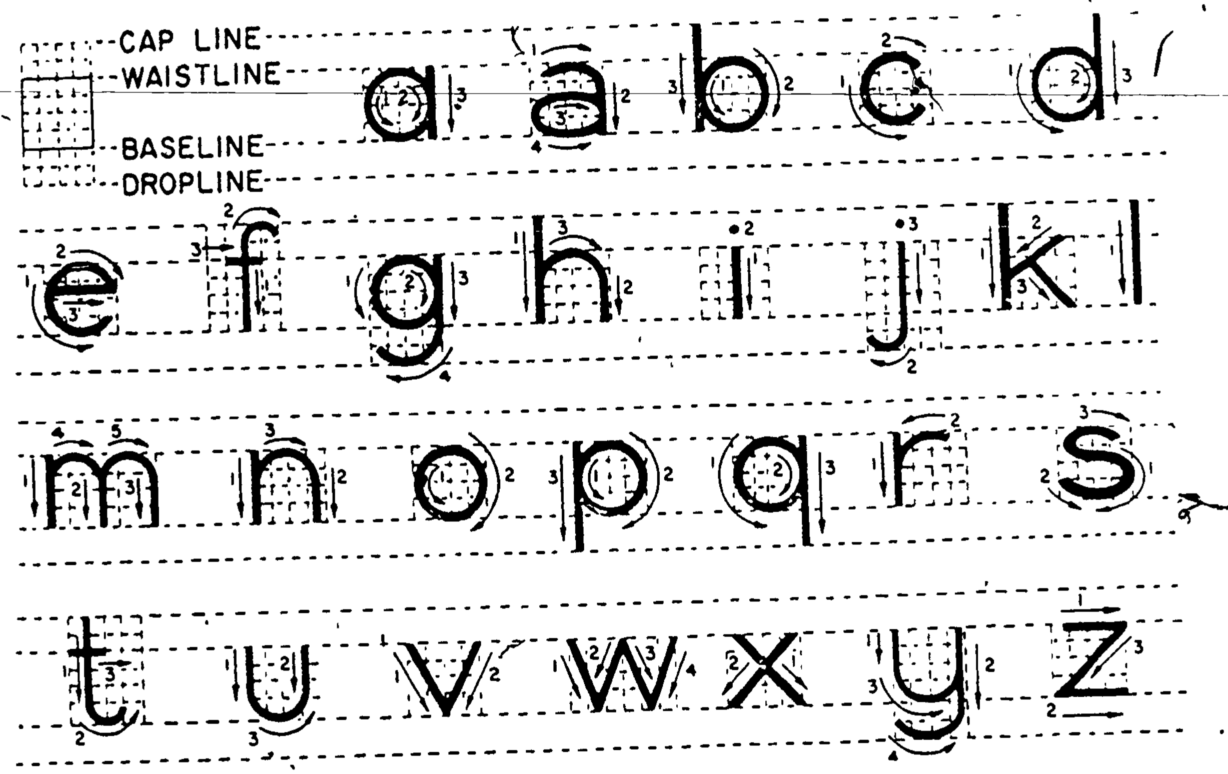

Figure 5-5. Vertical lowercase letters.

strokes are usually made from top to bottom and from left to right.

The position of the crossbar on the A, H, E, and F is an important consideration. Notice that the crossbar of the A is placed below the vertical center and that the crossbar of the H is slightly above the center. This is done to avoid a top-heavy appearance. Although it is not shown in this figure, usually the crossbar of the E and the crossbar of the F are raised slightly to improve the appearance of these letters.

Next, let us look at the wide letters M and W. The first and last strokes of the letter M are vertical, and the center section of the letter is the same as the letter V. The alternate strokes of the letter W are parallel. Notice that the two V-shapes used in its construction are narrower than a normal V.

We should also discuss the characteristics of the letters X, Z, K, and Y. The strokes of the X cross slightly above the center. This produces a slightly narrower width at the top of the letter than at the bottom and adds stability. The letter Z is stabilized by making the top stroke shorter than the bottom. Notice that the third stroke of the letter K, if extended, would pass through the top of the

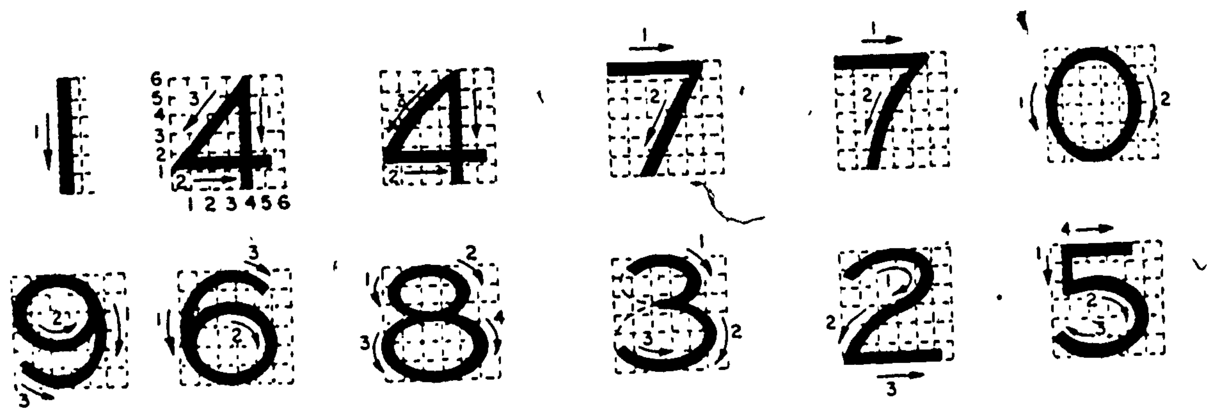

Figure 5-6. Numerals.

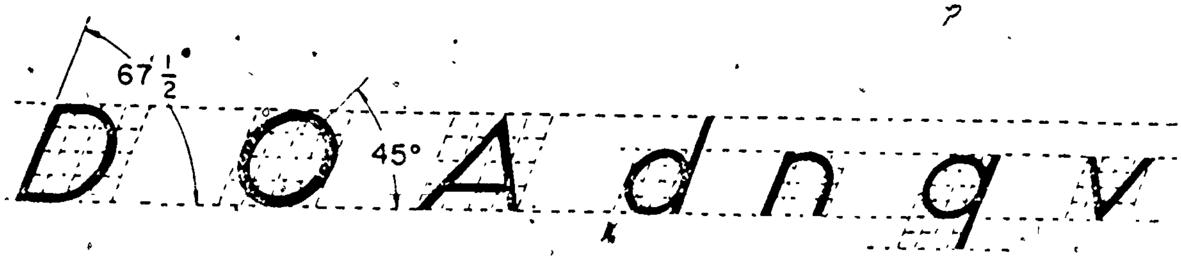

Figure 5-7. Inclined letter formation.

first stroke. The appearance of the letter Y is improved by making the branch of the letter below the vertical center.

Now, let us look at the letters formed by curved lines and combination of curved and straight lines. These are shown in figure 5-4. The only letters of this group that need special mention are the letters P, R, and B. The center horizontal line of these letters is usually drawn slightly above the vertical center, and the top of the R and B is smaller than the lower part to give the letter stability. (This is also true of the top and bottom curves of the letter S:) Notice that the letters P, R, and B appear somewhat squatty. Their appearance can be improved by making them one square narrower.

Small Letters. Seven of the small, or lowercase, letters are made with straight lines. Two are made with curved lines, and the remaining letters are constructed with a combination of curved and straight lines. The lowercase letters of a Gothic style alphabet are shown in figure 5-5. As you can see, the bodies of these letters are two-thirds the height of the capitals and the long stems or ascenders, with the exception of the letter t, which is generally shorter, are the same height as the capitals. The descenders of the letters g, j, p, q, and y extend as far below the lower guideline as the ascenders extend above the body of the letters.

Numerals. Figure 5-6 shows the numerals used with a Gothic style alphabet. Notice the similarity between the bottoms of the 3, 5, and 8 and between the top of the 2 and 3. The top of most numerals is smaller than the bottom. The height of numerals is always equal to the height of the capital letters.

Inclined Letters. Inclined or italic letters are made with the same number of strokes and in the same sequence as vertical letters. Figure 5-7 shows some of the things you should know about inclined lettering. The stems of slanted lettering are sloped so that they make an angle of 67½° with the horizontal guideline. This makes the major axis of curved letters slope at a 45° angle. Figure 5-8 shows the form of the capitals, lowercase, and numerals of an inclined Gothic alphabet. Compare these with the vertical alphabet which you have just completed studying.

Roman Style Letters. Since Roman style lettering is made with thin and in constructing this style of letter is the placement of the heavy and light strokes. For example, a very common error for beginners is placing the thick portion of an A on the wrong side. They darken the left slope rather than the right slope. Let us see if we can find a rule to determine which strokes should be light and which strokes should be heavy.

The design of the Roman alphabet (see fig. 5-9) is based on the reed pen used during its development. Since the nib of this type of pen is wide and is held parallel with the horizontal lines of the paper, a downward stroke produces a broad line and a horizontal

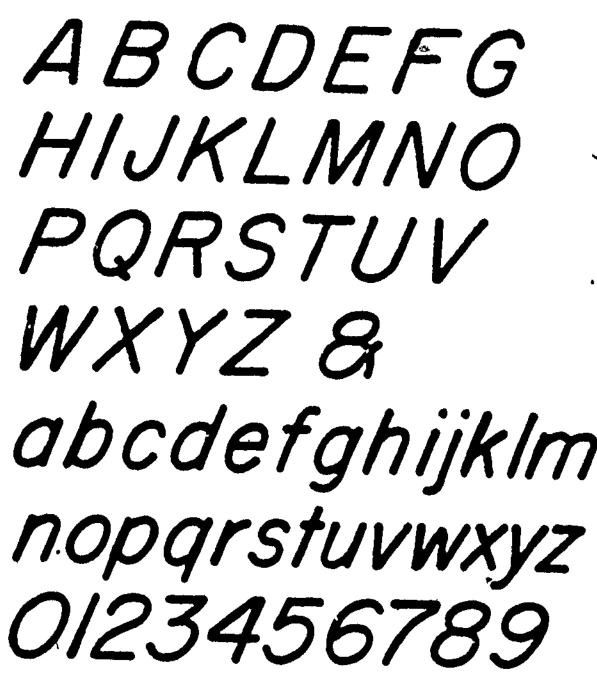

Figure 5-8. Inclined letters and numerals.

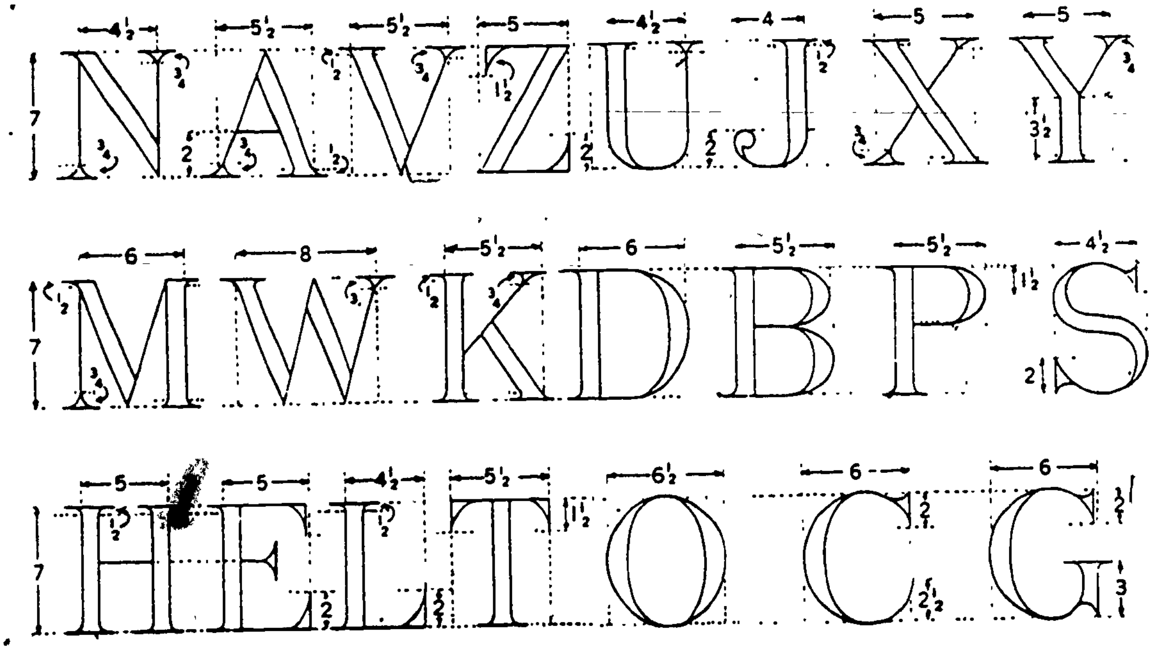

Figure 5-9. Roman capital letters.

stroke produces a thin line. A rule stating that downward strokes should be thick and horizontal strokes should be thin works fine for the letters B, C, D, E, F, G, H, I, J, L, O, P, Q, R, and T, but does not work for the letter U or with letters containing diagonal lines.

Let us see why this rule does not work with letters containing diagonal lines, starting with the letter N, shown in the upper left corner of figure 5-9. If we used this rule there, both vertical lines and the diagonal line would be thick. This would produce a letter out of character with the other letters. If we made the two vertical lines thick and turned the pen and made the diagonal line thin, we would have a letter with much the same character as the letter H, but one which would be very weak in design. The thick vertical strokes would have a tendency to divide the letter and would appear as part of the preceding and succeeding letters. Therefore, the diagonal of the N is made thick and the pen turned sideways to make the vertical strokes thin. This gives the N the right characteristics and produces a strong, well-designed letter. The last vertical stroke of the U is made thin for the same reason.

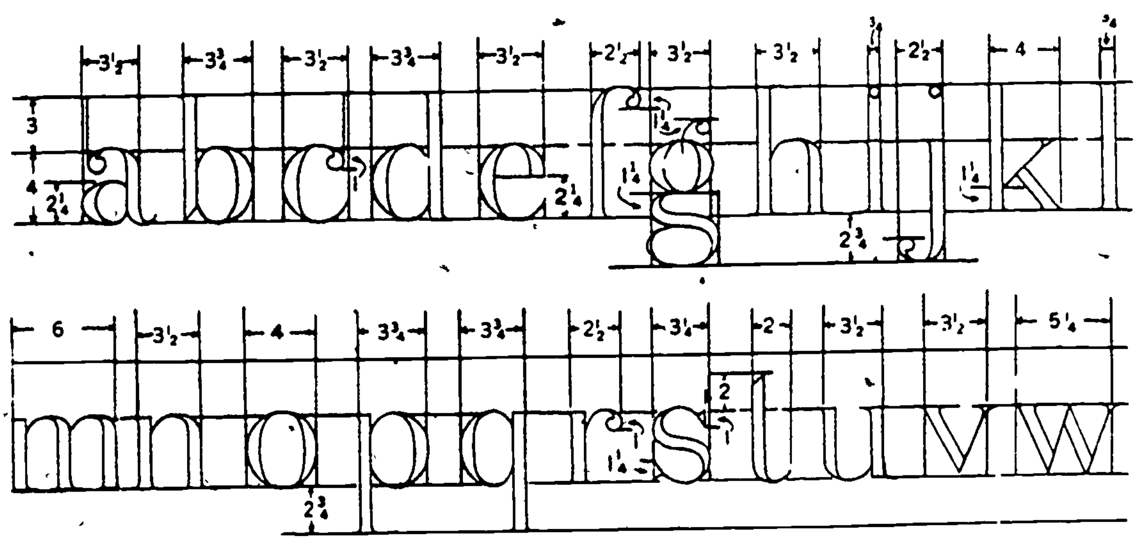

Figure 5-10. Roman lowercase letters.

As you can see in figure 5-9, the letters A, V, Z, X, Y, M, W, and K also contain diagonal lines and deserve special consideration. With the exception of the letter Z, all diagonal lines which are made downward from left to right are thick and those made downward from right to left are thin. You do not even have to remember which is thick and which is thin. Just try drawing them. Notice how much easier it is to turn the pen to make the right-to-left diagonals thin than it is to make the left-to-right diagonals thin. However, you will have to twist your wrist considerably to make the thick stroke of the letter Z.

We have several other suggestions to offer you in regard to his Roman style of letter. The beauty depends to a great extent upon uniform, clear-cut spurs or serifs, and a uniform stroke of all the characters. Notice that the serif is made with a thin horizontal line across the end of each thick and thin stroke and with circular arcs rounding off the area between the flat edge of the serif and the stem of the letter. Notice that the flat portion of the serif extends beyond the stems and the arcs do not extend to the end of the serif. They become tangent midway between the edge of the stem and the end of the serif.

The width of the round or oval stems of such letters as O, C, G, and D is slightly greater than the straight stems. Since the round or oval stem is full width at one point only, it will appear narrower than the straight stem if it is not made slightly wider at this point. Round letters, such as the O, C, and G, and pointed letters, such as the A and V, are affected by the same optical illusion. The round parts of letters and the pointed parts of letters should extend slightly beyond the guidelines to overcome this illusion; otherwise, these letters will appear smaller than the other letters.

The dimensions of the letters shown in figure 5-9 are based on the width of the stem. As you can see, these capital letters are seven units high and vary in width. Study them until you are familiar with each letter and its dimensions; then use figure 5-10 to become familiar with the lowercase letters. Notice that the long stems of the small letters are equal in height to the capitals but are slightly narrower in width. Using a narrower width for small letters gives them the same general appearance as the capitals.

Exercises (050):

1. What are the two elements of lettering?

2. What is a stem?

3. What are the six basic strokes that are used in lettering?

4. What is the standard slope of inclined letters?

5. Why should the point of the letter A extend slightly beyond the guidelines?

5-3. Principles of Lettering

To be effective, lettering must be legible. This means that the letters must be well-proportioned, stable, uniform, and properly spaced. We have already discussed proportions of letters during our discussion on forming letters. Let us review and add to this information.

051. List the three principles of good lettering.

Proportion. As we said before, there is no standard for the proportions of letters. Some are tall and thin, some are squat and thick, others are light, and still others are heavy. Each style has its own proportion of width to height and its own proportion of thin lines to thick lines. Each type of letter may be used effectively under certain conditions.

Lettering classified as Old Roman is usually 10 times as high as the width of the stems. The thin strokes of these letters are usually half as wide as the thick strokes. The height of the lowercase letters are six-tenths the height of the capitals. These proportions give this lettering a slightly heavy appearance, but one which is quite legible.

In Modern Roman lettering, the width of the stem is wider than the Old Roman style. The capital letters are made 7 units high and the lowercase letters 4. At the same time, the width of the thin strokes of the letters is reduced to a thin line. The contrast between the very thin and the very thick lines of these

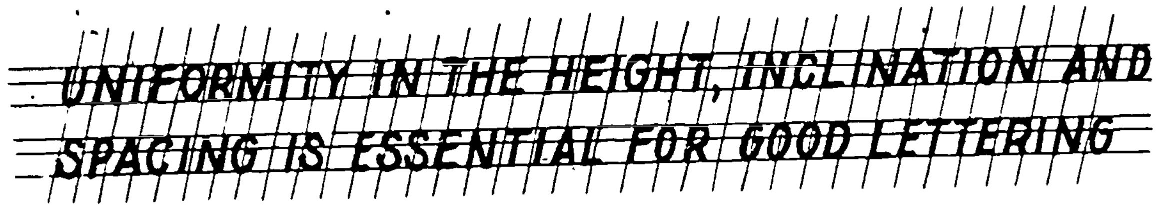

Figure 5-11. Uniformity.

letters produces lettering that is pleasing in appearance and very legible.

Stability. During our discussion of letter formation, we also discussed stabilizing some letters by constructing their centers slightly off center. The crossbar of the A is placed below center, and the upper parts of the Y connect to the lower stem below center to stabilize these letters. The crossbars of the H, E, and F are placed slightly above center, and the top portions of the P, R, B, X, and S are made smaller than half the letter to give these letters a more stable appearance. The tops of the letters K, X, and Z are made narrower than the bottoms for the same reason.

Uniformity. Perhaps the most important principle of good lettering is the principle of uniformity. As stated in figure 5-11, uniformity in the height, inclination, and spacing is essential for good lettering. We can add to this by including uniform weight of lines as a requirement for good lettering. Now, let us see how these principles are applied.

Height and inclination. The easiest way to insure that the height and inclination of lettering are uniform is to use guidelines. To keep the height of the letters uniform, you should draw light horizontal lines indicating the top and bottom of capital letters. If your lettering includes both capital and lowercase letters, you add another horizontal line

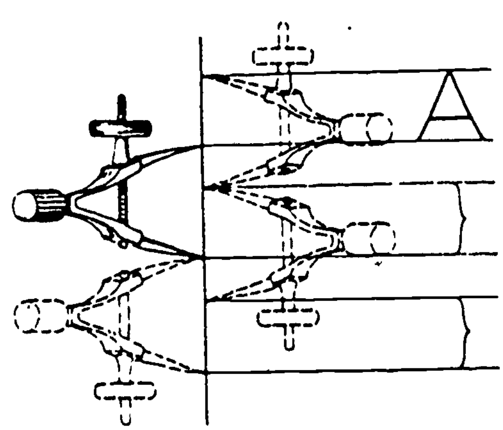

Figure 5-12. Using dividers to space guidelines.

indicating the height of the lowercase letters. Figure 5-12 shows you how to use dividers to obtain uniform spacing of these guidelines. After you have determined the height of the lettering and the space between lines of lettering, you set the divider for a span equal to this height and space. Then, starting at the bottom of the first line of lettering, you step off the number of lines desired, as shown on the left side of the vertical line in the figure. Then, using the same setting, you start at the top of the first line of lettering and step off the same number of times as shown on the right side of the vertical line. By drawing horizontal lines through the points established, you obtain the top and bottom guidelines for the height of capital letters. If you want a guideline for lowercase letters, you measure the desired height for these letters on the first line of lettering, and then use the divider as you did before.

If you have many lines of lettering to do, you will find that a lettering instrument, such as the Ames lettering instrument, shown in figure 5-13, is quite useful and timesaving. The top-left section of the figure shows how to use this instrument in conjunction with a T-square to draw properly spaced horizontal guidelines. You insert the point of your pencil through one of the holes and the instrument slides along the T-square as you move the pencil across the page. The enlarged drawing of the instrument in the lower part of the figure shows the details of how the instrument is used. Notice the three rows of holes in the circular disc of the instrument. The holes in the center row are equally spaced and are used to draw equally spaced guidelines. The two outside rows are used for drawing both capital and lowercase guidelines. The left row gives a proportion of 3 to 5 for lowercase and capital letters, and the right row gives a proportion of 2 to 3.

The design of this particular lettering instrument permits you to use it for lettering ranging in height from 2/32 to 10/32 inch. These various heights are attainable by rotating the circular disc within the outer section of the instrument. The numbers along the bottom edge of the disc are used to set

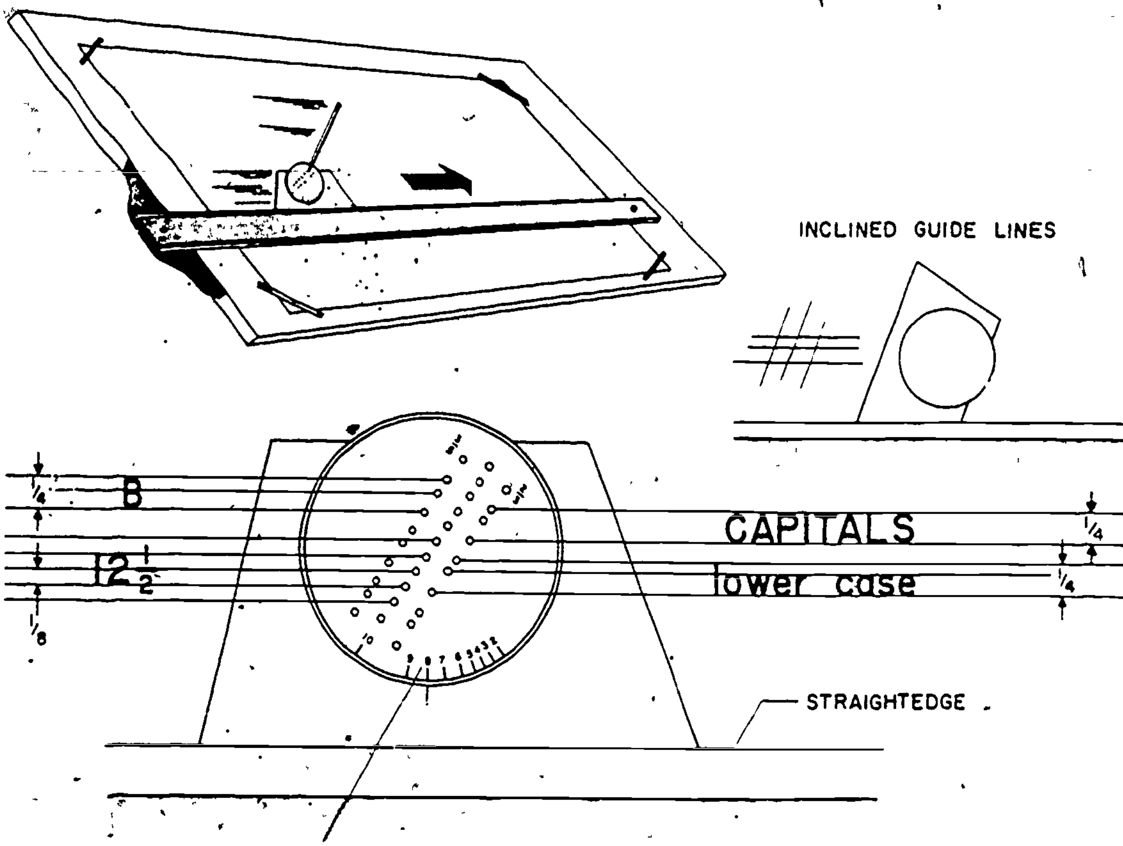

Figure 5-13. Using a lettering instrument.

the instrument for a particular letter height. The number aligned with the index on the outer section of the instrument indicates the height of the lettering in thirty-seconds of an inch. In figure 5-13, the number 8 is aligned with the index; therefore, the distance between the capital letter guides produced by this setting is 8/32 inch or 1/4 inch.

By standing the instrument on its greater sloping side, you can use it for drawing guidelines which slope at an angle of 67½° with the horizontal (see the upper-right portion of figure 5-13). Of course, you can always use a triangle and T-square to draw these lines if a lettering instrument is not available. The setup of the triangle and T-square is shown in figure 5-14.

Spacing. It is so important to obtain uniform spacing in lettering that we will discuss the principles of spacing as a separate topic.

Exercises (051):

1. What are the three principles that must be considered in the design of good lettering?

2. Which of the three principles is considered the most important?

5-4. Principles of Spacing

Since we see things that are close together as a unit rather than single items, the letters making up the text of a page of lettering appear to us as words rather than individual letters. If it were not for the spaces between words, this would not be so. Without these spaces, we would see only lines of lettering which would be almost impossible to read. Improper spacing between letters of words produces a like effect by breaking up words into groups of letters without meaning. Therefore, we can conclude that proper spacing of letters and words does more for the appearance and legibility of a block of lettering than the forms of the letters themselves.

Since the letters of the alphabet vary in shape, the letters in words cannot be spaced at a uniform distance from each other. They

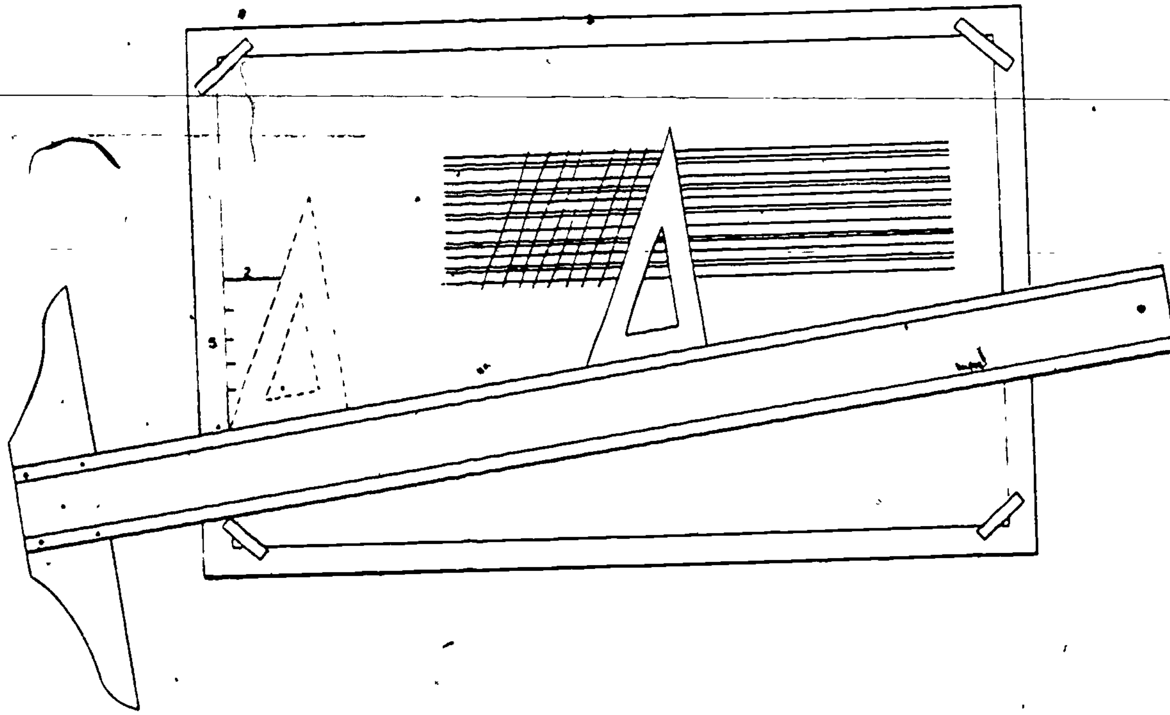

Figure 5-14. Drawing directional guidelines for inclined letters.

are arranged so that the areas of white space (the irregular backgrounds between the letters) are approximately equal. Each letter is spaced with reference to its shape and the shape of the letter preceding it. Adjacent letters with straight sides are spaced farther apart than those with curved sides. Sometimes combinations such as LT or AV may even overlap. Definite rules for spacing are not successful; it is more a matter of judgment and sense of design.

052. Answer three questions about good spacing.

Spacing Between Letters. Let us use the lettering in figure 5-15 to go over some of the important details of spacing. Lettering will form words more successfully if the area of spaces between the letters is equal to the area inside the letters. For example, look at the first two lines of figure 5-15. In the top line, after eliminating the area occupied by the diagonal line of the N, we divided the area between any two parallel sides into three equal parts. We used these divisions to arrive at the desired spacing between the N and the I, between the I and the N, etc. Since the spaces between the letters and within the letter appear to be equal to each other, the letters are seen together as one word.

Figure 5-15. Spacing between capital letters.

SPACES BETWEEN WORDS SHOULD BE EQUAL TO THE WIDTH OF THE LETTER O.

Figure 5-16. Spacing between words.

Look what happens in the second line. Notice that the letters are still the same three measured units apart, but because the round letter O does not occupy the full area of a straight-sided letter, the area between the N and O appears much larger than the area between the N and E. When we reduce the distance between the N and O to two units, as shown in the third line, the spaces appear equal. Notice how much better the letters form the word NONE in the third line than they do in the second line. Reducing the distance between two round letters to one measured unit, as shown in the fourth line, produces the same effect.

The spacing of letters that have odd outlines deserves special consideration. When certain of these letters follow one another in a word, obtaining good spacing between them is no problem. The easily spaced combinations are shown in the fifth line of figure 5-15. The design of these letters even permits overlapping to obtain the desired spacing. The combinations shown in the last line of figure 5-15 present a more difficult problem of spacing. In fact, you may have to shorten the horizontal stroke of some letters to obtain good spacing. For instance, the cross stroke of the L and T can be shortened to obtain better spacing between an LA or a YT combinations. As we said before, it is a matter of using good judgment rather than a set rule.

Spacing Between Words. The spacing between words is as important as the spacing between letters of words. There must be enough space to separate letters into words, but the space cannot be so large that it tends to force us to read one word at a time. A good general principle to follow is stated in figure 5-16. Some letterers like to use the letter N for this purpose, and others obtain correct spacing by sketching in a correctly spaced letter I. Using the O is much easier and quicker, since you need to make only a circular movement above the paper next to the last letter of the word.

Naturally, the design of the last letter of a word and of the first letter of the following word must be considered in determining the amount of space you leave between words. You should leave a space equal to a capital O between two full-height, straight-stemmed letters, such as *H* and *E*, or *d* and *b*. Of course, if one or both of the letters are curved, the space should be appropriately reduced. If the two letters involved are lowercase letters, use the lowercase letter o to determine the width of the space. If one letter is full height and the other in lowercase letters are waist high, such as in the words "*bid now*" or "*on him*," the space would be equal to half a capital O and half a lowercase o.

Spacing Between Lines. The clear distance between lines may vary from 1/2 to 1½ times the height of the letter, but for sake of appearance it should not be exactly the same as the letter height. The lettering instrument provides spacing that is two-thirds of the letter height. As you can see in figure 5-17, this spacing allows room for descenders of lowercase letters and still maintains a clear space of 1/3 letter height between the descenders and capital letters, or ascenders of lowercase letters of the following line.

Centering. Since the letters of an alphabet vary in width, it is rather difficult to center a line of lettering in a given area. Ending a line of lettering at a particular point is equally difficult. Figure 5-18 shows one way of solving this problem. First, take a piece of scratch paper and letter the required line. Then, place this line of lettering above the area in which your lettering is to go and center it. Finally, use the sample as a guide to lettering the desired line.

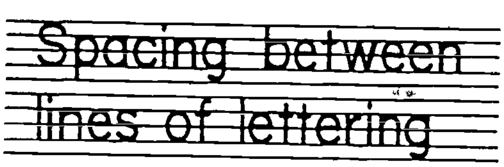

Figure 5-17. Spacing between lines.

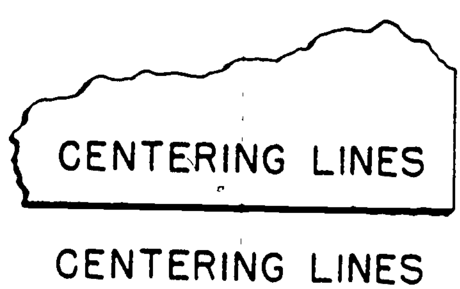

Figure 5-18. Centering a line of lettering.

Exercises (052):

1. When lettering, why must you vary the width of the spaces between letters?

2. What, if any, is the difference in the width of the space between the words "send by" and the words "go by"?

3. How many guidelines should you use for each line of lowercase lettering?

5-5. Lettering Tools and Their Use

As mentioned before, the trend in lettering is toward simplification and speed of production, and the style of lettering is influenced by the tools used to produce it. Therefore, let us discuss some of the tools of lettering and their uses.

053. List characteristics of good penciling, and of good pencil-holding technique.

Pencils. Good pencil technique is as essential in lettering as in drawing. The quality of lettering is important, whether it appears on finished work to be reproduced by one of the printing processes or as part of a pencil drawing to be inked. Penciling must be clean, firm, and opaque. The lettering pencil should be selected carefully by trying it out on the paper. In one instance, the same grade of pencil may be chosen as that used for the drawing; in another, a grade or two softer may be preferred. You should sharpen the pencil to a long, conical point and then round the lead slightly on the end so that it is not as sharp as a point used for drawing.

The first requirement in lettering is holding the pencil or pen correctly and comfortably. Place the thumb, forefinger, and second finger on alternate flat sides and rest the third and fourth fingers on the paper. Draw vertical, slanting, and curved strokes with a steady, even finger movement. Draw horizontal strokes with similar movements, but with some pivoting of the hand at the wrist. Exert pressure that is firm and uniform but not so heavy as to cut grooves in the paper. To keep the point symmetrical, form the habit of rotating the pencil after every few strokes.

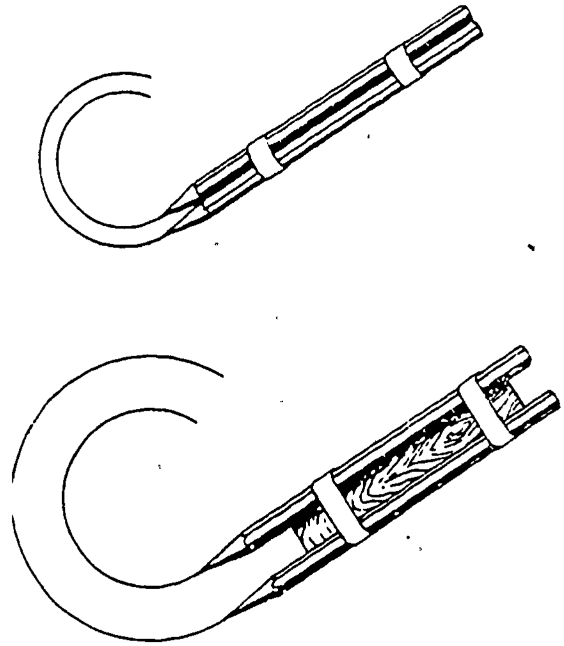

Figure 5-19. Use of double pencils.

Pencils may be used in pairs when you need large, thick letters such as those used on posters. By taping the pencils together as shown in figure 5-19, you can draw both edges of the letter at the same time. You can maintain the same thickness throughout the stroke by keeping the two points perpendicular to the stroke. By keeping the points parallel to the line of lettering, you can use the double pencils to form thin and thick strokes. The same technique can be used with a pencil which has a broad, flat lead. These broad lead pencils are very useful in layout work where you need to see the effect produced by certain types of lettering.

Exercises (053):

1. Penciling must be ________, ________, and ________.

2. What is the first requirement in lettering?

054. List some of the types of lettering pens.

Lettering Pens. There are many steel writing pens that are adaptable to or made

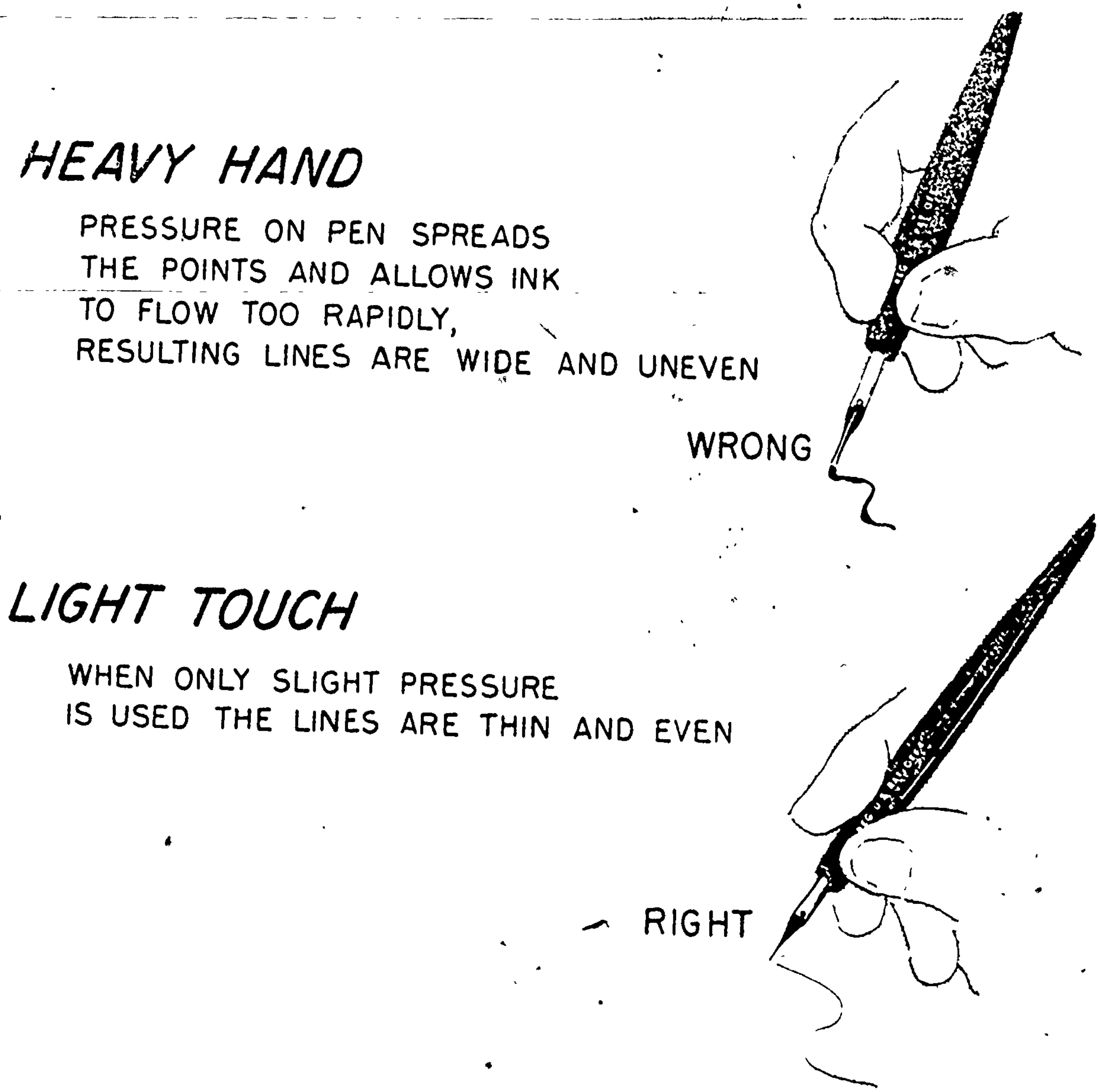

Figure 5-20. Using a lettering pen.

especially for lettering. The size of the strokes made by these pens varies with the make and number of the pen. They are used principally for average-size lettering on working drawings. Several special pens made in sets of graded sizes have been designed for single-stroke lettering and are particularly useful for large work. Among these are Barch-Payzant pens, speedball pens, technical fountain pens, and Leroy pens.

Common Lettering Pens. Some pens are equipped with an ink-holding reservoir which eliminates the problem of frequent refilling. A similar device can be made by bending a brass strip from a paper fastener, a strip cut from a piece of shim brace, or a strip cut from a thin aluminum pie plate. This strip is inserted in the penholder so that the curved end touches the pen nib at a point just below the eye.

There are several things to remember about the care and use of lettering pens:

- A new pen should be wet and wiped thoroughly to remove the oil film.
- A lettering pen well broken in by use is worth more than a new one. It should be kept with care and never lent.
- A pen that has been dipped into writing ink should never be put into drawing ink.
- When in use, a pen should be wiped clean frequently with a cloth penwiper.
- A pen should be cleaned thoroughly before it is put away.

Figure 5-21. Built-up letter.

To use a pen, set it firmly into a penholder. Many prefer to apply ink to the pen with the quill filler, toughing the quill to the underside of the penpoint rather than dipping the pen into the ink bottle. If you dip the pen, you should shake the surplus ink back into the bottle or touch the pen against the neck of the bottle as you withdraw it. Lettering with too much ink on the pen will likely result in blotting or bleeding, especially where two lines meet.

When lettering with a pen, hold the penholder firmly but without pinching (see the bottom illustration of fig. 5-20). Make the strokes of the letters with a steady, even motion and with a slight, uniform pressure on the paper that will not spread the nibs of the pen. Figure 5-20 shows the results of the right and wrong way of using the pen.

A light touch is extremely important when using a common lettering pen to make filled-in or built-up letters. As shown in the right illustration of figure 5-21, the tip of the pen should just barely touch the paper. Actually, it is better if the point is held so that it touches only the ink, because then it cannot pick up fiber from the paper. Here is how you should use the pen for this type of operation. First, apply a good supply of ink to the center of the stem. Then, use the point of the pen to push the ink out to the pencil outline of the letter as you move the pen back and forth through the supply of ink. Work the ink gradually along the entire side of the stem. Then turn the paper around and work the ink to the other edge. Never try to work the ink toward your hand; always work it away from your hand.

Technical Fountain Pens. Several manufacturers make technical fountain pens, which are very convenient for ink lettering and inking drawings. The advantage of these pens over ordinary pens is their great ink-holding capacity. A cutaway view of a typical technical fountain pen is shown in figure 5-22. Let us use this figure to learn a little about how this pen works. As you can see, the end cap can be unscrewed from the barrel of the pen to expose the plunger control knob. This knob is used to fill the pen. When you turn the knob, threads force the plunger down the cylinder of the barrel and force out any ink left in the reservoir. To fill the reservoir, place the point end of the pen into the ink and turn the control knob clockwise. As the plunger is pulled up through the cylinder, the suction pulls ink through the point to fill the reservoir. After you wipe the point clean and replace the end cap, the pen is ready for use.

Now let us look at the business end of the pen. The drawing does not show the details too clearly, so follow our explanation closely. The cleaning pin (you can see only the portion protruding from the cylindrical

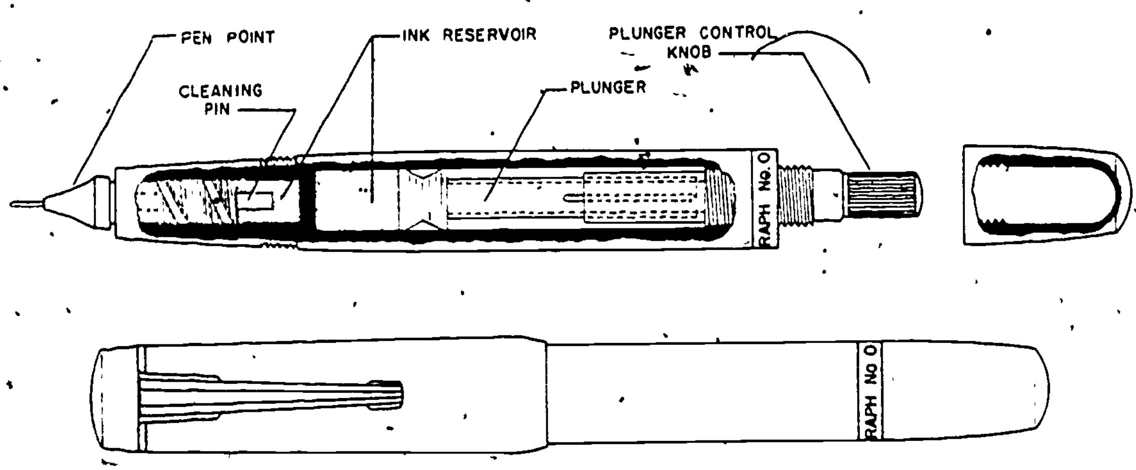

Figure 5-22. Technical fountain pen.

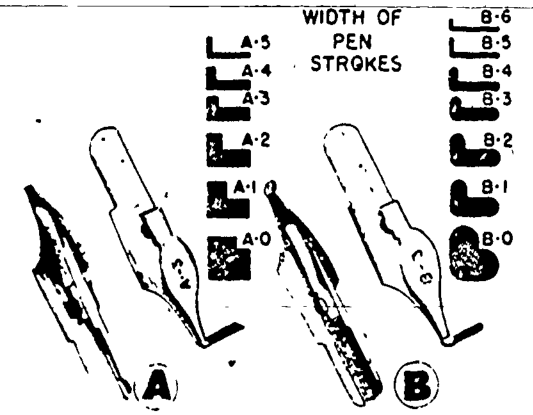

Figure 5-23. Speedball pens.

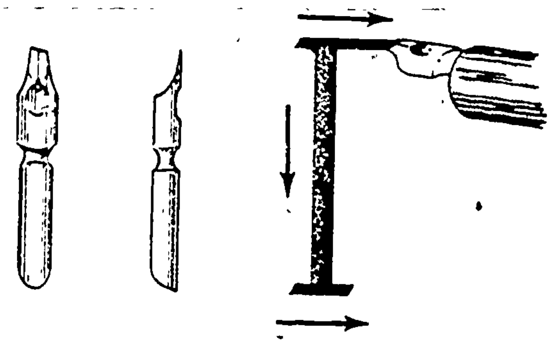

Figure 5-25. Text writer pen.

portion of the pen point) is free-floating. The thin, needlelike portion of the cleaning pin runs through the pen point and the hollow tip. As you shake the pen, the cleaning pin moves back and forth to clear the ink passageway. Notice the inclined grooves and hole in the outside surface of the cylindrical portion of the pen point. These allow the ink in the reservoir to enter the hollow passageway through the center of the point. The drawing at the bottom of the figure shows the pen fully assembled with its protective cap in place.

Some technical writing pens have a plastic cylindrical cup for an ink reservoir instead of the type we have just discussed. This cup fits over the end of the head of the pen. To fill the reservoir, you merely remove the cup, fill it with an eye dropper, and replace it.

When using the technical writing pen, you must hold it so that it is perpendicular to the paper at all times. If you don't, the point will wear on the edge, forming an elliptical writing surface. With the writing surface in this condition, the pen will not produce lines of a constant width.

Speedball Pens. These pens come in a variety of sizes and shapes identified by a letter and number. Figure 5-23 shows the A and B types of speedball pens. It also shows the width and shape of the strokes made by pens of different sizes. Notice that the nibs of the type A speedball pen form a flat, square writing surface, and that the strokes made by this type of pen have uniform width and square ends. The nibs of the type B pen form a round writing surface, and the strokes have uniform width and round ends. The nibs of the type C pen, shown in figure 5-24, form a chisel-shaped point which produces thin and thick strokes. Therefore, this type point can be used to make Roman style letters. The D-type speedball pen is similar to the B-type, except that the nibs are oval in shape. The letters produced by D-type pens have thin strokes which are only slightly thinner than the thick strokes.

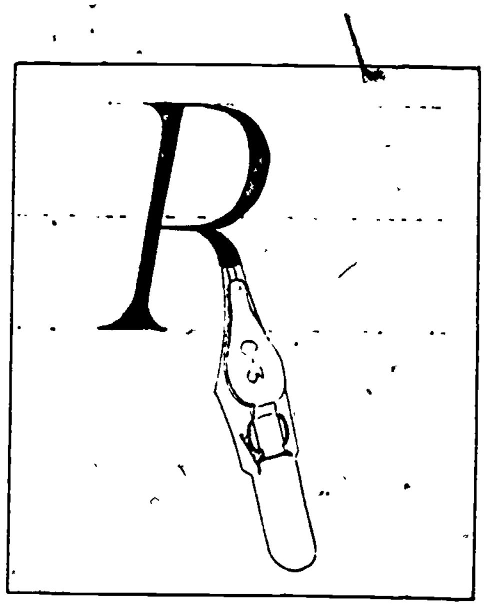

Figure 5-24. Using a speedball pen.

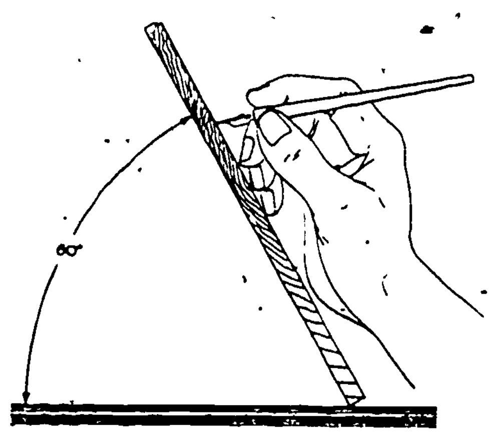

Figure 5-26. Angle of lettering surface and position of lettering pen.

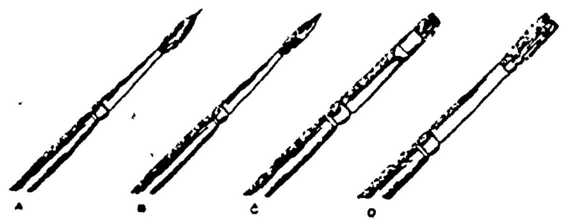

Figure 5-27. Brushes.

You probably noticed that speedball pens are equipped with a brass clip that serves as a well for the ink. Use the quill attached to the stopper of the ink bottle to fill the well and keep the outside of the nibs clean. Wipe the pen often with a piece of lintless cloth while you are working, and clean it carefully before you put it away.

Text writing pens. As you can see in figure 5-25, text writing pens are similar to type-C speedball pens. However, they are made of much thinner steel and therefore produce a much sharper stroke. They do not come equipped with an inkwell, but you can easily build one, as we described earlier in this chapter. Notice that the nibs of these pens are slanted so that they touch the paper when the pen is held in a natural writing position

You will find that both the position of the pen and the working surface are important when using either the text pen or speedball pen. The calligraphers of the Middle Ages worked with an angle of about 60°. At this angle, you see the letters in true size and shape; that is, you do not see them foreshortened. As you can see in figure 5-26, the position of the pen is almost horizontal when the writing surface is slanted 60°. This is important to the proper flow of ink. At this slight angle, the ink flows smoothly and is not as apt to flow excessively as it would at a steeper angle.

Exercises (054):

1. List four special pens used for single-stroke lettering.

2. Which is better, a pen well broken in from use or a new one?

3. Very briefly describe a speedball pen.

055. Describe lettering brushes and how they differ from other brushes.

Lettering Brushes. The hair and bristles used in the manufacture of brushes vary greatly in quality. Since the greatest element in brushmaking is skilled, expert workmanship, the best brushes are uncommon and expensive. The tips or points of brushes are the natural ends of the hair or

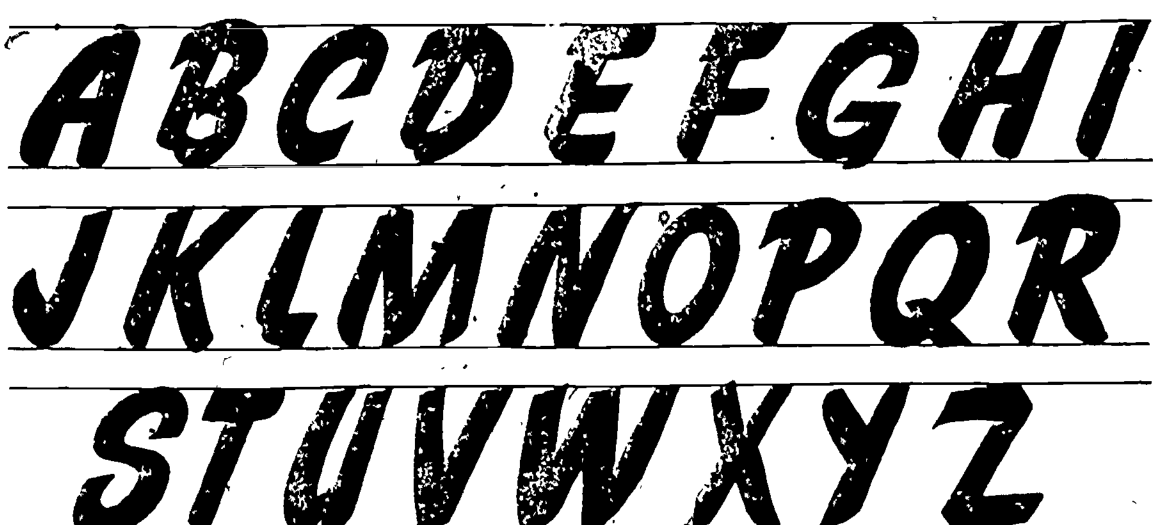

Figure 5-28. Brush lettering.

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bristle. They are never cut or trimmed. All shaping and trimming is done at the root end by skillful operations.

The best brushes are called red sable. The one source of hair for these brushes is the tail of the Kolinsky (known also as Siberian mink or red Tartar marten). No other hair has the same springiness, durability, and combination of desirable properties. This hair is delicately tapered; the tip is slender and comes to a fine point. Beyond its widest point, or "belly," the hair again tapers somewhat toward the boot. Some brushes are set so that the opening of the ferrule grips the belly; others are gripped above or below this point. The character of the brush varies according to the point at which the hairs are gripped.

The best brushes are shaped like brush B in figure 5-27. There must be no concavity between the tip and the belly. An exaggerated form of the concave tip is shown in brush A. Inferior brushes assume this "lemon-seed" shape when wet. Watercolor brushes may be examined by wetting them, shaking out the water, and shaping them gently with the fingers. Resiliency of hair and sharpness of point are apparent to the experienced user.

There are several other kinds of hairs used in brushes. Camel-hair brushes (actually made from nearly every kind of animal except camels; the best grades are made from squirrel tails) are too soft and do not have sufficient elasticity or "life" for average professional purposes. However, their floppy or moplike character makes them desirable for some manipulations. An inferior grade of sable is generally preferable to camel hair.

Brushes come in three major shapes—rounds, brights, and flats (see brushes B, C, and D in fig. 5-27). The rounds come to points which vary from fairly sharp to quite blunt. The brights are flat, have rather sharp corners, have less thickness of bristle, and their length is about 1½ times their width. The flats are broad with flattened ferrules and straight edges. The length is about 2½ times their width.

Showcard or tempera watercolor is usually used for brush lettering. You may use either a flat or round tipped brush. These come in different sizes for making different sizes of lettering. If you are fortunate enough to have red sable brushes, you should handle them carefully. Store them in a glass or jar, placing the handle down and the bristles up. In this position, the brush end does not rest against any surface, and there is less chance of the bristles becoming distorted. Always wash your brushes carefully and shape them before putting them away.

Lettering with a brush may be a little more difficult than with a pen. Before starting to letter, draw guidelines to define the top and bottom limits of the letters. Like single-stroke Gothic, the lettering will look more professional if each line of a letter is drawn with a single stroke. Mastering this will take considerable practice. Once you have learned the knack of handling the brush, you will find brush lettering satisfying and interesting. An alphabet of brushdrawn letters is shown in figure 5-28. Notice that to draw the letters as shown, you must turn the brush as you form the letters.

Exercises (055):

1. How does a lettering brush differ from other brushes?

2. What are the best brushes for lettering?

3. How often should a lettering brush be trimmed?

4. What are the three major brush shapes?

5. How do the three shapes of brushes differ?

5-6. Mechanical Lettering Sets

Because guidelines are not required, uniform and legible characters can be produced more rapidly by mechanical lettering sets than by freehand methods. Mechanical lettering is used principally for title blocks and marginal data for special maps, charts, graphs, and photographs for reproduction.

057. List the components of a mechanical lettering set.

Lettering Set. A standard lettering set consists of a set of templates, a scriber, and a

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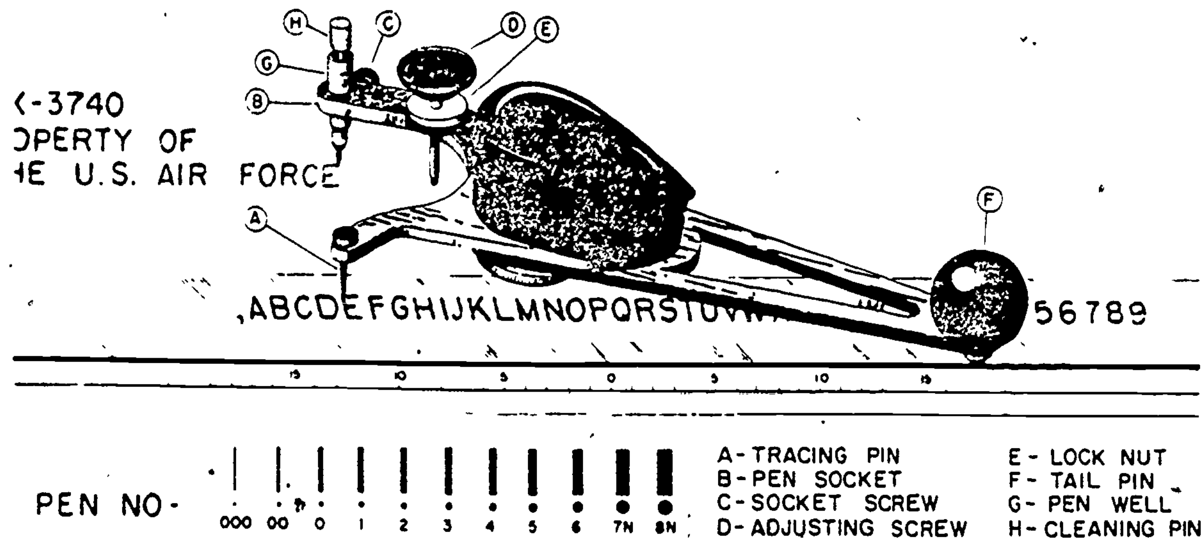

Figure 5-29. Mechanical lettering instrument.

set of pens. A typical setup is shown in figure 5-29. The templates are made of laminated plastic with characters engraved in the face so that their component lines are guide grooves for the scriber. The height of the characters, in thousandths of an inch, is given by a number on the upper righthand side of the template. The range of character heights offered by a standard set of templates is from 80 (0.08 inch, or 5/64 inch) to 500 (0.5 inch, or ½ inch). The scale at the bottom of each template has the zero in the center and is arranged for proper spacing in relation to character heights. The distance between consecutive scale divisions represents the area required by a normal letter.

A standard set of pens for producing various line weights consists of 11 sizes, ranging from 000, the finest, to 8N. Each pen is composed of two parts—the ink reservoir, or pen well, and the cleaning pin (see G and H, fig. 5-20). The reservoir is a series of connected tubes of decreasing diameters, the lowest establishing line thickness. The cleaning pin acts as a valve and protrudes beyond the edge of the bottom tube when the pen is not touching the drawing surface. In this position, the ink does not flow. When the pen is rested on a drawing surface, the cleaning pin is pushed up, allowing a flow of ink. Action of the pin in the tube minimizes ink clogging.

The scriber (see fig. 5-29) holds the pen in alignment and controls its motion as the tracing pin (A) is guided through the character grooves of the template, and the tailpin (F) riding in the straight groove of the template. Two types of scribers are available; one is adjustable and the other is fixed. An adjustable scriber produces vertical and inclined letters from a single template; a fixed scriber produces only vertical letters. Except for the locknut, the fixed scriber consists of the same components as the adjustable scriber. These are a tracing pin (A), pen socket (B), socket screw (C), adjusting screw (D), locknut (E), and tailpin (F).

The following table gives the recommended combinations of pens and templates. If a heavier line weight is required, do not use a pen more than two grades above the recommended size:

Template Number	*Pen Number*
80	00
100	00
120	0
140	1
175	2
200	3
240	3
290	4
350	4
425	5
500	6

The rules for freehand letter sizing and spacing apply to mechanical lettering. For blocks having more than one line of lettering, horizontal baselines may be drawn at intervals for the proper spacing between lines.

To center a line of lettering, the letters are arranged symmetrically about a vertical centerline. Here is how you do this. First, count the number of letters in the line, add one-half for spaces between words, and

Figure 5-30. Curving a line of lettering.

subtract one-half for each letter I. Select the template with letters of the desired size and place the zero of its scale on the vertical centerline. Mark the number of divisions equal to half the number of letters in the line, first to the left and then to the right of the zero. This indicates the starting and finishing points.

The procedure for using the mechanical lettering set follows:

- Loosen the socket screw.
- Select the appropriate template and the pen recommended for it.
- Insert the pen in the pen socket so that its shoulder seats up against the scriber arm, and tighten the socket screw.
- Loosen the adjusting screw locknut and fill the pen reservoir with drawing ink.
- With the template edge against a T-square, set the scriber tailpin in the straight groove of the template and the scriber tracing pin in the groove of the appropriate character.
- Using a piece of scrap paper for trial lines, regulate the adjusting screw until the cleaning pin is pushed far enough back to allow the ink to flow freely. If the pin is pushed back level with the end of the tube (that is, if no clearance is provided and the tube is allowed to rest against the drawing surface), ink will not flow smoothly. The amount of clearance varies with the consistency of the ink and the nature of the drawing surface. When trial lines are produced, tighten the adjusting screw locknut.
- Proceed with the lettering by moving the tracer pin in the desired character groove, but at the same time keep the tailpin in the straight groove. Spacing between letters and words is done by eye and involves the same considerations of equal letter areas as in freehand lettering.

Now let us go over the techniques that you should develop to use the lettering set properly. Hold the T-square in position with the ball of your left hand against the blade. Use the fingers of your left hand to hold the template against the working edge and to change the position of the template when necessary. Hold the scribe between the thumb and first three fingers of your right hand. You can rest your little finger either against the scriber or against the edge of the template.

The following are some important facts to remember when using a lettering pen:

- Keep the reservoir between ¼ and ¾ full; too low an ink level results in irregular lines.
- When the pen is filled and not in use, place it so that the tip is not in contact with any surface.
- Before you reuse the pen, twirl the cleaning pin in the tube to loosen any clotted ink.
- Never use pressure on the scriber if the ink does not flow.
- Check the adjusting screw setting and the reservoir level.
- To make fractions, use a template one size smaller than that used for whole numbers.

Maintenance of lettering pens is simple. You should clean the pens with running water and store them in their containers. If water

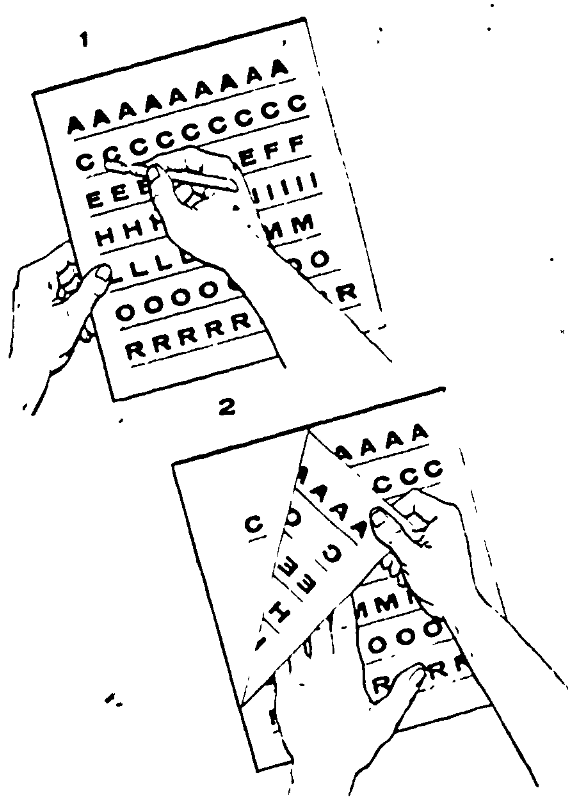

Figure 5-31. Using lettering sheet.

does not clean the pen satisfactorily, use a diluted solution of ammonia. Handle cleaning pins with care because they are fragile and bend easily.

Exercises (056):

1. What are the standard components of a mechanical lettering set?

2. How many pens are there in a set?

3. What is a tailpen?

5-7. Prepared Lettering

For our final discussion on lettering, let us take up the use of type or other prepared print as a means of obtaining lettering for illustrative purposes. The disadvantage of using printed lettering is that the type used to print the lettering must be handset. This is necessary to obtain good spacing, since machine type setting spaces all letters equally. You can observe this poor spacing technique in newspaper headlines, especially, when words containing irregular-shaped letters are used. Another limiting factor in using type for lettering purposes is its inaccessibility. Not many organizations are fortunate enough to have ready access to a printing press. However, most organizations do have photocomposing machines which produce type-like lettering.

057. List two advantages of using prepared lettering.

Lettering Procedure. Prepared lettering can be used as it comes from the press or printing machine by merely cutting it out of the printed page and pasting it in place on your drawing or layout. It can be changed from a straight line of lettering by the method shown in figure 5-30.

The following procedure is used to change a straight line of prepared lettering into a curved line:

- Draw a curved line where you want the lettering to go.
- Cut the line of lettering from the page of print, making sure that the cut edges are parallel to the top and bottom edges of the line of lettering.
- Draw another line parallel to the first line at a distance equal to the distance between the bottom edge of the lettering and the cut edge of the strip. (If the line of lettering is to be curved opposite from that shown in fig. 5-30, this line should be above the first line.)
- Using a sharp knife or razor blade, make cuts in the strip of lettering between letters. Be careful to leave a small portion of the strip uncut.
- Apply rubber cement to the back of the strip and to the surface of the paper to which the strip is to be attached.
- Center the strip on the midpoint of the curve and align the edge of the strip with the curved parallel line.
- Being careful not to let the strip touch the paper except at the point of alignment (you may have to insert two pieces of tracing paper edge-to-edge between the strip and paper, and peel or slide them back as you go), use the point of an Exacto knife to bend the strip until the bottom edge is aligned along the parallel line. You should start at the center and gradually work toward the ends. As you get each portion of the strip aligned, apply pressure to that portion so that it will adhere to the paper.
- When you get the strip completely aligned, white around the edges of the strip to eliminate shadows.

Lettering Sheets. When only a few letters or words are needed on a drawing or layout, lettering sheets can be used to great advantage. A large collection of alphabets, numbers, symbols, etc., in various sizes and styles is available under different trade names. These can be applied directly to the finished artwork. The characters are printed on cellophane or acetate sheets with a waxed back and are easily transferred to any smooth surface. You merely position the sheet over the drawing so that the letter to be transferred is correctly positioned, rub the area over the letter, using a glass or plastic burnishing rod, and lift the sheet from the drawing. The letter remains adhered to the paper. This process is shown in figure 5-31.

You must be careful when burnishing a letter that you do not rub over a letter previously transferred. If you do, the letter or part of it will be transferred back to the lettering sheet.

Exercise (057):

1. List two advantages of prepared lettering.

60

Techniques of Line and Tone Media

ONE OF THE PROBLEMS confronting you is that of deciding which medium and technique to use when producing a particular illustration. The term "media" refers to the material with which you work, such as pencil, pen and ink, tempera, etc. The term "technique" refers to the method of handling the materials to achieve the desired effect. Most of the time the ultimate use of a piece of art work determines how you will proceed. One would not spend a great deal of time and effort on an illustration that will only be used once. The technique on such an illustration must be adequate to get the job done. As you develop the skill of handling basic techniques, you will develop a style of expression unique to you alone.

The discussion will be on the techniques used in line and tone media. Line and tone are the two main classifications of such media.

6-1. Line Media

Line media include illustrations that are composed entirely of black and white areas. This means that there are no intermediate values of gray. For example, this page may be considered as being created in the line media—since only values of black and white are used to produce it. It is composed entirely of black letter shapes against the white background of the page. Notice that even though only black and white are used, a gray tone is produced if you consider the entire column of type as a whole. This effect can be used in line media illustrations.

Illustrations which contain varying values of gray in addition to black and white fall into the group identified as tone media. The grays in this media may vary continuously from black to white.

058. Answer four questions about the common media and techniques associated with line drawing.

Line Drawing. Many media can be used to render illustrations. Any substance which achieves the desired effect can be used. However, for illustrations which must be reproduced, preserved, and executed quickly and economically, the number of media is sharply limited. Since illustrations in line media generally fit into this category, there are only a few types of line media. Among these media are ink, pencil, crayon, shading sheets, and special surfaced paper.

Pen and Ink. All of the techniques that use ink as a medium depend on the opacity of the ink and its capacity to contrast sharply with the illustration surface. India ink is most commonly used because it is permanent, waterproof, opaque, and nonreflective. The ink is applied with open or closed reservoir-type pens and dip pens which come in a variety of points. A few of the most common types of pens are shown in figure 6-1. Descriptions of these pens and their uses are given below:

- A croquill is a small cylindrically shaped pen and is very flexible. This type of pen is used to produce very fine or very thick lines. The weight of the line is determined by the amount of pressure applied to the drawing surface.
- Quills are large feathers from a goose or turkey, which are shaped and used as pens. They produce a very flexible line that may vary from thin to very thick.
- Artist pens are available in a variety of sizes in degrees of flexibility. Some are very flexible and are used to draw very thin or very thick lines. Others are stiff and are used where a variety in line width is not desired.
- Lettering pens are available in many different sizes and four different shapes. The four shapes are round, oval, square, and chiseledge.
- Ruling pens are used to produce straight lines of uniform width when used with a straightedge and curved lines when used with an irregular curve.

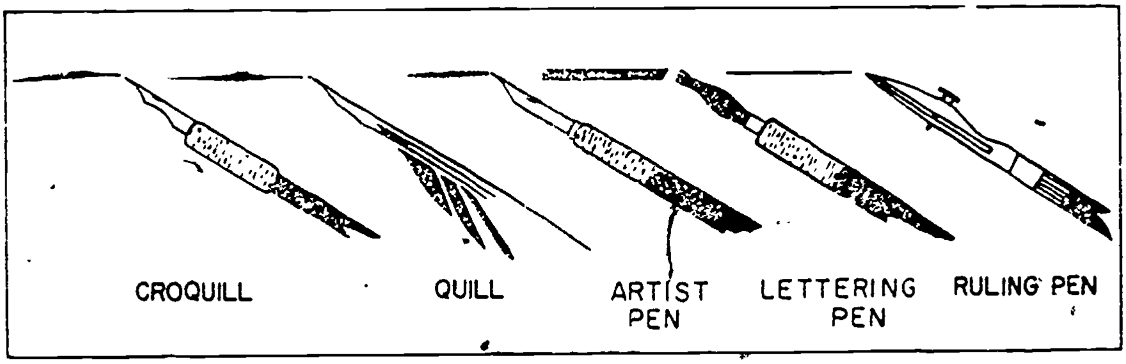

Figure 6-1. Typical drawing pens.

Outline rendering. The technique of outline rendering is relatively simple, yet it is not mastered without considerable practice. Outline drawings in ink should be clear, sharp, and of consistent density and width. The quality of a pen line is affected by many conditions and practices. The pressure on the pen, the smoothness with which the stroke is begun and ended, the evenness of ink flow, and the condition of the illustration surface affect the line. The angle at which the pen is held, the retracing of lines, and the number of times the pen is removed from and replaced on the illustration surface affect the quality of the inked line. The degree of pen pressure determines to some extent the width of the

Figure 6-2. Pen and ink illustration by outline technique.

Figure 6-3. Pen and ink illustration by accentuated outline technique.

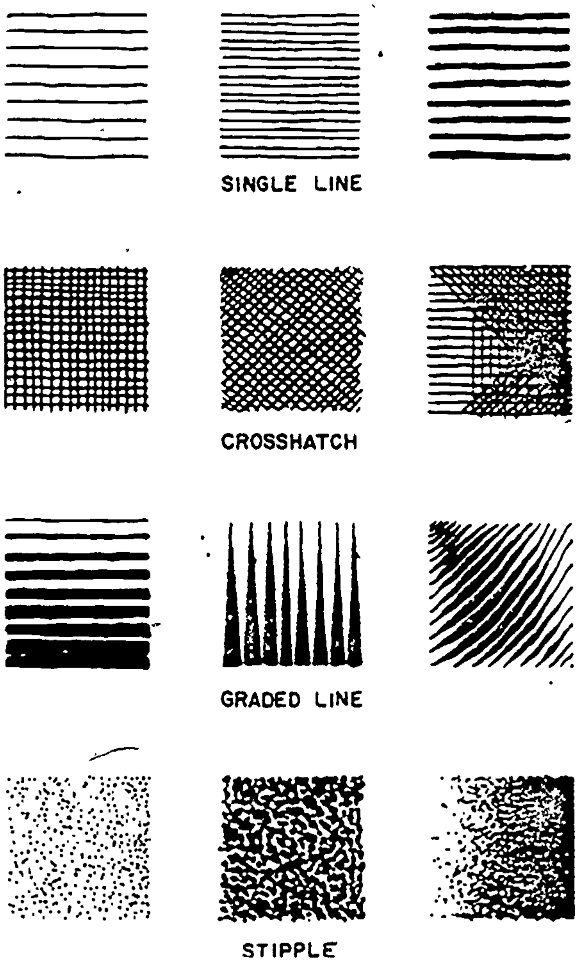

Figure 6-4. Examples of tone and shading by line technique.

at which the pen is held also affects the width and consistency of the line and the evenness of the ink flow. The number of times that the pen is lifted and replaced and the amount of retracing that is done affects the consistency and sharpness of the line. Pen strokes which are not smooth or which stop and start with uneven pressure will give uneven, rough lines.

Requisites of good pen and ink technique are that the lines be solid black, free of feathered or bleeding edges, and consistent in width and that adjacent lines join without irregularities, breaks, or overruns. An example of outline drawing is shown in figure 6-2. This figure shows the characteristics of outline drawing.

One of the important characteristics of outline drawing is the ability to remain two dimensional. Notice in figure 6-2 that the illustration remains flat even though it shows an airman in amplified perspective which would normally give the impression of three dimensions. This is an important feature to remember, especially when you include a human figure in an illustration and wish to have it remain subordinate to other parts of the illustration.

When you wish to give more three dimensional qualities to an outline drawing, you can use an accentuated line technique. This technique is shown in figure 6-3. Notice how varying the width of the line gives this illustration a feeling of three dimensions. That is, the figure of the airman seems to stand out from the background of the page. This feature is quite apparent when you compare the illustrations of figures 6-2 and 6-3.

Line rendering of tone. Drawing tone or shade by means of line is an extension of outline drawing. The effect of tone or shade can be produced by drawing a series of parallel lines. Some of the tonal effects that can be achieved by line are shown in figure 6-4. To give the effect of flat tone, the lines must be parallel, equally spaced, and uniform in width. Darker tones may be produced by either placing the lines closer together or by using thicker lines. Of course, each technique produces an effect that is quite different from the other. Combining the two techniques (that is, using a greater number of thick lines) produces still darker tones.

An entirely different tonal effect is produced when two series of parallel lines are crossed. This technique is called crosshatching. The lines may cross perpendicular to each other or at any angle. However, each technique produces a different effect. The direction in which the lines are drawn also affects the appearance of the crosshatching. Notice the difference in the effect of the examples shown in figure 6-4 when perpendicular crosshatching is drawn in horizontal and vertical directions rather than when drawn in diagonal directions. Also notice in figure 6-4 that darker tones are obtained by drawing additional lines in a different direction.

The use of graded lines is another technique of pen and ink medium. This technique uses lines of varying width to produce the effect of tone or shade. Three different methods of obtaining tone are shown in figure 6-4. One method uses lines of various thickness to show gradation from light to dark. Another method uses lines which vary from thin to thick. The final example shows the effect obtained by varying the pressure on a very flexible pen.

The bottom three examples of pen and ink technique shown in figure 6-4 present an

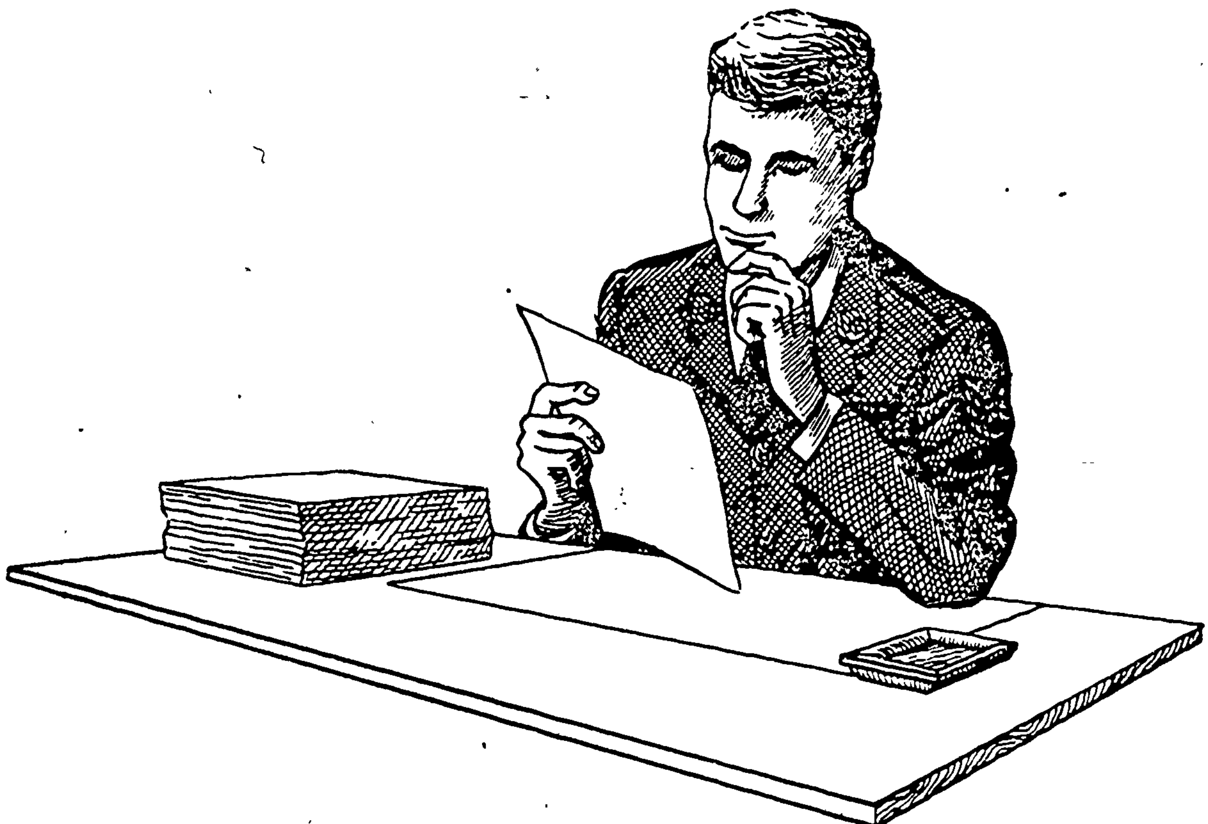

Figure 6-5. Pen and ink illustrations showing tone and shading by line technique.

entirely different quality of tone. Here the lines are so short that they appear as dots. The dots are distributed at random until the desired tone is obtained. As you can see, the stipple technique not only gives a tonal effect but also suggests texture.

Now let's see how these line-tone techniques can be used in illustrations. Figure 6-5 shows the use of line as shade to give the face and hands of the figure portrayed a feeling of form. It also shows how crosshatching can be used to represent the value of a material that has a definite color.

Figure 6-6 illustrates the use of graded lines. Here graded lines are not only used to give the subject of the illustration form but are also used to add character to the subject. The same technique could not be used for the subject portrayed in figure 6-7. The subject in figure 6-7 calls for a soft, more delicate touch. Notice, however, that the lines in both illustrations are applied to the form of the subjects. They follow the contour of the form.

Notice how effectively the stipple technique is used in figure 6-8. Not only is the form of the molded parts portrayed, but shadow and texture are also represented. Where the parts are machined, a line technique gives a smooth, flat representation.

Brush and ink. Some illustrators prefer to apply ink to an illustration with brush rather than a pen. This method is very adaptable to accentuated line techniques and to large solid areas of black. India ink is very hard on sable brushes; therefore, you should not use your best brushes for this type of work. Be sure to clean your brush thoroughly after using it with ink.

A brush can be used for other purposes than drawing lines. Ink, lampblack, and black tempera paint can be applied with a dry brush technique. This technique consists of applying the media in a rather thick state. That is, the media is almost dry. The application of this technique is illustrated in figure 6-9.

To apply ink or another medium by the dry brush method, you dip your brush into the medium, spread the hairs apart by pressing the brush down on a palette or piece of scratch paper and then rotating the brush slightly, lightly wipe off the excess medium on a blotter or piece of paper, and then drag the tips of the hairs across the drawing paper.

Figure 6-6. Pen and ink illustration by graded line technique

You should use an upward motion at the end of the stroke. Figure 6-10 shows a typical example of an illustration drawn with the dry brush technique.

Exercises (058):

1. On what two qualities do all techniques using ink depend?

2. What type pen has the ability to produce a very fine or very bold line?

3. Outline drawings in ink should be ________, ________ and of ________ density and width.

4. What is the technique called when two series of parallel lines are crossed?

Figure 6-7. Pen and ink illustration by crosshatch technique.

059. In one word, describe the best surface for producing a line drawing.

Pencil and Crayon. Lithographic, carbon, or other types of black pencil and crayon can be used with the same line techniques as those used with pen and ink. However, since the lines produced by these media are not as sharp and do not have the contrast that ink lines have, a different technique is usually used in a line media illustration produced with pencil or crayon. The drawing is applied to a textured surface. Figure 6-11 shows the principle of application.

The paper on which the sample techniques of figure 6-11 were originally drawn has a special surface. The paper is not only textured with a chalky surface but the texture has a definite pattern. In the top example, pencil was applied to a solid area and a knife was used to scrape away part of the top surface. This technique gives a pattern of white on black. A black on white pattern, as shown in the middle example, is produced by moving a pencil or crayon lightly over the surface. The side of the pencil or crayon is used, and the action is continued until the desired value is obtained. As you can see, in the bottom example, a graduation of value from light to dark can be obtained by continuing the process and by gradually increasing the pressure applied to the medium until the surface of the darkest area is entirely covered.

The black on white technique can be used on any rough or grained surface. The illustration shown in figure 6-12 is an example. The results are satisfactory as long as only the high parts of the surface are covered.

Exercise (059):

1. To be classified as a line media illustration, a pencil or crayon drawing is usually produced on what type of surface?

060. List the types and some special features of prepared shading media.

Prepared Shading Media. Although prepared shading sheets are not used to render a complete illustration, they are often used as a timesaving device and for special effects. Two different types of shading sheets are available—the transparent film patterns and tones and the chemical development patterns and screens.

Chemical developed shading media. The chemical development shading medium consists of papers and boards that contain invisible patterns and screens which are made visible by the application of chemicals. The process is simple. The invisible patterns or screens are brought out by applying a special colorless liquid by means of brush or pen. Both single-tone and double-tone patterns are

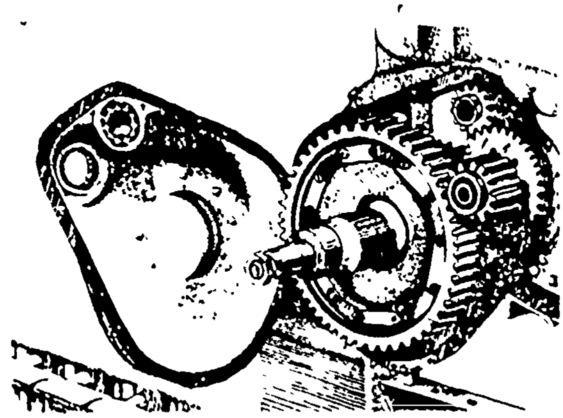

Figure 6-8. Pen and ink illustration by stipple technique.

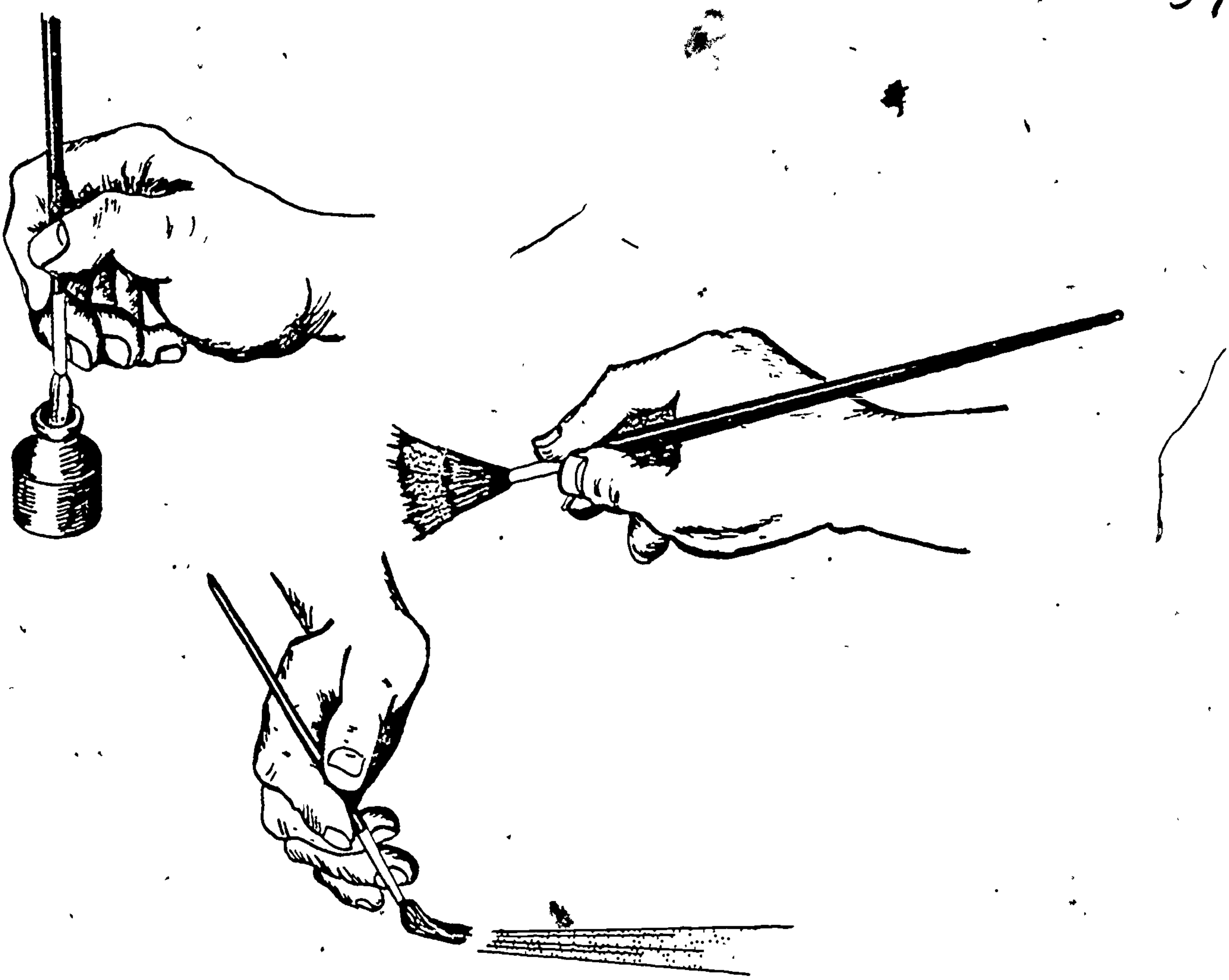

Figure 6-9. Dry brush application.

available. A sample of each type is shown in figure 6-13. The double-tone surface contains both light and dark tones which are developed with two different solutions.

The chemically developed method of obtaining tone is fairly fast and economical when compared with the same effect obtained with pen and ink. This technique is relatively simple and easy to master. An example of the effects achieved by this technique is shown in figure 6-14.

Transparent film patterns and tones. Transparent film patterns and tones are usually printed on clear cellulose acetate and may have an adhesive back. The film comes in a variety of line patterns for use in line rendering and for shading. Screens and tones are used to give a halftone rendering effect. Examples of both line and tone patterns are shown in figure 6-15.

Figure 6-15 shows how the transparent film is applied. First, cut off a piece of film large enough to cover the area where the line pattern is to be applied. Then, apply the film over the entire area, even including the intermediate areas where a line pattern is not desired. Now with a sharp knife, cut around the area where a pattern is not wanted and peel off the unwanted portion of the film. When cutting, be careful to cut only through the film and not to cut the surface of the illustration board. The film may not come off in one piece, because it tears easily. In our example, it has not been entirely removed from the subject.

Figure 6-15 shows the use of transparent film as a background. However, the media can be used as line rendering, as shown in figure 6-16. In this illustration, a film of one pattern is used to produce different tonal effects. To

Figure 6-10. Illustration by dry brush technique.

produce these effects, the entire area was covered with the original pattern. The additional pieces were applied to various smaller areas. These smaller pieces were applied over the original pattern but slightly offset from it. When the desired tone was obtained, the pieces were pressed into their permanent position.

Various patterns can be created by overlapping the same pattern or different patterns of transparent film. A few of the countless numbers of patterns that can be created in this manner are shown in figure 6-17.

Exercises (060):

1. What are the different types of prepared shading sheets?

2. What special feature does prepared shading media have that other shading techniques do not have?

3. How are unique patterns created with shading sheets?

061. List the advantages and disadvantages of using scratchboard.

Scratchboard. Another very versatile technique that uses ink as a medium is scratchboard. This technique uses a type of drawing board which has a chalky surface over which the ink is applied and then scratched off as necessary to show detail and highlights. This medium can present attractive, meticulously detailed and well-shaded line illustrations.

The scratchboard itself is basically a heavy illustration board covered with a deep chalklike coating. It is relatively non-absorbent, smooth, hard, and somewhat brittle. The scratchboard is not so brittle, however, that the surface chips or flakes uncontrollably when it is worked. The care required in preparing an illustration is one of

Figure 6-11. Drawing on texture board.

the major drawbacks of this technique. During and after preparation, the scratchboard illustration must not be allowed to become moist or oily. It is extremely susceptible to damage under these conditions. The ink is quite likely to chip if any attempt

Figure 6-12. Illustration on texture board.

is made to bend or roll the scratchboard. A sharp blow upon the back of the scratchboard or a dent made with a sharp object can ruin the illustration. Great care should be exercised in handling these illustrations throughout their life. Storage precautions must also be taken since scratchboard illustrations are adversely affected by changes in temperature and humidity.

The methods used in illustrating on scratchboard are shown in figure 6-18. Illustrations can be drawn with pen or brush, using stipple or line techniques similar to those described in the pen and ink section of this chapter. In addition, a thin layer of ink may be applied with a brush over a large area and then allowed to dry; a sharp instrument is used to scratch away the ink where a white line, dot, or area is desired.

Figure 6-19 shows some of the tools used in scratchboard illustrating. An Exacto knife with various shaped blades is a convenient and versatile tool. Sharp-pointed blades make excellent tools for scratching fine lines while those with flat or rounded edges are good for

Figure 6-13 Application of chemical developed shading sheets.

Figure 6-14. Chemical developed shading sheet illustration.

scraping off large areas. Multiple-line gravers are handy tools for making a series of narrowly spaced parallel lines. The effects of crosshatching with this tool are shown in figure 6-20. Of course, the same effect can be produced with a sharp-pointed tool by using a metal rule or T-square as a guide.

The methods of obtaining graded tones in line techniques are illustrated in figure 6-21. In the method shown on the left, a brush is used to apply a black area that comes to the midpoint of the area to be graded. Then the black tapered lines are added by using a ruling pen. Next, a sharp instrument in used to scratch out v-shaped lines. Finally, the centers of these wedges formed by the lines are removed with a curved-edge instrument.

The example on the right in figure 6-21 shows the scratch-out method of producing the same effect as shown on the left. In this method, equally spaced lines are first scratched in the area to be graded and the midpoints of the spaces are marked with a small dot at the edge of the black area. Then a sharp instrument is used to scratch out ruled lines between the ends of the lines and the dots. Finally, the wedgeshaped areas between the ruled lines are scraped away.

Figure 6-22 shows an example of an illustration produced in the scratchboard technique. Look for the different methods used to produce this illustration. As you can see, scratchboard is an excellent medium for rendering a predominantly dark object that has much detail and has sharp, white highlights.

Exercises (061):

1. In illustrating an object, in what way is scratchboard superior to other techniques?

2. What are the disadvantages of scratchboard?

6-2. Tone Media

Media used to produce illustrations that depict the characteristics of a subject in varying tones from white highlights to deep shadows are classified as tone media. These include pencil, crayon, charcoal, transparent wash, opaque paint, and airbrush.

062. State the properties of pencils in relation to tone.

Pencil, Crayon, and Charcoal. Pencil, crayon, charcoal, and other similar media are not ordinarily thought of as media for finished artwork. However, they are very useful both for the roughing in of ideas and for comprehensive layouts. Since the techniques of using these media are the same, we will discuss only the pencil medium.

In addition to lead or graphite pencils, others such as carbon and lithographic pencils are useful in illustrating. The lead pencil leaves a shiny surface, whereas a carbon pencil gives a mat finish, which has a much richer black.

As you learned in Chapter 4, lead is graded from the extremely hard to the very soft. The hardest lead produces a very light gray tone, while the tone varies progressively darker with each softer grade. This tonal effect is shown in figure 6-23, using three different grades of pencils.

Dark, mat-finished pencils come in various degrees of softness. All give an appearance of blackness when used on a paper with a slight

Figure 6-15. Application of transparent shading sheets

tooth, or texture, as compared with the gray effect of lead pencils.

Pencil can be used on any kind of paper stock, though a shiny paper does not take hard lead very well. A rough paper will naturally take the pencil on the higher ridges, resulting in a granular effect. This effect is shown in part A of figure 6-24. Where necessary, this effect can be altered by rubbing down the area with a paper stump or with the tip of a finger, as shown in part B. Darker tones can be added to a light area by going over the area with a softer pencil. Highlight can be brought out with a kneaded eraser, as shown in part C.

Figure 6-16 Transparent shading sheet illustration.

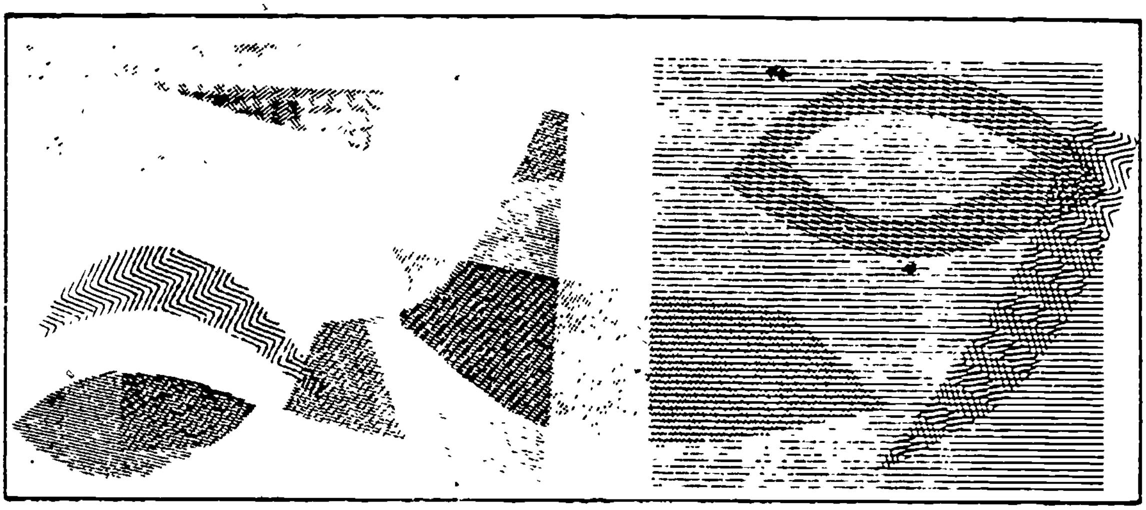

Figure 6-17. Overlapping transparent shading sheets to create different patterns.

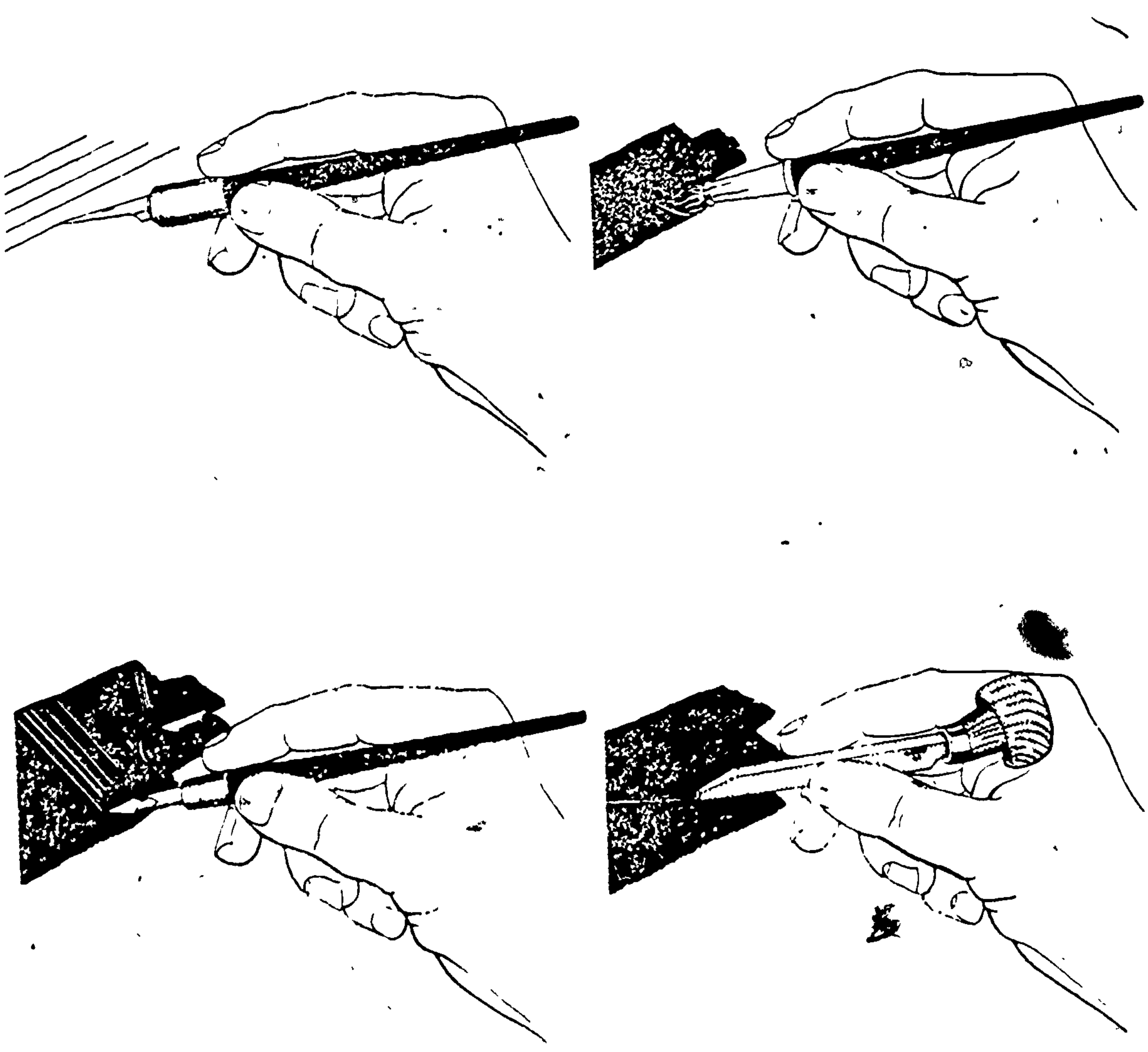

Figure 6-18. Scratchboard media technique

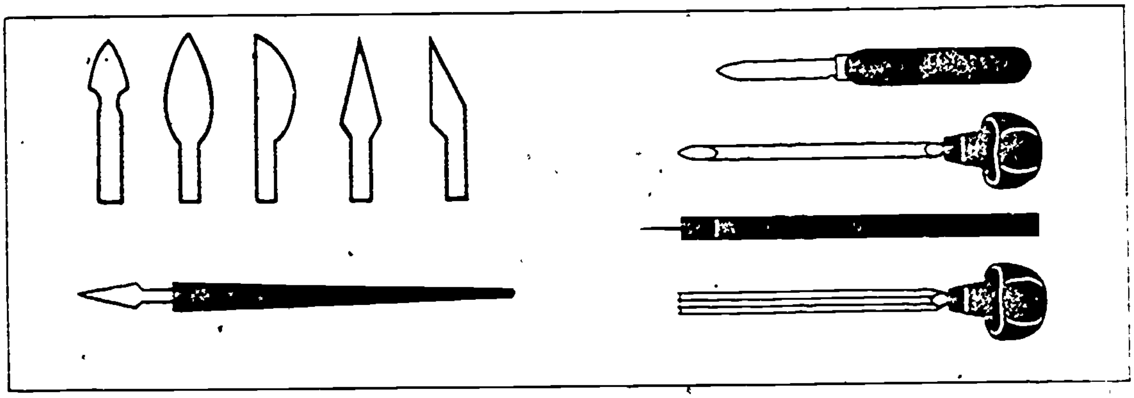

Figure 6-19. Scratchboard tools.

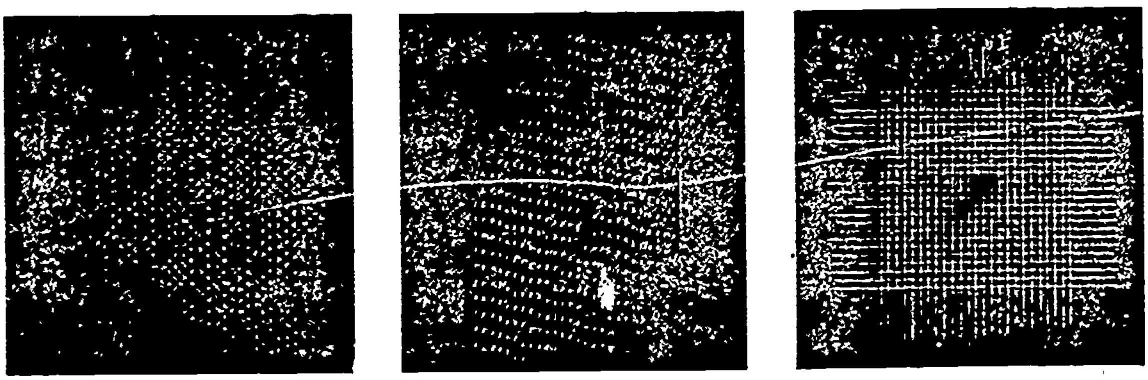

Figure 6-20. Scratchboard crosshatch effects.

When pencil is used on rough paper to cover only the high ridges, as in the illustration shown in figure 6-25, the illustration can be reproduced as a line cut. This is the printer's term for an illustration produced by a line technique. However, if the illustration is produced by rubbing or covering parts of the entire surface of the paper, as in figure 6-26, a halftone process of reproduction must be used to reproduce it. This is a process which reproduces the illustration by breaking the tones into tiny dots. Illustrations printed in newspapers are reproduced by this process.

Exercises (062):

1. What effect is produced by rubbing a pencil area with a paper stump or the tip of your finger?

2. How do lead or graphite pencils differ from carbon or lithographic pencils as they relate to the tonal media?

063. List the procedures for laying a wash.

Transparent Wash. Wash is a transparent watercolor made by diluting either lampblack, India ink, or Chinese stick ink. Lampblack is easiest to use, but India ink has the advantage

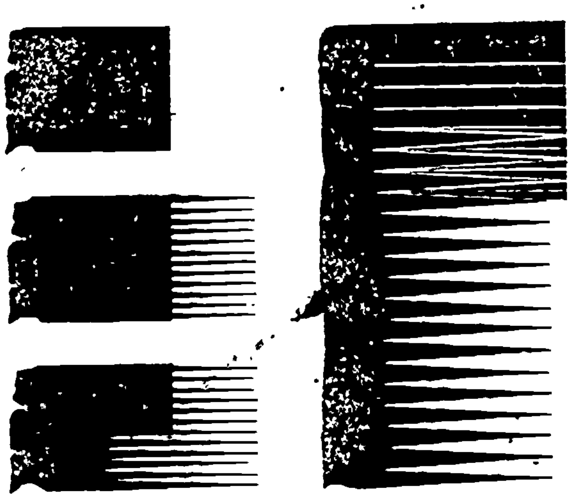

Figure 6-21. Scratchboard graded tone technique.

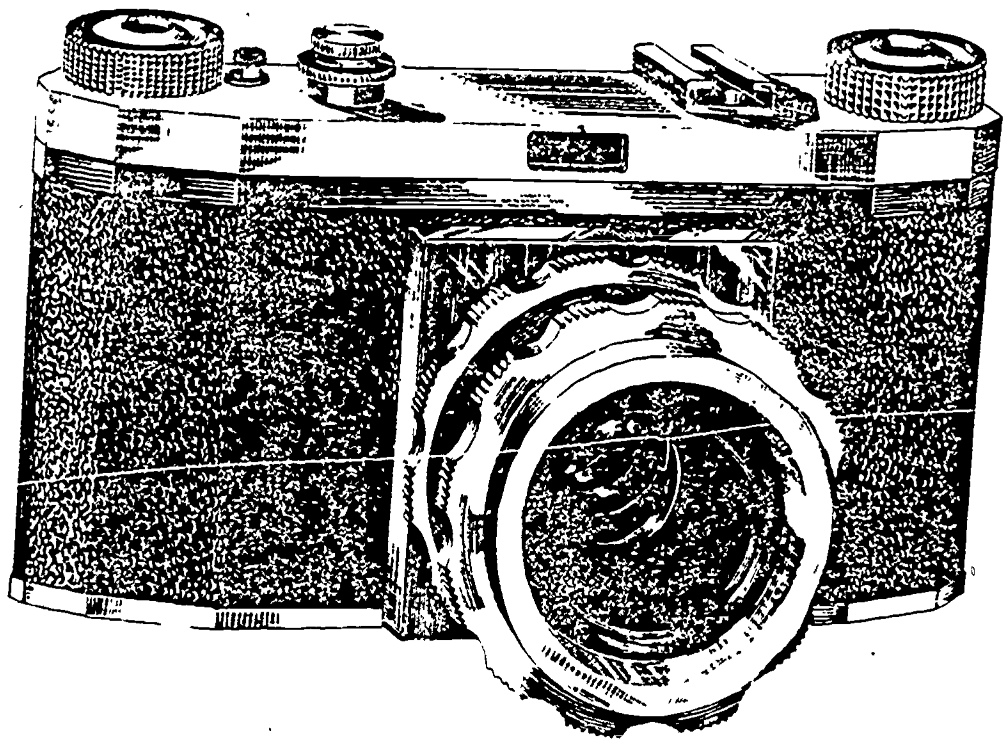

Figure 6-22. Scratchboard illustration.

of being waterproof, making it possible to lay one wash over another without picking up the one underneath. Chinese stick ink is prepared by rubbing the stick around in the porcelain dish with water until the desired amount is dissolved. This is strained through a wet cloth to get rid of any solid particles that may be left.

Wash is applied with round or flat red sable brushes. Thin wash (or ink) lines are drawn with a croquill pen or very small brush. After use, brushes should always be rinsed out in clean water, pointed up carefully, and laid flat where the hairs will not be disturbed. Brushes should be washed occasionally in warm water and a mild soap, rubbing the brush gently in the palm of the hand then rinsing it thoroughly in lukewarm water.

Flat wash. To lay a flat wash, the paper should be taped down to a drawing board, and the board should be tilted to about a 30° angle. The first step in laying a flat wash is to mix enough watercolor diluted to the desired value to cover the entire area over which the wash is to be laid. For best results, wet the area with clear water and allow it to dry until no moisture can be seen on the surface. Then load the brush with the watercolor. Starting at the top of the area, take an even, moderately fast stroke across the paper, holding the brush quite flat so that most of the hair touches the paper. The color is carried along at the heel of the brush, and a pool along the bottom edge of the stroke is formed. Remember that wash is floated on, not rubbed in. Upon reaching the end of the stroke, as shown in figure 6-27, bring the wash down without lifting the brush; then start back across the paper in the opposite direction, allowing a slight overlap with the previous stroke. This is continued over the area to be covered. Before the brush loses its pool of color, quickly dip it into the

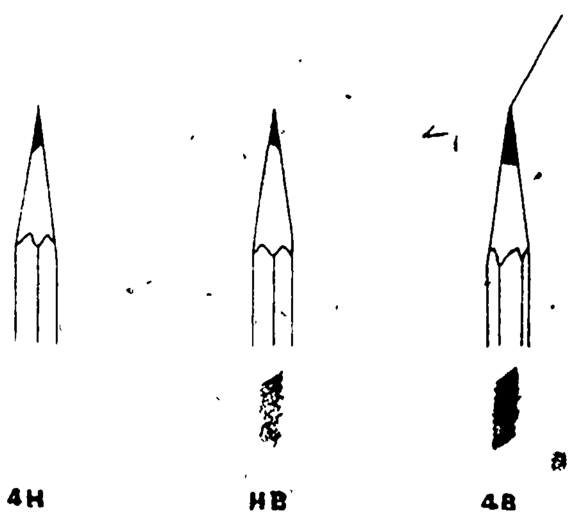

Figure 6-23. Effects of different grades of pencils.

A B C

Figure 6-24. Application of pencil technique.

watercolor previously mixed and continue the next stroke. When the wash is finished, the pool of color at the bottom is picked up by squeezing the brush dry and running the brush lightly over the pool of color. If this pool of color is not picked up, the color will settle and will form a dark line along the bottom of the washed area.

Graded wash. Laying a wash graded from dark to light value, like the one shown as part B of figure 6-27, is accomplished by starting out with the brush loaded with the dark tone and dipping it into clean water after every stroke or two, diluting the wash as you proceed.

A wash from light to dark can be accomplished in a similar manner. Starting out with clear water, you add a little color after each stroke.

Special techniques. Figure 6-28 shows some of the special effects of different wash techniques. The top example shows the technique of softening the edges of a wash. This can be done either on a wash applied on the surface of the paper, as shown, or on a wash applied over a previous wash. After laying the wash you rinse the brush out quickly in clean water and then drag the tip of the wet brush slowly across the edge of the still wet wash. The brush should be held flat so that the water wets the paper a short distance below the wash, allowing the color to run down into the wet area.

Very soft, fluid effects (characteristic of watercolor) can be obtained by working into a wet area. To produce example B, the paper was first moistened with clear water; then a light wash was applied while the area was still wet. When the wash was nearly dry, the spots were dapped in with a loaded brush. Working over wet paper increases the softness of the edges but also decreases the control of the wash. When the wash is dry, sharp, crisp accents can be added, as shown in example C.

When the wash must terminate in a very sharp, straightedge, masking tape is laid along the edge and the wash is brushed right up to it. Be sure that the wash does not collect along the tape; do not remove the tape until both the wash and tape are dry. A liquid masking medium or rubber cement can also be used as a mask over the area where you do not want wash. The results shown in example D of figure 6-28 were achieved in this manner. The advantage of using a mask is that the wash can be laid evenly over the entire area. After the wash is dry the masking medium is picked up, leaving the protected area without wash.

An example of a transparent wash illustration is shown in figure 6-29. Here the light washes were first laid down, then the darker areas were added, and finally the details were added along with the accents.

Exercises (063):

1. What is a wash illustration?

2. Why must a wash be started at the top of the illustration?

3. How are soft, fluid effects obtained in a transparent wash?

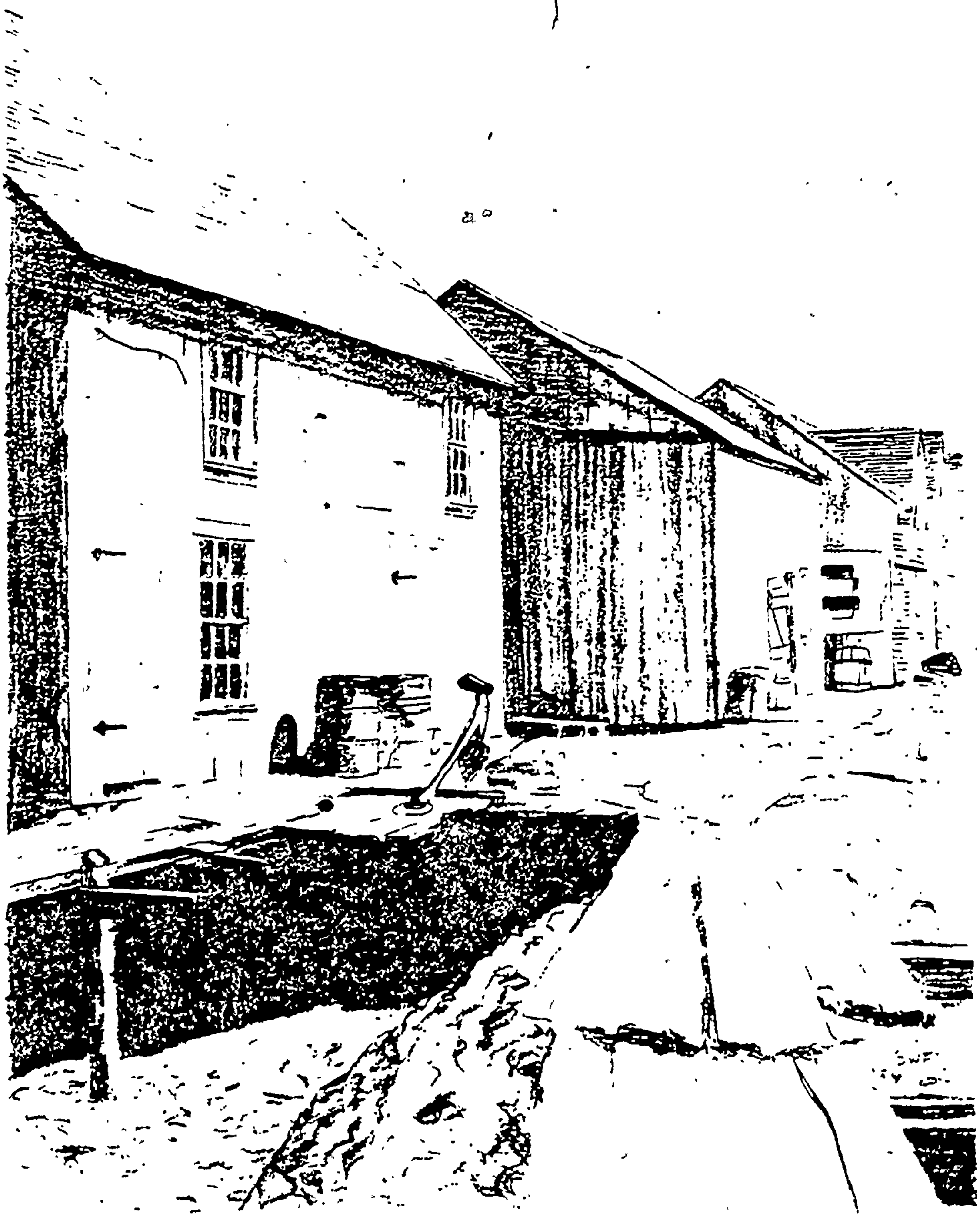

Figure 6-25. Pencil illustration for line cut.

Figure 6-26. Pencil illustration for halftone.

4. What is the easiest method of terminating a wash with a sharp, straightedge?

064. Name the two best techniques for using tempera watercolors.

Opaque Watercolor (Tempera). Tempera is often used for illustrating in flat tones, being particularly applicable to design and rendering. Although tempera is much harder to blend than transparent wash, it is much easier to apply in a flat tone.

Tempera is an opaque color which is a heavy, stiffer medium than transparent watercolor. An opaque color laid over any other color, either lighter or darker, covers and replaces the undercolor. Therefore, an illustration can be started with any value and worked up to lighter values or down to darker values. Example A in figure 6-30 shows this characteristic of opaque color. First, the larger area was covered with a medium gray tone; then the smaller area was painted on top. As you can see, the underpainted area is completely obliterated where the overpainting was done.

Opaque watercolor comes in all colors, plus black, white, and various premixed shades of gray. Although you can mix black and white paint to make any value of gray, it is not only more convenient to use the premixed grays, but it is more practical; thus, any gray can be matched by merely using the gray from the corresponding tube. These premixed grays are usually called retouch grays.

Painting techniques. Obtaining a flat area of uniform value with opaques presents no problem, because the color can be taken directly from the tube or mixed to the proper shade. The pigment is slightly diluted with water to the consistency of heavy cream and is applied smoothly to the paper with a brush. The brush should not be loaded too heavily with color. Proceed uniformly over the area in one direction, slightly overlapping each stroke without leaving a ridge of paint. Work back

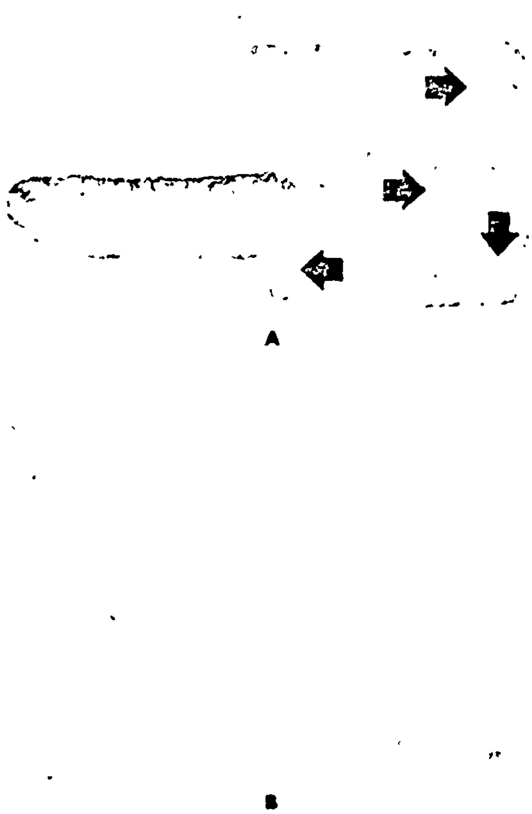

Figure 6-27. Application of transparent wash.

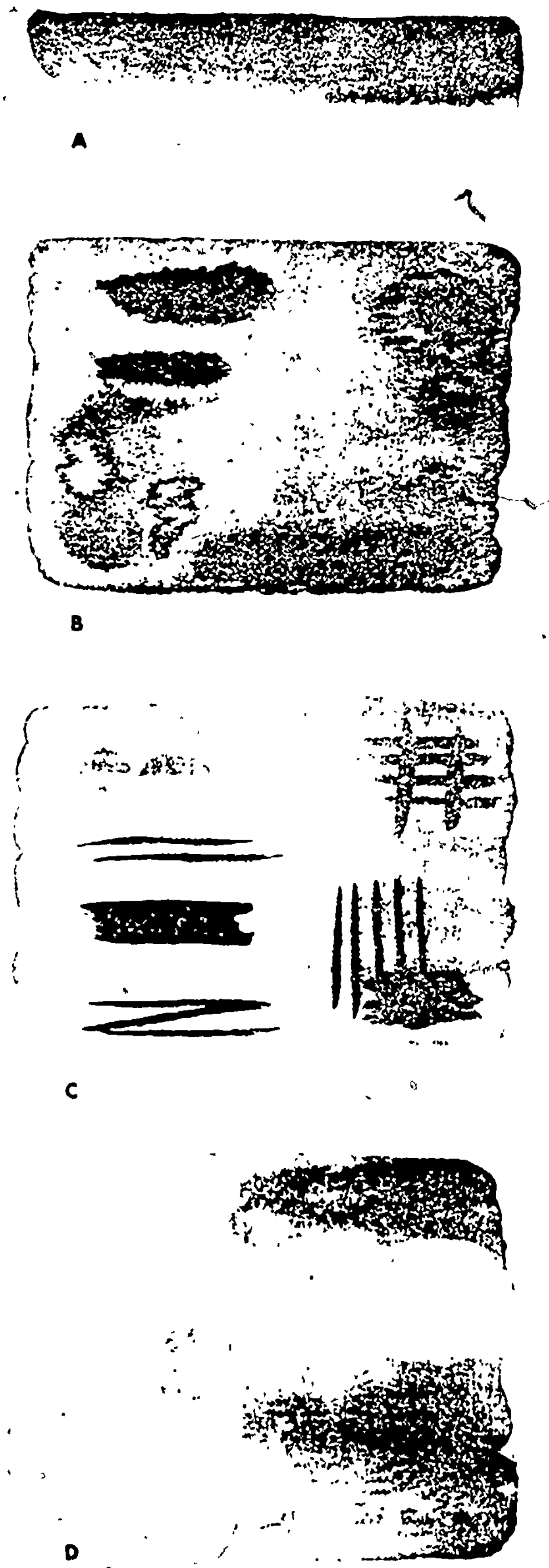

Figure 6-28. Special effects of transparent wash.

into the painted area to smooth it out while the color is still wet. If necessary, the whole area can be recovered with the same or another value after the previous one has dried.

Blending techniques. The transition from one value to another can be achieved in several different ways. The poster technique is shown in example B of figure 6-30. Actually, in this technique there is no blending of values. Light and dark colors are placed side by side, and the transition is made with a narrowband of color halfway in value between the two colors to be joined. By carrying this procedure further, as illustrated on the right, several values are used to make the transition. When mixing colors for such an effect, start with the two extremes, L and D (light and dark); mix these together to make the middle value, M; mix M and L to get the middle light value, ML; mix M and D to get the middle dark value, MD; and so on in both directions.

It is also possible to make a transition of two values by a wet blend technique, as shown in example C of figure 6-30. One color is brushed on, and the next color is immediately applied with a slight overlap. This allows the colors to blend along the edge of overlap. It is also possible to soften the

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Figure 6-29. Transparent wash illustration.

sharp edge after the colors have dried by wetting the edge slightly with a damp brush.

A dry-brush method can also be used to blend colors. This blending technique is shown in example D of figure 6-30. After preparing the color on the brush as discussed under the section on pen and ink application, the tip of the brush is drawn lightly over the edge to be blended. Either color may be used in the blending process, but the brushing must be done in one direction only. When three colors are used, the middle value is dry-brushed into the dark, and the light color is dry-brushed into the middle value. Also, a modified dry brush (or semistipple) can be achieved by spreading the hairs apart and gently tapping the paper with the ends of the hairs instead of drawing the brush across the paper. Figure 6-31 shows an example of the effects that can be obtained through the use of opaque watercolor.

Exercises (064):

1. Why is opaque watercolor hard to blend?

2. What are the best techniques for blending opaque watercolors?

065. List special techniques and preparations that apply to airbrushing.

Airbrush. The airbrush technique of using the wash medium presents the most lifelike rendering effects of any illustrating technique. This technique can present realistic effects in tone because it is capable of producing even tones, gradual variations in value, and sharp tone contrasts. The airbrush applies wash to the illustrating surface in a fine spray which is driven by compressed air. A typical airbrush, as shown in figure 6-32, applies paint in broad bands or sharp jets, either in a coarse or fine spray. Some airbrushes can regulate the density of the paint spray. Others are self-regulating, and the density increases as the opening to the paint reservoir is enlarged. The width of the spray is primarily dependent upon the proximity of the airbrush to the illustration surface—the closer the instrument is held to the surface, the narrower the spray will be.

The airbrush is an excellent medium for retouching photographic prints, and it is often used to render illustrations. Such airbrushed rendering is generally made on illustration board; however, any relatively nonabsorbent surface if mounted on a stiff board may be used.

The method of applying wash paints by the

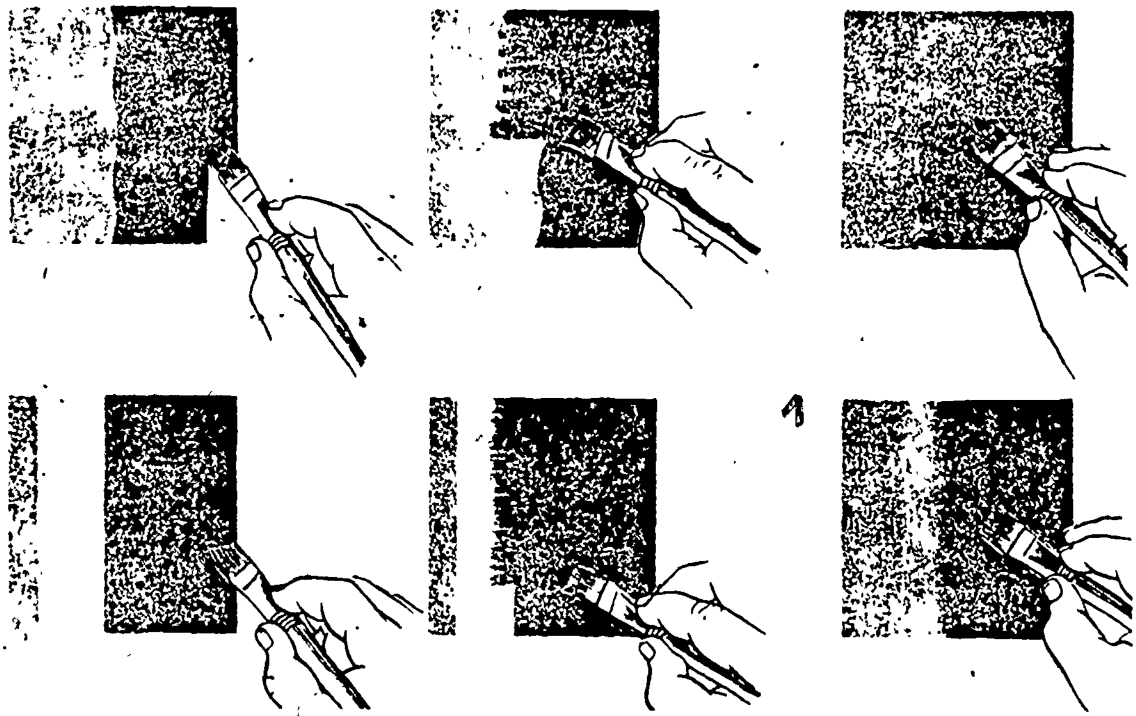

Figure 6-30. Opaque paint (tempera) application.

airbrush technique is relatively standard. As a tool, the airbrush has limitations and operating requirements which dictate its method of use. The most important requirement for rendering with the airbrush is a controlled and consistent application of paint. It is obvious that the density of the spray which reaches the illustration surface will decrease as the airbrush is moved away from the surface. Therefore, to achieve a consistent tone on a given area, the airbrush must be handled in such a way that the distance does not vary. Naturally, the size of the spray cone will vary in the same manner. Therefore, to obtain a band of tone of a specified and consistent width, the distance must not vary.

Since the very character of the spray is aerosol, it is not easily controlled by motions of the hand. Therefore, the presentation of sharply defined edges and details is aided by the use of shields or masks. A mask may be merely a piece of paper cut to the desired shape and held directly on the illustration surface. Thus, a sharp outline will be produced when paint is applied around it. The disadvantage of using a mask is that the mask temporarily obscures the area of the illustration that it covers. From the standpoint of accuracy and the fact that nothing is obscured, a frisket or other transparent or semitransparent paper is more desirable.

Frisket paper is a special type of paper that is semitransparent, very thin nonabsorbent, and easily cut. This type of mask is held or cemented directly to the illustrating surface, thus producing a sharp outline of the mask where airbrushed.

Another type of mask, or shield, is the raised mask. The raised mask is used when the density and sharpness of tone on the top and bottom of an airbrush stroke must vary. By varying the angle at which the spray strikes the mask, the sharpness of the bottom edge of the tone is made to vary. Of course, the width and diffusion of the top edge is controlled by the distance of the airbrush from the paper.

The airbrush may be used with either transparent or opaque wash. Generally, the transparent wash is lampblack diluted to the value used for middle gray washes. Tone gradations are accomplished by repeated application of paint. The tone will darken as the density of the applied pigment is increased in a particular area.

With opaque washes, tonal gradations are accomplished by the mixing of white with the black. These opaque washes are prepared in progressive values from slightly darker than white to slightly lighter than black. By diluting any one of these tones, a transparent

Figure 6-31. Tempera illustration.

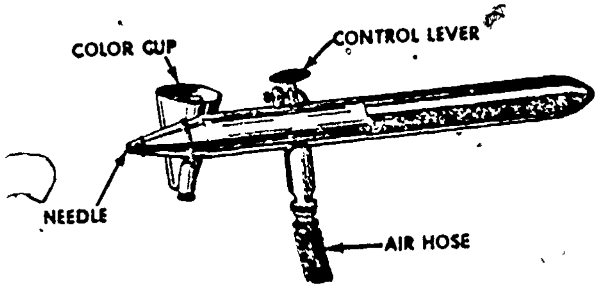

Figure 6-32. Main components of an airbrush.

effect can also be obtained. The transparency thus obtained can be graduated in tone value from slightly darker than white to the original opaque tone.

The methods of working in transparent or opaque media differ considerably. When working in transparent wash to render an area with strong highlights and shadows, only the darks are airbrushed, leaving the highlights. This is necessary since dark transparent pigments can only darken a white illustrating surface.

When using the opaque method, it is possible to apply a middle tone gray and then apply darker grays or blacks for shadow and lighter grays or white for the highlights. The opaque method allows more control over shapes and values. Corrections and changes can be easily made by repainting with any value desired whether the desired value is lighter or darker than the underpaint.

Preparations for airbrushing. It is advisable before using the airbrush to remove the handle and see that the needle is seated properly and tightened securely in place. Turn the needle locknut counterclockwise to loosen the needle. Gently remove the needle from the brush, as shown in figure 6-33. Notice that the point has a very fine taper. It is important to protect this point at all times and to handle it carefully, as the slightest injury to the tip of the needle will result in improper functioning of the brush. When replacing the needle, rest one of your fingers at the end of the needle locknut, as shown in figure 6-33, to steady your hand while inserting the needle.

After assembling the airbrush, attach the color cup to the brush by inserting it in the hole on the right side of the brush just forward of the control lever. Do not force the cup in too hard, or the hole will be enlarged. The cup is held in place by friction. The cup should be adjusted so that it is in a vertical position when the brush is held at an angle of at least 45° to the illustration surface.

The pressure used to operate the airbrush is supplied by an air compressor, carbon dioxide tank, or compressed air tank. In any case, a regulator is used to maintain the correct pressure to the airbrush. A typical setup is shown in figure 6-34. This particular regulator has two gauges—one indicates the pressure in

Figure 6-33. Removing or inserting the needle of an airbrush.

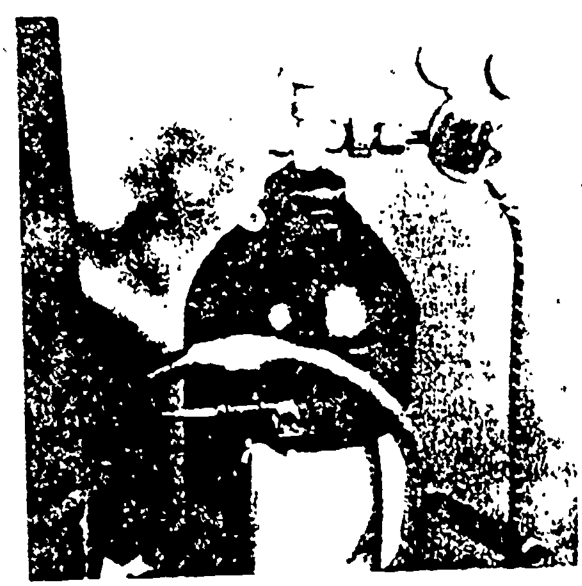

Figure 6-34. Air regulator.

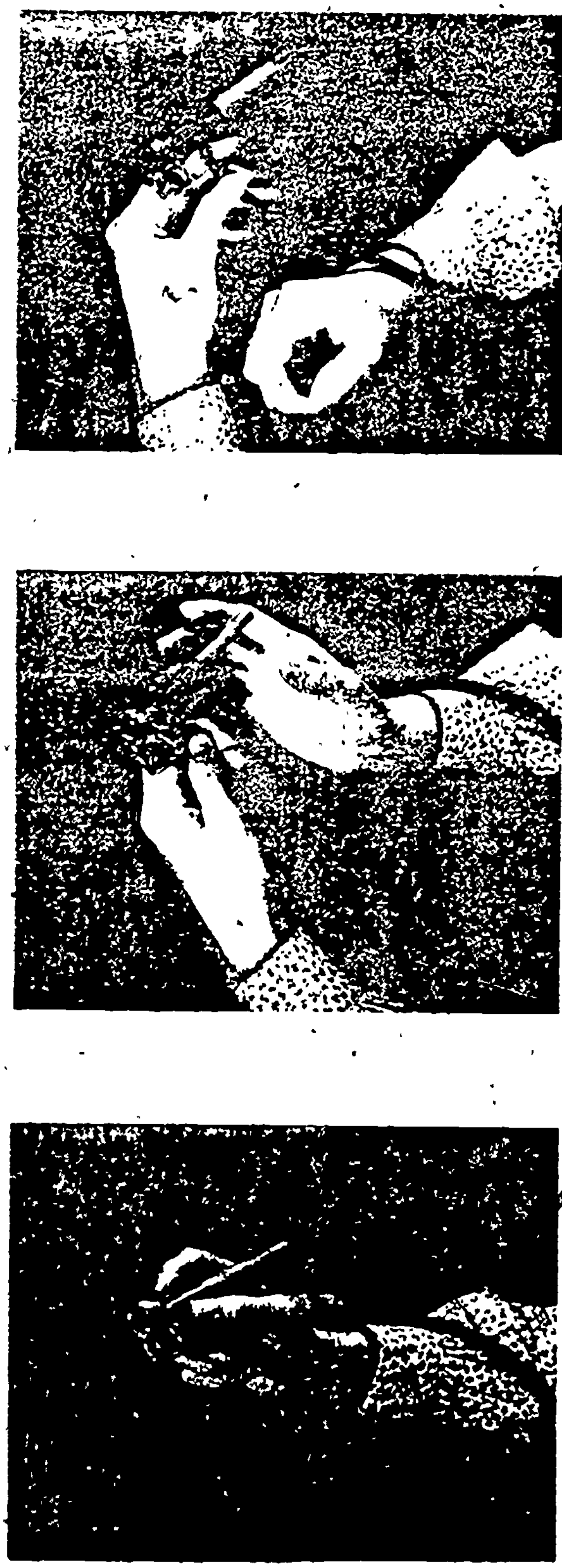

Figure 6-35. Procedure for obtaining the proper grip on an airbrush.

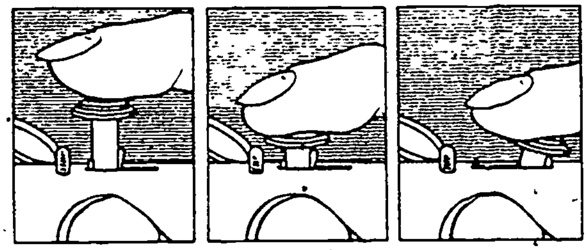

Figure 6-36. Controlling an airbrush.

the tank and the other indicates the amount of pressure applied to the airbrush.

To adjust the regulator to the proper pressure for airbrushing, first close the air outlet leading to the airbrush tubing and turn the regulator handle counterclockwise until all pressure is relieved. Then open the valve on the tank. The pressure in the tank should register on the guage on the right. If the regulating handle has been backed out all the way, there should be no pressure indicated on the airbrush pressure gauge dial. In the event that some pressure is recorded, wait until the pointer stops moving before turning the regulator handle. When the pointer comes to rest, the pressure can be increased by turning the regulator handle clockwise very slowly. Raise the pressure until the dial reads 25 pounds. The regulator is now set and will require no further attention. To turn off the air, you only need to cut it off at the tank valve.

Now you can attach the airhose to the

Figure 6-37. Proper airbrushing position.

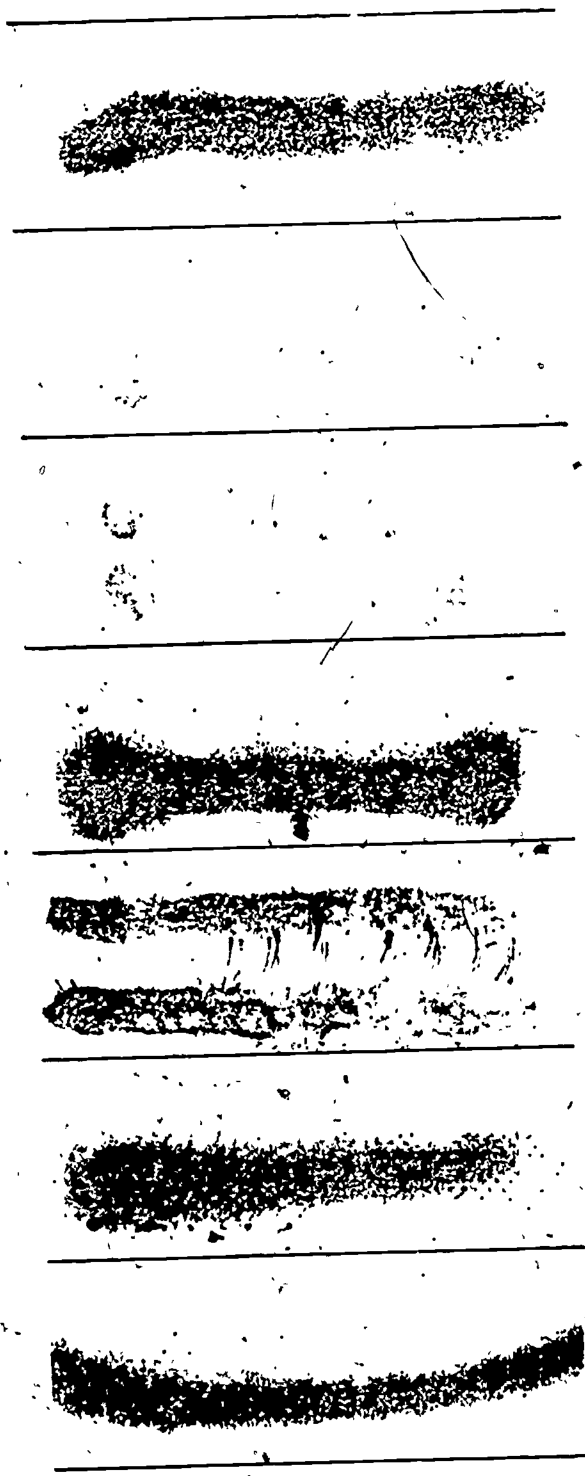

Figure 6-38. Identifying airbrush painting troubles.

regulator and to the airbrush. However, before attaching the hose to the brush, allow some air to pass through the hose to blow out any foreign matter that might be in the hose. Then screw the airbrush gently into the hose coupling, being careful not to strip any threads. As a general rule, hand-tightening is sufficient, but if air should leak out at the hose connection, tighten the swivel nut with the small wrench that comes with the airbrush.

Mix the desired pigment (lampblack or opaque color) to the desired consistency. Then transfer the solution to the cup by means of a bristle brush or an eye dropper.

Figure 6-35 shows the sequence you should use to obtain the proper grip on the airbrush. When you grasp the brush in this manner, the hose will be restrained by your wrist and will not flop annoyingly over the paper or in front of your work. You are now ready to airbrush.

Operating the airbrush. Air and paint that pass through the airbrush are controlled by manipulation of the control level. The operation is shown in figure 6-36. When the control lever is in the raised position, as shown in the illustration to the left, neither air nor paint passes through the brush. When the control lever is pushed down, as shown in the center illustration, air passes through the brush but no paint is discharged. Pulling the control lever rearward releases the paint, which is picked up by the airstream and sprayed from the nozzle. The amount of paint issuing from the brush is governed by the extent to which the trigger is pulled back.

As shown in figure 6-37, for airpainting flat tones, the airbrush should be held about 8 inches away from the paper. In applying a flat wash, you use an arm movement, moving the brush back and forth across the paper at a slow, deliberate speed. The brush should be maintained at the same height and be pointed almost at right angles to the paper throughout the stroke. You should move your hand and forearm across the page without bending the wrist, the movement being from the shoulder.

On approaching the right edge of paper on the first stroke, press the control lever all the way down. This action releases only the air. Do this without stopping or slowing down the movement of your hand. All actions must be smooth and coordinated.

Now, while holding the control lever down, pull back on it slowly and evenly, releasing the point. The paint should dry almost as soon as it reaches the paper; if it puddles or fans out in streamlets, you are pulling back too far on the control lever or you are working too close to the paper.

After reaching the left edge of the paper, allow the control lever to move forward to its starting position so that the paint flow is gradually cut off. Then stop the motion of your arm.

Now start the next stroke in the opposite direction, following exactly the same

Figure 6-39. Procedure for using a frisket, page 1.

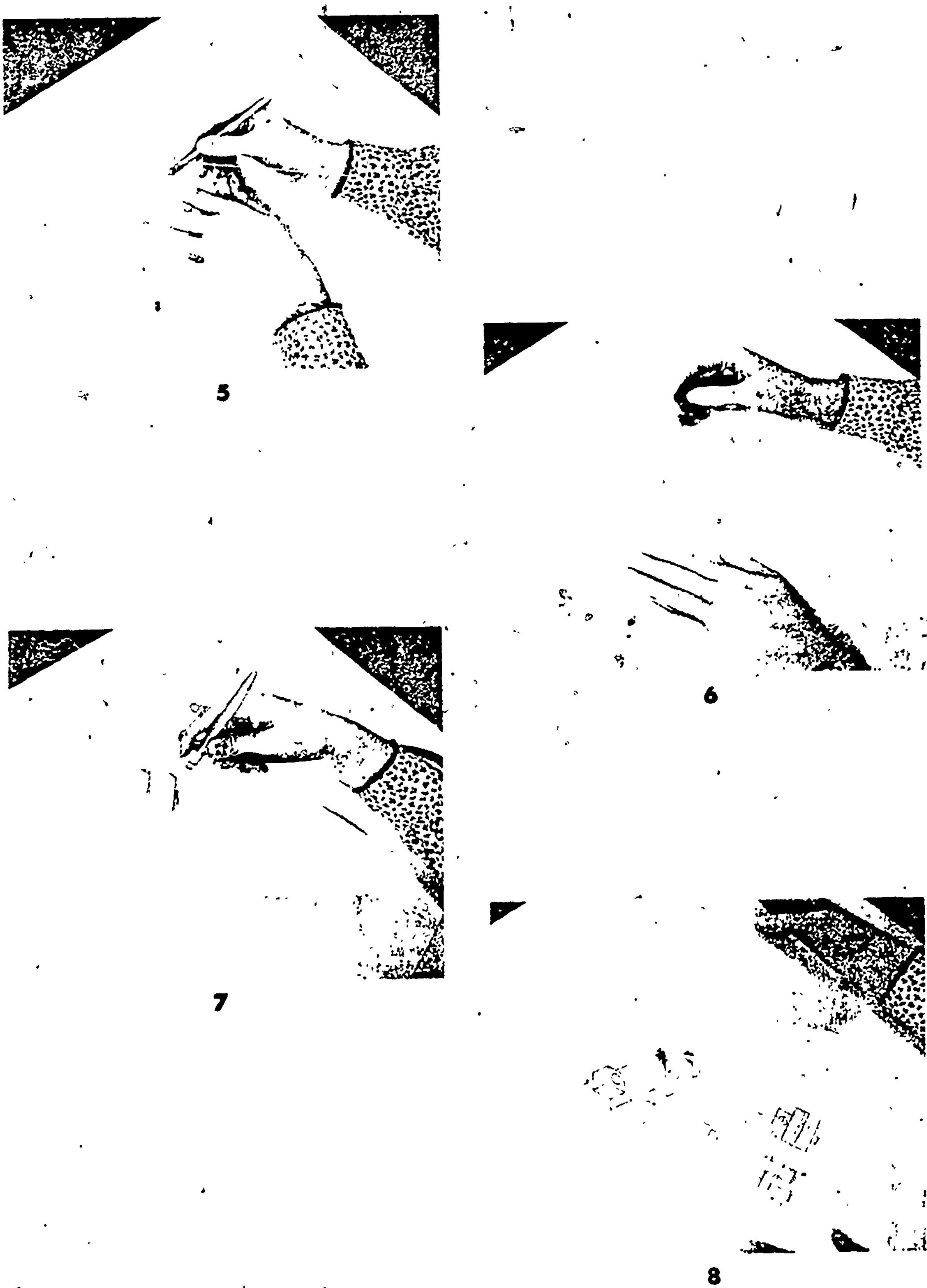

Figure 6-39. Procedure for using a frisket, page 2.

Figure 6-40. Use of mask while airbrushing.

procedure as before. Allow the spray to overlap the previous one along its edge. Continue these alternate strokes down the paper until the area is covered with a flat, even tone of color.

In airbrush painting, using transparent pigments, tones are built up gradually. If you desire a darker wash, go over the area again, starting at the top and repeating the procedure until the desired tone is obtained. A graded wash is best secured by starting at the bottom of the area with a light flat wash and allowing it to fade out near the top on the first passage. Then, start at the bottom again but do not take the spray up quite as far as on the previous passage, repeating this procedure until the required gradation is built up.

Figure 6-38 shows some of the common effects of improper airbrushing. The causes of the effects are listed below:

- Grain. If the pattern becomes very grainy, it is generally because the pigment has not been diluted sufficiently with water. Grain may also be caused by an accumulation of paint on the airbrush tip, too low air pressure, or a bent needle.
- Paper buckling. If the paper blisters or buckles, the paint is too thin, or too much paint is being applied to the paper during each stroke.
- Blobs. If large spots of paint occur at the beginning of each stroke, you are releasing the paint before the hand is in motion. If the blob is at the end of the stroke, you are not allowing the control lever to move forward at the end of the stroke, shutting off the paint supply.
- Flared strokes. This is caused by not moving the whole forearm across the paper when making strokes. You are merely turning the wrist in order to reach the edges of the paper.
- Centipede effect. This is caused by airbrush painting too close to the paper and by pulling back too far on the control lever.
- Splatter. Fairly large specks of color at the beginning of a stroke are generally caused by having allowed the control lever to "click" forward too abruptly at the end of the previous stroke. These specks may also be caused by clogging.
- Curved strokes. Curved strokes are caused by dipping the hand down toward the paper. The hand should be kept at a uniform distance from the paper during a stroke, except where a line of varying width is desired.

Using a frisket. When an area of an illustration is not to be painted, it is usually protected by means of a frisket or mask. The procedure for using a frisket is given and illustrated in figure 6-39, pages 1 and 2. The use of a mask is shown in figure 6-40. Masks may be cut out of paper or may be constructed out of masking tape, as the one shown in figure 6-40.

Basic rendering technique To show the basic steps used in rendering an illustration by airbrush, using transparent wash, let's go over the steps used in rendering the sphere, shown in figure 6-41, as if you were airbrushing it:

- First, draw a circle with a compass and place a frisket over it.

Figure 6-41. Rendering a sphere.

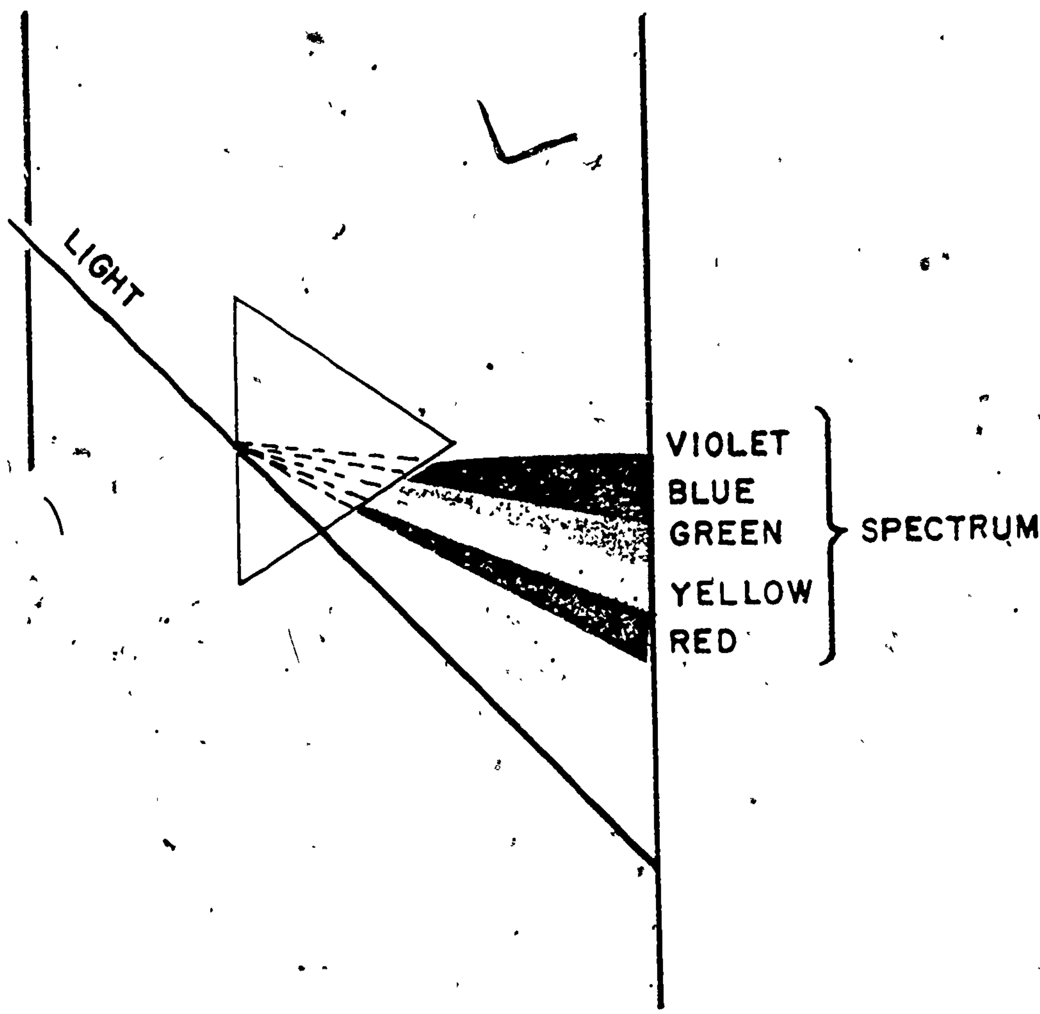

Figure 6-42. Dispersion of light.

• Cut out the circle. This can be done either freehand with a frisket knife, following the circle very carefully, or by using a blade in a compass.

• Remove the frisket from the sphere and clean off the excess rubber cement.

• Airbrush paint a very faint tone all around the edge of the sphere, allowing some of the tone to fall on the frisket. This should be done in short strokes, working in both directions. Long strokes would be more difficult to control. Keep the tone as even as possible, fading out gradually on the inside edge.

• Carry this tone up further from the bottom, leaving the highlight—a small circular area at the upper left of the sphere—as white as possible.

• Starting in the lower right area of the sphere a short distance in from the edge of the frisket, airbrush paint a shadow along the right side, across the bottom, and up the left side.

• Leaving a reflected light, begin the heavy shading. This shading should also be done with short strokes in all directions. When fading out at the upper right and upper left, however, work only in one direction.

• Airbrush paint a slightly darker tone off the edge of the frisket at the top of the sphere. Then, return again to the lower right shadow area and continue to darken it, working in solid black tone.

Using opaque color to paint the same sphere is a much easier method since you do not have to build up the tones gradually as you do with transparent wash. You merely lay down the middle tone and then add the highlights, shadows, and reflected light.

Exercises (065):

1. Why is the airbrush an excellent tool for illustrating?

2. To produce a sharp, straight edge of tone with an airbrush, you should cover part of the paper with a__________ or a __________.
3. To vary the sharpness and density of an airbrush stroke, you should use a________.
4. What is the principal difference between the techniques of airbrushing with transparent pigment and opaque pigment?

5. What preparations must be made before using an airbrush?

6. At what pressure should the airbrush be operated?

7. How is the airbrush controlled?

8. What factors of operator control determine the quality of an airbrush stroke?

9. What are the common effects that indicate an improper airbrushing technique?

6-3. Techniques of Color Illustration

Color is so constantly in evidence all around us that we give it very little attention. We merely accept it, as we do sunshine and shadow. Although we appreciate its beauty, we do not consciously realize what an important part it plays in our lives. But whether we realize it or not, color influences us during practically every waking moment.

The important part that color plays in our lives is shown in many ways. We are more inclined to be cheerful on bright, colorful days than when the sky is gray. We are more contented in harmoniously colored rooms of reasonably distinct hue than in those which are drab. Yet, we are disturbed by interiors that are gaudy and crude. We like the out of doors for its green trees, blue skies, and purple hills. Even our food is more attractive and more appetizing than it would be if it were a neutral tone.

In addition to its artistic and psychological values, color serves us in many practical ways. Color aids us, for instance, in identifying one object from another at a glance. It helps us to know whether fruit or vegetables are unripe, ripe, or spoiled; whether food is raw, sufficiently cooked, or overdone; and whether objects are extremely hot or cold. In fact, there is hardly a phase in our existence that is not affected in some way by color.

Is there any wonder, then why color is so important to you as an illustrator? You, who must portray people and things in a world of color, must learn to appreciate and understand color far more than those who merely enjoy it. You must learn to use it in many ways: to attract and to hold attention, to lead the eye, and to please, as well as to give many other desired effects.

To use color effectively, you must possess a basic knowledge of color theory. You must know the qualities of color, how different colors are related to each other, how to mix color, and how to select colors that go well in combination. You can learn these fundamentals by studying this chapter. In addition, this chapter includes techniques of using color in the following media: watercolor, tempera, casein, and oil.

066. Name the discoverer of light rays, and define dispersion and spectrum.

Relationship of Light and Color. From the beginning of time, man has been interested in color and has continuously sought to wrestle its secrets from nature. However, it was not until the advent of science that intelligent

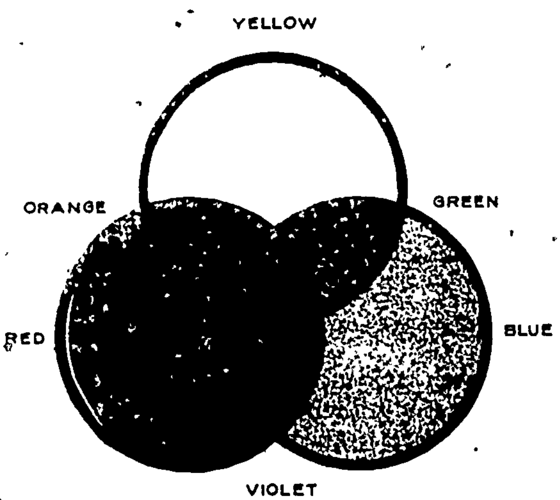

Figure 6-43. Subtractive process of color.

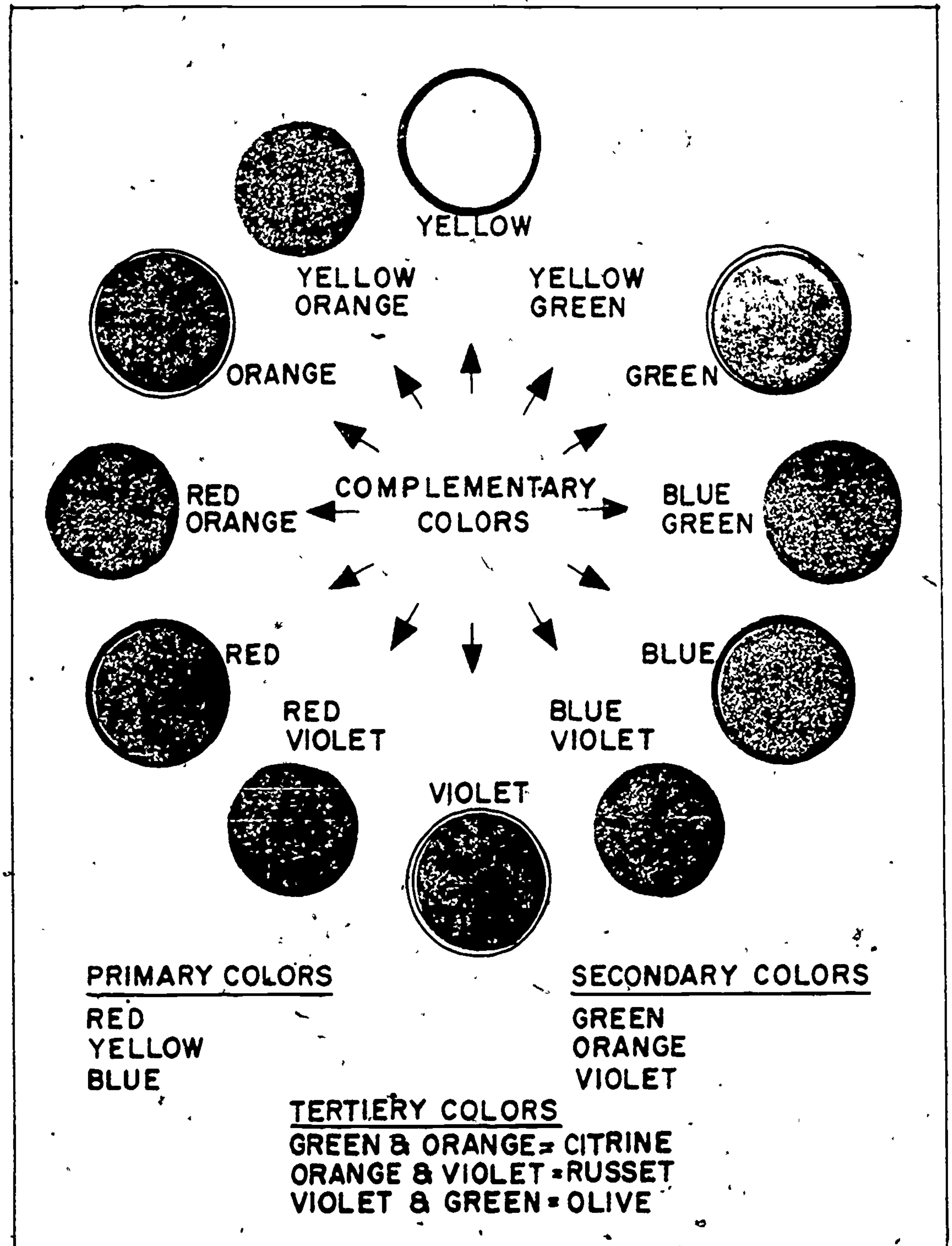

Figure 6-44. Color wheel.

research and experimentation was conducted. Especially in the last two centuries, physicists, physiologists, and psychologists have studied the problems of light and color and the processes of vision. Chemists, too, have made progress in the discovery and perfection of pigments.

We are indebted to Sir Isaac Newton who, in the 17th century, discovered that light consisted of many rays (each of which, when allowed to reach the retina of the eye, produces the sensation of a distinct color), and that the fusion of all the sensations generated by the mixture of rays gives the sensation of white. We also learned that light comes from its source (the sun) as a wave motion traveling at a speed of approximately 186,000 miles per second. The sensation known as color is produced by the action of these rays of light upon the optic nerve. The waves vary in length, and this variation causes the different colors.

Newton made his discovery by performing an experiment which is shown in figure 6-42. In a darkened room, he admitted a beam of sunlight through a slit in a window shade and allowed it to pass through a prism. This separated the light into a long line of colors such as those we see in a rainbow. This separation of light into its element is called *dispersion*, and the resulting band of color is known as the *spectrum*. The colors of the spectrum arrange themselves in order of their wavelengths, the long waves being less refracted than the short waves. Starting with red, which has the longest and slowest vibrating wave of any ray visible to the human eye, the colors follow in this order: red, orange, yellow, green, blue, and finally violet.

Newton also demonstrated that the separated colors can be recombined into white light. He proved this by using another prism and also by receiving them onto mirrors or lenses so curved that they convey the colors to a single spot.

Thus, long ago man learned that light is the source of color and that white light is made up of varying rays, each capable of producing the sensation of a distinct color. It is obvious, then, that when light is present, color is present and that when light is absent, color is absent. It follows that the nature of light influences the nature of color; objects look different under daylight, electric light, gas light, colored light, etc.

With this as a background, let us consider why one object looks red and another green. If we glance at an object (excepting self-luminous, fluorescent, or transparent ones), we see the object because some of the light cast upon it is reflected into our eyes. It is easy to understand why the object appears bright when it is in strong light and appears indistinct when it is in dim light. It is not so easy to understand why one object appears red and another green until we learn that surfaces exercise a selective power on the light. Every surface decomposes the particular light by which it is illuminated. Each surface absorbs some of the light rays while it reflects or scatters other rays in all directions.

A red object, as it decomposes the light that falls upon it, absorbs or annihilates all the rays except the red. These red rays are reflected. Thus, we see the object as red. A green object has the power to absorb all of the rays except the green. A white object is merely one which reflects a large percentage of all rays so balanced as to give the effect of an absence of color—white. A black object is one that absorbs nearly all of the light rays.

Other investigators of light made additional contributions to our knowledge of light and color. Sir David Brewster concluded after long experimentation with pigments and color glasses that light was made up of three primary colors—red, yellow, and blue waves. Dr. Thomas Young, and later Professor Helmholtz, working with spectral colors, conceived the theory that instead of red, yellow, and blue, the true primaries were red, green, and blue (blue-violet).

The important factor that we learned from these theories is that the laws that apply to light do not apply to pigments. Obtaining different colors by means of light is an additive process, while obtaining colors from pigments is a subtractive process. For example, in color television all colors are produced from the primary colors red, green, and blue. When the red dots of a color TV screen are illuminated, we see the area as red. If the green dots in this area are also illuminated, the combination of red and green appears yellow. If the blue dots are also illuminated, the area appears white. By adding the colors red, green, and blue in the correct proportions, all colors can be produced.

The subtractive process of pigments works entirely different. As shown in figure 6-43, the three primary colors—red, yellow, and blue— when mixed in the proper proportions, produce the remaining colors of the spectrum—orange, green, and violet. Notice that when all three colors are mixed together, the result is black rather than white as in mixing light.

The important fact to remember about this discussion of light and color is that although light and color are inseparable, we must treat color by pigmentation as a separate and distinct process. Since it is color by pigmentation in which we are most interested, when we refer to color from now on, we will mean pigmentation color unless we specify otherwise.

Exercises (066):

1. Who discovered light rays?

2. What is dispersion?

3. What is a spectrum?

6-4. Color Theory

It is difficult, if not impossible, to study any subject without first learning some of the terms that are used in discussing its various elements. The study of color is no exception. Therefore, let's begin by learning the three qualities of color.

067. Explain the qualities and the relationships of colors.

Color Qualities. If we look at any given color analytically—the red of an apple for instance—we discover that it possesses three outstanding characteristics of qualities—hue, value, and intensity.

Hue. The quality by which we recognize one color from another and which we suggest by its name is called hue. The apple is red; red is the hue (or name) of the color.

We can alter the hue of a color by mixing another color with it. If we mix red pigment and yellow pigment, we produce orange pigment. This is a change in hue.

Value. Next comes the quality by which we discern lightness or darkness in a color. This we call value. It is by value that we are able to discriminate between light red and dark red.

We change the value of a color by mixing something lighter or darker with it. If we mix black or white with a color, we change its value but not its hue. This change can probably be best shown by means of watercolor. If we add water to red pigment, we make the value lighter, but we do not change its color or hue. It appears as pink, which is still a red hue. It is not orange or green or blue.

We call a color in its full, natural strength normal color or a color of normal value. If the color is lighter than normal, we call it a tint. If it is darker than normal, we call it a shade. These latter terms are so often abused that it is better to use the word value; such as "a light value of red" rather than "a tint of red" or "a dark value of blue" rather than "a shade of blue." Tone is a word of such ambiguous meaning that it is best to employ it only in a general way to include all normal colors, tints, and shades.

Intensity. The third quality of color relates to strength. Some colors are strong and some are weak. The quality by which we distinguish between them is called *intensity*, or *chroma.* If we remark that an object is saturated, is colorful, or is strong in color, we refer to its intensity.

We can change the intensity of a normal color by mixing with it a pigment that tends to dull or fray it. We can change intensity without changing value or hue by adding neutral gray of equal value.

Color Relationships. The solar spectrum (as projected onto a screen by means of a prism) is extremely brilliant. It is light itself. If we try to represent this spectrum with even the purest pigments obtainable, we cannot approach its intensity. Each pigment absorbs many of the light rays that come in contact with it and tends to reflect portions of hues other than the dominant one. White paper reflects only a little more than half of the light that falls upon it.

As you know from our previous study of light and color, the spectral hues red, green, and blue-violet are classified as primary; and by mixing these three hues in proper combination, all other spectral hues can be produced. These primaries, in properly balanced mixture, also produce white. But in dealing with pigments, approximations of these spectral primaries do not prove primary. If we mix red and green for instance, we get gray instead of the yellow as is the case in spectral mixture. You cannot produce normal yellow by mixing any other colored pigments. You cannot produce white by mixing any combination of colors.

Primary colors. Various authorities select different pigment colors as primary. Perhaps the most widely used primary concept and by far the easiest to understand is the red, yellow, and blue concept of Brewster. From these three primary colors, almost any desired hue can be mixed.

Secondary colors. By mixing any two primary colors, we can produce a full range of intermediate hues. The hue that is midway between the two primaries is called a seconday color. For example, if we mix varying proportions of red and yellow, we obtain a full range of oranges. The orange that stands midway between red and yellow is a secondary color. In the same way we can produce green by mixing yellow and blue in the appropriate proportions and can produce violet by mixing red and blue. These three secondary colors—orange, green, and violet—together with the three primaries—give us six leading colors. Most coloring sets will include at least these six colors.

Some books say that mixing equal parts of primary yellow and primary blue will produce secondary green. This is not always true. Yellow, though extremely intense, is light in value. Blue is dark, but less intense. In equal mixture, therefore, one may outweigh the other, and a normal green may not result.

Tertiary colors. By continuing the mixing process further, you can obtain six tertiary colors—red-orange, yellow-green, blue-violet, yellow-orange, blue-green, and red-violet. In compounding these names, as "red" with "orange" to make "red-orange," the primary name is usually placed first, indicating an excess of red over the other component—primary yellow.

Experimenters in the field of color have invented an extremely valuable device commonly known as the color wheel. An example of one type of color wheel is shown in figure 6-44. A color wheel is really a simple scale for measuring hues. Although there is no arbitrary rule as to the number of colors in a wheel, a 12-hue wheel is convenient since it exactly accommodates the 3 primaries, 3 secondaries, and 6 tertiaries.

By saying that such a wheel is a scale for measuring hues, we by no means classify it as a scientific apparatus. The approximate measurement of any hue can, however, be quickly judged by the eye if the hue is referred to the hues of the wheel for comparison.

Complementary colors. The color wheel can also be used to show another color relationship—complementary colors. Before we use the wheel to determine or to show the relationship of complementary colors, let's go back to the study of light to get a clear definition of the term complementary.

Recall that we see an object because that object has the ability to absorb some of the light that falls on it and to reflect the rest of the light. The rays absorbed by the object are said to be complementary to those reflected because if the absorbed light could be combined with the reflected light, white light would be produced. Or if we take the spectral colors, we find that blue-green is the complement of primary red because when these colors combine they produce white light. Likewise, when blue-violet and yellow or green and purple are combined, they produce white light. Therefore, red and blue-green, green and purple, and yellow and blue-violet are complementary spectral colors.

The importance of these facts about complementary spectral colors is that we can draw valuable parallels in terms of pigmentation. For example, if we mix together our pigment primaries, we get gray instead of the white produced by spectral mixture—this difference being mainly due to the dullness or impurity of pigments when compared to light.

Pigment complements can be identified in much the same manner as the complements of spectral colors. By mixing primary red with primary blue, we obtain a secondary—violet. This is the complement of the third primary—yellow, and vice versa. In other words, the secondary obtained by mixing any two primaries is the complement of the third

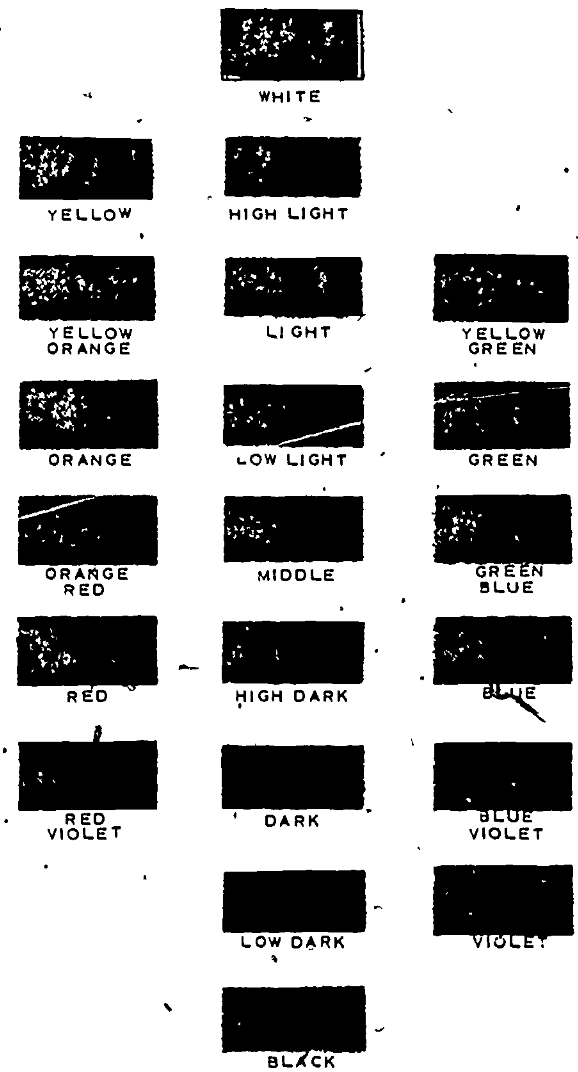

Figure 6-45. Color value scale.

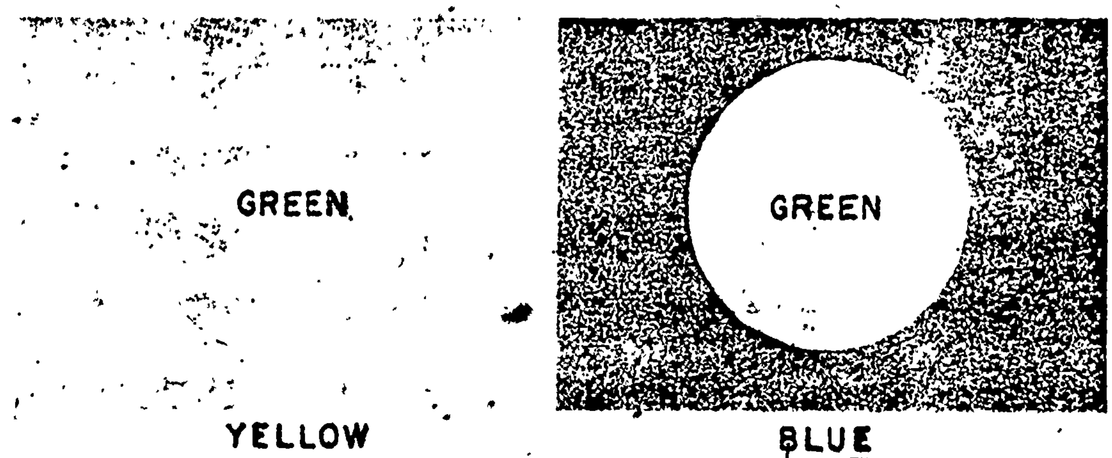

Figure 6-46. Influence of surrounding colors.

primary. It follows that if a primary is mixed with the secondary that is its complement, the result will approximate neutral gray—since the secondary is made up of the other two primaries, the three primaries are actually being mixed. Further (and this is the wonder of the color wheel to which we have been leading), any hues exactly opposite on a well-prepared color wheel are complementary, as you can see in figure 6-44.

We cannot overemphasize the prominent position these complementary hues have in work with pigments. You should use figure 6-44 to memorize the principal pairs. This will be very useful in mixing colors. When a color and its complement are mixed together, each tends to dull or neutralize the other; but when placed side by side, each emphasizes or accentuates the other. Thus, complements have the power to destroy and to reinforce, according to how they are used.

Let us examine the destructive characteristic of complements and see how we can use it. Suppose you have mixed a wash of orange and it is too bright for your purpose. Mixing it with water will make it lighter, but not duller. How can you modify its intensity? By adding gray? Yes, but the use of gray often has a deadening effect. Instead, add complementary blue. This will dull the orange but will not destroy its richness. In the same way, if you have painted a green hillside and it seems too vivid, lay a pale wash of red or red-violet over it.

As an example of the reinforcing characteristics of complements, suppose that you are painting a building that is in bright sunlight. You can enhance the brilliancy of the yellows and oranges by opposing them with blue or violet shadows.

Value. The easiest approach to the study of color value relationships is through comparison with black and white. In black, we have the lowest of all values—black standing for the absence of light. In white, we have the highest value that our paper and pigments permit—white representing the maximum presence of light. This gives us two predetermined extremes. By mixing black with white in varying proportions, we can obtain innumerable intermediate values of gray. It is customary to establish a limited number of progressive steps or intervals. If we use seven steps of gray plus black and white, we form a value scale like the one shown in the center column of figure 6-45. This scale can be used very successfully in comparing the value relationship of the 12 colors of the color wheel.

If we divide the 12 colors of the wheel into 2 equal groups and arrange them opposite to the gray values, as shown in figure 6-45, we can quickly compare the values of the colors with the values of the grays. Notice that these values have been given names on the scale. Also notice that yellow has the same value as the gray identified as high light; yellow-orange and yellow-green have the same value as light; orange and green match with low light; red-orange and blue-green with middle gray; red and blue compare with high dark; and violet has the value of low dark. Remember that the colors shown are at full intensity. Of course, if we use tints and shades of the various colors, we can create separate scales for each color. It is obvious that we could not get many tints of yellow or many shades of violet because of their nearness to the value limits of white and black.

Contrast. If we arrange colors (this includes black, gray, and white) side by side so that one is seen against a larger area of another, they tend to modify one another. In other words, colors are modified in appearance by their proximity to other colors. This modification can be seen in figure 6-46. Let us first consider modification in terms of gray. Notice that the two discs, which have the same value, appear to be of different values because their immediate surroundings have a different effect upon them. The apparent change in value is not the only way in which the discs are affected. There is also an apparent change in size. The disc surrounded by the darker value appears slightly larger than the one surrounded by the light value of gray. This is known as the radiation effect.

Value is not the only factor which is affected by environment. If you place a small square of neutral gray on a blue background, the gray seems to take on an orange cast. The same gray against orange shows a hint of blue. This is quite evident when you use large squares of blue and orange placed side by side and lay a piece of tracing paper over the whole area.

As a striking test, lay small green discs in the centers of two adjacent large squares, one light yellow and the other dark blue as represented in figure 6-46. The green against the yellow seems darker in value than against the blue and appears slightly blue-green in hue. The green against the blue seems slightly lighter and appears slightly yellowish. Not only do the two small green areas apparently change, but the yellow in contrast with the green and blue seems slightly orange, and the blue in contrast with the yellow and green appears a bit purple. This test demonstrates that colors are influenced in hue by adjacent colors, each tinting its neighbor with its own complement. Intensities, as well as values, are affected by environment. If two complementary colors lie side by side, each seems more intense than by itself.

Exercises (067):

1. Match the terms in the left column with the quality of color they most nearly describe or with which they are most nearly associated.

__1. Tint.	a. Hue.
__2. Lightness or darkness.	b. Value.
__3. Name.	c. Intensity.
__4. Chroma.	
__5. Shade.	
__6. Strength.	
__7. Color.	
__8. Normal color.	

2. Why don't we use the same primary colors in pigments that we use in spectral colors?

3. Designate the two primary colors which are mixed together to produce each secondary color listed in the left column.

__1. Green	a. Red
__2. Orange	b. Yellow
__3. Violet	c. Blue

4. Why is it convenient to use a 12-hue wheel as a measuring scale rather than a wheel of more or less colors?

5. Where on the color wheel are the complementary colors located?

6. In what way does the environment in which a color is placed affect the color?

6-5. Color Harmony

Certain combinations of colors, whether in nature or art, are agreeable to the eye and mind, whereas others give offense. We call the former harmonies and the latter discords.

Just as numerous attempts have been made to discover the laws of light and color, great effort has been expended in trying to find the reasons why some color combinations are pleasing and others are not, and to devise laws to insure harmonious use of color. However, in view of our previous discussion on the effects of environment on color, we know that color harmony is not merely a matter of selection but also a matter of arrangement. Area, oscillation, radiation, texture, and color fitness are all factors that influence color harmony. Therefore, these factors must all be considered when we select color schemes.

068. Relate the terms monochromatic, analogous, complementary, and triad to color harmony.

One Color with White, Gray, and/or Black. The simplest scheme is that of an individual hue used in one value and intensity in conjunction with white, gray, and/or black, and sometimes with silver or gold. A common illustration of this scheme is the booklet printed with black ink on white paper (the type masses giving the impression of gray) and a cover of colored stock.

Schemes of this type seldom give offense. As a rule, if a single color is used with large areas of black, a warm one—red, orange, or rich yellow—is most effective. These color have a brilliancy and vigor which appear to relate them to black. If such cool colors as blue, blue-green, or blue-violet are used with black, they are at their best when quite intense.

White often impresses us as somewhat warm. If a single color is used against it, a rather dark, cool one gives the happiest contrast. Blue and white have always been a popular combination. For softer effects, the light, warm colors are suitable, though many colors, especially if used as tints, are usually pleasing against white.

Monochromatic. This scheme is merely an extension of the previous one to include all values and intensities of a hue, and is used with or without white, gray, or black. The most frequent illustration, perhaps, is the drawing on white paper with a single color such sepia, the values ordinarily varying from light tints to dark shades. We might say that the use of one color does not constitute color harmony, since there is nothing with which the color can possibly agree or disagree. Strictly speaking, this is true, and such schemes run the danger of becoming monotonous. However, it is surprising how colorful some such arrangements are. If you wish to get slightly more variety than the strictly monochromatic scheme affords, you can simply add inconspicuous suggestions of other colors.

Analogous. An analogous or, as it is sometimes called, *related color scheme* is made up of colors which are nearby in the spectrum. For example, orange, yellow, and green form an analogous scheme, since they all contain the common factor yellow.

A glance at the color wheel will show you which groups of colors are analogous. If we start with yellow, we note that yellow-orange and yellow-green (which are made up largely of yellow) are particularly close in relationship. These three form a close analogy. If to these we add orange and green, each of which contains some yellow, this entire 5-hue group is analogous. We can even include red-orange and blue-green because both of these contain a slight amount of yellow. Out of the 12 hues of our scale, this gives us 7 hues that are somewhat related due to their yellow content. In arranging analogous schemes, the more of the circle that we include, the greater our difficulties become. Therefore, typical analogous schemes usually do not take in more than one-third or a quarter of the color wheel.

Although analogous schemes are often among the most pleasing and are as easy as any to handle, the very unification which makes them harmonious may at the same time make them monotonous. As an illustrator, you must seek to develop in them sufficient hue interest (as well as variety of value, intensity, and arrangement) to prevent monotony.

One of the easiest means of obtaining interest in an analogous scheme is by placing emphasis on a dominant hue. There are various ways of making a particular hue dominant. You can give it a large area, a dark value (against a lighter background), a light value (against a darker background), or make it intense.

You can also prevent an analogous scheme from becoming monotonous by introducing complementary accents. Such accents, particularly if brilliant, generally have a power out of all proportion to their size. A single touch of color complementary to one hue—usually the dominant—can give surprising life to an otherwise dull analogous scheme.

Complementary. Under this heading, sometimes known as *harmonies of contrast*, we can include any pleasing schemes which conspicuously introduce opposite colors. In fact, the majority of all color schemes are to an extent contrasting, the contrast usually being developed by means of complements. However, you should not base a color scheme on complementary colors in equal areas and full strength. A large red area and a small green area, for instance, often seem harmonious because the dominant red gives unity to the combination. Likewise, a brilliant red can be employed successfully with a neutralized green, even though the areas are equal, for the red will dominate because of its superior intensity.

Near and split complements. Complements which are only approximate, commonly called near complements, seem more pleasing than those that are true complements. The term "near complements" is self-explanatory. Violet is the true complement of yellow, while blue-violet and red-violet are near complements. If we speak of these near complements in their relation one to the other, we call them split complements, as they are split or separated by the true complement.

Triad. If we base a color scheme on a color and its split complements, or on hues mixed from them, we can obtain a fairly wide range of hues; but none of them will be brighter than the color itself and the two split complements in their full intensity. Sometimes, such a range proves too limited; so in place of these split complements, which are closely related to the complement itself, we use other split complements, each a step further removed. In the 12-color wheel, for example, if we take yellow as a hue to dominate a color scheme and the split complements red-violet and blue-violet prove too dull to hold their own, we can substitute red and blue. In this case, we are using three colors equally spaced on the wheel. We call this a triad.

Though mixtures obtained from triads can be very rich and beautiful, triads by no means guarantee color harmony. The red, yellow, and blue triad is made up of our three primaries from which we know practically all colors can be mixed—discords as well as harmonies. To get effective results, therefore, you must use one of the three hues as the dominant one and mix a little of it with the other two.

Exercises (068):

1. What colors are considered warm, and what colors are considered cool?

2. Which type of color harmony is most likely to become monotonous?

3. You can prevent an analogous color scheme from becoming monotonous by adding __________ accents to your illustration.

4. A complementary color scheme is based on ____________________.

5. A color scheme which is based on three equally separated colors is called a ________.

** NOTE: Pages 90 and 91 are missing due to deleted material. No pertinent information was omitted.

CHAPTER 4

035 - 1. Choose any two:
   a. Have a place for each piece of equipment and keep it there when not in use.
   b. Keep all instruments used to dispense ink or other liquid media CLEAN.
   c. Never expose any pointed equipment to the possibility of point damage.
   d. Never use any instrument for any purpose except that for which it was designed.

036 - 1. A drawing table, chair or stool, and a tabouret or storage area.
036 - 2. Over the left shoulder and from the left-front.
036 - 3. So that if you desire to work in a standing position, you can do so without stooping or raising your arms.
036 - 4. Because it is timesaving and decreases the likelihood of damage.

037 - 1. So that if an erasure does occur the surface can be redrawn upon.
037 - 2. So the drawing will fit a standard letter size filing cabinet.
037 - 3. Tracing paper is a translucent or transparent paper used to trace drawings or blueprints when reproduction of the original is not possible.

038 - 1. Hard, medium, and soft.
038 - 2. Conical, wedge, and elliptical.
038 - 3. The disadvantage of using an ordinary drawing pencil is that as you sharpen it, it becomes shorter and more difficult to handle.

039 - 1. It will not destroy the surface of the paper if used properly.
039 - 2. It can hold any shape, has few erasure crumbs, picks up graphite dust and tends to clean itself when kneaded.

040 - 1. Drawing ink is finely ground carbon suspended in liquid with gum arabic added.
040 - 2. Light blue and white.

041 - 1.

Materials	Tools
a. Pencils.	a. Drawing board.
b. Paper or illustration board.	b. T-square.
c. Erasers.	c. Triangles.
d. Ink.	d. Protractor.
	e. Scales.
	f. Irregular curves.
	g. Instrument set.

041 - 2. A drawing board should be well seasoned clear white pine or basswood. It should be cleated together to prevent warping.
041 - 3. By drawing a line the complete length of the working edge, turn the T-square over, and draw the line again along the same edge.

042 - 1. 30° to 60° and a 45°.
042 - 2. To draw lines vertically for sloping at a prescribed angle in conjunction with the T-square.
042 - 3. A protractor is used for setting off and measuring angles from 0° to 360°.

043 - 1. Mechanical engineer's, civil engineer's and architect's scales.
043 - 2. a. A mechanical engineer's scale is used to draw machine parts and small structures where the size is never less than 1/8 the original.
   b. A civil engineer's scale is used mainly for plotting and drawing maps and any work where the divisions are in tenths of inches.
   c. An architect's scale is used on any dimension where feet and inches are required.

044 - 1. An irregular curve is used to draw a smooth line through a number of predetermined points.

045 - 1. Because you might bend the nibs and ruin the pen.
045 - 2. Detail.
045 - 3. Sharp points, unequal length of nibs, and flattened points.

046 - 1. Compass and dividers.
046 - 2. A proportional divider is a type of divider that has a movable pivot point with needle points on each end. The movable pivot allows the short end to be adjusted to a ratio of the long end.
046 - 3. Three instruments—bow pen, pencil, and divider.

047 - 1. A drafting machine is a timesaving device that replaces the T-square, triangle, scale, and protractor.

CHAPTER 5

048 - 1. Text, Gothic, and Roman.
048 - 2. Printing imposed changes in the mechanically prefected letter—it began a trend toward simplicity and ease of construction.
048 - 3. Compressed; condensed.
048 - 4. Extended.

049 - 1. Letter nomenclature is the naming of the various parts of the letter.
049 - 2. Roman letters.
049 - 3. A swell.

050 - 1. The stem and oval.
050 - 2. The stem is that straight vertical or vertical slant lines that forms more than four-fifths of all letters.
050 - 3. The six basic strokes of lettering are horizontal, vertical, diagonal left, diagonal right, counterclockwise curve, and clockwise curve.
050 - 4. 67½°.
050 - 5. If the letter A does not extend slightly above the cap line, it will appear smaller than the rest of the letters.

051 - 1. Proportion, stability, and uniformity.
051 - 2. Uniformity.

052 - 1. Because all letters are not regular in shape.
052 - 2. There should be a full space between d and b because the stems of these letters are full height. The space between the o and b should be slightly narrower to compensate for the space above the o.
052 - 3. Four.

053 - 1. Clean; firm; opaque.
053 - 2. The first requirement in lettering is holding the pencil or pen correctly and comfortably.

054 - 1. Barch-Payzant pens, speedball pens, technical fountain pens, and Leroy pens.
054 - 2. One that is well broken in.
054 - 3. A speedball pen is a pen that comes in various sizes, and no less than four types.

055 - 1. The tips or points of the lettering brush is always the natural end of the hair or bristle. Other brushes may have trimmed ends, or even artifical hair or bristles.
055 - 2. Red sable.
055 - 3. Never.
055 - 4. Rounds, brights, and flats.
055 - 5. a. Rounds are brushes that come to a point—which varies from fairly sharp to quite blunt.
b. Brights are flat brushes with sharp corners—have little thickness of bristle and their length is about one and one-half times their width.
c. Flats are broad with flattened ferrules and straight edges.

056 - 1. A standard lettering set consists of a set of templates, a scriber, and a set of pens.
056 - 2. Eleven.
056 - 3. The tailpen is the back part of the scriber that rides in the straight groove of the template.

057 - 1. a. Letters can be applied directly to finished artwork.
b. Can be applied to any smooth surface.

CHAPTER 6

058 - 1. Opacity of the ink and its capacity to contrast sharply with the illustration surface.
058 - 2. A croquill.
058 - 3. Clear; sharp; consistent.
058 - 4. Crosshatching.

059 - 1. Textured or rough.

060 - 1. Chemical developed shading medium, transparent film patterns, and tones.
060 - 2. Timesaving and special effects.
060 - 3. By overlapping the same patterns or different patterns of transparent film.

061 - 1. Scratchboard is an excellent medium for illustrating dark objects with many details and highlights.
061 - 2. Scratchboard is greatly affected by moisture, oil, changes in temperature, and humidity. Sharp blows or dents will cause the chalk like coating to chip or flake.

062 - 1. The rubbing with either a stump or the finger will cause a blending into a smooth grayed tone.
062 - 2. Carbon or lithographic pencils have a dark, mat-finish. Lead or graphic pencils leave a shiny grayed surface.

063 - 1. A wash illustration is an illustration painted with a diluted pigment in water to produce a transparent effect.
063 - 2. Since a wash is laid on an inclined surface, it must be started at the top so that the diluted pigment will settle toward the bottom, producing an even tone.
063 - 3. Soft, fluid effects in wash are obtained by working in the area while the wash is still wet.
063 - 4. By laying masking tape along the edge and applying the wash right up to the tape.

064 - 1. Because opaque watercolor laid over any color, either lighter or darker, covers and replaces the undercolor.
064 - 2. Semistipple and dry brush.

065 - 1 An airbrush is an excellent tool for illustrating because it is capable of producing even tones, gradual variations in value, and sharp tonal contrast.
065 - 2. Mask; frisket.
065 - 3. Raised mask.
065 - 4. With transparent pigments, the amount of paint applied determines the value. With opaque pigment, the addition of white for lighter values, and black for darker values.
065 - 5. Before airbrushing, you should check the needle for proper seating and security, attach the color cup, attach the hose, check the air pressure, mix paint, and fill the cup.
065 - 6. 25 pounds.
065 - 7. The airbrush has a control level, push down releases the air and pull back releases the paint.
065 - 8. (a) The distance between brush and paper.
(b) The position of brush in relation to paper.
(c) The movement of brush across paper.
(d) The amount of paint released by the control level.
065 - 9. Improper airbrushing techniques are indicated by grain, paper buckling, blobs, flared strokes, centipede effect, spatter, and curved strokes.

066 - 1. Sir Isaac Newton.

066 - 2. Dispersion is the separation of light rays into bands of color.

066 - 3. Spectrum is the resulting bands of color caused by dispersion.

067 - 1. 1 - b; 2 - b; 3 - a; 4 - c; 5 - b; 6 - c; 7 - a; 8 - b.

067 - 2. The same pigment colors when mixed will not produce all colors. It is impossible, for instance, to produce yellow by mixing colored pigments.

067 - 3. 1 - b and c.
2 - a and b.
3 - a and c.

067 - 4. A 12-hue wheel is convenient because it exactly accomodates the 3 primary, 3 secondary, and 6 tertiary colors.

067 - 5. Complementary colors are located directly opposite each other on the color wheel.

067 - 6. The environment affects the hue, value, and intensity of the color. It can even cause an apparent change in the size of the area occupied by the color.

068 - 1. Red, yellow, and orange are considered warm colors, while blue-green, blue, and blue-violet are considered cool colors.

068 - 2. Monochromatic schemes are most likely to be monotonous.

068 - 3. Complementary.

068 - 4. Contrasts.

068 - 5. Triad.

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STOP– 1. MATCH ANSWER SHEET TO THIS EXERCISE NUMBER. 2. USE NUMBER 1 OR NUMBER 2 PENCIL.

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EXTENSION COURSE INSTITUTE
VOLUME REVIEW EXERCISE
FUNDAMENTALS OF GRAPHICS

Carefully read the following:

DO'S:

1. Check the "course," "volume," and "form" numbers from the answer sheet address tab against the "VRE answer sheet identification number" in the righthand column of the shipping list. If numbers do not match, take action to return the answer sheet and the shipping list to ECI immediately with a note of explanation.
2. Note that numerical sequence on answer sheet alternates across from column to column.
3. Use a medium sharp #1 or #2 black lead pencil for marking answer sheet.
4. Circle the correct answer in this test booklet. After you are sure of your answers, transfer them to the answer sheet. If you *have* to change an answer on the answer sheet, be sure that the erasure is complete. Use a clean eraser. But try to avoid any erasure on the answer sheet if at all possible.
5. Take action to return entire answer sheet to ECI.
6. Keep Volume Review Exercise booklet for review and reference.
7. If *mandatorily* enrolled student, process questions or comments through your unit trainer or OJT supervisor.
   If *voluntarily* enrolled student, send questions or comments to ECI on ECI Form 17.

DON'TS:

1. Don't use answer sheets other than one furnished specifically for each review exercise.
2. Don't mark on the answer sheet except to fill in marking blocks. Double marks or excessive markings which overflow marking blocks will register as errors.
3. Don't fold, spindle, staple, tape, or mutilate the answer sheet.
4. Don't use ink or any marking other than a #1 or #2 black lead pencil.

NOTE: NUMBERED LEARNING OBJECTIVE REFERENCES ARE USED ON THE VOLUME REVIEW EXERCISE. In parenthesis after each item number on the VRE is the *Learning Objective Number* where the answer to that item can be located. When answering the items on the VRE, refer to the *Learning Objectives* indicated by these *Numbers.* The VRE results will be sent to you on a postcard which will list the *actual* VRE *items you missed.* Go to the VRE booklet and locate the *Learning Objective Numbers* for the items missed. Go to the text and carefully review the areas covered by these references. Review the entire VRE again before you take the closed-book Course Examination.

MODIFICATIONS

Pages 3- 7 of this publication has (have) been deleted in adapting this material for inclusion in the "Trial Implementation of a Model System to Provide Military Curriculum Materials for Use in Vocational and Technical Education." Deleted material involves extensive use of military forms, procedures, systems, etc. and was not considered appropriate for use in vocational and technical education.

62. (035) Which of the following choices states an incorrect rule for proper equipment care?

    a. Use special solvents for all equipment cleaning.
    b. Never use any instrument for any purpose other than that for which it was designed.
    c. Keep all instruments used to dispense ink clean.
    d. Never expose any pointed equipment to the possibility of point damage.

63. (036) Which of the following are needed in the work area of a graphic specialist?

    a. Table, low stool, and tabouret.
    b. Filing cabinet, easel, and table.
    c. Table, chair, and tabouret.
    d. Table, lavatory, and tabouret.

64. ((036) If you are right-handed, your light source should come

    a. from the right side—directly above.
    b. over your left shoulder and from the left-front.
    c. over your right shoulder and from the right-front.
    d. from the left side—directly above.

65. (037) Drawing paper should have all of the qualities <u>except</u>

    a. a smooth surface after erasures.
    b. a slick surface.
    c. a hard surface.
    d. grain.

66. (038) Which of the following is most important in a drawing pencil?

a. Size of the pencil.
b. Quality of the pencil.
c. Condition of the point.
d. Quality of the lead.

67. (038) Which of the following grades of pencil is most suitable for tonal sketches?

a. 4H.
b. 7B.
c. HB.
d. F.

68. (039) Which of the following articles is especially useful for removing graphite dust from a drawing?

a. Dusting brush.
b. Art gum eraser.
c. Electric eraser.
d. Kneaded eraser.

69. (040) What ingredient makes drawing ink cohesive and waterproof?

a. Gum arabic.
b. Finely ground carbon.
c. Fish glue mixture.
d. Mucilage.

70. (040) Which drawing ink will not reproduce photographically?

a. Dark blue and white.
b. Red and light blue.
c. Light blue and white.
d. Dark blue and light blue.

71. (042) Which of the following basic tools can be used to draw vertical parallel lines?

a. T-square and scales.
b. T-square and triangles.
c. Irregular curves and triangles.
d. Irregular curves and scales.

72. (042) Using two 30°-60° triangles, you can draw all of the following angles <u>except</u> one of

a. 15°.
b. 40°.
c. 90°.
d. 120°.

73. (043) What is the smallest division on a mechanical engineer's scale?

a. $\frac{1}{8}$ inch.
b. $\frac{1}{4}$ inch.
c. $\frac{1}{2}$ inch.
d. 1 inch.

74. (043) Which of the following scales is divided into decimals?

a. Architect's scale.
b. Mechanical engineer's scale.
c. Ruler.
d. Civil engineer's scale.

75. (043) Which of the following scales is divided into proportional divisions representing feet and inches?

a. Mechanical engineer's scale.
b. Civil engineer's scale.
c. Architect's scale.
d. Ruler.

76. (044) When you use an irregular curve to draw a smooth line through predetermined points, the curve should match the line at a minimum of how many consecutive points?

a. 3.
b. 5.
c. 7.
d. 9.

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77. (044) Which of the following can be used to draw curved lines which are not segments of circles?

a. String.
b. Compass.
c. Dividers.
d. Irregular curves.

78. (045) The primary purpose of a ruling pen is to make

a. straight lines of uniform thickness.
b. straight lines of varying thickness.
c. curved lines of varying thickness.
d. curved lines of uniform thickness.

79. (045) For proper ink flow, the nibs of a ruling pen should be

a. equal in length and pointed.
b. unequal in length and flat.
c. equal in length and rounded.
d. unequal in length.

80. (047) Which of the following illustrating tools can be replaced by the drafting machine?

a. T-square, compass, triangle, and scale.
b. T-square, triangle, scale, and protractor.
c. Compass, triangle, scale, and protractor.
d. Triangle, scale, protractor, and compass.

81. (048) The alphabet we use today was developed from hieroglyphics into a cursive form by the

a. Egyptians.
b. Phoenicians.
c. Greeks.
d. Romans.

82. (048) Which of the following lettering styles is used for most books, magazines, and newspapers?

a. Italic.
b. Gothic.
c. Text.
d. Roman.

83. (048) How many styles of lettering are in use today?

a. 3.
b. 5.
c. 8.
d. 9.

84. (049) The stem of a lowercase letter that extends above the body of the letter is called the

a. serif.
b. ascender.
c. swell.
d. descender.

85. (049) The vertical straight line that is used as the basis for most letters is called the

a. stroke.
b. ascender.
c. descender.
d. stem.

86. (049) Serifs are characteristic of what type letter?

a. Gothic.
b. Italic.
c. Roman.
d. Text.

87. (050) What are the six basic strokes used in lettering?

a. Vertical, horizontal, slanted, oval, curve, and reverse curve.
b. Vertical, horizontal, diagonal, slanted, round, and oval.
c. Vertical, horizontal, diagonal, oval, round, and straight.
d. Vertical, horizontal, diagonal right, diagonal left, clockwise curve, and counterclockwise curve.

88. (050) What is the standard slope of inclined letters?

a. 67 1/2°.
b. 60°.
c. 57 1/2°.
d. 30°.

89. (050) A rule stating that downward strokes should be thick and that horizontal strokes should be thin does not work for which of the following letters?

a. P.
b. Q.
c. R.
d. U.

90. (051) What is the distinguishing characteristic of Old Roman lettering as compared to Modern Roman?

a. Greater contrast between thick and thin lines.
b. Lighter appearance.
c. Heavier appearance.
d. Absence of serifs.

91. (051) Which principle of good lettering is considered the most important?

a. Stability.
b. Uniformity.
c. Proportion.
d. Height and inclination.

92. (052) To obtain good spacing, you might have to alter which of the following combinations of letters?

a. UM.
b. AY.
c. LA.
d. AU.

93. (052) The lettering instrument provides spacing that is what fraction of the letter height?

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

94. (053) When you are lettering, it is not necessary that the penciling be

a. shaded.
b. clean.
c. firm.
d. opaque.

95. (054) When you are lettering with a common lettering pen, blotting or bleeding could be caused by

a. an oil film on the pen.
b. applying too much pressure.
c. using a quill to apply the ink.
d. too much ink on or in the pen.

96. (054) Which type of speedball pen can be used to make Roman style letters?

a. A.
b. B.
c. C.
d. D.

97. (055) The tips or points of good lettering brushes are

a. never cut or trimmed.
b. always cut and trimmed.
c. always shaped by hand.
d. sometimes shaped by hand.

98. (055) What are the major shapes of lettering brushes?

a. Rounds, squares, and flats.
b. Rounds, squares, and ovals.
c. Rounds, brights, and flats.
d. Rounds, flats, and ovals.

99. (054) Text writing pens are similar to type-C speedball pens in that both

a. have slanted nibs.
b. are made of plastic.
c. have cleaning pins.
d. are equipped with inkwells.

100. (055) The best lettering brushes are made of hair from what animal?

a. Pig.
b. Camel.
c. Squirrel.
d. Kolinsky.

101. (056) A standard mechanical lettering set consists of

a. a body, an adjusting screw, and a tail pen.
b. templates, a scriber, and pens.
c. a lockout, a socket screw, and a scriber.
d. a body, pens, and templates.

102. (057) If a strip of prepared lettering is placed on a curved line, you should cut

a. each letter and place it individually along the curve.
b. between the letters except in the center of the strip.
c. notches along the top and bottom of the strip.
d. between the letters leaving the bottom of the strip uncut.

103. (057) An advantage of using printed prepared lettering is that it can be

a. machine set.
b. applied directly to the finished artwork.
c. obtained easily.
d. easily transferred to any rough surface.

104. (058) In the pen-and-ink technique of line drawing, India ink is most commonly used because it

a. is permanent.
b. is opaque.
c. is waterproof.
d. has all of the above characteristics.

105. (059) In a line media illustration produced with pencil or crayon, the drawing is usually applied to what type of surface?

a. Smooth.
b. Lined.
c. Textured.
d. Colored.

106. (060) What are the two types of prepared shading media?

a. Transparent film and chemical.
b. Transparent film and paper.
c. Chemical and paper.
d. Chemical and opaque.

107. (061) One of the disadvantages of using scratchboard is that

a. the board is extremely absorbent.
b. illustrations cannot be drawn with a pen.
c. illustrations are adversely affected by changes in temperature and humidity.
d. cost is prohibitive.

108. (061) Which technique is best suited for rendering a predominantly dark object that has much detail and sharp, white highlights?

a. Crayon.
b. Pen and ink.
c. Pencil.
d. Scratchboard.

109. (062) Which of the following gives a mat finish and a rich dark black?

a. Crayon.
b. Carbon pencil.
c. Lead pencil.
d. Graphite pencil.

110. (063) When you apply a wash, it should be

a. painted on.
b. rubbed on.
c. floated on.
d. rubbed in.

111. (063) What advantage does India ink have over lampblack or Chinese stick ink when you are preparing and laying a wash?

a. It is easier to use.
b. Lampblack and stick ink must be strained.
c. Chinese stick ink and lampblack are messy.
d. One wash can be laid over another without picking up the one underneath.

112. (064) The most difficult medium to blend is

a. opaque watercolor.
b. acrylics.
c. transparent watercolor.
d. oil paint.

113. (065) When working in transparent wash to render an area with strong highlights and shadows, you should

a. cover the highlights with white paint after painting all the dark tones.
b. cover the area with a frisket so that the area will not be painted.
c. airbrush the dark tones only, leaving the highlights.
d. cover the highlights with white paint before painting the dark tones.

114. (065) On a double-action airbrush, the largest amount of paint will be sprayed when the lever is

a. all the way down and all the way to the rear.
b. all the way down and slightly to the rear.
c. all the way up and all the way to the rear.
d. slightly down and slightly to the rear.

115. (065) Fairly large specks of color at the beginning of an airbrush stroke are generally caused by your

a. pulling back too slowly on the control lever.
b. releasing the control lever too quickly on the previous stroke.
c. pulling back too quickly on the control lever.
d. releasing the control lever too slowly on the previous stroke.

116. (066) The separation of light into colors is called

a. value.
b. density.
c. dispersion.
d. light separation.

117. (066) A black object is one that

a. absorbs nearly all light rays.
b. reflects nearly all light rays.
c. reflects all colors except black.
d. absorbs all colors except black.

118. (066) The colors of the spectrum arrange themselves in order of

a. their density.
b. dispersion.
c. the color wheel.
d. their wavelengths.

119. (067) The quality by which we recognize one color from another is called

a. intensity.
b. value.
c. hue.
d. density.

120. (068) Which of the following colors is considered cool?

a. Red.
b. Blue.
c. Yellow.
d. Orange.

121. (067) When a small amount of red is added to green, what quality of color is changed the most?

a. Intensity.
b. Value.
c. Hue.
d. Tone.

122. (068) When a single color value varies from a light tint to a dark shade, the color is said to be

a. analogous.
b. monochromatic.
c. complementary.
d. triad.

123. (068) An analogous color scheme is sometimes called a

a. triad color scheme.
b. complementary color scheme.
c. related color scheme.
d. monochromatic color scheme.

124. (068) You can prevent an analogous scheme from becoming monotonous by

a. taking in more of the color wheel.
b. introducing white as an accent.
c. placing emphasis on a hue that is not dominant.
d. introducing complementary accents.

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CDC 23151

GRAPHICS SPECIALIST

(AFSC 23151)

Volume 2

Applied Basic Drafting Techniques (Part I)

Extension Course Institute

Air University

Preface

IN VOLUME 1, you studied the fundamentals of illustrating. Now with this background you are ready to learn about specific areas. Some of these areas are projections, dimensioning, graphic construction, and sectional views. It is important that these areas be thoroughly covered, because they are basic to all drawings.

Chapter 1 of this volume explains the basic elements of graphic construction. It prepares you for further study into forms of geometric figures.

Chapter 2, on projections, prepares you for drawings as they relate to multiview, isometric, oblique, and auxiliary views. Perspective is also a projection, but will be dealt with as a separate chapter.

Chapters 3 and 4 on sectional views and dimensioning are in the same category as Chapters 1 and 2. If you are training toward your 5-level AFSC, this will prepare you for the end-of-volume review exercises. Satisfactorily completing these exercises and those of the rest of the volume will prepare you for the end-of-course examination and your SKT.

Foldouts 1 and 2 are printed and bound in the back of the volume.

Code numbers, such as 231-1, appearing on figures are for preparing agency identification only.

If you have questions on the accuracy or currency of the subject matter of this text, or recommendations for its improvement, send them to Tech Tng Cen/TTOC, Lowry AFB CO 80230.

If you have questions on enrollment or administration or on any of ECI's instructional aids (Your Key to Career Development, Behavioral Objective Exercises, Volume Review Exercise, and Course Examination), consult your education officer, training officer, or NCO, as appropriate. If he cannot answer your questions, send them to ECI, Gunter AFS AL 36118, preferably on ECI Form 17, Student Request for Assistance.

This volume is valued at 18 hours (6 points).

Material in this volume is technically accurate, adequate, and current as of May 1974.

Contents

NOTE: In this volume, the subject matter is developed by a series of Learning Objectives. Each of these carries a 3-digit number and is in boldface type. Each sets a learning goal for you. The text that follows the objectives gives you the information you need to reach that goal. The exercises following the information give you a check on your achievement. When you complete them, see if your answers match those in the back of this volume. If your response to an exercise is incorrect, review the objective and its text.

Geometric and Graphic Construction

DRAWING PROBLEMS encountered by the graphics specialist can usually be solved in several different ways. For instance, in ordinary drawing practice the graphics specialist would use a T-square and a triangle to draw a line perpendicular to a given line, arc, or what have you, or he may locate a point of tangency on a circle by estimating its position. When extreme accuracy is of first importance, the task should be accomplished by geometric construction. Also, when making a drawing of an unusually large size—such as full-size sheet-metal patterns—the geometric principles should be used.

Actually, you apply the principles of geometry whenever you use your drawing tools. Therefore, increased knowledge of these principles, coupled with skills acquired in using your drawing instruments, prepares you to do more difficult jobs in the future. For now, let's concern ourselves with procedures, and not with mathematical proof of geometric construction.

1-1. Terms and Principles

Perhaps the material in this section may be a review for you, perhaps not. In any case, the more common definitions of terms and principles must be known by you as they are important in technical drawing. Let's begin with lists of definitions of terms and basic principles, and then follow with a discussion of important facts which, in many cases, is a combination of the two. The lists which follow will serve as a quick reference during your studies.

200. Define the terms and basic principles of geometric construction.

Definitions of Terms. As you study these definitions, refer to figure 1-1.

Angle—The figure formed by the coming together of two lines at a point.
Arc—A curve which is not closed.
Asymptote—A line that is the limiting position which the tangent to a curve approaches, as the point of contact recedes indefitely along an infinite branch of a curve.
Chord—A straight line intersecting a curve
Circle—A closed curve all points of which are equidistant from a point called the center.
Concentric circles—Circles having the same center.
Cycloid—A curve traced by a point on a circle rolling in a plane along a line in the plane.
Diameter—The length of a straight line through the center of an object.
Eccentric circles—Circles not having the same center point.
Ellipse—A plane curve, the path of a point the sum of whose distances from the foci (two fixed points) is constant; a conic section, the closed intersection of a plane with a right circular cone.
Helix—The curve formed on any cylinder by a straight line in a plane that is wrapped around the cylinder, such as an ordinary screw thread.
Heptagon—A polygon of seven angles and seven sides.
Hexagon—A polygon of six angles and six sides.

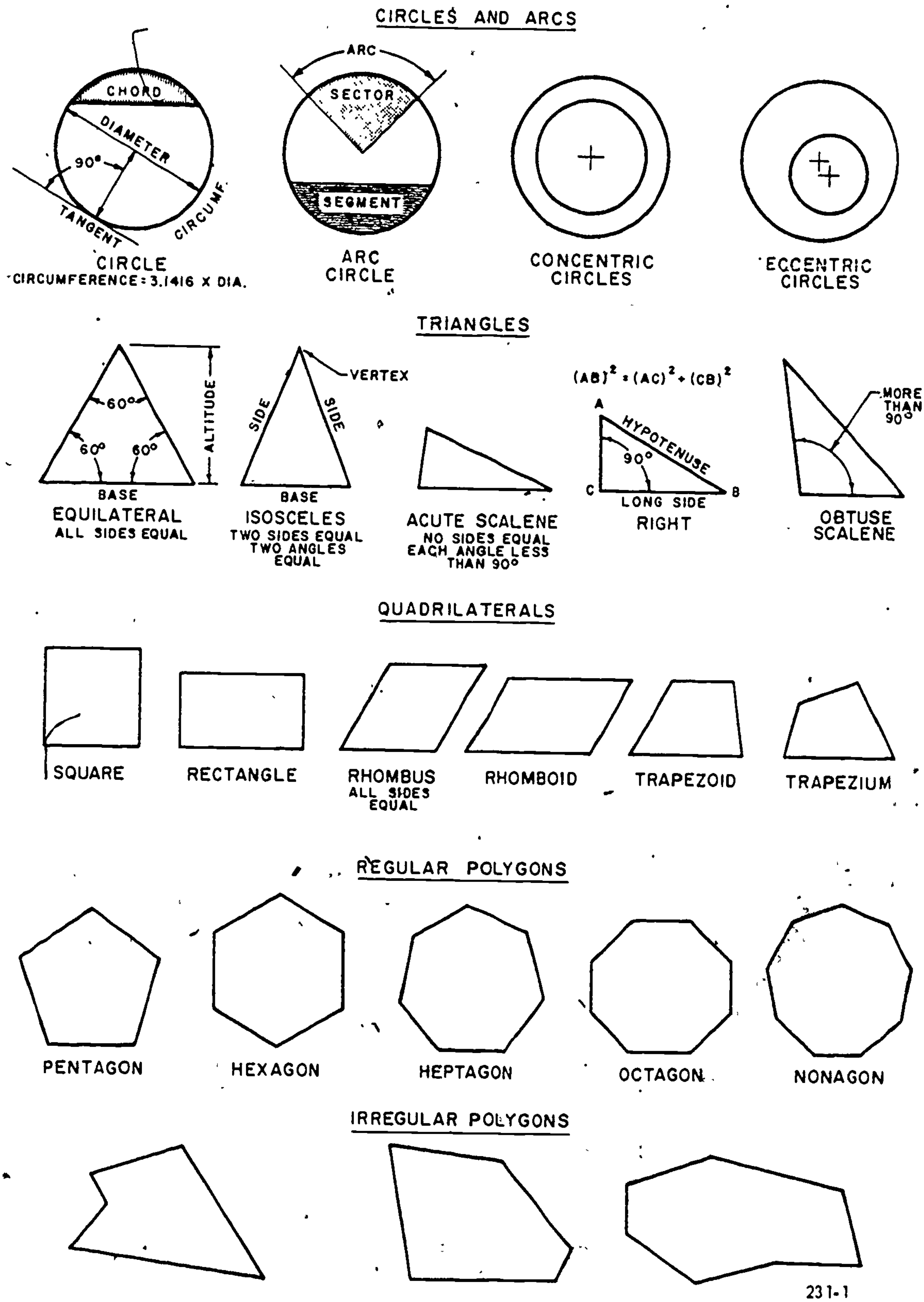


Figure 1-1. Geometric figures.

Hyperbola—A curve formed by a section of a right circular cone when the cutting plane makes a greater angle with the base than the side of the cone makes. Also, a hyperbola may be produced by a point moving so that the difference of its distances from the foci (two fixed points) is constant and equal to the transverse axis of the hyperbola.

Involute—A curve traced by any point of a perfectly flexible, inextendible thread kept taut as it is wound or unwound from another curve or object.

Nonagon—A polygon having nine angles and nine sides.

Octagon—A polygon having eight angles and eight sides.

Parabola—A conic section formed by the intersection of a cone with a plane parallel to its side.

Parallelogram—A quadrilateral whose opposite sides are parallel.

Pentagon—A polygon having five angles and five sides.

Plane—A two-dimensional flat surface.

Plane figure—A surface or space completely inclosed by lines.

Polygon—Any plane figure completely inclosed by straight lines. When a polygon has equal sides and equal angles, it can be inscribed within or circumscribed around a circle. In this case, it is known as a regular polygon. (In common practice, the term "polygon" usually implies that a figure has five or more sides.)

Quadrilateral—A plane figure bounded by four straight sides.

Radius—A straight line extending from the center of a circle or sphere to the curve or surface.

Sector of a circle—The figure bounded by two radii (an angle) and the included arc of a circle, ellipse, or other central curve.

Segment of a circular area—That part which is bounded by a chord and an arc.

Trapezoid—A quadrilateral with two sides parallel.

Trapezium—A quadrilateral with no sides parallel.

Triangle—A plane figure bounded by three straight sides, and the sum of the interior angles is always 180°.

Some Principles of Plane Geometry. Any one or all of these principles may apply to a particular drawing.

- A straight line is the shortest distance between two points.
- A point represents a specific location; it has no dimensions.
- Two lines are perpendicular when the angle formed at their intersection is 90°.
- When measuring the distance between a point and a line, measure along a perpendicular from the point to the line.
- Parallel lines are equidistant from each other at all points.
- Curves are tangent to straight lines or to other curves at only one point.
- Regular polygons have all sides and angles equal.
- A line intersected by equally spaced parallel lines is cut into equal segments.
- Any figure may be moved from one place to another without altering its size or shape.
- From a given point on a given line, only one perpendicular can be drawn.
- The diagonals of a parallelogram bisect each other.
- Through three points not in a straight line, only one circle can be drawn.
- When two circles are tangent to each other, the straight line joining their centers passes through the point of tangency.
- The major and minor axes of an ellipse divide the figure into four equal parts.

Exercises (200):

1. A straight line intersecting a curve is called a ________.

2. What represents a specific location, but has no dimensions?

3. Is question 2 a definition of a term or a principle of plane geometry?

201. Identify the geometric figure or figures on a flat surface that are generated by movement.

Points, Lines, and Planes. The branch of geometry that we are concerned with is called

Figure 1-2. Points.

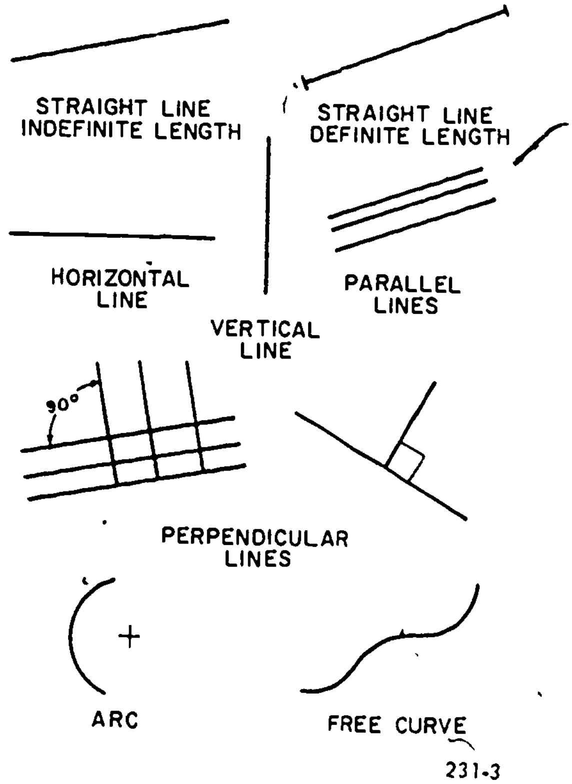


Figure 1-3. Lines.

plane geometry. It derives its name from the fact that it deals with the position of points and lines on flat surfaces, which are called planes.

A point. A point is a position representing a location in space or a flat surface; it has no height, width, or depth. Figure 1-2 shows three ways to represent a point. Notice, as illustrated, that a point may be represented by the intersection of two lines, by a small crossbar on the line, or by a small cross. A point is never represented by a simple dot on the paper.

Line. A line is an imaginery geometric figure. A line does not exist in nature; it is generated by a point in motion. It has length but not thickness. (Dots, lines, and points in drawings have thickness merely as a convenient way to represent small areas or planes.) (See fig. 1-3.)

- A line that has the same direction for its entire length is a *straight line.*
- A line that changes in direction along its length is a *curved line.*

Plane. A plane or flat surface is generated by a straight line moving in a direction other than that of its length, creating an area or surface with length and breadth, but no thickness.

Exercises (201):

1. Under the concepts of geometry, how is a straight line produced?

2. How is a curved line produced?

3. What is a plane?

202. Given definitions of types of angles, match each with a class or group and illustrate.

Angles. An angle is formed by two lines meeting at a point. The lines are the sides of the angle, and the point at which they meet is the vertex. Angles are divided into five general classes and two general groups. The classes are:

- An angle formed by perpendicular lines with one angle at 90° is a right angle.
- An angle that is less than a right angle, or 90°, is an acute angle.

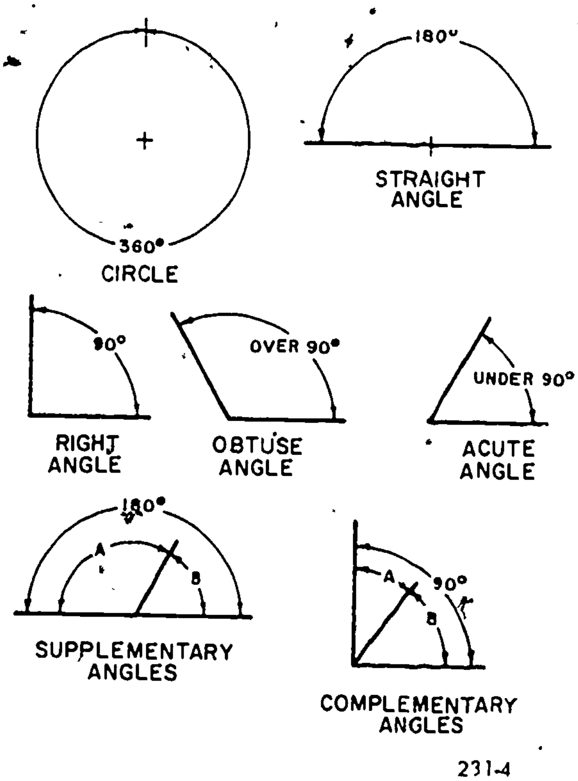


Figure 1-4. Angles.

- An angle that is greater than a right angle but less than a straight angle is an obtuse angle.
- An angle whose sides extend in opposite directions from the vertex, or 180°, is a straight angle.
- An angle that is greater than a straight angle but less than 360° is a reflex angle.

The two general groups are: (1) right and straight angles and (2) oblique angles. Since there are only two groups, you can define one in relation to the other—oblique angles are all angles other than straight or right angles.

Adjacent Angles. Angles which have a common vertex and side are adjacent angles. They can be supplementary or complementary angles, as shown in figure 1-4.

Triangles. A triangle is a plane figure bound by three straight sides and the sum of the interior angles always totals 180°.

Exercises (202):

1. Two angles with a common side and vertex are called ________.

2. Match the terms in column A with the definition in column B by writing the correct letter in the blank provided.

Column A	*Column B*
(1) Obtuse ______	*a.* Angles other than straight and right angles
(2) Right ______	*b.* An angle that is less than a right angle
(3) Reflex ______	*c.* An angle that is greater than a right angle but less than a straight angle
(4) Oblique ______	*d.* An angle formed by perpendicular lines
(5) Straight ______	*e.* Angles with a common vertex
(6) Acute ______	*f.* An angle that is greater than a straight angle but less than two straight angles
	g. An angle whose sides extend in the opposite direction from the vertex

3. Draw and identify each of the following angles.
   a. Acute and oblique.

   b. Right.

   c. Obtuse and oblique.

   d. Straight.

   e. Reflex and oblique.

1-2. Bisecting Figures and Constructing Perpendicular Lines

Bisecting figures and constructing perpendicular lines are just as basic to drafting as addition is to arithmetic. These are simple and may be drawn by several methods. Whatever method is used, the accuracy depends on you. Now is the time to start practicing accurate drawing as you study the following procedures.

203. Given a line or an arc, bisect and construct lines perpendicular to each and identify the method used.

Bisecting an Arc or a Line. An arc or a line may be bisected by use of either a compass or triangles. The geometric (compass) method is by far the more accurate. Given line or arc AB, as shown in figure 1-5, use the following procedures:

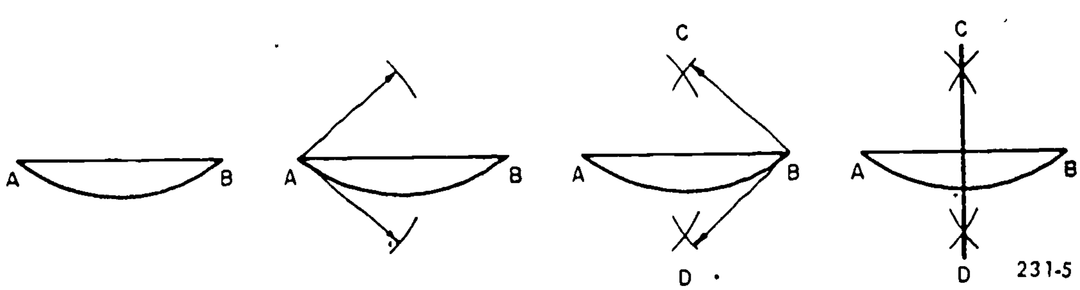


Figure 1-5. Bisecting an arc or a line.

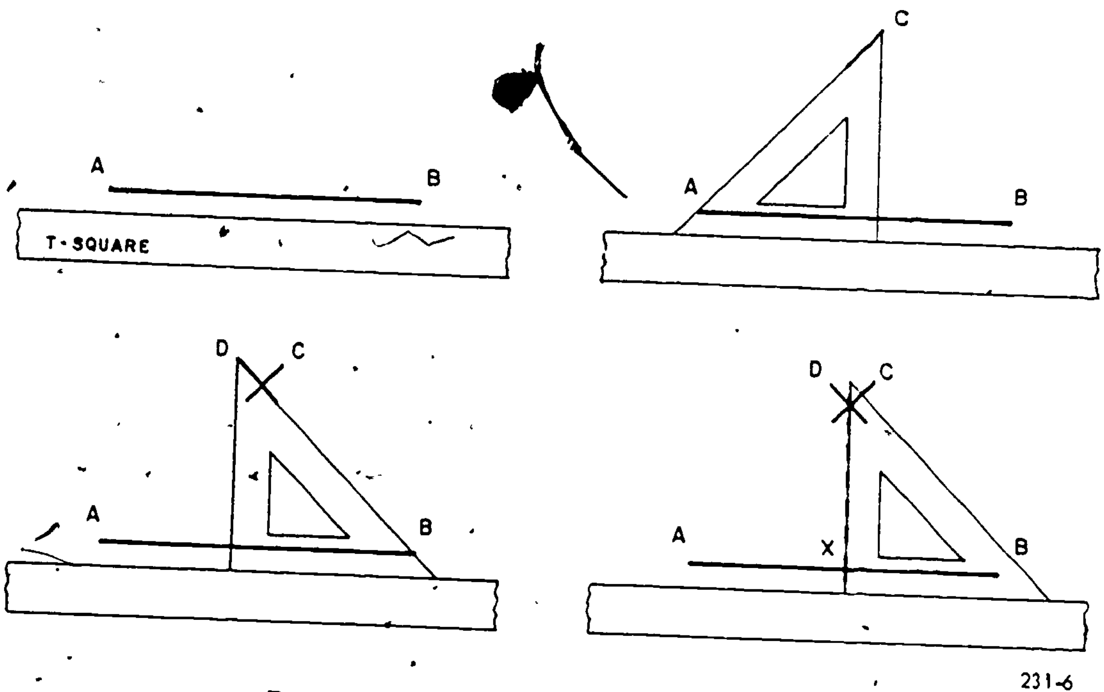


Figure 1-6. Bisecting a line with T-square and triangle.

• Set the compass for any radius greater than one-half of AB.

• Using A and B as centers, draw two arcs to intersect at points C and D, as shown in figure 1-5.

• The point at which line CD crosses AB is the center, and also line CD is perpendicular to line and arc AB.

Bisecting a line or an arc with a T-square and 45° triangle is not the most accurate method, but it is the fastest. If the given line or arc is a long line or large arc, this method is unusable. Here is the procedure for bisecting a line or an arc, as shown in figure 1-6.

• Place the 45° triangle on the T-square so that the hypotenuse of the triangle passes through point A; draw line AC.

• Turn the triangle over and repeat the operation, using point B. Draw line BD.

• Place the vertical edge of the triangle at the intersection of AC and BD, and draw the vertical line which bisects line AB at point X.

Bisecting an Angle. Given angle BAC, use the following procedures:

• With A as the vertex or center, set the compass at any radius, and draw an arc cutting lines AB and AC at points 1 and 2.

• Set the compass at a radius greater than one-half of points 1 and 2.

• With 1 and 2 as centers, draw two arcs to intersect at 0.

• Draw line A0 to bisect the angle. (See fig. 1-7.)

Construction of Perpendiculars. Constructing perpendicular lines follows the same procedure as bisecting a line, arc, or angle, except that a perpendicular may be constructed to a point, or from a point. When

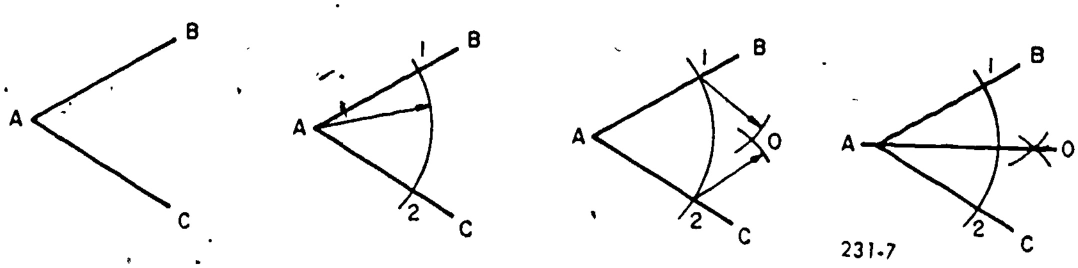


Figure 1-7. Bisecting an angle.

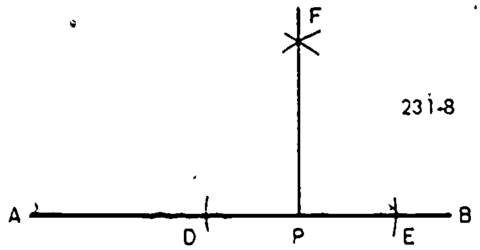


Figure 1-8. Constructing perpendiculars.

constructing a perpendicular to a given point on a line, using P as the point on line AB, as shown in figure 1-8, use any practical radius and strike an arc that intersects line AB at points D and E. Using points D and E as centers, strike the arc to intersect at some point F. Draw a straight line through points F and P. This line is perpendicular to line AB.

Exercises (203):

1. Bisect a line $2\frac{7}{32}''$ long drawn at an angle of 33°.

2. Draw a line perpendicular to a given arc at 241° with a radius of 2".

1-3. Construction of Linear Figures and Division of Figures into Equal Parts

This segment first presents several methods of drawing parallel lines and then the procedures to divide lines and spaces into any number of equal parts. This is one of the procedures that will be used throughout your illustrating career. Of course, lines can be drawn parallel by using a T-square and triangle. However, when the demand is for accuracy or the drawing is very large, such as banners, large posters, etc, the T-square and triangle should not be used for drawing parallel lines.

204. Given a line through a point, draw another line parallel.

Given a Line. Given line AB and the required point C, as shown in figure 1-9:

- With C as the center and any convenient radius, strike an arc DE to intersect line AB at point F.
- With F as the center using the same radius, draw an arc GH to intersect line AB at K.
- With CK as a radius and F as the center, strike an arc intersecting arc DE at L.
- Through points L and C draw the required parallel line.

This problem can also be drawn by the triangle method using the following procedure (See fig. 1-10.)

Place the hypotenuse of a triangle on the given line AB with the base on the triangle resting against the T-square.

Hold the T-square in position and slide the triangle to point C and draw line CD.

To draw a line parallel to another line at a given distance is like drawing perpendiculars to a point on a line. You can do most of the straight line by either geometric construction or the triangle method (see fig. 1-11), but the curved lines can be done only by geometric construction, as shown in figure 1-12.

Exercises (204):

1. Given a line 2½ inches long, draw another line parallel ¾ of an inch away.

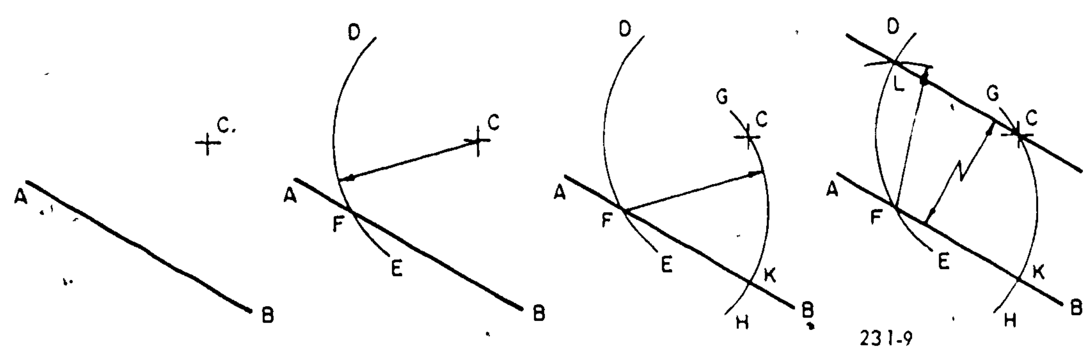


Figure 1-9. Drawing lines parallel to a given point.

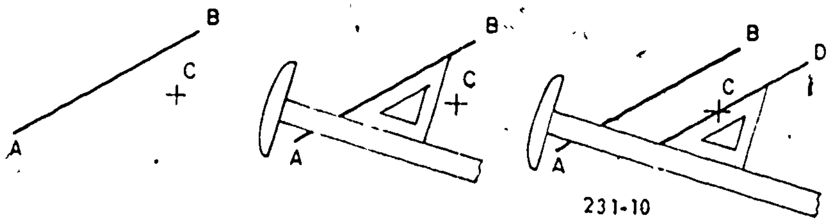


Figure 1-10. Drawing lines parallel using T-square and triangle.

2. Given a curved line 2½ inches long, draw a parallel line ⅝ of an inch away.

205. Given a line or space, explain how each is divided into equal parts.

Given a Line or Space. Assume that a given line is to be divided into equal parts.

- Draw line AB which is to be divided.
- From point A draw a line any length at any convenient angle.
- From point A lay off the number of equal parts with either a scale or a pair of dividers on line AC.
- From the termination point of the last space on line AC, draw a line connecting the last point with point B.
- With the edge of the triangle set parallel with the last point on line AC and point B, draw lines from the points on line AC to line AB. (See fig. 1-13.)

Dividing spaces into equal parts employs the same method as the draftsman's method for dividing a line with a scale. The one difference is as shown in figure 1-14. To divide spaces, the scale is placed at a convenient angle covering the number of equal spaces needed, whereas in the division of a line with a scale, the scale is placed so that zero coincides with the end of the line A and the last point on line AC falls on the line BC, and line BC can be any length.

Exercises (205):

1. Given a line 3⅝ inches long, divide it into six equal parts, using the geometric construction method.

2. Repeat exercise 1, using the scale method.

1-4. Construction of Lines Tangent to Circles and Arcs, and Rectifying Arcs

Often, as a graphics specialist, you will be required to construct lines tangent to circular

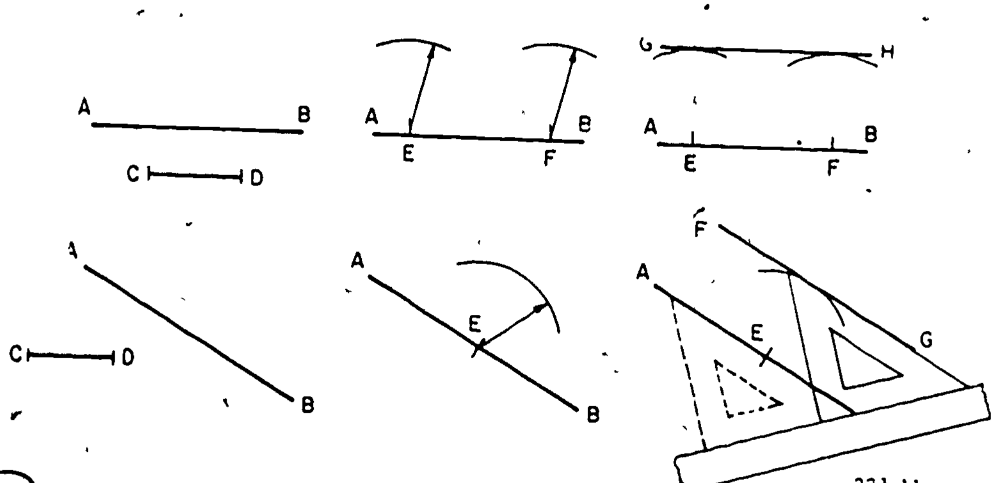


Figure 1-11. Drawing lines parallel at a given distance.

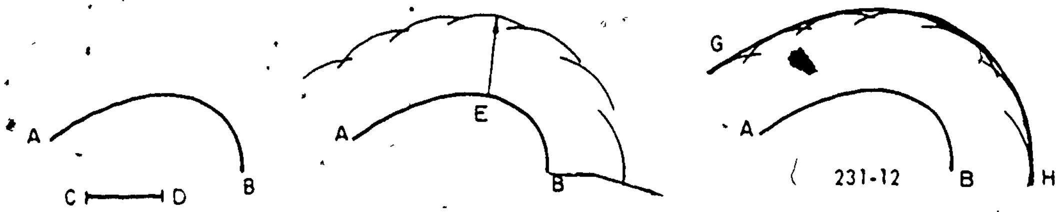


Figure 1-12. Drawing curved lines parallel at a given distance.

arcs. A circular arc is a portion of the circumference of a circle. Accurately drawing straightline tangents to circles or arcs is difficult, because there are elements of optical illusion involved. Therefore, you must know how to construct tangents by several methods.

A tangent to a circle may be drawn either to a point on the circle or to a point not on the circle. You will also be required to draw a straight line which is approximately equal in length to the length of an arc. This is known as rectifying an arc. But first we shall cover lines of tangency, then methods of rectifying an arc.

Construction of lines tangent to a point on a circle, circular arc, or curves will be the principle drawing exercises of this section. Study each figure carefully; then practice making the construction.

206. Given a point on a circle, construct a line tangent to that point.

Constructing a Line Tangent to a Point. Figure 1-15 illustrates the procedure to construct a line tangent to a circle at point S.

- Given point S on the circle with 0 as the center, set the compass to a radius equal to SO; with S as the center, strike arc OD to cut the circle at O and E.
- With E as a center, using the same radius, draw an arc to cut OD at X.
- With X and E as centers and any convenient radius greater than SO, strike an arc. From this point draw a line tangent to the circle at point S.

Figure 1-16 demonstrates the same procedure for constructing a tangent to a point on a circle by means of a perpendicular. Often, depending upon the type of drawing, this method is the most practical. Remember that a tangent to a circle is perpendicular to a radius at the point of tangency.

- With P as the point on the circle, draw a line through P and extend it to some convenient point X.
- Using P as the center, construct line AB perpendicular to line OX at point P.
- Line AB is tangent to the circle at point P.

Exercises (206):

1. Using the geometric construction method, construct a line tangent to a circle.

2. Using the perpendicular method, construct a line tangent to a circle.

207. Given a point outside a circle, construct a line tangent to the circle.

Constructing a Tangent to a Circle. The procedure for constructing a tangent to a circle from an outside point is just as easy to do as the previous construction. (See fig. 1-17.)

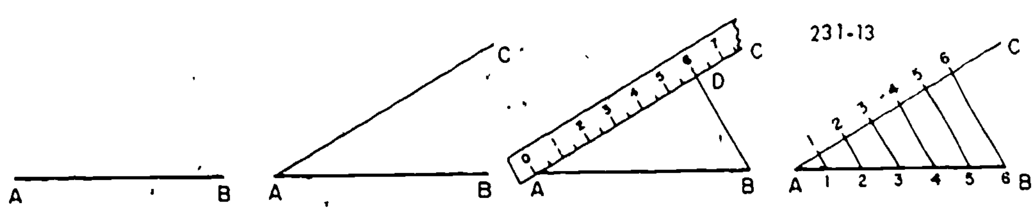


Figure 1-13. Dividing a line into equal parts.

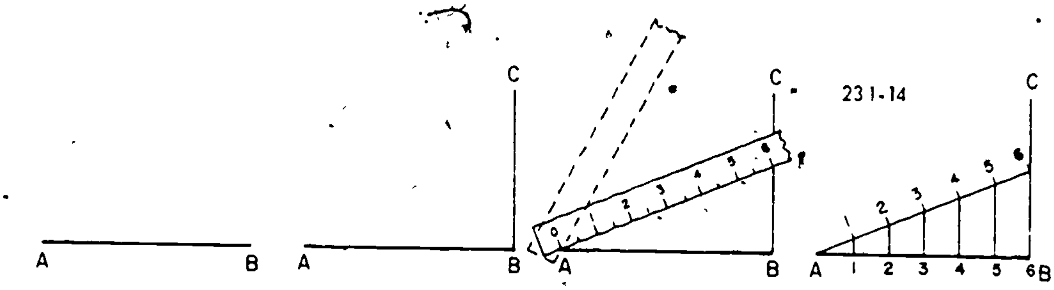


Figure 1-14. Dividing a space into equal parts.

• Using P as the point, draw a line from 0, the center of the circle, to the point P.

• Bisect the line OP; at the point of the bisector, point A, strike an arc with AO as the radius.

• Where the arc strikes the circle forming point T, draw the tangent PT.

Exercises (207):

1. Construct a tangent to a 3-inch-diameter circle from a point 2 inches from the center of the circle at an angle of 269°.

208. Given a line, a circle, or an arc, and another radius, draw an arc tangent to the circle or arc and the straight line. (See figure 1-18.)

Given a Line, Circle, or Arc.

• Take the given radii R1 and R2; strike an arc with 0 as the center.

• Draw a line CD parallel to the given line AB at a distance of R2.

• Where the arc R1+R2 crosses line CD, strike an arc that is tangent to line AB and the circle.

Drawing Tangent Arcs. In this type of construction, two conditions may exist. In one case, the centers of the given arc are

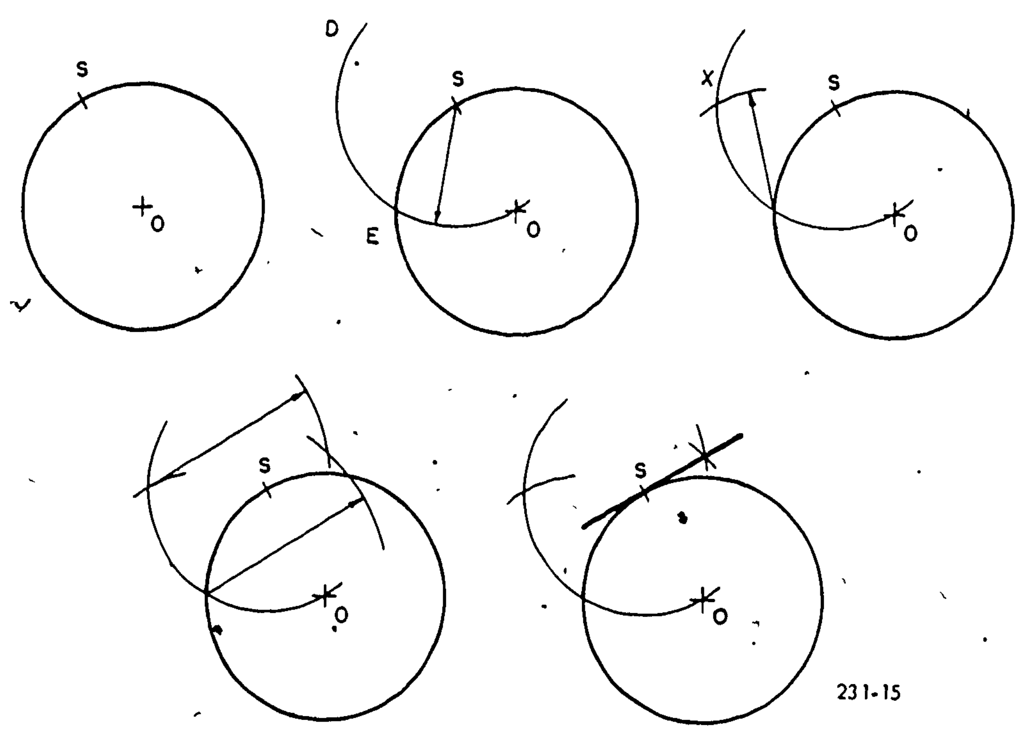


Figure 1-15. Constructing a line tangent to a point on a circle.

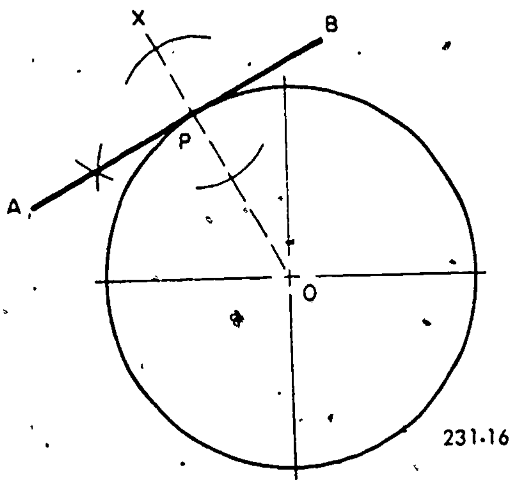


Figure 1-16. Constructing a line tangent by means of a perpendicular.

outside the required arc; in the other, the centers are included inside the required arc.

- Given R1, R2, and R3, with 0 as the center, strike an arc with R1+R2.
- With 0′ as the center of the second arc or circle, strike an arc R2+R3 that intersects the first arc at point P.
- Using P as the center and radius R2, strike the required arc.

The center of the circle is included inside the required arc. Use figure 1-19 as you practice this procedure, given the radii R1, R2, and R3.

- Using 0 and 0′ as centers, take R1-R3 and strike the first arc.
- Take R2-R3 and strike the second arc, forming point P.
- At point P, using R3, you can strike an arc that is tangent to both circles 0 and 0′.

Exercises (208):

1. Draw an arc tangent to a given line and circle.

2. Draw an arc tangent to two circles.

1-5. Construction of a Plane Geometric Figure

Remember that a plane is a two-dimensional surface. A plane figure is a figure completely inclosed on all sides and which lies on a flat surface. For example, a square cannot exist alone in nature. When we speak of a square, we are actually speaking of one surface or plane of a cube. So drawing the planes of a figure will aid you in developing your drawing accuracy, not only in the application of geometric construction principles, but also in the construction of three-dimensional figures. The construction of a plane geometric figure has no right or wrong way, but some procedures are more accurate than others. We will begin with the triangle and cover as many shapes and procedures as necessary.

209. Given the procedure for constructing several types of triangles, list the procedure and the type of triangle.

Construction of a Triangle with Three Given Sides (Fig. 1-20). As you practice, follow this procedure:

- Draw one side, such as side A, in any position.
- With side B as a radius, strike an arc from either end of the line A.
- With side C as a radius, strike an arc from the opposite end of A and intersect the first arc.
- Draw a line from the ends of side A to the point of intersection.

Construction of a Right Triangle with Hypotenuse and One Side Given. Figure 1-21 illustrates the following procedure for constructing a right triangle with hypotenuse (P) and a side (T) given.

- Draw a line (any position) and mark off BC equal to the length of line P.
- Bisect the line BC (point S).
- Using point S as center and radius BS or CS, swing the semicircle.
- With point C as center and radius T, strike an arc cutting the semicircle at point D.
- Draw lines BD and CD.

Construction of an Equilateral Triangle with One Side Given. Recall that all sides of an equilateral triangle are equal and each angle is 60°. So the construction of this triangle is extremely simple. The following procedure is illustrated in figure 1-22.

- Draw line AB any required length.
- Using line AB as radius and point B as center, swing an arc.
- Using the same radius and point A as center, swing another arc to intersect the first arc.
- Draw sides AC and BC.

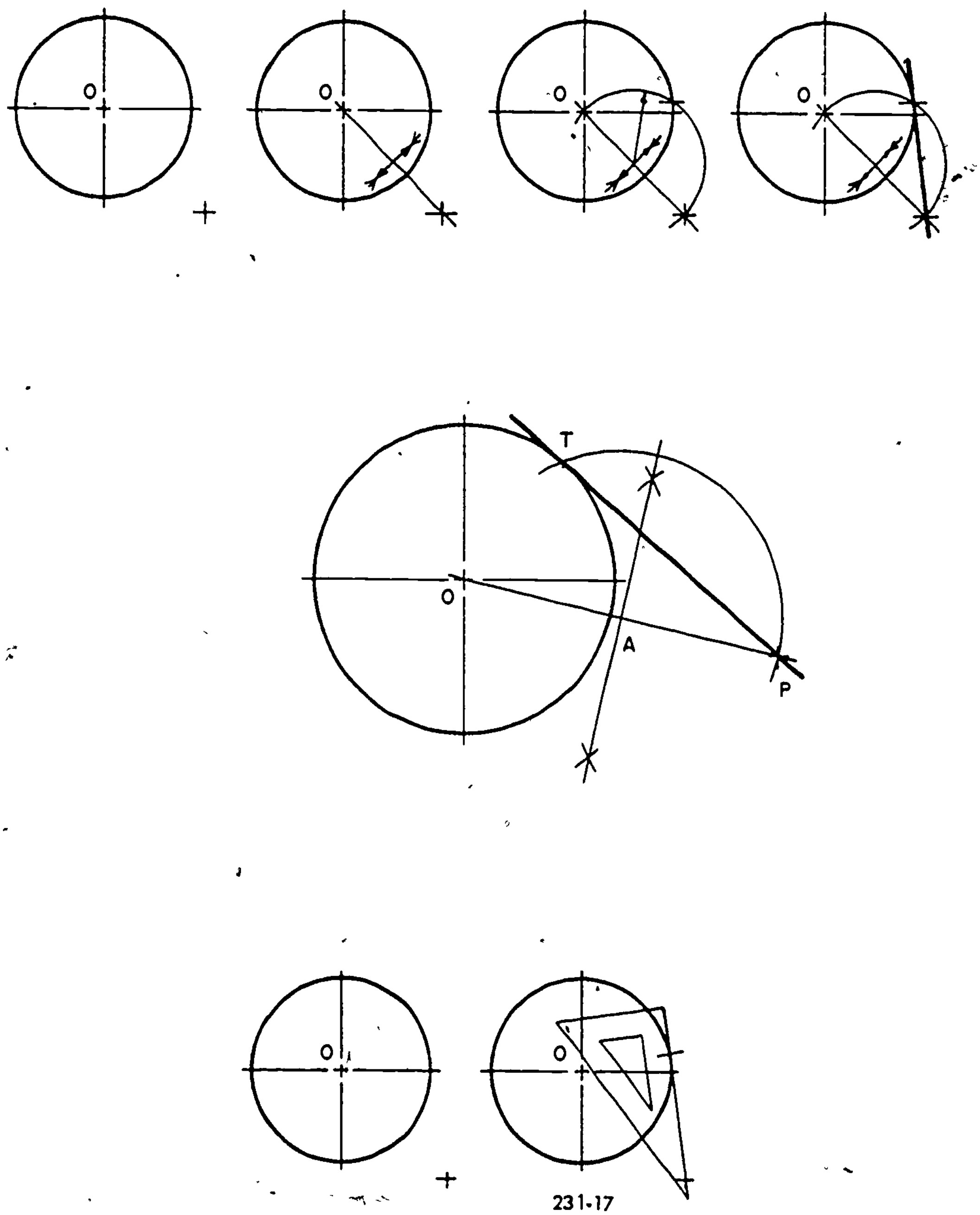


Figure 1-17. Constructing a line tangent to a circle from an outside point.

Construction of an Equilateral Triangle, Using a T-square and Triangle. This is a convenient method, particularly if the base of the triangle is horizontal. Figure 1-23 illustrates the following procedure.

- Place a 30°-60° triangle against a T-square and draw a line which makes a 60° angle with one end of given base AB.
- Draw a line which makes a 60° angle with the other end of base AB.
- The intersection of these two lines at point C completes the triangle.

Exercises (209):

1. Given three sides of a triangle, side A equals 1¾ inches. What is the actual length of the other two sides?

2. Draw a triangle with the hypotenuse 1¼ inches and one side ¾ inch. Find the length of the other side.

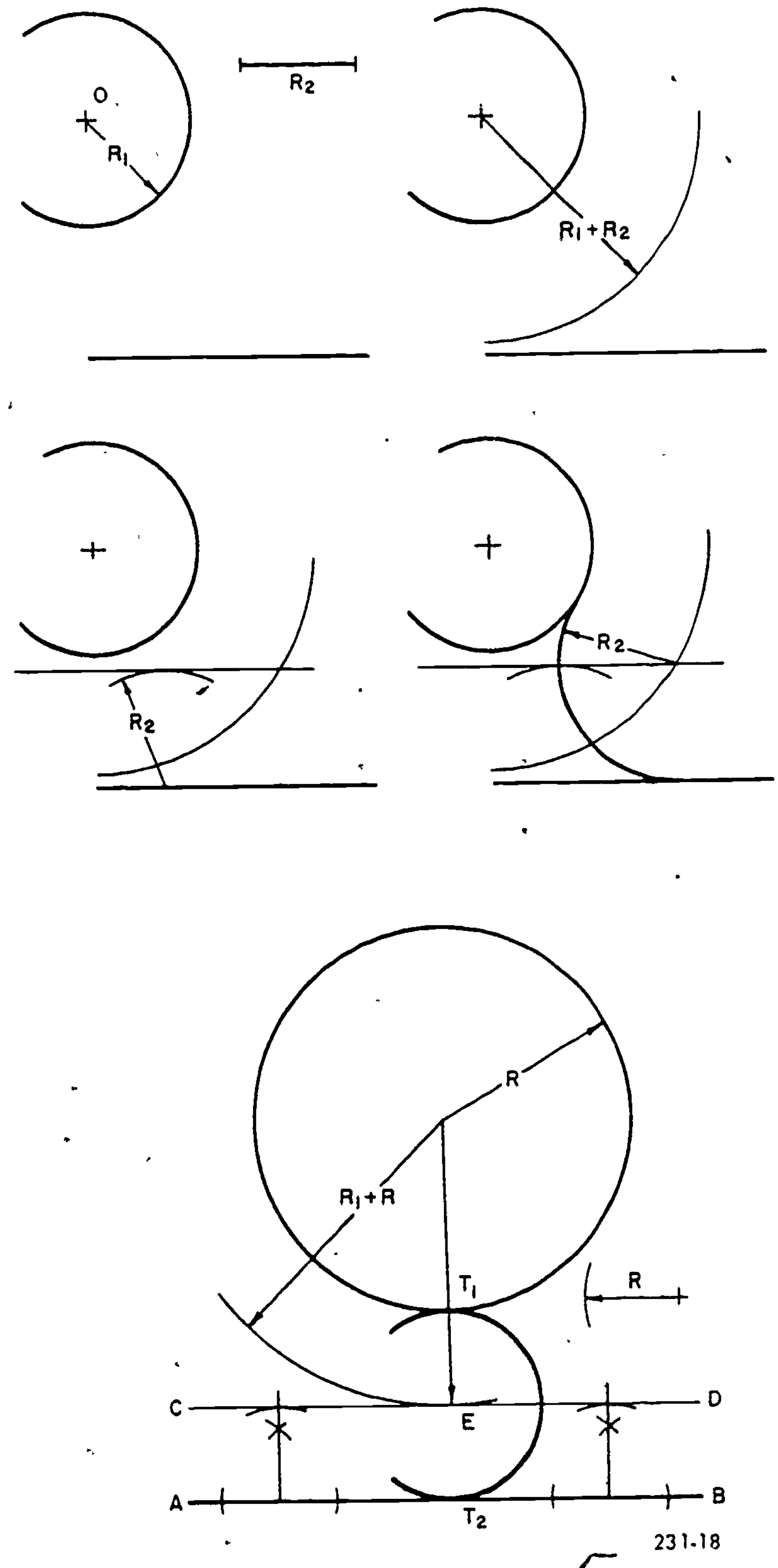
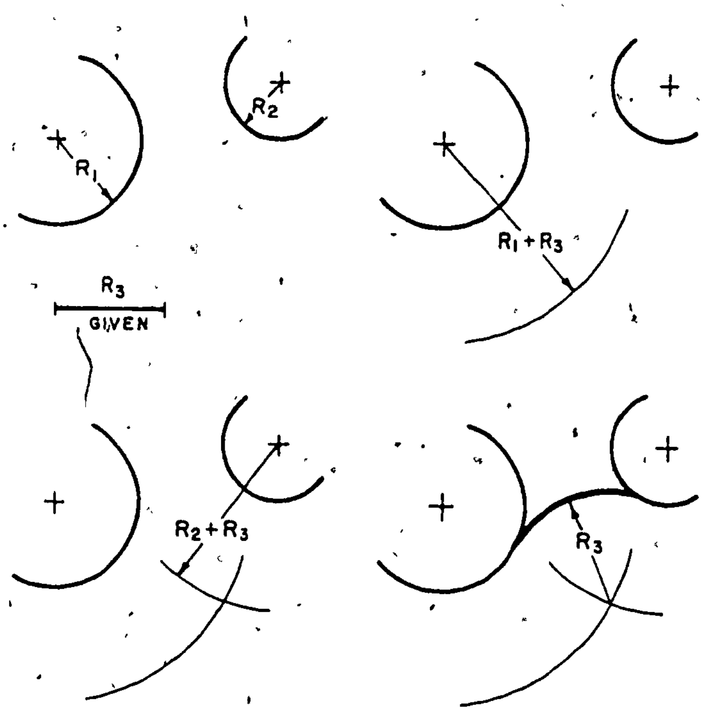


Figure 1-18. Constructing an arc tangent to a given arc and line.



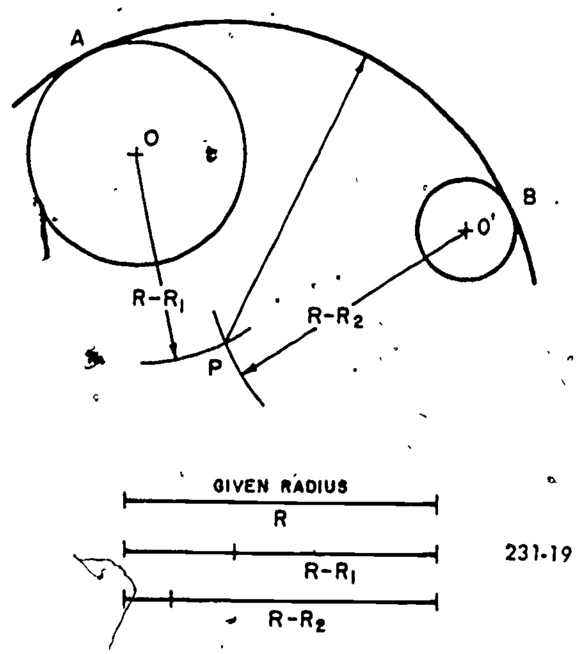


Figure 1-19. Centers of circle outside the tangent arc.

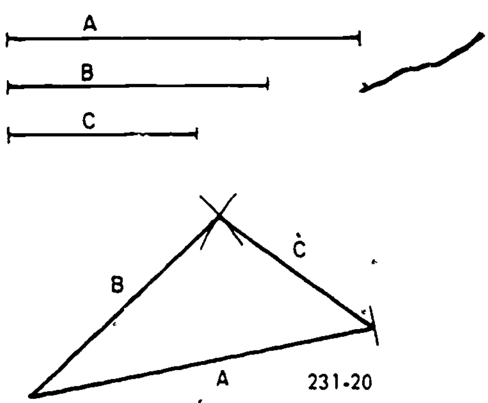


Figure 1 20. Constructing a triangle with three given sides.

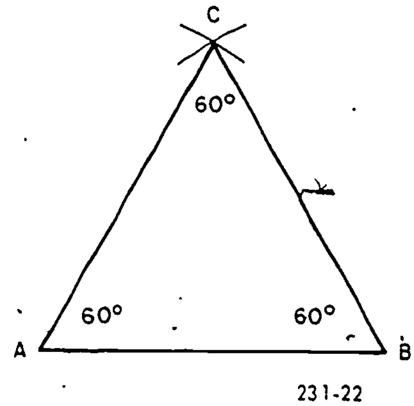


Figure 1-22. Constructing an equilateral triangle with one given side.

3. Using a T-square and triangle, draw an equilateral triangle with a height of 2 inches.

210. Given the rules for constructing a square, demonstrate procedures that will result in a square.

Construction of a Square with One Side Given. As in the construction of many other figures, there are several ways to draw a square. The following method, illustrated in figure 1-24, should come in handy at times for drawing a square at any angle.

- Draw a perpendicular to given side BC at point B.
- Using point B as center and radius BC, strike an arc to intersect the perpendicular (point D).

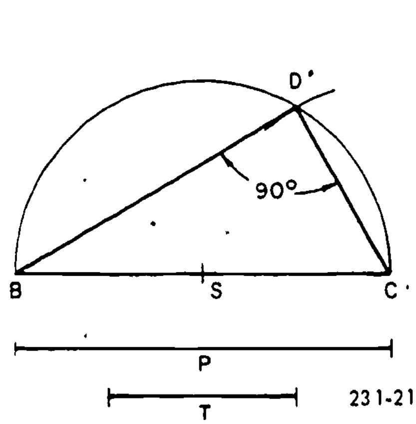


Figure 1-21. Constructing a right triangle with hypotenuse and one side.

- With points C and D as centers and radius BC, strike arcs which intersect (point E).
- Draw lines DE and EC to complete the square.

Construction of a Square with Distance Across Corners Given, Using T-square and Triangle. The following method to make this construction is illustrated in figure 1-25.

- Through points A and B of given distance AB, draw lines AC and BD, using a T-square and a 45° triangle.
- Turn the triangle over and draw lines AD and BC in the other direction through the same points.
- These lines which intersect at points C and D complete the square.

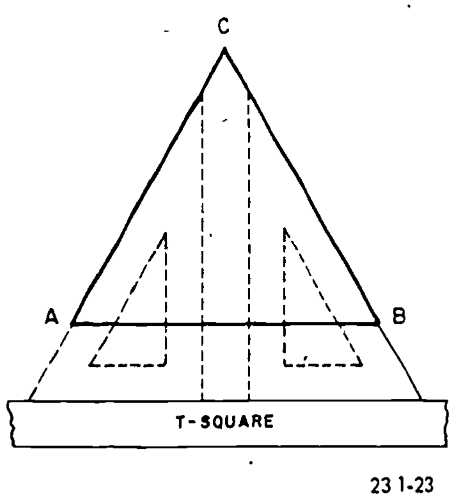


Figure 1-23. Constructing an equilateral triangle with T-square and triangle.

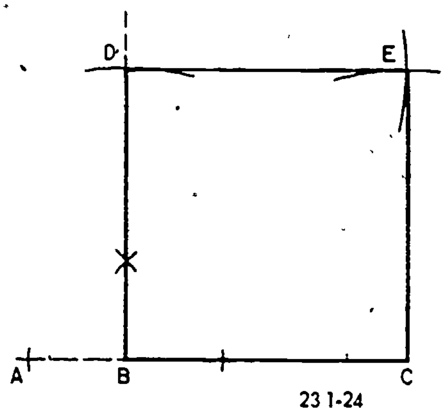


Figure 1-24. Constructing a square with one side given.

Exercises (210):

1. Construct a square with one given side.

211. Given the construction techniques of a regular pentagon, demonstrate two methods used in these constructions.

Constructing a Regular Pentagon Inscribed within a Given Circle.

The following procedure to construct this pentagon is illustrated in figure 1-26.

- Draw any diameter, AB, of the circle.

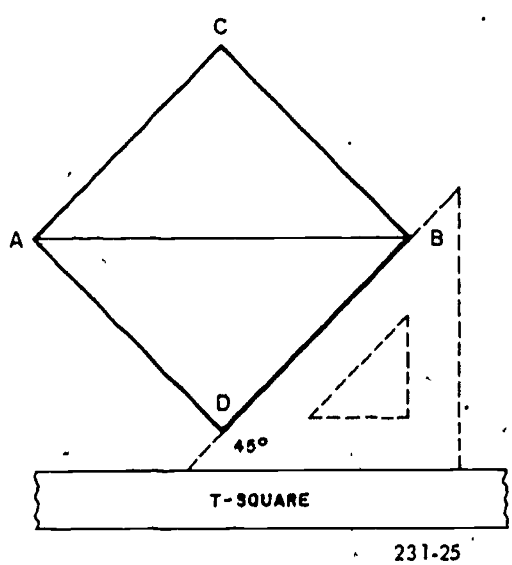


Figure 1-25. Constructing a square with the distance across corners given.

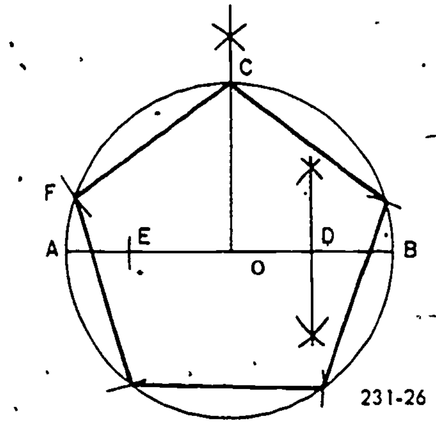


Figure 1-26. Constructing a regular pentagon inscribed within a given circle.

- Construct radius OC perpendicular to diameter AB.
- Bisect OB to find point D.
- Using point D as center and CD as radius, swing an arc cutting the diameter AB to find point E.
- Using C as center and CE as radius, swing an arc cutting the circle at point F.
- Draw chord CF. This chord is one side of the pentagon.
- Using the same radius CE which is equal in length to chord CF, step off the remaining points around the circle and connect them with chords.

Constructing a regular pentagon with length of one side given. The following procedure to construct a pentagon on given side AB is illustrated in figure 1-27.

- Using given side AB as radius and point A as center, draw a semicircle to cut the construction line extended from side AB.
- Divide the semicircle into five equal

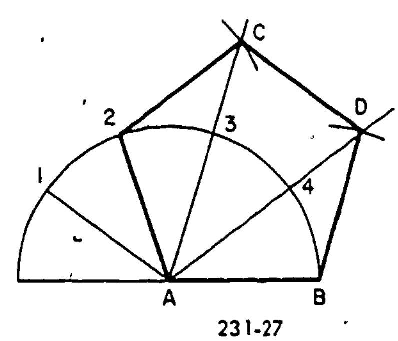


Figure 1-27. Constructing a regular pentagon with length of one side given.

125

parts by using dividers. (This may require several attempts before you have the divisions accurate.)

- Through division 2, draw a radial line A2. This line is one side of the pentagon.
- Through divisions 3 and 4, draw radial lines, extending them beyond the semicircle.
- Using side AB as radius and point B as center, swing an arc which cuts extended line A4 to find point D. Using the same radius and division 2 as center, swing an arc which cuts extended line A3 to locate point C.
- Connect the points thus found to complete the pentagon.

Exercises (211):

1. Using a diameter of 2½ inches, construct a pentagon inscribed in the circle.

2. Given one leg of a pentagon 1¼ inches long, construct a regular pentagon using the method described in figure 1-27.

212. Given the procedures for constructing a hexagon, demonstrate three that are most commonly used.

Construction of Regular Hexagons. There are several methods of constructing regular hexagons. The method you use in your drawings, as well as the particular situation, is largely up to you. Hexagon constructions are common in both mechanical and architectural drawing. An example is the hexagonal-headed bolt frequently represented in mechanical drawings. Now, let's cover three of the several ways to construct these figures.

Constructing a regular hexagon with the width, AB, across corners given. The procedure which follows is illustrated in figure 1-28.

- Draw a circle with given width AB as its diameter.
- With the same radius (one-half of diameter AB) and using points A and B as centers, draw arcs intersecting the circle as shown.
- Draw the chords, as shown, thus completing the hexagon.

Construction of a regular hexagon, using T-square and triangle. This method is often used when one side is horizontal with your

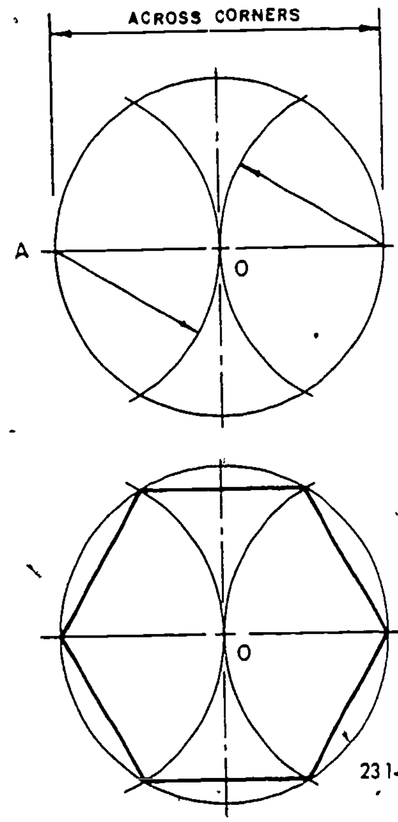


Figure 1-28. Constructing a regular hexagon with width across corners given.

drawing. Figure 1-29 illustrates the following procedure.

- From the ends of the given line, AB, draw lines 1, 2, 3, and 4 at an angle of 60° with AB.
- Draw two construction lines making a 30° angle with line AB.
- From points where one leg of each 30° angle intersects a leg of the 60° angle lying opposite it on line AB, construct parallels to line AB. These two parallels and the four legs of the 60° angles intersect to form a regular hexagon.

Construction of a regular hexagon with width across flats given. This method of construction is illustrated in figure 1-30. Refer to this illustration as you follow the procedure.

- Draw a circle with line CD, the width across the flats, as the diameter.
- Draw the vertical and horizontal center lines.
- Using the 30°-60° triangle and T-square, draw the sides of the hexagon tangent to the inscribed circle.

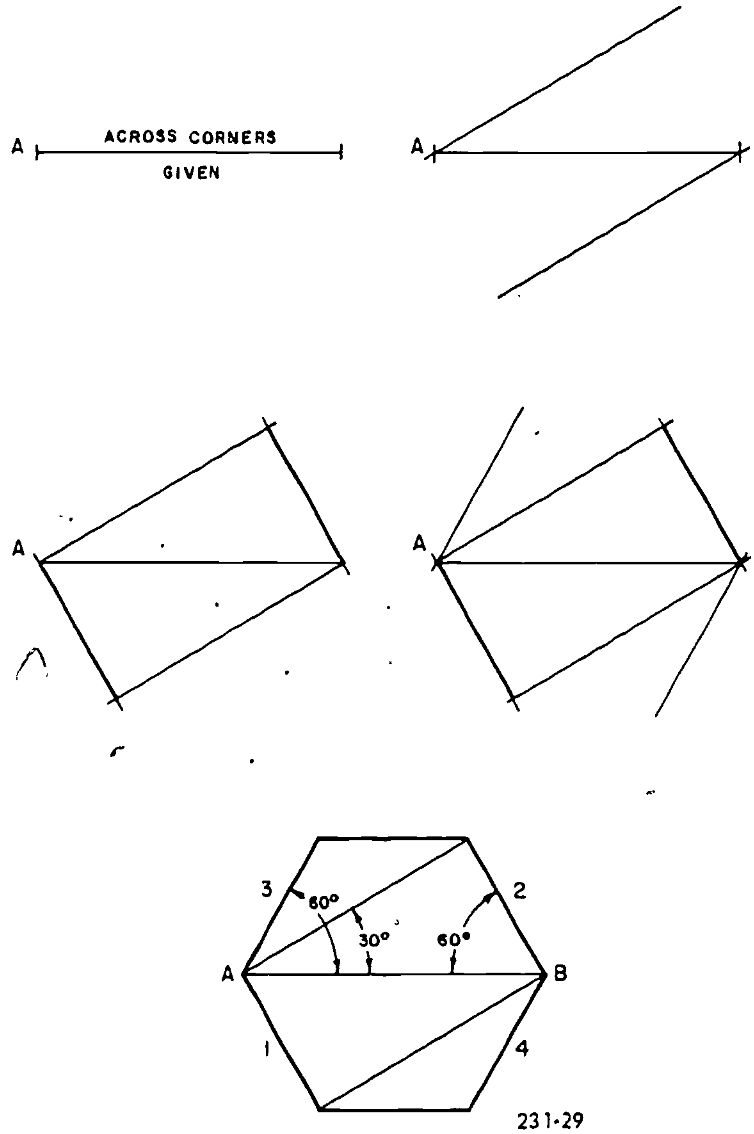


Figure 1-29. Constructing a regular hexagon using T-square and triangle.

Exercises (212):

1. Construct a regular hexagon with width across the flats as described in figure 1-30.

213. Given the procedures for constructing a regular octagon, demonstrate the method of construction.

Construction of a Regular Octagon. Two methods for constructing a regular octagon are described below. First, we'll cover the procedure used when the width across flats is given, and then when the width across corners is known.

Constructing a regular octagon with width across flats given. Refer to figure 1-31 as you follow this procedure.

- Construct a square having sides equal to the given width across flats (AB in the figure).
- Draw the diagonals of the square to locate point 0, their intersection.
- Using OA (or OB) as radius, swing an arc from each corner of the square to intersect two sides of the square.
- Connect the points (intersections) thus found to complete the octagon.

Constructing a regular octagon with the distance across corners given. Figure 1-32 illustrates the following procedure.

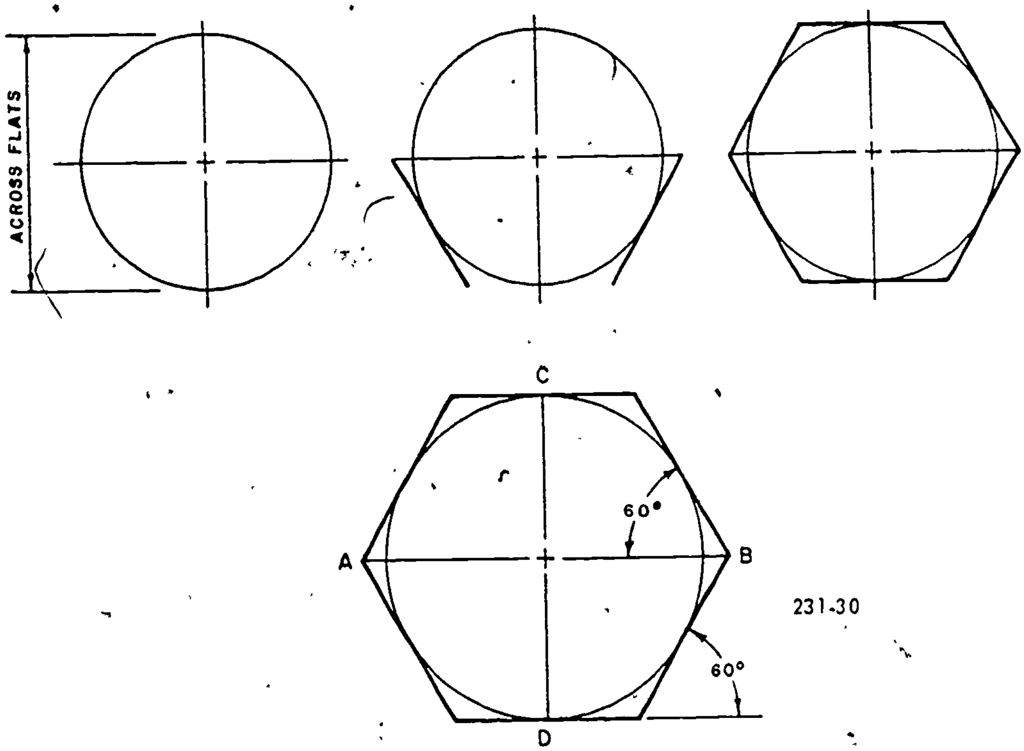


Figure 1-30. Constructing a regular hexagon—width across flats given.

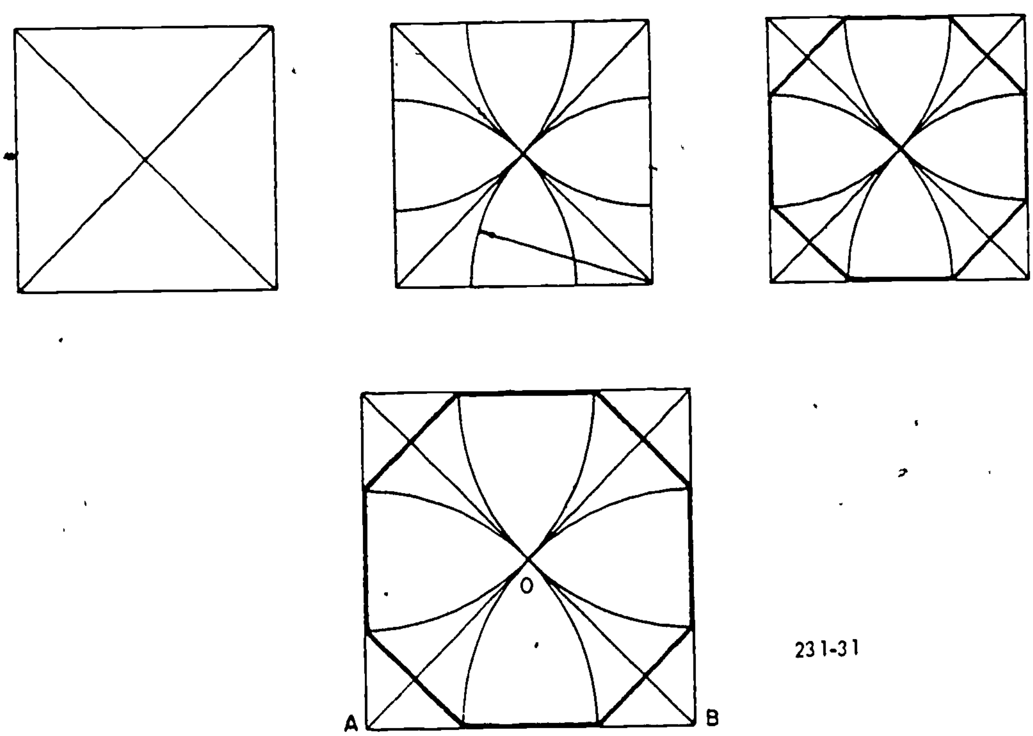


Figure 1-31. Constructing a regular octagon—width across flats given.

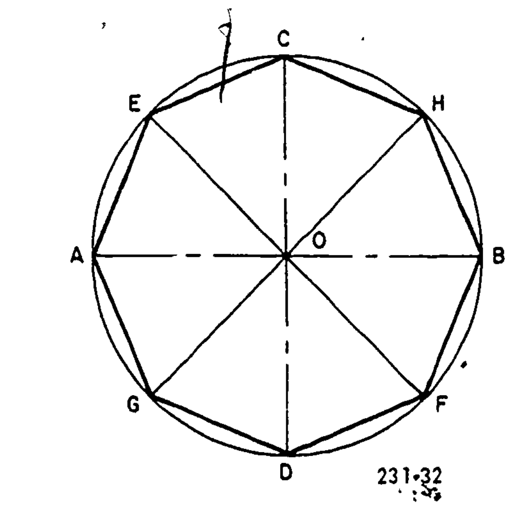


Figure 1-32. Constructing a regular octagon—distance across corners given.

- Draw a circle whose diameter is equal to the given distance across corners.
- Using a T-square and triangle, draw horizontal diameter AB and vertical diameter CD.
- Using a T-square and a 45° triangle, draw diameters EF and GH.
- Connect the points where the diameters intersect the circle to complete the octagon.

Exercises (213):

1. Draw a regular octagon using the across-flats method.

2. Draw a regular octagon using the across-corners method.

214. Given the procedure for constructing a regular polygon, demonstrate the procedures by constructing a polygon with a given number of sides.

Construction of a Regular Polygon with Any Number of Sides. This method is particularly useful for constructing a ploygon of an odd number of sides such as 7, 9, etc. When the length of a side is given, this construction is similar to that of a pentagon. The following procedure for constructing a regular polygon of 7 sides is illustrated in figure 1-33.

- Extend given side BC as shown.
- With point B as center and given side BC as radius, draw the semicircle, EC.
- Divide the semicircle into as many equal parts as the required number of sides—in this case 7. (This may be done with dividers and the "trial and error" method.)
- Draw line B2 which is a side of the polygon.
- Draw the perpendicular bisectors of lines BC and B2 to locate point 0, their intersection. (The perpendicular bisectors are drawn by means of the construction arcs, as shown.)
- Using point O as center and distance OC as radius, draw a circle.
- From point B draw lines passing through points 3, 4, 5, and 6, located on the semicircle previously subdivided, and extended these lines to intersect the circumference of the circle.

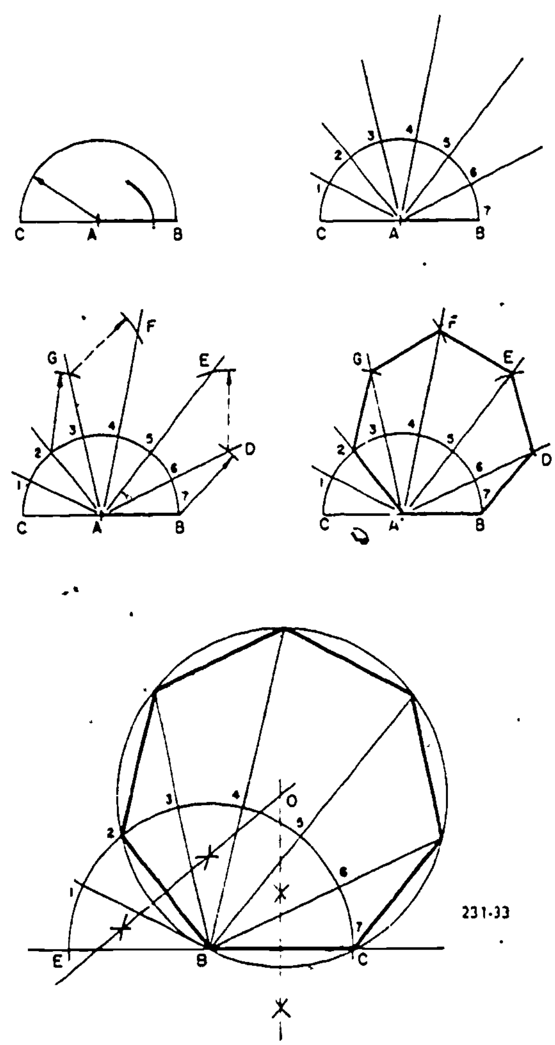


Figure 1-33. Constructing a regular polygon with any number of sides.

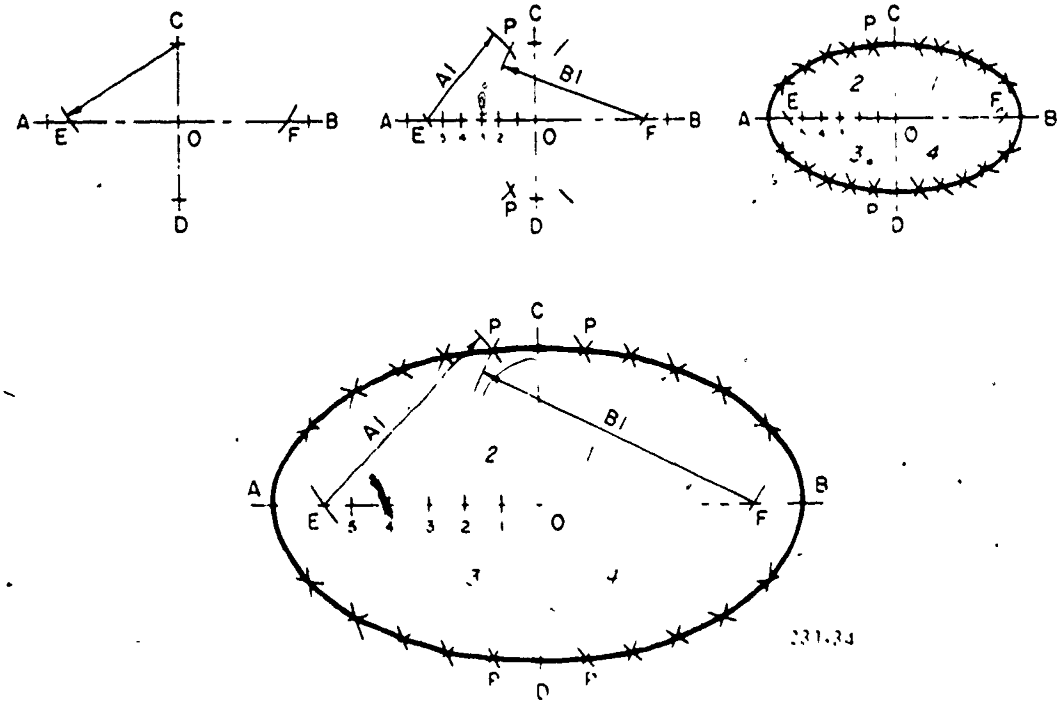


Figure 1-34. Constructing an ellipse by foci method.

• Connect these intersections to complete the polygon as shown.

Exercises (214):

1. Draw the following regular polygons.
   a. With one side 1¼ inches long, draw a seven-sided polygon.
   b. With one side 1¼ inches long, draw a nine-sided polygon.

215. Given six procedures for constructing an ellipse, demonstrate each different method.

An Ellipse Constructed by Foci Method—True Ellipse. This method is frequently used because it is very accurate and particularly useful for constructing an ellipse with a major axis of between 2 inches and 6 inches in length. With major axis AB and minor axis CD given, the following procedure is illustrated in figure 1-34.

• Locate the foci, points E and F, by swinging an arc of radius AO (half of major axis) and point C (one end of minor axis) as center.

• Divide the distance between points E and O on the major axis into a number of units, such as 1, 2, 3, 4, 5, etc. (For larger ellipses, more units are required to draw a smooth curve.)

• Using A1 as radius and point E as center, strike arcs in quadrants 2 and 3. Then, using the same radius and point F as center, strike arcs in quadrants 1 and 4.

• With B1 as radius and point F as center, strike arcs intersecting the first arcs in quadrants 2 and 3 (marked points P) in each quadrant. Using the same radius and point E as center, repeat this operation. Thus, arc

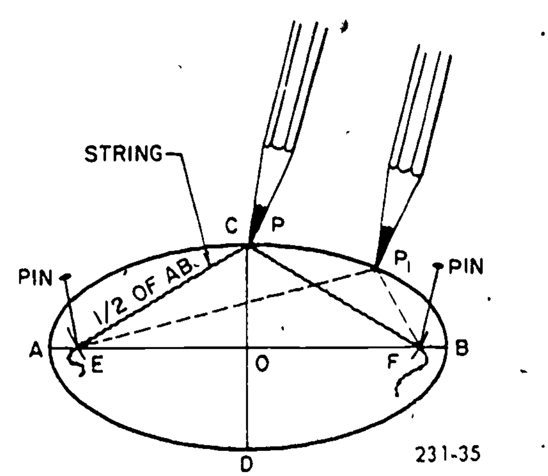


Figure 1-35. Constructing an ellipse by pin and string method.

intersections (points P) in each quadrant are established.

- Using each of the remaining points on EO, measured radii A2, B2, A3, B3, etc. Repeat the process described above, using the same centers.
- Use the irregular curve in joining the plotted points (arc intersections) to draw the ellipse.

An Ellipse Drawn by Pin and String Method. This method is not accurate enough for drafting in general. However, it is very handy for large constructions. For instance, it is a common method of laying out ellipses for flower gardens, etc.

Recall that an ellipse may be generated by a point moving in such a way that the sum of its distances from two points (the foci) is constant and equal to the major axis. This principle is shown by the following procedure and illustrated in figure 1-35. The given major and minor axes are AB and CD, respectively.

- Locate the foci, points E and F, as described in the foci method.
- Fasten the end of a string (of length equal to distance ECF) at points E and F with pins so that there will be no slack when the midpoint of the string is held by a pencil (or other marking device) at point C.
- By moving the pencil around the maximum orbit allowed by keeping the string taut, the ellipse will be described. The method of movement is shown in illustration (from point P to P1, etc.)

An Ellipse Constructed by Trammel Method—True Ellipse. This method is preferred by many draftsmen. If you are careful to be accurate, you will find this method simple and fast. Refer to figure 1-36 as you practice the following procedure.

- On the straight edge of a slip of paper, cardboard, or plastic, mark half the distance (AO) of the major axis, and then mark half the distance (CO) of the minor axis.
- Place the trammel so that point A is on the minor axis and point C is on the major axis. Point O is then marked on the curve.
- Locate additional points of the curve by moving the trammel to other positions, always keeping point A of the trammel on the minor axis and point C on the major axis.
- After you have established a sufficient number of points for the curve, draw the ellipse with an irregular curve.

An Ellipse Constructed by Four-Center Method. Although this method of construction produces an approximate ellipse, it is useful, since the use of an irregular curve

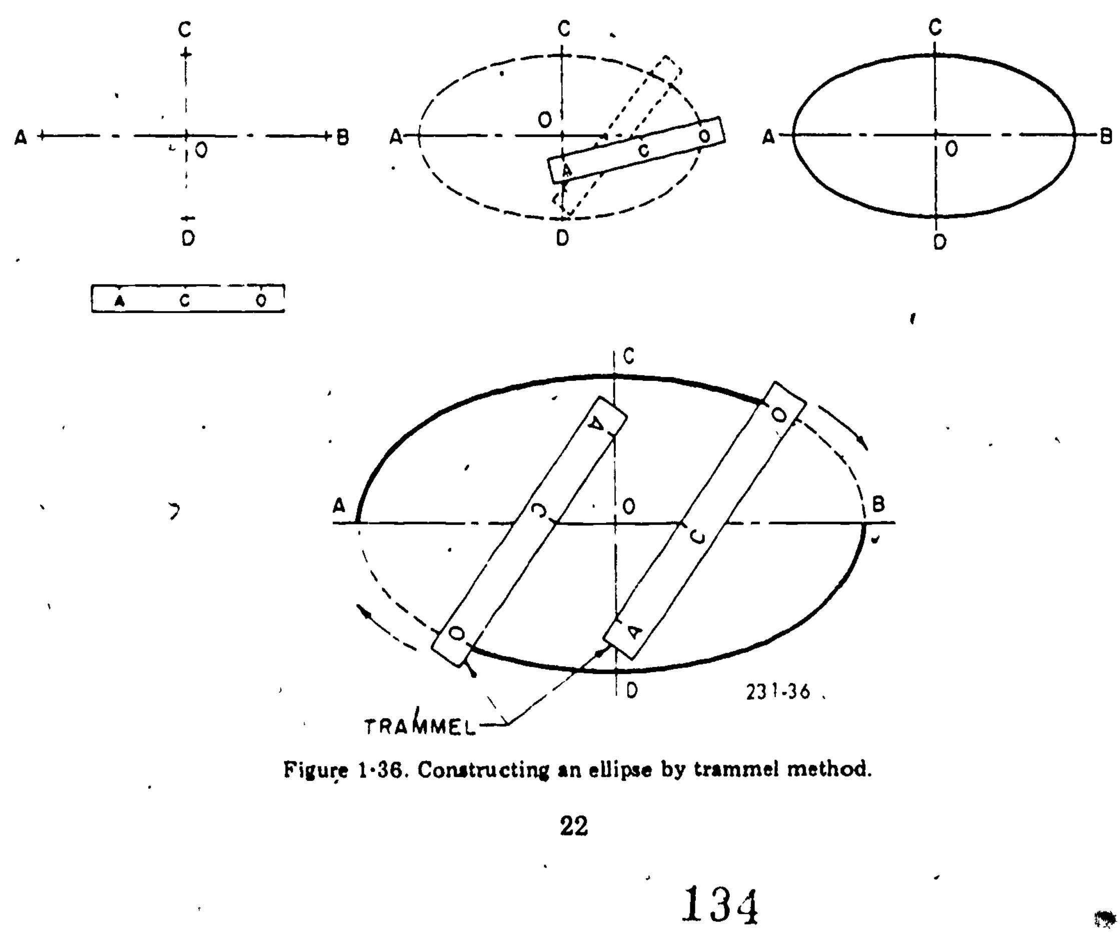


Figure 1-36. Constructing an ellipse by trammel method.

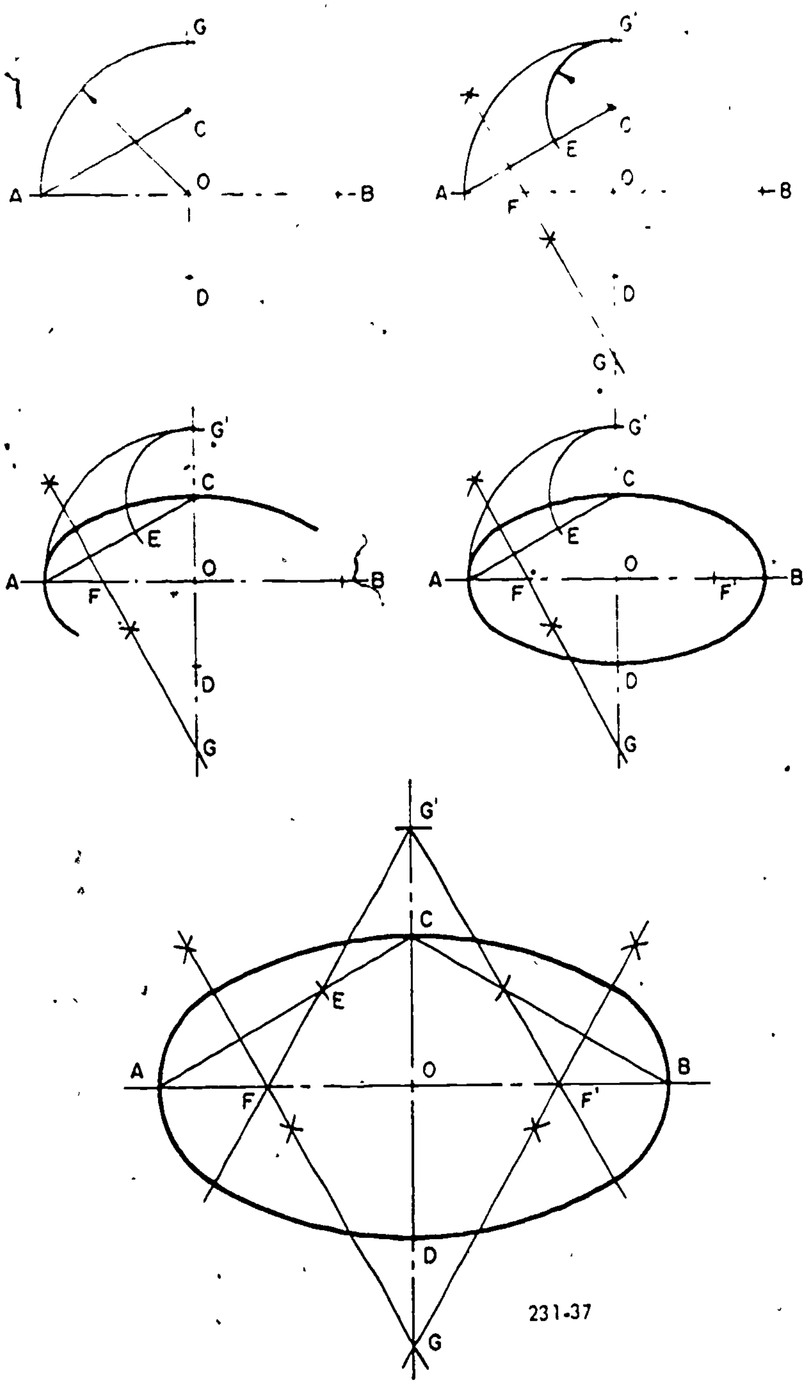


Figure 1-37. Constructing an ellipse by four-center method.

is not required. Given the axes AB and CD, the following procedure is illustrated in figure 1-37.

- Draw line AC to connect the ends of the major and minor axes.
- Mark on line AC the distance CE, which is equal to AO minus CO.
- Draw the perpendicular bisector of AE, extending the bisector to intersect the major axis at point F and the extended minor axis at point G. These two intersection points are centers for two of the required arcs.
- Locate points F′ and G′ in a similar manner or, more simply, by using dividers. When using dividers, set off OG′ equal to OG and OF′ equal to OF.

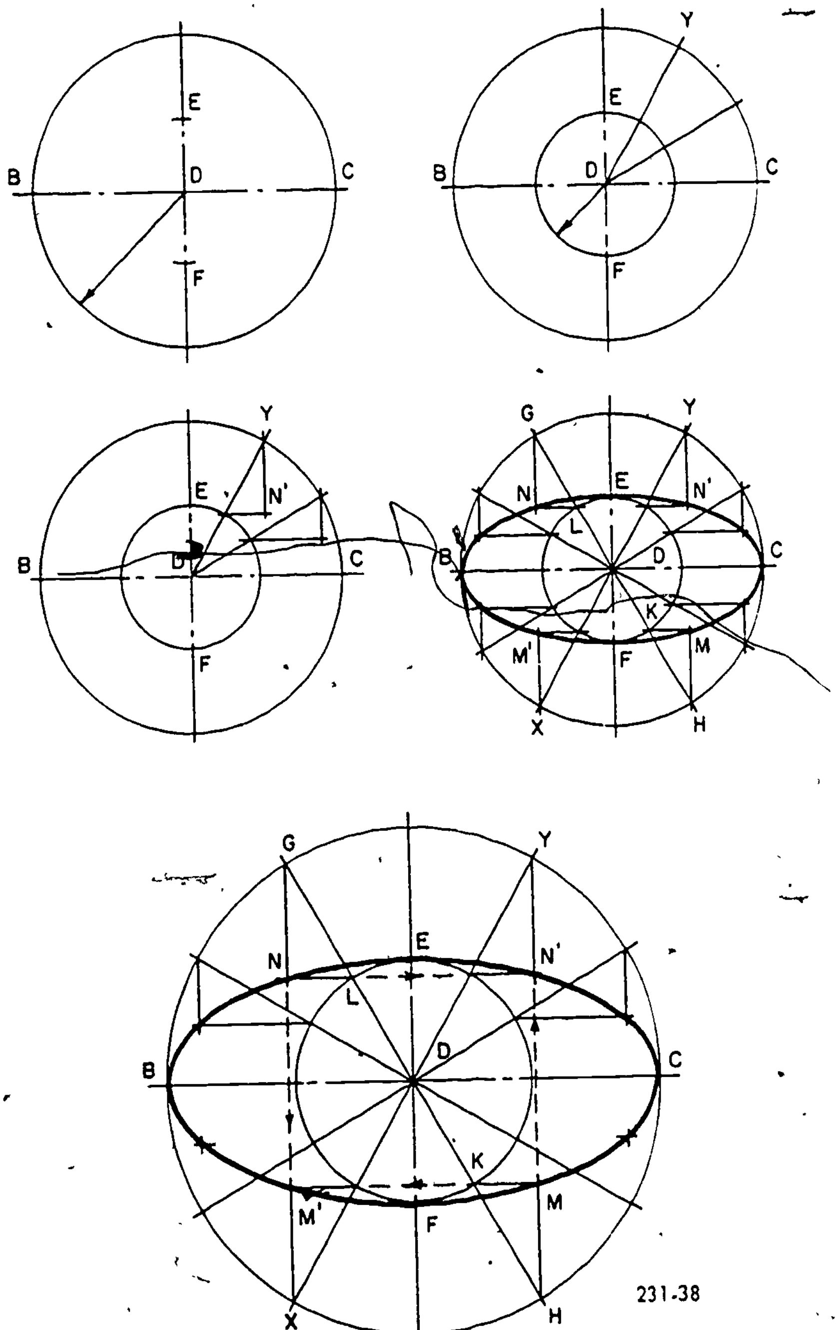


Figure 1-38. Constructing an ellipse by concentric circle method.

• Using points G and G′ as centers and CG as radius, swing the two (long) arcs. Then, using points F and F′ as centers and radius FA, swing the two (short) arcs.

• Thus, these four arcs meet to complete the ellipse.

An Ellipse Constructed by Concentric Circle Method—Ture Ellipse. This is another method which you may prefer to use at times. An ellipse constructed by this method is very accurate. Refer to figure 1-38 as you practice the following procedure.

• Using the intersection of the given major axis BC and minor axis EF (point D) as center for the ellipse, draw two concentric circles having the major and minor axes as diameters.

• Draw any diametral line GH.

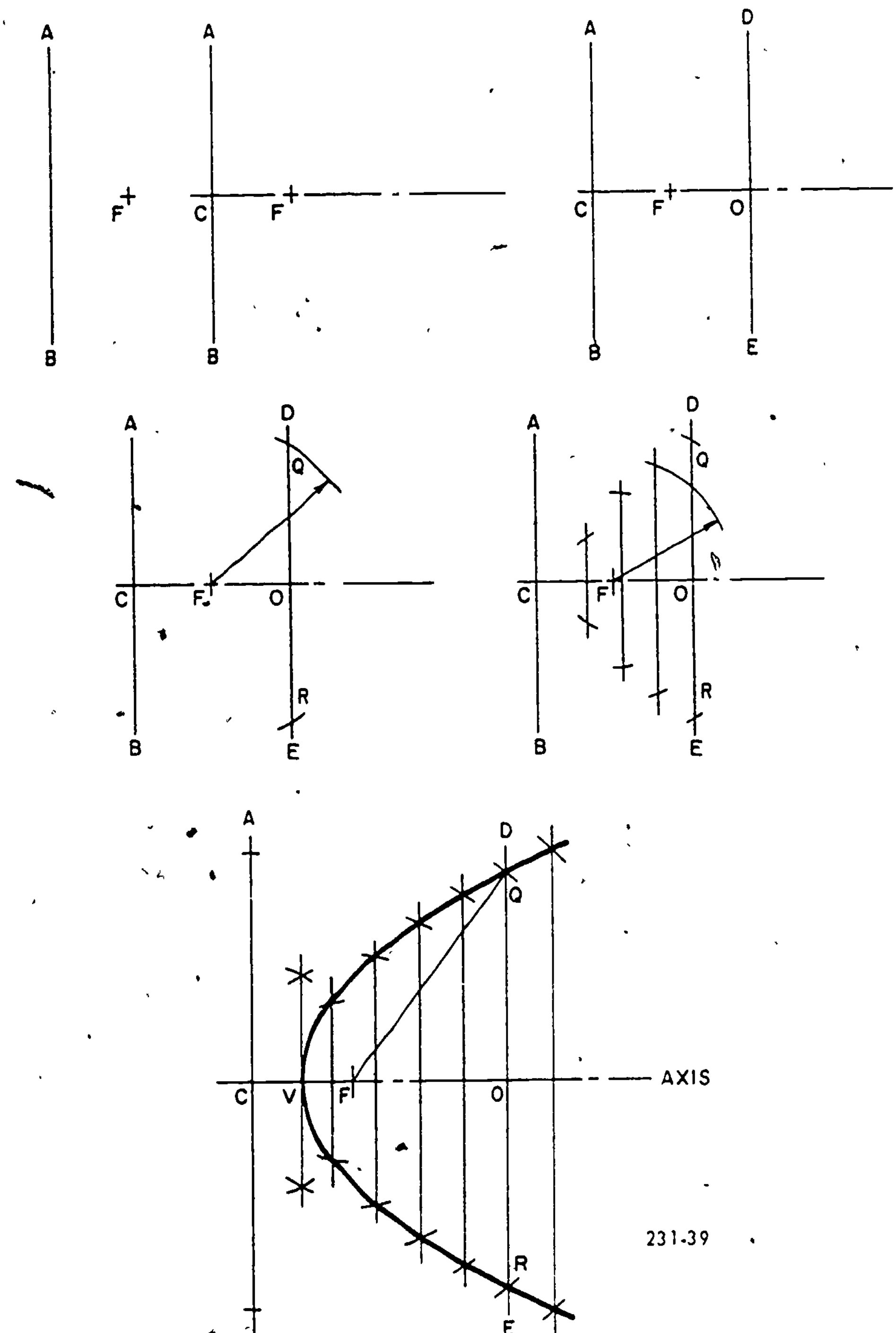


Figure 1-39. Constructing a parabola by focus method.

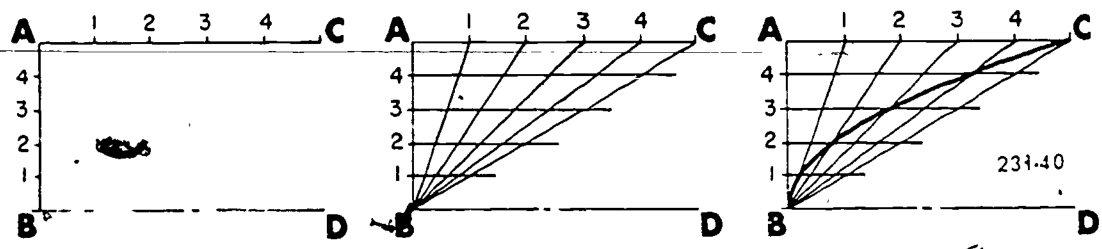


Figure 1-40. Constructing a parabola by intersection method.

- Through points where the diametral line GH cuts the circumference of the outer circle, draw vertical lines MH and GN.
- At points where the same diametral line, GH, intersects the circumference of the inner circle, draw horizontal lines KM and NL.
- The intersection points M and N of the vertical and horizontal lines are points on the required ellipse.
- Next, locate point M′ by extending line GN and line KM to intersect as shown on the illustration. In a similar manner, locate point N′.
- Thus, four points are established on the ellipse by drawing one diametral line.
- Repeat the entire procedure several more times to locate enough points so that a smooth ellipse can be drawn by use of an irregular curve.

Exercises (215):

1. Construct an ellipse using the foci method.

2. Construct an ellipse using the pin and string method.

3. Construct an ellipse using the trammel method.

4. Construct an ellipse using the four-center method.

5. Construct an ellipse using the concentric circle method.

6. Which of these are true ellipses?

216. Given three procedures for constructing a parabola, demonstrate each different method of construction.

Construction of Parabolas. There are many uses for the parabola. It is used for reflecting surfaces of light, sound, radar pulses, etc., as well as for vertical curves in highways, for forms or arches, machine design, and others. Following are several methods of constructing a parabola.

Parabola constructed by focus method. In the following construction, illustrated in figure 1-39, the focus (F) and directrix (AB) are given. (A directrix is a fixed line or curve used as a guide in describing a curve or surface.) Refer to the figure as you practice the following procedure.

- Draw a line DE parallel to directrix AB and at any distance CO from the directrix. (Points C, F, and O lie on the axis of the parabola.)
- With focus F as center and CO as radius, strike arcs to intersect line DE at points Q and R, which are points on the parabola.
- Determine as many additional points as are required to draw the parabola accurately and draw the corresponding parallel lines.
- Using focus F as center and radii equal to the distance from point C to each additional parallel line, strike the intersecting arcs as before.
- Using an irregular curve, draw a smooth curve through the points of intersection of the lines and arcs and vertex V to complete the parabola. (Vertex V is the midpoint between points C and F.)

Parabola constructed by intersection method. In this method of construction, the rise and span of the parabola are given. In figure 1-40 the rise and span of the parabola are determined by the dimensions of given rectangle ABCD. Refer to this figure as you follow the procedure.

- Divide side BC into any even number of

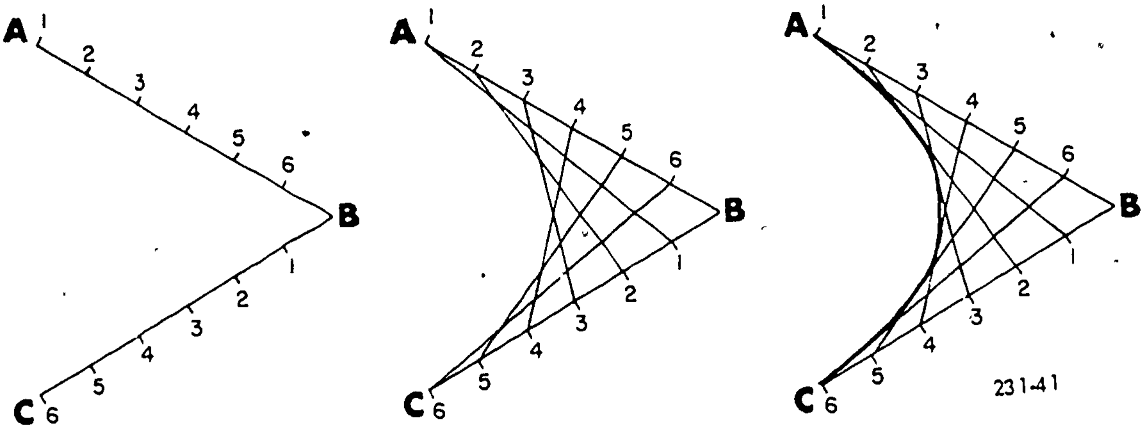


Figure 1-41. Constructing a parabola by tangent method.

equal parts (eight, for instance), and divide each side AB and CD into half as many parts.

- Draw lines as shown in the figure.
- The intersections of like-numbered lines are points on the parabola.
- Draw a smooth curve through the intersections to complete the parabola.

Construction of a parabola by the tangent method. For this construction, two given points of the parabola (points B and C in figure 1-41) are required. Refer to this figure as you follow the procedure.

- Assuming any point D, draw tangents to points B and C, lines DB and DC, respectively.
- Divide lines DB and DC into the same number of equal parts (six, for instance), and number the division points as shown in the illustration.
- Connect the corresponding points 1-1, 2-2, etc.
- These lines which connect the corresponding points are tangents of the required parabola.
- Sketch a light, smooth curve; then finish the curve by using an irregular curve.

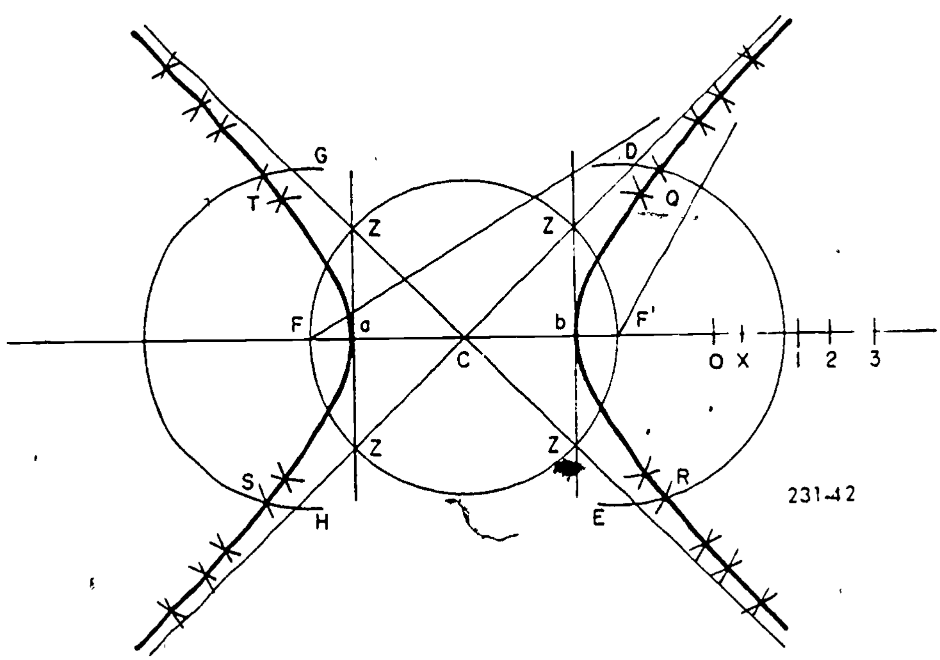


Figure 1-42. Constructing a hyperbola by foci method.

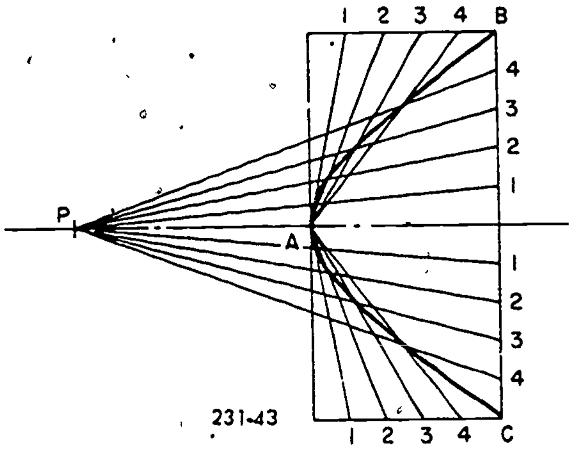


Figure 1-43. Constructing a hyperbola by intersection method.

Exercises (216):

1. Draw parabolas using each of the following methods:
   a. Focus.

   b. Intersection or parallelogram method.

   c. Tangent.

217. Given the procedures to construct a hyperbola, demonstrate the two most common methods by constructing a hyperbola by each method.

Construction of a Hyperbola by Foci Method. A hyperbola is a curve generated by a point moving so that the difference of the distances from any point of the curve to two fixed points, called the foci, is a constant equal to the transverse axis of the hyperbola. In the foci method, the foci and vertices of the hyperbola are given. These given points are indicated by F and F′, and a and b, respectively, in figure 1-42. Refer to this figure as you practice the following procedure.

- Select any point X on the extended transverse axis. (The transverse axis is ab; that is, the axis between the vertices, a and b.)
- With bX as radius and F′ as center, swing arc DE; with F as center and the same radius, swing another arc GH.
- With aX as radius and F as center, strike arcs to intersect arc DE at points Q and R; with the same radius and F′ as center, strike arcs to intersect arc GH at points S and T. These intersections are points on the hyperbola.
- Mark off additional points similar to point X on the extended transverse axis, such as points 0, 1, 2, 3, etc., as illustrated. Repeat the preceding procedure by progressively substituting each additional point for original point X.
- Draw the curve through the intersections of the arcs.

Construction of a Hyperbola by Intersection Method. This construction is derived from the perspective construction of a circle where the points have been formed by a series of intersecting lines. When you study perspective drawing later in this course, you will better understand this type of perspective. However, it is not necessary, at this point, for you to have this knowledge in order to construct a hyperbola by the intersection method.

For this construction, it is necessary to have the vertex and two symmetrically placed points on the hyperbolic curve given. In figure 1-43 point A is the vertex and points B and C are the symmetrically placed given points. Since figure 1-43 illustrates only the construction of the hyperbola, point P may be selected at any convenient distance from point A, the vertex. Actually, the distance of point P from the vertex controls the shape of the hyperbola. After you practice the construction of the hyperbola by the following procedure, we'll cover the locating of point P when a specified conical dimension is given.

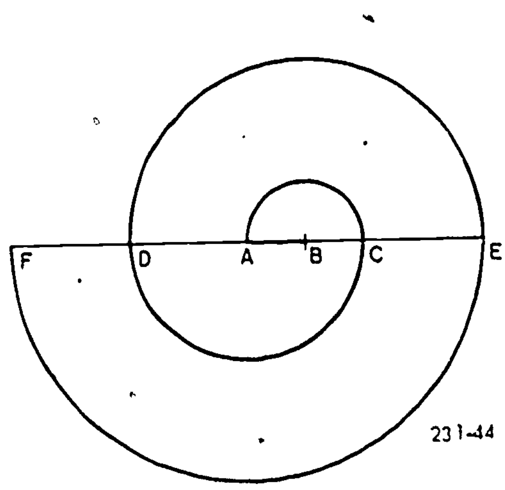


Figure 1-44. Drawing an involute of a line.

• Draw the rectangle as shown in the illustrations. (Notice that the dimensions are in accordance with points A, B, and C.)

• Divide BC into an even number of equal parts (10, for example).

• Divide the sides into half the number of equal parts (5, for example).

• Connect point P with the divisions on BC.

• Connect point A with the divisions on the sides.

• The intersection of the corresponding numbered lines, together with points A, B, and C, are the points of the parabola. (For example, the intersection of lines P4 and A4 is a point on the hyperbola.)

Exercises (217):

1. Draw a hyperbola using the foci method.

2. Draw a hyperbola using the intersection method.

218. Given the procedure for drawing an involute, construct an involute to any circle or regular polygon.

Drawing an Involute of a Line. An involute is a spiral curve made as if by a point on a perfectly taut string as it unwinds from around another object, such as a line, polygon, or a circle.

The following procedure to draw the involute from given line AB is illustrated in figure 1-44.

• Using line AB as radius and point B as center, draw semicircle AC.

• Using distance AC as radius and point A as center, draw semicircle CD.

• Using distance BD as radius and point B as center, draw semicircle DE.

• Continue this procedure, alternating centers between A and B, until a figure of the required size is obtained. For instance, arc EF is the next one.

Drawing an Involute of a Square. Now, let's draw an involute from the given square ABCD, as illustrated in figure 1-45. Notice that the following procedure is similar to that for a triangle.

• Using DA as radius and point D as center, strike the 90° arc, AE.

• With distance CE as radius and point C as center, strike arc EF.

• With distance BF as radius and point B as center, strike arc FG.

• Continue with this procedure until a figure of the desired size is completed.

Drawing the Involute of a Circle. The involute of a circle is often used in the construction of gear teeth. For this drawing a circle may be regarded as a polygon having an infinite number of sides. The involute is constructed by dividing the circumference into an equal number of parts and drawing a tangent at each division point, and then setting off each tangent equal to the length of the corresponding circular arc. The length of each tangent from the circumference is a point through which the involute curve will be drawn. Refer to figure 1-46; then refer again to the method for rectifying an arc as you practice the following procedure.

• Divide the circumference into a number of equal parts, such as 12, as shown in the illustration.

• Draw a tangent (A1) to the circumference at division point 1, making the length of tangent A1 equal to arc X1.

• Draw a tangent (B2) to the circumference at division point 2, making the length of tangent B2 equal to arc X2.

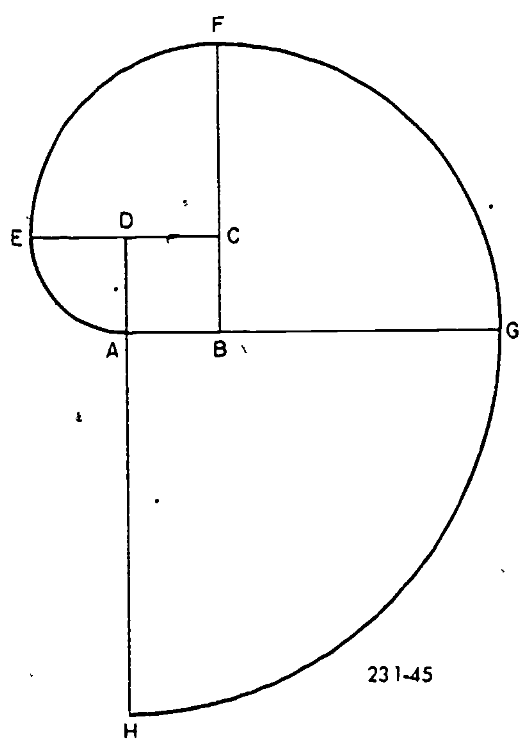


Figure 1-45. Drawing an involute of a square.

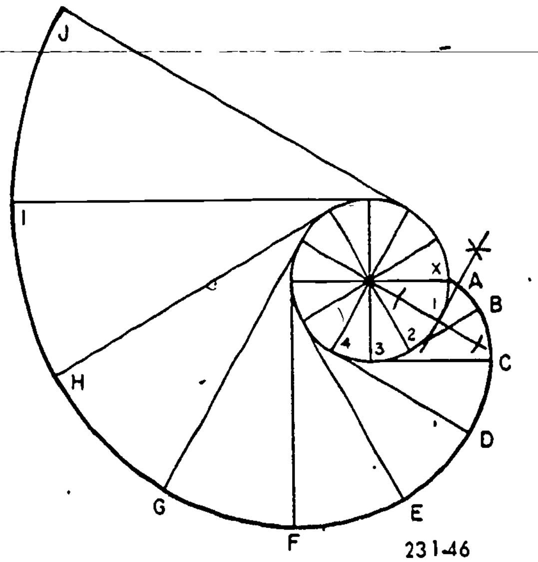


Figure 1-46. Drawing an involute of a circle.

- Draw a tangent (C3) to the circumference at division point 3, making the length of tangent C3 equal to arc X3.
- Continue this procedure until the desired number of points (A, B, C, D, etc, in the illustration) is established.
- Draw a smooth curve through the established points by means of an irregular curve.

Exercises (218):

1. Draw an involute to the following:
   a. Line.

   b. Square.

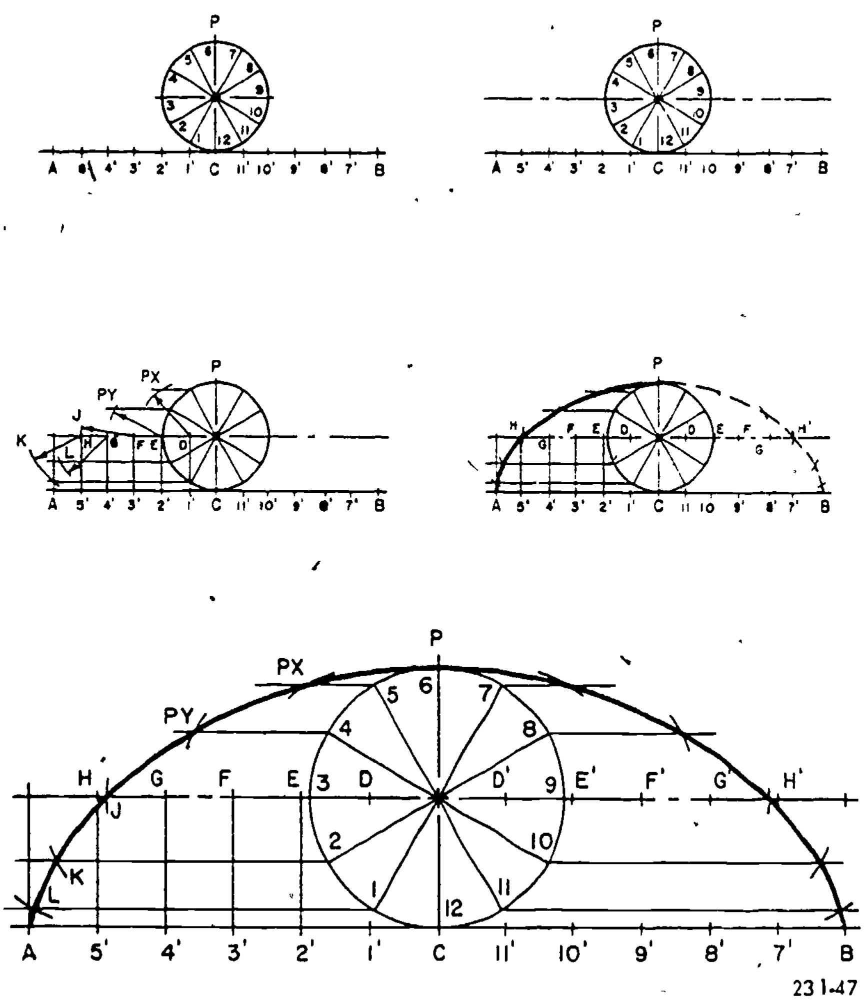


Figure 1-47. Drawing a cycloid.

c. Circle.

219. Given the procedure to construct a cycloid and a spiral, demonstrate the procedures and show how they are used.

Construction of a Cycloid and the Spiral of Archimedes. A cycloid curve is often used for the outline of gear teeth. The spiral of Archimedes curve is commonly used in cam design. Now, let's see how to draw these two curves.

Drawing a cycloid. Recall that a cycloid is the curve generated by a point on the circumference of a circle which rolls along a straight line. Refer to figure 1-47, as you practice the following procedure, assuming the circle to roll to the left.

- Draw straight line AB tangent to the circle at point C, making distances AC and BC both equal to the semicircumference of the circle. (That is, the distance A to B is equal to the circumference.)
- Divide the circle into equal parts, such as 6 for each semicircumference.
- Divide line AB into the same number of equal parts as the circumference, and draw perpendiculars to intersect the extended center axis.

NOTE: As the circle rolls to the left, when point 1 coincides with point 1′ on line AC, the center of the circle will be at point D. Similarly, point 7 will move to the previous

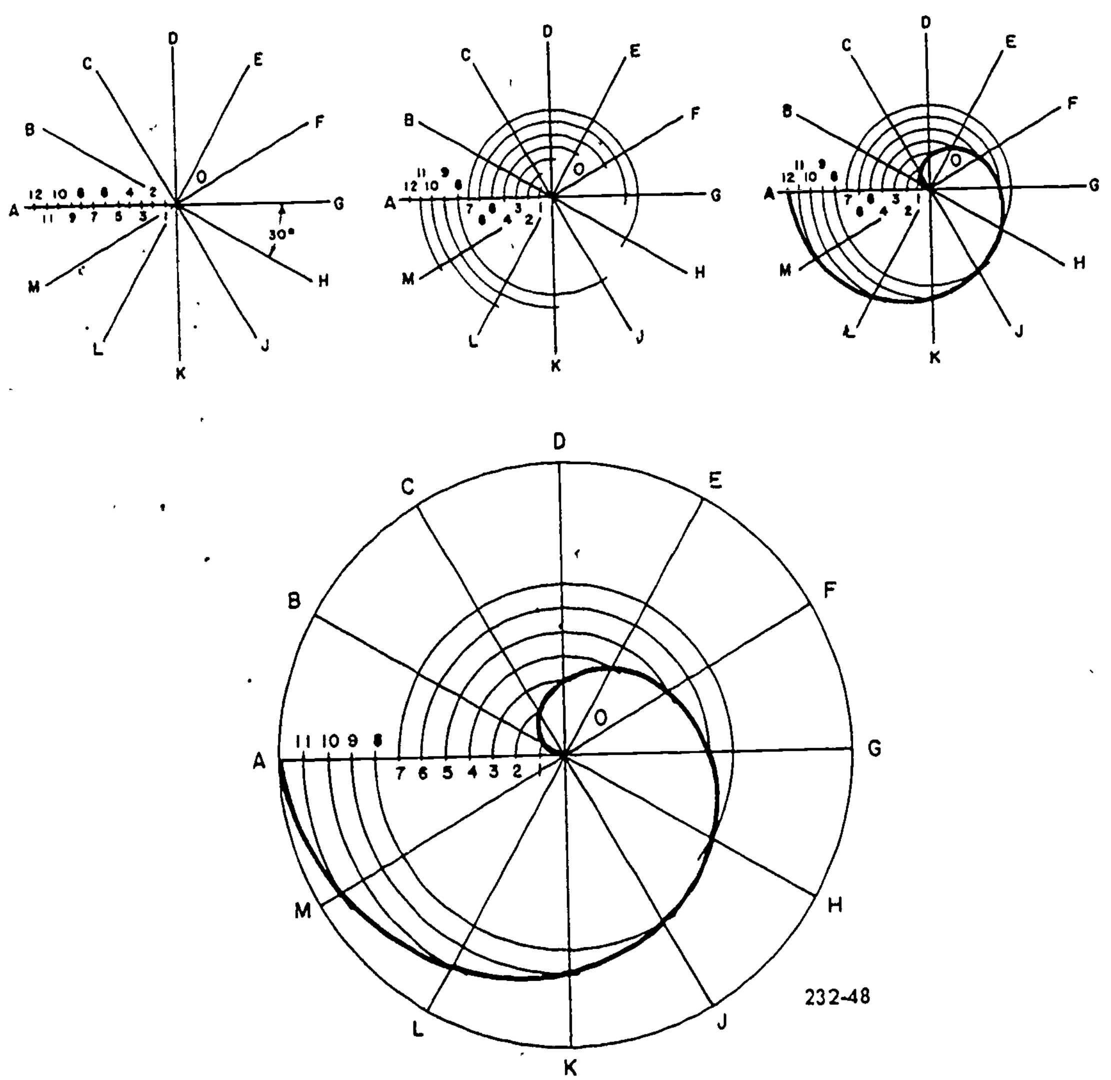


Figure 1-48. Drawing the spiral of Archimedes.

position of point 6, point 6 will move to point 5, etc.

• Find point Px by drawing a line through point 5 parallel to line AB and intersecting it with an arc drawn with point D as center and the radius equal to that of the circle. This intersection is a point on the curve.

• Find point Py by drawing a line through point 4 parallel to line AB and intersecting it with an arc drawn with point E as center and the radius equal to that of the circle. This intersection is another point on the curve.

• Continue this procedure using the same radius and points F, G, and H as centers to find points J, K, and L of the curve. Draw the curve by use of an irregular curve.

Assuming that the circle rolls to the right, the method of locating the points on the curve is the same. However, for simplicity, the lines drawn parallel to line AB may be extended, and the points on the curve established by marking off the distances obtained on the left by use of dividers.

Drawing the spiral of Archimedes. Recall that this spiral may be generated by a point moving around a fixed point, called the pole, and away from it in such a manner that the distance from the pole increases uniformly with the angle. Notice in figure 1-48 that the spiral of Archimedes makes one turn in a given circle.

Refer to figure 1-48 as you practice the following procedure.

• Divide the circle into equal parts (such as 12), drawing the radii as shown in the illustration. (This may be done with a 30°-60° triangle.)

• Divide the radius, AO, into the same number of equal parts, numbering outward from the center. Thus, one division of the radius is the increment by which the radius of the curvature increases in passing through an angle of 30°. (The angles are 30° because we divided the circle into 12 equal parts.)

• Using center O (the pole) and O1 as radius, draw an arc to intersect radius OB. This intersection is a point on the spiral.

• Continue this procedure progressively around the circle until all points are located.

• Using the irregular curve, draw the spira through the intersection points of the arc an radii.

Exercises (219):

1. Draw the spiral of Archimedes.

2. Draw the cycloid.

Introduction to Projections

THE FUNCTION of any drawing is to illustrate and describe an object in sufficient clarity and detail so that it is understood with very little explanation. Even in ancient times, man drew pictures to convey his ideas or as a substitute language. In those days a large part of drawing was confined to building construction and the fine arts. Although few drawings of that era were preserved, some interesting information can be gathered from those which were.

The crude sketches made by the early builders, on clay tablets, limestone slabs, papyrus and wood, still exist for us to study. Besides having crude and bulky drawing material, the major problem confronting the early draftsman was that of representing solid objects on flat surfaces. Dimensions of length, width, and height could not be shown accurately on a two-dimensional surface. Little progress in solving this problem was made until the 15th century when Leonardo da Vinci, an Italian, discovered in his studies how to give the illusion of depth to solid objects. He developed and taught his technique until his death in 1519. After his death, mathematics scholars used various other methods to show exact measurements in their drawings.

Progress in this area was very gradual until the 17th century. During the Napoleonic era, Gaspard Monge, a Frenchman, developed a system of right-angle projections on planes set up perpendicular to each other. This system was not only measureable but is the basis for the three-dimensional representations that we know today.

The ability to think in three dimensions is a prerequisite, no matter what type of drawing you happen to be engaged in. Every drawing has a space relationship involving four factors:

- The observer's eye, or the station point.
- The object.
- Projection lines.
- The plane of projection.

In technical drawing, three kinds of projections are used: orthographic, oblique, and perspective. All three projections describe the shapes of objects, but only orthographic and oblique describe the size of the object and show dimensional markings.

2-1. Types of Projections

Projections are generally listed in two categories: parallel projections and perspective (or central) projections. In this chapter we will be concerned with parallel projections and the major units under parallel projections. These major units are orthographic and oblique projections.

220. Given the principles of orthographic projections, list the different types and categories of projections.

Orthographic Projections. An orthographic projection is any projection made by lines of sight which are perpendicular to the image plane. Since these projection lines are perpendicular to the same plane, they are parallel to each other. Notice in figure 2-1 that there are two types of orthographic projections, multiview and axonometric.

There are four different types of multiview drawings. These drawings make up the greater part of all engineering, industrial, and architectural drafting. Sometimes a multiview drawing is supplemented by a pictorial drawing, such as an axonometric.

Multiview drawings are made to represent a three-dimensional object drawn on a two-dimensional surface. This method of orthographic projection is relatively easy to understand. It simply consists of the observer viewing an object as if it were placed inside a glass box (see fig. 2-2). The observer is always on the outside looking in. Notice that the object is positioned so that each face is parallel with a respective surface or image

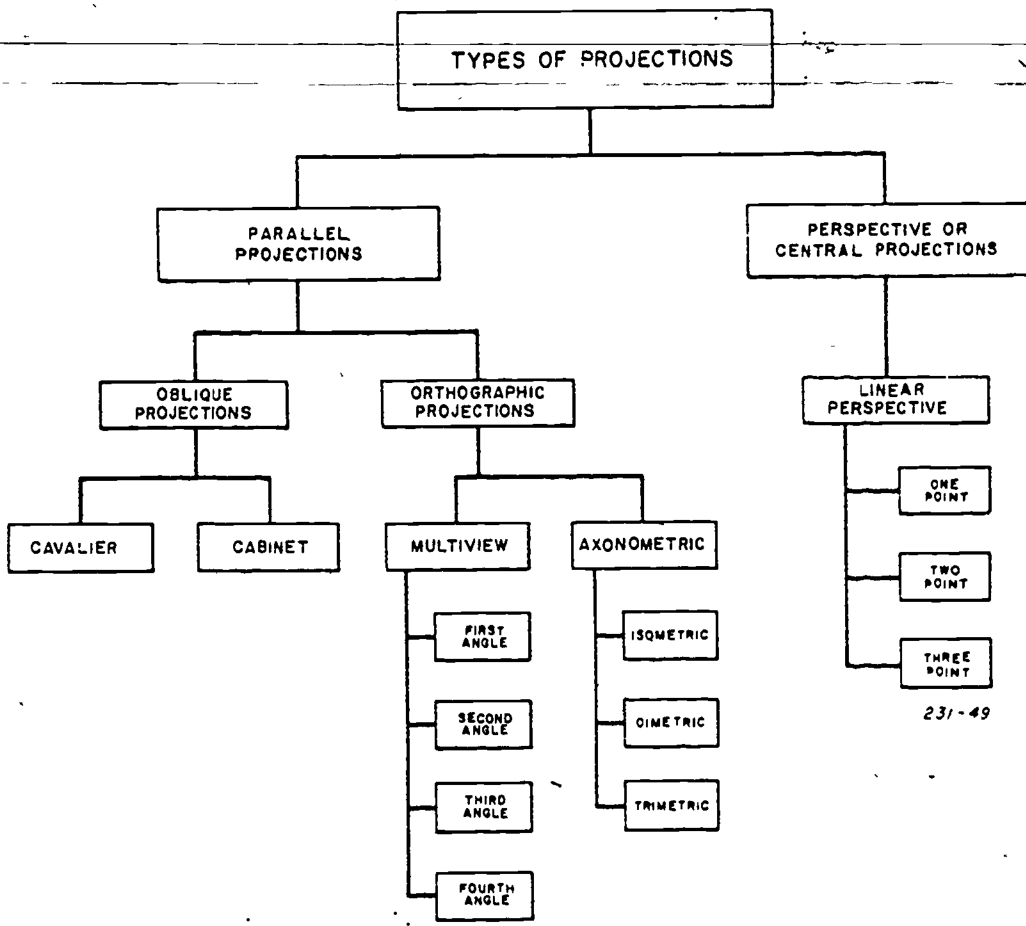


Figure 2-1. Projection classifications.

plane of the glass box. The observer assumes the position of viewing one surface at a time so that his line of sight is perpendicular to the surface and the image plane. Thus, each face is projected and can be drawn on the appropriate image plane in its true size and shape.

Opening the glass box. To obtain all the views of the object laid out in a single plane and in the proper position, one must assume that the sides of the glass box are hinged. The partially opened box as shown in figure 2-3 has five of the six views rotating from the front view of the object, thus putting the right side view on the right of the front view, and all of the other views in their proper places as shown in figure 2-4.

Selection of views. In drawing an orthographic projection, it is necessary to select only those views that will describe the object completely. The first step is to determine the front view. This may be done by placing the object in its natural position, so that the top is parallel to the top image plane, etc. The front view should be that side that shows the greatest contour or the most irregular shape. If any doubt exists concerning which view fulfills this condition, select the side with the greatest length. Foldout 1 shows an object with the three multiview projections and a pictorial, so that its true size and shape can be seen. Notice that the view selected for the front shows the greatest contour of the object. This may or may not be the actual front of the object. In this projection only the three views are essential to understand the object. Generally, it is the practice to show the side view that requires the fewest hidden lines. If a drawing becomes cluttered and confusing because of the hidden lines, the practical thing to do would be to draw the other side and eliminate the hidden lines. When there is little difference between the right-side view and the left-side view, the right side is preferred.

Exercises (220):

1. Projections are classified into what two major categories?

2. Usually, what determines which side of the object should be the front view?

3. Using the glass box theory, when are the top, front, and bottom views in the same vertical line?

2-2. Number of Views

The basic purpose of all multiview projections is to show the true size and shape of the object being represented. Although an object has six possible views, it does not necessarily follow that all six views must be shown to completely describe the object.

221. Given an object to be drawn, identify the number of views needed to show size and shape.

How to Determine the Number of Views. The guide for determining the number of views needed to show size and shape of an object is to include only those views, which are absolutely necessary. Very thin objects with uniform thickness such as shims, gaskets, and plates need only a single view to be effective, as shown in figure 2-5. Symmetrical objects can often be limited to just one or two views, as shown in figure 2-6. In most cases the top view of a symmetrical object would be a duplication of the front view.

The front, the top, and the side views are necessary in most other multiview drawings. It is sometimes necessary to show more than the three views or to show the left side view instead of the right side view. Certain types of objects may need only two of any of the

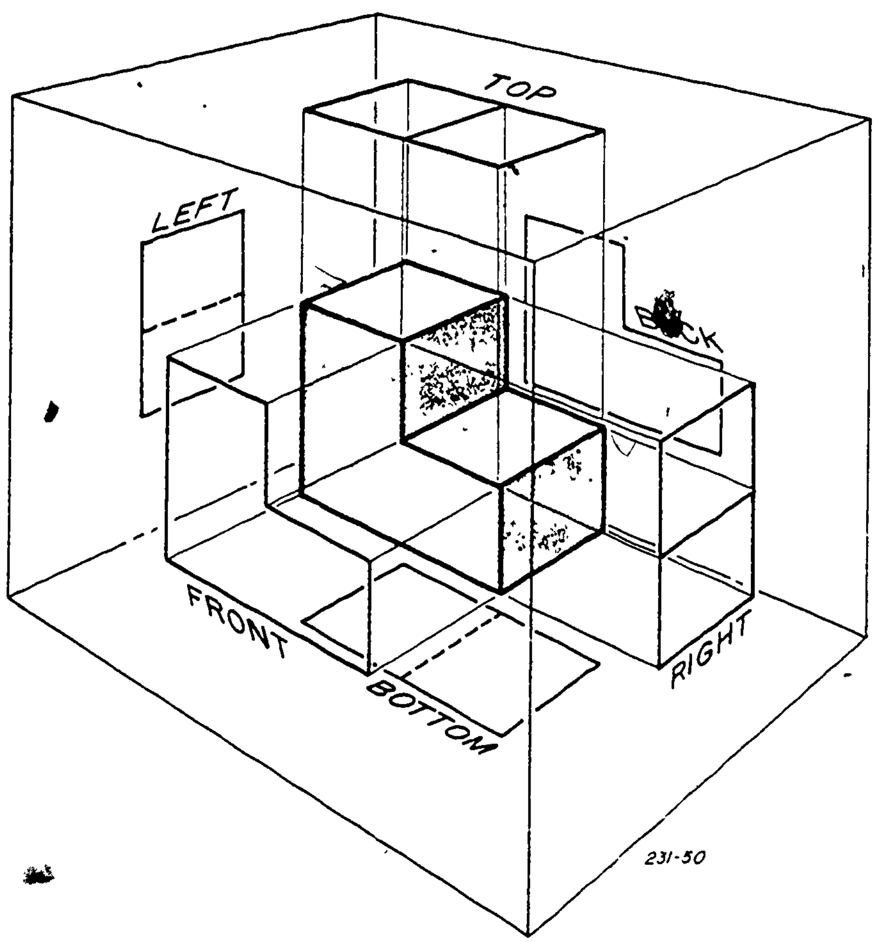


Figure 2-2. Glass-box method.

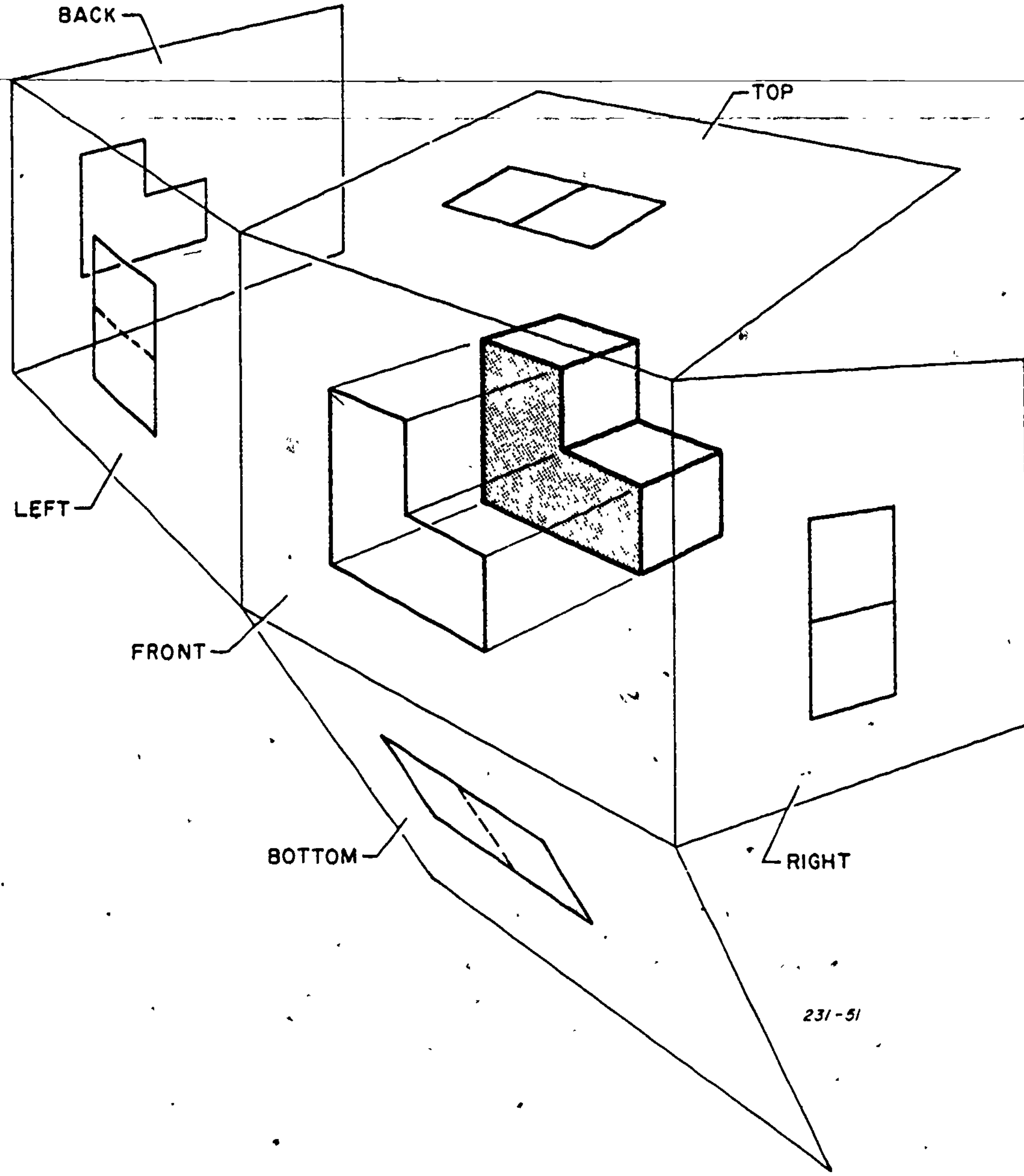


Figure 2-3. Opening the glass box.

three views if the detail is such that it would be virtually impossible to present a true representation any other way.

The practice in drawing is to show all features, hidden or otherwise. Hidden features are shown by short, evenly spaced dashes appearing on at least two of the three views and appearing as a solid on the surface of the third. In laying out a drawing there will be a time when hidden lines, center lines, and story lines (visible lines) will coincide. The essential point of any drawing is the story it's trying to tell, so visible lines are the most important. Visible lines must always take precedence over all other lines; hidden lines are next, then center lines. If a center line coincides with a cutting plane or any other lines that are a part of the story, the line that contributes the most to the readability of the illustration takes precedence. Dimension lines and extension lines should never be placed so that they would coincide with any of the other lines.

Exercises (221):

1. How many views are possible from one object?

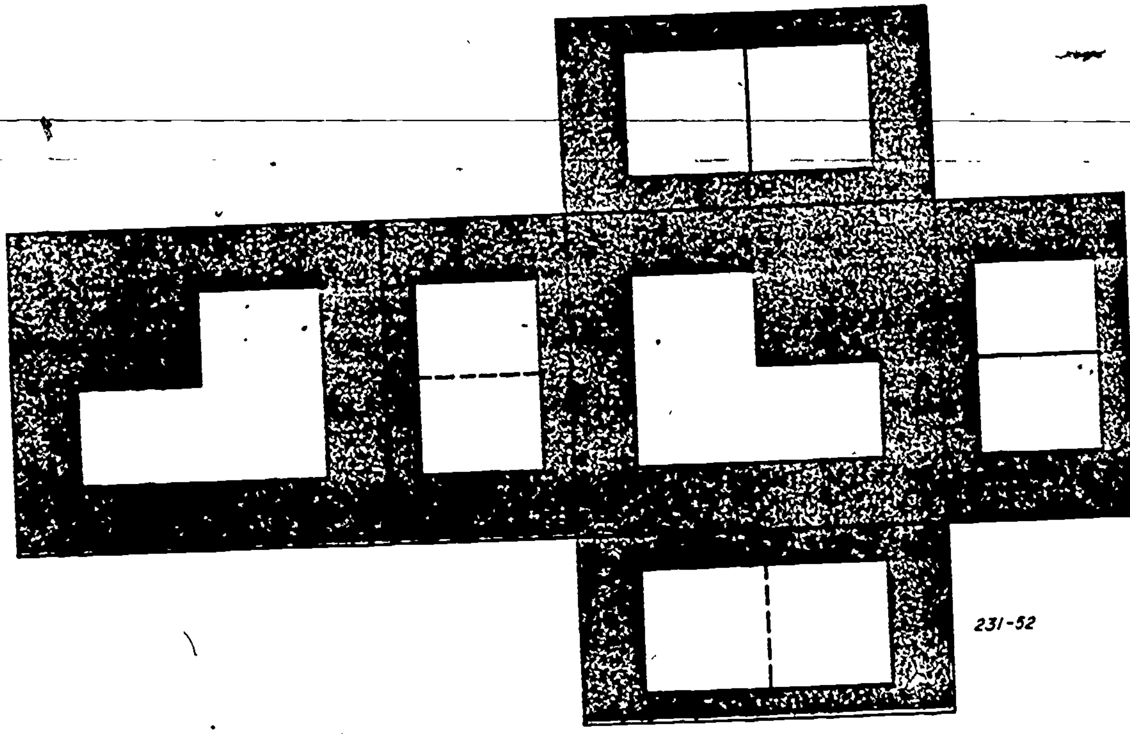


Figure 2-4. Layout of sides of glass box on paper.

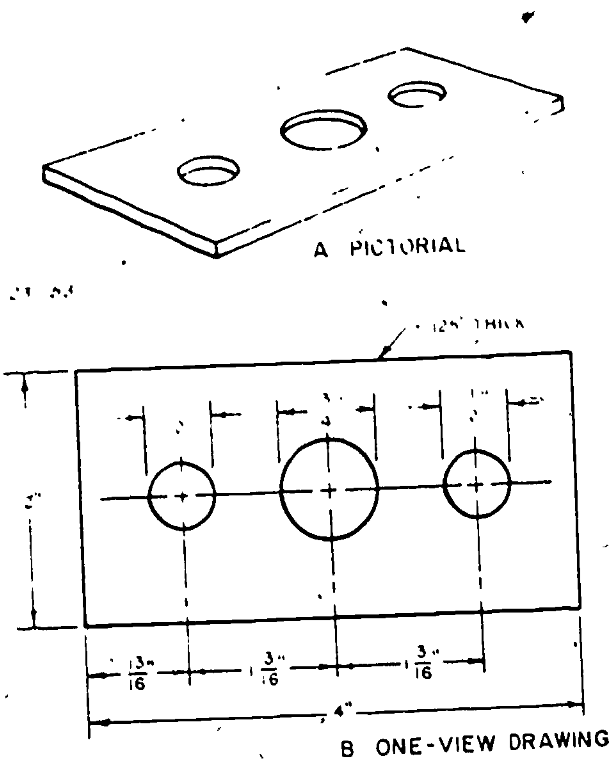


Figure 2-5. One-view drawing of a flat object.

2. How many views are needed to illustrate one object?

3. Which lines take precedence over all other lines?

222. Given a situation when space is a problem, give some of the possible solutions.

Drawing Multiview Illustrations. When drawing multiview illustrations and space is limited, it is permissible to use a partial view when symmetrical objects are being represented. The half view of the drawing should always be the portion nearest to the full view of the drawing. For clarity, where two views of opposite planes can be used to best describe the object, these views need not be complete—provided that when considered together they describe the object as one unit. Therefore, only hidden lines immediately behind the surface being viewed need be shown.

Spacing also becomes a problem with objects that are wide. Drawing wide objects in the conventional three-view method will leave

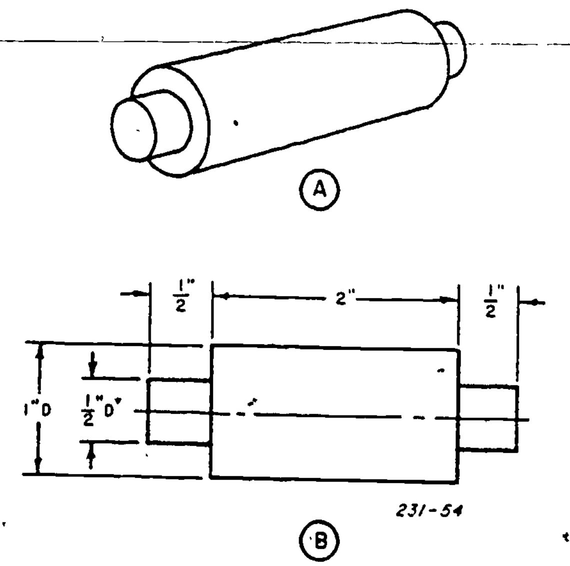


Figure 2-6. One-view drawing of a cylindrical object.

large open areas, as shown in figure 2-7. To avoid this situation, it is permissible to draw the side view to the right of the top view. This appears to give better balance to the page and achieves the same purpose as the conventional three-view method. A rear view can also be drawn as an alternate view; but, to avoid confusion, be sure that alternate views are labeled for identification.

Sometimes when two views are needed to represent an object, you may choose the one to accompany the front view from two or more equally descriptive views. When any one of several possible view combinations will describe the object adequately, you should choose the combination which can be spaced best on the paper. Figure 2-7 illustrates the principle of choosing and arranging views to give a pleasing effect.

In a two-view drawing of a symmetrical object, only a partial view may be needed to describe the object adequately. A break line may be used to limit a partial view. A half-view drawing is shown in figure 2-8. This type of drawing is covered in a later volume of this CDC. However, by carefully analyzing the half-view shown in figure 2-8, you should see the principle of this method.

Exercises (222):

1. Where should a half view of a drawing be used?

2. What two views are permissible to construct a two-view drawing?

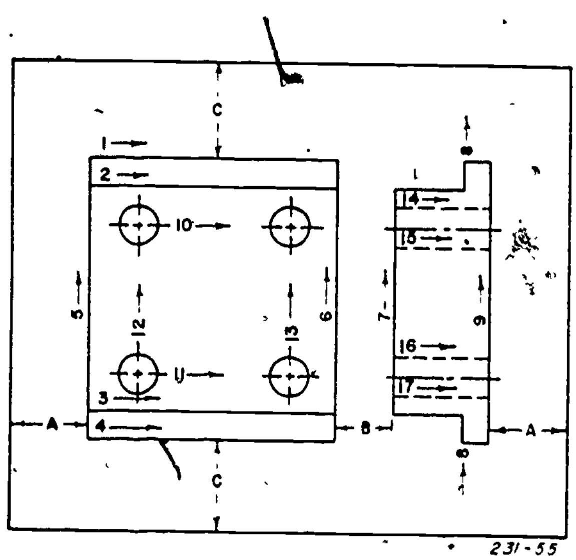


Figure 2-7. Layout for a two-view drawing.

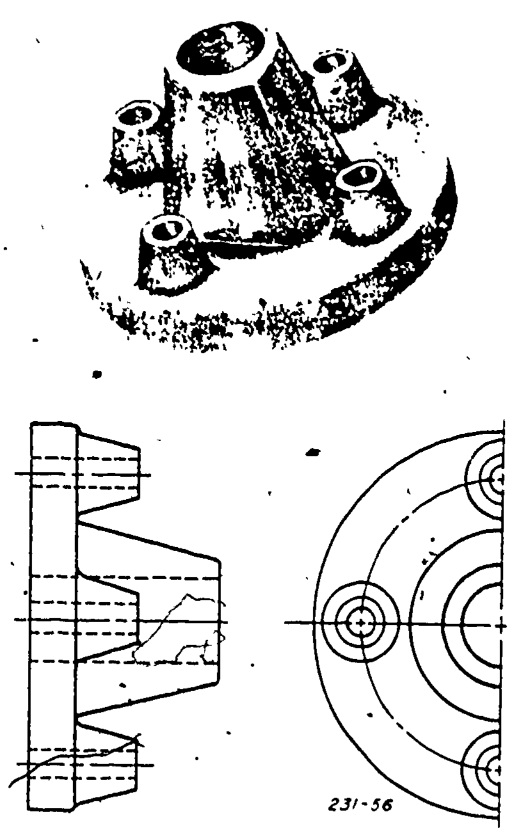


Figure 2-8. Partial view.

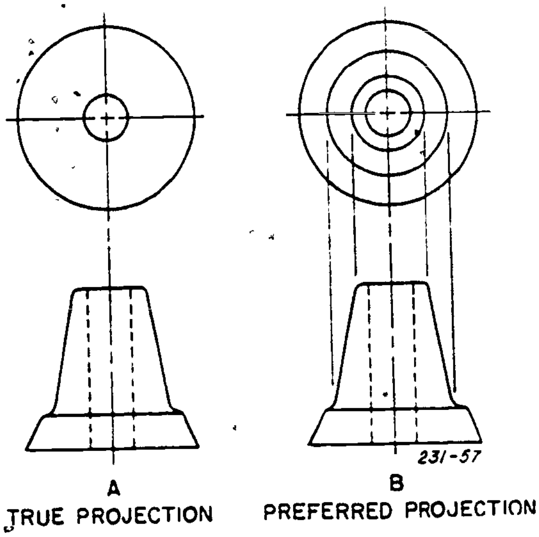


Figure 2-9. Top and side views of curved surfaces.

223. Given the projection of oblique and curved surfaces, fillets, and rounds, identify each.

Oblique Surfaces. When a surface is at an acute or obtuse angle to all parallel or principal planes of projection, it is an oblique surface. The true size of an oblique surface will not appear in any of the normal or principal views of a drawing. To show the true shape and size of an oblique surface, a secondary, or auxiliary, view must be drawn. Oblique or auxiliary views are described in more detail in Chapter 3 of this volume.

Curved surfaces, curved edges, fillets, and rounds are a vital part of the graphic specialist's vocabulary. He should understand how and why these elements apply to his profession. Many objects have curved surfaces and edges tangent to a straight plane. When objects have continuously curved surfaces, as in point B of figure 2-9, that are perpendicular and tangent to each other, they are perpendicular to the plane of projection. When a circle or curve is parallel to the plane of projection, it is drawn as a circle or curve on the parallel plane and as a straight line on the adjacent plane. If the plane of tangency of two curves is at an angle, no line is shown in the plane of projection (see points H and I of fig. 2-10).

Fillets and rounds are always shown on drawings to indicate corners of unfinished castings. Since most castings of machine parts and tools are made by pouring molten metal into specially constructed molds, precautions are taken to eliminate sharp corners wherever possible. Besides improving the appearance, rounded corners and edges provide greater strength and ease of handling of the finished product. (See fig. 2-11.)

If the finished product is to have machined

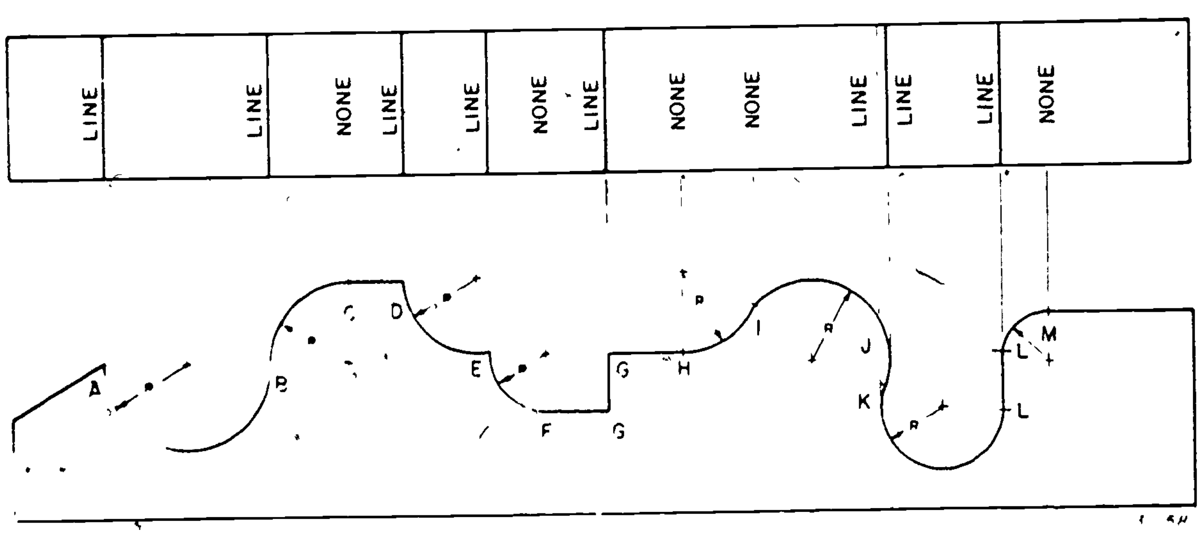


Figure 2-10. Intersections of rounds and fillets.

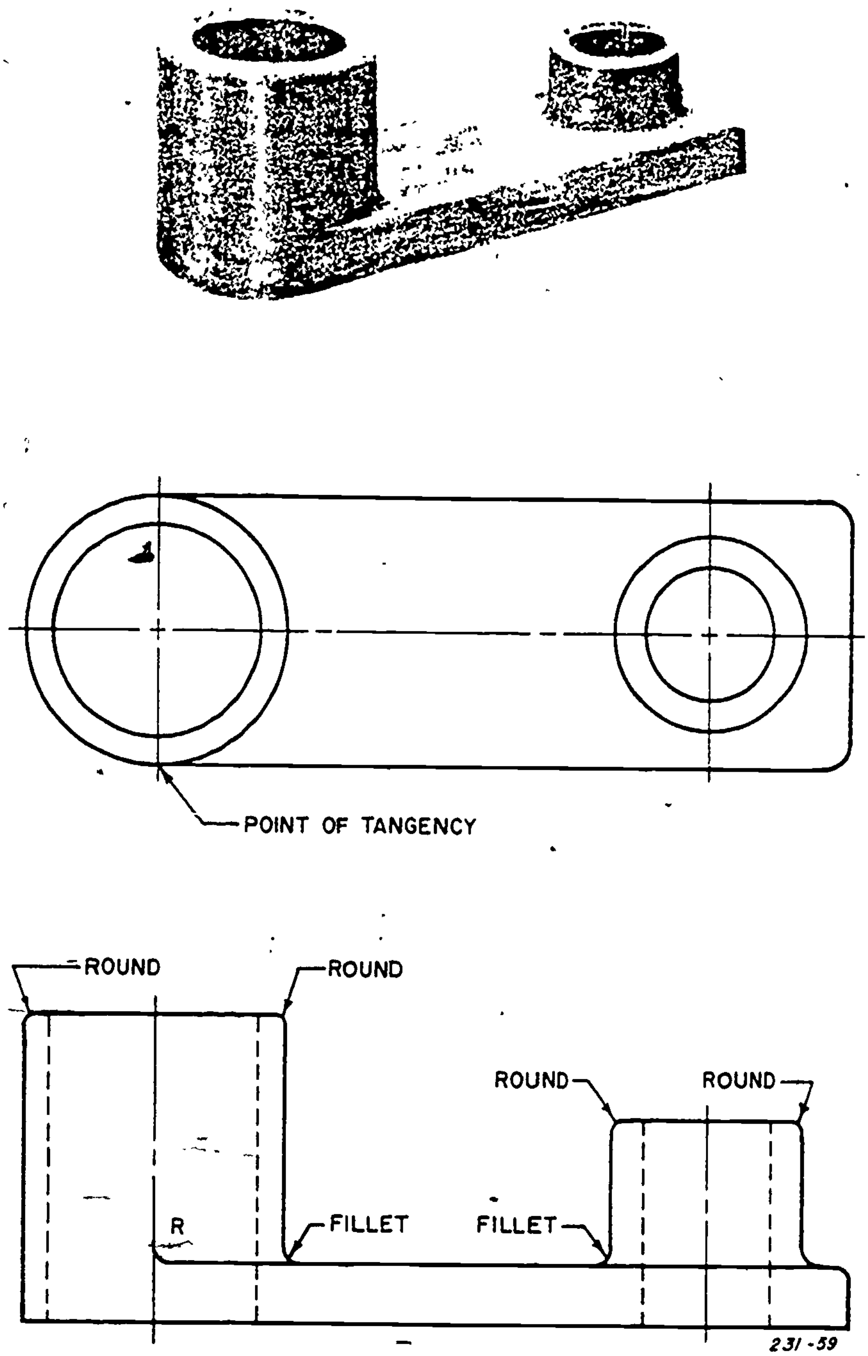


Figure 2-11. Conventional representation of fillets and rounds.

intersecting surfaces, the corners are to be drawn sharp and square. Fillets and rounds are to be designated by note as to the size of the radius. The note should read in this manner, "All fillets and round ¼ inch radius unless otherwise specified." These notes should be placed near a principal view or in a general area designated for notes. Notice in part A of figure 2-9 that a true projection of a rounded edge has no line to define the intersection of the two different surfaces. But, in the preferred method shown in part B, lines on the projected (top) view represent the rounded edges joining the surface. The added lines show where the surface would intersect if the fillets and round were not there.

Exercises (223):

1. What is a fillet?

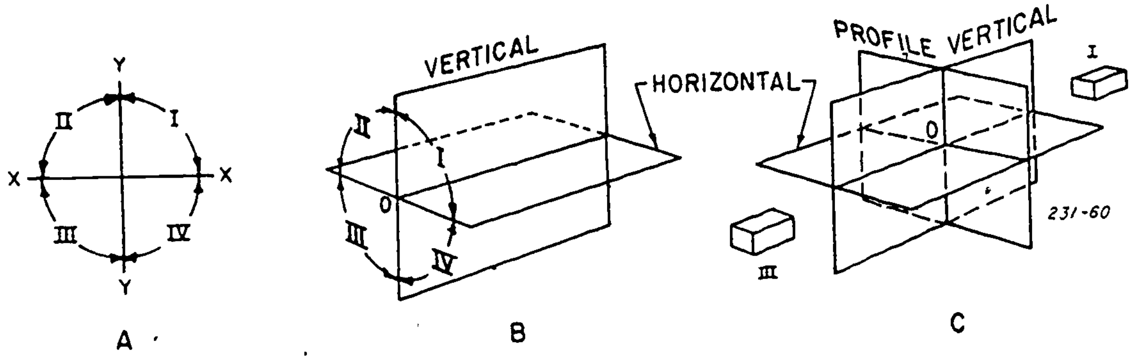


Figure 2-12. Planes and quadrants.

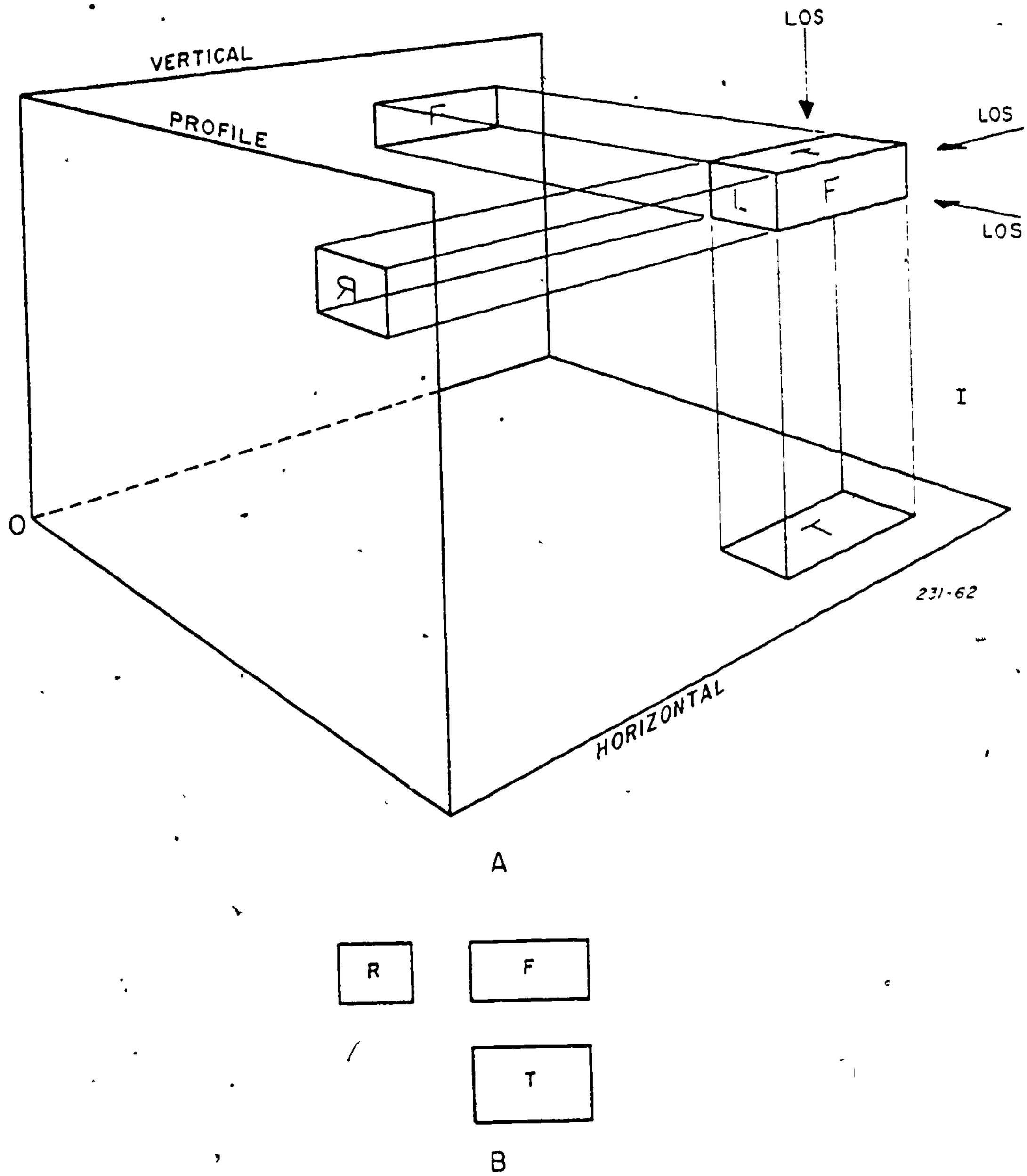


Figure 2-13. Three essential views.

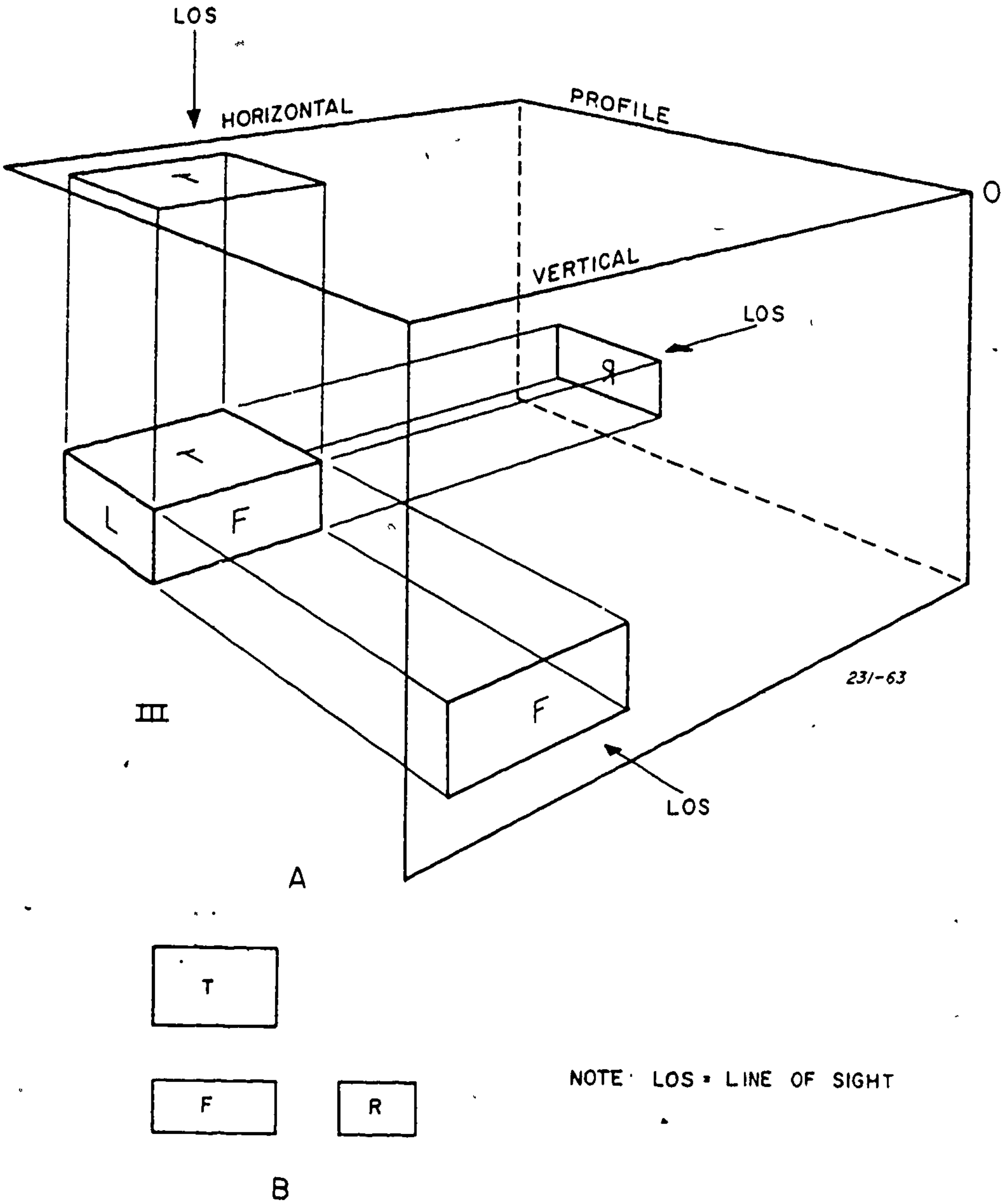


Figure 2-14. First angle projection.

2. What is a round?

3. What is an oblique surface?

4. What do fillets and rounds indicate on a drawing?

224. Given a definition of a projection plane, explain the planes of projection and their function.

Planes of Projection. The three planes used in orthographic projection are the vertical (or frontal) plane, the horizontal plane, and the profile plane. These planes revolve about certain axes to bring the three essential views of a multiview drawing into a single plane. The horizontal plane revolves around the X-axis and the profile revolves around the Y-axis. The axes are formed by crossing the horizontal and vertical planes, as shown in figure 2-12. The intersection of the horizontal and vertical planes generates four quadrants, known as first, second, third, and fourth angles. Objects may be placed in any of the four quadrants and its surfaces projected onto the respective planes.

First angle projection is a system used exclusively in European countries for making drawings. By placing the object in the first quadrant, the viewer looks through the object to the plane of projection. Upon revolving the horizontal and profile planes into the vertical planes, the three essential views assume the position shown in figure 2-13. Notice that the top view is below the front view, and the left side view is to the right of the front view.

Second and fourth angle projections are rarely if ever used in working drawings. When the horizontal and profile planes are revolved into the vertical plane, both the top and front views are superimposed. This overlapping of views tends to restrict the clear visibility of either view.

Third angle projection is the system used in the United States and Canada for orthographic projection. As shown in figure 2-14 in quadrant III the observer is always on the outside looking in, as compared to the first angle projection where the observer is looking through the object to the image plane. When the horizontal and profile planes are revolved into the vertical plane, the views of the object fall into a logical order. The top is directly above the front views, and the right side view is to the right of the front view. (See fig. 2-15.)

Exercises (224):

1. What are the image planes or planes of projection?

2. What angle projection do the horizontal and the profile planes fall into in a logical order when revolved into the frontal plane?

2-3. Axonometric Projection

Axonometric projection is an orthographic pictorial projection of an object whose three major surfaces are angles to a single plane of projection. As with other pictorial drawings, this type of projection gives us only an overall

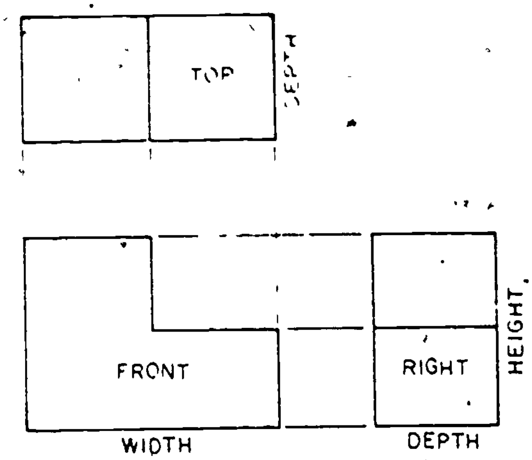


Figure 2-15. Third angle projection.

description of the external surfaces of an object and a three-dimensional concept of its shape, form, and mass. Since it is often necessary to show the natural appearance of the whole object, you can see the necessity for representing it pictorially.

Objects having very complicated outlines can be represented by means of orthographic multiview drawings. However, to read some multiview drawings, a person must have a high degree of skill and a constructive imagination. To insure that the person gets the correct impression from a drawing, a pictorial (axonometric or perspective) drawing is often used instead of, or in conjunction with, an orthographic drawing. Many technical illustrations, design and patent-office drawings, etc., are made as one-plane pictorial projections.

Since an object can be placed in an infinite number of positions in relation to the plane of projection, it is possible to make an infinite number of axonometric projections of the same object.

The inclined position of the object with respect to the plane of projection is the distinguishing feature of axonometric projection as compared to multiview projection. Since the principal edges and surfaces of the object are inclined to the plane of projection, the length of the lines, the size of the angles, and the general projections of the object vary with the infinite number of possible positions in which the object may be placed with respect to the plane of projection. Projections from these infinite numbers of possible positions may be classified into three general types of axonometric projection—isometric, dimetric, and trimetric.

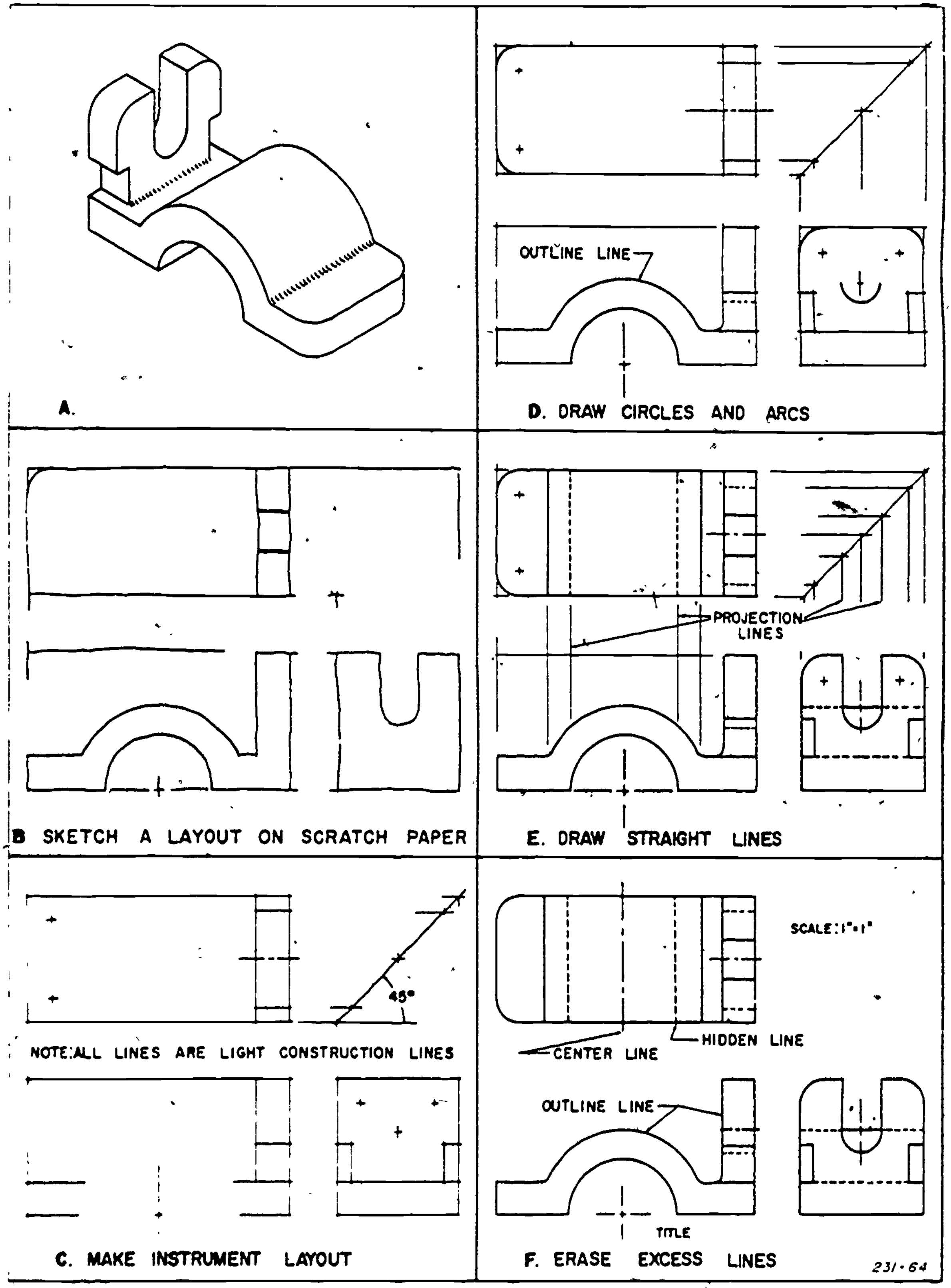


Figure 2-16. Steps in making a drawing.

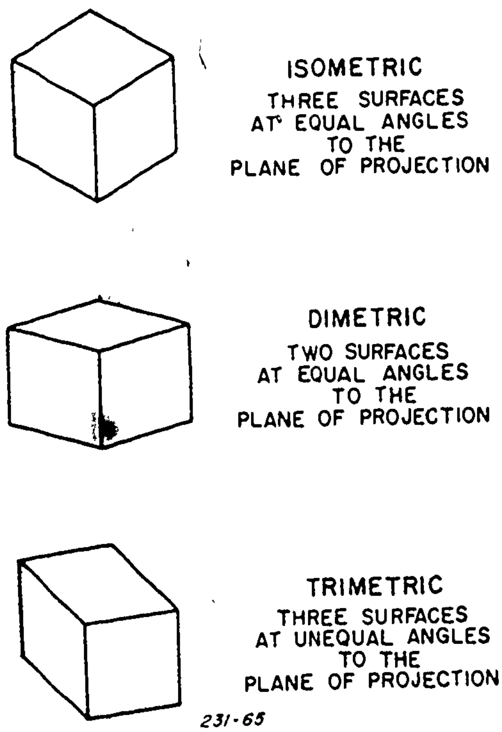


Figure 2-17. Types of axonometric projection.

225. Answer key questions relative to axonometric drawings.

Types of Axonometric Projections. As shown in figure 2-16, a projection of an object whose three visible surfaces are at equal angles to the plane of projection is classified as an isometric projection. A projection of an object which has two of its three visible surfaces at equal angles to the planes of projection is called a dimetric projection. When all three surfaces are at unequal angles to the plane of projection, the projection is called a trimetric projection.

Figure 2-17 shows the projection of a cube in the three different types of axonometric projection; the edges of the cube are foreshortened, since they are inclined to the plane of projection. The degree of foreshortening of any line depends on its angle with the plane of projection. The foreshortening increases as the angle becomes greater.

It is customary to consider the three edges of the cube which meet at the corner nearest the observer as the axonometric axes. If the degree of foreshortening of these axes is determined, scales can be easily constructed for measuring along these edges or along any other edges parallel to them.

Since the principles of the three different types of axonometric projections differ only with respect to the angles of the axes and the degree of foreshortening, we will limit our discussion of axonometric projection to isometric projection. The same or similar methods of construction can be used in dimetric and trimetric projection.

Principles of isometric projection. To produce an isometric projection, the object must be placed so that its principle edges make equal angles with the plane of projection (frontal plane). This means that from its normal orthographic position the object must be rotated 45° about its vertical axis and then tilted forward around its horizontal axis until its principal edges make equal angles with the plane of projection.

Figure 2-18 shows how an isometric is projected. Refer to this figure as you read the procedure which follows. First, draw the top view showing the cube rotated 45° from the normal multiview position. This places the two lateral faces of the cube at an angle of

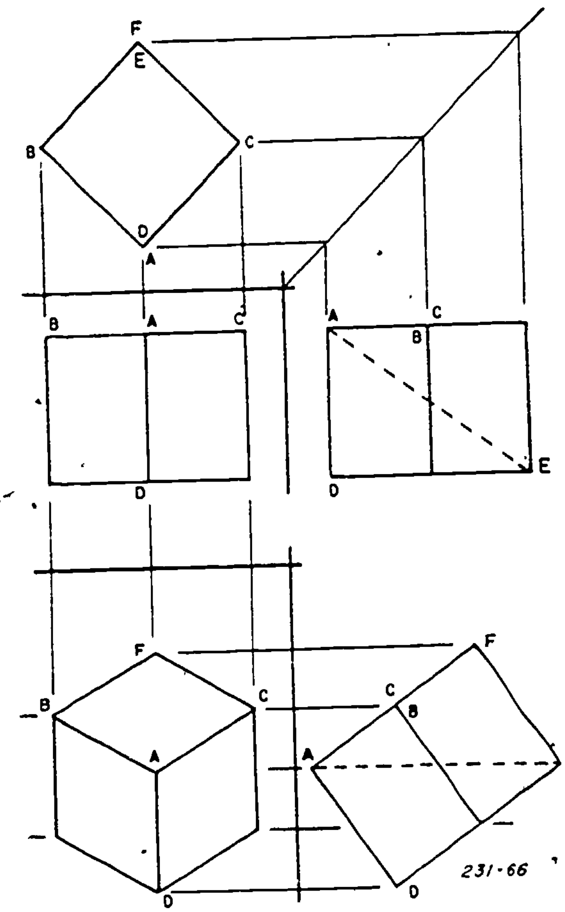


Figure 2-18. Isometric projection.

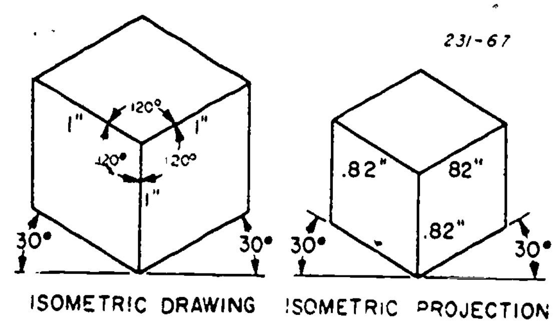


Figure 2-19. Isometric views compared.

45° to the plane of projection. Next, project the front and elevation views from this top view. Transfer the elevation view so that the line AE representing the diagonal axis of the cube is perpendicular to the plane of projection. Line AE is now a horizontal line. Locate points A, B, C, D, and F on your drawing paper by projecting them from the orthographic front view and the repositioned elevation view. Complete the isometric by drawing lines between the appropriate points.

Notice in figure 2-18 that the three edges AB, AC, and AD of the isometric are foreshortened equally. If you measure these lines and compare them with the dimensions in the original cube, you will find that they are about 82 percent of true length. Also notice that the isometric axes (in this case AB, AC, and AD) make 120° angles with each other. All lines parallel to these isometric axes are called isometric lines. All planes parallel to the faces of the cube are called isometric planes. Lines and planes which do not fulfill these conditions are called nonisometric.

Foreshortening. A correct isometric view may be drawn by actual projection of by foreshortening all isometric distances to approximately 82 percent of true size when the view is drawn. A three-quarter size scale (¾" = 1") may be used to approximate the correct measurements for foreshortening isometric lines. When an isometric view is prepared by using a normal scale, the resulting representation is called an isometric drawing. An isometric drawing is similar to an isometric projection, except for size; the drawing is not foreshortened. Because isometric drawings are made full size or full scale, it is standard practice to make isometric drawings instead of true isometric projections. Figure 2-19 shows the comparison between an isometric drawing and an isometric projection. When the axes measurements are drawn full size using a regular scale, the isometric drawing is about 22.5 percent larger

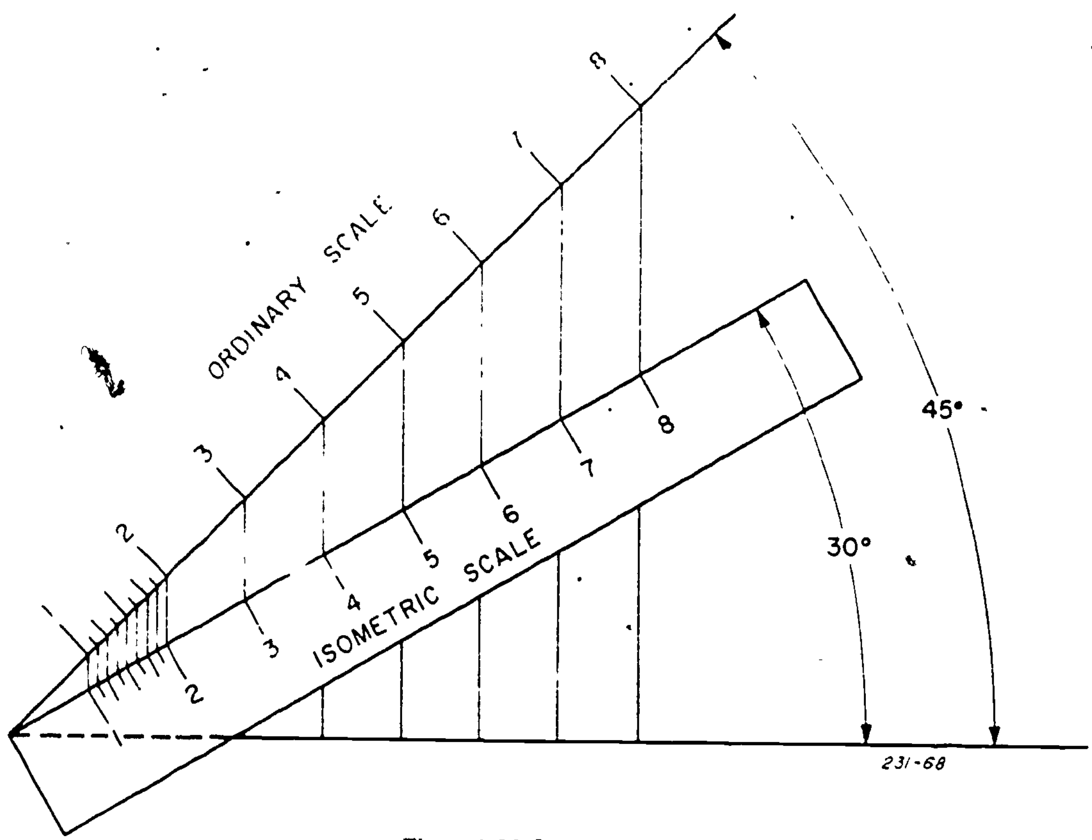


Figure 2-20. Isometric scale.

than the true projection. It is much more practical to use an isometric drawing than it is to use an isometric projection, since measurements can be made much more easily. However, when a projection is required, it is easier to construct the isometric by isometric measurements than it is by the actual projection method. The following is a method you use to construct an isometric scale if the correct scale is not available to you.

Isometric scale. When a drawing is made with an isometric scale, the isometric dimensions of the object are the same as if it were actually projected on a plane of projection. As we stated previously, an isometric scale is a three-quarter size scale. Its dimensions are approximately .82 percent of a regular scale. The following procedure for constructing a scale is illustrated by figure 2-20.

- Draw a horizontal line.
- Draw the 45° line to the horizontal line.
- Using your regular scale, mark off the units and intermediate divisions on the 45° line.
- Draw lines perpendicular to the horizontal line to each division mark.
- Draw the 30° line.
- Place a piece of paper, cardboard, or some similar material along the 30° line as shown and mark the isometric divisions on the material.

During the discussion which follows on making an isometric drawing by the box method, no numerical dimensions (only literal) are used. If numerical dimensions were give, they could be either isometric scale or regular scale units—the method of drawing would be the same.

Isometric drawing. Remember, the only difference between an isometric drawing and an isometric projection is the scale used. Refer again to figure 2-19. Note that the

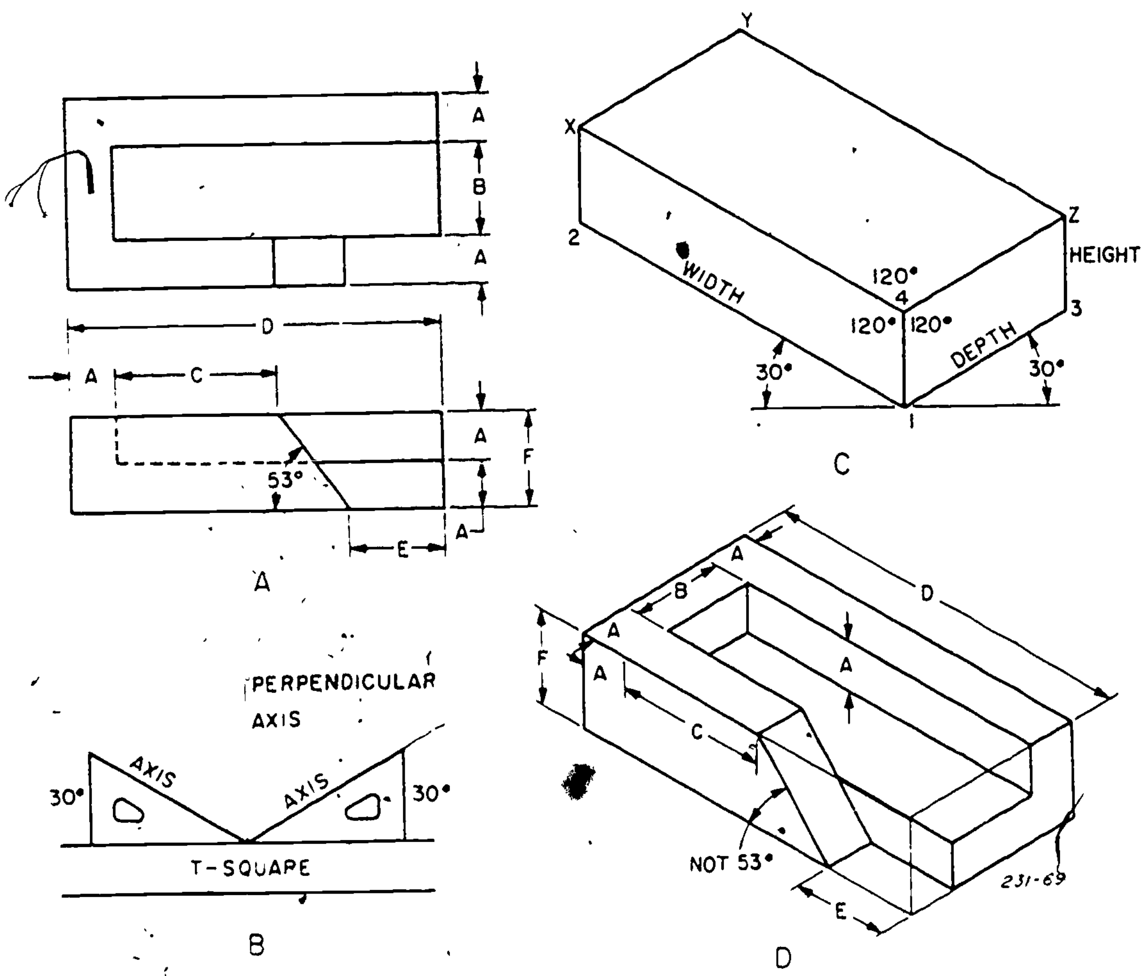


Figure 2-21. Box method for isometric drawing.

isometric projection was "drawn" with an isometric scale, and the drawing with a regular scale. Isometric drawings are built on a skeleton of three lines representing the three principal edges or axes of a cube. All measurements are made along these axes or lines parallel to them (isometric lines). The location of nonisometric lines and other points must be found by coordinate measurements which are made parallel to the isometric axes. (Only isometric lines and planes are shown in true length in isometric drawing and projection.) An easy way to represent an object in an isometric drawing is by the box construction method. First, we'll discuss the construction of an isometric box and follow with inserting the object in it.

Box construction. The procedure which follows shows the method for drawing an isometric rectangular box whose sides coincide with the main faces of the object—height, width, and depth. Refer to figure 2-21 as you study the following procedure.

a. From a point which represents the lower front corner (1) of the box, draw the three light construction lines as shown in part B of figure 2-21. These lines, 1-2, 1-4, and 1-3, are the three major axes for constructing the isometric box shown in part C.

b. From this lower front corner (see part C), start building the inclosing box by transferring the height, width, and depth dimensions from the orthographic (multiview) drawing of part A. After the corners (1 through 4) have been established, complete the box by drawing the parallel edges (isometric lines) as shown in the illustration. These lines establish corners X, Y, and Z.

c. The box can also be completed in the following manner. Notice that at the top front corner (4) of the box, the axes make 120° angles with each other. Because the inclosing box is made up of isometric lines, you can complete it by using your T-square and 30° - 60° triangle and architect scale or dividers. Now, let's draw the object by means of the isometric box.

Drawing the object. The object drawn by means of the box is shown in part D of figure 2-21. Notice how measurements from part A set off on the corresponding isometric edges. Be sure to follow the rule of making all measurements on only the isometric axes or isometric lines. As you study these illustrations, use your dividers to compare the measurements. These measurements coincide with those in the multiview drawing because this is an isometric drawing, not a projection.

Now use the coordinate method to draw nonisometric lines. This is done by making measurements along isometric lines to locate the end points of the nonisometric lines. An example of a nonisometric line located in the way is the front edge of the oblique plane in the isometric view. This oblique edge is located on the isometric view by first marking off distance A + C (see part A) on the upper left edge of the left front face of the box. This establishes one end point of the oblique edge. The other end point is located by marking distance D-E off on the lower part of the base line of the same face. Remember that in drawing both isometric and nonisometric lines all lines parallel with each other in the object are represented by parallel lines on an isometric view. Furthermore, notice that the only dimensions which do not coincide with the multiview are those of the oblique portion and the angle. The size of an angle is changed when it is in an isometric drawing.

After the drawing is finished, erase the light construction lines. These lines are indicated in part D of figure 2-21.

NOTE: In isometric drawing, do not show invisible edges unless they are necessary for a clear description of the part. It is common practice in all pictorial drawing to omit all invisible lines, provided they are not needed to explain some hidden feature. Also, you should avoid excessive use of center lines, to show the axes of symmetrical parts. Use dimension lines to indicate dimensions.

Curves in isometric. The offset method of measuring is widely used in the drawing of curved lines. This method consists of locating points through which the desired curve is drawn. Figure 2-22 shows how to draw noncircular curves from points plotted by offset measurements. The curves in solid figures usually appear in pairs as parallel curved edges of the object. To simplify your drawing, draw one curve by plotting the points and then draw isometric lines from the points. Fine the remaining parallel curve by stepping off the distance along corresponding isometric lines. Here's how this is done.

Figure 2-22 consists of four parts which show the steps used to make an isometric drawing of an object containing a curved surface. First, draw the orthographic top and front views of the object as shown in part A. In the top view, select at random along the curve any number of desired points, such as 2 through 6. (Points 1 and 7, being the ends of the curve, are established points.) Use enough points to fix accurately the path of the curve.

Draw vertical and horizontal offset grid lines from these points.

Draw the isometric box as shown in part B of figure 2-22. Lay off along isometric lines the dimensional measurement A and the offset measurements B and C from the top view to locate points 1 and 2 on the curve in the isometric box. Locate the remaining points by using the same offset method. This step is shown in part C of the figure and represents a continuation of step B. After locating all points, sketch a light freehand curve through the points as shown in the illustration.

Notice in the front view of the multiview projection that points 1′ through 7′ are established by projection from the top view. Locate these points in the isometric (see part D of fig. 2-22) by drawing vertical lines downward from points 1 through 7, making all lines equal to the dimension D shown in the orthographic front view. Sketch a light freehand curve through the ends of these lines (points 1′ through 7′). Complete the curved surface by drawing the finished curve, using an irregular curve as a guide.

Circles in isometric. When a circle lies in a plane which is not parallel with the plane of projection as in isometric drawings, the circle projects as a true ellipse. However, an approximate ellipse is accurate enough for nearly all isometric drawings. (Ellipses were presented in Volume 1.) An approximate view of a circle can be drawn by the four-center method. This construction can be used only for a circle which lies in an isometric plane.

Part A of figure 2-23 shows a circle inscribed in a square which is parallel to the image plane. To draw this circle in isometric form, the first step is the construction of an isometric square with sides equal to the diameter of the circle, the same dimensions as in part A. Part B of figure 2-23 shows the construction of the isometric square. You can see that it is drawn by means of the 30° - 60° triangle using the principle of parallel lines. Now, let's inscribe the ellipse within this isometric square by means of the four-center method.

Locate the midpoints, a, b, c, and d, of each side of the square, and then connect points ag and bh (see part C). Next, draw the long diagonal. This diagonal makes an angle of 60° with the horizontal. The points of intersection, e and f, of the lines ag, bh, and the long diagonal are centers for the two short

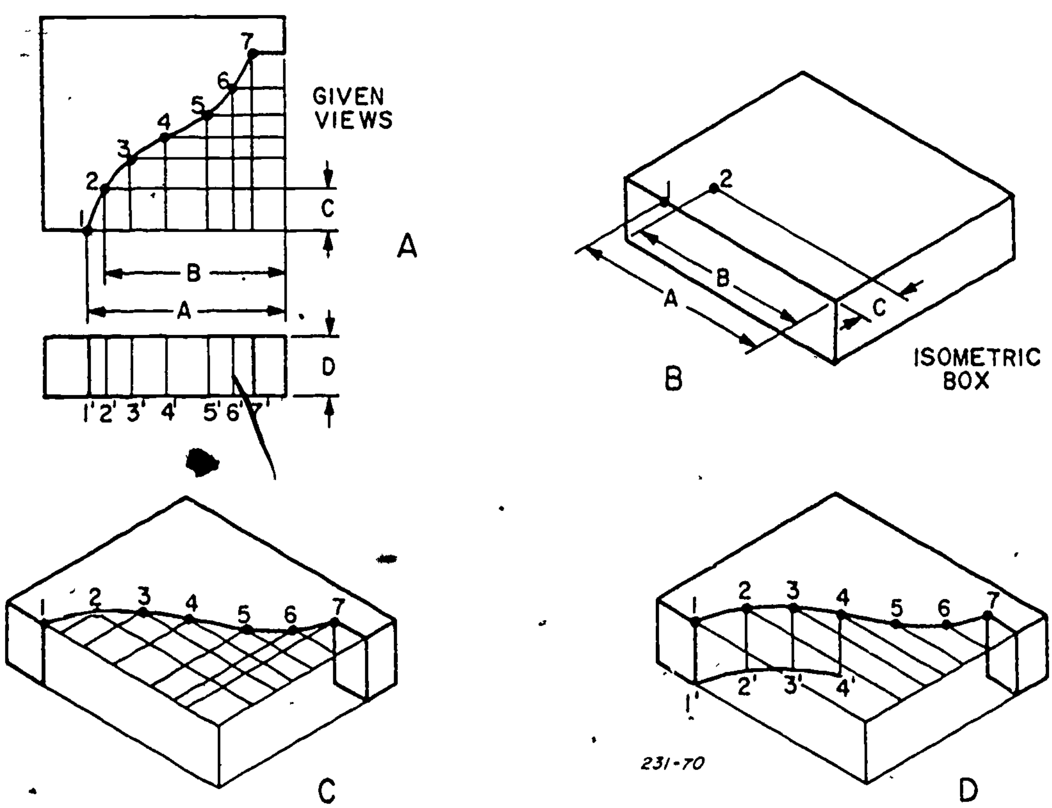


Figure 2-22. Curves in isometric projection.

arcs. The centers for the two long arcs are points g and h. Now draw the ellipse with a compass (see part D).

Using point e as center and radius ae, draw arc ac. Similarly, using point f as center and radius bf (same as ae), draw arc bd. Now we have the two short arcs. The long arcs are drawn in the same way. Using point g as center and radius ag, draw arc ad; and then using point h as center and radius hb, draw arc cb. Thus, the four-center ellipse is completed. The four arcs shown in part D were purposely not connected to show the four separate arcs.

Part E of figure 2-23 shows the construction of the four-center ellipse upon the three visible faces of a cube. Notice that two of the long diagonals are 60° to the

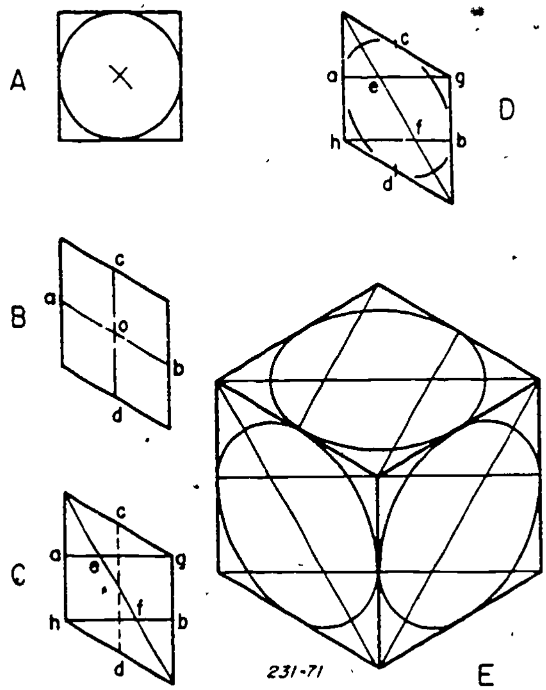


Figure 2-23. Circles in isometric projection.

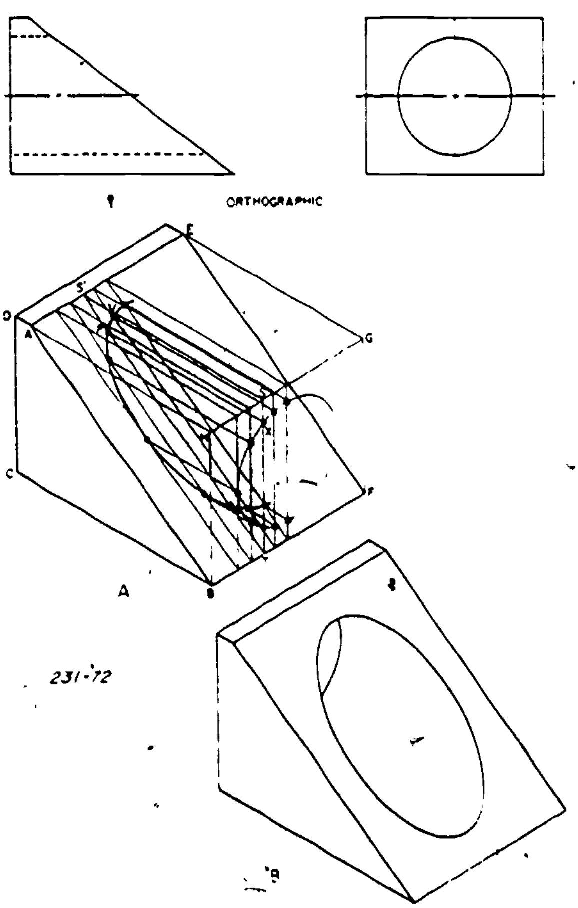


Figure 2-24. Isometric circle on nonisometric plane.

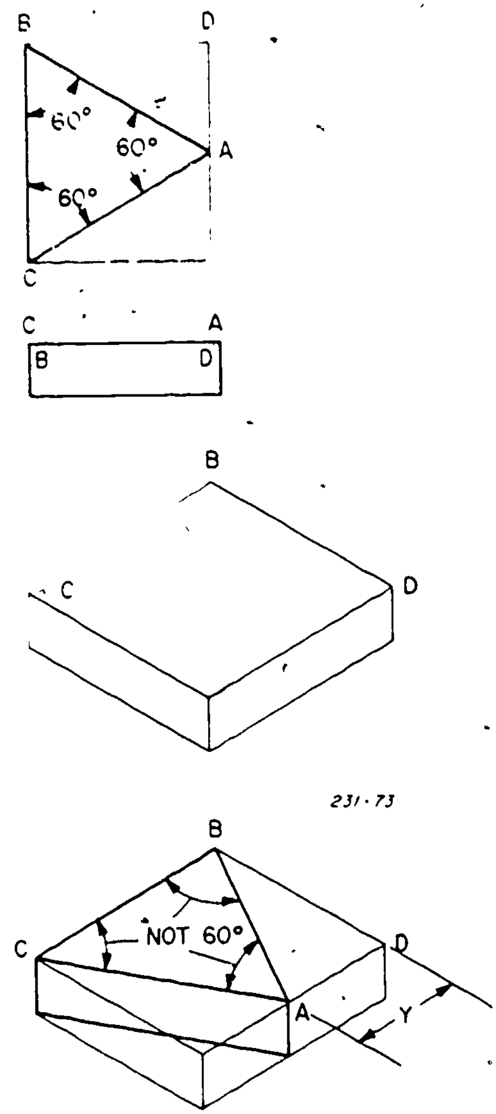


Figure 2-25. Angle in isometric.

horizontal, the other is horizontal, and all three are of equal length. Hence, the entire construction can be made with a T-square and 30° - 60° triangle. Observe this figure closely, and you will see that each ellipse is constructed by the four-center method in the way we described earlier. Use your compass or dividers and locate the centers and radii of the arcs on the faces by the method just explained.

Isometric circle on nonisometric plane. Circles and circular arcs in nonisometric planes are plotted by using the offset or coordinate method. Figure 2-24 illustrates how this construction is made. Observe this illustration carefully as you study the following procedures.

a. To being, draw an isometric box around the object according to the orthographic dimensions (see part A). Notice that the object is drawn without the ellipse on the inclined face.

b. Next, draw an ellipse on face BHGT using the orthographic dimensions to construct it and space it correctly. The isometric circle (ellipse) may be constructed by means of the four-center method.

c. Construct a series of planes parallel to face ADCB. (Five planes are shown in the figure.) One edge of each plane is represented by a line parallel with face AEGH and the other edge by a line parallel with face BHFG. For instance, notice edges S'S and ST which represent one of the planes.

d. Draw diagonal lines (parallel with AB) along the sloping surface to complete the limits of the constructed planes. For instance, S'T is the diagonal for one particular plane. These diagonal lines lie on the sloping surface.

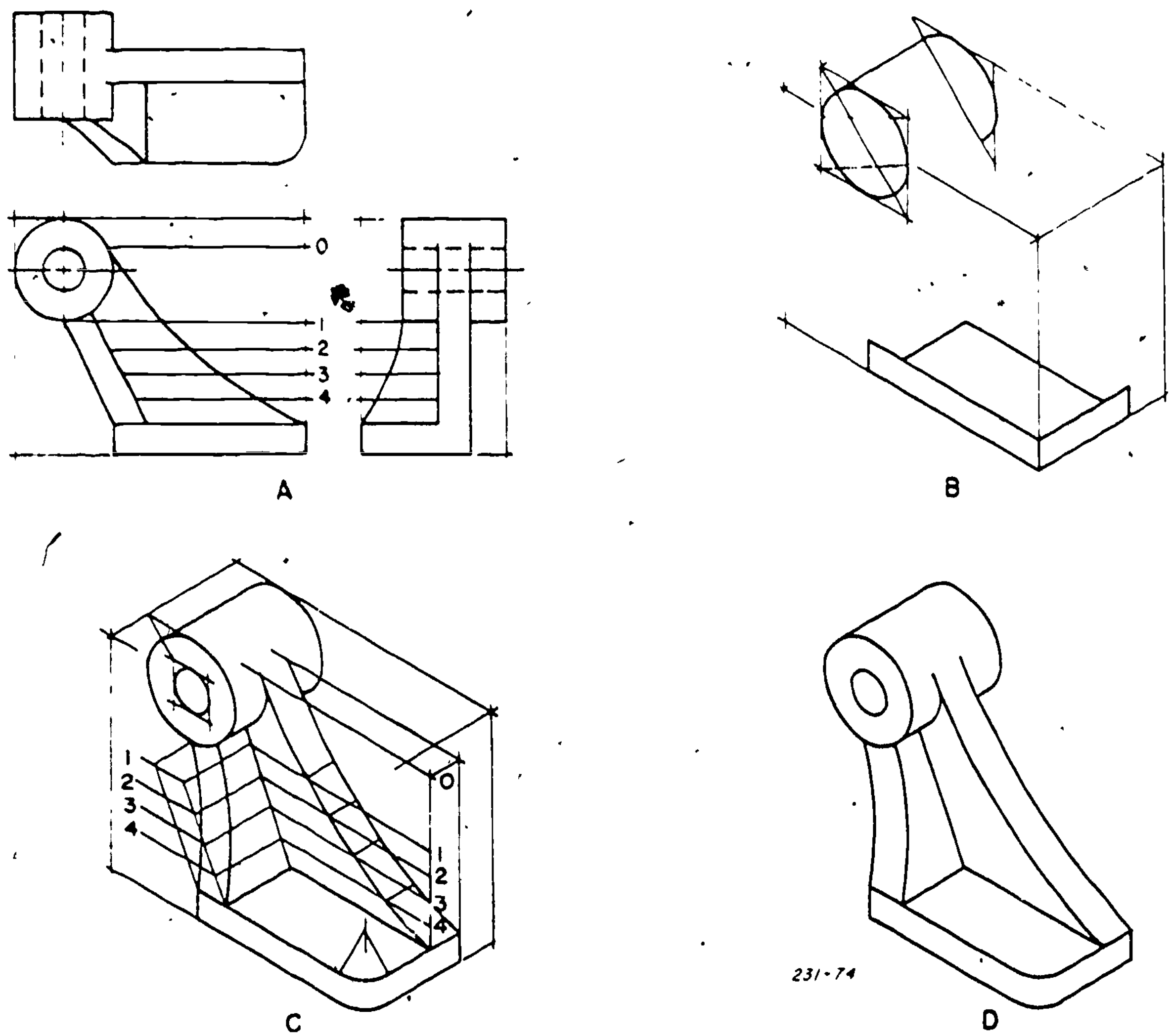


Figure 2-26. Construction of object.

e. At points where the planes cut the isometric circle, draw isometric projection lines parallel to AH to intersect corresponding sloping lines. The point at which a projection line intersects a sloping line is a point on the required ellipse. For example, note that line ST cuts sloping line S'T at point P. Thus, point P is an established point on the required ellipse.

Other points are established in exactly the same manner. You can see the more planes that are drawn, the greater the number of points that can be established; hence, a smoother ellipse can be drawn through the points by means of irregular curve.

Angles in isometric. Recall that an angle projects true size only when the plane of the angle is parallel to the plane of projection. Since in isometric the surfaces of the object are inclined to the plane of projection, the angles are not projected in true size. Any angle may project larger or smaller than true size, depending upon its position. Hence, an angle must be drawn by linear measurements along isometric lines, not drawn by the actual degrees of the angle.

Figure 2-25 shows the isometric drawing of a triangular object from the multiview. The inclosing isometric box is constructed by transferring dimensions from the multiview. The vertex of the equilateral triangular surface is found by locating point A by measurement (from the multiview) along an isometric line, as shown. Of course, point A is midpoint because the triangle is equilateral. Notice that none of the angles are 60° in the isometric. To verify this fact, measure each angle in the isometric with your protractor.

Construction of an object containing curves. Figure 2-26 shows the steps in constructing an isometric drawing of an object which is composed of a cylinder and curved surfaces. Study the steps shown in the illustration. Use your dividers to compare measurements, and you should see the principles of this particular method.

First box in the object as shown in part A of figure 2-26. Then mark off points on the object and draw horizontal lines from these points to the box. Using the dimensions of the orthographic views, draw an isometric box as shown in part B. Then draw the cylindrical portion and the base of the object. Next, as shown in part C, lay out the isometric lines representing the horizontal lines drawn on the orthographic views. Use these lines to locate the two curves and webs. Complete this step by using your irregular curve to draw the two curves through the points as shown. Part D shows the finished drawing.

Exercises (225):

1. What does the term *isometric* mean?

2. For isometric projections, the object must be rotated how many degrees around its horizontal and vertical axes?

3. In all axonometric projections, the sum of the angles formed by the three axes is ___.
4. In which type of axonometric projection are the three angles formed by the axes unequal?

2-4. Oblique Projections

The construction methods for isometric and oblique drawing are similar. To simplify an oblique construction, choose as the front face the one showing the most description of the object and place it parallel to the image plane. After this, the drawing is made by the *box construction* method—similar to isometric. Other steps in oblique drawing include skeleton construction method, circle and arcs not parallel with the image plane, and angles. We'll cover these in order. But first we'll discuss foreshortening of receding lines and the construction of oblique drawing, based upon cavalier and cabinet.

226. Given the two different types of oblique projections, define cavalier and cabinet drawing:

Cavalier and Cabinet Types. Following are the definitions for these two particular types of oblique projections. (See fig. 2-27.)

- An oblique drawing is called a cavalier when the receding lines are true length. (Projectors at an angle of 45° with the image plane.)
- An oblique drawing is called a cabinet when the receding lines are drawn half of true length.

A projection which does not fall into either category is usually called just an oblique projection. Since in the oblique projections shown thus far the projectors have been at an angle of 45° with the image plane and the

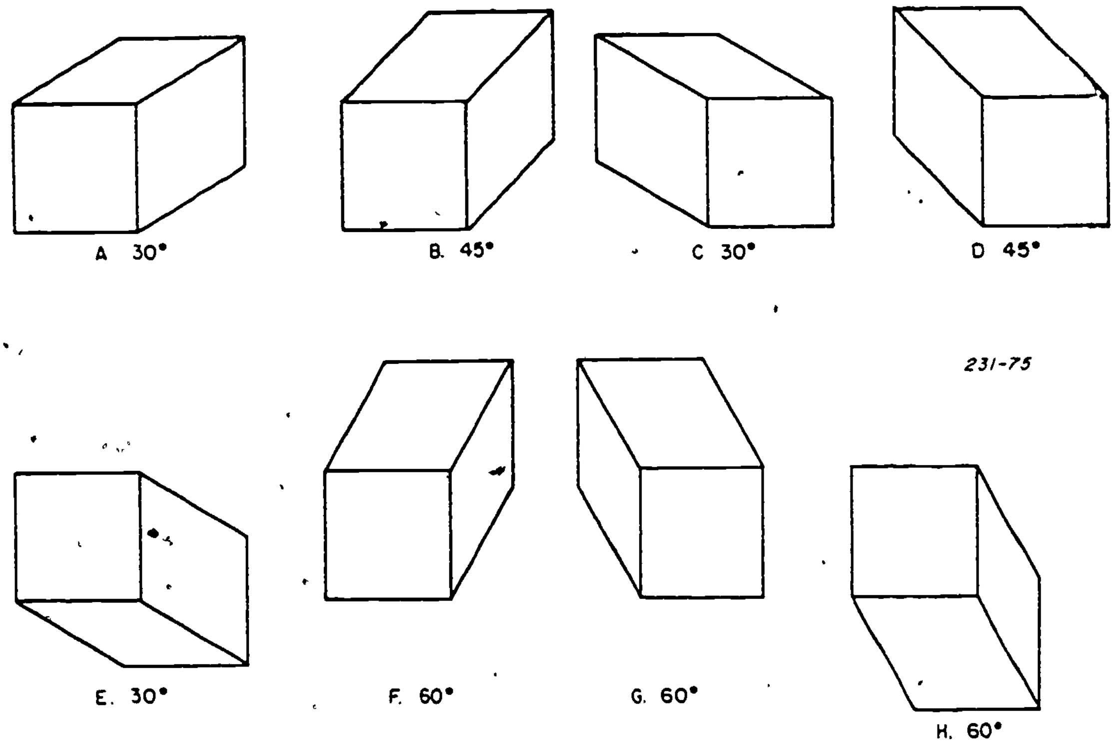


Figure 2-27. Variations in views by angle of receding axes.

projected lines in a cabinet drawing, the receding lines are half of the true length. Theoretically, this means that the projectors make an angle of about 63.5° with the image plane; consequently, the lengths of the receding lines are foreshortened to half of true length. However, we'll not cover the actual mathematics, since the desired length of receding edges may be drawn by measurement.

Figure 2-28 shows the difference in the apparent shape of a cube that results by foreshortening the receding lines. Notice that the receding lines of the cabinet drawing are half the true length of the cavalier. Often a cabinet drawing is preferred to a cavalier, depending upon the dimensions of the object. As in the case of the cube, the cabinet projection appears less out of proportion than the cavalier.

Box construction method. The steps for making an oblique drawing from the orthographic views are shown in figure 2-29. Refer to the figure as you check the following steps. You'll see that the principles of box method in oblique and isometric drawing are identical.

a. As shown in part A, construct the box whose dimensions coincide with those in the orthographic drawing. In this case, the angle chosen between the receding lines and the horizontal is 30°. However, this angle may be

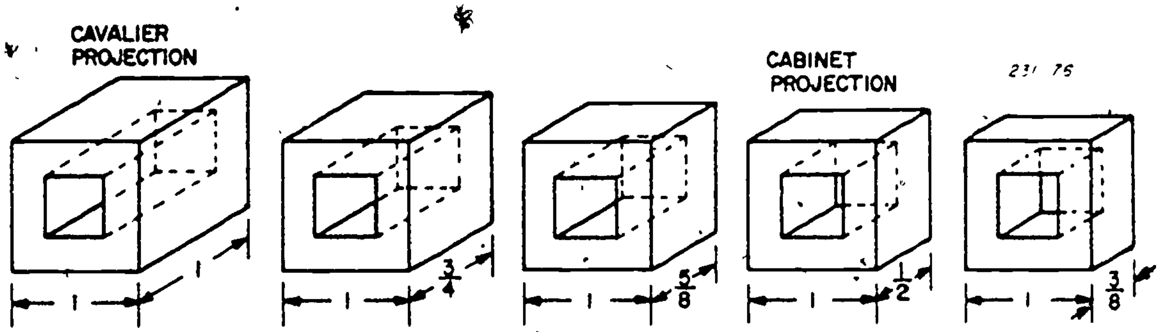


Figure 2-28. Changes in appearance by foreshortening.

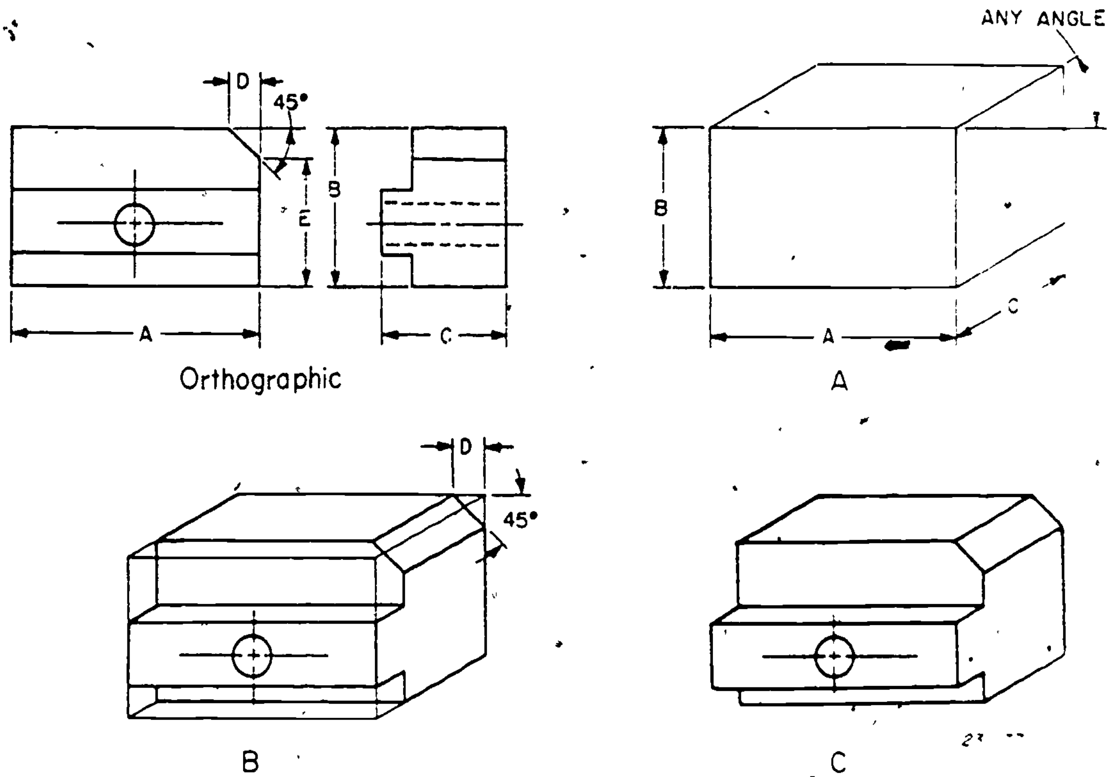


Figure 2-29. Box construction method.

45° -- 60° or any number of degrees, as noted in the figure. Note that dimensions A, B, and C are the same as in the orthographic drawing. Since dimension C is true length, the drawing is a cavalier. (measure the dimensions with your dividers.) Observe that the box is constructed by using parallel lines, as in isometric.

b. As shown in part B, lay out the various shapes in detail in accordance with the orthographic drawing. Notice that the 45° sloping surface may be drawn by using dimensions D and E.

c. Make all outlines heavy as shown in part C. Then erase all construction lines.

The box method of constructing a cabinet drawing is the same as that of the cavalier, except that the receding lines are foreshortened by measurement to one half of true length.

Skeleton construction method. If the curved outlines of an object lie in planes that are parallel to the image plane, it is not difficult to make an oblique drawing on a center-line skeleton.

Often objects adaptable to oblique representation consist of cylindrical shapes built upon axes or center lines. In such cases, the oblique drawing is usually constructed upon the projected center line. This method is known as skeleton construction.

Figure 2-30 illustrates the procedure in making an oblique drawing of an object, which is composed of cylindrical shapes, from the orthographic views. Now let's discuss this construction in a logical sequence.

a. First, construct the *center-line skeleton* as shown in part A of the illustration using the following steps.

(1) Draw the receding axis abc of sufficient length at the desired angle with the horizontal. (In this case, 30° is used.)

(2) At points a, b, and c on this receding axis, draw the horizontal and vertical center lines to establish centers of the corresponding circular surfaces. Observe that distance ab in part A equals distance ab in the orthographic side view and, likewise, distance bc equals the depth bc in the side view.

(3) Draw perpendiculars downward from points b and c.

(4) Using the distance between the centers of the circular surfaces in the front orthographic view—or the corresponding distances in the side view—locate points d and e on the perpendiculars.

(5) Through points d and e, draw receding axis de, which is parallel to receding axis abc. Notice that distances bc and de on the

receding axes are equal and are the same as depth bc in the orthographic side view. Thus, we've established the centers of the circular surfaces.

b. Part B of figure 2-30 shows the method of constructing on the circular surfaces and the corresponding outlines. The steps are as follows:

(1) Using points a and b as centers, draw the two circles to correspond in diameter with the one representing the shaft in the orthographic. The distance ab between the two centers is the length of the cylindrical shaft of the object.

(2) Using points b and c as centers, draw the arcs which represent the rounded top of the object.

(3) With point d as center, draw the circle with the same diameter as the one in the orthographic. As shown by the side view, this is a circular hole which extends through the object.

(4) Using d and e as centers and a radius the same as the orthographic, draw the two arcs which represent the rounded bottom part of the object.

(5) Draw tangent lines between both the top and bottom arcs and the arcs with centers a and b, thus completing the contour of the object.

(6) Heavy-in all final lines and erase construction lines, as shown in part C.

Circles in Oblique. It is not always possible to place an object so that all its curved surfaces are parallel with the image plane. In such cases, a four-center approximate ellipse may be used to represent circles which are not parallel with the image plane. However, this method can be used only when the sides of the inclosing parallelogram are equal. In a cabinet drawing or in any oblique drawing where the receding axis is foreshortened, the curve must be plotted by coordinate (offset) measurements. The principles used in drawing an ellipse by this method are shown in figure 2-31.

Since the ellipse shown on the receding surface in figure 2-31 represents a circle on the surface of the object, the receding surface is first drawn as an orthographic view. This view is then used to establish coordinate

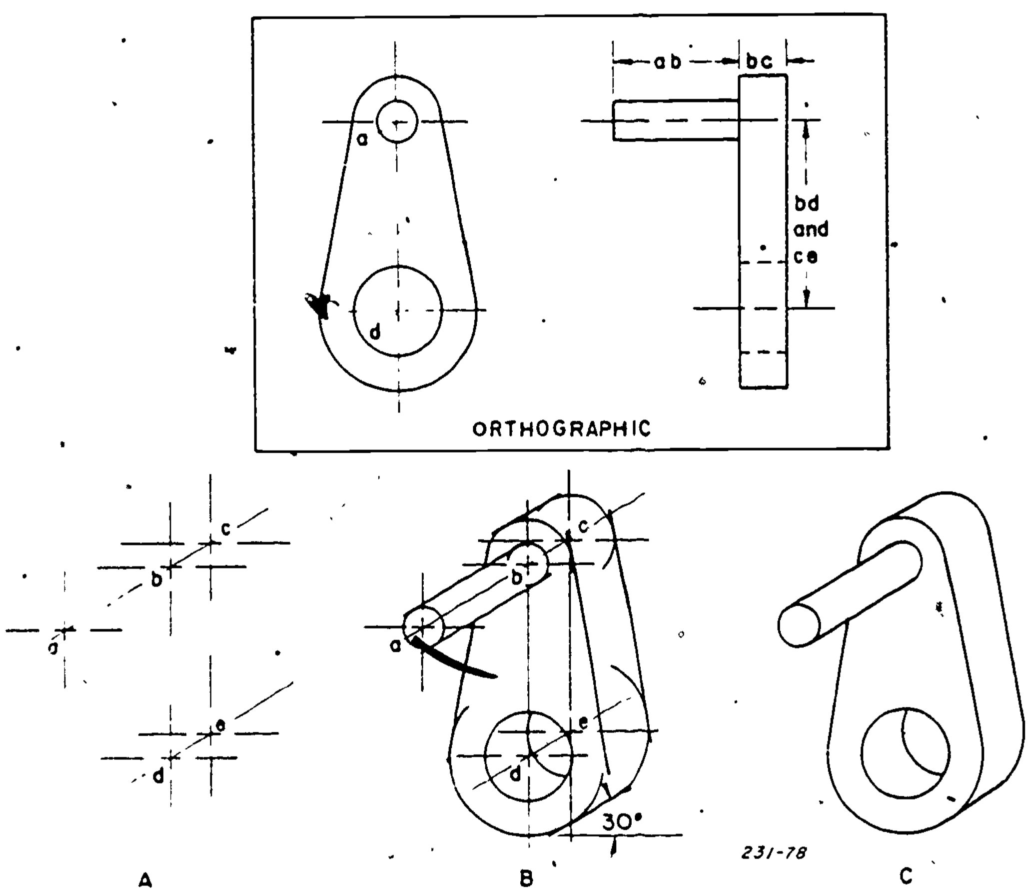


Figure 2-30. Skeleton construction.

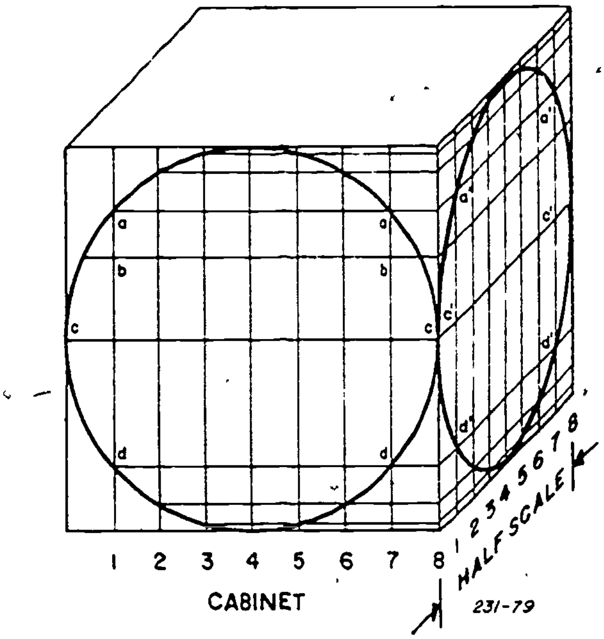


Figure 2-31. Foreshortening an ellipse.

points which are used to establish similar points on the receding surface. The ellipse is then drawn through these established points. The following steps are used to construct the ellipse.

- Draw an orthographic view of the receding surface on a separate piece of paper and position it on the front surface of the drawing as shown in the illustration.
- Divide the surface of the orthographic view and the receding surface of the drawing into the same number of equal vertical segments by drawing vertical coordinate lines as shown in the figure. As you know, the segments of the receding surface are one half the size of the orthographic segments.
- On the orthographic, draw horizontal coordinate lines through the points at which the vertical coordinate lines intersect the circle. Extend these lines to the right edge of the view.
- Draw receding lines from the right ends of the horizontal coordinate lines. The intersections of these receding lines and the vertical coordinate lines on the receding surface which correspond to the intersections of the vertical coordinate lines, horizontal coordinate lines, and the circle in the orthographic view establish the path of the ellipse.
- Use an irregular curve to draw the finished ellipse.
- Remove the orthographic drawing and erase all construction lines.

Angles of Oblique. To draw an angle of a specified number of degrees on the receding plane of an oblique drawing, you must first convert the angle into linear measurements. For example, if you are given the dimensions and a sketch of the pictorial shown in figure 2-32, you must construct a right triangle whose dimensions are the same as the given angle. You can then use the dimensions of this triangle to obtain the correct dimensions of the angle on the receding surface. The following steps are used to construct the 30° angle of the receding surface of the object shown in figure 2-32.

- Construct the right triangle with the dimensions XY and the 30° angle. The purpose of this triangle is to establish the length YZ.
- Draw a line representing the receding axis of the oblique drawing.

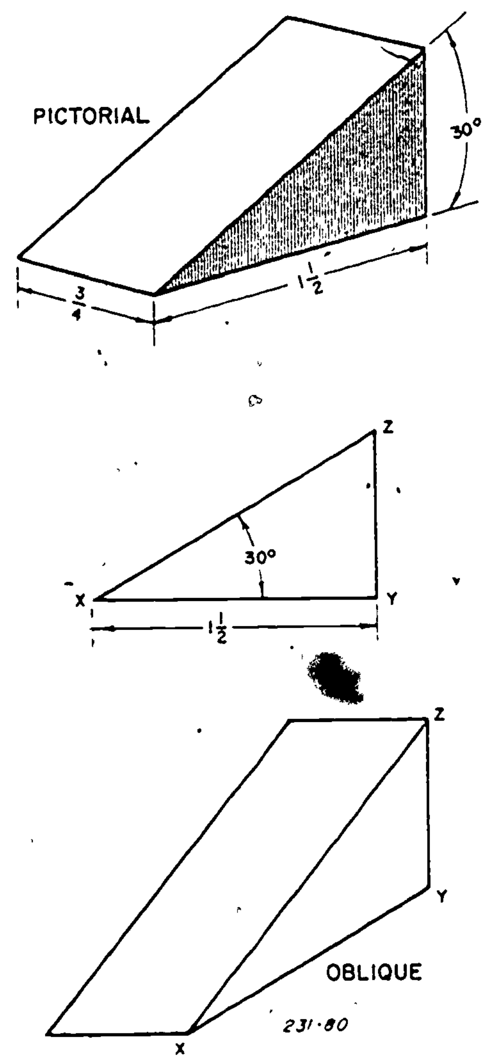


Figure 2-32. Angles in oblique projection.

• Mark off the given dimension XY on this receding line.

• Draw a vertical line from point Y on the receding line.

• From the triangle drawing, obtain the dimension ZY and mark this distance off along the vertical line, starting at point Y.

• Draw a line between points Z on the vertical line and point X on the receding line. This completes the required angle.

• Complete the oblique by drawing the two horizontal lines from points X and Z by marking off the depth dimension and by drawing the sloping line parallel to line XZ.

Exercises (226):

1. What determines whether a drawing is a cavalier or cabinet projection?

2. Why is an orthographic view of a circle drawn before the ellipse in a cabinet drawing?

3. To draw an angle of specific size on the receding plane, the angle must be converted into what measurement?

Sectional Views

SECTIONAL VIEWS are used to clarify the internal details of an object which can be represented only by hidden lines in regular orthographic (exterior) views. When the internal details are complicated, a perplexing mass of hidden (invisible) lines may be required to describe the invisible features on an exterior view. Whenever an illustration becomes so confused by hidden lines that it is difficult to read, it is customary to draw one or more sectional views.

A sectional view is one obtained by imagining the object cut by a cutting plane and a portion moved so that the internal details can be seen clearly. Thus, the invisible lines of a regular view become visible lines in a sectional view. A view may be partial sectional or full sectional, depending upon the particular requirement.

3-1. Principles of Construction

Since a sectional view is obtained by imagining the object to be cut by a plane passing through it in a selected position and direction, this plane is called the *cutting plane*. The purpose of the cutting plane is to cut off a portion of the object, thereby exposing the internal features in the remaining portion. The position and direction of the cutting plane are determined by you, the draftsman. You must visualize the object being cut by the plane placed in various positions, and then select the position which adequately exposes the desired internal details. The pictorial drawings in figure 3-1 show an object before and after being cut by a plane.

The orthographic top and front (exterior) views of the object are shown in part A of figure 3-1. Notice the hidden lines in the front view which are required to show the internal details. Part B shows the left portion of the object imagined to be removed by the cutting plane, thereby exposing the interior features in the right portion which lies behind the cutting plane. Observe that the hidden lines in the orthographic front view are shown as solid outlines in the sectional view. Notice how much clearer the internal features appear in the sectional view.

The arrow in the pictorial part of figure 3-1 shows the direction in which the remaining portion of the object is viewed. Section lines in the sectional view represent the surfaces cut by the cutting plane. In this figure, the sectional view is constructed by projecting from the top view in the same way as the front orthographic view.

227. Given the principles of sectioning, identify the cutting plane and its purpose.

Cutting Plane Lines. A cutting plane line represents where a section of the object is imagined to be removed by the cutting plane. The cutting plane is indicated only in the view showing the plane as a line; therefore, a cutting plane line represents an edge of the cutting plane. The top edge of the cutting plane is shown by the cutting plane line in the top view of part B, figure 3-1.

Figure 3-2 shows three types of cutting plane lines whose parts are drawn to conventional proportions. The dimensions shown on line AA are approximate, and may be increased or decreased in accordance with the size of the drawing. All cutting plane lines are weighted heavily. Arrowheads at the ends of any type of cutting plane lines are used to indicate the direction in which the imaginary cut surface is viewed. Since the cutting plane line represents the edge of the plane, it is apparent that the cut surface is viewed through the surface of the cutting plane.

Line AA represents the edge of a cutting plane which cuts the object into two sections, either lengthwise or crosswise. When an object is cut in this manner, a full sectional view is obtained.

Line BB represents the edges of two right-angle cutting planes which cut a section in half. The view obtained is a half-section. In a half-section view, one-quarter of the object is imagined to be removed.

Line CC represents the edges of a cutting plane which is "bent." In drawing an irregular object, it is often desirable to show several features which do not lie in a straight line. This is done by "offsetting" or bending the cutting plane. The view obtained is an *offset section*, and the "bends" may be at any angle.

A cutting plane line may be omitted when the position of the cutting plane is obvious. This practice is acceptable in the case of symmetrical objects, where the cutting plane is understood to pass through the axis of symmetry. In brief, the cutting plane line may be omitted unless it is needed for clarity. However, if an offset cutting plane is used, its position must always be shown by cutting plane lines.

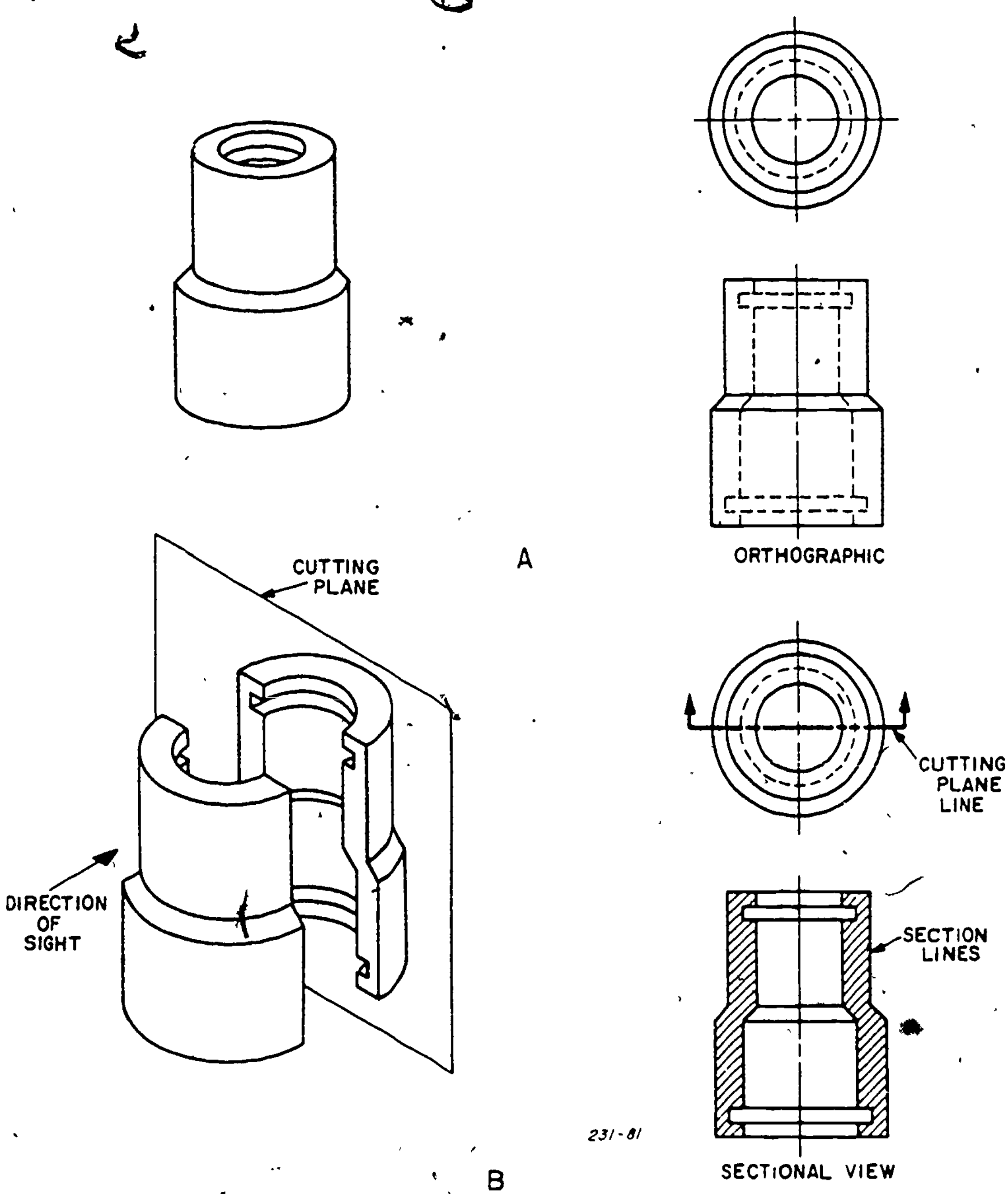


Figure 3-1. Principles of a sectional view

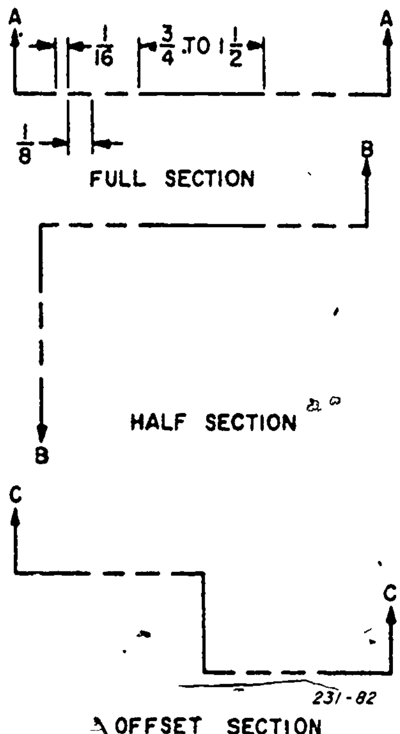


Figure 3-2. Cutting plane lines.

Exercises (227):

1. What is the purpose of a cutting plane?

2. What is indicated by arrows at the ends of cutting plane lines?

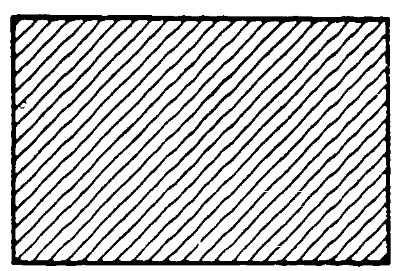
228. **Given the configurations for section lining, explain the reason for general-purpose section lining.**

General-Purpose Section Lining. There are different types of configurations for section lining used to identify various types of materials. In brief, a particular type of section lining is a symbol for a specific material. However, the symbol for cast iron (see fig. 3-3) is also the general-purpose section lining representation. It is used when a symbolic identification of the materials is not required. General-purpose section lining may be used to represent a section of any material, and the type of material can be identified by a note.

Drawing section lines. Section or crosshatch lines are drawn to indicate precisely the surface of the object cut by the cutting plane. An example of drawing general-purpose section lining is shown in figure 3-3. In lining the cut surface of a sectional view, there is no set rule governing the angle of the section lines or the spacing between them. Generally, the angle used is 45° to the horizontal, and the spacing may vary from one thirty-second of an inch on small views to one-eighth of an inch on large views. Usually, they are drawn about one-sixteenth of an inch apart. Although line spacing is usually done by eye, extreme care should be taken in spacing section lines uniformly, since slight variations can be readily noticed. Section lining can either enhance or mar the appearance of an otherwise good drawing.

Frequently the shape of the part requires that an angle other than 45° be used for the slope of the lines. If section lines drawn at 45° to the horizontal were parallel or perpendicular (or nearly so) to a prominent, visible outline, the angle must be changed to 30° - 60°, or any appropriate angle. Figure 3-4 shows a view in which a 30° angle is used more satisfactorily than a 45° angle. You must choose the angle which will give the best effect for a particular view.

Section lining in assembly drawings. In addition to showing the cut surfaces, sectional views are used to distinguish individual parts of an assembly. This is done by drawing section lines sloping in different directions, as shown in part A of figure 3-5. When necessary, "odd" angles may be used. Section lines in a small area are more closely spaced, as shown. Notice that the section lines in adjacent areas do not meet at the visible outlines separating the areas. You must be



GENERAL PURPOSE
SECTION LINING
ALSO
CAST IRON SYMBOL

Figure 3-3. Section lines.

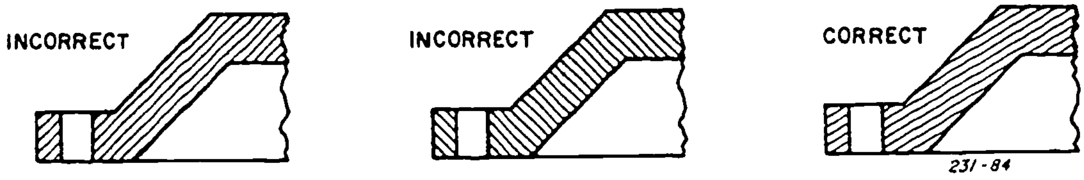


Figure 3-4. Angles of slope for section lines.

careful in drawing section lines in assembly views so that the section lines do not meet. If section lines meet, an optical illusion of bending outward or inward may result. You can see this by comparing the two views in part B of figure 3-5.

Views not requiring section lining. When the cutting plane passes through the longitudinal (lengthwise) axis of solid parts, such as rivets, bolts, and screws, it is common practice to show them uncut by the plane. This practice is shown by the rivets in part A of figure 3-6. Notice that the elimination of section lines in the rivets gives better contrast between adjoining parts. (The elimination of section lines is a part of conventional violations, which are covered a little later in Section 3, Conventional Methods.)

In sectioning comparatively thin parts, such as gaskets, sheet metal, shims, etc., the edges are shown by black solid lines. This practice is shown by the gasket in part A of figure 3-6. Assemblies of structural parts, such as angles, channels, and plates, are shown with the adjoining pieces separated to distinguish the individual parts. This practice is illustrated in part B of figure 3-6. Often the drawing is reduced to a small scale.

Combining Basic Principles. The cutting plane line in the orthographic front view (fig. 3-7) shows the position of the imaginary cutting plane, and the arrowheads indicate the direction from which the internal features of the object are viewed through the plane. The internal features exposed by the cutting plane are shown in the sectional side view.

Notice that the brass portion, which has a cylindrical hole centered around its longitudinal axis, is separated from the steel plates by shims and secured by two screws. Even though the shims and screws are cut by the plane, they are shown as being uncut by omission of section lines. As we stated previously, the edges of thin parts are shown by black solid lines; and rivets, screws, bolts, etc., are shown with more contrast when shown uncut by the plane. (The representation of screw threads is presented in the next volume.) The screwhead slots in the sectional view are another conventional violation. Since the sectional view is rotated 90° from the orthographic view, these slots normally do not show. However, it is good practice to use variations from true projection if the drawing is made easier to read.

Exercises (228):

1. At what angle should section lines be drawn?

2. Why are section lines in adjacent areas drawn at different angles?

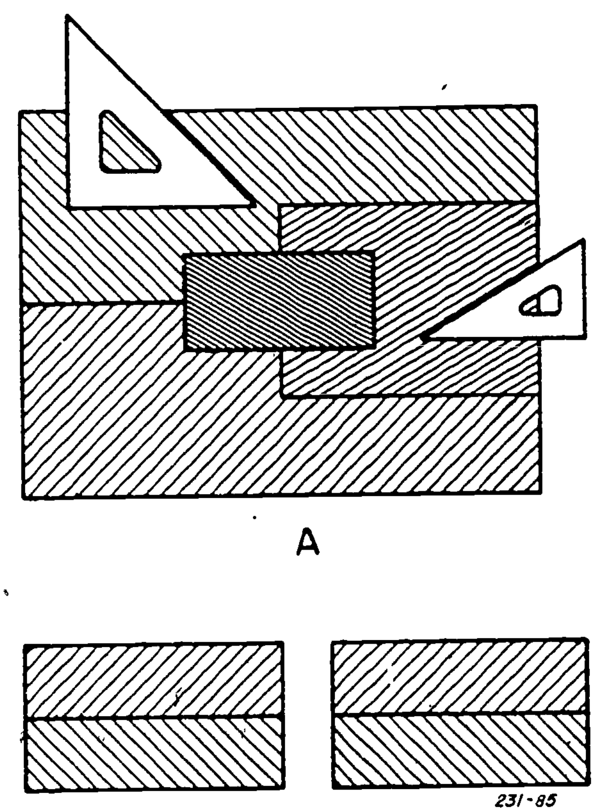


Figure 3-5. Slope of section lines in assembly drawing.

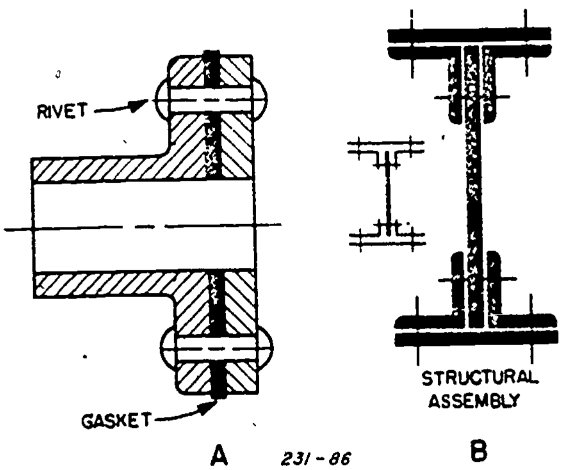


Figure 3-6. Method of showing solid parts and thin materials.

3. Why is it a common practice when a cutting plane passes through a rivet, bolt, or screw, to show them uncut?

3-2. Types of Sections and Methods of Sectioning

When a cutting plane cuts an object lengthwise, the sectional view is called a longitudinal view. When an object is cut crosswise, the sectional view is called a cross-section view. In general, sectional views are further designated according to the percent (amount) of a section shown and by the position in which a view is placed. For instance, the terms "full," "half," and "broken sections" indicate the percent; while "revolved," "removed," etc., indicate position or location. You, the draftsman, must determine which type of sectional view to use.

229. Identify the types and methods of sectioning.

Full Section. A cutting plane that passes entirely through an object cuts a full section, as shown in figure 3-1. A full-sectional view, showing the characteristic shape of an object, usually replaces an exterior front view. However, either the top or side may be converted into a sectional view if some internal features can be shown to better advantage. Generally, the cutting plane passes along a main axis, but it may be offset to reveal important features. As you can see by examining figure 3-1, a full-sectional view is actually an orthographic projection in which the cutting plane passes along a main axis. The imaginary cut face of the object is shown as it would appear to an observer looking directly at it from an infinite distance.

The full-sectional view is used for objects which have complex interiors. It shows the interior of the object from one side to the other; it does not show exterior details. All visible lines which lie behind the cutting plane are shown, and the surfaces cut by the plane are lined or crosshatched. In a full or any sectional view, it is customary to omit all hidden lines unless such lines are necessary to clarify the representation. Since this view

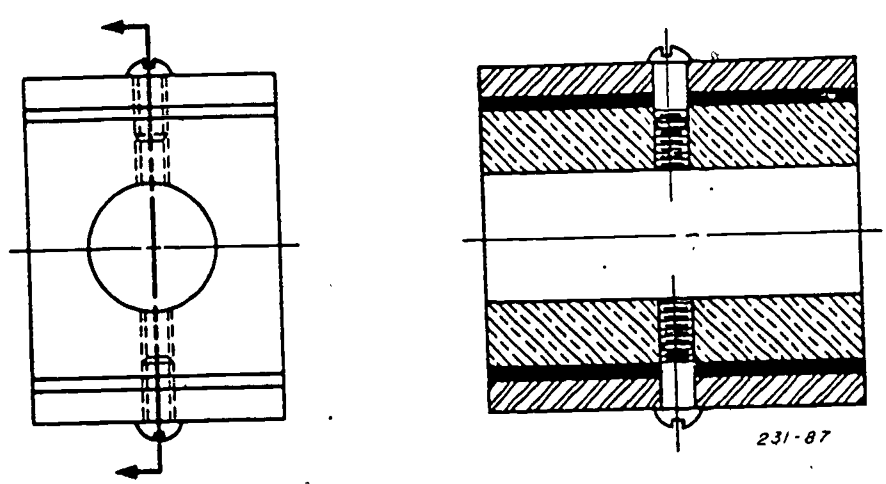


Figure 3-7. Section view with symbolic section lining.

doesn't show external features, an additional view is often necessary.

Half Section. A half-sectional view of a symmetrical object shows both internal and external features. This view is obtained by cutting the object with a right-angular cutting plane. As shown in figure 3-8, the plane passes halfway through the object; that is, the plane extends to the object's axis or center line, resulting in the removal of one-quarter of the object. Consequently, one-half the complete view appears sectional and the other half appears external.

The cutting plane lines in the top view of figure 3-8 show that the third quadrant is removed. Thus, the internal features of the second quadrant are shown in the sectional half of the complete view. Although a center line is shown separating the internal and external portions of the view, a solid line (outline) may be used. Hidden lines are not shown in the external portion, since it is common practice to omit them unless they are absolutely necessary for dimensioning purposes or for explaining the construction.

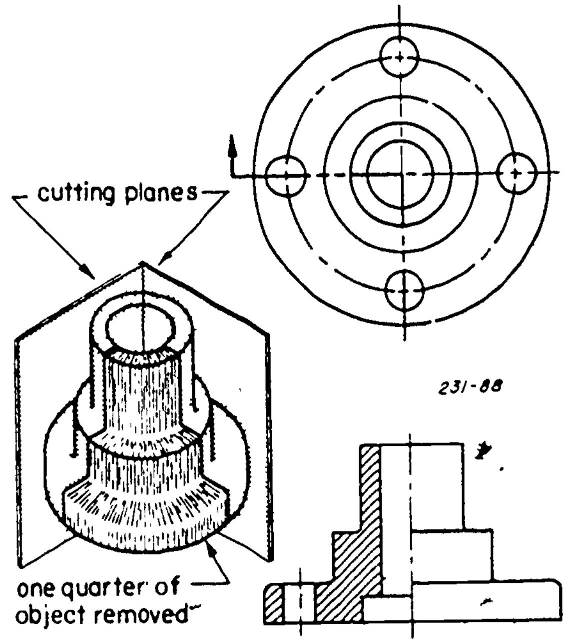


Figure 3-8. Half section.

Offset Section. An offset section is a full-sectional view in which the cutting plane is bent or "offset" (usually at 90° intervals), as shown in figure 3-9. This method is used in sectioning through irregular objects. The pictorial drawing in part A shows the offset cutting plane, and the orthographic top view shows the cutting plane lines. Part B shows the pictorial view obtained when the front portion of the object is imagined to be removed, and the full-sectional view which is projected. Careful examination of this illustration will show you that an offset cutting plane is necessary to obtain the sectional view shown.

Broken-Out Section. Sometimes, only a partial section of a view is sufficient to expose interior details. This kind of section (see fig. 3-10) is made as if a piece were broken from the object, leaving an irregular line at the junction of the sectioned and unsectioned parts. Notice in the figure that the internal features and types of material are shown by breaking out the area indicated by the irregular lines. When it is possible to use a partial section, external details are affected very little.

Resolved Sections. The cross section of a part may be shown in the longitudinal view by means of a revolved section. Such a section is made by assuming a cutting plane perpendicular to the axis or center line of the part, and then revolving the plane 90° around an axis which is perpendicular to the center line (see fig. 3-11). Part A of figure 3-11 shows the plane, which is perpendicular to the center line, cutting the part crosswise. Part B shows the plane revolved 90° around the vertical axis until the cross section is parallel with the center line. Notice, in part C, that the revolved section is superimposed on the external view and that one of the original visible outlines covered by the revolved section is removed. Further, since the revolved section is superimposed on the original view, any line of the object interfering with the revolved section may be broken, as shown in part D.

The true shape and size of a revolved section must be maintained after revolving the cutting plane, regardless of the direction of the lines. Compare the two drawings in part A of figure 3-12; you can see the error in shape of the revolved section in the incorrect drawing. Also, there is another error shown in the incorrect drawing. The visible outlines covered by the revolved section should be removed as shown in the correct drawing. In part B, notice that the two revolved sections are necessary to show the construction of the spoke and the groove when just the front view is used.

Removed Sections. A removed or detailed section is drawn similar to a revolved section, with these exceptions:

- Instead of being superimposed on the

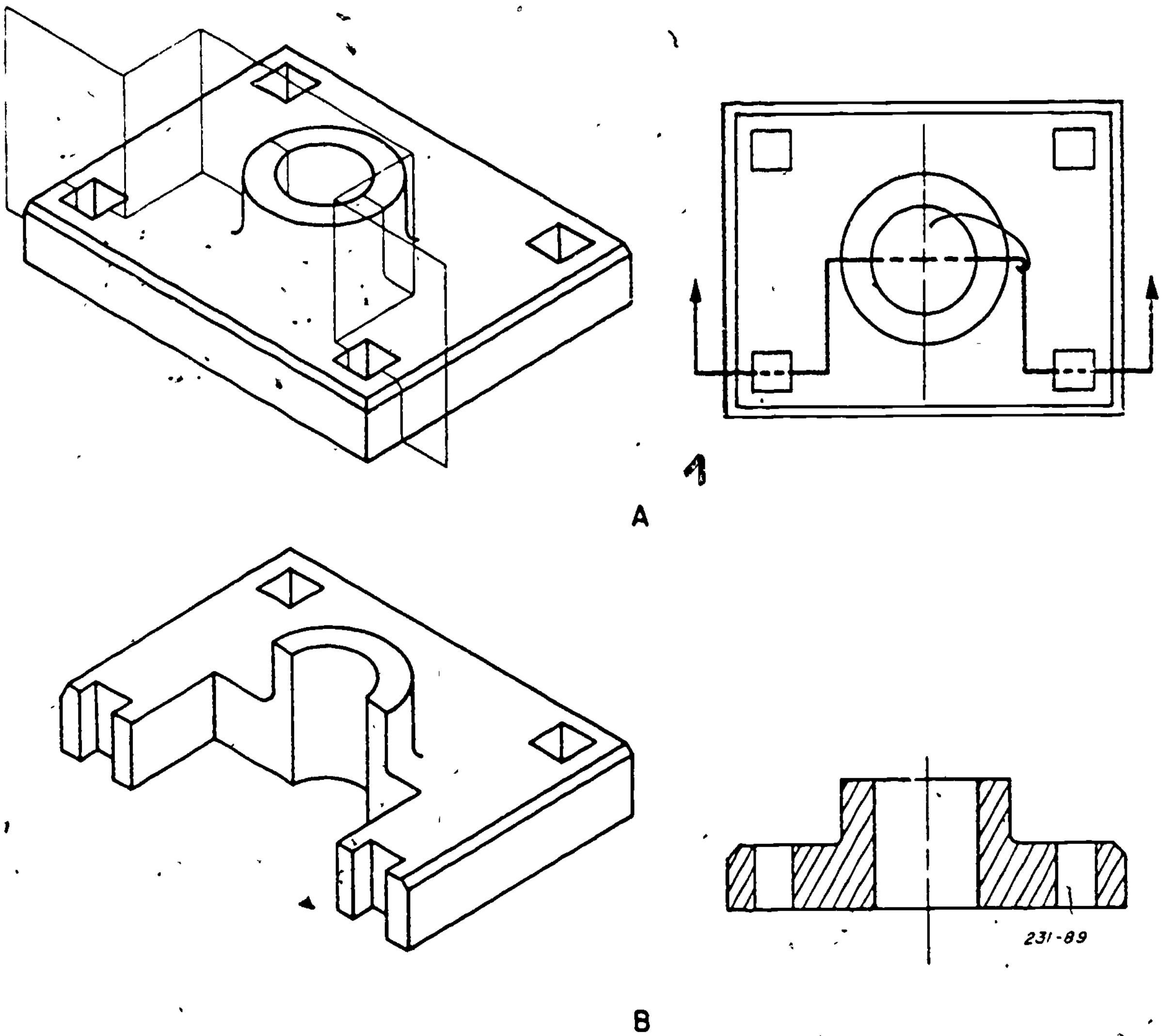


Figure 3-9. Offset section.

external view, the section is removed and may be shown adjacent to the external view, as shown in part A of figure 3-13.

- It may be entirely separated from the external view, as shown in part B.

Regardless of the location of a removed section, it should be identified with the respective cutting plane with letters.

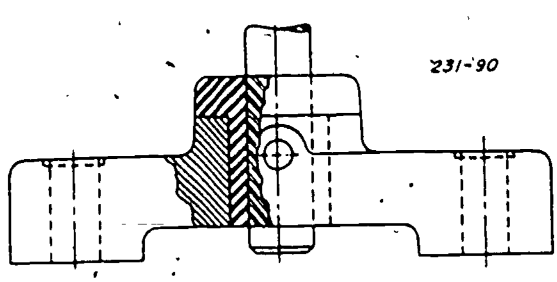


Figure 3-10. Broken-out or partial section.

A removed section may be drawn to an enlarged scale to show internal details more clearly, and it is easily dimensioned when sufficient space is allowed, as shown in part B.

Removed sections located adjacent to cutting planes. Note that adjacent sections B-B and C-C (part A, fig. 3-13) are positioned with their center lines aligned with the respective cutting plane lines BB and CC. As with revolved sections, the cutting plane arrowhead indicates the direction of sight to the imaginary exposed cross section, and the section lines identify the material. As you can see, a removed section is placed so that it does not line up in projection with any view, as the revolved section does.

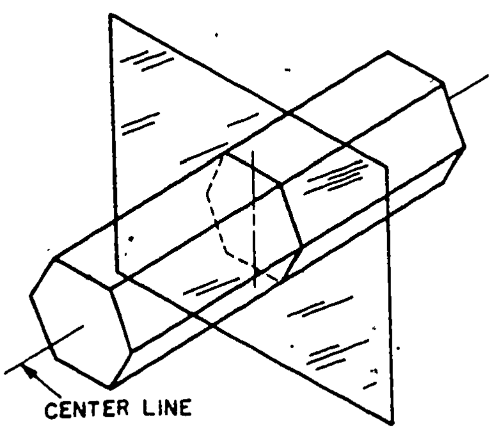
Removed section separated from external view. In part B of figure 3-13, section A-A is shown enlarged and located on a different sheet. When a section is placed on a different sheet, it must be cross-referenced in a manner like that shown in the illustration. (For explanatory purposes, part A of figure 3-13 is assumed to be sheet 2 and part B is sheet 4.) Whenever possible, removed sections should be on the same sheet with the regular view. That is, section A-A could be placed in some position on the sheet represented by part A. When a section, placed in any location, is enlarged, the scale is indicated as shown on the illustration.

Alternate method. Sometimes removed sections are placed on center lines extended from the section cuts. This method is shown in figure 3-14.

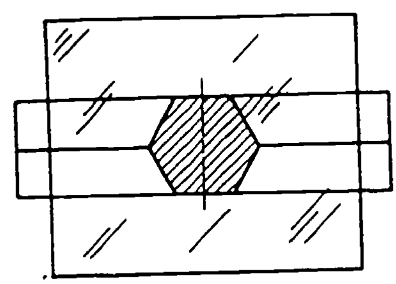
Phantom Section. A phantom section is made by imagining the object to be cut by a plane but not removing the part in front of the cutting plane. That is, the internal features which would be exposed by removing the part in front of the cutting plane are superimposed on the external view. Consequently, the internal construction of a part can be shown without disturbing its relationship with the exterior front part, which remains in place. In a phantom section, broken section lines are used to show the imaginary cut surfaces; likewise, the internal object outlines which would show as solid lines if the front part of the object were removed are shown by hidden lines.

Figure 3-15 is a phantom section of the object shown in figure 3-1. Compare these illustrations. Notice in the phantom section that the section lines are broken to show that the cut surface is superimposed on the external view and that the internal object lines are represented by hidden lines because the front part of the object is not removed.

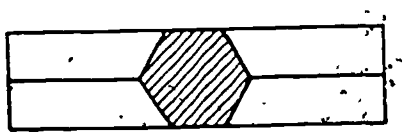
Outline sectioning. It is permissible to section-line large areas, as shown in figure 3-16. Notice that the section lines are drawn from the visible outlines of the cut portion of the object and are extended only a short distance over the cut surface. This practice eliminates an overly shaded appearance.



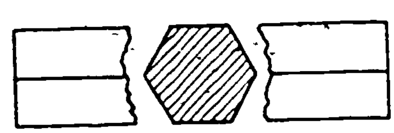
A



B



C



D

Figure 3-11. Revolved section.

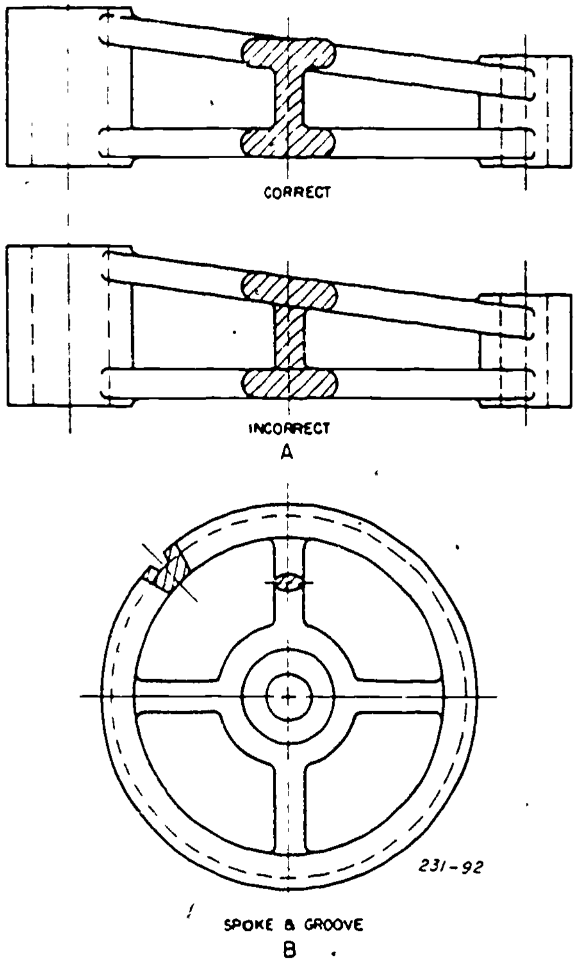


Figure 3-12. Drawing techniques and typical use of revolved sections.

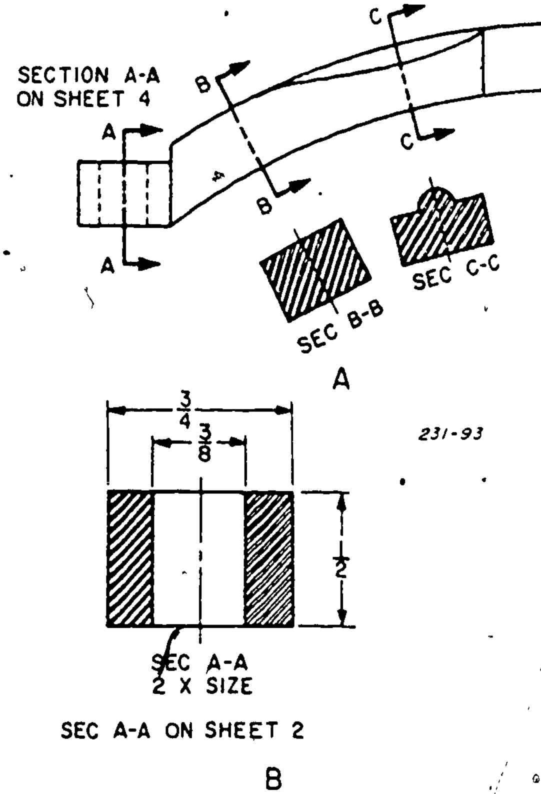


Figure 3-13. Removed sections.

Exercises (229):

1. A full-sectional view may replace an ________ front view.

2. When are hidden lines omitted in a full-sectional view?

3. How much of the object is imagined to be removed for a half-sectional view?

4. What is an offset section?

5. Why and when is a broken-out section used?

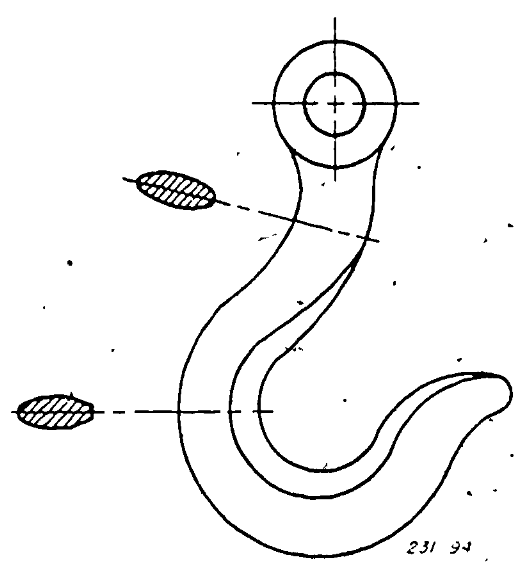


Figure 3-14. Removed sections on center lines.

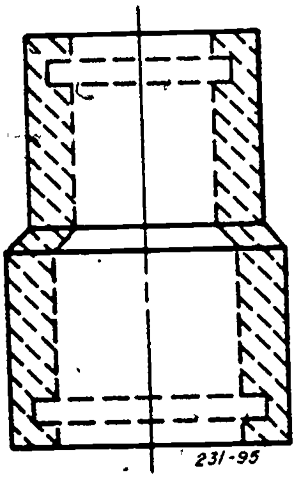


Figure 3-15. Phantom section.

6. When a removed section is enlarged, what information must be shown on the illustration?

7. In which types of sectional view are both internal and external features of the object shown?

3-3. Conventional Methods

Occasionally, some of the strict rules of projection are violated in sectioned representation. In drafting, any approved variation from true projection is known as *conventional violation.* These variations, sometimes called *conventional methods* or *practices,* simplify drafting and make drawings more understandable without sacrificing accuracy. Several conventional violations or variations from true projection practices are covered in this section.

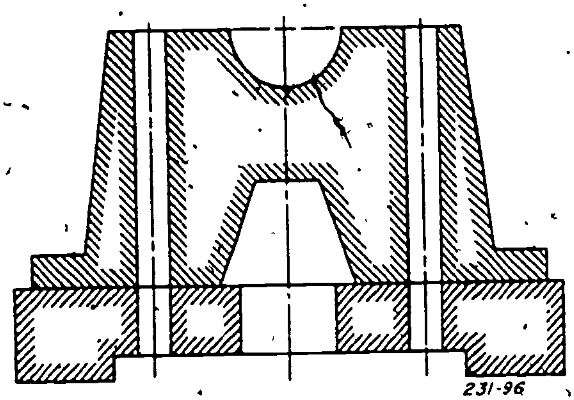


Figure 3-16. Outline sectioning.

230. Given the procedures for conventional methods, explain conventional violations.

Aligned Section. If an unbalanced sectional view is the result of a true projection drawing, a so-called *aligned section* is used. Symmetry is obtained by showing unsymmetrical features as if they were aligned into one plane. This is done by passing an imaginary offset cutting plane through the object and then revolving an unsymmetrical portion until it is symmetrical. Figure 3-17 shows the principle of revolution, although it does not show a sectional view. Part A shows the true front projection of the top view, and part B shows the conventional method. Notice that the angled portion of the object appears foreshortened in the true projection. However, when the sloping portion is imagined to be revolved until its longitudinal axis coincides with the horizontal axis, as shown by the arrow, it projects true length as in part B.

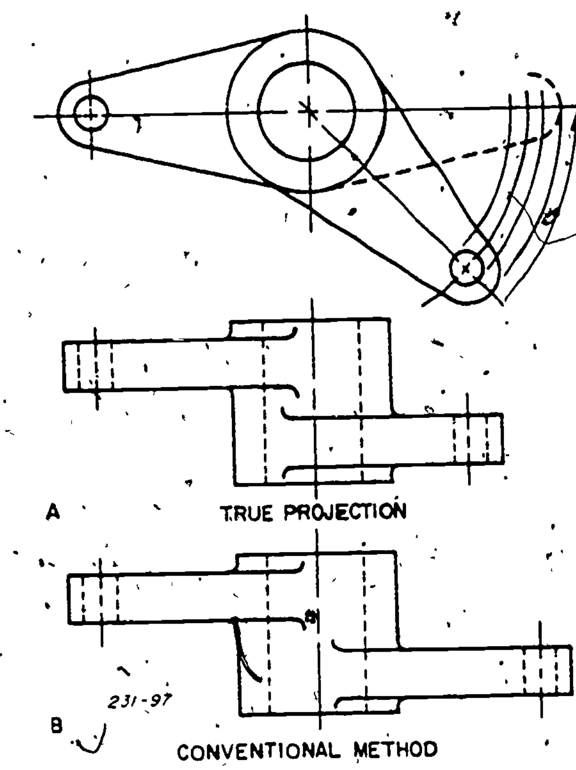


Figure 3-17. Revolved view.

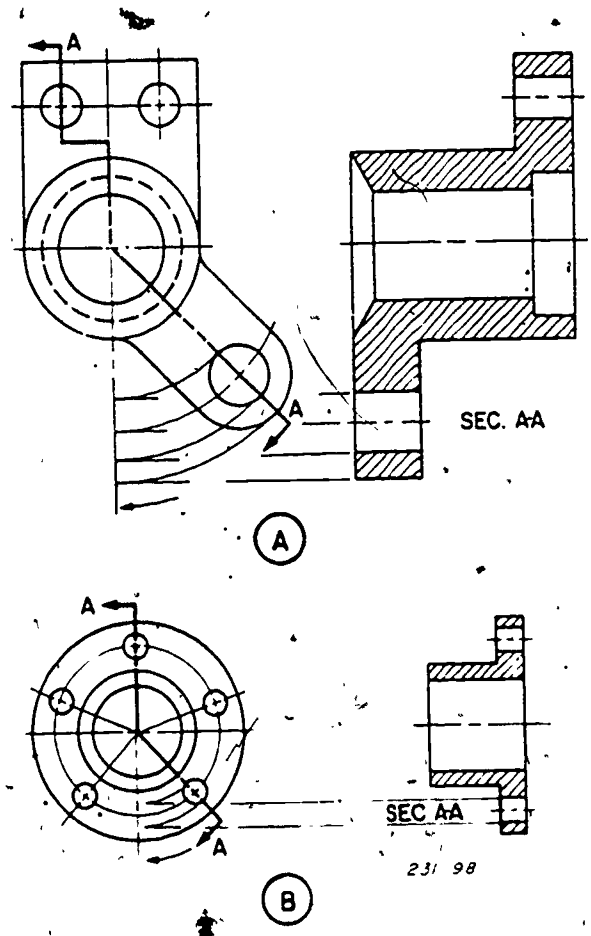


Figure 3-18. Aligned sections.

The application of revolution to sectional views is shown in figure 3-18. In part A, the offset cutting plane line, AA, is bent in order to pass through the angled features of the object. The angled part of the cutting plane and feature are then imagined to be revolved until the angled part of the cutting plane is aligned with the other part of the cutting plane as shown. Or, you may assume that the plane is in the aligned position, and then imagine the angled feature to be revolved into the plane. In either case, the revolution permits the portions of the object behind the cutting plane to be projected symmetrically and of true size in the sectional side view A-A.

When there are an odd number of holes in a circular object, as in part B of figure 3-18, they should be aligned in the sectional view in order to show their exact location with reference to the circumference and center of the object. Notice, as before, that the angled part of the offset cutting plane line, AA, and the cut portion of the hole are imagined to be revolved until the two parts of the cutting plane are aligned. Thus, the true radial distance of the holes relative to the circumference and center are shown in the sectional side view, A-A. You can see that, if the angled part of the cutting plane were not revolved, only the top hole would project true radial distance from the center and circumference in the sectional view.

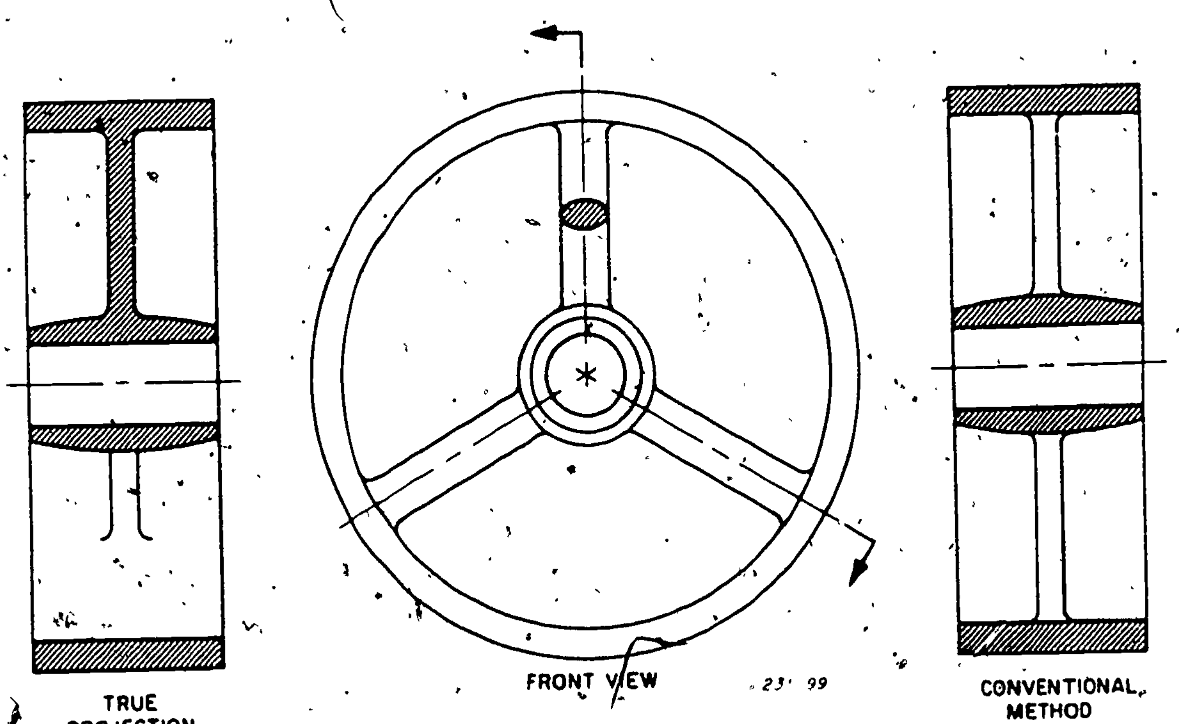


Figure 3-19 Conventional presentation of spokes.

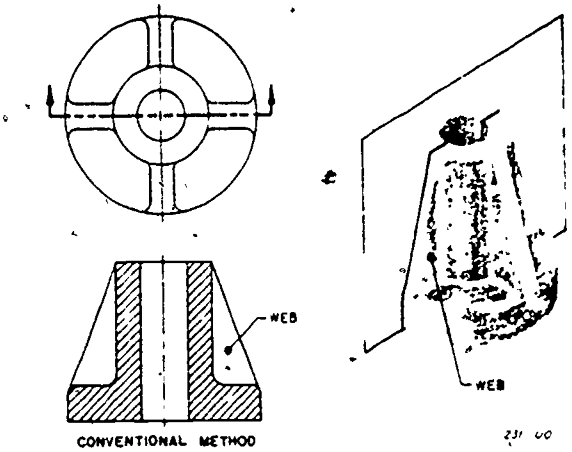


Figure 3-20. Conventional presentation of webs or ribs.

Spokes, webs, or ribs. Several conventional violations or methods are shown by the wheel in figure 3-19. The spoke is shown revolved in the front view so that it projects true length in the conventional method. If the spoke were not revolved, it would project foreshortened as shown in the true projection. Now, notice that the spokes in the conventional method are not section-lined even though the cutting plane passes through them, as is the case with small solid parts such as rivets, screws, and shafts. This is done to distinguish the spoke more clearly from other parts of the wheel.

The shape and internal features of the spoke are shown by the revolved section in the front view (fig. 3-19). This section is sectioned-lined because the cutting plane (not shown) passes crosswise through a rib, web, or any thin member, the member should be sectioned lined.

When an object has a web (or rib) cut by a cutting plane, the web is not section-lined as it would be in a true sectional view. Figure 3-20 shows this type of presentation. Note that the webs are not section-lined in the conventional method of representation, even though the plane cuts the webs longitudinally. In a true projection, the webs would be section-lined, and the object would appear solid in the sectional view. Consequently, by using the conventional method (conventional violation), the sectional view is not misleading.

Conventional Breaks. When drawing a uniform object whose length is long in comparison with its diameter, the drawing may be made to a larger scale by breaking out a portion so that the ends can be placed closer together (length shortened). This principle is shown in figure 3-21, which illustrates the use of a conventional break for drawing a 2-foot rod whose diameter is 1 inch. Notice that, when the rod is shown one-eighth size, its length measures 3 inches in the drawing and its diameter one-eighth inch. However, by breaking out a portion and drawing the rod one-half size, the diameter is shown one-half inch. Accordingly, the 1-inch threads of the rod are shown one-half inch in the broken-out drawing. You can see that, by use of a conventional break, the small features of long, uniform objects (such as bars, rods, and tubes) can be clearly shown.

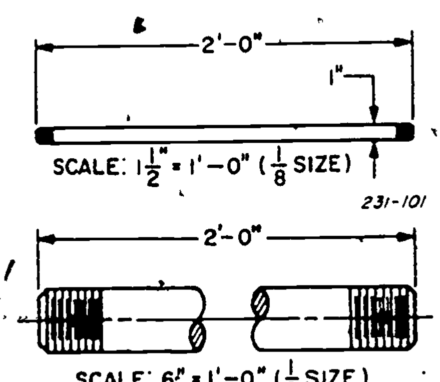


Figure 3-21. Conventional breaks.

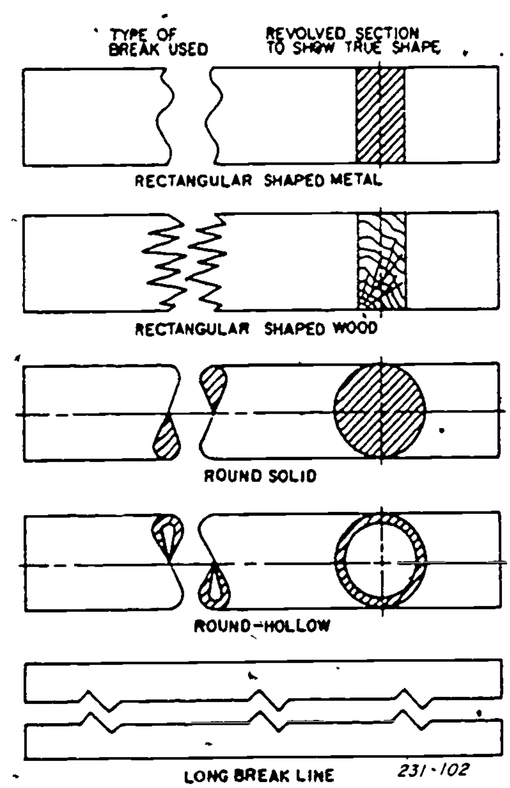


Figure 3-22. Application of a conventional break.

A conventional break indicates that the length of a part is not drawn to scale. However, the actual length is indicated by dimensioning, as shown in figure 3-21.

The conventional breaks shown in figure 3-22 are designed to give a fairly accurate representation of the cross-sectional features of the part, in addition to the usage just explained. Breaks may be drawn freehand or with drawing tools, depending upon the size. However, breaks for wood sections should always be drawn freehand. Breaks should be located at a point on the object where the cross-sectional shape is constant, since it would be confusing to break the length at a point where a change in shape occurs.

Notice that a revolved section may be used in conjunction with a break to reveal the internal features accurately, but a revolved section does not represent a break in the object. It is common practice to draw a revolved section when the scale of the drawing is increased by use of a break.

Exercises (230):

1. Explain a conventional violation.

2. In figure 3-21 if the conventional method were not used, the true length of the sloping portion of the object would be shown only in the ________.

3. What is the purpose of revolving the cutting plane in part B of figure 3-18?

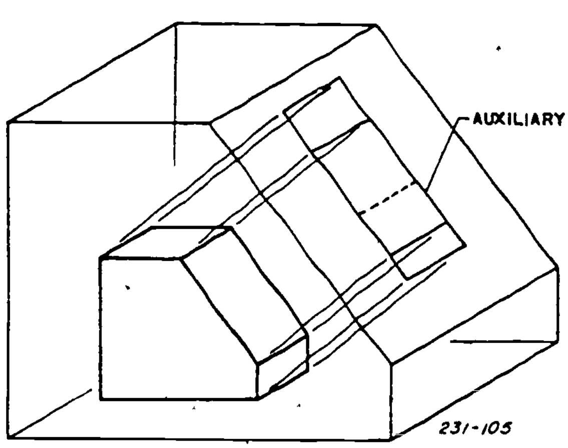


Figure 3-23. Auxiliary plane position.

4. What is indicated by a conventional break?

5. What determines where a drawing may be broken?

3-4. Auxiliary Views

On many objects, there are surfaces and lines which do not show in true size and shape because they are not parallel to any one of the regular projection planes. To build an object, the builder must know the true lengths of all lines, the true sizes and shapes of all planes, and, in some cases, the true size of the angle between intersecting planes. When these conditions are not shown in regular top, front, and side views, additional planes of projection must be set up to show views giving the needed information. These additional planes are called auxiliary planes, and the views are called auxiliary views. In this section, we'll discuss the glass-box method for explanatory purposes and then cover the method more generally used—sometimes called the customary method of projection.

231. Given the procedure, identify the methods of projection and classification of auxiliary views.

Glass-Box Method. Figure 3-23 shows an object with an inclined face inclosed in a glass box. Notice that the auxiliary plane is parallel with the inclined face. Therefore, the projection of the inclined face on this plane is true size and shape. Using the same method of opening the glass box as shown in figure 3-24, the various planes are hinged around the front plane and are rotated until they coincide (lie in the same plane) with the front plane. The result of this rotation is shown in figure 3-24.

Although the glass-box method is rather cumbersome and seldom used, it shows the principles of auxiliary views. Now we'll discuss the customary method of projection.

Customary Projection Method. In this method, you assume a plane which either coincides with or is parallel with a selected surface of the object. In either case, that portion of the object projected upon this plane is shown on the drawing. This statement applies to all types of orthographic projection, including auxiliary projection.

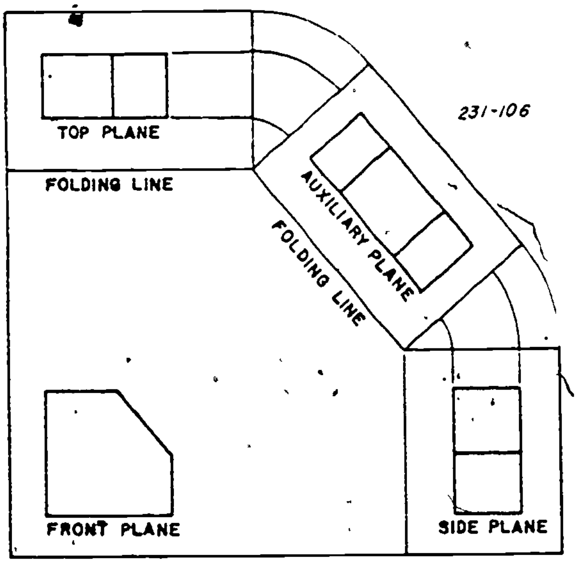


Figure 3-24. Complete auxiliary.

Figure 3-25 shows the projected top view and front view of the object shown in the pictorial drawing. It is apparent that an auxiliary view is necessary to show the slanting surface in true size and shape. This auxiliary view is drawn as if we were viewing the surface in a direction perpendicular to the inclined face, as shown by the arrow.

To obtain the true size and shape view, imagine a plane placed so that it is parallel to the inclined face. Notice that the reference line represents the edge view of the reference (auxiliary) plane. Since the reference line is parallel with the edge of the inclined surface, the reference plane is parallel with the inclined surface. Consequently, the inclined surface projected on this plane is true size and shape.

Figure 3-26 shows the reference plane rotated to coincide with the plane of the front elevation. Notice that the plane is rotated about the reference line—the reference line (edge of plane) remains in the same position as it is in figure 3-25.

On the imaginary auxiliary plane, reference lines can be placed at any logical distance from the inclined surface of the object. If the object is nonsymmetrical, such as the one shown thus far, the reference line represents the edge of the auxiliary plane. This line is called a nonsymmetrical reference line. However, if the face of the object is such that the auxiliary view will be symmetrical, the reference line is the line of symmetry. In this case, the line is called a symmetrical reference line, and it lies between and is parallel with edges of the auxiliary plane.

Classification of Auxiliary Views. Auxiliary views fall into three general categories: a single or primary auxiliary view, a partial auxiliary view, and a complete auxiliary view. Let's discuss them in this order.

Single or primary auxiliary views. These views may be subdivided into front auxiliary view, plan or top auxiliary view, and side or end auxiliary view. A single or primary auxiliary view is obtained by projecting from a principal view of the object, in which the inclined surface of the view appears as a line or edge. Figure 3-26 shows the auxiliary view projected from the front view. Since the projection is from the front view, it is a front auxiliary view. The principles of projecting auxiliary views from the plan or top view and

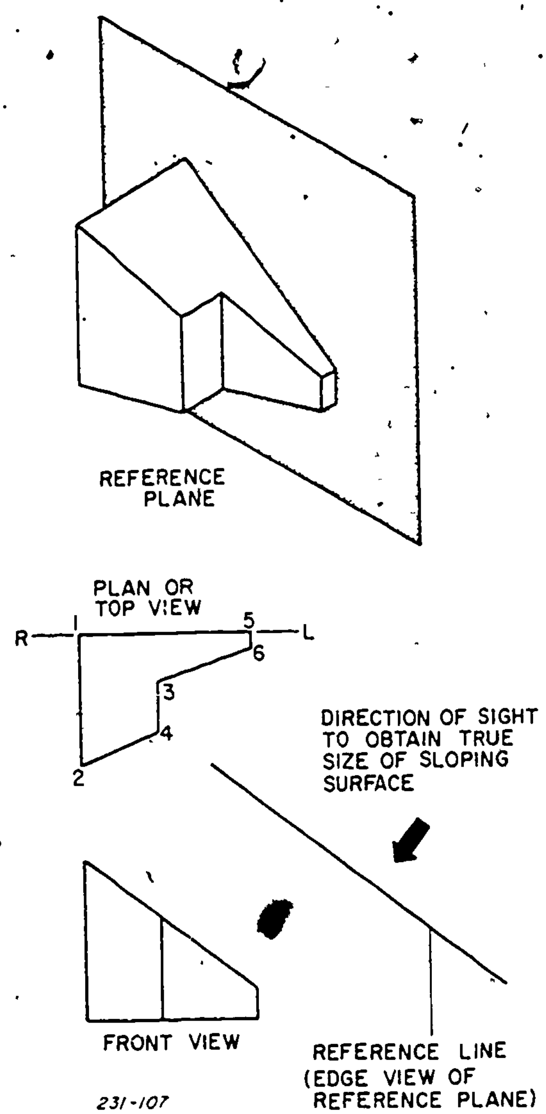


Figure 3-25. Object with inclined face in glass box.

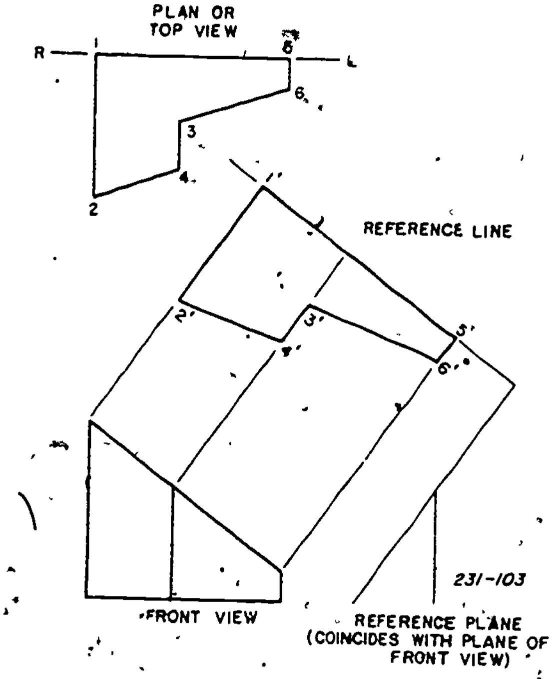


Figure 3-26. Open glass box showing auxiliary plane position.

the side or end view are the same as from the front view.

Partial auxiliary views. Since figure 3-26 shows only the inclined face of the object, it represents a partial auxiliary view. Since partial auxiliary views are the most commonly used, in the next section we'll present the principles of drawing them.

Complete auxiliary views. Occasionally, it may be necessary to indicate how the entire object appears when the inclined face is shown in true size and shape. A complete auxiliary view is shown in figure 3-27. Notice that sloping edge ab projects true length as shown by a'b', but edge bc is foreshortened as shown by b'c'. This is because the plane in which bc lies is not parallel with the auxiliary plane. Compare other dimensions in the same manner.

Now let's cover the basic methods of drawing nonsymmetrical and symmetrical partial views.

Partial Auxiliary View Drawing of Nonsymmetrical Object. In making a partial auxiliary view of a nonsymmetrical object, the first step is to draw a reference line that is parallel to the line which is the edge of the inclined surface (see fig. 3-25). Since this reference line is the edge of the auxiliary plane, this plane is imagined as being parallel with the inclined surface. Hence, any line which lies on the auxiliary plane will also be parallel with the inclined surface.

Next, draw light projection lines at right angles from all points on the inclined surface (see fig. 3-26) to the reference line. Then lay off along these projection lines the perpendicular distances from the near edge of the surface as shown in the plan view. In this case, there are three lines, lines 1-2, 3-4, and 5-6, in the plan view, which show as 1'-2', 3'-4', and 5'-6' in the auxiliary view. Notice that lines 1-2, 3-4, and 5-6 are equal in length to lines 1'-2', 3'-4', and 5'-6', respectively. As you can see, the length of the reference line is the same as the inclined surface of the front view. Furthermore, notice that lines 2'-4' and 3'-6' are not the same length as the corresponding lines in either the plan view or the front view, because now they are shown in true length.

Remember that the auxiliary plane is imagined to be hinged to the plane to which it is perpendicular and is revolved into the plane of the paper, as shown in figure 3-24.

Drawing a Partial Symmetrical Auxiliary View. Often it may be advantageous to position the reference plane through the center of the object. If the object is symmetrical, the construction is not difficult if the reference line is used as a center-line axis. Figure 3-28 shows a symmetrical curve

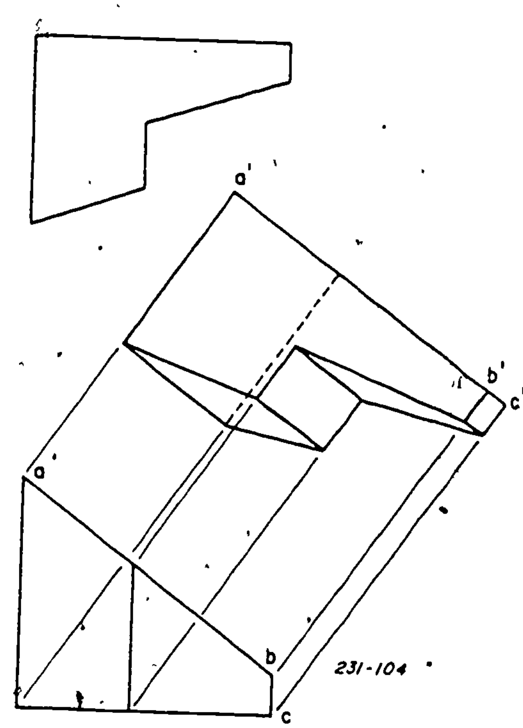


Figure 3-27. Object requiring auxiliary view.

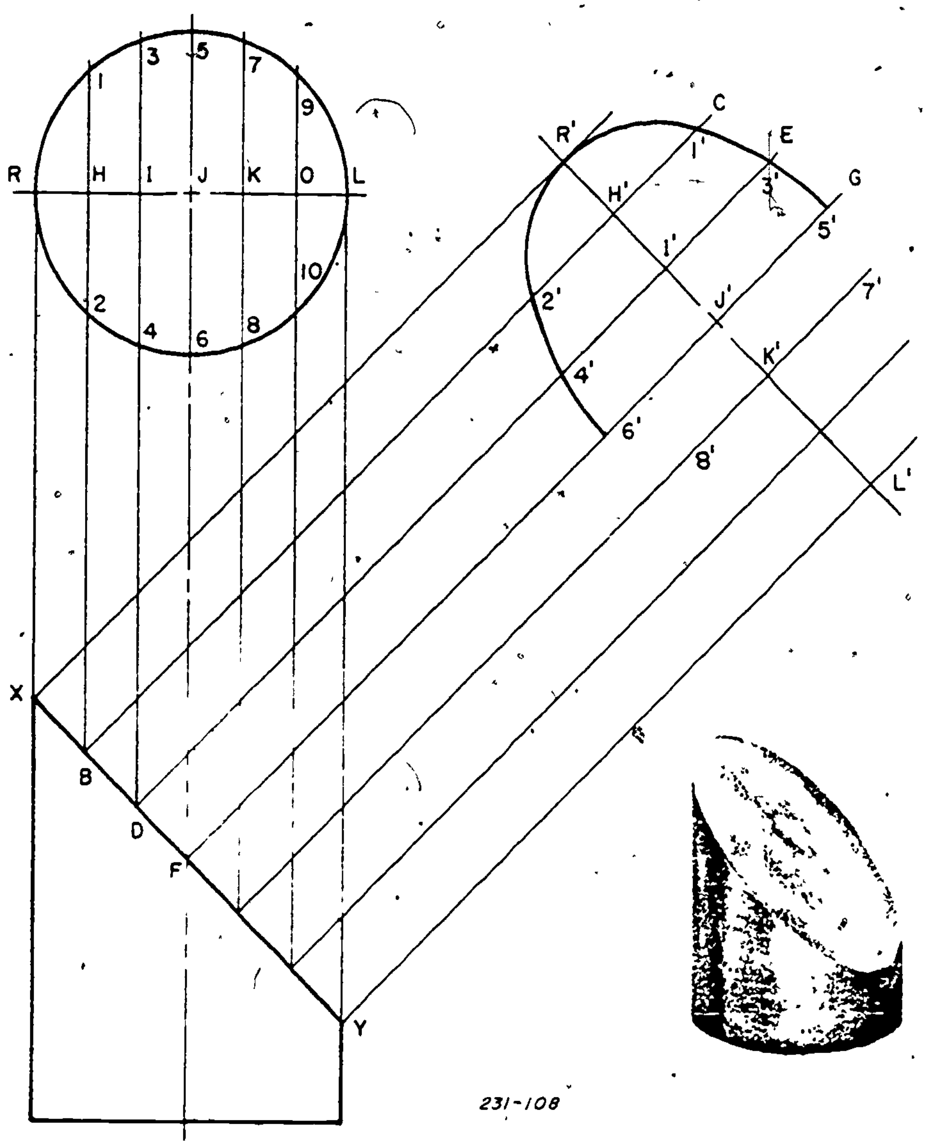


Figure 3-28. Symmetrical auxiliary view

plotted on a reference line which is a center-line axis. The partial auxiliary view is constructed by locating a series of spaced points along the curve by projecting lines determined by points established on the top view. Notice that the top or plan view shows the diameter of the circular cylinder, and the front view shows the slope and length of the inclined portion of the cylinder.

In constructing the auxiliary view of the inclined surface, draw reference (center) line R'L' parallel to the inclined surface and at any convenient distance from the surface; and draw reference line RL in the top view through the center of the circle, as shown in figure 3-28. Next, draw some vertical lines which are perpendicular to the reference or center-line RL (top view) to intersect the inclined face, and extend them upward to intersect the upper portion of the circle circumference. For example, line 1-2 in the top view intersects inclined edge XY at point B. The other points on line XY are established in the same manner. Then from point B, draw line BC parallel with lines XR' and YL'. (Lines XR' and YL' are perpendicular to the inclined edge XY.) Continue this procedure by drawing the parallel lines from the other points located on the inclined edge, as shown in figure 3-28.

Now, notice that points 1 and 2 in the top view are equidistant from the center line; consequently, the length H1 is equal to the length H2. Since this is also true of points 3 and 4, 5 and 6, etc., we can locate points on the curve in the auxiliary view. On line BC, mark off H'1' equal to H1 and H'2' equal to H2, so that points 1' and 2' are equidistant from reference line R'L'. These two points 1' and 2' are points on the ellipse of the auxiliary view. Repeat this operation until sufficient points are established for drawing the ellipse through them, using an irregular curve.

You can see that if more points are located on the inclined line, more points can be established on the ellipse and, consequently, a smoother curve may be drawn.

Exercises (231):

1. When is an auxiliary view required?

2. Is an auxiliary plane of a glass box rotated in the same manner as the other planes?

3. If an auxiliary view is symmetrical, the reference line is on the _______ of ______.

Dimensioning

IN ADDITION to the complete shape description of an object, a drawing must give the complete size and location description; that is, it must be dimensioned. A properly dimensioned drawing must show extension lines and dimension lines terminated by arrowheads, easily read numerals indicating size, finish marks, and notes with or without leaders. From a drawing with these dimension standards, a machinist can make parts that fit properly when assembled. Dimensions are given as linear distances, angles, or notes. Learning to dimension consists of three major factors:

- You must learn the techniques of dimensioning, and know such things as the character of the lines used, the spacing of dimensions, and the making of arrowheads.
- You must learn the rules of dimension placement on a drawing to assure logical and practical arrangement with maximum legibility.
- You also must learn how to choose. These choices are based on the function of the part and the manufacturing process.

4-1. Dimension Elements

The two basic methods used to give a distance on a drawing are a dimension and a note. A dimension is used to give a distance between two points, lines, planes, or combinations of points, lines, or planes.

232. Given the basic elements of dimensioning, list and explain the elements used.

Typical dimensions are shown in foldout 2. Refer to this illustration as you read the following description of the dimension elements.

Notes. This method of distance description (see the local note, item 1, at the top of foldout 2, and the general note, item 2, at the left center of the foldout) provides a means of giving explanatory information along with a size dimension. The leader and arrowhead of a local note refer to the word statement of the note to the proper feature of the drawing. Notes applying to the object as a whole (general note) are given without leaders. These general notes are placed in some convenient place on the drawing.

Lines Used in Dimensioning. Extension lines, dimension lines, and leaders are thin solid lines placed on the drawing for dimensioning purposes. They are made the same thickness as center lines so that they contrast with the heavier outlines of the object. Refer to foldout 2 as you read the following characteristics of each line.

Extension line. An extension line (item 3) extends from the view to the dimension outside the view. Extension lines start about one-sixteenth of an inch from the outline of the object and extend about one-eighth of an inch beyond the last dimension line. As shown in the upper-left portion of foldout 2, outlines and extended center lines may be used as extension lines.

Dimension line. A dimension line (item 4) is a thin, solid line terminated at each end by arrowheads. It indicates the direction and extent of the dimension. A numerical value placed along the dimension line specifies the number of units indicated. When the numerals are in a single line, the dimension line is usually broken near the center, and the numerals are placed in the open space. When the numerals are in two lines, the dimension line is not broken, and one line of numerals is placed above the dimension line and the other below.

Leader. A leader (item 5) is a thin, straight line that begins at a dimension or note and terminates in an arrowhead at the point on the drawing to which the dimension or note refers. The note end of a leader usually terminates with a short horizontal bar at the mid-height of the lettering at either the

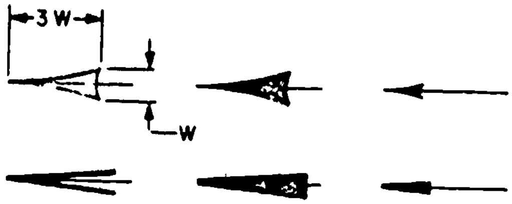


Figure 4-1. Arrowheads.

beginning or ending of the note. Leaders that end at circles or arcs are drawn as radial lines; that is, if extended, they would pass through the center.

Arrowheads. The pointing ends of leaders and both ends of dimension lines are terminated with arrowheads (item 6). Draw these pointing symbols freehand. Use either one stroke or two strokes to form the point. Then complete the shape by drawing a line across the open end. If you use the one-stroke method to form the point, make the stroke toward the point and then away from it. If you use two strokes, make both strokes toward the point. After completing the shape of the arrowhead, fill in the center.

Figure 4-1 shows the two common shapes of arrowheads. One has curved sides; the other has straight sides. Notice the proportion of the length to the width. The length of the arrowhead with curved sides is three times the width. Straight-sided arrowheads are longer and narrower and are made with a broader stroke, which produces a blunter point. The two small arrowheads on the right indicate the normal size used on small drawings. These are approximately one-eighth of an inch long. For large drawings, arrowheads may be as long as three-sixteenths of an inch.

Dimensions. Since the numerical value or dimension (item 7, FO 2) is the most important element of dimensioning, the numerals must be carefully lettered. Either a vertical or an inclined style can be used. One-eighth of an inch for small drawings and five thirty-seconds of an inch for larger drawings are good general sizes.

Common fractions. As shown in figure 4-2, a dimension may consist of whole numbers, fractions, feet and inches, or decimals. When common fractions are used, the fraction bar is placed parallel with the guide lines, and the numerator and denominator are made somewhat smaller than the whole number so that the total height of the fraction is twice that of the whole number. The numerals do not touch the fraction bar. Notice that when the dimension occupies the open space of a dimension line, the fraction bar is aligned with the dimension line, but the two do not touch. The three presentations at the right of the top row show the different ways to place the dimension when the space is limited. In one method you place the dimension figure between the extension lines and the dimension lines on the outside pointing toward the figure. When the space is too small to allow enough room for a figure, the dimension may be placed as in the two presentations on the right.

Feet and inches. Dimensions in feet and inches are represented with the symbols (′) and (″), as shown in the center row of figure 4-2. When the dimension is in even feet, such as 6 feet and no inches, the dimension is written as 6′ 0″. When a dimension is in feet and a fraction of an inch, a zero is used in front of the fraction; for example, 6′ 0½″. When the dimension is all in inches, the inch mark is usually omitted from all dimensions and notes unless there is some possibility of misunderstanding. For example, a note consisting of 1 DRILL would be written as 1″ DRILL so that it would not be interpreted as "drill one hole."

On Air Force machine drawings, if no foot or inch marks appear, the dimension values indicate inches, unless a different unit of measurement is indicated by a general note. Parts of inches are given as common fractions or decimal fractions. Three different systems are used.

Systems of writing dimension values. When the smallest fraction of a dimension is one-sixty-fourth or an inch or greater, the *common-fraction system* is generally used. With this system all dimension values are written as units and common fractions. The

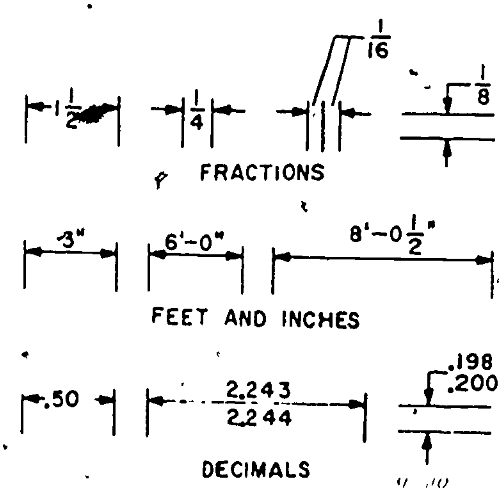


Figure 4-2. Dimensioning method.

common fractions used are ½, ¼, ⅛, $\frac{1}{16}$, $\frac{1}{32}$, $\frac{1}{64}$, and the appropriate multiples of these fractions. Values containing these fractions can be laid out with a steel tape or with a scale graduated in sixty-fourths of an inch.

The *common-fraction, decimal-fraction system* is used principally in machine drawing whenever the degree of precision required calls for fractions of an inch which are smaller than those on the ordinary steel scale. The method used is as follows: (1) Give values in units and common fractions for distances not requiring an accuracy closer than one sixty-fourth inch, and (2) give values in units and decimal fractions for distances requiring greater precision. The decimal fractions are given to as many decimal places as needed for the degree of precision required. In any case, the decimal point is made somewhat larger than is normal so that its position will not likely be misinterpreted.

The complete decimal system uses two-place decimal fractions exclusively for all dimension values. The digits after the decimal point are preferably written to even fiftieths, such as .02, .04, .06, etc., so that when halved, as for radii, etc., the resulting figures are two-place decimals. Writing the values in even fiftieths allows the use of scales divided in fiftieths, which are much easier to read than scales divided in hundredths.

Dimension values for distances requiring greater precision than that expressed by the two-place decimal are written to three, four, or more decimal places as needed for precision.

When decimal equivalents are used for common fractions, some of them come out to a greater number of decimal places (significant digits) than is necessary or desirable for use as a dimension value. In such cases, the decimal should be adjusted or rounded off to a smaller number of decimal places. The following procedure is recommended:

a. When the figure beyond the last figure to be retained is less than 5, the last figure retained should not be changed. For example, 3.14162 when rounded off to four places becomes 3.1416.

b. When the figure beyond the last figure to be retained is more than 5, the last figure retained is increased by 1. For example, 1.6875 becomes 1.69 when rounded to two places.

c. When the figure beyond the last place to be retained is exactly 5 with only zeros following, the preceding number, if even, is left unchanged; if odd, it is increased by 1. For example, 1.8125 becomes 1.812 and 1.6875 becomes 1.688 when rounded off to three places.

Finish mark. A finish mark (item 8, FO 2) indicates that a certain surface of a metal part must be finished in some manner. That is, the surface must be changed by some process, such as machining, drilling, filing, or grinding. When the part is to be machined from rolled stock, finish marks are not required, because it is understood that all surfaces are finished. Neither are finish marks necessary on drilled, reamed, or counterbored holes, or on similar machined features when the machining process is specified by a note.

The symbol used as a finish mark is a 60° V whose point touches the line representing the edge view of the finished surface. The sides of the symbol also form 60° angles with the line representing the surface. Finish marks are placed on the "air side" (no material side) of the line. They are placed on all views in which the surface to be machined appears as a line. If the part is to be machined on all surfaces, the note "FINISH ALL OVER" is used, and the marks are omitted from the views.

Exercises (232):

1. By what two methods may a distance be given in a drawing?

2. List and identify the lines used in dimensioning.

3. What is the length of an arrowhead?

4. Why place a finish mark on a drawing?

4-2. Techniques of Dimensioning

Any object can be broken down into a combination of basic geometric shapes or forms. These forms are usually prisms, cylinders, pyramids, and cones. Any form may be positive or negative, in the sense that a steel shaft is a positive cylinder and a round hole is a negative cylinder. This feature of breaking down an object into simple geometric forms is the basis of dimensioning.

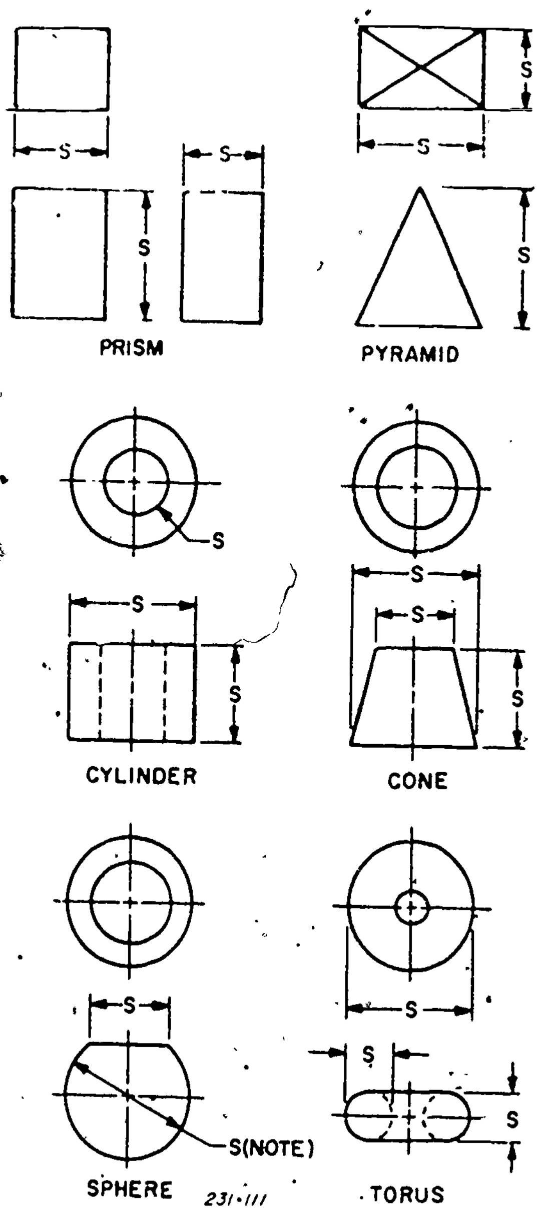


Figure 4-3. Dimensioning geometric shapes.

The complete description of an object consists of giving the shape, size, and location of all the object's basic forms. These dimensions must show the size of each geometric form and the relative location of all forms. Knowing how to dimension simple geometric forms is essential to describing any object.

233. Given the techniques of dimensioning, identify the size, location, and standard dimensioning features.

Size Dimensioning. Since every solid has three dimensions, each of the geometric forms which make up the object must have its height, width, and depth indicated in the dimensioning. These distance values are called size dimensions. Refer to figure 4-3 as you read the following information on dimensioning simple geometric forms.

Prism. The prism is the most common shape found in objects. Square, rectangle, or triangular prisms require three dimensions. The method of dimensioning a rectangular prism is shown in the illustration. The letter "S" in the illustration indicates that this is a size dimension. Notice that the dimensions are placed between the views. Since two views (the top and front views) are all that are necessary to adequately describe this particular prism, the depth dimension can refer to the top view and be in line with the height dimension, thus eliminating the need for the side view. For regular hexagonal or octagonal types of prisms, usually only two dimensions are given: the length and either the distance across the corners or the distance across the flats.

Pyramid. Right pyramids are dimensioned by giving the dimensions of the base and the altitude. Right pyramids are often frustums (portion of a pyramid with the pointed section removed) which require dimension of both bases.

Cylinder. A cylinder is the next most common geometric form. It obviously requires only two dimensions: length and diameter. The general method of dimensioning a cylinder is to give both its diameter and its length in the rectangular view. If clearness is gained, a diagonal diameter may be used in the view that shows the cylinder as a circle. The use of several diagonal diameters is usually confusing and should seldom be used. The radius of a cylinder is never given, since measuring tools, such as the micrometer caliper, are designed to check diameters. Small cylindrical holes, such as drilled, reamed, or bored holes, are usually dimensioned by means of notes specifying the diameter and the depth, along with the required shop operation.

The top view of the cylinder shown in figure 4-3 would be unnecessary if the dimension of the hole were placed on the rectangular view in the same position as the corresponding dimension on the view of the cone below. However, the dimension in this position would not indicate a diameter. In such cases where it is not clear from the view that a dimension indicates a diameter, the abbreviation "DIA" or "D" is given after the dimension figure.

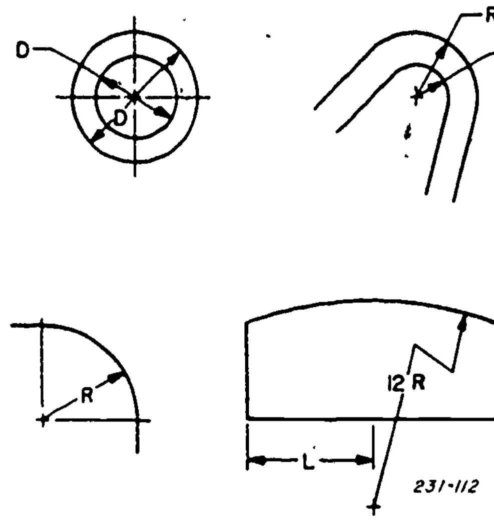


Figure 4-4. Dimensioning circles and arcs.

Cone. Right cones are dimensioned by giving the altitude and the diameter of the base. They usually occur as frustums which require dimensions of height and both diameters. Oblique cones are dimensioned in the same way as right cones but with an additional dimension parallel to the base to give the offset of the vertex.

Sphere. A sphere is dimensioned by giving the diameter and adding the abbreviation "SPHER." Figure 4-3 also shows how a flat surface on a sphere is dimensioned.

Torus. This doughnut-shaped form is dimensioned by giving its outside diameter and its thickness. As you can see in the figure, both of these dimensions are given on the front view.

Location Dimensioning. In addition to dimensioning the basic geometric shapes for size, you must give dimensions which will position each form in relation to the other. Establish the location or position in height, width, and depth directions. Locate rectangular shapes with reference to their faces and cylindrical and conic shapes with reference to their center lines and their bases.

Particular care must be exercised in the selection and placing of location dimensions, because upon them depend the accuracy of the operations in making a piece and the proper mating of a piece with other parts. To select location dimensions intelligently, you must first determine the contact surfaces, finished surfaces, and center lines of the basic geometric forms and, with the accuracy demanded and the method of production in mind, decide from what other surface or center line each should be located. Mating location dimensions must be given from the same center line or finished surface on both parts. Location dimensions may be from center to center, surface to center, or surface to surface.

Dimensioning Standard Features. Many basic shapes occur so often in mechanical parts that they can be considered as standard features. As such, they deserve special dimensioning consideration. The standard features include circles and arcs, curves, angles, chamfers, tapers, holes, countersinks, counterbores, spotfaces, and shapes with rounded ends.

Circles and arcs. The methods of dimensioning circles and arcs are shown in figure 4-4. For a circle the diameter is the essential dimension. When a series of concentric circles are dimensioned on their circular view, the dimension values should always read from the same direction, if possible.

Arcs are dimensioned by giving the radius on the view that shows the true shape of the curve. The dimension line for the radius is always drawn as a radial line and at an angle

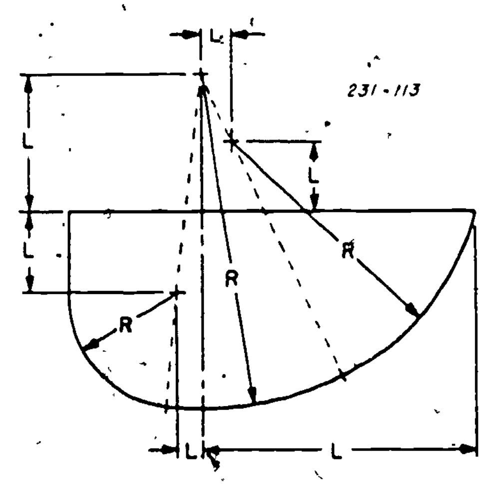


Figure 4-5. Dimensioning compound circular curves.

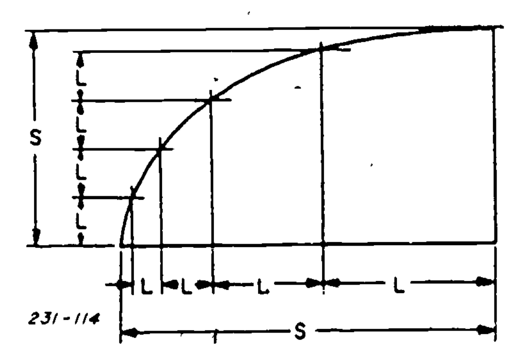


Figure 4-6 Dimensioning irregular curves.

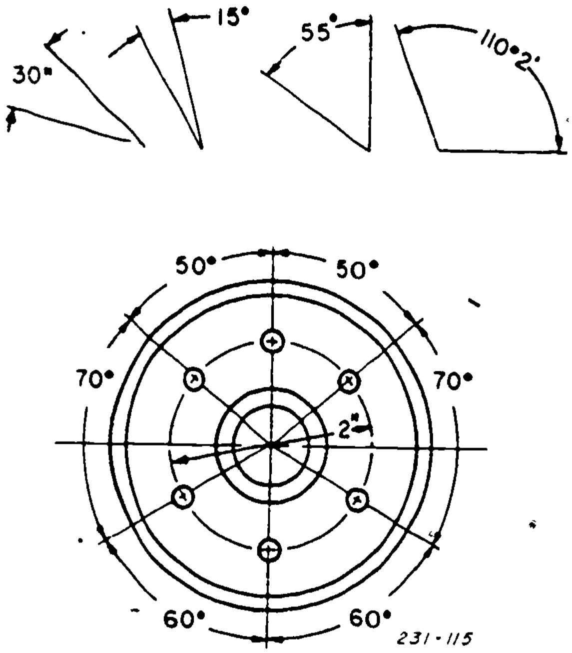


Figure 4-7. Dimensioning angles.

with the horizontal. A radial dimension line should never be drawn horizontally or vertically. A small cross is used to mark the center. The numerical value is usually followed by the letter "R," designating radius. If the size of the radius and the space for the value permit, both the dimension line and the value are placed inside the arc. If the space for the value is limited, the line may be placed inside and the value outside. For very small arcs, both the line and value may be placed outside the arc.

When the center of an arc lies outside the limits of the drawing, move the center closer along the center line of the arc, and jog the dimension line to meet the new center. Draw the portion of the dimension line adjacent to the arc as a radial line of the true center.

Curves. Dimension a compound curve composed of circular arcs by giving the radii of these arcs and the location of their centers, as shown in figure 4-5. An important consideration of this type of curve is the termination of each arc. For this particular curve, the arcs adjacent to each other terminate at the intersection of the curve and a line drawn through their centers.

Dimension curves are those for which great accuracy is not required by offset or coordinate points on the curves, as shown in figure 4-6. For greater accuracy, dimension from datum features. If the curve in figure 4-6 were dimensioned by the datum system, each horizontal dimension would be measured from the right vertical edge, and the vertical dimensions would be measured from the bottom edge. Thus, each dimension would be independent of the others and would be more accurate.

Angles. The dimension line for an angle is a circular arc with its center at the intersection of the sides of the angle. Four different methods of dimensioning angles are shown at the top of figure 4-7. The dimension value is usually placed horizontally, as shown in the three examples on the left. Occasionally, the value is aligned with the dimension arc, as

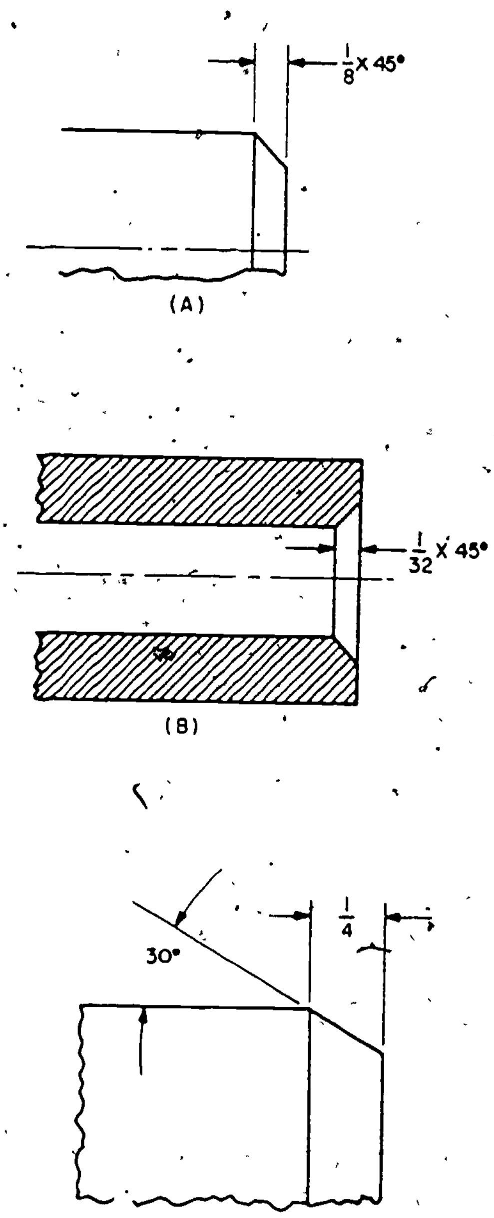


Figure 4-8. Dimensioning chamfers.

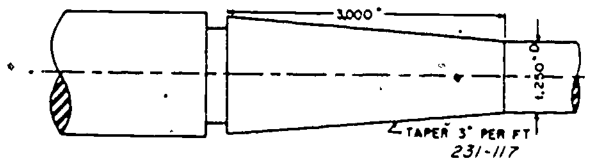


Figure 4-9. Dimensioning tapers.

shown on the right. As you can see, this system requires a large angle. A typical application of angle dimensioning is shown at the bottom of the figure.

The space available determines the position of the dimension value and dimension arc. When there is enough space, both value and arc are placed inside the two sides. When the space is limited, the value may be placed inside and the arcs outside, or both may be placed outside.

Chamfers. These are beveled external or internal edges. The 45° chamfers are dimensioned as shown in figure 4-8 at (A) and (B) or by a note, such as chamfer ⅛ x 45°. If the chamfer angle is other than 45°, it is dimensioned as at (C) of figure 4-8.

Tapers. A taper is a conical surface of a shaft or a hole. The method of dimensioning tapers depends on the method of manufacture and the accuracy required. If the specification calls for a standard taper, the dimension indicates one diameter and the length. The general method shows the diameters of both ends and the taper per foot. An alternate method is shown in figure 4-9. This method gives one diameter, the length, and the taper per foot. The taper per foot is defined as the difference in diameter in inches for one foot of length.

Holes. Drilled, reamed, bored, punched, or cored holes are usually dimensioned by note, giving the diameter, operation, and depth if required. The order of items in a note corresponds to the order of procedure in the shop in producing the hole. A typical note is as follows:

½ DRILL ⅝ DP - 2 HOLES

Two or more holes of the same diameter are dimensioned by a single note with the leader pointing to one of the holes. The leader generally points to the circular view of the hole. It is placed on the rectangular view only when it promotes clearness.

Figure 4-10 shows three methods of dimensioning the depth of a hole. Shown at A is the method used when the depth of the hole is not important to the functioning of the part. When the clearance at the bottom of the hole is important, use the dimension method shown at B. When the depth of the hole is important to the functioning of the part, dimension the hole as shown at C.

Measure the location dimensions for holes from a finished surface used as a datum plane, or from an important center or center line. Dimension holes equally spaced about a common center by giving the diameter (diagonally) of the circle of centers (commonly called the bolt circle) and by specifying "EQUALLY SPACED" on the note.

Locate holes which are unequally spaced about a common center by means of the two

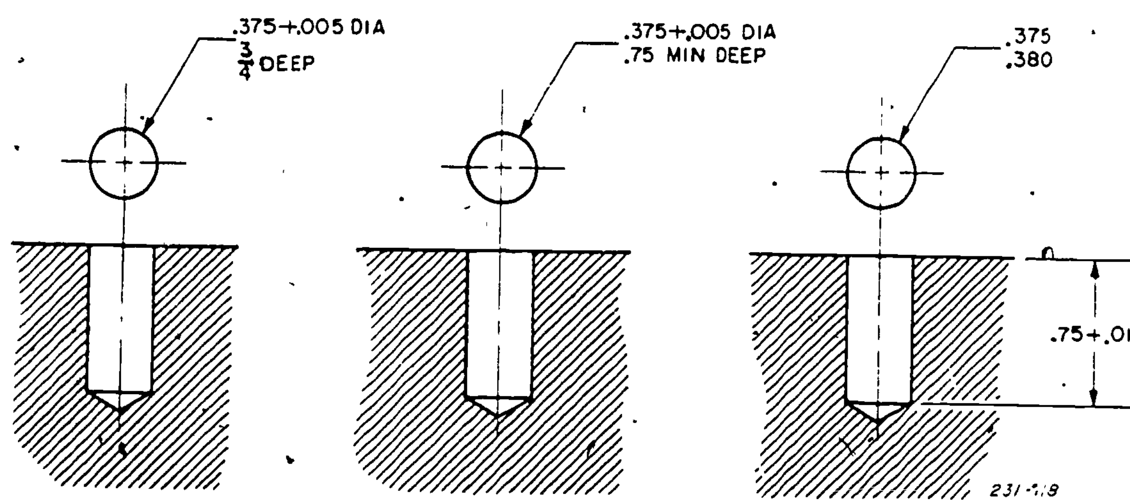
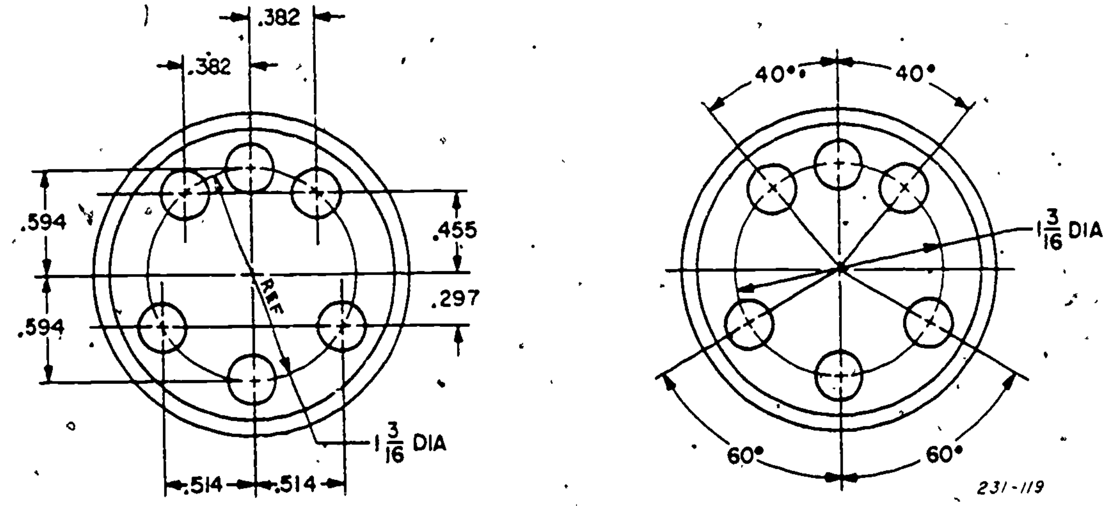


Figure 4-10. Dimensioning holes.



RECTANGULAR DIMENSIONING   ANGULAR DIMENSIONING

Figure 4-11. Two methods of dimensioning holes.

methods shown in figure 4-11. Locate them by means of the bolt circle diameter plus angular measurements with reference to only one of the center lines, as shown by the illustration on the right. Where greater accuracy is required, give rectangular or coordinate dimensions. This method is shown on the left. When using rectangular dimension, mark the diameter of the bolt circle "REF" to indicate that it is to be used as a reference dimension. Reference dimensions are given for information only. They are not intended to be measured and do not govern the shop operation.

The two small holes in foldout 2 are on a common center line. In such cases, one dimension locates one hole from the center line of the part; the other gives the distance between the holes. Note the omission of a dimension between the center line and the lower hole. This method is used when (as is usually the case) the distance between the holes is the important consideration. When the relation between the center line and each of the small holes is more important, the dimension is included between the center line and both holes, and the overall dimension is marked "REF."

Holes may be located by giving dimensions from a base line or datum. When all holes are located from a common datum, the sequence of measuring and machining operations is controlled, overall tolerance accumulations are avoided, and proper functioning of the finished part is assured. The datum surfaces selected must be more accurate than that required of any measurement made from them, must be accessible during manufacture, and must be arranged so as to facilitiate tool and fixture design. It may be necessary to specify accuracy of the datum surfaces in such terms as "straightness," "roundness," and "flatness."

Countersink. A countersink is a conical depression at the top of a hole to accommodate the head of a screw. Countersinks are dimensioned as shown in figure 4-12. The linear dimension indicates the distance across the top of the countersink. The dimensions of the rivet, bolt, screw, or other device to be inserted in the countersink determine the angle of its conical sides.

Counterbore. The counterbore is an enlargement of the end of a drilled hole. It is cylindrical in shape and deep enough to allow a specific clearance. Each counterbore is dimensioned by a note with the abbreviation "C BORE," a leader, the diameter, and the depth of the bore. The two methods of dimensioning a counterbore are shown in figure 4-13.

Spotface. A spotface is a machined area around a hole to permit accurate seating of a bolthead, washer, or nut. A spotface is specified by a leader from a note carrying the abbreviation "SF" and giving the diameter of the spotface. This leader-note combination is usually grouped with the leader and note giving the diameter of the hole, as shown in figure 4-14.

Shapes with rounded ends. Methods of dimensioning shapes with rounded ends depend upon the degree of accuracy required. When extreme accuracy is required, the methods shown in figure 4-15 are recommended. The top illustration shows the dimensioning required for a rounded-end slot, and the bottom illustration shows the dimensioning required for a rounded-end link. Overall lengths of rounded-end shapes are given in each example. The width of the slot and the link are given and the radii are indicated, but without specific values. In dimensioning the link, the center-to-center distance is required because it is necessary to locate the holes accurately.

When precision is not necessary, the two parts may be dimensioned by giving the distance between the centers, the width, and the radius of the rounded end of each shape. Of course, the diameter of the holes in the link must also be given.

Exercises (233):

1. What is meant by size dimensioning?

2. What is the most common shape found in objects?

3. Identify a right cone, a frustum of cone, and an oblique cone.

4. What is meant by location dimensioning?

5. List the shapes that are considered standard features.

4-3. Dimensioning Practices

With clarity the important consideration, there are many dimensioning practices or principles, some with the force of a rule, that must be used in dimensioning drawing. Most of these practices are concerned with the placement of dimension elements and the procedure for dimensioning.

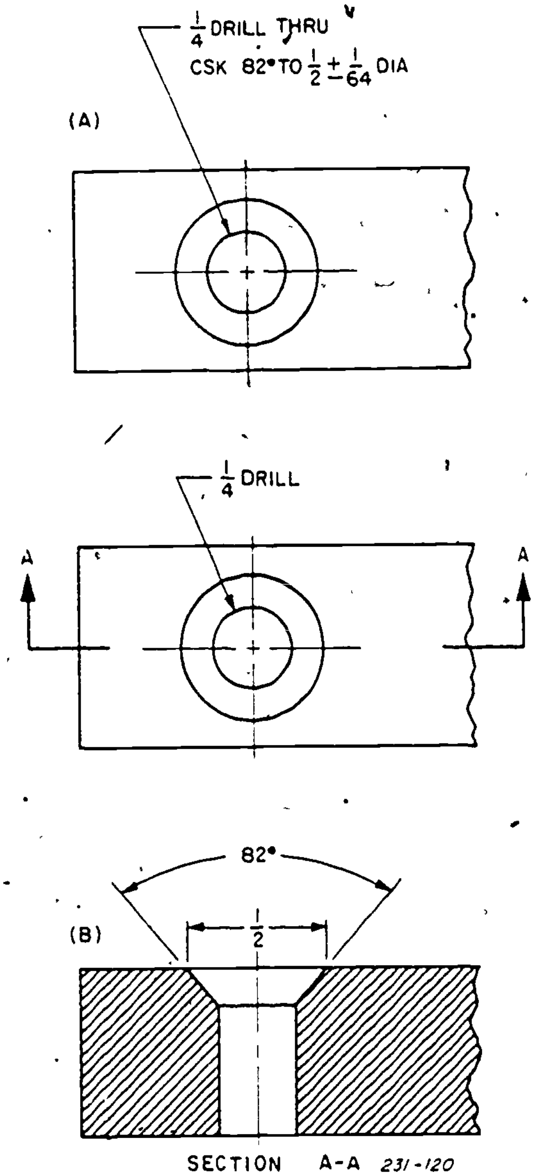


Figure 4-12. Dimensioning countersinks.

234. Given the procedures for dimensioning practices, explain placement and order of dimensioning elements.

Placement of Dimensions. In addition to the methods of dimensioning basic geometric forms and shapes that we have already discussed, the following principles or rules apply to good dimensioning.

a. Place dimensions between views whenever possible (see fig. 4-16). If this is not possible, the next best position is on the outside of the views. When it is impossible to use either of these two positions, place the dimensions on the views themselves. If you place the dimension on the surface of a

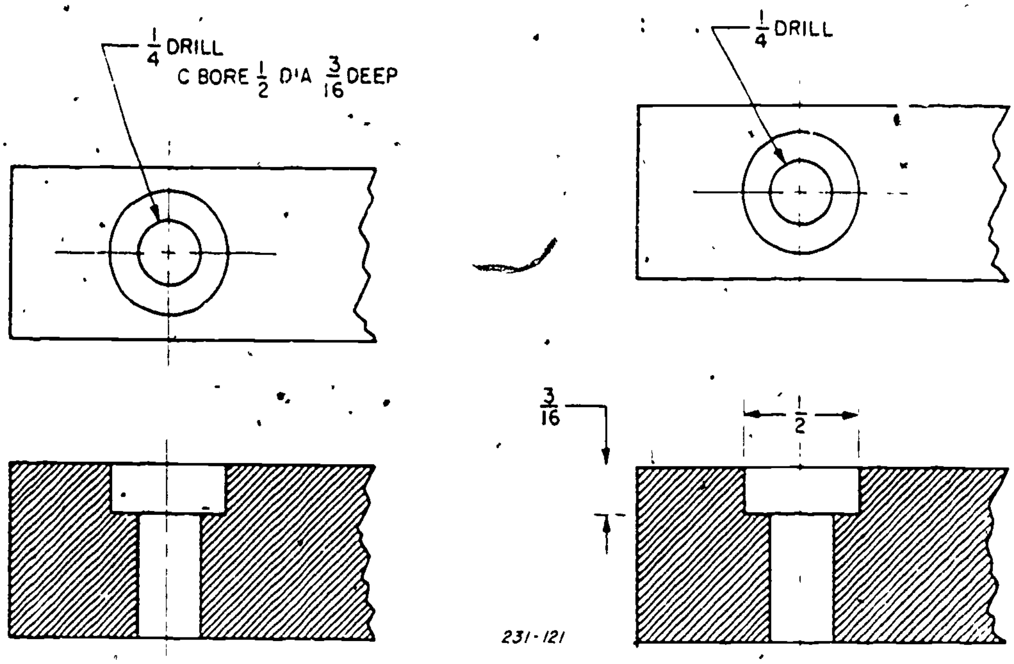


Figure 4-13. Dimensioning counterbores.

sectional view, omit the section lining around the numbers.

b. Dimensions must read from the bottom and right side of the sheet of paper unless the unidirectional system of dimensioning is used. This means that the dimensions are placed in the position shown in figure 4-16. As you can see, the horizontal dimensions run from left to right, and the vertical dimensions run upward. In the unidirectional system, all dimensions are placed horizontally.

c. Without duplicating or crowding,

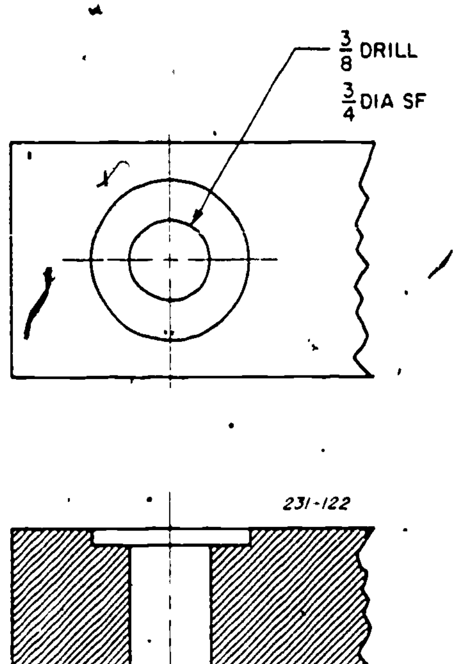


Figure 4-14. Dimensioning spotfaces.

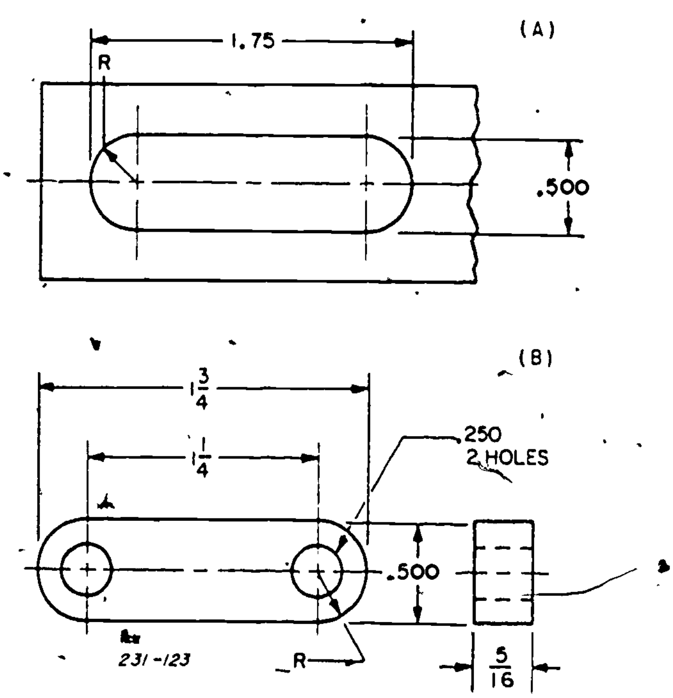


Figure 4-15. Dimensioning parts with rounded ends.

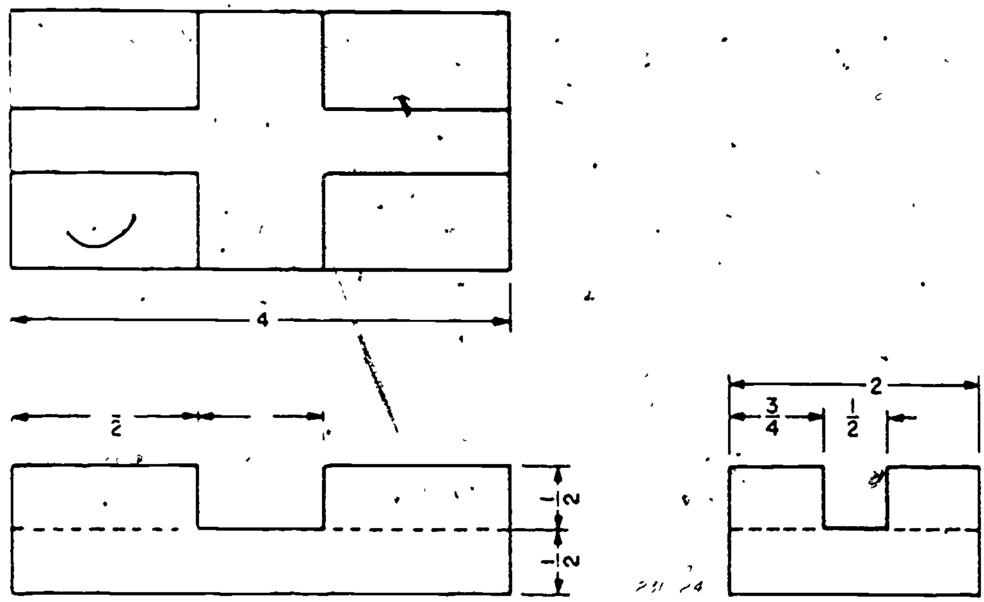


Figure 4-16. Dimensioning placement.

indicate as many dimensions as practicable on the principal view; that is, the view which best shows the characteristic contour of the object. This rule is demonstrated in figure 4-16, where width dimension is placed on the top view, the height dimensions of the features are placed on the front view, and the depth dimensions are placed on the side view. The dimensions apply to one view only; that is, with dimensions between views, the extension lines should be drawn from one view, not from both views.

d. Do not place unnecessary dimensions on a drawing. This rule is also applied in figure 4-16. Notice that no dimensions are needed for the features on the right side of both front and side views because the other dimensions have already established these dimensions.

e. Whenever possible, avoid crossing one dimension line with another. As shown in figure 4-17, the best method of preventing crossed dimension lines is to place the dimension line of the shortest distance nearest the outline of the object and to add parallel dimension lines in the order of the size of distances dimensioned. When crossing

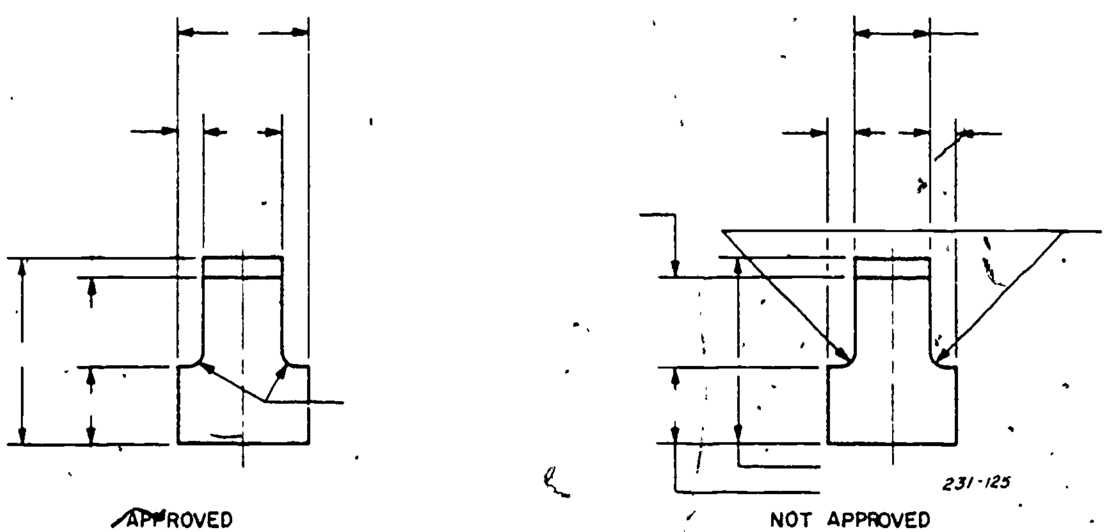


Figure 4-17. Dimensioning line arrangement.

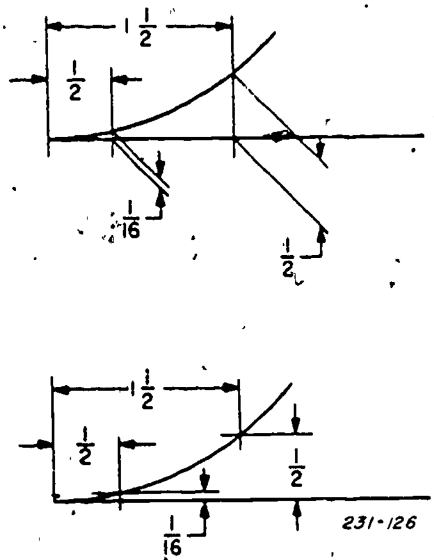


Figure 4-18. Use of inclined extension lines.

dimension lines with extension or leader lines is unavoidable, make a break in the extension line or leader line at the point of crossing. However, when two extension lines cross, neither line is broken, nor are extension lines broken when they cross outlines.

f. Place dimensions by either the aligned system or the unidirectional system. The aligned system of dimensioning is used in figure 4-16. In this system, the dimensions parallel the surface they dimension. The unidirectional system is used in figure 4-15. Here all dimension values are horizontal.

g. Draw extension lines perpendicular to their related dimension lines unless increased clarity may be obtained otherwise. For an example of the exception, observe figure 4-18. The top illustration shows that inclined extension lines permit a much clearer presentation of the curved line than do the horizontal extension lines used in the lower illustration.

h. Keep parallel dimensions equally spaced. An example of this practice is shown at the upper right portion of foldout 2. The space between the outline and the first dimension line is slightly larger than the spaces between the dimension lines. The ratios 2 to 3 and 3 to 4 are commonly used. For example, if the spaces between dimension lines are one-fourth unit or three-eighths unit, the distance between the outline will be three-eighths or one-half, respectively.

i. Group related dimensions on the view showing the contour of a feature.

j. As shown in figure 4-19, arrange a series of dimensions in a continuous line. When this practice places the dimension values so close together that they are hard to read, stagger the values to form two columns, as shown in figure 4-20. This makes the numeral much easier to read.

k. Place dimension values midway between arrowheads except when a center line interferes or when the values are staggered.

The following dimensioning practices have been so definitely established that they may be called rules.

a. Do not use an object line, extension line, or center line as a dimension line.

b. Always give location dimensions to the center of circles that represent holes, cylindrical projections, or bosses.

c. When dimension figures appear on a sectional view, show them in a small, uncrosshatched portion so that they can be read easily.

d. When an arc is used as a dimension line for an angular measurement, use the vertex of the angle as the center.

e. Show the diameter of a circle, never the radius.

f. Make dimensioning complete so that it is not necessary for workmen to add or subtract to obtain a desired dimension or to scale the drawing.

g. Place dimensions on the view that shows the distance in its true length.

Order of Dimensioning. A systematic order of working is a great help in placing dimensions. Foldout 2 illustrates the procedure. The steps are as follows:

a. Complete the shape description.

b. Place the extension lines and extend the center line where necessary. Plan for the location of both size and location dimensions.

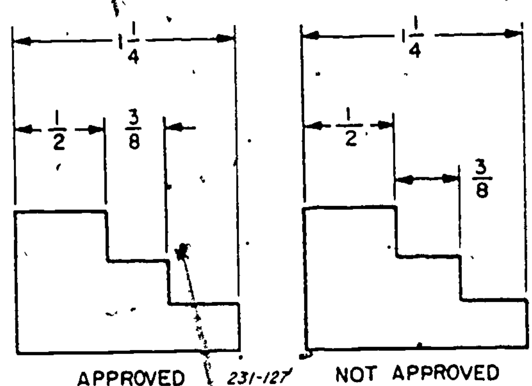


Figure 4-19. Grouping dimensions.

Study the placement of each dimension and make alterations, if desirable or necessary.

c. Add the dimension lines.
d. Draw arrowheads and leaders for notes.
e. Add dimension values.
f. Letter notes.

Although the preceding procedure on the order of dimensioning is simple, a beginning draftsman may have trouble with the first step, because the drawing of the shape description must be done to scale; that is, the distances such as those representing the width, height, and depth must be in correct relationship with each other, as indicated by the dimensions. To show you how this is accomplished, let's go through the steps of the process used to draw the shape description of foldout 2.

Before starting the actual drawing, mentally divide the object into its component geometric shapes, make a multiview sketch, and add size and location dimensions. Use this sketch as a model for the drawing. Make all construction lines light and use the following steps to make the drawing.

a. Establish a reference line for each view. Since the bottom surface of the object is machined and appears as a line in the front view, it is the logical choice for the reference line of the front view. The horizontal center line makes the best reference for the top view. Position these two lines on your paper so that the two views are properly spaced. These two lines serve as reference lines for vertical measurements.

b. On the top view, establish the vertical center line for the large hole. Then project it to the front view. These two lines serve as references for horizontal measurements.

c. Establish the position of the vertical center lines for the hole on the left and the two holes on the right by marking off from the vertical center lines distances of 2¼ units to the left and 1½ units to the right. Then draw the two vertical center lines in both views.

d. On the vertical center line of the two holes on the right, mark off the distance ⅞ of a unit to locate the center of the upper hole. From this center, mark off the distance 1¼ units to locate the center of the lower hole. Then draw the horizontal center lines through these two points.

e. Draw the forms that appear as circles in the top view, using ¼ unit for the radius of the small holes, 17/32 unit for the radius of the large hole, 5/16 unit for the radius of the hole on the left, 1 unit for the radius of the large cylindrical form, and ¼ unit for the radius of the small cylindrical form. Then, project the resultant circles to the front view.

f. Using the center of the hole on the left as the center and a radius of 1½ units, draw

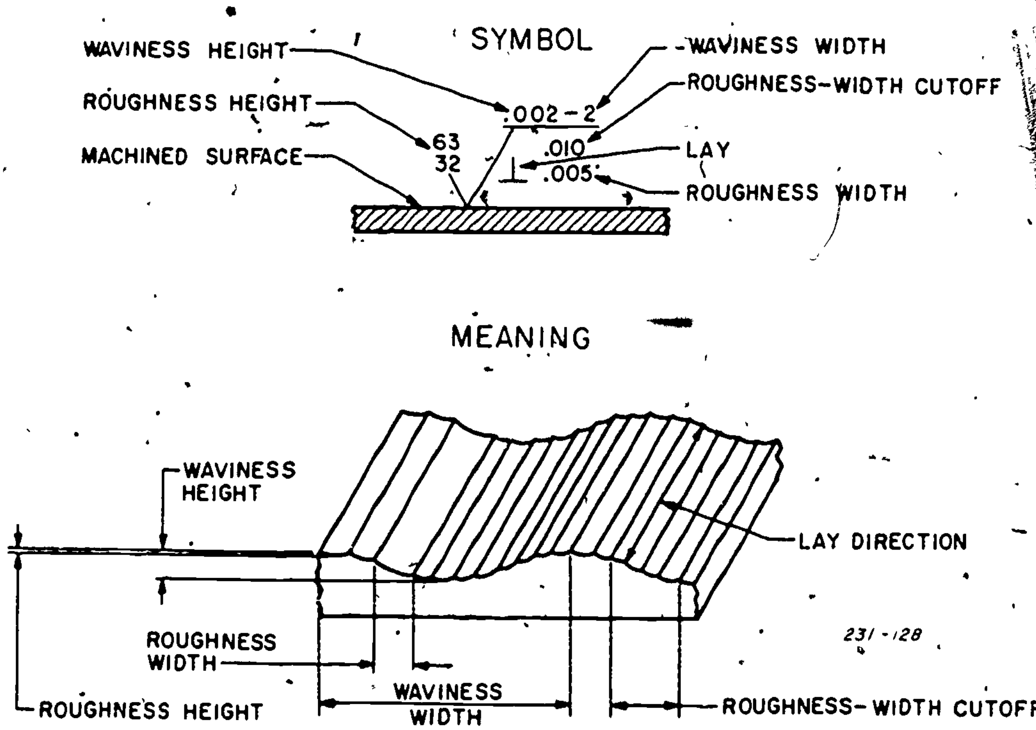


Figure 4-20. Surface roughness

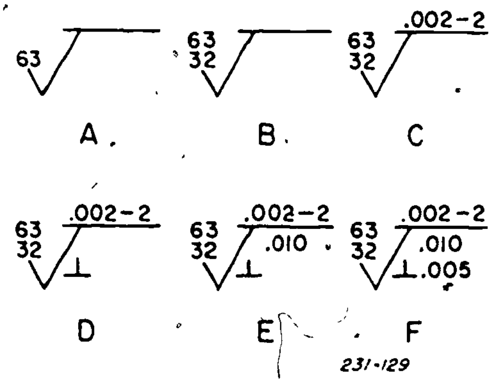


Figure 4-21. Surface roughness symbols.

the rounded end of the object. Then project the left end of the object to the front view.

g Draw the remaining edges of the object in the top view. The two edges that appear as horizontal lines are tangent to the semicircle which represents the rounded end of the object. The vertical line representing the edge at the other end of the object is located 4⅞ units from the left vertical center line. Then project the right edge to the front view.

h. In the front view, draw horizontal lines representing the heights of the different forms of the object, making the height of the base ½ unit, the height of the small cylindrical form ¾ unit, and the height of the large cylindrical form 1¾ units.

i. In both the top and front views, draw the lines representing the web between the two cylindrical forms.

j. Draw all fillets and rounds, using a radius of ⅛ unit. This completes the construction part of the drawing.

k. Finish the drawing of the shape description by erasing all unnecessary construction lines and tracing over all lines, giving them correct weight and character.

Dimensioning Surface Quality. The proper functioning and wear life of a part frequently depend upon the smoothness quality of its surfaces. Simple finish marks, as used on the drawing of foldout 2 to show where material is to be removed, are not sufficient to specify surface finish on such parts. A system of symbols defining roughness, waviness, and lay is used. The relation of these symbols to surface characteristics is illustrated in figure 4-21. Refer to this figure as you read the following definitions of surface characteristics and explanations of how these characteristics are specified on the surface quality symbols.

Roughness. Surface roughness is the relatively finely spaced surface irregularities that are produced by the cutting action of tool edges. Roughness is expressed as the arithmetic-average deviation from the mean line of the surface in profile. The microinch (millionths of an inch) is the unit of measurement. A higher number of microinches indicates a rougher surface that does the lower number.

When surface quality is specified on a drawing, the V finish mark is used as a base. The right side of the V is extended upward as on a checkmark, and a horizontal crossbar is added over the top. When it is necessary to specify only roughness height (the width between ridges or the direction of tool marks being unimportant), the simple symbol shown in part A of figure 4-21 is used. In such cases, the horizontal crossbar may be omitted. When it is desired to specify maximum and minimum average roughness height, the upper and lower value numbers are placed as those at B.

Additional factors included in the measurement of roughness are roughness width and *roughness-width cutoff*. Roughness width is rated in inches and is the maximum permissible spacing between repetitive units of the surface pattern. Roughness-width cutoff is the maximum width of surface irregularities used in the measurement of roughness height. Both roughness width and roughness-width cutoff are measured in inches. The values are placed under the horizontal crossbar with the roughness-width cutoff directly over the roughness width, and the roughness width value is placed to the right of the lay symbol.

Waviness. Waviness is the surface undulations on which the roughness features are superimposed. The undulations are of much greater magnitude than roughness irregularities. Waviness may result from machine or work deflections, vibrations, warping, strains, or similar causes. The height of waviness is rated in inches as peak-to-valley waves.

The waviness height of a surface is specified in inches by placing the numerical value above the horizontal crossbar of the symbol, as shown in part C of figure 4-21. The maximum waviness width is expressed in inches and is given at the right of the waviness height number. In the examples shown in figures 4-20 and 4-21, the waviness width is 2 inches.

Lay. Lay is the predominant surface pattern produced by tool marks. The predominant pattern may lie parallel to the boundary line of the surface, perpendicular to the boundary line, angular in both directions

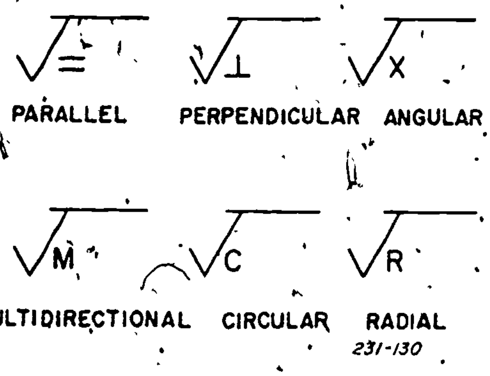


Figure 4-22. Lay symbols.

to the boundary line, multidirectional, approximately circular relative to the center of the surface, or approximately radial relative to the center of the surface. The symbols used to express these conditions are shown in figure 4-22. They are placed to the right of the V.

Exercises (234):

1. What is the most important consideration in dimensioning practice?

2. Where should dimensions be placed on a drawing?

3. List the order of dimensioning.

4. How are rough surfaces dimensioned?

4-4. Tolerancing

To achieve a particular function such as free rotation, free longitudinal movement, clamp action, or permanent fixed positions, the working parts of any machine must have some definite relationship to their mating parts. The degree of accuracy with which the parts are manufactured determines their ability to function as a unit. As an example, a cast part usually has two types of surfaces: mating surfaces and nonmating surfaces. The mating surfaces are machined to the proper smoothness so that they will be at the correct distance from each other. The nonmating surfaces with no important relationship to other parts of surfaces are left in their original rough-cast form. Thus, mating surfaces ordinarily require much greater manufacturing precision than nonmating surfaces. The dimensions on a drawing must indicate which surfaces are to be finished and the degree of precision required in finishing. However, because it is impossible to produce all distances to absolute size, some variation must be allowed in manufacture. This allowable variation is called tolerance, and the system used to provide a practical means of achieving the precision required is called tolerancing or limit dimensioning.

235. Explain tolerancing or limit dimensioning.

Basic Terms. The terms used in limit dimensioning are so interrelated that you should know their meaning before making a detailed study of dimensioning techniques. The following are definitions of common terms:

- Normal size. The normal size is a close approximation of a standard size. It is used for general identification purposes. For example, a bolt whose actual diameter is 0.2495 inch may be referred to as a 1/4-inch bolt.
- Basic size. This is the exact theoretical size from which limits are derived by application of allowances and tolerances. When there is no allowance involved, the basic size is referred to as the design size.
- Limits. The dimensions prescribing the maximum and minimum size of a part are called size limits. Similarly, location limits define the allowable variation in location dimensions.
- Clearance. This is the space between two mating parts, such as a shaft and a hole.
- Interference. This is the total amount of deformation which results from forcing an internal member into a smaller external member.
- Allowance. An allowance is an intentional difference between the maximum material limits of mating parts. It is a minimum clearance (positive allowance) or maximum interference (negative allowance) between mating parts.
- Maximum material limit. A maximum material limit is the maximum size limit of an external dimension or the minimum size limit of an internal dimension.
- Minimum material limit. A minimum material limit is the minimum size limit of an

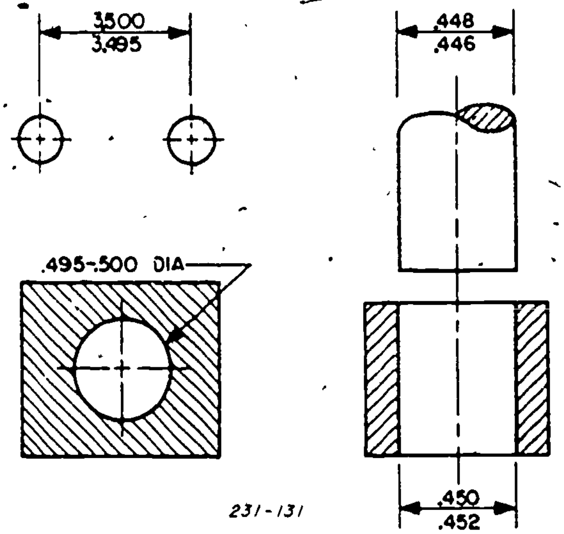


Figure 4-23. Limit dimensioning.

external dimension or the maximum size limit of an internal dimension.

• Tolerance limit. A tolerance limit is the variation, positive or negative, by which a size is permitted to depart from the design or preferred size.

Tolerancing Methods. The maximum and minimum values of a dimension may be indicated on a drawing by one of three methods: limit dimensioning, unilateral tolerancing, or bilateral tolerancing may be used.

Limit dimensioning. The limit dimensioning method is preferred where gages are extensively used in quantity-production work. In this method, the two limits representing the maximum and minimum acceptable sizes of a dimension are placed on the drawing. The two limits may be arranged in two different ways, but both arrangements are never used on the same drawing. In the first arrangement when dimensions are given directly (not by note), the high limit is always placed above the low limit. The low limit always precedes the high limit when dimensions are given in note form.

The second arrangement, shown in figure 4-23, differs slightly. For dimensions of position given directly, the high limit (maximum dimension) is placed above and the low limit (minimum dimension) is placed below. For dimensions of size given directly, the value representing the maximum material condition is placed above, and the value representing the minimum material condition is placed below. When the limits are given in note form, the value that otherwise is placed above precedes the other. Thus, the two differences in the positions of the limits in the two arrangements are on inside dimensions given directly and on outside dimensions given as notes. The advantage of the second arrangement is that in the shop operation the

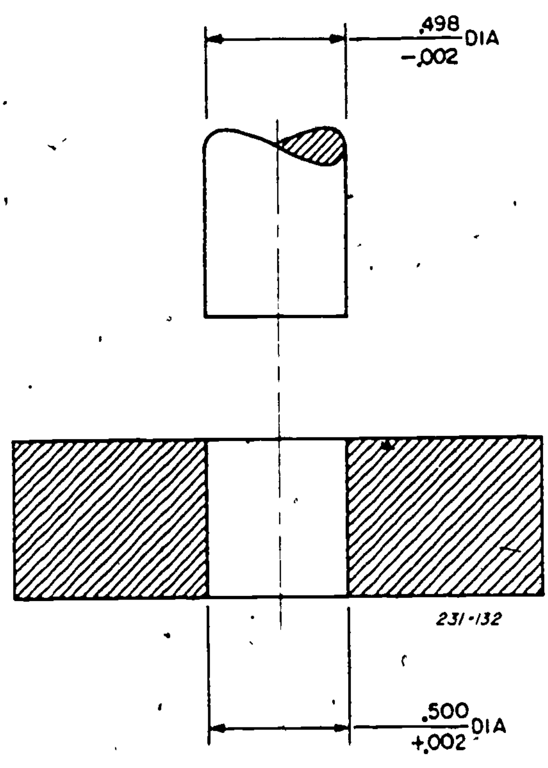


Figure 4-24. Unilateral tolerancing.

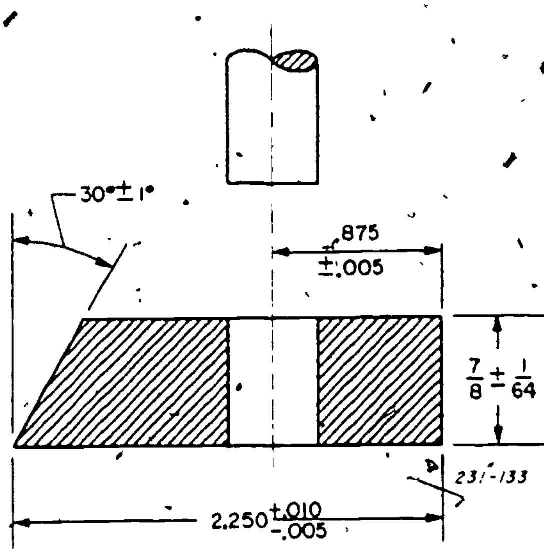


Figure 4-25. Bilateral tolerancing.

limit which is on top or precedes the other is reached first.

Unilateral tolerancing: Unilateral tolerances are expressed by giving two limits: the desired size and the minimum allowable size. They may also be expressed by giving one limiting size and the tolerance in one direction. The tolerancing expressed in figure 4-23 would be considered unilateral if the upper dimension were the basic size.

Figure 4-24 shows the other method of unilateral tolerancing. Here, the preferred dimensions of the shaft and the hole are placed above the dimension line, and the tolerance values are placed below the dimension line. Each tolerance may be plus or minus but not both. The tolerance is unilateral because it applies to only one side of the desired dimension.

Bilateral tolerancing. As shown in figure 4-25, bilateral tolerances are expressed by giving the tolerances in two directions. A plus tolerance and a minus tolerance indicate the limit on each side of the desired dimension. When the plus and minus tolerance values are equal, a combined plus and minus sign followed by a single tolerance value can be used. The sign and value may be placed in line with the dimension as shown at the left and right sides of figure 4-25, or they may be placed on a separate line as illustrated by the upper dimensioning values.

If the plus and minus tolerance values are unequal (as in the lower dimension values of figure 4-25), the plus value is placed below the line.

Cumulative and Noncumulative Tolerances. When the location of a surface of an overall dimension is controlled by more than one tolerance, the tolerances are said to be cumulative. As can be shown by discussing the top illustration of figure 4-26, when dimensions are continuous from surface to surface, an undesirable condition may result. Notice that there is only 0.005 permissible variation in the overall length of the object, while each dimension is also allowed 0.005 deviation. If minimum tolerances are obtained between all surfaces, the length of the object could be 3.980 as against a minimum specified length of 3.995. If it is necessary to maintain the overall dimension within the specified limits, the allowable variation of 0.005 must be distributed among the four dimensions. Therefore, the machinist would find it necessary to work to limits closer than those specified.

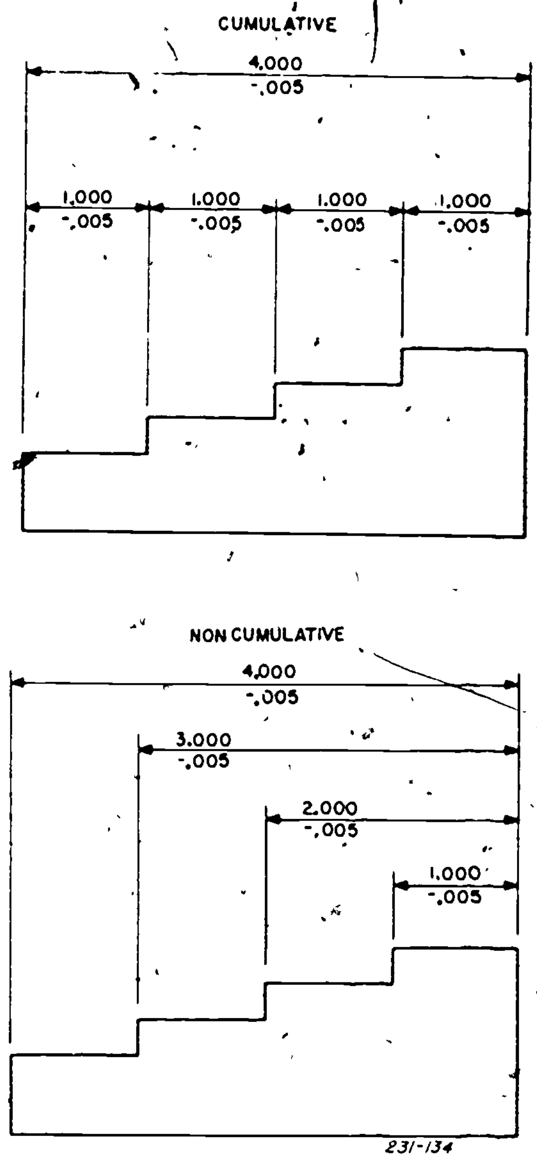


Figure 4-26. Cumulative and noncumulative tolerancing.

To avoid the undesirable situation resulting from cumulative tolerances, the preferred practice is to locate the surfaces from a datum plane, as shown in the bottom illustration. Each surface is then affected by only one dimension. This type of tolerancing is noncumulative tolerancing.

Exercises (235):

1. What is tolerancing or limit dimensioning?

2. Define unilateral and bilateral tolerances.

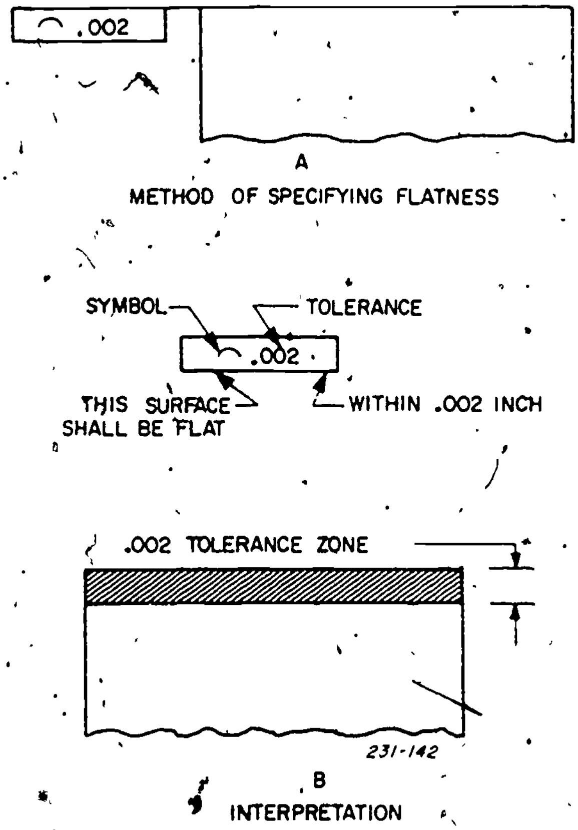


Figure 4-27. Method of specifying flatness and its interpretation.

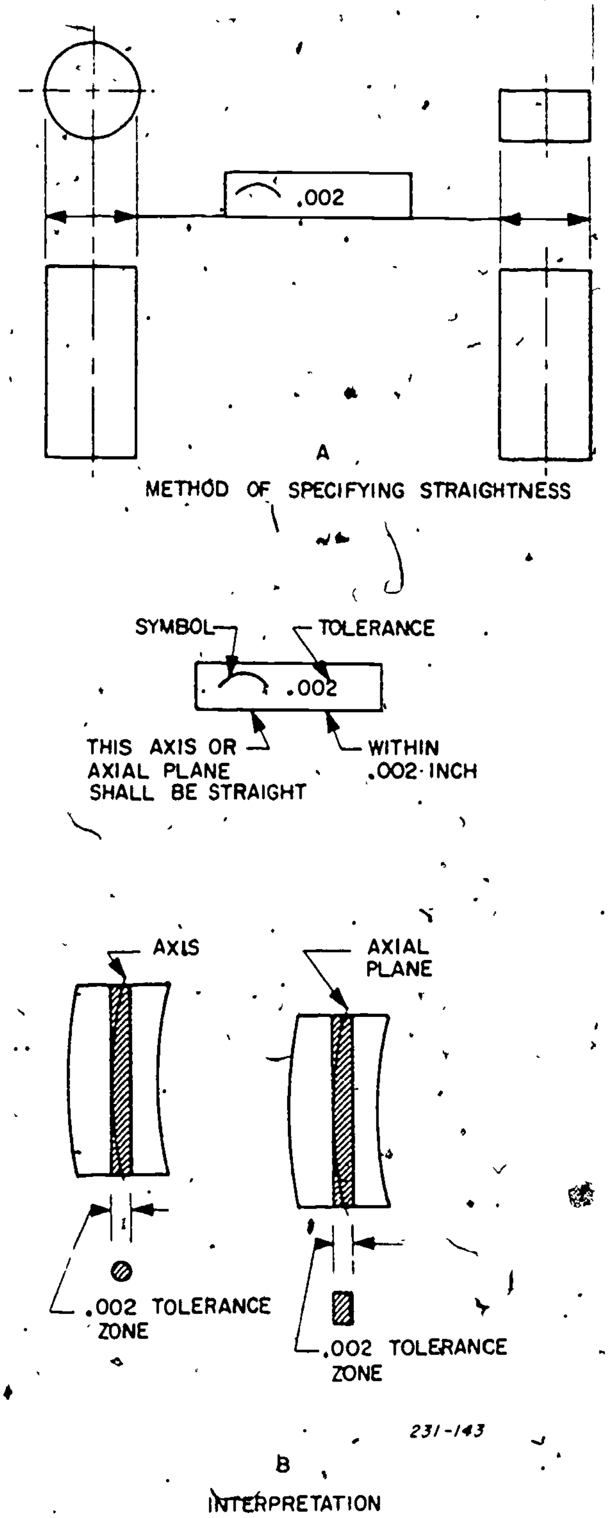


Figure 4-28. Method of specifying straightness and its interpretation.

4-5. Geometric Tolerancing

A geometric tolerance is the maximum permissible variation in the specified form of an individual feature of a part. Materials are fabricated into shapes or forms using geometric terms to define them. To maintain a specified quality, variations must be restricted because the perfect form or shape cannot be produced.

The definition of geometric form being perfection, geometric tolerances should satisfy the necessary standards of accuracy for proper functioning and interchangeability.

236. Given the methods of specifying surface tolerances, identify these surface tolerances.

Tolerance of Forms. Tolerances of forms often affect one another. For example, tolerances of parallelism includes flatness or straightness. As we have already discussed, tolerances of forms are also interrelated with tolerances that limit size or position. Let us now discuss tolerances of form individually, ignoring the effects of combination with other tolerances of form, size, or position.

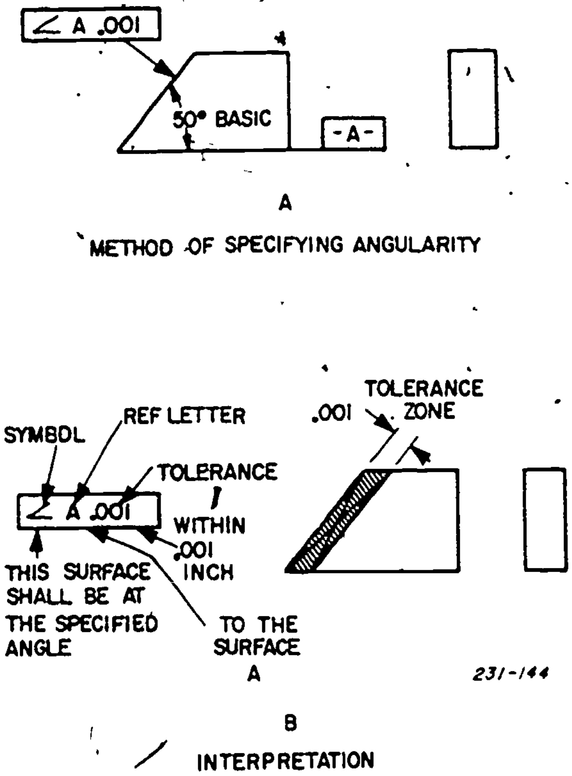


Figure 4-29. Method of specifying angularity and its interpretation.

Specifying flatness. Part A of figure 4-27 shows the method of specifying flatness. Notice that the feature control symbol is associated with the feature being toleranced by attaching the corner of the box to an extension line from the feature. As shown in part B, this presentation is interpreted to mean that this surface shall be flat within 0.002 inch. This means that the surface may deviate from a plane as long as it remains between two parallel planes that are 0.002 inch apart.

Specifying straightness. The method of specifying straightness is shown in part A of figure 4-28. Here, a dimension line is used to associate the symbol with the desired surface. The interpretation is shown at B. For the cylinder, this means that the axis must lie within a cylindrical zone 0.002 inch in diameter. For the bar, this means that its axial plane must lie within the 0.002-inch tolerance zone. However, since the parts are usually measured on the surface with the gage, the surface tolerance zone is equal to the diameter plus the 0.002-inch tolerance zone.

In practice, applications of tolerances of form apply to the surface, regardless of length or area. For long parts, therefore, it may be necessary to specify the tolerance per unit of length or area. For example, on long tubes the tolerance could be expressed as straight within 0.002 inch per foot. This would permit greater variation over the total length, if it is functionally permissible.

Specifying angularity. Two systems for specifying the tolerance on angles may be used. One system gives an angular zone of tolerance, and the other gives a zone between two parallel planes. The latter system is shown in part A of figure 4-29. A leader is used to associate the feature control symbol with its toleranced surface, and a datum identifying symbol is used to show the surface used as a reference. The two parallel planes between which the entire toleranced surface must lie are inclined from the datum by exactly the specified basic angle. The two acceptable extremes for the angles are shown within the shaded area.

Specifying perpendicularity. As shown in figure 4-30, the perpendicularity tolerance applicable to a plane surface is the distance between two parallel planes between which the entire surface must lie. The two parallel

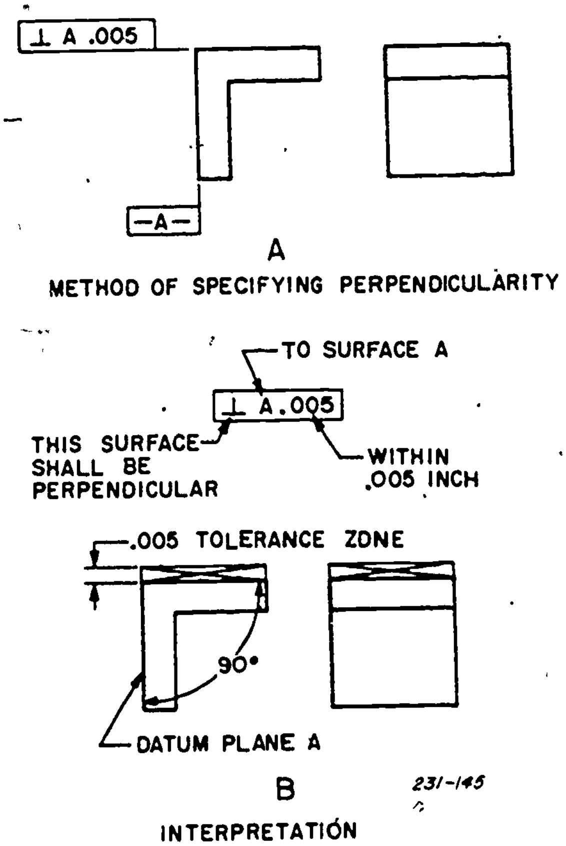


Figure 4-30. Method of specifying perpendicularity and its interpretation.

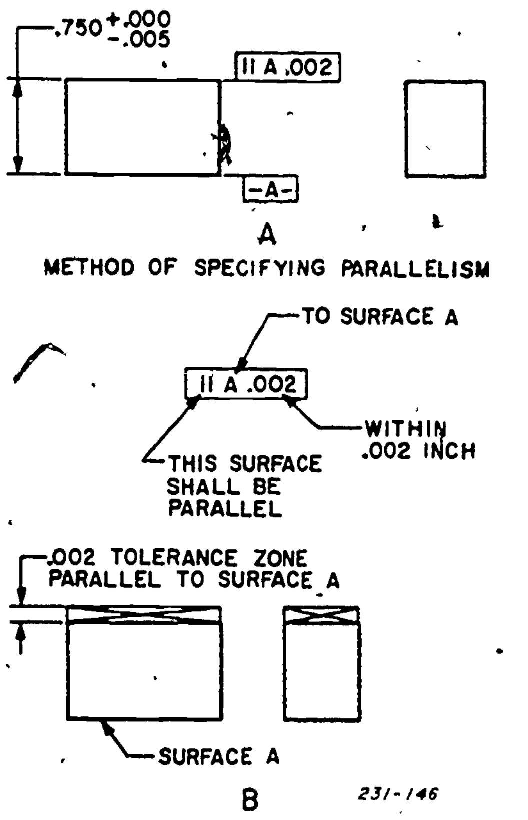


Figure 4-31. Method of specifying parallelism and its interpretation.

planes must be exactly 90° from the datum plane.

If the feature being toleranced is a cylinder (or other form of revolution) and the datum is a plane, the perpendicularity tolerance is the diameter of the tolerance zone within which the axis of the cylinder must lie. The axis of the tolerance zone must be at exactly 90° from the datum plane.

If both the feature and the datum are cylinders, the perpendicularity tolerance is the distance between two parallel planes between which the axis of the cylinder must lie. Of course, here too, the planes must be exactly 90° from the datum axis.

Specifying parallelism. The method of specifying parallelism between two planes is shown in part A of figure 4-31. As shown, parallelism is the condition of a plane which is equidistant at all points from a datum plane. The condition may also apply to an axis which is equidistant at all points from a datum axis.

As shown in part B of figure 4-31, parallelism tolerance applicable to a plane surface is the distance between two parallel planes between which the surface must lie. The two parallel planes must be parallel with the datum plane.

Specifying concentricity. Concentricity is a condition in which two or more regular features (such as cylinders, cones, spheres, hexagons, etc.) in any combination have a common axis. The method of specifying concentricity of two cylindrical forms is shown in part A of figure 4-32. Part B interprets the symbols and illustrates their meaning. As indicated by the shaded areas, the toleranced surface can be controlled in two ways. As long as the axis of the cylinder remains within the 0.001 axis tolerance zone or the surface variation does not exceed 0.005 (one-half the acceptable total indicator reading) the concentricity of the small cylinder is acceptable. As shown in the

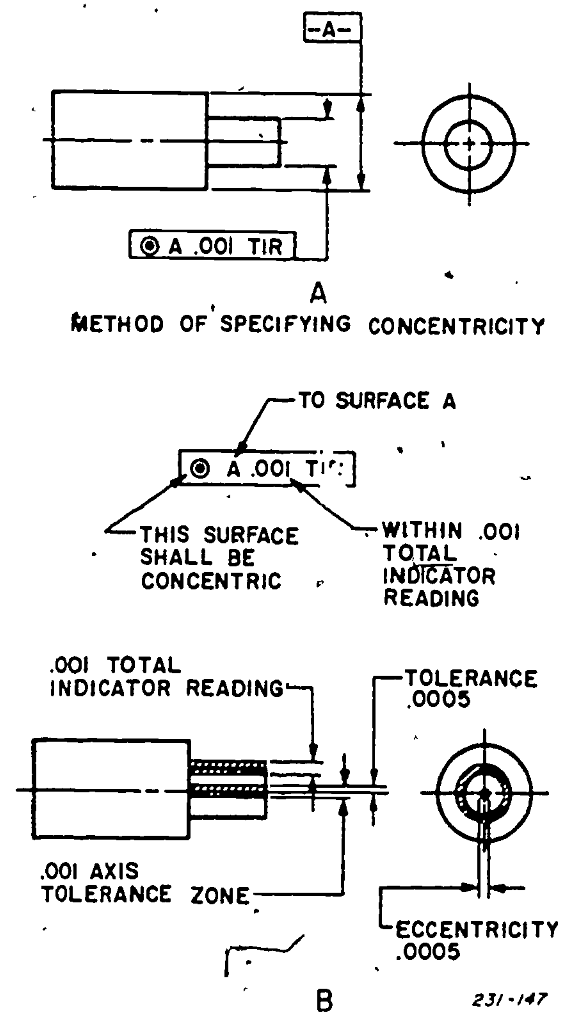


Figure 4-32. Method of specifying concentricity and its interpretation.

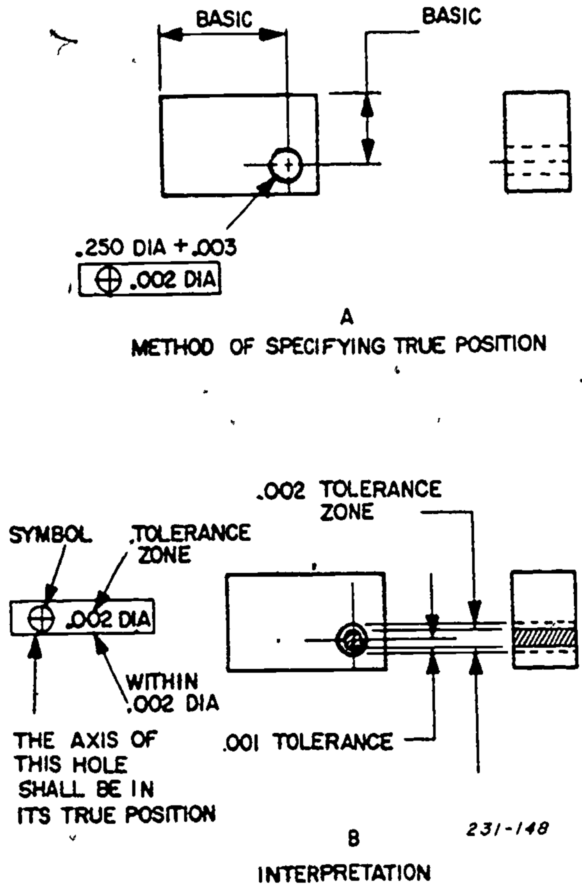


Figure 4-33. Method of specifying true position and its interpretation.

illustration on the right, the maximum allowable eccentricity is 0.0005 inch.

Specifying true position. Specifying the location of holes or other features by means of rectangular coordinates or angular dimensioning results in a square, rectangular, or wedge-shaped tolerance zone. The engineering intent can often be expressed more precisely if locations are given as true positions and with tolerances to state how far the actual positions can be displaced from true positions. This method is expressed in part A of figure 4-33. This practice results in a circular tolerance zone.

For cylindrical features the true position tolerance is the diameter of the tolerance zone within which the axis of the feature must lie. The center of the tolerance zone is considered to be at the true position. For other features, such as slots and tabs, the true position tolerance is the total width of the tolerance zone within which the axial plane of the feature must lie. The center of the zone is considered as being at the true position.

When true position tolerancing is used on a drawing, the untoleranced dimensions locating the true positions are identified by one of the following methods:

a. Add the word "BASIC" or the abbreviation "BSC" to the right of, or underneath, each dimension establishing the true position.

b. Tolerance each dimension on the drawing not involved in true position dimensioning, or not labeled "REF," "MAX," or "MIN," and add the note "DIMENSIONS LOCATING THE TRUE POSITION ARE BASIC."

In interpreting true position in terms of the axis of a hole, the true position tolerance means that, when RFS is the modifier or MMC is the modifier and the hole is at its maximum material condition, the axis of the hole must lie within a cylindrical zone having a diameter equal to the true position

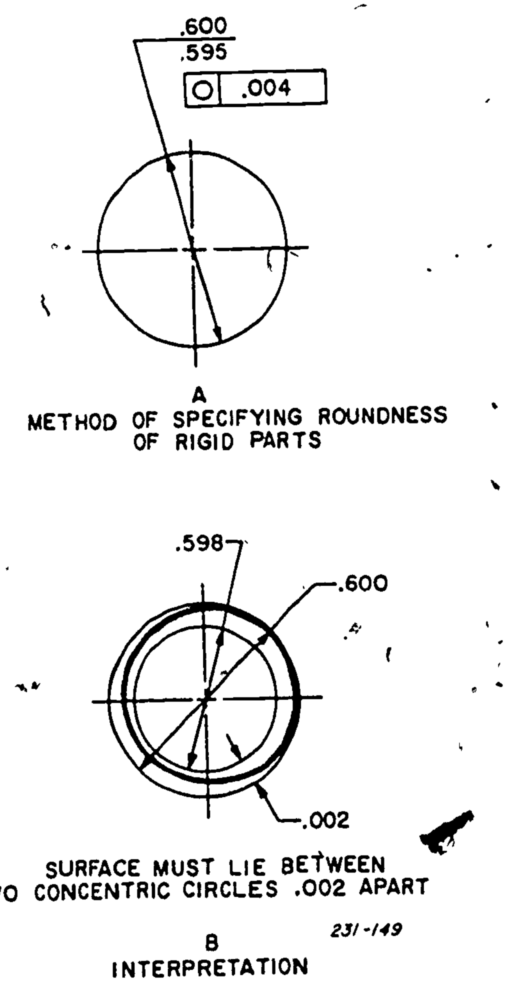


Figure 4-34. Method of specifying roundness of rigid parts.

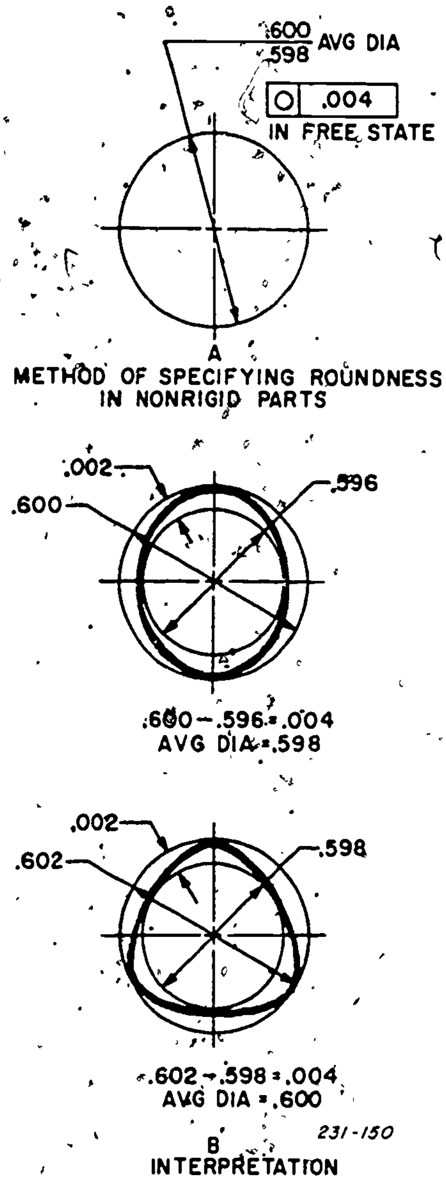


Figure 4-35. Method of specifying roundness of nonrigid parts.

tolerance and having its center at the true position. The tolerance zone is perpendicular to the surface on which the holes originate and to which they are drawn perpendicular on the drawing. Hence, the tolerance zone also defines the limits of variation in perpendicularity of the hole with respect to this implied datum surface. For a pattern of holes, the cylindrical tolerance zones are parallel. Hence, the true position tolerance controls both position and parallelism. When no modifier or maximum material condition is specified, true position tolerance applies only when the feature is at maximum material condition.

Specifying roundness. The tolerance governing the roundness of a feature is the difference in the diameter of two concentric circles between which the surface must lie. When roundness is measured on the surface, the total indicator reading corresponds roughly with the "out-of-roundness" on the diameter. When roundness is checked by rotating the part about its nominal center, the indicator reading indicates the out-of-roundness on the radius. Naturally, this tolerance measurement corresponds with one-half of the roundness tolerance.

The concept of free-state variation must be considered in specifying roundness tolerance. Free-state variation is the amount a part distorts after removal of external forces applied during manufacturing. A part is considered rigid (not subject to free-state variation) when it does not distort due to its own weight or flexibility, or when its structural forces are greater than those that can be exerted when the expected method of

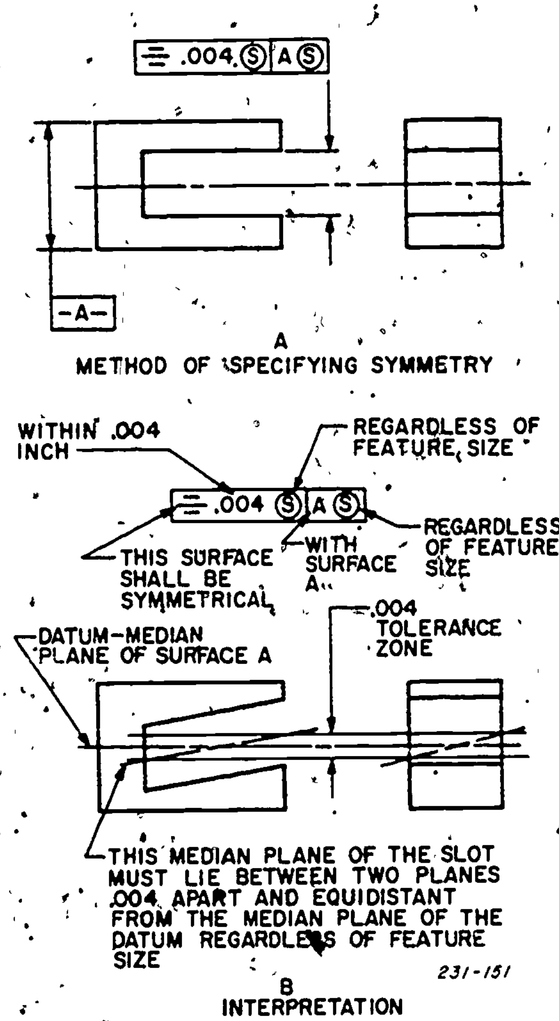


Figure 4-36. Method of specifying symmetry.

assembly is used. Part A of figure 4-34 shows the method of specifying roundness of such parts. Notice that the roundness symbol is blocked off with a vertical line to eliminate the possibility of misreading the symbol as part of the tolerance.

Part B of figure 4-34 shows the meaning of the roundness specification. As shown, the surface meets specifications when it lies entirely between two concentric circles which are 0.002 inch apart and have diameters somewhere between 0.595 and 0.600 inch.

For parts consisting essentially of shells with a thin wall thickness in proportion to the diameter, geometric tolerances (such as roundness and concentricity) cannot be properly applied without controlling free-state variation. The method of specifying roundness tolerance for this type of part is shown in part A of figure 4-35. Notice that the note includes the abbreviation "AVG DIA" (average diameter) and the phrase "IN FREE STATE."

An average diameter is the mean of several diameters (not less than four) across a circular or spherical part. It is used only to determine conformance to diameter tolerance. A diameter is labeled "AVG DIA" only when it is allowed a maximum roundness tolerance in the free state.

The average diameter of the part toleranced in part A of figure 4-35 may be anywhere between 0.598 and 0.600 inch. The two illustrations in part B give two interpretations of the meaning of the roundness specifications. The top illustration in part B shows the maximum allowable distortion of a suspended part in the maximum material condition. The bottom illustration shows the maximum allowable distortion of the part with minimum average diameter as if the part were resting on a flat surface.

Specifying symmetry. Part A of figure 4-36 shows the method of specifying symmetry. Symmetry is a condition in which a part or feature has the same contour on opposite sides of a control plane, or a condition in which a feature has a common plane with a datum feature.

Part B of figure 4-36 shows the interpretation of the symbols used to specify symmetrical tolerance. The tolerance governing the symmetry of a feature with respect to a datum is the distance between two parallel planes between which the control plane of the feature must lie. Of course, the parallel planes are parallel to and equally disposed about the control plane or the control axis of the datum feature.

Exercise (236):

1. What does the word "BASIC" mean when referring to a dimension?

ANSWERS FOR EXERCISES

Reference:

200 - 1. Chord.
200 - 2. A point.
200 - 3. A principle of plane geometry.

201 - 1. A straight line is produced by a point in motion in one direction for its entire length.
201 - 2. A curved line is produced by a point in motion changing direction along its entire length.
201 - 3. A plane is a flat surface generated by a straight line moving in a direction other than its length, creating an area with length and breadth but no thickness.

202 - 1. Adjacent angles.
202 - 2. *a, d, f, b, g, b.*
202 - 3. Figure 1

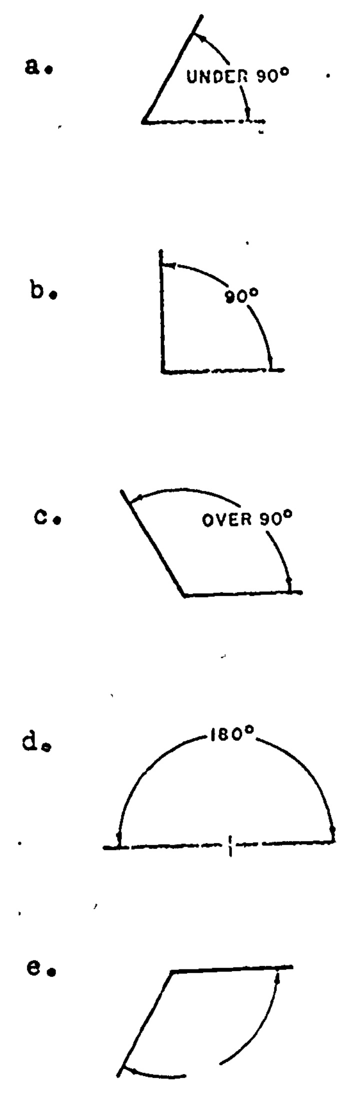


Figure 1. Answer for objective 202, exercise 3.

203 - 1.

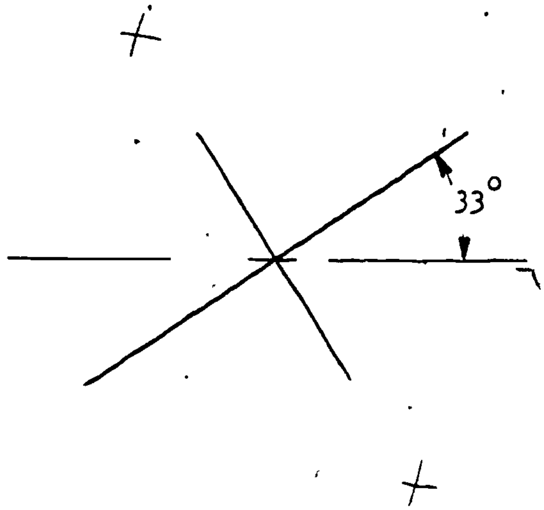


Figure 2. Answer for objective 203, exercise 1.

203 - 2.

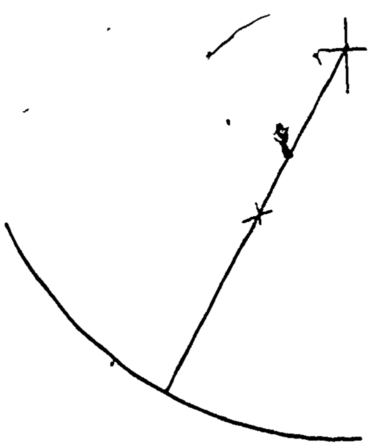


Figure 3. Answer for objective 203, exercise 2.

204 - 1. See text figure 1-9.
204 - 2. See text figure 1-12.

205 - 1. See text figure 1-13.
205 - 2. See text figure 1-14.

206 - 1. See text figure 1-15
206 - 2 See text figure 1-16.

207 - 1.

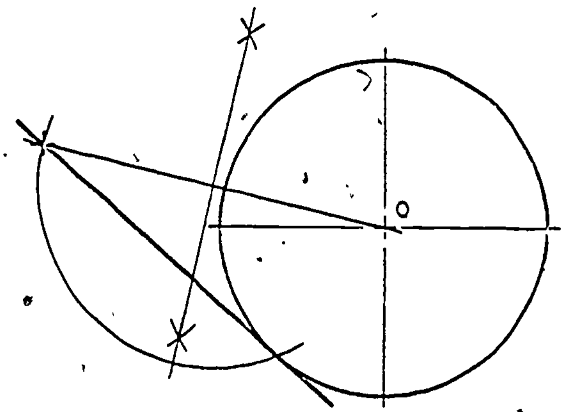
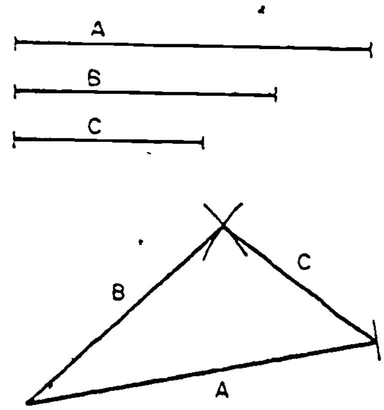


Figure 4. Answer for objective 207, exercise 1.

208 - 1. See text figure 1-18.
208 - 2. See text figure 1-19.

209 - 1.



ide B = 11/16 inch

ide C = 1 5/8 inch

Figure 5. Answer for objective 209, exercise 1.

209 - 2.

side c = 1 inch

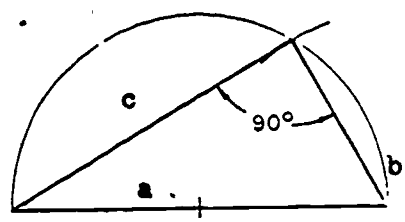


Figure 6. Answer for objective 209, exercise 2.

209 - 3. See text figure 1-23.

210 - 1. See text figure 1-24.

211 - 1. See text figure 1-26.
211 - 2. See text figure 1-27.

212 - 1. See text figure 1-30.

213 - 1. See text figure 1-31.
213 - 2. See text figure 1-32.

214 - 1. *a.* See text figure 1-33.
b.

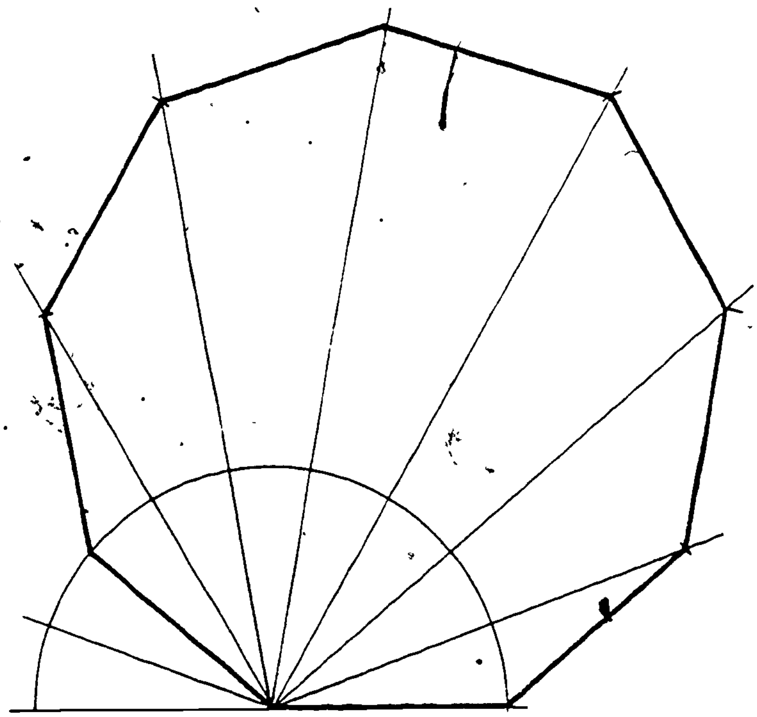


Figure 7. Answer for objective 214, exercise 2.

215 - 1. See text figure 1-34.
215 - 2. See text figure 1-35.
215 - 3. See text figure 1-36.
215 - 4. See text figure 1-37.
215 - 5. See text figure 1-38.
215 - 6. Foci, trammel, and concentric circle methods.

216 - 1. *a.* See text figure 1-39.
b. See text figure 1-40.
c. See text figure 1-41.

217 - 1. See text figure 1-42.
217 - 2. See text figure 1-43.

218 - 1. *a.* See text figure 1-44.
b. See text figure 1-45.
c. See text figure 1-46.

219 - 1. See text figure 1-48.
219 - 2. See text figure 1-47.

220 - 1. Parallel projections and central projections.

209

220 - 2. The side which shows best the contour or shape of the object.
220 - 3. When the glass box is open.

221 - 1. Six: front, top, right side, back, bottom, left side.
221 - 2. Three: front, top, right side.
221 - 3. Visible (or story) lines.

222 - 1. Half views should always be near a full view of a drawing.
222 - 2. Any view may accompany the front view, if each is equally descriptive.

223 - 1. Rounded intersections of surfaces of inside corners are known as fillets.
223 - 2. Rounded intersections of surfaces occur at outside edges and are called rounds.
223 - 3. An oblique surface is a nonparallel surface to any principal plane of projection.
223 - 4. Fillets and rounds are always shown to indicate corners of unfinished castings.

224 - 1. Vertical (or frontal plane), horizontal plane, and profile plane.
224 - 2. Third angle projection.

225 - 1. Isometric means equal measure.
225 - 2. The object is rotated 45° on its vertical axes.
225 - 3. 360°.
225 - 4. Trimetric.

226 - 1. All receding lines of the cabinet drawing are half the true length of the cavalier.
226 - 2. The ellipse is drawn by means of projections from the circle.
226 - 3. Line.

227 - 1. It is used to expose internal features of an object.
227 - 2. The arrows show the direction in which the cut surface, is viewed through the cutting plane.

228 - 1. Any appropriate angle may be used, depending upon the angular positions of the visible outlines.
228 - 2. Section lines in adjacent areas should not slope in the same direction since they can cause confusion.
228 - 3. The elimination of section lines on rivets, bolts, and screws gives better contrast and understanding to the illustration.

229 - 1. Exterior.
229 - 2. Hidden lines are always omitted unless they are necessary to clarify the view.
229 - 3. One-quarter of the object.
229 - 4. It is a full-sectional view obtained by bending the cutting plane to expose features which otherwise would not show.
229 - 5. It is used when only a part of a section view is required to show internal features, and external details are affected very little.
229 - 6. The scale must be shown.
229 - 7. Phantom section.

230 - 1. It is a variation from a true projection to make a drawing easier to read.
230 - 2. Top view.
230 - 3. The true radial distance of two holes can be shown.
230 - 4. It indicates that the length of the object is not drawn to scale
230 - 5. A break should be located at a point where the cross-sectional shape is constant

231 - 1. An auxiliary view is required when the true size and shape of a portion of an object are not shown in the regular top, front, or side view.
231 - 2. Yes, the auxiliary plane is rotated until it coincides with the front plane
231 - 3. Line; symmetry.

232 - 1. A distance on a drawing may be given either by a dimension or by a note
232 - 2. Extension lines, dimension lines, and leader lines.
 a. Extension lines are thin, solid lines that start about $^1/_{16}$" from the object and extend about $^1/_8$" beyond the last dimension line.
 b. Dimension lines are thin, solid lines terminated at each end by arrowheads and indicate the direction and extent of the dimension.
 c. A leader is a thin, straight line that begins at a dimension or note and terminates in an arrowhead at the point of reference.
232 - 3. An arrowhead is three times as long as it is wide.
232 - 4. A finish mark indicates that a certain surface must be changed by machining, drilling, filing, or grinding.

233 - 1. Size dimensioning involves the dimensions of height, width, and depth.
233 - 2. Prism.
233 - 3. A right cone is a conical-shaped object with the apex perpendicular to the base.
 A frustum of cone is a conical-shaped object with a portion of the top removed
 An oblique cone is a conical-shaped object with the apex angle other than 90
233 - 4. Location dimensioning involves dimensions that will position each form in relation to the other.
233 - 5. Dimensioning shapes that are considered standard features are circles and arcs, curves, angles, chamfers, tapers, holes, countersinks, counterbores, spotfaces, and rounded ends.

234 - 1. Clarity.
234 - 2. Dimensions should be placed between views whenever possible, outside the views if there is no room between views, on the views if all else fails.
234 - 3. a. Complete the shape description
 b Place the extension lines and extend the center line where necessary. Plan for the location of both size and location dimensions. Study the placement of each dimension and make alterations if desirable or necessary.
 c. Add the dimension lines.
 d Draw arrowheads and leaders for notes.
 e. Add dimension values.
 f. Letter notes.
234 - 4. Roughness is expressed as the arithmetic average deviation from the mean line of the surface profile.

235 - 1. Tolerancing or limit dimensioning is the variation allowed in manufacturing an object.

235 - 2. Unilateral tolerances are expressed by giving two limits; the tolerance applies only to one side and may be plus or minus but not both.

Bilateral tolerances are expressed by giving tolerances in two directions; the tolerance applies to both sides and are plus and minus on both sides.

236 - 1. "BASIC" or the abbreviation "BSC" to the right of, or beneath, each dimension establishes the true position.

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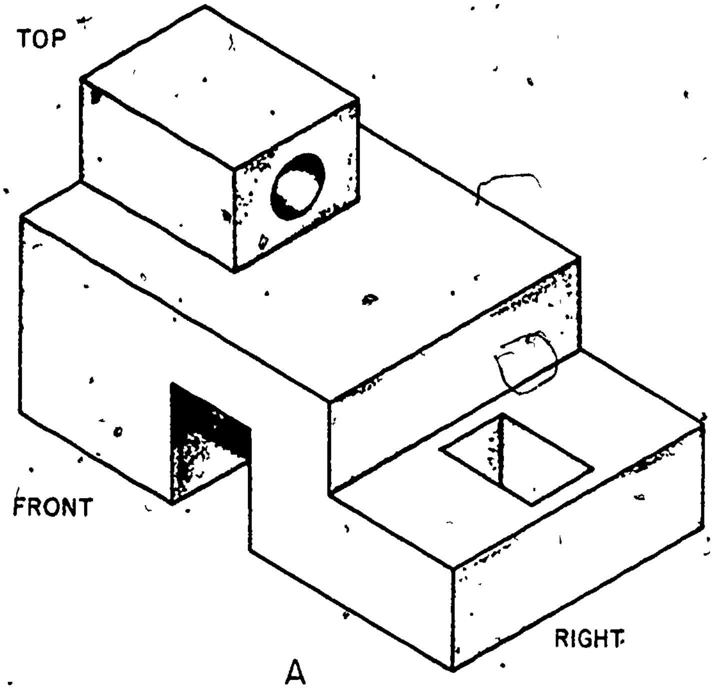
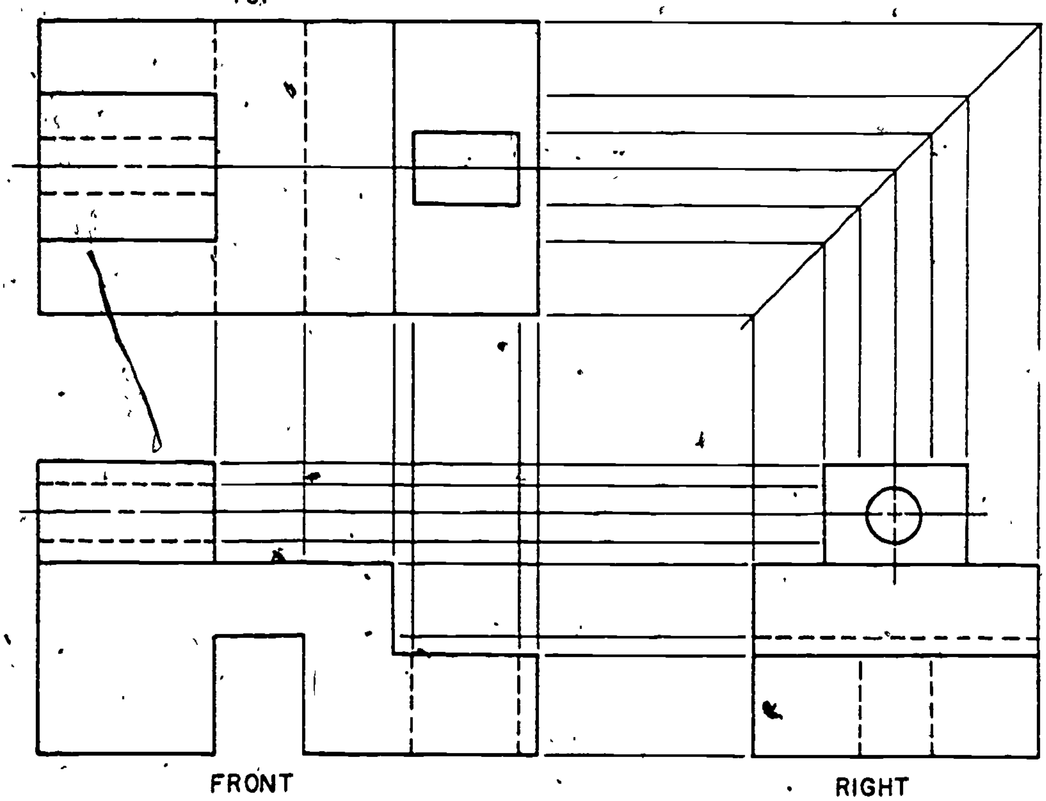
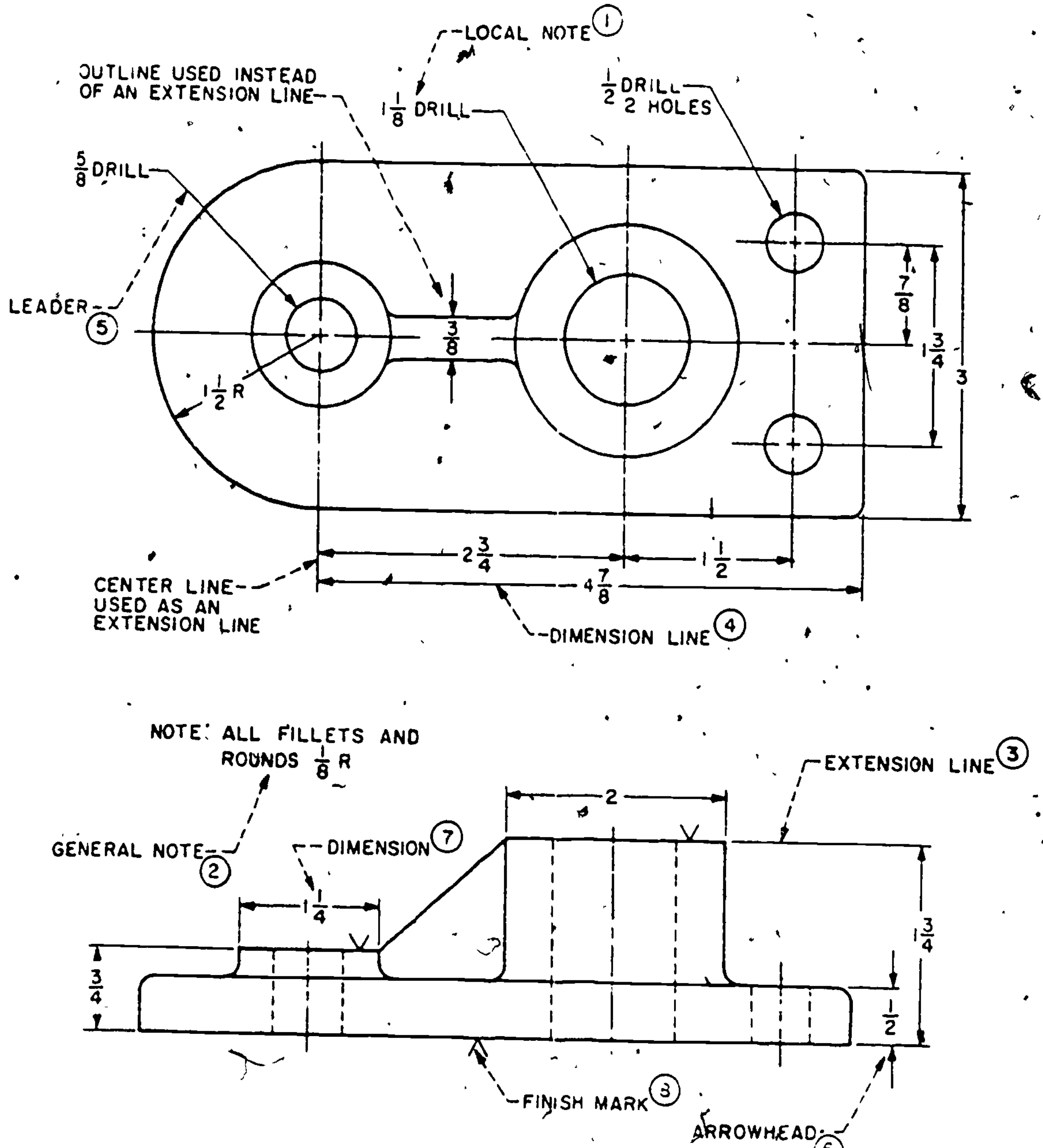


A

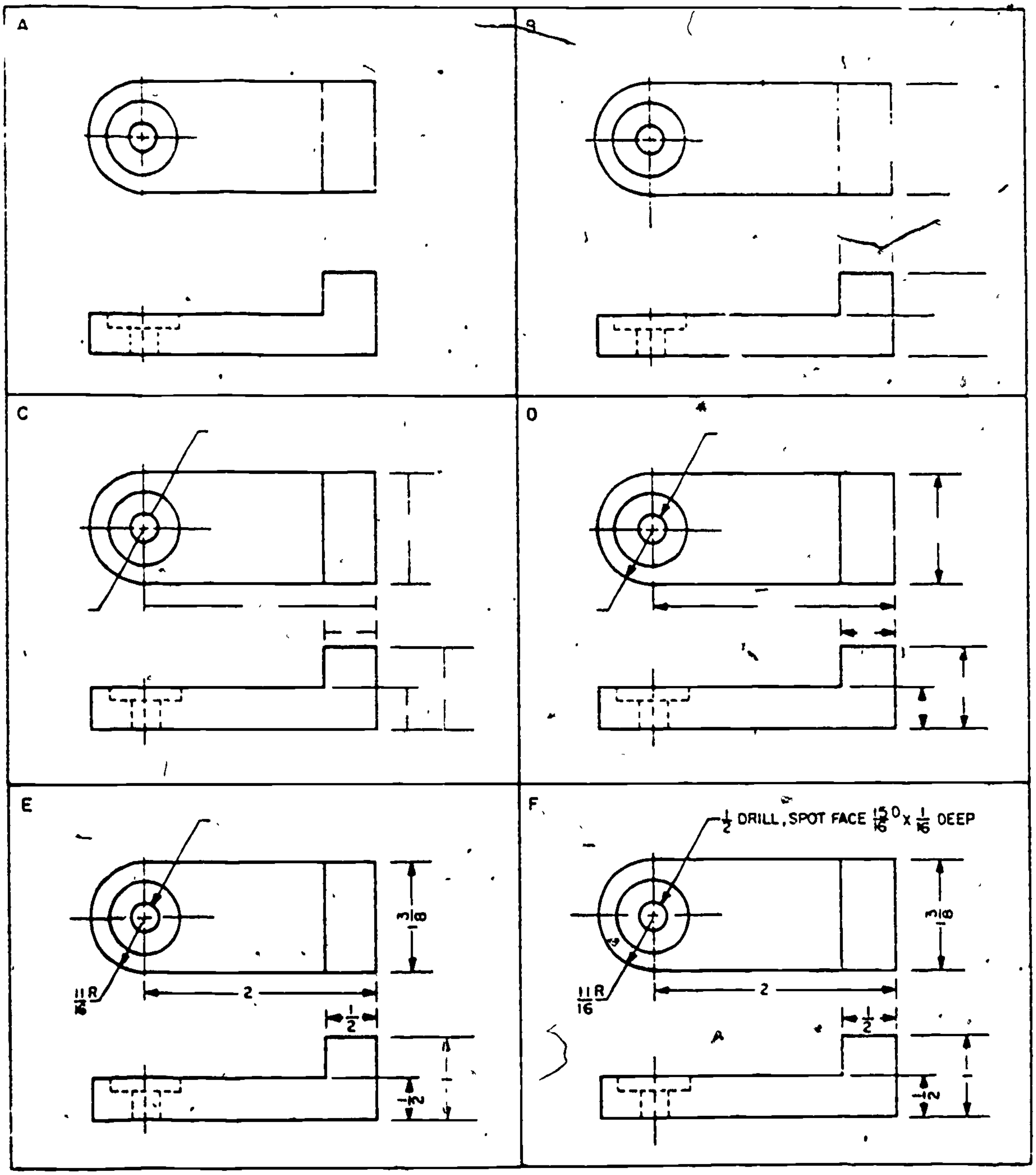


B

Foldout 1. Multiview projection.



Foldout 2. Order of dimensioning.



Foldout 2. Order of dimensioning.

214

STOP– 1. MATCH ANSWER SHEET TO THIS EXERCISE NUMBER. 2. USE NUMBER 1 OR NUMBER 2 PENCIL.

6-1

23151 02 21

EXTENSION COURSE INSTITUTE
VOLUME REVIEW EXERCISE

APPLIED BASIC DRAFTING TECHNIQUES (PART I)

Carefully read the following:

DO'S:

1. Check the "course," "volume," and "form" numbers from the answer sheet address tab against the "VRE answer sheet identification number" in the righthand column of the shipping list. If numbers do not match, take action to return the answer sheet and the shipping list to ECI immediately with a note of explanation.
2. Note that numerical sequence on answer sheet alternates across from column to column.
3. Use a medium sharp #1 or #2 black lead pencil for marking answer sheet.
4. Circle the correct answer in this test booklet. After you are sure of your answers, transfer them to the answer sheet. If you *have* to change an answer on the answer sheet, be sure that the erasure is complete. Use a clean eraser. But try to avoid any erasure on the answer sheet if at all possible.
5. Take action to return entire answer sheet to ECI.
6. Keep Volume Review Exercise booklet for review and reference.
7. If *mandatorily* enrolled student, process questions or comments through your unit trainer or OJT supervisor.
   If *voluntarily* enrolled student, send questions or comments to ECI on ECI Form 17.

DON'TS:

1. Don't use answer sheets other than one furnished specifically for each review exercise.
2. Don't mark on the answer sheet except to fill in marking blocks. Double marks or excessive markings which overflow marking blocks will register as errors.
3. Don't fold, spindle, staple, tape, or mutilate the answer sheet.
4. Don't use ink or any marking other than a #1 or #2 black lead pencil.

NOTE: NUMBERED LEARNING OBJECTIVE REFERENCES ARE USED ON THE VOLUME REVIEW EXERCISE. In parenthesis after each item number on the VRE is the *Learning Objective Number* where the answer to that item can be located. When answering the items on the VRE, refer to the *Learning Objectives* indicated by these *Numbers*. The VRE results will be sent to you on a postcard which will list the *actual VRE items you missed*. Go to the VRE booklet and locate the *Learning Objective Numbers* for the items missed. Go to the text and carefully review the areas covered by these references. Review the entire VRE again before you take the closed-book Course Examination.

Note to Student. This Volume Review Exercise contains 67 four-option items and 1 three-option item.

Multiple Choice

1. (200) A plane curve, the path of a point the sum of whose distances [illegible] the foci (two fixed points) is constant; a conic section, the closed intersection of a plane with a right circular cone perpendicular to its side, describes

   a. a helix.
   b. an ellipse.
   c. eccentric circles.
   d. concentric circles.

2. (200) When two circles are tangent to each other, the straight line joining their centers passes through

   a. the major axis.
   b. the minor axis.
   c. the point of tangency.
   d. parallel lines.

3. (201) Which of the following statements about the relationship of line is not correct?

   a. A line is an imaginary geometric figure.
   b. A line does exist in nature.
   c. A line is generated by a point in motion.
   d. A line that has the same direction for its entire length is a straight line.

4. (201) A line that changes in direction along its entire length is a

   a. curved line.
   b. broken line.
   c. straight line.
   d. helix.

5. (201) A flat surface that is generated by a straight line moving in a direction other than its length is a

   a. curved line.
   b. cylinder.
   c. prism.
   d. plane.

6. (202) When two straight lines meet at a point, which of the following figures is formed?

   a. A rhombus.
   b. An angle.
   c. A prism.
   d. A triangle.

7. (202) A plane figure bound by three straight sides is a

   a. rectangle.
   b. trapezoid.
   c. pentagon.
   d. triangle.

8. (203) Which one of the following statements about bisecting a straight line by the T-square and triangular method is correct?

   a. Points are located on each side of the line, and then the bisector connecting them is drawn.
   b. Either a 45° triangle or a 30°-60° triangle may be used.
   c. Two drafting triangles are required.
   d. The bisector is not perpendicular to the bisected line.

9. (203) Which one of the following statements about the procedure for bisecting a line with a compass is entirely correct?

   a. The compass should be set to a radius greater than the length of the line.
   b. The compass should be set to a radius less than one-half the length of the line.
   c. Two pairs of intersecting arcs are required.
   d. When one set of intersecting arcs is drawn, the radius of the compass may be changed slightly to draw the other set, if desired.

10. (204) A line can be drawn parallel to a given curved line at a given distance by

   a. striking a series of arcs of the given radius with centers selected at random on the given curve, and then drawing tangents to the arcs with an irregular curve.
   b. placing the irregular curve in a position which coincides with the given curve at the given distance, and then drawing the parallel curve.
   c. erecting perpendiculars from the given curved line to establish points for drawing the parallel curve with the irregular curve.
   d. establishing given radius points with a scale, and then using the irregular curve to complete the parallel curve.

11. (204) Curved parallel lines can only be drawn by

   a. trial and error.
   b. the hypotenuse method.
   c. geometric construction.
   d. the pin-and-string method.

12. (205) Dividing a given straight line into a number of equal parts requires that

   a. a corresponding number of equally spaced parallel lines be drawn to the given line from an angular construction line of any appropriate length.
   b. twice the number of equally spaced parallel lines be drawn to the given line from an angular construction line of any appropriate length.
   c. a corresponding number of equally spaced parallel lines be drawn to the given line from an angular construction line which is the same length as the given line.
   d. a corresponding number of equally spaced perpendiculars be constructed from an angular construction line to the given line.

13. (206) Which one of the following statements is correct when constructing a line tangent to a circle at a point?

   a. A tangent to a circle is perpendicular to a radius at the point of tangency.
   b. A tangent to a circle is never perpendicular to a radius at the point of tangency.
   c. A line tangent to a circle is only perpendicular to a radius when using a 45° triangle.
   d. A line tangent to a circle is sometimes (but not always) perpendicular to a radius at the point of tangency.

14. (206) When a tangent to a circle is drawn by means of triangles, the

   a. triangles must be a 30°-60° triangle.
   b. tangent is perpendicular to a radius of the circle.
   c. tangent is not perpendicular to a radius of the circle.
   d. triangle must be a 45° triangle.

15. (207) To draw a tangent to a circle through a point outside the circle, the point must be

   a. measured from the circle.
   b. given.
   c. parallel to the 90° line.
   d. 270° from 0° on the circle.

16. (207) When drawing a tangent to a circle through a point outside the circle using the Draftsman's method, one must

   a. use the divider to stop off the point.
   b. place a triangle 90° from the center of the circle and the point.
   c. place a triangle so that one side passes through the point and is tangent to the circle.
   d. draw the tangent and then establish the point.

17. (208) When drawing an arc tangent to a straight line and an arc or a circle, the first step is to

   a. take the given radii 1 and 2 and strike an arc from the center of the circle. or arc.
   b. draw a line parallel to the given line.
   c. draw a line parallel to the given line halfway between the circle and the given line.
   d. adjust the compass to a distance equal to twice the distance of R_1.

18. (209) Which type of triangle can be constructed by drawing a semicircle?

   a. Isosceles.
   b. Acute.
   c. Equilateral.
   d. Right.

19. (209) When all three sides of a triangle are given, how many arcs are required to construct a triangle?

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

20. (210) The procedure for constructing a regular polygon with two sets of parallel lines could be the construction of

   a. a pentagon.
   b. an octagon.
   c. a hexagon.
   d. a square.

21. (211) When a pentagon is to be inscribed within a given circle, what determines the dimensions of the pentagon?

   a. The length of the diameter of the circle.
   b. The length of a tangent to the circle.
   c. The sum of the degrees of the internal angles of the pentagon.
   d. The intersection point of the perpendicular bisectors of the chords.

22. (211) When you are constructing a regular pentagon with length of one side given and the semicircle drawn, what instrument is used to divide the semicircle into five equal parts by trial and error?

   a. Dividers.
   b. Scales.
   c. Protractor.
   d. Triangles.

23. (212) When you are constructing a hexagon that is not inscribed in or circumscribed about a circle, you must use the across corner method

   a. with a compass.
   b. with a 30°-60° triangle.
   c. using a T-square only.
   d. using a 45° triangle.

24. (212) Which of the following is the first step in constructing a regular hexagon with width across flats given?

a. Draw a circle with a line whose length is the same as the width across the flats as the diameter.
b. Draw a circle with any distance as a diameter.
c. Draw the vertical and horizontal center lines.
d. Draw two construction lines making a 30° angle with line AB.

25. (213) Which one of the following procedures is correct for constructing a regular octagon with distance across corners known?

a. A circle with its radius equal to the distance across the corners is drawn. The diametrical lines are drawn to divide the circle into eight equal parts by means of a 45° triangle.
b. A circle with its diameter equal to the distance across the corners is drawn. Then diametrical lines are drawn to divide the circle into four equal parts by means of a 45° triangle.
c. A circle with its diameter equal to the distance across the corners is drawn. Then diametrical lines are drawn to divide the circle into eight equal parts by using a 30°-60° triangle.
d. A square with its sides equal to the distance across the corners is drawn. Then diagonals are drawn to divide the square into eight equal parts.

26. (213) The two methods for constructing a regular octagon are described as using the width across flats and the width across corners. What is meant by flats?

a. The distances measured from one flat surface to another parallel flat surface.
b. Any surface of an octagon.
c. The distances measured from any corner.
d. The distances measured from the center.

27. (214) When drawing a regular polygon, you should always divide the semicircle into

a. one less division than needed.
b. one more division than needed.
c. the same number of divisions as sides.
d. two less divisions than needed.

28. (215) When you are drawing an ellipse using the foci method, the focus points are located by using a compass radius equal to

a. the major axis minus one-half the minor axis.
b. the major axis minus the minor axis.
c. one-half the major axis.
d. one-half the minor axis.

29. (215) Which of the following methods will only result in an approximate ellipse?

a. Pin-and-string method.
b. Trammel method.
c. Foci method.
d. Concentric-circle method.

30. (216) When you are constructing a parabola by the focus method, the vertex of the parabola is established by

a. bisecting the distance between the directrix and the focus point.
b. using one-fourth the length of the parabola's major axis.
c. the length of the directrix.
d. the intersection of the parabola with its axis.

31. (216) To construct a parabola by the intersection method, what dimensions are given?

    a. The rise and two points on the parabola.
    b. Two points on the parabola.
    c. One point on the parabola and the span.
    d. The rise and span.

32. (217) To construct a hyperbola by the foci method, what dimensions must be given?

    a. The foci and a point on the hyperbola.
    b. The length of the transverse axis and two points on the hyperbola.
    c. The vertices and the foci.
    d. The length of the transverse axis and the foci.

33. (217) To construct a hyperbola by the intersection method, what information must be given?

    a. The vertex and one given point on the hyperbolic curve.
    b. Four symmetrically placed points on the hyperbolic curve.
    c. The vertex and two symmetrically placed points on the curve.
    d. The shape of the parabolic curve.

34. (218) What geometric figure is a spiral curve made as if by a point on a perfectly taut string as it unwinds from around any object or itself?

    a. An irregular polygon.
    b. An involute.
    c. An ellipse.
    d. A hyperbola.

35. (218) For which one of the following drawings may a circle be regarded as a polygon having an infinite number of sides?

    a. An irregular polygon.
    b. An ellipse.
    c. An involute of a circle.
    d. A hyperbola.

36. (219) What is a curve generated by a point on the circumference of a circle which rolls along a straight line?

    a. Hyperbola.
    b. Parabola.
    c. Cycloid.
    d. Ellipse.

37. (219) What is a spiral of Archimedes and how is it often used?

    a. It is a figure generated by a point moving around a fixed point in a manner that the distance from the pole increases uniformly with the angle. It is used often in cam design.
    b. It is the figure generated by the end of a piece of string as the string is unwound from a circle. It is often used in cam design.
    c. It is a figure generated by a point moving around a fixed point in a manner that the distance from the pole increases uniformly with the angle. It is often used to outline gear teeth.
    d. It is the figure which results from winding a piece of string uniformly around a cylinder. It is used in cam design.

38. (220) Any projection made by lines of sight which are perpendicular to the image plane is

    a. a central projection.
    b. an orthographic projection.
    c. an oblique projection.
    d. a trimetric projection.

39. (220) When the glass box is opened, how do the views appear on paper when they coincide with the front plane?

   a. The front view, top view, and right-side view are in the same vertical line.
   b. The front view, right-side view, and back view are in the same horizontal line.
   c. The front view, top view, and bottom view are in the same horizontal line.
   d. All views lie in the same line when they coincide with the front plane.

40. (221) The basic purpose of all multiview projections is to show .

   a. the approximate size of the object being represented.
   b. the approximate size and shape of the object being represented.
   c. all six views of the object being represented.
   d. the true size and shape of the object being represented.

41. (221) Which views are necessary in most multiview drawings?

   a. Back, front, and top views.
   b. Front, right-side, and top views.
   c. Front, left-side, and bottom views.
   d. All six views.

42. (222) A half view of a drawing should always be the portion

   a. showing the most detail of the drawing.
   b. nearest to the other half of the drawing.
   c. nearest to the full view of the drawing.
   d. nearest to the top view of the drawing.

43. (222) Why is it permissible to draw a right-side view of the top of an object as opposed to the conventional three-view method?

   a. It appears to give better balance to the page and achieves the same purpose.
   b. It leaves large open areas.
   c. It appears to give better balance, but leaves large open areas.
   d. It has no particular advantage over the conventional method.

44. (223) When a surface is at an acute or obtuse angle to all parallel or principal planes of projection, it is said to be

   a. a right angle.
   b. an oblique surface.
   c. an auxiliary surface.
   d. an auxiliary angle.

45. (224) In what type of projection is the image plane between the observer and one face of the object?

   a. First angle projection.
   b. Oblique projection.
   c. Third angle projection.
   d. Central projection.

46. (224) When the right-side view is projected with the object between the observer and the profile plane, the type of projection is .

   a. first angle.
   b. oblique.
   c. third angle.
   d. central.

47. (225) In which of the following types of projection would each angle formed by the axonometric axes equal 120°?

   a. Perspective projection.
   b. Trimetric projection.
   c. Isometric projection.
   d. Dimetric projection.

48. (225) What method is used to draw nonisometric lines in an isometric drawing?

a. Coordinate.
b. Orthographic projection.
c. Nonisometric projection.
d. Drawing parallel projection.

49. (226) In a cabinet drawing, which dimensions are one-half those of a cavalier drawing?

a. All dimensions.
b. Only the vertical lines.
c. Only the horizontal lines.
d. Only the receding lines.

50. (226) In what way is the oblique box construction similar to the isometric box?

a. In both constructions the boxes can be completed by using parallel lines.
b. The front view is parallel with the image plane in both constructions.
c. In neither construction can receding edges be shown in true length.
d. The three major axes in each construction make similar angles with the image plane.

51. (227) What is the effect of passing a cutting plane through an object?

a. Solid outlines are eliminated.
b. The portion of the object behind the plane is removed.
c. Internal features can be viewed through the plane.
d. The need for an orthographic view is eliminated.

52. (227) What are the three types of cutting planes?

a. Full section, half section, and quarter section.
b. Full section, removed section, and quarter section.
c. Full section, offset section, and half section.
d. Full section, offset section, and quarter section.

53. (229) Which of the following options is correct about hidden lines in a half-sectional view?

a. Hidden lines should never be shown on a half section for dimensioning purposes.
b. If hidden lines are required for dimensioning, they should be shown.
c. If hidden lines are required, they should be dimensioned on a full view.

54. (229) An offset section is a

a. section set aside from the main drawing.
b. partial section of the drawing.
c. full-section view, bending the outlying plane to expose features which otherwise would not show.
d. half-sectional view, bending the cutting plane to expose features which otherwise would not show.

55. (230) Conventional violations are

a. drawings that are altered for more artistic presentation.
b. any approved variation from true projection, simplifying without sacrificing accuracy.
c. drawings that are not altered in any way.
d. removed sections enlarged so that the information contained within is shown in detail.

56. (230) Is the conventional method of showing a spoke revolved in a sectional view misleading? Why?

   a. No, because the actual position of the spoke is shown in the front view.
   b. Yes, because the actual position of the spoke is not as it is shown in the front view.
   c. Yes, because the sectional view is misleading.
   d. Yes, because the sectional view exposes more than one spoke.

57. (231) Which statement about a primary auxiliary view is true?

   a. It is not used as a partial view.
   b. It is used to show how the entire object appears.
   c. It is projected from a principal view in which an inclined surface appears as a line.
   d. It is projected from a principal view in which an inclined surface appears foreshortened.

58. (231) What determines the slope and length of the reference line in an auxiliary view of a nonsymmetrical object?

   a. The slope and length are determined by measurements obtained from the plan view.
   b. The slope is obtained from the front view and the length is obtained by measurement of the plan view.
   c. The slope and length of the reference line are the same as the inclined surface in the front view.
   d. The reference line may be drawn at any angle with the horizontal and its length equal to the inclined surface.

59. (232) What kind of lines are the thin solid lines placed on a drawing for dimensioning purposes?

   a. Center lines, extension lines, and leader lines.
   b. Dimension lines, center lines, and extension lines.
   c. Extension lines, dimension lines, and center lines.
   d. Extension lines, dimension lines, and leader lines.

60. (232) The length of the arrowhead with curved sides is how many times the width?

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

61. (232) A finish mark indicates that

   a. the surface of that metal part must be finished in some manner.
   b. the surface of that metal part is not to be finished.
   c. all metal surfaces are finished.
   d. all metal surfaces are to be finished.

62. (233) Since every solid object has three dimensions (height, width, and depth), dimensioning these distances is called

   a. location dimensions.
   b. size dimensions.
   c. standard dimensions.
   d. regular dimensions.

63. (233) For dimensioning purposes, circles, arcs, angles, chamfers, tapers, holes, countersinks, counterbores, spotfaces, and rounded ends are considered

   a. special features.
   b. essential features.
   c. standard features.
   d. regular features.

64. (234) When dimensioning basic geometric forms, dimensions should be

a. placed between views whenever possible.
b. placed on the views whenever possible.
c. duplicated whenever possible.
d. placed to the right on all views.

65. (234) When space for dimensioning is limited, what arrangements are usually used for placing the dimensions?

a. Leave some of the dimensions off.
b. Leave all the dimensions off.
c. A staggered arrangement is used.
d. Only dimension the front view.

66. (235) The space between two mating parts is the

a. tolerance limit.
b. allowance.
c. interference.
d. clearance.

67. (235) The variation, positive or negative, by which a size is permitted to depart from the design or preferred size is called

a. tolerance limit.
b. unilateral tolerancing.
c. interference.
d. clearance.

68. (235) When extreme accuracy is an important factor in tolerancing a group of consecutive dimensions, which type of tolerancing should you use?

a. Cumulative.
b. Noncumulative.
c. Bilateral.
d. Unilateral.

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GRAPHICS SPECIALIST

(AFSC 23151)

Volume 3

Applied Basic Drafting Techniques (Part II)

Extension Course Institute

Air University

Preface

THIS VOLUME is a continuation of the previous volume, *Applied Basic Drafting Technique (Part I)*. In this volume (Part II), machine drafting involves the drafting or drawing practices and conventions which have been developed for the field of mechanical engineering and for those jobs which are done in the shops and factories. These practices are presented through the study of fasteners, intersections and developments, and structural drawings. When this information is combined with the previous information of the other volumes, you should be able to make satisfactory engineering drawing of machine details and assemblies.

If you have questions on the accuracy or currency of the subject matter of the text, or recommendations for its improvement, send them to Tech Tng Cen/TTOC, Lowry AFB CO 80230. NOTE: Do not use the suggestion program to submit corrections for typographical or other errors.

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This volume is valued at 24 hours (8 points).

Material in this volume is technically accurate, adequate, and current as of February 1975.

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NOTE: In this volume, the subject matter is developed by a series of Learning Objectives. Each of these carries a 3-digit number and is in boldface type. Each sets a learning goal for you. The text that follows the objective gives you the information you need to reach that goal. The exercises following the information give you a check on your achievement. When you complete them, see if your answers match those in the back of this volume. If your response to an exercise is incorrect, review the objective and its text.

Machine Drawings

WHEN A COMPLEX piece of machinery is to be made, whether it will be produced as a single unit or in quantity, the problems involved are worked out on a drawing board. First the design drawing is made from sketches, then detail drawings of each part are made from this design drawing. Finally, an assembly drawing is drawn to show how the machine is assembled. Often a mistake in a detail drawing shows up on the assembly drawing—thus an assembly serves as a check on the earlier work.

The detail and assembly drawings of a piece of machinery comprise the working drawings from which the machine is made. Design and display drawings are intended for other purposes.

A working drawing tells what manufacturing processes and materials are used, and how the different parts are assembled and finished, as well as dimensioned.

You must be thoroughly familiar with the different types of fasteners used in the making and assembling of different unit parts. In addition to knowing their design and use, you must know how to draw them. The simplest type of fasteners such as nails and wood screws are seldom shown on a working drawing. On the other hand, bolts, structural screws, and threaded parts are always drawn and identified according to an approved practice. They may be drawn as true projections or represented as symbols. In some industries it is permissible to omit the outline view of fasteners and just specify their location, type, and size by notes. However, where there is a chance for misunderstanding, a detailed drawing of the part should be drawn. This is especial true in detail drawings where threaded parts are used as fasteners, in parts designed to transmit motion, and in parts serving as adjusting mechanisms.

1-1. Fasteners

In manufacturing or putting together any large structural assembly, there are various ways to fasten parts together. The fastener must be suited to the materials being fastened together. Because of the importance of fasteners in structural assembly, the graphic specialist needs to have a thorough understanding of different fastening processes.

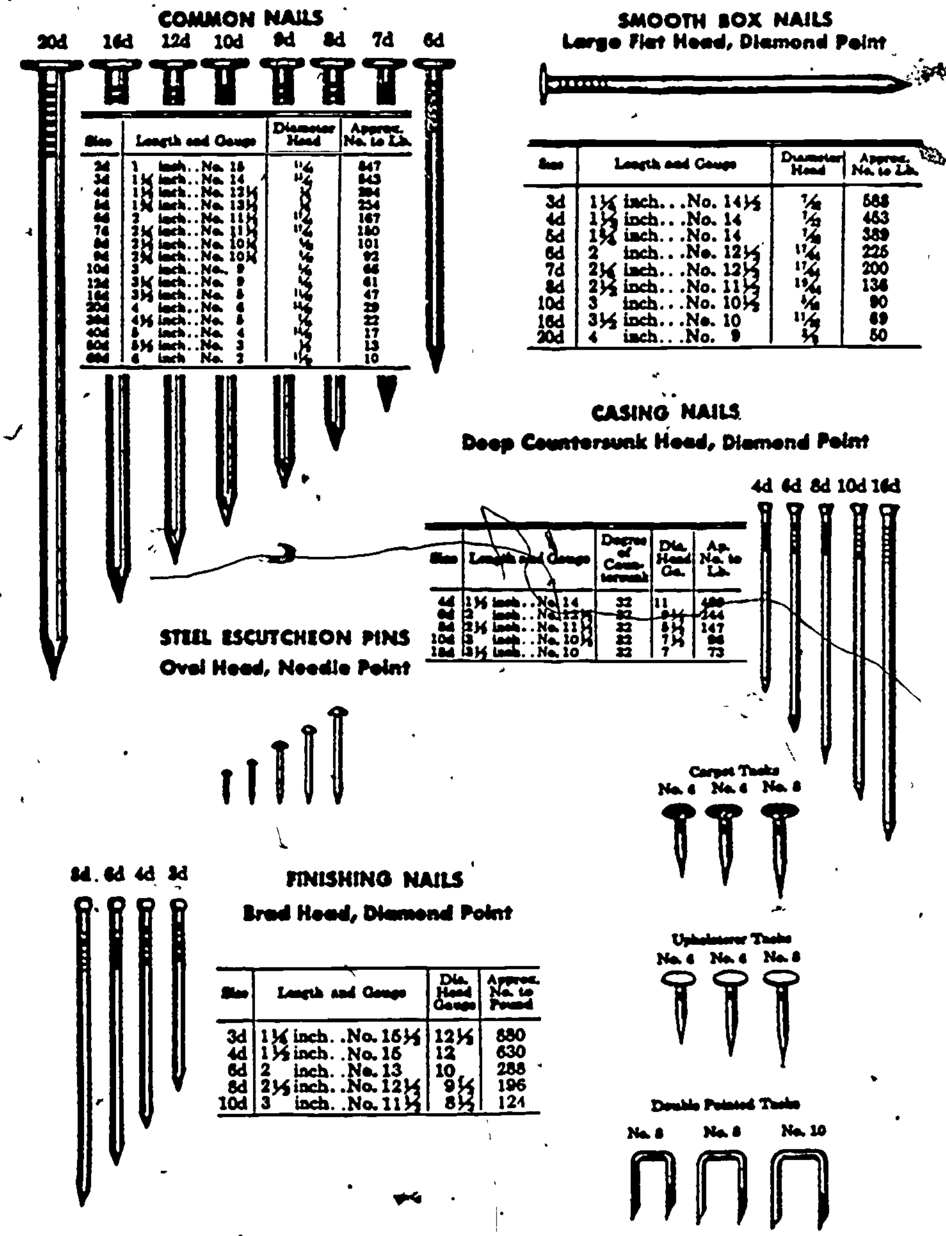
400. Name four fasteners from each of the two main types of fasteners and complete sentences relating to the different types of nails.

All fasteners are classified into two main groups. One group includes fasteners of a permanent nature. Permanent fasteners are nails, rivets, wood screws, and welding.

The second group of fasteners are those permitting parts to be disassembled and re-assembled whenever necessary. Such devices as pins, keys, cap screws, set screws, machine screws, and bolts make up this category.

Nails are classified in these categories—common, box, casing, finishing and tacks. (See fig. 1-1.) Nails are sized according to weight and are designated by the term *penny* or *penny weight*. (Symbol: d). The term penny refers to the weight per thousand. Thus a 10d nail means that there are ten pounds by weight per thousand nails, a direct weight to size relationship.

Common nails are—as the term common implies—the most frequently used. They are larger in diameter with wider heads and are used mostly for rough carpentry work. *Box nails*, like common nails, have the wide head, but a thin or smaller diameter. They are used extensively in box



COMMON NAILS

Size	Length and Gauge	Diameter Head	Approx. No. to Lb.
2d	1 inch..No. 15	[illegible]	847
3d	1¼ inch..No. 14	[illegible]	543
4d	1½ inch..No. 12½	[illegible]	294
5d	1¾ inch..No. 12½	[illegible]	254
6d	2 inch..No. 11½	[illegible]	167
7d	2¼ inch..No. 11½	[illegible]	150
8d	2½ inch..No. 10¼	[illegible]	101
9d	2¾ inch..No. 10¼	[illegible]	92
10d	3 inch..No. 9	[illegible]	66
12d	3¼ inch..No. 9	[illegible]	61
16d	3½ inch..No. 8	[illegible]	47
20d	4 inch..No. 6	[illegible]	29
30d	4½ inch..No. 5	[illegible]	22
40d	5 inch..No. 4	[illegible]	17
50d	5½ inch..No. 3	[illegible]	13
60d	6 inch No. 2	[illegible]	10

SMOOTH BOX NAILS
Large Flat Head, Diamond Point

Size	Length and Gauge	Diameter Head	Approx. No. to Lb.
3d	1¼ inch...No. 14½	7/32	588
4d	1½ inch...No. 14	7/32	453
5d	1¾ inch...No. 14	7/32	389
6d	2 inch...No. 12½	17/64	225
7d	2¼ inch...No. 12½	17/64	200
8d	2½ inch...No. 11½	19/64	136
10d	3 inch...No. 10½	5/16	90
16d	3½ inch...No. 10	11/32	69
20d	4 inch...No. 9	3/8	50

CASING NAILS
Deep Countersunk Head, Diamond Point

Size	Length and Gauge	Degree of Countersunk	Dia. Head Ga.	Ap. No. to Lb.
4d	1½ inch..No. 14	32	11	[illegible]
6d	2 inch..No. 12½	32	9½	244
8d	2½ inch..No. 11½	32	8½	147
10d	3 inch..No. 10½	32	7½	[illegible]
16d	3½ inch..No. 10	32	7	73

FINISHING NAILS
Brad Head, Diamond Point

Size	Length and Gauge	Dia. Head Gauge	Approx. No. to Pound
3d	1¼ inch..No. 15½	12½	880
4d	1½ inch..No. 15	12	630
6d	2 inch..No. 13	10	288
8d	2½ inch..No. 12½	9½	196
10d	3 inch..No. 11½	8½	124

Figure 1-1. Common fasteners.

construction or any situation requiring two end pieces to be joined and where a common nail would be unsuitable.

Casing nails have smaller head size and diameter than the box nails and are designed especially for blind nailing. Blind nailing is used in the finishing of flooring, ceilings, and cabinet work where large heads are undesirable. *Finishing nails* have the smallest diameter and head. These nails are used mainly for cabinet work and furniture construction where it is often necessary to sink the nail head below the material surface. *Brads* are also finishing nails. These smallest type of finishing nails are sized by the length in inches and the gage number of the wire. The higher the gage number, the smaller the diameter.

Tacks are used mostly for fastening through materials to wooden or other framing and holding surfaces. Sizes of tacks and their length are indicated by the gage number. When illustrating nails, brads, and tacks, a note on the drawing is indicated such as:

6d—FINISHING NAIL
1"—NO 18 BRAD
No 4—UPHOLSTERING TACK

Exercises (400):

1. Name four permanent fasteners and four fasteners which permit parts to be disassembled and re-assembled whenever necessary.

2. The term ______ refers to the weight per thousand of nails.

3. A nail designed especially for blind nailing is the ____ ______.

4. When a nail has a large head and shaft, it is often referred to as a ______.

5. The smallest type of finishing nail is called a ____.

1-2. Screw Threads

A screw thread is a ridge in the form of a helix on the external or internal surface of a cylinder, cone, or a frustrum of a cone. The threads formed on a cylinder are *straight* or *parallel* threads, as distinguished from the *taper thread* which is formed on a cone or frustrum of a cone.

Threads have three basic purposes: to fasten, to adjust, and to transmit power.

401. Match selected definitions and thread terms relating to types of screw thread.

The Helix. There are very few machines or structures that do not have a helix somewhere in their makeup, either as a screw thread or a coil spring. The helix is a double-curved line generated by a point moving around an axis and parallel to that axis at the same time. If the point remains a fixed distance from the axis, a cylindrical helix is generated since the point is traveling around the surface of a cylinder. If the point moves on the surface of a cone so that it revolves around the axis as it travels toward the vertex of the cone, it generates a conical helix. An example of a conical helix is a conical spring.

Figure 1-2 shows the top and front view of a cylindrical helix which is generated by a point starting from A and traveling gradually up and around the surface of the cylinder. While the point travels around the cylinder once, it moves the distance L parallel to the axis of the cylinder. The distance L is called the lead or pitch of the helix. To draw a cylindrical helix, the top view is divided into equal parts, and the pitch or lead is divided into the same number of equal parts. The movement of the point is uniform. When the point moves from 1 to 2 in the circular top view, it will also move parallel to the axis in the front view from 1 to 2. The front view of the helix can, therefore, be drawn by projection as indicated in figure 1-2.

Although helical curves are usually represented by straight lines, the true projection of a helix may be used in the construction of thread drawings. However, true projection is difficult and takes considerable time. Still, threads may be drawn in true projection for display drawings or when the scale of the drawing is such that large diameter threads look distorted when drawn with straight lines. In such cases, one thread is drawn by projection, and then the remaining helical curves are drawn by using a template cut to fit the projected curve.

Thread Terms. Basic screw thread terminology is given in figure 1-3. The terms given are defined as follows:

a. Major diameter—the largest diameter of the screw thread.

b. Minor diameter—the smallest diameter of the screw thread, sometimes called the "root diameter."

c. Pitch diameter—the distance between two imaginary lines, one drawn through the threads on one side of the screw and the other line drawn on the opposite side. These two imaginary lines would divide the threads so that the width of each thread is equal to the space between threads measured on this line.

d. Lead—the distance a screw moves along its axis during one complete turn.

e. Pitch—the distance from any point on a thread to the corresponding point on an adjacent thread, measured parallel to the axis.

f. Helix angle—the angle the helix makes with a plane perpendicular to the axis of the screw.

g. Thread angle—the angle between the sides of adjacent threads.

h. Root—the bottom surface joining the sides of adjacent threads.

i. Crest—the top surface joining the two sides of a thread.

j. External thread—a thread which is a ridge of uniform shape in the form of a helix, on the outside of a part.

k. Internal thread—a thread on the inside of a

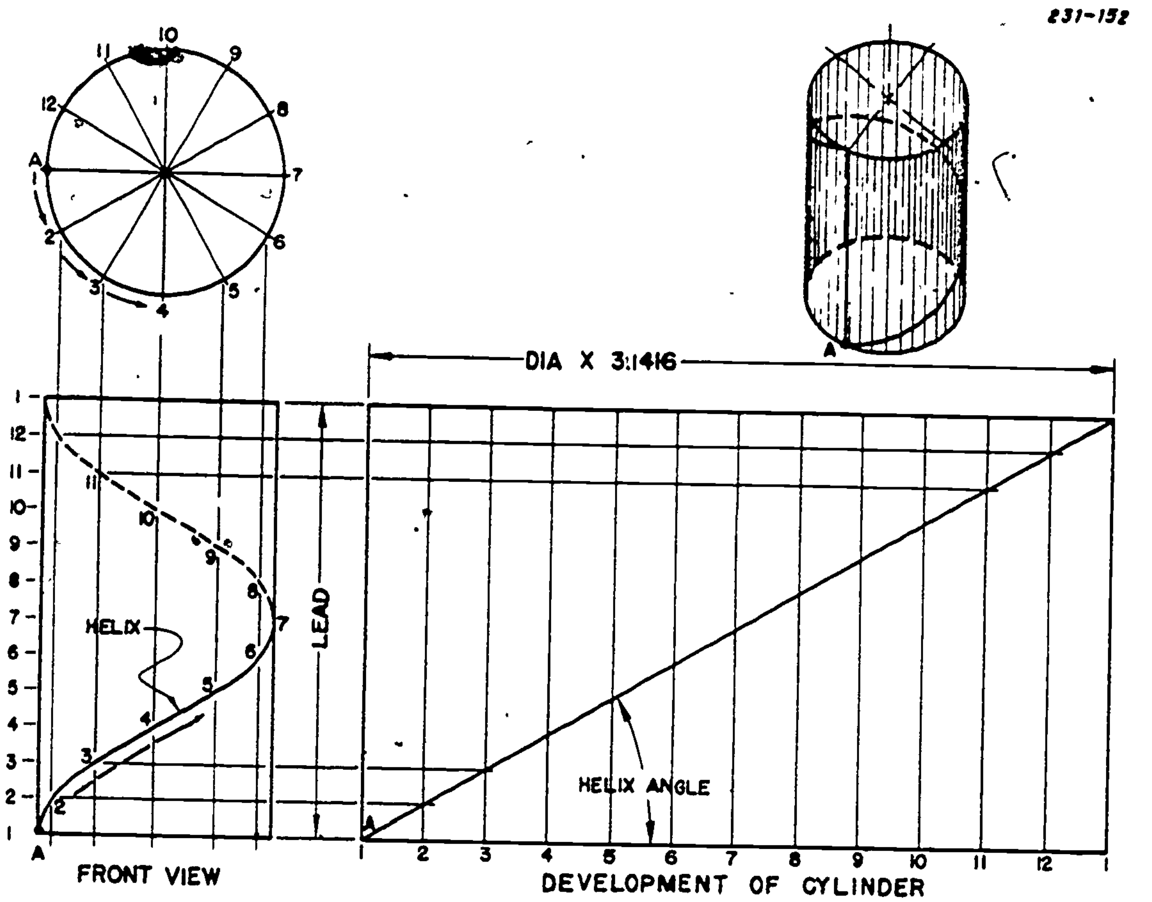


Figure 1-2. The helix.

member, such as a nut or a tapped hole. Note in figure 1-3 that the crest of an internal thread meshes with the root of an external thread.

l. Depth of thread—the distance between the root and crest of a thread, measured perpendicular to the axis.

Exercises (401):

Match the following terms and definitions by placing the letter of the item from the column on the right beside the number of the definition on the left it fits. Each term may be used once, more than once, or not at all.

___ 1. The distance between the root and crest of a thread, measured perpendicular to the axis.	*a.* crest
___ 2. The distance from any point on a thread to the corresponding point on an adjacent thread, measured parallel to the axis.	*b.* depth of thread
___ 3. A double-curved line generated by a point moving around an axis and parallel to that axis at the same time.	*c.* helix
___ 4. The distance a screw moves along its axis during one complete turn.	*d.* lead
___ 5. The bottom surface joining the sides of adjacent threads.	*e.* pitch
___ 6. The top surface joining the two sides of a thread.	*f.* root

402. Given particular demands placed upon threads, identify the type of thread that best meets each demand.

Multiple Threads. When all threads on a bolt are built on a single helix, it is called a single thread. A double thread is formed by two parallel helical ridges wrapped around a cylindrical body. When two or more parallel helices form the thread, it is called a multiple thread. In figure 1-4, single, double, and triple threads are compared. The lead of a single thread is equal to the pitch, whereas the lead of a double thread is twice the pitch. Therefore a double thread advances twice as far as a single thread in one complete turn; a triple thread advances three times as far as the single thread in one turn.

Multiple threads are used on parts where quick action is desired over power. The threads on valve stems, jar caps, and other devices (where a minimum of turning will close or lock the parts together) are multiple threads. Threads on screw-type jacks are single threads since the jack must raise heavy loads without the exertion of too much turning effort. Single threads, especially those in the fine thread series, give slower advance; but they have greater holding power and will withstand more stress.

In drawing single and multiple threads, note that single and triple threads have a root opposite a crest; double and quadruple threads have a crest opposite a crest. To determine the number of threads on a bolt, examine the end to see how many separate threads terminate at the end. Single, double, and triple threads have, respectively, one, two, and three threads showing at the end of the bolt or threaded hole.

Types of Threads. The different types of threads shown in figure 1-5 are standard thread forms which meet most practical requirements. In some cases these forms are modified to meet special design requirements. When a thread that is standard in form is modified to include some nonstandard feature, such as a change in minor diameter, the special feature must be indicated as "Special" and the special dimensions must be given.

A right-hand thread advances into a threaded opening when the threaded part is turned clockwise; a left-hand thread advances when turned counterclockwise. On a drawing and in the shop, all threads are considered to be right-hand unless otherwise specified. When left-hand threads are used, the words "Left-Hand" must be included in the thread identification notes. A right-hand thread of a horizontal axis always slants upward to the left, as shown in the illustrations contained in this chapter. A left-hand thread on a horizontal shank

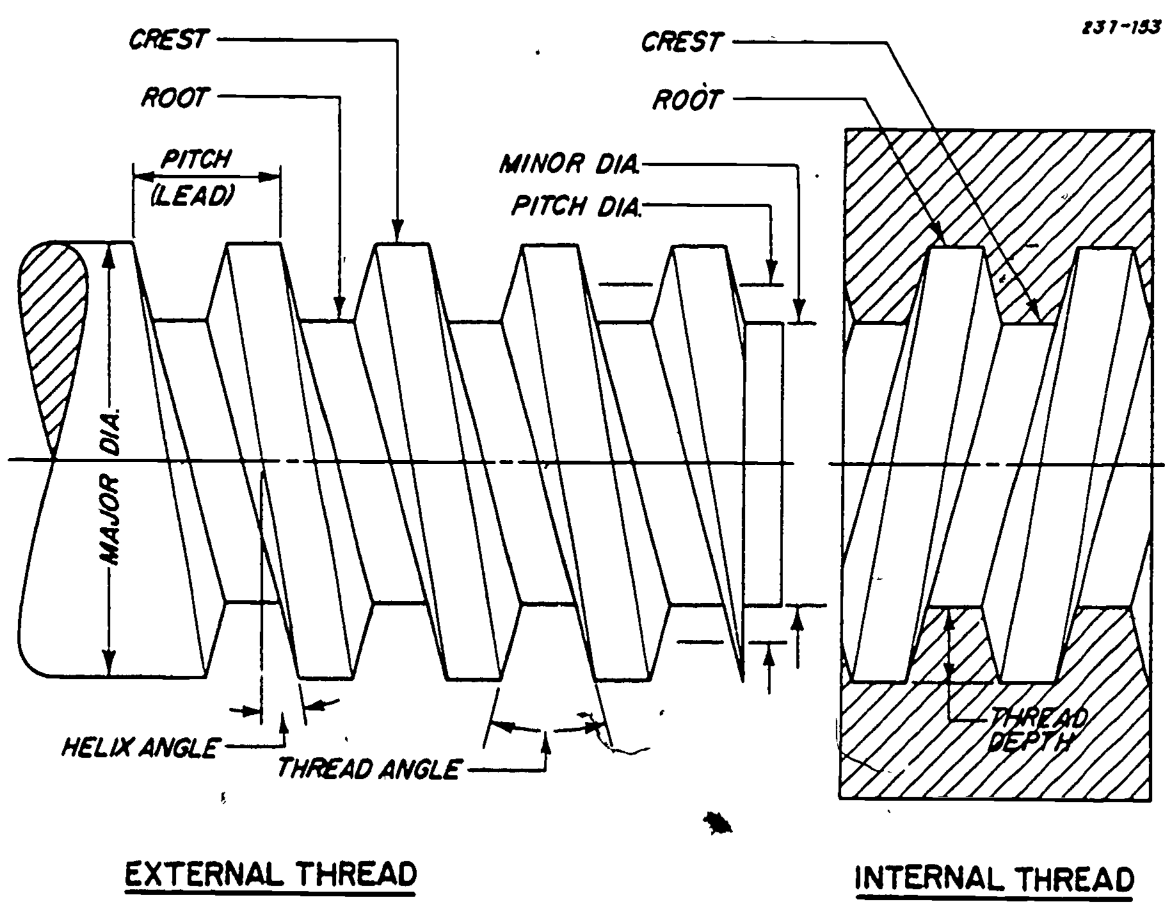


Figure 1-3. Thread terms.

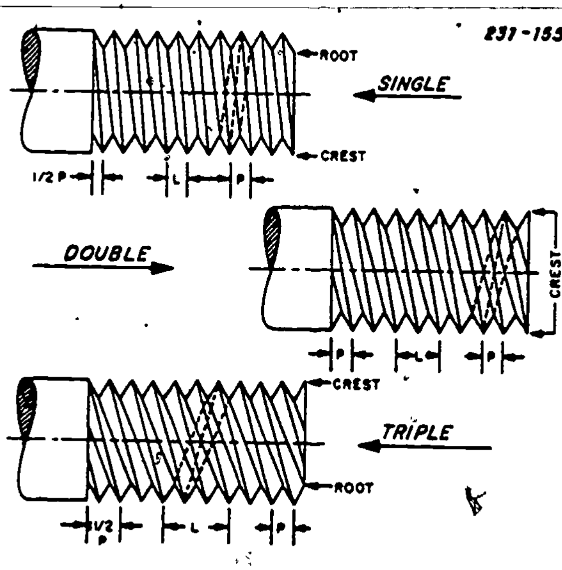


Figure 1-4. Multiple threads.

always slants upward to the right. Where drawing threads are concerned, the difference in thread slant is the only difference between right-hand and left-hand threads.

If a cutting plane passes through the axis of a thread, the shape or profile of the thread is shown to a better advantage. Figure 1-5 illustrates several thread profiles with dimensions for each type. The SHARP-V, AMERICAN NATIONAL, and UNIFIED thread forms are used primarily for fasteners. The SQUARE, ACME, and BUTTRESS threads are used to transmit motion. A thread similar to the acme thread is used to form a worm thread on a cylindrical shaft. A worm thread, in mesh with the teeth on a worm-gear wheel, is used to transmit motion. KNUCKLE threads are usually found on lamp bulbs and lamp sockets, and on other objects where such threads can be easily formed by rolling or casting. Note that the dimensions in figure 1-5 are given in terms of pitch (P) and thread depth (h). No reference is made to specific major or minor diameters since the pitch varies with diameter. When it is necessary to draw a

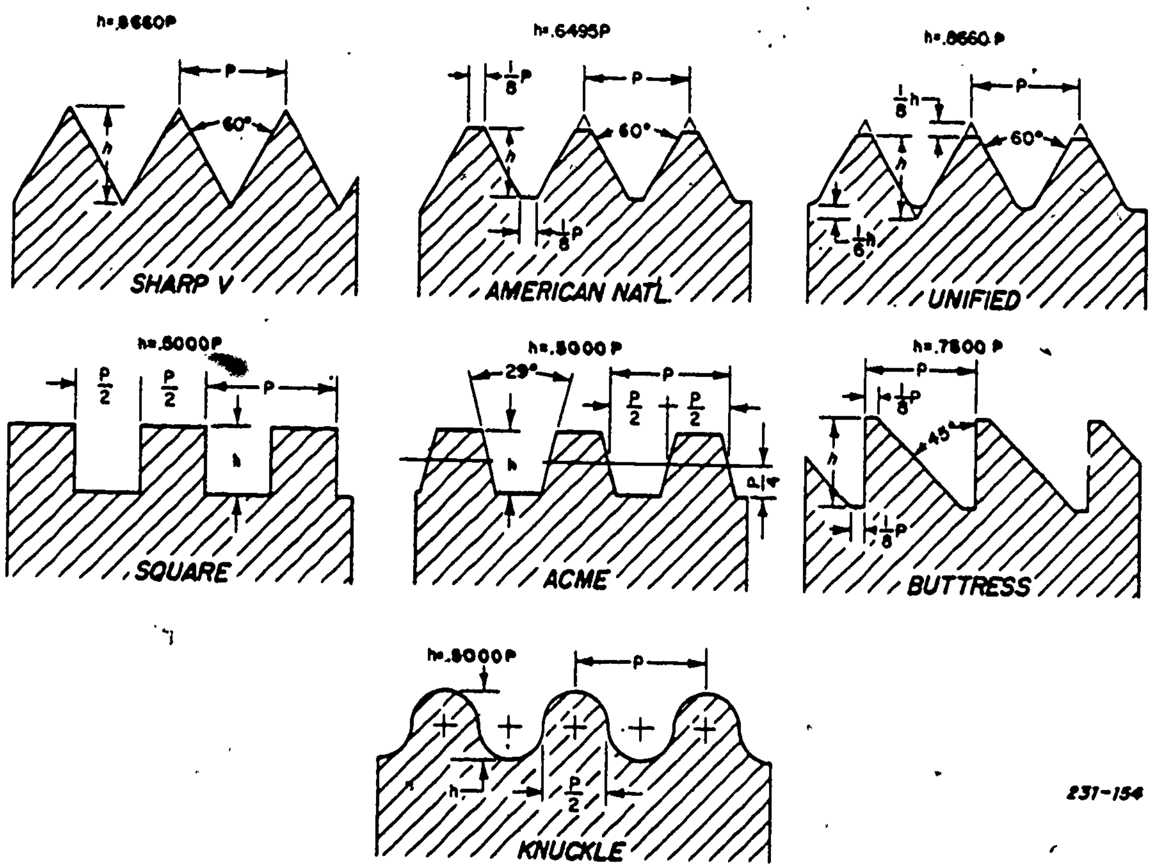


Figure 1-5. Thread profiles.

standard bolt or threaded part, you should refer to Tables of Standard Dimensions which give all basic diameters, threads per inch, and other size specifications for standard threads.

The American National thread, which is a modified version of the V-thread but with a flattened root and crest, is the most common form of screw thread in use for fastening parts together. The sharp-V form is little used, because the crest of the thread breaks even under very little stress. The acme thread, which is a modified version of the square thread, is used to transmit motion and is stronger than the square thread. The buttress thread is designed to take exceptionally high stress in one direction only. It is used in the breechblock mechanism of guns and on aircraft propeller hubs. The Unified thread is the thread form agreed upon by the Standards Associations of the United States, Great Britain, and Canada. This form, which is a compromise between United States and British thread designs, provides for the interchange of parts and simplification of manufacture.

Exercises (402):

1. What type of threads are used on parts where quick action is more important than power?

2. What type of thread is designed to take exceptionally high stress in one direction only?

3. What type of thread is used on objects where the threads must be formed by rolling or casting?

4. Which thread, used to transmit motion, is stronger than the square thread?

1-3. Drawing Screw Threads

When the proejcted view of a screw thread has a diameter over 1 inch, the threads may be drawn by the method shown in figures 1-3 and 1-4. This method of drawing screw threads is the semiconventional method, where helical curves are represented by straight lines. This semiconventional treatment of threads is not used where thread diameters project less than 1 inch. On smaller sizes, the threads are represented by symbols. Where time is essential, simplified symbols may be used instead of regular symbols. These three methods of representing threads are explained in the following paragraphs and figures.

403. Given various procedural steps for drawing the three semiconventional threads and the regular and simplified symbols, identify the particular thread or symbol to which the step belongs.

Semiconventional V-Threads. The same semiconventional symbol is used to represent V-threads, American National, and Unified threads, since the flat roots and crests are disregarded except on very large drawings. The exact type of thread must then be designated by a standard form of note. The manner of placing the note on the drawing is explained later in this chapter.

The steps to follow in drawing semiconventional National threads are illustrated in figure 1-6. Start by laying out the centerline and two parallel lines to represent the outside diameter. The length of the threaded part is set off as required, and the number of threads per inch for the given diameter is obtained from standard tables.

The pitch distance is found by dividing 1 inch by the number of threads per inch. The pitch distance is then set off along the upper line. On the lower line, a space equal to one-half pitch is set off before marking off full pitch spaces. Straight lines connecting pitch points establish the angle of the crests of the thread. For right-hand threads, the lines slope upward to the left. Next, draw 60° lines from each crest point; these V's are vertical and should not lean with the thread. The intersections of the V's locate points which are connected to form foot lines. Note that crest lines are sharp, then lines, whereas root lines are heavy lines. Also note that root lines are not parallel to crest lines. The end of the screw shaft is usually chamfered at 45°, and the chamfer extends to the root of the thread. When the end if chamfered, a new crest line is drawn to join the crests, formed by the chamfering operation. The procedure for drawing internal double threads in section is shown at the bottom of figure 1-6. Again, root lines are dark and crest lines are thin. However, in internal threads the major diameter is the depth or root of the depth or root of the thread. (Refer to fig. 1-3.)

Semiconventional Square Threads. The steps for drawing external and internal square threads by the semiconventional method are shown in figure 1-7. In the first step, lay out a centerline and four parallel lines spaced as shown and mark off distances equal

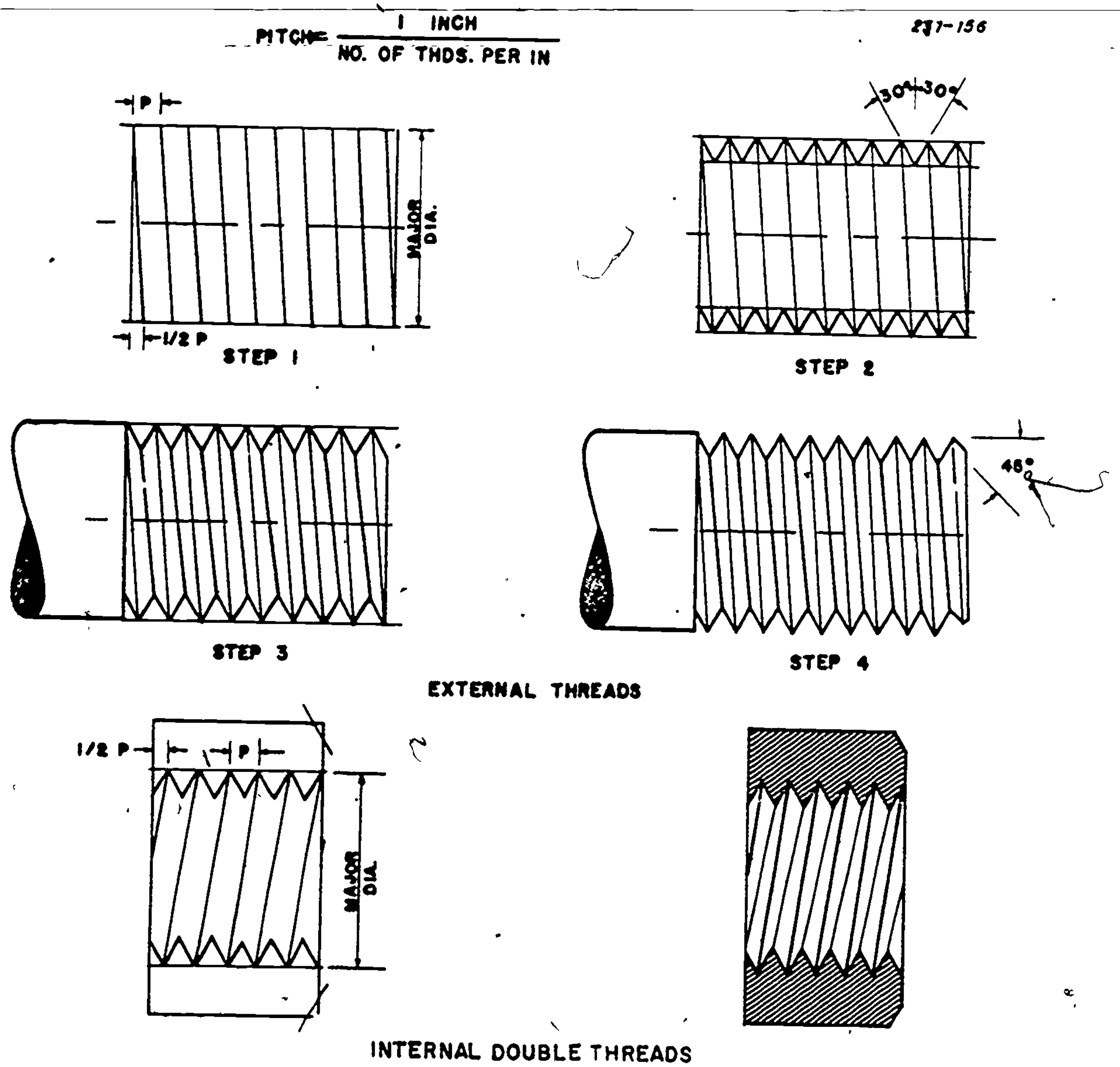


Figure 1-6. V-threads.

to one-half pitch on two outside lines. Add the indicated inclined lines to establish the slope of the thread crests. As shown by the dotted lines in the second step, draw the short inclined lines which follow the edges of each thread for one complete revolution. These short lines are the visible portion of the back edges of the threads. To establish the slope of the root lines, which are added to the next step, draw vertical construction lines from the external corners of the crests. These verticals cross the minor diameter, forming interior square corners. Root lines are drawn to join these interior corners. Only one-half of the root line lies outside the crest line; therefore only one-half of the root line is drawn, as the other half is invisible. In the fourth step, all construction lines are erased, and the necessary lines are darkened to bring them to the same width. The root lines are not accented, as in the drawing of V-threads.

Semiconventional Acme Threads. The layout for acme threads requires two sets of three parallel lines, as shown in figure 1-8. The intermediate lines represent the pitch diameter, and pitch distances are set off along these lines, as indicated in step 1. Through these points on the pitch lines, draw lines making 15° with a perpendicular to the axis. For a single thread, draw a crest opposite a root; then draw lines joining the crests, as completed in step 2. The parallel crest lines must be fine, black lines. Note that the root lines drawn in step 3 are not parallel to the crest lines. The drawing is completed in step 4 by erasing excess lines and making the outline lines and root lines medium weight to contrast with the crest lines. Internal acme threads are drawn by teh same steps; and when shown in section, the internal thread slopes in an opposite direction to the external thread. When drawing multiple acme threads, be sure to draw that part of the crest line which is visible on the back of the thread. None of the back edges will be visible on the drawing of a single acme thread.

Regular Thread Symbols. Thread symbols are used to represent all types of threads on drawings where the projected view of the thread is 1 inch or less in diameter. Regular thread symbols are shown in figure 1-9. The alternate thin and thick lines represent the crests and roots of the thread. Usually, the root and crest lines are spaced by eye, and no attempt is made to show the actual pitch or root diameter. However, when several different sizes of screw threads appear on the same drawing, the draftsman varies the spacing of the thread symbols

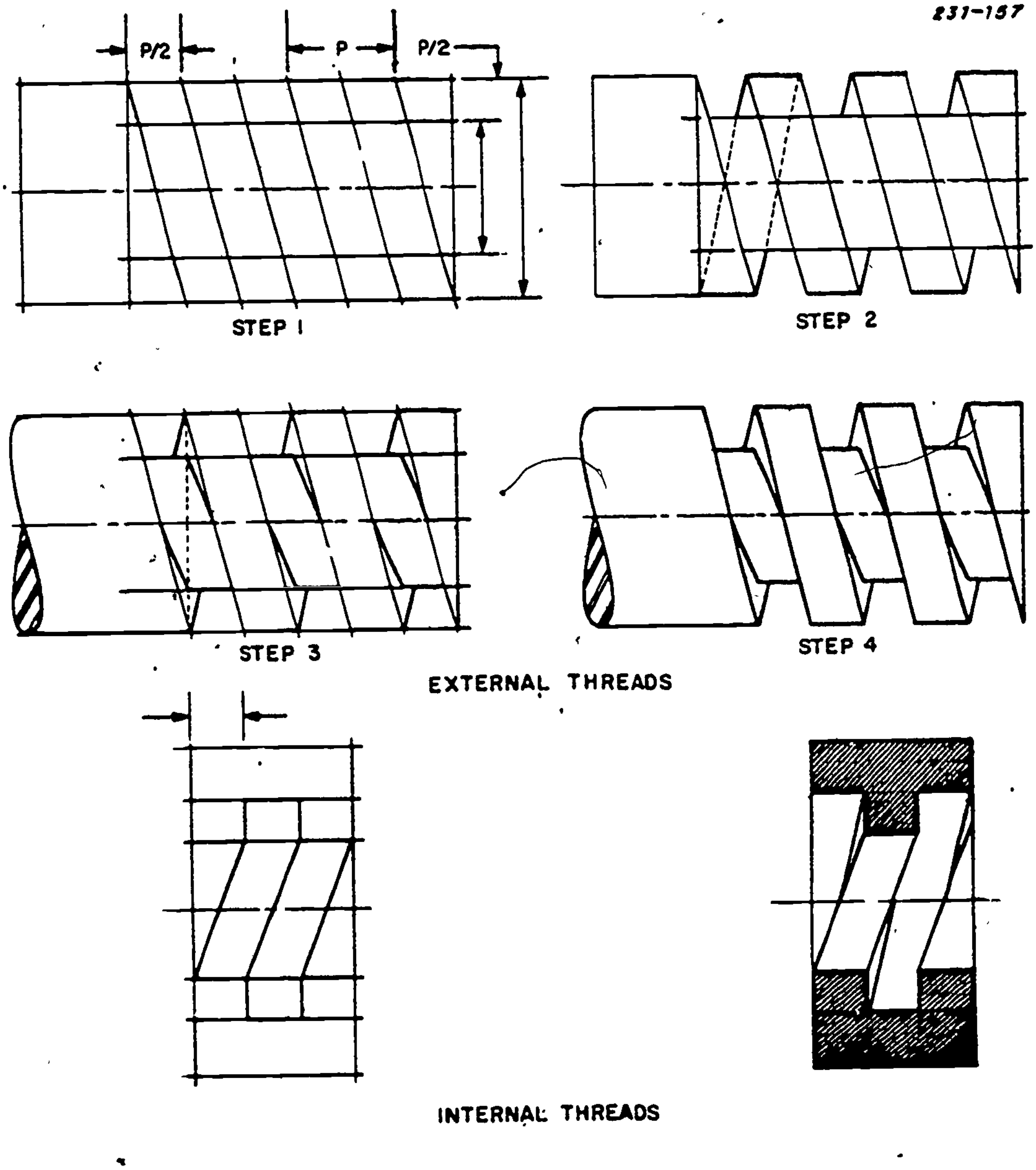


Figure 1-7. Square threads.

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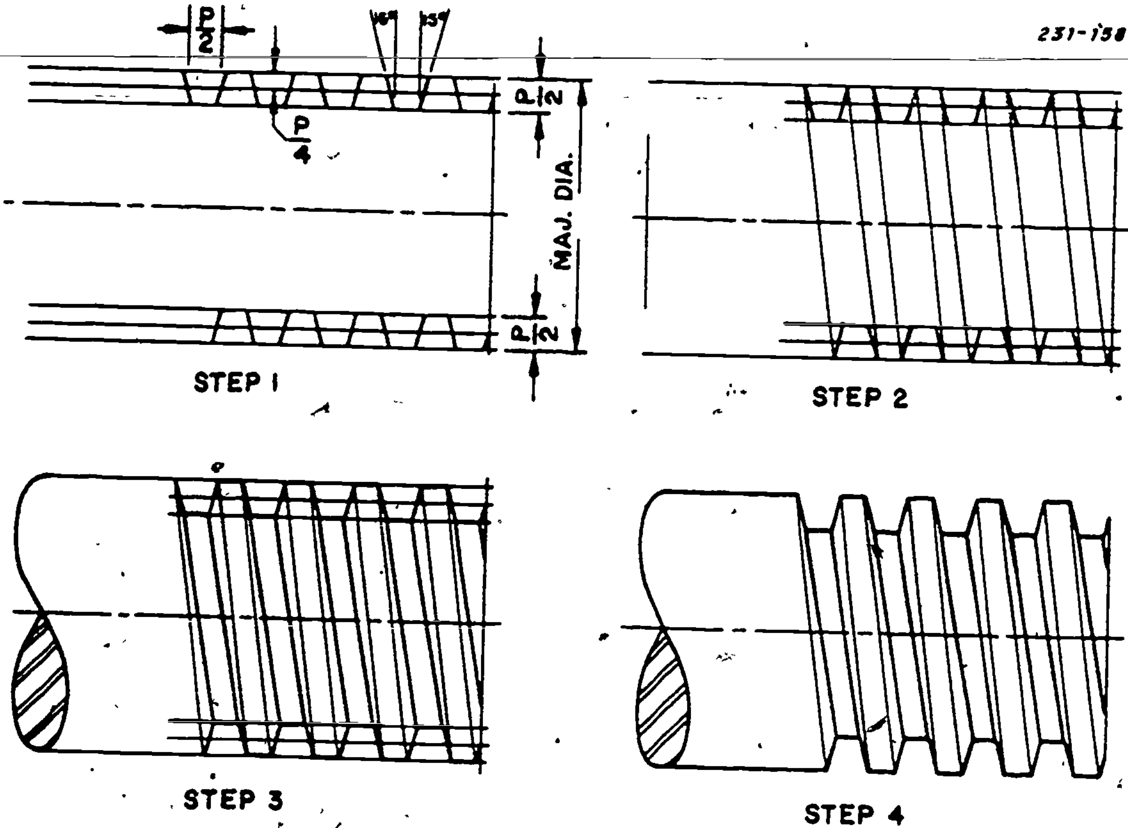

Figure 1-8. Acme threads.

to indicate to the reader that there is a difference in the number of threads on one part as compared to the threads on another part.

As indicated in figure 1-9, the spacing of vertical root and crest lines may be actual (as obtained from Tables of Standard Dimensions) or approximate. The main requirements in drawing these regular symbols are that the spacing be sufficient to give a good print from a tracing and sufficiently varied to indicate noticeable differences in thread sizes appearing on the same drawing. As the diameter of the part decreases, the spacing and depth values become proportionally greater in order to avoid crowding root and crest lines together. For diameters below 1 inch and down to 1/2 inch, little distinction in spacing is made. The same symbol is used to indicate coarse, fine, and extra-fine threads. The specific identification of diameter, number of threads per inch, thread series, and class of fit are indicated by thread notes. After considerable experience, you may space the lines by eye and come very close to the actual thread proportions.

Simplified Thread Symbols. Simplified symbols are used when speed in drafting is essential. These symbols are illustrated in figure 1-10. However, these symbols should be used with discretion, especially on drawings where there are many invisible lines. Where there is a chance for misinterpretation of the drawing, use regular thread symbols or show the parts in an enlarged detail view.

In the simplified representation, thread roots are shown as invisible lines drawn parallel to the axis of the thread. The steps in drawing the simplified symbols are the same as for the regular symbols, as shown in figure 1-9. The dash lines are drawn at the approximate root diameter. The end views and elevation views for internal threads are the same for both regular and simplified symbols.

Exercises (403):

Identify each of the procedural steps below as appropriate to the drawing of a *V, square,* or *acme* semiconventional thread; or a *regular* or *simplified* thread symbol by putting one of the preceding italicized words in the blank following each procedural statement.

1. Draw only one-half of the root line, as the other half is invisible. ________.
2. Draw 60° lines from each crest point. ________.
3. In the first step, lay out a centerline and four parallel lines. ________.
4. Show thread roots as invisible lines drawn parallel to the axis of the thread. ________.
5. Start by laying out the centerline and two parallel lines to represent the outside diameter. ________.
6. Use alternate thin and thick lines to represent the crests and roots of the thread. ________.
7. For the initial layout, draw two sets of three parallel lines. ________.
8. Leave the root lines unaccented. ________.
9. When drawing the single thread, do not leave any of the back edges visible. ________.

1-4. Thread Identification

You have seen how the representation of threads on drawings has been simplified to the extent that notes must be added to provide a complete picture. Dimensions are placed on the drawing to mark the location of the thread, and thread notes give the man in the shop the necessary information about size, type, and the like.

404. Answer some questions about thread information; and given the necessary information, write a standard thread note and indicate any special quality or use recognizable for the particular thread.

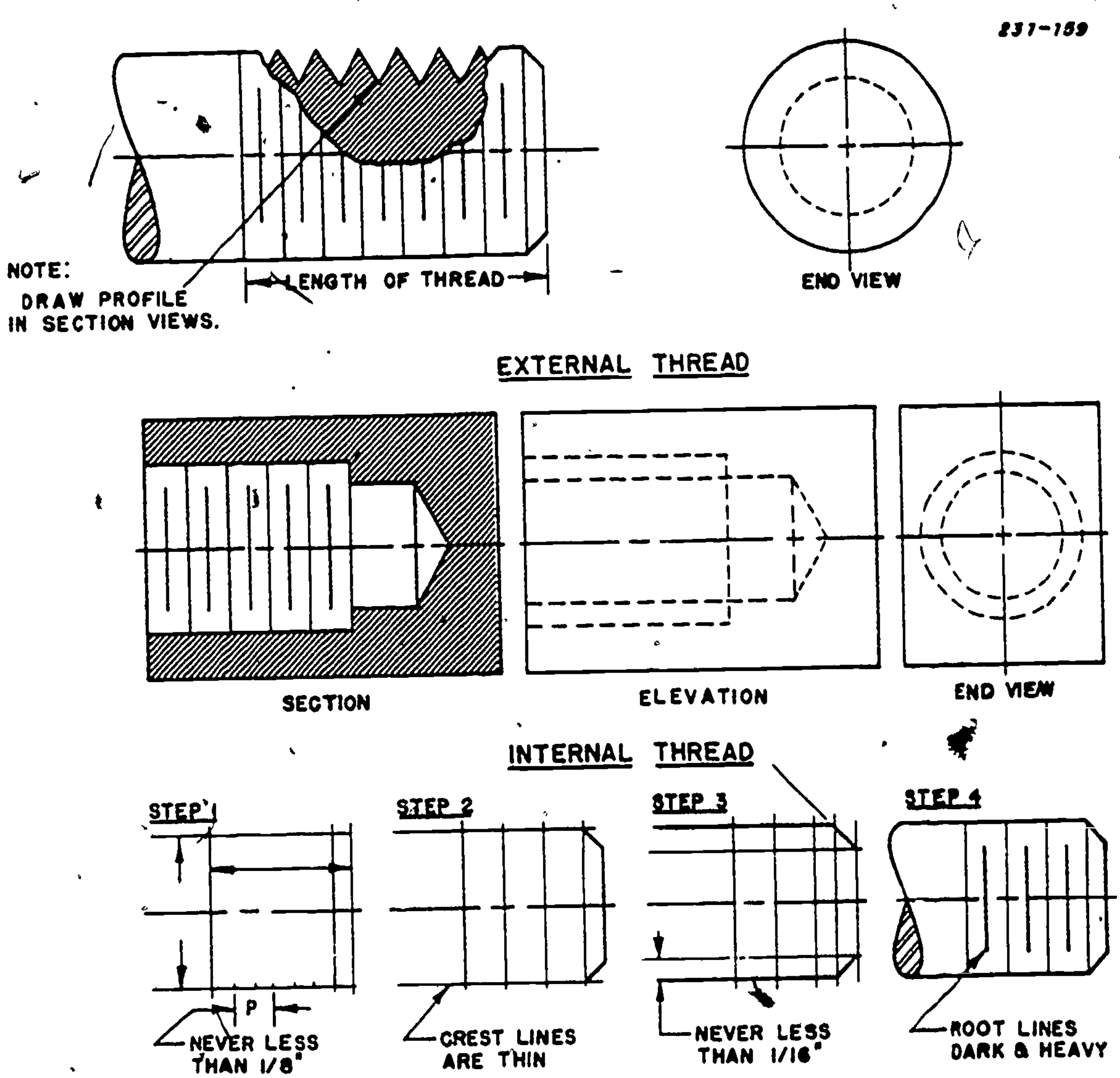

Figure 1-9. Regular thread symbols.

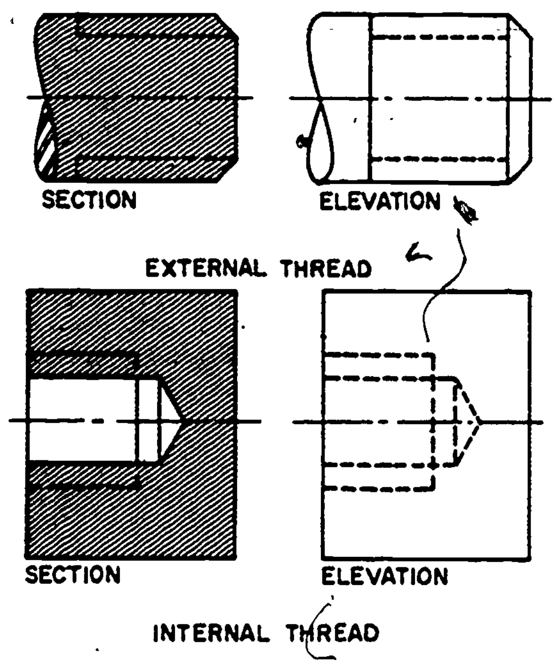

Figure 1-10. Simplified thread symbols.

Thread Information. The information contained in thread notes must be presented in the following order:

a. Diameter in inches (or number size).
b. Number of threads per inch.
c. Letters to identify form and series.

N = National form.
U = Unified form.
C = Course series.
F = Fine series.
EF = Extra-fine series.

d. Class of fit and tolerance symbol. American standard classes of fits are indicated by number only. Under the Unified system, a letter suffix is added to indicate that Unified tolerances are to be applied. The letter A indicates external threads; the letter B indicates internal threads.

e. Other symbols. If the thread is left-hand, the symbol LH should appear at the end of the specification. If the thread is non-standard, the word "Special" should appear.

In order to make thread notes meaningful, you must understand the meaning of the terms "thread series" and "thread classes."

Thread Series. Unified and American National threads have substantially the same thread form, and threads of both standards are interchangeable when they have the same diameter and pitch. The main difference between these two types of threads consist of differences in the application of tolerance and allowance. Threads under these two standards are classified into six series groups. One thread series is distinguished from another by the number of threads per inch applied to a specific diameter. The series and their recommended use are as follows.

Course-thread series. The course-thread series is recommended for general use in work where conditions do not require the use of a fine thread. This series is used in soft materials and in designs where its characteristic of rapid engagement is desirable. For example, with a 1/4 inch diameter bolt this series would be specified as 1/4-20 UNC-2A.

Fine-thread series. The fine-thread series is recommended for aircraft and engines where special conditions require greater strength, resistance to vibration, ease of installation, and less weight per given strength. It is widely applied in fastenings, such as bolts, screws, tie-rod terminals, etc. A 1/4-inch diameter bolt in this fine-thread series is specified thus: 1/4-28 UNF-2A. In the coarse and fine-thread series, all sizes below 1/4 of an inch are designated NC and NF (National Standard).

Extra-fine-thread series. This series is used particularly in equipment where thin material is to be threaded and where a maximum number of threads is required within a given thread length. A 1/4 inch nut in the extra-fine series would be specified as: 1/4-32 NEF-2B. A few specific sizes of this series are designated UN. For example: 1/2-28 UNEF-2B.

The following thread series, known as the fixed-pitch series, have the same thread profile as other American National threads, but the pitch remains the same for all diameters.

The 8-thread series. This series has eight threads per inch in all diameters from 1 to 6 inches. It is used for bolts on high pressure pipe flanges, cylinder head studs, and similar fasteners against pressure. It is specified as 2½-8N-3A. The 8-thread series serves as a continuation of the course-thread series for sizes over 1 inch.

The 12-thread series. This series has 12 threads per inch in all diameters from 1/2 inch to 6 inches. It is used in machinery, boiler work, and in aeronautical construction of the fine-thread series for sizes over 1½ inches. A sample specification would be 1¾-12 UN-2A.

The 16-thread series. This series has 16 threads per inch for all diameters from 3/4 inch to 4 inches and is used for threaded adjusting collars, bearing retaining nuts, etc. It serves as a continuation of the extra-fine series for sizes over 1¾ inches in diameter. To specify this thread, a note like the following would be used: 3¼–16N–3B.

When it is necessary to draw screw threads and specify thread sizes by notes, you must refer to Tables of Standard Dimensions. A complete list of tables covering Unified and American National screw threads is contained in military specification MIL-S-7742 in the appendix.

Thread Classes. Threads are classified by the manner in which two mating parts, such as a bolt and nut, fit together when assembled. Thread standards provide for four classes of fits for various purposes, and these classes are distinguished by numbers from 1 through 4. Class 1 is the loosest fit and class 4 is the closest fit. Under National Standards, the four classes of fits are described as follows:

Class 1 fit. This class is used where clearance between mating parts is necessary for ease of assembly and where looseness between the mating parts is not objectionable.

Class 2 fit. This class gives a free fit between mating parts but provides for a higher quality screw thread product than the class 1 fit. When total class 2 pitch diameter tolerances are applied to both parts, there is some play between the mating parts.

Class 3 fit. This class is used for exceptionally high-grade screw threads, and it is used only when the higher production cost is warranted. The maximum play between parts is about 70 percent of that found in class 2.

Class 4 fit. This class of fit is used where exacting requirements must be met, and the parts are usually selectively fitted together by hand.

Under Unified Standards, tolerances for external threads differ from those for internal threads. For this reason, the letter A is used in the thread symbol to denote an external thread, and the letter B is used to denote an internal thread. Unified thread sizes are identified by the letter U in the thread symbol. Where the letter U does not appear but the letters A and B are retained, all thread tolerances conform to Unified Standards. Where the letters U, A, or B do not appear in the thread symbol, all thread tolerances are American National.

Identification Symbols. Figure 1-11 illustrates correct methods for specifying screw threads on a drawing. For external threads, the thread note is placed on the profile view of the thread, as shown in figure 1-11,A. The note for internal threads is preferably placed on the circular view of the hole; but where no circular view appears, the note is attached as shown by B and C in figure 1-11. In these two examples, the sequence of operations is expressed in the thread note. The workman selects the proper tap drill for the given thread, then drills, countersinks, or counterbores the hole before cutting the threads. For other types of threads, such as square, acme, and worm, the standard note gives the major diameter and the number of threads per inch. Unless otherwise specified, all threads are considered to be right-hand and single. If left-hand or multiple threads are needed, the note must clearly state what is required. To specify a threaded part 1½ inches in diameter, nine threads per inch (special pitch), left-hand, double, the proper note would be 1½–9N–2, LH DOUBLE. Note in figure 1-11,C, that the drill depth does not include the cone-shaped bottom of the hole. This shape is formed by the point of drill, and on drawings an angle of 30° is used to approximate the angle of the drill cutting edge.

Pipe Threads. The standard pipe thread illustrated in figure 1-12, is similar in shape to the ordinary screw thread and it has the same thread angle. However, pipe threads are tapered 1/16 inch per inch to insure a tight joint at fittings. The crest of the thread is flattened slightly, and the root of the thread is filled in so that the depth of the thread is approximately 80 percent of the pitch. The pitch of pipe threads has been standardized for the various size of pipes. The number of threads per inch for any given diameter can be obtained from standard tables.

Both internal and external threads are tapered. Tapering allows the first threads to be engaged by hand and insures a tight joint when the threads are wrench tightened. A National straight pipe thread is used for some parts, such as hose couplings. This thread has the same shape and pitch as taper pipe threads, and a common procedure is to use a taper external thread with a straight internal thread. This is possible when pipe materials are soft enough to allow the threads to adjust to each other by a slight deformation of the metal. Taper threads are specified by the letters NPT (National Pipe Taper) and straight threads by the letters NPS (National Pipe Straight).

Pipe threads may be represented on a drawing by semiconventional, regular, or simplified symbols. The taper is not usually shown; but if it is shown, it is exaggerated to 1/8 inch per inch. Standard notes for pipe threads are shown in figure 1-13. On larger drawings, it may be desirable to use the semiconventional symbol, especially where the pipe diameter projects 1 inch or more and when pipe threads are shown in assembly with other parts in a

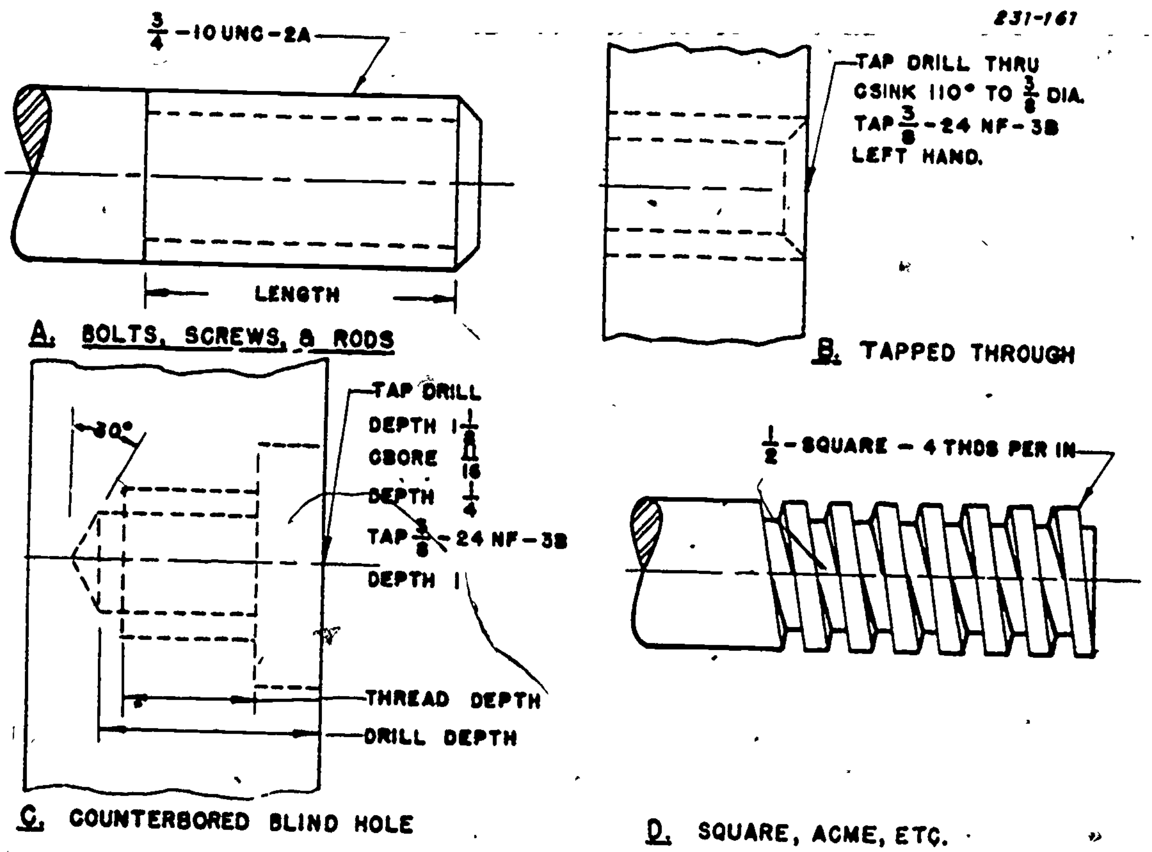

Figure 1-11. Thread notes.

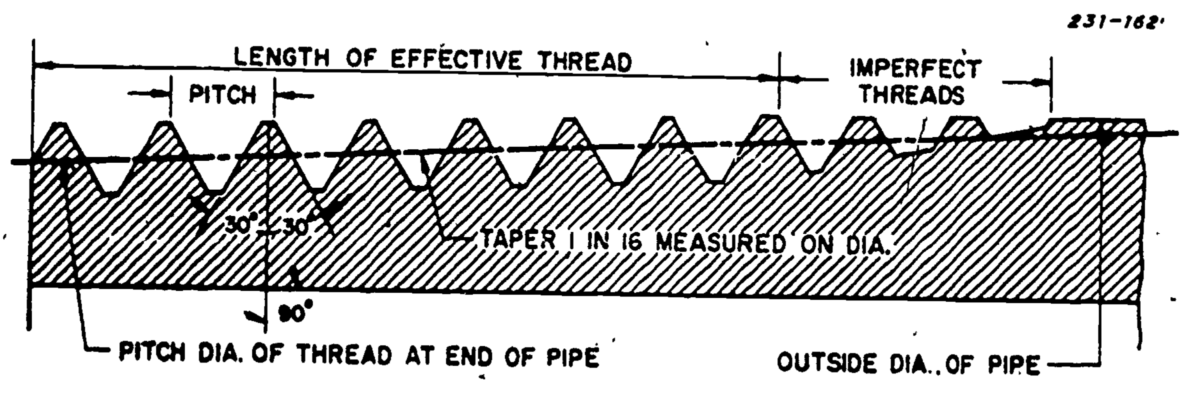

Figure 1-12. Pipe thread.

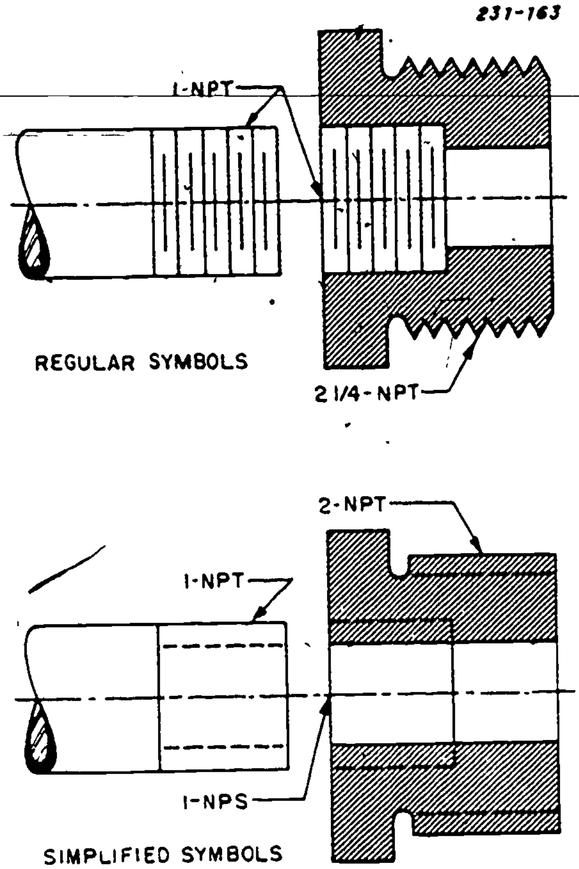

Figure 1-13. Representation of pipe threads.

section view. Usually, regular or simplified symbols are used. The thread note always gives the nominal diameter of the pipe, followed by the letters indicating the type of thread. The inside diameter is used to identify pipes through the 12-inch size; pipes more than 12 inches in diameter are sized by their outside diameters. The "nominal diameter" for pipes 12 inches or under is close to but not the exact inside diameter. Except where taper is shown, pipe thread symbols are the same as the symbols used for ordinary screw threads.

Exercises (404):

1. What distinguishes one thread series from another?

2. Under Unified standards what does "A" and "B" denote in classifying threads?

3. Why are pipe threads tapered?

4. You have a nut, 1/4 inch in diameter, threads coarse, Unified Standard, 20 threads per inch, fit class 2. Write the formula and probable use.

1-5. Bolts and Screws

Bolts and screws are threaded fasteners which appear frequently in machine drawings, in both assembly and detail views. In making assembly drawings, you will save time by using a procedure which allows you to scale the principal features of the fastener in proportion to its given diameter. When precise dimensions are required, you must then refer to standards which given the actual dimensions for bolts, nuts, and screws. The Air Force has established specifications for these fasteners and for many similar machine parts. Therefore, a part number may be used on the drawing to identify standard fasteners, and no dimensions are given. When a fastener is not listed in the Air Force standards book and not stocked as a standard part, its size and shape must be described in a detail drawing.

405. Give the two classification breakouts of bolts and nuts, the significance of symbols used in drawing a nut or bolt, and the five items of information specified for a bolt on a drawing.

Drawing Bolts and Nuts. Bolts and nuts are classified by series as regular, heavy, and light. The regular series is for general use, and the heavy series is used where weight and load factors require greater bearing surfaces on the bolt head and nut. The light-series nut is used where weight saving is important. Bolts and nuts are further classified by the type of machining they have undergone in their manufacture. Unfinished bolt heads and nuts are not finished on any surface except the threads. Semifinished bolt heads and nuts are machined to form a smooth bearing surface or a washer face. Finished heads and nuts are washer-faced, and all surfaces are finished for accuracy and appearance. As shown in figure 1-14, B, this washer face has a diameter equal to the width across flats and is 1/64 inch thick. Since the forming of a finished surface requires the removal of metal, the height of a semifinished bolt head is slightly decreased. Also the thickness of a semifinished nut is less than that of an unfinished nut. In the finished series, however,

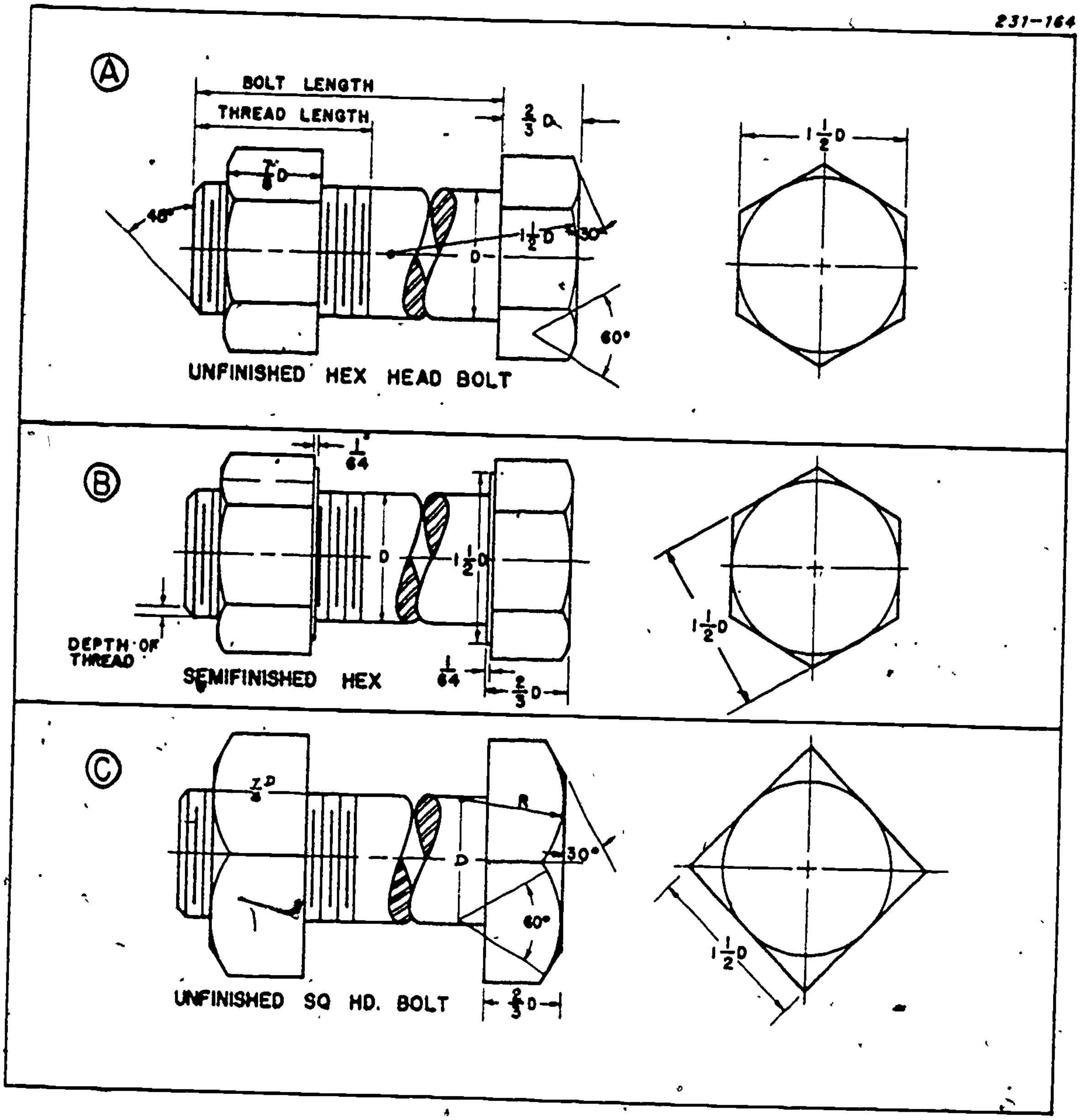

Figure 1-14. Bolt and nut proportions.

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the bolt head and nut are originally made slightly larger to allow for the metal removal in machine finishing. Thus the head height and nut thickness in this series are greater than in the semi-finished series.

In most cases, the conventional representation of bolts and nuts is used. Figure 1-14 shows three typical bolts and illustrates the use of proportions based on their diameters. These proportions are used to draw regular-series bolts and nuts. To draw the heavy-series, the following proportions are used:

Width across flats	$1\frac{1}{2}D + \frac{1}{8}''$
Height of head	$\frac{3}{4}D$
Thickness of nut	D

Bolt heads and nuts are drawn with the "across corners" width showing in all views. Although this is a violation of true projection, it is done to distinguish between square head and hex head bolts and nuts. Therefore, a hexagon head and nut will usually be represented as showing three of its sides. If it is ever necessary to draw a hex head or hex nut with only two faces showing (width across flats), a radius equal to the bolt diameter is used to draw the curves produced by the chamfer on the head and nut. A radius of 2D is used on a square head and nut when it is drawn across flats. This is illustrated in figure 1-15.

Square and hexagonal heads and nuts are drawn "across corners" in all views showing the faces unless there is a special reason for drawing them "across flats." Figure 1-16 shows the steps which you should use in drawing square heads, both across corners and across flats. Figure 1-17 shows the same for hexagonal heads. The principles apply equally to the drawing of nuts.

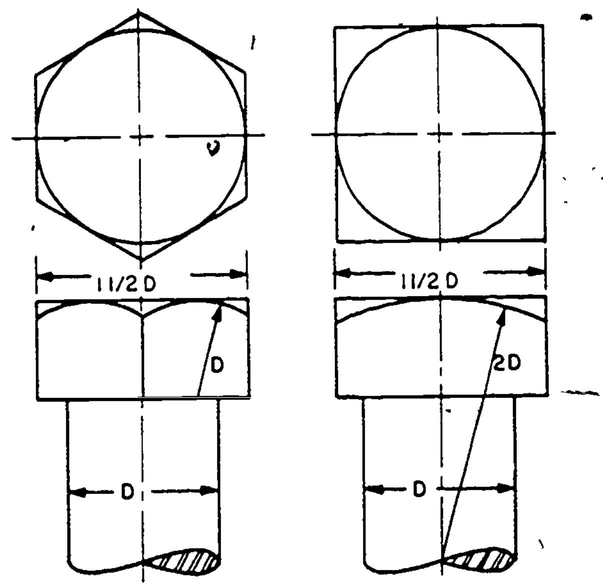

Figure 1-15. Bolt dimensions across flats.

First, determine the type of head and the nominal diameter. Using this information, additional data W (width across flats), H (height of head), and T (thickness of nut) can be obtained from the tables

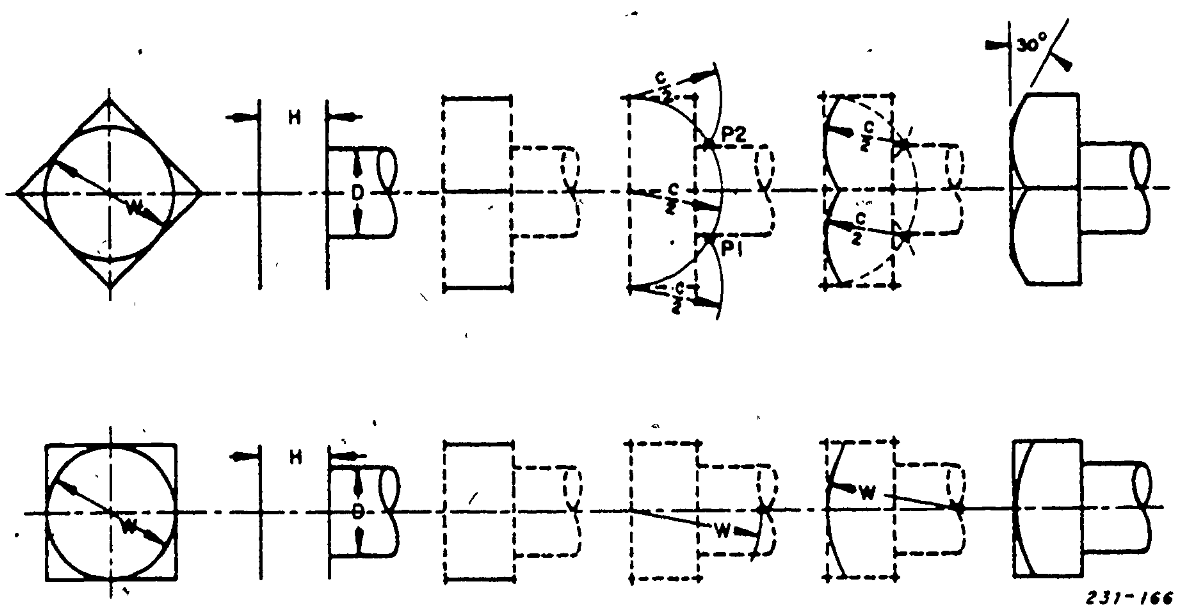

Figure 1-16. Stages in drawing a square head.

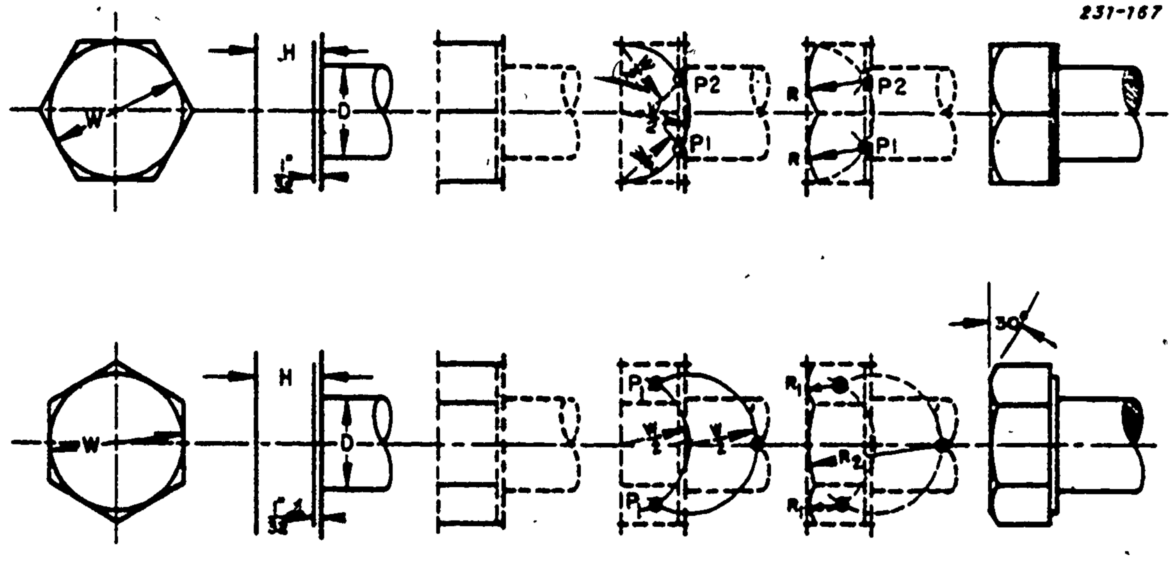

Figure 1-17. Stages in drawing a hexagonal head.

(see appendix). Then draw the edges of the faces, projecting from the end view. Set the compass to a radius of C/2 and draw the circle arcs locating centers P_1 and P_2. In the case of the drawing across the flats, set the compass to radius of W, and draw the circle arc locating the center P. Draw the chamfer arcs, using the radii and centers as shown and then complete the views. Show a 30° chamfer on the across-corners view.

A similar procedure is used in drawing hexagonal bolts using radius W/2 to draw the circle arcs locating centers P_1 and P_2, as shown in figure 1-17. In the case of semifinished bolts, the actual thickness of the washer face is 1/64 inch, but may be increased up to 1/32 inch for the drawing. The length of the bolt and the length of the thread can be determined from the footnote to the bolt table in the appendix.

The drawing may require considerable time when, for example, clearance conditions require an accurately drawn bolt, using exact dimensions from the tables. Often, however, the representation of bolts may be approximate or even symbolic because the note specifications invariably give the exact information.

Specifications for Bolts. Specifications for bolts on drawings or parts lists must include the diameter, length, thread type, finish, and head type. The length of a standard hex-head or square-head bolt is the distance from the underside of the head to the tip of the bolt shank. On countersunk heads, the length is measured to the top of the head. The bolt material is assumed to be steel unless another material is specified; and, if the head and nut are different from the regular hex or square, this must also be specified. The bolt series is not specified. The bolt series is not specified unless it is heavy or light series. If the bolt is to be finished, the type of finish must be specified. Some types of finishing which must be specified are cadmium plate, chrome plate, zinc plate, and milling or grinding operations which are essential to the proper functioning of the part.

The term "bolt" is used to identify a through fastener which has a head on one end and is threaded to take a nut on the shank end. A stud bolt is threaded on both ends; one end is turned into a threaded hole, and a nut screwed on the other end holds two parts together. Detail views of bolts and studs are dimensioned and specified, as shown in figure 1-18. In parts lists and bills of material, the Air Force part number or standard specification is used to identify fasteners. Examples of bolt specifications used on assembly drawings are as follows:

1/2-13UNC-2A x 2 SEMI-FIN. HEX. HD. BOLT
1/2-20UNF-2A x 2¾ STUD.

Exercises (405):

1. How are nuts and bolts classified?

2. What do the letters W, H, and T mean when giving information on nuts?

3. Specifications for bolts on drawings or parts lists must include what five items?

406. State particular characteristics of cap, machine, and set screws; and write the formula for a designated screw.

Screws. Screws are made in so many shapes and varieties that a clear-cut method of classification is difficult. However, they are generally classified by head shape and use.

Cap screws are structural screws designed to serve the same function as bolts. They are used without nuts, and are passed through an unthreaded hole in one member to engage a threaded hole in another member. A hex-head cap screw is similar to a standard finished hex-head bolt. Other types of cap screws may be semifinished or finished all over, but they are usually produced in finished form since they are used where accuracy and appearance are important. They are available in body diameters ranging from $\frac{1}{4}$ to $1\frac{1}{4}$ inches. If the length of a cap screw is less than 1 inch, the threads extend up to the head. In lengths greater than 1 inch, the minimum length of thread is generally $2D + \frac{1}{4}$ inch. Cap screws are specified by giving diameter, threads per inch, thread series, fit, length, type of head, and name, as in the following example:

5/8-11UNC-2A x 2 FIL. HD. CAP SC.

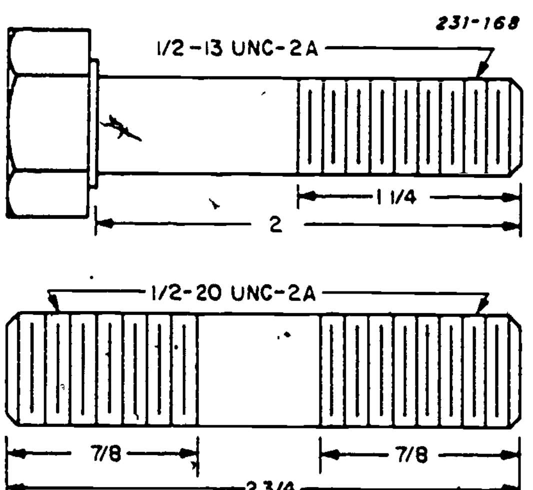

Figure 1-18. Bolt details.

The proportions for drawing the various heads for cap screws and machine screws are shown in figure 1-19. Note that the head slots are drawn at a 45° angle in the circular view so that the slot lines are not confused with center lines. The points of all cap screws are flat, with a chamfered edge at 35° to the flat end surface. The depth of the chamfer is equal to the thread depth.

Machine screws are similar in use to cap screws but are usually smaller in diameter, ranging from .060 to 1 inch. They are available in the head types shown in figure 1-19 but are rarely made with hex or socket heads. All machine screws, except hexagon, may be manufactured with a cross-recessed slot, as shown in figure 1-20. Unlike cap screws, machine screws have unchamfered ends; and the symbol is shown in figure 1-20.

Set screws are used to prevent rotary motion between two parts, such as a pulley mounted on a shaft. The set screw passes through a threaded hole in the pulley and is tightened so that its point presses against the shaft. The friction created prevents the pulley from slipping when the shaft is turned. Set screws are also used to adjust the position of parts in relation to each other. For example, a set screw is used to lock a lathe tool in its holder for cutting operations. Set screws are specified by giving the diameter, thread per inch, thread series, class of fit, length, type of head, type of point, and designation, as follows:

1/4-20UNC-2A x 1/2 HEXAGON SOCKET CONE PT SET SC.

The forms of set screw heads and points are shown in figure 1-21. Headless types are preferred since there is no projecting head to cause injury personnel working around revolving parts.

Cap screws, machine screws, and set screws are available in National and Unified thread forms, either coarse or fine series. Cap screws are usually produced with a class 3 fit, machine screws with a class 2 fit, and set screws with a class 2 fit. In order to make accurate representations of these fasteners, you must refer to Standard Tables which give the basic dimensions for each type. The standard which covers screws is contained in Military Specification 933B. Copies of these specifications may be obtained by Air Force activities by applying to the Command General, Air Force Logistics Command, Wright-Patterson Air Force Base, Dayton, Ohio.

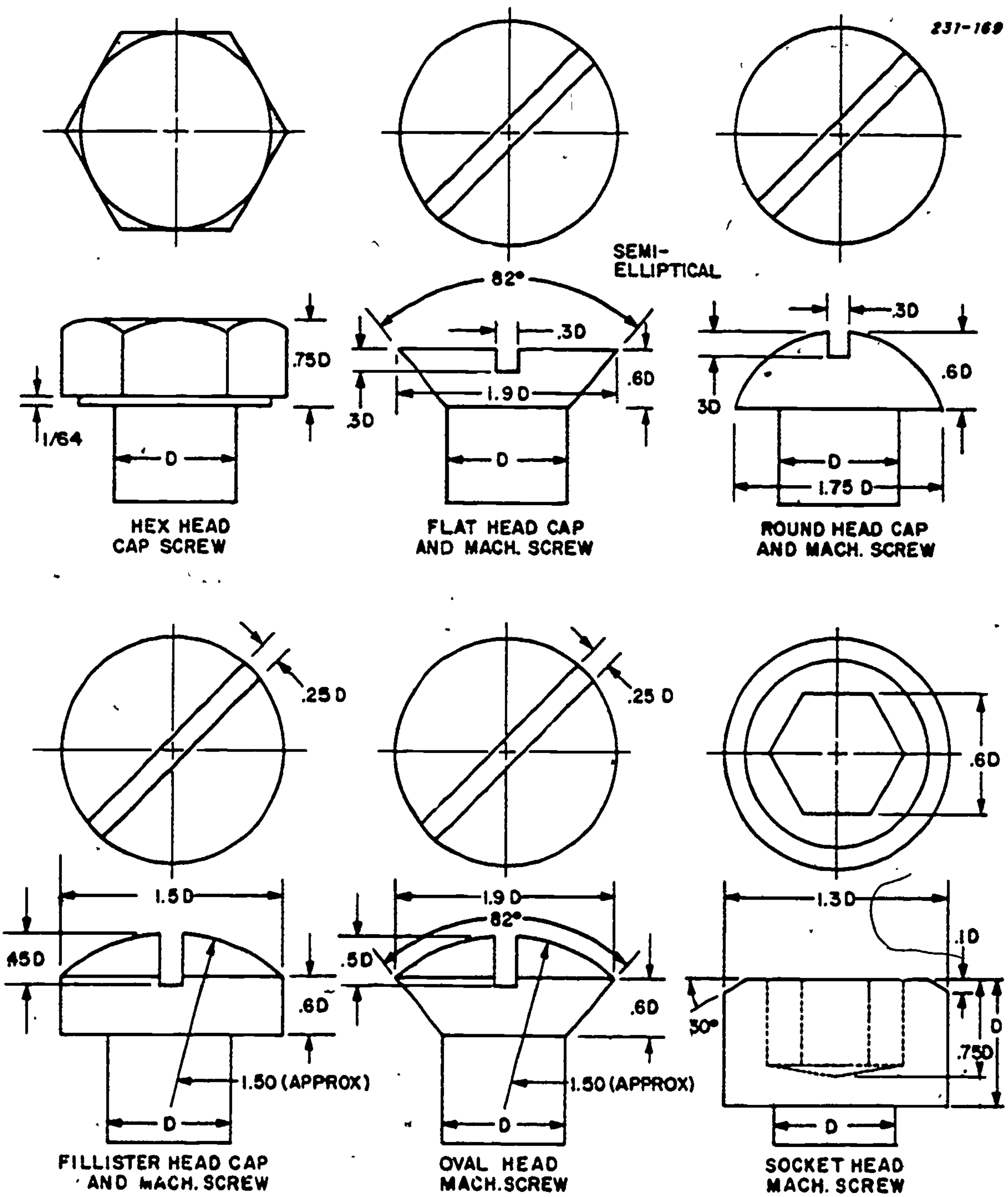

Figure 1-19. Proportions for machine and cap screws.

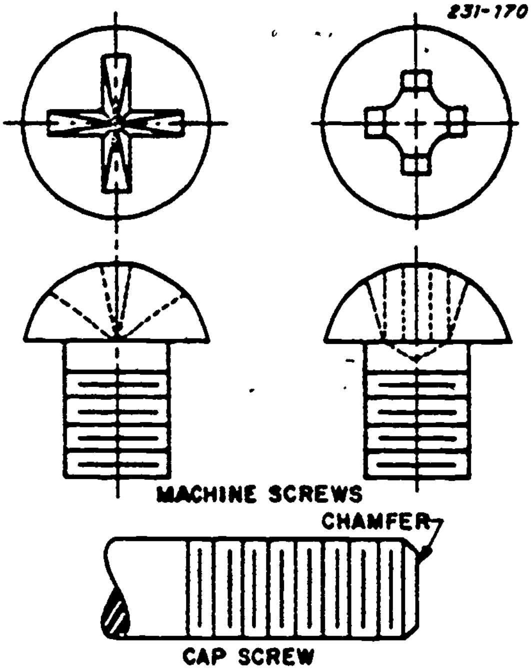

Figure 1-20. Cross-recessed screw head.

Exercises (406):

1. How are screws generally classified?

2. If a screw is designated as 5/8 diameter, 11 threads per inch, Unified National coarse series, external thread finished hex head cap screw, how would you write the formula?

3. What are the major differences between a machine screw and a cap screw?

4. What is the primary purpose of a set screw?

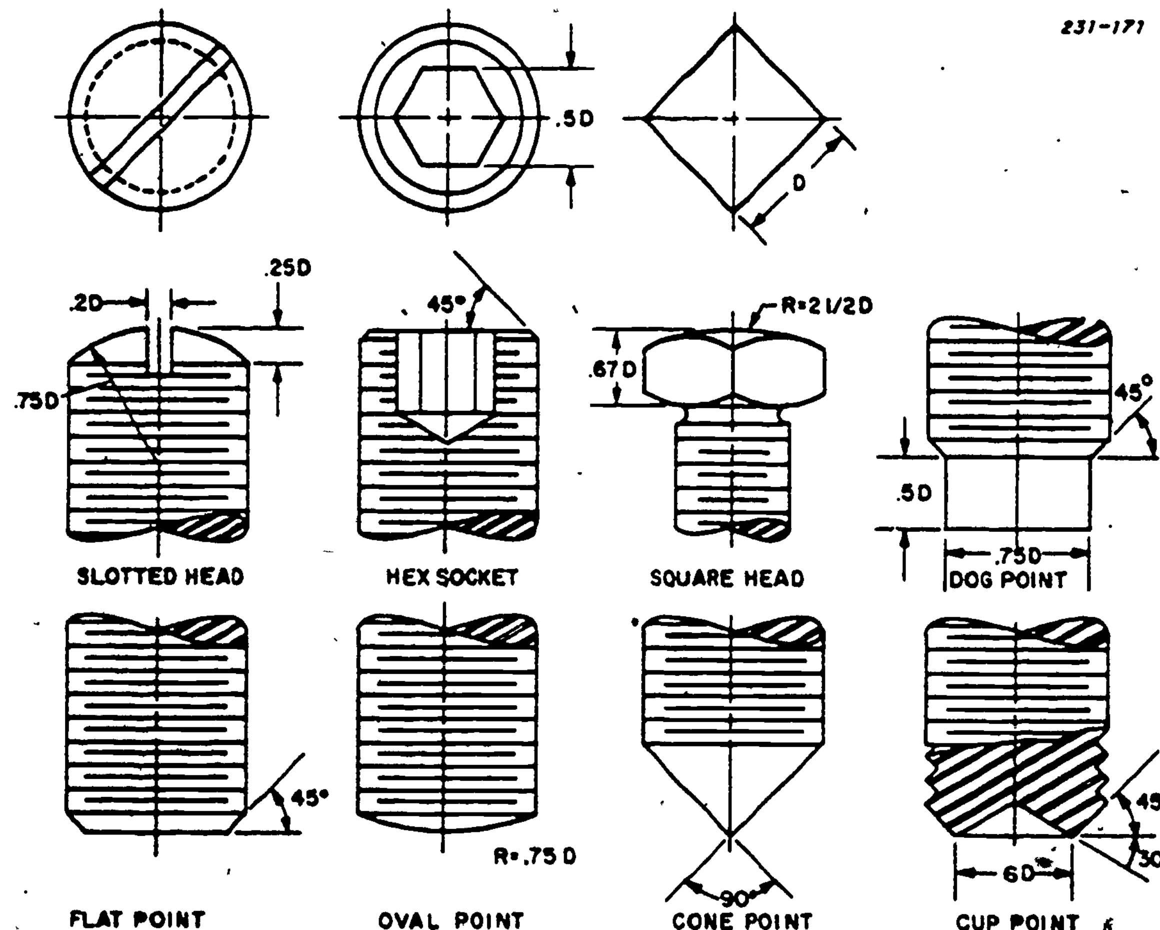

Figure 1-21. Set screws.

1-6. Keys, Pins, and Springs

A key is a square, rectangular, or semi-circular piece of metal which is inserted in a keyway cut in a shaft and pulley. When installed in this position, the key prevents relative motion between the two parts. Metal pins, either cylindrical or round tapered, are used for the same purpose in lighter work where the load to be transmitted from shaft to pulley is not so great as to warrant a heavy key. Springs, while not classed as fasteners, are presented on a drawing in much the same manner as are screw threads. The methods for representing springs are discussed in this section.

407. State the physical characteristics of keys and pins and name three types of springs.

Keys. Figure 1-22 shows several types of standard keys. Square, flat, taper, and gib-head keys are American Standard, while Woodruff and Pratt and Whitney are *patented keys*. In commercial drafting, these keys are not drawn in detail unless they are changed to include a nonstandard dimension. They are, however, drawn to scale on assembly drawings and their specifications given in an attached note. Keyways on shafts and internal parts are dimensioned as shown in the figure. Patented keys are specified by a number, the shaft key seat being specified by the same number. Complete information on keys and keyways may be found in engineering handbooks and in military specifications. Appendix G gives dimensions for Woodruff keys. All keys are drawn on detail drawings in Air Force drafting practice. The related assembly drawing contains a reference to the detail view which gives all necessary information about the key, including dimensions.

Pins. Cylindrical dowel pins are used for a variety of work where two parts must be kept in alignment with each other. Taper pins are used where absence

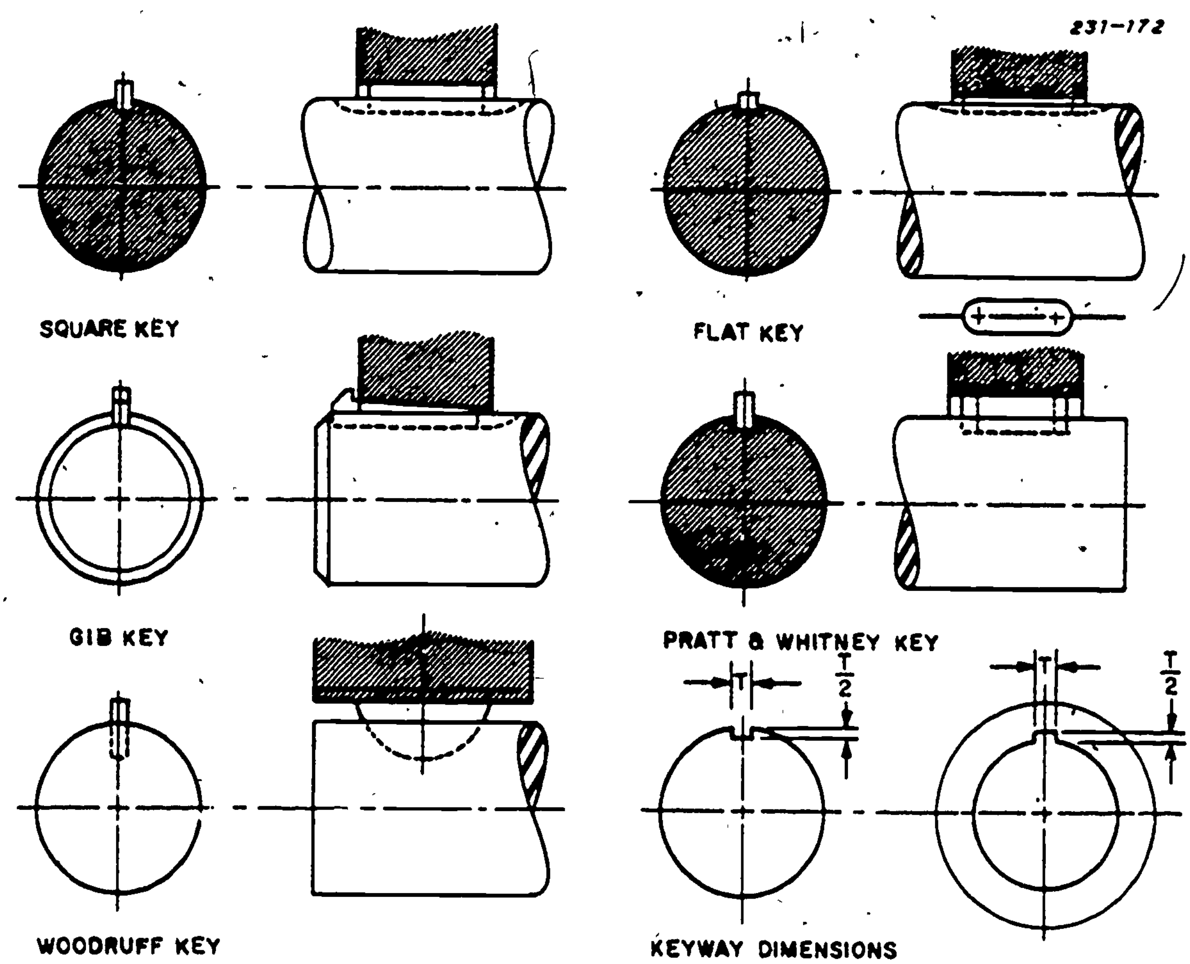

Figure 1-22 Keys.

of play is essential, being driven into mating holes in a hub and shaft. A threaded taper pin is threaded on the small end and is used where disassembly for maintenance is required. Standard dowel and taper pins, their diameters, and their maximum and minimum lengths are listed in various publications.

Springs. Springs are formed by winding steel wire into the form of a conical or cylindrical helix. In drafting practice, the helical curves are conventionalized into straight lines. Figure 1-23 illustrates the semiconventional representation of compression, tension, and torsion springs and shows the method of dimensioning each type. When the springs are small in size, a single line representation is used.

In production work, a spring is largely a matter of mathematical calculation rather than a matter of drafting. The spring is usually designed to meet certain requirements, and these are specified on the drawings. In laying out a semiconventional representation, you find that the steps which you should use are similar to those for drawing screw threads. Pitch distance is determined by dividing the spring length by the number of coils in the spring, and the coils are given a slope of one-half pitch. A fairly accurate representation usually satisfies all requirements. Of more importance are the spring dimensions and notes which must give the free length, controlling diameter, number of coils, style of ends, and size, shape, and kind of material. The shape of the spring material is important, since springs are also made from square wire. The representation of a spring made from square stock is the same as the representation of a square thread minus the core of the shaft. Steps in laying out semiconventional round wire and square wire springs are shown in figure 1-24. A spring having a closed and ground end means that the last coil has its lead reduced to zero, touching the adjacent coil at the end of the last loop.

Exercises (407):

1. What are the physical characteristics of a key?

2. What are the physical characteristics of a pin?

3. What are the three types of spring?

1-7. Basic Gears

The basic types of gears are mechanical devices which appear frequently on machine drawings. The elements of gear design are complex, and their design is usually the task of an engineer. Draftsmen are rarely concerned with problems of design, such as strenght, velocity, weight, and type of materials. However, it will be your job as a draftsman to translate engineering designs into working drawings.

On detail drawings of gears, it is customary to draw only one or two gear teeth to show their shape. The draftsman then adds dimensions and specifications to explain features which arenot detailed. In assembly drawings used for display purposes, it is usually necessary to draw a complete view of gear mechanisms. On such drawings, the shape of the gear teeth may be approximated. These approximate or "conventional" methods are presented in this chapter, and enough elements of design are included to enable you to make proper drawings of the simpler types of mechanisms.

408. Match terms used when drawing spur gears with their proper definitions.

Spur Gears. Gears are used in machines to transmit motion and power from one part of the machine to another. The parts connected by gears have a uniform motion but their speed ratios depend upon their relative size. Basic types of gears are spur gears and bevel gears. A spur gear is represented in figure 1-25 by two cylinders in contact. It is a bevel gear, with two cones whose surfaces contact. They illustrate how motion can be transmitted by contact alone. You can readily see that pegs or teeth attached to one surface to mesh with recesses on the other surface would give a constant motion without slippage. Spur gears and bevel gears are pictured first as cylinders and cones in order to explain pitch diameters. The diameters of the cylinders are pitch diameters, from which tooth forms are calculated. In the study of bevel gears, the basic pitch diameters of the gears are the largest diameters of the imaginary cones. As in the study of spur gears, the layout of teeth for bevel gears is based upon data relating to pitch diameters.

Gear Teeth. The proportions and shapes of spur gear teeth are shown in figure 1-26, and the terms used in designing and drawing gears are explained as follows:

a. Pitch diameter and pitch circle—the diameter of the imaginary cylinder from which the spur gear is derived. The pitch circle has a diameter equal to the pitch diameter.

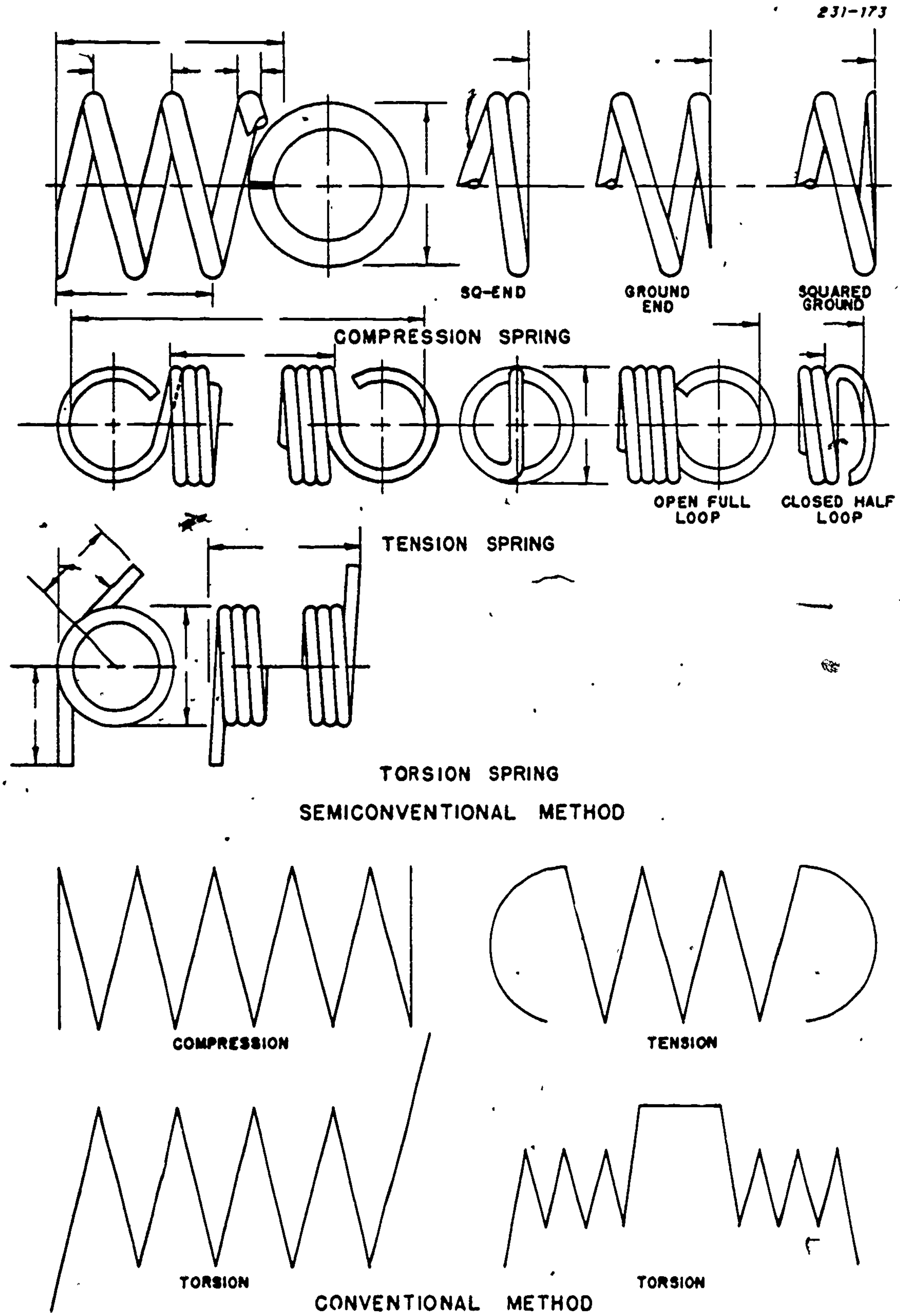

Figure 1 23 Springs.

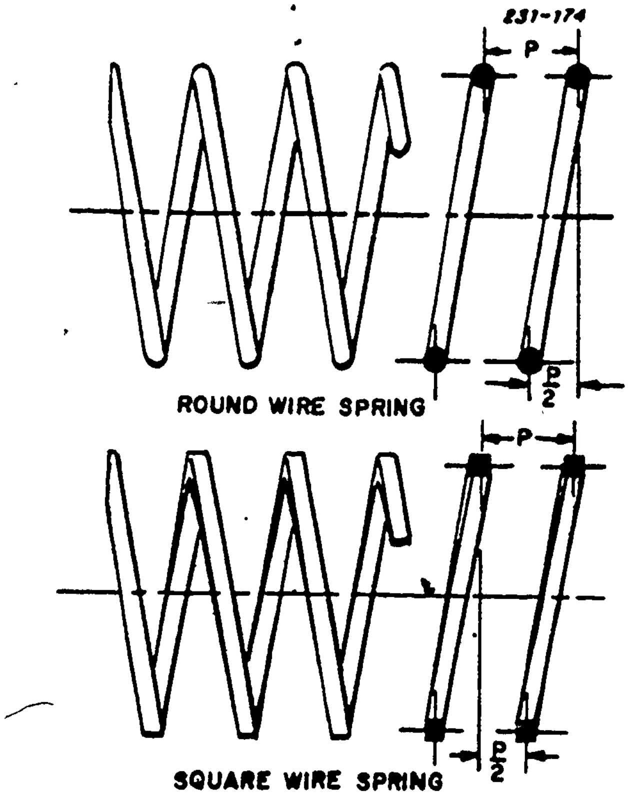

Figure 1-24. Drawing springs.

b. Addendum—the portion of the tooth added to the cylinder. It is the radial distance from the pitch circle to the top of the tooth. Corrected addendum is the radial distance from the top of the tooth to the chord of the pitch circle.

c. Dedendum—the recesses into which the projecting teeth of a mating gear enter, allowing the teeth to mesh. It is the radial distance from the pitch circle to the bottom of the tooth.

d. Outside diameter—the diameter of the addendum circle.

e. Root diameterS—the diameter of the root circle.

f. Depth of tooth—the total height of the tooth; equal to addendum plus the dedendum.

g. Working depth—the distance that a tooth projects into the space between two teeth on the mating gear. It is equal to twice the addendum.

h. Clearance—the distance between the top of a tooth and the bottom of the mating space. Since the dedendum (recess) is slightly greater than the addendum (projection), there is a clearance.

i. Circular thickness—the thickness of a tooth as measured along the pitch circle.

j. Chord thickness—the thickness of a tooth as obtained along the chord of the pitch circle.

k. Base circle—the circle from which tooth curves are formed. This circle is illustrated in the drawing shown in figure 1-27.

l. Diametral pitch—the number of gear teeth per inch of pitch diameter.

m. Circular pitch—the distance between corresponding points of adjacent teeth, measured along the pitch circle.

n. Pressure angle—when two gear teeth are in contact, a line perpendicular to the common centerline of the gears is drawn through the point of contact. This line is called the common tangent. Another line is drawn through the point of contact at an angle of 14½° to the common tangent. The angle formed by these lines is the pressure angle. The point through which these lines pass is the tangent point of the pitch circles. This angle can be seen in figure 1-27.

This angle determines the size of the base circle and, therefore, determines the shape of involute gear teeth. Three gear tooth forms which are standardized are the 14½°, 20° full-length form, and 20° stub form.

- Gear—the larger of two mating gears.
- Pinion—the smaller of two mating gears.

Tooth Forms. Two systems of gear tooth profiles in use are the involute and cycloidal. An involute curve is the curve generated by a point on a taut string as the string is unwound from the cylinder. A cycloid is the curve generated by a point on the circumference of a circle as the circle rolls on a straight line. If the circle rolls on the outside of another fixed circle, an epicycloid is generated; if it rolls on the inside of the other circle, a hypocycloid is generated.

The involute form is used more in making machine-cut gears. The cycloidal form is used for making cast gears, since it lends itself to pattern-making techniques. On a working drawing of a gear which is to be cast, it is necessary to draw the outline

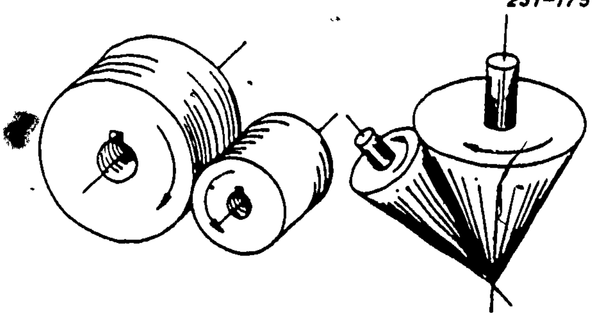

Figure 1-25. Friction gears.

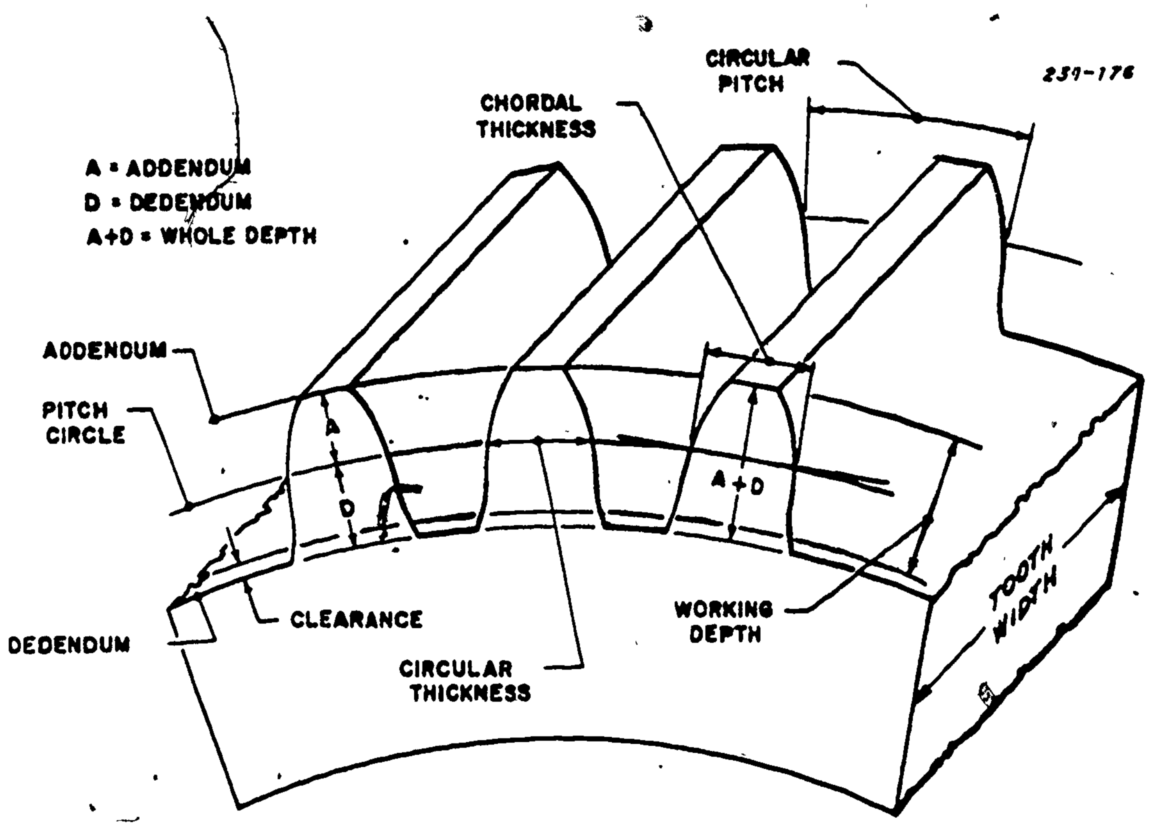

Figure 1-26. Gear nomenclature.

of one tooth. If the gear is to be made by a machine cutter, a blank gear is drawn showing only the necessary dimensions of the blank. Information about cutting is given in the form of notes. The most common form of gear is the involute form.

A convenient conventional method of representing both types of gear teeth is used on working drawings. It does not give the actual profile of the tooth, but a note indicates the type required. The task of making the gear then falls to the machinest or patternmaker who must produce a gear which meets the design specifications.

The axes of spur gears are parallel to each other; and in order for a gear and pinion to mesh, they must have the same circular pitch and teeth of the same form. They must both have an integral (whole) number of teeth. The shape of the involute curve which forms the tooth outline is determined by the diameter of the base circle for each gear. The procedure for finding the base circle is contained in the steps listed in the next paragraph.

Rather than develop involute or cycloidal curves by geometric construction, an approximate curve is drawn by the method shown in figure 1-27. This method is suitable for all dimetral pitches and pitch diameters. Assuming that all necessary dimensions are furnished, you would proceed as follows:

(1) Locate the centers for the spur and the pinion on the same centerline. From these centers, draw the pitch, addendum, and dedendum circles for both gear and pinion. The pitch circles should be tangent, as illustrated by point A in figure 1-27.

(2) Through A, draw the common tangent XY. The common tangent is perpendicular to the common centerline and is tangent to both pitch circles. Draw the line of action; this line passes through point A and makes a 14½° angle with the common perpendicular. The acute angle formed by the intersecting common perpendicular and the line of action is called the pressure angle. The next steps will show how the pressure angle determines the size of the base circle and thereby determines the shape of the teeth. A large pressure angle would reduce the diameter of the base circle and give the tooth face a slightly sharper slope.

(3) From the center of each gear, draw perpendiculars to the line of action. As indicated in figure 1-27, lines MC and ND are radii for the base circles. Draw base circles for the gear and pinion.

(4) Divide the circumference of the pitch circle by the number of teeth to obtain the circular pitch. In

figure 1-27, the gear is to have 24 teeth, and the pinion is to have 16 teeth.

(5) Divide the pitch circle circumference of the gear into 24 equal segments. The circular length of these segments is the circular pitch of the gear. Bisect each segment, making a total of 48 equally spaced points on the pitch circle. These points will be used to draw the required teeth.

(6) With a radius equal to one-eighth the diameter of the gear pitch circle, and with centers on the base circle, draw arcs through each point on the pitch circle as shown. Start the circular arc at the addendum circle and extend it through the plotted points to stop slightly below the base circle. Below the base circle, draw a radial line from the center of the gear tangent to the tooth face curve. Stop the

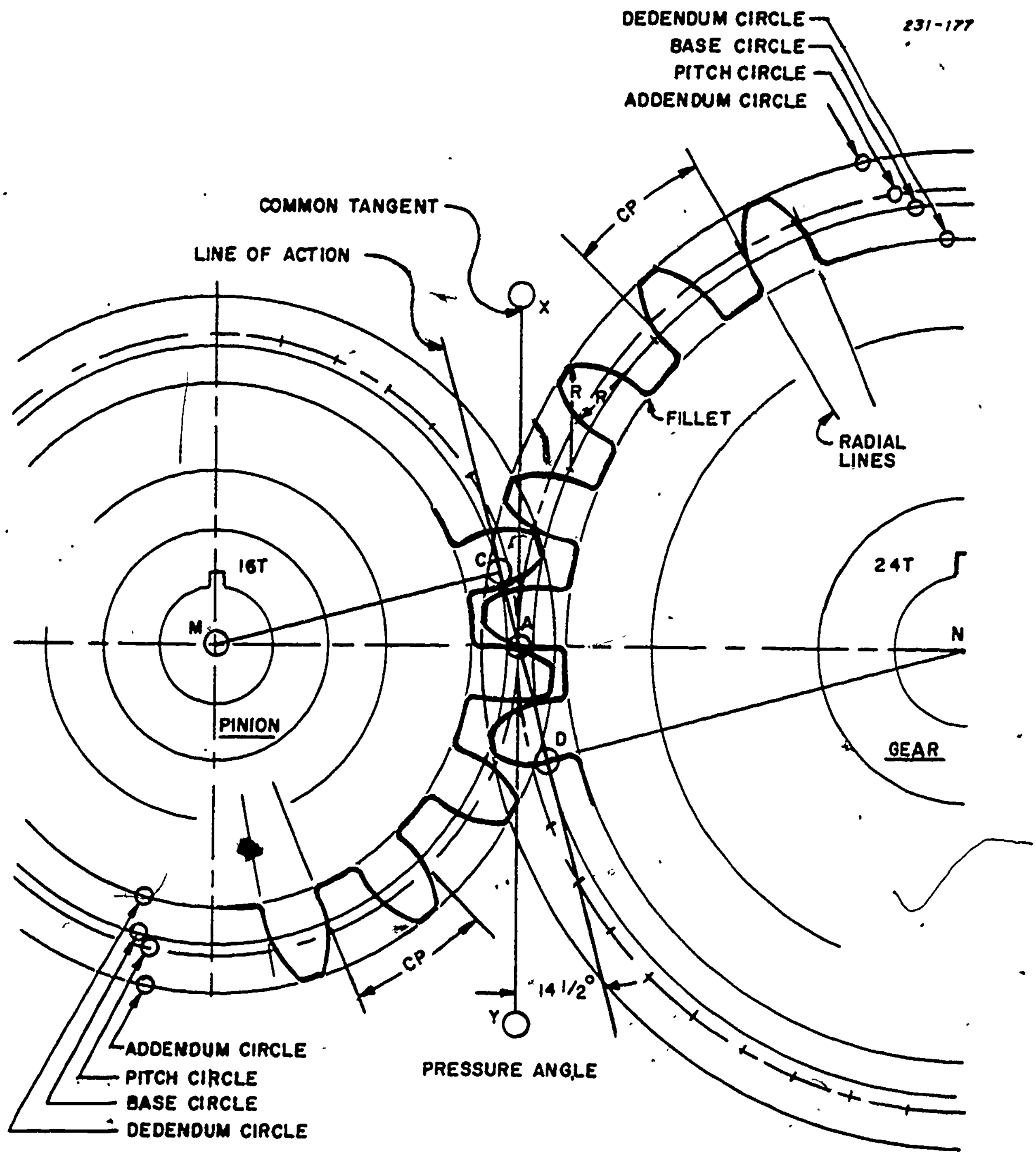

Figure 1-27. Spur gear and pinion.

straight radial line slightly above the bottom of the tooth. Round the inner corners at the bottom of each tooth recess by drawing a small fillet.

(7) The pinion is drawn by following the same steps. Divide its pitch circle into 16 equal segments; then bisect each segment to give 32 points on the pitch circle. The circular pitch of both gears should be the same.

(8) Use a radius equal to one-eighth of the pitch diameter, making sure that you take one-eighth of the *pinion* pitch diameter—not that of the larger gear. With this radius, draw arcs to define the face and part of the flank of each tooth on the pinion. Draw radial lines to complete the flanks and fillet the inner corners of each tooth recess. On gears with 16 teeth or fewer, the radius used to draw tooth curves may be increased to reduce undercutting. Undercutting produces a tooth whose chordal thickness is much greater than its thickness measured along the root circle.

Stub Tooth. When this "conventional method" is used, the true shape of the gear tooth profile is only approximated, but the method is sufficiently accurate for assembly drawings. If the pressure angle is drawn at 20° and the height of the tooth decreased, a stub tooth gear is produced. Stub teeth are drawn in the same manner as standard teeth, the only difference being that smaller diameters are specified for the addendum and the dedendum circles.

Rack. When gear teeth are cut on a straight, flat surface, a rack is formed. The teeth on the rack usually engage with a spur gear, which revolves to move the rack in a straight line. The linear pitch of the rack must be the same as the circular pitch of the gear, and the straight sides of the rack teeth must be inclined at an angle equal to the pressure angle of the gear. The rack teeth must also have the same height proportions (addendum and dedendum) as the spur gear teeth. To draw a rack, you must know the number of teeth, the linear pitch, and the tooth depth. Tooth thickness and other dimensions are calculated in the same manner as for spur gear teeth. A profile view of a rack resembles a section view of acme threads.

Detail Drawing of Spur Gear. Detail drawings of spur gears are very simple to prepare if the gear is to be machine cut from a blank cylinder. Dimensions of the gear blank and other necessary information concerning the teeth are given in the notes, as illustrated in figure 1-28. It is customary to show only one view, this view being in section. Occasionally, a circular view is needed to show keyways, spokes, and other features not evident in the section view. A partial circular view may be used if it will supply the needed details. Where a full circular view is shown, the addendum (outer) circle is represented by a fine solid line or by a fine line composed of long dashes separated by two short dashes. The pitch circle is drawn as a centerline, and the dedendum or root circle as a hidden line, or as a line similar to the addendum line.

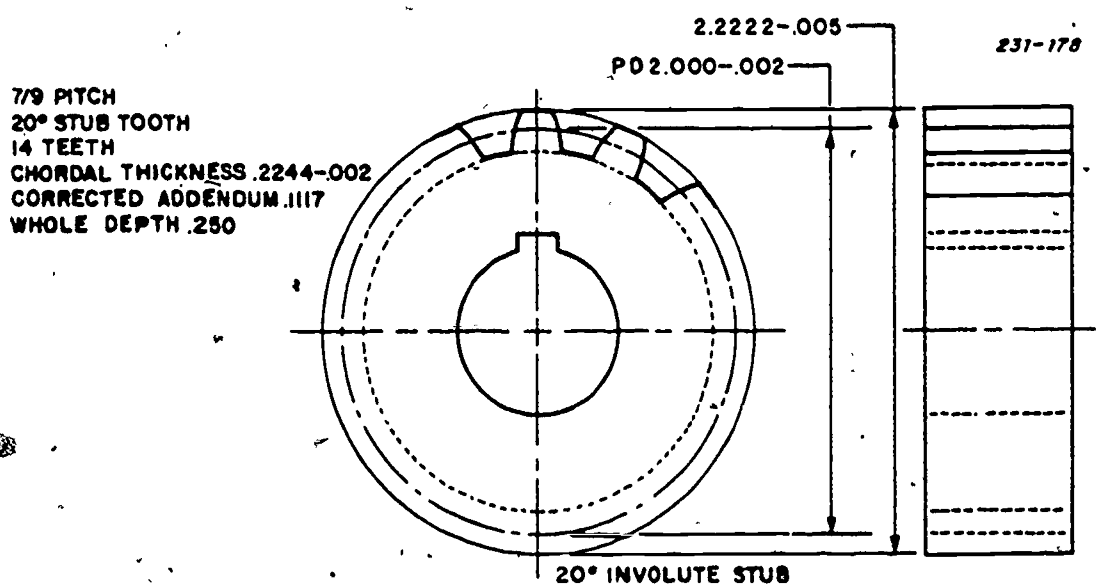

Figure 1-28. Spur gear detail drawing.

Exercises (408):

1. Match the following terms and definitions.

___ (1) The diameter of the imaginary cylinder from which the spur gear is derived. The pitch circle has a diameter equal to the pitch diameter.
___ (2) The portion of the tooth added to the cylinder. It is the radial distance from the pitch circle to the top of the tooth. Corrected, it is the radial distance from the top of the tooth to the chord of the pitch circle.
___ (3) The recesses into which the projecting teeth of a mating gear enter, allowing the teeth to mesh. It is the radial distance from the pitch circle to the bottom of the tooth.
___ (4) The diameter of the root circle.
___ (5) The total height of the tooth.
___ (6) The distance that a tooth projects into the space between two teeth on the mating gear. Equal to twice the addendum.
___ (7) The distance between the top of a tooth and the bottom of the mating space.
___ (8) The circle from which tooth curves are formed.
___ (9 The number of gear teeth per inch.
___ (10) The distance between corresponding points of adjacent teeth.
___ (11) The diameter of the addendum circle.
___ (12) The smaller of two mating gears.
___ (13) A curve generated by a point on the circumference of a circle as the circle rolls on a straight line.
___ (14) A curve generated by a point on a taut string as the string is unwound from a cylinder.
___ (15) Gear teeth drawn on a straight flat surface.

a. Clearance
b. Pressure angle
c. Circular pitch
d. Diametral pitch
e. Base circle
f. Chord thickness
g. Working depth
h. Depth of tooth
i. Root diameter
j. Outside diameter
k. Dedendum
l. Addendum
m. Pitch diameter and pitch circle
n. Cycloid
o. Rack
p. Involute
q. Pinion

1-8. Bevel Gears

Although the axes of spur gears are parallel, the axes of bevel gears intersect. Generally the axes of bevel gears are at right angles to each other, but they may make a greater or smaller angle than 90°. Figure 1-25 illustrates bevel gears as cones whose surfaces are tangent and whose axes intersect at a common apex.

409. Define five terms associated with drawing bevel gears.

Terminology. Figure 1-29 illustrates the important dimensions and terms associated with bevel gears. Let's look at a few of these terms:

- Pitch diameter—the diameter of the base of the pitch cone.
- Pitch cone radius—the slant height of the pitch cone.
- Addendum and dedendum—the same as for a spur gear of the same diametral pitch. These distances are measured at the large end of the tooth, as indicated in the illustration.
- Pitch cone angle—the angle formed by an element of the pitch cone and the cone axis.
- Edge angle—is usually equal to the pitch cone angle.
- Cutting angle—the pitch cone angle minus the dedendum angle.
- Face—the width of the gear tooth. This width should not be greater than one-third the length of the pitch cone radius.

Drawing Bevel Gears. A detail drawing of a bevel gear gives dimensions and necessary data for cutting the gear. A sectional view usually provides all the necessary information. Figure 1-30 illustrates the method commonly used for bevel gear working drawings. On assembly drawings, it may be necessary to draw the gear teeth. The following method does not give exact tooth shape, but it is sufficiently accurate for assembly drawings. In figure 1-31, the bevel gear tooth profiles are developed on a plane surface which is a developed cone surface. When thus constructed on a plane surface, the tooth profiles are drawn in the same manner as for spur gears. The construction is explained in the following paragraphs.

Side view. For a side view of the gear, draw the pitch cone, addendum angle, and dedendum angle to define the whole depth of the gear tooth.

Then draw the outline (element) of another cone, called a back cone; this element is at right angles to the pitch cone element. The apex of both cones should be on the shaft centerline. With the back cone apex as a center, draw the developed arcs of the pitch, addendum and dedendum circles. On these arcs, lay out gear tooth profiles just as you did for spur gears. The diameter of the base circle can be

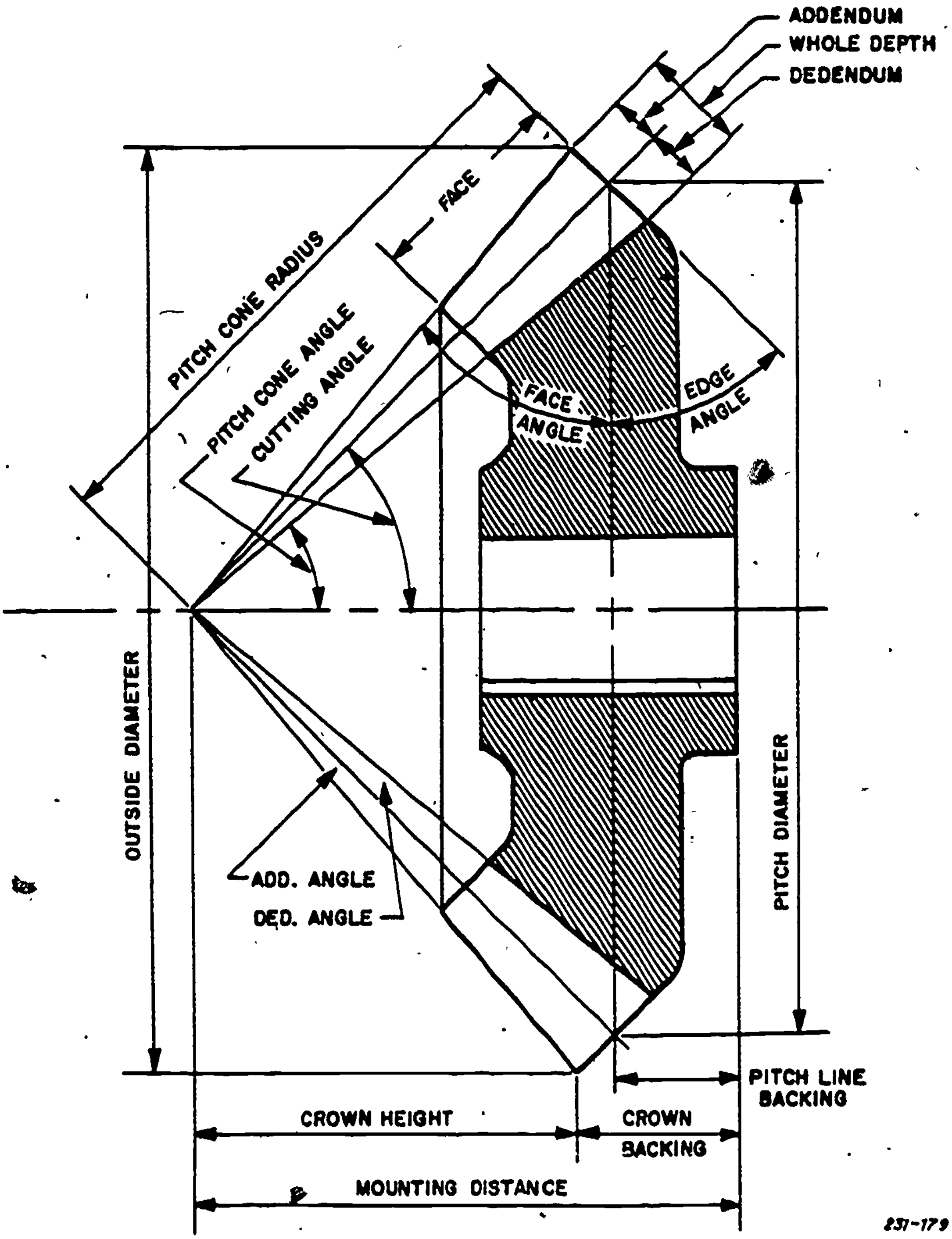

Figure 1-29. Bevel gear nomenclature.

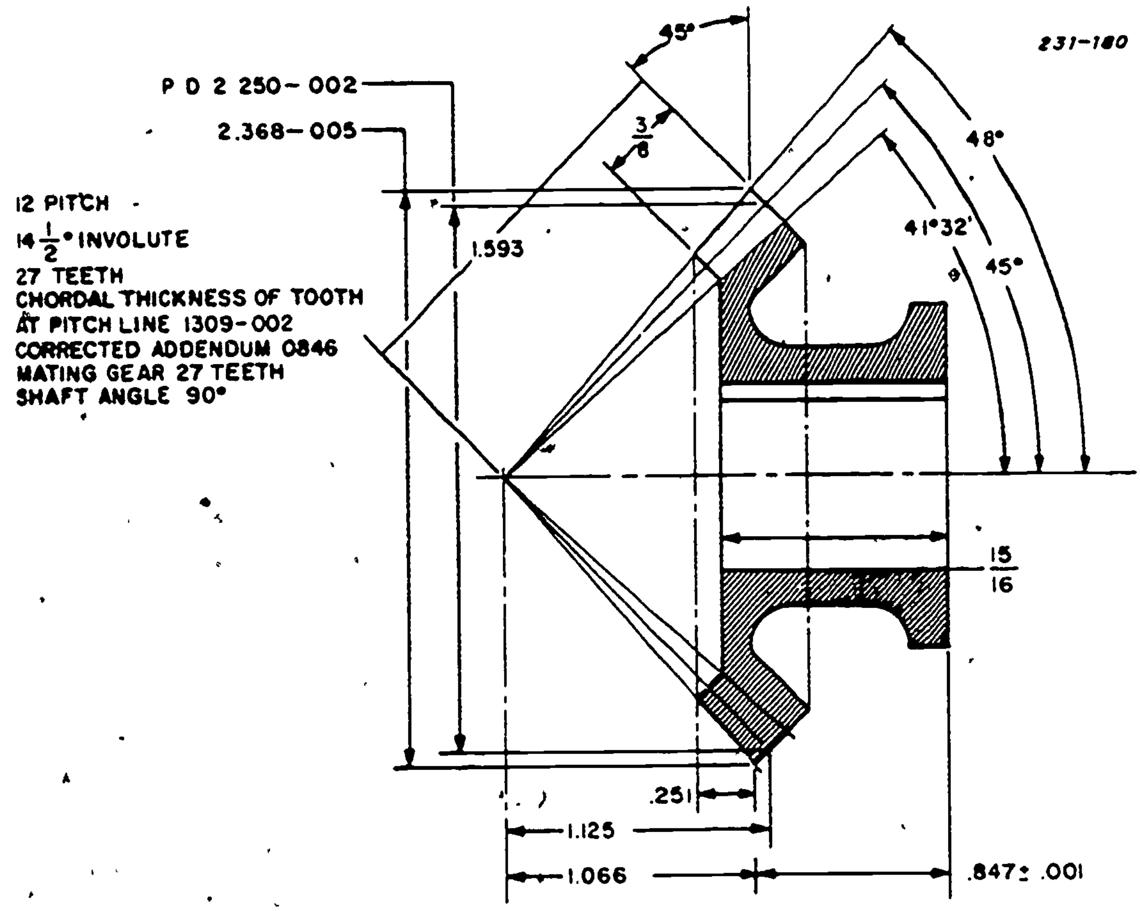

Figure 1-30. Working drawing of bevel gear.

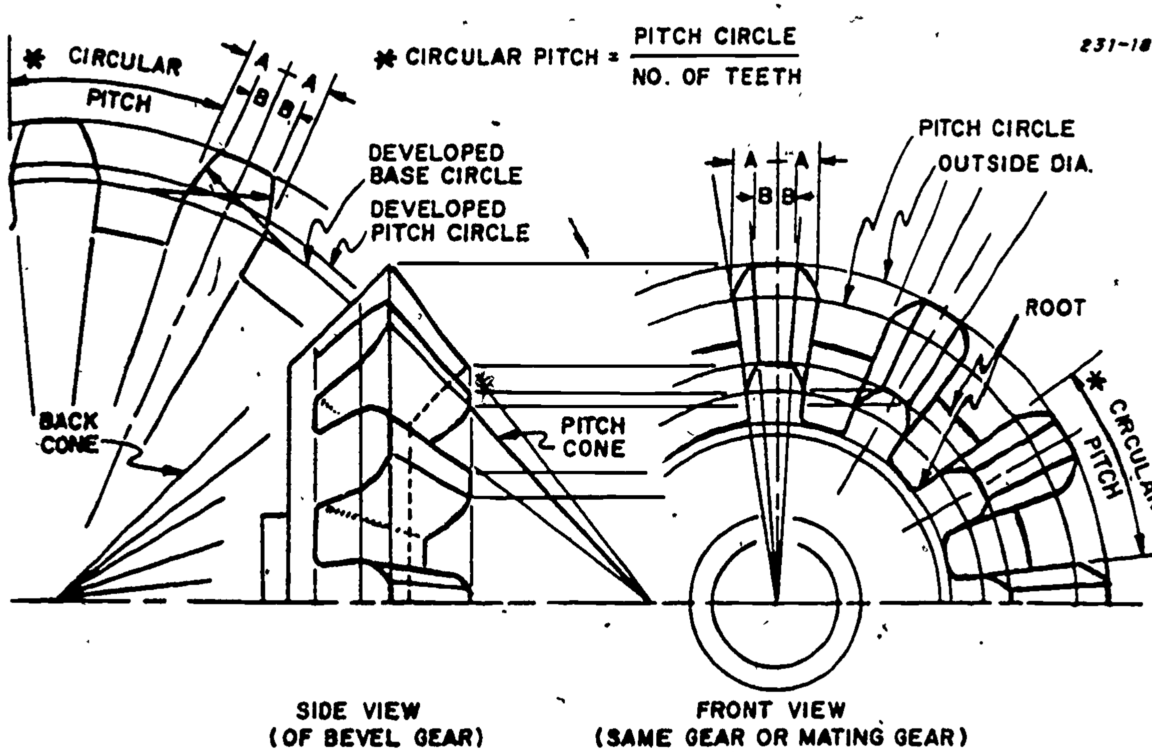

Figure 1-31. Bevel gears in assembly.

estimated, or it can be constructed as shown in figure 1-27.

You must remember that the actual circular pitch is found by dividing the circumference of the pitch circle by the number of teeth. Do not use the developed pitch circle to compute circular pitch—the width of the large end of the tooth would be too great.

Having found the circular pitch, lay out two or three tooth profiles on the developed back cone. Pass a center line from the apex of the back cone through the center of the developed tooth profile. From this centerline, you will obtain width measurements as indicated. These measurements are used to draw the front view of the gear.

Front view. The front view of the same gear would, of course, belong to another view. Therefore, the location of the center of the view will depend on the layout of the entire drawing. If the side view is the only view required, one half of the front view is drawn as a construction. After a half view is thus drawn and used to complete the side view, the front view construction will be erased. If the front view is used only as a construction, it may be drawn on a separate sheet taped in place on the main drawing sheet.

To draw the front view of the same gear which is shown in the side view:

(1) Extend the side view axis to the right, so that the front view can be properly alined upon it. From a centerpoint on this axis, draw circles to define the outside diameter, inner and outer pitch circles, tooth depths, and the diameter of the small end of the tooth surface.

(2) Divide the outer pitch circle circumference into the same number of spaces as the number of teeth required. In figure 1-31 the gear is to have 12 teeth, so the teeth will be spaced as shown.

(3) Draw radial lines from the center of the circular view through the 12 points found by dividing the pitch circle. This provides centerline axes of symmetry upon which to construct each tooth.

(4) Transfer width dimensions for the large end of the tooth. Take these dimensions from the developed tooth profile and lay them out on tooth centerlines as indicated. Draw the outer end tooth curves in the front view with an irregular curve.

(5) Draw radial lines from the center of the gear tangent to the curves which were plotted on the large end of the tooth. These radial lines will locate corresponding points on the small end of the tooth. Again, use an irregular curve to draw the tooth face curves which form the small end of each tooth.

(6) Draw all teeth in the front view; then complete the side view by projecting points from the front view of the side view. Points on the tooth face curves and depth line must be projected for each tooth. Each tooth in the side view will appear different from adjacent teeth. However, symmetrically placed teeth will be alike in the front view.

Exercises (409):

1. Define the following terms as they relate to the bevel gear.
   a. Pitch diameter.

   b. Pitch cone angle.

   c. Cutting angle.

   d. Face.

   e. Circular pitch.

1-9. Production Drawings

Now that you have learned how to draw threads, bolts, nuts, gears, as individual items, we will discuss production drawings. In this type of drawing, you will be showing a combination of many of the individual items. These drawings furnish data which will give the exact size of parts, the kind of material from which they are to be made, and the manner in which the parts are to be assembled in the completed machine. From the design sketches and layouts already prepared, you will prepare detail and assembly drawings. These are the working drawings used by workmen who are to produce the product.

410. Given a situation calling for a type of drawing, name the type of drawing described.

Machine Drawings. Machine working drawings are generally divided into two general classes; assembly drawings and detail drawings. There are, however, three other types of drawings with which you should be familiar: modification drawings, installation drawings, and wiring diagrams.

Assembly drawing. An assembly drawing is an orthographic drawing which shows all the parts of a machine fitted together in their relative working positions. These drawings vary greatly in regard to dimensioning and completeness of detail. The dimensions are sometimes shown for installation purposes only so that another designer who wishes to use the unit will allow adequate space for it to be fitted into place. Such drawings show the appearance of the unit as a whole. When the unit is small, complete information is given on the drawing; and it may be used as a working drawing. On such a drawing, called an assembly working drawing, each piece is completely dimensioned and no additional drawings are required.

If the object is complicated, a complete assembly may not be drawn. A set of subassembly drawings would be prepared to take the place of a complex drawing of the entire object. Thus, a subassembly drawing is an assembly drawing of a group of related parts that form a unit in a more complicated machine. This subunit would be fitted with other subunits and individual pieces to make up the complete object. This type of drawing is often called a group assembly.

Detail drawing. This type of drawing is one which gives complete information for the manufacture of a component part of an assembly. The drawing includes dimensions, specifications of materials, shop notes, changes, part number, number of parts required, and other information relative to the manufacture and assembly of the part.

Only parts which are not standardized need to be detailed. For example, it would not be necessary to draw a detail of a ball bearing since this particular part is purchased as a complete unit from a commercial manufacturer.

In machine detailing, each piece may be detailed on the same sheet. when several details are placed on the same sheet, the same scale should be used to draw each part. If different scales are used, the scale for each individual detail must be specified in an appropriate place. The usual practice is to denote the scale directly under the view.

Modification drawing. When changes are to be made to existing equipment, a modification drawing is used. The title of the drawing, illustrated in figure 1-32, indicates that parts are to be modified rather than manufactured. Some modification drawings call out parts that must be added or changed in making the modification. The drawing number is usable as a new part number for the modified part.

Installation drawing. Assembly drawings are frequently used to give the information required for the installation or erection of equipment, and are then called installation drawings. This type of drawing (see fig. 1-33) shows the location and means of attaching one or more related parts to the complete article or to one of its major components. These drawings give complete information for installing the parts. Unlike the modification drawing, installation drawing numbers are not usable as part numbers.

Wiring diagrams. A wiring diagram, illustrated in figure 1-34, shows the wiring necessary to connect components together electrically. Schematic wiring diagrams show how electrical or electronic equipment will operate. With these diagrams, we can trace circuits and understand their functions. Reading a schematic diagram consists of tracing circuits and visualizing what action occurs as the result of changes in operating controls and receiving signals.

Wiring diagrams often specify part names and numbers in addition to those for wires, but the wiring diagram should not be used as a source of part numbers or names. These part numbers and names should be taken from assembly, detail, and modification drawings only. Title block information is the same as detail drawings with the exception of scale and weight which are not applicable. An application column on the drawing shows the applicable models of aircraft or other units for which the drawing is made.

You will find that the proper selection of views will do much to make drawing easier and at the same time will give complete descriptions of an object. Each drawing in a complete set of drawings must supplement the others by adding to the total picture; each view must contribute, or it is not needed.

With more complex structures, more views are needed. Some of these are auxiliary views, partial views, and section views. Your first question should be, "Is this view necessary?" While making a drawing, you must keep the reason for making it clearly in mind and also remember that the final value of a drawing is its clearness and exactness in giving information necessary for making the finished product.

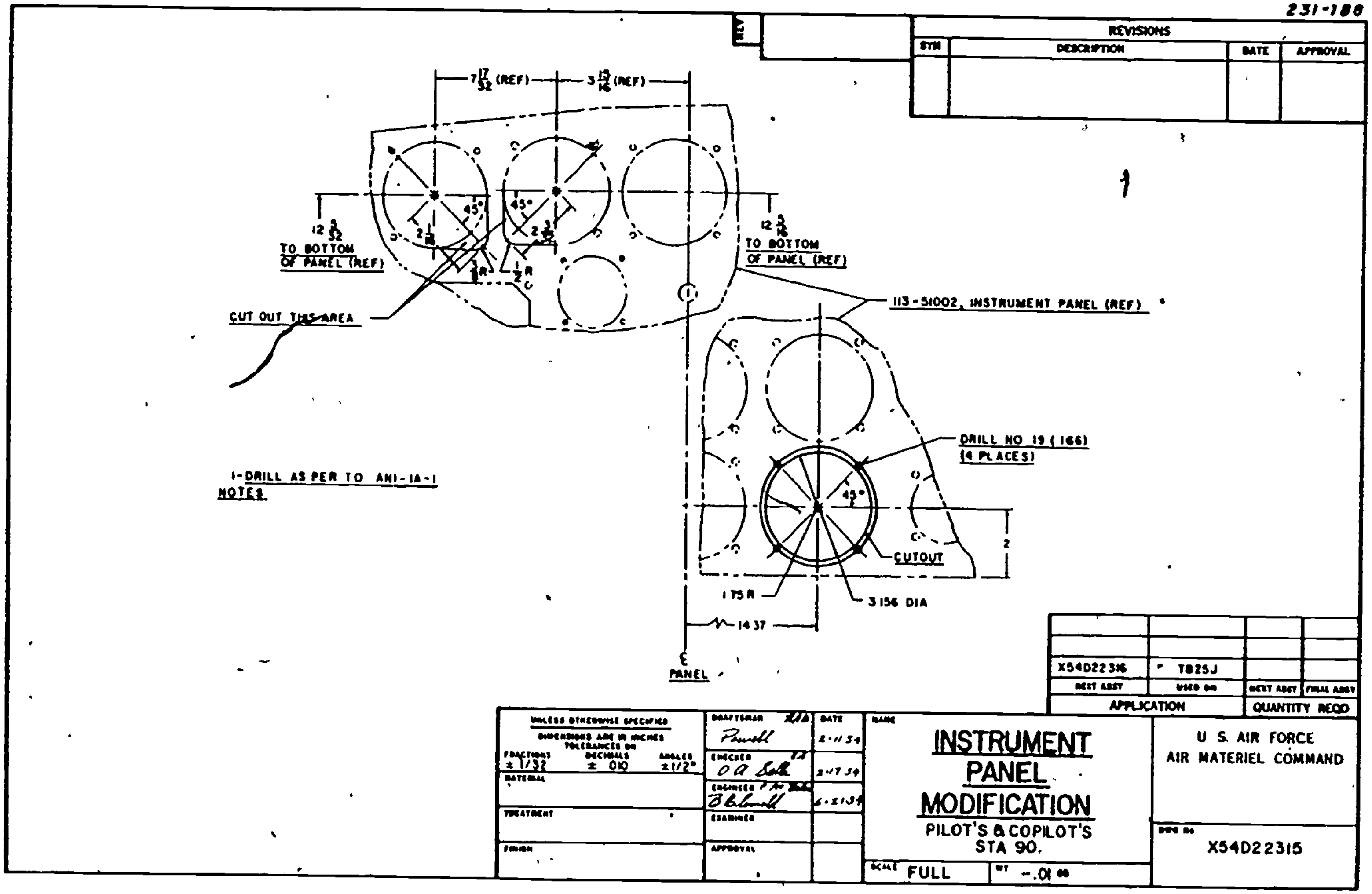

Figure 1-32. Modification drawing.

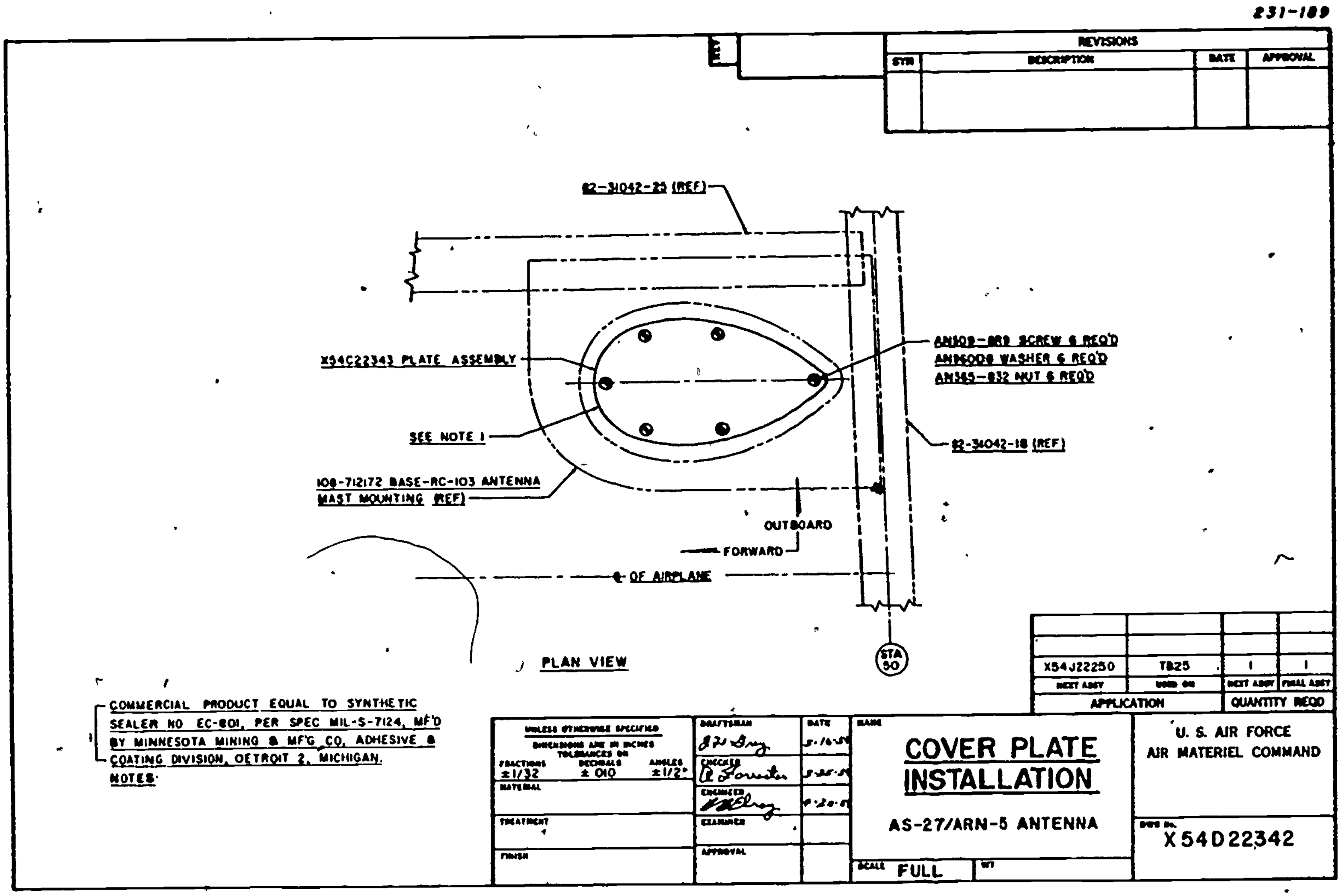

Figure 1-33 Installation drawing.

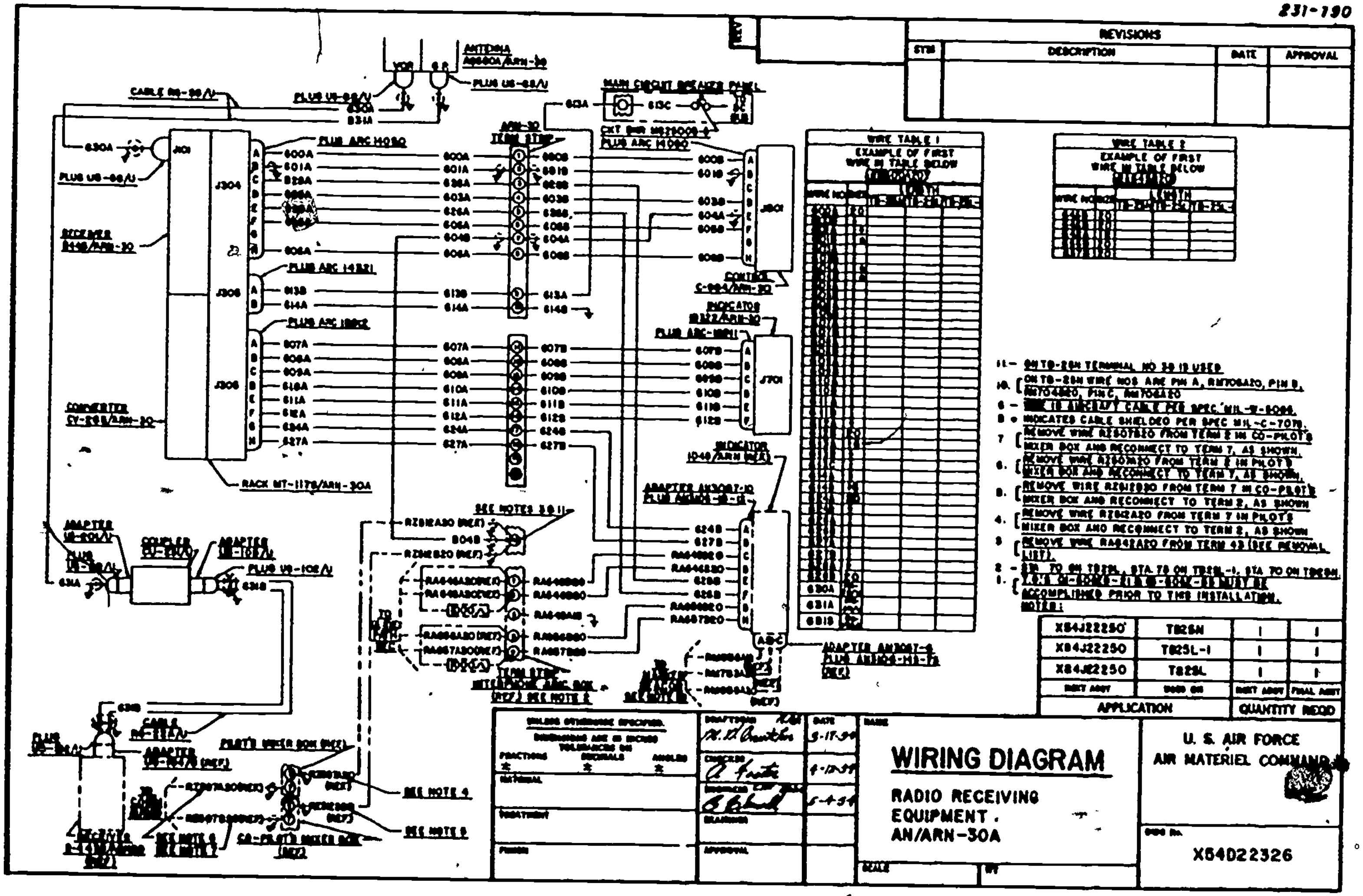

Figure 1-34. Wiring diagram.

Exercises (410):

1. What type of drawings are orthographic drawings, and show all parts of the machine fitted together in their working positions?

2. What type of drawings contain dimensions, specifications of material, shop notes, changes, part numbers, number of parts required, and other information related to the manufacture and assembly of the parts?

3. What type drawing specifies changes when changes on the original drawings are to be made?

411. Give three factors affecting the scale of a drawing, and the five scale sizes usually used.

Scale. Machine drawings are usually made double size, full size, one-half size, one-quarter size, or one-eighth size. The choice of the scale depends upon the size of paper used, the necessity for showing small details clearly, and the amount of dimensioning to be added to the view. Details should be drawn to full size when possible; but if the part is very small, it must be drawn to an enlarged scale, perhaps twice actual size. You must, therefore, know how to scale a drawing.

The problem of scaling a drawing is greatly simplified if you have a mechanical engineer's scale. On this type scale, the primary units represent inches. Divisions of primary units represent the commonly used decimal fractions of an inch. For example, on the scale labeled "20" the primary unit is one-half inch. One-half inch is then marked off (divided) into fractions in the same manner as the full-sized scale. When all units are subdivided throughout the length of the scale, the scale is called full-divided. When only the first primary unit at the end of the scale is subdivided, the scale is called end-divided. You learned to use the various types of scales, used by mechanical engineers, civil engineers, and architects, in an earlier volume of this course. However, a review of the use of these scales at this time in connection with machine drawing would be helpful to you.

The architect's scale is usually end-divided. The primary unit at the end of the scale represents 1 foot and is divided into parts representing inches, and in some cases fractions of inches. Figure 1-35 shows two of the scales which you will find on an architect's scale.

To compare the two types of scales, take one-fourth inch as a primary scale unit. On a mechanical scale having one-fourth inch as the primary unit, the scale is labeled "40," and the end unit is subdivided to represent fractions of an inch. Any object drawn to this scale appears one-fourth its actual size. On the other hand, an architect's scale having one-fourth inch as the primary unit will scale the object down to 1/48 actual size.

The end unit on the architect's scale represents 1 foot and is divided into 12 parts, each representing 1 inch. You can see by examining your own scale that the larger scales, such as the number "3" scale shown in figure 1-35, are subdivided so that the smallest division represents a fraction of an inch. On the smaller scales, the subdivisions cannot be carried out quite so extensively. The smallest scale, 3/32, has an end unit divided into 6 equal parts, so that each subdivision represents 2 inches. On these small scales, it is impossible to measure out fractions of an inch. The drawing will be slightly inaccurate; but since true-size dimensions are given, the workman will have no difficulty.

To use an architect's scale for a machine drawing, you must always remember that the end units are subdivided to represent 1 foot—not 1 inch. Listed below are various scales for machine drawings; and with each one listed, there appears a procedure for using an architect's scale.

- *Full size.* Use the full size scale and let each inch represent 1 inch.
- *Half size.* If the object is too large to fit on the paper in full size, it can be reduced to half size. Use the full-size scale and let each half inch represent 1 inch, as shown in figure 1-37. Or you may mentally divide every given dimension in half and lay it out accordingly.

- *Quarter size.* If further reduction is needed, you may use the full scale and let $^1/_4$ inch represent 1 inch. Or you can use the side labeled "3" on the architect's scale. On this 3" = 1') scale, the subdivided portion representing 1 foot is actually 3 inches long; each mark representing 1 inch is actually $^1/_4$ inch long. Therefore, this scale can be used directly to make machine drawings to one-fourth actual size (see fig. 1-35).

Eighth size. For this size, $^1/_8$ inch equals 1 inch. Therefore, the "$1^1/_2$" ($1^1/_2$" = 1') architect's scale can

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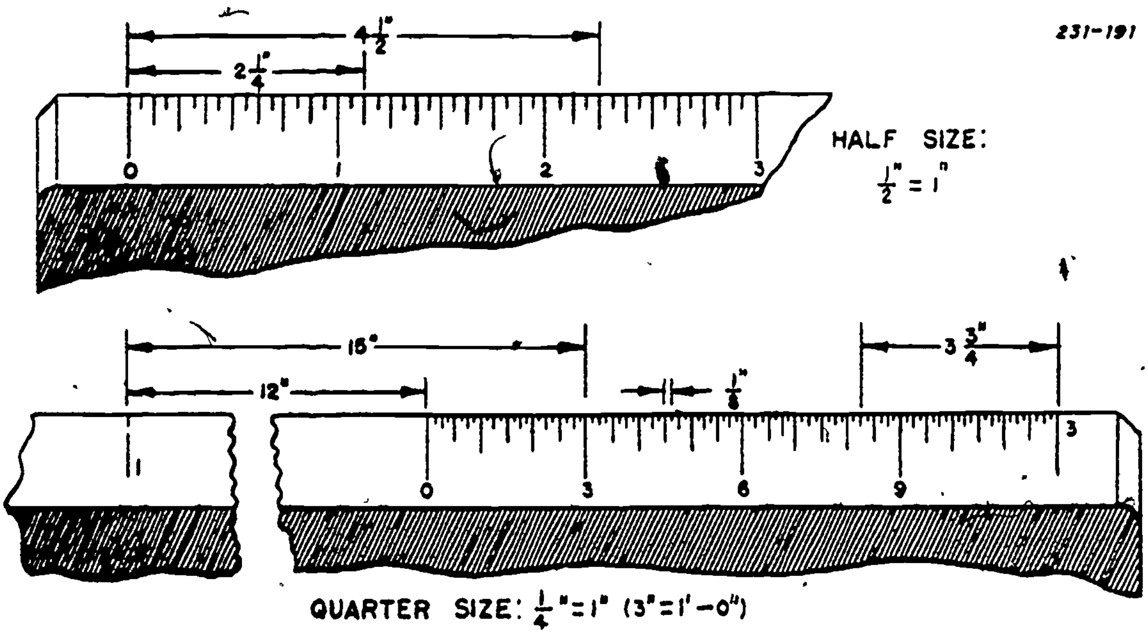


Figure 1-35. Use of scale.

be used since its divisions representing inches are actually ¼ inch in size.

• *Eighth size.* Use the full scale and double every dimension. On the end-divided architect's scale, as you know, only the end units are subdivided. The inner end of each subdivided unit is marked with a zero, and two scales appear on one face. There are two lines of numbers on one face—one line of numbers applies to one scale and the other line of numbers applies to the scale at the opposite end of the same face. The smaller of the two scales appearing on any one face is always half of the larger, and the division marks of the smaller scale coincide with markings which also apply to the larger scale. You must be sure that you follow the correct line of numbers when you work with such a scale. When a scale on the right end of the stick is used, foot measurements are read to the left of the zero mark and inch measurement are read to the right. Conversely, with a scale on the left end of the stick, foot measurements are made to the right of the zero point and inch measurements are made to the left. As shown in the lower part of figure 1-37, measurements involving inches may be set off from either end of the subdivided unit. For distances over 1 foot, the zero end of the subdivided unit is easier to use, because it can be used along with the foot divisions. For example, to mark off 15 inches, set the 1-foot mark on one end of the object, read back toward the zero point to obtain 12 inches, and add three 1-inch divisions to the right of the zero point to make the total distance of 15 inches.

Very often you will be required to give decimal dimensions on a drawing, and you must change common fractions to decimals. You can find handy charts, called conversion tables, which can be used to convert common fractions into their decimal equivalents.

Exercises (411):

1. What are the three factors affecting the scale of a drawing?

2. List the five scale sizes usually used to scale a drawing.

412. Name the types of information usually found in title blocks and other types of information sometimes used on assembly drawings.

Title Blocks. The type, form, location, and completeness of title blocks vary greatly. Every commercial drafting room has developed its own standard titles; and likewise, various military organizations have developed standard title blocks to suit their particular mission. In general, titles should contain the following information.

a. Name of the part or structure.

b. Name and location of organization.

c. Scale or scales used.

d. Date.

e. Name or initials of draftsman, tracer, checker, and head engineer.

f. Drawing number. (The drawing number assigned will depend upon the system used. The number may serve a dual purpose; for filing drawings and to give information in code form.)

Some of the illustrations in this chapter show drawings which in addition to having title blocks, have other blocks for recording information. On figure 1-33, for example, the Revisions block contains no entries. When a revision is made, this block is used to state what change was made, when it was made, by whom it was made, and the approving agent. In the same figure, another block deals with Application and Quantity Required. The Quantity Required section is filled in with the number needed in the next assembly and also in the final assembly. You can see by this block in figure 1-33 that only one is required for the completed unit.

The Application section tells where the part is used. The type number of all equipment using the part is entered in the correct block. The next Ass'y position of the Application block is filled out with the drawing number of the assembly in which the part is found.

This basic system of identification and information blocks makes for easier filing, and all drawings which are related to each other can be easily located for use. This system, with necessary variations, is used by all Air Force organizations.

Other types of information blocks which you may use on assembly drawings are Bill of Material, List of Parts, Not Detailed, Bolt List, and Assembly Parts List. These lists are technical records which make supplementary oral or written information unnecessary.

Value of Machine Drawing. The information in this chapter has been presented from the standpoint of machine drawing. However, you should realize that machine drawing is the application of fundamental principles to one specific branch of engineering. Assembly and detail views and the use of notes, titles, and record blocks on drawings are by no means exclusive to drawings made for the machine industry. You will find that the ability to make neat and accurate machine drawings prepares you for the study of other specialized types of drawing, such as architectural, structural, electrical, and topographic, to name only a few.

Since section views appear quite frequently on machine drawings, there is no better way to become proficient in this type of drawing than by using machine parts to illustrate the principles of sectioning. The study of fasteners was presented in a like manner—from the standpoint of machine drawing and as knowledge essential to structural and aircraft drawing. Although the study and drawing of gears and cams are primarily concerned with machine elements, they also involve the neatness, accuracy, and exactness which characterize all engineering working drawings.

Exercises (412):

1. What type of information should a title block contain?

2. What are the two sections required for a title block in an assembly drawing?

CHAPTER 2

Intersections and Developments

GEOMETRIC SURFACES are often combined in the design of machine and structural parts. It is important to understand how objects are made up of the intersections of different types of surfaces. In the first section of this chapter, we will see how the use of intersections helps produce drawings of three-dimensional objects. In the second section, we will see how to develop a two-dimensional surface to use for producing a three-dimensional object, for example from sheet metal.

2-1. Intersections

When an object is made up of two or more different types of surfaces which intersect, each surface extends only as far as the line of intersection. If the two surfaces which intersect are plane surfaces, the line of intersection is a straight line. If the intersecting surfaces are a plane and a curved surface or two curved surfaces, their line of intersection is a curved line.

Frequently, the intersection line between adjoining surfaces is difficult to represent in multiview drawing. However, if the component parts of a sheet-metal object consisting of a number of different geometric shapes are to fit accurately and smoothly, an accurate drawing of the intersecting surfaces is required. Therefore, you must know how to represent the intersection lines between various types of surfaces. Such intersection lines fall into one of two general groups. In The first group, straight-line intersections are produced by intersecting plane surfaces. In the second group, curved-line intersections are produced when a curved surface intersects a plane surface of another curved surface.

To find the intersection of two surfaces, locate the points where the edges of one plane pierce the other plane. To find the intersection which involves a curved surface, locate the points of intersection of surface elements by using a series of cutting planes, each of which contains a surface element. These planes cut lines on both surfaces. The intersections of these elements are points on the required line of intersection. The cutting planes must be drawn through points which will accurately locate the curve of intersection. The procedures for finding intersections by the "piercing-point" and the "cutting-plane," methods are explained in this section.

413. Answer key questions concerning procedures for determining the point of intersection of various plane surfaces.

Intersection of Plane Surfaces. Before discussing the intersection of plane surfaces, let's review some of the important basic facts of multiview projection as they pertain to intersection. Let's start with the intersection of lines and planes.

Intersection of Lines and Planes. The position of both lines and planes affects the intersection. Both the line and the plane may be in a principal position; that is, the line may be parallel with two of the three principal planes of projection (horizontal, frontal, or profile) and the plane parallel with one plane of projection and perpendicular to the other two; the line may be inclined and the plane in a principal position; the line may be skew (inclined to all principal planes) and the plane in a principal position; the line may be skew and the plane inclined; or both line and plane may be skew.

Line and plane in principal position. Principal positions of lines occur when the lines are not inclined to any principal plane. Therefore, if the line is parallel with, or lies in, the principal plane, no single point of intersection is possible; but in other positions, such as when the line is perpendicular to the plane, a single point of intersection exists. Figure 2-1 illustrates this fact. It shows a horizontal profile line AB and the three principal planes of projection. Since the line is parallel to the horizontal (top view) and profile (side view) planes, the line and these planes do not intersect except at infinity. However, the line is perpendicular to the frontal plane, and there is a single point of intersection. Consider the bottom edge of the horizontal plane and the left edge of the profile plane as edge views of the frontal plane. Line AB pierces the frontal plane

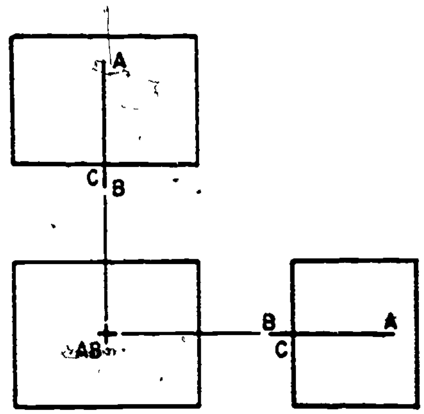


Figure 2-1. Intersection of a line and plane.

at point C in each view. This apparent point of intersection is often called the *piercing point;* and when it pierces a plane as seen as an edge, it establishes the location of the point in the remaining view. By projecting point C to the front view, you find the point of intersection to be at point AB. Thus, you have established that *the intersection of a line and a plane is a point on the line coincident with the edge view of the plane.*

Line inclined, planes in principal positions. When a line is not parallel to two of the principal planes, two points of intersection occur. For example, figure 2-2 shows a frontal line AB which is not parallel to either the horizontal or profile plane. The line will not intersect the frontal plane (except at infinity). The intersection with the profile plane is established by point C in the top and front views where the profile plane appears as an edge; the intersection is then easily projected to point C in the profile plane. The intersection with the horizontal plane is established by point D in each of the front and profile views. Then it is projected to the top view to locate the point of intersection.

If you use the top and left side of the rectangular top view as the edge views of frontal and profile planes, observe that line AB does not intersect these two planes. However, when you extend the planes, points of intersection do exist.

Line skewed, planes in principal positions. A skew line (a line inclined to all principal planes) intersects all three principal planes. Figure 2-3 shows the skew line AB in all three views. Notice in the top and front views that line AB intersects the edge representing the profile plane at point D. The line and the horizontal plane intersect at point E (shown on the figure with dashed lines for extensions).

Note in every case that the intersection is found by observing where the line intersects the surface in the edge view of the surface. For horizontal, frontal, and profile surfaces, two views always show the surface as an edge. Thus, to determine the point of intersection, you must (1) consult two views and (2) project the apparent point of intersection from one view to the surface in the other view.

Line skewed, plane inclined. It is easy to find the intersection of a line and an inclined plane because the inclined plane appears as an edge in one of the views. In figure 2-4, the inclined plane appears as an edge in the profile view. Project the apparent point of intersection C to line AB in the front view where you can see that it falls within the confines of the front plane. Point C is, therefore, the real point of

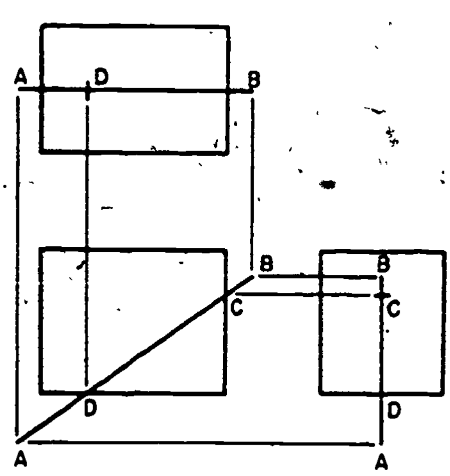


Figure 2-2. Intersection of an inclined line and plane.

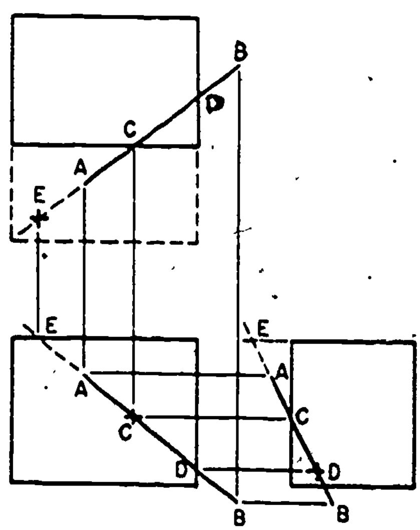


Figure 2-3. Intersection of a skew line and planes.

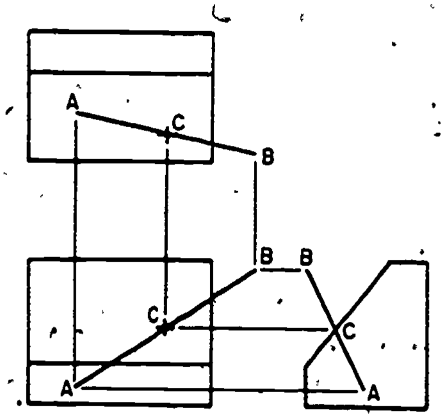


Figure 2-4. Intersection of a skew line and an inclined plane.

intersection. By the same method, you can establish point C in the top view as the real point of intersection of line AB and the horizontal plane.

Line and plane skewed. Since a skew surface does not appear as an edge in any principal view, you must make an edge view of it if you want to use the same methods just discussed. This is illustrated in figure 2-5, which shows the line AB intersecting plane FGH. First make an edge view of the skew plane by looking in the direction of line FG, which is a horizontal line of the skew plane. Next, project line AB into the edge view, and after locating the intersection E, project the intersection point back to the top view and then to the front and side views.

It is not necessary to use an extra (edge) view to find the intersection of skew lines and planes. If you pass an edge-view plane through the line, the intersection of this plane with the skew plane will contain the point of intersection between the line and the skew plane. Use figure 2-5 to learn how this is done.

The intersection of the edge-view plane and the skew plane is easily located. Through line AB, pass a plane that appears as an edge in the top view. The plane intersects edge FG at point C and edge FH at point D. Then project these two points to the front view to establish points C and D on lines FG and FH of this view. A line through these two points in the front view establishes the line of intersection between the edge-view plane and the skew plane FGH. Thus, the front view shows the intersection of line AB with line CD as point E—the point common to line, skew plane, and edge-view plane. To complete the location process, project point E to the top and side views.

Intersections of Planes. The process of finding the intersection of two planes is similar to that of finding the intersection of a line and a plane because you merely find the piercing points to establish the line of intersection. Since the edge of a plane is represented by a line, the process is a continuation of the process that has just been discussed. Let's continue our discussion with the planes in a principal position, then use an inclined position, and finish with the planes in a skewed position.

In principal position. Any line of a given plane intersects a second plane on the line of intersection between the two planes. Therefore, to establish the line of intersection between two planes, find either the intersection of two lines of one plane with the other plane or one line of each plane with the opposite plane. The simplest case is one of the two planes in a principal position.

Figure 2-6 shows the plane ABCD inclined to a principal plane in both top and front views. When you extend lines AB and CD to front view, you find the piercing points E and F that these lines make with the horizontal plane, which appears in the front view as an edge. Then project these points until they intersect the extensions of lines AB and CD in the top view at points E and F. Since points E and F are in both horizontal and skew planes, a line drawn through them establishes the line of intersection between the two planes.

In inclined position. Figure 2-7 shows a similar situation. Here, the intersection is with an inclined surface of an object. Here again, we find the intersection by extending lines AB and DC to the edge view of the inclined surface and then by projecting the piercing points to the top and side views.

In skewed position. As in the intersection of any two planes, the intersection of two skew planes is

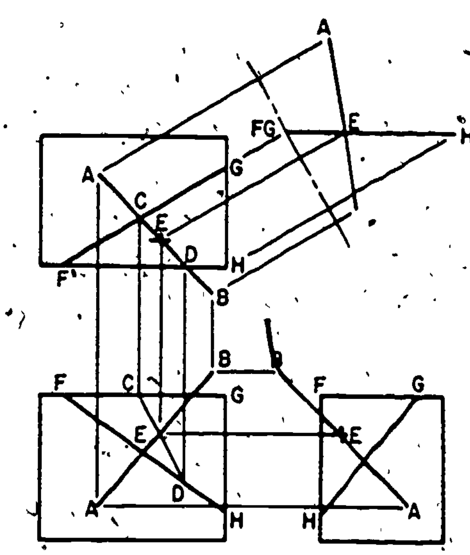


Figure 2-5. Intersection of a skew line and a skew plane.

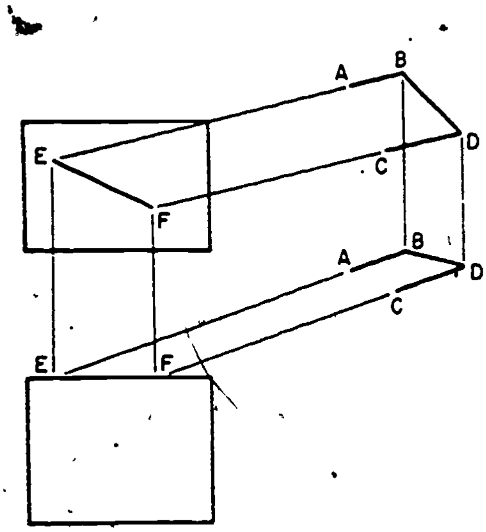


Figure 2-6. Intersection of a plane and a plane in the principal position.

determined by the points where two lines on one plane intersect the other plane. Figure 2-8 shows the skew plane ABCD intersecting the skew plane GHIJKL. To find the intersection of these two planes, use the following procedure:

(1) In the front view, pass edge-view planes through the edges AB and CD extended. The edge-view planes then intersect the skew plane GHIJKL in lines GH and JK at points M, N, P, and Q.

(2) Project points M, N, P, and Q to the corresponding lines in the top view.

(3) Draw lines NP and MQ which represent the intersections of the edge-view planes with the skew plane in the top view.

(4) In the top view, extend edges AB and CD until they intersect lines MQ and NP, respectively. The intersection points E and F determine the top view line of intersection of the two skew planes.

(5) Complete the solution by drawing line EF in the top view and by projecting line EF to the front and side views, as shown in the illustration.

Exercises (413):

1. What does the term "skew line" mean?

2. What are the two steps used to determine the point of intersection of a line skewed, planes in principal position?

3. How do you establish the point of intersection between a line and a plane?

4. Which of the three principal planes will be intersected by a line parallel to the top plane?

5. A skew line intersects the six projection planes of a complete-view drawing a total of ____ times.

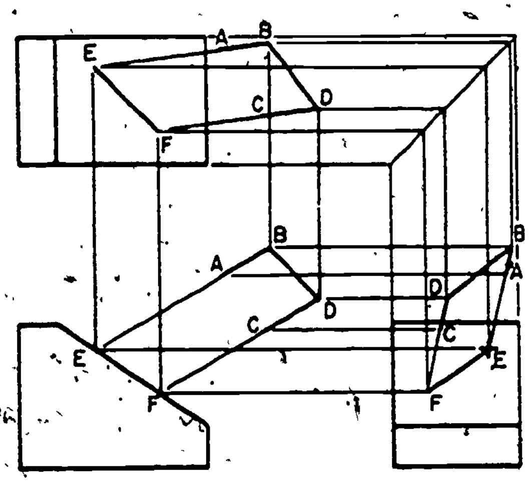


Figure 2-7. Intersection of a plane and an inclined plane.

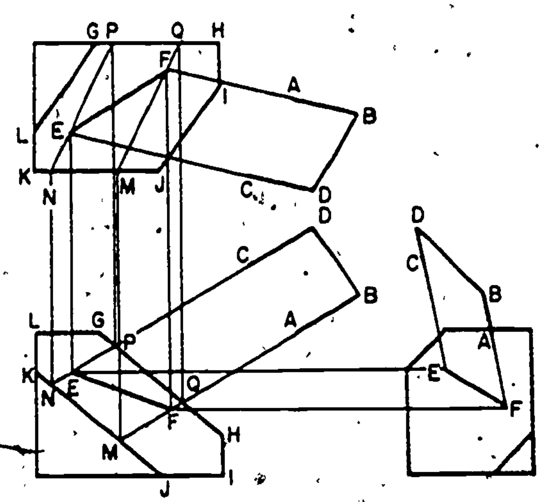


Figure 2-8. Intersection of skew planes.

414. Describe the procedures for determining intersections of certain planes and curved surfaces, and draw a sample intersection.

Intersections of Planes and Curved Surfaces. Finding the intersections of curved surfaces or a curved surface and a plane, especially when one or both of the surfaces are in a skew position, is a difficult accomplishment. It requires engineering geometry. Therefore, it is not included in this course. However, the intersections of cylinders and cones in simple positions occur more or less frequently on machine parts. Therefore, they are discussed in the following paragraphs.

Intersection of plane and cylinder. If you shoot a bullet through a tin can, the bullet makes two holes: one where it enters and another where it comes out. You can consider the two holes as points of intersection between the path of the bullet and the sides of the can. In the same way, a straight line intersects a cylinder at two points. Since a plane theoretically contains an infinite number of lines, the intersection of a number of lines on a plane with a cylinder determines the intersection of the plane and cylinder. As shown in the top view of figure 2-9, for example, the horizontal lines on plane ABCD intersect the cylinder at points 1, 2, 3, 4, and 5. (Four of the lines intersect the cylinder again, but only the five points are shown to keep the drawing as simple as possible.)

To locate the points of intersection in the front view, extend the horizontal lines to the side view and from there to the front view. Now, by projecting points 1, 2, 3, 4, and 5 from the top view to the appropriate lines in the front view, you establish five

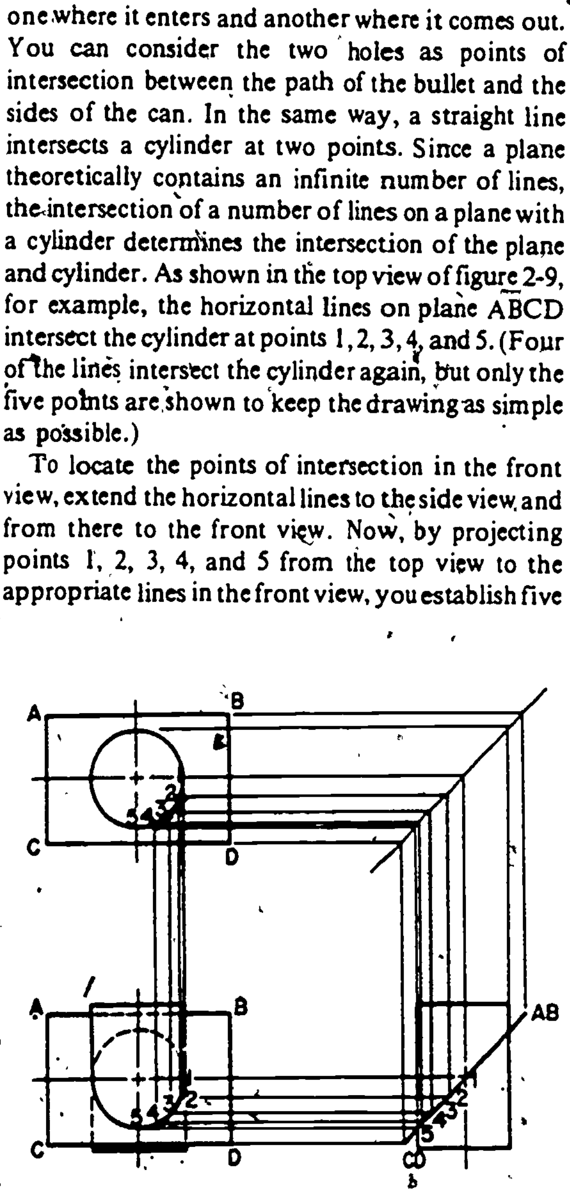


Figure 2-9. Intersection of an inclined plane and a cylinder

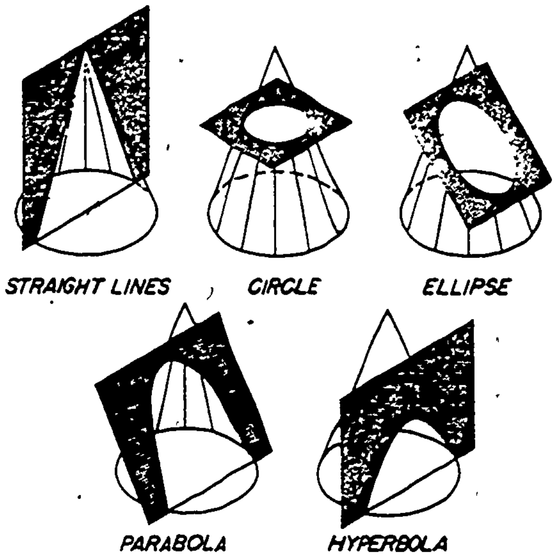


Figure 2-10. Types of intersection of planes and cones.

points of intersection. Using the same procedure, you can establish enough points to locate the entire line of intersection. Since in the illustration presented the plane is inclined at 45° with the horizontal, the intersection in the front view appears as a circle. If you wanted to show the true size and shape of the elliptical intersection, you would need to draw an auxiliary view.

Intersection of plane and cone. As shown in figure 2-10, the shape of the intersection of a plane and cone depends on their relative position. When the plane cuts through the axis of the cone, the intersections are straight lines. When the plane cuts the cone perpendicular to the axis, the intersection is a circle. An elliptical intersection occurs when the plane is inclined to both the axis and all elements of the cone. The intersection is parabolic when the plane is parallel to one of the elements and is hyperbolic when the plane is parallel with the axis.

To find the intersection of a plane and cone, use the same principles that were discussed in the preceding part of this section. Locate the piercing points in the view that shows one of the surfaces as a line. Then, project the points to the same element in another view. Follow the procedure used to locate the top-view intersection of the plane and cone shown in figure 2-11. The steps of the procedure follow:

(1) Draw equally spaced elements in the view that shows the cone as a circle and project these elements to the view which shows the plane as a line.

(2) Draw the elements in this second view to find where they intersect the edge-view of the plane.

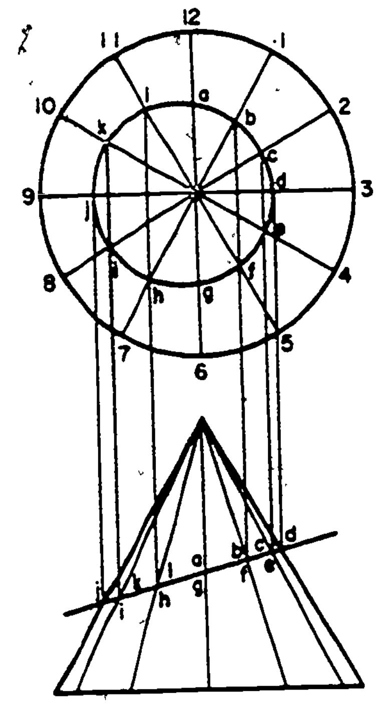


Figure 2-11. Intersection of a plane and a cone.

(3) From the edge-view plane, project the points of intersection back to the corresponding elements on the first view. This establishes points on the line of intersection between the plane and cone.

(4) Complete the intersection by drawing a smooth curve through the points.

Although only a few of the possible combinations of forms that produce intersections have been discussed, the ones discussed demonstrate the basic principles involved. You use these same principles to find the intersections of three-dimensional objects.

Intersections of Three-Dimensional Objects. Just as it was impossible to show all examples of intersecting planes and curved surfaces, all examples of intersecting three-dimensional objects can not be shown. However, enough representative samples are discussed to show how the principles you have learned about intersections are applied to three-dimensional objects. The intersections of two prisms, a prism and a cone, a cylinder and a cone, and two cylinders are discussed.

Intersection of two prisms. You find the intersection of two prisms by locating the intersection lines of the limiting surfaces of the two solids. To do this, locate the points where the edges of one prism pierce the surfaces of the other prism. The example illustrated in figure 2-12 is simplified by the fact that the top view shows the surfaces of the triangular prism as edges and the side view shows the lateral surfaces of the rectangular prism as edges. By examining the top view, you can see that line a-b, which represents an edge of the rectangular prism, pierces two surfaces of the other prism at points 5 and 6. Project these points from the top view to the front view as shown. Other points are found by a similar process. For example, locate points 2 and 4 where edge c-d pierces the rectangular prism in the side view. Then, project these points to the front view.

After finding all of the piercing points which are common to both surfaces, complete the intersection by drawing lines between each pair of points. In this example, points 4, 5, and 6 are located in the front view. Therefore, you can now draw lines 4-5 and 4-6 of the intersection. Notice that each intersecting edge stops at the point where it intersects a surface of the other prism. You solve drafting problems of this type as if the intersecting objects were a single unit rather than two individual units. Consequently, a line connecting points 8 and 9 would be inappropriate on a view of these intersecting prisms since it would be inside one prism and not be common to surfaces of both prisms.

When the lateral surfaces of intersecting prisms do not show as edges in any of the principal views, it is necessary to draw a complete auxiliary view showing an end view of one of the prisms. Then, locate the piercing points in the auxiliary view and project them to the top, front, and/or side view where you complete the intersection by drawing straight lines between the appropriate pairs of points.

Intersection of prism and cone. The two intersections of a prism and a cone shown in figure 2-31 frequently occur in drafting work. In the intersection shown at A, the axis of the square prism coincides with the axis of the right circular cone. The following steps are used to draw the intersection of these two forms:

(1) In the top view, which shows the surfaces of the prism as edges and the base of the cone as a circle, draw several cone elements which cut the front surface of the prism. These piercing points are shown as points A, B, C, and D.

(2) Locate the cone elements in the front view by projecting the numbered points to their proper positions on the base of the cone.

(3) The top view shows that the piercing points A, B, C, D, and E lie on surfaces of both forms. Locate these points in the front view by drawing a vertical projection line from each point to its corresponding element in the front view.

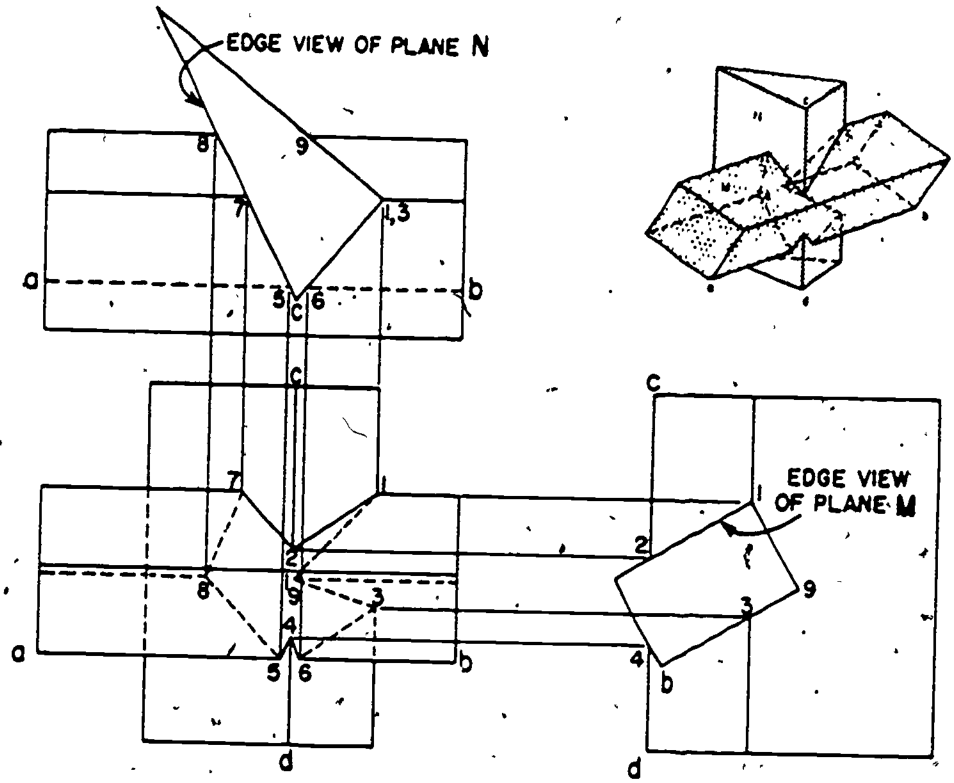


Figure 2-12. Intersection of a prism and a cone.

(4) Since the object is symmetrical, points A and E are equidistance from the base of the cone in the front view. Locate point A in one of two ways. Either resolve it to a frontal position as indicated or place it at the same height as point E whose position is found by projecting point E from the top view to element 1 in the front view.

(5) After locating all piercing points in the front view, complete the intersection of the front surface of the prism with the cone by drawing a smooth curve through the plotted points. Since the entire object is symmetrical, the intersection of the three remaining vertical surfaces with the cone are identical with the curve shown in the front view of figure 2-13.

When the axis of the intersecting prism is at right angles to the cone as shown at B in figure 2-13, start the drawing procedure in the view where the lateral surfaces of the prism are shown as edges. In both front and top views, draw cone elements which pass through the triangular prism at various points. Project the piercing points from the line of intersection in the front view to the top view, as illustrated by point C. Now, project points A and B to the true length element VO in the front view. Then project these points to the frontal line VO in the top view and revolve them counterclockwise to their correct positions (point A on line V–7 and point B on line V–4). Since the bottom surface of the prism is horizontal, its intersection with the cone is an arc of a circle with the radius VA_R.

Intersection of cylinder and cone. To find the intersection of the cone and cylinder shown in figure 2-14, use horizontal cutting planes. First, draw these planes in the side view where the lateral surface of the cylinder appears as an edge. Then project the elements cut from the cylindrical surface to the top and front views. The pictorial view shows that these planes cut elements on the cylinder and circles on the cone. For example, cutting plane 2 cuts element 2 of the cylinder and circle 2 of the cone. Obtain the top view of this circle by direct projection from the front view to locate point 2 on line OA. Then, using point O as a center and a radius O–2, draw an arc which intersects element 2 of the cylinder. This intersection point lies on the required line of

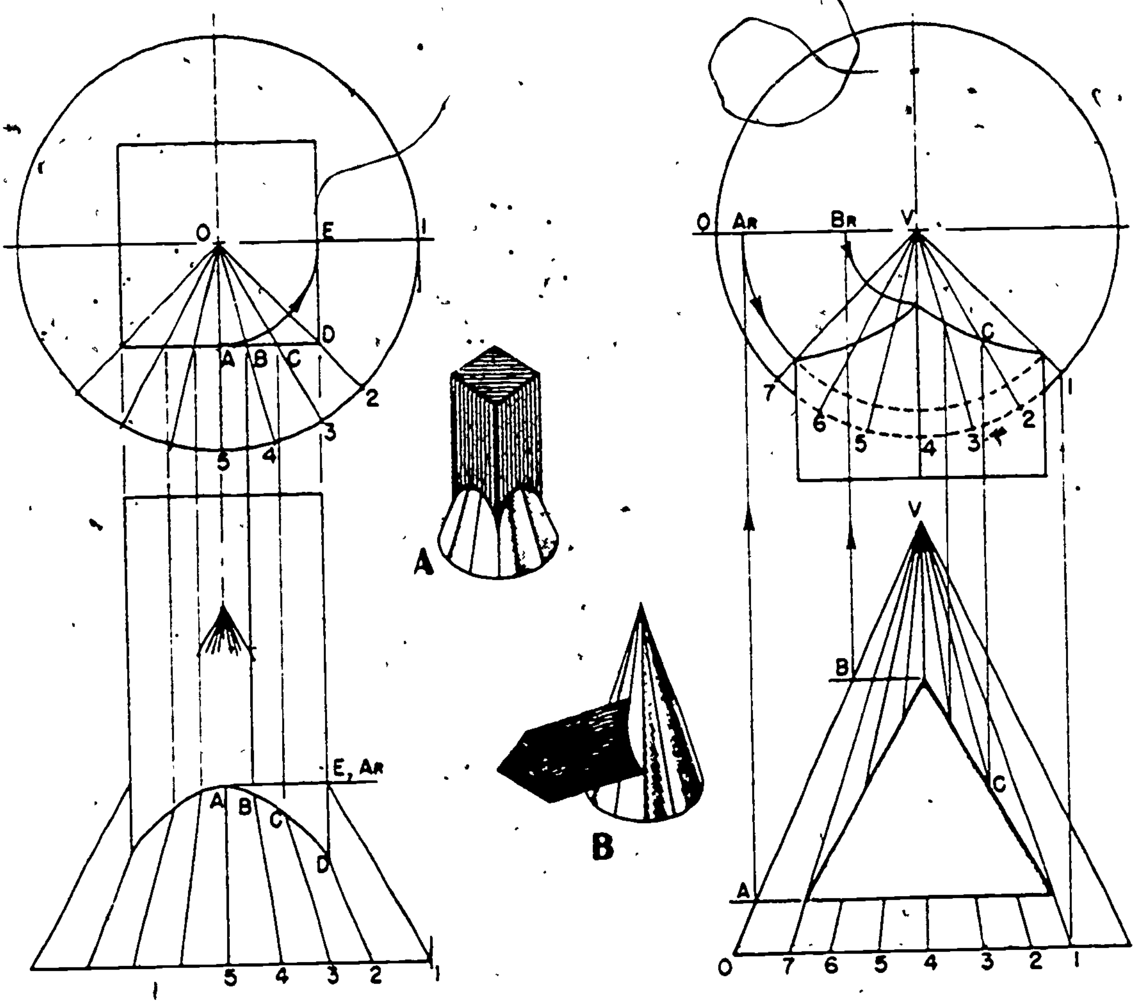


Figure 2-13. Intersection of a prism and a cone.

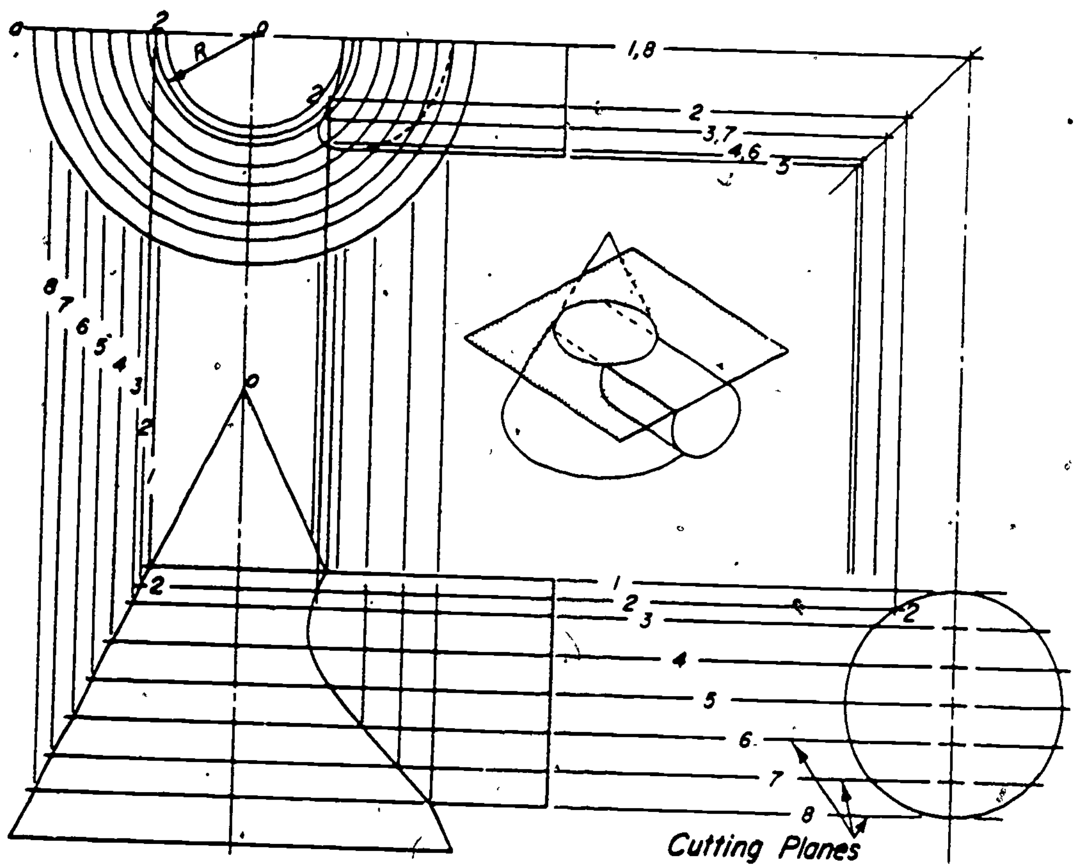


Figure 2-14. Intersection of a cone and a cylinder.

intersection. After locating all such points in the top view, project each point to its corresponding element in the front view. Complete the intersection by drawing a line through the established points.

Intersection of two cylinders. Sheet metal ducts and machine parts often contain two intersecting cylindrical forms. The intersection may have any one of several shapes—the shape in each case being determined by the sizes and positions of the surfaces involved. These possible intersections of two perpendicular cylinders are illustrated in figure 2-15. The procedure for drawing the intersection of the single loop is representative of all these types.

a. Perpendicular cylinders. Figure 2-16 illustrates the use of frontal cutting planes to locate the intersecting elements of two perpendicular cylinders. Refer to this illustration as you read the following steps of the procedure:

(1) In the side view, draw a series of vertical lines representing the edge-views of cutting planes and project these lines to the top view where they also appear as edges of cutting planes. These cutting

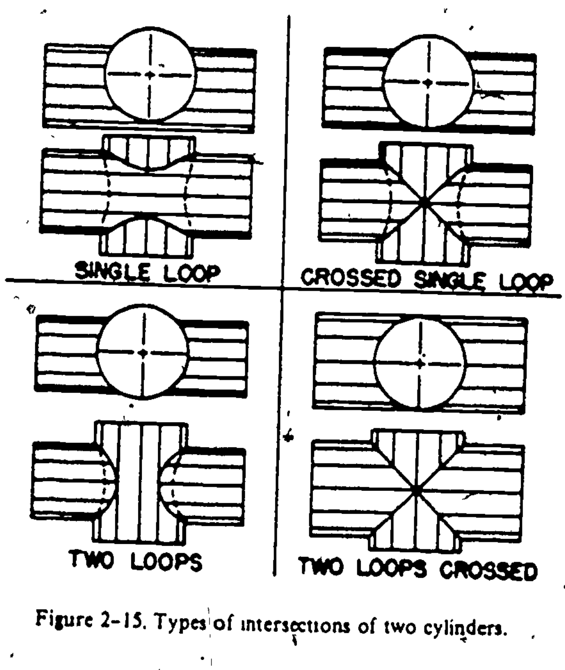


Figure 2-15. Types of intersections of two cylinders.

planes pass through elements of both cylinders. For example, cutting plane 2 passes through pont a of the horizontal cylinder as shown in the side view and through point a of the vertical cylinder as shown in the top view.

(2) From point a in the side view to the front view, project line representing plane 2.

(3) From the top view, project point a to cutting plane 2 in the front view. This locates point a as a point common to both surfaces. Point a is, therefore, on the line of intersection.

(4) In the same manner, locate all necessary points on the line of intersection.

(5) Draw a line through all established points. Since the curve of intersection closely approaches a compass curve, you can draw the intersection line with a compass when accuracy is not important. Set the radius equal to that of the large cylinder and place the compass center on the axis of the smaller cylinder so the arc passes through the critical points O and D of the true curve. When accuracy is important, plot enough points and use an irregular curve to draw the true curve.

b. Inclined cylinders. The curve of the intersection of two inclined cylinders is different from the curve which is formed when two perpendicular cylinders intersect. However, the methods used to find the curve are quite similar. As shown in figure 2-17, draw a revolved cross-sectional view of the inclined cylinder in the front view (a semi-sectional view is sufficient). Divide the circular outline of the sectional view into an equal number of parts. Then project the points of division to the top view. Draw horizontal parallel lines (representing vertical cutting planes) through the points of projection. The intersection of these lines with the circular view of the vertical cylinder represent points which are common to the surfaces of both cylinders. For example, cutting plane lines a, b, and d intersect the top view of the vertical cylinder at points 1, 2, and 3, respectively. Thus, these three numbered points are on the line of

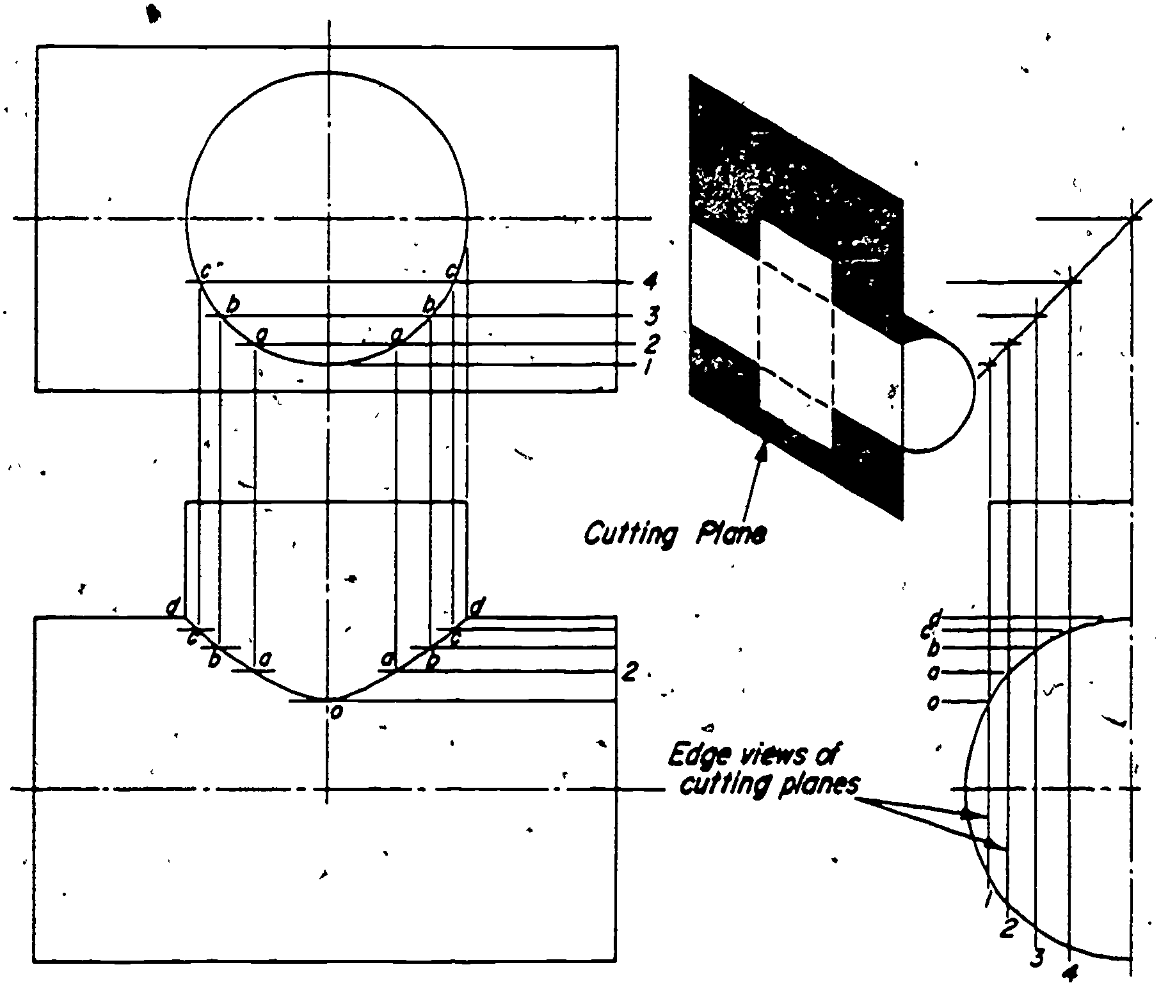
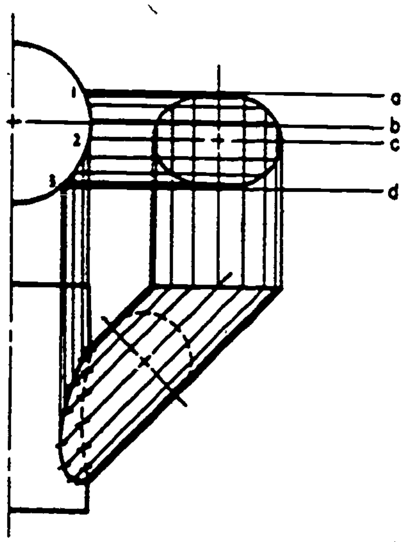


Figure 2-16. Intersection of two cylinders.



Figures 2-17. Intersection of two inclined cylinders.

intersection. They can be located on the front view by means of projection. Locate enough intermediate points so you can draw an accurate line of intersection by using an irregular curve as a guide. Notice that the line of intersection is not symmetrical because the axes of the two cylinders are not aligned.

Exercises (414):

1. How cwn the intersection of a plane and a cylinder be determined?

2. What is the relationship between a plane and the axis of a cylinder when the following intersections between a plane and a cylinder are produced?

   a. Elliptical.

   b. Circular.

   c. Straight lines.

3. What determines the shape of the intersection between a plane and a cone?

4. Draw the right-side view showing the intersection of the two prisms whose top and front views are shown in figure 2-18.

2-2. Developments

If you have ever used scissors, paste, and heavy paper to buid a 3-dimensional object such as a box, you are familiar with the problems involved in developing a surface. First, you lay the outline of all surfaces in their true size and with all possible common edges joined; then, you bend the material along the edges until the rest of the common edges meet; and finally, you fasten the joined edges together. The most important part of this process is the pattern or layout on the 2-dimensional surface. This pattern is called the *development of the surface,* and is considered as the unrolling or unfolding of the shape so that it lies in a single plane.

On many drawings, a development must be shown to furnish the necessary information for making a pattern to facilitate the cutting of a desired shape from sheet metal. Such developments of a surface are drawn with the inside face up, as it theoretically would be if the surface were unrolled or unfolded. This practice is further justified because sheet-metal workers must make the necessary punch marks for folding on the inside surface.

Since it is the draftsman who creates the developments from which thin-material objects are made, you must have a broad knowledge of the methods of constructing various types of developments. Before we discuss these methods, let's take up some fundamentals of development.

415. List four types of surfaces theoretically created by moving lines, the four most common shapes of developable forms, and the three methods of finding the true length of a line.

Most of the objects involved in drafting are bound by simple geometric surfaces or combinations of them. You should be familiar with the classifications and properties of these surfaces.

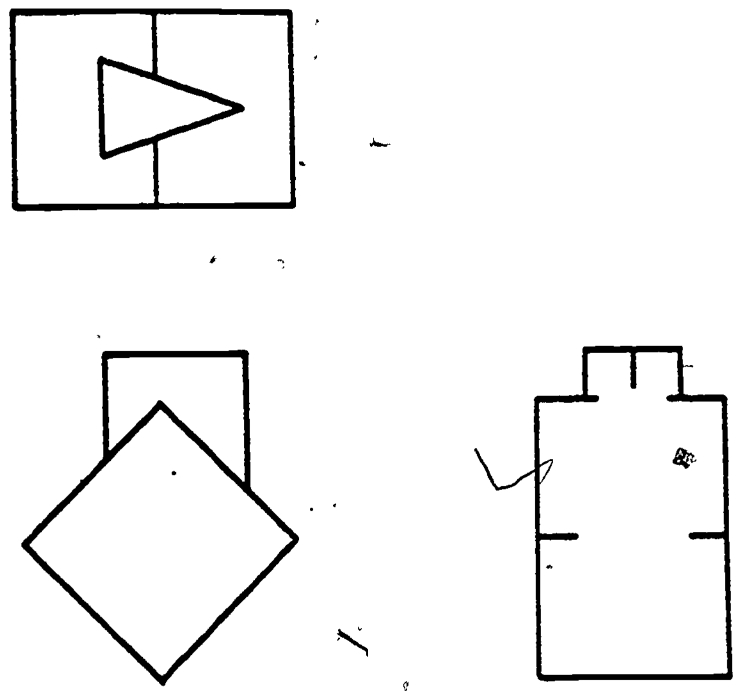


Figure 2-18.—Finding the intersection of two prisms.

Classification of Surfaces. First of all, let's define the term "surface." It is a 2-dimensional pattern which, theoretically, is generated by the movement of a geometric line. Surfaces generated by moving a straight line are called *ruled surfaces*, and those generated by moving a curved line are called *double-curved surfaces*. Figure 2-19 shows the four types of surfaces created by these moving lines.

a. Ruled surfaces. A great variety of surfaces can be formed by moving a straight line along another line. As shown at the top of figure 2-19, as line AB (called the *generatrix*) moves along line AA' (called the *directrix*), it forms a *plane surface* as long as the *elements* (intervening positions of the generatrix) are parallel.

b. Single-curved surface. A *single-curved surface* is generated by a straight line moving in contact with a curve in such a manner that any two successive positions of the generatrix either intersect or are parallel. The cylinder and cone shown in figure 2-19 are examples of such surfaces.

c. Warped surface. A *warped surface* is a ruled surface in which no two successive positions of the straightline generatrix are parallel or intersect each other. The hyperbolic paraboloid shown in figure 2-19 is an example of such a surface. It is produced by moving the straight line AC along the two nonparallel lines AB and CD.

d. Double-curved surfaces. A double-curved surface is a surface generated by moving a curved line in accordance with some mathematical law. The revolution of any curved generatrix about an axis or along a curve produces a double-curved surface.

(1) A sphere is a familiar example. As shown at the bottom of figure 2-19 it is formed by moving a circle about one of its diameters.

(2) A spheroid and torus are other examples of double-curved surfaces. A spheroid is generated by revolving an ellipse about either its major or minor axis. A torus (doughnut shape) is generated by revolving a circle in a circular path about an axis which is in the same plane as the circle. Closed curves which are not true circles may also be used to generate tori.

Developable Surfaces. Only objects made up of planes and single-curved surfaces can be developed accurately. Figure 2-20 shows the four most common forms that are developable: the prism, pyramid, cylinder, and cone. As you can see, the developments shown on the right are obtained by unfolding or unrolling the forms.

Although warped surfaces and double-curved surfaces are not developable, they may be developed approximately by substituting developable surfaces that closely resemble sections of their nondevelopable surfaces. Usually, a nondevelopable surface is formed by distorting the material from which it is made. For example, a sphere can be formed (or covered smoothly) only by using a material which can be stretched into the desired shape. A practical way to determine whether or not a surface is developable is to wrap the object with paper or metal foil. If the surface can be wrapped smoothly without stretching or crimping the wrapping, the surface is developable. In industry, flat sheets, of material are pressed, stamped, spun, or otherwise formed to produce double-curved or warped surfaces.

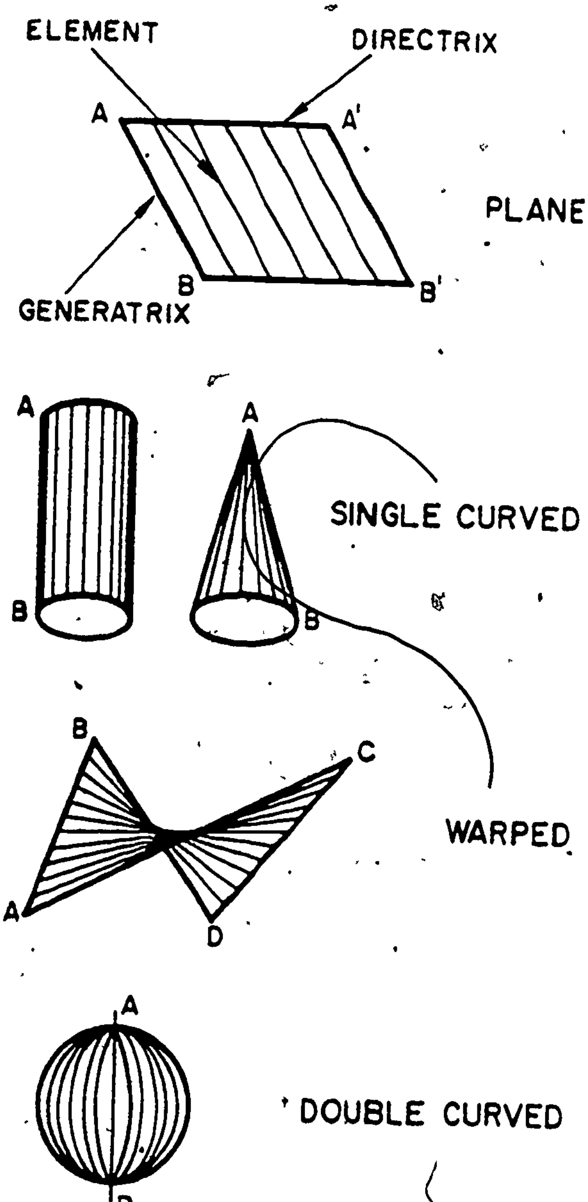


Figure 2-19. Classification of surfaces.

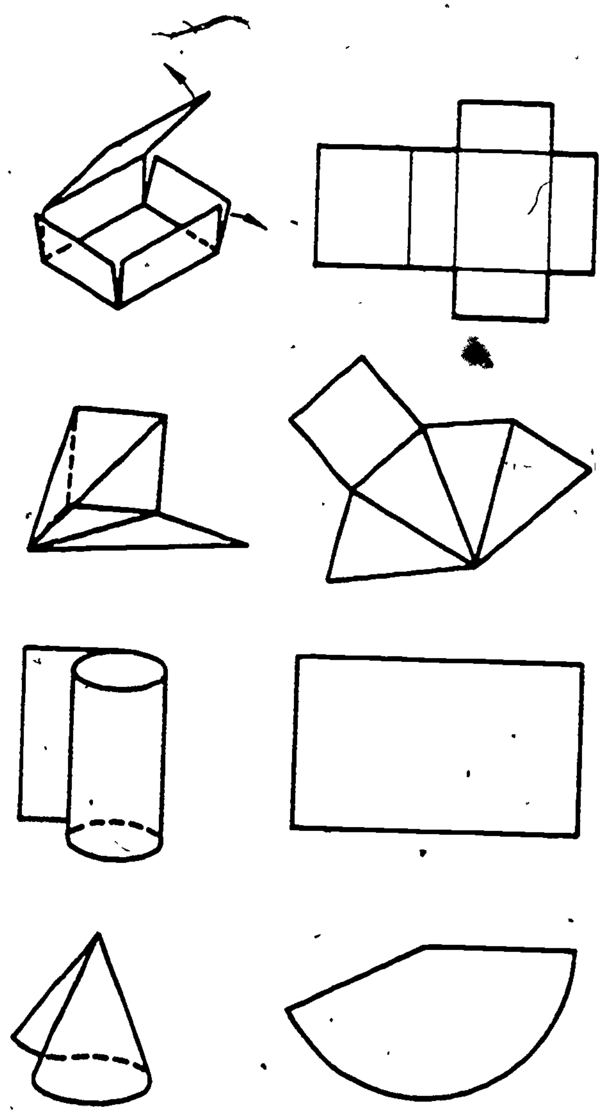


Figure 2-20. Developable surfaces.

Revolution of a Line. The development of an object must show each surface in true size, shape, and relative position. It is usually constructed from multiview drawings. Since in drafting we present a surface by drawing its outline, these lines that represent edges of the surface must be *true length.* If they do not show in the drawing in true length, we must find their true length by any one of three methods. We can find the true lengths by drawing an auxiliary view, by revoluting the lines, or by drawing true-length diagrams.

Figure 2-21 shows the principles of finding the true length of a line by revolution. The line AB is inclined to both the top and front views and, therefore, does not appear true length. To find its true length, we must rotate it until it is parallel to

3. What are the three methods of finding the true length of a line?

416. Given the top and front views of selected developable surfaces, construct half or full developments as instructed.

Types of Developments. Developments may be classified according to the type of surface involved or according to the method used in drawing them. Since we are interested in the drawing aspect of developments, we will use the method of construction as the basis for classification.

The three methods used to develop surfaces are known as *parallel line, radial line,* and *triangulation.* The parallel-line method is used to develop surfaces of prisms and cylinders. The radial-line method is used to develop surfaces of regular tapering forms, such as pyramids and cones. The triangulation method is used to develop warped and double-curved surfaces which are considered nondevelopable.

The rest of this chapter deals with the principles on which developments of the forementioned types are based. These principles all have practical application in solving drafting problems. In addition to knowing how to draw the developments discussed here, you must be familiar with the factors inherent in the manufacturing process. This means that you must know or be able to find out the amount of extra material needed to form bends and seams. The recommendations concerning the minimum bend radii which should be allowed for sheet metal vary considerably depending on the thickness of the metal. For this reason, the equipment in a drafting room usually includes standards which serve as practical guides for laying out developments. These standards list the bend radii recommended for metals of various thicknesses. They also carry illustrations of the types of seams used in fabricating sheet metal parts. To keep our explanations as simple as possible, we will present our developments without the allowances for bending and seams.

Parallel-line Developments. Since prisms and cylinders are forms having parallel elements on the lateral surfaces, the parallel-line method is naturally suited to their development. To develop the surface of a prism or cylinder, you must know the following three factors:

(1) The true shape of a right section (perpendicular to the axis) and the positions of the lateral edges in relation to the right section.

(2) The true length of the lateral edges or elements.

(3) The perimeter or circumference of the base and the distance on this perimeter between each pair of edges or elements.

If you cannot determine the above-mentioned factors from the given views of the prism or cylinder, you must draw auxiliary views or use some other means to obtain the required true sizes and lengths before you can develop the forms.

Right prism. The development of the lateral surface of the truncated prism shown in figure 2-23 can be drawn without first making auxiliary views. The true lengths of all lateral edges are shown in the front view, and the plane of the base is perpendicular to these edges. Therefore, the top view is a right section showing the perimeter of the base and the true distance between edges. Since the base is perpendicular to the edges, the development can be drawn along a straight base line (serving as a stretchout line) with parallel lateral edges drawn perpendicular to the base line. The steps in the development are as follows:

(1) On a stretchout line drawn to the right of the horizontal base line, lay off six divisions, each equal in length to the width of one side as measured in the top view. This gives the perimeter of the base and the true distance between the vertical edges.

(2) At points A, B, C, D, E, and F, draw vertical lines equal in length to the corresponding edges of the prism. Since the stretch-out line is aligned with the base, these vertical heights can be projected from the front view.

(3) Complete the development of the lateral surfaces by drawing a straight line to connect each point on the upper surface to the point(s) adjacent to it. That is, connect 3 to 2, 2 to 1, 1 to 6, etc.

(4) Attach the bottom to the base line between two of the lateral edges, as shown in the full development.

(5) Draw an auxiliary view to find the true size and shape of the inclined surface. Attach a duplication of this upper surface to the upper edge of one of the lateral faces as shown in the full development.

Oblique prism. Before developing the lateral surface of the oblique prism shown in figure 2-24, you must draw an auxiliary view which shows the true distance between the lateral edges. To draw this view, pass a cutting plane through the front view so that it is perpendicular to the axis and to the edges of the prism. Notice that this cutting plane, represented by line WX, must be drawn in the view where the axis appears true length. To obtain the one of the two views. Using a vertical axis through point B in the top view, we revolve point A until line AB is parallel to the front view. The line will now appear in its true length in the front view. Note that revolving the line does not alter the elevation of point A. As you can see, point C, the new position, is still on a horizontal line through point A. Line CB not only indicates the true length but also shows the true slope of the line. As shown in the lower portion of figure 2-21, the true length of line AB can also be found by revolving it about a horizontal axis. The same procedure and principles are involved.

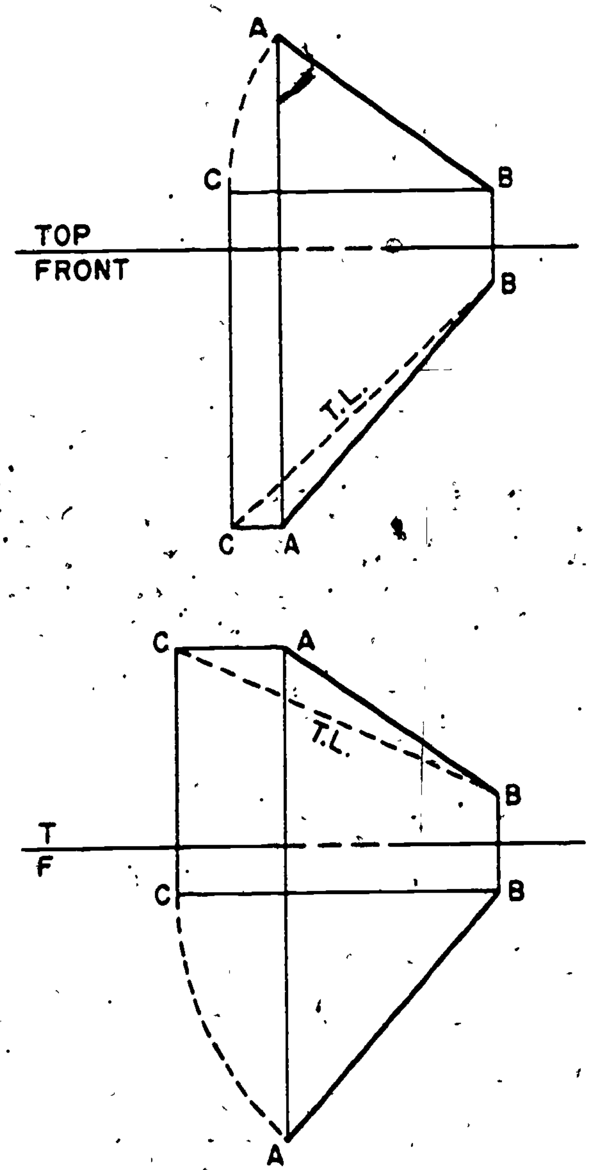


Figure 2-21. Finding the true length of a line by revolution.

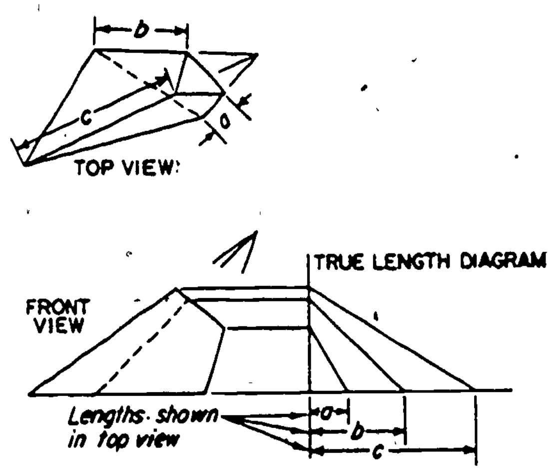


Figure 2-22. Constructing a true length diagram.

True-length diagrams. It is sometimes impractical to use the revolution method to find the true length of the lateral edges of the object shown. used in such cases. Figure 2-22 illustrates this method of finding true lengths of lines. To find the true lengths of the lateral edge sof the object shown, draw a series of right triangles by using a horizontal and a vertical reference line for the bases and heights of the triangles. First, mark off distances on the base line that are equal to the lengths of the lines shown in the top view. Then taking the measurement from the front view, mark off on the vertical reference line the height of each edge. If you establish the base line in line with the base of the front view, you can project the heights to the diagram as shown in the illustration. The hypotenuses of these triangles represent the true length of the lateral edges. When using this method, you should identify the ends of each line with numbers or letters to reduce the possibility of using the wrong line.

Exercises (415):

1. What four types of surfaces are theoretically created by moving lines?

2. What are the four most common shapes of developable forms?

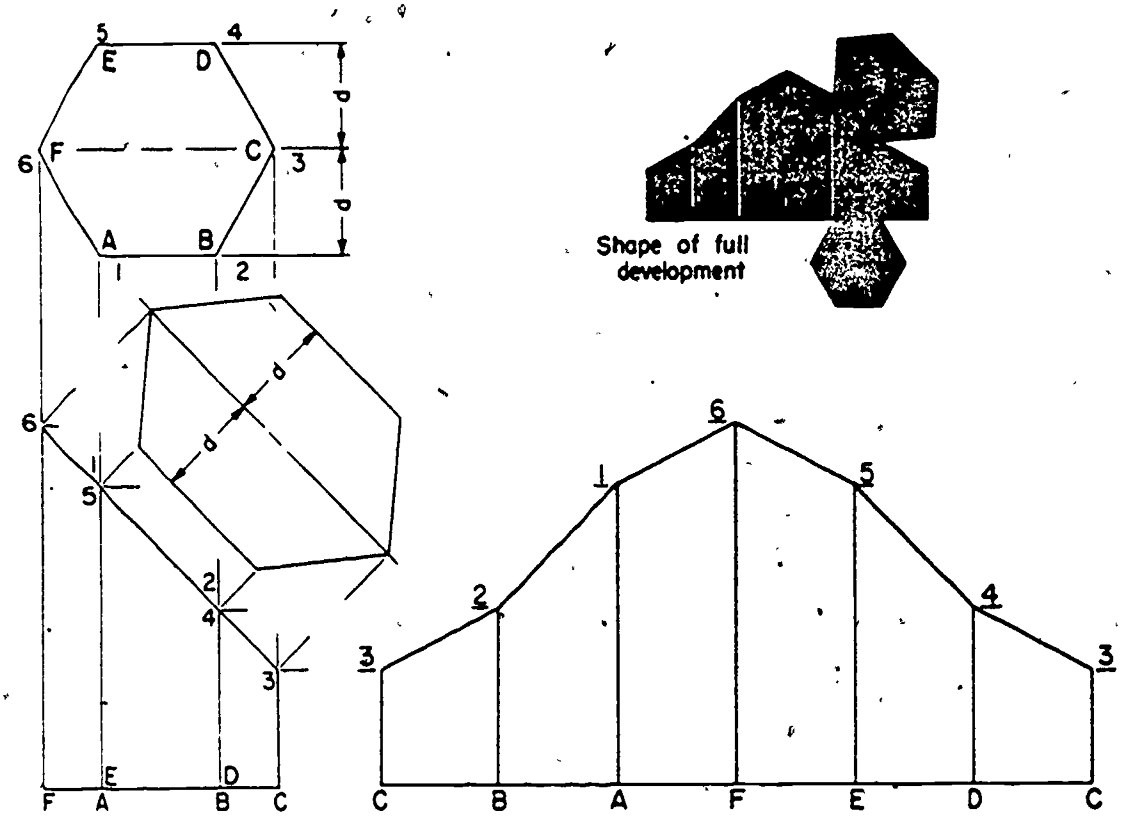


Figure 2-23. Developing a truncated right prism.

needed view, assume that the line of sight for the auxiliary view is parallel to the axis and, therefore, is perpendicular to the plane of the right section. This auxiliary view, on which the axis appears as a point, shows the true distances between the lateral edges. In this instance the right section is a regular hexagon. As you know, this right section may also be called a *cross section*. The top and front views do not show the actual cross-sectional shape, but the top view does show the true shape of the horizontal base of the prism.

Since the rig[illegible]ction, 1-2-3-4, is perpendicular to the edges, it will unroll in a straight line. Therefore, draw a straight line and use it as a stretchout line. Along this stretchout line, mark off six equal divisions, using the distance in the auxiliary view as the unit of measurement. You use equal divisions because all sides of the prisms are of equal width. Through these numbered points, draw perpendiculars to the stretchout line. (During construction, the material will be folded along these perpendicular "fold lines" to form the edges of the prism.) Transfer the true length of each lateral edge from the front view to the appropriate edge of the development. Use dividers to obtain these lengths, measuring from line WX first to the upper surface of the prism and then to the lower surface. Draw straight lines between the successive points in the lower surface (points A, B, C, etc.) and then connect the points in the upper surface in the same manner. If the upper surface is part of the development, find its true size by drawing a right side view having the sight line indicated by the arrow Z.

Right cylinder. When the bases of a cylinder are parallel to each other and are perpendicular to the axis, the development is a rectangle. The width of the rectangle is equal to the height of the cylinder, and the length is equal to the circumference of the cylinder. The development of a truncated cylinder, such as that shown in figure 2-25, is made in a manner similar to that used for developing a prism.

When developing a cylinder, consider the cylinder to be a many-sided prism so that its surface can be divided into segments. The first step in making this development is to select at least 12 equally spaced points on the base circle and then draw an element from each of these division points. You can approximate the length of the development by laying out the chord distances 1-2, 2-3, 3-4, etc., along the stretchout line. For a more accurate development, use the formula $C = \pi d$ to find the length of the stretchout line, where C is equal to the circumference of the circle and is therefore equal to the length of the stretchout line, d is equal to the diameter of the base circle, and π is equal to 3.1416. To make an accurate development, mark off the circumference distance on a stretchout line and then divide the line into 12 equal parts. From each of these points, draw an element perpendicular to the stretchout line. Next, transfer the true length of each element (1–1′, 2–2′, 3–3′, etc.) from the front view to the development and draw a smooth curve through the end points of the elements, as shown in the illustration. Compare this development of the right cylinder with the development of the right prism in which the end points of the elements are connected by straight lines. When the inclined surface is needed for a full development of the cylinder, project from the front view an auxiliary view using lines of sight perpendicular to the edge view of the surface.

Oblique cylinder. The procedure for making a development of an oblique cylinder is similar to that used to develop an oblique prism. First, find the true length of all elements; second, find the true size of a right section by the method explained in the discussion of the oblique prism. Roll the right section out as a straight line equal to the length of the circumference, and draw an auxiliary view from which you can find the true distances between elements. Draw 13 equally spaced elements perpendicular to the stretchout line. Transfer the true length of each element from the front view and draw a smooth curve through the end points.

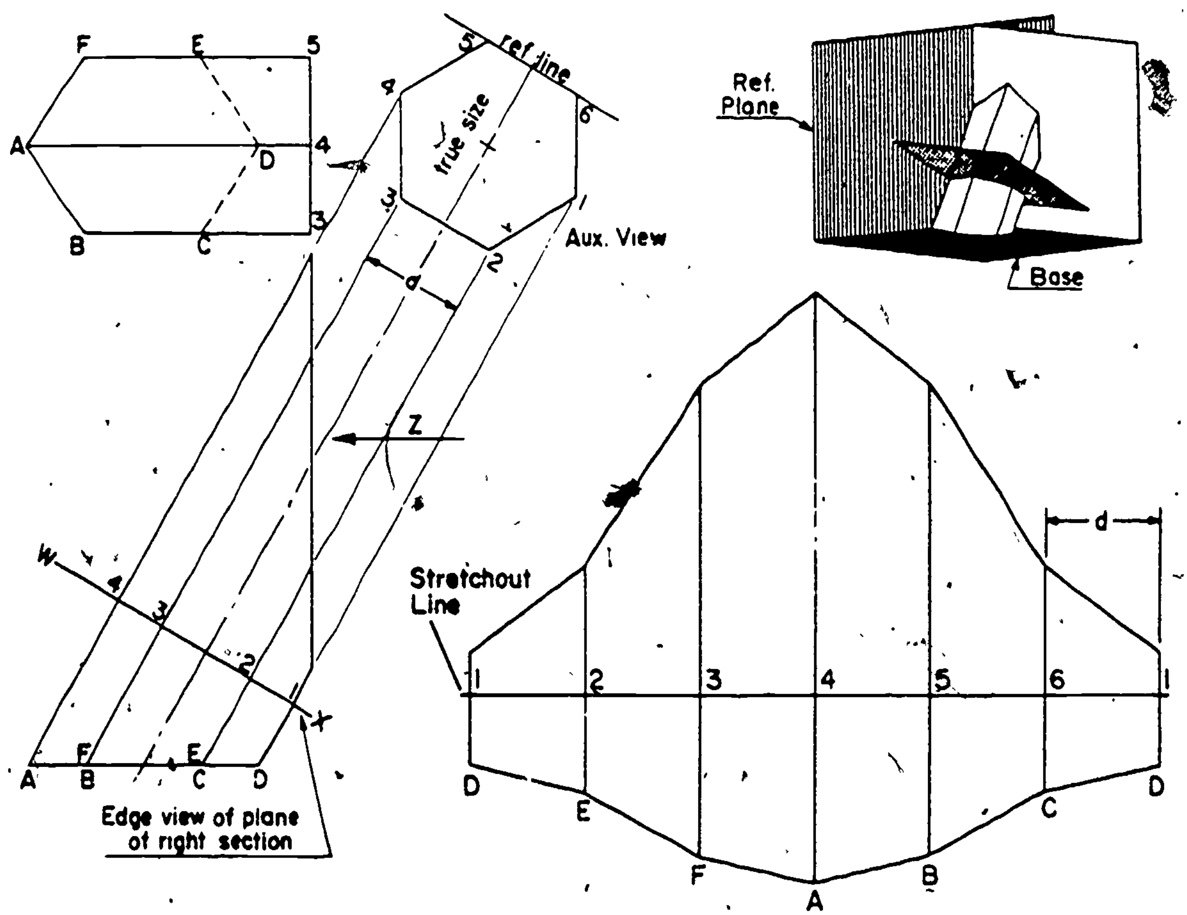


Figure 2-24. Developing an oblique prism.

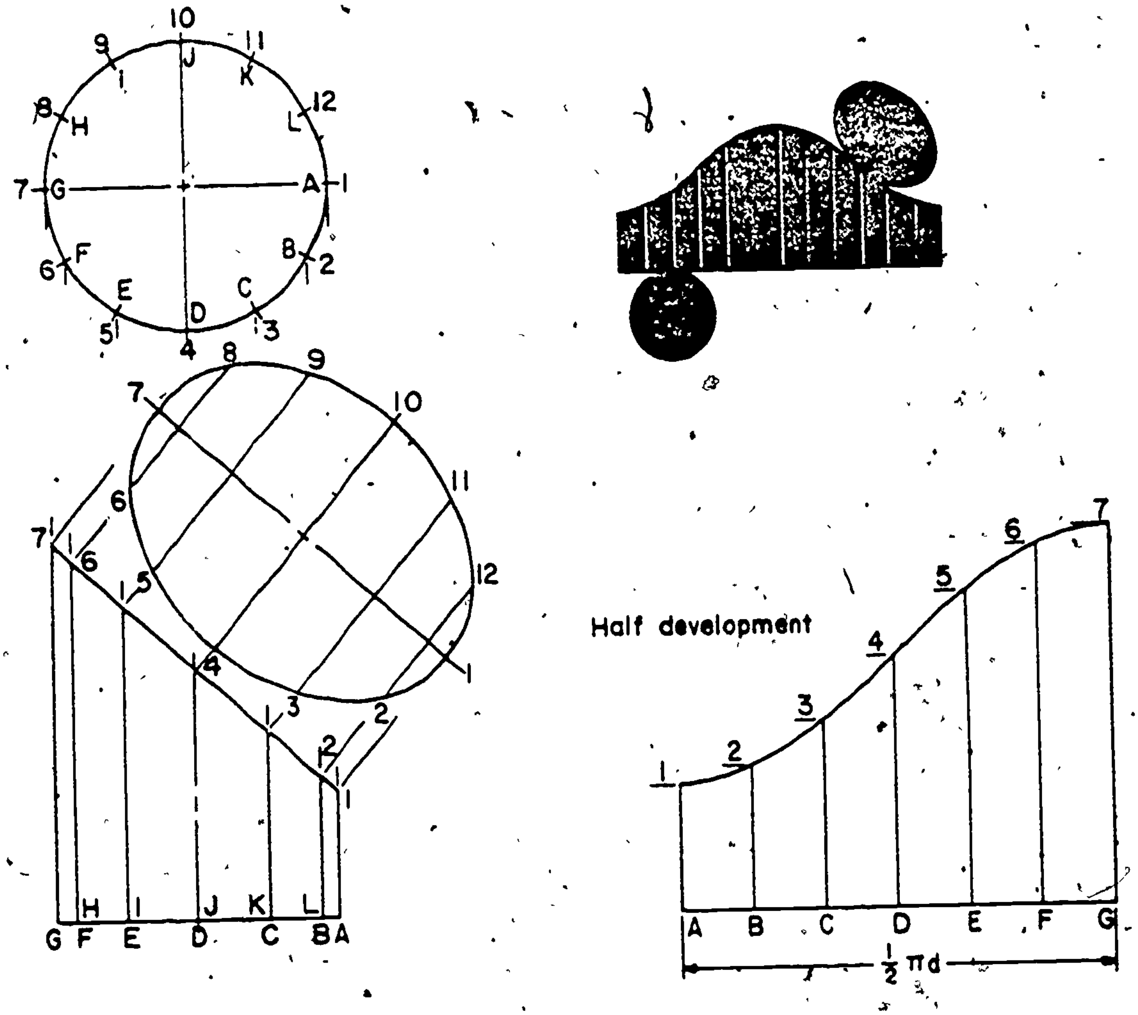


Figure 2-25. Developing a truncated right cylinder.

Exercises (416):

1. From the top and front view of a prism shown in figure 2-26. construct the full development by using the appropriate method.

2. Construct a half development of the lateral surfaces of the right cylinder whose top and front views are shown in figure 2-27. Use the divisions of the surface given for the elements of the cylinder.

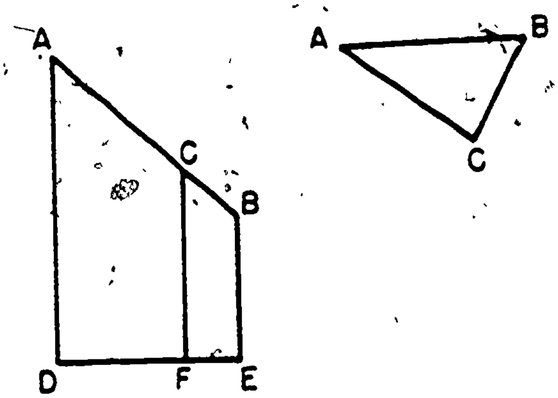


Figure 2-26. Developing a prism.

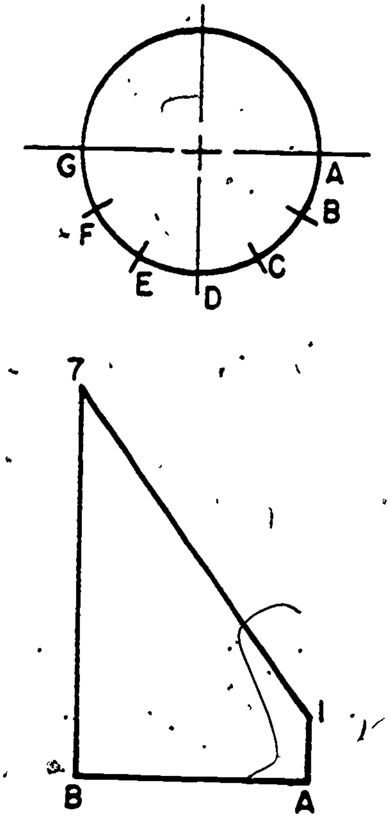


Figure 2-27 Developing a truncated cylinder.

417. Describe the basic formation of, and the appropriateness of the radial-line method for, certain forms; and given top and front views of a selected form, draw the full development of the surface.

Radial-Line Developments. The radial-line method is appropriate for developing pyramids and cones because the elements of these forms intersect at a common point.

Before we discuss the development of these forms, let's review some of the important characteristics of pyramids and cones. The descriptive classification of a pyramid is determined by the shape of its base and by the position of its axis in relation to the base. When the axis of a pyramid is perpendicular to the base plane, the pyramid is called a *right pyramid*. When the axis is inclined to the base, the pyramid is called an *oblique pyramid*. A *truncated pyramid* is formed by cutting off the upper portion of a pyramid. When the cutting plane is parallel to the base plane, the portion of the pyramid remaining between the base plane and the cutting plane is called a *frustum*.

Cones are classified by the positions of their axes and the shapes of their right sections. A *right section* is the cut surface resulting from cutting the cone with a plane perpendicular to the axis. The altitude of a cone is the height of a perpendicular from the vertex to the base plane. If the axis and altitude of a cone coincide, the form is called a *right cone*.

Since the lateral faces of a pyramid are triangles, the development of a pyramid consists of drawing these triangular areas in true size and in proper relation to each other. To make an appropriate development of a cone, you divide the surface into segments which are triangular in shape and then lay out these triangles in the proper sequence.

Right pyramid. To develop the surface of a truncated pyramid shown in figure 2-28, find the true length of each edge bounding the surfaces. We can obtain some of these directly from the top view. The four edges of the base plane appear in true length in the top view because the base of the pyramid is horizontal. Since this pyramid is symmetrical about its axis through the vertex O, we know that the extended edges OA, OB, OC, and OD are equal. Likewise, we know that the length of edge CC' equals the length of edge DD' and length AA' equals BB' because the plane in which these lines lie shows as a line in the front view.

We obtain the true lengths of the lateral edges by revolving the lines representing these edges in the top view, projecting their end points to the front view, and drawing the line OA_R. We obtain the true lengths by measuring along this line.

The next step is to draw an auxiliary view showing the sloping surface in true size. Draw this by assuming that the line of sight is perpendicular to the inclined surface. First, establish the center line of the auxiliary view parallel to line A'D' in the front view. Next, establish the height of the auxiliary view by projecting lines from points A' and D'. Find the four corners of the surface by establishing the distances between the center line and points A', B', C', and D'. These distances are obtained from the top view. We are now ready to draw the development.

The steps in drawing the development are as follows:

(1) Locate point O on the drawing paper so that there is adequate space for the layout of the development.

(2) Use the true length of line OA as a radius and draw an arc of indefinite length. This arc is the stretchout line.

(3) Set the divider for a span equaling the length of side BC in the top view and use the divider with

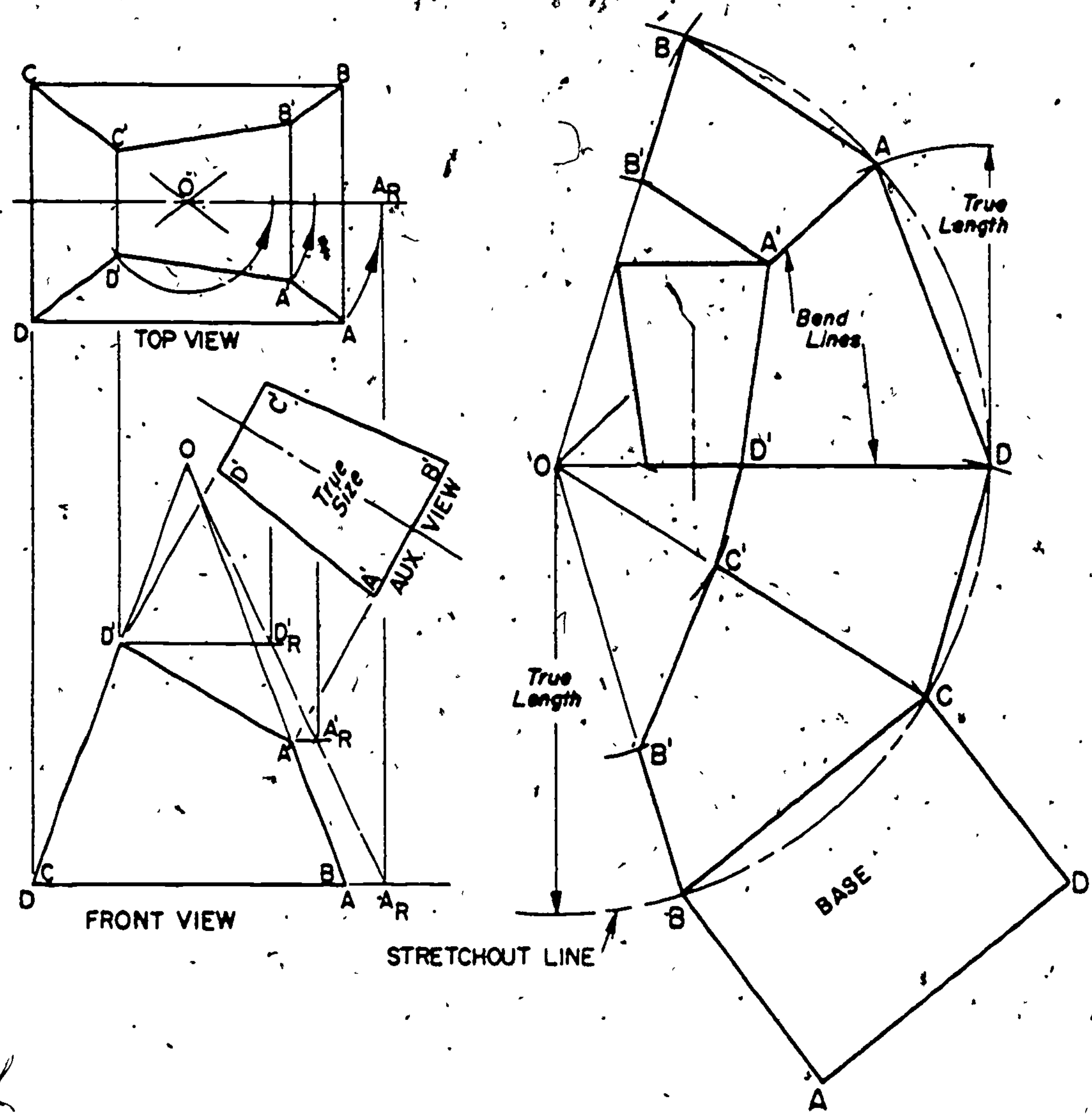


Figure 2-28 Developing a truncated right pyramid

this setting to locate points B and C on the stretchout line. In the same manner, locate the remaining points in the order: D, A, and B.

(4) Starting at point B, draw lines from B to C, C to D, D to A, and A to B. These lines form the base edges of the lateral surfaces.

(5) Connect the end points of each base line to point O to form the "bend lines" along which the development will be folded to form the edges and surfaces of the pyramid.

(6) Locate points A', B', C', and D' on their respective edges. Locate point A' and B' by setting the dividers for the true-length distance of line OA and by transferring this distance on the respective lines of the development. Locate points C' and D' in the same manner, using the distance OD' from true-length line. Then draw lines between adjacent points.

(7) Connect the base of the pyramid to a base line of one of the lateral surfaces.

(8) Transfer the irregular top surface to the development by triangulation.

Notice that the development starts with one of the shorter edges and that the two end surfaces are attached along one of their longer edges. Splitting the part on a short edge, and connecting the bases along a long edge, reduces the amount of work required later to rivet or weld the seams.

Oblique pyramid. The first step in developing the surface of the oblique pyramid shown in figure 2-29,

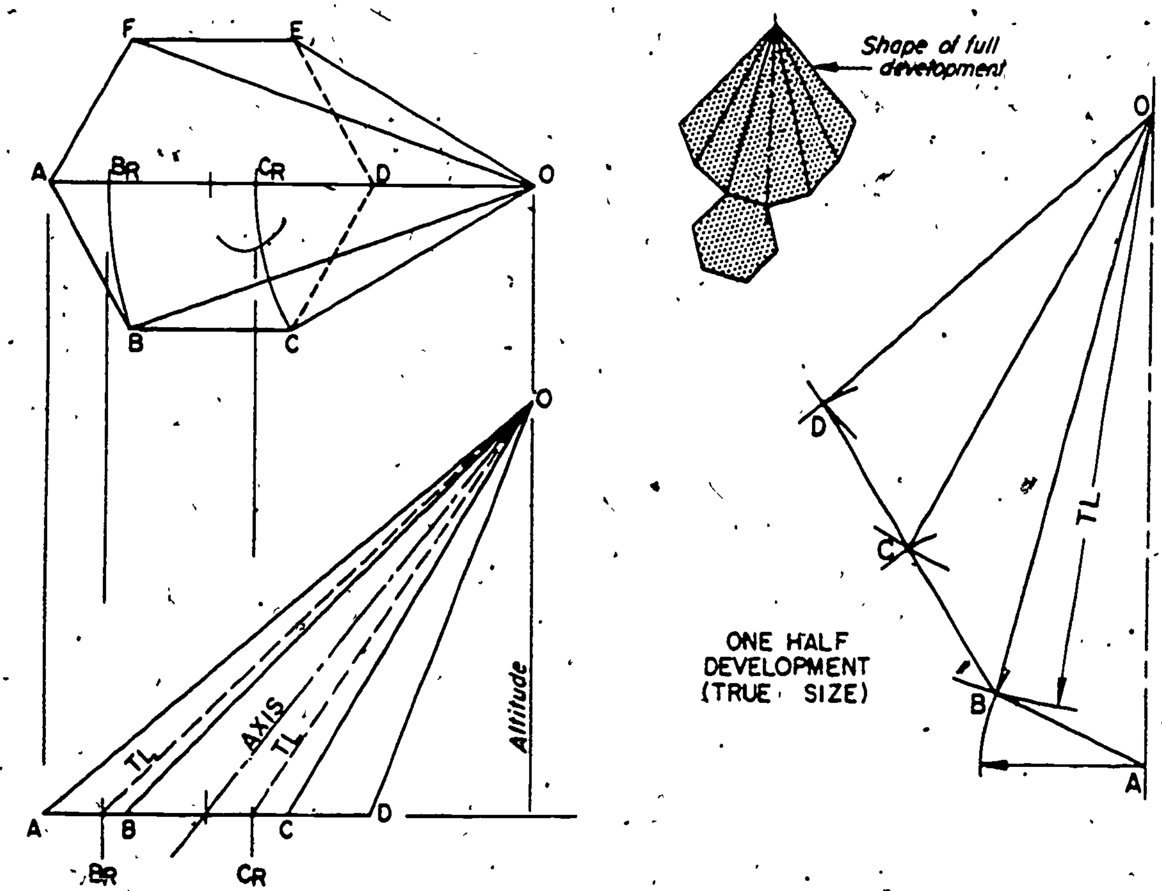


Figure 2-29 Developing an oblique pyramid.

is to find the true length of all lateral edges. Edges OA and OD are frontal lines and, therefore, appear in true length in the front view. Since the pyramid is symmetrical about a frontal plane through the vertex, edges OB and OF are equal and edges OC and OE are equal. To find the true length of these four edges, we revolve line OB and OC into frontal positions to obtain true-length lines OB_R and OC_R in the front view. The remaining true length required for the development can be obtained directly from the top view which shows the horizontal base in true size.

Notice that the half development of this symmetrical surface is made by dividing the full development along edge OA. Draw edge OA and, with the divider set for the distance OA, locate point A. Locate point B by drawing two arcs: one with the distance AB as the radius and the other with the true-length distance OB as the radius. The triangle formed by drawing straight-line connectors from point B to points O and A is the true size and shape of one face of the pyramid Add surfaces OBC and OCD by using the same procedure. The base plane is attached as shown on the small full-development drawing.

Circular cone To develop the truncated right circular cone shown in figure 2-30, use the following information which you can obtain from the top and front views. The top view is a normal view of the base and shows a right section since the base plane is perpendicular to the axis of the cone. All elements of the whole cone are the same length. The extreme right and left elements (A-1 and G-7) appear in true length in the front view. (If the upper surface is required as part of the development, you must make an auxiliary view to show the true size and shape of the inclined surface.)

Make the main development by dividing the conical surface into a series of narrow triangles which when laid out in true size and assembled in proper sequence form an approximate surface of the cone. In the development shown, the base circle has been divided into 12 equal parts and 12 elements have been drawn on the top and front views. A more accurate development may be obtained if you use a greater number of divisions. The steps in the development are as follows:

(1) Establish point O and use it as a center, and the slant height OA as the radius, to draw a circular base line of indefinite length.

(2) Using a divider set for the distance between elements as measured on the base circle of the top view, establish the positions of the elements along the base line. Then draw lines from these points to point O.

(3) Find the distances from the vertex O to the upper surface along each element. For example, to locate point 1 on element OA set the divider for the distance O-1 in the front view and transfer this distance to the two lines OA in the development. You can locate points 2 through 12 in the same manner except that elements B-2 through F-6 and H-8 through L-12 do not show in true length in the orthographic views. Therefore, in the front view you must draw horizontal projection lines from the upper ends of these elements to line OA and use line OA as a true-length diagram.

(4) Sketch a smooth curve through the points you have just established and then use an irregular curve as a guide in drawing the finished curve.

You may have noticed already that this development is smaller than the original cone, because the straight-line distance between points A and B on the top view is less than the length of the arc AB. To make the distance around the base line of the development the same as the circumference of the circle, you may use one of two methods.

The first method is to rectify the arc distance on a tangent line and to use this distance to step off the base line of the development. We discussed the rectification of an arc in Volume 1.

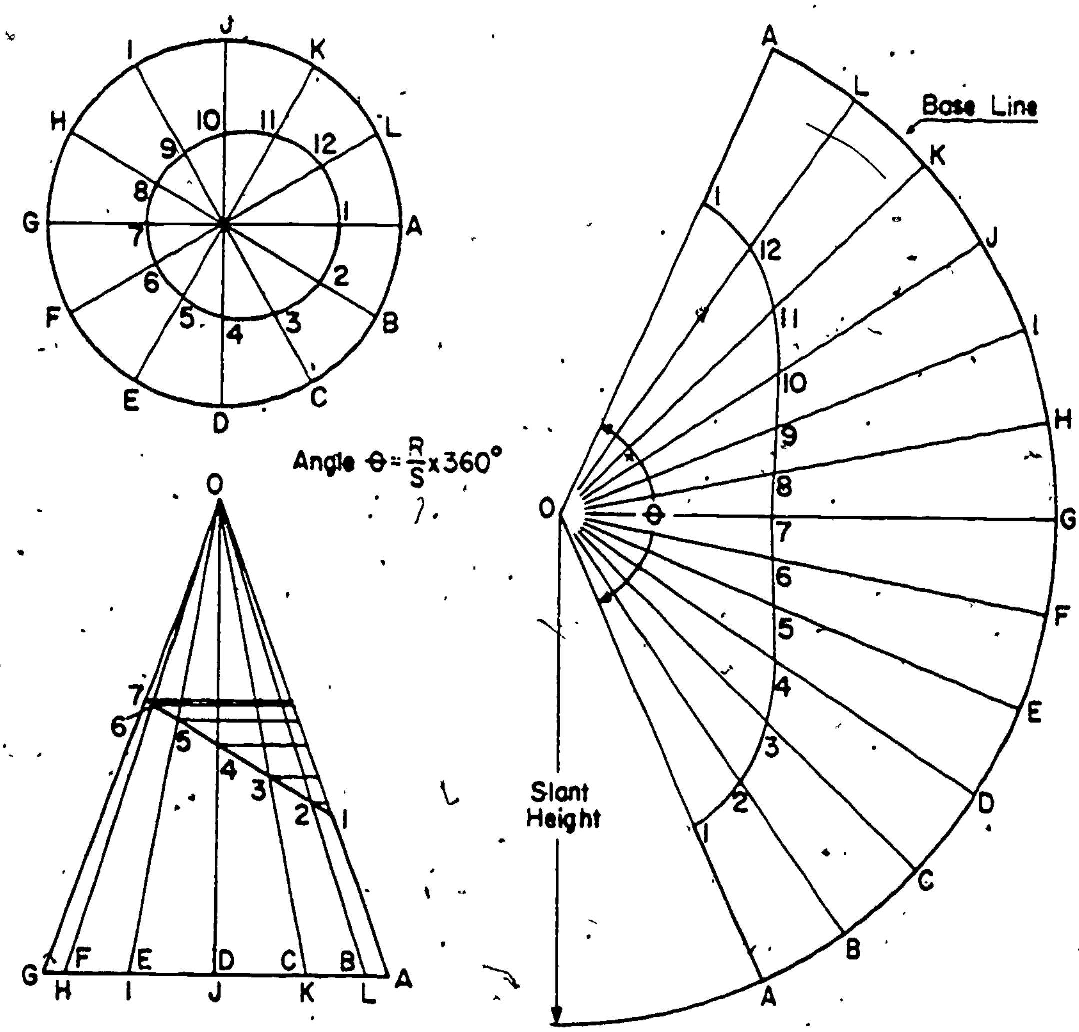


Figure 2-30 Developing a truncated cone

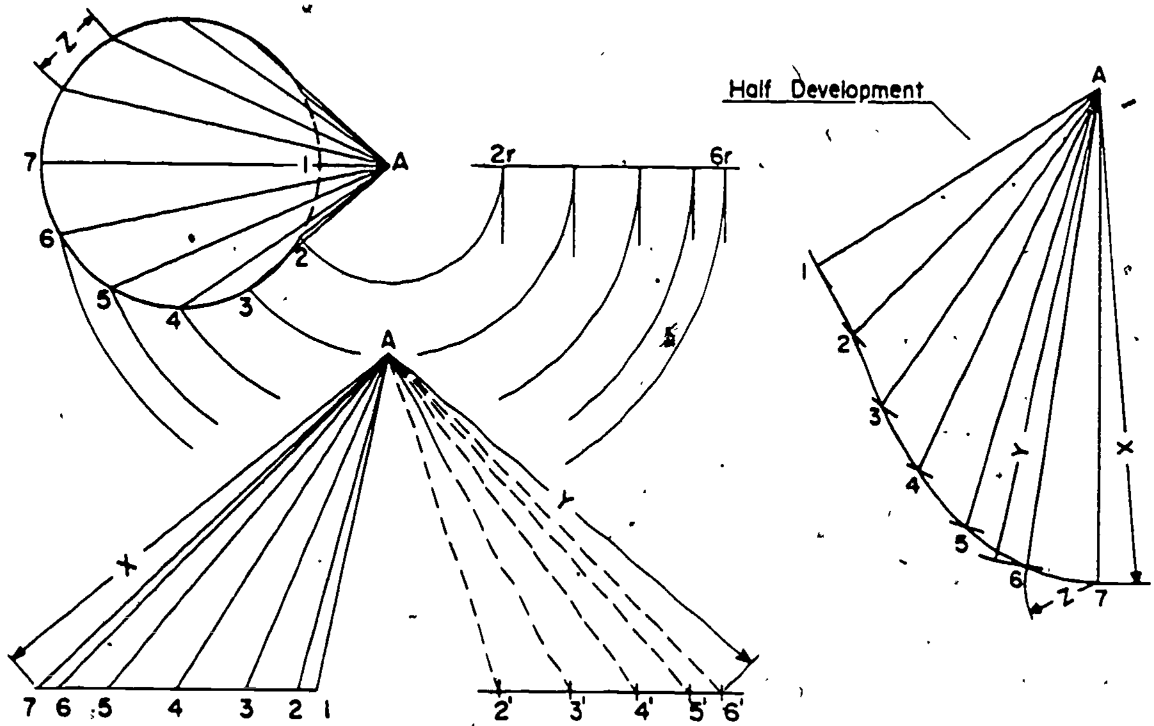


Figure 2-31. Developing an oblique cone.

If greater accuracy is required than can be obtained by the rectification method, you can use the formula shown in figure 2-30 to compute the angle formed by the intersection of the limiting or outer elements of the development. In this formula, R is the radius of the base circle, S is the slant height of the cone, the angle θ (theta) is the angle of the required arc. The formula is derived from the formula for finding the area of the sector of a circle. The ratio of the radius to the slant height determines the number of degrees in the sector angle. For Example, an extremely flat cone having a radius of 1 and a slant height of 1 would develop as a complete 360° circle. When the ratio is 1 to 2, the development is a semicircle and has 180° at angle θ.

When you use the angle method to lay out a base line in the development of a cone, you locate the elements by dividing the base line into the same number of equal parts as used in the top view. Use a protractor or a divider and the trial and error method to obtain the equal divisions.

Oblique cone. Develop an oblique cone as if it were a many-sided pyramid. Use a large enough number of sides to get a close approximation of the cone. Use a construction similar to that for developing an oblique pyramid.

Let's follow the construction procedure used to draw the half development of the oblique cone shown in figure 2-31. First, locate equally spaced elements on the base circle and draw the elements on both top and front view. Since only elements A-1 and A-7 are parallel with the frontal plane, only these elements appear true length in the front view. Obtain the true length of the other elements by revolving them about a vertical axis and by making a true-length diagram. The development is then a matter of construction by triangulation. Draw the line representing element A-7 and on this line locate points A and 7 by using a divider set for the distance X. Then to locate element A-6, draw an arc by using point 7 as the center and the distance Z as the radius; draw another arc to intersect the first by using point A as the center and the distance Y as radius; and draw a line from the point of intersection (point 6) to point A. Locate and draw elements A-5, A-4, A-3, A-2, and A-1 in that order by using the same procedure. Then sketch a smooth curve through the end points and finish the curve with the aid of an irregular curve.

Note that the half development is made by dividing the cone along the axis of symmetry. You have probably already noticed the important fact that half developments can be made only when the full development is a symmetrical figure.

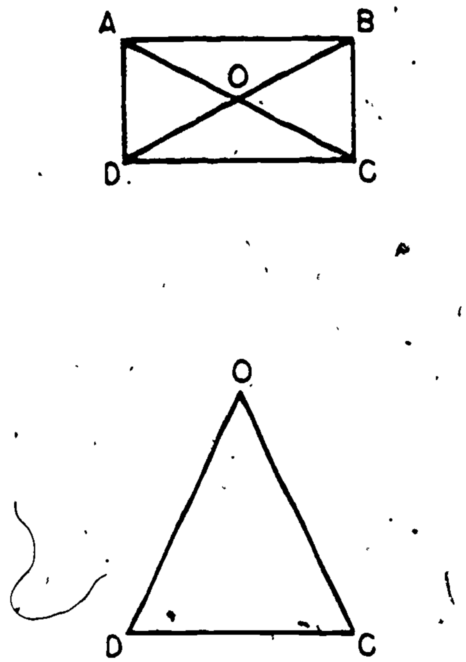


Figure 2-32. Developing a simple pyramid.

Exercises (417):

1. Why is the radial-line method appropriate for developing pyramids and cones?

2. How is a truncated pyramid formed?

3. Draw the full development of the surface of the pyramid whose top and front views are shown in figure 2-32. Lay out the development so that edge OA is vertical on the page and so that it also appears as the seam line.

418. Give the definition and uses of triangulation development.

Triangulation. Nondevelopable surfaces are developed approximately by assuming that they are made of narrow sections of developable surfaces. The most common and best method for approximate development is that of *triangulation*. This means that the surface is assumed to be made up of a large number of triangular strips or plane triangles with very short bases. This method is used for all warped surfaces and also for oblique cones.

The triangulation method is extremely simple. It consists merely of dividing the surface into triangles, finding the true lengths of the sides of each triangle, and constructing them one at a time so they join along their common sides. Sounds familiar, doesn't it? It should. This is very similar to the method used to develop the oblique cone in figure 2-28.

Warped surface development. A transition piece is a typical warped surface that can be developed by means of triangulation. A transition piece is a connecting piece used to join ducts of different shapes. It usually consists of plane surfaces and sections of oblique cones. Let's see how two transitions pieces are developed:

a. Transition piece from sloping square to horizontal circle. The transition piece shown in figure 2-33 is designed to connect a vertical cylindrical conductor to an inclined rectangular duct. Use the following steps to make this development:

(1) Draw the horizontal circle and the rectangular opening in the top and front views according to the size and position specifications. These specifications will indicate the size of the circular opening and its position in relation to the lower opening. The angle of inclination will be specified for the rectangular lower opening.

(2) Divide the circle into equal parts about the axis of symmetry XY. The transition piece contains conical sections having vertices at points A, B, C, and D. Draw these conical parts of the transition piece so that each has as its base boundary line one quarter of the circumference of the circle as it appears in the top view. Then divide these conical sections into three qual parts and add the two additional elements to each section.

(4) Using the true lengths from the true-length diagram and the other required true lengths from the top and front views, construct each triangular area of the development in proper sequence. Since the object is symmetrical about axis XY, a half development is sufficient. Make the seam line on the finished transition piece along line Y-1 at the center of the shortest flat side.

b. Transition piece from horizontal circle to sloping circle. Figure 2-34 shows the development of a warped reducing section. A reducing section is a sheet metal part used to join ducts which are shaped alike but are of different sizes. Here is how we develop such transition pieces:

(1) Start the development by dividing the upper and lower openings into the same number of divisions. Divide the lower openings in the top view

where it appears in true size and shape. Draw an auxiliary view of the upper surface and make the divisions for this surface in this view. Use any number of equal divisions. Twelve divisions were used in the example because this number is very convenient. You can use the ends of the two perpendicular diameters as centers and the radius of the circle to scribe arcs that divide the circles into twelve equal divisions.

(2) To avoid confusing the points on one circle with those on the other, mark all points in the upper circle with even numbers and all points in the base circle with odd numbers.

(3) Divide the surface into traingular areas by drawing lines to connect points in the following sequence: 1-2, 2-3, 3-4, 4-5, etc. In the example, every other line is broken, and the solid lines and broken lines are separated in the true-length diagrams to lessen the likelihood of your confusing the lines.

(4) Draw two such diagrams to enable you to select the correct true-length of each line as you lay out the development. Obtain the true length lines representing the distance between elements on the two circles in the top and auxiliary views.

(5) Use the true lengths as radii to construct the development by triangulation. Start the development by drawing a line for element 1-2. Then using a divider or a compass, set for the true length of this element, locate points 1 and 2 on this line. Next, draw two arcs. Make one arc by using point 1 as the center and the distance R as the radius. Draw the other arc by using point 2 as the center and the true length of element 2-3 as the radius. The intersection of these two arcs locates point 3 and establishes the apexes of the first

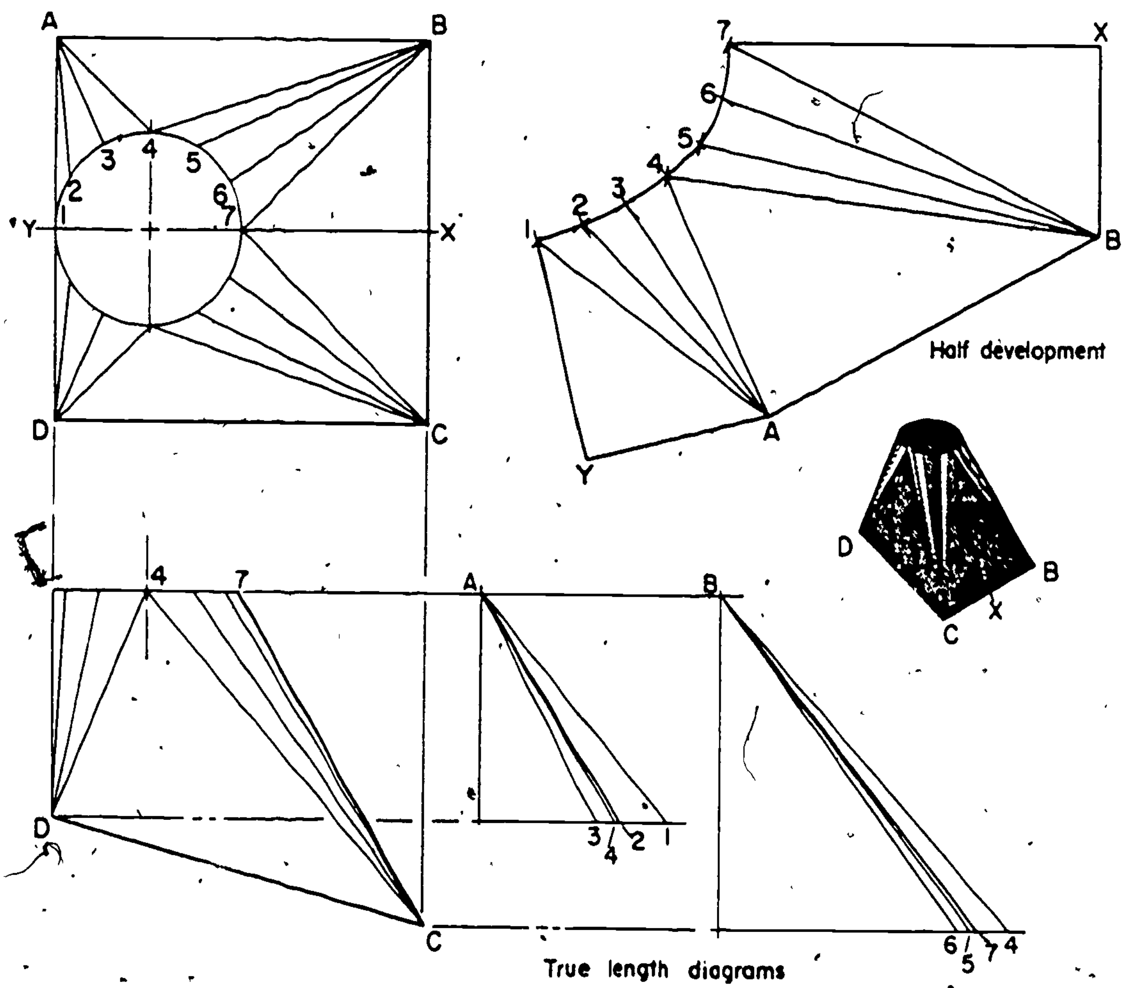


Figure 2-33. Developing a transition piece.

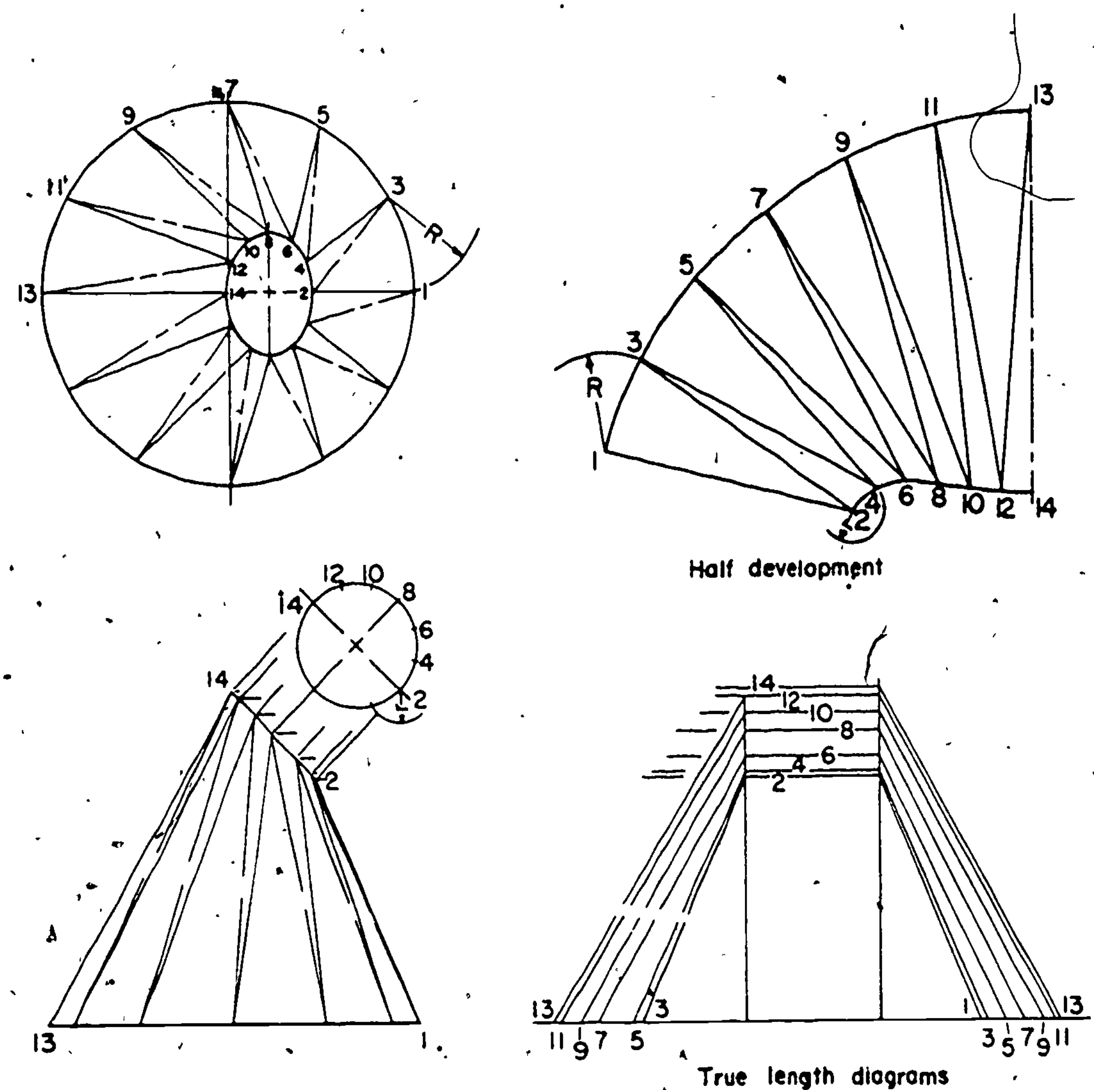


Figure 2-34. Developing a warped surface.

triangular section of the development. Locate the next triangular section by using the same procedure. For this section, draw an arc by using point 2 as a center and the distance r (the distance between elements on the upper circle) as the radius. Then locate point 4 by intersecting this arc with another arc by using point 3 as the center and the true length of element 3-4 as the radius. Continue this process until you have located all points. Then draw straight lines representing the elements. Finish the development by drawing curved lines through the established ends of these lines.

Double-curved surface development (sphere). The surface of a sphere is a double-curved surface generated by a curved line and contains no straight-line elements. Therefore, the development of sphere is only an approximation. The steps for developing a sphere are as follows and as illustrated in figure 2-35:

(1) Draw the top and front views.

(2) Consider that the sphere in the front view is cut by a series of planes passing perpendicularly to the axis. There projection in the top view shows them as circles. Also consider that the sphere is cut by vertical planes which appear as radiating lines in the top view. Although we describe only a one-quarter development here, the remaining quarters are developed in the same way. The development of one longitudinal section provides the pattern for the remaining sections.

(3) Draw a horizontal stretchout line representing the horizontal cutting plane D.

(4) Set your divider for a span equal to the distance between points 1 and 2 on the top view. Then use it to step off distances along the stretchout line, locating points 1 through 5.

(5) Draw a perpendicular bisector to each segment of the stretchout line.

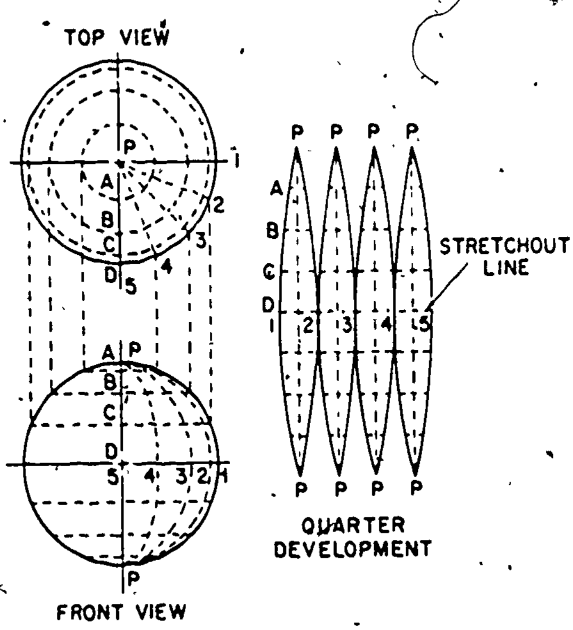


Figure 2-35. Developing the surface of a sphere by the gore method

(6) On the perpendicular bisectors, above and below the stretchout line, mark off four spaces each equal to the distance between points C and D in the front view. Then draw horizontal lines through the points of division. These horizontal lines represent the horizontal cutting planes A, B, and C.

(7) Establish the width of each section at each of the horizontal cutting plane lines by transferring the corresponding distances from the top view.

(8) Draw a smooth curve through the points established in step g. Each section is symmetrical about the line PP and the stretchout line. In this example, a full development requires 16 sections.

Exercises (418):

1. What is meant by triangulation development?

2. This method is used for all ______ ______ and ______ ______.

Structural Drafting

A BRIEF SURVEY of the development of structural engineering practice indicates that the term "structural engineering" was first applied to a branch of civil engineering concerned with bridge building. These structures represented a high degree of progress in the application of the science of mechanics and of a knowledge of the strength of materials to the design of framed structures. Later on, the term "structural engineering" was used in connection with the development of large, steel-framed and reinforced concrete structures, and it is mainly in this connection that the term is used today. It is correct to conclude, then, that structural drafting is the preparation of working drawings for buildings and other construction whose vital supporting framework is composed of timber, steel, concrete, or other material and that the technique of structural drafting, while very similar to architectural drafting, is influenced by the materials and methods of construction.

3-1. Terminology

Figure 3-1 is a line diagram of a building. It is true, the roof truss outlined is not typical of reinforced concrete structures. However, other parts shown are frequently encountered structural members. They are classified according to purpose.

419. Define selected terminology used in timber construction drawings.

Structural Terms. A "member" is a unit part of a larger structure. The member itself may be composed of several pieces fastened together, but it functions as a unit. Any part of a framework, such as a beam or a column, is always spoken of as a member. In order to develop an understanding of the standard practices and conventions connected with structural drafting, study the discussion of the more common structural terms given below and see the members illustrated in figure 3-1.

a. Footings support columns, piers, and masonary walls. They receive the weight of the structure and distribute the load into the ground. The increased bearing area prevents the building from sinking where the natural surface material is too weak to support the building weight. Footings are usually made of reinforced concrete, but the footing for a very light building may be a simple slab of plain concrete.

b. Piers rest on footings and support vertical columns or horizontal girders. In bridge construction, a pier is an intermediate support for the adjacent ends of two bridge sections.

c. Columns are vertical members which support loads acting downward; that is, they are members in compression. Columns are the main load-carrying vertical members in steel, timber, or concrete framing.

d. A *girder* is a heavy member spanning between columns and serving to support beams and joists. They are the heaviest or strongest members of a floor system.

e. A *beam* is usually lighter than a girder, its ends being supported by a girder or column. A lintel is a beam which spans a door or window opening to carry the structure directly above these openings.

f. Joists are lighter than beams and are spaced closer than beams. The ends of joists are supported upon beams or girders.

g. A *truss* is a built-up member designed to support loads over long spans. The principal truss members are the upper and lower chords (see fig. 3-1); the members between the two chords are called web members. Many basic truss designs are used for wood and steel construction, the five most common designs being the Pratt, Warren, Fink, scissors, and bowstring. A typical Pratt truss is illustrated in figure 3-1. Although most trusses have a triangular outline, a few truss applications, such as support for a flat or curved roof, require a truss whose upper chord is horizontal or curved. Regardless of the truss outlines, the web members are always arranged to form a series of triangular units between the two chords. The triangular arrangement gives a

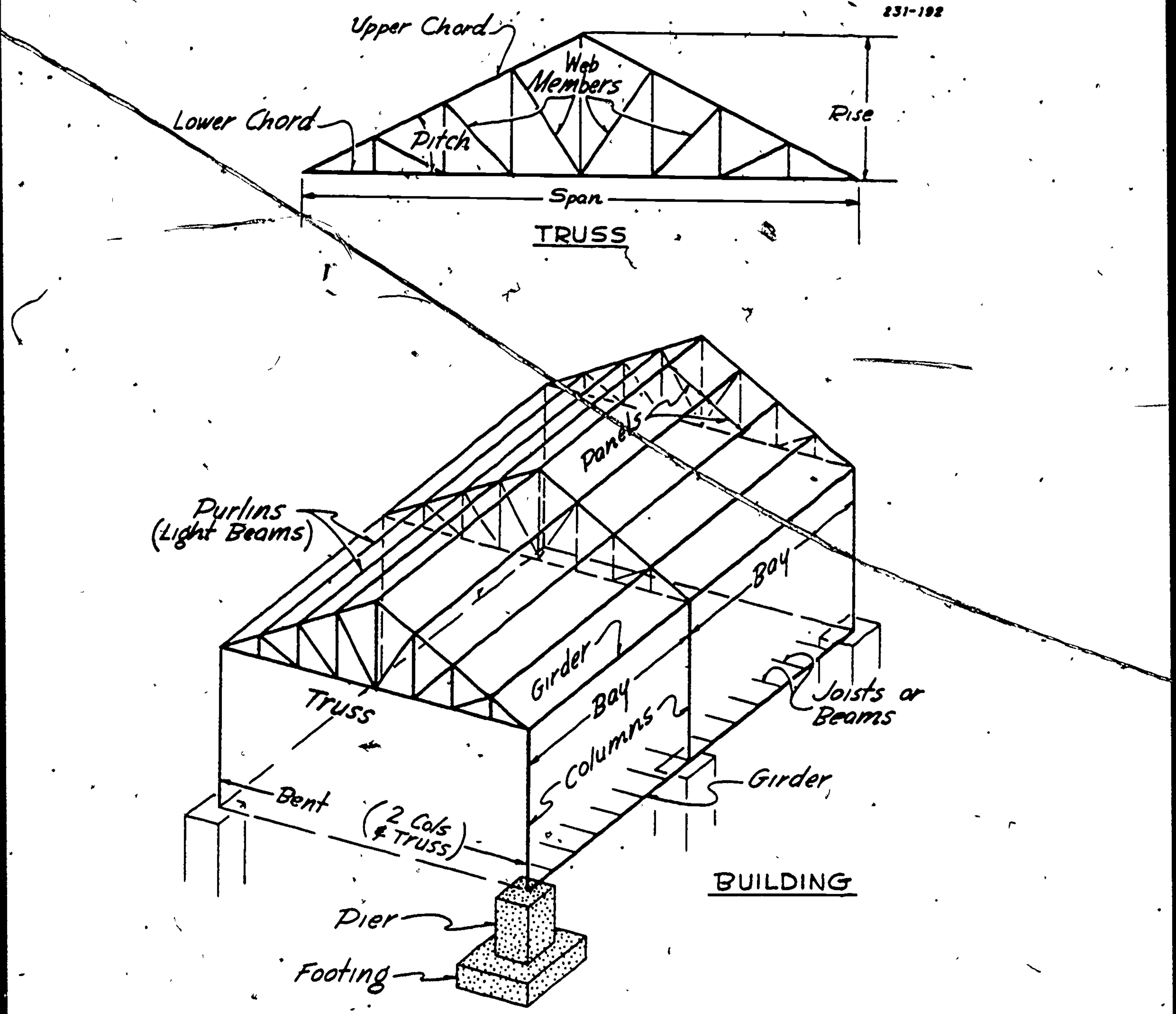


Figure 3-1. Structural terms.

truss a high degree of rigidity. On long spans, trusses are usually substituted for girders because their increased depths provide greater resistance to deflection, pound for pound, than the built-up girders or rolled shapes that would otherwise be used.

h. A *bent* is formed by a truss and the columns supporting it. Any vertical framework, consisting of columns and beams to support other members, is called a bent.

i. A *bay* is the space between adjacent or consecutive bents.

j. A *purlin* is a beam spanning the space between trusses, girders, or rafters, and it supports the roof covering.

k. A *panel* is that protion of a truss between adjacent joints in the upper or lower chords. The space between two purlins on a roof is also called a panel.

The terms "span," "pitch," and "rise" are also indicated in figure 3-1. Other terms associated with steel, wood, and concrete construction will be introduced and defined as we discuss the drafting conventions peculiar to these materials.

Exercises (419):

1. What is a "member," as related to a strucutral drawing?

2. What is a girder?

3. What is a truss designed to do?

4. How is a pier used?

5. How does a joist differ from a beam?

3-2. Timber Construction

Timber construction, or heavy wood framing, is used for warehouses, shops, bridges, and other structures where heavy loads and long spans are encountered.

420. State the particular function of selected metal fasteners and connections.

Fasteners and Connections. Long, unsupported areas between walls are spanned by roof trusses rather than rafters. Floor systems, either for bridges or buildings, consist of thick plank flooring supported by heavy beams or closely spaced joists. The wood members for these structures must be carefully selected and sized to support their respective loads. They are then connected with spikes, bolts, screws, or special timber connectors. Spikes are used for the smaller sizes of lumber, while square or hexagonal head bolts are used in larger timbers. Metal connections (see fig. 3-2) are used in conjunction with bolts to make wood-to-wood joints stronger. With these connectors, the members of built-up frames are held in place more rigidly than with spikes or bolts alone, and it is possible to use a greater percentage of the tensile and shearing strength of the wood. Specially shaped cast iron or pressed steel blocks are used at joints to connect single piece members together. Steel rods are used to take tensile stresses since it is difficult to fasten wood so that its tensile strength can be used to the best advantage. Connectors, used to join the members of built-up trusses, are set in precut grooves or forced into the wood by pressure.

Bolts used in timber construction vary in diameter from 1/4 to 1¼ inches. They are usually squarehead type and they take square or hexagonal nuts. Round washers or square metal plates are used under boltheads and nuts to increase the bearing area on the wood.

Figure 3-2 also illustrates the use of steel plates to connect and reinforce joints in framing. Plates are placed on both sides of the joint and bolted in place. Depending upon their function, these plates are given various names, such as tie, splice, batten, or gusset. Wood plates may be used, but the wood must be very strong where the joint is subjected to tension or compression stresses. Gusset and batten plates are used more extensively in steel framing.

Exercises (420):

1. What purpose does a metal connection serve in timber construction?

2. What particular type of stress are steel rods designed to take?

421. Complete sentences with key words or phrases indicating conditions affecting drafting practices for framed structures.

Working Drawings. In preparing a set of working drawings for a framed structure, the nature and size of the structure determine the number and type of drawings required. Where one sheet may be adequate to describe a simple tower, a dozen or more sheets may be needed to completely describe a building or bridge. In the case of a building, factors such as overall size, external appearance, arrangement of interior space, doors, windows, and fittings are described in general and detail drawings.

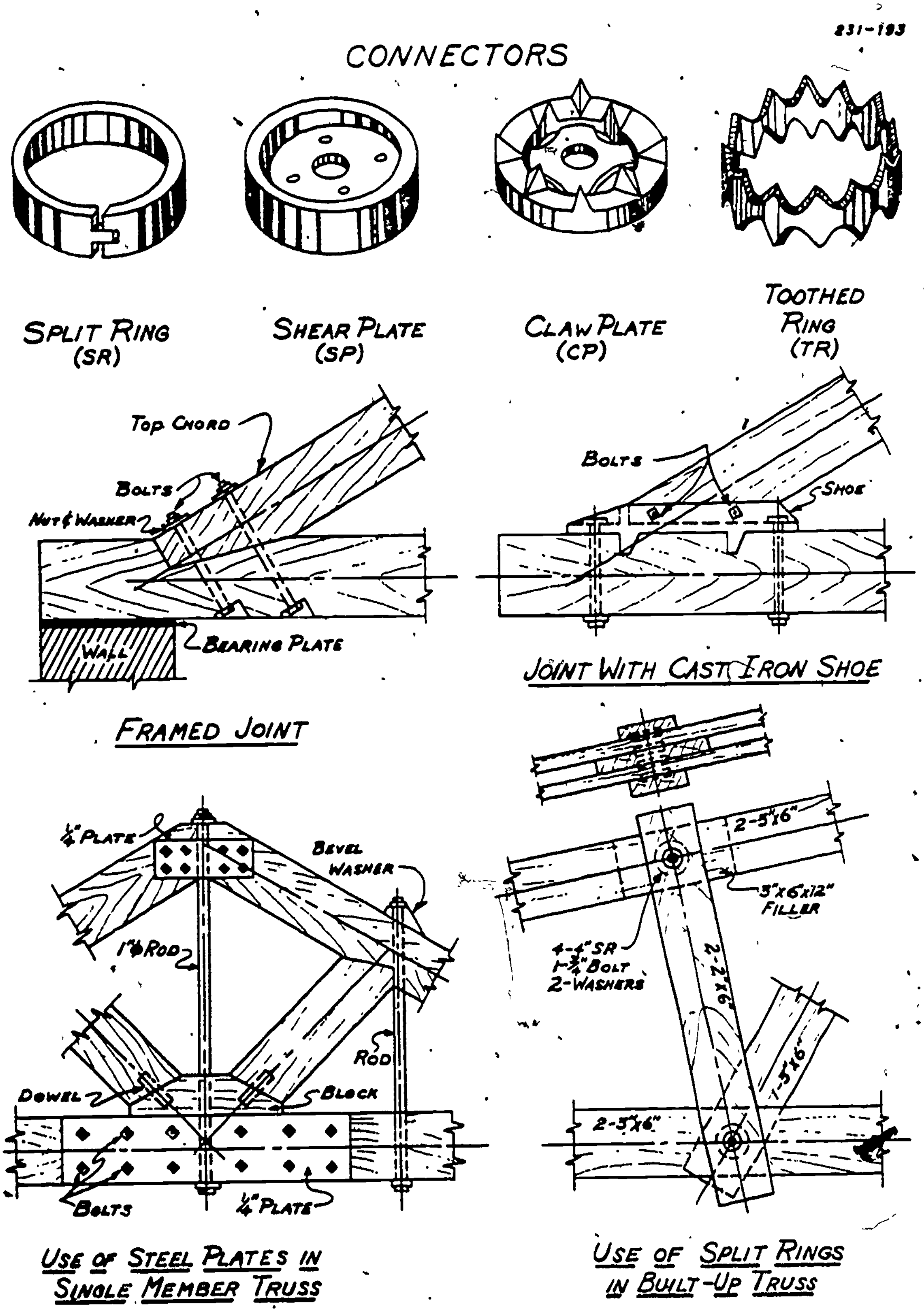


Figure 3-2. Timber construction details.

As we will learn in the study of architectural drafting, general views consist of small-scale plans and elevations, and details consist of large-scale section and detail drawings. Closely related to the matter of architectural design are the engineering calculations concerned with the strength of the supporting framework of the structure. These details must be carefully worked out by an architect or construction engineer. From their engineering design sketches, you will prepare structural plans and details showing the method of construction. Separate framing plans may be drawn for floors, walls, and roofs. Floor framing plans specify the size and location of columns, girders, beams, and joists. Wall framing plans are elevation views showing the framing for windows, doors, columns, and bracing. Roof framing plans are drawn and used in the same manner as floor framing plans, with rafters shown in the same manner as floor joists. Trusses are detailed in large-scale views, as indicated in figure 3-3. Framing plans may be accompanied by a cutting list giving the size, length, and details of special cuts for timbers. This information is organized in a schedule or table on the sheet to which it refers.

Structural Drafting Practices. The best way to point out the drafting practices and conventions employed in structural drafting is to study them as they are applied to a typical problem. Figure 3-3 is the detail for a built-up roof truss. If a truss or other large member is symmetrical about its centerline, it is customary to show only the left half. This left half view is taken looking in the direction which shows the most detail in regard to connections and other important features. The view is never stopped exactly on the centerline, but is extended far enough to show the construction through the center axes. A wavy, short breakline or a long breakline is used to terminate broken-off members. Note that the breaklines are drawn only through the members and not across the space between members.

The placing of views on structural drawings is similar to the practices followed in machine drawing. That is, the top view appears above the front view, and an end view is placed to the right or left of the front view. This is especially true in detailing single small members where the views can be conveniently aligned vertically and horizontally as in regular multiview projection. As shown in figure 3-3, inclined parts are presented in auxiliary projections. Thus, the top chord of the truss is shown as an auxiliary view instead of showing a regular top view of the truss. This method is convenient since it shows true lengths and provides for easier placement of dimensions and notes.

Another practice followed in structural drafting is the use of bottom views. However, bottom views of structural members are made, as horizontal sections looking downward. The theoretical cutting plane is assumed to be placed so as to show only essential details of the lowe member. In figure 3-3 therefore, the bottm view is in reality a "top view" of, the lower chord. No cutting plane line appears in the front view, and the bottom view is not classified as a section. This arrangement places the front face of the lower chord below the bottom view centerline. Similarly, the front face of the upper chord is below the centerline of the top view. Since the front and rear details of the truss members are shown on the same side of corresponding centerlines in the top and bottom vews, parts are shown in their true relationship to each other. The terms "near face" (NF) and "far face" (FF) are frequently used in notes on structural drawings. When applied to any view, the term "near face" indicates the surface nearest the observer for that particular direction of sight. The far face is, of course, the opposite side. Some draftsmen prefer the terms "near side" (NS) and "far side" (FS). You may use either set of terms as long as you're consistent.

In figure 3-3, all members of the truss are detailed in the assembled position which they occupy in the structure. Had each piece been detailed separately, they would still be shown in the same position. That is, horizontal members are detailed horizontally, vertical members are detailed in an upright or vertical position, and inclined members are usually shown in an inclined position. When vertical members, such as columns, are too long to be placed upright on the sheet, they are drawn in a horizontal position with the base at the left side of the sheet. Also, in some drafting rooms, it is standard practice to detail inclined members horizontally.

Sections are frequently shown on structural drawings. These views are placed in convenient spaces on the sheet, and each view is identified with letters. For example, section A-A is indicated on the truss by cutting plane line A-A. When several sections appear on the same sheet, their cutting planes must be located at the particular point at which the view is taken. Standard architectural material symbols are used as indicated. Filler pieces, plates, and blocking need not be crosshatched if clarity is improved by omitting the section symbols.

Exercises (421):

1. In preparing a set of working drawings for a framed structure, the ______ and ______ of the

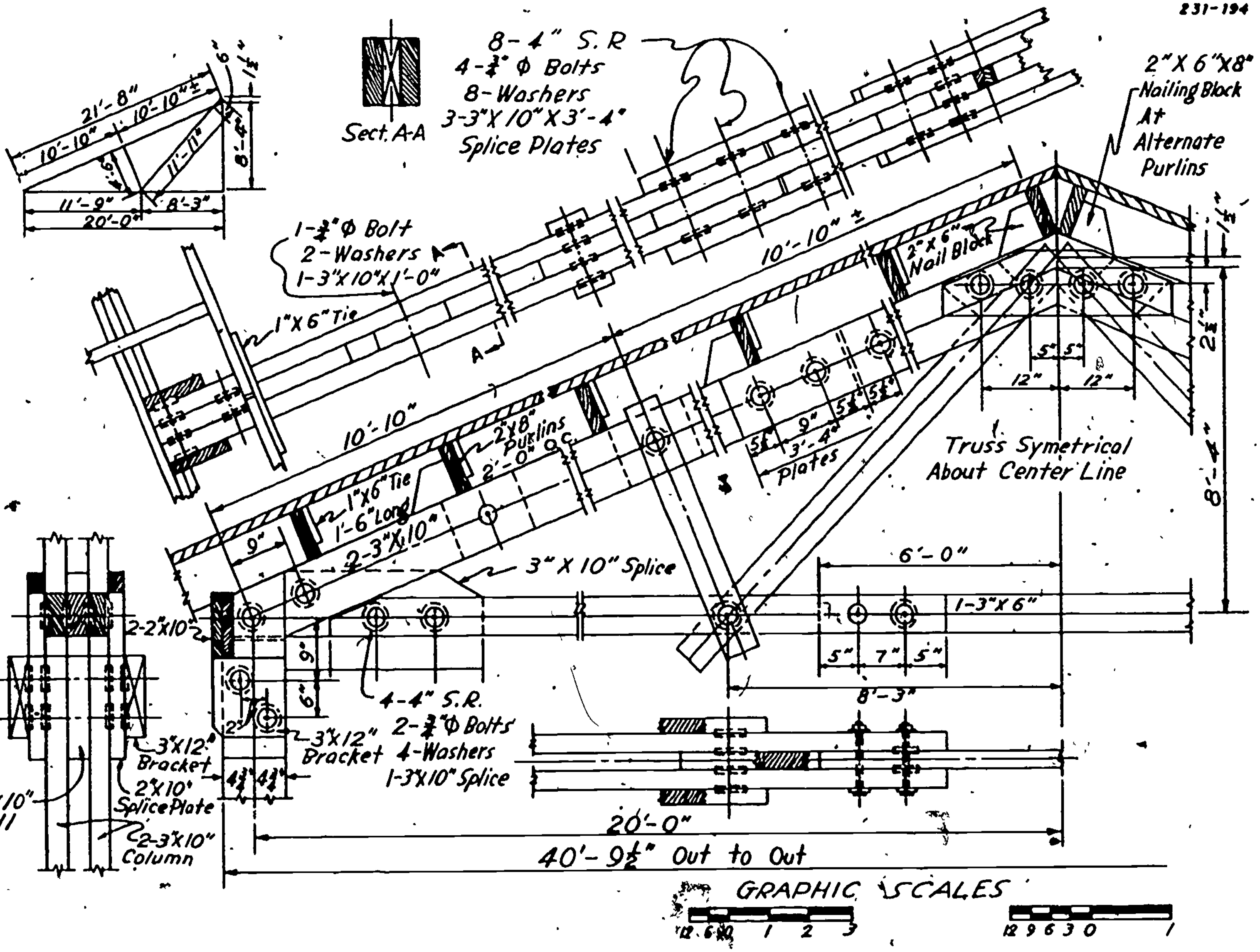


Figure 3-3. Truss detail.

structure determine the number and type of drawings required.

2. Floor framing plans specify the size and location of ______, ______, ______, and ______.

3. If a truss or other large member is ______ about its ______, it is customary to show only the left half.

422. State an important consideration to keep in mind concerning dimensioning scale and skeleton diagrams.

Dimensioning. The technique of dimensioning wood structures is the same as for architectural draftings. Light, solid dimension lines are used, and the figures are placed above the line near the center of the space between the arrows. Indications for feet, inches, and fractions are the same as in architectural drafting. Dimension lines are placed in continuous rows from end to end of the object, with the outermost dimension giving overall size. The dimension line nearest the object should not be closer than 5/8 inch, and succeeding rows should be no closer together than 5/16 inch. Spread the lines farther apart when space is available, and avoid dimensioning upon the object. A note or dimension placed in the clear and connected to the object by a leader is an effective method of dealing with crowded conditions.

Dimensions must always be checked for accuracy. Be sure that it is not necessary for the workman to perform mathematical computations in order to get needed information. Because of limited space, the views in figure 3-3 are not spaced far enough apart to permit the inclusion of all necessary notes and dimensions. In blocking out views, be sure to leave adequate space for dimensions.

Scale. The architect's scale is the only scale used in making structural drawings. As we have already pointed out, the scale most generally used for general drawings is 1/4" = 1'0". However, it is often necessary to use a smaller scale for very large structures. Detail drawings of large members are drawn in the middle range of scales, whereas small members and special construction joints may be drawn quarter size (3" = 1'0") or half size (6" = 1'0").

An important feature in structural drafting is the frequent use of two scales. In figure 3-3, the centerlines of the truss members are laid out first to a scale of 1/2" = 1'0". The truss members themselves are drawn to 1" = 1'0" scale—except for their length. Thus, the timbers are to scale in only one direction in the front, top, and bottom views. The section view is to scale in both directions. Likewise, the end view is to scale in all directions except that the full vertical length of the column is not shown. This is done to save space and time.

Skeleton diagrams. One of the first steps in preparing a truss detail is to draw a small, scaled diagram often called a skeleton diagram. A skeleton diagram is constructed of "working lines" which usually coincide with the front view centerlines of the truss members. These diagrams have various purposes. In figure 3-3, the diagram shows dimensions to the "working points"—the intersections of the working lines are referred to as working points. The diagram in figure 3-3 also serves as a reference in laying out and dimensioning the truss members. When only one member of a truss is to be detailed, a skeleton diagram is used to show the position of the detailed member with respect to the other members. The member being detailed is indicated in the line diagram by a heavy line.

Nominal and actual sizes. You must keep in mind, especially in drawing details, that commercial timbers are designated by nominal size and drawn to actual size. As you learned in architectural drafting, surfacing lumber and timber reduces its dimensions. A 3-inch x 10-inch joist has an actual size of 2⅝ inches x 9½ inches, and a 1-inch x 6-inch board is actually 25/32 inch x 5⅝ inches.

Note also in figure 3-3 the use of centerlines and notes to designate the location of bolts rather than by drawing all bolts in place. This practice is acceptable as long as notes fully explain construction. In some drafting rooms, bolts are designated by giving the diameter, length, type of head with type of nut, and number and type of washers. Special bolts are detailed separately and designated by a code number or letter on structural views. Practices differ somewhat in different drafting shops. However, these are merely variations to the standard practices and conventions which have been explained and illustrated in the preceding paragraphs.

Exercises (422):

1. What is an important consideration you should keep in mind concerning dimensioning?

2. An important feature in structural drafting is ______.

3. What does a skeleton diagram show?

3-3. Steel Construction

Structural steel may be used to form the framework for many kinds of structures, such as bridges, towers, hangars, and office and factory buildings. To insure that construction is carried out properly and efficiently, all necessary information must be furnished to those who are responsible for the various phases of construction. This information is contained in drawings, specifications, orders, and bills of material. The following drawings are used in the fabrication and erection of steel structures.

423. Define terms and identify drawings related to the fabrications and erection of steel structures.

Layout Drawings. Layout drawings, which are sometimes called general plan and profile drawings, convey necessary information on the location of the structure in relation to the site. Other items of information, such as elevations for principal points in the structure, nature of the underlying soil, or the location of other structures, roads, and utilities, may be included on the drawing.

Layouts. Figure 3-4 is an example of a layout drawing for a steel railroad bridge. Notice in figure 3-4 that the information for the location of the bridge abutments and piers is presented by means of survey stations and ground elevation contour lines.

General drawings consist of plan views, elevations, and sections of the structure. Information on size, materials, and the makeup of all main structural members is given. Depending upon the size of the structure and the complexity of the construction, a few or many general drawings may be required. Figure 3-5 is an example of a general drawing for part of the superstructure of the bridge shown in figure 3-4.

Fabrication drawings, often called shop detail drawings, are detail drawings which give all information on size, shape, material, connections, and attachments for each member of the structure. Fabrication is the process of cutting, drilling, and assembling steel parts into members. An erection mark which usually consists of capital letters and numbers—see MK414, MK416, MK51, etc., in figure 3-5—is painted on each member before it leaves the shop. These erection marks are assigned by the designer and are used on design layouts, general drawings, and framing plans. The erection marks are used throughout the fabrication process to identify the members and later to assemble the members in the structure. Identical members are given the same mark. Notice the repetition of numbers in figure 3-5. Figure 3-6, a shop detail drawing shows component parts and dimensions for fabricating "stringers" for the bridge shown in figures 3-4 and 3-5. Note that the drawing in figure 3-6 serves for fabricating two different members—MK414 and MK415 stringers. The dimensions and notes explain the differences between the two beams. This method is frequently used when members are alike in all respects, except for variances in length or in other minor details. As an aid in assembling or fitting together the individual parts of built-up members, each part is assigned an assembly mark. Assembly marks appear on the drawing and are assigned in the drafting room where fabrication drawings are prepared. Although there is no standard system for assigning assembly marks, the usual method is to use a combination of lowercase letters and numbers. Usually the letter indicates the shape of the steel member—"a" for connection angles, "p" for splice plates, etc. The number differentiates between pieces of the same shape which are different in size or detail. If more than one of a specific part is required, the assembly mark is entered on the drawing after the size of one part—similar parts are identified by the same assembly mark without repeating the size. Notice in figure 3-6 that the connection angles shown on the right end of the stringer are identified by the assembly mark "a15" following the designation L4 x 6 x 3/8 x 2'10". The connection angles on the left end are identified only as "a15." A word of caution: be sure that you are familiar with the marking system used in your shop because simple errors in the fabrication of steel members can be very costly.

Erection drawings are simplified, small-scale diagrams which show the mark, location, and position of each member in the structure. These drawings are prepared for more complex structures and serve as guides in fitting structural members together at the job site. In constructing a building framework, a floor framing plan usually serves as the erection diagram. The larger and more complicated the structure, the simpler the diagram symbols must be. On small-scale diagrams, a straight line may be used to represent any steel shape as long as the proper notation appears adjacent to the line.

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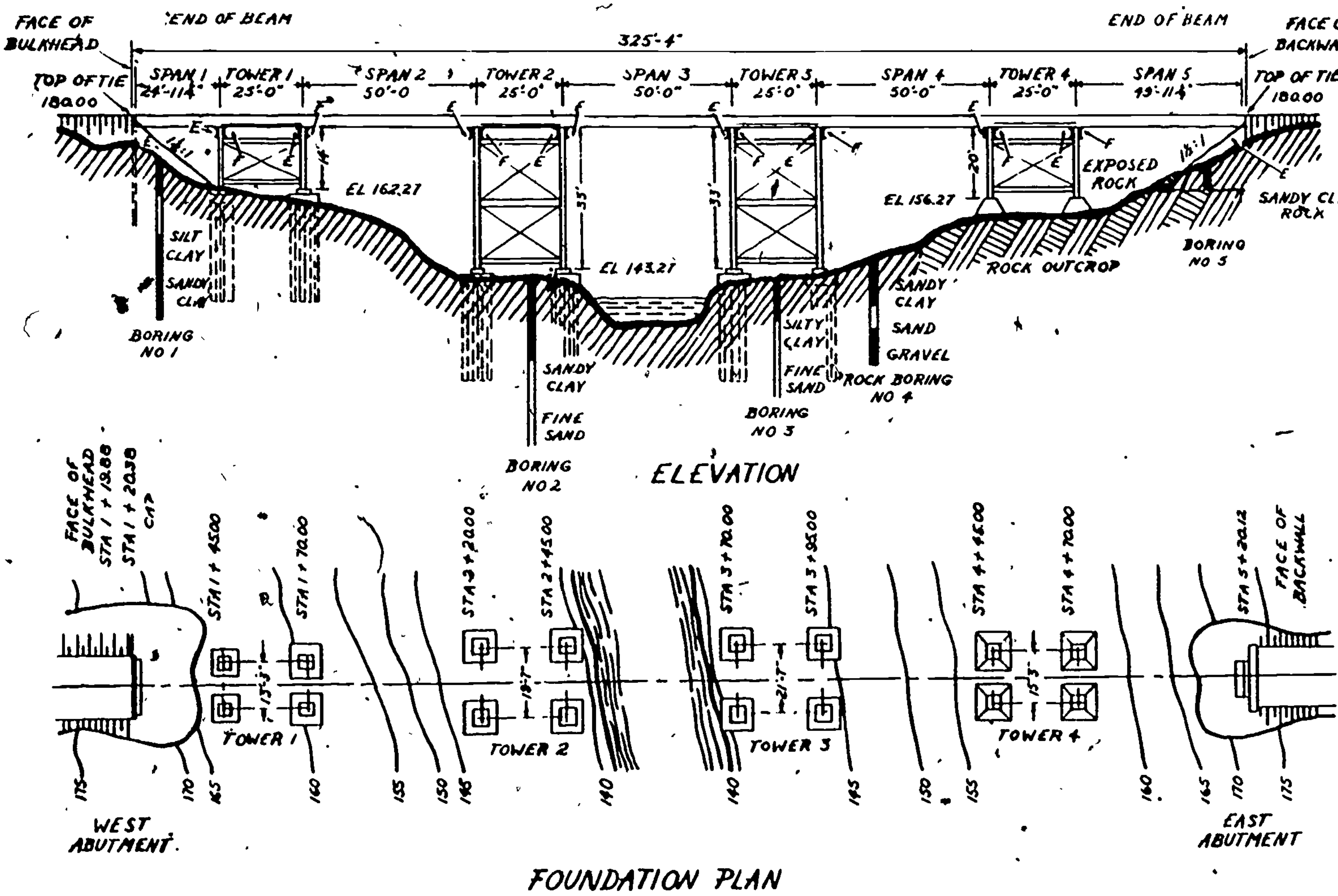

Figure 3-4. Typical layout drawing.

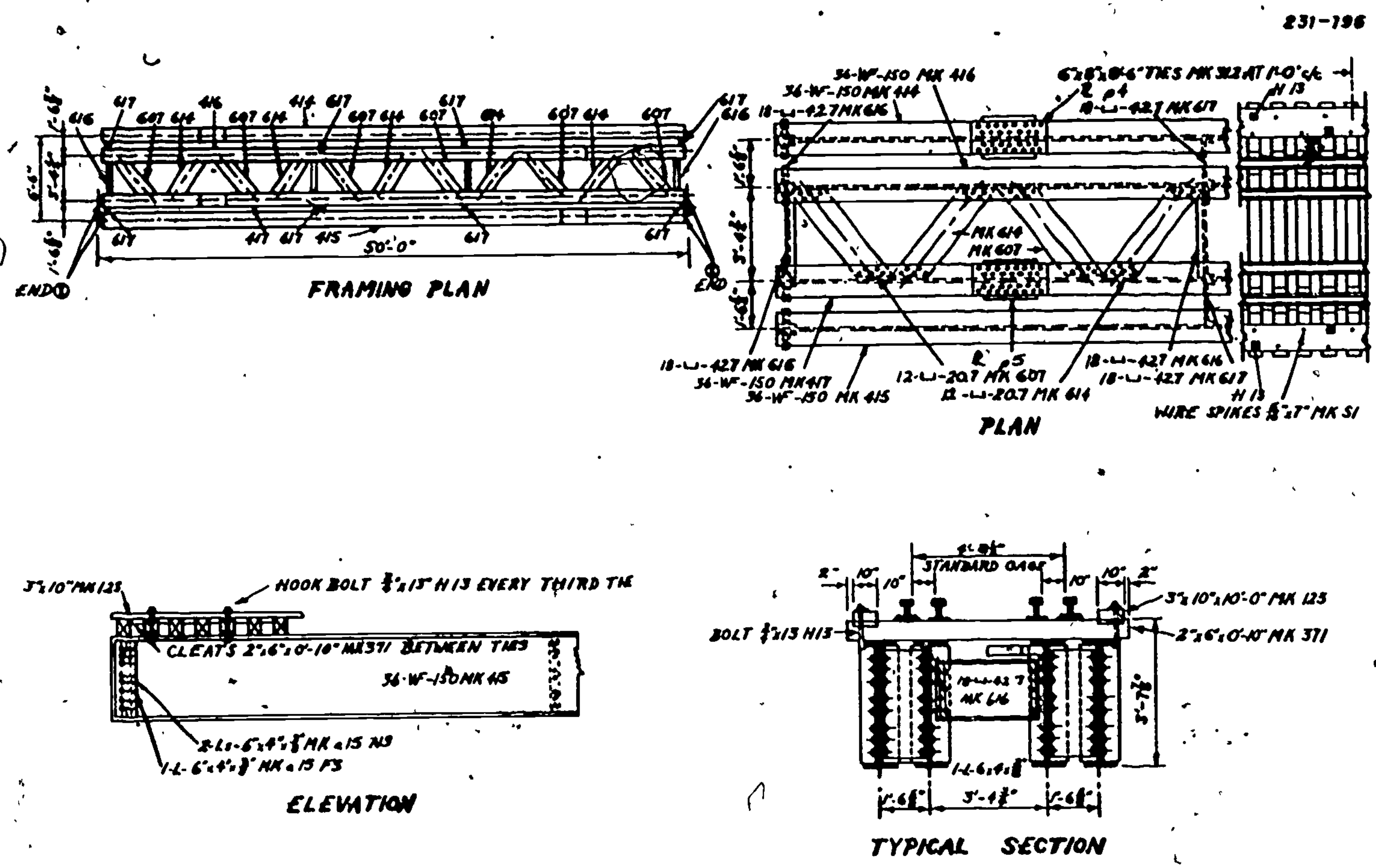

Figure 3-5. General drawing.

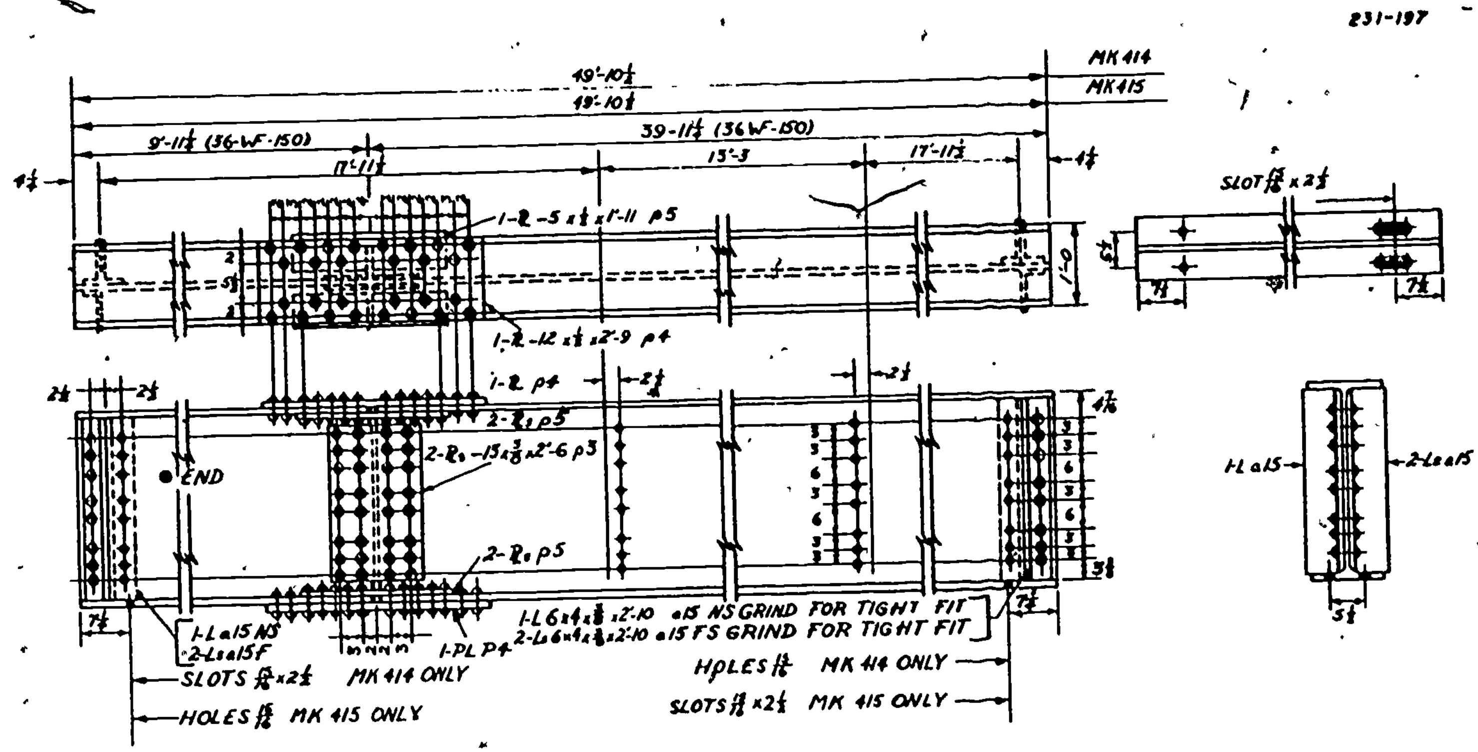

Figure 3-6. Fabrication drawing.

Falsework plans are prepared to show the method of constructing temporary supports, usually timber, which are needed in the construction of large steel structures. Buildings under 40 feet high do not ordinarily require falsework, but falsework is especially important in bridge building and in reinforced concrete construction. In simple construction, the supporting falsework may be designed at the job site by the erector or contractor.

A bill of materials is a listing of the quantities, lengths, and other necessary descriptions of all materials needed for construction. Each part of the structure is listed by its identifying marks and its total weight. This is necessary for checking on shipping weight and for determining the required capacity of hoisting equipment and falsework construction. A rivet list may also be included in a set of plans. It lists the size and number of rivets, bolts, and pins used in erecting the steel structure.

Exercises (423):

1. What is meant by "fabrication?"

2. What is an erection drawing?

3. What is falsework and when is it used?

424. Give the sequence for writing the dimensions of selected steel shapes.

Steel Shapes. Figure 3-7 shows cross sections of the more common structural steel shapes. Their general proportions remain the same throughout a wide range of sizes, and the shapes are standardized. Although the dimensions of the more commonly used shapes are easily memorized, a complete listing of each shape by size and weight should be kept on hand. This information is furnished in handbooks and manuals published by steel manufacturers and trade associations.

As was previously explained in the study of architectural drafting, symbols are used in notes or dimensions to identify these shapes. However, a more thorough discussion is required because of the importance of correctly specifying standard shapes on structural drawings. You should give particular attention to the sequence used for writing the dimensions of the various steel shapes. When dimensioning steel members, it is permissible to omit the inch (") and pound (#) symbols. In making notes or bills of materials, structural members should be specified, as indicated in figure 3-7 and as explained below.

Angles. Angles, consisting of two legs set at right angles, may be equal leg, unequal leg, or bulb angle. Equal leg angles are specified by giving the symbol and the size of legs by thickness and by length. Unequal angles are billed by giving the length of the long leg first. Bulb angles are specified by name, giving the length of the legs in the same manner as for unequal leg angles. No thickness is given for bulb angles, as the thickness is standard for specific shapes. Instead, the weight per linear foot is given for bulb angles.

Bars. Round, square, and flat bars are used for various purposes in steel framing. Round bars are the most widely used as tie rods between members to steady them, or as diagonal braces in framed structures. Square and round bars are specified by giving their size, symbol, and length. Flat bars are specified by giving width by thickness by length.

Standard beams. These are generally called I-beams. Their notational sequence is nominal depth by weight per foot by length. Junior beams are lightweight I-beams. Plates are specified as width by thickness by length. In addition to the special symbol used to indicate plate material, descriptive words are commonly employed in the notation.

Standard channels. Standard channels are specified in depth by weight per foot by length. Like I-beams, standard channels have sloping flanges, rounded-off toes at flanges, and fillets between web and flanges. The symbol for a channel is usually drawn lying on its back to prevent its being confused with the symbol for an angle or an I-beam. Special channels are specified by giving depth by flange width by length.

Tees. Rolled tees are specified by flange width by stem height by weight per foot by length. Structural tees are made by cutting standard I-beams, wide-flange beams, or junior beams lengthwise through the center of their web. The notation sequence for structural tees is different from that for standard rolled tees, as shown on figure 3-7.

Wide-flange beams. Wide-flange beams are sometimes called B, CB-, or H-shapes. The notation gives the standard depth in inches, by weight per foot by length. These sections have straight flanges and filleted interior angles between web and flanges.

Rails. Rails are designed by giving the standard type (American Society of Civil Engineers or American Railway Association), weight per yard, and length in feet and inches.

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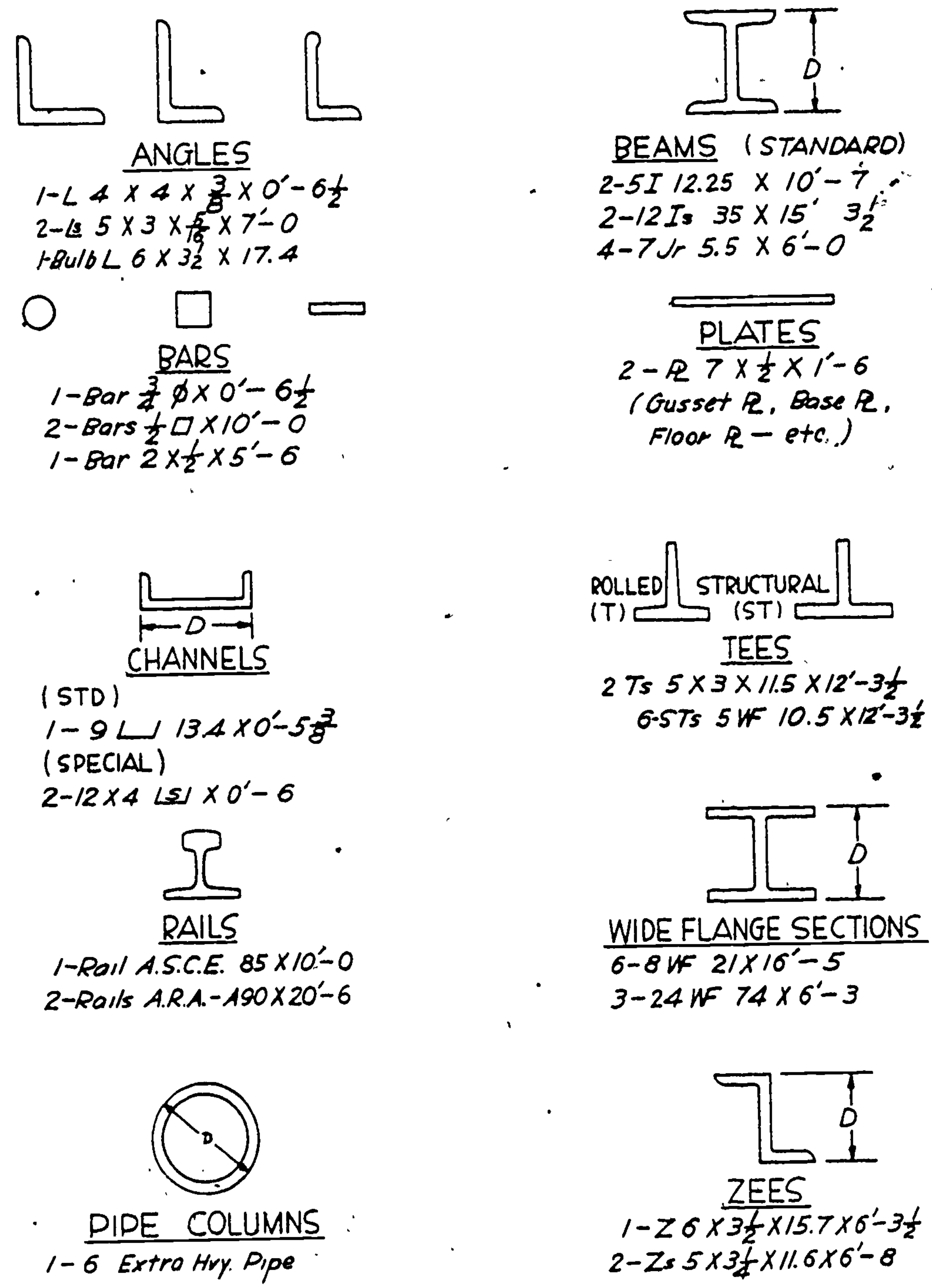


Figure 3-7. Structural steel shapes.

Pipe columns. Pipe columns are identified by giving the nominal diameter and name. A "lally" column is a pipe column filled with concrete.

Zees. Zees are designated by giving web depth by flange width by weight per linear foot by length. Zees, like channels, are used primarily in the construction of built-up members.

Exercises (424):

1. How are flat bars specified?

2. How are rolled tees specified?

3. What is the notational sequence for writing the dimensions of standard beams?

425. List the two major types of framing, a use for each, and drawing practices for selected aspects of framing plans.

Framing Plans. Steel structures involving triangular framework, such as bridges and roof trusses, represent one major type of steel framing. The other type is known as rectangular framing, and it includes buildings and other structures, whose skeleton frame is composed mainly of vertical and horizontal members connected at right angles to each other. Rectangular framing may be further subdivided into wall-bearing, beam-and-column, and long-span framing. In wall-bearing construction, both interior and exterior walls are used to support steel framing members. The walls must be strong enough to carry loads transmitted by the supported members. In beam-and-column framing, steel columns are used to support floor and wall systems. Long-span framing is used where it is desired to span distances greater than those which can be safely spanned by single members. Built-up trusses or girders are used to span between widely spaced columns or walls. Girders are usually built up using a plate for the web and angles at the top and bottom flanges. On longer spans, trusses are used because they have a greater strength, pound for pound, than built-up girders.

As a graphic specialist, you must be able to draw framing plans for buildings. These plans are also known as design layouts, because they show the arrangement of columns, girders, and beams for each floor of the building. A framing plan also serves as an erection plan. The first step in drawing a framing plan such as the one illustrated in figure 3-8, is to lay out light working lines to mark the centerlines of the columns. These lines are laid out in both directions and may later serve as extension lines for dimensions. The columns may be numbered, or the rows mav be given letters and numbers. A common practice—the one used in figure 3-8S—is to assign numbers to the lines running at right angles. Each column can then be identified by its coordinates, such as A-1, B-1, and so on. Each column will have the same identification throughout its entire height. Columns built in sections will bear an additional mark such as A-1 tier I. Tier 1 would be the first section erected on the column footing, and the first section usually extends through two stories. The mark A-1 (0-2) is another method of marking which would convey this same information. That is, the designation (0-2) means the column extends from the footing through the second story. The designation (3-4) identifies a column that extends through the third and fourth stories.

A column schedule is prepared in addition to the framing plans. It is organized in tabular form and gives the sizes of each column section throughout its height. It also indicates the points at which the splices occur, the elevation of controlling points, and the sizes of column base plates. Base plates are heavy plates which rest upon the concrete foundation to provide a bearing surface and an anchorage for the column ends.

A heavy line is used as the symbol for girders and beams, and it is drawn up to the column symbol. A small space is left between th line in the column to indicate that the members do not touch. This represents the "clearance" which is always left between adjoining members to allow for errors in fabrication and changes in temperature and to facilitate erection. Clearance varies depending upon the size of the member, and clearance values can be established by consulting steel handbooks. Sizes of girders and beams in framing plans are noted, as shown in figure 3-8. The notations are placed directly above horizontal line symbols and to the left of vertical line symbols. When a beam (or series of beams) duplicates the size noted directly above or to the left, the abbreviation "DO," meaning ditto, may be used instead of repeating the notation. Do not use the usual ditto symbol (") because it is easily confused with the standard inch symbol.

Dimensions are given to the centerlines of beams and girders, and they are placed outside the plan. Extension lines are drawn in accordance with the usual dimensioning practice. Each horizontal

231-199

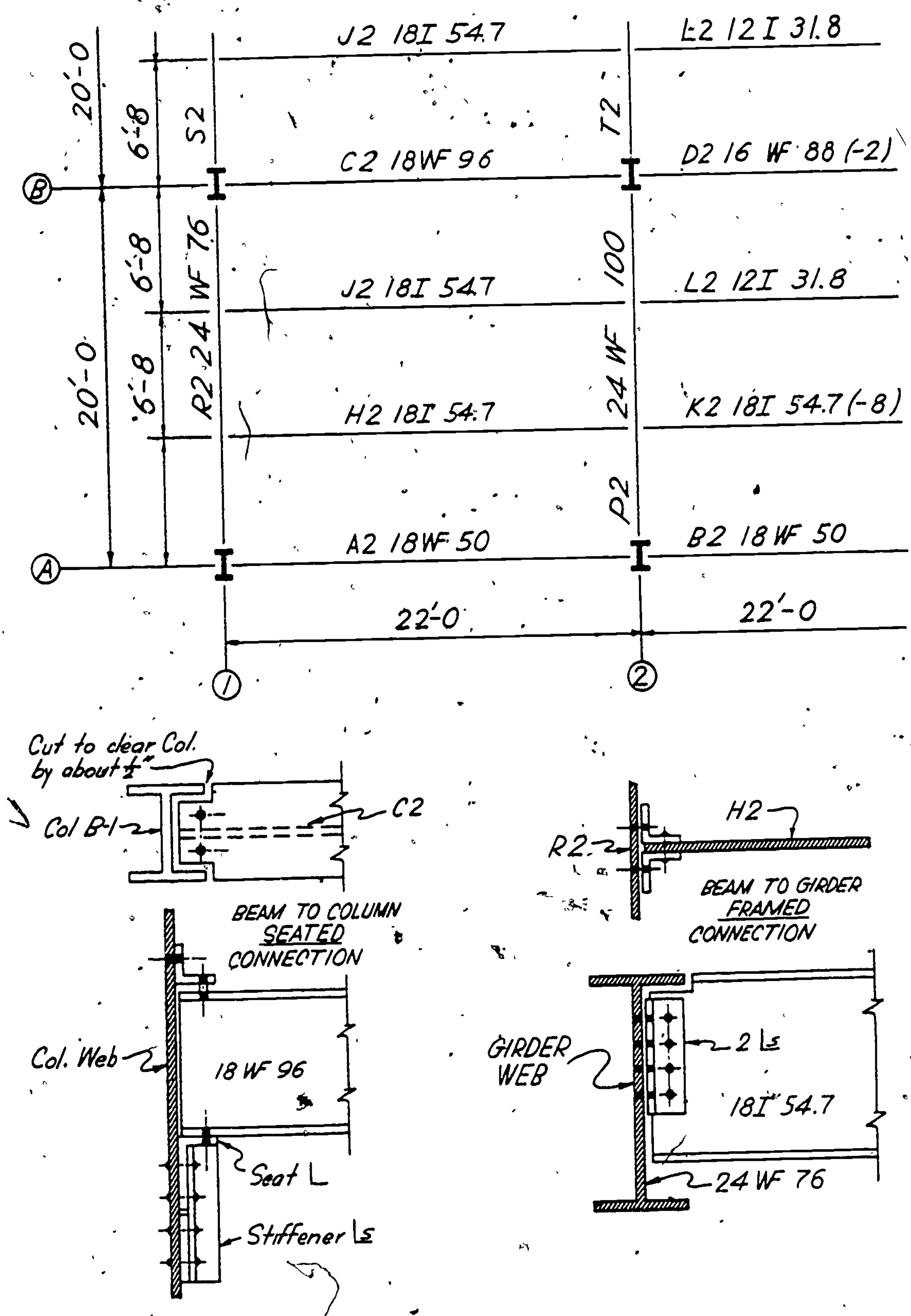


Figure 3-8. Partial framing plan (steel).

member is assigned an identification mark, usually a capital letter, which serves also as an erection mark. The letter may be followed by a number which may be used to refer to a detail drawing for that member, or it may be the floor number of a multistory building. In figure 3-8, we notice that each identification letter (A, H, J, etc.) is followed by the number 2, indicating second floor members. When two members are identical, they may be given the same mark, and only one detail view is necessary.

Exercises (425):

1. What are the two major types of framing?

2. What is the practice for assigning numbers and letters to lines in a drawing?

3. How are these framing plans used?

4. What symbol is used for girders and beams?

426. Define how structural members are connected and detailed.

Connections. The usual method of connecting one structural member to another is by means of small connection angles which are bolted, riveted, or welded in position. Although many basic connections are in use, the seated and framed connections (see fig. 3-8) are the principal connections used to join I-beams, wide-flange beams, and channels. The identifying feature of the seated connection is the seat angle which forms a ledge to support the load. The dimensions of the seat angle and the number and size of the fasteners must provide sufficient strength to safely carry the entire vertical load transmitted to the column from the beam. When very large loads are involved, stiffener angles and a filler plate are added to increase the load-carrying capacity of the seat. The main purpose of the top angle—shown connected to the top flange of the beam and web of the column—is to prevent the beam from moving sidewise. Some designers eliminate the need for a top angle by using a small angle, or clip angle, connected between the webs of the two members. Although the seated connection illustrated in figure 3-8 shows a flange-to-web connection, this connection is also used to fasten the webs of two members.

Examination of the framed connection illustrated in figure 3-8 shows the webs of two members fastened together by two standard angles. The length of the connection angle is determined by the web depth of the member they support. The leg dimensions of the angle and the number, size, and arrangement of the bolts or rivets are varied according to beam loads.

To obtain some degree of standardization in steel construction, the American Institute of Steel Construction (AISC) has recommended six major series (A, B, H, HH, K, and KK) of standard framed connections. Each connection within a series is identified by a number; for instance, there are 10 connections within the A series ranging from A1 to A10. According to the AISC Steel Construction Manual, there are 52 standard framed connections used for beams ranging in depth from 5 to 36 inches. The structural engineer or designer has the responsibility to determine the type connection required for a given set of conditions. Your primary task is to draw the details of the connections. Since complete information for detailing these connections is found in a good trade manual, it is impractical for you to memorize the information.

Notice in figure 3-8 that in both connections a clearance is left between the two members. This clearance simplifies erection. If a beam is to be fitted between two other members, the beam is normally cut 1/2 inch short, and the connection angles are allowed to extend 1/4 inch beyond the ends of the beam.

Detail Drawings. Detail drawings include all the information for fabrication of various parts of the structure, and they are prepared in the fabrication shop rather than by the architectural or construction draftsman. In preparing details for steel framing, you will follow the same general rules explained previously. Briefly, all parts are detailed in the position which they occupy in the structure. Beams and girders are detailed horizontally, and columns are detailed vertically. Also, two scales may be used in detailing a structure such as a truss. In detailing a single member such as a beam, the overall length of the member need not be drawn to scale. These practices will be illustrated and explained in the following paragraphs. First, however, certain details of steel construction should be studied.

Exercises (426):

1. What is the usual method for connecting one structural member to another?

2. How are beams, girders, and columns detailed in a drawing?

427. State selected construction and drafting practices relating to rivets.

Riveting. Structural members are assembled as much as possible in the fabrication shop. Rivets driven in the shop are called shop rivets, and those driven during actual erection are called field rivets. All holes, whether for shop or field rivets, are punched or drilled in the fabrication shop. Two different symbols are used on detail drawings to distinguish between these two types of rivets. The conventional symbols used to show shop rivets and field rivets on detail drawings are illustrated in figure 3-9. Examine the symbols to be sure you understand the significance of the diagonal (sloping) lines. Notice, for instance, that a circle with no lines indicates that the rivet is to be driven so as to have a full head on both sides of the connection. On the other hand, a circle with two parallel lines passing through and extending beyond the circle means that the rivets will be 1/2 inch or 5/8 inch in diameter and both ends will be flattened to within 1/4 inch of the sides. The black portion of the field rivet symbol indicates a drilled or punched hole in which rivets are placed for erection.

When rivet symbols are shown on detail drawings, the diameter of the rivet shank is used for field rivets. Shop rivets are detailed by showing the diameter of the rivet head. Note in figure 3-9 that for all rivets except the countersunk and conehead the head diameter is equal to 1.75 times the shank diameter. Thus, the head diameter of a 3/4-inch rivet is equal to 1.75 times 0.75, or approximately 1.3 inches.

On small-scale drawings, centerlines may be used to indicate rivet positions. The centerlines represent pitch and gagelines. As shown in figure 3-9, gagelines extend longitudinally along the steel shape to indicate the line along which rivets should be placed. The gagelines for each structural shape have been standardized. The gageline of an angle is measured from the back of the angle. The gageline on the flange of a channel is measured from the back of the channel. In I-beams, gages are referenced to the centerline of the web. Distances from the back or centerline of a structural shape will keep the gagelines in the proper position. Distances from the edge of the flanges are not used because of the variety of sizes and weights for each type of steel shape. When more than one gageline is required in a riveted connection, the rivets can be placed along the gageline in either of two arrangements. The rivets may be staggered (see fig. 3-9) so that the rivets on one gageline are placed halfway between the rivets on the adjacent gagelines. In the second arrangement, called chain riveting, the rivets are placed opposite each other on adjacent gagelines.

Pitchlines are centerlines which are drawn perpendicular to gagelines. When only one gageline is used or chain riveting is employed, the term "pitch" refers to the distance between the centers of consecutive rivets in a line of rivets. In staggered riveting, pitch is the distance from the center of a rivet on one gageline on the center of the nearest rivet on the adjacent gageline.

The primary reason for riveting two members is to transfer a load from one member to the other member. One of the critical factors which determine the strength of a riveted connection is the spacing between rivets. When the rivets are too closely spaced— the distance between gagelines and pitchlines is too small—a fracture may develop in the material between rivet holes. Conversely, when the spacing is too great, the strength of the connection will be impaired. As a rule of thumb, the centers of consecutive rivets should not be closer than three times the diameter of the rivets. For example, in a connection which uses 3/4-inch rivets, the minimum spacing is $3 \times {}^{3}/_{4} = 2\frac{1}{4}$ inches. Normally, the preferred spacing is greater than three times the diameter—2½ inches for 3/4-inch rivets, 3 inches for 7/8-inch rivets, etc.

Other factors which must be considered when spacing rivets are edge distance and head clearance. Edge distance is defined as the perpendicular distance from the edge of a shaped member to the center of the nearest rivet. If a rivet is placed too close to the edge of a riveted member, the material may fracture, allowing the rivet to pull out. The minimum recommended edge distance for the various steel shapes will be found in most trade manuals. The maximum edge distance should not be greater than 12 times the thickness of the thinnest riveted member or 6 inches, whichever is less. For example, when 1/4-inch and 5/16-inch members are riveted, the maximum edge distance should not exceed 12 times 1/4 inch, or 3 inches. On the other hand, if 5/8-inch and 3/4-inch members are riveted

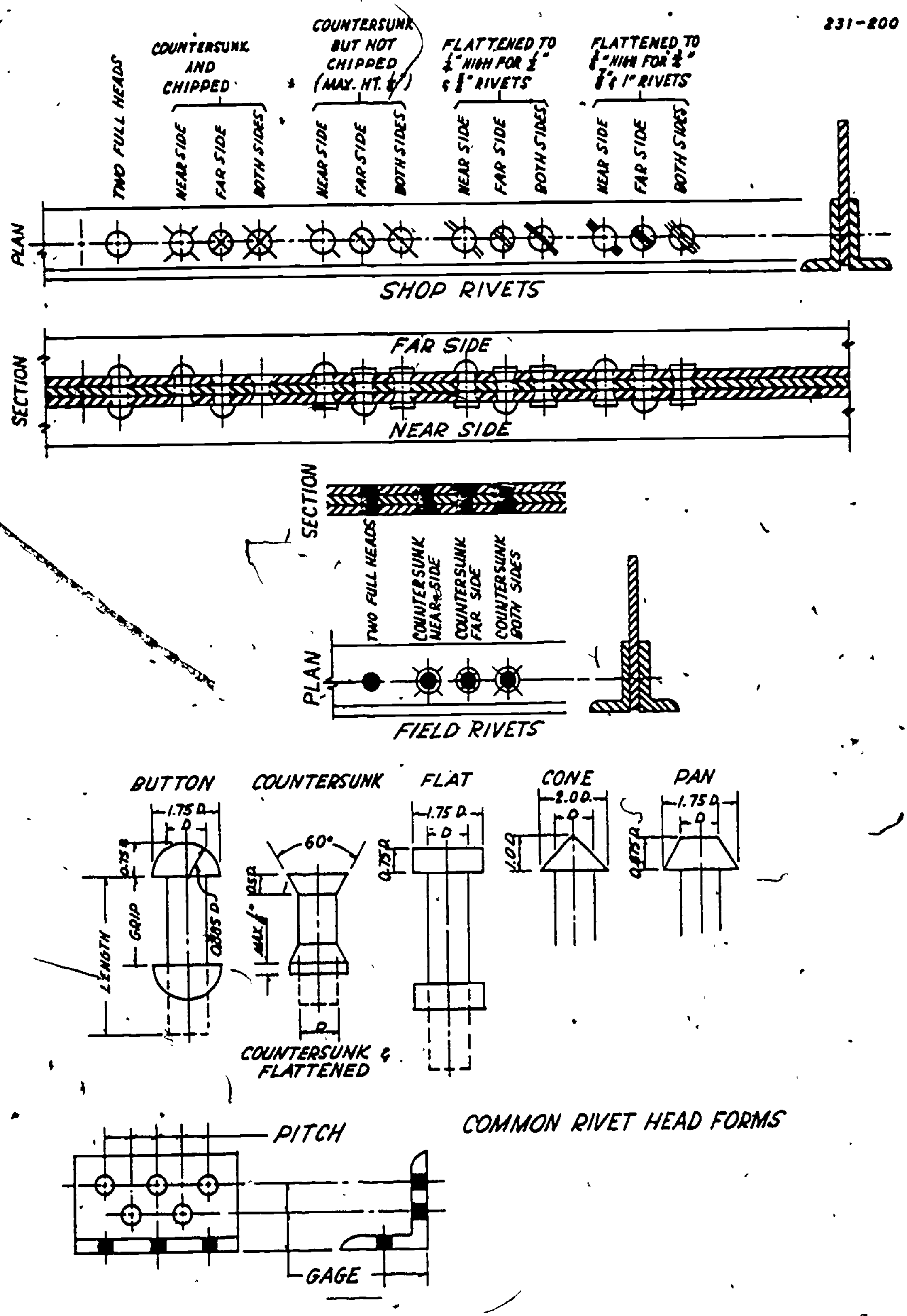


Figure 3-9. Rivet symbols.

together, the maximum edge distance will be 6 inches because 12 times 5/8 exceeds 6 inches.

Head clearance refers to the clearance between the head of any rivet to be driven and any other part of the structural member. Since most rivets used in steel construction are driven by riveting machines, the head clearance must be sufficient to permit proper positioning of the riveting machine. The minimum head clearance is specified in manuals according to the diameter of the rivet—typical clearances are 1¼ inches for ¾-inch rivets and 1⅜ inches for 7/8-inch rivets.

Generally, all information about the size, weight, and spacing of rivets will be located in the same section of steel construction handbooks as the standard connections. Where possible, most structural designers will use standardized connections. Thus, when you are assigned to detail riveted connections, you will be able to obtain most of the information from the reference manuals. If the designer indicates that a special connection is necessary, you will get the detailed information from the designer.

Exercises (427):

1. How is the distinction between shop and field rivets shown on a detailed drawing?

2. What is the primary reason for riveting two members?

3. How are rivet positions indicated on small-scale drawings?

428. State the difference between a weld symbol and a welding symbol and give the standard locations of certain elements of welding symbols.

Welded Structures. Welding is another method of making permanent fastenings in steel structures. One advantage of welding is that parts can be joined at almost any position in relation to each other and the joint is equal in strength to a riveted connection. Construction methods for welding follow closely to the methods of riveting. Beams and columns are not welded directly to each other, but are framed by the use of plates, angles, and connecting pieces. The parts to be welded together may be held in position by temporary fastenings, bolts or pins, until the welding process is completed.

There are many different types of welded joints and several welding processes; and a system of symbols, listed in JAN-STD-19—Welding Symbols, has been developed to indicate the type of weld desired. As shown in figure 3-10, this symbol is in the form of an arrow upon which other symbols, marks, and letters are placed. A complete symbol consists of eight elements which have a standard arrangement with respect to the reference line and arrow. The location of the arrow has a special significance, as indicated in figures 3-10 and 3-11. A distinction should be noted between a weld symbol, which is an element to indicate the type of weld, and the welding symbol, which consists of as many elements as are needed to state the required information.

Figure 3-11 shows symbols for arc (electric) and gas (oxygenacetylene) welding and illustrates several types of joints. A square groove, or plain butt joint, is used for thin metal, but thicker plates must be grooved so that weld metal can be deposited in successive layers. The basic directions for using welding symbols on drawings are as follows:

a. The welding symbol may be drawn either freehand or mechanically, with elements of the symbol in standard location in reference to the arrow.

b. The side of the joint to which the arrow points is called the arrow side; the opposite side is called the other side. Formerly, the terms "near side" and "far side" were used with welding symbols. Since the terms "near side" and "far side" are meaningless when joints are shown in section, the terms are no longer used. Welds to be made on the arrow side of the joint are indicated by placing the basic weld symbol on the side of the reference line toward the reader. For example, the symbol $\frac{\underline{1}}{\overline{16}}$ G (symbol A in fig. 3-11) is placed on the bottom side of the reference line. Welds to be made on the other side of the joint are indicated by placing the weld symbol on the side of the reference line away from the reader (symbols B and E in fig. 3-11). When welds are to be made on both sides of the joint, weld symbols are placed on both sides of the reference line (symbol C in figure 3-11).

c. The perpendicular leg of fillet, bevel, and J-groove weld symbols is always placed on the left in accordance with standard drafting conventions. The size dimension of a weld is shown to the left of the symbol, and weld spacing is shown to the right (fig. 3-11).

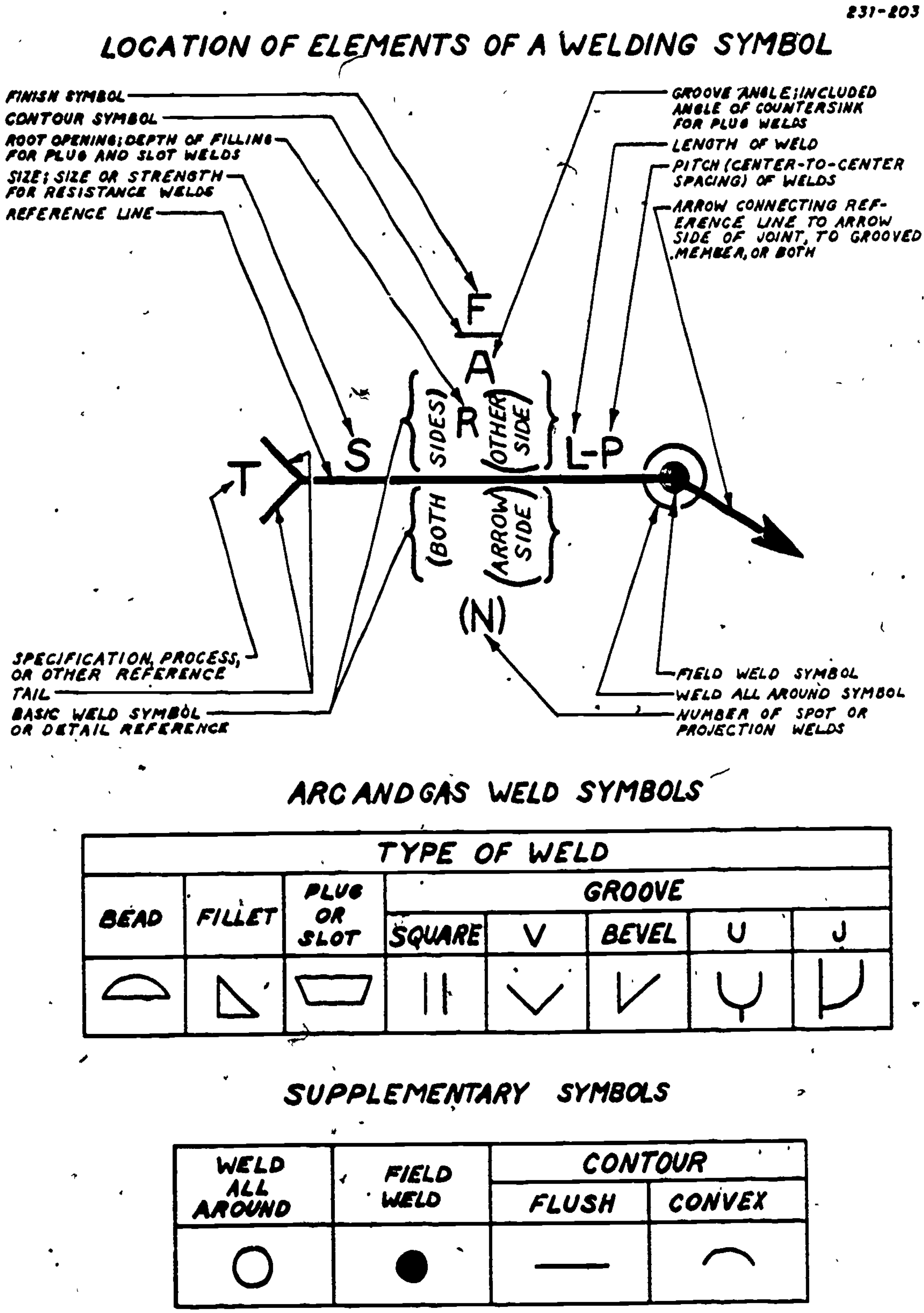


Figure 3-10. Elements of welding symbols.

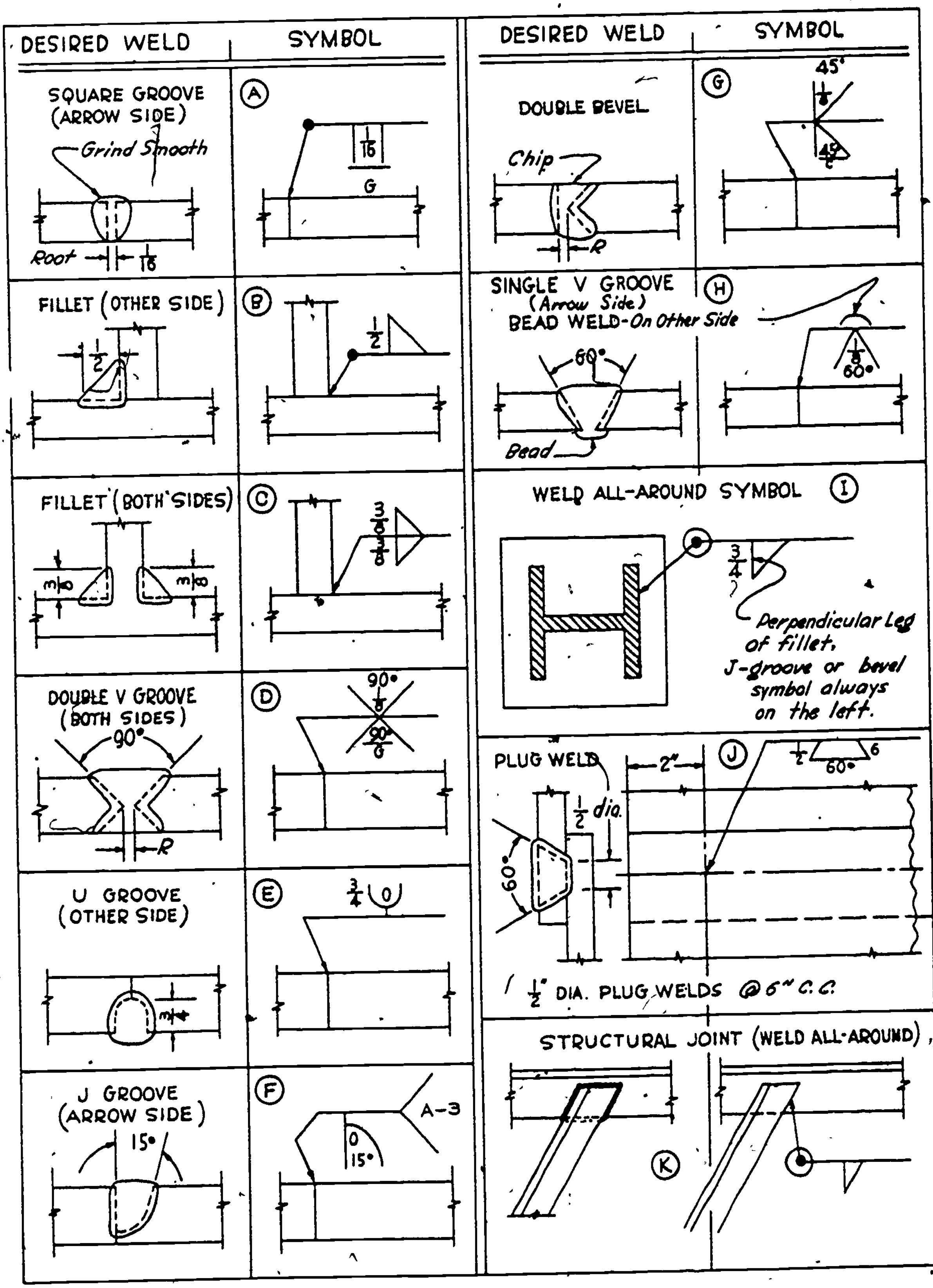


Figure 3-11. Application of welding symbols.

d. When a bevel or J-groove weld is indicated, the arrow (connecting the reference line to the joint) has a definite break toward the member which is to be beveled or grooved (symbol F in fig. 3-11).

e. The contour and finish of a weld are indicated as shown in figure 3-11,D. The letters "C," "G," and "M" are used to indicate chip, grind, or machine. Groove welds which are to be welded approximately flush (without using mechanical grinding, chipping, or machining) are indicated by adding only the flush contour symbol to the weld symbol.

f. A legend should be placed with the drawings to guide in interpreting welding symbols. Sample joints and their significant symbols should be included in the legend to give the standards for the job. These symbols govern the forming and welding of similar joints appearing on the drawings. This simplifies the symbols which appear on the drawing by making it possible to omit dimensions on symbols for standard joints. For example, the legend states that "all bevels are 45° unless otherwise shown." Therefore, you may omit the angle dimension on all standard joints of this type and dimension only bevels which are exceptions to the rule established by the legend.

g. When a tail is used on an arrow, it refers to a weld listed in specifications for individual welds. If it is desired, the tail and reference may be omitted when the welding procedures to be used is described elsewhere. All dimensions given on a welding symbol are understood to be in inches and in degrees of angle, and inch and degree marks are omitted from the symbols in most drawings.

Exercises (428):

1. What is the difference between a weld symbol and a welding symbol?

2. Where are the size dimension of a weld and weld spacing shown in reference to the welding symbol?

3-4. Reinforced Concrete Construction

Reinforced concrete buildings may be constructed by the skeleton frame method or with load-bearing walls. According to the first method, the floors and roof rest upon columns, or they are carried by beams and girders which rest upon columns. Exterior walls and interior partitions inclose the spaces between columns, and the walls must be supported by the beams and girders. The majority of modern concrete buildings are designed according to the skeleton frame method.

In the usual types of concrete construction, wooden forms are prepared in advance of the mixing of the concrete and are made so that their inside surfaces form an exact outline of floors, beams, girders, and columns. The concrete for these members can be poured at the same time, thus forming strong, integral connections between members. Concrete structures having such continuity between parts are called monolithic, which means one stone. All reinforcing steel must be placed within the forms before the concrete is poured.

429. Give the reason for certain practices used in reinforced concrete construction.

Floor Systems. Figure 3-12 illustrates the prevalent types of floor construction. Each of these types may be cast monolithically, so that it is possible to construct one floor of a building with one continuous pour. First, columns are poured up to the underside of the floor girders and the concrete is allowed to set. This allows shrinkage to take place in the columns before the floor system is poured. After the floor concrete has set sufficiently, the floor forms may be removed and reused to construct another story of the building. Although it is preferred that slab, beams, and girders be poured in one continuous operation, it is impossible to do so on large jobs. Therefore, divisions between work done at different periods require the use of construction joints. Permissible locations for construction joints must be determined by the engineer, since such joints affect the strength of the structure. Their location is indicated on a drawing by a heavy line, and it is standard procedure to have structural joints for horizontal members lie in a vertical plane. For vertical members, such as columns, the joints would lie in a horizontal plane. These joints provide a convenient stopping place in the work.

Expansion joints are provided in large concrete structures to allow the mass to expand and contract with temperature changes. Various joint designs are used, and in all cases they form a clean break between two adjoining sections of a building; no reinforcing extends across the break. Joint construction is shown in detail drawings.

Beam and girder system. In this system, concrete beams span between heavier girders which rest upon

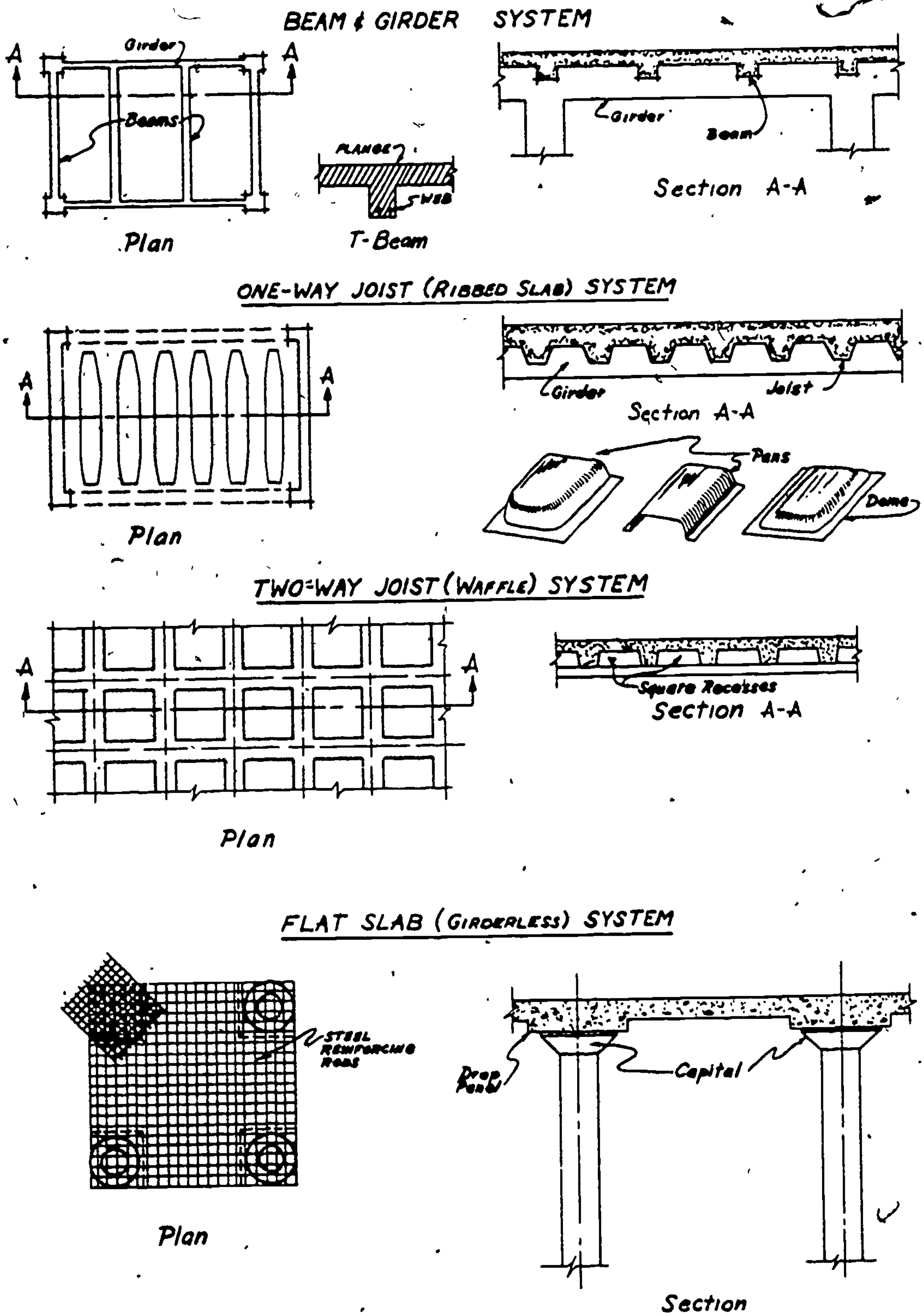


Figure 3-12. Floor systems.

columns. When floor loads are light, long span floor slabs may be run between girders without the use of intermediate supporting beams. In some beam and girder systems, the main slab reinforcement runs at right angles to the beam reinforcing. Secondary slab rods, called temperature reinforcement, are placed at right angles to the main slab bars. In a monolithic structure of this type the slab is often considered to act as the upper part of a beam, forming what is known as a T-beam.

Joist system. In this system of construction, the concrete slab is supported by closely spaced joists running between girders. The joists, or ribs, are lighter in weight than the beams described above. In one-way joist construction, the ribs run in one direction only; in a two-way system, the ribs form a waffle pattern. At one time, these ribs were formed by placing hollow structural tile in the wooden forms. Concrete was then poured over and between the tile to form the ribbed slab. However, joist construction with reusable metal pans offers many advantages. The metal pans are 6 to 14 inches deep and from 15 to 30 inches wide. Straight pans laid end to end are used as forms for one-way joists; metal domes are used to make two-way joists. The pans are spaced to form joists about 5 inches wide at the bottom and slightly wider at the top because of the sloping sides of the pans. The center-to-center spacing of joists is 25 inches when 20-inch pans are used. A straight pan with one closed end is used as an end pan for one-way systsms, illustrated in figure 3-12. Narrow width pans are sometimes used to fill out spaces next to girders and beams or to align joists in adjacent slab areas. Spaces under 10 inches wide are made as solid slabs the full depth of the joist.

The reinforcement in one-way ribbed slabs is usually one way; that is, the main reinforcement is contained in the joists. Small diameter "temperature reinforcement" wire mesh is used in the floor slab, which ranges in thickness from 2 to 3 inches for light floor loads.

Flat slab system. This system consists of a slab supported by columns without beams and girders. The columns have wide capitals, and the floor slab is thickened around the column capital by a drop panel, usually square in outline. Reinforcing bars are placed as shown in figure 3-12. Additional bars are placed over the column heads to increase the shear resistance in these areas. This system provides a greater load-carrying capacity for a given amount of concrete and steel.

The most difficult part of making drawings for reinforced concrete construction is giving accurate information concerning the size, amount, shape, and placement of reinforcing steel. We have seen how this information can be combined in a single detail view when the structure is simple. For a large structure, however, every member must be considered individually. General plans and elevations are prepared to show the arrangement of footings, columns, beams, and other parts. Details and sections give more accurate descriptions of these members and also give the location of reinforcing steel. However, these drawings do not provide enough information for the fabrication and placement of reinforcement. Bar bending diagrams and placement schedules must also be prepared. Together with general and detail drawings, these bar diagrams and schedules provide a complete picture of the desired construction. Typical examples of plans, sections, and schedules are shown in figure 3-13 and explained in the following paragraphs.

Exercises (429):

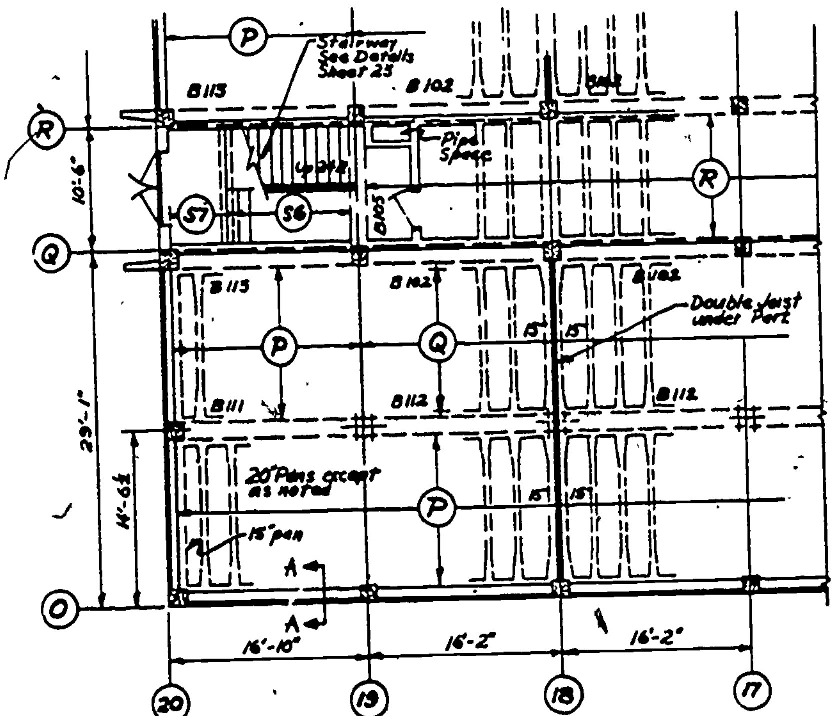
1. Why are columns poured and allowed to set?

2. Why are expansion joints used in concrete construction?

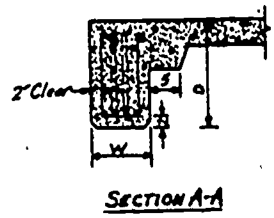
3. What feature does the flat slab system provide that other systems do not?

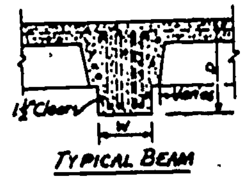
430. Explain briefly the reason a floor framing plan is classed as a structural drawing and the marking system for showing the location of columns, beams, and joists.

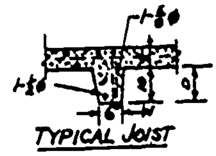
Floor Framing Plans. A floor framing plan, classes as a structural drawing, shows the location of columns, beams, and joists and identifies each by a mark. The marking system established in these first drawings is used throughout all related drawings and schedules, the same mark being used to designate a part in any view in which it appears or is listed. The first step in drawing a floor framing plan is to establish the outside lines of the floor, exterior wall thickness, and column centerlines. Then, from sketches provided by the designer, draw in columns, beams, and interior walls. The next step is the spacing of concrete joists. In figure 3-13, the joists are spaced so that joists in adjoining slabs will

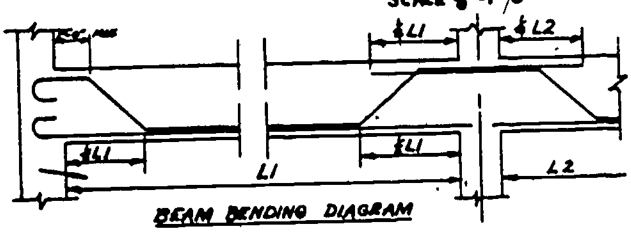


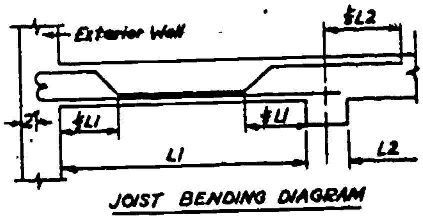
FIRST FLOOR FRAMING PLAN
SCALE ⅛"=1'-0"



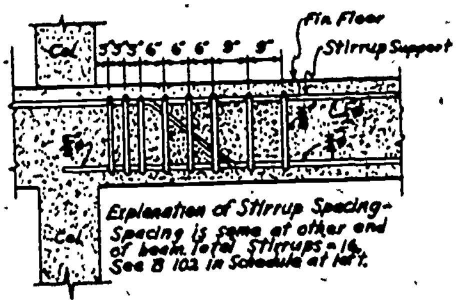








BEAM REINFORCEMENT SCHEDULE																
BEAM				STRAIGHT			BENT			STIRRUPS			SUPPORT BARS			
MARK	NO.	W	D	NO.	SIZE	LENGTH	NO.	SIZE	LENGTH	NO.	SIZE	SPACING-EACH END	NO.	SIZE	LENGTH	
B102	4	14	24	2	5	16'-0	3	6	21'-0	16	3	3@3, 3@6, 2@9	2	[illegible]	13'-10	
B111	1	14	22	2	6	16'-8	2	6	22'-1	12	3	1@3, 4@6	2	00	14'-8	
B112	2	14	22	6	5	16'-0	3	6	21'-0	16	3	3@3, 3@6, 2@9	2	00	13'-10	
B113	2	14	22	6	5											



JOIST REINFORCEMENT SCHEDULE										
JOIST				STRAIGHT			BENT			
MARK	NO.	W	D	NO.	SIZE	LENGTH	NO.	SIZE	LENGTH	TYPE
P	20	6	10+4	1	4	14'-[illegible]	1	5	19'-7	
Q	6	6	10+4	1	4	14'-[illegible]	1	5	19'-7	
V	10	6	10+4	1	5	16'-7	1	6	22'-9	

STIRRUP SHAPES

Figure 3–13. Reinforced concrete plans and schedules.

be in line. Narrow pans are used next to exterior walls and double joists. The next step is to assign marks to beams and joists, and indicate the span and the area covered by each type of joist. Vertical and horizontal lines (originating from the circled letters) terminated by arrowheads may be used to show the floor areas which incorporate a certain type of joist. The same letter can be used to designate all floor areas which are the same type of joist. For example, notice in figure 3-13 that many sections of the first floor are designated by the letter "P." Where joists are outlined by dashed lines, the direction of span is apparent to the reader. However, in areas where joists are not outlined, it is important that joist direction be indicated by arrows.

Stairs are indicated on plan views by showing about one-half the flight to the floors above and below the floor being shown. The succeeding floor plan would show the other portion of the stairway; two consecutive floor plans would show the complete stairway connecting them. The direction and number of stair risers are indicated on the stairway by an arrow and the letter "R." In the plan shown on figure 3-13, there are 24 risers leading to the second floor. Stairs are usually proportioned so that the sum of one riser plus one tread is approximately 17 to 18 inches. Large-scale details of stairway construction are required in the majority of cases. Stair details for figure 3-13 are described in objective segment 432.

Another important item which should be shown on floor plans for reinforced concrete is the location of passageways for piping and electrical conduit. These must be located before concrete is poured, since cutting through floors and beams is costly and also damaging to the structure.

Exercises (430):

1. Why is a floor framing plan classed as a structural drawing?

2. How are beams, columns, and joists indicated?

431. State the reason why section views are necessary for reinforced concrete plans and schedules, and state the practices for specific requirements in a section view.

Sections. Section views are necessary to show the shape of members and the typical arrangement of reinforcing steel. Figure 3-13 shows sections taken through a girder, beam, and joist. The drawings show how reinforcing must be placed if the members are to withstand the loads they must carry. The bars are supported in place by using accessories such as "beam bolsters" and "high chairs" which are illustrated in figure 3-14. These supports rest upon the bottom of forms for beams and slabs to hold parallel bars the proper distance apart and to give the proper concrete covering over steel. Reinforcing rods and stirrups are held in position by the use of wire ties; in some cases, the bars may be "tacked" together by welding. Bolsters and chairs are not shown on drawings, but their use is indicated in specifications or in beam and slab schedules.

The thickness of the concrete covering over reinforcing bars depends upon the position and function of the member. Footings and other principal structural members situated against the ground should have at least 3 inches of concrete between steel and ground. If the concrete surface is exposed to the weather, such as the exterior face of a beam, the steel should have 2 inches of concrete cover. This may be reduced to 1½ inches for interior beams and columns, and to 3/4 inch for interior slabs and interior wall surfaces.

The bar bending diagrams in figure 3-13 show that bent reinforcing bars are overlapped from one slab into the adjoining slab. However, the amount of overlap is usually determined by using the relationship shown in the bending diagram (fig. 3-13). Note for instance that the reinforcing steel for the beam extends beyond the column by one-fourth the total length of the reinforcing member. A similar proportion is used for the overlap in joist. This overlapping is done to provide enough bond surface at the beam support to transmit tension stresses.

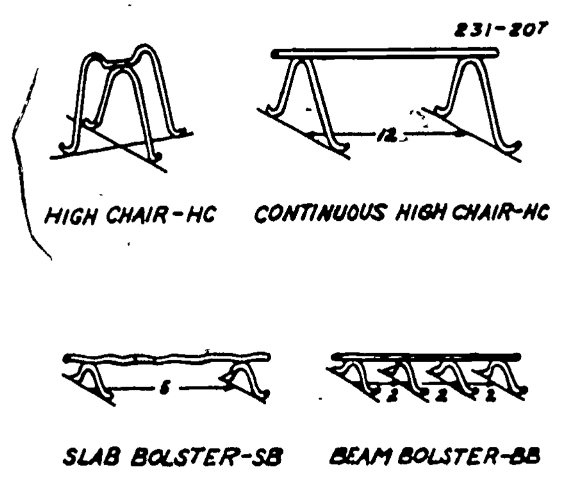


Figure 3-14. Reinforced steel supports.

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This arrangement is practical at interior supports, but at end supports the bar must be hooked as shown. The hook usually has an inside radius of at least 3 bar diameters (the radius depending upon bar size), and it should hook over a crossbar to distribute the pull on the concrete. Bars, when spliced, are joined by lapping the bars at least 30 bar diameters. The bars are tied (wired) together at these laps and supported by slab bolsters.

The beam and joist reinforcing shown in figure 3-13 is typical of standard practice. Beam reinforcing consists of straight bars, bent bars, and stirrups. The main reinforcing, consisting of the straight and bent bars, is placed near the bottom of the beam to resist tensile stresses. Compressive stresses, which concrete is able to withstand, occur at the top of the beam and also at the bottom of the supported ends. Straight bars in the bottom of the beam take care of this compressive stress. It is not necessary to reinforce for compressive loads at the top of a beam or slab except where the concrete is thin. Bent-up bars resist tensile stress at the top of the beam over columns. They are bent up to fit the tension pattern—usually at one-fifth points of the length of the beam.

Stirrups are used to resist shear stress, which is maximum at the supported ends of a beam and decreases toward the center of the span. The stirrups are passed under longitudinal tension bars and are hooked over top stirrup support bars. All bars, stirrups, and supports are wired together at frequent intervals so that they will hold their position during concrete pouring operations. Stirrups are not usually employed in joists because of the narrow joist width. In extra wide beams, a double stirrup or a W-shaped stirrup may be used. The size, amount, and placing of all reinforcing must be determined by a structural engineer.

The schedules shown in figure 3-13 give information for bending steel. However, the steel fabrication would be required to prepare a bending diagram complete with dimensions for each type of bar. The height of bent-up bars is calculated by subtracting the top and bottom concrete covers from the beam depth. The length of the sloping portion is found by trigonometric calculations, or it may be taken from a table of lengths. Extra length for hooked ends must be added, and the direction of hooks must be determined. The lenght of straight bars is usually the same as the center-to-center distance between interior columns. At an exterior column, the end of a straight bar is hooked and embedded in the wall. The dimensions for stirrups are obtained by subtracting the concrete cover from the size of the beam. In this case, 3 inches is subtracted from the beam width and depth. Thus, for a 14 x 24-inch beam, the stirrup inside dimensions become 11 x 21 inches. The covering over stirrups and other secondary reinforcing is, therefore, reduced by the diameter of the stirrup rod. The direction in which stirrup hooks are to extend must be determined during detailing. Hooks are usually turned outward unless it results in insufficient protective cover over this bar. Note in figure 3-13 that exterior beam stirrups have one hook turned inward.

Slab reinforcement for the building shown in figure 3-13 consists of main reinforcing and temperature reinforcing. The main bars run parallel to floor joints, and the temperature bars run parallel to the long dimension of the slab. Because of differences in reinforcing, each slab is identified by the letter "S" and a number. A partial slab schedule for the building being discussed is shown in figure 3-15. For lighter floor loads, the slab may be thinner, and wire mesh may be substituted for bar reinforcement. In this instance, all slab reinforcing bars are straight and continuous, with bars terminating in exterior beams hooked into the beam.

Exercises (431):

1. Why are section views necessary?

2. How do you indicate usage of bolsters and chairs when making drawings of a concrete structure?

3. If you are preparing a bar bending diagram and the bar to be used is 1¼-inch in diameter, what dimension should you show for the inside radius of the hook?

432. Identify certain terms and details related to drawing columns and staircases.

Stair and Column Details. Typical column details are shown in figure 3-16. The columns illustrated are "tied columns," consisting of vertical reinforcing rods held together at intervals by horizontal bars or ties. The horizontal ties usually have a minimum diameter of 1/4 inch and vertical spacing of about 12 inches or the least column diameter. In some cases the lateral reinforcement for a round column

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SLAB REINF. SCHEDULE						
MARK	THICK	MAIN REINF.		TEMP. BARS		REMARKS
		SIZE	SPACING	SIZE	SPACING	
S1	4"	#4	7½" O.C.	#3	15" O.C.	
S2	4"	#3	12" O.C.	#3	12" O.C.	
S6	5"	#5	8½" O.C.	#3	12" O.C.	
S7	5"	#5	12" O.C.	#3	12" O.C.	#5@12" O.C. TOP

Figure 3-15. Slab schedule.

is made of coiled wire which forms a long spiral from the column base to the top. Another type of column is the composite column consisting of a structural steel column encased in reinforced concrete. Pipe columns consist of a steel pipe filled with concrete. Interior columns are usually round in section, while wall columns may be square, rectangular, or angular as required by the wall arrangement.

As indicated in figure 3-16, the vertical steel bars are spliced by lapping. The amount of lap is determined by the grade and size of steel and by the strength of concrete used. Due to the change in column size at the second story, the vertical bars are sloped within the area where beams and slab furnish lateral support to the column. The columns for the building shown in figure 3-13 are set on round concrete piers having enlarged lower ends to distribute the load. No reinforcing is needed in the piers since they are large enough in diameter to withstand compressive stress and the surrounding earth provides lateral support. Dowels, which are vertical reinforcing bars, are placed at the top of the pier to anchor the column base.

Figure 3-16 also shows footing details. The reinforcement consists of round rods laid in two directions on the lower or tension side of the footing, with both ends of all rods hooked to provide anchorage. This type footing is usually made square or rectangular with a flat top surface. In some instances, the top surface may be sloped or stepped down, leaving the thickest concrete adjacent to the column base. While this saves concrete, the expense of special form work and additional labor must be considered.

The dimensions and reinforcing for columns, piers, and footings are usually shown in schedules. Separate schedules for each may be prepared, but where sizes and other factors are fairly uniform, a single schedule will be sufficient. The schedule shown in figure 3-16 gives the size of each column and lists the amount of steel to be used in each. The top dimension in each block gives the column or pier size. The second number is the number of vertical bars; for example, 4—#10. The last entry at the bottom of the block gives the number, size, spacing, and outside dimensions for lateral ties. Details and sections should always clearly illustrate the arrangement of reinforcing so that schedules may be easily interpreted.

In stair construction, a riser is the vertical face of a step, and the tread is the horizontal face. The rise of a stairway is the total height from floor to floor or the height from a floor to an intermediate platform. The run is the horizontal length of the stairway. The stairway shown in figure 3-17, is divided into two short runs by a platform. Thus, two stairways are used to accomplish the total rise between floors, and a long straight-run stairway is avoided. The stair tower is inclosed by fireproof walls and doors to provide a fairly safe exit.

Stairs of the type illustrated are called standard stairs, and they are intended for constant and everyday use. Hence, a practical tread to riser ratio is chosen for ease in climbing. A good ratio is provided by using the formula:

$$\text{Tread} + (\text{riser} \times 2) = 24 \text{ or } 25$$

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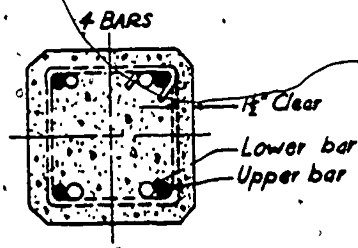
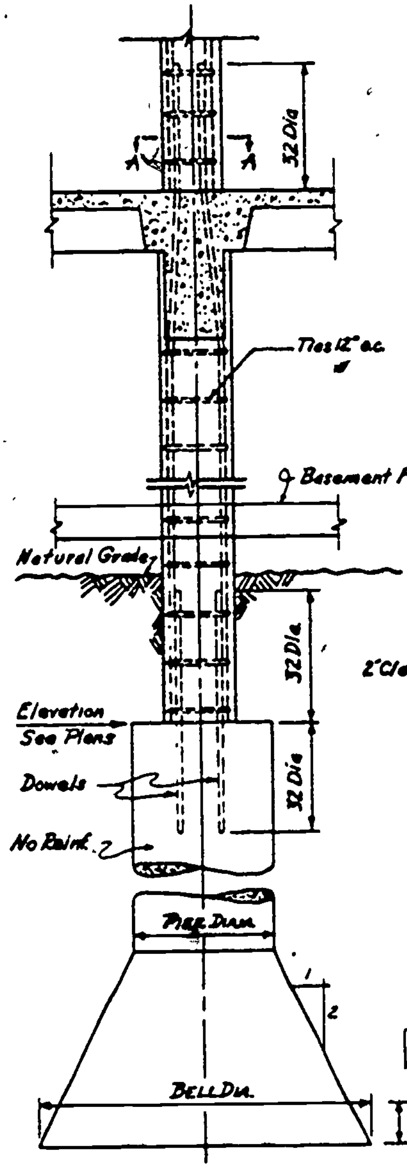
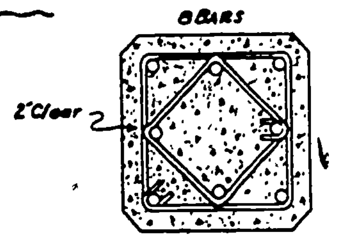


SECT. A-A
Scale 1½"=1'-0"

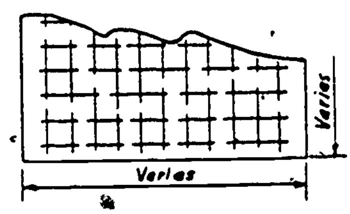
COLUMN SCHEDULE				
Col. Mark / Story	O1, O20 T1, T20	O13 to O18 T13 to T18	Q13 to Q18 R13 to R18	MN 7
Roof — 15'-0" — 3rd Floor	14"x14" 4-#7 12-¼φ @12" 11"x11"	14"x14" 4-#7 Do	12"x12" 4-#6 12-¼φ @12" 9"x8"	12"x12" 4-#7 Do
12'-6" — 2nd Floor	16"x16" 4-#7 11-¼φ @12" 11"x11"	14"x14" 4-#7 Do	14"x14" 4-#7 Do	12"x12" 4-#7 11-¼φ @12 8x8
13'-6" — 1st Floor	14"x14" 4-#8 12-¼φ @12" 11"x11"	14"x14" 4-#10 Do	14"x14" 4-#11 Do	14"x14" 4-#8 Do
12'-6" — Basement Floor	14"x14" 4-#10 11-¼φ @12" 11"x11"	16"x16" 4-#11 14-¼φ @9 15"x15"	16"x16" 8-#9 22-¼φ @12" See Det	14"x14" 4-#10 11-¼φ @12" 11"x11"
Pier — Varies	3'-0"	3'-0"	3'-0"	16"x16" 4-#10 8-¼φ @12" 11"x11"
Bell or Footing	7'-0"	7'-8"	8'-0"	6'-0"x6'-0" x 16" 12-#5 EW 4-#10 Dowels

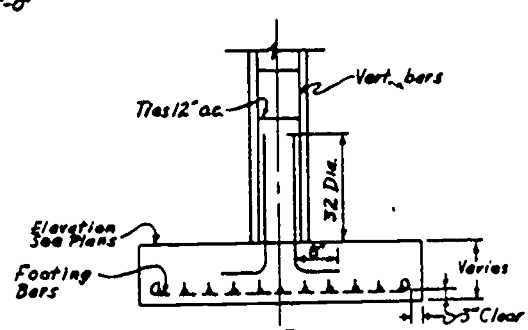


TYPICAL COLUMN DETAILS
Scale ½"=1'-0"



DETAIL - COLS R13-R18
Scale 1½"=1'-0"





FOOTING DETAILS
Scale ½"=1'-0"

Figure 3-16. Column details and schedules.

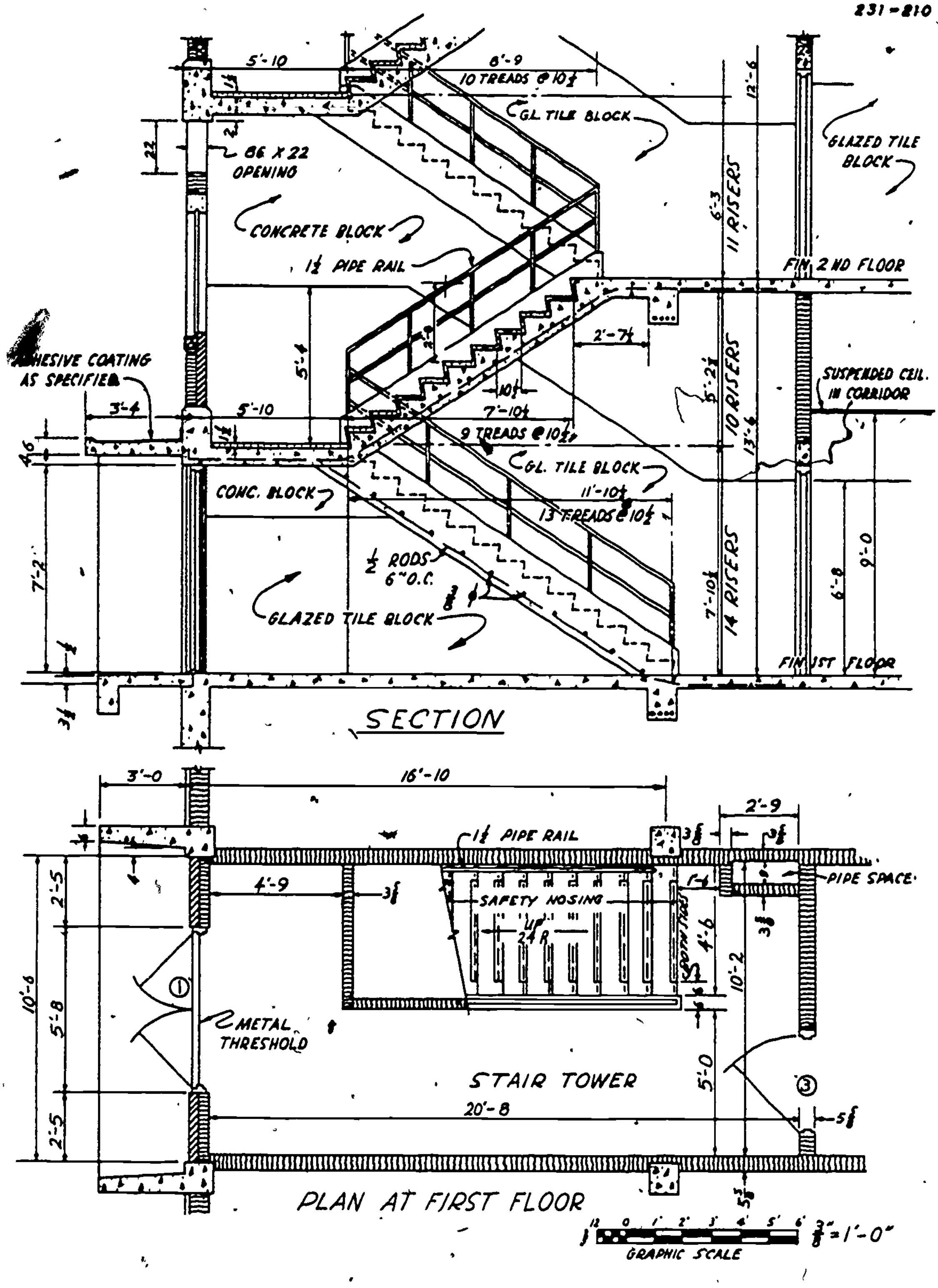


Figure 3-17. Stair details.

Treads for standard stairs are rarely made less than 9 inches or more than 12 inches wide, and risers between 6 1/2 and 7 1/2 inches are most suitable. To determine riser height, divide the total stairway rise by a riser height which is within the desirable range. If the quotient is uneven, divide the rise by the next nearest even number above or below the quotient. In figure 3-17, the total rise from first to second floor is 13 feet 6 inches. A riser of 7 inches is selected as a trial riser.

$$13'6'' \text{ divided by } 7'' = \frac{162''}{7''} = 23\,1/7 \text{ (risers)}$$

Then divide 162 inches by the next nearest even number, which is 24.

$$\frac{162''}{24} = 6.75'' \text{ (riser height)}$$

By the formula above, a 10 1/2-inch tread is selected. A tread of 11½ inches could have been used, but a narrower tread is chosen in order to have shorter runs and to provide room for the intermediate platform.

Main reinforcing rods for the stair slab are placed near the bottom of the slab and run longitudinally. The bars are bent into adjacent floor slabs and beams in order to get good support. Cross reinforcement consisting of short bars is placed under each riser. The stairs and platform are usually poured monolithically. A welded pipe railing installed on the open side of each stairway has its vertical supports anchored in the concrete. A pipe handrail is attached to the wall side of each stairway by means of brackets and anchor bolts.

After the stair slab has hardened and the forms are removed, a bonded cement finish is applied, as indicated in figure 3-17. The finished cement surface is troweled smooth to provide a neat, good-wearing surface. Safety nosing, consisting of formed metal strips with abrasive chips imbedded in the exposed surface, is installed on each tread. The nosing is fastened by screws which fit into anchors set in the stair-slab.

Exercises (432):

1. Define the term "tied columns."

2. Where are the dimensions and reinforcing for columns usually shown?

3. In stair construction, what is the rise? A riser?

3-5. Architectural Drawings

Architectural drawings may be divided into two general classes: preliminary drawings, which consist of design sketches and drawings for display purposes, and working drawings, which consist of orthographic views giving detailed information necessary for actual construction of the building.

In architectural practice, design is the responsibility of the trained professional. In large firms, all drawings (with the exception of original design sketches) are prepared by a staff of expert draftsmen, some of whom specialize in display drawings; others specialize in preparing working drawings. In a small firm where only one or two draftsmen are employed, the draftsmen must be able to prepare all types of drawings and in many instances do a portion of the design work.

For planning and construction in the Air Force, Headquarters USAF has published a guide (AF Manual 88-2, *Air Force Design Manual, Definitive Designs of Air Force Structures*) which contains "definitive designs" for specific types of buildings. These standard designs, prepared by professional architects according to established construction criteria, may be classed as preliminary drawings. They contain very little information which could be used by the construction workman. However, with these designs as a guide, the engineer and draftsman can prepare working drawings for Air Force buildings such as mess halls, dormitories, office, and shops. These basic designs may be changed when necessary to meet local conditions, the designers thus being allowed to produce a plan which is appropriate to the site, climate, available building materials, and other conditions.

From the foregoing paragraphs, we can see that the construction of a building is described by a set of drawings which give a thorough graphic description of each part of the operation. Usually, a set of plans begins by showing the boundaries, contours, and outstanding features of the construction site. Succeeding drawings give instructions for erecting the foundation and superstructure; installation of lighting, heating, and plumbing; and details of construction required to complete the building.

Although these drawings are prepared in accordance with the general principles of orthographic projection, they differ from machine drawings in certain practices. Therefore, as an approach to the study of architectural drawing, let us first take a general view of the various types of drawings, and then learn some "architectural techniques" before attempting to prepare working drawings.

433. Give the basic distinctions and important drafting considerations for selected plans needed for a working drawing.

Types of Drawings. The working drawings of a structure are presented in general and detail drawings. General drawings consist of plans and elevations; detail drawings are made up of sectional and detail views. Since it is the purpose of working drawings to be exact about shape and size, all working drawings are third angle orthographic projections. In some instances, an isometric detail drawing may be included to show how parts look when they are assembled.

In architectural drawing, "plan" views are obtained looking down on the object with a vertical line of sight. Plan views correspond to top views and involve only horizontal dimensions of width and depth. Any view involving vertical dimensions is an "elevation." This could be a front view, side view, or any other elevation view. Different elevations are indicated as front, right, etc., or according to the direction from which the view is taken; e.g., north elevation.

Because of the size of the object being represented, different scales are used for general and detail drawings. In general, plan views and elevation views are drawn on separate sheets in order to make the view large enough for practical use. Detail views, drawn to a larger scale, furnish information not provided on general views. They are strategically placed on main views and on additional sheets as needed to give the mechanic on the job a complete picture.

Plot plan. A plot plan (fig. 3-18) or site plan shows the boundaries of the construction site and the location of the building in relation to the boundaries. It also shows roads and walks and locates utility lines, such as sewer, water, gas, etc. A plot plan may also show the ground contour. These plans are drawn to scale from sketches and notes based on a survey of the area. By locating the corners of the building at specific distances from established reference points, the plot plan gives the builder a definite starting point. Since the plot plan is a location plan, it must have an arrow indicating the north direction. This plan, like all others in the set, contains a standard title block in the lower righthand corner. (See figure 3-19 and table 1 for the proper way to fill out the title block and the continuation sheet.) You will note that the information to be placed on the continuation sheet is the same as the information contained in blocks F, G, H, J, K, and L of the title block.

Foundation plan. The foundation is the starting point in the actual construction, and a completely dimensioned plan is furnished except for very simple buildings. Figure 3-20 shows a concrete slab foundation which has warm air ducts imbedded in the slab. When a "post and wall" type foundation is used, the foundation plan may be combined with a floor framing plan, as shown in figure 3-21.

Framing plans. Framing plans show the size, number, and location of structural members which form the building framework. Separate framing plans may be drawn for floors, walls, and roof. As shown in figure 3-21, a floor framing plan specifies the size and spacing of joists, girders, and columns used to support the floor. Detail views are usually added to show the methods of anchoring joists and girders to the foundation. Wall framing plans show

TABLE 3-1

INFORMATION CONTAINED IN EACH BLOCK OF THE TITLE BLOCK

Block	*Information in Each Block*
A	Preparation, checking, approval, and date of the drawing
B	Title of the drawing
C	Name and address of the design activity
D	Approval of the design activity
E	Approval by an activity other than the design activity
F	Code identification number of the design activity
G	Letter size of the drawing
H	Drawing number
J	Scale used for the drawing
K	Optional. May be used to record the actual or calculated weight of the object, reference to specifications, etc.
L	Sheet number of bookform and multisheet drawings

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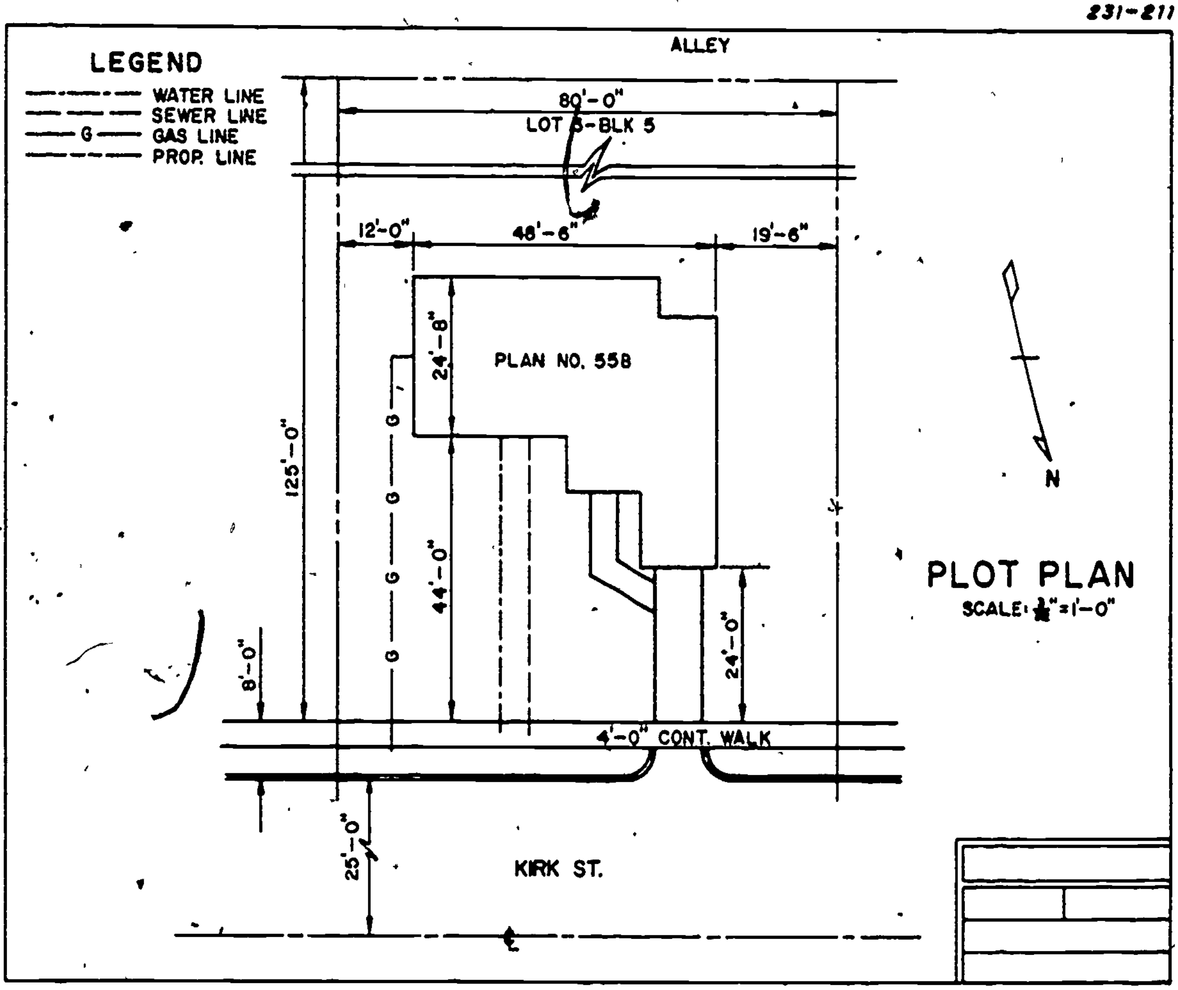

Figure 3-18. Plot plan.

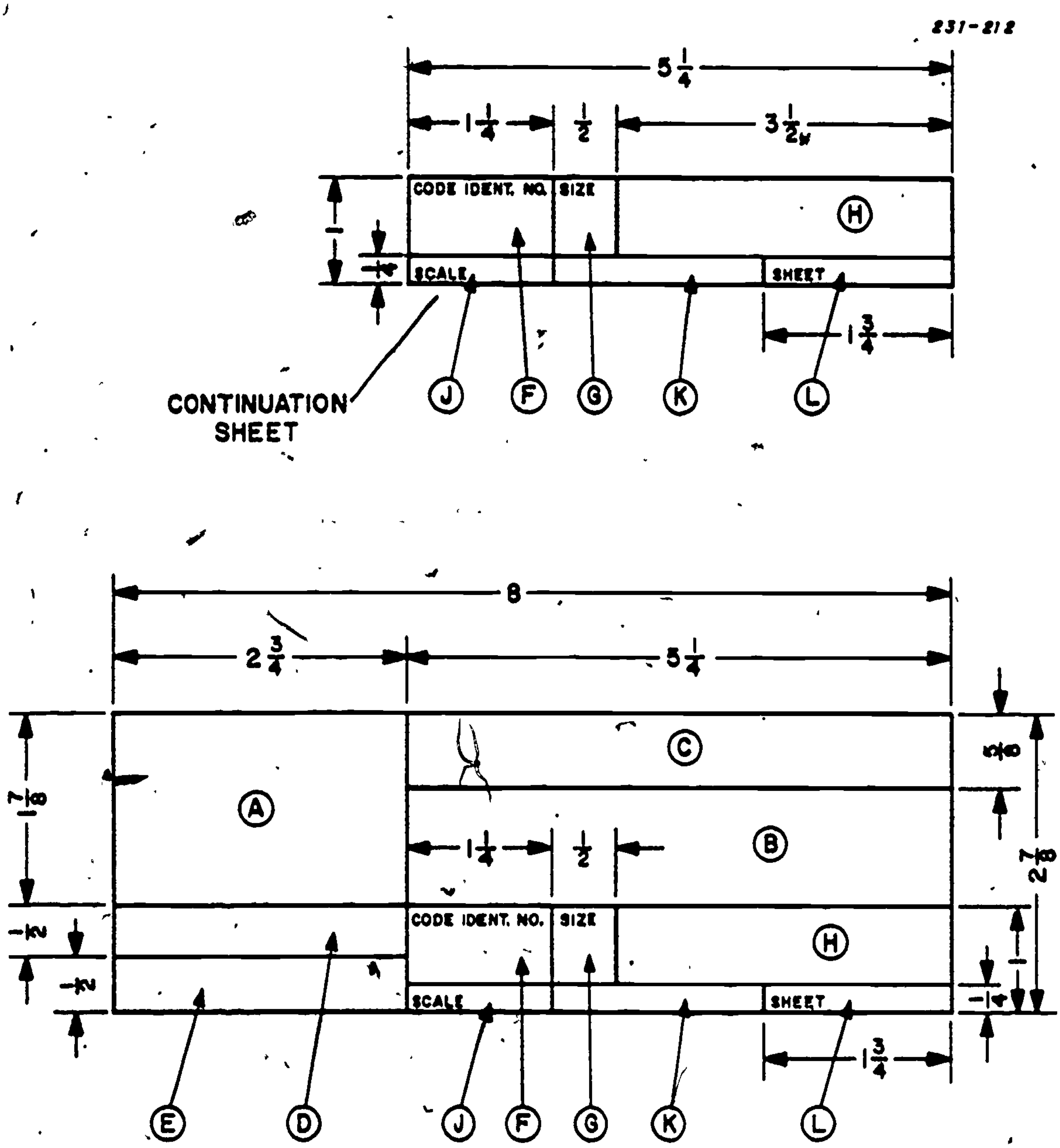

Figure 3-19. Title block.

231-213

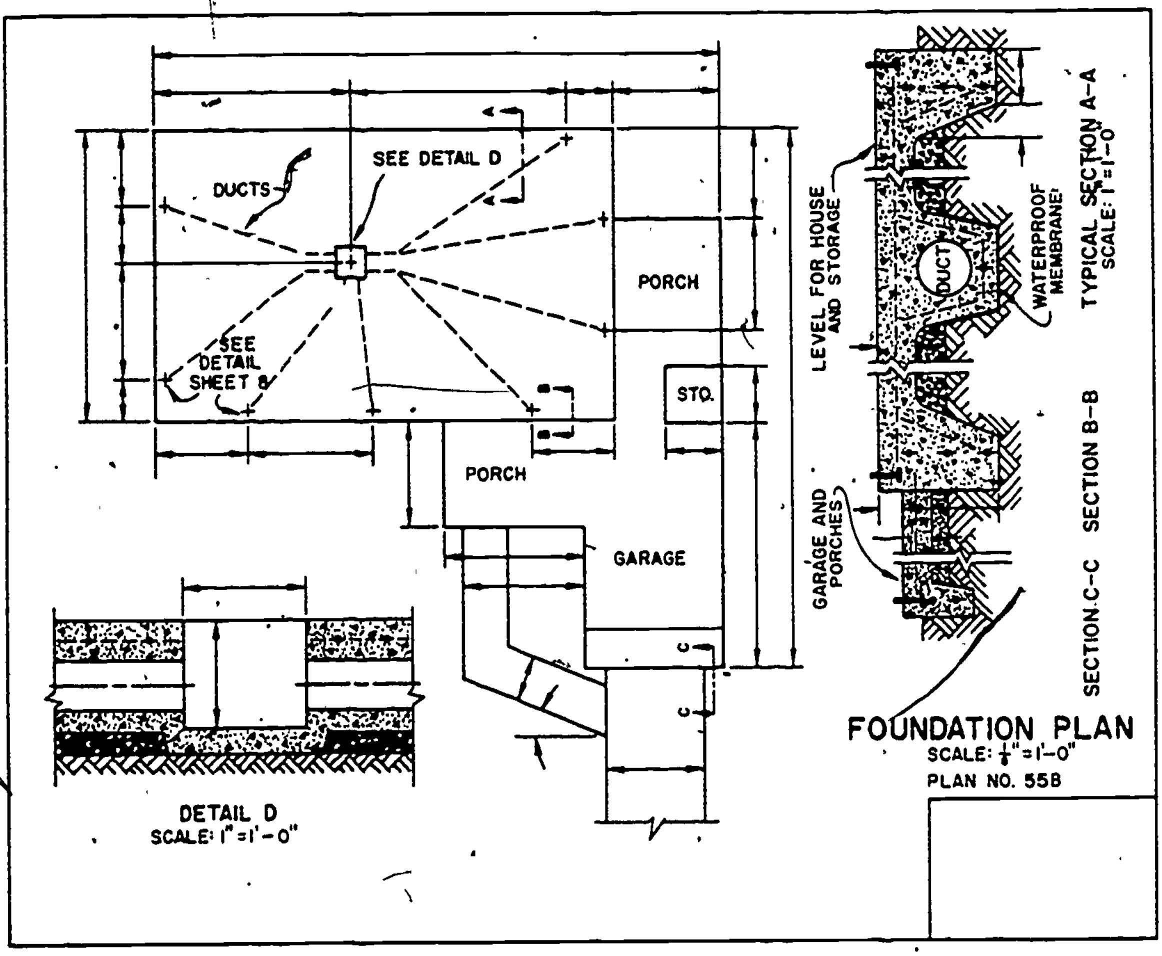

Figure 3-20. Foundation plan.

the size and location of wall openings, ceiling height, and other details. Roof framing plans (see fig. 3-22) show the construction of the rafters or trusses used to span the building and support the roof.

Floor plan. A floor plan is a cross-sectional view of the building. This view is obtained by assuming that a horizontal cutting plane is passed through the building in such a manner that it cuts through all walls, doors, and windows. If the building has more than one floor, a floor plan for each floor is drawn. As you can see by studying figure 3-23, the floor plan shows the outside shape of the house; the arrangement and size of rooms; the type of material; and the type, size, and location of doors and windows. In addition it shows heating, lighting, and plumbing fixtures.

Floor plans are usually drawn to a small scale such as 1/4" = 1'0" or 3/16" = 1'0". For this reason, conventional symbols are used to indicate fixtures and materials. For complex structures, it may be necessary to draw separate utilities plans to show electrical, heating, and plumbing layouts. In regard to this, figure 3-23 is not a complete plan since it does not show all features which are usually shown on the floor plan for a house of similar size. These items were omitted to simplify the illustration.

A floor plan sheet may also contain details of construction although these are generally presented on a separate sheet. An examination of figure 3-23 shows the need for detail drawings which point out how to construct cabinets, closets, lavatories, shelves, walls, ceilings, and other parts of the house. When a detail drawing is furnished to show a particular construction, a reference is noted on the floor plan. Also shown on figure 3-23 are "schedules" for doors and windows. A schedule is a method of presenting notes and other construction data in the form of a table. A door schedule specifies the type, size, description, and location of each door; a window schedule gives the same information for windows. Since all information

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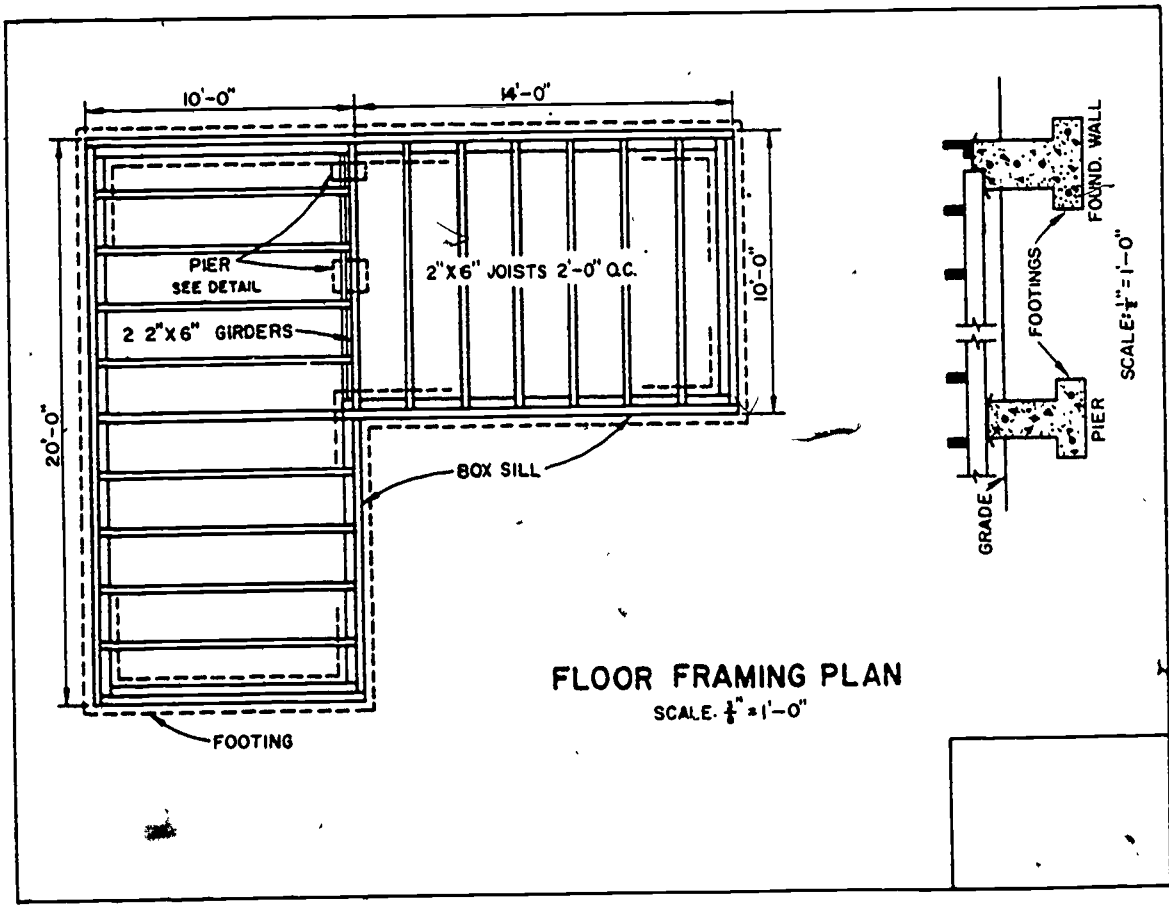

Figure 3-21. Floor framing plan.

231-215

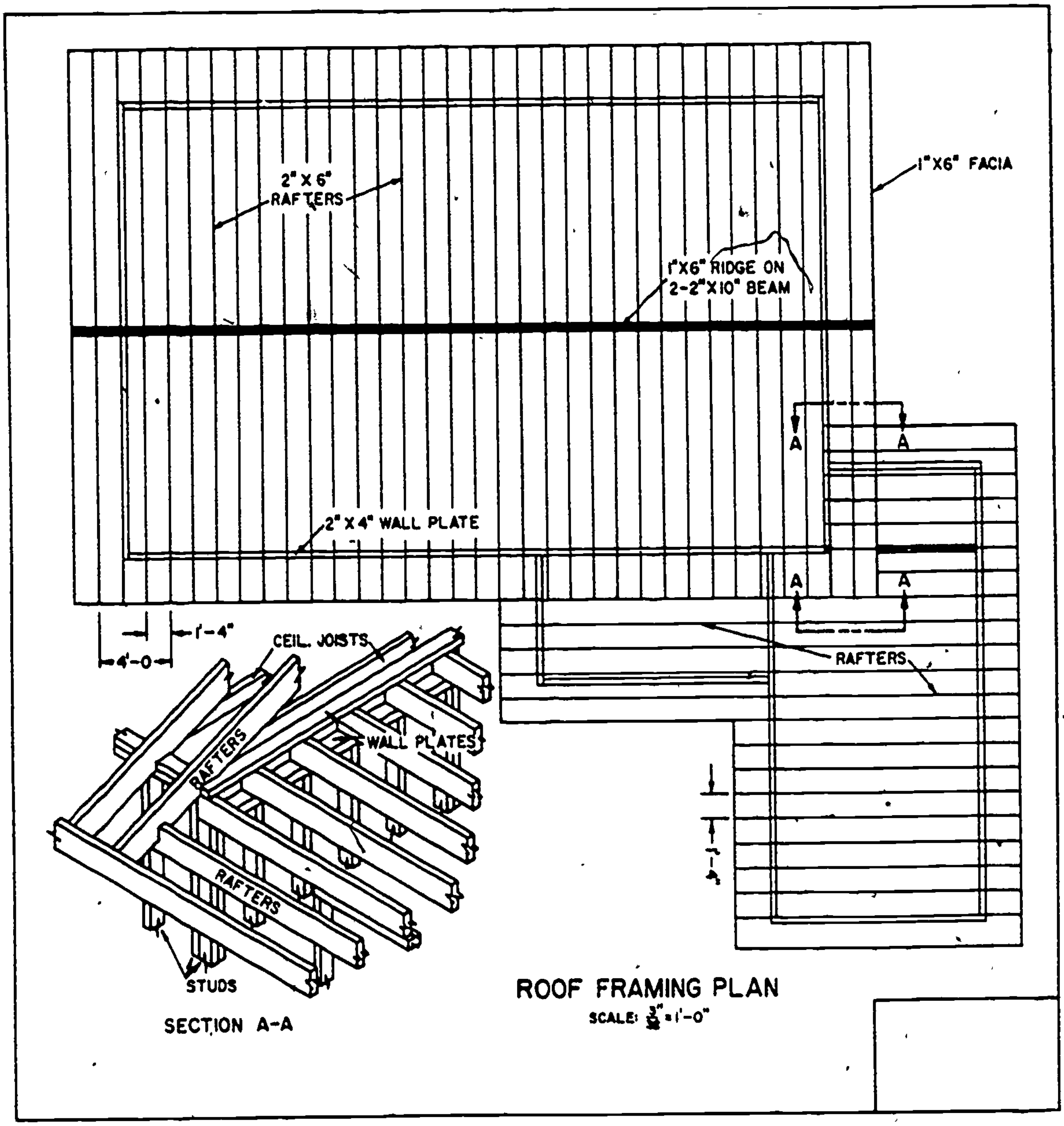

Figure 3-22. Roof framing plan.

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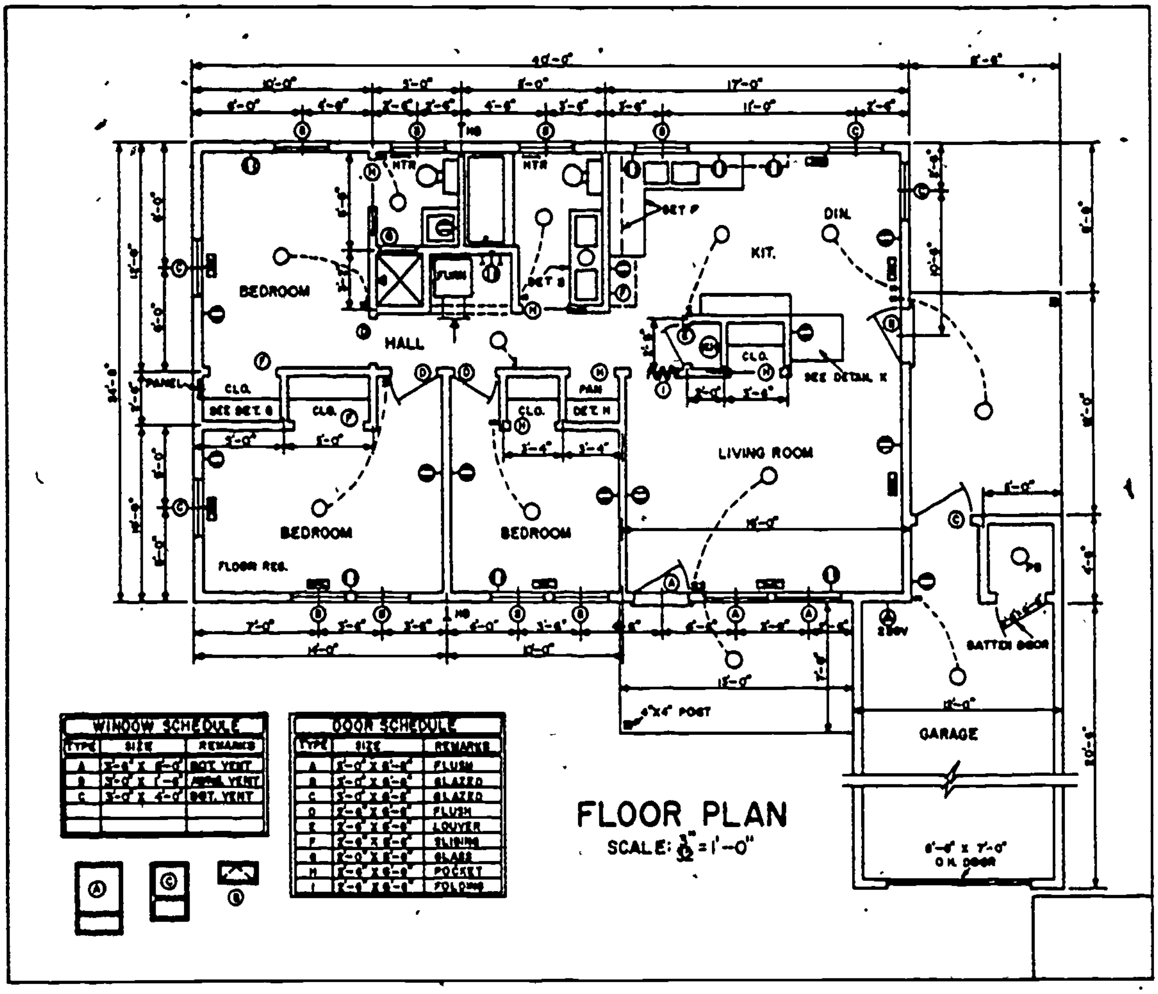

Figure 3-23. Floor plan.

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cannot be presented graphically, we must make extensive use of notes. These notes are a vital part of every construction drawing, and it is important that you word all notes carefully. There will be general notes pertaining to the entire set of plans and also local notes that are important only to certain sheets or to certain parts of the drawing.

Elevations. Elevations are exterior views of a structure, and they may be taken from the front, rear, right, or left side. Being projections on a vertical plane, they show a picturelike view of the structure as it actually is and not as it would appear to the eye. Exterior materials, the height of doors, windows, and rooms, and the surrounding ground level can be shown in elevation views. On the elevation view for a single-story building, the floor level is located in reference to the surrounding ground level or "grade." Additional floors above the first floor are located by dimensioning between finished floor surfaces. If the sides of a building are not identical, an elevation for each side must be drawn. Note that the dimensions given in figure 3-24 are practically limited to vertical measurements. Horizontal dimensions may be placed on an elevation view if it is not possible to show them to better advantage on a plan view.

Since plan and elevation views cannot be drawn as related views on one sheet (except for small structures), the architectural draftsman must make scaled measurements to draw each view. However, a completed plan view may be taped in the proper position on the drawing table, and the main dimensions and door and window locations may be projected to an elevation sheet.

Elevation views can be made more lifelike by accenting certain lines and adding straight lines to represent the type of material used on the exterior. Lines which may be accented are window, door, roof, and building outline lines. In accenting these lines, you must assume that light is coming from a certain direction and that accented lines represent areas which are shaded. The use of straight lines to suggest the texture of the exterior materials is a form of architectural "rendering." Rendering, as

231-817

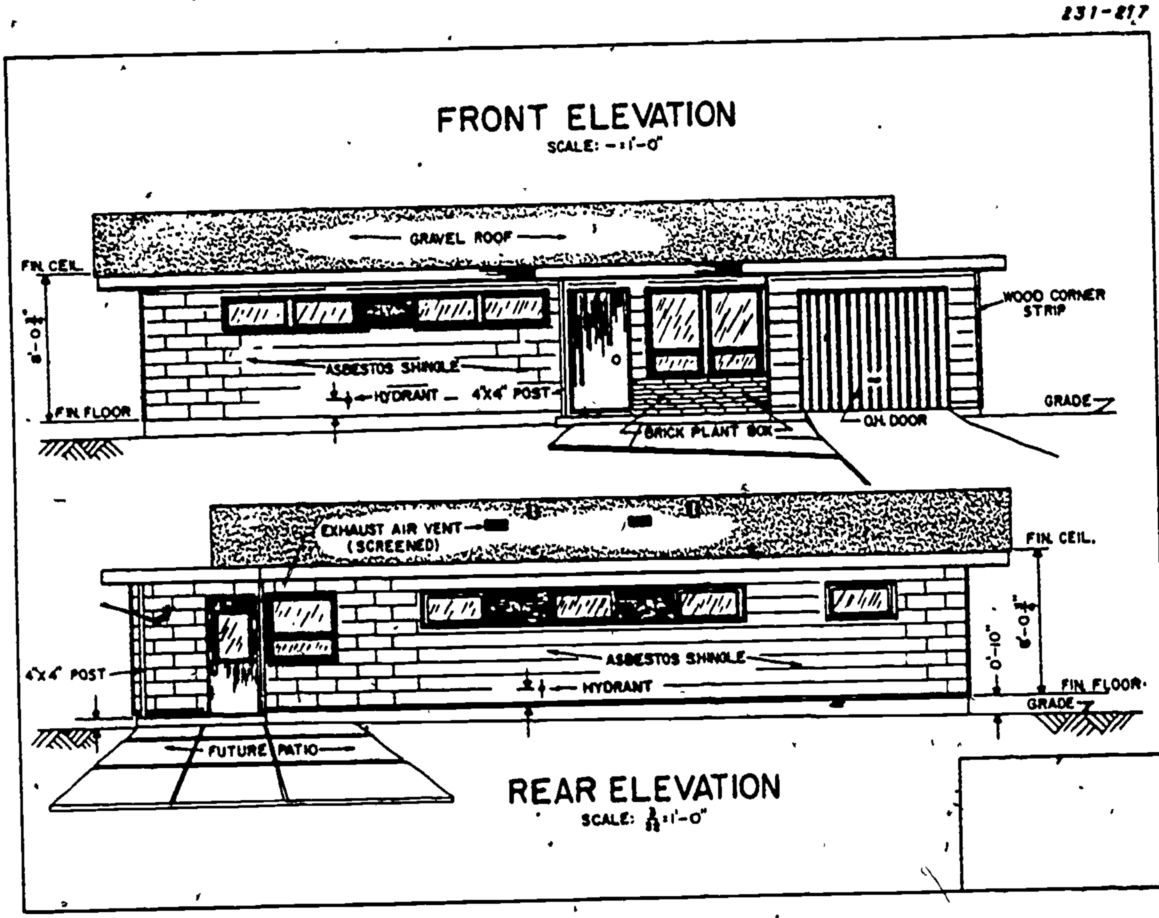

Figure 3-24. Elevations.

applied to architectural drawing, is the use of pencil, ink, water color, or a combination of these to depict a structure and bring out its form and shape. Since elevation views are primarily working drawings, you can see why straight line rendering and line accenting should be held to a minimum—subdue it; don't overdo it! Figure 3-24 has what is considered the "usual treatment" for elevation working drawings. A foreground in parallel perspective is an "extra" to give a realistic touch, but in using this technique you should avoid covering up important details.

Exercises (433):

1. How does the builder locate a starting point by looking at a plot plan?

2. What is the starting point for actual construction?

3. What is a floor plan?

4. What is an elevation?

434. List the distinctive features of detail drawings, four detail sections usually shown, two possible projections for exterior detail views, and the usual source for details of prefabricated units.

Sections and Details. In architectural drawing, the words "section" and "detail" are practically synonymous. However, no view should be called a detail unless it is drawn to an enlarged scale to show construction features more clearly. Figure 3-25 illustrates the difference between a "section" view and a "detail section." The detail sections show parts of the structure with greater exactness than the small-scale section taken through the house. When the cutting plane cuts across the narrow part of a building, the view is called a transverse section. Section views taken lengthwise of the building are called longitudinal sections. Detail sections which are usually shown are foundation, wall, door, and window sections, and any other section which is considered necessary to explain the construction. All cut parts shown in section are crosshatched to indicate the type of material used. Visible lines behind the cutting plane are shown, and hidden lines are used sparingly if at all. Standard forms of symbolic crosshatching are generally recognized by those who are familiar with building plans and construction. These conventional symbols will be further explained as we study the materials and methods of construction.

Exterior detail views, like detail sections, are large-scale drawings designed to show features which are too small or too complex to be shown in other views. They are usually developed in orthographic projection, but a pictorial projection may be used if it shows the construction to a better advantage. If you study figure 3-23, you can see that there are many parts of the construction which need additional explanation and that a set of plans would not be complete without a few large-scale detail drawings to show how these parts are to be built. Several detail drawings appear on figure 3-26. However, several more detail sheets would be required to complete this set of plans. Important parts of detail and section views are the notes and dimensions to show the size of materials and the placement of parts in relation to each other.

The task of detailing certain parts of a structure is made easier by the fact that prefabricated or preconstructed units are integrated in the design. For example, the architect obtains scaled detail drawings and technical data for doors, windows, heating and cooling units, cabinets, plumbing equipment, and many other products. This information is furnished by the manufacturer, and a progressive architectural office maintains an up-to-date reference file of manufacturers' catalogs and manuals. When these "stock" units are used in a building, the working detail drawings show how to "frame" the structure so that the windows, doors, and other shop-made assemblies can be installed. Schedules and written specifications complete the information and permit the contractor and workman to build the structure to the satisfaction of both designer and owner.

Exercises (434):

1. When should a drawing be labeled "detail"?

2. What are the four detail sections usually shown?

3. What are the two possible projections used for exterior detail views?

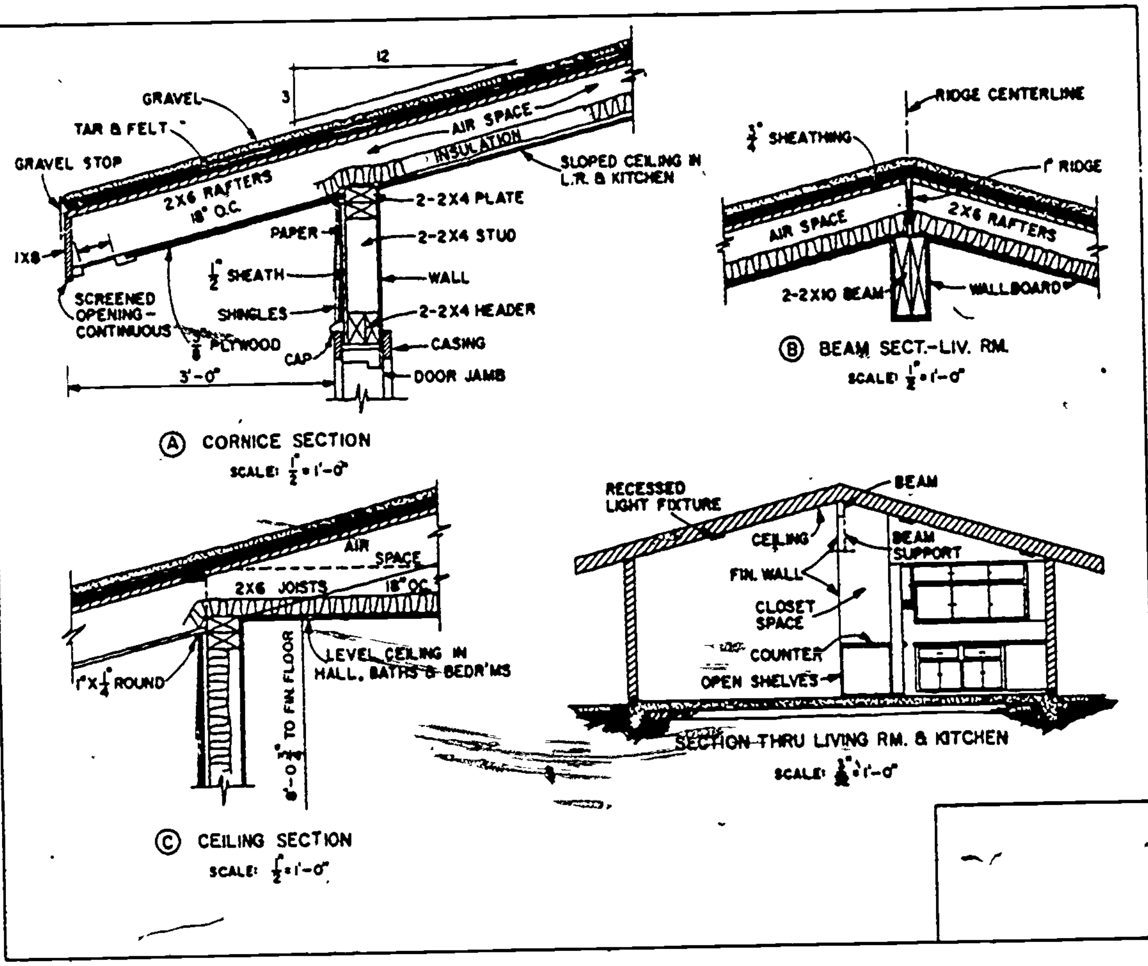

Figure 3-25. Sections.

4. What is the usual source for details of prefabricated units?

435. Give the techniques, or factors determining certain techniques pertaining to particular lettering and dimensioning situations.

Drawing Technique. The views used to illustrate the types of architectural drawings may seem complex for the beginner. However, they show how the architectural draftsman's technique gives a distinctive character to the drawing. This is due to varying the line weights, overrunning lines at corner, and using freehand lines and dimensioning techniques. Even though there is greater freedom in architectural expression, there is no sacrifice of accuracy. As the next step is our study, let us examine the figures from the standpoint of the architectural drawing techniques used.

Lettering. Lettering style shall be single-stroke uppercase, commercial Gothic, except when typewritten characters are used. Either inclined lettering or vertical lettering may be used; however, only one style should appear in a single drawing. Normally, lowercase letters are used on construction drawings. The exception to using lowercase lettering is for titles, where uppercase lettering is normally used. If typewritten characters can be used, this method is perhaps the most acceptable because it is normally faster. Where available, typing should be done in Varitype Gothic; second choice for type style would be Bodoni or book types.

The method of lettering on drawings may be freehand or by means of template, typewriter, or a lettering machine (typewriter is quite often the most acceptable, as previously indicated). Regardless of the particular method used, all lines of the lettering must be sufficiently opaque to be legible in full size or reduced size copy by any generally accepted method of reproduction. Lettering may be underlined, but this is normally done only when particular emphasis is desired.

The division sign of a common fraction is drawn parallel to the direction in which the dimension reads. However, when such fractions are included in typewritten notes, tables, lists, etc., a diagonal line may be used.

The size of lettering and the line spacing used on a drawing are controlled by the size of the object to be shown in relation to the size of the drawing paper, the amount of detail to be shown, whether the drawing will be reduced when reproduced, and on the amount of reduction which will be used. The modern procedure of reducing drawings to small size (to save storage space) and then reproducing the drawings in their original size limits the minimum size of lettering and the line spacing which may be used and still maintain legibility. It is recommended that the minimum size of lettering after reduction be not less than 3/64". In the absence of factors making larger lettering desirable, the recommendations for size of lettering for drawings up to 17" x 22" are as follows: title—3/16", subtitle—5/32", letters and figures for body of drawing—1/8", and fractions or tolerances—3/32". For larger drawings, the sizes of lettering should also be governed by the considerations set forth in the first part of this paragraph. When commercial lettering guides are used, appropriate sizes should be used. The regular line spacing of typewriters and other lettering machines is acceptable, provided that nothing smaller than standard pica type should be used.

Dimensioning. Dimension lines on architectural drawings are unbroken between extension lines, and dimensions are given in feet and inches. Since there are numerous "in-line" dimensions on

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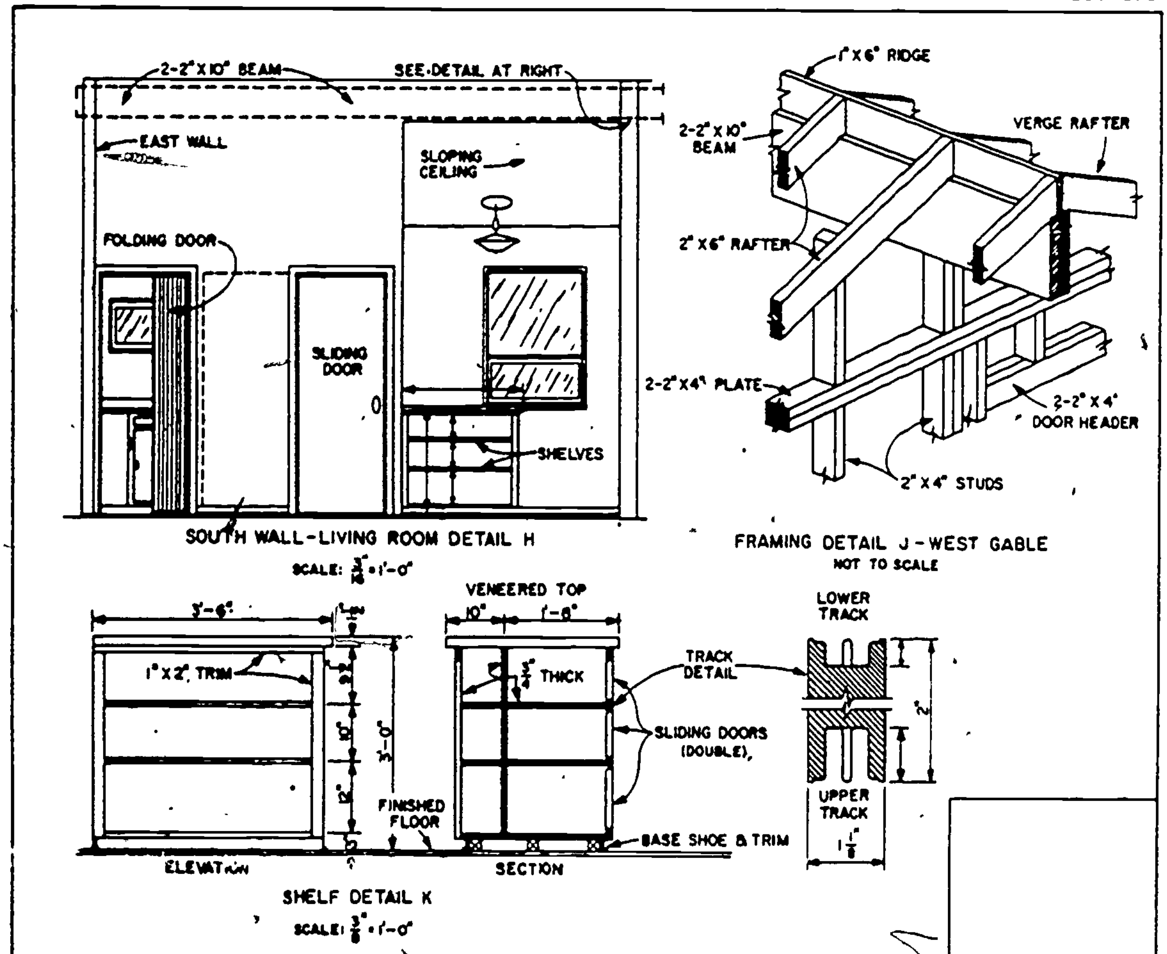


Figure 3-26. Details.

architectural drawings, a continuous line is easier and faster to make and leaves less chance for mistakes in reading. The numerals are placed slightly above the dimension line. All horizontal dimensions and all dimension notes are placed on the drawing so that they are read from the bottom of the sheet. Vertical and angular dimensions may be placed so that they can be read from either the bottom or righthand side of the drawing. Where there is plenty of space on the sheet, the first dimension line (nearest the building outline) should be about an inch away from the wall line. Spacing between dimension lines varies, depending upon the scale, lettering height, and available space. The main requirement is that dimensions must be clear, definite, and unmistakable. For example, when lettering size is 1/8", the space between successive dimension lines should not be less than 1/2". When you are forced to place dimension lines closer together, you should stagger dimension figures to avoid crowding. Be sure to place the numerals close to the line to which they refer—about one-half the numeral height above the line.

Figure 3-27 shows correct methods for specifying fractions, inches, feet, and combinations of these on drawings. In dimensioning views, the following points are important:

a. Keep outside dimension lines a good distance from building lines. The outermost dimension line should give the overall size.

b. Dimension to the centerline of window and door openings and partition walls. Place interior dimension in a "string" to span the width of the building.

c. Locate columns by coordinate dimensions to the column centerlines.

d. When required by the materials or methods of construction, locate wall openings by dimensioning up the side of the opening; then give the distance across the opening.

The above practices are general. You must realize, however, that your dimensioning of any drawing is governed by knowledge of construction procedure. It is only by experience that you can learn what to dimension and how to place the dimensions on the drawing. In machine drawings, dimensions express accuracy within thousandths of an inch. Dimensioning for construction does not involve such fine measurements, but dimensions must be sufficiently accurate for the type work involved. Dimensions must always check and add up correctly with one another from place to place and from one view to the next.

Generally, the sizes of common building materials are not uniformly accurate enough to allow dimensioning to the edge of the material. This difficulty is overcome by giving center-to-center dimensions for doors, windows, interior walls, etc. This type dimensioning allows for variation in size, and it also allows the designer or builder to make necessary adjustments without redrawing the plans. For example, if the specifications call for 4" x 4" wood columns for the building shown in figure 3-27, these could be changed to 6" x 6" size or another material could be used without altering the location dimensions. Window and door sizes may also be changed, but any change must be made with careful consideration of other factors such as cost, appearance, usefulness, and structural practicability.

Dimensions in section and detail views are given to working points and are not repeated. A great many sizes and locations are dimensioned by means of notes which also name the part. Dimensions for ceiling height above the finished floor are determined by the design. Diimensions for doors and windows are obtained from design sketches or by reference to a manufacturer's catalog. The best way to dimension detail views is to make a list of questions which the workman might ask. Dimensions are then selected to furnish answers which give necessary information for construction.

Exercises (435):

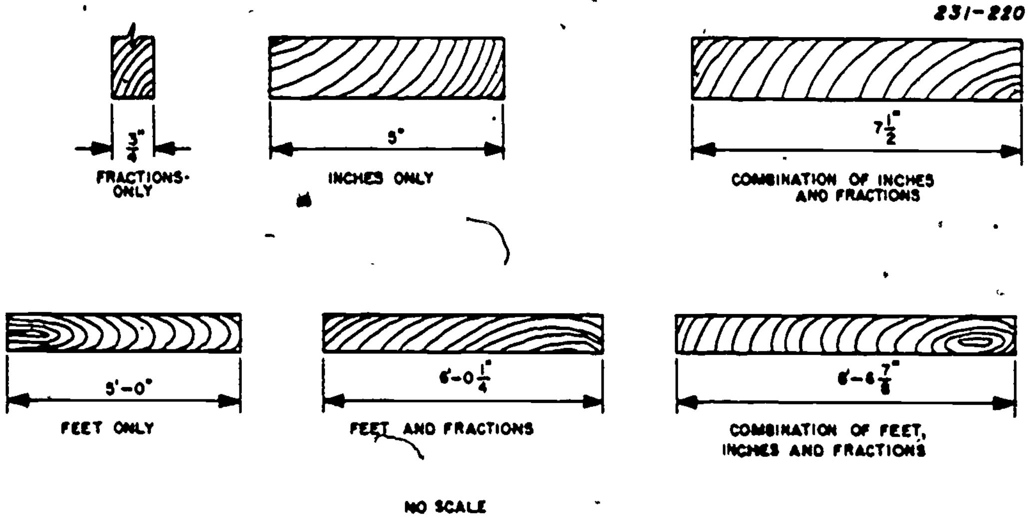
1. What factor mainly determines the size of lettering to be used on a drawing?

2. Why is a continuous dimension line used on architectural drawings?

3. To what point on a partition wall should you usually dimension?

436. Identify the drawing scales used in architectural drawing and list three general considerations and, for designated situations, the specific practices for drawing scales.

Drawing Scales. The architect scale is an "equation" scale. The relationship of the drawn figure to the true size of the structure is expressed as an equation; for example, 3" = 1'0", ¼" = 1'0", etc. This type of scale is generally used for drawings where dimensions are expressed in feet and inches.



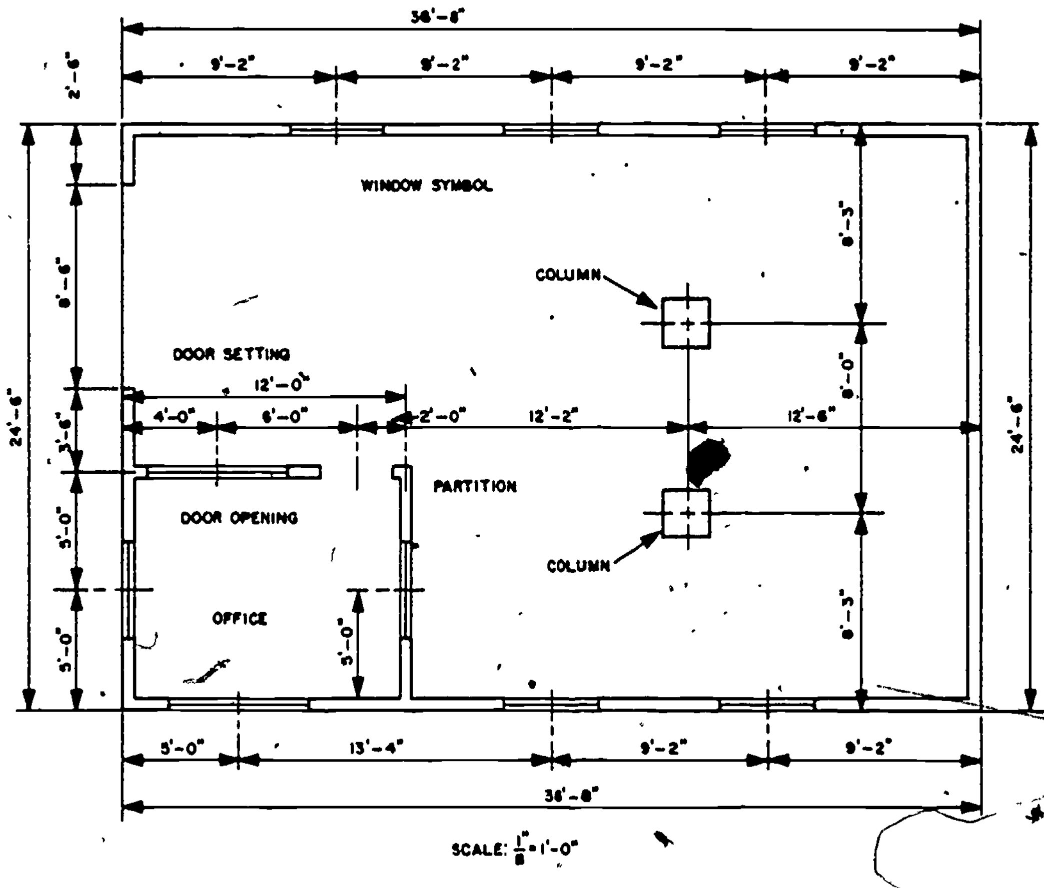
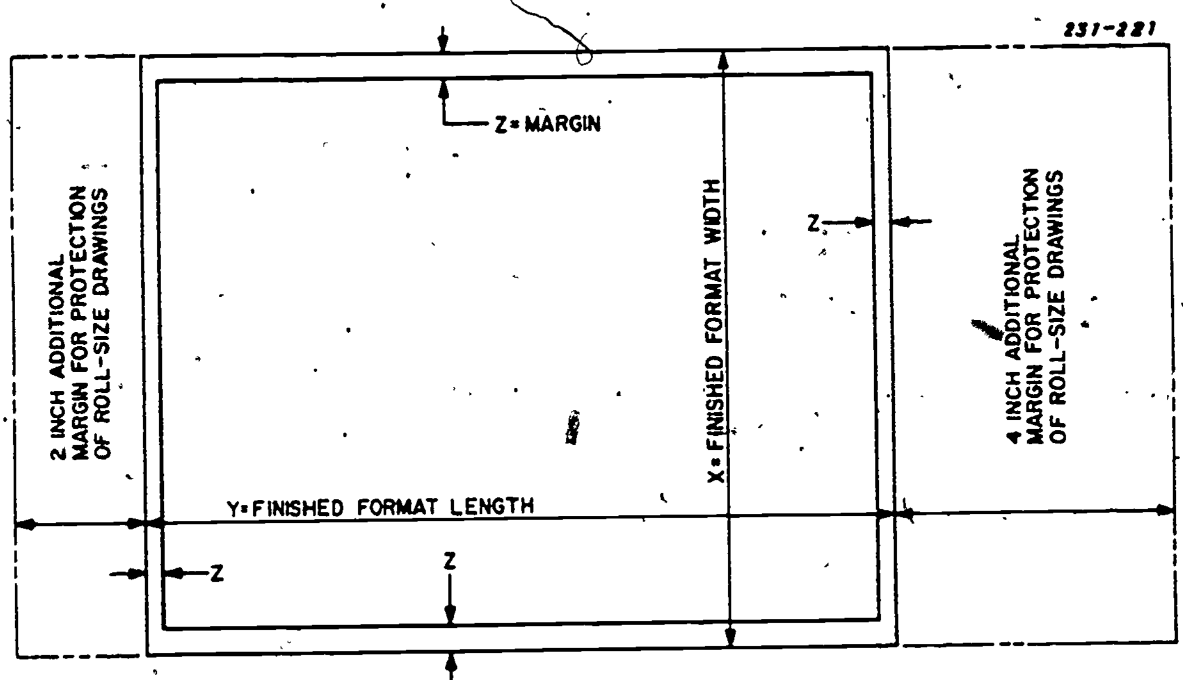


Figure 3-27. Dimensioning.

There is a full-size scale and 10 reducing scales on the triangular architect scale. To determine which scale to use for a drawing, you must consider the following: the size of the object, the size of the drawing paper, and the desire to show details clearly. The size of the paper is important because working drawings must be convenient to handle on the job. There must also be space for dimensions and notes. The clearness of the drawing is perhaps the most important consideration, since a small scale will not show details clearly. For example, suppose that the size of the paper is 11" x 17" and the overall length of the building is 120'. Rather than use a scale smaller than 1/4", a larger size sheet should be used. This would provide space for the view which would span 30" of space when drawn to the 1/4" scale. The finished sheet sizes for construction drawings are shown in figure 3-28. This figure is reproduced from Mil—Std—2B, *Format for Construction Drawings*, and these sizes correspond to standard sizes in commercial use.

After a view is drawn, dimensioned, and given a title, the scale to which it is drawn must be noted in the proper place. Until you do this, the drawing is not complete. As a rule, the scale indication is placed directly under the title of the view, whether it



FLAT SIZES				ROLL SIZES				
SIZE DESIGNATION LETTER	X (WIDTH)	Y (LENGTH)	Z (MARGIN)	SIZE DESIGNATION LETTER	X (WIDTH)	Y MINIMUM (LENGTH)	Y MAXIMUM (LENGTH)	Z (MARGIN)
A(HOR)	8½	11	¼ & ⅜*	G	11	42	144	⅜
A(VERT)	11	8½	¼ & ⅜*	H	28	48	144	½
B	11	17	⅜	J	34	48	144	½
C	17	22	½	K	40	48	144	½
D	22	34	½					
E	34	44	½					
F	28	40	½					

*HORIZONTAL MARGINS ⅜ INCH; VERTICAL MARGINS ¼ INCH.

Figure 3-28. Drawing sizes.

is a main view or a detail view. If the reader knows the scale, he may use the same scale to find missing dimensions. The missing dimensions can also be found by measuring the distance with a full scale and dividing by the given scale. However, these methods apply only to drawings which are reproduced to the same size as the original drawing.

If a drawing is to be reduced or enlarged, a graphic scale should be placed on the sheet. Graphic scales, as shown on figure 3-23 and 3-24, are actual measuring scales which can be used to determine approximate sizes of objects shown on reduced or enlarged prints. The greatest advantage with this kind of scale is that the drawing and its scale are proportionally enlarged or reduced together. Approximate dimensions can then be determined by using dividers to scale the drawing. These scales are not intended to be used as a means of obtaining accurate dimensions.

Graphic scales are generally placed on drawings where complete dimensions are not required, such as display drawings and preliminary drawings. Equation scales are usually placed directly under the views to which they apply, and the corresponding graphic scale is placed below the equation scale.

When no scale is used on a drawing, the notation "NO SCALE" is placed under the view. When a dimension is not to scale, the abbreviation "NTS" is placed above or below the dimension affected.

To construct a graphic scale for construction drawings, you must first understand how the scale functions. The scale is usually divided into two parts (see fig. 3-29). The part to the right of the zero mark is marked off in units representing one or more feet, or fractions of 1 foot. This part of the scale is called the primary scale. The part to the left of the zero mark, called the extension scale, is marked off in fractions of one primary unit. The number of small divisions to place in the extension is determined by the size of the scale.

When you make a drawing to a very small scale, you will find it difficult to represent fractions of an inch, and the general rule is to disregard fractions when laying out a distance on one of the smaller scales. The drawing may be a fraction of an inch inaccurate, but since the written dimensions are always followed by the worker, no damage is done. For example, a drawing made to 1/8" = 1'0" scale can be accurate only within 2". Each small division on the 1/8" scale represents 2", and since the lines are so close together, it is impossible to show fractions of an inch. On larger scales, such as 3" = 1'0", fractions of an inch can be shown more accurately. You should practice using all of the equation scales until you become skilled in their use. The same principle is involved in using each one, and the amount of drawing accuracy is determined by your skill and the habit of checking all work carefully.

Exercises (436):

1. What type of scale is an architect scale, and how are dimensions usually expressed?

2. What are the two parts of a graphic scale?

3. What are three things you should consider to determine the scale for a drawing?

4. Where, in relation to a view, are equation scales and graphic scales placed on a drawing?

3-6. Detail Views

The best way for the beginner to acquire skill in architectural drawing is to trace or copy completed plans. By following this practice you soon learn the correct use of symbols, dimensions, and notes, and you develop skill in lettering and line work. A completed drawing may look very complicated, but if it is broken down and analyzed according to the steps of construction, it becomes much clearer. The step-by-step procedures suggested in this section are designed to simplify or speed up the task of laying out and completing working drawings. You may find it necessary to modify these basic steps to suit a specific job. The important thing is that you develop a systematic procedure for making working drawings. Systematic procedure, like skill in lettering and line work, is part of your individual drafting technique. When you have developed these abilities by copying existing drawings, you are ready to create working drawings from rough sketches and other sources of information.

The following sections discuss the methods used for drawing plan, elevation, and detail views. We will take you step by step through the procedure used in constructing each of the three types of working drawings. After you have studied each procedure, you should make reproductions of each drawing to increase your proficiency in this area.

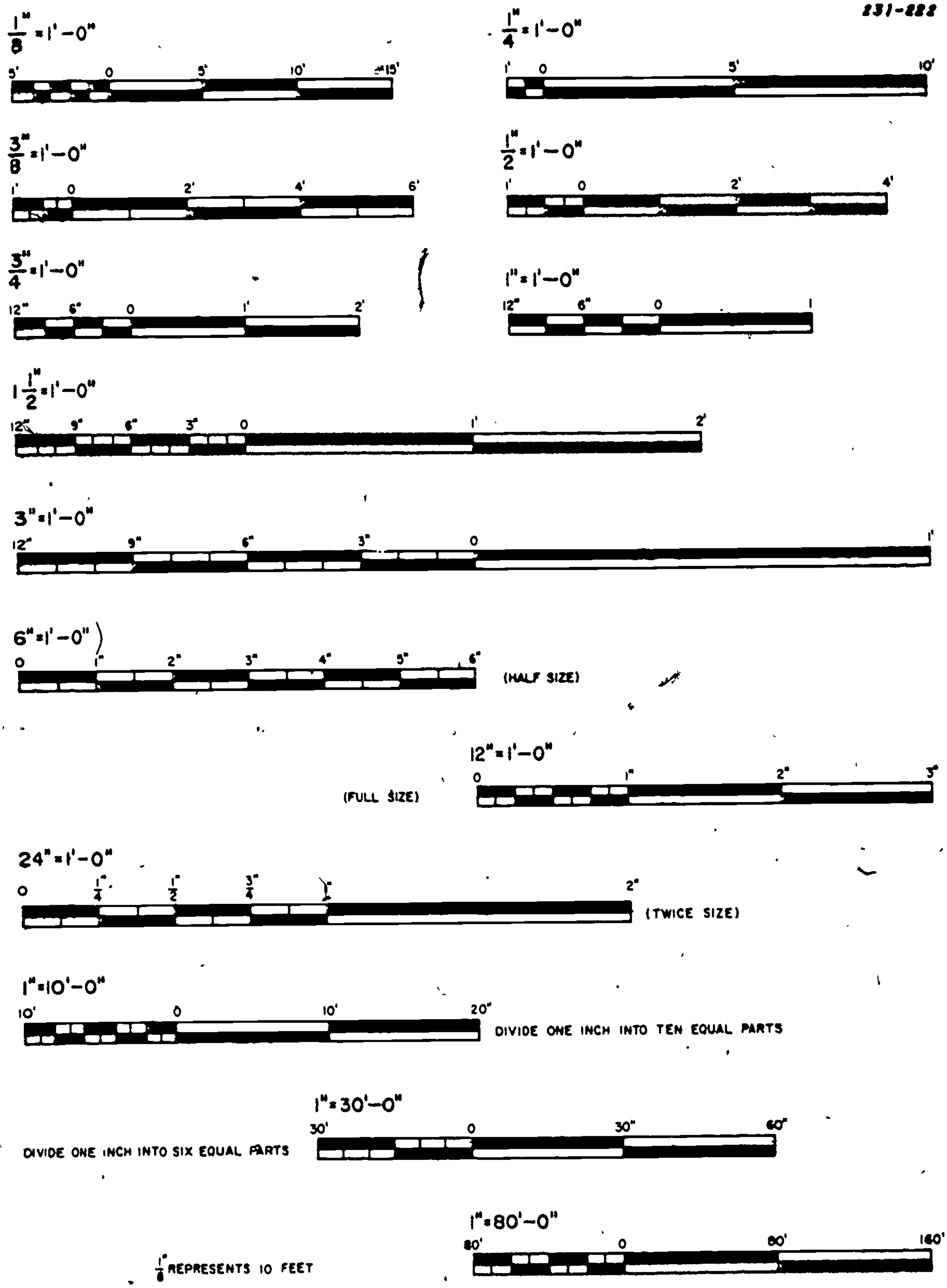


Figure 3-29. Scales.

The steps in each procedure are, as nearly as possible, laid out and built up much the same as actual construction is carried out on the job.

437. Give certain procedures, or purposes of certain procedures, used in the preparation of floor plans.

Drawing a Floor Plan. To illustrate the procedure for drawing a floor plan, you must follow the steps described here and shown in figures 3-30 and 3-31. Note that the overall size of the house is 25' x 30'. When drawn to the scale 1/4" = 1'0", the plan will measure 6 1/4" x 7 1/2" on the drawing sheet. However, you must also have space for dimensions, general notes, schedules, and title block. Therefore, you will need an 11" x 17" sheet for the job. In following the steps below, be sure to draw the entire plan in light lines. When it is completed and checked, you can go over the lines to darken them and bring them to the correct weight as indicated below:

- Heavy: Border lines, title block lines, cutting plane lines.
- Medium Heavy: Main outline lines of the house, such as wall and roof outlines, and outlines of parts shown in section.
- Light: Dimension lines, extension lines, symbol section lining, shade lines, long break lines, invisible lines, and centerlines. Equipment symbols for doors, windows, plumbing fixtures, etc., are also shown with light lines.

The use of different weights of lines will emphasize the important parts of the plan and make it easier to read the drawing. If all lines on a blueprint were the same weight, it would be very confusing and difficult to read. It is important that the main outlines of the building stand out clearly. All lines should be black in order to make a good copy by blueprinting or other processes.

(1) Step 1 (see fig. 3-30)

(a) Take the total length and width of the building and draw a rectangle representing the outside wall lines. Place the rectangle in the drawing space so as to have the necessary room for dimensions and yet have the rectangle nearer the top border line. This provides room at the bottom of the sheet for titles and title block. The front of the building is always faced toward the bottom edge of the sheet.

(b) The thickness of the exterior wall is determined by the materials to be used. A wood frame wall with 2 x 4 studs is usually drawn 6" thick; this includes outside boarding and interior wall finish. Locate the centerlines of interior walls and draw them in lightly. The thickness of a 2 x 4 partition wall, covered on both sides with 1/2" wallboard, is 4¾". Draw the wall about 5" thick when using a small scale. Draw all interior and exterior walls in full with light lines—disregard the location of the wall openings at this time.

(c) Note that partition walls on one side of the house are often a continuation of walls on the other side. Also, several short walls must be located by making individual measurements for each one. Always work to the centerlines of interior walls and be sure to make the wall the correct thickness on either side of its centerline. In some cases, it may be necessary to increase the thickness of a partition wall to accommodate plumbing lines and vent stacks. The wall between the kitchen and bath may be framed with 2 x 6 studs for this purpose. This information would be furnished by the designer.

(2) Step 2 (see fig. 3-30)

(a) Locate and draw the centerlines for all exterior doors and windows.

(b) Draw the symbols for windows and doors according to the following dimensions. Show the window and door swings by drawing compass arcs and then drawing lines at 45° for windows and 90° for doors (if interference occurs with a 90° swing, use 45°).

Kitchen window: 1'4" x 3'0" casement sash, hinged on left side.

Dining area window: 5'0" x 3'0" casement. Center section is fixed sash; vent sashes are 1'2" wide.

Living room glass wall: 6'0" wide; made up of two equal sections 6'8" high. The bottom part of each section has a 16" bottom hinged vent, opening in.

Bathroom window: 3'0" x 3'0" double casement.

Bedroom windows: 3'0" x 4'0" double casement.

Living room window: 3'0" x 4'0" double casement.

Exterior doors: 2'8" x 6'8" flush doors, glazed.

The height dimensions for the windows and doors will be needed when you draw elevation views. The dimensions given for windows are the overall dimensions for metal sash.

(3) Step 3 (see fig. 3-31)

(a) Locate and draw interior door openings to the correct door width. In cases where the centerline of a door is not located, the door is centered between the available wall space. Erase partition lines before drawing the door symbols.

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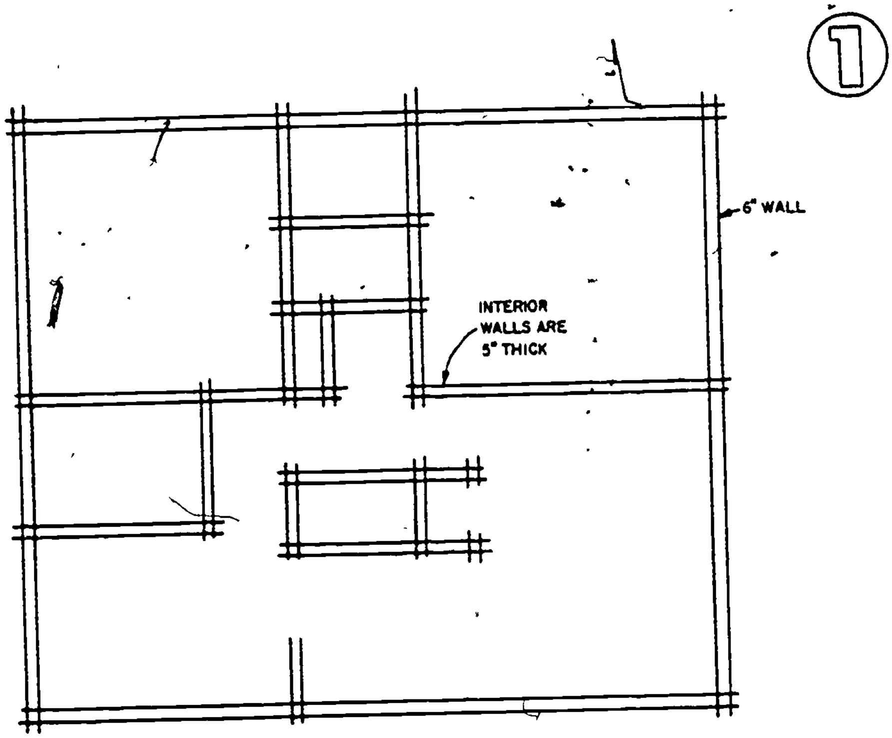

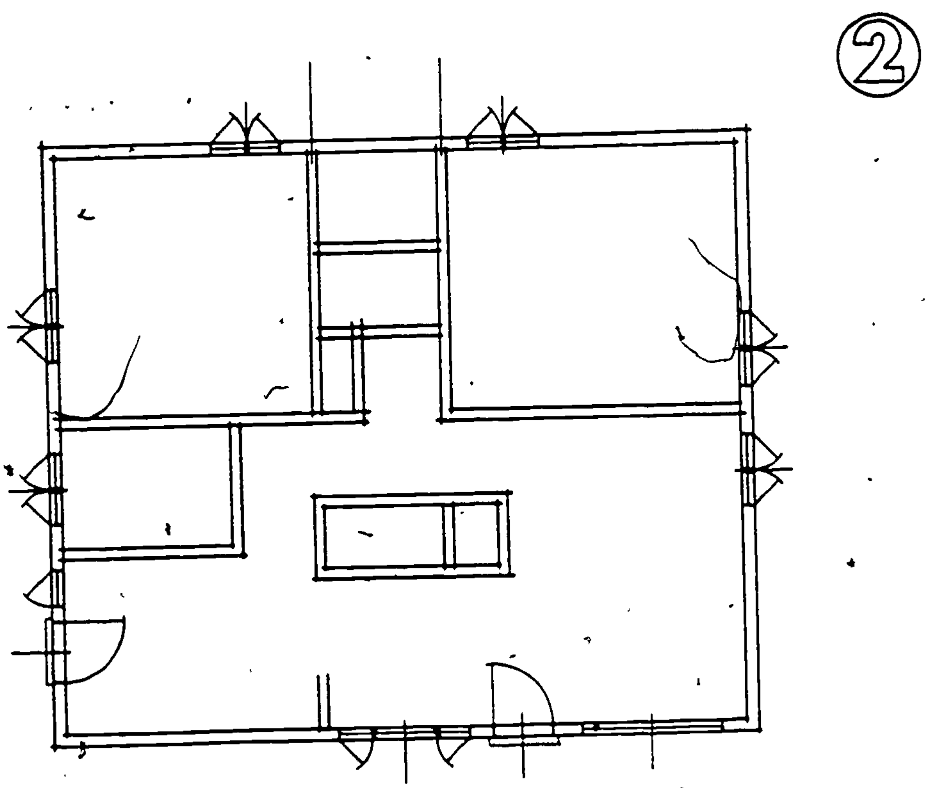

Figure 3-30. Drawing a plan (steps 1 and 2).

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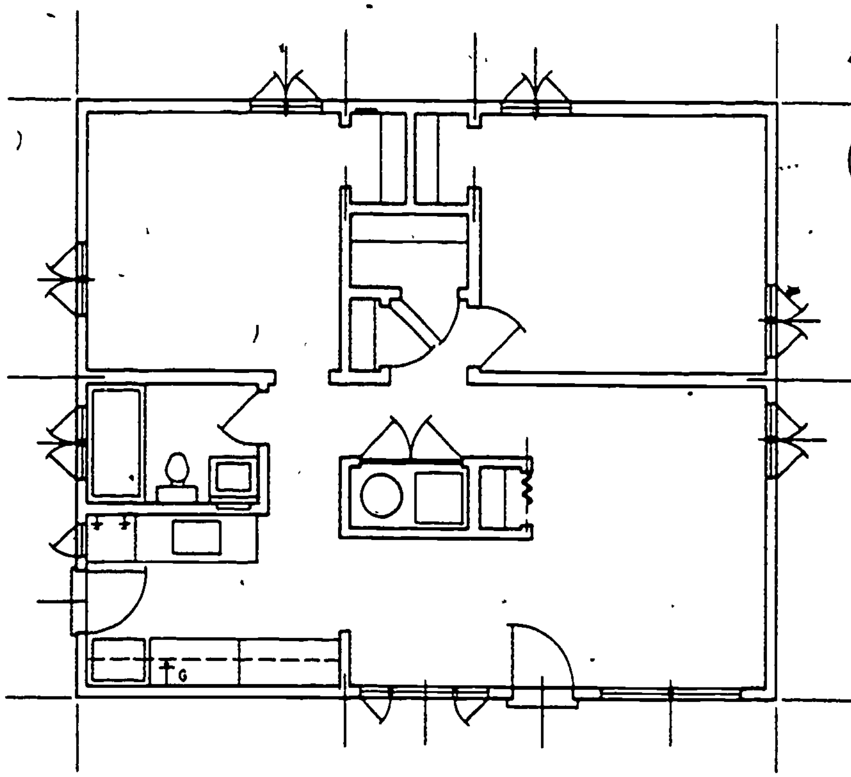

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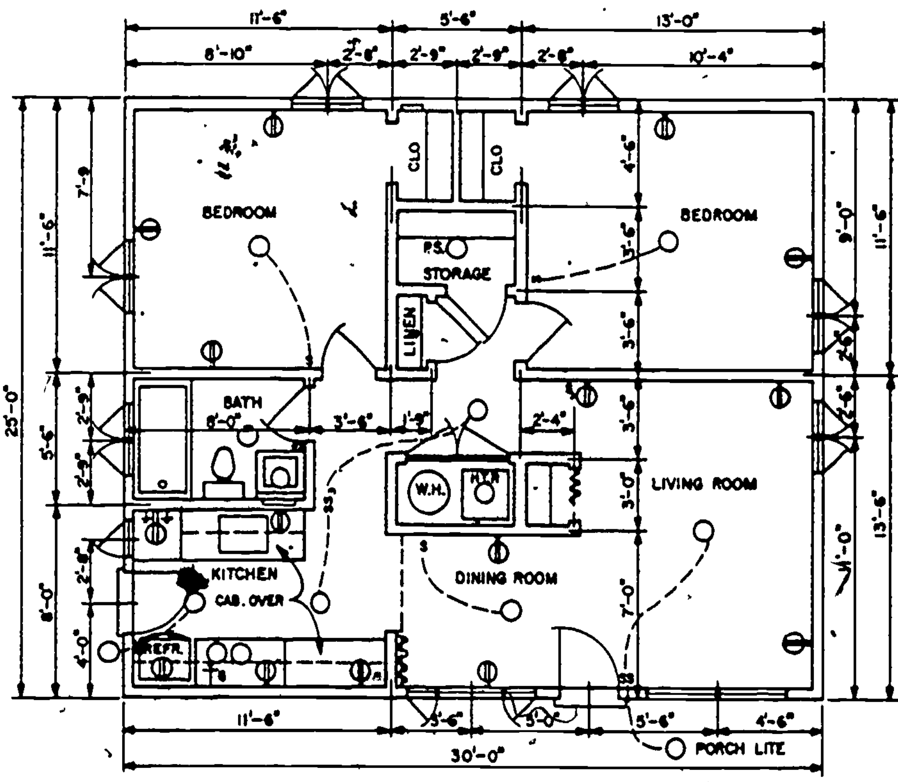

Figure 3-31. Drawing a plan (steps 3 and 4).

The dimensions and types of interior doors are as follows:

Bathroom: 2'4" x 6'8" (flush door)
Bedrooms: 2'6" x 6'8" (flush door)
Bedroom closets: 2'6" x 6'8" (sliding, flush door)
Storage closet: 2'6" x 6'8" (flush door)
Guest closet: 2'6" x 6'8" (folding door)
Linen closet: 2'4" x 6'6" (flush door)
Heater space: 2'0" x 6'6" (louvered)
Dining area: 6'0" x 7'6" (folding door)

(b) Locate and draw kitchen equipment, such as counters, wall cabinets, and sink. Designate spaces for range, refrigerator, and washer by drawing symbols as shown. Wall cabinets are indicated by dashed lines about 1'0" from wall lines. The following approximate dimensions are given for kitchen and plumbing equipment. The first diemnsion given is the depth dimension from the wall to the outer face of the object. The second dimension is the width across the object.

Range: 24" x 36"
Referigerator: 26" x 30"
Washer: 24" x 28"
Sink (built-in) 16" x 24"
Lavatory (built-in) 14" x 16"
Bathtub: 2'8" x 5'0"
Water closet: 8" x 18" for tank; 16" x 14" for bowl
Heater: 24" x 24"
Water heater: 18" diameter
Closet shelves: 10" to 12" deep

(4) Step 4 (see fig. 3-31)

(a) Locate electric light outlets, switches, and convenience outlets as shown. Draw dashed lines as shown to indicate the light controlled by each switch. Note that the hall light can be controlled from two positions by using two three-way switches.

(b) Draw exterior dimension lines, locating subordinate dimensions next to the wall lines. The outermost dimensions should be overall dimension. Exterior windows and doors are located by dimensions to the centerline of the opening.

(c) Location interior partitions of the house by dimensions to their centerlines. When dimensioning to an exterior wall, the dimension is given to the outside face as shown. It is customary to run a dimension line across the plan in each direction if it is convenient to do so. However, this should not be done if it repeats too many dimensions or causes crowding and reduces clarity. Be sure to put arrowheads at the ends of each dimension line.

(d) Letter in dimension numerals, titles, and any notes required. Mark door and window sizes, or use a code symbol as shown on figure 3-23. These symbols were omitted from figure 3-31 in order to simplify the drawing. Make sure that intermediate dimensions along the same line add up to the correct overall size of the building.

(e) Place the title and scale on the lower part of the drawing, using the format shown in figure 3-31. From the size dimensions given and from other information given on the completed plan and elevation views, make a window and door schedule using the format shown in figure 3-23. All windows are aluminum sash. When drawing the elevation view, you may design the glassed openings for the two exterior doors, or pattern them after doors that you think are good examples.

After you have completed the layout, you should spend considerable time checking every detail of the drawing. Make sure that every part is correctly drawn and placed. See if improvements can be made in lettering, in placement of dimensions, and in notes. Be sure that switches and outlets are conveniently placed. For example, it would be an improvement to add one more convenience outlet to the right wall of the living room. This would allow the occupant a wider choice in the arrangement of interior furnishings.

Exercises (437):

1. On a floor plan drawing, which way should a building face?

2. Why should a plan view be drawn in light lines first?

3. What is the difference between dimensions to an interior wall and an exterior wall on a floor plan?

438. Give certain procedures, or purposes of certain procedures, used in the preparation of elevation drawings.

Drawing an Elevation. The method of constructing an elevation drawing follows the same principles used in drawing a floor plan. The drawing of the elevation will also be explained in four steps.

First, we must assume that all necessary design information has been worked out. Many details of construction, such as floor and ceiling heights, sill construction, wall and cornice construction, roof pitch and type of roofing, types of doors and windows, and exterior finishing materials, must be considered. The more complicated the building, the more details there are to consider. Details may vary with design and materials, but the method of constructing this or any other working drawing must follow logical steps to get the best results.

On an 11" x 17" drawing sheet, draw an elevation at 1/4" = 1'0" scale following the suggested sheet layout shown on figure 3-32. Place the front elevation view at the lower part of the sheet as indicated. The space required by the elevation view will be a little wider than that for the plan because of the roof overhang which projects beyond the gable ends of the house. The height of the house is approximately 11'; this will be roughly 3" on the drawing sheet. Therefore, the space required by the front elevation view is about 3" deep by 8½" wide. If a title block is placed on the drawing, the elevation view must be moved over to the left. Extra space on the sheet can be used for schedules, notes, and detail views. Ordinarily, there are no schedules shown on elevation views, but it is good practice to show one or two enlarged details, as a cornice detail, to help clarify exterior construction features. Follow the procedure described here and shown in figures 3-32 and 3-33.

(1) Step 1 (see fig. 3-32)

(a) Draw the floor and ceiling lines as shown; then establish a finish grade line at least 8" below the floor line. The grade is placed so that the surface of the porch will be at least 3" above the grade line.

(b) Tape a floor plan above the elevation view and project down the main corner lines of the building. Use this plan view to locate as many points as possible by projection. However, you should check your work and see that dimensions add up to correct distances on the elevation view.

(c) With light lines, construct a section view which is to serve only as an aid in completing the front view. Place the section view opposite the front elevation view as shown. A partial view is used here because space is limited. However, you should extend the roof rafters to determine the height of the roof ridge. The total roof rise from the top of the plate to the underside of the ridge is 25". Then add the depth of the 2 x 6 rafter and roofing. Roofing thickness can be approximated.

(d) Project the roof ridge, eave lines, and porch lines over to the front view. The porch is formed by continuing the roof raters 5'0" past the exterior wall line, running them at the same slope as the main roof. The porch slab and porch roof were not shown on the floor plan because of the lack of space. Only the main lines of the roof are drawn at this time. Details will be worked out in subsequent steps. After the entire drawing is completed, the partial section view will be erased.

(2) Step 2 (see fig. 3-32)

(a) By projecting from the floor plan and by taking location dimensions from the plan, locate the centerline of the chimney, which is the same as the centerline of the heater. The chimney is rectangular, measuring 16" x 24", and it is positioned as indicated. Draw the chimney outlines according to the given dimensions. These dimensions are placed on the illustration for information only—they should not appear on the final drawing. The section view shows where the chimney comes through (intersects) the roof.

(b) Locate the centerlines of the exterior door and windows. Draw in the outside outlines of door and windows by using the dimensions given in the previous section. First, the height of the door is measured upward from the floor line. The heads of the windows are next lined up with the top of the door. Measure downward from the window sash head to locate the window sill line. Draw a sill under the door and extend it across under the large windows.

(c) Draw the front porch and kitchen door entrance step. Use the detail shown to find the porch level in relation to the floor level.

(d) Draw the horizontal line which represents the bottom edge of the siding. In the process of actual construction, the horizontal courses of siding may be shifted upward or downward in order to give the best exterior appearance.

(3) Step 3 (see fig. 3-33)

(a) Draw the trim around the door and windows as shown. The trim is approximately 3" wide; window rails and stiles are shown about 2" wide.

(b) Draw the roof trim lines as shown, referring to the roof detail developed in the preceding steps. The small projection shown at the lower roof corners is slightly larger than actual size for the sake of clarity and appearance.

(c) Scale the 6" divisions for the vertical boarding, including the spaces between door and windows, and the space above the door and front windows. Also, mark off the 9" spaces for the shingle siding, beginning at the lower edge and working up the wall.

(d) Draw brick symbol on the chimney. Leave a space about 4" high at the base of the chimney to represent metal flashing.

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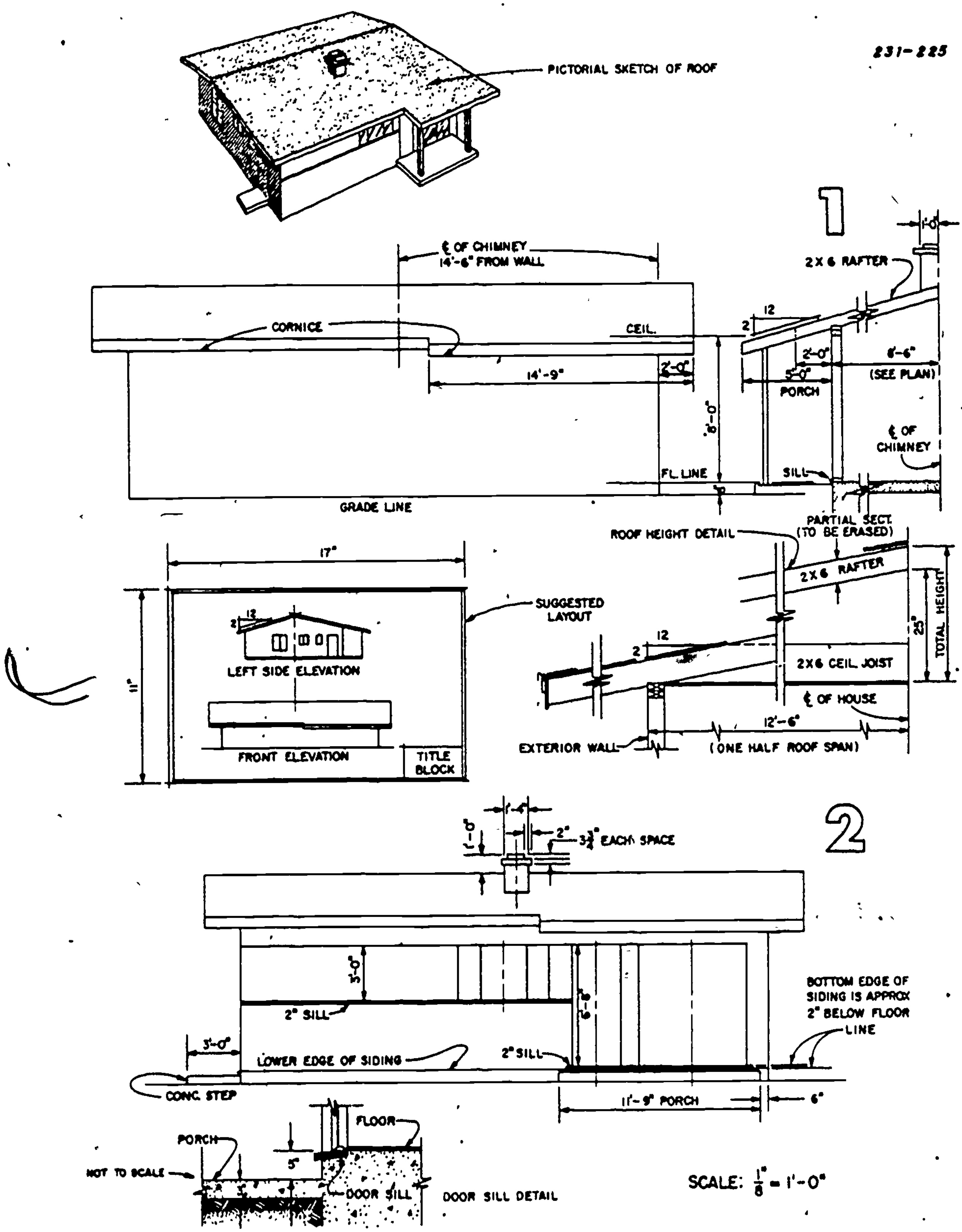

Figure 3-32. Drawing an elevation (steps 1 and 2).

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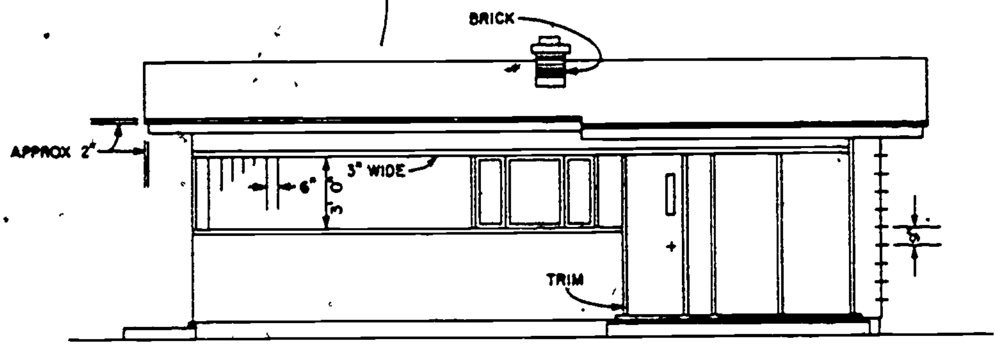

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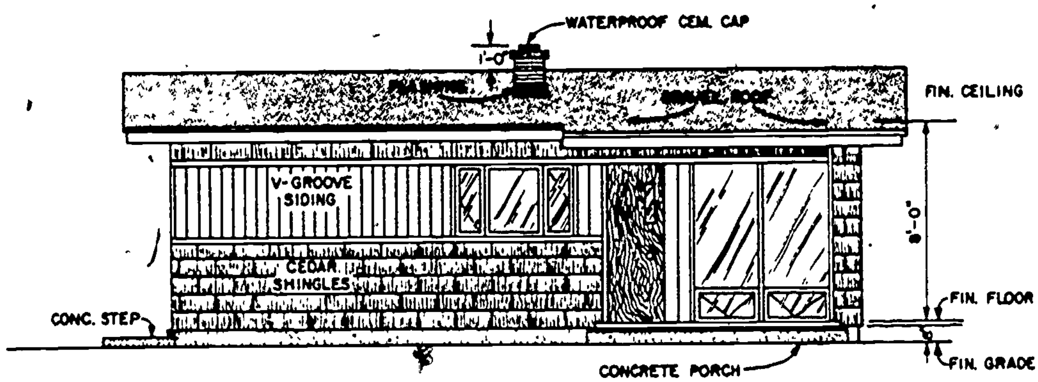

FRONT ELEVATION

SCALE $\frac{1"}{8} = 1'-0"$

Figure 3-33. Drawing an elevation (steps 3 and 4).

(4) Step 4 (see fig. 3-33)

(a) Add stipple marks to represent the gravel roof. It is not necessary to make an exact reproduction of the stipple marks shown. Shading and stippling serve only to give a pleasing appearance to the view—they are not necessary for accuracy. Add the necessary notes.

(b) Draw vertical and horizontal lines to symbolize the type of siding used. Since this building is small, the entire wall may be drawn with shingle symbol, as shown on figure 3-33. For large exterior wall areas, a few lines drawn to scale in the lower left corner of the building would be sufficient to indicate the type of wall material. Add the necessary notes.

(c) Dimension the floor to ceiling height, floor to grade, and ridge to top of chimney. Add identifying notes, placing the notes where they will look well on the drawing. Lettering on notes should be at least 1/8".

(d) Erase construction lines and other lines which are not required on the final drawing. Darken the main outlines of building. Darken and accent door, window, and trim lines. The lines representing shingles and siding should be the lightest in weight, the main outlines of the house the heaviest. Add diagonal straight lines to symbolize glass, and use light, vertical shade lines on the shingles. Draw dashed lines to indicate the hinge points on windows. The concrete symbol should consist only of scattered dots.

Check your drawing thoroughly to see that it is complete and accurate. On the 1/4" scale, it is necessary to approximate the size of small parts. However, you should strive for a high degree of accuracy on those parts of the view which are larger in size and can, therefore, be more accurately laid out. Be sure to letter the drawing title and drawing scale below the completed view. After the pencil drawing is complete in every detail, it can be traced on tracing paper so that it can be reproduced by blueprint on other processes. If the pencil drawing is well done, the tracing will be easier to make, and it will be accurate as well as artistic.

To complete the drawing sheet, draw a left side elevation view of the house in the space above the front elevation view. The left side of the house is covered with cedar shingles up to the ceiling line. A 2" horizontal trim is run from cornice to cornice to separate the rectangular wall from the triangular gable end. The gable is covered with plywood to present a smooth surface for painting. Window and door sizes are as previously listed. Reposition the same plan view to use in projecting wall lines and centerlines for wall openings. The front porch roof is supported by two 4" x 4" wood posts. The front porch floor slab is 4'6" deep from the foundation to the porch outer edge. The concrete step at the kitchen door is 4'0" by 3'0" deep. The upper half (approximate) of the kitchen entrance door should be glass to provide light and visibility.

Exercises (438):

1. What use is made of a floor plan when drawing an elevation view?

2. How is the centerline of the chimney located on an elevation view?

439. Give certain procedures, or purposes of certain procedures, used in the preparation of detail drawings.

Drawing a Detail. Every set of plans must include construction detail drawings. These large-scale drawings show clearly those parts of the structure which cannot be shown accurately in small-scale plan and elevation views. Generally, some details are placed in available spaces on plan and elevation views. However, it is not possible to place all details on the main drawings to which they apply. When the available space has been used, detail drawings are put on sheets containing nothing but details. It is necessary, then, to use a reference on the main drawing to tell where the required detail may be found.

Thus, if we consider it necessary to show the details for the kitchen cabinets (see fig. 3-31, step 4) on another sheet, we would put a note on the floor plan sheet—"Cabinet details on Sheet 5." If "typical" wall construction is to be shown in a detail section, there is no need to show the position of the cutting plane on the plan. However, if the section is intended to show a wall detail at a definite place, we must draw a cutting plane line through that specific part of the plan view which the detail section is to picture. The cutting plane line must be identified by letters, and the corresponding detail view must be identified by the same letters. Without a proper reference and title, the detail may be meaningless. Details should be arranged in the order of their need—that is, the work sequence of actual construction.

Details are drawn as large as possible, the scales ranging from 1/2" = 1'0" on up to full size. Some small parts, such as special moldings, may be drawn twice size if necessary. Usually, the smaller the part, the larger the scale used. Always letter the scale used under the title of the view. Detail drawings must also be thoroughly dimensioned or they will not serve their purpose. The dimension may be given by using notes and leaders, or they may be given by using regular dimensioning methods. Distances are always dimensioned, while parts such as concrete, brick, and framing materials are identified by notes and symbols.

Cornice detail. The cornice detail shown in figure 3-34 is for the simple frame house shown in the preceding figures. Although this is a simple construction, the same procedure should be followed in drawing any type of cornice, whether it be for wood or masonry walls. All framing and other materials must be scaled to actual size. Refer to illustrations available to you to obtain the finish sizes of lumber, molding, and other materials.

To draw the cornice detail shown in step 3 of figure 3-34, use an 8½" x 11" sheet, spacing the views as shown by the suggested layout. Draw the detail in light outlines at first.

(1) Step 1

(a) Draw a 2 x 4 wall stud with a double 2 x 4 top plate as shown.

(b) From the inside corner of the top plate, draw a pitch diagram to establish the underside of the roof rafter. Scale the width of the 2 x 6 rafter and draw the top line of the rafter.

(c) Draw lines to indicate 5/8" roof decking and exterior wall sheathing.

(2) Step 2

(a) Project the roof rafter out to the full length of the cornice and add the cornice trim as shown. The 1 x 6 facia should project about 3/4" below the plywood soffit.

(b) Locate the double 2 x 4 window header by mentally measuring up from the finished flooring. Since the window head casing trim is in line with the door head casing (see figs. 3-32 and 3-33), the height of the door is used as a means of locating the headers for window openings. In this construction, the underside of the door header is 6'10⅞" above the finished floor surface. This is found by adding the following dimensions:

Height of door threshold	7/8"
Height of door	6'8"
Space allowed above door	2"
TOTAL	6'10⅞"

The space allowed above the door is for the thickness of the doorframe, plus space for fitting the frame in place.

(c) After adding the 1/2" ceiling and interior wall covering, draw in the window frame, trim, and cap as indicated in the finished view. Add the plywood soffit and shingle siding. Complete the cornice by adding the quarter-round mold.

(d) Indicate the position of the 2 x 6 ceiling joist by dashed lines.

(3) Step 3

(a) Draw the roof material, gravel stop, and pitch diagram.

(b) Darken outlines and draw material symbols to indicate wood parts in section.

(c) Show vent hole in cornice, and insulation in ceiling space.

(d) Add necessary notes, titles, and dimensions.

Sill section. The sill of a frame building is the wood strip, fastened to the foundation, on which the vertical wall studs rest. The procedure for drawing the sill section shown in figure 3-34 is the same as the procedure just described for the cornice detail. These two details should be developed together in order to space the view properly on the drawing sheet. Note that the bottom sill plate of the 2 x 4 stud wall is set back from the edge of the foundation wall to accommodate the plywood sheating. Indicate materials by using the proper symbols and notes. All dimensioning and lettering should be put in last.

Standard and special parts detail views. It has been explained that it is necessary to detail all parts of a structure that are not fully explained in the main views. However, there are exceptions to this rule. Many items such as windows, doors, trim, stairs, flooring, cabinets, and walls can be obtained ready to incorporate into a building. These standard parts need not be detailed. They are indicated on the main views and in written specifications by name, catalog number, and size. In some instances it may be desirable to detail the framing required for the installation of a standard part, such as a window, but the window itself need not be shown in the view. This would give the designer control over the installation and assure the desired construction. If some special style or shape of construction is wanted, such as a door, window, stair, etc., complete details must be drawn to supply necessary information to the estimator, contractor, and builder, and to the mill or factory where the special parts are to be fabricated.

Standard practices in construction can also save detailing. Written specifications will state fully how the work is to be accomplished and also state where to make changes from the usual procedure. It would not be practical to discuss and illustrate all standard

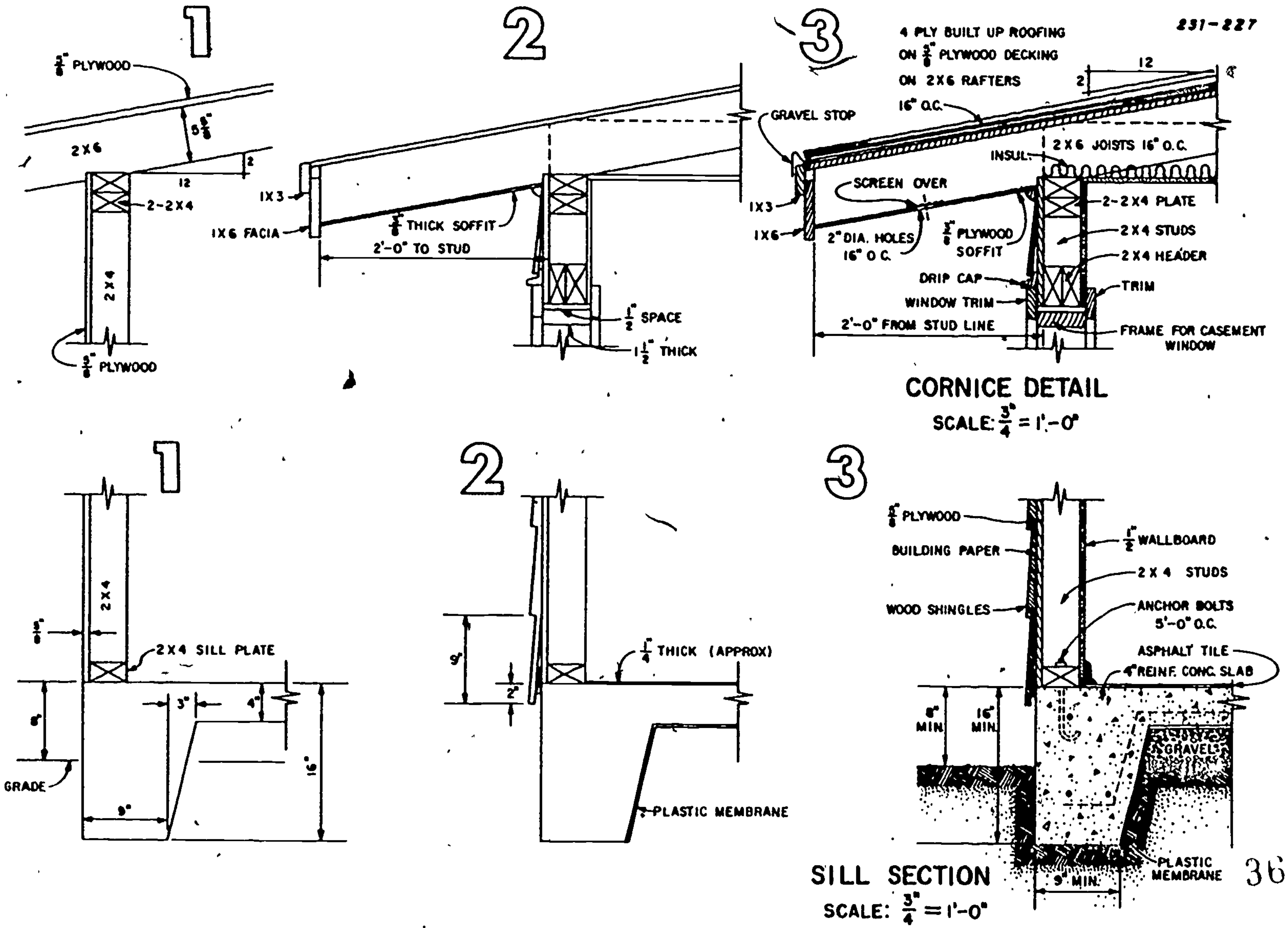

Figure 3-34. Drawing a detail.

and special items in relation to architectural detailing. Through experience in construction work, we can determine whether or not certain parts of the design need detailing. Assuming that it is desired to show the exact relationship between design and construction, there are a number of items which can best be explained in detail views (see fig. 3-35). Features which are usually detailed are as follows:

Foundations and footings.
Sills for doors and windows.
Main wall framing.
Cornice construction and roof trim.
Special molding and trim.
Special doors and windows.
Fireplaces and chimneys.
Stairways.
Special roof framing.
Special partitions.
Built-in cabinets, closets, etc.
Arches and special openings.
Porch and entrance construction.
Exposed panels and beams.

You should study books on building construction and become acquainted with manufacturers' catalogs. Catalogs on lighting equipment, plywood construction, roofing materials, flooring, heating, air conditioning, doors, windows, walls, kitchen appliances, and many other products are furnished free upon request. These catalogs give detailed descriptions and construction data which are invaluable in designing and detailing. Bulletins and pamphlets dealing with many practical aspects of building construction may be obtained from trade associations; college and university departments of architecture; and from Federal agencies, such as the Federal Housing Administration, National Bureau of Standards, and the Government Printing Office.

Specifications. The detail drawings and the written specifications for a proposed building are very closely related. The specification is a written document which supplements the building plans by explaining those points which are not readily explained by drawings. Although it is not a draftsman's job to prepare specifications, he should be familiar with them since they not only control design and materials but are also an important source of information for drawing plans.

Specifications usually begin with a statement of the general conditions of the contract and then proceed to consider the various phases of construction. Each phase of construction is related to a particular operation or material. A separate specification is written for each phase of construction, and these are compiled to parallel the job sequence of the phases. The specifications cover type and quality of material, kind and quality of labor to be used, methods of construction, standards of workmanship, kinds of equipment, delivery and storage of materials, inspection of work, protection of finished work, and many other points which could not be covered if drawings alone were used. Some specifications may be placed on the drawings in the form of notes. Care should be taken that details and drawing notes agree with written specifications.

Exercises (439):

1. If there is not room on the main drawing to place the detail drawing, where is the detail drawing placed?

2. To what scale are details drawn?

3. In detail drawings, is the actual or nominal size of construction materials shown?

4. What is the purpose of written specifications?

440. List the four main types of electrical and electronic drawings and given various symbols used in these drawings, state their meanings.

Electrical and Electronic Graphic Symbols. Electrical and electronic diagrams are generally drawn in the form of freehand sketches by the electrical design engineer. It is the draftsman's job to transform the engineer's sketch into a well-balanced and neatly constructed drawing, making no errors in connections. Electrical and electronic drawings can be classified into four main types:

- Pictorial drawings.
- Wiring diagrams.
- Block diagrams.
- Schematic diagrams.

Graphic symbols play a major part in electrical and electronic drawing. In floor plans of buildings, factories, etc., a simplified set of symbols is used by the architect to show the location of electrical units.

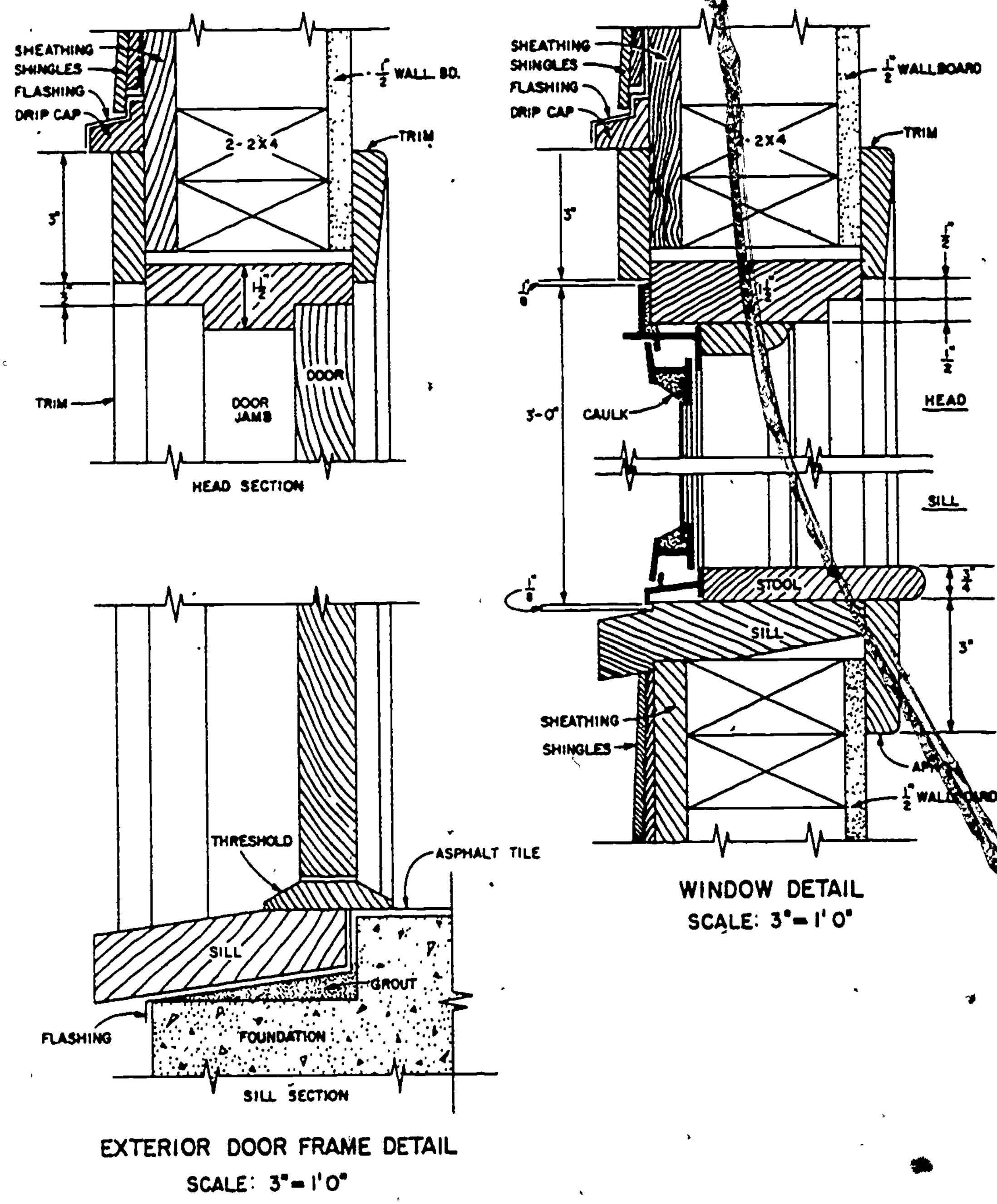

Figure 3-35. Typical detail

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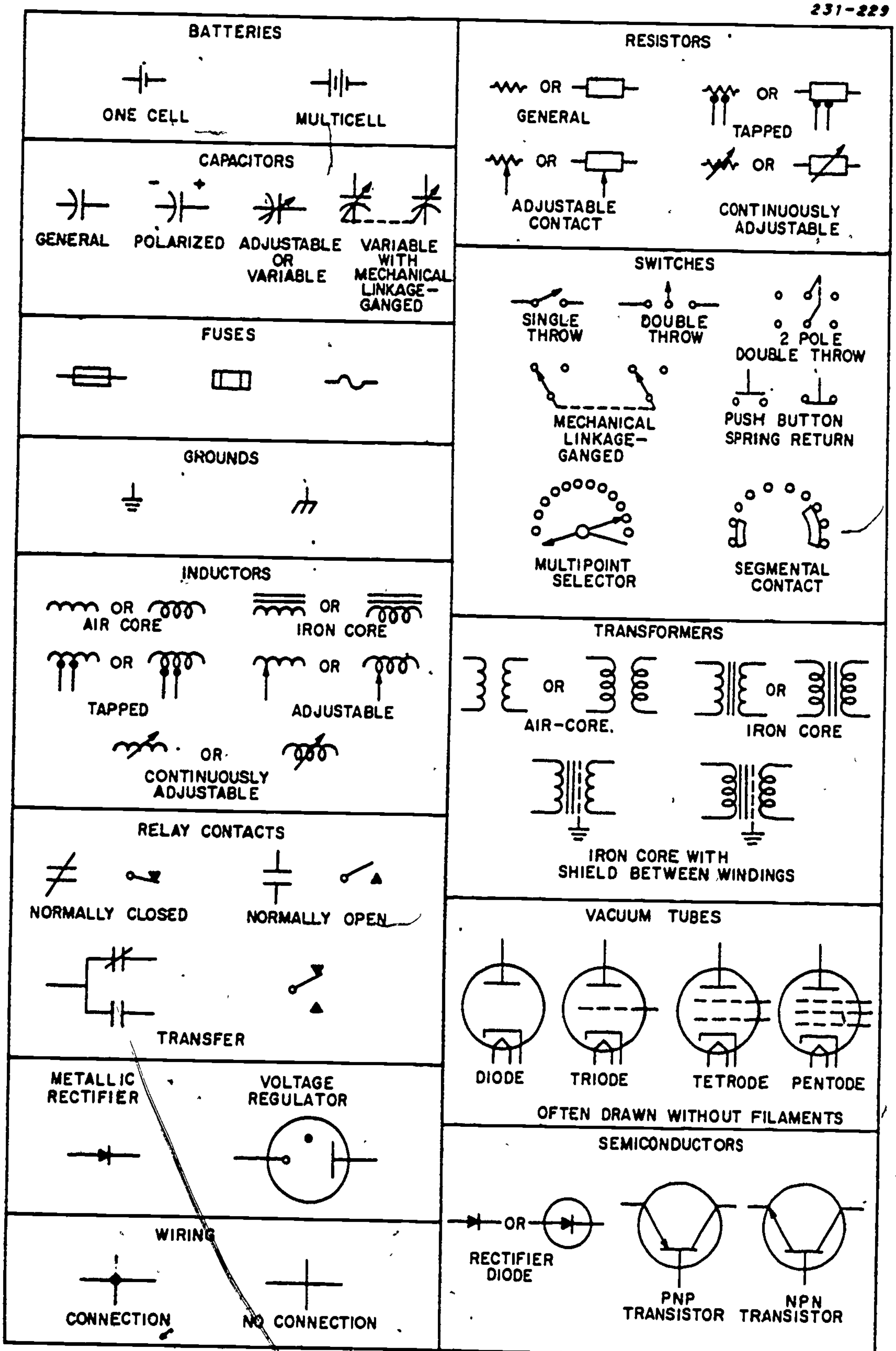

Figure 3-36. Common electrical symbols.

The electrical contractor uses another set of symbols since circuit components and wiring must be broken down to show precise connection details. You have previously seen some of the symbols used by the architect. The symbols used in the following pages apply strictly to electrical and electronic diagrams. Schematic diagrams are comprised entirely of graphic symbols. Wiring diagrams may or may not contain graphic symbols.

Mil—Std—15—1A contains a complete list of electrical and electronic symbols. The title of this publication is *Military Standard, Graphic Symbols for Electrical and Electronics Diagrams.* There are other symbol lists such as the one approved by the American Standards Association (ASA). In some cases, a particular symbol in one list may not be exactly the same as in another list. However, many of them are nearly the same in any list. A study figure 3-36 will familiarize you with a few of the more common graphic symbols.

NOTE: Mil—Std—15—1A contains approximately 51 pages of electrical and electronic symbols. Other symbol lists are about the same length. Your drafting activity will, no doubt, furnish you with some list. But, no matter what list you are furnished, variations in symbols may be encountered in actual practice. For instance, sometimes a particular part is drawn similar to its configuration for clarification.

Symbols may be drawn by construction methods. However, various templates to aid the draftsman in drawing symbols are commonly used. These templates are usually either the stencil or the guiding type. Figure 3-37 shows the actual arrangement of symbols on a typical guiding type electrical-symbol template. With this type of template, and symbol, or part of a symbol, may be combined with another regardless of locations on the template. Thus, it is possible to draw a symbol which does not appear on the template in its complete configuration. For example, a variable resistor may be shown first by drawing the zigzag symbol and then inserting the arrow. Generall, this method applies to other types of templates, although the symbol may differ on some of them.

The actual drawing of graphic symbols, either by construction or use of a template, is not covered in this chapter. Your drafting activity will, no doubt, advise you of their method—there is nothing difficult.

Pictorial drawing. A pictorial drawing may be used to show a component, series of components, or a complete device. Also, a pictorial outline may be used to provide a background for a wiring circuit. A pictorial drawing shows the locations and configurations of components and the positions of the connecting wires. A definition of the work pictorial is "in the form of a picture." An actual photograph is sometimes used, and the parts may be identified by the draftsman by inserting "callouts."

Figure 3-38 shows the pictorial drawing of a simple service meter box. Notice that the lines representing wires are drawn as heavy as, or heavier than, the weight of visible outlines. This heavy line weight is commonly used in pictorial drawings and wiring diagrams and may be used in schematic diagrams to emphasize particular wires. The components and wires may be identified by callouts as shown in the illustration.

Figure 3-39 shows a pictorial, drawn in perspective, which shows the positions of some of the electrical components and wiring of an automobile. Isometric and oblique drawings also may be used to provide backgrounds for wiring circuits.

Notice that the exact connections of each wire are shown in figure 3-38, but not in figure 3-39. It is obvious that a pictorial drawing, such as in figure 3-39, must be supplemented by either a wiring or schematic diagram to show the connection details.

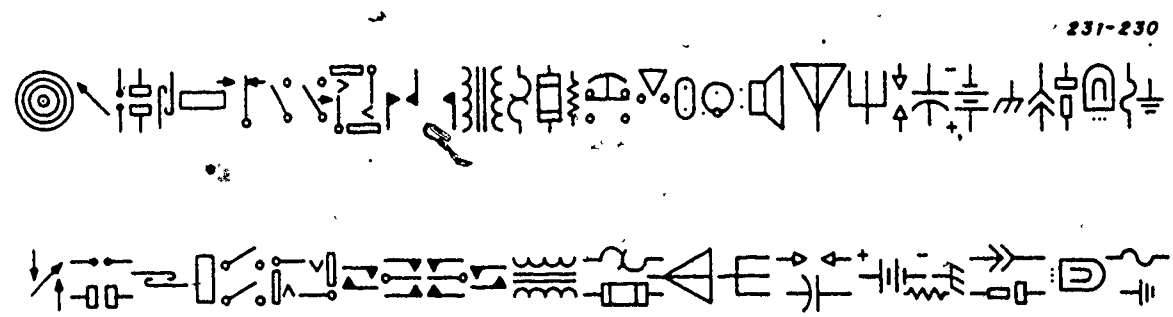

Figure 3-37. Arrangement of symbols.

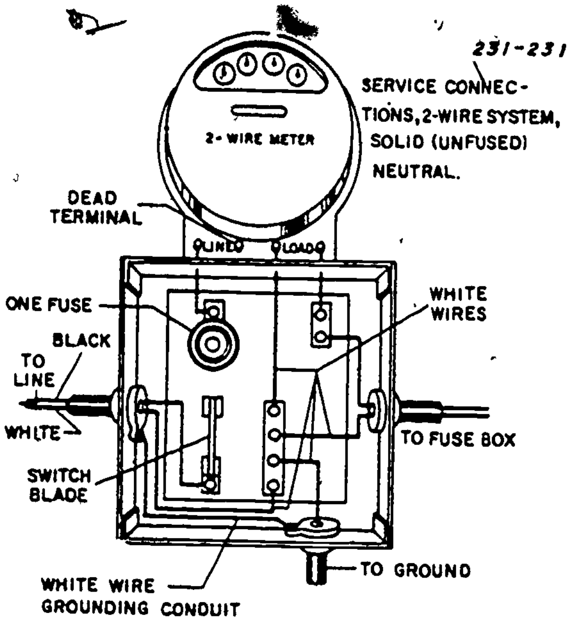

Figure 3-38. Pictorial drawing of a simple service meter.*

A wiring diagram of one of the automobile circuits is shown in figure 3-40 and discussed in a following paragraph.

Several factors should be considered when you are determining the necessity for a pictorial drawing. The use which will be made of the drawing must be recognized, and the technical background of the interpreter must be considered. It is usually the obligation of the engineer or draftsman to make the decision.

Wiring diagrams. The term "wiring diagram" pertains to several types of drawing. Actually, a pictorial drawing such as shown in figure 3-38 could be considered a wiring diagram, since it clearly shows the wiring connections to the circuit components. However, the exact location of the components, as shown in figure 3-38, is not required in a wiring diagram. The following three illustrations show the general concepts of this type of drawing.

a. Wiring diagram of automobile electrical circuit. Figure 3-40 shows a typical wiring diagram

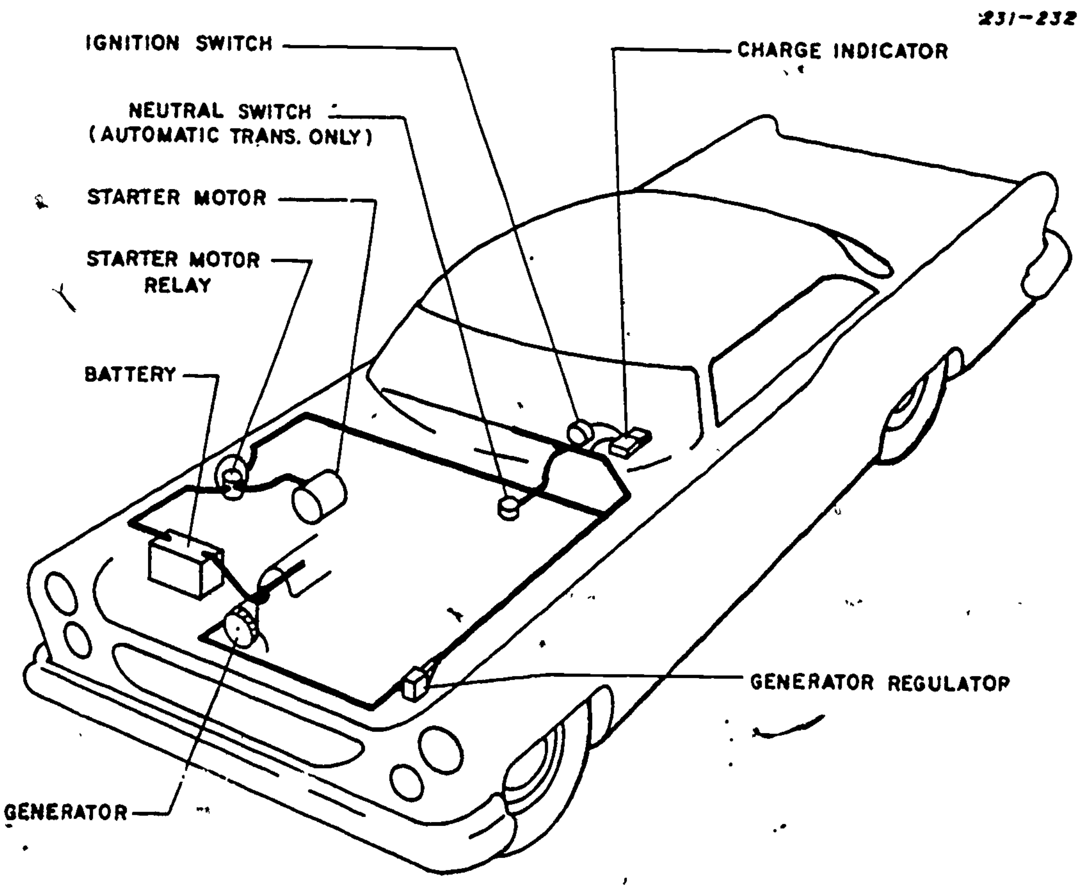

Figure 3-39. Auto electrical circuit.

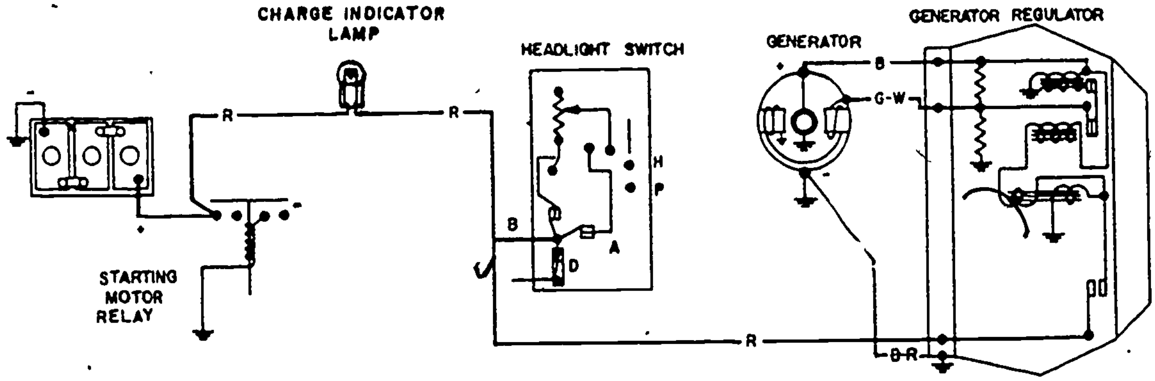

Figure 3-40. Wiring diagram for auto electrical circuit.

of the power circuit of the automobile (fig. 3-39). In this type of wiring diagram, the circuit components are represented by several methods. Notice, for instance, that the battery actually is pictorial; the starting motor relay is represented by a symbol; and the generator regulator can be classed as schematic (covered later in this chapter). Thus, you can see that there is no definite set of rules for drawing the components in a wiring diagram. However, in all cases, the wiring must be clearly shown, and the drawing constructed in a well-balanced manner.

Because of the various circuits used in many electrical devices, wire color coding is often used. This is shown in figure 3-40 by R, B, G-W, and B-R. The color code may be placed on the drawing as a note, such as:

Wiring Color Code

R	RED
B	BLACK
G-W	GREEN-WHITE BAND
B-R	BLACK-RED BAND

Other notations which are necessary to explain the circuitry may be placed on the drawing. Always allow adequate space for notes when planning a drawing.

b. Symmetrical layout of a wiring diagram. Figure 3-41 shows the wiring diagram of an electronic power supply circuit as extracted from a technical order. The drawing is laid out in a symmetrical manner. Notice that the circuit components, tube socket contacts, and terminal connections are identified. When additional information, such as notes, callouts, and electrical values, is required, sufficient space must be allotted for this information when laying out the drawing. If the original drawing must be made to exact overall dimensions, the draftsman first should lay out the pencil drawing to approximate proportions and then make necessary revisions (increasing or decreasing scale) until the required overall dimensions are obtained. But, as often is the case, the drawing may be made to any convenient size when it is to be either enlarged or reduced by a photographic method.

In any type of electrical drawing, the draftsman should plan the layout so that the number of "bends" and "crossovers" of the wires are held at a minimum. Figure 3-42 shows how some bends and crossovers could be eliminated in figure 3-41. This revision is shown in figure 3-42 by the heavy and the dashed lines. The heavy lines represent the change in the position of a connection, whereas the dashed lines represent the original positions (fig. 3-41) to be erased. For instance, notice that two bends are eliminated in the wire from contact 4 of tube socket XV 101.

c. Interconnection type of wiring diagram. Figure 3-43 shows a portion of an interconnection diagram as extracted from a technical order. This type of drawing, sometimes called a *highway diagram*, is commonly used in showing the wiring of switchboards, panels, and the cabling between electrical units. The heavy lines represent the so-called *highways*. Notice that the wires or feed lines (light lines) merge into the heavy lines, thereby eliminating the terminal-to-terminal connections of the wires in a point-to-point drawing. The direction which a feed line takes when it enters a highway is indicated by the slanted part of the line.

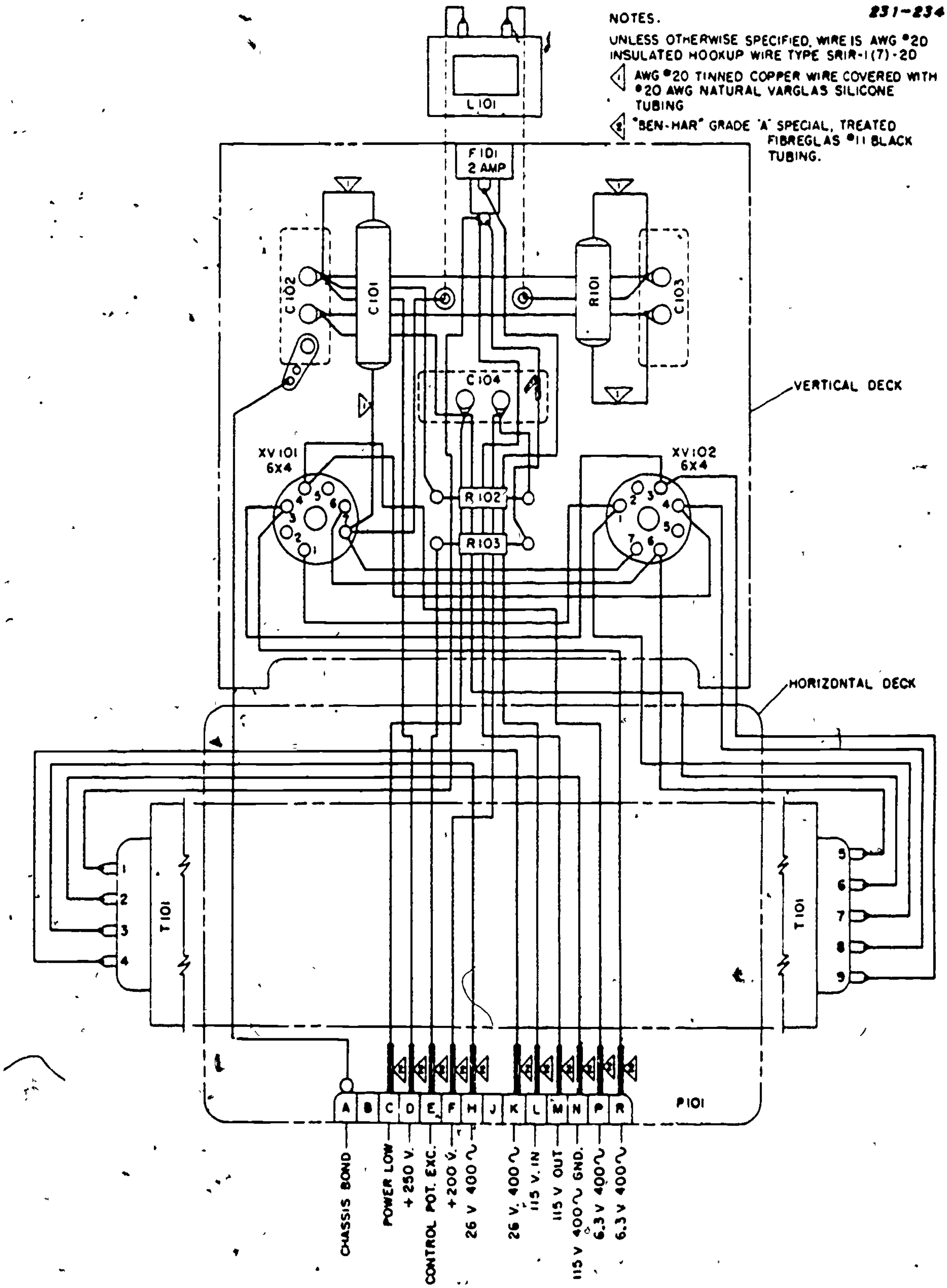

Figure 3-41. Wiring diagram of electronic power supply.

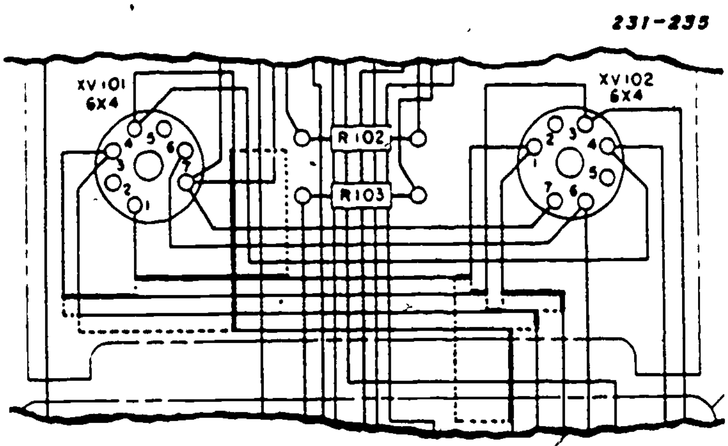

Figure 3-42. Rearrangement of wiring.

Exercises (440):

1. What are the four main types of electrical and electronic drawings?

2. What is indicated by polarity (+ and -) in a capcitor symbol? (See fig. 3-36.)

3. The end of three arrows which cut three capacitor symbols respectively are connected by dashed lines. What does this represent? (See fig. 3-36.)

441. Identify particular characteristics as belonging to either a block or a schematic diagram.

Block Diagram. A block diagram is a drawing which shows the function of a unit or a complete system in simplified form. The major components (or stages) are indicated by blocks, and the path which the electrical energy travels from input to output is shown by arrowheads on the connecting lines. The path and direction of electrical energy are commonly called *data flow*. Block diagrams are used in conjunction with both wiring and schematic diagrams. The diagram shown in figure 3-44 (extracted from a technical order) shows the receiver circuitry of a typical radar system.

In figure 3-44, each individual stage is shown in block form. There is no set rule for the size or shape of a block; sometimes blocks are drawn in circular or triangular forms. Notice that the arrowheads show the direction of data flow from input to output, each stage is labeled, and the vacuum tubes are identified. The information inserted inside a block depends entirely on the particular requirement. Usually, line weights for the blocks are about the same as for visible outlines. However, different line weights may be used in a diagram for purposes of emphasis.

Schematic Diagrams. A schematic diagram is a drawing which traces the signal or signals through an electrical circuit and shows the functional relationship (technical details) of the circuit elements. The elements (parts or components) are shown by symbols such as are prescribed in the military standard. All the required technical circuitry details are included. Since the engineer is particularly interested in the relationship of electrical (or electronic) components, the schematic diagram is the one most often seen on engineering drafting boards.

The layout of a schematic diagram should be considered as a creative design. The drawing must be constructed with regard to symmetry and balance. That is, it must be drawn uniformly by the precise alignment and regularity in spacing of symbols; and, of course, it must be drawn accurately and neatly. Following are some important facts for preparing a schematic diagram:

a. A symbol may be drawn to any proportional size that fits a particular drawing, considering the possibility of reduction or enlargement.

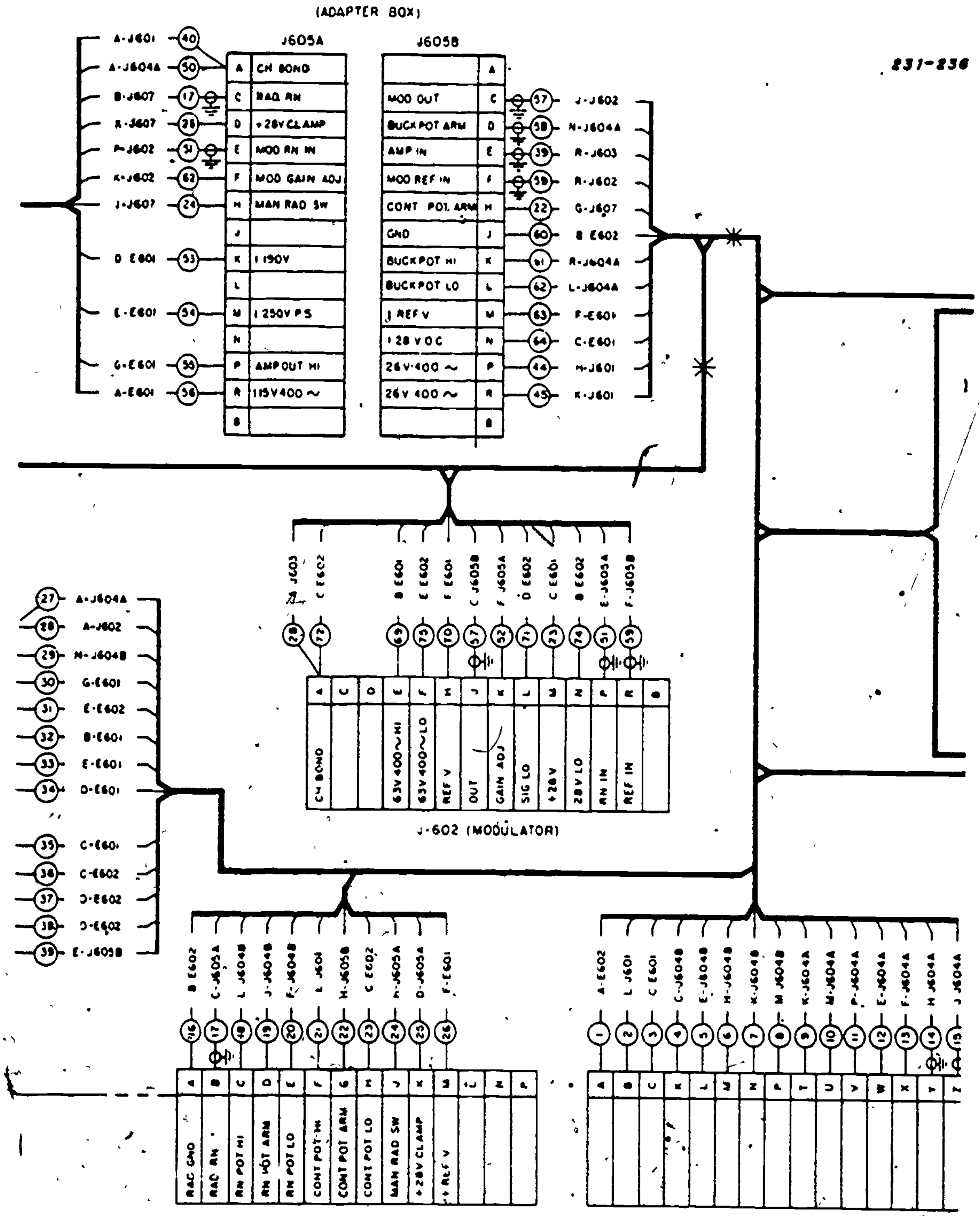

Figure 3-43. Interconnection type wiring diagram.

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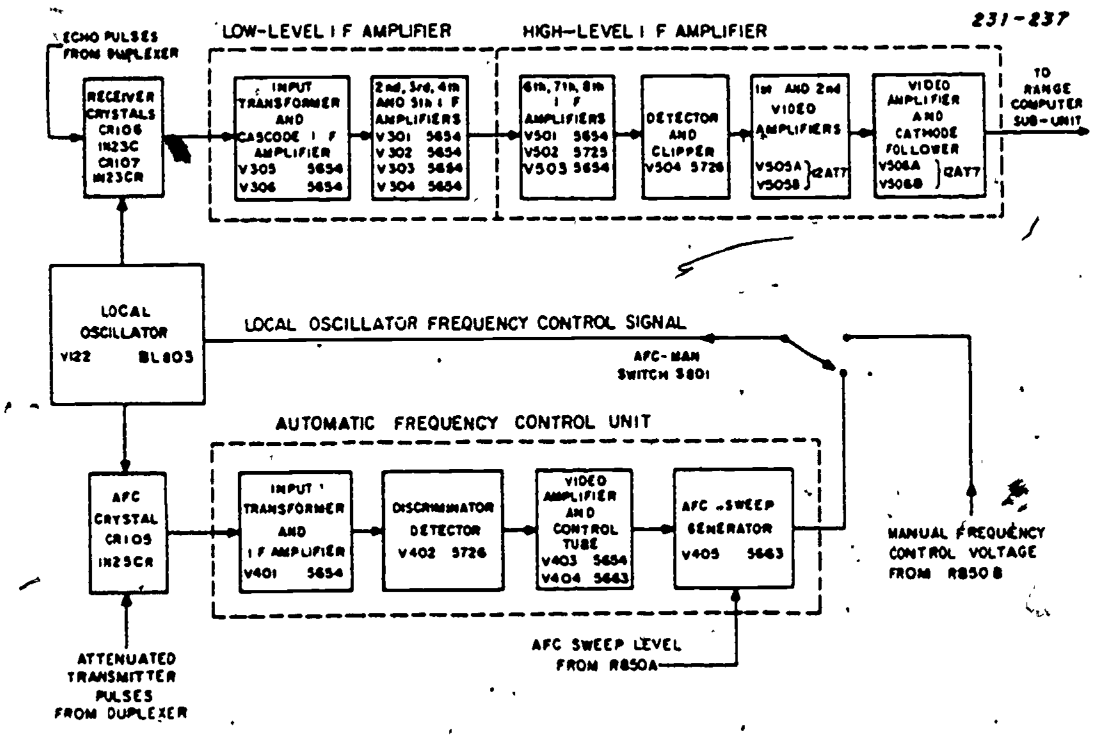

Figure 3-44. Block diagram of radar receiver.

b. The weight of a line has no bearing on the meaning of a symbol. Occasionally, extra heavy lines are used for emphasis.

c. The angle at which a lead is connected to a symbol has no significance unless otherwise noted on the drawing.

d. The orientation of a symbol in a diagram does not change its meaning. That is, a symbol may be rotated 90° or 180° from the position in which it appears in a symbols list.

e. Lines which represent the connections are usually drawn horizontally and vertically, but they may be drawn at any angle when particular circumstances require it.

f. Symbols should be uniformly spaced throughout the drawing so that no congested areas appear.

g. Details of type, rating, etc., may be placed adjacent to any symbol. When this is required, care must be exercised in planning the drawing to allow space for the letters and figures.

h. Lettering must be faultless. Poor lettering on a schematic or any electrical drawing cannot be condoned in either a design office or in a drafting room.

i. Usually the signal path is from left to right. That is, the source of energy, such as the antenna of a radio receiver, is at the left; and the output which may be a loudspeaker is at the right. In large drawings (two or more horizontal alignments of stages), the input usually appears at the upper left and the output at the lower right.

Schematic diagrams of a radar unit and a stage. Since schematic diagrams are designed to show the technical details of a circuit, these diagrams are usually required in conjunction with other type drawings. Often a small portion of a complete schematic, such as a stage, is shown separately in schematic form for technical purposes. Examples of these practices follow. As you study the illustrations, notice how the general principles of schematic drawings are applied in each case.

a. Schematic diagram of a unit. Figure 3-45 shows the schematic diagram of the automatic frequency control unit which is represented in block form in figure 3-44. Notice that the symbols are laid out in a manner which points toward uniformity. Each symbol is identified by the part number; and the rating of each part is shown, except for the tubes. The "V" numbers identify the tubes in accordance with the technical order; the numbers shown in conjunction with the "V" numbers are the commercial nomenclatures. Since ground is a common connection, it is represented by the heavy

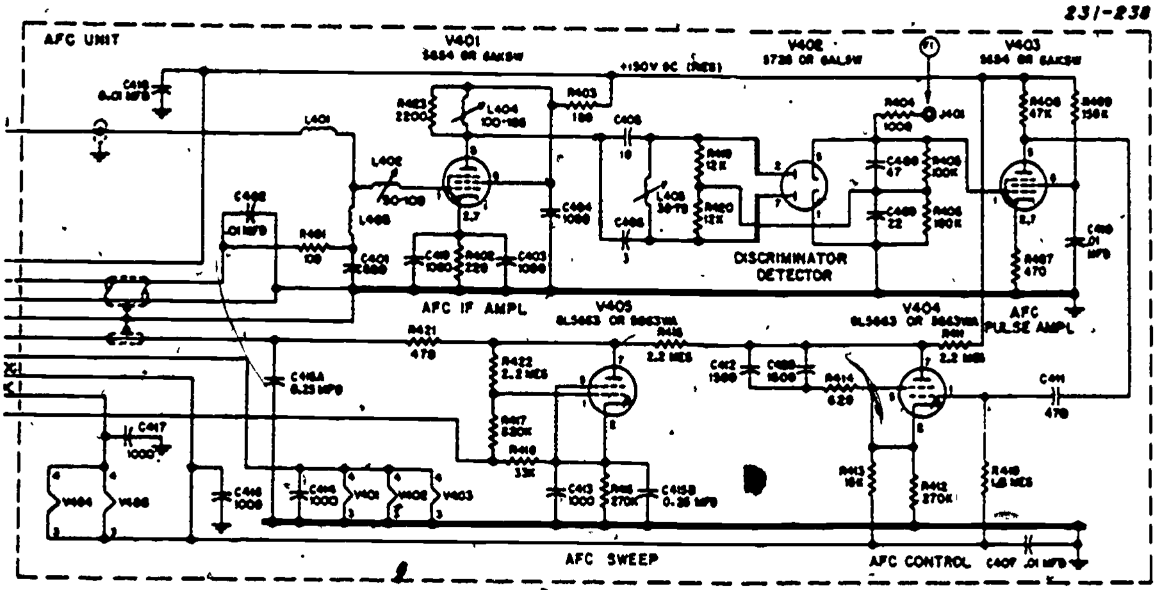

Figure 3-45. Schematic diagram—automatic frequency control.

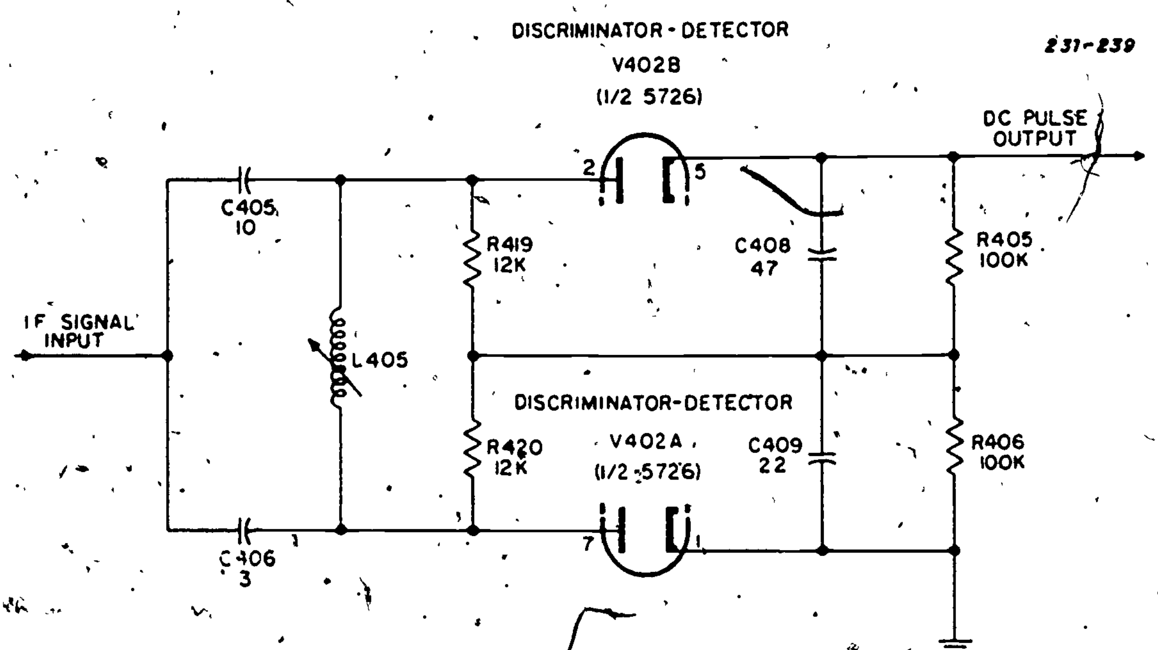

Figure 3-46. Schematic diagram—discriminator detector stage.

horizontal lines; however, use of heavy lines for a common connection is optional. Further, note that the filaments of the tubes are shown separately at the bottom of the drawing to avoid congestion. For instance, the filament of tube V401 is labeled "V401."

b. Schematic diagram of a stage. Figure 3-46 is the diagram of the discriminator-detector stage shown in both figures 3-44 and 3-45. In a technical publication, a stage is often shown individually for analysis purposes. Notice how well this diagram is drawn in regard to symmetry and balance.

As you can see, the circuitry is identical to the detector-discriminator stage in figure 3-45. However, the drawing is a little different. Since tube V402 is a dual-purpose tube (two tubes in one glass envelope), it is drawn in two sections, A and B, resulting in a well-balanced drawing. Notice that the symbol representing the variable inductance, L405, is drawn in the alternate method to that in figure 3-45—this is a matter of choice.

Schematic diagram drawing. You may be called upon to make a finished schematic drawing from an engineer's rough sketch. Even though the sketch will show the elements correctly connected, some of the principles just listed may be neglected. It is the job of the schematic draftsman to prepare a finished drawing which is based on these principles and which reflects symmetry and balance.

Figure 3-48 shows the finished schematic diagram laid out by the draftsman from the rough sketch in figure 3-47. The draftsman, who laid out the finished schematic diagram, had to use visualization and initiative, keeping in mind the following practices for good schematic drawing:

a. Determine scale or size of drawing.
b. Divide drawing area into uniform sections.
c. Confine symbols within their respective sections.
d. Insure equal proportioning of symbols.
e. Avoid crowding in any area.
f. Allow sufficient space for lettering.
g. Correct any drawing error made on the rough drawing.

If you have trouble interpreting the symbols and wiring connections, check with the originator of the sketch.

You probably realize by this time that there is no "cut-and-dried" procedure for drawing a schematic diagram. You must study the rough sketch to determine how to lay out the drawing. The following steps which are offered as suggestions pertain to figure 3-48.

(1) Draw the horizontal center construction line (dashed lines in the illustration) for tubes V1 and V2 which are in the main part of the circuit. When a series of tubes progress horizontally, they should be aligned on the horizontal axis.

(2) Draw tube V1.

(3) Lay out the components on the left of tube V1 in a symmetrically spaced manner-both horizontally and vertically—as shown in the illustration.

(4) Draw horizontal construction lines as guides for alignment of the components to be drawn

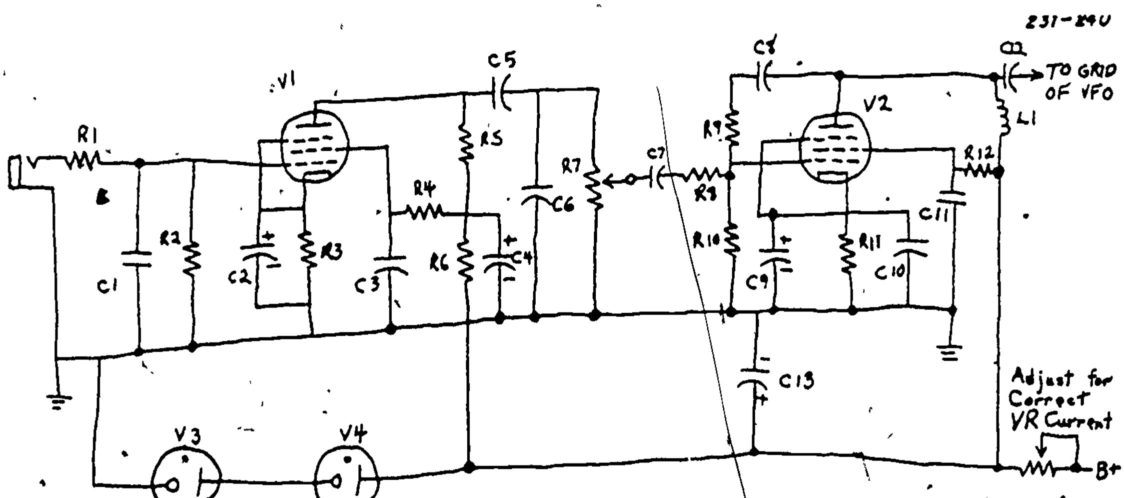

Figure 3-47. Rough schematic diagram.

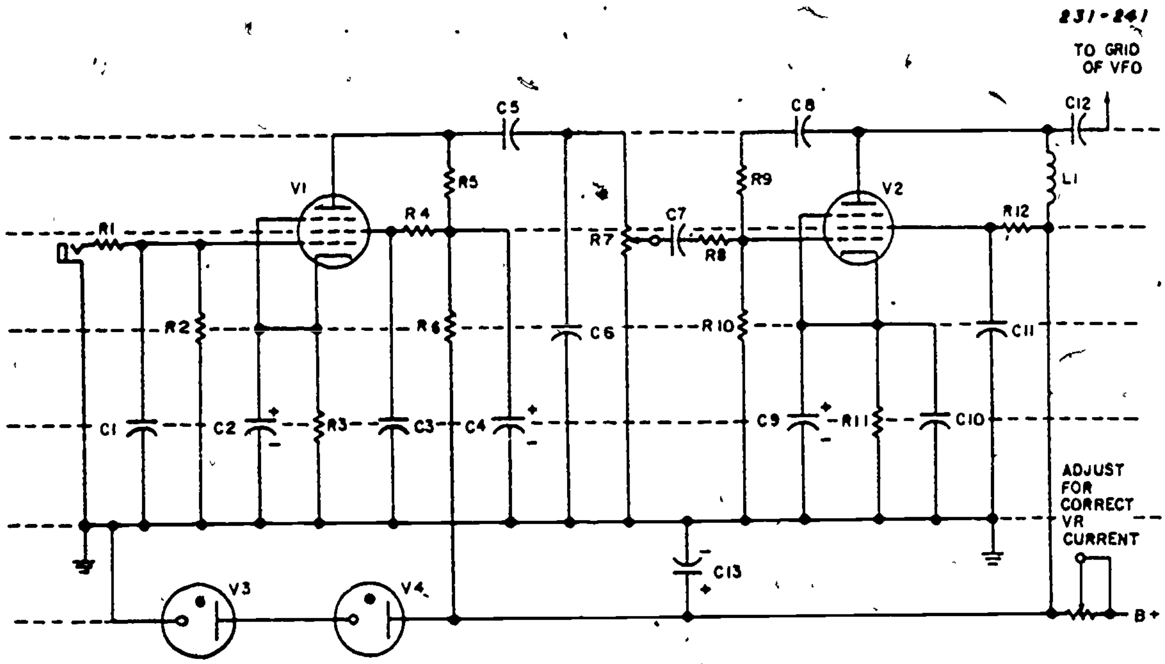

Figure 3-48. Schematic diagram prepared from rough sketch.

between tubes V1 and V2. Draw these components in an evenly spaced manner.

(5) Draw tube V2, centering it on the horizontal tube center construction line.

(6) Continue in the same manner until the drawing is completed.

NOTE: Of course, in the finished drawing all construction lines are erased, as in the other types of drawing.

Notice the drawing errors (oversights) in figure 3-47 which the draftsman "caught" and corrected in figure 3-48. Here are several of them:

- Corrected symbols for C1, C11, and C13.
- Inserted missing connection dots in the finished drawing. For instance, notice that the connection from V3 to the ground wire is missing a connection dot in figure 3-47.
- Improved the configuration of tube symbols. (Cathodes should not touch envelope.)

In overall dimensions to which a schematic diagram is drawn depend upon the way it is to be reproduced. The dimensioning of a drawing was discussed under "Wiring Diagrams."

Exercises (441):

1. What type of diagram is used to show the function of an electronic system in simplified form?

2. All the elements are shown by symbols in a ______ diagram.

ANSWERS FOR EXERCISES

CHAPTER 1

Reference:

400 - 1. Four permanent fasteners are nails, rivets, wood screws, and welding. Four nonpermanent fasteners are pins, keys, screws, and bolts.

400 - 2. Penny

400 - 3. Casing nail.

400 - 4. Common nail.

400 - 5. Brad.

401 - 1. *b.*

401 - 2. *e.*

401 - 3. *c.*

401 - 4. *d.*

401 - 5. *f.*

401 - 6. *a.*

402 - 1. Multiple threads.

402 - 2. The buttress thread.

402 - 3. Knuckle threads.

402 - 4. The acme thread.

403 - 1. Square.

403 - 2. V.

403 - 3. Square.

403 - 4. Simplified.

403 - 5. V.

403 - 6. Regular.

403 - 7. Acme.

403 - 8. Square.

403 - 9. Acme.

404 - 1. One thread series is distinguished from another by the number of threads per inch.

404 - 2. "A" symbolizes external thread; "B" symbolizes internal thread.

404 - 3. Tapering allows the first threads to be engaged by hand and insures a tight joint when wrench tightened.

404 - 4. 1/4-20 UNC-2B. Probably for general use in soft materials where rapid engagement is desirable.

405 - 1. Nuts and bolts are classified by weight and by finish.

405 - 2. W (Width across flats), H (Height of head), and T (Thickness of nut).

405 - 3. Diameter, length, thread type, finish, and head type.

406 - 1. By the head shape and use.

406 - 2. 5/8-11 UNC-2A x 2 FIL HD CAP SC.

406 - 3. A machine screw is usually smaller, ranging from .060 to 1 inch in length and rarely made with hex or socket heads, and has unchamfered ends.

406 - 4. A set screw is used to prevent rotary motion between two machined parts.

407 - 1. A key is a square, rectangular, or semicircular piece of metal which is inserted in a key way cut in a shaft and pulley.

407 - 2. A pin is either cylindrical or round tapered and performs the same purpose as a key, but for lighter loads.

407 - 3. Compression, tension, and torsion.

408 - 1. (1) *m*, (2) *l*, (3) *k*, (4) *i*, (5) *h*, (6) *g*, (7) *a*, (8) *e*, (9) *d*, (10) *c*, (11) *j*, (12) *q*, (13) *n*, (14) *p*, (15) *o*.

409 - 1. *a.* The diameter of the base of the pitch cone.
b. The angle formed by an element of the pitch cone and the cone axis.
c. The pitch cone angle minus the dedendum angle.
d. The width of the gear tooth.
e. The circumference of the pitch circle divided by the number of teeth.

410 - 1. Assembly drawings.

410 - 2. A detail drawing.

410 - 3. Modification drawing.

411 - 1. (1) The size of paper used, (2) the necessity for showing small details clearly, S(3) and the amount of dimensioning to be added to the view.

411 - 2. Double size, full size, one-half size, one-quarter size, or one-eighth size.

412 - 1. (a) Name of the part or structure.
(b) Name and location of the organization.
(c) Scale or scales used.
(d) Date.
(e) Name or initials of draftsman, tracer, checker, and head engineer.
(f) Drawing number.

412 - 2. Application and Quantity Required section.

CHAPTER 2

413 - 1. A skew line is a line which is inclined to all principal planes.

413 - 2. (1) Consult two views.
(2) Project the point of intersection from one view to the other.

413 - 3. To establish the point of intersection between a line and a plane, draw the line to the plane in the view which shows the plane as an edge, then project the apparent point of intersection to the desired view.

413 - 4. The frontal and profile planes are intersected.

413 - 5. 6.

414 - 1. The intersection of a plane and a cylinder is determined by finding the intersection that a number of lines on the plane make with the surface of the cylinder. The line of intersection can then be drawn through these points.

414 - 2. *a.* The plane is angular to the axis and all elements of the cylinder.

b. The plane is perpendicular to the axis of the cylinder.

c. The plane is parallel to the axis of the cylinder.

414 - 3. The shape of the intersection between a plane and a cone is determined by the relationship between the plane and the axis, or to the elements of the cone.

414 - 4. See figure 1. The side view is shown there. The illustration also shows the lines of construction used to determine the view and the intersection.

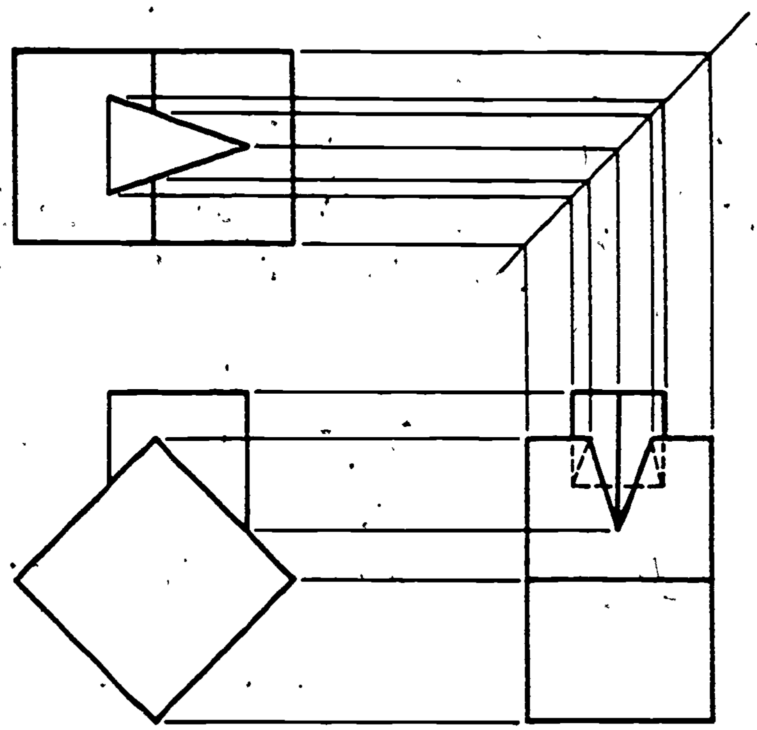

Figure 1. Objective 414, answer for exercise 4.

415 - 1. Plane, single-curved, warped, and double-curved.
415 - 2. The prism, pyramid, cylinder, and cone.
415 - 3. The true length of a line can be found by revolving the line parallel to one of the principle planes and by measuring its projection in that plane, by drawing an auxiliary view or by drawing a true-length diagram.

416 - 1. See figure 2.

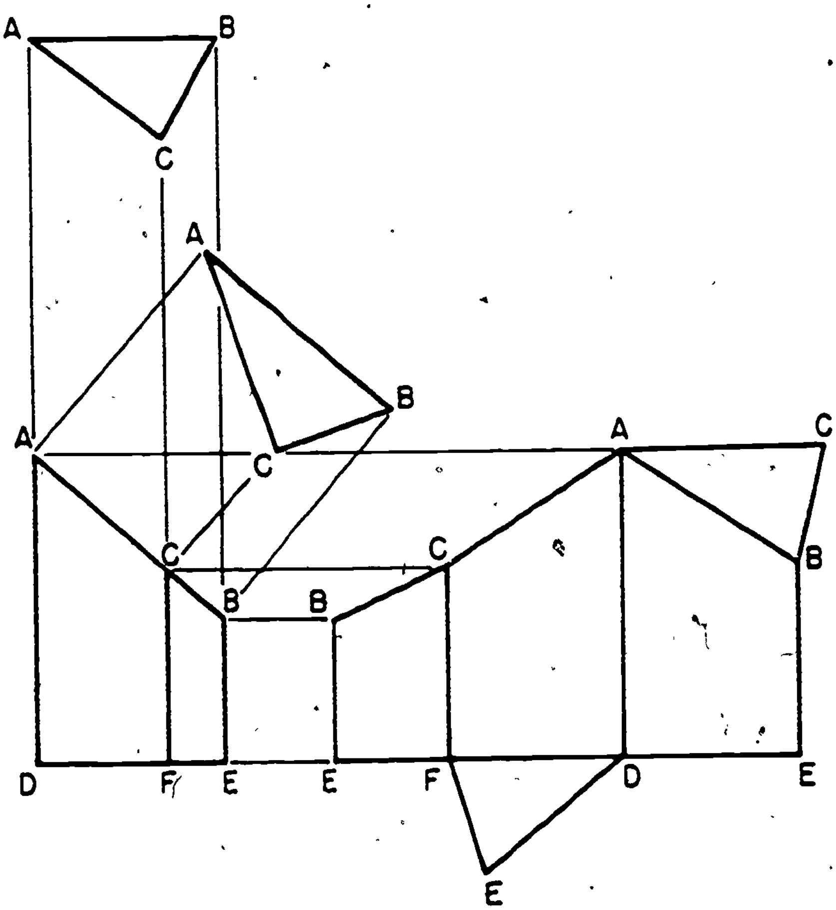

Figure 2. Objective 416, answer for exercise 1.

416 - 2. See figure 3.

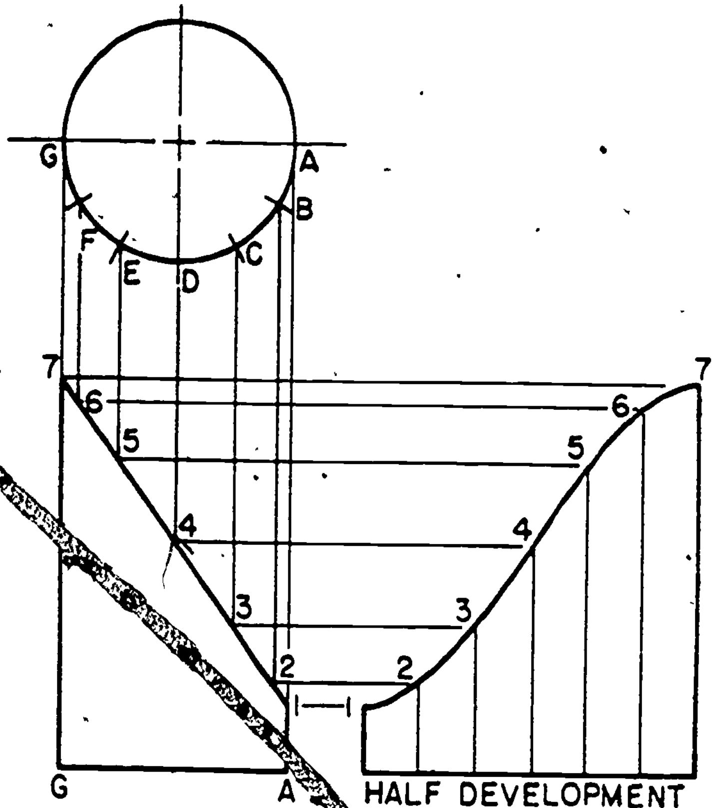

Figure 3. Objective 416, answer for exercise 2.

417 - 1. Because the elements of these forms intersect at a common point.

417 - 2. A truncated pyramid is formed by cutting off the upper portion of a pyramid.

417 - 3. See figure 4.

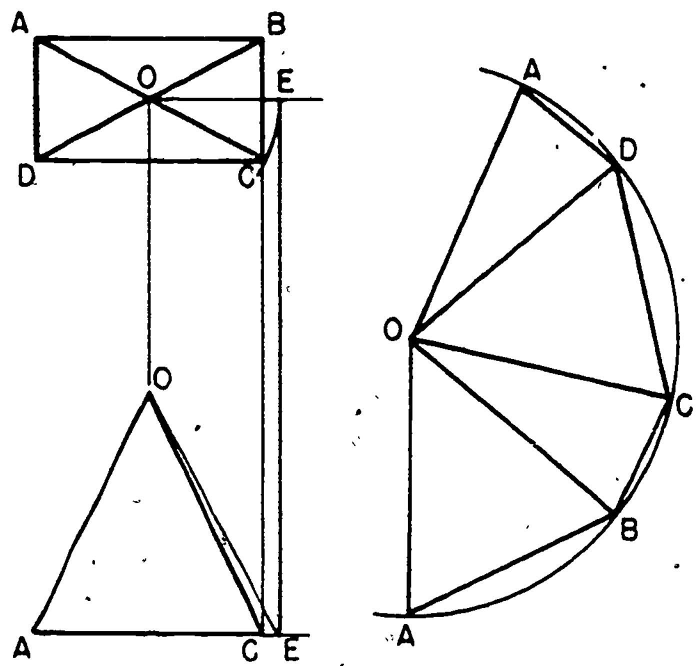

Figure 4. Objective 417, answer for exercise 3.

418 - 1. This means that the surface is assumed to be made up of a large number of triangular strips.

418 - 2. Warped surface; oblique cones.

CHAPTER 3

419 - 1. A member is a unit part of a larger structure.

419 - 2. A girder is a heavy member spanning between columns.

419 - 3. A truss is a built-up member designed to support loads over long spans.

419 - 4. A pier rests on the footings and supports vertical columns or horizontal girders; also it is an intermediate support for the adjacent ends of two bridge section.

419 - 5. A joist is lighter and is spaced closer together. The ends of joists are supported by beams.

420 - 1. Metal connections are used in conjunction with bolts to make wood-to-wood joints stronger.

420 - 2. Tensile.

421 - 1. Nature and size.

421 - 2. Columns, girders, beams, and joists.

421 - 3 Symmetrical, centerline.

422 - 1. Dimensions must always be checked for accuracy

422 - 2. The frequent use of two scales.

422 - 3. A skeleton diagram usually coincides with the front view centerlines of the truss members and shows detail member with respect to the other members.

423 - 1. Fabrication is the process of cutting, drilling, and assembling steel parts into members.

423 - 2. Erection drawings are simplified, small-scale diagrams which show the mark, location, and position of each member in the structure.

423 - 3. Falsework is a term used for the construction of a temporary support for large steel structures. Falsework is rarely used on structures under 40' high.

424 - 1. Width by thickness by length.

424 - 2. Flange width by stem height by weight per foot by length.

424 - 3. Nominal depth by weight per foot by length.

425 - 1. Triangular framing and rectangular framing.

425 - 2. Numbers are assigned to lines running in one direction and letters to lines running at right angles.

425 - 3. Triangular framing is used to construct bridges, roof trusses, etc., while rectangular framing is used in buildings or other structures mainly composed of vertical and horizontal members.

425 - 4. A heavy line.

426 - 1. Structural members are usually connected by small connection angles which are bolted, riveted, or welded in position.

426 - 2. Beams and girders are detailed horizontally; columns are detailed vertically.

427 - 1. Shop rivets are detailed by showing the diameter of the rivet head, while field rivets are detailed by showing the diameter of the rivet shank.
427 - 2. The primary reason for riveting two members is to transfer a load from one to the other.
427 - 3. On small-scale drawings, centerlines may be used to indicate rivet positions.

428 - 1. A weld symbol indicates the type of weld. A welding symbol indicates the information required.
428 - 2. Size dimension of a weld is shown to the left of the symbol and weld spacing is shown to the right.

429 - 1. Columns are poured and allowed to set, so shrinkage can take place before the floor system is poured.
429 - 2. Expansion joints are provided in large concrete structures to allow the mass to expand and contract with temperature changes.
429 - 3. This system provides a greater load-carrying capacity for a given amount of concrete and steel.

430 - 1. Because it shows the location of columns, beams, and joists.
430 - 2. By a marking system that is used throughout.

431 - 1. Section views are necessary to show the shape of members and the typical arrangement of reinforced steel.
431 - 2. The use of bolsters or chairs is indicated in specifictions or in beam and slab schedules.
431 - 3. The inside radius of the hook should be 3¾ inches.

432 - 1. The term "tied columns" refers to vertical reinforcing rods held together at specified intervals by horizontal bars or ties.
432 - 2. In the schedules.
432 - 3. The rise of a stairway is the vertical distance between floors or between a floor and an intermediate platform. A riser is the vertical face of a step.

433 - 1. By locating the corners of the building at specific distances from established reference points.
433 - 2. The foundation.
433 - 3. A floor plan is a cross-section view of the building.
433 - 4. An elevation is the exterior view of any structure.

434 - 1. No view should be called detail unless it is drawn enlarged and shows construction features clearly.
434 - 2. Foundations, walls, doors, and window sections.
434 - 3. Orthographic and pictorial.
434 - 4. The manufacturer.

435 - 1. The size of the lettering is controlled by the size of the object in relation to the size of the drawing paper and the amount of detail.
435 - 2. Since there are numerous "in-line" dimensions, a continuous line is easier and faster to make and leaves less chance for mistakes in reading.
435 - 3. Dimension to the centerline of partition walls.

436 - 1. The architect scale is an equation scale and the dimensions are usually expressed in feet and inches.
436 - 2. The part to the left of the zero is called the extension scale, the part to the right the primary scale.
436 - 3. Size of the object, size of the drawing paper and the desire to show details clearly.
436 - 4. Graphic scales are generally placed on drawings where complete dimensions are not required. Equation scales are usually placed directly under the views to which they apply.

437 - 1. The front of the building is always faced toward the bottom edge of the sheet
437 - 2. It is easier to correct if an error should occur.
437 - 3. Exterior walls are dimensioned from corner to corner, interior walls from centerline to centerline.

438 - 1. The floor plan is used to project as many main points of the building as possible.
438 - 2. By projecting from the floor plan.

439 - 1 Detail drawings are then placed on a sheet containing nothing but detail drawings.
439 - 2. Details are scaled as large as possible ranging ½" = 1'0" to full scale.
439 - 3 Actual size.
439 - 4. To explain those points which are not readily explained by drawings.

440 - 1 Pictorial, wiring, block, and schematic diagrams.
440 - 2. A polarity sign indicates a polarized capacitor.
440 - 3. The dashed lines indicate mechanical linkage: that is, the three capacitors rotate together.

441 - 1. Block diagram.
441 - 2. Schematic.

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STOP– 1. MATCH ANSWER SHEET TO THIS EXERCISE NUMBER. 2. USE NUMBER 1 OR NUMBER 2 PENCIL.

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EXTENSION COURSE INSTITUTE
VOLUME REVIEW EXERCISE
GRAPHICS SPECIALIST

Carefully read the following:

DO'S:

1. Check the "course," "volume," and "form" numbers from the answer sheet address tab against the "VRE answer sheet identification number" in the righthand column of the shipping list. If numbers do not match, take action to return the answer sheet and the shipping list to ECI immediately with a note of explanation.
2. Note that numerical sequence on answer sheet alternates across from column to column.
3. Use a medium sharp #1 or #2 black lead pencil for marking answer sheet.
4. Circle the correct answer in this test booklet. After you are sure of your answers, transfer them to the answer sheet. If you *have* to change an answer on the answer sheet, be sure that the erasure is complete. Use a clean eraser. But try to avoid any erasure on the answer sheet if at all possible.
5. Take action to return entire answer sheet to ECI.
6. Keep Volume Review Exercise booklet for review and reference.
7. If *mandatorily* enrolled student, process questions or comments through your unit trainer or OJT supervisor.
   If *voluntarily* enrolled student, send questions or comments to ECI on ECI Form 17.

DON'TS:

1. Don't use answer sheets other than one furnished specifically for each review exercise.
2. Don't mark on the answer sheet except to fill in marking blocks. Double marks or excessive markings which overflow marking blocks will register as errors.
3. Don't fold, spindle, staple, tape, or mutilate the answer sheet.
4. Don't use ink or any marking other than a #1 or #2 black lead pencil.

NOTE: NUMBERED LEARNING OBJECTIVE REFERENCES ARE USED ON THE VOLUME REVIEW EXERCISE. In parenthesis after each item number on the VRE is the *Learning Objective Number* where the answer to that item can be located. When answering the items on the VRE, refer to the *Learning Objectives* indicated by these *Numbers.* The VRE results will be sent to you on a postcard which will list the *actual* VRE *items you missed.* Go to the VRE booklet and locate the *Learning Objective Numbers* for the items missed. Go to the text and carefully review the areas covered by these references. Review the entire VRE again before you take the closed-book Course Examination.

Multiple Choice

1. (400) Which of the following fasteners are not classified as permanent?

   a. Nails.
   b. Set screws.
   c. Rivets.
   d. Wood screws.

2. (400) Which of the following nails has the smallest diameter?

   a. Box.
   b. Casing.
   c. Common.
   d. Finishing.

3. (401) An example of a helix is a

   a. nail.
   b. brad.
   c. spring.
   d. rivet.

4. (401) In basic screw thread terminology, pitch means the

   a. distance from any point on a thread to the corresponding point on an adjacent thread, measured parallel to the axis.
   b. angle the helix makes with a plane perpendicular to the axis of the screw.
   c. distance a screw moves along its axis during one complete turn.
   d. distance between the root and crest of a thread, measured perpendicular to the axis.

5. (402) The lead of a single thread is equal to the pitch, the lead of a triple thread is equal to

   a. one and one-half times the pitch.
   b. three times the pitch.
   c. six times the pitch.
   d. the same pitch as a single thread.

6. (402) What type of thread is designed to take exceptionally high stress in one direction only?

   a. Buttress.
   b. Square.
   c. Sharp V.
   d. American National.

7. (402) Where drawing threads is concerned, what is the only difference between right-hand and left-hand threads?

   a. The difference in heads.
   b. The difference in thread slant.
   c. The use of thicker lines for right-hand threads.
   d. The letters "RH" and "LH" marking the respective threads.

8. (403) What type of semiconventional thread requires two sets of three parallel lines?

   a. V-threads.
   b. Square threads.
   c. Acme threads.
   d. Regular threads.

9. (403) Simplified thread symbols are used on drawings when speed is essential and the projected view of the thread is

   a. 2 inches in diameter.
   b. over 1 inch in diameter.
   c. 1 1/2 inches in diameter.
   d. 1 inch or less in diameter.

10. (404) Which thread series is used for soft materials and in designs where rapid engagement is desirable?

   a. Fine series.
   b. Coarse series.
   c. Extra-fine series.
   d. 16-thread series.

11. (404) Which thread series serves as a continuation of the extra-fine series for sizes over 1 3/4 inches in diameter?

a. 8-thread series.
b. 12-thread series.
c. 14-thread series.
d. 16-thread series.

12. (404) Which of the four classes of threads has the loosest fit?

a. Class 1 fit.
b. Class 2 fit.
c. Class 3 fit.
d. Class 4 fit.

13. (404) Both internal and external threads are tapered on a standard pipe thread to

a. make assembly easy.
b. insure a tight joint.
c. make nuts unnecessary.
d. prevent damage to the pipes.

14. (405) Nuts and bolts are classified by series as light, regular, and heavy. They are further classified by

a. color.
b. length.
c. finish.
d. head shape.

15. (405) Specifications for bolts on drawings or parts lists must include all of the following <u>except</u> the

a. series.
b. length.
c. diameter.
d. head type.

16. (406) Cap screws are designed to serve the same function as

a. set screw.
b. brads.
c. nails.
d. bolts.

17. (406) Which of the following screws are used to prevent rotary motion between two parts, such as a pulley mounted on a shaft?

a. Cap screws.
b. Set screws.
c. Machine screws.
d. Screws with class 3 fit.

18. (407) Which of the following keys are <u>not</u> American Standard?

a. Flat keys.
b. Taper keys.
c. Patented keys.
d. Gib-head keys.

19. (407) Which of the following terms does <u>not</u> refer to a type of spring?

a. Taper.
b. Torsion.
c. Tension.
d. Compression.

20. (408) In order for a spur gear and pinion to mesh, they must have

a. teeth of the same form.
b. the same circular pitch.
c. an integral (whole) number of teeth for each.
d. all of the above characteristics.

21. (408) The size of a spur gear base circle is determined by the

a. pitch circle diameter.
b. common perpendicular.
c. pressure angle.
d. tooth curve.

22. (408) To draw a rack, you must know

a. the number of teeth.
b. the linear pitch.
c. the tooth depth.
d. all of the above.

23. (409) In the terminology associated with bevel gears, what does the term "cutting angle" mean?

a. The pitch cone angle minus the dedendum angle.
b. The angle formed by an element of the pitch cone and the cone axis.
c. The pitch cone angle minus the addendum angle.
d. The angle formed by an element of the edge angle and the cone axis.

24. (409) When drawing a bevel gear, you obtain a tooth curve

a. from a plane surface.
b. by drawing with radial lines.
c. from the developed pitch cone.
d. from the front view of the gear.

25. (409) When drawing a bevel gear, you divide the circumference of the pitch circle by the number of teeth in the gear. This gives you the value of the

a. pitch diameter.
b. pitch cone angle.
c. pitch cone radius.
d. circular pitch.

26. (410) What type of drawing gives complete information for the manufacture of a component part of an assembly?

a. Detail drawing.
b. Assembly drawing.
c. Modification drawing.
d. Assembly working drawing.

27. (410) On an assembly working drawing, each piece is

a. detailed.
b. full size.
c. sectional.
d. completely dimensioned.

28. (410) Part numbers and names should not be taken from which of the following production drawings?

a. Wiring diagrams.
b. Assembly drawings.
c. Detail drawings.
d. Modification drawings.

29. (411) The choice of the scale for a machine drawing depends upon all of the following <u>except</u> the

a. size of paper used.
b. amount of lettering to be added to the view.
c. necessity for showing small details clearly.
d. amount of dimensioning to be added to the view.

30. (411) Which of the following sizes is <u>not</u> usually used for machine drawings?

a. Full size.
b. One-half size.
c. One-eigth size.
d. One-sixteenth size.

31. (412) The Revisions block on a drawing is used to show all of the following <u>except</u>

a. who made the changes.
b. what changes were made.
c. why the changes were made.
d. when the changes were made.

32. (412) On a machine drawing, the name of the part of structure, the scale or scales used, and the name or initials of the draftsman are shown in the

a. title block.
b. Revision block.
c. application section.
d. Quantity Required section.

33. (413) The principal planes of projection include

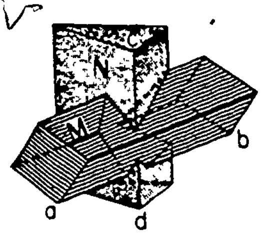
a. frontal.
b. profile.
c. horizontal.
d. all of the above.

34. (413) A skew line is inclined to

a. all principal planes.
b. the horizontal plane only.
c. the frontal plane only.
d. the profile plane only.

35. (413) The intersection of two skew planes is determined by the

a. angle of one of the planes.
b. edge of the inclined surface that is projecting.
c. points where two lines on one plane intersect the other plane.
d. intersection of the plane in the principal position.



VRE figure 1

36. (414) The illustration shown in VRE figure 1 represents the intersection of

a. two prisms.
b. a prism and cone.
c. two cylinders.
d. a square and cone.

37. (415) All of the following are examples of a double-curved surface <u>except</u> the

a. spheroid.
b. pyramid.
c. sphere.
d. torus.

38. (415) Which of the following is <u>not</u> one of the four most common developable forms?

a. Cone.
b. Prism.
c. Sphere.
d. Pyramid.

39. (415) A single-curved surface is

a. generated by a straight line moving in contact with a curve in such a manner that any two successive positions of the generatrix either intersect or are parallel.
b. a ruled surface in which no two successive positions of the straightline generatrix are parallel or intersect each other.
c. generated by revolving a circle in a circular path about an axis which is in the same plane as the circle.
d. generated by moving a curved line in accordance with some mathematical law.

40. (415) If the lines that represent edges of the surface do not show in the drawing in true length, we can find their true length by

a. revolving the lines.
b. drawing an auxiliary view.
c. drawing true-length diagrams.
d. any of the above methods.

41. (416) The three methods used to develop surfaces are known as

a. curved line, parallel line, and radial line.
b. radial line, triangulation, and curved line.
c. parallel line, radial line, and triangulation.
d. triangulation, curved line, and parallel line.

42. (416) The radial-line method is appropriate for developing

a. prisms and curves.
b. cones and pyramids.
c. prisms and cylinders.
d. pyramids and cylinders.

43. (416) To develop the surface of a prism or cylinder, you must know

a. the true length of the lateral edges or elements.
b. the perimeter or circumference of the base and the distance on this perimeter between each pair of edges or elements.
c. the true shape of a right section (perpendicular to the axis) and the positions of the lateral edges in relation to the right section.
d. all of the above factors.

44. (417) When the axis of a pyramid is perpendicular to the base plane, the pyramid is called

a. a frustum.
b. a right pyramid.
c. an oblique pyramid.
d. a truncated pyramid.

45. (417) When the cutting plane is parallel to the base plane of a pyramid, the portion of the pyramid remaining between the base plane and the cutting plane is called a

a. frustum.
b. right section.
c. left section.
d. right cone.

46. (418) The most common and best method for approximate development of nondevelopable surfaces is called

a. radial line development.
b. parallel line development.
c. triangulation development.
d. double-curved surface development.

47. (418) Triangulation development is used for all of the following surfaces <u>except</u>

a. spheres.
b. oblique cones.
c. warped surfaces.
d. oblique pyramids.

48. (419) In structural drawing, a member is

a. a unit part of a larger structure.
b. never a part of the framework.
c. always composed of one part.
d. never part of a truss.

49. (419) The strongest member of a floor system is the

a. beam.
b. truss.
c. girder.
d. joist.

50. (420) Specially shaped cast iron or pressed steel blocks are used with heavy wood framing to

a. take tensile stresses.
b. connect single piece members together at joints.
c. increase the bearing area on the wood.
d. connect double piece members together at joints.

51. (420) Steel plates used to connect and reinforce framing joints are called

a. piers.
b. joists.
c. trussess.
d. battens or gussets.

52. (421) In structural drafting, if a truss or other large member is symmetrical about its centerline, it is customary to show

a. only the right half.
b. all of the important details.
c. only the left half.
d. a partial view stopped exactly on the centerline.

53. (421) When vertical members, such as columns, are too long to be placed upright on the sheet, they are drawn in

a. a smaller scale.
b. two vertical sections.
c. a horizontal position with the base at the right side.
d. a horizontal position with the base at the left side.

54. (422) Which of the following statements is true concerning dimensioning of wood structures?

a. Dimensions can be approximations.
b. Dimensions must always be checked for accuracy.
c. Workman must perform simple mathematical computations.
d. Notes and dimensions are not necessary for the workman to get the needed information.

55. (422) In making structural drawings, you should use

a. an architect's scale.
b. a civil engineer's scale.
c. a full-divided scale.
d. a mechanical engineer's scale.

56. (423) Fabrication drawings are often called

a. plan views.
b. framing plans.
c. profile drawings.
d. shop detail drawings.

57. (423) Small-scale drawings which show the mark, location, and position of each member in the structure are called

a. plan diagrams.
b. erection drawings.
c. falsework diagrams.
d. location drawings.

58. (423) Falsework plans are prepared to show the method of constructing temporary supports needed in the construction of all of the following <u>except</u>

a. bridges.
b. large steel structures.
c. buildings under 40 feet high.
d. reinforced concrete structures.

59. (424) When the dimensions for angles are written, bulb angles are specified by

a. name.
b. symbol.
c. thickness.
d. weight per linear inch.

60. (424) Square and round bars are specified by giving all of the following <u>except</u>

a. size.
b. weight.
c. symbol.
d. length.

61. (424) Flat bars are specified by giving all of the following <u>except</u>

a. width.
b. thickness.
c. length.
d. symbol.

62. (424) Standard beams are generally called

a. angles.
b. channels.
c. I-beams.
d. wide-flange beams.

63. (424) Which of the following are made by cutting standard I-beams through the center of their web?

a. Bars.
b. Rails.
c. Structural tees.
d. Wide flange beams.

64. (425) What are the two major types of framing?

a. Square and oval.
b. Triangular and square.
c. Rectangular and square.
d. Triangular and rectangular.

65. (425) Wall-bearing framing, beam-and-column framing, and long-span framing are subdivisions of

a. square framing.
b. rectangular framing.
c. falsework framing.
d. triangular framing.

66. (426) Stiffener angles and filler plates are added to members to

a. increase the load-carrying capacity of the seat.
b. prevent movement of the beams.
c. increase the load-carrying capacity of the beams.
d. prevent movement of the seat.

67. (426) The usual method of connecting one structural member to another is by means of

a. lap joints.
b. set screws.
c. wood screws.
d. small connection angles.

68. (427) When rivet symbols are shown on detail drawings, the diameter of the shank is used for

a. shop rivets.
b. field rivets.
c. rivet heads.
d. all rivets.

69. (427) The primary reason for riveting two structural members together is to

a. make them stronger.
b. allow them to expand and contract.
c. transfer a load from one member to the other.
d. equalize the load.

70. (427) Edge distance is the

a. perpendicular distance from the edge of a shaped member to the center of the nearest rivet.
b. clearance between the head of any rivet to be driven and any other part of the structural member.
c. distance between the centers of consecutive rivets in a line of rivets.
d. perpendicular distance from the center of a rivet to the flange edge.

71. (427) The factors which must be considered in the spacing of rivets include

a. edge distance.
b. head clearance.
c. distance between gagelines and pitchlines.
d. all of the above.

72. (428) One advantage of using welding to make permanent fastenings in steel structures is that

a. no framing is ever needed.
b. parts can be joined in almost any position in relation to each other and the joint will be equal in strength to a riveted connection.
c. beams and columns can be welded directly to each other.
d. parts can be joined in any position in relation to each other and the joint will be stronger than a riveted connection.

73. (428) If the legend on a drawing includes sample joints and their significant symbols to give the standards for the job,

a. dimensions on symbols for nonstandard joints are omitted.
b. the tail on an arrow should not be omitted.
c. dimensions on symbols for standard joints may be omitted.
d. inch and degree marks are included in the symbols in most drawings.

74. (429) Why are columns poured and allowed to set before the floor system is poured?

a. To allow shrinkage to take place in the columns.
b. So that the column form can be removed and used elsewhere.
c. To prevent the floor from cracking at the joints.
d. So that the floor can be constructed with one continuous pour.

75. (429) In the plans for a concrete structure, possible locations of construction joints are

a. drawn in a vertical plane.
b. determined by the builder.
c. indicated by heavy lines.
d. indicated by symbols.

76. (429) Which system of reinforced concrete floor construction provides the greatest load-carrying capacity for a given amount of concrete and steel?

a. Flat slab system.
b. One-way joist system.
c. Beam and girder system.
d. Two-way joist system.

77. (429) The first step in drawing a floor framing plan is to

a. draw in columns, beams, and interior walls.
b. show the location of passageways for piping and electrical conduit.
c. establish the outside lines of the floor, exterior wall thickness, and column centerlines.
d. assign marks to beams and joists and indicate the span and area covered by each type of joist.

78. (430) In a floor framing plan for concrete construction, if the joists are not outlined, their

a. location may be coded.
b. direction should be indicated by arrows.
c. spacing and size may be shown with dashed lines and arrows.
d. location, span, and area covered may be shown with solid lines and arrows.

79. (431) When making a drawing of a concrete structure, you must show how reinforcing should be placed so that the members will withstand the load they must carry. This information is given in

a. framing plans.
b. general views.
c. cutaway views.
d. section views.

80. (431) The main steel reinforcing of a concrete beam is placed near the bottom of the beam to resist

a. shear stresses.
b. torsion stresses.
c. tensile stresses.
d. compressive stresses.

81. (432) In stairway construction, the total height from floor to floor or the height from a floor to an intermediate platform is called the

a. run.
b. rise.
c. riser.
d. tread.

82. (432) In concrete column construction, the amount of lap of vertical reinforcing steel bars is determined by

a. the grade of the steel.
b. the size of the steel.
c. the strength of the concrete.
d. all of the above factors.

83. (433) An architectural drawing involving only horizontal dimensions of width and depth is

a. a plan view.
b. a front view.
c. an elevation view.
d. a perspective view.

84. (433) Elevations are exterior views of a structure, and they may be taken from

a. the front.
b. the rear.
c. the right or left side.
d. any of the above.

85. (434) To be called a detail, a view must be

a. drawn to an enlarged scale to show construction features more clearly.
b. developed in orthographic projection.
c. drawn to a smaller scale to show more details.
d. drawn to show all hidden lines.

86. (435) Which method of lettering on architectural drawings is usually fastest?

a. Freehand.
b. Template.
c. Typewriter.
d. Lettering machine.

87. (435) Which of the following is a correct statement concerning architectural drawings?

a. Dimension lines are broken between extension lines.
b. Dimension lines are always given in feet and inches.
c. Dimensions of sections and detail views are repeated on other views.
d. Dimensions of all doors and windows are standard.

88. (435) Why are center-to-center location dimensions used on architectural drawings?

a. They are more accurate.
b. Construction plans are usually changed.
c. To allow for variations in size of building materials.
d. To prevent mistakes in constructing wall openings and in locating columns.

89. (435) In general, your dimensioning of any work drawing is governed by

a. window and door sizes.
b. construction procedures.
c. allowances for design changes.
d. the location of wall openings.

90. (436) If a detail view is drawn to the 3/4" = 1'0" scale, what is the size of the detail in relation to the actual size of the object?

a. 3/4 actual size.
b. 1/4 actual size.
c. 1/8 actual size.
d. 1/16 actual size.

91. (436) The relationship of the drawn figure to the true size of the structure is expressed as

a. an equation.
b. a general scale.
c. a half-size scale of the drawing.
d. a full-size scale of the drawing.

92. (436) After a view is drawn, dimensioned, and given a title, you should always complete the drawing by

a. placing a graphic scale on the sheet.
b. initialing the drawing in the bottom left corner.
c. indicating the scale to which the view is drawn.
d. initialing the drawing in the bottom right corner.

93. (437) What is the overall size of a building if the floor plan is 20" x 25" and the scale used is 5/8" = 1'0"?

a. 27' x 33'.
b. 32' x 40'.
c. 40' x 50'.
d. 53' x 66'.

94. (437) When you draw a floor plan, which of the following lines should be heaviest after the lines are brought to the correct weight?

a. Cutting plane lines.
b. Roof outlines.
c. Centerlines.
d. Wall outlines.

95. (438) On an elevation view, the lightest lines should be those representing

a. doors.
b. windows.
c. trim lines.
d. shingles and siding.

96. (438) On an elevation drawing, glass is symbolized by

a. light, vertical shade lines.
b. diagonal straight lines.
c. scattered dots.
d. dashed lines.

97. (439) It is necessary to use a reference on the main drawing to tell where the required detail may be found when the

a. scale is small.
b. elevation view overlaps the floor plan.
c. detail drawings are placed on a separate sheet.
d. detail drawings are omitted from the first set of plans.

98. (439) In a drawing which shows a cornice detail and a sill section, you should develop the

a. sill section first.
b. cornice detail first.
c. cornice detail and the sill section detail together.
d. details after all dimensioning has been put in.

99. (439) Bulletins and pamphlets dealing with many practical aspects of building construction may be obtained from

a. the Federal Housing Administration.
b. the National Bureau of Standards.
c. the Government Printing Office.
d. all of the above.

100. (439) Written specifications for a proposed building cover all of the following <u>except</u> the

a. type and quality of material.
b. cost of material and labor.
c. methods of construction.
d. inspection of work.

101. (440) Which of the following is <u>not</u> a main type of electrical and electronic drawings?

a. Highway diagram.
b. Block diagram.
c. Schematic diagram.
d. Wiring diagram.

102. (440) Which of the following statements concerning pictorial drawings is <u>not</u> correct?

a. The locations of components are shown.
b. The lines representing wires are drawn slightly lighter than visible outlines.
c. The positions of connecting wires are shown.
d. A pictorial outline may be used to provide a background for a wiring circuit.

103. (441) What type of diagram shows the function of a unit or complete system in simplified form?

a. Block diagram.
b. Pictorial drawing.
c. Wiring diagram.
d. Schematic diagram.

104. (441) Which type of electrical or electronic diagram is most often seen on engineering drafting boards?

a. Block.
b. Wiring.
c. Schematic.
d. Interconnection.

105. (441) Which of the following statements concerning the preparation of a schematic diagram is <u>not</u> correct?

a. The weight of a line has no bearing on the meaning of a symbol.
b. Symbols should be uniformly spaced throughout the drawing.
c. The signal path is usually from left to right.
d. The orientation of a symbol changes its meaning.

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CDC 23151

GRAPHIC SPECIALIST

(AFSC 23151)

Volume 4

Basic Drawing

6-1

Extension Course Institute

Air University

Preface

IN THIS VOLUME, the study of basic form, layout and composition, human form, cartoons and caricatures, and landscapes, all deal with the drawing of form and how to construct a basic layout.

Most of the drawings in this volume are plate on basic construction. Foldouts 1 through 12 are oversized figures and are therefore printed and bound as a separate inclosure to this volume. Whenever you are referred to one of these foldouts, please turn to the separate inclosure and locate it.

This CDC also contains Behavioral Objectives designed to help you understand what the subjects are all about. Studying the text and achieving the objectives will give you the fundamental knowledge you need to perform as a graphic specialist. Guided by the Behavioral Objectives, answer the exercises for each chapter. Then, refer to the answer section in the back of the volume and check your answers.

If you have questions on the accuracy or currency of the subject matter of the text, or recommendations for its improvement, send them to Tech TNG Cen TTOC, Lowry AFB CO 80230.

If you have questions on course enrollment or administration, or on any of ECI's instructional aids (Your Key to Career Development, Behavioral Objective Exercises, Volume Review Exercise, and Course Examination), consult your education officer, training officer, or NCO as appropriate. If he can't answer your questions, send them to ECI, Gunter AFS AL 36118, preferably on ECI Form 17, Student Request for Assistance.

This volume is valued at 6 hours (2 points).

Material in this volume is technically accurate, adequate, and current as of May 1974.

Contents

NOTE: In this volume, the subject matter is developed by a series of Learning Objectives. Each of these carries a 3-digit number and is in boldface type. Each sets a learning goal for you. The text that follows the objective gives you the information you need to reach that goal. The exercises following the information give you a check on your achievement. When you complete them, see if your answers match those in the back of this volume. If your response to an exercise is incorrect, review the objective and its text.

Basic Form

FORM IS THE SHAPE and structure of anything and everything that exists in this world. When we talk about form, we generally think of a three-dimensional shape—with height, width, and depth. When starting an illustration, all form should be thought of as solid and basic.

1-1. Form

Form exists because all things have mass, they occupy space, and have an appearance that you can "feel" without touching.

600. Define and characterize basic form.

Form. Every object that exists anywhere—from aardvarks to zebras—has form. Any picture you draw must be drawn so that the illustration is a convincing illusion of real form. For this reason, we teach the basic principle of all drawn form as being solid form. When you understand this principle and that everything has a top, bottom, and sides—a small step in understanding all basic form will have been accomplished. Most drawings that lack these fundamentals seem flat and lifeless.

Starting with this section we are going to show you and teach you the principles of drawing objects so that they look solid, as if they really existed. You will be shown how to make each object look near or far, and to accentuate its form by the proper use of light and shade. When you understand these principles of form drawing and are able to apply them to any illustration—the art world is your oyster.

Exercises (600):

1. All form is drawn as ______ form.

2. How should all objects be drawn?

601. Describe and draw the four basic forms.

Four Basic Forms. The four basic forms are the sphere, the cylinder, the cone, and the cube as shown in figure 1-1. Gifted artists perceived long ago that all things can be reduced to one of the four basic forms—or modifications or combinations of one or more of these basic shapes. They found that all objects, no matter how complicated or sophisticated they may appear at first glance, are basically made up of the sphere, the cone, the cylinder, the cube, or some combination of these shapes. When you learn to draw these forms and combine them where necessary you can draw anything you see or can imagine.

The principle of drawing form is the backbone or foundation of your training. You will be reminded of form at every opportunity. Naturally, you are not expected to master the drawing of basic form in one or two sessions, but as time goes on, and with a minimum amount of practice, you are expected to get the idea. When you first realize how to see basic forms in everything you come in contact with daily, you then will realize how profoundly form influences your thinking and improves your drawing.

When the sense of using form as a base, and the *feel* of solid form becomes second nature to you, you will be thinking like an artist. All the things your draw will be convincing and you will receive great satisfaction in your accomplishments. See foldout 1 (printed as a separate supplement to this volume).

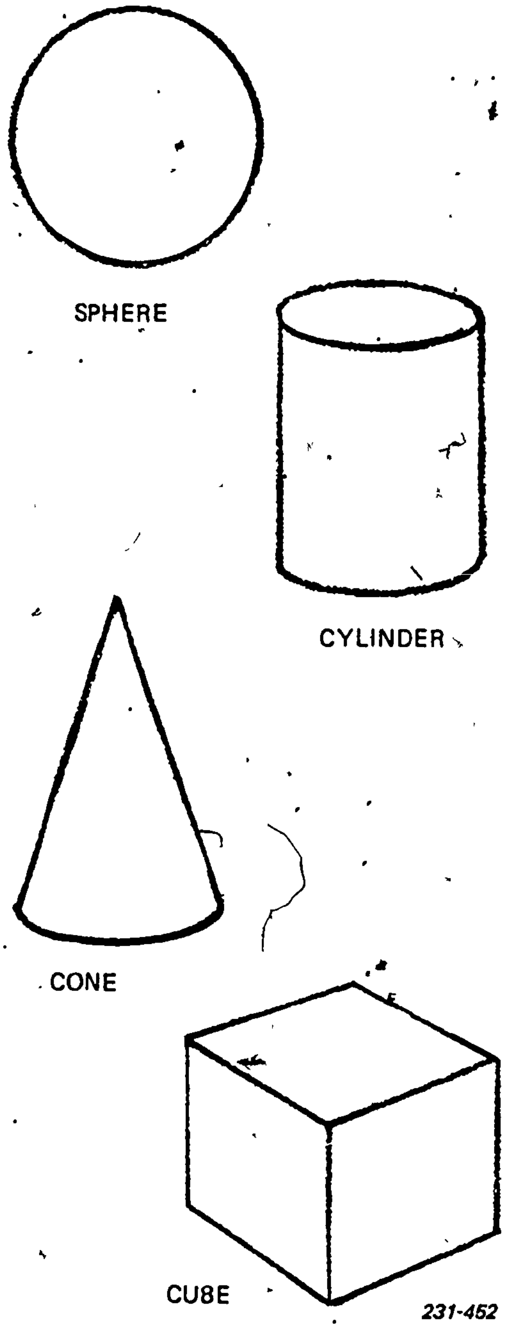

Figure 1-1. Basic form.

Exercises (601):

1. What are the four basic forms?

2. What is the foundation of all art?

1-2. Form in Depth

In showing you how to draw form, it would help if you also viewed the object in your picture with a sense of reality. All pictures should have the feeling of being three-dimensional, particularly the dimension of depth.

602. Define form in depth and explain "drawing through."

The Dimension of Depth. Depth is the dimension that creates the illusion of a three-dimensional object drawn at a two-dimensional surface. Since your drawing paper is a flat two-dimensional surface, the one dimension that you strive for is depth.

To draw depth, you must sense the mass and substance of the object being drawn. To draw a convincing illusion of any object, the basic form of the object must be seen to extend back into the space you have created for your picture. All sides of the object must be drawn, not just the flat outline—this is called *drawing through.*

Drawing through is the one principle that makes your picture look real and convincing even if the actual drawing is not the greatest. In figure 1-2 are examples of what is meant by the "draw through" method. Let's assume, for example, that you wanted to draw a book. From where you are sitting, only the top and two sides can be seen. There are two other sides and a bottom to this book. The draw through method, all sides, top and bottom, should be sketched in just as though you could see all the other parts.

No matter what you draw, make it a rule to first sketch in the basic form as if you could see through the object and see all sides. If you disregard this rule, objects may appear to be lopsided, or seem to occupy the same space in your drawing. Beneath the shading and texture of all good illustrations lies a form—a form in depth. Beginners tend to concentrate on the obvious when drawing. Everyone wants to be another Michelangelo and start drawing pretty pictures right now. In other words, they respond too quickly to the surface appearances. All shading and texture seen in a drawing are part of the final stages. A great deal of preparation must be worked out with the basic forms to create that feeling of depth. Then and only then can the final stages be drawn so that you get the feeling of being.

Exercises (602):

1. What is depth?

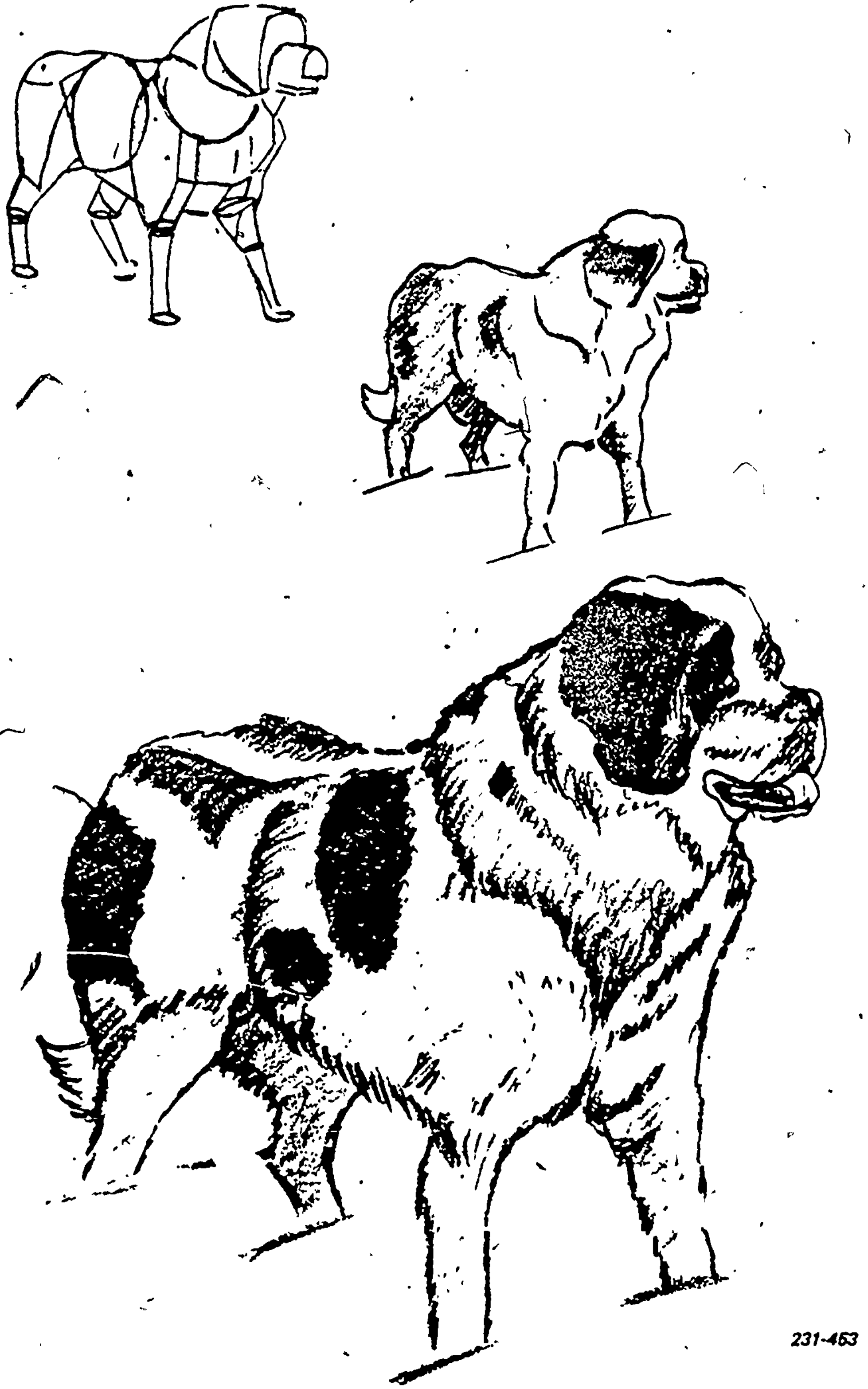

Figure 1-2. Drawing through.

2. What do we mean by drawing through?

603. Use light and shade in combination with basic forms.

Light and Shade. After you have drawn the form using the draw through method, the basic drawing must be able to stand by itself as a sound form structure. Light and shade are essential to emphasize form in the drawing. They will help to make a good basic drawing more convincing, but will not save a poor one.

Begin now to train your eyes to see the basic form in all things. Remember too, that most objects are combinations of two or more basic forms. In manmade structures the basic forms are easy to see, but nature can complicate matters somewhat with forms like clouds, mountains, animals, and man. So don't get bogged down with light and shade before you have the basic form. Light and shade can help you once the basic form has been drawn.

Complex form. Complex form can be a problem in that you must create the illusion of space with combinations of form. Furthermore, this sense of space must extend around these objects and beyond them in every direction. Space, forms and perspective contribute a strong dramatic impact to every picture drawn. Work out the size, placement, and proportion of the big forms in your picture, then proceed to carefully draw in the details. See foldout 2 (printed as a separate supplement to this volume).

Exercise (603):

1. When should you shade on a drawing?

Layout and Composition

LAYOUT AND composition denote the selection and arrangement of appropriate elements within a picture so as to express the illustrator's idea clearly and effectively. The success of a picture depends on how well these elements are put together.

2-1. Composition

Composition, in a sense, is combining basic form and space—arranging the elements of the picture to produce a harmonious whole. In composing a picture, we are chiefly interested in what the finished product has to say. Regardless of the subject of your picture, the questions that you should ask yourself are: "What is or what isn't important to the picture, and what is the basic idea that you want to get across?"

Good illustrations don't just happen. They are the result of careful planning and the sketching of many basic ideas on a small scale.

604. State the purpose and function of a thumbnail.

Thumbnail Sketches. Thumbnail sketches are small, quickly drawn illustrations used to formulate and work out the design of ideas (fig. 2-1). They are called thumbnails because of their size, and are usually 1 to 3 inches square. Thumbnails are used primarily to work out general layout details, such as arrangement or composition, balance, movement, continuity, and other factors of design.

The first thumbnail shown in figure 2-2 is very much like the primary or preliminary sketch shown in figure 2-1. The results are not satisfactory because the composition is too static and uninteresting. Therefore, we try another. The composition or design of the second thumbnail is much less static than the first. Your eyes move throughout the design, first across the dark area representing lettering at the top of the thumbnail, down across the airplane, and across the dark area representing lettering across the bottom of the sketch. Still, the layout is rather old fashioned. The remaining four thumbnails show more interesting designs for our layout. Any one of these ideas might be used as our model. Notice that the last three sketches are quite

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Figure 2-1. Preliminary sketch.

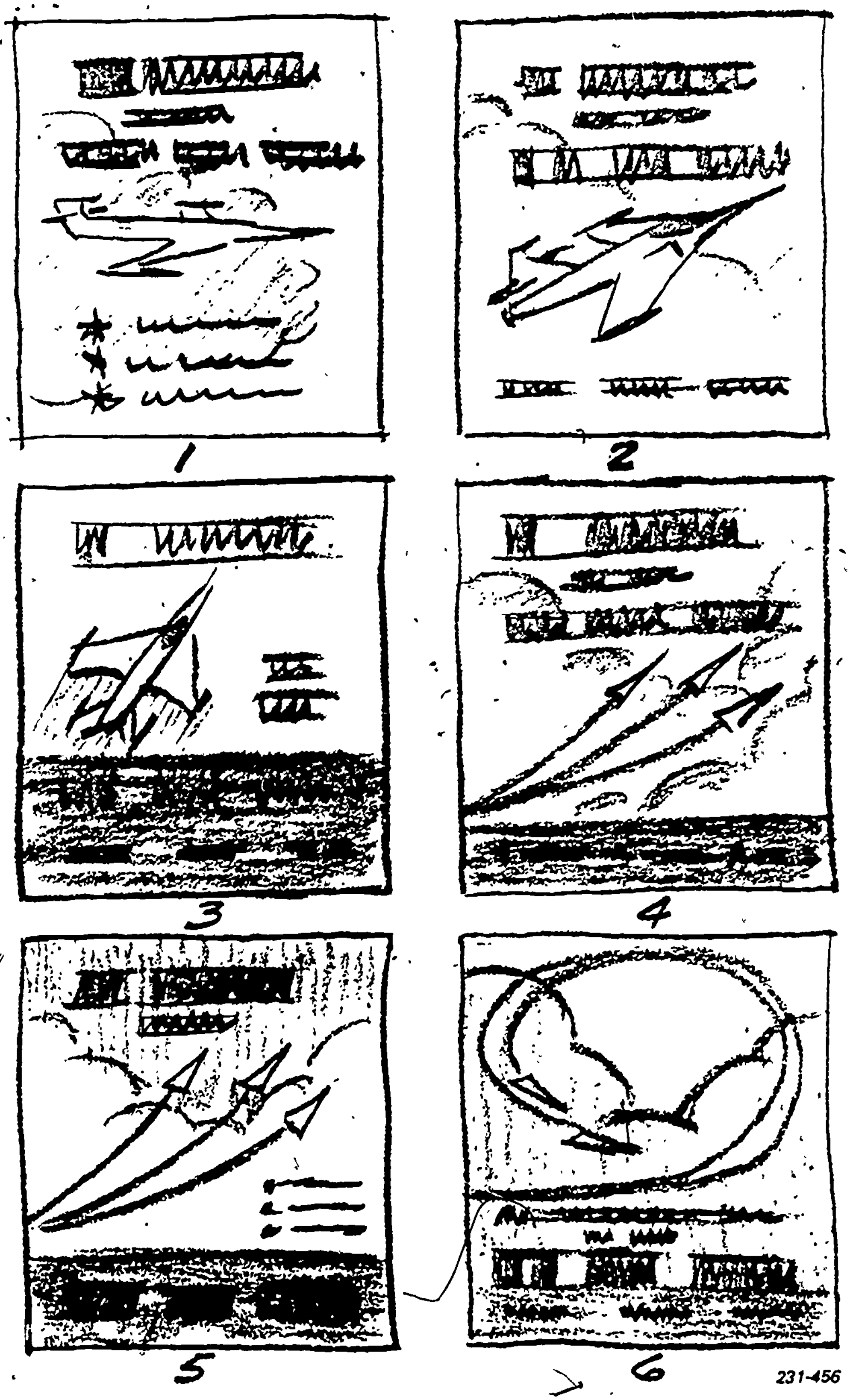

Figure 2-2. Thumbnails.

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Figure 2-3. Roughs.

similar and show how we can change the design slightly in searching for the best means of presenting our idea. This brings us to the next step in layout and composition development—the *rough sketch.*

Exercises (604):

1. What is a thumbnail?

2. How is a thumbnail used?

605. Compare a thumbnail and a rough.

Roughs. After selecting one or two of the most promising thumbnail sketches, the usual procedure is to draw a more detailed sketch called a *rough*. Although a good thumbnail can sometimes be used as a satisfactory model from which you can draw the finished art work, usually you need a more detailed drawing. The rough permits you to refine the design of a thumbnail sketch, to work out any details, and to show in a general way just how the finished illustration will look.

The rough should be drawn the same size as the final product. Of course, in the case of a poster where the size might be quite large, it would be impractical to make the rough the same size. However, if the poster is to be placed in some publications, then its size might be relatively small. Usually the finished art work for such a reproduction is drawn larger and reduced to the correct size by the printer. By drawing the rough the same size as the poster that will appear in print, we can see exactly how well the design of the poster works in the given space. Any faults in the design that are unnoticeable in the thumbnail usually become quite apparent in the rough and can be easily eliminated.

The illustration and lettering in the rough made from the thumbnails in figures 2-1 and 2-2 are made with a bold, simplified technique and a soft pencil (see fig. 2-3.) This is the usual practice, although hard pastel, colored pencil, or tempera is often used. Notice that the rendering of the rough has a quick and incisive character that is easily distinguished from the painstaking, detailed rendering of the finished work of art. Colored

231-458

Figure 2-4. Comprehensives.

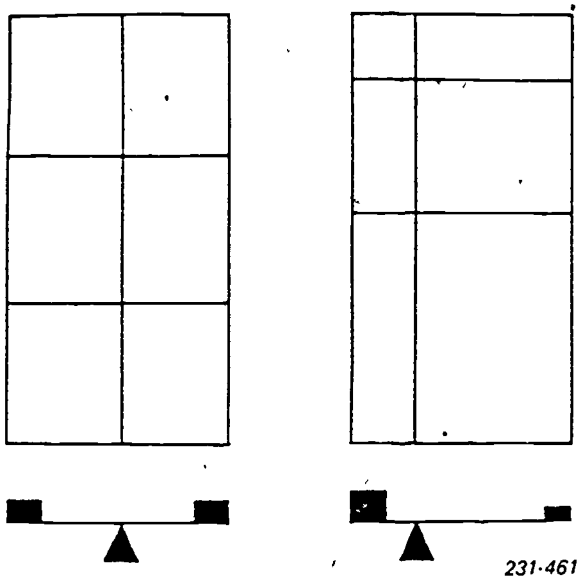

Figure 2-5. Balance.

papers are a great help when colored backgrounds or panels are necessary. Tempera is useful when indicating colored or reverse lettering on a pastel background. Smooth white bond paper, either opaque or semitransparent, and tracing paper are satisfactory for rough layouts. Refer to foldout 3 (printed as a separate supplement to this volume).

Exercises (605):

1. What is the difference between a thumbnail and a rough?

2. Why is a rough necessary?

606. Define a comprehensive, according to purpose and function.

Comprehensives. If you have done a good job on your rough, it will probably be adequate to use as a guide for the finished art work. However, there are times when the person for whom the art work is being done would like to know exactly what the finished product will look like before getting the same. To satisfy him, you must draw a comprehensive layout.

A comprehensive is a detailed layout that is a step closer to the finished product than a rough. Comprehensives are used to show exactly what the finished product will look like. The tones, color, and details are all carefully drawn. In fact, sometimes a comprehensive is rendered with such precision that it could almost be used as the finished art work. If a more detailed drawing is needed for some complicated parts, you can make comprehensives of the parts. For example, in our sketch the drawing of the airplane is very general. In the finished art work, the drawing of the airplane is quite precise. Therefore, we can draw an accurate comprehensive of the airplane on tracing paper and use this drawing to trace the airplane on the final art work.

Comprehensives can also be used for other purposes (fig. 2-4). For example, comprehensives are used in connection with this course and the preparation of the SKT (Specialty Knowledge Test.) Since the test items of an SKT are based on the information presented in the CDC, the people preparing the test items must have a complete CDC manuscript (including illustrations.) The test must be ready at the same time or very shortly after the CDC becomes available. We think of these knowledges as fundamentals, because you will use them in nearly all phases of illustration.

Exercises (606):

1. What is a comprehensive layout?

2. Why use a comprehensive layout?

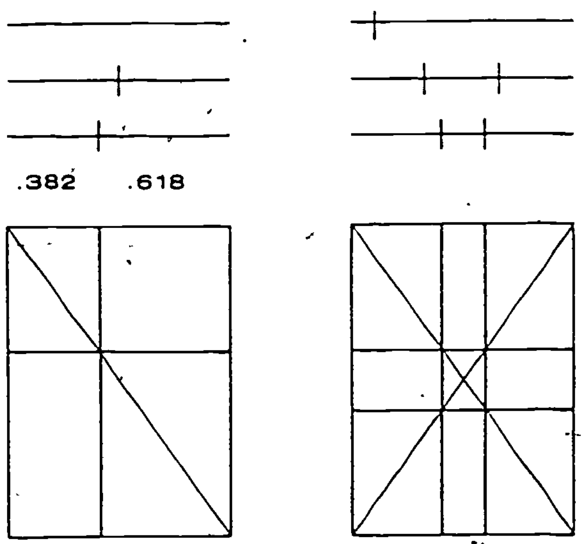

Figure 2-6. Proportion.

607. Name and define the main elements of composition.

Elements of Composition. Composition is divided into four basic elements—area, depth, line, and value.

Area. Picture area is simply the borders in which you draw or paint your picture. To use this area most effectively, you must weigh carefully where you place the objects within the picture area and what size to make them. This is one of the primary reasons for a thumbnail sketch. It enables you to move a crude drawing around within the borders of a confined area for better planning. After each of these sketches is completed, ask yourself: "Does this create the effect I had in mind?" (Study foldouts 4, 5, 6, and 7 in your supplement.)

The size we give to the objects of a composition and where they are placed control their importance in the illustration. Size should never be chosen without regard to the effect it will have on the final product. It is just as important as the action or the pose.

Depth. Depth, the second-dimension of a drawing, is the creation of an illusion on a two-dimensional surface. The illusion created is distance. Overlapping, cropping, and making objects appear smaller with less detail are useful devices in creating a convincing sense of reality. The illusion of distance is not enough to give an illustration the sense of reality—it must be done in an interesting way. Don't ever be satisfied with the same basic arrangements; there are always new possibilities worth considering. Think—experiment—and try to make different and interesting uses of the varied shapes and objects in your picture.

Line. The term line, as it is generally used in the preparation of art work, is the outline of a shape. As it applies to composition, line means the direction in which the eye moves to focus on a point of interest when looking at an illustration. Direction lines are created by the arrangement of the objects in the illustration so that the shape or the main lines lead the eye unconsciously to the center of interest. Controlling the movement of the viewer's eye within the picture is a very important function in picture construction. Line can be a strong or a subtle force in picture construction, but it should always lead the viewer to the center of interest.

Value. The fourth element of composition is value, the lightness or darkness of a picture. Value creates the mood or gives the overall key to a picture. In fact light shades are frequently called *high key values* and dark shades *low key values.* For example, a picture of children playing at a picnic is a gay and happy scene and should be fairly high keyed, whereas, when portraying a fisherman on a lonely stretch of beach in the rain, the weather has set the mood. Line value is used to lead the viewer's eye to the point of greatest contrast. We can and do use this principle to focus attention.

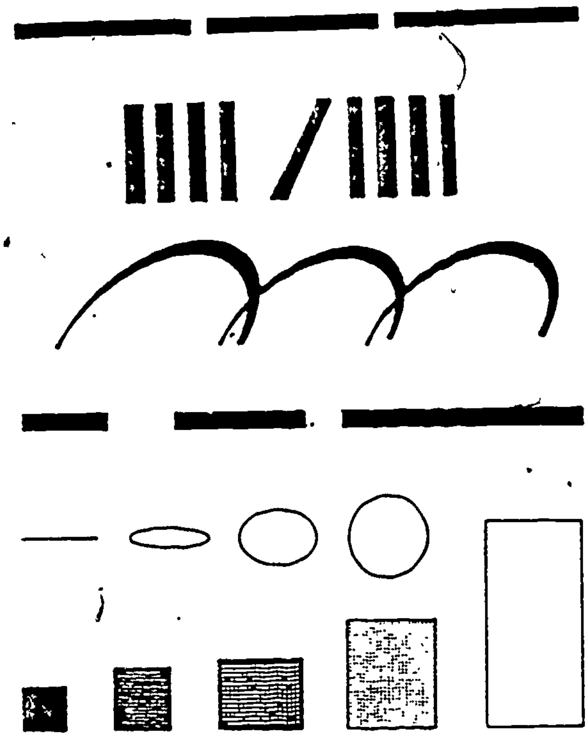

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Figure 2-7. Rhythm.

Exercises (607):

1. What are the four elements of composition?

2. Which of the four creates a sense of reality?

2-2. Principles of Composition

The limitation of our nervous system defines not only the number and extension of the individual optical units which can be perceived as a whole but also defines the lifespan of the visual experience. We cannot look at a static picture long without losing

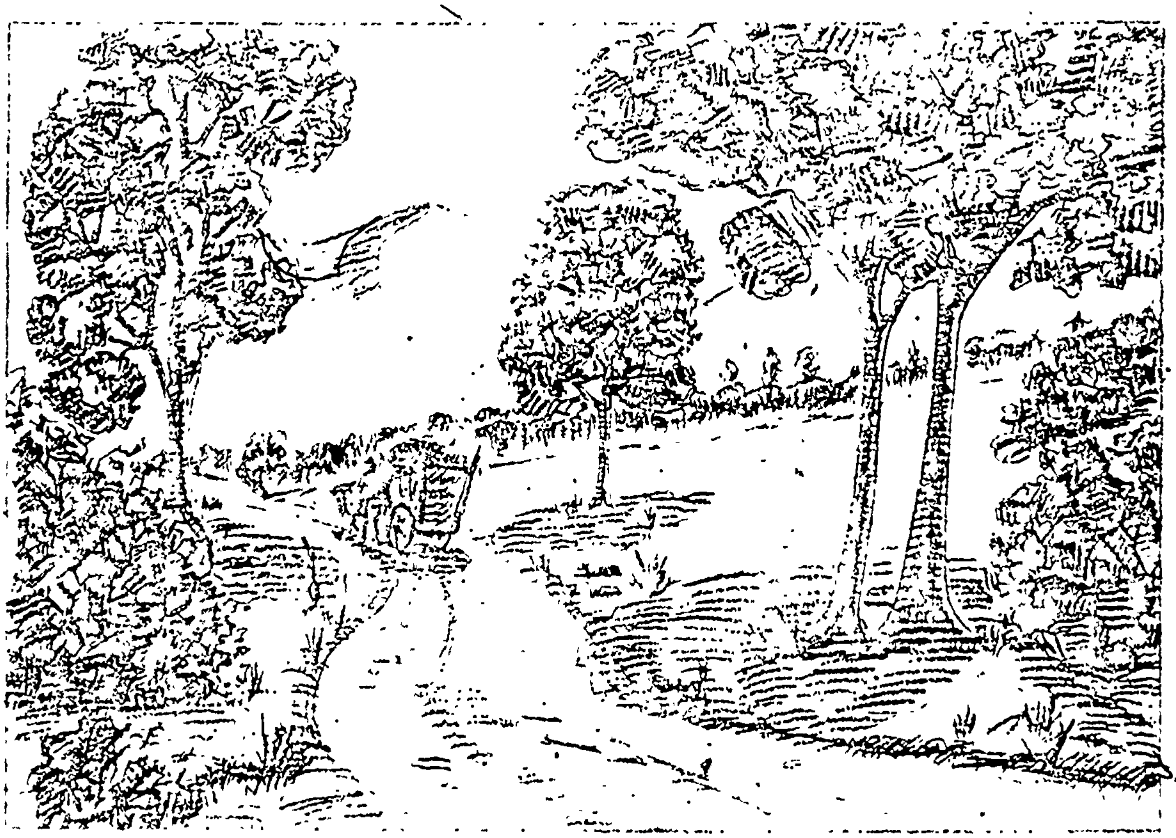

Figure 2-8. Progression.

interest. However, an illustration based on sound principles will hold the observer's interest for a longer period of time. These are the principles of balance, proportion, rhythm, movement, unity, clarity, and simplicity. Let us study these principles.

608. Name and describe the seven principles of composition.

Balance. One of the most important principles of composition is known as balance. We are not used to seeing objects which appear to be toppling over. The leaning Tower of Pisa attracts our attention and interests us because it is precariously balanced. However, if or when the tower loses this balance, its attraction will cease to exist. An illustration or layout must also be balanced if it is to attract attention and maintain interest. This balance can take two forms, symmetric and asymmetric; or as they are more commonly called formal and informal.

Formal balance. Formal balance is obtained by placing each visual element squarely on an imaginary vertical centerline, or by duplicating each mass, shape, or line that appears on one side of this vertical in a corresponding position on the other side. The result is considered perfect symmetry. An example of formal balance is shown on the left side of figure 2-5.

Formal balance is commonly used in layouts, illustrations, and posters where the subject matter calls for reserve and dignity. However, since this type of balance produces a static composition without movement, it cannot hold the interest of the observer for very long. Therefore, an illustration, layout, or poster with formal balance must be simple so that the observer can understand it before he loses interest.

Informal balance. Notice how much more interesting the area of the rectangle which is shown in the right side of figure 2-5 is divided. This is an example of informal balance. As you can see, a much greater variety of shapes and design can be used with this type of balance. However, the problem of balance is much more complex. The left side of the rectangular area must balance the right side, and the top half must balance the bottom half.

A large heavy mass placed on one side of the center may be balanced by a small one placed farther from the center on the opposite side. In the example shown, the heavier lines on the left are balanced by the large light areas on the right. This type of balance is dynamic, the composition is alive, and there is movement caused by the interactions of the various shapes and lines.

When using informal balance, you must depend to a great extent on your own sense of balance, since no mathematical rules apply. The more elements you use, the more involved balance becomes.

Proportion. Another principle used to maintain interest and make a composition attractive is proportion. This adds variety to your picture. When a speaker talks in a monotone, you soon lose interest in his speech. When someone strikes the same note on a piano over and over again, you soon lose interest in its tone. This same effect can be found in drawings and illustrations. To prevent this from happening in your art work, you must divide the elements and the area of your illustration into varying sizes, ratios, or proportions. For example, look at the lines shown in the top portion of figure 2-6.

If we divide a line as shown on the top, right, we do not actually get division. Instead, we merely chop off part of the line, and the small portion becomes insignificant and is lost. If we divide the line in half, we have a static division and a conflict of interest. We do not know which half to look at and therefore cannot become interested in either.

If we divide the line into thirds, we get a better division because the parts are repeated. This creates rhythm which is definitely more interesting.

When we divide the line between the one-half division and one-third division, we get another division of equality. However, it is an equality of proportion. That is, the ratio of the smaller part to the larger part is equal to the ratio of the larger part to the whole line. This is known as the Golden Division of a line and is very important in composition.

As you can see in the lower half of figure 2-6, if the Golden Division rule is applied to an area such as a picture surface, interesting and related areas are created. The intersection

Figure 2-9. Movement.

of the two dividing lines locate an extremely strong point on the picture surface. For this reason the center of interest in an illustration or other form of art work should be located at or near this point on the picture surface.

If we divide the area of the picture plane by the Golden Division rule from both sides, top and bottom, we divide the area as shown in the diagram on the right side of figure 2-6. We now have four strong points at which we can place our center of interest.

If we draw lines between any of the points of the Golden Division, these lines form strong lines of construction for any composition. For example, if you are drawing a mountain, you should place the edge of the mountain on one of these strong lines of division.

Rhythm. We have mentioned before that interest can be maintained by rhythm. As you know, in music the beat or rhythm is an essential part of the tune. Rhythm in illustrating is just as important. We can obtain rhythm in two ways; by repetition and by progression.

Repetition. Rhythm can be obtained through regularly alternating or orderly repeating shapes, positions, lengths, angles, curves, direction, and intervals. A simple example of repetition is shown at the top half of figure 2-7.

Progression. Rhythm may also be obtained by slightly varying the shape, value, size, and other factors. For example, in the bottom half of figure 2-7, a progression of lines is achieved by lengthening a line each time it is repeated. Revolving a circle also creates progression. In one position the circle appears as a line, next as a thin ellipse, then a thicker ellipse, and finally, a circle. Progression can be obtained in value as well as size and shape, as shown by the bottom elements. These elements also show progression of shape from a square into rectangles of different shapes.

Movement. Figure 2-8 shows the use of all of the principles of composition that we have discussed thus far. It uses balance, proportion, and rhythm. There is also present another important factor of composition—movement. This factor is perhaps the most important. As long as you can keep the eyes of the observer moving about the picture, you will hold his interest. These movements about our illustration are pointed out by figure 2-9. Notice that the movement is generally clockwise in direction. The eyes of the observer should be guided up the left side of a picture across the top; then down the right side and across the bottom. There may be intermediate paths of movement throughout the picture. All movement, however, should lead to the center of interest. You want to keep the observer interested until you can lead him to the point you want to show him most.

Unity, Clarity, and Simplicity. These three principles of illustrating are closely related. Combining elements into a unified whole is an important principle of composition. A composition without unity appears to fall apart and produces a disturbing effect.

Clarity is another principle you should follow in illustrating. Guard against blending elements to the extent of making them confusing to the observer. Clarity can be achieved by using legible lettering, tones which are not too close in value, and sharp clear lines.

The object of a layout or illustration is to command attention. Usually, the simpler a production is, the easier it is to get the observer to stop and look at it.

Since many elements have a tendency to divide the observer's attention, it stands to reason that the fewer elements you use, the easier it will be to make him concentrate on the few things you want him to notice. Therefore, omit all items that can be eliminated without impairing the purpose of your art work.

Exercises (608):

1. What are the principles of composition?

2. Why is the principle of balance important in the composition of an illustration?

3. The principle of unity is closely related to the principles of _______ and _______.

Human Form

DRAWING THE HUMAN figure is probably the most rewarding achievement that an artist can experience—when it is done right. On the other hand, it can be one of the most exasperating chores ever undertaken by a human being. You may have concluded from these frist two statements that drawing the human figure is extremely difficult—well, it is. Now, we are going to show you in this chapter that it can be made easier than you think by following a few simple procedures.

3-1. Drawing the Human Form

In drawing any form, one must be willing to proceed one step at a time, mastering each step as you go. Each portion of the drawing must be given some special consideration as it compares with the rest of the figure. If you wish to achieve even moderate success in the art field, the drawing of the human figure is a must, because 87 percent of all illustrations, posters, and drawings contain the human figure or some portion of the figure in them.

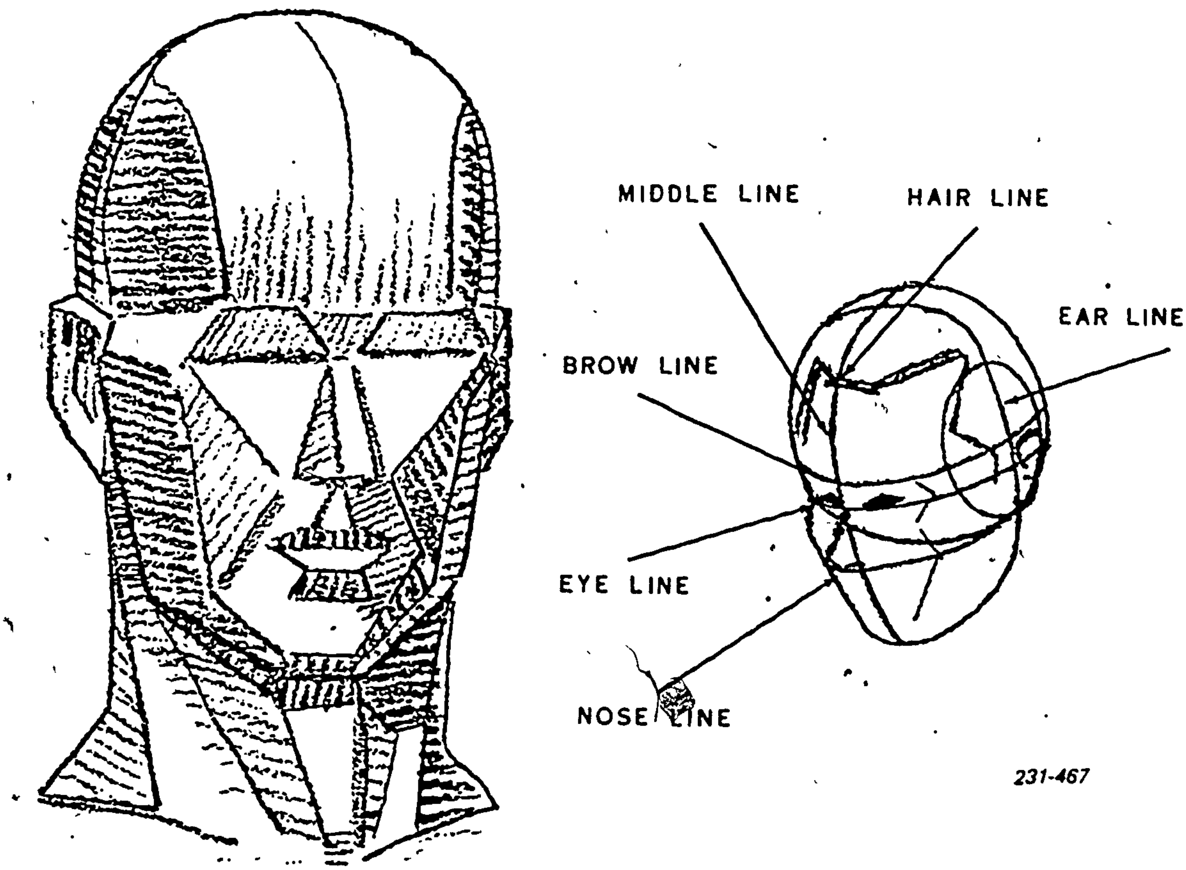

Figure 3-1. Human head.

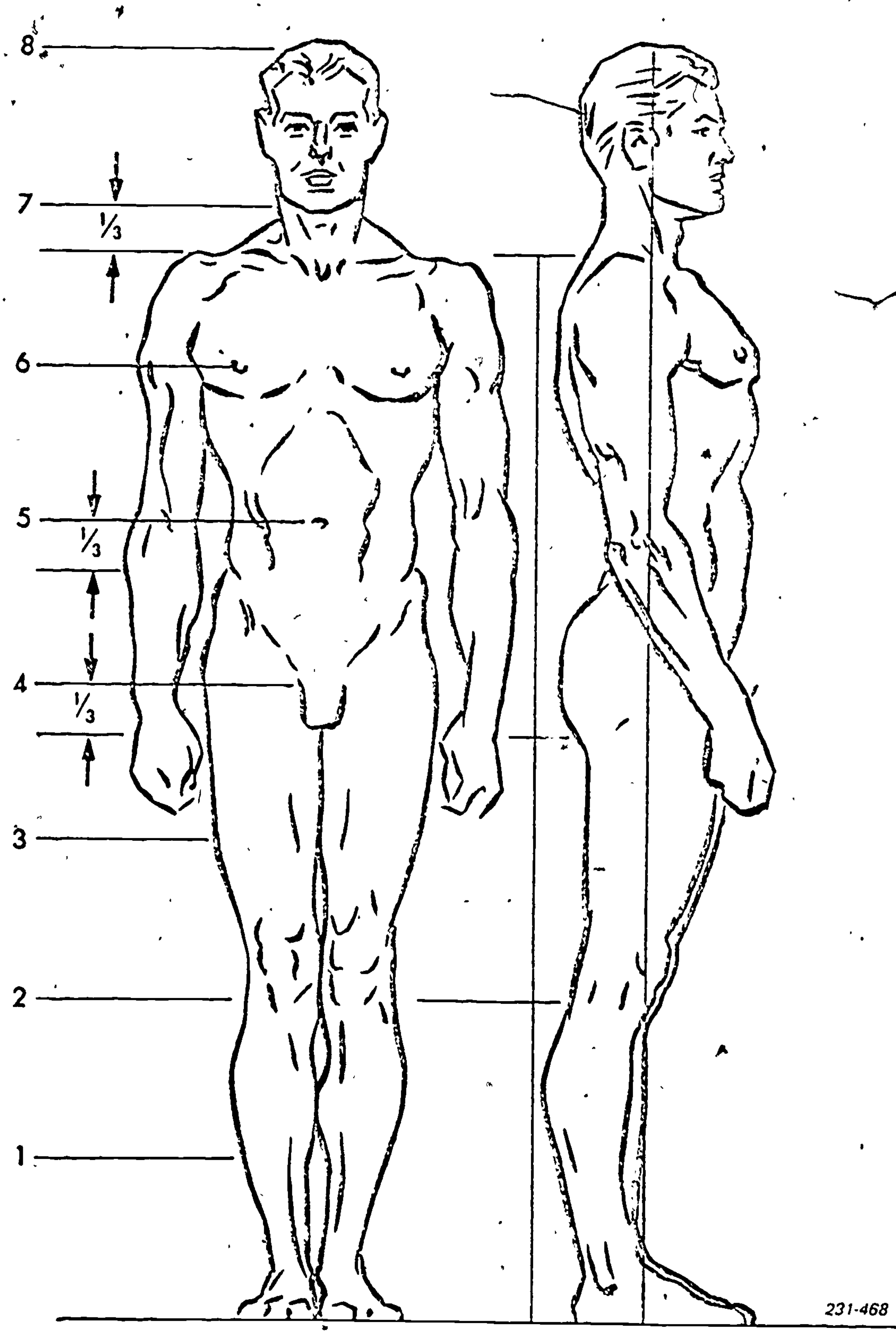

Figure 3-2A. Proportions of the male figure.

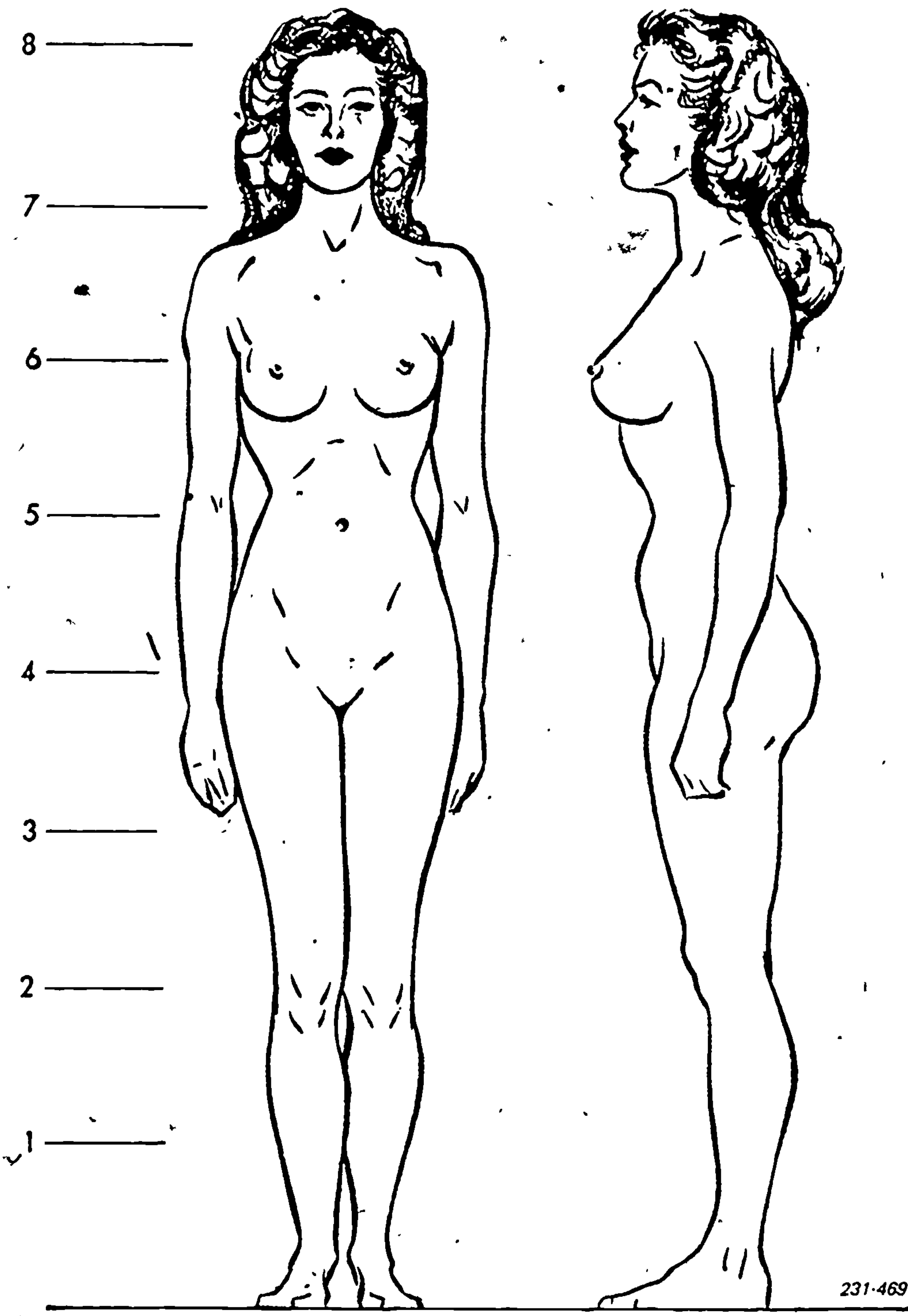

Figure 3-2B. Proportion of the female figure.

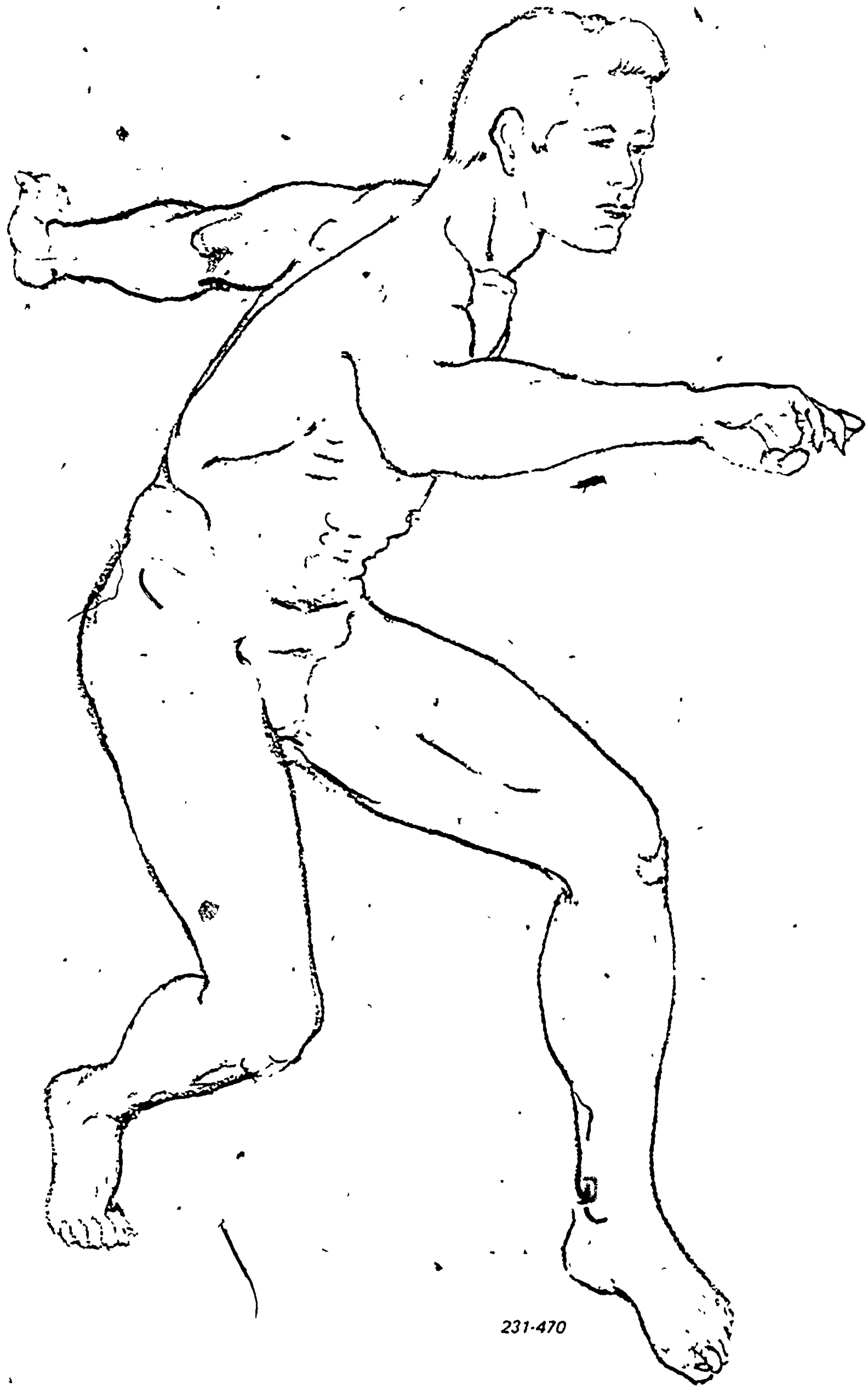

Figure 3-3. Foreshortened.

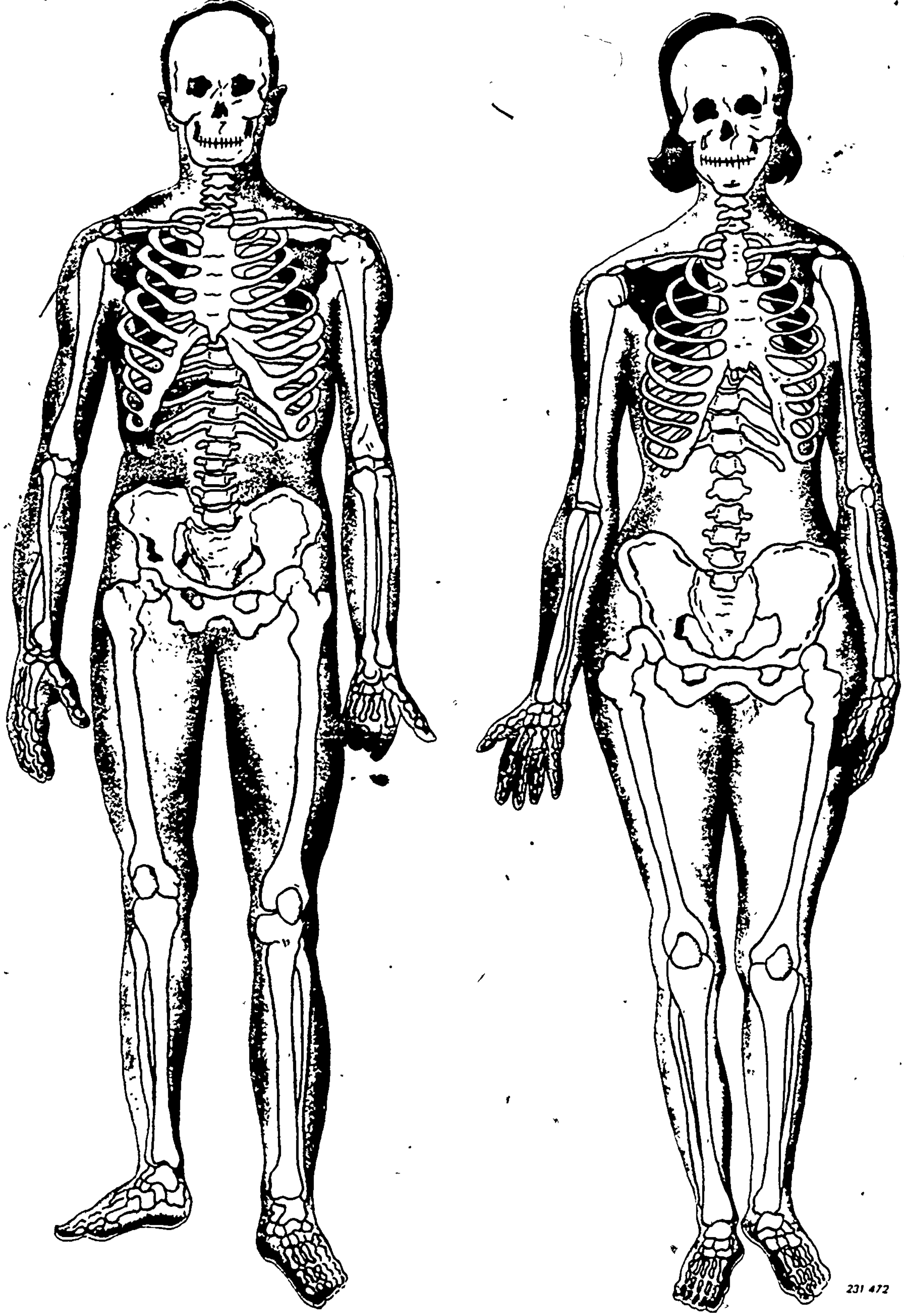

Figure 3-4. Skeletons.

609. Describe the method of measuring the human figure and compare male and female characteristics.

Figure Proportions. The human head is used as the basic unit of measurement for proportioning the entire human body. The vertical height of the head from the chin to the top of the skull is used for all vertical measurements (fig. 3-1). The width of the head is used to make all horizontal measurements. For example, the average human figure is 6½ to 7 heads high, but the ideal height for any illustrated figure is 8 head units high, and 3 head widths wide.

After the height of the figure has been decided, it should be divided into eight equal parts. This makes the figure slightly taller and slimmer than the average person. The rest of the body is then proportional as the figures in 3-2A and 3-2B.

In figure 3-2A, the other seven heads are divided as follows:

- One-third of a head for the neck.
- Two and two-thirds heads for the torso (from the bottom of the neck to the crotch).
- Two heads to the knee.
- Two heads to the soles of the feet.

The male figure is usually taller than the female with the same proportions. The average length of the male head proportion is about 9 inches. The female head proportions are between 8 and 8½ inches from the chin to the top of the skull.

These are average proportions for the figure standing in an upright position. Most of the time, you will find that the figure, or some parts of it are foreshortened as in figure 3-3. For the best result, when proportioning the figure, you must rely on your visual perception. Only the human eye can determine the amount of foreshortening necessary, because it is a relative judgment.

Foreshortening is a principle of perspective in which an object seems to change its size and shape, because it changes its plane of projection.

The Adult Figure. The structural differences between the male and female are more in the bones and muscle tissue than anywhere else. (See foldout 8, printed as a separate supplement to this volume.) The bones of the female are smaller and smoother than the bones of the male. The female body appears much smoother and less muscular, although the female has the same muscle structure as the male. This appearance is caused by a heavier covering of fatty tissue over the entire body.

The narrower rib cage, shorter and more curved breastbone and a small straighter collar bone, the female's shoulders arenot as broad as her male counterpart. The female also has a longer torso, shorter legs with a broader, shallow pelvis. Note the greater distance between the pelvis and rib cage of the female in figure 3-4. Also notice that the male's pelvis and rib cage are about the same width, whereas, the female's pelvis and shoulders are about the same width. These differences are subtle in most cases, but to an illustrator—these are differences that count.

Proportion changes. Proportion changes as the body grows from birth to adulthood. At birth, a baby's head is quite large compared to the rest of his body. At the age of about 1 year, the body from the neck to the feet is about three and one-half times the length of the head. The center of the body at 1 year is across the stomach.

At the age of 8 years, the overall height of the body is approximately 6¼ heads. The arms and legs are somewhat longer and the head is a little larger and the center of the body has moved to the hips.

At age 12, the overall figure is 7 heads high, and the centerline is now at the crotch (see fig. 3-5). From this age on, the body broadens out, becomes taller, and assumes most of the characteristics of an adult.

Exercises (609):

1. What is the average ideal height of the human figure?

2. Why does the female body appear smoother than the male?

3-2. Constructing the Human Figure

For the purpose of construction, the human figure may be divided into five component parts: torso, arm, leg, hand and foot, and head and neck. Each of the components, in turn, may be considered to consist of the basic forms or combination of the basic forms.

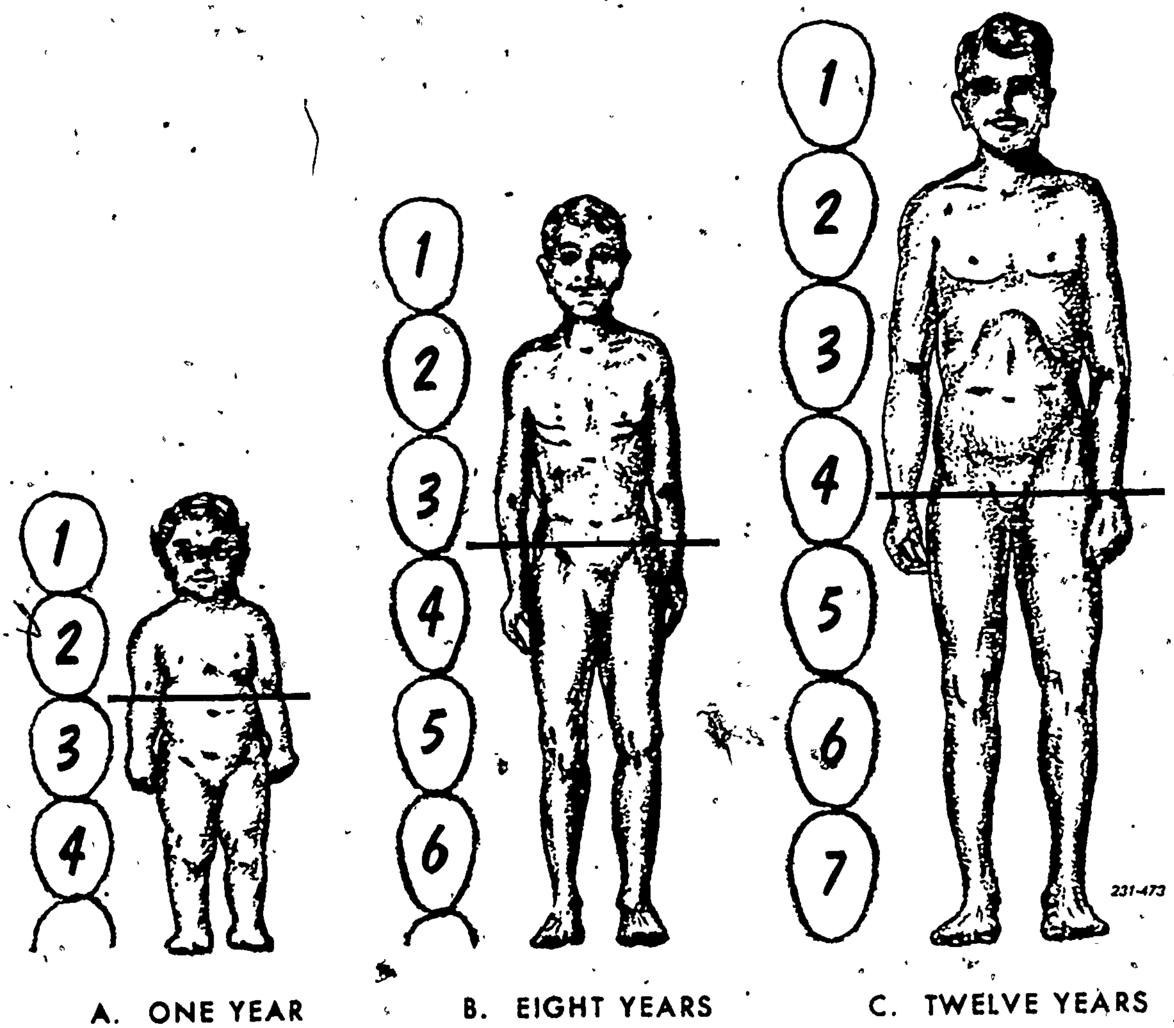

Figure 3-5. Body, age 8, age 12.

610. Name and describe the components of the torso.

The Torso. You must study the torso from many angles to fully understand its function. The torso is made up of three masses: the chest, the abdomen, and the pelvis (fig. 3-6).

The chest is made up of the rib cage, shoulder, and collar bones. The rib cage is a modified cone-shaped mass with the base below. The upper portion of the rib cage appears broader than it actually is, due to the shoulders and collar bones. This causes the shape of the rib cage to be lost from view.

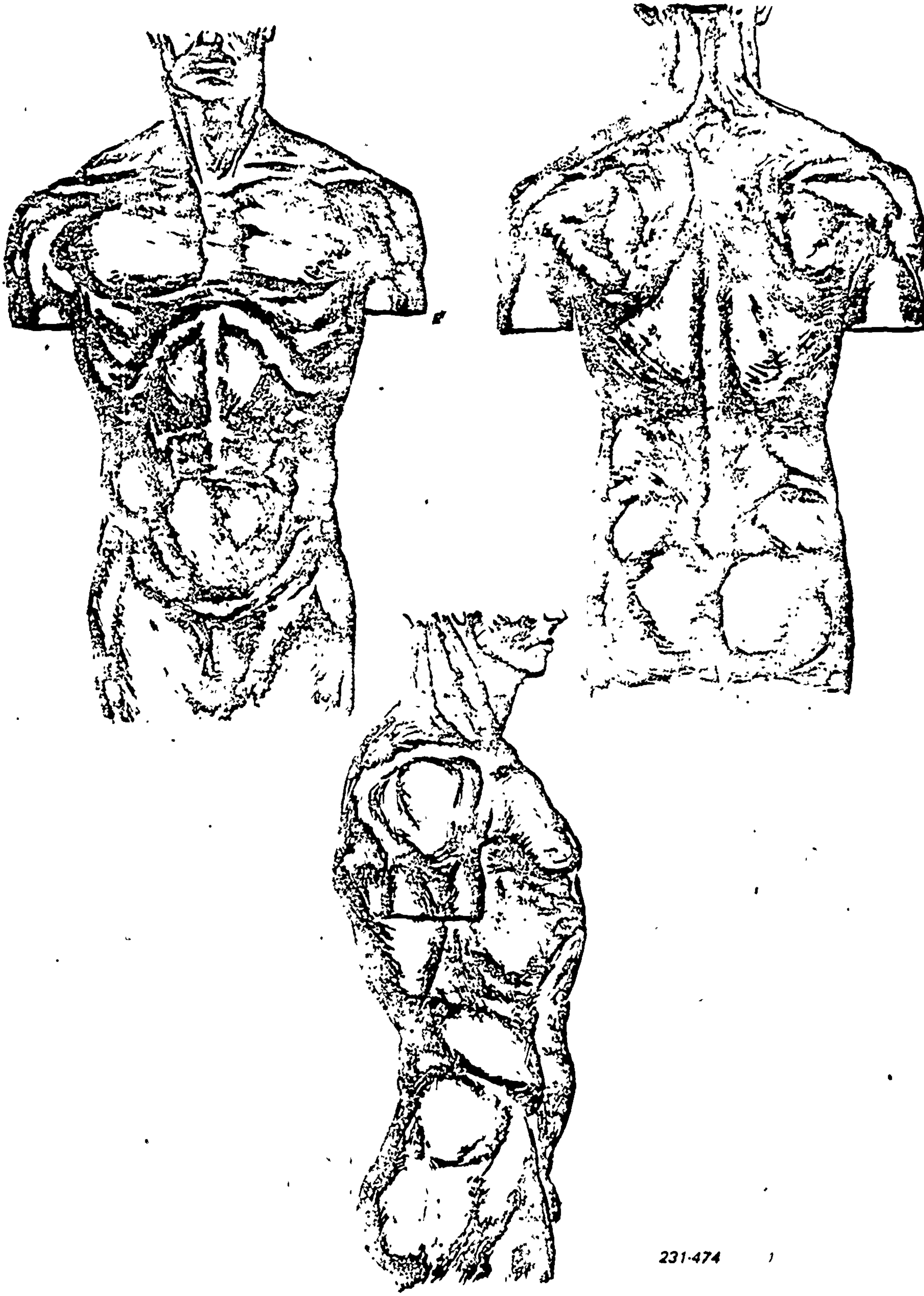

Figure 3-6. Torso.

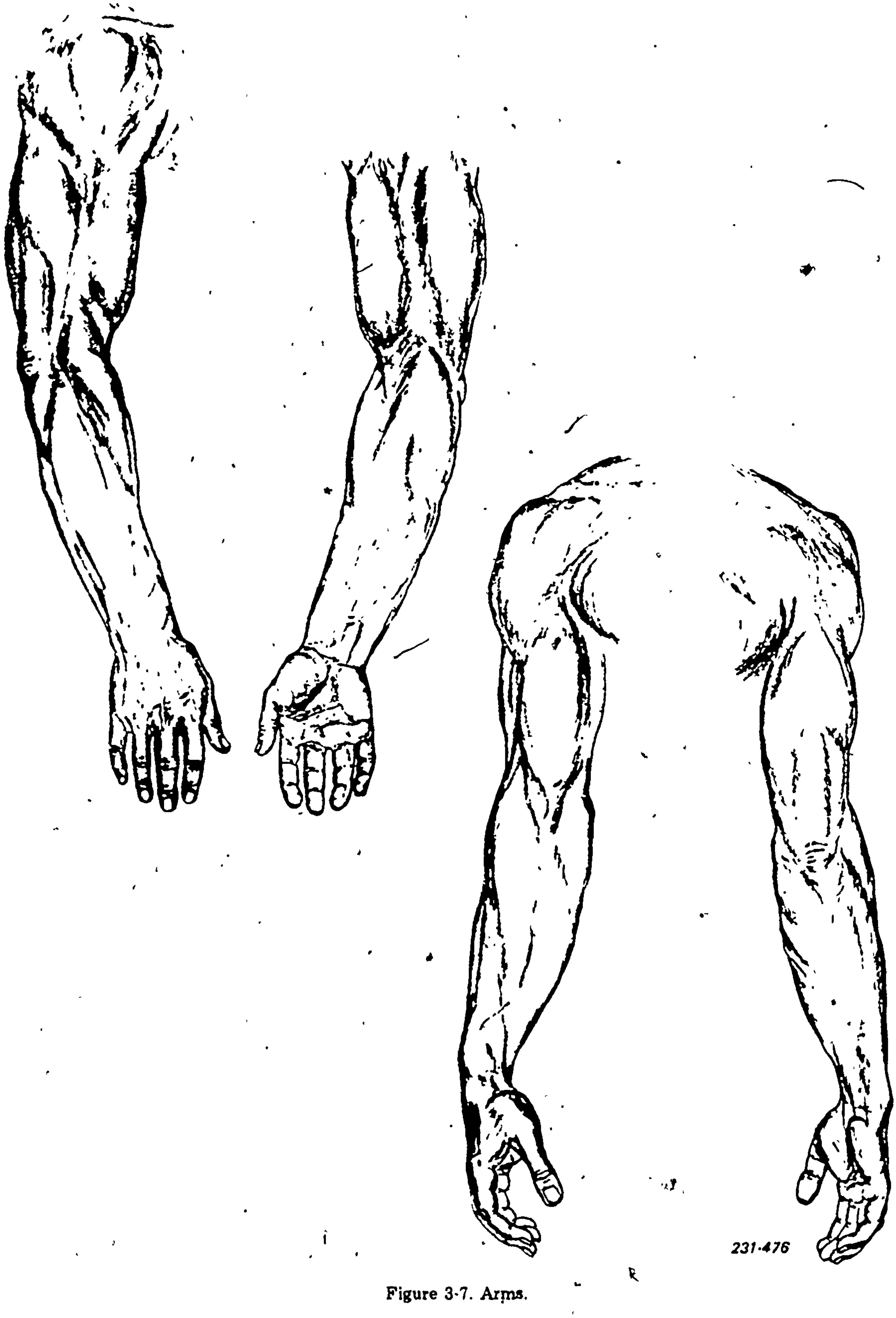

Figure 3-7. Arms.

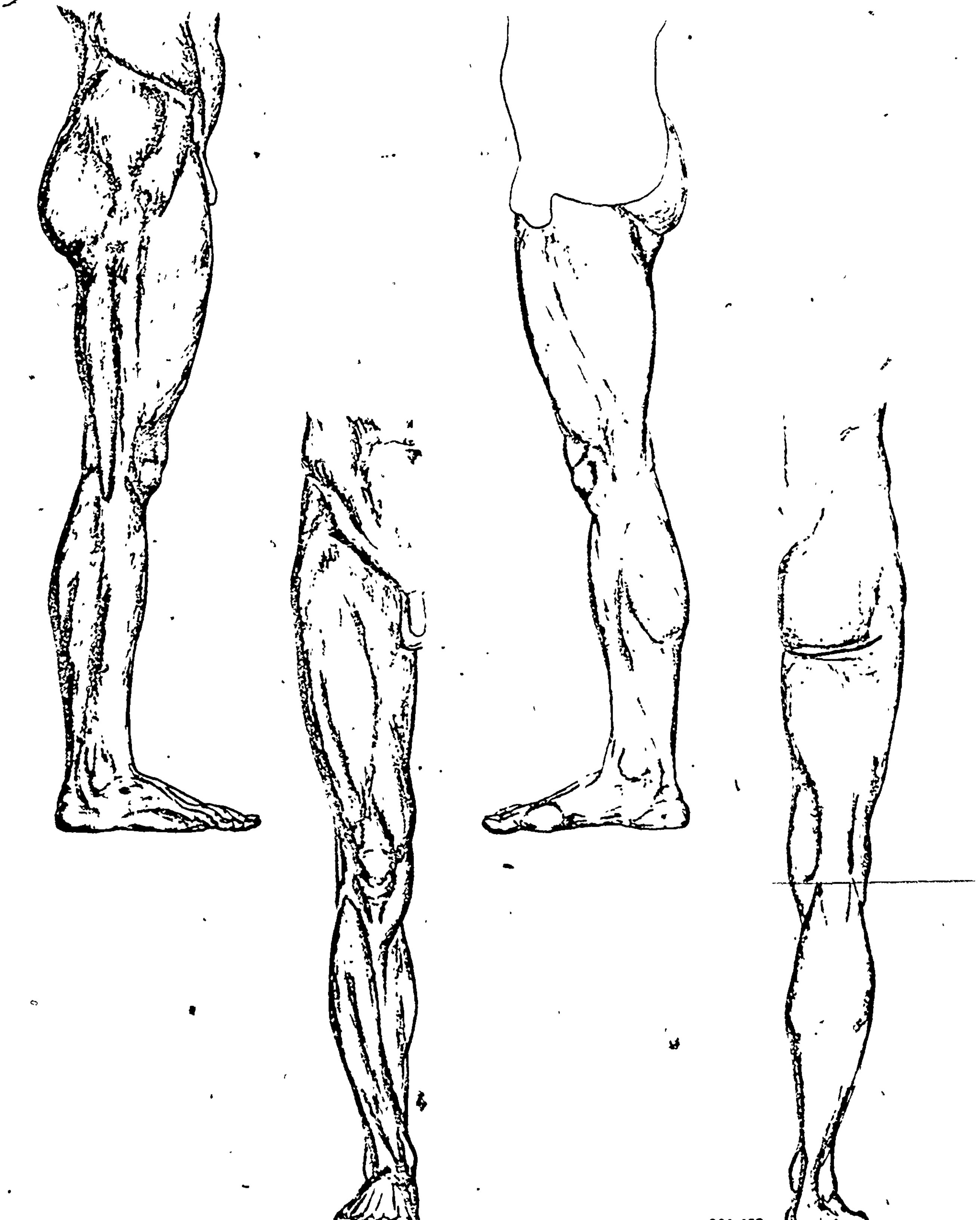

Figure 3-8. Leg.

The pelvis is the lower part of the torso that serves as a base for the other parts of the body. The chest and pelvis are fairly stable masses. The epigastrium or the upper portion of the abdomen is a soft, fleshy and quite movable part of the torso.

These three central masses are connected by the spinal column. The only reason for the study of bones and muscles is that the artist has to understand the framework if he intends to build. (See Foldout 9.)

Exercises (610):

1. What are the three masses of the torso?

2. What is the shape of the rib cage?

611. List the bones in the arms and legs and state how bones affect arm and leg shapes.

The Arms. The arm is based in the shoulder girdle. It has one bone in the upper arm (the humerus) and two in the lower arm (the ulna and the radius). The upper and lower arms are modified cylinders of approximately equal lengths as in figure 3-7. The mass of the shoulder descends as a wedge, sinking into the flattened outer arm halfway down. From the front, the arm wedges downward and enters the forearm just below the elbows. When the thumb is turned away from the body, the mass of the forearm is oval in shape, becoming round when the thumb is toward the body because the bones of the forearm cross. From the back, the mass of the shoulder enters the arm on the side, and at the elbow, the arm and forearm arc as a hinge joint. (See Foldout 10.)

The Leg. The lower limbs, the thigh and the leg, correspond to the arm and the forearm of the upper limb. The thigh extends from the pelvis to the knee, and the leg from the knee to the foot. The longest and strongest bone of the body is the femur or thigh bone (fig. 3-8). The column of the thigh and leg diminish in thickness as it descends to the ankle. From any view it also has a reverse curve that extends its entire length. From either side a wedge shape overlaps the rounded form of the thigh and this again overlaps the square form above and below the knee joint. The leg and the calf are triangular in shape and the ankle a square. The femur (thigh bone) is the most perfect of all levers. It is balanced by the muscles that pass up the shaft of the thigh bone to the pelvis. The human body is provided with a system of levers and pulleys that cannot be matched by any machine for mobility and response. (See Foldout 11.)

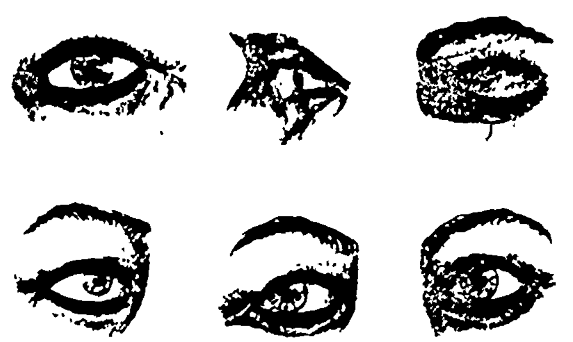

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Figure 3-9. Eyes.

Exercises (611):

1. When the thumb is turned away from the body, what is the shape of the forearm?

2. What bone in the body is considered to be a perfect lever?

612. Describe the parts of the human head and characterize each from the standpoint of drawing it.

The Head. The head, like other parts of the body, is considered along with the neck as a unit. The division of the body is somewhat arbitrary because the neck is also considered part of the trunk or torso. Making arbitrary divisions is useless because no one part can logically be considered independent of its adjacent parts.

When drawing the head, a step-by-step demonstration gives you the fundamental method for blocking in and locating the features. The egg-like shape with some simple measurements to find the location of the features of the head will give you the basic foundation of knowledge for drawing heads in any position. (Foldout 12.)

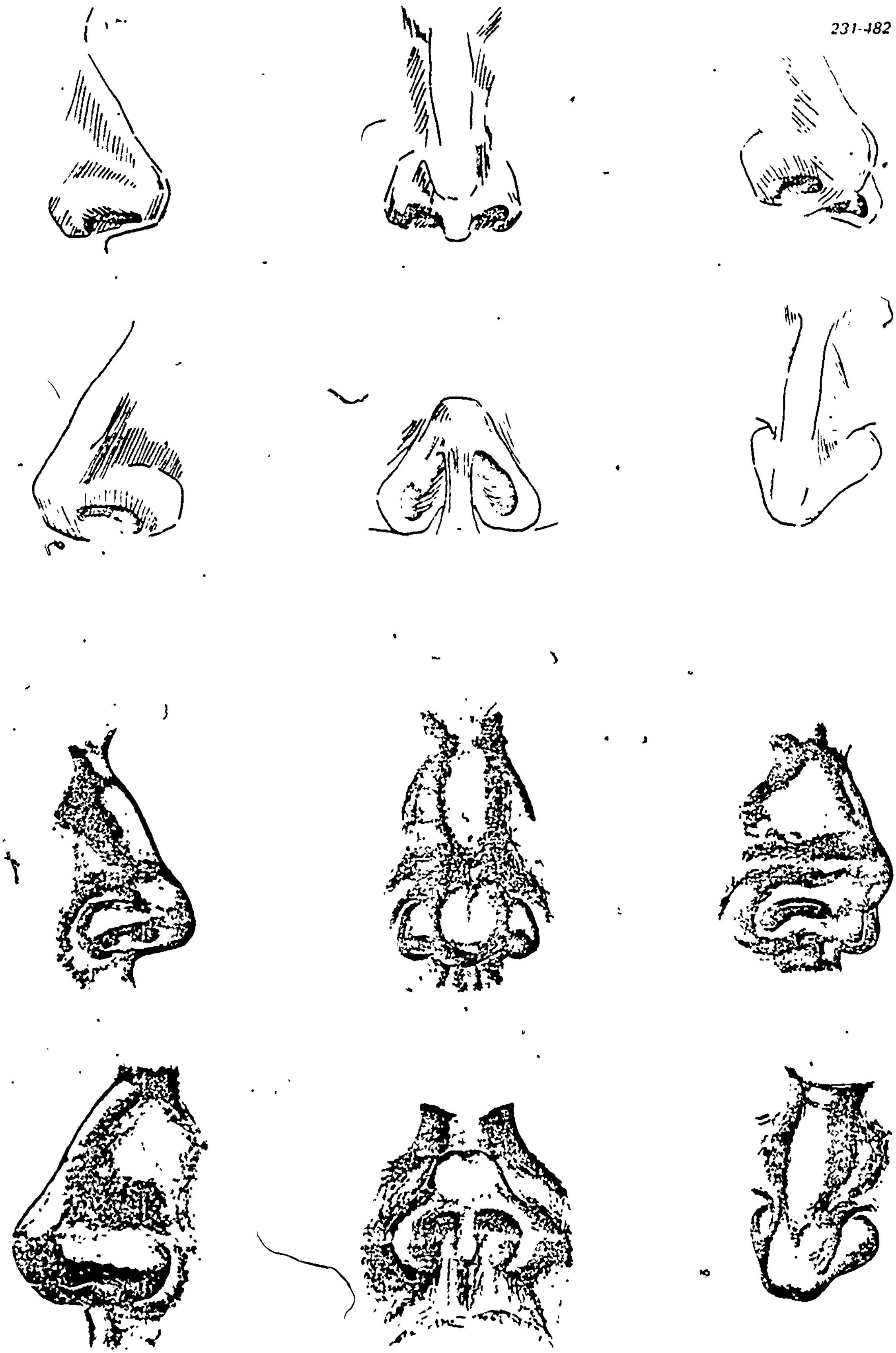

Figure 3-10. Nose.

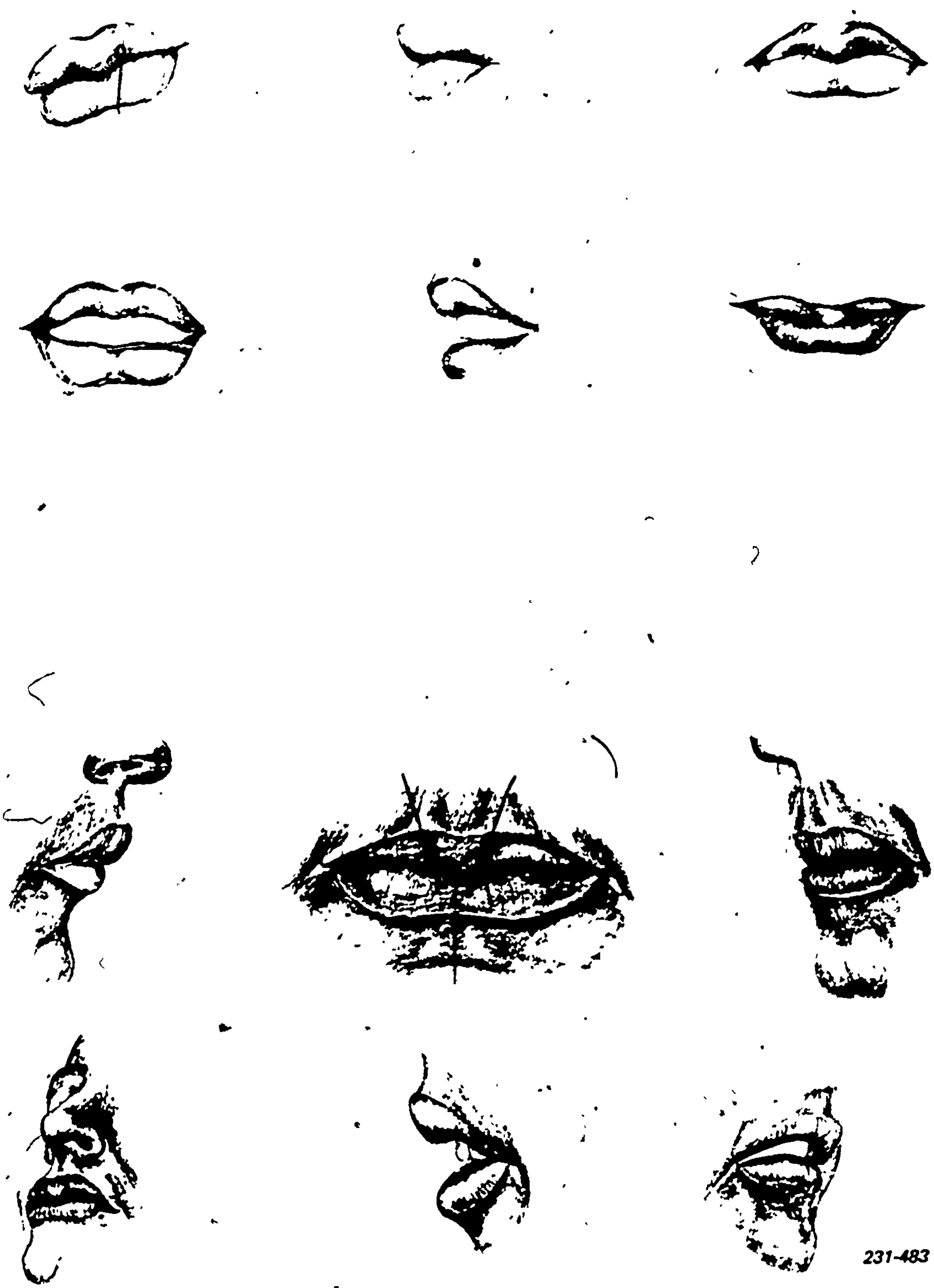

Figure 3-11. Mouth.

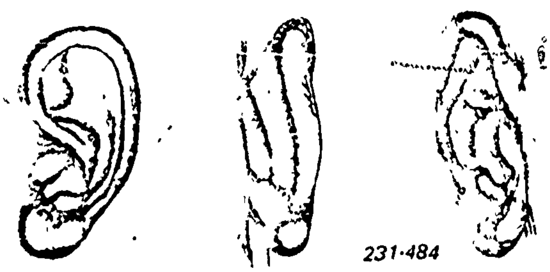
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Figure 3-12. Ear.

The Eye. The eyes are the most expressive and the most delicate features of the face and are well protected by nature. The eye is set deep in a bony recess in the face—the eye socket (fig. 3-9). The eye is protected by the frontal bone of the forehead from above and the cheekbone below. The inner side of the nose affords a great deal of protection to the eye, because of the protrusion of the nose itself. The eyeball is round in shape, with three parts exposed when the eye is open. One is a small dark center called the pupil, through which we see. Surrounding the pupil is a colored area called the iris, and around all of this is the white of the eye.

The two lids that are the outer covering for the eye are fringed with lashes that serve as shades and sensitive feelers to protect the eye. Notice that the inner and outer corners of the eye are different. The upper lid overlaps the lower lid at the outer corners. The exposed part of the eye is always moist. The moisture reflects light and causes a distinct highlight. The location of this highlight depends on the direction of the light. It is a very important factor in making your drawing appear lifelike.

The Nose. As shown in figure 3-10, the nose is narrow at the upper end and wider at its base. The upper part consists of bone and reaches halfway down. The lower part is cartilage. The wide, lower end of the nose is composed of two sides, the front and under surface. The front plane leaves the root of the nose in a well-rounded form and widens as it forms the flattened bridge. The plane narrows as it descends, and again becomes round as it wedges between the bulbs forming the tip. This front surface continues down and under, and forms the small separation between the nostrils. The nostrils are inclosed by the wings, which form the lower sides of the nose. The wings also form the triangular shape that you can see when the head is tilted back. These wings and the end of the nose curl up into the nostrils in a rounded surface.

The Mouth. The mouth, like the eyes, is capable of much expression and movement. Of course, its shape depends to a large extent on the shape of the teeth; the rounder the teeth, the rounder the mouth. As you can see in figure 3-11, the upper lip is thickest in the center and thins with a downward curve to corners which are depressed. The forms in the upper lip are comparatively flat and angular; those of the lower lip are convex and rounded.

When the lips are seen in profile, their thickness, projection, and connection with the face are apparent. The upper lip projects beyond the lower lip which, in turn, projects beyond the chin. Consider the convex shape of the lips at the outer ends with extreme care when you draw the lips.

The Ears. The ears are formed of cartilage and have complex shapes, as shown in figure 3-12. Therefore, a good drawing of the ears can be made only after careful study. The length of the ears is the same as the nose and is about twice as much as the width. Notice that they slant downward and inward when viewed from the front, thus paralleling the sloping planes of the sides of the head. Notice how the contour of the inside edge of the ear spirals down into the depression above the canal. Other distinguishing features are the triangular form directly in front of the canal and the U-shaped space leading to the canal.

Exercises (612):

1. What part of the body is considered to be the most expressive?

2. Which feature of the face is located in the vertical center of the head?

3. Which two parts of the head are about the same length?

613. Describe the structure and action of the hands and feet as related to drawing them.

The Hands. Other than the face, the hands are the most expressive parts of the human body. Therefore, give them careful attention when you draw them. You should be able to make excellent drawings of hands, using your

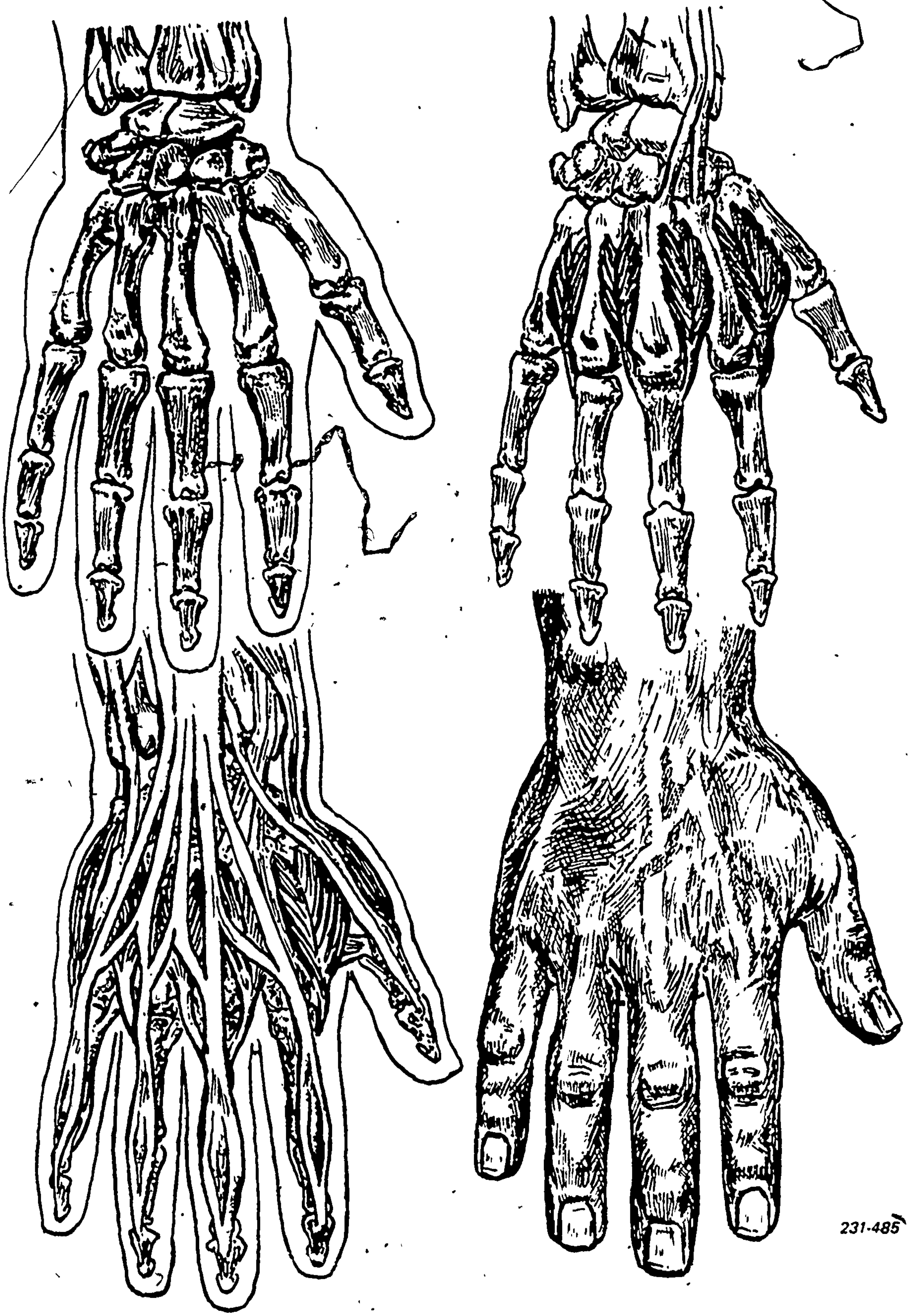

Figure 3-13. Hands.

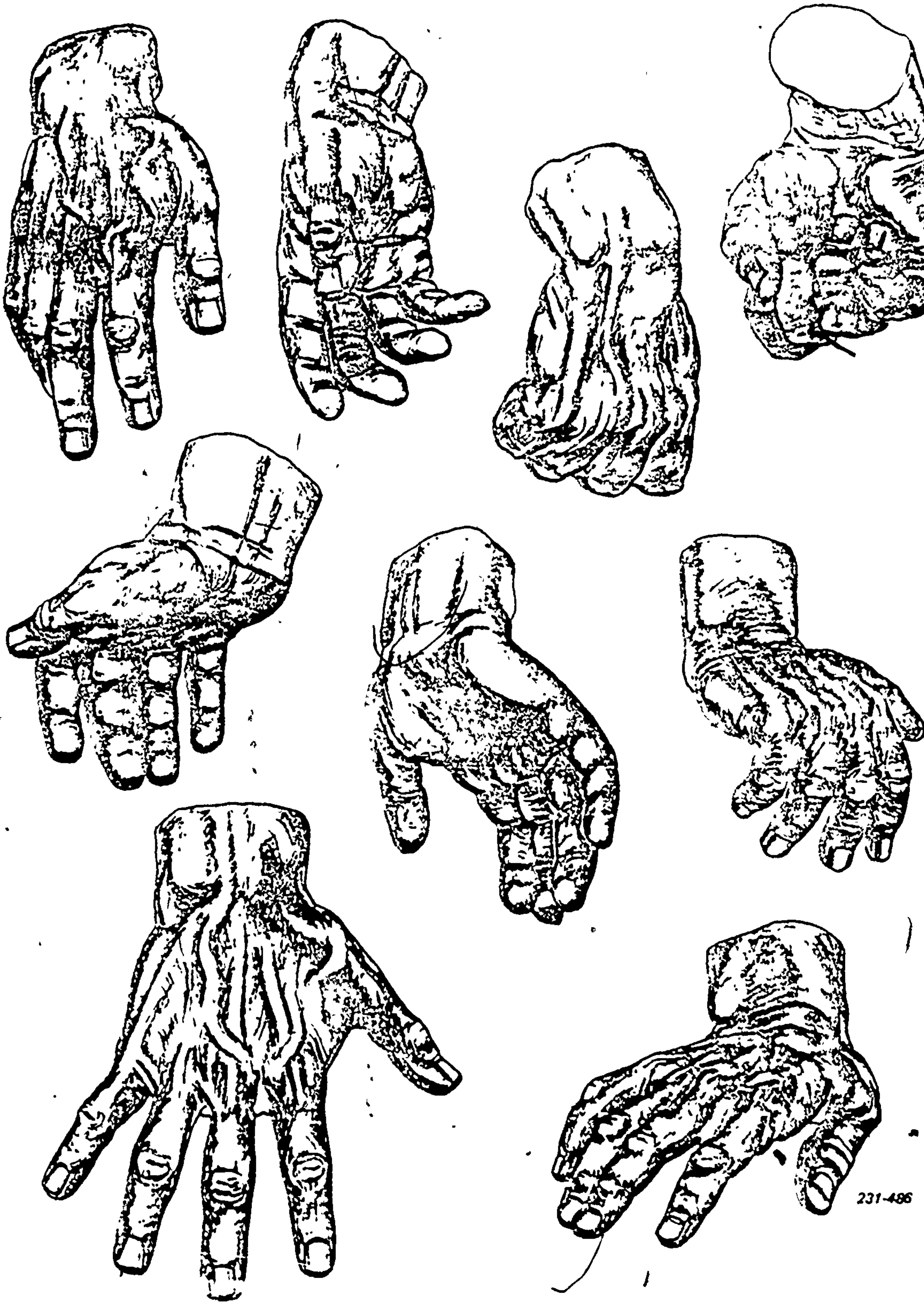

Figure 3-14. Hands.

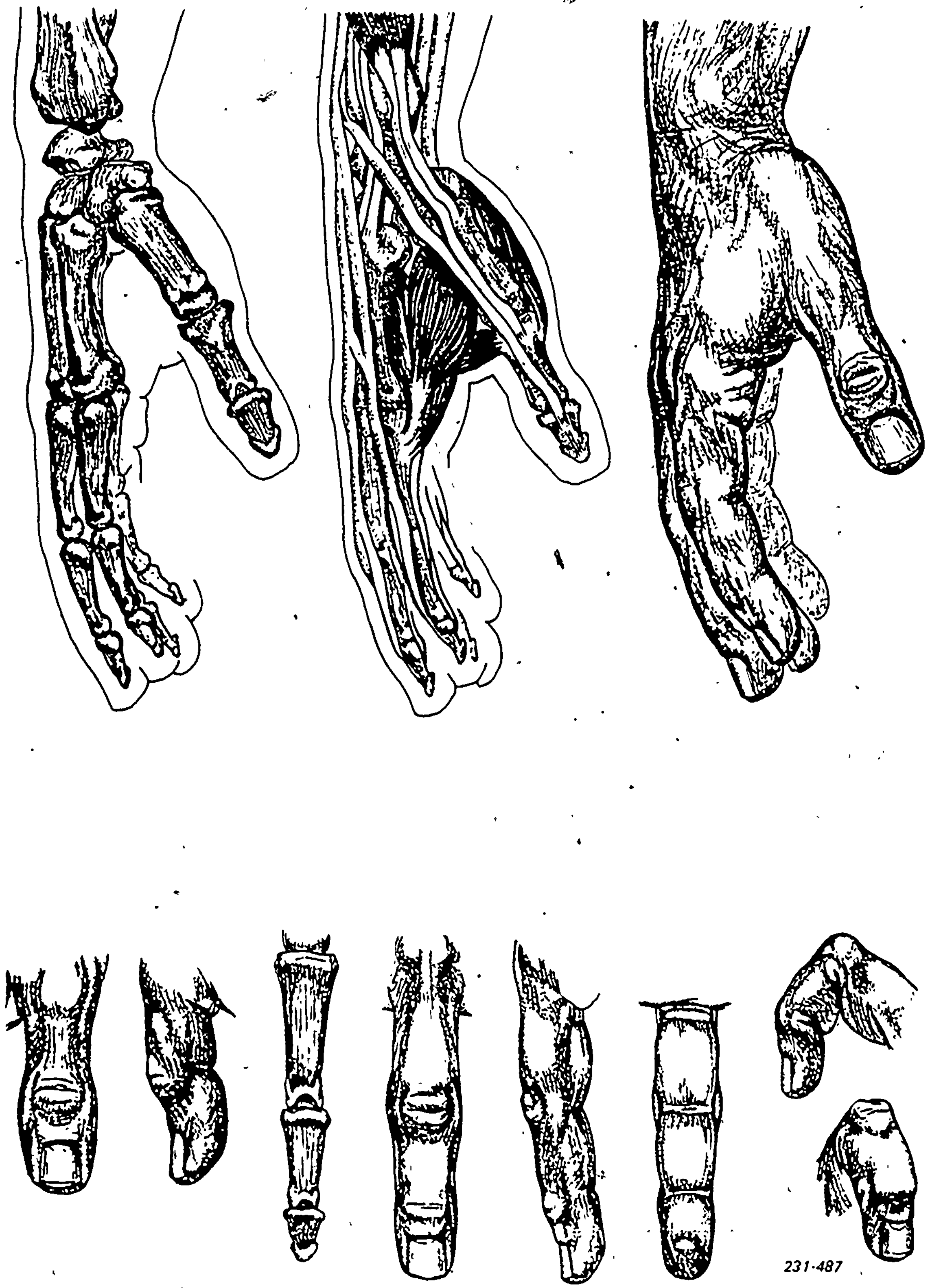

Figure 3-15. Hands.

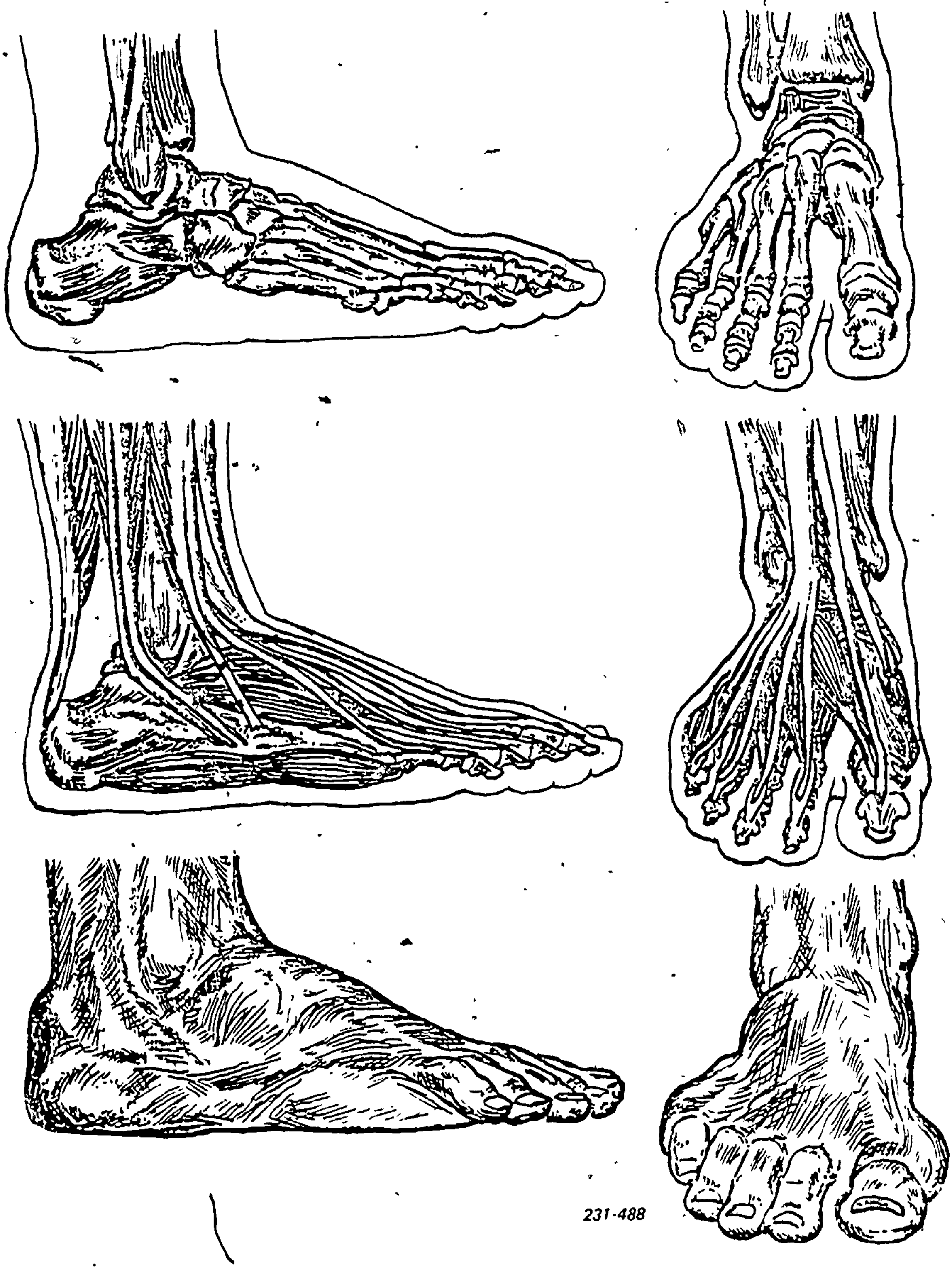

Figure 3-16A-B. Back.

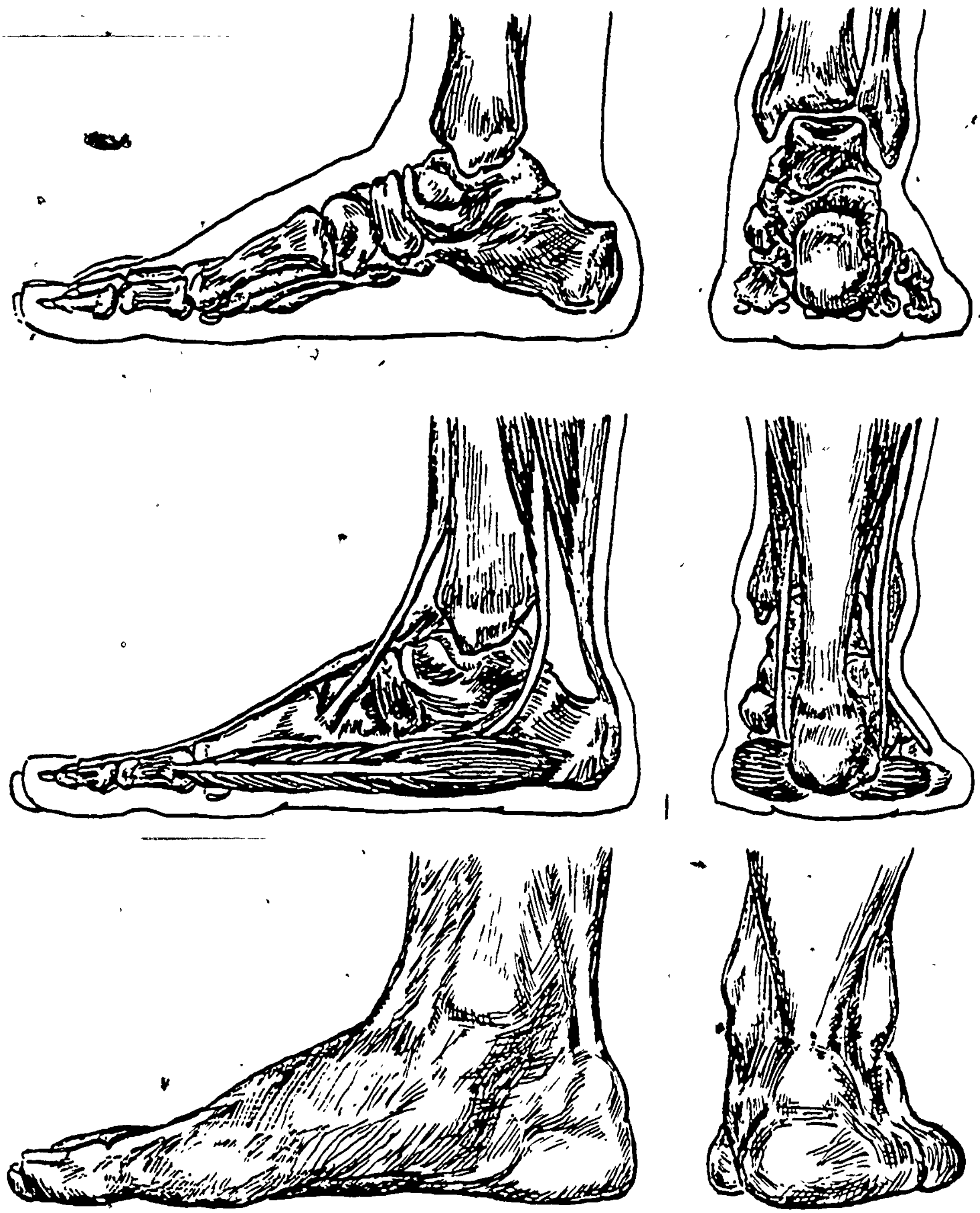

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Figure 3-17. Back.

own as models. Since there is very little flesh on the hand except on the palm side, you need to have a good knowledge of the bone structure to draw it well. Figure 3-13 shows the bone structure. Notice the proportions between the length of the individual bones. Notice also how bones of the fingers and of the thumb connect together, how the bones of the fingers connect to the bones of the hand, and how these bones and the bone of the thumb connect to bones in the wrist.

Observe in figure 3-13 that the palm without the fingers is nearly square, and that the fingers are about as long as the palm.

When the fingers are extended, the hand is about three-quarters as long as the forearm, or is equal to the distance from the chin to the hair line. In drawing hands, be sure to draw them large enough.

Figures 3-13 and 3-14 show another important detail of hands. Notice in figure 3-13 that when the fingers are held close together, as they are when lifting a heavy desk, the force is exerted in a straight line through the hand to the wrist. Thus, there is no tendency for the bones to twist as the fingers exert force. Notice in figure 3-13 that the lines of action shift toward the base of the thumb when the fingers and thumb are formed into a fist or used in any gripping action.

One of the important details in drawing hands is the placement of the folds (see fig. 3-15). Observe that the two folds of the finger come directly at the joints, and that there are two folds when the finger joins the hand. The first of these folds comes between the fleshy part of the finger and the palm; the other is created as the palm bends.

Figure 3-16 shows the back and palm side of the hand. Notice that the form of the back of the hand is basically convex, and that the form of the palm side of the hand is concave.

The Feet. The feet have about the same number of bones as the hands. However, the proportions are different, as you can see in figure 3-17. The feet are as long as one-half the distance from the knees to the bottom of the feet. Notice that the outside anklebone is slightly lower than the inside anklebone. The high part of the foot is at the inside between the ankle and the big toe. As you can see, the foot slopes toward the toes and also toward the outside edge.

The foot has very little movement. Most of its action is accomplished through the movement of the anklebones and between the joints of the toes and the foot.

Exercises (613):

1. Other than the face, what is the most expressive part of the body?

2. The important details that you should remember about the hands are:
   a. The basic shape of the palm is ______.
   b. The length of the fingers is approximately the same as the ______.
   c. The length of the outstretched hand is equal to about three-quarters of the ______ or the distance between the chin and the ______ ______.
   d. The action of the fingers when outstretched is in line with the ______.
   e. When the fingers are in a gripping action, the line of action shifts from the wrist to the base of the ______.
   f. The form of the palm side of the hand is basically ______ and the back of the hand is basically ______.

Cartoons and Caricatures

THE ABILITY TO cartoon and draw caricatures is a specialized field for most commercial artists. To become a good cartoonist, every student should begin his studies with a reasonable amount of self-confidence. Since the same knowledges that apply to figure drawing apply as well to cartooning and caricatures, a good artist may find that all he lacks to become a cartoonist is self-confidence.

4-1. Cartoon Definition

The popular definition of a cartoon is a humorous drawing but there are no formal boundaries to the style of drawing called cartoons. Cartoons range from realistic illustrations to totally abstract design. All of the basic aspects of cartooning and caricatures can be summed up in one basic principle—behavability. Cartoons are simplified exaggerated forms that show expressions.

614. Define expressions and exaggerations.

Expressions and Exaggerations. Expression is action. For example, all jumping figures have both feet off the gound, but all walking figures have both feet touching the ground. You make visual studies of real people and convert their movement and expressions into humorous drawings. A cartoon differs from the more serious-type drawing in that it is usually drawn with a much looser treatment. That is, you concentrate on the action and attitude of the figure more than you do on the fine detail. Then, too, cartoons are usually simple line drawings, requiring substantially less variation in mediums than used in other types of art work.

Facial Expressions. In cartooning, the features of the face are usually drawn as simple geometric shapes. As you can see in figure 4-1, the eyes can be drawn as circles, ellipses, dots, or lines. Humorous effects in the face are produced by exaggerating or distorting the average measurements and relative proportions within facial features. When the caricature of a person's face is being drawn, all the irregular characteristics should be observed and exaggerated.

The one set of rules generally accepted by all cartoonists is that facial expressions are

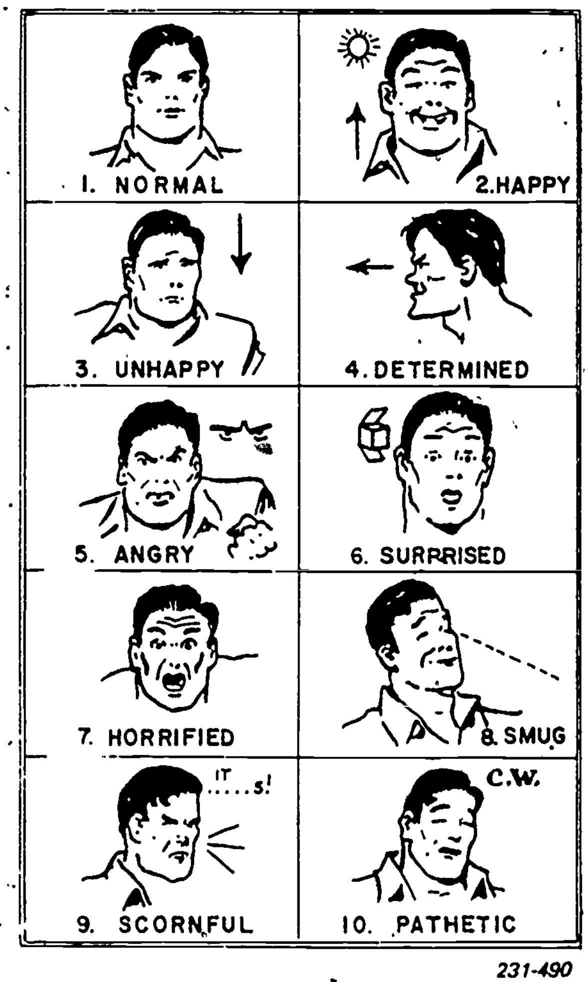


Figure 4-1. Cartoon eyes.

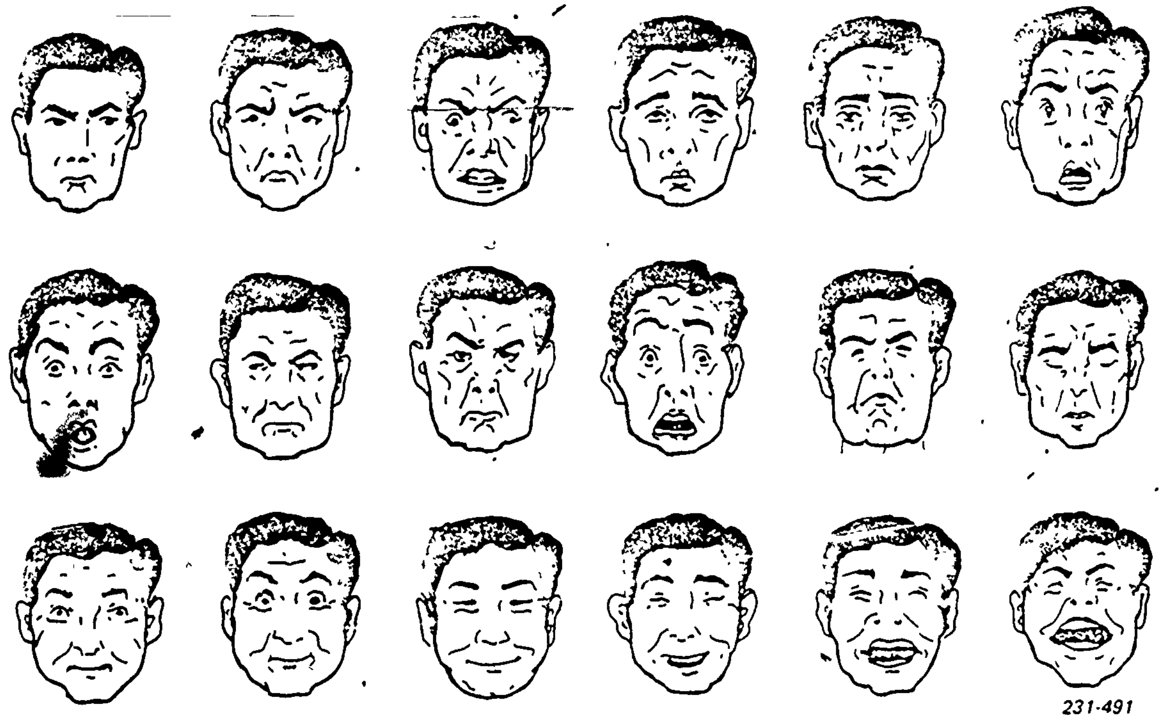


Figure 4-2. Facial expressions.

produced by the movement or lack of movement of the eyes, mouth, nose, and forehead. Figure 4-2 shows some examples of emotional expressions produced simply by changing the shape or position of those facial parts.

When the face assumes a happy expression, the parts of the face are lifted. The corners of the mouth are pulled up and out. The cheek muscles are bunched by this action so that the lower lid of the eye is pushed up and almost closed.

An unhappy face is just the opposite, the corners of the mouth are dropped, the eye, and eyebrows are lowered, and the forehead wrinkled, whereas, determination is expressed by the lowering of the brow and the jutting out of the lower lip and chin. Other emotions such as anger, surprise, horror, smugness, and scorn can be expressed by similar facial movements. Along with the facial expressions, body movements should fit the emotional appearance of the face.

Exaggeration. Exaggeration is the one exception in cartooning where the cartoonist must use a little discretion. Although the rules of expression and exaggeration are generally accepted, exaggeration can be cruel. So let it be reemphasized that as a cartoonist, you are bound by no rule except that of GOOD TASTE.

Exercises (614):

1. What is a cartoon?

2. Expression is created by both the ______ and the __________.

4-2. Captions

Ordinarily, there are two types of cartoons. Those that are pantomime—all action and tell the story in picture, and the captions or punch-line type. In many instances, it is the punch-line, gag, or joke that inspires the cartoonist to draw. Keep punch-lines as short as possible and let the action of the drawing do the work.

615. Name the two types of cartoons and state the procedures for creating cartoon characters.

Character Creation. The number of different characters a cartoonist can draw is limited only by his imagination. Because the face controls the mood and emotional expression, it is the important part of a cartoon character. The head can be any basic shape, and this shape can be used to create many other characters. Characters are created

When creating a cartoon character, it is best to use the physical features and dress that have become popularly identified with certain types of people and with people from certain areas. These symbolic features have been associated with certain types of people for so long that the public instinctively relates a certain appearance to a particular-type person; for example, the hillbilly right out of the hills. His symbolic attire is a torn checkered flannel shirt, bib-type overall with patches, a rumpled wide brim hat; he is also

Figure 4-3. Facial structure.

by adding or making changes in the facial structure as shown in figure 4-3. As shown in figure 4-4, one character can be many different characters by making very minor changes. When a cartoon character is required, one should consider the end use.

When cartooning, you may not always be called upon to cartoon or caricaturize the human being. Some jobs may call for the animation of animal with human characteristics, or ships, planes, and other pieces of machinery with animal characteristics. Figures 4-5 through 4-7 are good examples of this type of animation.

Figure 4-4. Changes in facial structure.

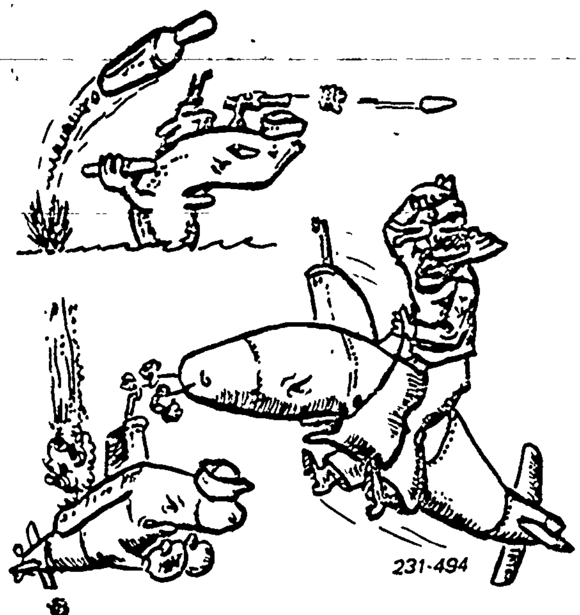


Figure 4-5. Animation animal with human characteristics.

Figure 4-7. Animation animal with human characteristics

usually in need of a haircut and shave. He is often shoeless and carries a long barreled squirrel gun.

Although this may not be factual in relation to backwoods people, this type is usually pictured as rather ugly and has a warm relationship with his jug of corn whiskey.

The female from this area is usually illustrated in two styles. One, the beautiful, well proportioned lass, and the other one, whose appearance more closely parallels the man's appearance. These three characters are shown in figure 4-8. As you can see, one look at the characters will place them in your mind as hillbillies, and you will have no trouble getting them mixed up with the characters from a more affluent society in figure 4-9.

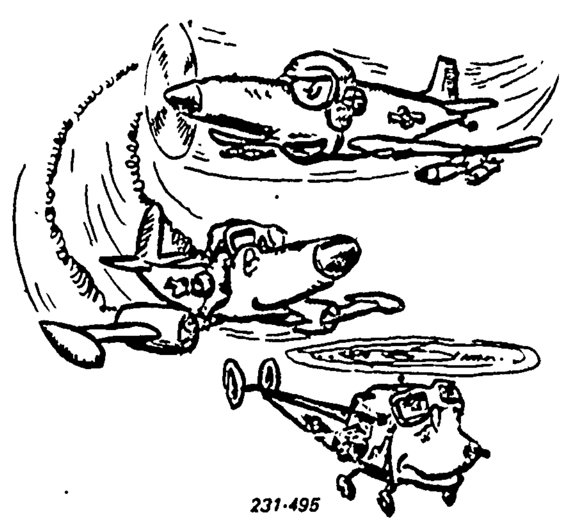


Figure 4-6. Animation animal with human characteristics.

Figure 4-8. Hillbilly female.

Figure 4-9. Affluent society.

Figure 4-11. Hip-swinging performer.

You should, when possible, use the established public impression that is readily accepted for a particular type of person. There is a symbolic type for nearly every type and for every geographical area in existence, including foreign nations. The list is unending; and the following illustrations show but a few of the long, long list of possibilities.

You will see in these examples that some of the characters are drawn as having large noses while others are drawn having short noses. You must experiment in cartooning just as in all phases of illustrating in order to find just the right design, the right nose or mouth, type of eyes or hairstyle, to fit the character so that he will blend into the situation properly. You will find that cartooning is more than mere doodling; it takes practice, experimentation, more practice, and a firm determination to become a good cartoonist. The cartoons shown in this chapter are the writer's creations—his style of drawing. Although it is proper for you to copy them for practice, it is essential for you to develop your own style of cartooning before you can consider yourself a cartoonist of any caliber. Remember, it is your style; develop it to fit your abilities and needs.

Just as there is an almost unending list of different types of people, many of these can be seen as two distinct characters, the good guy and the bad guy. For example, there are both good cowboys and bad cowboys (fig. 4-10). In cartooning, it is not necessary for the good guy to always win. It often adds to the humor of the situation when the bad guy wins.

Figure 4-10. Cowboys.

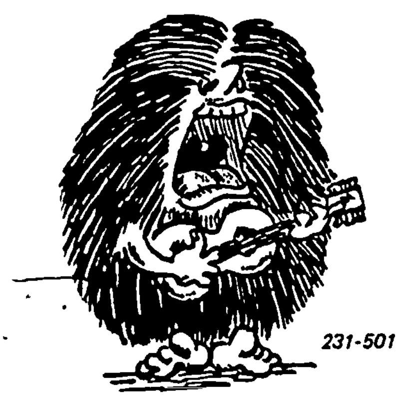


Figure 4-12. De-humans performer.

231-502

Figure 4-13. German cartoon.

In the world of music there are many different types of personalities. There is the classical musician and the modern day, no talent, hip swinging howling type of performer (fig. 4-11). Of the latter, some have almost lost their identities as humans (fig. 4-12).

Some of the people of foreign countries offer themselves as excellent specimens for cartooning. The people of Germany (fig. 4-13) have always been well known for their aristocratic, military leaders and the Bavarian-type costumes and beer steins. Typical Russian cartoon characters are shown in figure 4-14.

Remember, it has already been said that not everybody will like your cartoons. What will fracture one group's funny bone may bring screams of protest from another. Solution: always know your audience.

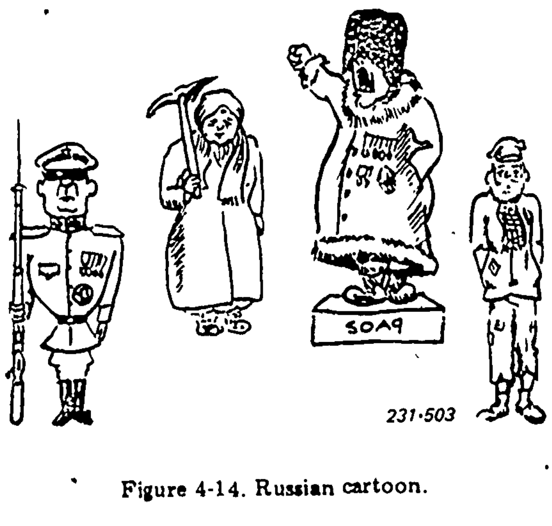
The different people of the world have many different characteristics and costumes and it is most interesting to work up several different interpretations of each of them, as you have been shown by a few examples.

When you are drawing a cartoon depicting a certain nationality, race, or period of history, it is extremely important to use the correct costume on the character. This aids in his identification and correctness, and when done well, adds to the humor of the character. You may be able to see this in the drawing of the Roman toll collector (fig. 4-15), and the drawing of the Viking and Italian explorers. (fig. 4-16). In any cartoon, not only must the costume be correct for the character, but any supporting characters, the stage or background if there is one, all must be in place with the main theme. The pattern must be consistent with all particulars related. In cartoons, the background is usually greatly simplified and reduced to just those elements essential to clarify the picture. In some cartoons there is no background at all; other times, the background may be highly detailed. This again is usually a choice of the cartoonist. The use of background is usually determined by the style of the cartoonist. Most frequently, a cartoonist will use no more background than is needed to identify his character to a specific area or location.

You can also use cartoons effectively to make good-natured fun of someone or some group. This points out again that taking any situation, person, or group, you can create an effective cartoon out of it. For example, figure 4-17 is a cartoon prepared by a DM who is not an ex-Seabee for the benefit of the many DMs who are ex-Seabees.

Caricatures. Drawing caricatures is very much like having the subject stand in front of the bent mirror found in carnivals and penny arcades. The mirror distorts and exaggerates the features, but does not add or subtract anything not already existing about the subject. The cartoonist does the same thing. The predominant features are exaggerated or distorted; but you must be careful not to get away from the character.

Don't offend; exaggerate, but be reasonable. When possible, incorporate a hobby or anything identified with the subject.



231-503

Figure 4-14. Russian cartoon.

Figure 4-15. Roman.

Figure 4-16. Viking and Italian explorers.

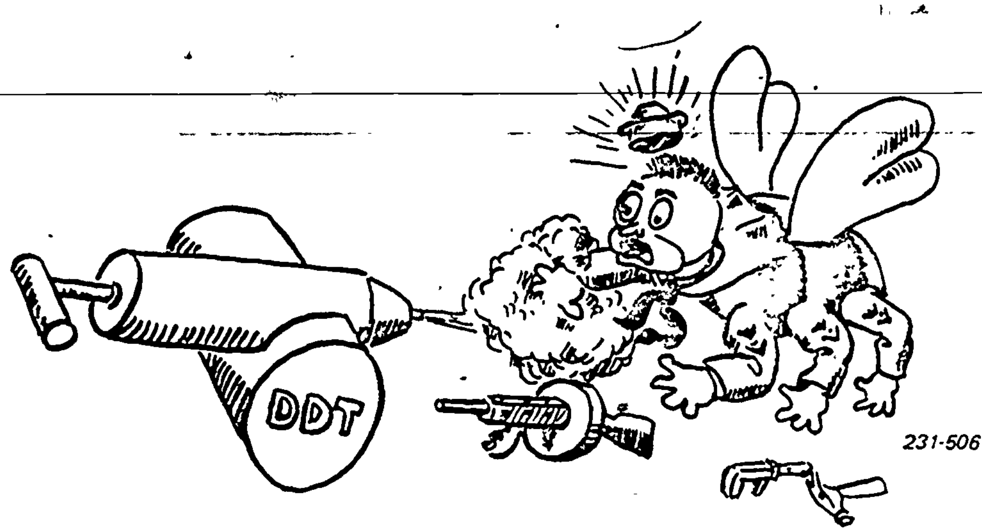


Figure 4-17. Bee of Sea bees.

"Local color" always helps for a truer characteristic.

Capture at least one outstanding feature—a typical expression or mannerism. Put that down (slightly distorted) and draw around it. Once the head is drawn, the body can be drawn in. A good proportion for caricature is two-thirds head, one-third body. The only possible way to learn to do caricatures is to practice. Strive for a likeness, then add small distortions to add humor.

Exercises (615):

1. What are the two types of cartoons?

2. How many different characters can be drawn from one head shape?

Landscapes

NATURE HAS ALWAYS been a valuable aid to the artist, with her dappled birches, somber pines, and rolling meadows. No matter how creative you may be or how original your landscapes are, in time your ideas will wear thin. The same trees, rocks, and skies, no matter how you recombine them in different pictures, are still the same skies, rocks, and trees. Nature has others in infinite supply. Take them from her and use them to refresh your mind and your pictures.

5-1. Landscapes

Landscapes are all around you. Careful observation wherever you go makes nature the most valuable and inspiring teacher an artist can have. No matter how creative you think you are, nature with her strong stonefaced cliffs, majestic mountains, and turbulent waterfalls has an endless reservoir of scenes to offer you.

The imaginative artist never takes nature just as he finds her. He must *create*. He must rearrange and redesign a scene to suit the particular situation he has in mind.

616. State how the elements of a landscape impart cogent information and create mood and feeling.

Mood and Feeling. Every region has a character and a mood. Often the picture situation calls for a landscape to set the scene, to tell the viewer exactly where the action is taking place. An artist can plan the landscape so that the viewer knows where the scene is as if the name was painted on a sign.

North, South, East, or West—every part of the country has its own characteristics by which it can be recognized. You know it by its trees, bushes, flowers, buildings, and especially by the terrain. If your picture is of a coastline, sandy beach, and a warm easy lazy feeling prevails, a western cowboy in a park would seem out of place. Every place has something that is typical of the region and something that will give the viewer a feeling of being there. Photographs, books, movies, television are all good sources of information for creating the mood and feeling for a particular area. No one can be in, or have been to, every location that could be used to establish the scene of an illustration. So keep these sources in mind and use them.

Controlling the Mood. A landscape never exists apart from mood and feeling, whether in nature or in a picture. When a man stands on the edge overlooking the Grand Canyon, he feels the grandeur of nature and his own insignificance. By contrast, a bubbling brook, a shade tree, and lazy white clouds create a mood and feeling of a warm summer afternoon with not a care in the world.

You can control the response of your audience if you are able to capture this illusion in your drawing. Experience the wide open space of the plains or the cramped hemmed-in feeling of the city. The scenes that are deeply felt, closely observed will communicate your impressions clearly and forcefully if thoughtfully recreated.

Background. Rarely will a landscape be the chief subject of an illustration. The main purpose of a landscape is to set the scene for the center of interest. The landscape, even as a background, is usually secondary but it must look genuine because it is important to the story. As an illustrator, you are expected to show a convincing scene at any time of day, under any kind of weather conditions, anywhere in the world. You may use photographs and other means to identify your background scene, but try to be original. Symbols are very helpful in placing a scene, but some symbols are overdone. The Eiffel Tower is in a great many scenes of Paris. Overdoing symbols can bore your audience, and it also says that your imagination is running dry. Always remember, a landscape background is never something hastily brushed in to fill up the white space.

Time and Weather. Time and weather are

valuable tools for any artist. By using them to their best advantage, the landscapes you draw will have more meaning. A storm in the background can underline the stormy temperarament of the figures in the foreground or strenthen the drama and excitement of the action taking place with the principal figures. Sunlight can do many things to an illustration. It can be bright and gay or eerie and mysterious, depending on the time of day, just as darkness can shroud your scene in gloom.

Nature is always changing—especially the clouds and water. In almost every landscape, there is a sky. Skies usually have clouds of some kind. They may be huge threatening thunderheads or light, fleecy forms that drift slowly. Carefully selected, the right cloud formation can add conviction to the scene and help the composition. Water, like clouds, depends on the whims of nature as to the conditions you will find. A body of water may be flat and smooth on a calm day, choppy with whitecaps if there is a brisk wind or have a storm-swept surface with waves rising to mountainous heights.

First-hand observation is the best teacher you can have if you are willing to observe and not take what is happening for granted. Weather is all around you and time goes on forever. We have a saying for those people who are unfamiliar with the continuous weather changes that are experienced by the locals that live around the foothills of the Rockies. "If you don't like the weather—wait a few minutes, it will change."

Weather and time are important—there will be some in every landscape you draw.

Exercises (616):

1. How does a landscape create mood?

2. Why is a landscaped background important?

ANSWERS FOR EXERCISES

CHAPTER 1

Reference:

600 - 1. Solid.
600 - 2. To show that they have a top, bottom, and sides.

601 - 1. The sphere, the cylinder, the cone, and the cube.
601 - 2. Form.

602 - 1. The illusion that gives an object a third dimension.
602 - 2. The process of drawing all sides of an object, even those that are unseen.

603 - 1. Shading aids in seeing the planes of a form.

CHAPTER 2

604 - 1. A small, quickly drawn illustration.
604 - 2. To work out design ideas.

605 - 1. Instead of being small and quickly drawn, the rough is a drawing of actual size and is a more detailed sketch.
605 - 2. Any faults in the design that are unnoticeable in the thumbnail are quite apparent in the rough.

606 - 1. A detailed layout that is a step closer to the finished product.
606 - 2. Comprehensives show exactly what the finished product will look like.

607 - 1. Area, depth, line, and value.
607 - 2. Depth.

608 - 1. Balance, proportion, rhythm, movement, unity, clarity, and simplicity.
608 - 2. Because balance is used to hold the interest of the observer.
608 - 3. Clarity; simplicity.

CHAPTER 3

609 - 1. 8 heads.
609 - 2. Less muscle development and a heavier layer of fatty tissue.

610 - 1. The chest, the abdomen, and the pelvis.
610 - 2. A modified cone.

611 - 1. Oval.
611 - 2. The femur.

612 - 1. The eyes.
612 - 2. The eyes.
612 - 3. The nose and ears.

613 - 1. The hands.
613 - 2. a. Square.
b. Palm.
c. Forearm; hair line.
d. Wrist.
e. Thumb.
f. Concave; convex.

CHAPTER 4

614 - 1. Simplified, exaggerated form that shows expressions.
614 - 2. Face; eyes.

615 - 1. Pantomime and captions.
615 - 2. As many as the mind can imagine.

CHAPTER 5

616 - 1. By setting the scene to tell the viewer exactly where the action is taking place.
616 - 2. Because the background tells the viewer where, what time of day, and the weather.

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SUPPLEMENTARY MATERIAL

CDC 23151

GRAPHIC SPECIALIST

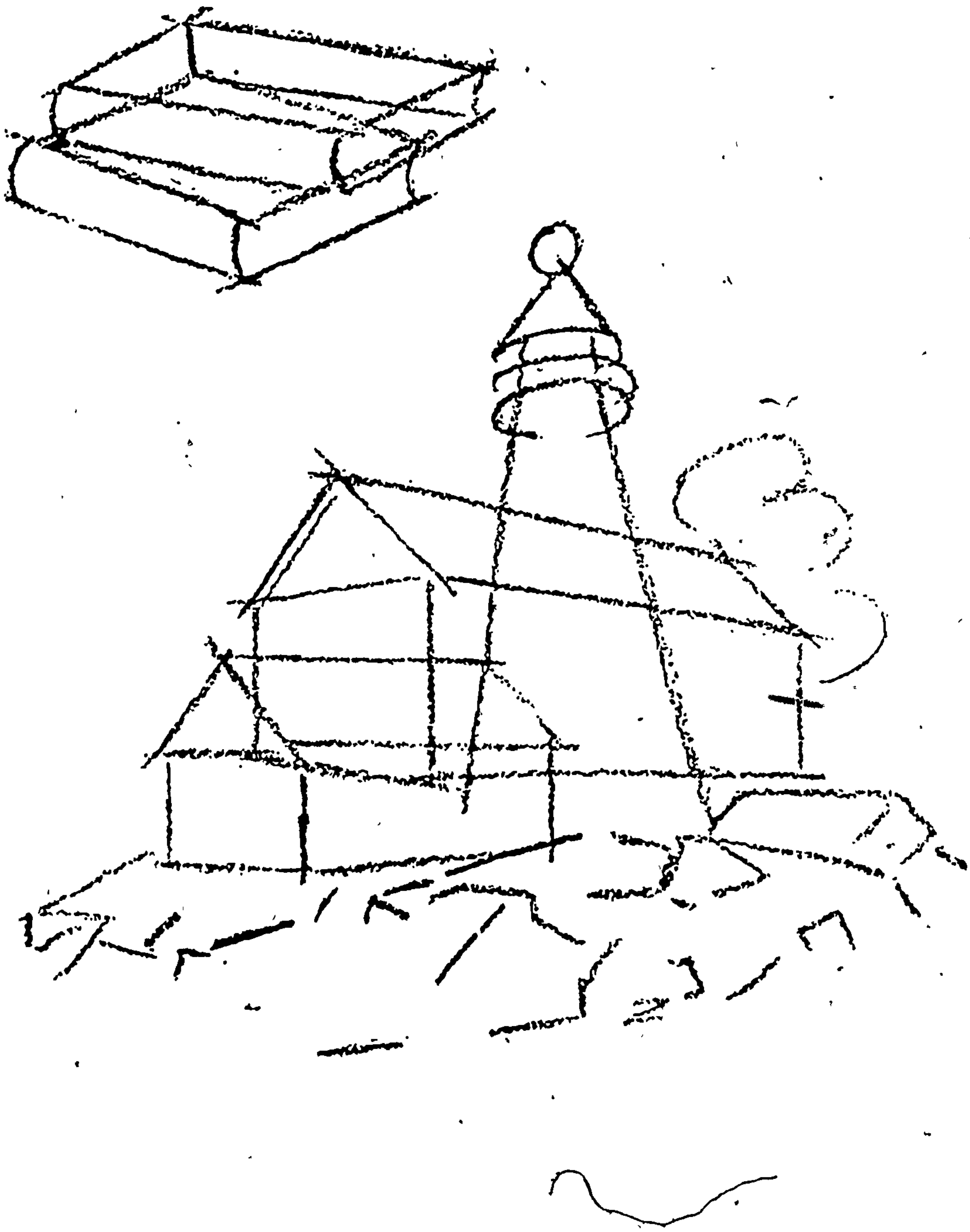
(AFSC 23151)

Volume 4

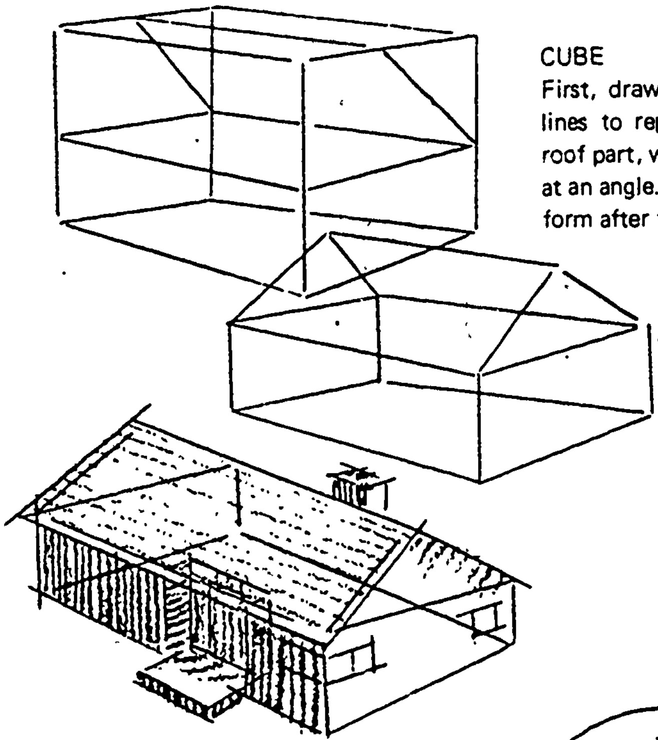
Foldouts 1 through 12

Extension Course Institute

Air University

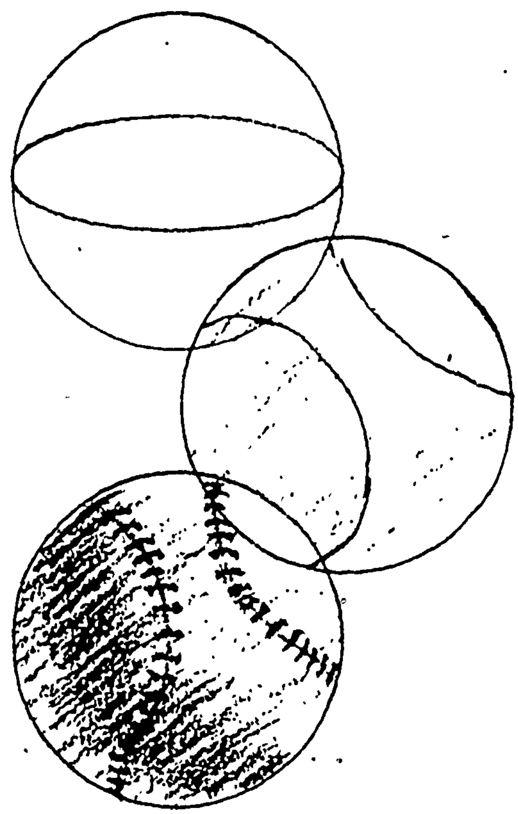


Foldout 1. Drawing basic form



CUBE

First, draw the base of the cube, then the lines to represent the walls. Next, add the roof part, which is a section of a cube turned at an angle. Light and shade to emphasise the form after the basic construction.



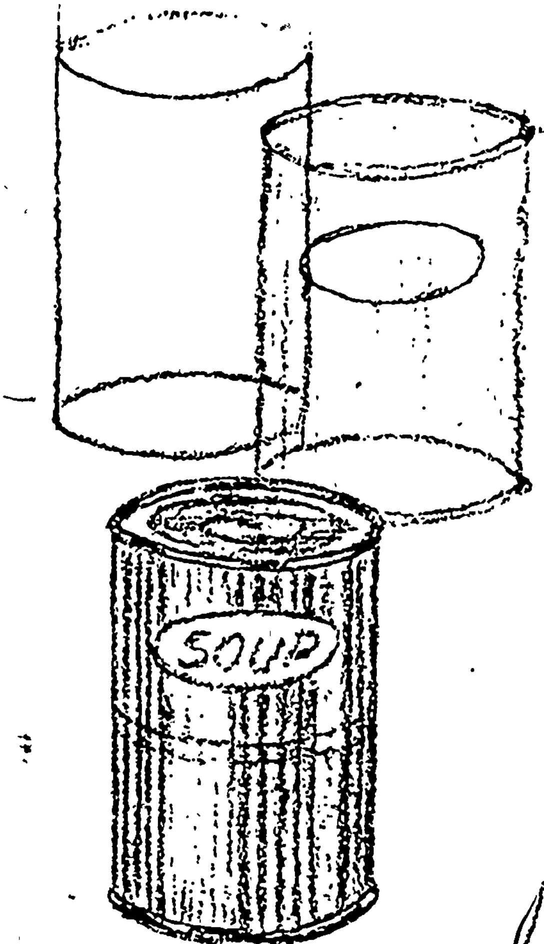
SPHERE

The sphere suggests any form that is round or oval. Add shading and it will give realism to any form.

Foldout 1. Drawing basic form

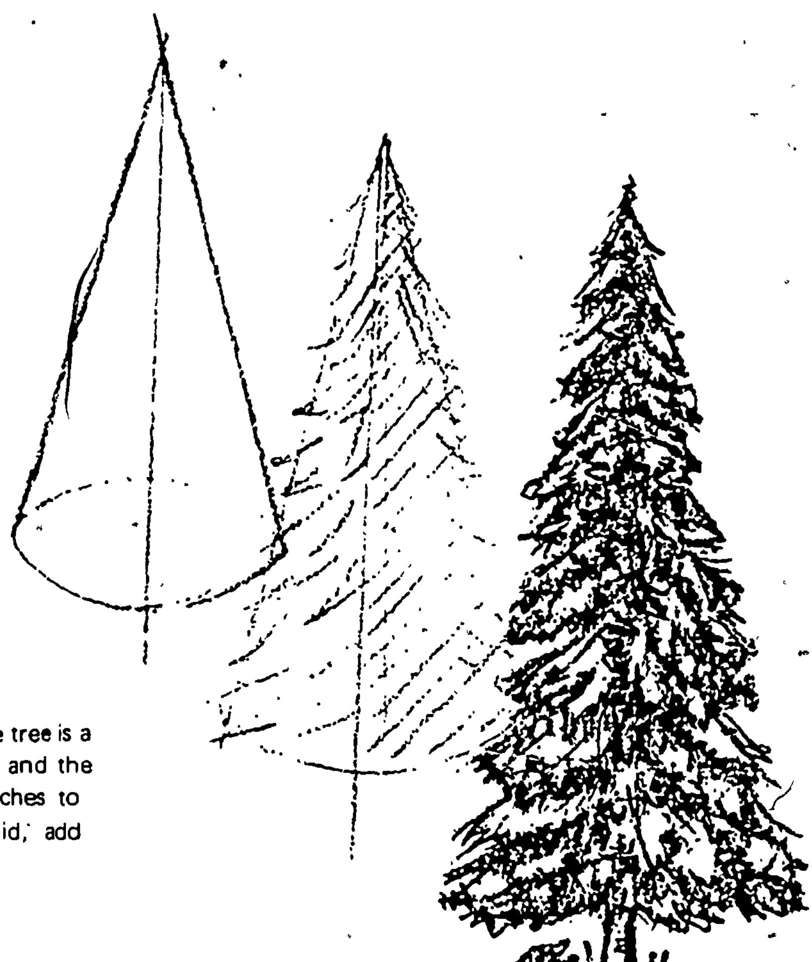
DRAWING THE BASIC FORM

In drawing the basic forms, each form is drawn through first as a basic form then the details.



CYLINDER

The can is essentially a cylinder, so when you start the drawing - - draw a cylinder. To help the basic shape of the can, light and shade should be established. Shading gives the form a needed emphisis.

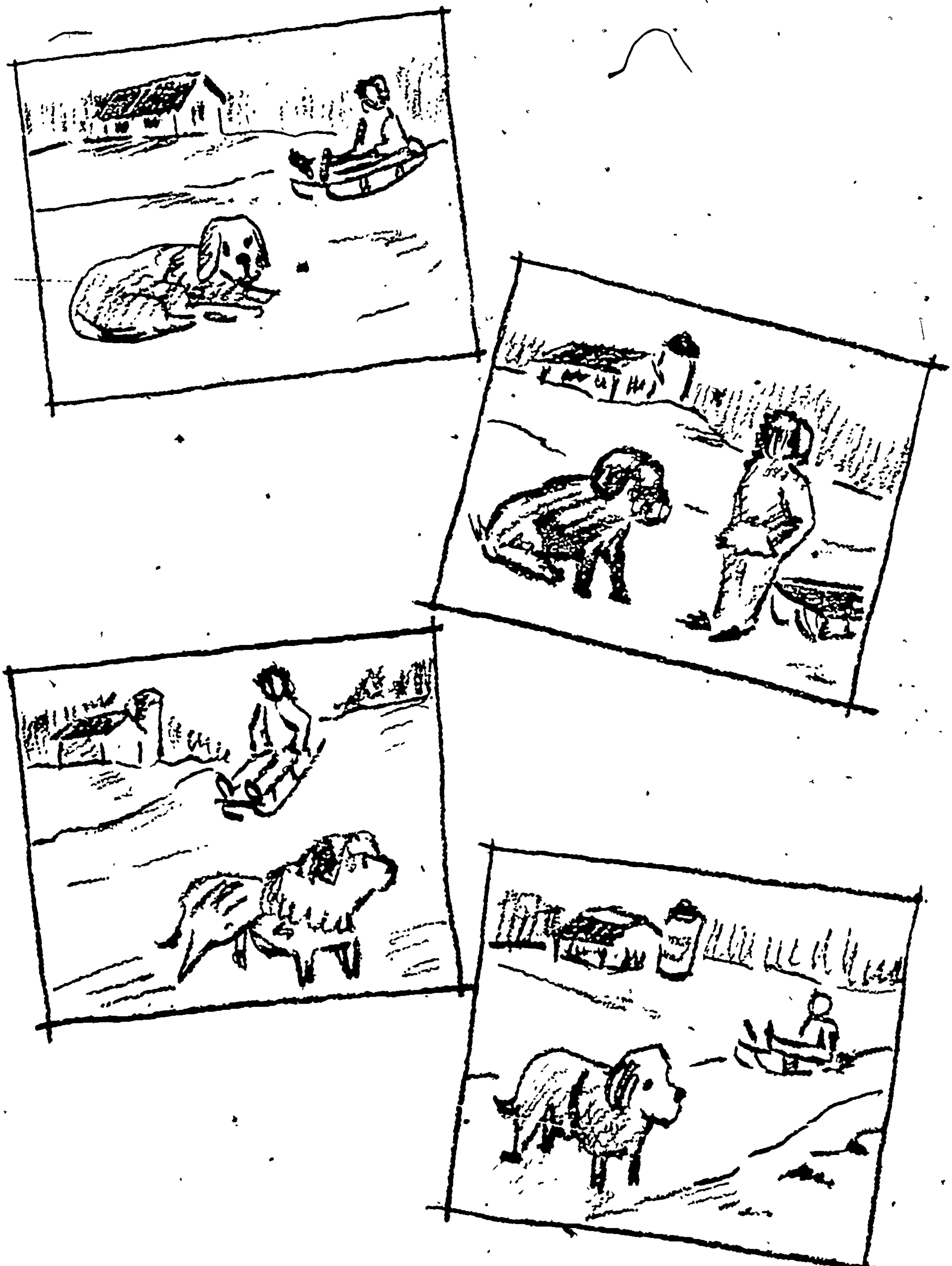


CONE

The basic shape of the pine tree is a cone. The use of shading and the drawing of irregular branches to make the form look solid, add realism.

231-454

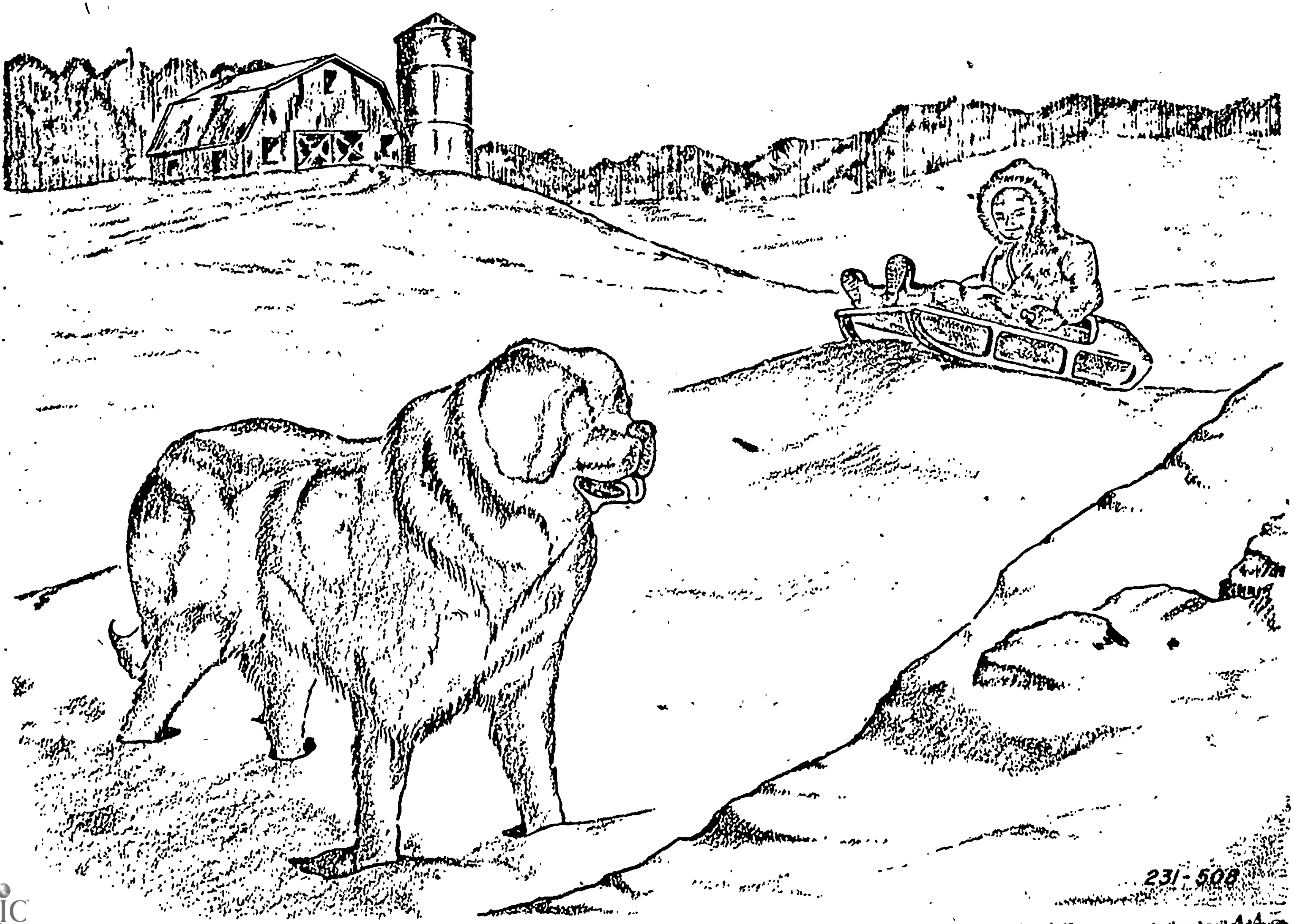
Foldout 1. Drawing basic form.



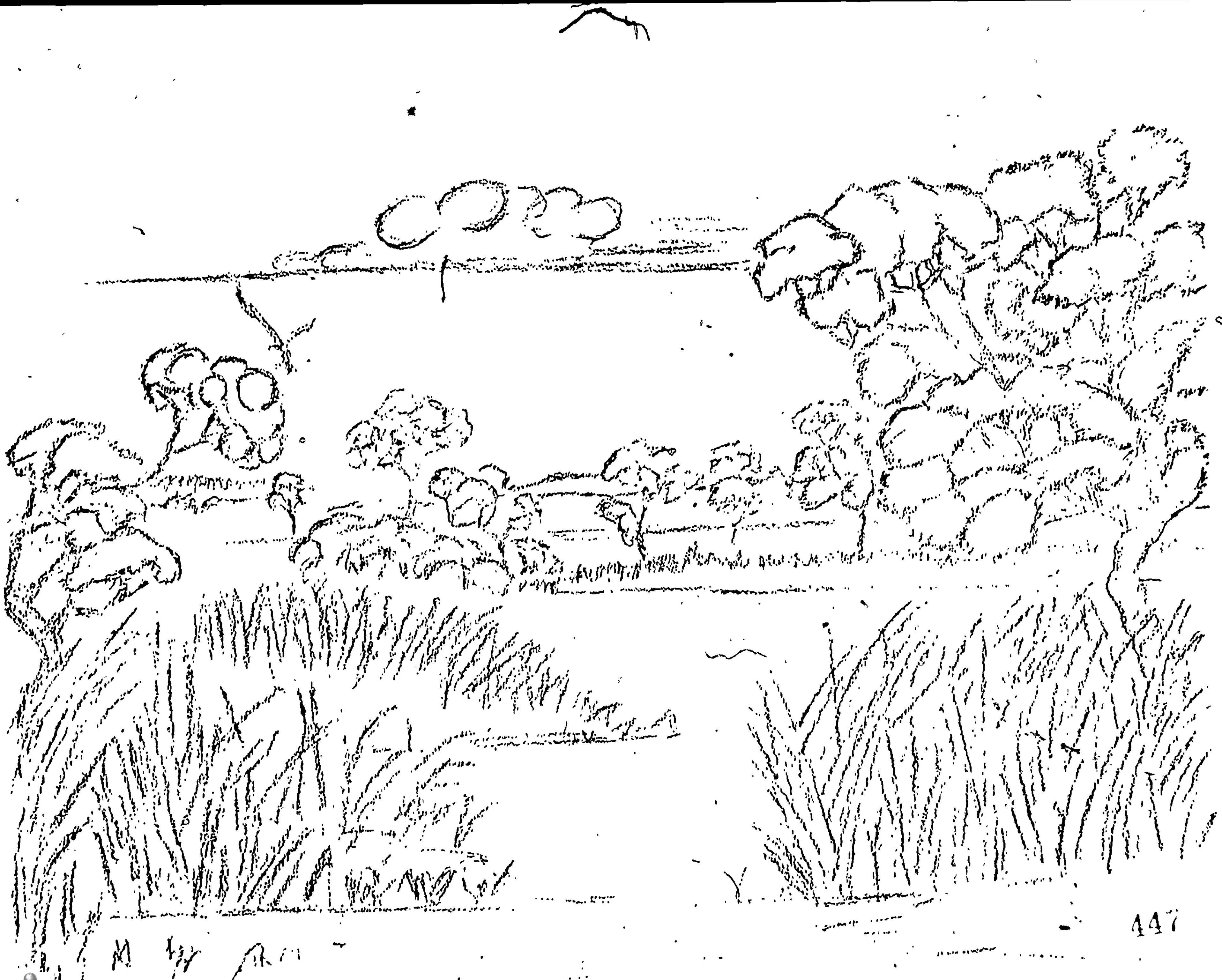
231–509

Foldout 2. Depth, drawing through, light, and shade.

6-1



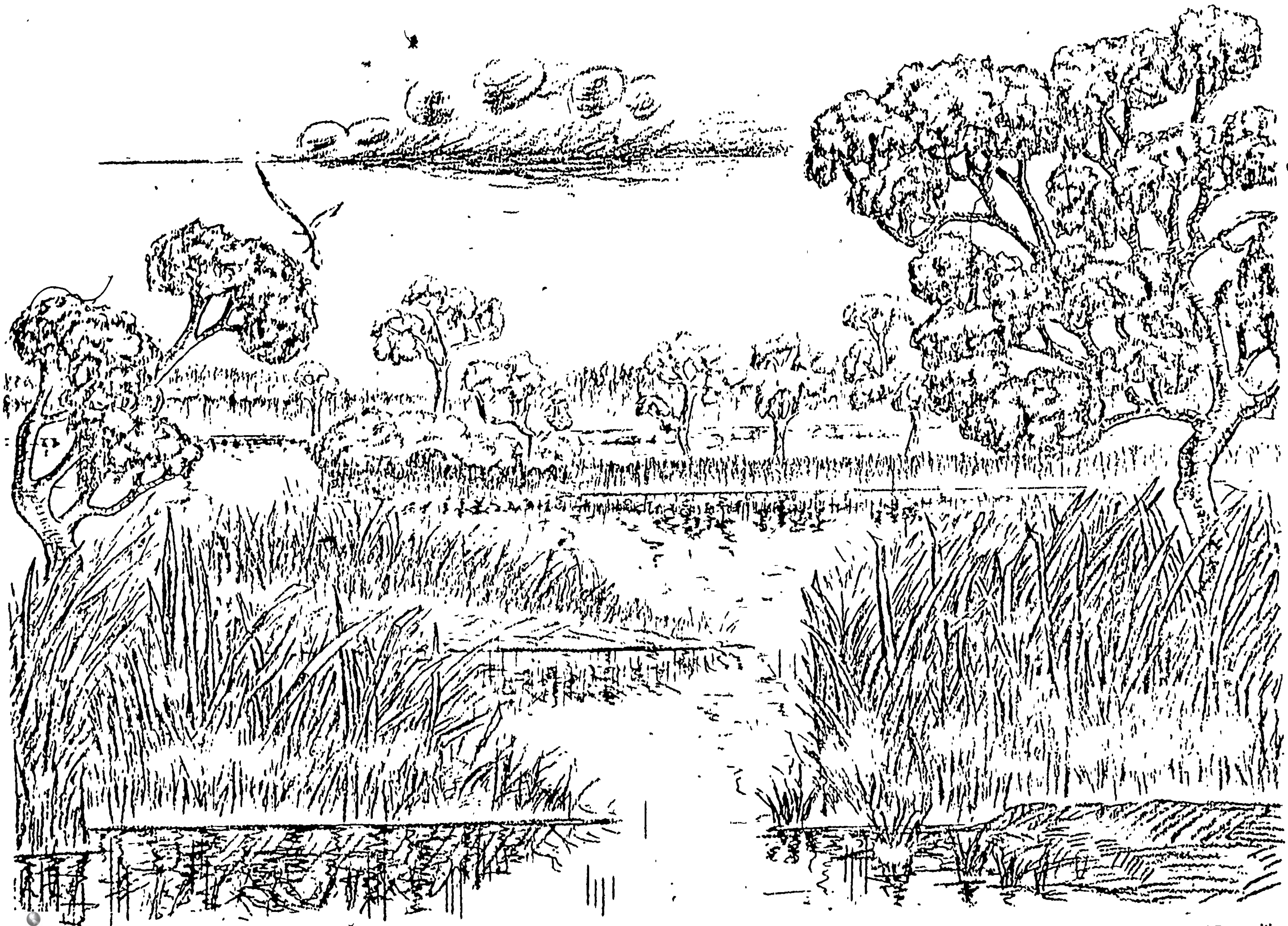
Foldout 3. How to present a thumbnail and rough.



Foldout 4. Element of Composition.

449

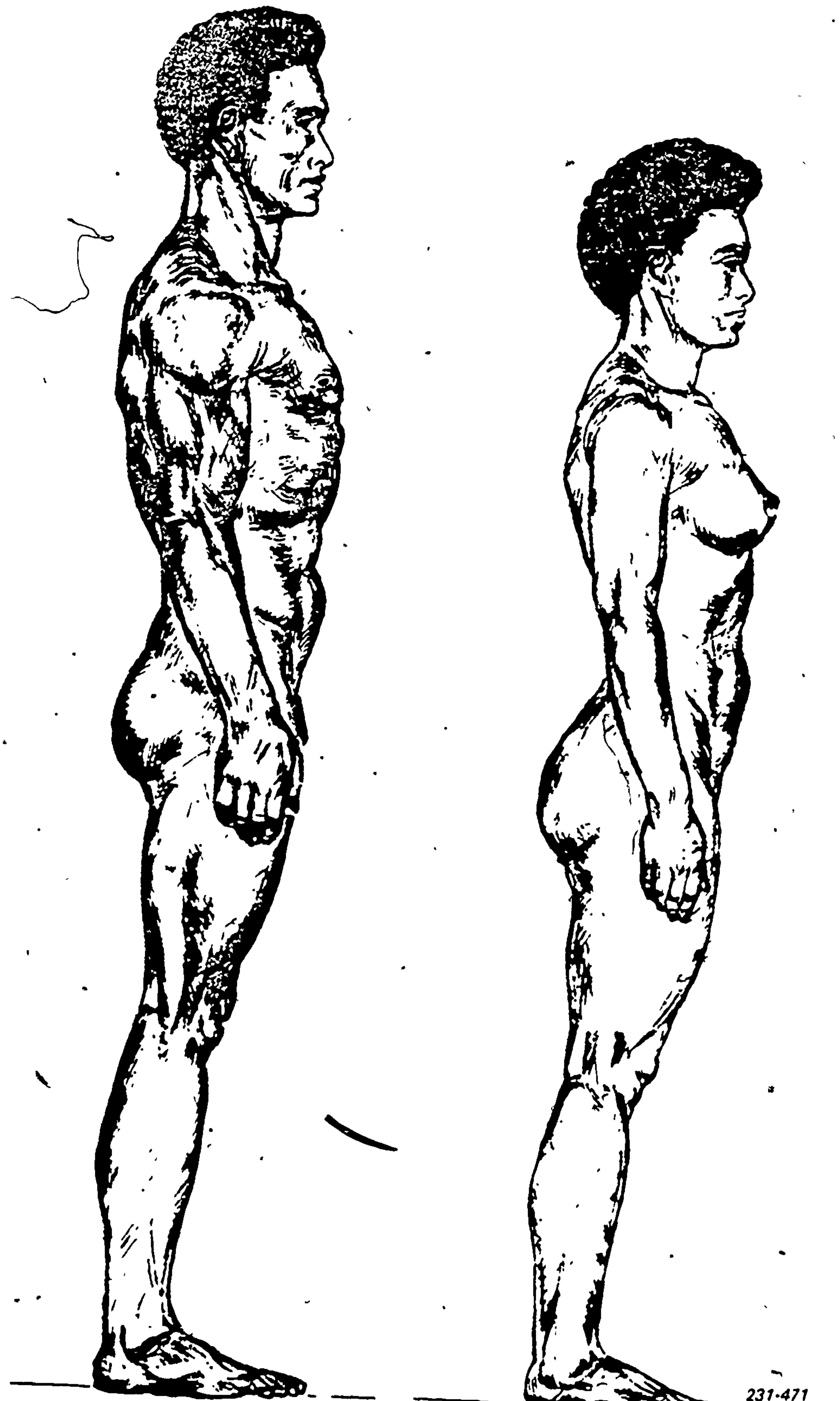
Foldout 5. Element of Composition.



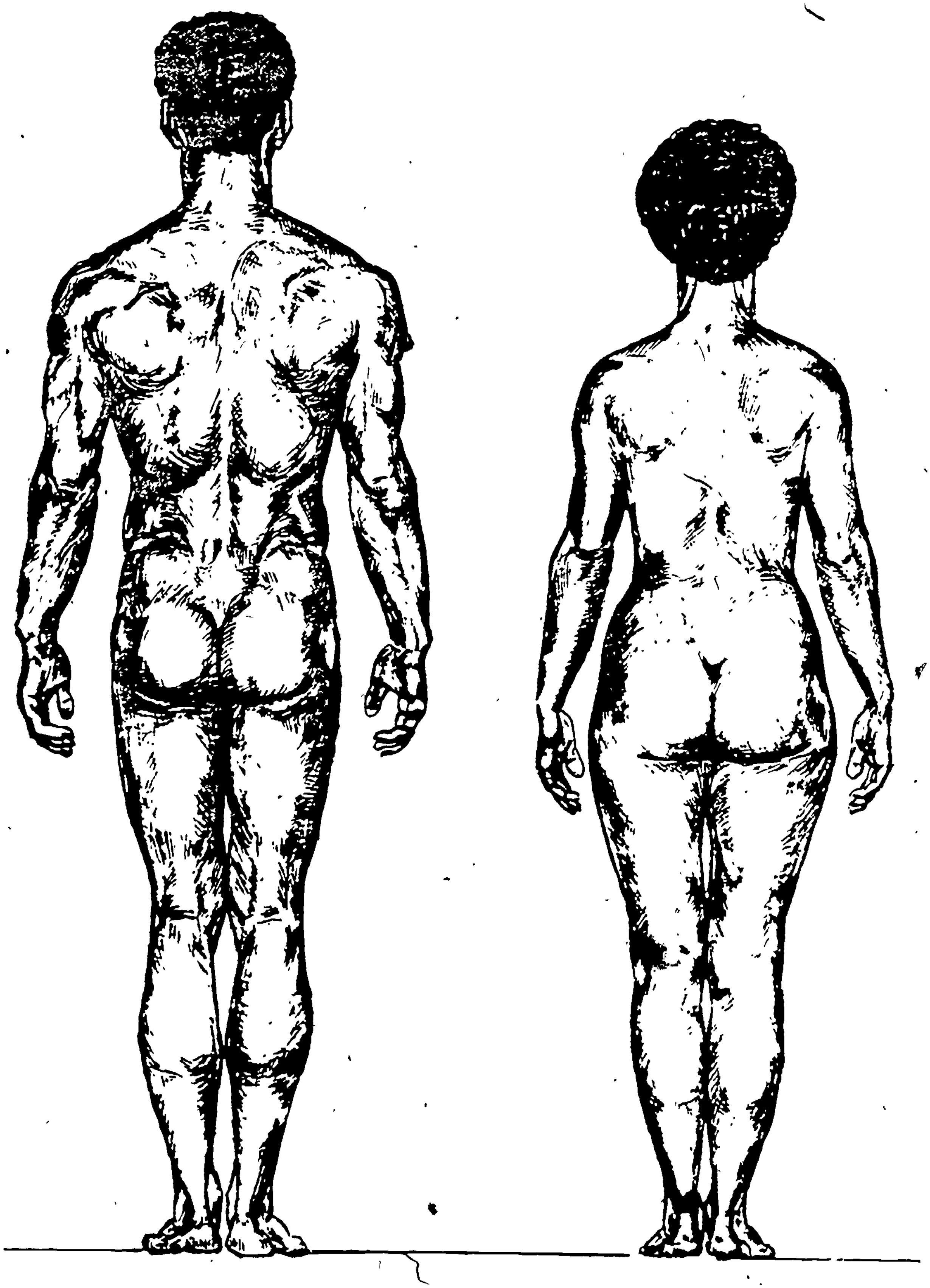
Foldout 6. Element of Composition.

231-480

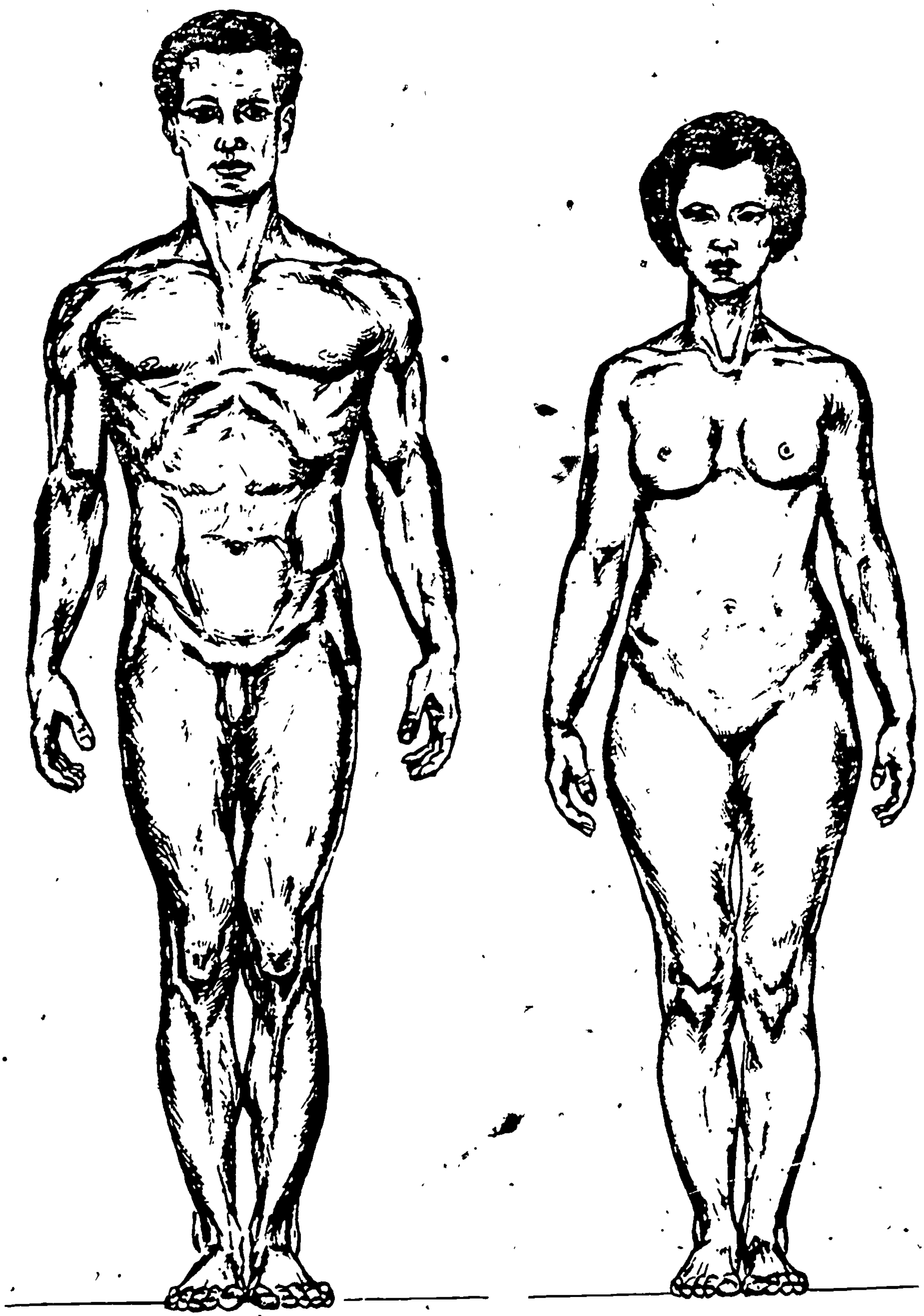
Foldout 7. Principles of Composition.



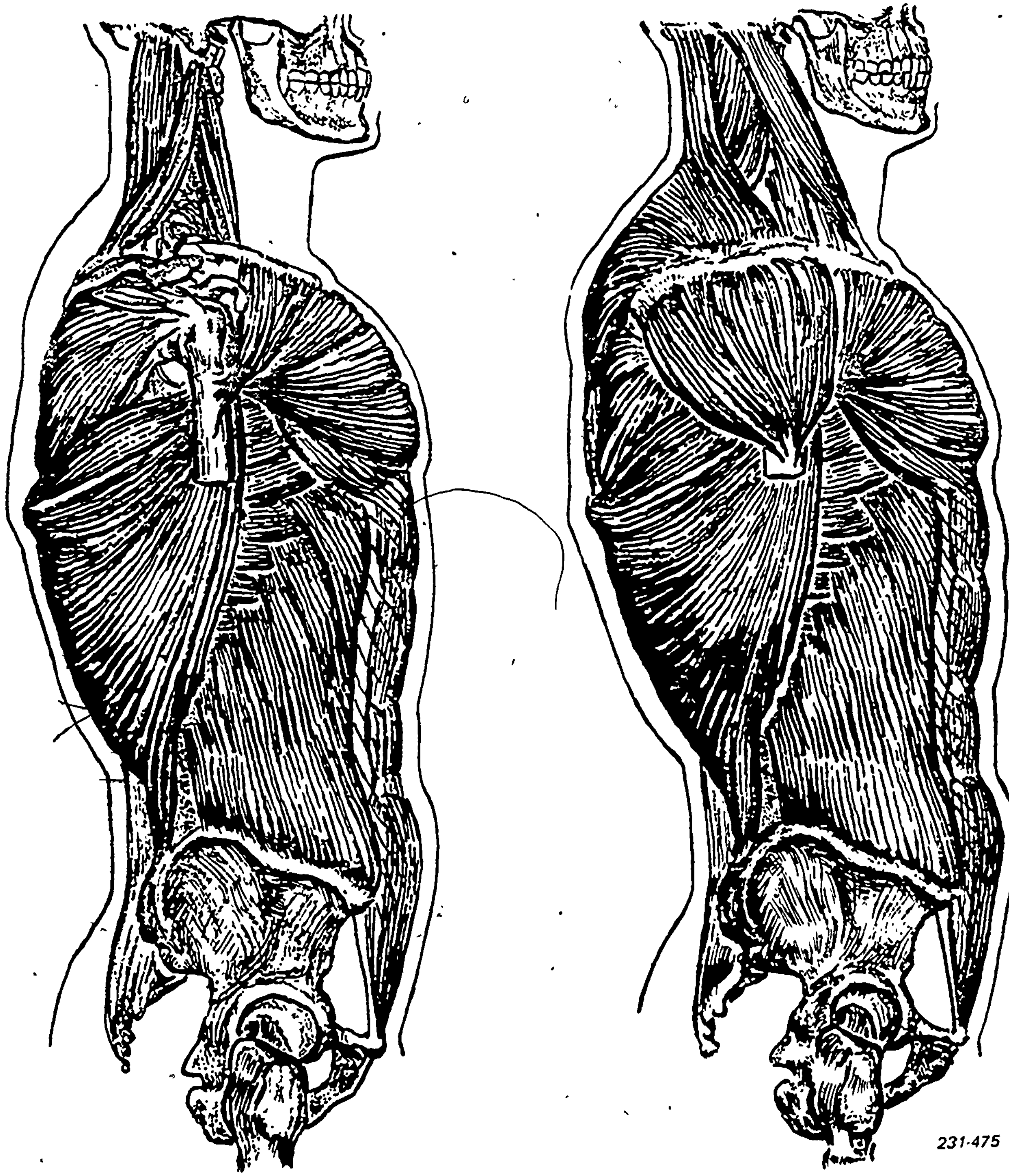
Foldout 8. Male and female figure.



Foldout 8. (continued



Foldout 8. (continued)



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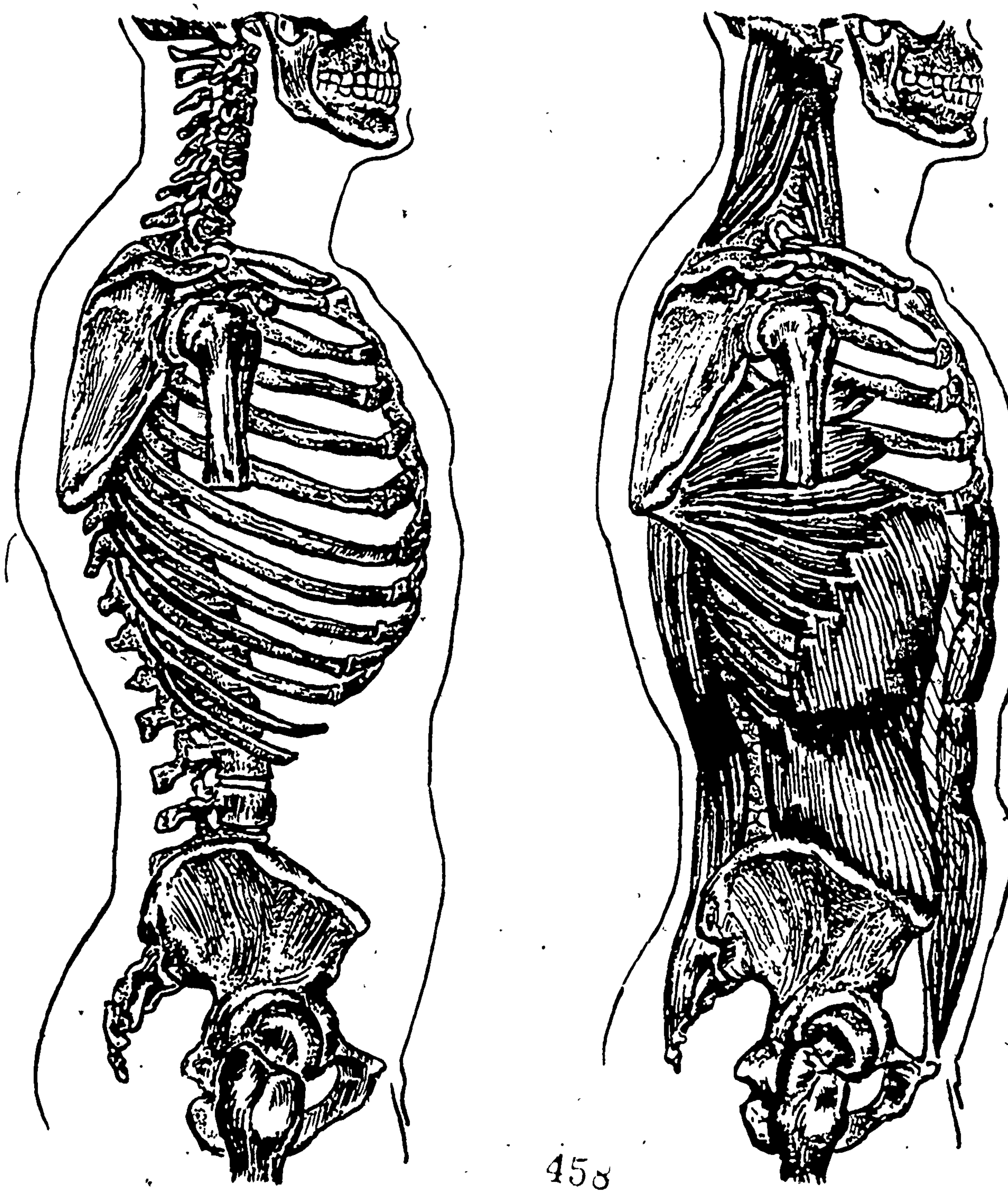
Foldout 9. Torso.



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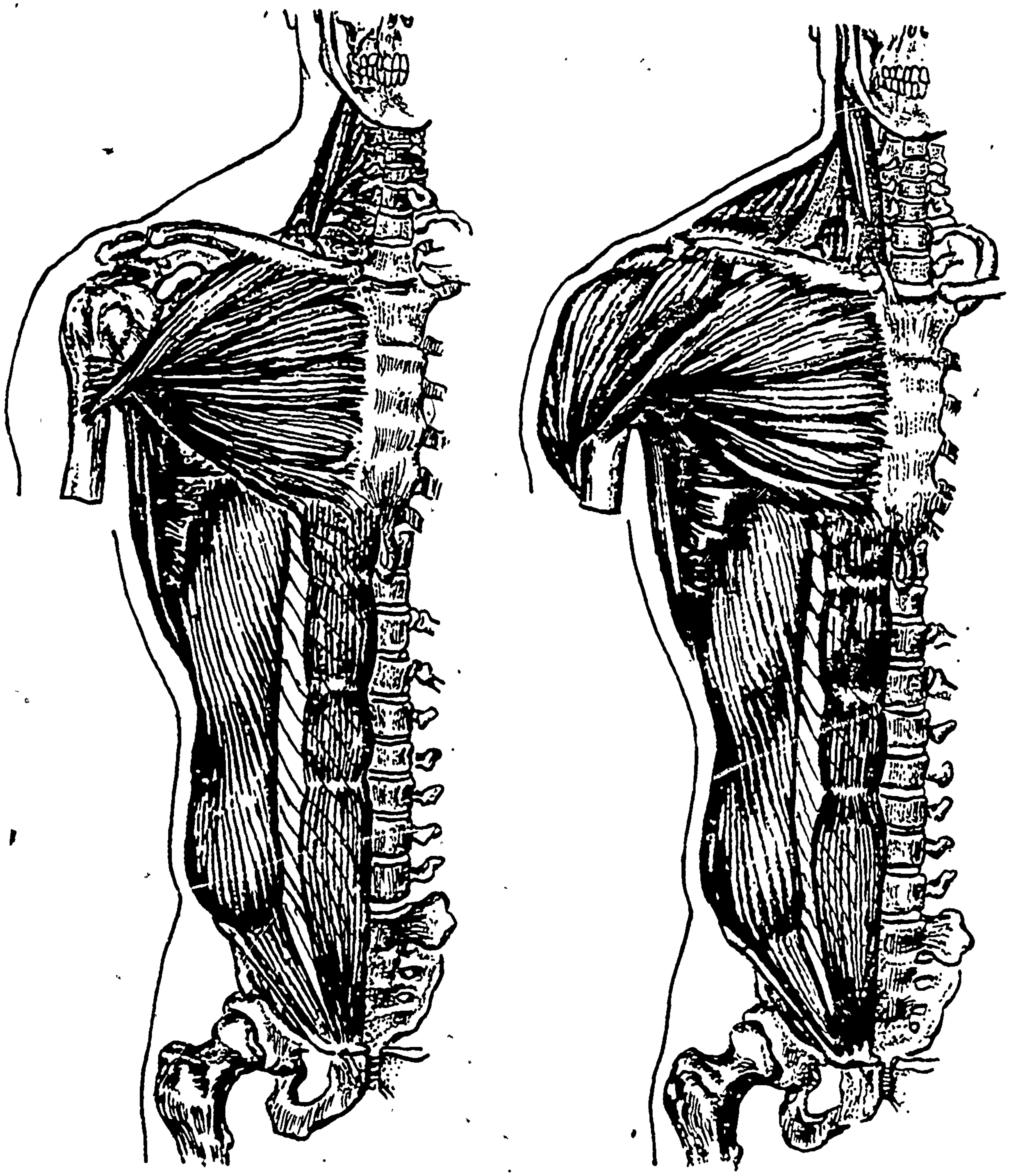

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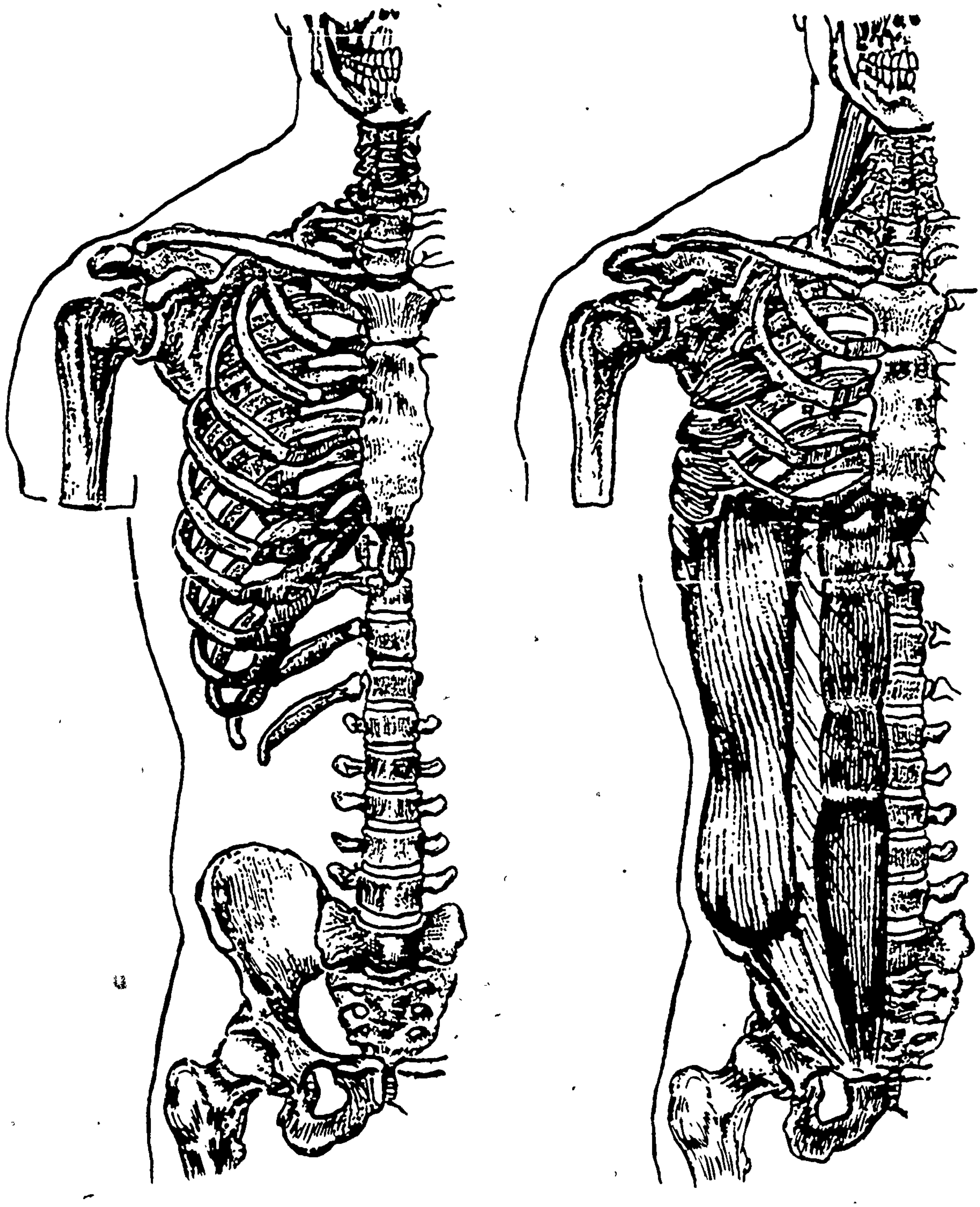
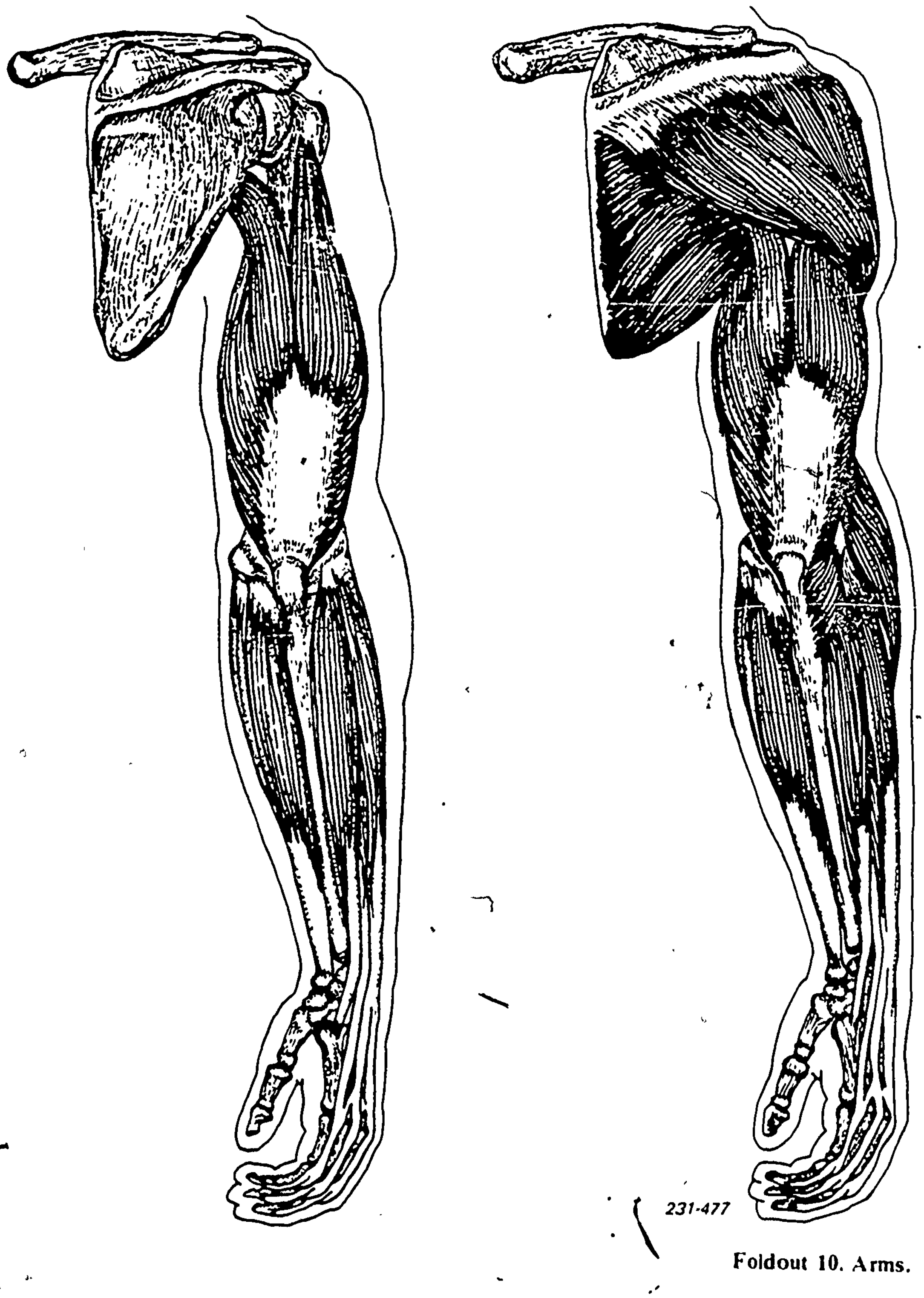


Foldout 9. (continued)



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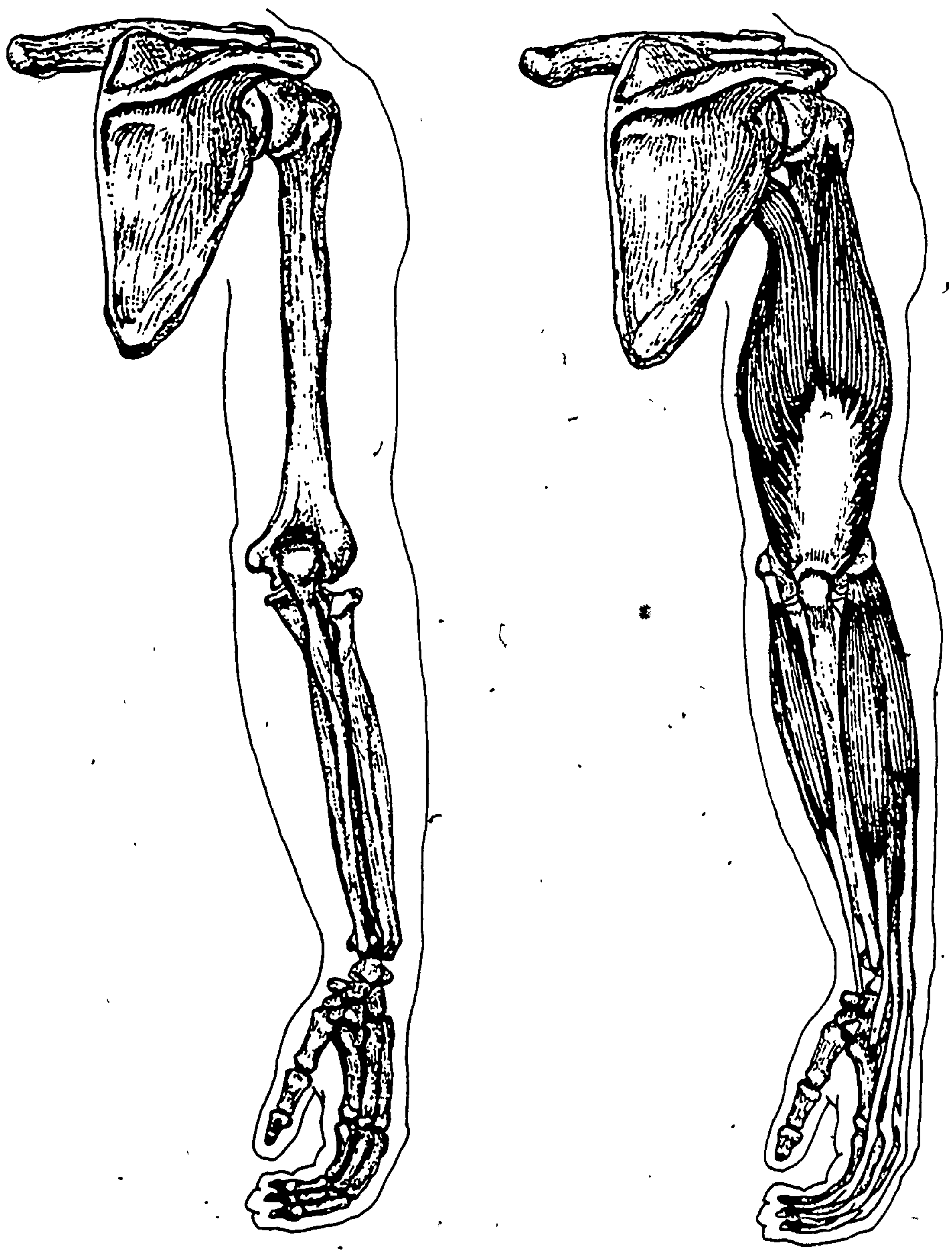
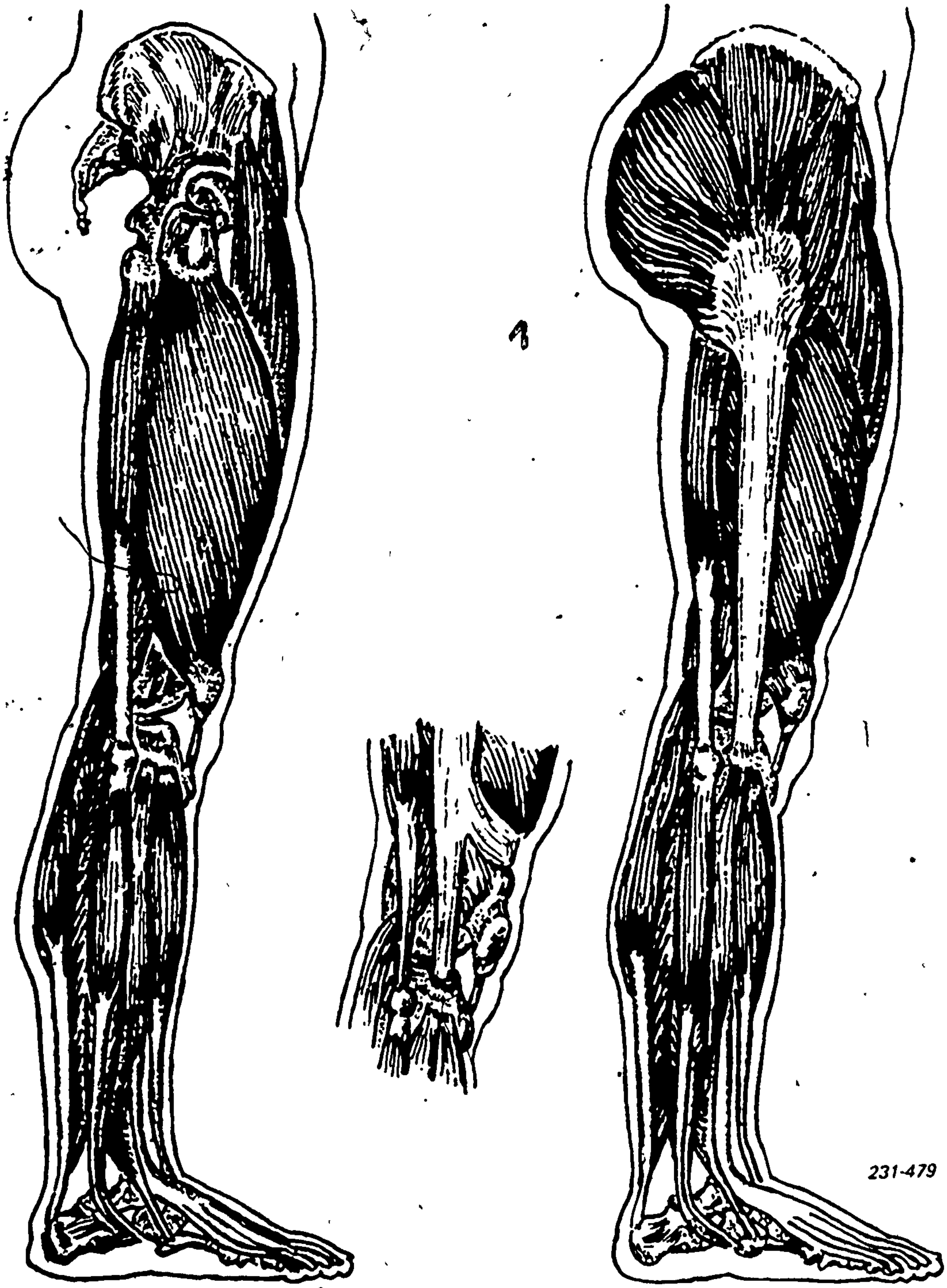
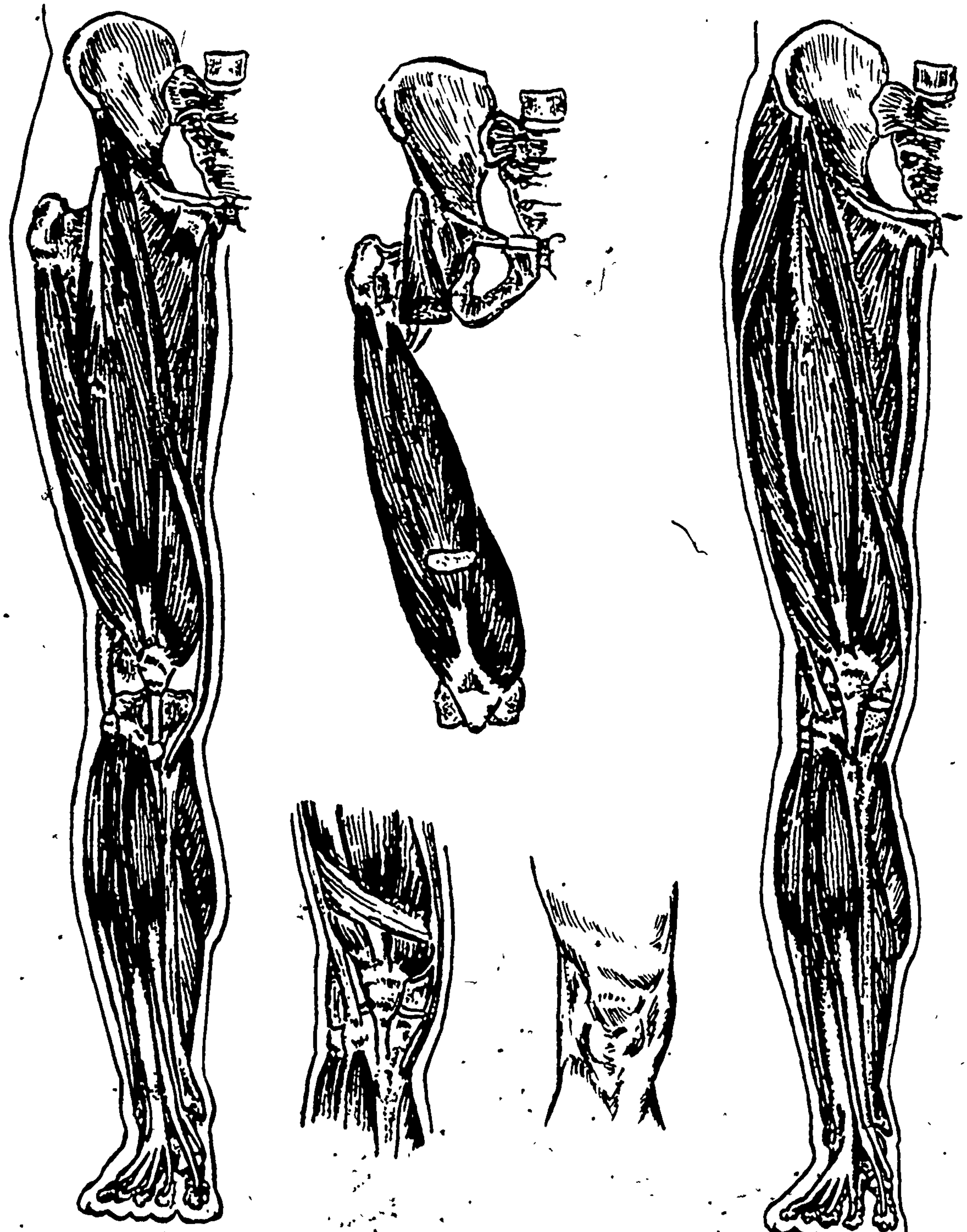
Foldout 10. Arms.



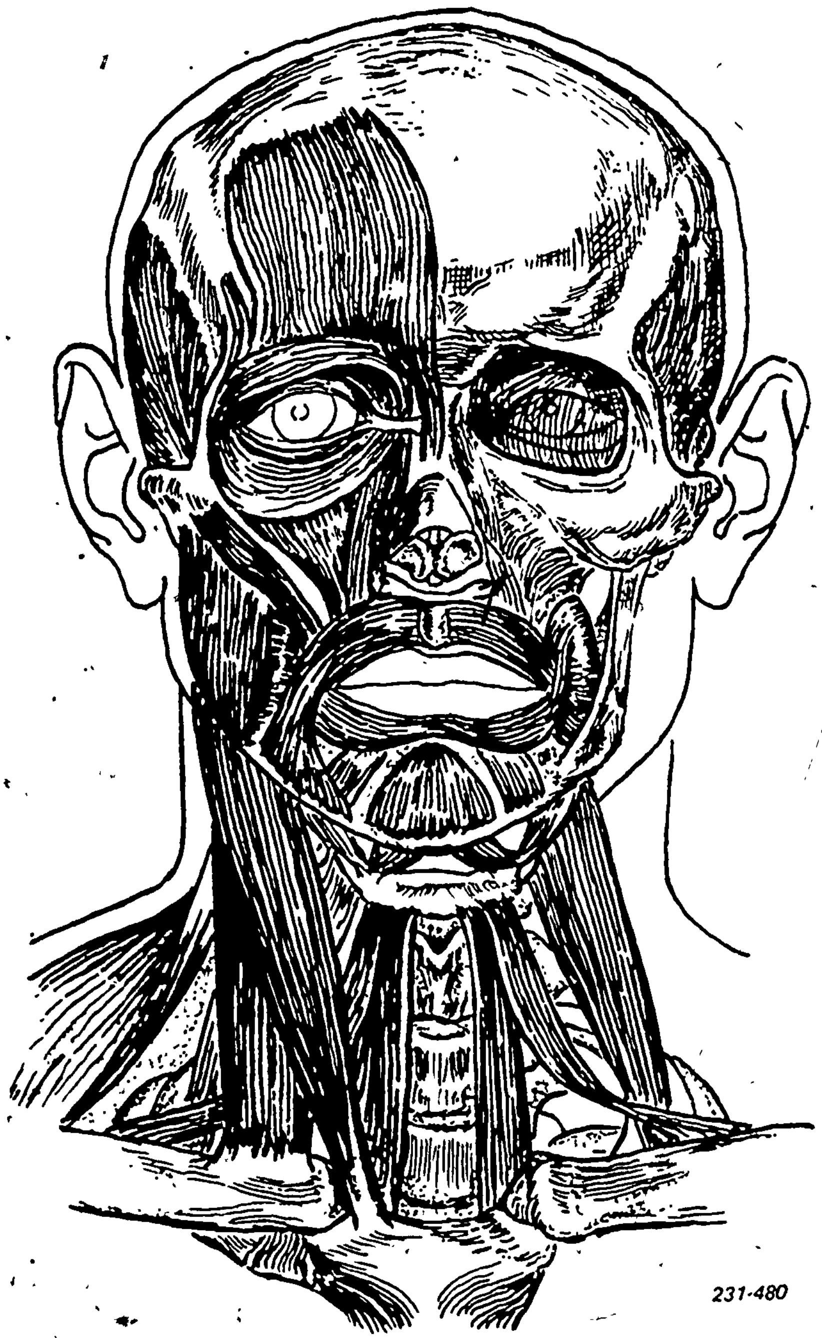
Foldout 10. (continued)



Foldout 11. Leg.

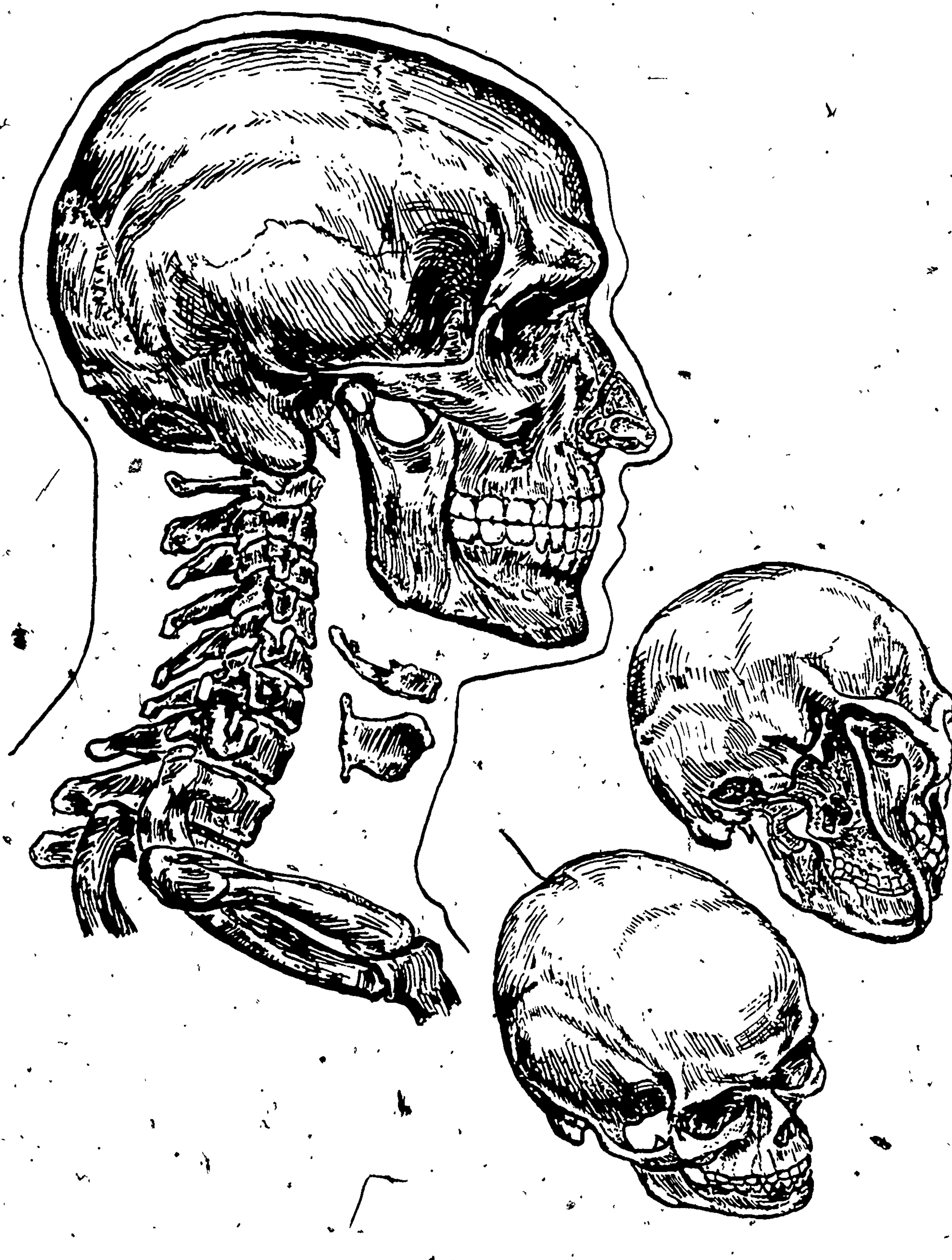


Foldout 11. (continued)



Foldout 12. Head

Foldout 12. (continued)



Foldout 12. (continued)

STOP— **1. MATCH ANSWER SHEET TO THIS EXERCISE NUMBER.** **2. USE NUMBER 1 OR NUMBER 2 PENCIL.**

23151 04 21
EXTENSION COURSE INSTITUTE
VOLUME REVIEW EXERCISE
BASIC DRAWING

Carefully read the following:

DO'S:

1. Check the "course," "volume," and "form" numbers from the answer sheet address tab against the "VRE answer sheet identification number" in the righthand column of the shipping list. If numbers do not match, take action to return the answer sheet and the shipping list to ECI immediately with a note of explanation.
2. Note that numerical sequence on answer sheet alternates across from column to column.
3. Use a medium sharp #1 or #2 black lead pencil for marking answer sheet.
4. Circle the correct answer in this test booklet. After you are sure of your answers, transfer them to the answer sheet. If you *have* to change an answer on the answer sheet, be sure that the erasure is complete. Use a clean eraser. But try to avoid any erasure on the answer sheet if at all possible.
5. Take action to return entire answer sheet to ECI.
6. Keep Volume Review Exercise booklet for review and reference.
7. If *mandatorily* enrolled student, process questions or comments through your unit trainer or OJT supervisor.
   If *voluntarily* enrolled student, send questions or comments to ECI on ECI Form 17.

DON'TS:

1. Don't use answer sheets other than one furnished specifically for each review exercise.
2. Don't mark on the answer sheet except to fill in marking blocks. Double marks or excessive markings which overflow marking blocks will register as errors.
3. Don't fold, spindle, staple, tape, or mutilate the answer sheet.
4. Don't use ink or any marking other than a #1 or #2 black lead pencil.

NOTE: NUMBERED LEARNING OBJECTIVE REFERENCES ARE USED ON THE VOLUME REVIEW EXERCISE. In parenthesis after each item number on the VRE is the *Learning Objective Number* where the answer to that item can be located. When answering the items on the VRE, refer to the *Learning Objectives* indicated by these *Numbers*. The VRE results will be sent to you on a postcard which will list the *actual* VRE *items you missed*. Go to the VRE booklet and locate the *Learning Objective Numbers* for the items missed. Go to the text and carefully review the areas covered by these references. Review the entire VRE again before you take the closed-book Course Examination.

Note to Student: This Volume Review Exercise contains 47 four-option items and 3 three-option items.

Multiple Choice

1. (600) An illustration that is flat and lifeless is most likely to be deficient in the basic principle known as

   a. solid form.
   b. background application.
   c. foreground application.
   d. formal presentation.

2. (601) Which of the following is not considered as one of the four basic forms of drawing?

   a. Cylinder.
   b. Circle.
   c. Cone.
   d. Cube.

3. (601) The foundation of the training of a graphic specialist is the principle of

   a. combining colors.
   b. using light and shade.
   c. drawing form.
   d. drawing depth.

4. (602) The term "drawing through" means that you are

   a. adding a background to your drawing.
   b. making an original drawing through the use of an optical drawing aid.
   c. attempting the three-dimensional effect of depth.
   d. merely putting the finishing touches on an otherwise completed drawing.

5. (602) The proper application of the principle of drawing through will give your picture the effect of looking

   a. flat.
   b. two-dimensional.
   c. lopsided.
   d. real.

6. (603) You have just completed drawing a basic form using the draw through principle. What, if anything, should you do to enhance the appearance of this basic form?

   a. Add lighting or shading to emphasize the form.
   b. Do nothing as the form will stand by itself.
   c. Add a dark background.
   d. Add a light foreground to the drawing.

7. (603) To create the illusion of space in conjunction with a series of complex forms, the space must be extended

   a. only to the largest form in the drawing.
   b. around all the forms and in all directions.
   c. around a single form and in one direction.
   d. to encompass all the forms, but in no specific direction.

8. (604) Thumbnail sketches are usually

   a. 6 to 8 inches square.
   b. [illegible] to [illegible] inches square.
   c. 1 to 3 inches square.
   d. [illegible] to [illegible] inches square.

9. (604) Thumbnail sketches are

   a. always drawn to a specific scale.
   b. complex drafting illustrations.
   c. accomplished in realistic color.
   d. used as an aid for general [illegible].

10. (605) The term "roughs" means

a. the refinement of design of a thumbnail sketch.
b. that your drawing must be made on a rough textured paper.
c. that a complex form has been poorly drawn.
d. the first drawing in a series of scale drawings of a new prototype aircraft.

11. (605) The "rough" should be drawn to

a. one-half the size of the original.
b. the same size as the final drawing.
c. any scale that the illustrator wishes to use.
d. show only the important parts of the design.

12. (605) As an illustrator, it would be impractical of you to produce a "rough" on a sheet of

a. white bond paper.
b. tracing paper.
c. semi-transparent material.
d. pebble-grained textured display board.

13. (606) A comprehensive drawing is

a. usually accomplished after a thumbnail sketch has been made.
b. always made to the same size as a thumbnail sketch.
c. normally finished in pastel colors.
d. used to show what the final product will look like.

14. (606) A comprehensive drawing is

a. made prior to the final product.
b. never used for a detailed layout.
c. always used in place of the final product.
d. not necessary in the production of the final product.

15. (607) Composition is divided into how many basic elements?

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

16. (607) What are the basic elements of composition?

a. Depth, value, and color.
b. Area, depth, line, and value.
c. Line, value, and color.
d. Area, depth, value, and pose.

17. (607) The creation of an illusion of distance on a two-dimensional surface is called

a. depth.
b. area.
c. value.
d. composition.

18. (607) The term "line" when used in conjunction with composition means

a. the number of lines used in the construction of the drawing.
b. the direction in which the eye moves to focus on a point of interest in an illustration.
c. the number of complex vertical lines which lead to the main point of interest.
d. all of the horizontal and vertical lines used in the composition of the drawing.

19. (607) The element of composition which creates the mood or gives the overall key to a drawing is called

a. color.
b. line.
c. focus.
d. value.

20. (607) An illustration of a downed aircraft in the Dismal Swamps of North Carolina would be best portrayed using shades having

a. high key values.
b. normal key values.
c. low key values.
d. very thin key values.

21. (608) Which of the following is not normally considered a principle of composition?

a. Style.
b. Rhythm.
c. Balance.
d. Proportion.

22. (608) The act of placing two identical forms on either side of an imaginary vertical centerline is an illustration of which kind of balance?

a. Informal.
b. Geometric.
c. Asymmetric.
d. Formal.

23. (608) A large mass balanced by a smaller mass in an illustration is known as

a. informal balance.
b. geometric balance.
c. formal balance.
d. symmetric balance.

24. (608) Since no mathematical rules apply to achieving informal balance in a drawing, the artist must depend largely on

a. textbook materials.
b. his own sense of balance.
c. the number of elements used.
d. the kind of paper used.

25. (608) By dividing an illustration into equal thirds, you have applied the principle known as

a. informal balance.
b. quartering the illustration.
c. the Golden Division.
d. analytical balance.

26. (608) An illustration that has the appearance of "falling apart" is lacking the compositional element known as

a. clarity.
b. unity.
c. simplicity.
d. rhythm.

27. (609) The preferred height of an illustrated human figure is

a. 2 head units high.
b. 4 head units high.
c. 6 head units high.
d. 8 head units high.

28. (609) The chief structural difference between the male and female figure is found in

a. the bone and muscle areas.
b. the size and shape of the head.
c. the facial features.
d. the tone and texture of the skin.

29. (609) An illustration of a twelve-year-old boy should be

a. 8 head units high.
b. 7 head units high.
c. 6 head units high.
d. 5 head units high.

30. (610) The torso of the human figure is composed of how many masses?

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

31. (610) The part of the torso which serves as a base for the other parts of the body is the

a. abdomen.
b. rib cage.
c. pelvis.
d. epigastrium.

32. (610) In an illustrated figure of the human body, the chest, abdomen, and the pelvis should be connected by the

a. rib cage.
b. shoulder girdle.
c. collar bone.
d. spinal column.

33. (611) How many bones are contained in the upper and lower arm?

a. 3.
b. 4.
c. 5.
d. 6.

34. (611) What is the relationship between the lengths of the upper and lower arms of the human body?

a. The upper arm is about 3 inches longer.
b. The lower arm is about 5 inches longer.
c. They are approximately the same.

35. (611) What is the shape of the leg and calf of the human form?

a. Square.
b. Triangular.
c. Circular.
d. Conic.

36. (611) Which bone of the human body is considered to be the most perfect of all levers?

a. Ulna.
b. Radius.
c. Humerus.
d. Femur.

37. (611) In a drawing of the human leg, the ankle is represented as a

a. square.
b. triangle.
c. reverse curve.
d. inverted wedge.

38. (612) The lashes on the upper and lower lids of the eye serve

a. only as shades for the pupil.
b. as shades and sensitive feelers to protect the eye.
c. as body decoration only.
d. no purpose at all.

39. (612) What part of the face is capable of much expression and movement, aside from the eyes?

a. Nose.
b. Chin.
c. Forehead.
d. Mouth.

40. (612) The normal length of the ear in comparison to that of the nose is

a. shorter.
b. longer.
c. the same.

41. (613) What part of the body is capable of great expression, other than the face?

a. Feet.
b. Arms.
c. Hands.
d. Torso.

42. (613) One of the significant details in drawing hands is the

a. form of the back of the hand. c. form of the palm.
b. placement of the folds. d. length of the fingers.

43. (613) The length of the feet is approximately

a. twice that of the thumbs.
b. one-half the distance from the elbows to the wrists.
c. twice the distance from the pelvis to the knees.
d. one-half the distance from the knees to the bottom of the feet.

44. (614) The main difference between cartooning and figure drawing is in

a. simplification of features. c. movement.
b. foreshortening. d. balance.

45. (614) Cartoon facial expressions are produced by the movement or lack of movement of the

a. eyes, ears, mouth, and nose.
b. forehead, eyes, ears, and mouth.
c. nose, forehead, eyes, and mouth.
d. ears, nose, forehead, and mouth.

46. (615) Cartoon character and emotional expressions are controlled by

a. the body only. c. the body and the hands.
b. the hands only. d. the face.

47. (615) What does the term "animation" mean?

a. Drawing animals.
b. Drawing animals with human characteristics.
c. The process of drawing cartoons.
d. Making figures appear to move.

48. (616) The main purpose of the landscape is to

a. serve usually as the chief subject of an illustration.
b. set the scene for the center of interest.
c. serve only as a fill-in for the total picture.

49. (616) You have just completed a series of drawings of the Air Force Academy. In each drawing you have included the chapel as a means of identification. This means that all of your drawings will

a. have a good background.
b. tend to be boring.
c. have good audience appeal.
d. create a mood of joy and splendor.

50. (616) An artistic painting of the Paseo del Rio in San Antonio, properly executed, should be able to reveal to a viewer

a. the style used by the artist.
b. the type of materials used by the artist.
c. the geographical location of the subject.
d. when the painting was accomplished.

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GRAPHICS SPECIALIST

(AFSC 23151)

Volume 5

— *Drawing and Production*

6-1

Extension Course Institute

Air University

Preface

THE INFORMATION in this volume is not intended to be a complete text on any of the subjects contained. Instead, it is intended to cover the subject only well enough that you will have the necessary background knowledge to carry out your job related assignments.

The first chapter in this volume contains information on perspective and its uses. The second chapter is on visual communication (what the illustration field is all about). Chapter 3 is on graphic reproduction methods and processes. Almost all art work ends up as a reproduction item in some form or another. Your job in the Air Force is to produce visual aids so that other people can comprehend complicated subjects simply.

We suggest that you study each chapter carefully before proceeding to the next. You can check your understanding of the text by completing the review exercises at the end of each objective.

If you have questions on the accuracy or currency of the subject matter of this text, or recommendations for its improvement, send them to Tech Tng Cen/TTOC, Lowry AFB CO 80230. NOTE: Do not use the suggestion program to submit corrections for typographical or other errors.

If you have questions on course enrollment or administration, or any of ECI's instructional aids (Your Key to Career Development, Behavioral Objective Exercises, Volume Review Exercise, and Course Examination), consult your education officer, training officer, or NCO, as appropriate. If he can't answer your questions, send them to ECI, Gunter AFS AL 36118, preferably on ECI Form 17, Student Request for Assistance.

This volume is valued at 18 hours (6 points).

Material in this volume is technically accurate, adequate, and current as of April 1975.

Contents

NOTE: In this volume, the subject matter is developed by a series of Learning Objectives. Each of these carries a 3-digit number and is in boldface type. Each sets a learning goal for you. The text that follows the objective gives you the information you need to reach that goal. The exercises following the information give you a check on your achievement. When you complete them, see if your answers match those in the back of this volume. If your response to an exercise is incorrect, review the objective and its text.

Perspective

DRAWING A three-dimensional object on a two-dimensional surface is problematical. Children ignore such problems by drawing the objects as they know them to be, not as they appear. For example, when a child draws a house, he draws it as a rectangle (a square or oblong box form) and draws all the furniture in it. From his drawing, it would be very difficult to imagine how the actual house appears to a viewer. Unfortunately perhaps, an illustrator is not often allowed a child's freedom. When he draws a house, he wants the observer to get an accurate image. Therefore, he cannot overlook the problems; instead, he uses a technique called perspective to make a two-dimensional drawing appear three-dimensional.

Like any graphics specialist, you need to know the basic principles involved in perspective drawing. We discuss these principles in this chapter. If you learn thoroughly the fundamentals of perspective, you will be able to apply them in your drawing; these principles will become automatic. Let us begin our study with the fundamentals of perspective.

1-1. Fundamentals of Perspective

If you were looking out the observation window at the rear of a train, you might see a scene something like the one in figure 1-1. Why do some people have difficulty drawing such a scene? It is probably because they do not understand the principles of perspective on which such a drawing is based. If they draw a line slightly out of perspective, they do not know how to make it look right. By discussing how to make the illustration accurately reproduce what you might see, we can introduce you to the principles, terms, and definitions of perspective drawing. Before you can use the language of perspective, you must learn these fundamentals.

800. Given an illustration (fig. 1-3) that shows fundamental elements of perspective, identify each element and define it; explain why the station point so greatly influences the perspective, and explain the relationship between the picture plane and the object.

Perspective Principles and Nomenclature. One of the most important lines of perspective drawing is the *horizon*. It may be a visible line (as shown in fig. 1-1) that represents the actual horizon and the eye level of the observer, or it may be imaginary and not show at all. When the horizon does not show in the final picture, an imaginary horizon is used to establish both the eye level of the observer and the vanishing point (VP). The *vanishing point* is that point on the horizon toward which all lines representing parallel horizontal edges converge. Thus, in figure 1-1 the lines representing the rails and fences, which are parallel horizontal edges of the objects shown in the picture, converge to the single point, VP. Notice in the scene that only the horizontal lines that are not parallel to the picture plane (represented by the rectangular outline) vanish at VP. The lines representing the fence that runs parallel to the picture plane do not converge and are therefore drawn as parallel horizontal lines.

The *ground line*, which represents the intersection of the ground plane (surface of the ground) and the *picture plane* (rectangular outline), is another important line used in perspective drawing. Although we know the

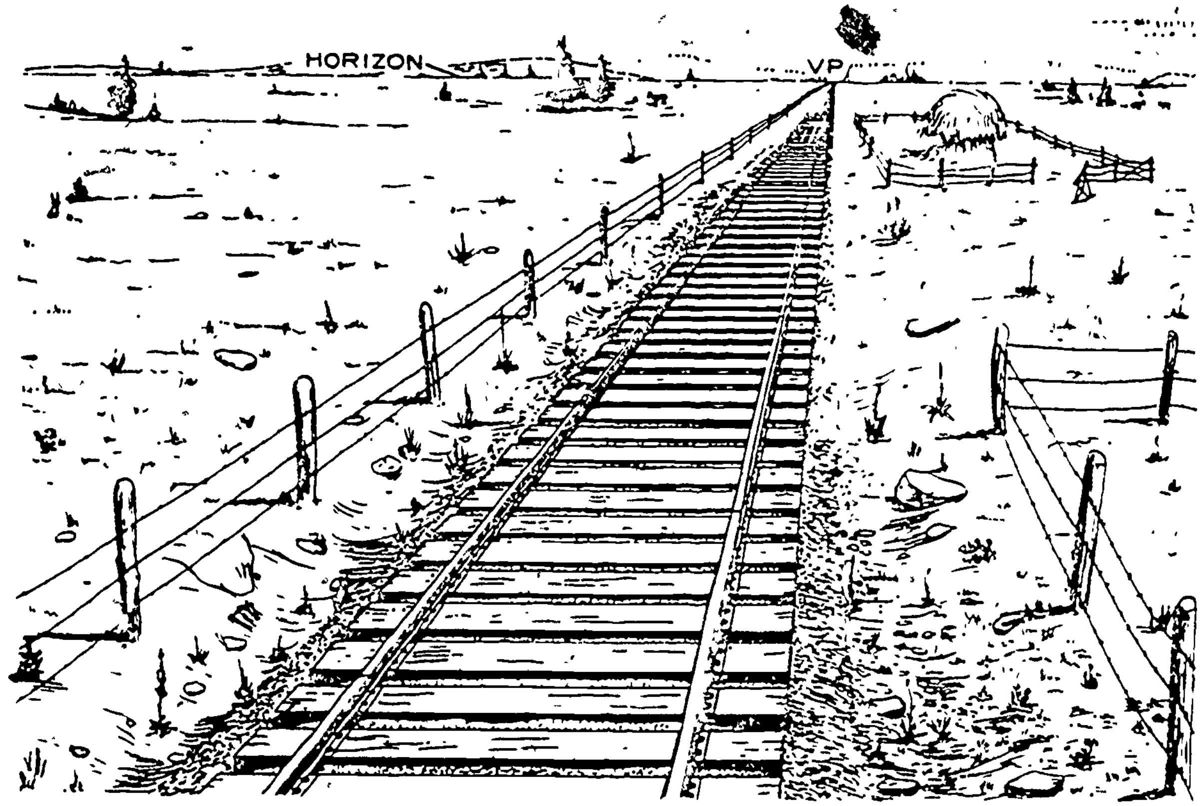


Figure 1-1. Vanishing point and horizon.

lines in the picture are all drawn on the same two-dimensional surface, only the points of these lines that touch the ground line appear to be in this plane. For example, only the parts of the two rails that touch the outline of the picture appear to be in the picture plane. The remainder of all of the lines appear to recede behind this surface. This is what gives the two-dimensional drawing the appearance of having three-dimensions. Thus, the parts of the picture that touch the picture plane are the only parts shown true-size. All other parts appear smaller and smaller as we look back to the horizon. Since the ground line is in the picture plane, we can use it as a *measuring line* for establishing the relationship between parts of the picture. For example, if we know that the two rails of the railroad track are 4 feet 8½ inches apart, we can use the distance between the rails at the ground line as a unit of measurement to establish the lines of the fences on each side of the tracks. Of course, we will have to extend the ground line on each side so that we can measure the actual distance between the tracks and the fences. If we estimate that the fences are 30 feet from the tracks, then the measurement along the ground line from the tracks to the fence will be approximately six times the distance between the two rails.

Now let's study some of the principles of perspective drawing. As shown in figure 1-2,A, when a person looks at an object, light rays reflected by the object are focused by the lens of the eye so that they pass through a focal point and strike the spherical rear surface of the eye, forming an inverted image. This is a perspective image, since it has only two dimensions; yet it appears to have three. The closest we can come to duplicating this process by pictorial means is by drawing the object in perspective.

The simplest method of making a perspective drawing that looks like the object is to make a tracing on a piece of glass. That is, you place a pane of glass between you and the object and use a suitable marking tool such as a grease pencil to trace all visible edges of the object. But this method works only if you have some means of holding the glass, and you don't move your head while making the drawing. However, even though this method is rather impractical, it does illustrate some of the principles of perspective.

Note the similarity between the illustrations in figure 1-2,A, and figure 1-2,B. In both, light rays that converge at a single point determine the prominent points of the perspective image. If we moved the pane of glass to the other side of the *station points*, which represents the eye of the observer and the point through which the rays are not passing, and blocked out all other light rays, an inverted image would be produced just as the one in figure 1-2,A, so you can see the same principles are used in both illustrations. Now, let us go over the illustration in figure 1-2,B, to learn other terms and their definitions.

One of the most important terms of perspective drawing is *station point*. It is the point through which all converging light rays (called *visual rays* in perspective drawing) pass. Actually, the station point represents the position of the observer's eyes in relation to the object. The position of the station point greatly influences the perspective; if it changes, so does the perspective change accordingly.

In figure 1-2,B, the station point is located directly in front of the object. If the observer moves some distance to his left, his line of sight is at an angle to the object plane (one of

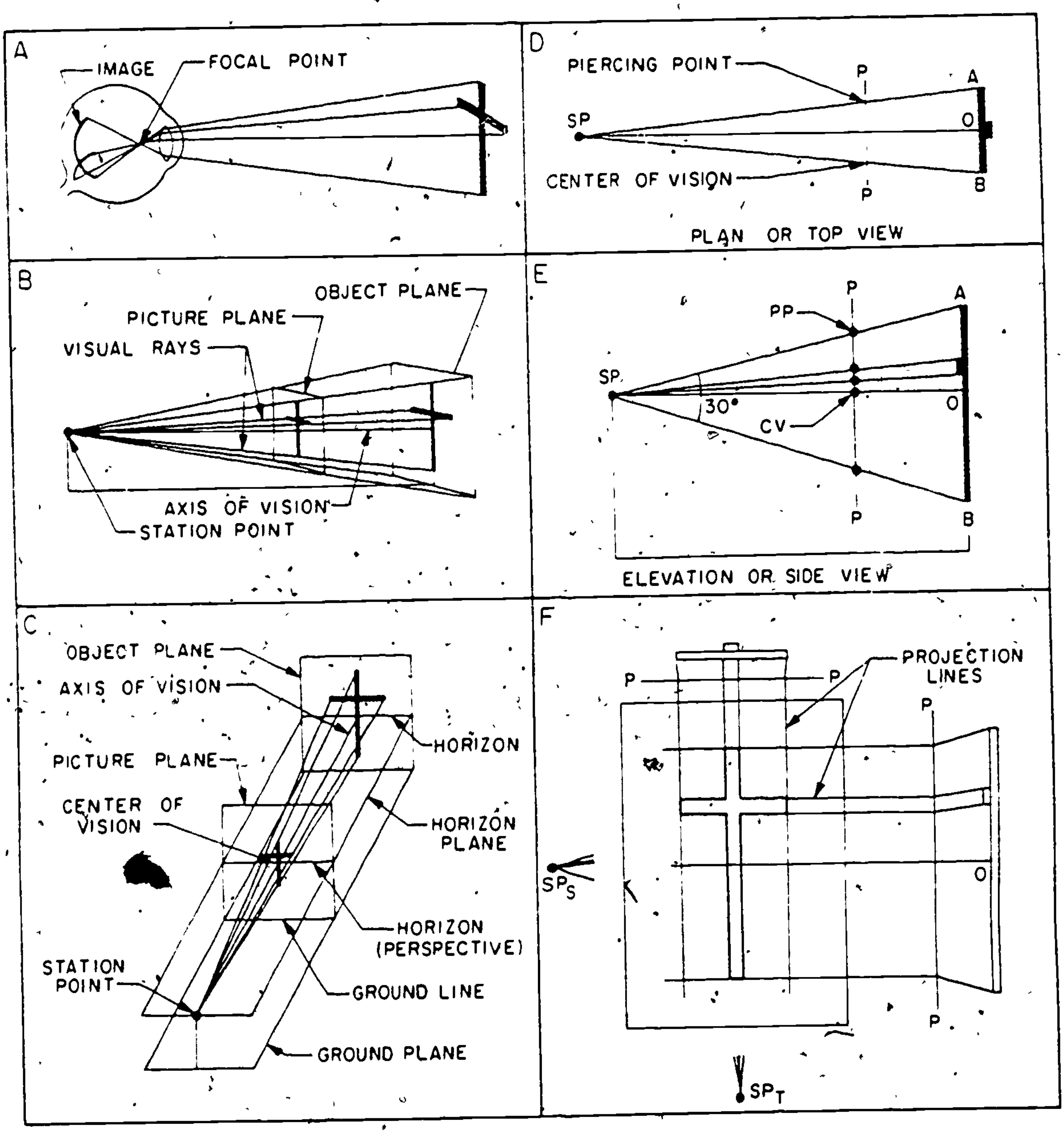


Figure 1-2. Perspective principles and nomenclature.

the object's surfaces), and naturally, the object appears different. He is able to see the left side of the object as well as its front surface. Moving to the right, upward or downward, has a similar effect. Moving nearer or farther away makes the object appear larger or smaller. Since the position of the station point is so important, it is one of the first things to establish when you make a perspective drawing. You will see how this is done after we discuss other important terms shown in figure 1-2,B, and 1-2,C.

The picture plane is another important element in perspective drawing. As we said before, the picture plane can be real or imaginary. In figure 1-2,B, it is the surface of the pane of glass on which the perspective is drawn. Since we seldom draw a perspective this way, we sometimes imagine the picture plane in this position, but use the drawing paper as the picture plane. We always consider the surface of the picture plane to be perpendicular to the observer's line of sight and to the horizontal ground plane.

In the language of perspective, the observer's line of sight (*centerline of vision*) is known as the *axis of vision*. Since the axis of vision and the ground plane are both perpendicular to the picture plane, the axis of vision is parallel with the ground plane. The axis of vision is represented in figure 1-2,B, by a horizontal line drawn from the station point to the object and, as you can see, it is drawn parallel to the ground plane and perpendicular to the picture plane. The point at which this line intersects the picture plane is called the *center of vision*.

Now look at figure 1-2,C. This figure shows the four planes involved in perspective drawing. Two of these are vertical planes and two are horizontal planes. We have already discussed the picture plane and the object plane in figure 1-2,B. Let us add some information about the object plane before we discuss the two horizontal planes.

The *object plane* represents any vertical surface of the object. In the case of the illustration shown, it represents a wall on which a cross is attached. An object plane can be perpendicular or oblique to the axis of vision, depending on its position in relation to the station point.

Since the ground plane and horizon plane are both horizontal planes, they are always parallel to each other. The ground plane represents the surface of the earth, while the *horizon plane* represents an invisible plane passing through the station point and the earth's horizon. The important fact about these planes is their intersection with the picture plane. The intersection of the ground plane and the picture plane forms the ground line, which we have already discussed. The intersection of the horizon plane and the picture plane forms a line called the horizon.

If we were to place our drawing paper in the same position as we placed the pane of glass in figure 1-2,B, and 1-2,C, we could not see the object; we must therefore use some other method of drawing an object in perspective. The principles of various methods of drawing perspective are illustrated in figure 1-2,D, 1-2,E, and 1-2,F.

To draw a three-dimensional object on a two-dimensional surface, you must know the shape and dimensions of the object. The best ways of using this information is to make two-dimensional drawings of the plane and elevation views of the object. D, E, and F of figure 1-2 show the principles involved in using these views to locate the prominent points on the picture plane. After establishing these points on the picture plane, you can draw the perspective.

We establish the prominent points on the picture plane by drawing visual rays between the station point and all prominent points on the object and finding where these visual rays pierce the picture plane. Notice how clearly D and E of figure 1-2 show the points at which the visual rays intersect the picture plane. The reason for this is that our line of sight is perpendicular to the edge of the picture plane in both top and side views. For this reason, we can also take direct measurements between the points of intersection, which we call the *piercing points*, to establish the width and height of our perspective as well as all other prominent points. (Piercing points, to say it another way, are the points where line of vision intersects with the picture plane.)

A much easier method of establishing the prominent points of the perspective on the picture plane is to position the top and side views as they are shown in figure 1-2,F. The top view is placed above the drawing paper so that the picture plane, P-P, is parallel with the top edge of the paper. The side view is placed to the side of the paper so that its picture plane, P-P, is parallel with the vertical edge of the paper. After drawing visual rays to the station point in each view, you draw vertical projection lines from the piercing points in the top view and horizontal projection lines from the piercing points in the side view. The intersections of the projection lines from the corresponding piercing points in both views establish the prominent points of the perspective on the drawing paper. To draw the perspective, you draw lines between the appropriate points.

Before we leave figure 1-2, let us use it to show how important the position of the picture plane really is. Actually, there are two aspects of its position to consider. The distance between the picture plane and the object affects the perspective. The perspective is also affected by the angle between the picture plane and the object. In our examples, we used the simplest angular position. In fact, to simplify our explanations, we eliminated any angular position altogether by placing the picture plane parallel to the object plane.

The distance between the picture plane and the object affects the size of the perspective. Use figure 1-2,D and E, to visualize what would happen if we were to move the picture plane further from the object (closer to station point). You can see that this would reduce the perspective even more. As we move the picture plane closer to the object, the perspective becomes larger since the picture plane intersects the visual rays at points nearer the object. If we wanted the perspective of the front surface of the object to be true size, we would place the picture plane right on the object plane. If the object was small and we wanted our perspective drawing to be an enlargement, we would place the picture plane beyond the object. You can visualize the arrangement if you imagine that the object and picture planes in figure 1-2,B, are reversed in position.

Positioning the picture plane at an angle with the object complicates the perspective drawing. Since we must keep the axis of vision perpendicular to the picture plane, we must also change the position of the station point. When we do this, we see one side and possibly the top or the bottom surfaces of the object as well as the front surface. This will make it necessary to use a different type of perspective drawing.

Since the position of the station point has a great effect on perspective, let us find out where the station point should be placed. Of course, its position depends on the effect you desire. If you place the station point close to the object, the corners of the perspective will be sharp, and your perspective will appear distorted. Actually, the farther you place the station point from the object, the more lifelike your perspective will appear. However, if you place the station point so far from the object that it is not on your drawing paper, you will find it more convenient to locate the station point somewhere on your drawing paper or at least on your drawing table.

In figure 1-2,E, the station point is placed so that the largest angle between any two visual rays is equal to 30°. This is a good rule to use in placing the station point, since it gives an interesting perspective without too much distortion. A simple, practical way to establish the station point using this 30° rule is to first draw the line representing the axis of vision (which you know is perpendicular to the picture plane and is level with the horizon). Then, using the view with the widest span, slide the 30° corner of a 30° to 60° triangle along this line until the edges of the triangle just touch the outermost points of the top or side view. The tip of the triangle establishes the position of the station point. Since the side view of the object had the widest span, we used it to establish the position of the station point, SP, in figure 1-2,E. Then, we placed the SP in figure 1-2,D, at the same distance from the picture plane. If you have a triangle handy, try this method on the station point shown in figure 1-2,E, and see how it works.

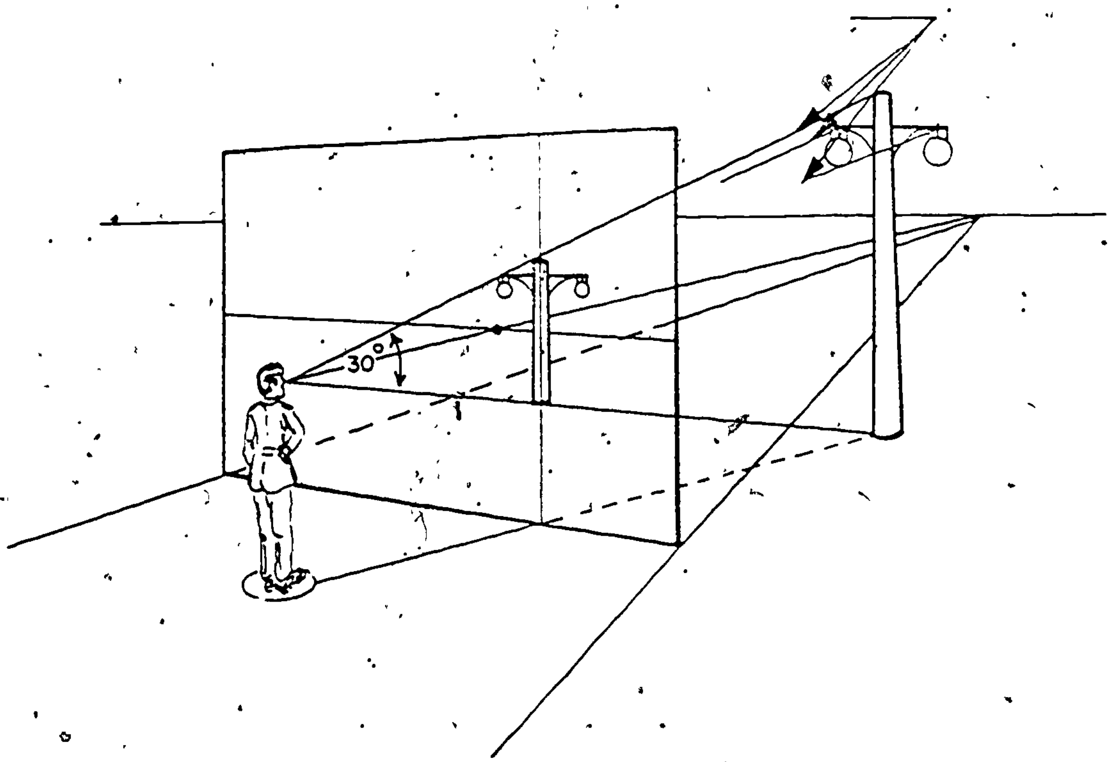


Figure 1-3. Perspective nomenclature.

Exercises (800):

1. Using exercise figure 1-3 that shows various unnamed elements of perspective, write in the appropriate term for each (from the following list).
   a. Horizon.
   b. Vanishing point (VP).
   c. Ground line (GL).
   d. Picture plane (PP).
   e. Station point (SP).
   f. Visual rays (projectors).
   g. Centerline of vision (CV).
   h. Object plane.
   i. Horizon plane.
   j. Measuring line (ML).

2. Define each of the above terms.

3. Why does the station point critically affect perspective?

4. How does the distance between the object and the picture plane affect perspective?

801. Name and briefly describe the three types of perspective, and given figure 1-12, specify each of the respective types.

Types of Perspective. Perspective drawings are one-view drawings in that one view shows a three-dimensional object in a definite proportional relationship. While perspective drawings do not show an object in its true

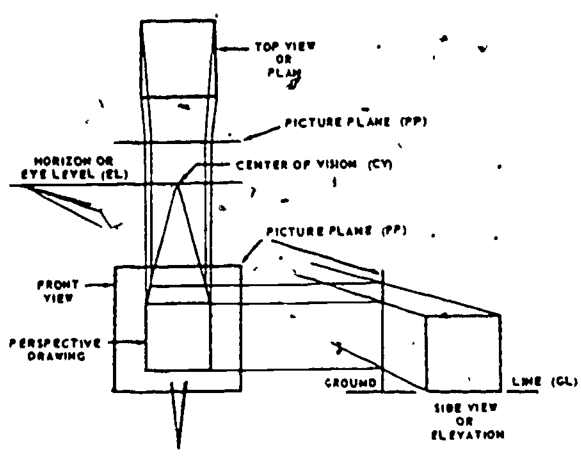


Figure 1-4. One-point perspective drawing.

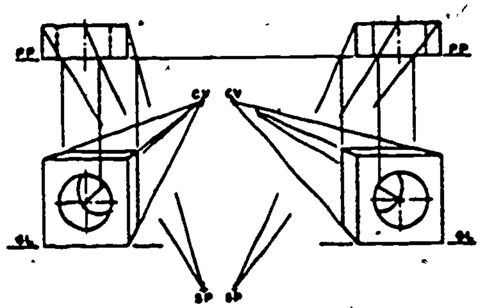


Figure 1-5. Position of station point.

shape and dimension, they do show how the object looks from that point of view.

Parallel perspective. Parallel (one-point) perspective occurs when two dimensions are parallel to an imaginary plane of reference called the picture plane.

Figure 1-4 is a one-point perspective projection of a cube from a top and side view in orthographic projection. The technical terms used in discussing perspective projection are appropriately displayed in the figure.

Notice that the picture plane becomes a line in the top and side orthographic views. Projectors from the corners of the top view are drawn converging toward the station point but, from the points where the projectors, or visual rays, pierce the picture plane, parallel projectors are drawn down to the perspective view.

The station point for the side view is actually the same station point as that shown for the top view. It is, therefore, the same horizontal distance from the cube, but its elevation shows the height of the station point above the level of the cube. The picture plane in the side view is also the same distance from the cube as in the top view, and the ground line in this view, on which the picture plane rests, defines the ground line of the picture plane in the perspective drawing.

In the side view, projectors are drawn converging to the station point, and at their piercing points on the picture plane, parallel horizontal projectors are drawn to the perspective drawing. The intersection point of a projector from a corner of the cube in the top view with the projector from the same corner in the side view locates the corner in the perspective drawing.

Notice that the center of vision in this drawing is located directly above the station point in the perspective drawing and on the same line with the station point for the side view of the cube.

The center of vision defines the point at which all lines perpendicular to the picture plane in the perspective drawing converge. It is also called parallel perspective because the front face of the object is parallel to the picture plane.

In parallel perspective drawings, the center of vision is not necessarily centered on the object. It may fall to one side or the other as shown in figure 1-5. However, when the front face is parallel to the picture plane and the center of vision is at one side of the drawing,

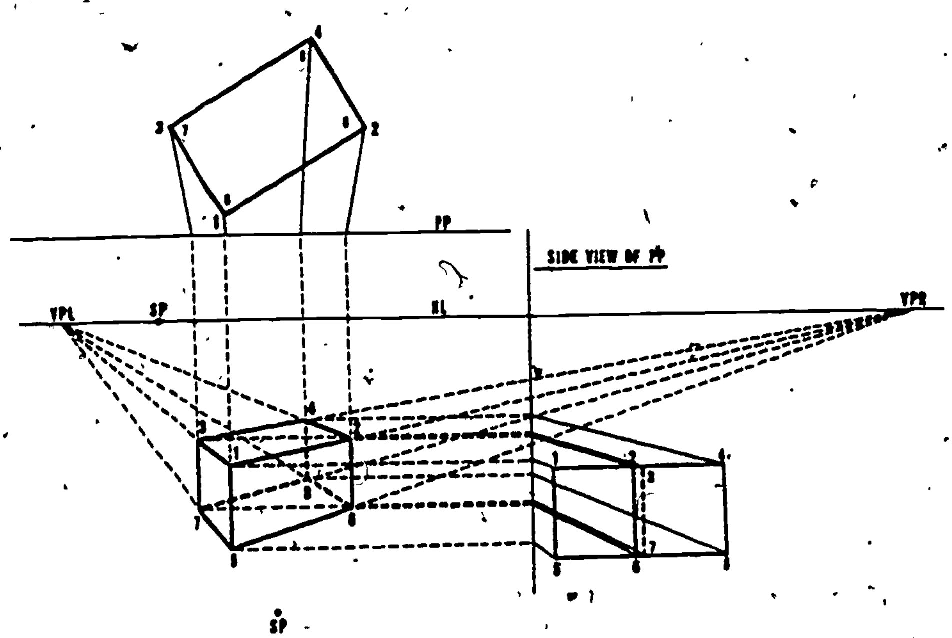


Figure 1-6. Two-point (angular) perspective.

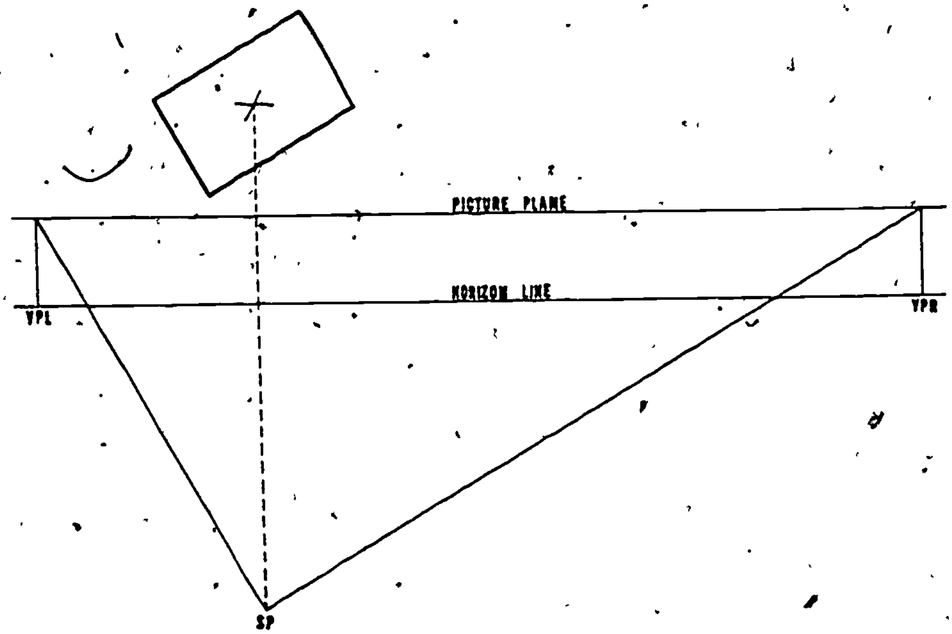


Figure 1-7. Locating vanishing point.

there will necessarily be some distortion. Actually, the drawing becomes an oblique projection and not a true perspective drawing. Notice that in order to make such a drawing, the object must be considered as resting with its front face against the picture plane. If this were not so, converging projection lines from the corners of the front face would alter its appearance so that it would no longer appear to be parallel with the picture plane. In fact, as you will see, it would then become a two-point, rather than a one-point, perspective drawing.

Two-point perspective. The second type of perspective—two-point—is the most commonly used for making perspective drawings. In two-point, or angular perspective, the object is considered as sitting

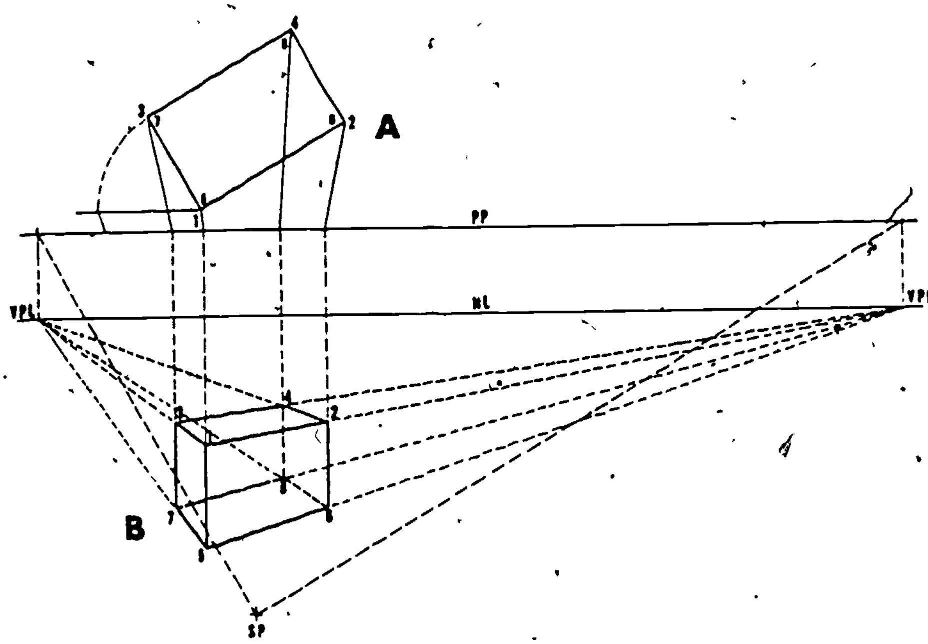
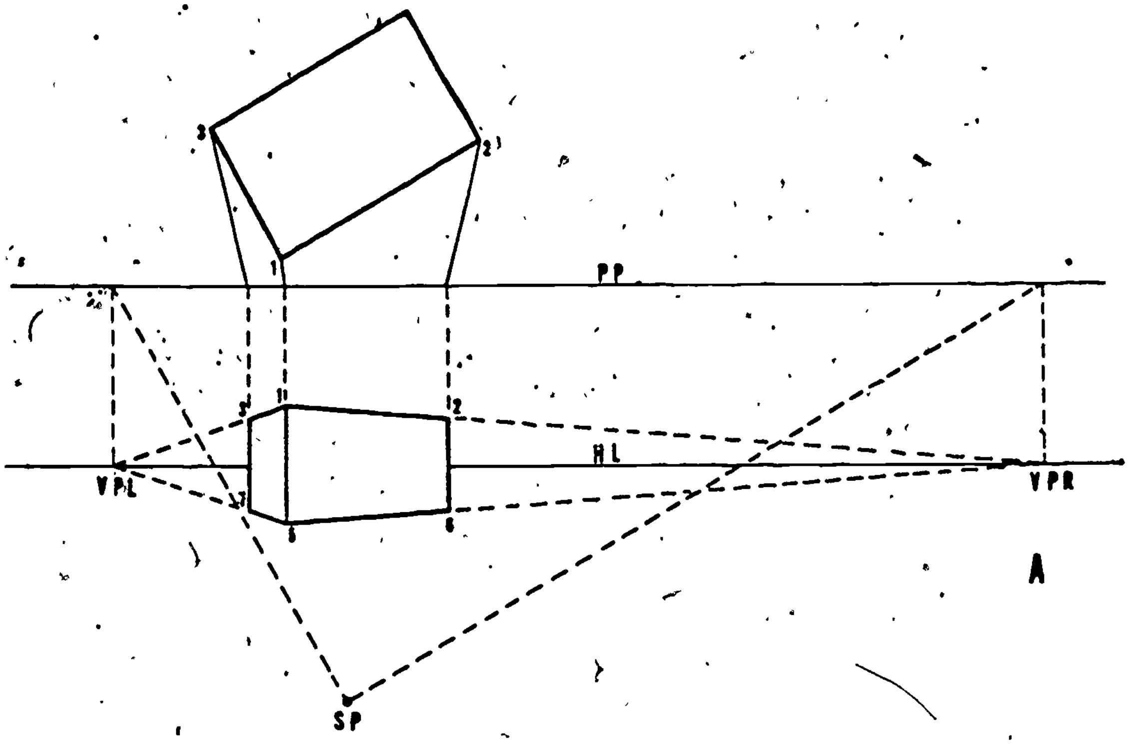


Figure 1-8. Two-point (without elevation of object).



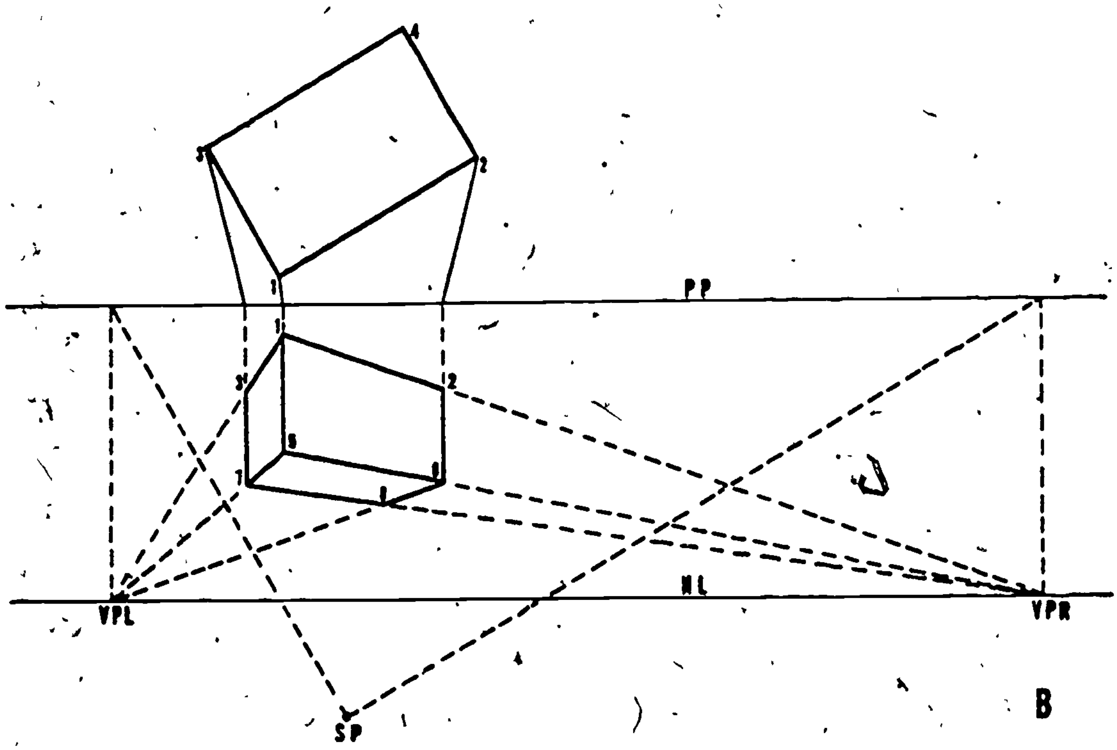


Figure 1-9. Object on eye level (A), object above eye level (B).

at an angle to the picture plane. In the perspective drawing of such an object, there are two sets of horizontal edges converging toward two different vanishing points on the eye level or horizon line. The parallel lines that slope to the right will vanish at a point in the distance called the right vanishing point (VPR), and those that slope to the left at a point called the left vanishing point (VPL). (See fig. 1-6.)

In the figure, the top orthographic view of the block was drawn first. The position of the picture plane was then determined.

When the corner of the object rests against the picture plane, the vertical line representing the corner in the perspective drawing will be full size (just as in one-point perspective, where the front face is full size if it rests against the picture plane). In any perspective drawing, the comparative sizes will be reduced proportionately as the distance is increased between the picture plane and the object.

Once the picture plane was established, the station point for the top view in figure 1-6 was located approximately opposite the center of the block. The distance from the station point to the object should not be less than twice the width of the object.

When this rule is neglected, a distorted appearance may result in the perspective drawing. There is a cone of about 30° in which the human eye sees clearly. For this reason, the angle formed by the lines of sight from the sides of the object to the station point should not exceed 30°. In no case, even when the perspective drawing depicts a panoramic scene, should it exceed 45°.

Next, the picture plane for the side view was established. Then the side view was drawn. (Points may be projected from the top view if necessary.) Remember that the picture plane in the side view (elevation) is the same picture plane shown in the top view and, thus, it is the same horizontal distance from the object.

The station point for the side view was located next. This station point is the same point seen in the top view and, therefore, it is the same horizontal distance from the object. However, its angle to the object can vary. This variation of the station point in the side view determines the height of the eye level or horizon line. Note that the station point for the side view always falls on the horizon line.

This horizon line is a very important one. If it is high, objects in the perspective view will appear as if they were viewed from a height. If it is low, objects will appear as if they were viewed from directly in front or below. Generally, it is best to select a station point approximating that from which a real observer might view the object.

This method is usually used when architectural drawings are made in two-point perspective. However, two-point perspective may be drawn (as in fig. 1-6) from a plan view of the object alone, without the elevation. When this is done, the vanishing points are first projected on the picture plane and then located on the horizon line. In order to do this, a line parallel to one set of horizontal lines in the top view is drawn from the station point to the line of the picture plane. The point at which this line intersects the picture plane is then projected to the horizon line to locate a new point, either VPL or VPR. (See fig. 1-7.)

When this method is carefully used, it will produce as much accuracy as the method illustrated in figure 1-6. For example, in figure 1-8, the horizon line has been placed at the same level as the horizon line in figure 1-6, and the cube is the same size so that the two methods can be compared. In figure 1-6, the vanishing points were found after the drawing was completed, and it was not necessary that they be found at all. In figure 1-9, the vanishing points were found at the start, because they control the drawing.

In figure 1-9 lines are drawn converging toward the station point from the corners of the block in the top view. From the points where these lines pierce the picture plane, verticals are dropped to give the apparent width of the block in the perspective view. Since an elevation is not used, the various heights cannot be found directly. However, the bottom of the block (B) may be located, as shown in figure 1-9, by drawing lines to the vanishing points from the point selected as the near corner.

Now if the perspective height of any one vertical line can be determined, the height of the other verticals can be found automatically. This is easy to do when one edge of the object rests against the picture plane. This edge will then appear in its true height in the perspective view. If you have the dimension for this height in the orthographic projection (A), you can transfer that dimension directly to the perspective view (B). Lines drawn to the vanishing points from this top corner will locate the top of the two sides (3-1, 4-2 B), lines drawn to the vanishing points from the far corners on these sides will complete the drawing of the block.

Still discussing figure 1-9,B, when the front

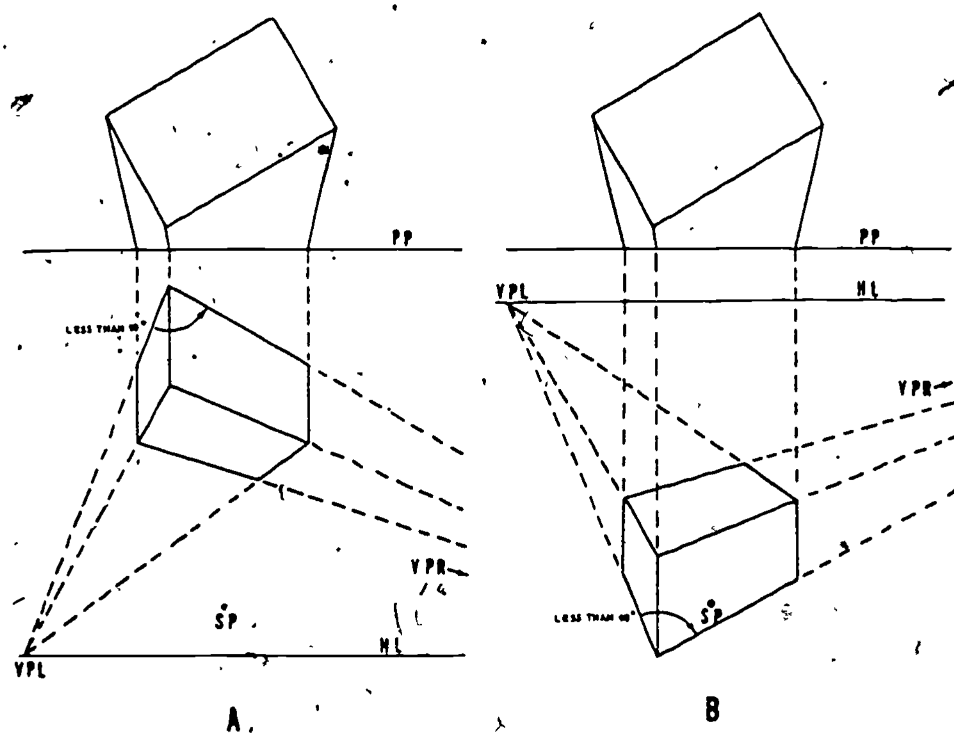


Figure 1-10. Perspective distortion.

edge of the subject does not rest against the picture plane, it is necessary to use some other dimension. Because the end of the block is square, it is possible to find the perspective length of a horizontal line and use this dimension for the edge of 1-5. This is done by drawing a line parallel to the picture plane from point 1, measuring a length of this line equal to 1-3, and drawing a line converging on the station point to the picture plane from the end of this line.

This length can then be transferred to the front edge of the perspective view (B) and the view completed as shown in figure 1-8. To

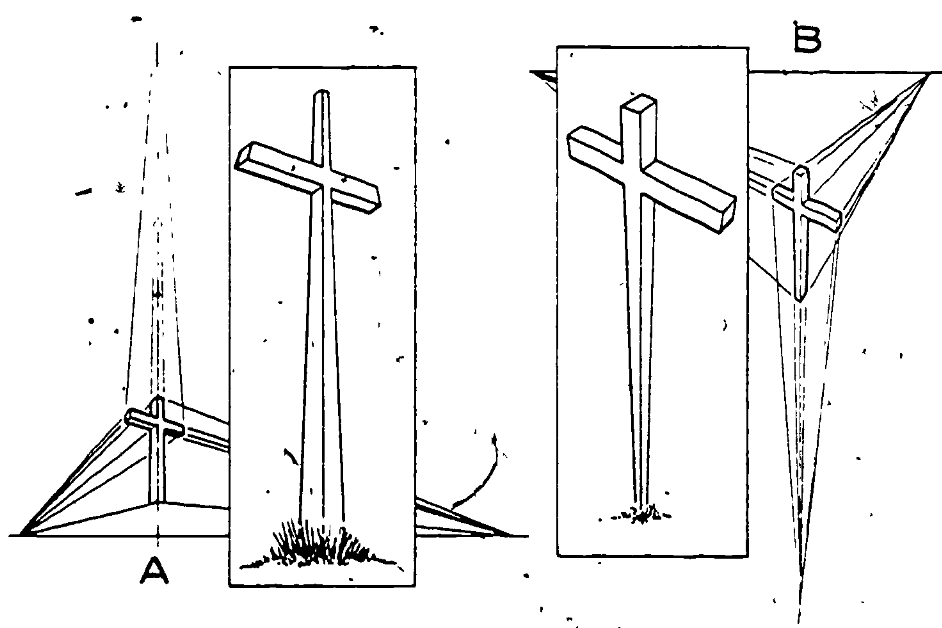


Figure 1-11. Cross.

check the accuracy of this method, compare figure 1-8 with figure 1-7. You will find that, since the station point, horizon level, and the bottom of the cube correspond, the two perspective views are similar. It is possible to make them correspond exactly.

In figure 1-8 the bottom of the front edge of the block (B) has been placed arbitrarily at a certain point. Actually it could have been placed on the vertical projection from the cube at any desired point. Thus, the perspective view may be drawn below the eye level, or, as shown in figure 1-9, it may be drawn at eye level (top) or above it (bottom).

However, if the object is placed too high above the eye level or too low below it, the effect will be one of distortion. A block drawn in these positions will cease to look right as shown in figure 1-10. When the station point is too close to the object, there will be a similar distortion. The angle indicated in the figure should never be less than 90° and preferably not more than 100°.

To overcome distortion such as that illustrated in figure 1-10, the station point may be moved further from the object, or the picture plane may be tilted so that a third vanishing point is needed for the third set of parallel lines in the drawing.

Three-point perspective. Oblique, or three-point, perspective occurs when none of the object's surfaces are parallel to the picture plane. Three-point perspective is usually needed when the station is close to the object and the picture plane is at an angle to the horizon line as shown in figure 1-11. Looking up at a tall building, large trees, or the cross pictured here can produce such a situation. The horizon in this case is usually very low, or entirely below the object being viewed (fig. 1-11,A). If you were looking down from above (fig. 1-11,B) the horizon may or may not appear in the view at all.

A general rule to follow in a case like this is: small objects look better if the three vanishing points are well separated. The perspective angle should not be acute. To emphasize the bigness of an object, sharp diagonal lines are important. Here the closeness of the vanishing points strengthens the bigness effect.

Be sure that the horizontal lines end at the eye level line, because one cannot be higher or lower than the other. Regardless of their distance apart, they must be established on the same eye level. In any perspective drawing it is a good idea to use the sketching method and lightly sketch the object before finding the horizon line and vanishing points.

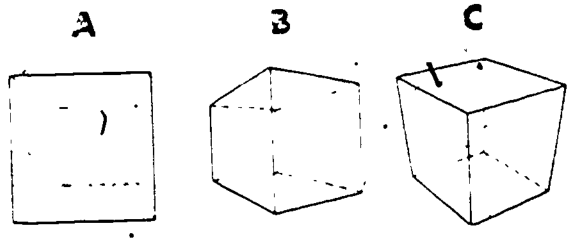


Figure 1-12. One-, two-, and three-point perspective (objective 801, exercise 2).

Exercises (801):

1. Name and describe each of the three types of perspective.

2. Using figure 1-12, specify which types of perspective A, B, and C are?

1-2. Measurement and Form in Perspective

In drawing any form, the proportions should be correct. This is especially true when drawing form in perspective. At the beginning of this chapter, we introduced into our discussion the cube—the basis for all good drawing. In order to solve many practical problems in art, you must become acquainted with methods of measurement as they apply to this geometric solid, here are a few of those methods.

802. Using two-point perspective and receding plane given in exercise figure 1-16, divide a rectangular area into uniform patterns; then state the two steps necessary before measuring.

Measurement. Before making measurements of any kind, establish the needed vanishing points and station point. Next, correctly sketch in the overall shape of the object. If you do not, you may wind up making endless corrections, and the drawing will never be quite right artistically. To divide a rectangle or a square, draw a diagonal line from corner to corner as shown in figure 13,A. The point where the diagonals cross is the center of the rectangle or square. This

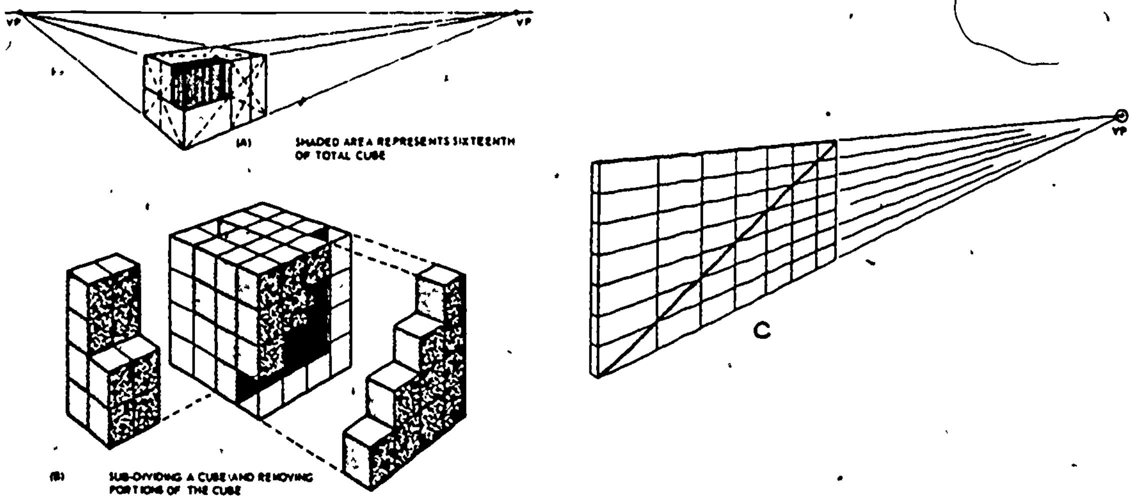


Figure 1-13. Division.

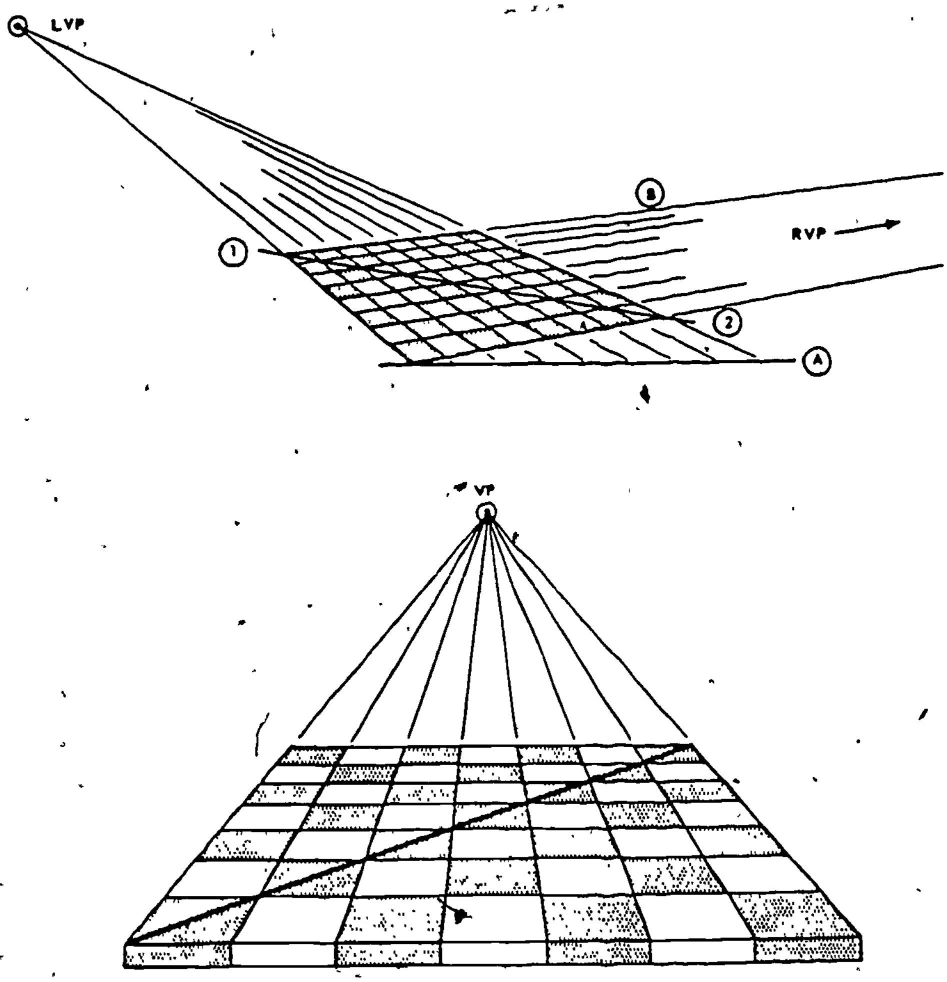


Figure 1-14. Division of rectangular area.

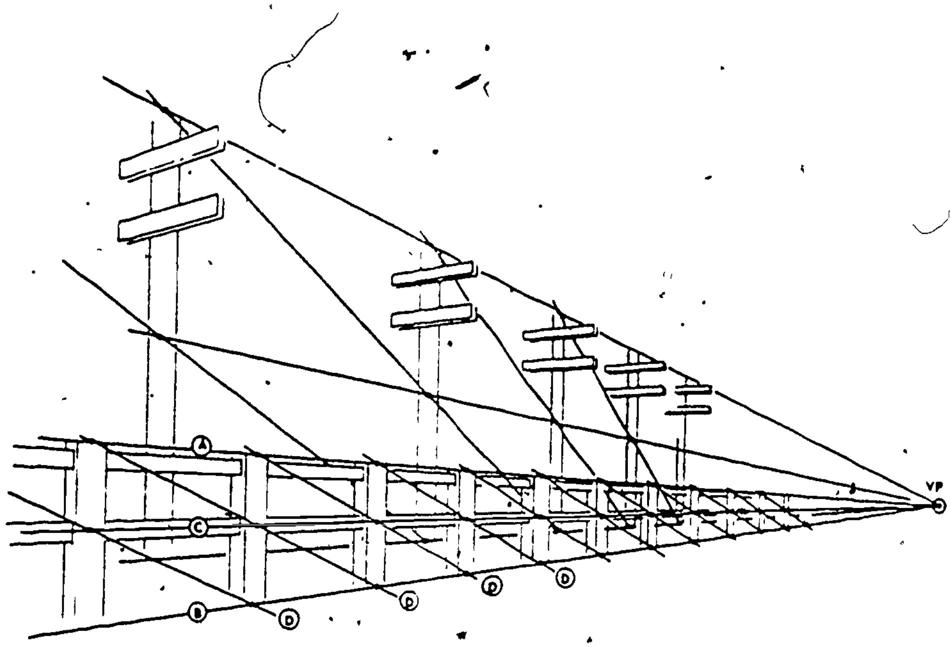


Figure 1-15. Vertical division.

simple rule is invaluable—it enables you to solve problems that are seemingly unsolvable.

At other times it is necessary to divide an area, or a diagonal, into a number of parts, here a ruler alone will not suffice. As with most division of space, the vertical (fig. 1-13,C) or horizontal line (not shown) parallel to the picture plane is the key. Aspect B of figure 1-13 shows the subdivision of a cube, portions removed. For example, to divide a receding plane into any number of units, divide the left vertical height into the desired number of parts with a ruler as shown in figure 1-13,C. Draw lines from the points of division on the vertical line out to the vanishing point. Then draw a line from corner to corner as shown, and the intersections of the diagonal and the horizontal lines drawn to the vanishing point are the correct points to add the other vertical lines.

Figure 1-14 shows the correct method of dividing a rectangular area into uniform rectangular patterns, such as floor tiles. The width of the squares are first measured on a horizontal line (A). Two vanishing points are established and lines are drawn from the divided horizontal line to the left vanishing point, then the depth is established by drawing lines to the right vanishing point. A diagonal line is drawn from corner to corner, points 1 and 2. Where the diagonal intersects the lines drawn to the left vanishing point are the correct points for the receding lines to be drawn to the right vanishing point. Notice that the lower drawing is a one-point perspective.

Figure 1-15 shows the method for drawing vertical divisions of posts, telephone poles, or any object with evenly spaced units. First draw two posts any distance apart. Locating the vanishing point is accomplished by drawing lines (A) and (B) from the two original posts. At no time should any posts extend above or below the receding lines. Locate the center of the first post, then draw a line through the center point of the first post to the vanishing point on the horizon. From the top of the first post draw a line through the center of the second post. The third post will be located where the diagonal line touches line (B). Repeat this procedure as many times as you desire doing one at a time.

4.10

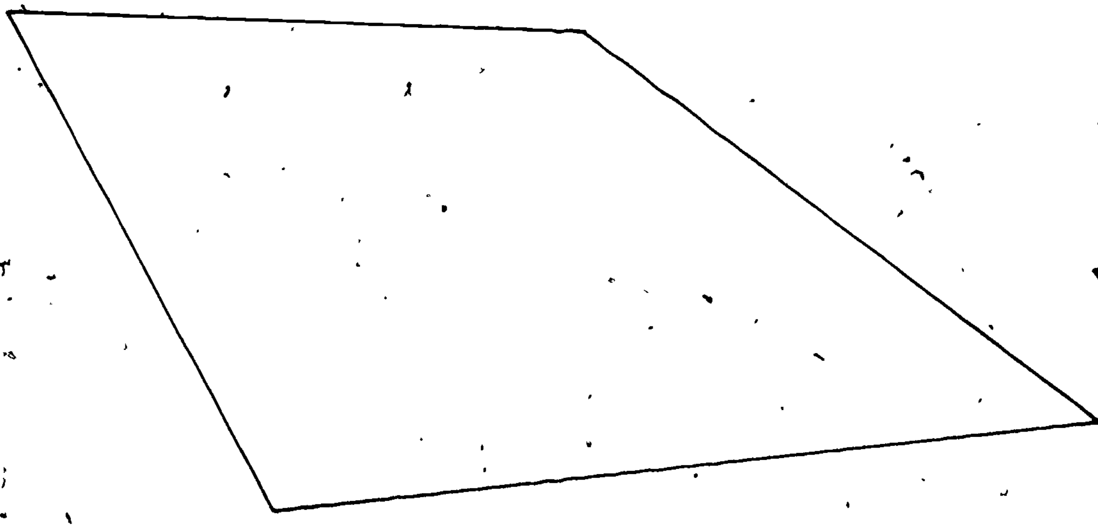


Figure 1-16. Exercise rectangle (objective 802, exercise 1).

Exercises (802):

1. Using figure 1-16, divide the area into 25 uniform shapes (like floor tiles).

2. What are the two steps necessary before making measurements?

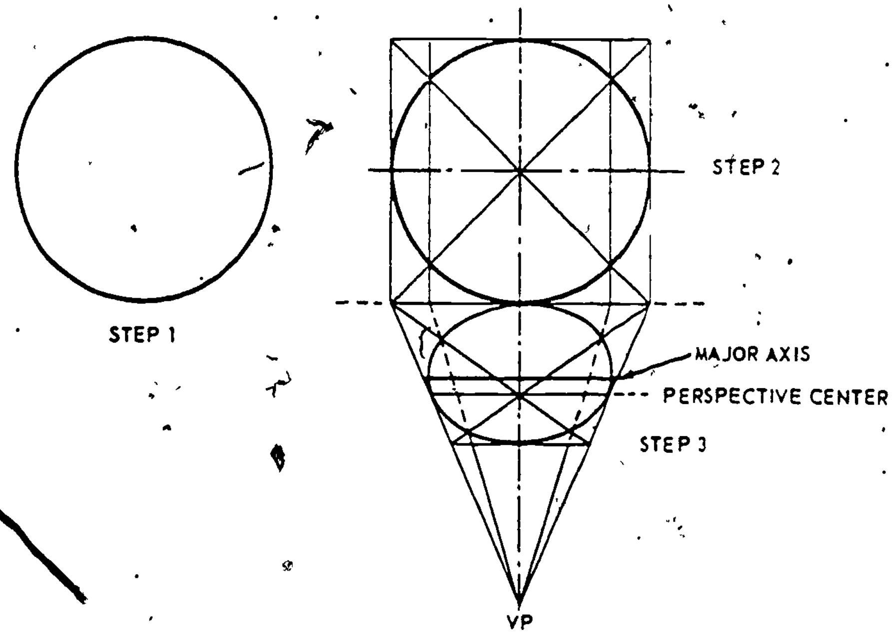
803. Given the requirements, draw two circles in perspective—one in freehand, the other in instrument layout.

The Cube and Circle. The cube is in many ways the most important single shape you will study in your art career. Both simple and complex structural development can be illustrated by this one geometric form. Its importance will become increasingly evident as you work with three-dimensional forms and measurement, especially when you draw objects in perspective. As the preceding text segment pointed out, in order to solve many practical problems in perspective, you will use the cube or some portion of it as a medium of measurement. This may be a tedious business, because you may make several sketches before you get an acceptable drawing. But it is time and effort well spent. Some artists who make cubes too wide or too narrow, have never really learned what a square—hence a cube—looks like in perspective.

Although the cube is perhaps the most important shape, the circle is the guide for drawing all two-dimensional curves, ellipses and ovals in perspective. Even so, its basis is the square, or one surface of the cube. The square is used because there are no direct measurements on a curve in perspective. Vanishing points are determined from the square, and proportions of the curve can easily be seen within the square. Figure 1-17 shows the proper layout of a circle in perspective. The first step in the instrument layout is to draw a circle with the desired dimensions. Second, draw the square around the circle and add the diagonal and centerlines as shown in step 2. This will give you eight checkpoints for drawing the circle in perspective. Next, draw the perspective lines back to the desired vanishing point, to establish the square in perspective.

The back line of the new square is determined by the method presented in figure 1-17. Now diagonal lines are drawn from corner to corner in the perspective square. Within the original square, short vertical lines are drawn downward to the picture plane from the points where the circle line and the diagonal lines intersect. From these two points, draw lines back to the vanishing point. The points at which these lines cross the diagonal lines in the perspective square are the points through which the curve is drawn.

The center of the circle shifts from the center of the square when the circle is in perspective. The intersection of the diagonals is the perspective center; the intersections of the horizontal centerline with the lines drawn back to the vanishing point does not indicate the widest part of the circle in perspective.



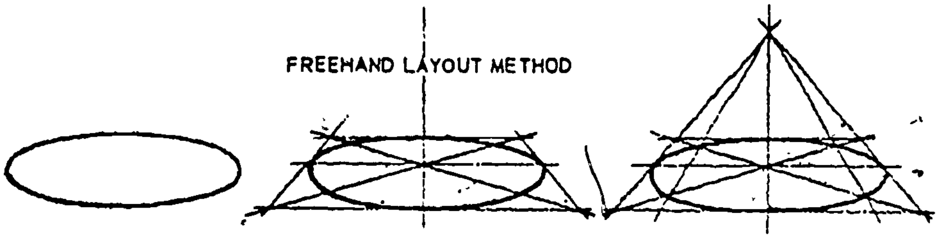


Figure 1-17. Mechanical tool and freehand layout methods.

When drawing circles in perspective, it is often best to rough them in freehand and get the general shape desired. When the square is proportionally correct, cross the center with two diagonal lines and cross these with a vertical line through the intersection of the diagonal lines. Draw a horizontal line through the center to determine the perspective center. Use the vanishing point to have the direction of the receding lines correct.

Exercise (803):

1. Using your own paper:
   a. Draw a circle (in one-point perspective) using the freehand method.
   b. Construct a circle (in one-point perspective) using the T-square and triangle (instrument method).

804. Name the three major things to remember in perspective drawing.

Compound Form. Most objects consist of compound forms that can be reduced to a basic form—as you've just seen. You can solve most of your perspective problems if you understand the cube and its relationship to perspective. The three most important things to remember are: the horizon, the station point, and the vanishing points. These are the only elements that affect the appearance of your drawings. If these elements are poorly selected but definitely established, your drawing is correct although it may be unattractive.

Remember, keep the vanishing points as far apart as possible; this gives the final picture a more pleasant appearance. Also keep all vertical lines truely vertical, except for special effects. If special effects are necessary, a third vanishing point may be needed.

Drawing a cube or a rectangle in perspective is a simple operation if you understand measurement. A rectangle in perspective can be thought of as two cubes placed end to end. If you can draw a cube and measure it, you can divide it into halves, thirds, or any number of divisions found in compound form. Compound forms need not be complex, if they are thought of as cube-upon-cube in perspective.

Exercise (804):

1. What are the three most important things to remember in perspective?

805. List the first two steps in drawing a plan and elevation view, and explain why line A, figure 1-18, is most important.

Making a Plan and Elevation View. Plan and elevation views can become very complex; compound forms are to be expected. When making such a plan and elevation view in perspective, the first step is to draw a line to represent the picture plane. The plan view is arranged behind the picture plane with the nearest corner of the building just touching the picture plane (A) as shown in figure 1-18. Next, select the station point. Make the station point approximately the center of the plan view at a 30° overall angle.

Draw lines from the station point to the corners of the important parts of the building that you want to locate in your perspective drawing. Where the lines intersect the picture plane, draw vertical lines to establish accurately the width of the different parts of the structure. The most important of these lines is the line that is actually touching the picture plane (line A). It is the only line that is not foreshortened, therefore, the only line

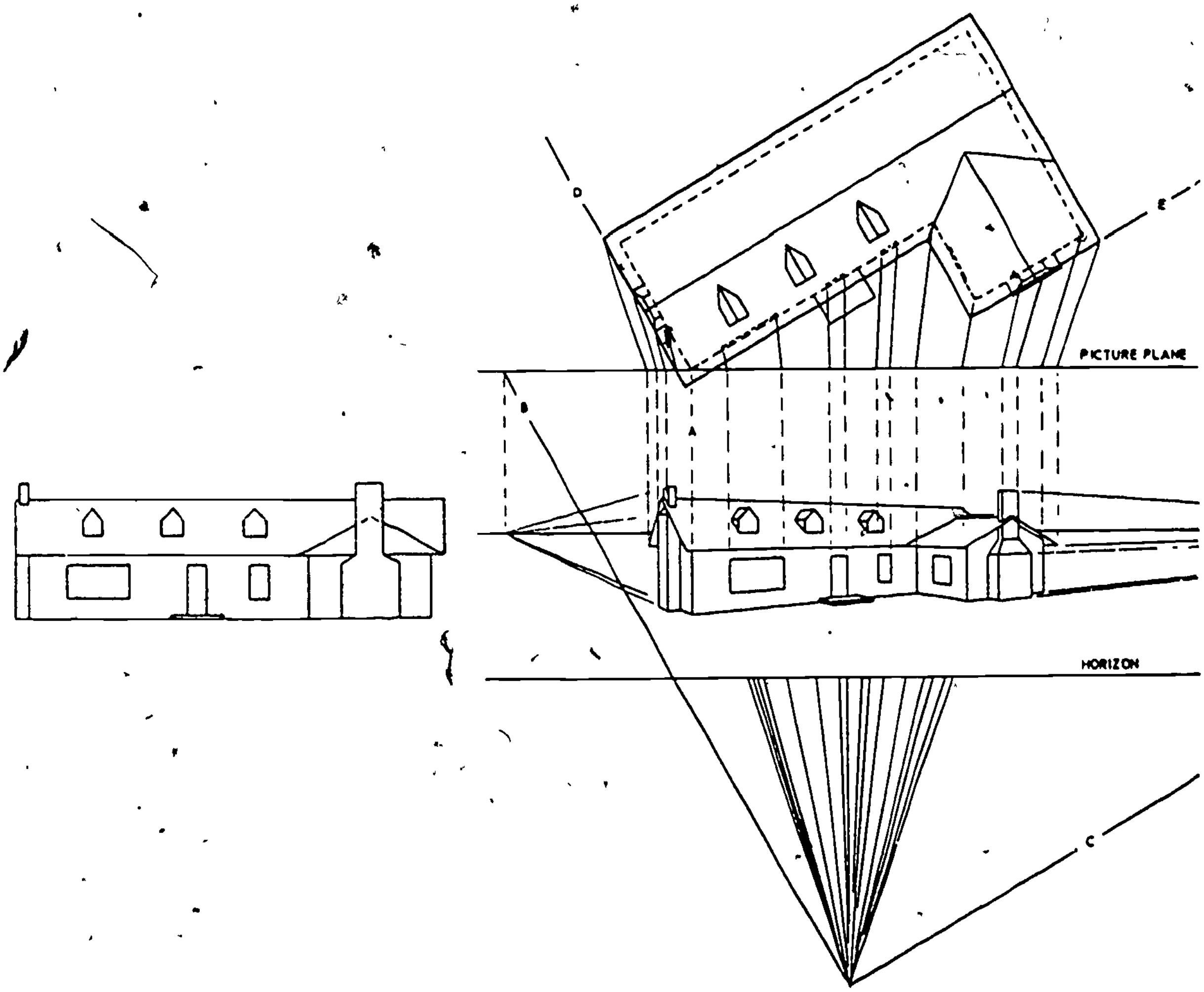


Figure 1-18. Plan and elevation views.

Figure 1-19. Foreshortening.

that can be used for vertical measurement from the elevation view.

Now you must decide on the location of the horizon line. After you have located the horizon line, draw lines (B) and (C) parallel to lines (D) and (E) in the plan view. From the points at which lines (B) and (C) intersect the picture plane, drop vertical lines to the horizon line to establish the right and left vanishing points.

The next step is to carry across vertical measurement from the elevation view to line (A) and draw construction lines from the points on line (A) to the vanishing points using the same procedure already discussed. The vertical lines dropped from the picture plane will automatically establish the width of doors, windows, walls, etc., in the perspective drawing. Remember, you can make direct vertical measurement only on line (A); it is the only true length line in the whole drawing.

Exercises (805):

1. What are the first two steps in drawing a plan and elevation view in perspective?

2. Why is line (A), figure 1-18, the most important line?

806. Define foreshortening; and state the main consideration (in each case) when placing figures, drawing reflections, and drawing shadows.

Foreshortening. When working with compound forms, a graphics specialist must

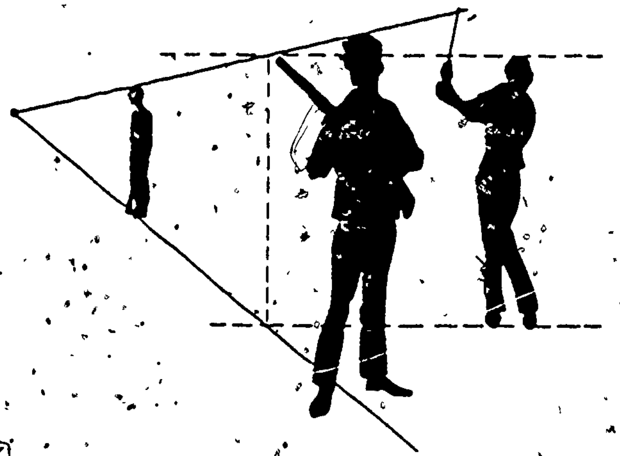


Figure 1-20. Background figure placement.

be conscious of an illusory effect called foreshortening. When an irregular (free) form appears to go toward or recede from the viewer, it is foreshortened. If in the irregular or "free" forms there are many curves, such as in the human figure, foreshortening is very difficult to create. A great deal of practice in drawing the human figure in a variety of different positions will give you experience in foreshortening. Also, the principles of measurement that apply to geometric forms can be used to great advantage in foreshortening the human figure. In figure 1-19, these principles have been applied in determining how much or how little is seen of the human figure sitting on the floor with parts of the body toward the viewer. Notice particularly the lettered areas; the lowercase letters designate foreshortening. In some unusual views, it is helpful to draw the figure in a cube or rectangular form that will quickly determine if and where a part of the human anatomy can be seen and in what approximate shape. Perspective can be the cure for many problems you may run into while drawing all types of forms. Remember to give careful consideration to the location of the station point so that distortion is minimized.

Placement of human figure. As with foreshortening, the correct placement of the figure in a perspective drawing is difficult but important. The viewer of any picture automatically relates the proportions, scale, and size of all forms to the figure in the picture. Too, the viewer assumes that all adult persons are approximately the same height—somewhere between 5 feet and 7 feet.

Proper use of the vanishing point is the main consideration in correctly placing the figure. Use the vertical distance between the receding guidelines to the vanishing point to establish the height of any figure anywhere in the picture (as in fig. 1-20). To place the figure to the left or the right of these guidelines, extend horizontal lines from the head and feet off the vanishing point lines as shown in figure 1-20. Once the height is determined for one figure, the others are automatically taken from the intersection of the two horizontal lines and the receding lines going to the vanishing point.

Reflections. Another aspect related to compound forms is reflection. An object reflects as far below a reflecting surface line as it projects above the reflecting surface. The reflection is not a mere reversal of the scene

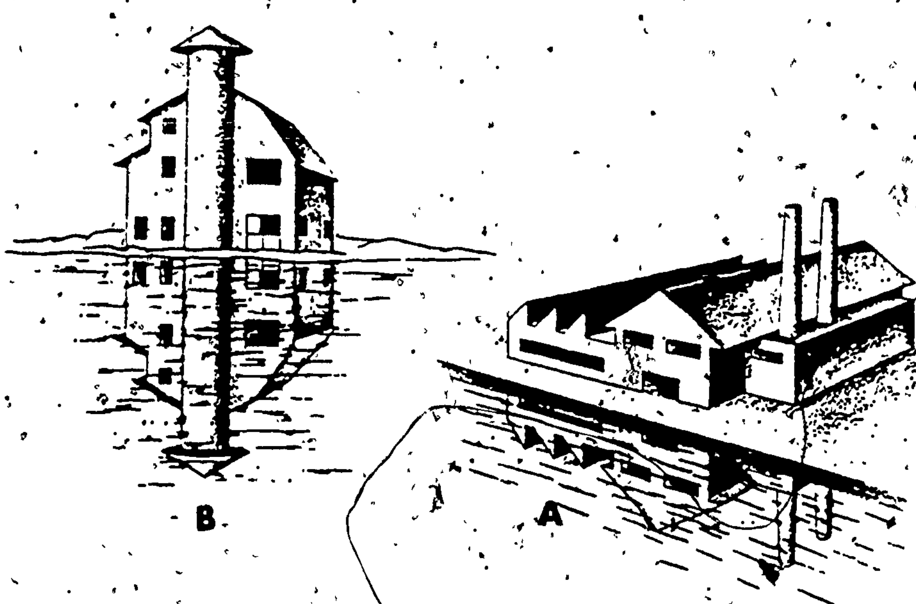
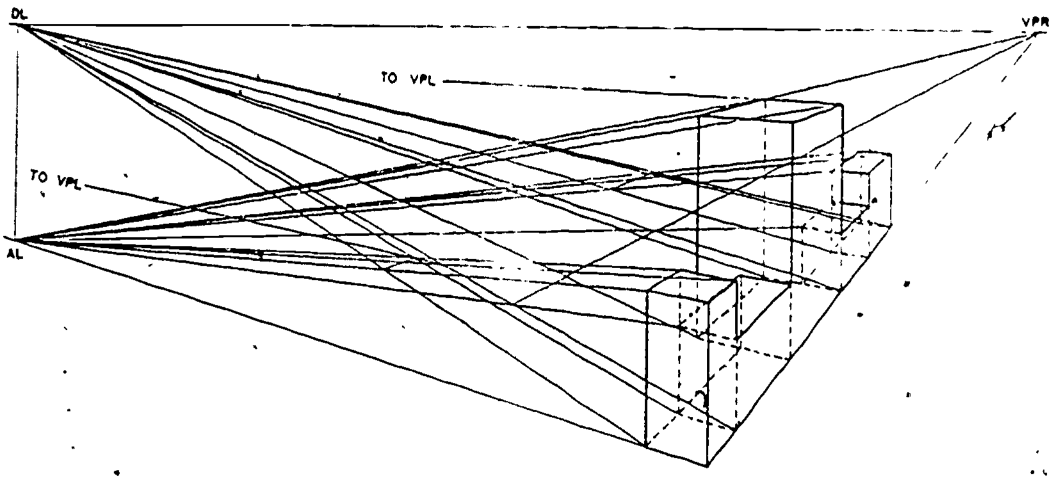
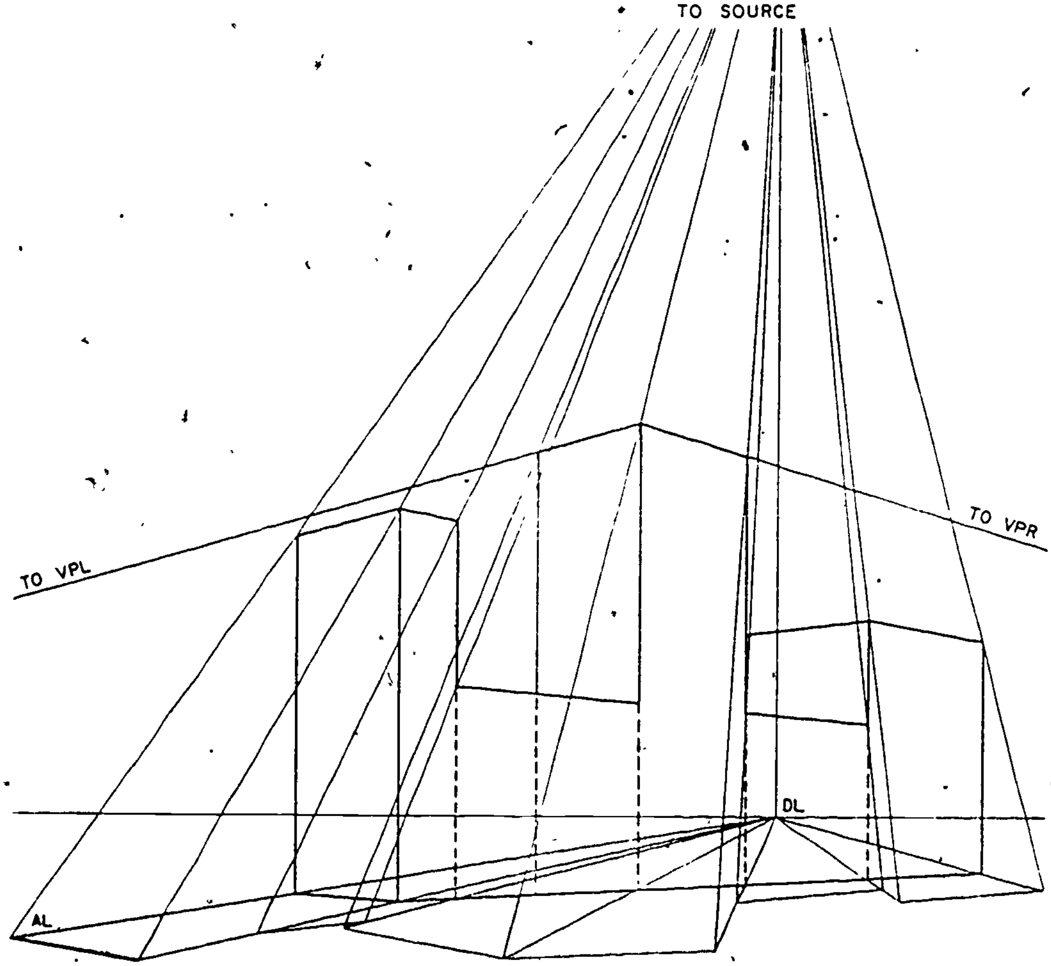


Figure 1-21. Reflections.



Ground shadow, looking away from light.



Ground shadow, looking toward light.

Figure 1-22. Shadows.

being reflected. Although the eye level remains constant, the view is a reflected one. When the eye is above an object, you are looking down at the object; and, since the object is reversed in a reflection, the proportions remain the same; but you are now looking up at the object. See figure 1-21. When the object being reflected is close to the eye level, the reflection is nearly a duplicate in reverse, but not so when the object is well below the level of the eye. Eye level is the main consideration.

Shadows. Light travels only in straight lines. From an established light source, lines are drawn to touch the corners of the form and are continued until these lines touch the surface of the plane on which the object rests. All shadows recede to the same vanishing point when there is a single source of light. The shadow's vanishing point will fall on the horizon line directly below the source of light. Shadows follow the contour of the plane upon which they fall, as shown in figure 1-22. The main consideration when drawing shadows is light source.

Exercises (805):

1. What is foreshortening?

2. What is the main consideration when:
   a. Placing figures?

   b. Drawing reflections?

   c. Drawing shadows?

CHAPTER 2

Visual Communication

AIR FORCE commanders at all levels of command normally have to deal with a great variety of cold, hard facts. For example, the Air Force Chief of Staff must have data that shows the combat readiness of the entire Air Force, and the squadron commander must know which aircraft are ready to fly and how many qualified mechanics and pilots are available to keep them flying. In both cases, the commanders need data (statistics) readily available and so presented that they don't have to spend time reading lengthy, abstract, dry statistical reports. They are not interested in the flood of details that can be put on the printed page. They want facts in a form they can grasp quickly; one that gives them a clear picture of their operation or mission without requiring them to waste their time studying statistics. As an illustrator, you must be able to give them this information in well-prepared graphics that communicate visually and that may stand alone or be supplemented with written or spoken words.

Unfortunately, many people are not gifted with the ability to draw rapid and accurate conclusions from a mass of numerical data. Since people usually learn more quickly when facts are illustrated by a picture or series of sketches, a set of good tables, charts, or graphs will make any analysis clearer. Regardless of how the data is presented (table, chart, or graph), the specific medium must be such that it can be easily understood by those for which it is intended; in other words, what best determines whether a table, chart, or graph is used are the people for whom it is designed. Normally, we consider three basic ways in which statistical data and analysis may be presented—narrative, tabular, and graphic presentation. A presentation may be limited to one of these methods, or it may be any combination of them. The data to be presented must be examined carefully, and a method of presentation chosen to highlight the essential elements.

The actual presentation of a chart, table, or graph requires a certain amount of imagination as well as the manual deftness. Since the people (commanders, supervisors, etc.) are usually not artists, they have to turn to someone to help them with the conception of, as well as the preparation of, the proper chart, table, etc. Therefore, as an illustrator, you will be expected to take the figures or data and translate them into simple and understandable graphics. Creating this type of material requires that you understand the possibilities and limitations of the various types of graphics and learn to select the proper type for each particular presentation. Before we go into the actual work of preparing graphics, let's first discuss briefly the methods of presentation (narrative, tabular, and graphic) which may be used.

2-1. Methods of Data Presentation

We previously indicated that there are three basic ways in which data may be presented; these are narrative, tabular, and graphic. The method of presentation selected is normally determined by the type of data and the intended use of the data. In this respect, there are times when a combination of the styles of presentation may be used to good advantage. For example, material may be presented orally in narrative form; it may be presented orally using charts or other graphics as visual aids; or in the case of this CDC, graphics may be combined with the written word. Let's review some of the advantages and disadvantages of each type of presentation.

807. Given a list of characterizing statements concerning data presentation, match the appropriate term or classification with the definition.

Narrative Presentation. A narrative

presentation may be either written or oral. The information is normally presented in story form, and the text is frequently supplemented by tables, graphs, and charts. There is usually a discussion of the data being considered, and usually there is justification for the conclusions reached. In addition, the narrative presentation may trace the steps of a situation and explain the reasoning behind certain conclusions. From the foregoing you can see that the narrative presentation can take on just about any style necessary to accomplish its intended purpose.

Written Presentation. A written narrative presentation is often used when it is expected that the user will sit down and study the report in detail. In this respect, a narrative report can show a great amount of detail. Studies that are submitted to a higher headquarters or to agencies outside the military service—organizations such as congressional committees, scientific research bodies, or educational institutions—are examples where the written narrative form of data presentation is quite frequently used.

Although the written-type narrative presentation takes advantage of the additional data we can get through seeing, when used alone, this method too has a big disadvantage. A written narrative report containing many numbers or types of data throughout the report is very difficult to use because comparing the data and arriving at a conclusion may be an involved process. Unless you memorize the facts, you must turn first to one page and then to another until a firm picture of the comparative characteristics of these facts forms in your mind. In this particular instance a table could be included along with the narrative, thus making it possible to see all the significant data in one group and to afford an opportunity to make an analysis.

Oral Presentation. Probably the easiest method of delivering a report is by oral presentation. However, it is the least effective and the one most easily forgotten by the audience. Two advantages of the oral presentation are that it gives the preparer the opportunity to present an enormous amount of detail and it gives him the chance to answer questions on any point of possible misunderstanding. As a result, he can bring out details that might be overlooked in other forms of presentation.

The advantages of the oral presentation are overshadowed by one big drawback; in an oral presentation the speaker has to rely on one of the least effective learning senses of the human body—hearing. According to some authorities, only 13 percent of what we learn is acquired through the sense of hearing. Contrast this with the fact that we learn 75 percent of what we know through the sense of seeing. That is why the oral presentation is considered to be a poor method of presenting statistical data. Considering the amount of work that goes into a statistical study, why waste it by making a report that is only 13 percent effective?

Tabular Presentation. A mass of data sorted, counted, and arranged in a systematic order in the form of a table is called a *tabular presentation*. The particular arrangement of the data into rows and columns depends upon what purpose the table is to serve. All data appearing in a table should be clearly identified, thus eliminating supplementary explanations. It is well to remember that all the user may know is what he sees before him.

There are normally two types of tables used in statistical presentations—the *general-purpose table* and the *special-purpose table*. Each type is particularly useful in certain situations. A general-purpose table is designed to present a broad range of data on a specific subject, whereas a special-purpose table is a method for highlighting a particular part of a study. The special-purpose table, in this respect, furnishes specific information about a specific subject. The data for a special-purpose table may be taken from a general-purpose table or from an original source.

While the general-purpose table may be lengthy (and possibly, cumbersome), the special-purpose table is usually brief and to the point. Special-purpose tables are useful for presenting comparisons. Either type of table may be used in conjunction with a chart or graph to show detail that is lost or difficult to observe on the chart alone. Before we go into a few basic rules and concepts of table construction, let's briefly analyze the last method of data presentation to be discussed here—graphic presentation.

Graphic Presentation. Even though tables normally present data in a well-arranged order, the reader or user must still make his own comparisons many times between one bit of information shown and some other information (shown or not shown). Since it is much easier to make comparisons, evaluations, etc., based upon data clearly shown and graphically illustrated, the graphic presentation, either alone or used in conjunction with tabular presentation, is a very effective means of presenting data.

Graphic presentations may be made in many forms and styles. They may be simple or complex in form, as you determine necessary to accomplish the job for which they are intended. The choice of form or style of presentation could well be your responsibility, since the persons who require the data normally states the information needed and expect you, the graphics specialist, to come up with the type of presentation that will best do the job. In this respect, you not only have an obligation, but also an excellent opportunity to demonstrate your effectiveness in your job. Remember, you share an important part in helping the requester make an effective report.

The type of graphic representation used in data presentations depends upon many factors—such as these factors are listed below:

- General purpose of the graph or chart.
- Occasion for its use.
- Type of reader (audience) to be reached.
- Nature or amount of data to be presented.
- The significant relationships to be obtained from the graphic.

The list as shown above could no doubt be expanded significantly; however, the factors portrayed should give you some idea of what you must consider to select the type of graphic representation that will do the best job.

Exercises (807):

1. Match the items in the left column with the most appropriate descriptive statement in the right column.

A. Hearing.
B. Narrative containing many numbers or types of data.
C. Graphic.
D. Seeing.
E. General-purpose table.
F. Tabular presentation.
G. Special-purpose table.
H. Oral presentation.
I. Written presentation.

__1. User will sit down and study details . . . presentation can shown great amount of detail . . . is submitted to higher headquarters or agencies outside military service
__2. Disadvantageous because arriving at a conclusion may be an involved process.
__3. Easiest method of delivering report . . . poor method of presenting statistical data . . . presenter can give large amount of detail and at same time answer questions that arise . . . depends on sense of hearing.
__4. 13 percent of what we learn.
__5. 75 percent of what we know.
__6. A mass of data sorted, counted, and arranged in systematic order.
__7. Presents a broad range of data on specific subject.
__8. Highlights a specific part of study, usually brief and to the point, and useful for presenting comparisons.
__9. Helps make comparisons, evaluations, etc., easier . . . used alone or in conjunction with tabular presentations . . . a very effective means of data presentation.

2-2. Production of Technical Illustrations

The Air Force requires many illustrations of a technical nature; they usually supplement written technical text material. These illustrations are needed whenever the text alone is difficult to understand. In some instances, illustrations alone are used in lieu of text material.

The two basic types of technical illustrations are *symbolic* and *pictorial*. The pictorial illustration can be either line or halftone, but the symbolic illustration is presented primarily with lines. Though a line illustration can be a detailed pictorial, it is more frequently used as a simple outline drawing that suggests rather than mirrors the illustrated subject. Exploded views are best presented in line form. Diagrams, charts, graphs, or any symbolic representations use line most effectively. When the purpose of an illustration is orientation or identification, the halftone pictorial is generally the preferred type because it shows the object as it actually appears. The halftone is also preferred when it is necessary to use part of the human figure in an operational view.

Although the actual techniques used in technical illustrating do not differ from those of any other type of illustrating, there are a few basic standards that you need to know about drawing mechanical devices and electronic diagrams. Before we go into these fundamental drawing techniques, we discuss the procedures used to produce technical illustrations.

The writer, in several respect, usually is the motivating force behind each technical illustration. It is his responsibility to perceive the need for, conceive, and then discuss with the illustrator (you) those requirements for the proposed illustration. If he conceives poorly his illustration, you will possibly be unable to improve it because most likely you have little or no knowledge of the text. Since you are not set up to research extensively the background of the illustration, you must follow the writer's instructions in preparing the illustration. You are concerned with taking the information supplied to you by the writer and presenting it in the clearest, most interesting manner in accordance with the writer's instructions. This often requires a good deal of coordination between you and the writer.

808. Renumerate the general intermediate steps involved in converting a request into the comprehensive layout; and distinguish the incorrect procedures from those steps that properly belong to rendering.

Illustration Requests. Requests for illustrations may be verbal or written. The method is satisfactory if it supplies you with everything you need to know to do your job. The use of a standard written form is more likely to give you the information you need (verbal instructions sometimes become hazy recollections a day or two later when finally you get time to work on the request). You usually need to know for what publication you are preparing the illustration, who made the request, and what the request is. If you are not sure about any part of the request, talk it over with the writer, find out exactly what he wants, work out an idea that will fill his needs, and after you have the illustration pretty well worked up, check with him to make sure it will do the job before you make the finished illustration. Although this coordination between you and the writer may seem time consuming at the time, it is time well spent. You usually have just time enough to prepare an illustration. That being the case, if you don't do it right the first time, where are you going to find time to do it over?

Layout procedures. The general procedures you use in composing and laying out any illustration are basically similar. Although the specific operations you use in the major steps may vary considerably, the overall procedures are based on the same goal. You may combine the layout and rendering in almost simultaneous operation, or you may overlap or combine many of the steps in either layout or finished work. The steps are there and you consider them, nevertheless. As you become more expert, you may not stop and think out each step, but you still use the basic steps.

Your first step in laying out an illustration is to understand and familiarize yourself with the request for the illustration. You must fully understand both the purpose and the scope of the requested illustration. The writer usually provides you with the necessary reference material (technical orders, blueprints, models, microfilm, sketches, etc.). Your responsibility then is to utilize that reference material and the already-developed information so that you can produce a technically correct illustration. This detailed research may not be a single disconnected step. Throughout the preparation of the layout you may have to dig out new information.

Visualization and rough layout. The procedures or steps involved in visualizing and making a rough sketch of the illustration are difficult to describe since this is a creative or imaginative step. While what to illustrate and what to show may be firmly established, you must decide how it is to be presented, how it should look, and in what medium it is to be done. Based on the illustration request, the information resulting from research and, if possible, the text that the illustration is to support, you develop in your imagination and/or roughly on paper your plan for the illustration. You must visualize the arrangement and position of parts or objects and decide what basic illustration type is needed. During this visualization and rough layout step, you usually establish whether you use perspective, orthographic, or some other type of presentation. You also decide on the angle of view or the position of the parts. You determine whether you use line or halftone, and whether or not color is needed. Your rough layout may be nothing more than a simple sketch of the major shapes and objects involved, or it may be a carefully drawn freehand sketch showing the general appearance of the subject(s), the placement of all the important parts, and special details or considerations.

Comprehensive layout. This procedure contains all the steps that the illustration takes to make a basic, nonreproducible presentation. You not only make a technically accurate drawing but also indicate what is required in rendering or finishing the illustration. To become a technical illustration, the complete comprehensive layout lacks only rendering in a reproducible medium. The steps that you usually use are these:

• Translate the basic composition of the rough layout into an accurate, well-drawn, or projected outline drawing.

• Based upon the data secured from the request and research, show the complete detail in proper position, perspective, and proportion.

• Indicate form, texture, and physical characteristics such as transparency, flexibility, moisture, etc.

• Make indications (notes, colored areas, etc.) of the rendering required to show tones, highlights, shadows, to subordinate by tone or line-weight, or other rendering.

• Make flaps that will be translated into overlays showing callouts, leaderlines, keys, color plates, etc.; then register and affix them to the comprehensive. If the callouts, leaderlines, etc., should be drawn on the art, draw them on the layout rather than on a flap.

• Mark the borders, crop marks, or trim lines on the layout and indicate the reduction required.

You seldom perform in a rigid order these steps and the variations that you make on them. Instead, you generally follow a single continuous process wherein the individual steps are rarely evident.

Review of layout. Before proceeding to the rendering stage, the review of the comprehensive layout is a most practical and helpful procedure. This review may be a formalized inspection procedure by established checkers or a satisfaction review by the writer to insure that the illustration does what he intended it to do. The review should insure that the layout has technical accuracy, presentation effectiveness, proper style, illustration type, and format. The obvious advantage in such a review lies in the fact that changes resulting from this check can be made with relative ease and economy. Errors caught or changes required after the rendering stage is begun may be minimized or avoided altogether by an effective layout review.

Rendering procedure. The variation of rendering techniques and media makes the rendering phase a multistep process that leads to the desired final presentation. While here again you use basic steps common to most techniques and media, each medium technique diverges at one stage or another on its own path.

There are five or six somewhat broad and interlocking steps that can be suggested for rendering in any medium. Here are the steps you usually use in the most logical order to the task at hand.

• Choose the medium and technique based upon publication type, effectiveness in the type of presentation planned, the factors relating to ease of reproduction, and the time required to accomplish the rendering.

• Trace or transfer the comprehensive layout to a surface suitable for rendering in the chosen medium, if you have not already made the layout on such a surface.

• Render the illustration in the medium chosen. Place particular emphasis on obtaining reproducibility, use of correct line weights, and/or tonal values. This step and the substeps within are the basis for converting a good layout into an effective technical illustration.

• Apply pasteups, lettering, indexes, keys, legends, etc., on the artwork.

• Prepare and attach overlays, establish and affix registration points and marks.

• Mount the illustration as needed. Add a cover flap for protection and add the proper reduction and other reproduction instructions along with proper identification and classification.

Keep the quality of the rendering process high. Just as a good layout is vital to a good finished illustration, the best layout will be ineffective unless properly rendered.

Final review of illustration. Your final responsibility is to carefully inspect the finished illustration. As you make this inspection, you are primarily concerned with reproducibility, accuracy, effectiveness of the rendering, and completeness of the artwork. While the technical accuracy of the layout was checked and accepted before rendering began, you may not assume the accuracy of the final artwork on that basis. Because changes and corrections can be very time consuming at this stage, you should make every effort to avoid errors. Make this final check an exhaustive and thorough one, since changes to negatives or photolithographic plates are extremely difficult and expensive.

Exercises (808):

1. What are the general steps in converting the request into a comprehensive layout?

2. Put a checkmark beside the procedures that properly belong to the actual rendering.

a. Mount the illustration (as needed).
b. Review comprehensive layout.
c. Render the illustration in the medium chosen.
d. Indicate form, texture, and physical characteristics.
e. Research for technical information.
f. Establish and affix registration.
g. Visualize.
h. Choose the medium and technique.
i. Apply lettering, indexes, legends, pasteups, etc.

2-3. Types of Technical Illustrations

Just as we stated earlier in this volume, technical illustrations used by the Air Force fall into two basic categories. The pictorial category, which is the largest in scope, covers all illustrating types that represent objects as they actually appear. The symbolic category includes those illustrations that represent objects, quantities, values, and function with lines, symbols, patterns, tones, and color. Many of the illustrations used for Air Force publications combine parts of the pictorial and the symbolic.

809. Given illustrations and drawings (fig. 2-8), name correctly the pictorial views or line types.

Pictorial Illustrations. Pictorial illustrations may be exact representations of natural objects or may be merely images showing only parts of an outline of the actual form of the object. The type discussed here may be more or less exact, depending upon its purpose.

Comprehensive views. Illustrations that fall under the comprehensive type are those that represent a complete object in its normal state. Such illustrations are views of objects or groups of objects that are not altered physically through cutting or modification; whose appearance is not changed by making portions transparent; and who contain no symbolic representation of function, motion, or purpose. The comprehensive pictorial is most commonly used in orientation views, operational views, and part or area identification.

Orientation views must portray an object or area in proper relation to its normal surroundings. This lends itself to the use of halftone rendering, photographs, or carefully

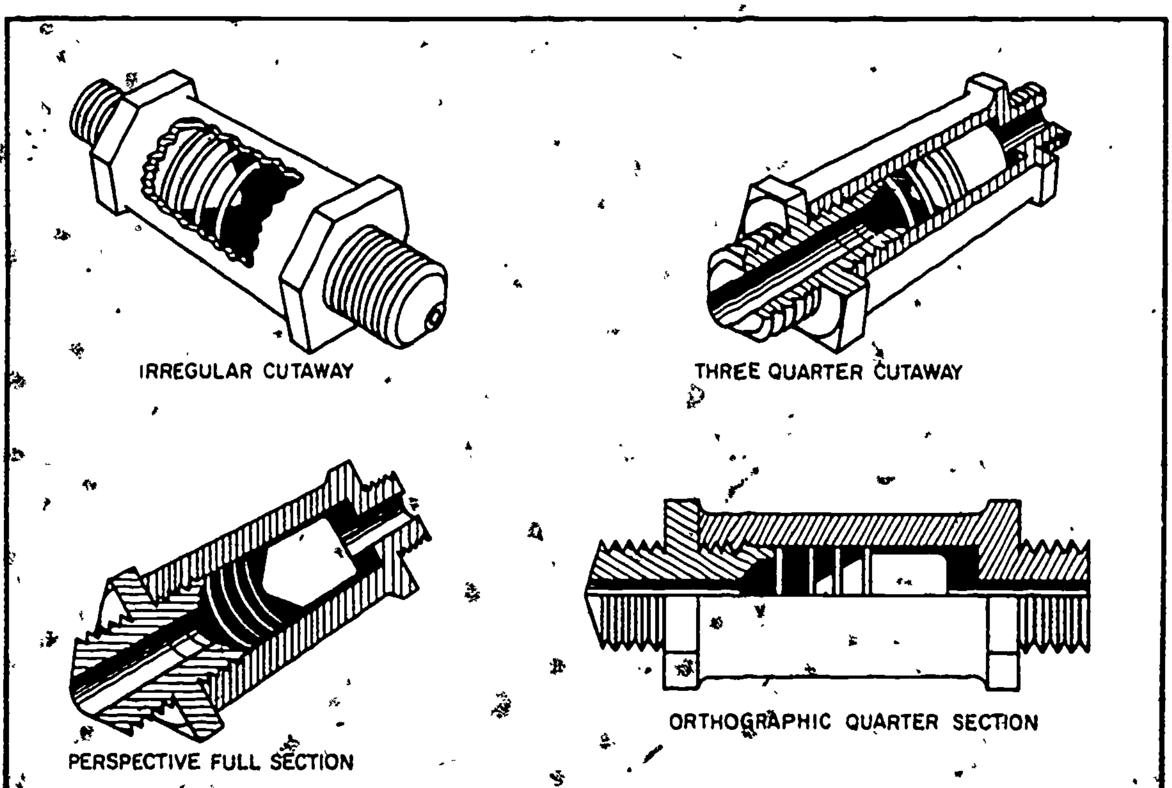


Figure 2-1. Cutaways and sections.

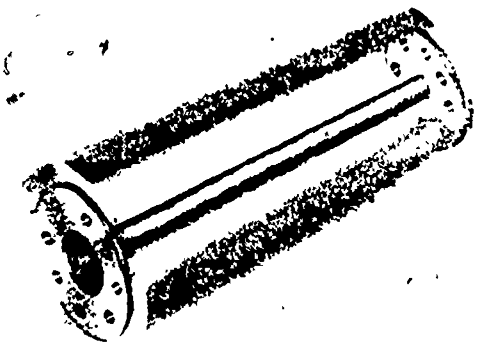


Figure 2-2. Phantom view.

and realistically rendered line work. Such a view must be in perspective since a person sees only in three dimension.

The operational illustration, one that shows an actual operation or mechanical function in progress, has a wider range of realism. An operation that involves part of the human figure is more effective when precise realism is used. Often a retouched photograph is preferred for such an illustration. Simple operations on objects or areas to which the reader is presumed to be well oriented can be simple line drawings of the basic function. One point is most important in all operational views—parts of the body, tools, or surrounding objects should never obscure the object of the operation.

Exploded views. Pictorial illustrations that depict a piece of equipment disassembled, and that show the parts in their correct relationship regarding their assembly, are known as exploded views. These illustrations convey the impression that the parts of the assembly are suspended in the motion of simultaneous disassembly. This type of illustration is used primarily for part identification. Almost as important as its role in part identification is its place in showing assembled and disassembled relationships. Exploded views made as line drawings generally use connecting center lines to help indicate the assembled position. It is difficult to insure that the assembled position is evident in halftone exploded views, especially if none of the exploded components overlay. An assembly stack, as a group of exploded components is called, can effectively show the assembly relationship of the components by allowing portions of each part to overlap slightly. Since exploded views are almost always shown in perspective, this overlapping seldom obscures much of any part.

Cutaway views. Cutaway views are pictorial illustrations that show internal parts of an object through a cut or break in the surface and/or a cut or break in portions of the interior. The cuts or breaks may be irregular holes in one surface, smooth cuts from the surface through the axis or centerline of the objects, or any type of cut or break necessary to show a portion of the interior. Figure 2-1 shows typical cutaways used in technical illustrations. The depth of the cut, whether it is a single clean slice, a wedge-shaped section, or irregular hole depends upon the purpose of the illustration. If the illustration is designed to show a cross section of all the internal parts, a full section, such as the one shown in the lower left portion of figure 2-1, is required. As you can see, the cut is made through the object's center line. If you want an illustration to show the outside of the internal parts, you can use an irregular, three-side cutaway.

Since the cutaway view is a pictorial illustration, your drawing should be realistic and accurate. When the focal point(s) of the illustration is in the interior portions of the object, you should emphasize these parts and subordinate the interior. Many illustrations show both external and internal parts, with both bearing equal importance. In such illustrations, you must still show a definite break in the appearance of the surface and interior parts. In line work you may use different rendering treatment on interior parts and show the cut portions by means of crosshatching. When you make halftone cutaways, you can separate the interior and exterior portions by using contrasting light values.

Phantom views. The illustration type known as the phantom view is used to show portions of the subject as if it were transparent or semitransparent. This type of presentation allows internal parts and mechanisms and underlying surfaces to be

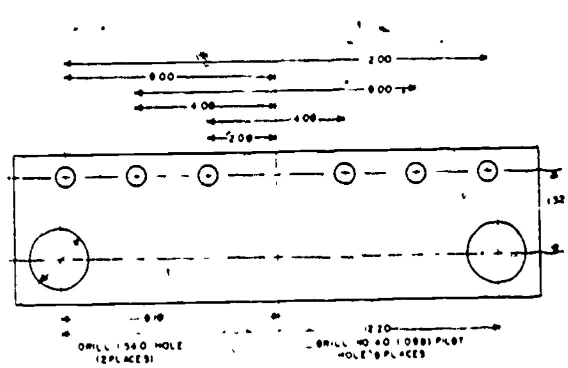


Figure 2-3. Dimension data.

viewed through the outer surface. The phantom view is used also to show structures and objects in reference to the subject of the illustration. Phantom representation is usually used in combination with other types of pictorial illustrations. The phantom view in halftone media usually shows a portion of the object as if it were semitransparent, thereby giving the realistic effect of seeing the phantom portion and still seeing the object beyond. Figure 2-2 shows this effect that enables the viewer to realize the appearance of the whole object and yet see interior details as if the surface were removed.

Orthographic views. Sometimes it is not necessary to show an object in a purely pictorial manner. A two-dimensional representation may be quite satisfactory. In this case, an orthographic view is used. This type of view gives the effect of looking directly at one face of the object. If one view is not enough to give a full description of the object, two or more views are used in the same illustration. This type of illustration is particularly valuable in showing the exact size and shape of an object. Since this type of illustration is used to actually build the object, accurate drawing is essential. Equally important is the relative weight or thickness

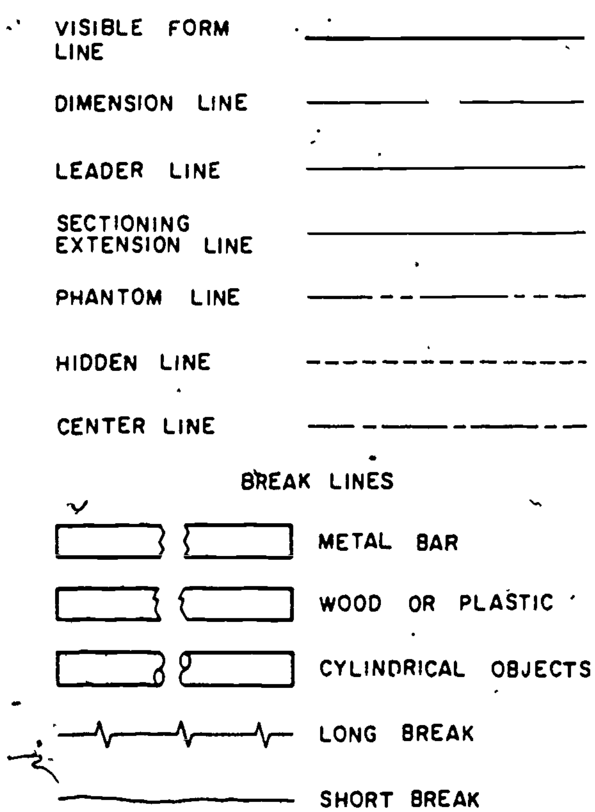


Figure 2-4. Line types.

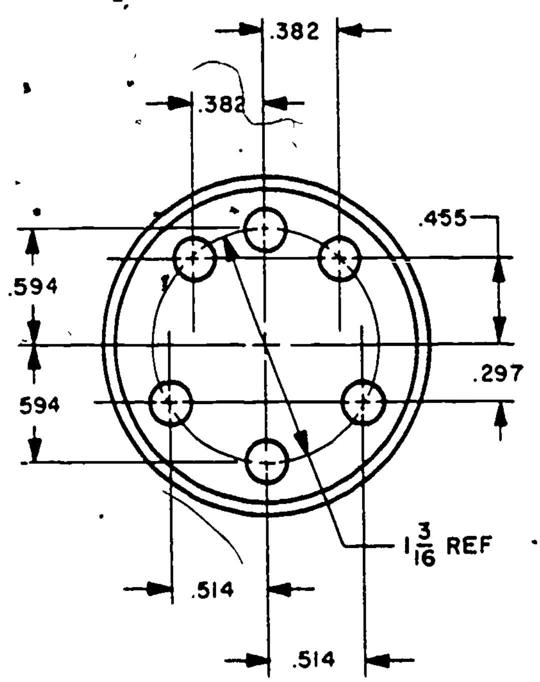


Figure 2-5. Rectangular dimensioning.

of the different lines used to represent the various aspects of the object, such as outlines, centerlines, hidden lines, etc.

If we draw all of the lines of an orthographic view with the same weight or thickness, we would have difficulty distinguishing between lines representing the features of the object and those used for determining size and location of the various features. As shown in figure 2-3, by making the outline and holes in the object portrayed heavier than the other lines, it is easier to make out the shape of the object. (Actually, we could improve this drawing by making these lines even heavier than they are.) In addition, different types of lines are used to help make this distinction. Both the weight and type of line are more or less standard.

Since we usually make our drawings larger than they are reproduced, the actual weight of the lines cannot be prescribed, but the relative weights can be. The following are the characteristics of line types (see fig. 2-4):

- *Visible form line:* An unbroken line of medium to heavy weight used to represent a visible or apparent line on an object.
- *Dimension line:* An unbroken line, except to allow space for the dimension, which is terminated at each end by an arrowhead. Line weight is generally less than that of the visible form line.
- *Leader line:* A line used to indicate the part of an object or piece of equipment to

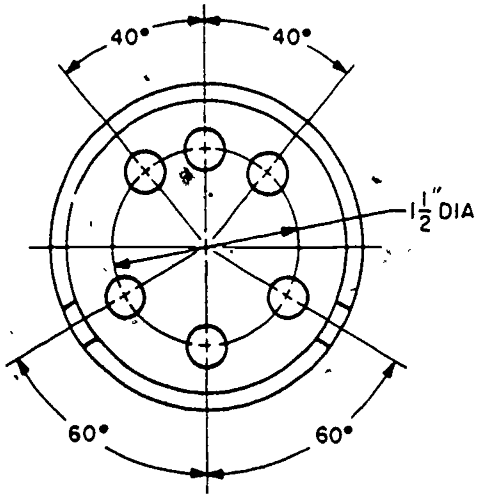


Figure 2-6. Angular dimensioning.

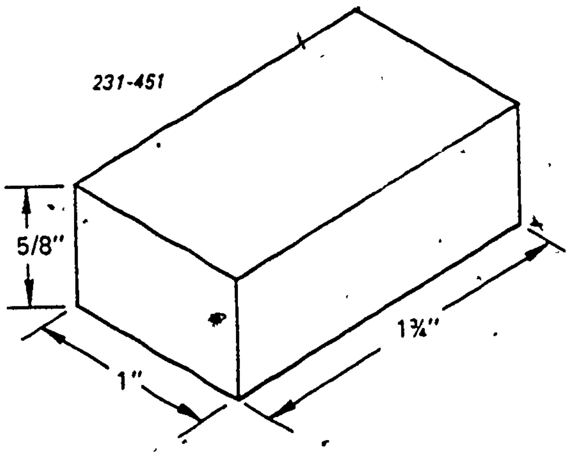


Figure 2-7. Incline dimensioning.

which a number, note, or other callout applies. The leader line is terminated with an arrowhead that appears to touch the outline of the point of reference. Leader lines originate at the beginning or end of an index number, line of lettering, or another type of callout as applicable. Any line that is crossed by a leader line is voided (broken) on one side of the leader line and intersected by the other side of the leader line.

- *Sectioning and extension lines:* Lines that are used to indicate the exposed cut surface of an object in a sectional view are sectioning lines. Extension lines are used to indicate the extent of a dimension but do not touch the outline. Both are thin lines.
- *Phantom line:* A thin weight line of consecutive series of one long and two short dashes. This line indicates the alternate position of a moving part, a part shown for reference, or a part which appears transparent for the purpose of exposing parts beneath.
- *Hidden line:* A line that consists of a series of short, evenly spaced dashes. It is used to show the hidden features of a part. When a hidden line changes its direction, the dashes must touch at the corners on a sharp turn or extend to the tangent points of an arc.
- *Center line:* These lines generally consist of a series of one long line and one short dash. Center lines that are very short may be unbroken. They are used to denote the axis of an object. Center lines are commonly found indicating the assembly axis of an object in an exploded view.
- *Break lines:* These lines indicate an interruption on a surface. Short breaks are shown by an irregular solid freehand line. Long breaks use full ruled lines with zigzagged lines. Shafts, rods, and tubes should show the ends of the break as drawn in figure 2-4.

Dimensioning circular objects may be done by either rectangular dimensioning or by angular dimensioning. Figure 2-5 shows the rectangular method. Horizontal and vertical dimension lines are used to locate the holes of the circular piece on a circular center line. Also shown in figure 2-5 are the two methods of presenting dimensions when the distance between two points is too short to permit us to place the dimension in the open space of a dimension line. One of these methods is shown at the top of the illustration; the other is shown at the right.

The angular method of dimensioning is shown in figure 2-6. Notice that the holes are located by the intersection of radial dimension lines and a circular center line.

When dimensioning is given on a perspective drawing, the dimension lines are drawn parallel to the outline of the object, as shown in figure 2-7. The dimension themselves are usually placed in a horizontal position, as shown.

Exercise (809):

1. Name the views and line types shown in figure 2-8.

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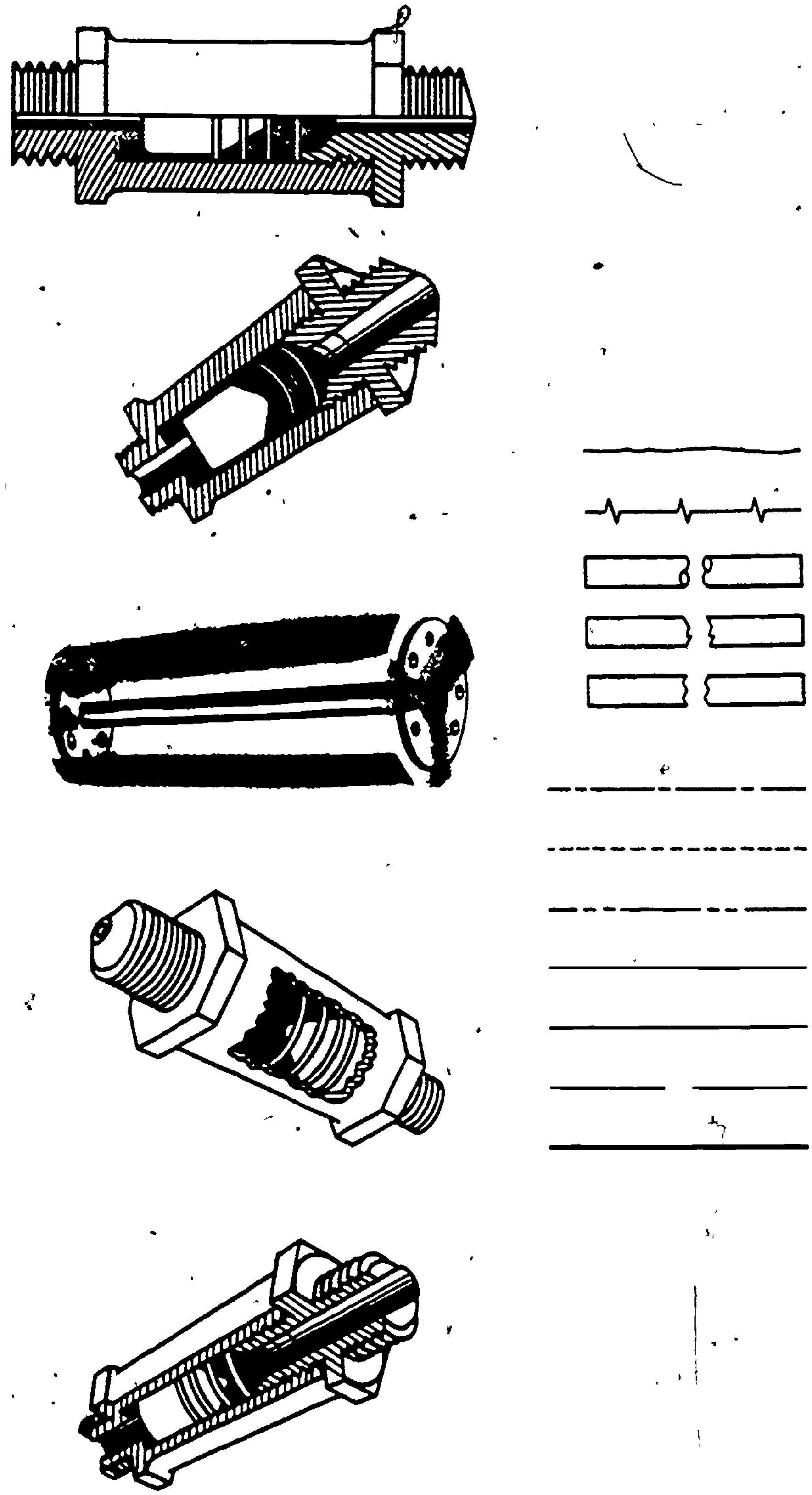


Figure 2-8. Objective 809, exercise 1.

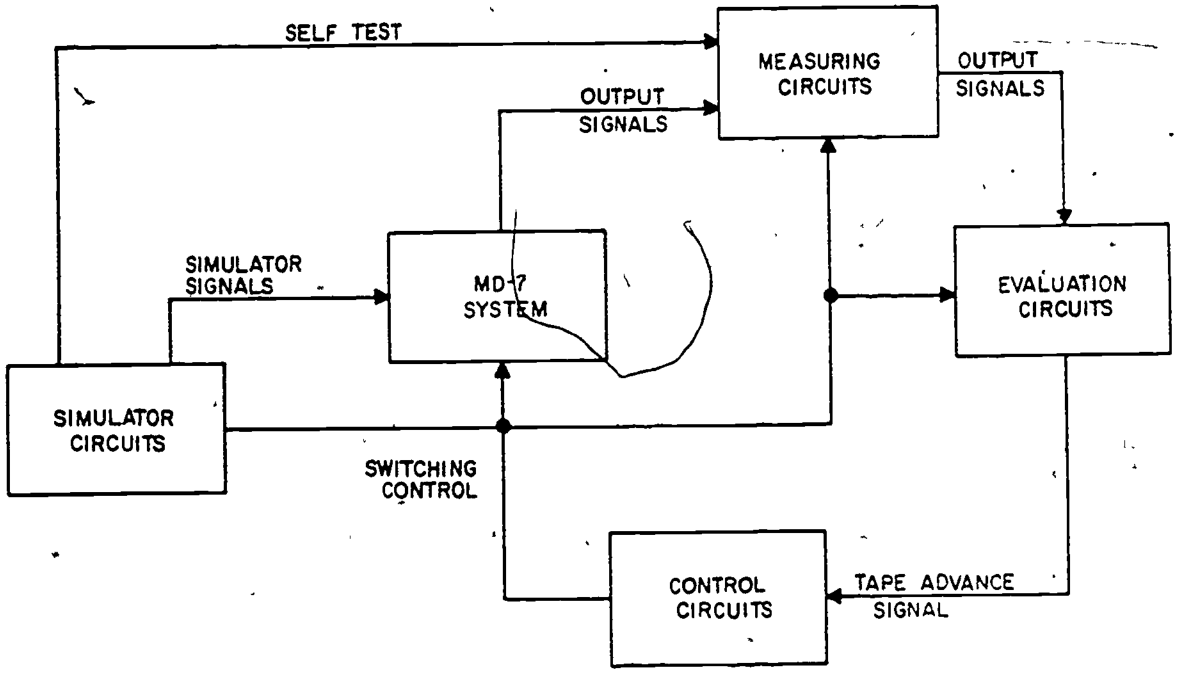


Figure 2-9. Poorly designed block diagram.

810. Differentiate between the three main types of symbolic illustrations; given an illustration showing the types of story lines, name each type (use fig. 2-10).

Symbolic Illustrations. Symbolic illustrations use lines, colors, graphic symbols, and words to represent actual objects, motions, quantities, and values. An illustration that is purely symbolic is not a picture of anything. The symbols used in these illustrations either have an obvious meaning, are following a specification stating the meaning of the symbols, or are explained in a legend that is part of the illustration. The most popular symbolic illustrations are the block diagram, schematic diagram, and wiring diagram.

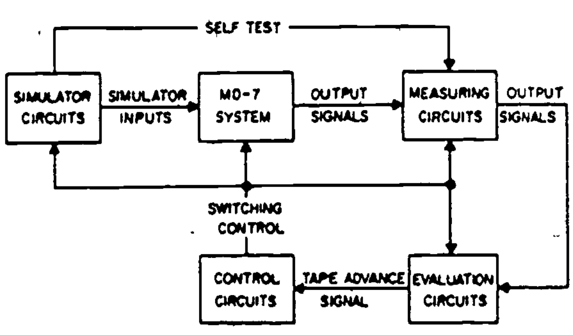


Figure 2-10. Well-designed block diagram.

Block diagrams. This type of diagram is generally used to show a theoretical arrangement of components and symbolic interconnection. They make broad use of word symbols to identify interconnections and items. Block diagrams actually do not show motion or function. They may show the source, route, and destination of a motion, impulse, or flow; but they do not indicate kinetic energy.

The most important consideration in designing a block diagram is organization. Let's use figures 2-9 and 2-10 to compare a poorly organized diagram with a well-organized block diagram. Notice how much improvement is accomplished by merely arranging the blocks in vertical columns and horizontal rows whenever possible. The diagram in figure 2-10 appears more stable and less confusing than the one in figure 2-9. Aligning the paths of data flow also improves the design and makes it much easier to follow. This is quite apparent in the lines representing the switching control data. In figure 2-10, you can tell at a glance that these paths go from the control circuits to four other circuit groups; whereas in figure 2-9, you must follow each branch to tell where it goes. Now, to you this may not seem too important, but it certainly is to the person using the diagram. It may make the difference between a quick, easy understanding or a slow, tedious study of the diagram to obtain the same understanding.

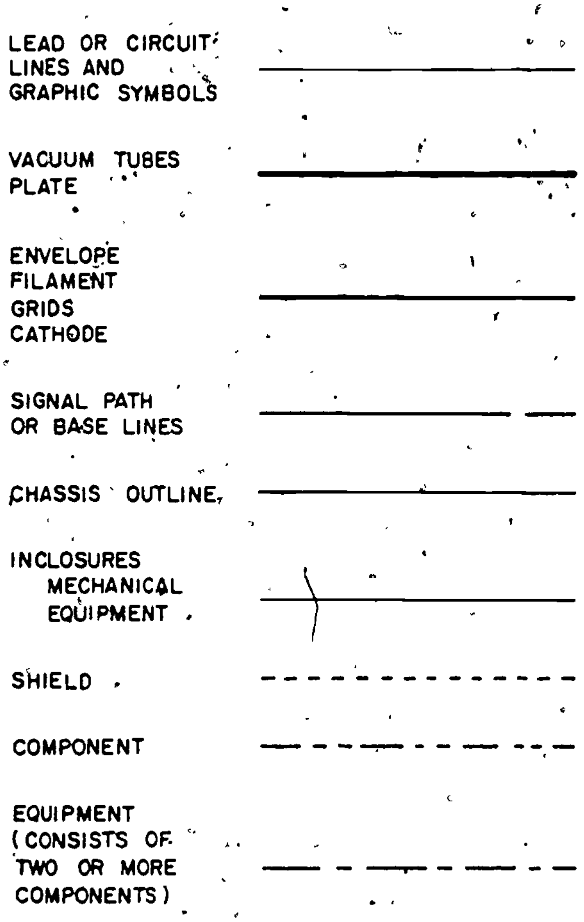


Figure 2-11. Lines and symbols.

Schematic diagrams. This type of diagram uses symbols to show theoretical arrangement and static appearance of functional devices, mechanisms, or systems. Schematics use symbols in the form of color, line, line patterns, tones, and the like to show function or motion. The type of motion or function represented may be any form of mechanical or electrical energy, fluid, or gaseous pressure.

The types of lines (called story lines) used in circuit diagrams have special characteristics. Consistent use of these standardized types and weights aid in making the diagram more effective and easier to use. Figure 2-11 shows the appearance and relative weights of these types, as follows:

- *Lead or circuit lines and graphic symbols:* Lead or circuit lines are thin lines that represent wires and physical connections through which signal flow or electrical impulses are conducted. Graphic symbols, with the exception of vacuum tubes, have the same line weight as circuit lines.

- *Vacuum tube lines:* The plate of a vacuum tube symbol is drawn with a thick line. The envelope, filament, grids, and cathode are drawn with a medium weight line.

- *Signal path and base lines:* Signal path lines are the leads of circuit lines that have been increased in weight to designate the specific path of a certain signal or electrical impulse. Base lines may represent the cording harness within a unit. Base lines are also used to terminate all leads in the airline type of wiring diagram.

- *Chassis outline:* A solid line used in wiring and voltage-resistance diagrams for orientation purposes.

- *Inclosures:* Varying combinations of long and short dashes or solid lines used to represent physical objects in a circuit diagram. Four major subtypes are used:

(1) Mechanical equipment: Medium-weight solid lines used to designate mechanical apparatus that appears within a circuit diagram.

(2) Shield: A series of short dashes designating inclosure of components within an electrical shield.

(3) Component: Lines used to represent a circuit or circuits that may appear on one or more chassis that form a component of an equipment.

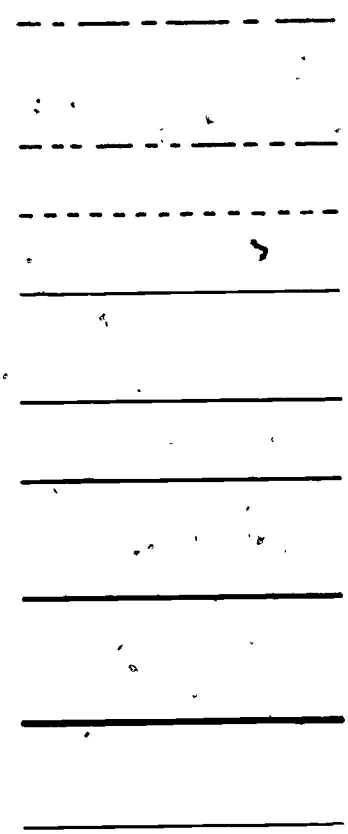


Figure 2-12. Objective 810, exercise 2.

(4) Equipment: Lines used to designate the overall equipment that is comprised usually of two or more major components.

Line types and weights play an important role in effective illustrating. The proper balance of line weights makes the presentation pleasing to the eye; proper relation of line weights to the forms they represent makes the presentation understandable. Consistent use of specific line types for specific representation helps to insure proper interpretation of line drawings.

Exercises (810):

1. Differentiate between the three main types of symbolic illustrations.

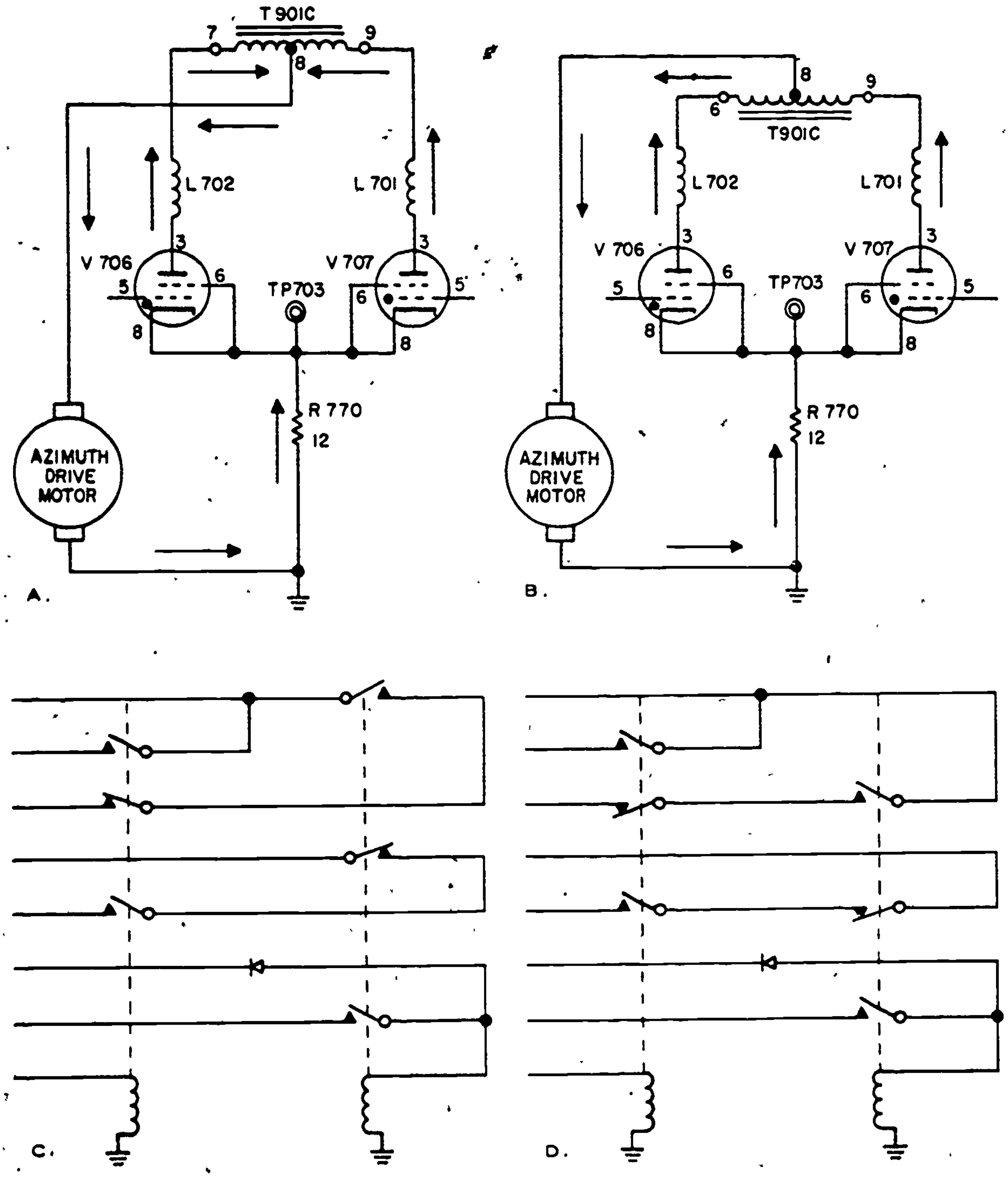


Figure 2-13. Improving circuit layouts.

2. Using figure 2-12, properly name the types of story lines.

811. Given a poorly designed schematic, redesign and draw a better illustration.

As in designing block diagrams, a little careful planning and organizing help produce a schematic diagram that is much more effective. Let's study a few simple examples. First, let's take the two circuits shown in parts A and B of figure 2-13. Notice that by simply inverting one component (T901C), we can draw the circuit without crossing lines. Although this particular change only makes this circuit slightly simplier, you can see that if the diagram were a complex circuit many of these slight changes would make quite a difference in the simplicity and effectiveness of the overall diagram.

Parts C and D of figure 2-18 also show what a little more planning can do to improve the effectiveness of a schematic diagram. The components in these circuits represent contacts or relays. The dashed line of each relay indicates that all of the contacts move together when the relay is energized. The open contacts close and the closed contacts open. In the circuit shown in part C of figure 2-13, the movable contact must move down to close the open contacts or up to open the closed contacts. While this opposite movement may seem like a minor point, it still adds confusion to the operation and makes it just that much more difficult for the person who is using the diagram to understand it.

Let's see how the overall design of the circuit shown in part C of figure 2-13 can be improved by a few simple changes. Notice in part D of figure 2-13 that the closed contact of the relay shown on the left has been inverted. Now, when the relay energizes, all of the movable contacts move in the same direction. As a result, the operation is much easier to understand. By simply moving the contacts of the relay shown on the right to a slightly different position in the circuits, we

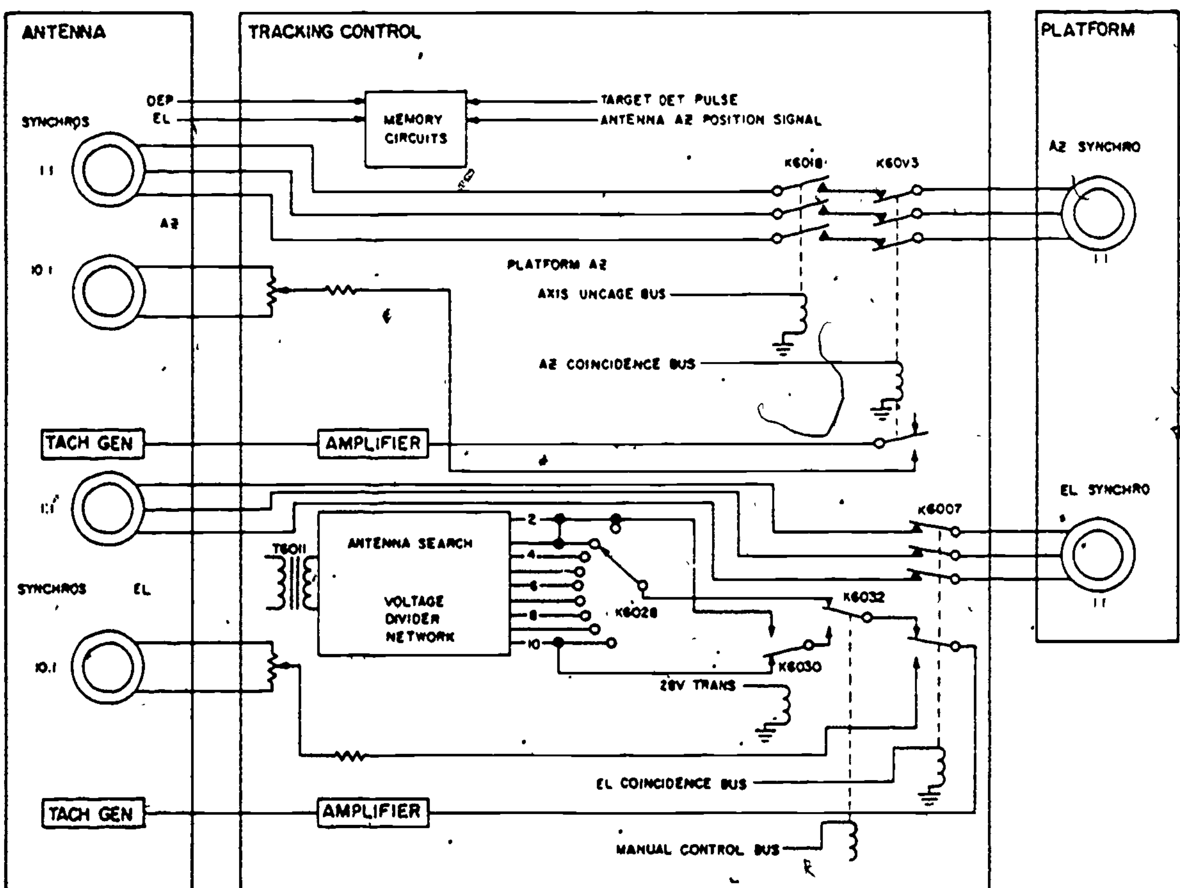


Figure 2-14. Poor layout of circuit diagram.

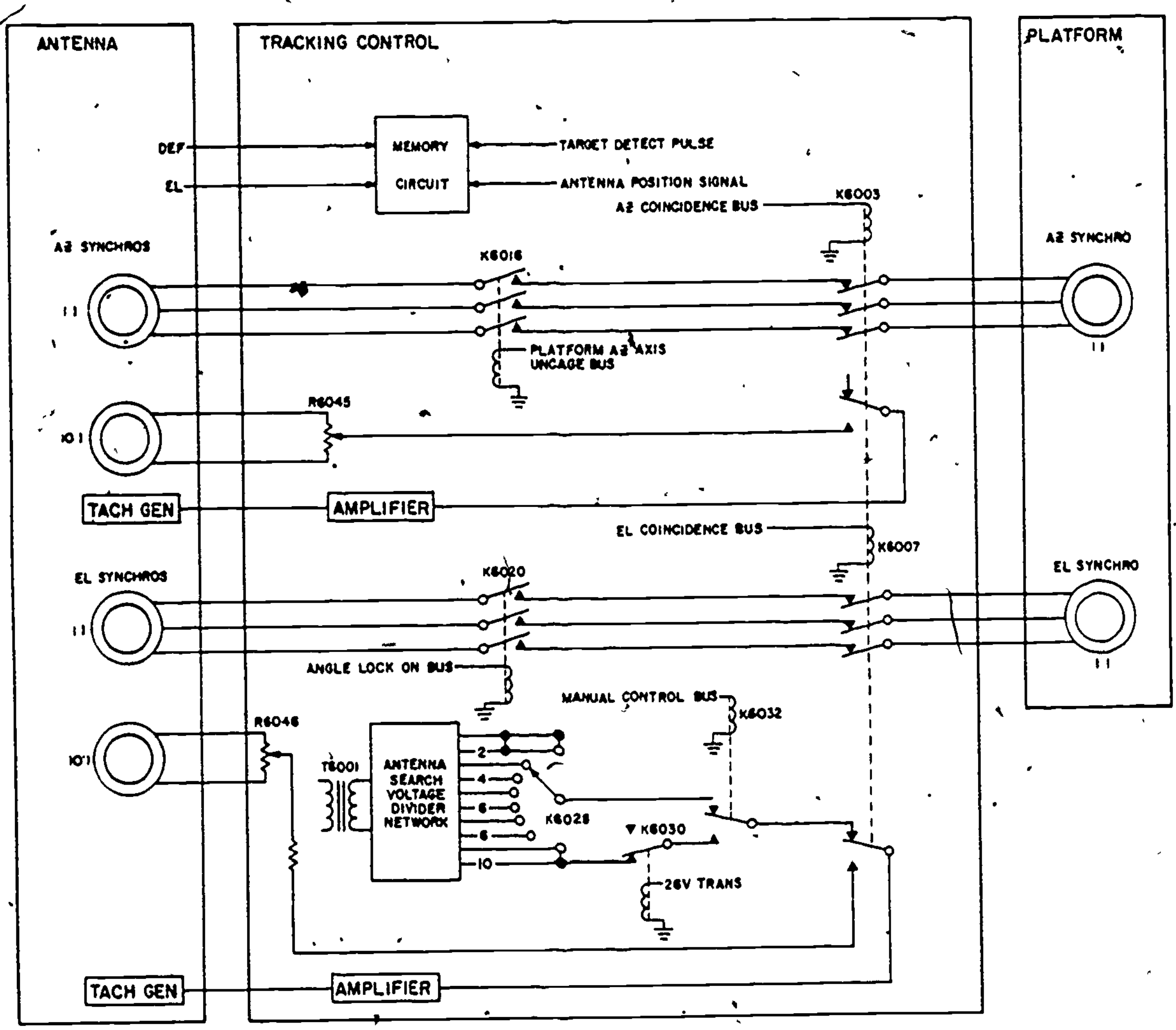


Figure 2-15. Improved layout of circuit diagram.

get the same result. In addition, the contacts now all pivot from the same side, which makes the circuit much easier to understand.

Let's make one more comparison between poorly designed and well-designed diagrams by using figures 2-14 and 2-15. Let's pick out the most distracting characteristics of the circuit shown in figure 2-13 and show how they have been improved in figure 2-15.

The most evident defect of the diagram shown in figure 2-14 is the crowding of circuits in the center of the lower portion of the figure, while other areas are almost completely bare. Notice in figure 2-15 that the various circuits are so spaced that each is clearly shown as a separate unit. It is very difficult to distinguish one circuit from another in the lower half of figure 2-15.

Another characteristic of the poorly designed diagram is the excessive use of dog legs (zigzag lines). These are extremely disturbing to the person using the diagram. For example, let's take the three circuits from the upper synchro on the left ~~to the~~ upper synchro on the right. Although these circuits make only a small zigzag near the left side of the diagram, the user must make three separate eye movements to follow the circuits across the diagram. In figure 2-15, he needs only one sweeping eye movement to follow the circuits.

The crossed lines and dog legs were also eliminated in the circuit directly below. Notice how much simplier the circuit appears in figure 2-15.

The lower three-wire synchro circuit is a classic example of poor designing. It would almost take an electronic magician to trace this circuit in figure 2-14. When you see how simple it appears in figure 2-14, you might wonder what the designer of the circuit in figure 2-14 was thinking. Obviously he wasn't.

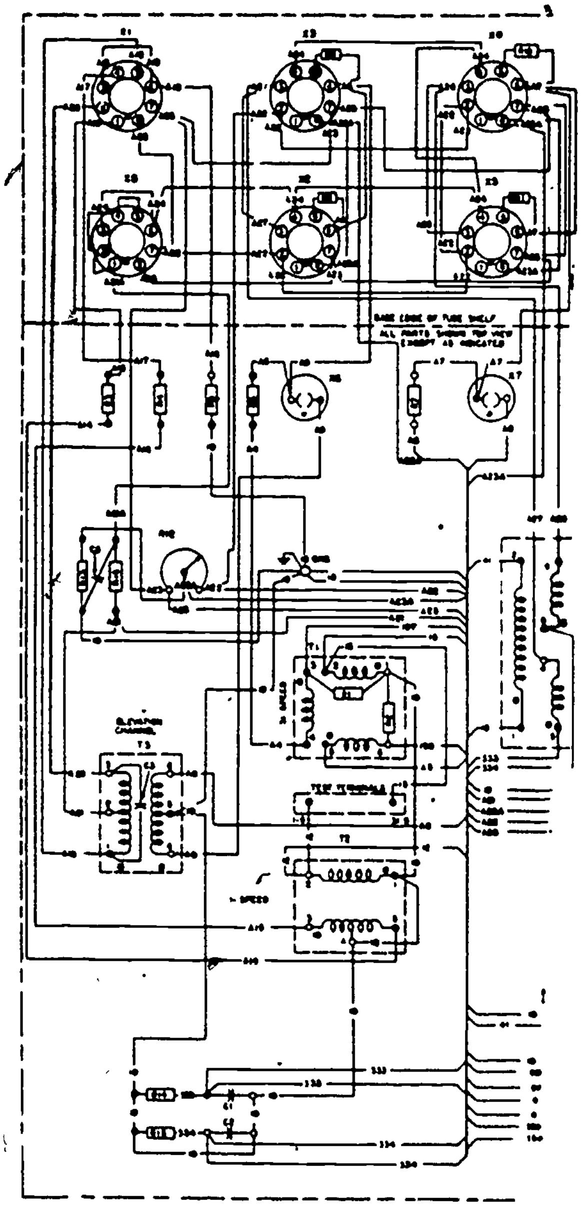


Figure 2-16. Wiring diagram.

But don't let this happen to you. It is just as easy, or perhaps even easier, to do the job right as it is to do a sloppy one.

Even though the diagram in figure 2-15 is so much better than the one in figure 2-14, there is still room for improvement. Can you see where? You probably noticed that the circuit at the bottom is quite close to the outline of the component and since there is plenty of room at the top, the whole diagram could easily have been shifted up to achieve better distribution and balance. In fact, if the whole lower portion of the diagram were completely flipped over so that the lower tach generator circuit were directly under the top tach generator circuit and the three-wire synchro circuit were at the bottom, the whole group of circuits could be drawn much simplier and without any dog legs.

Wiring diagrams. This type of symbolic illustration shows only theoretical locations and connections. Signal or impulse flow is not directly indicated on the diagram. While not

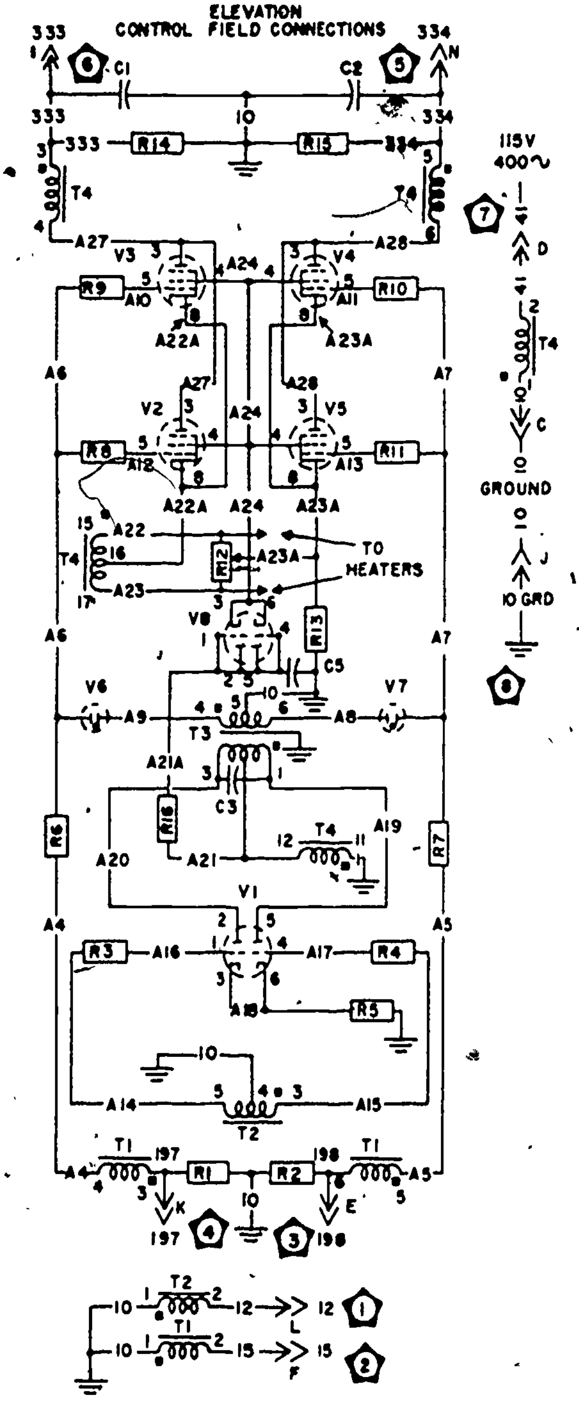


Figure 2-17. Schematic diagram.

directly shown, the impulse path can be traced by an experienced man.

A typical wiring diagram of a system component is shown in figure 2-16. Notice that the primary purpose of this diagram is to show the wiring connections between the various component items. In this particular diagram the locations of the parts are also shown. You can see the difference between a wiring diagram and a schematic by comparing the wiring diagram of figure 2-16, with the schematic of the same piece of equipment shown in figure 2-17. Notice that the wiring diagram is primarily concerned with showing the interconnection of the various components with the lines representing the path that the actual wires take in the actual system component. In the schematic the principal concern is with showing signal flow. Therefore, the whole diagram is designed for that purpose.

Exercise (811):

1. Redesign figure 2-18 to improve its quality.

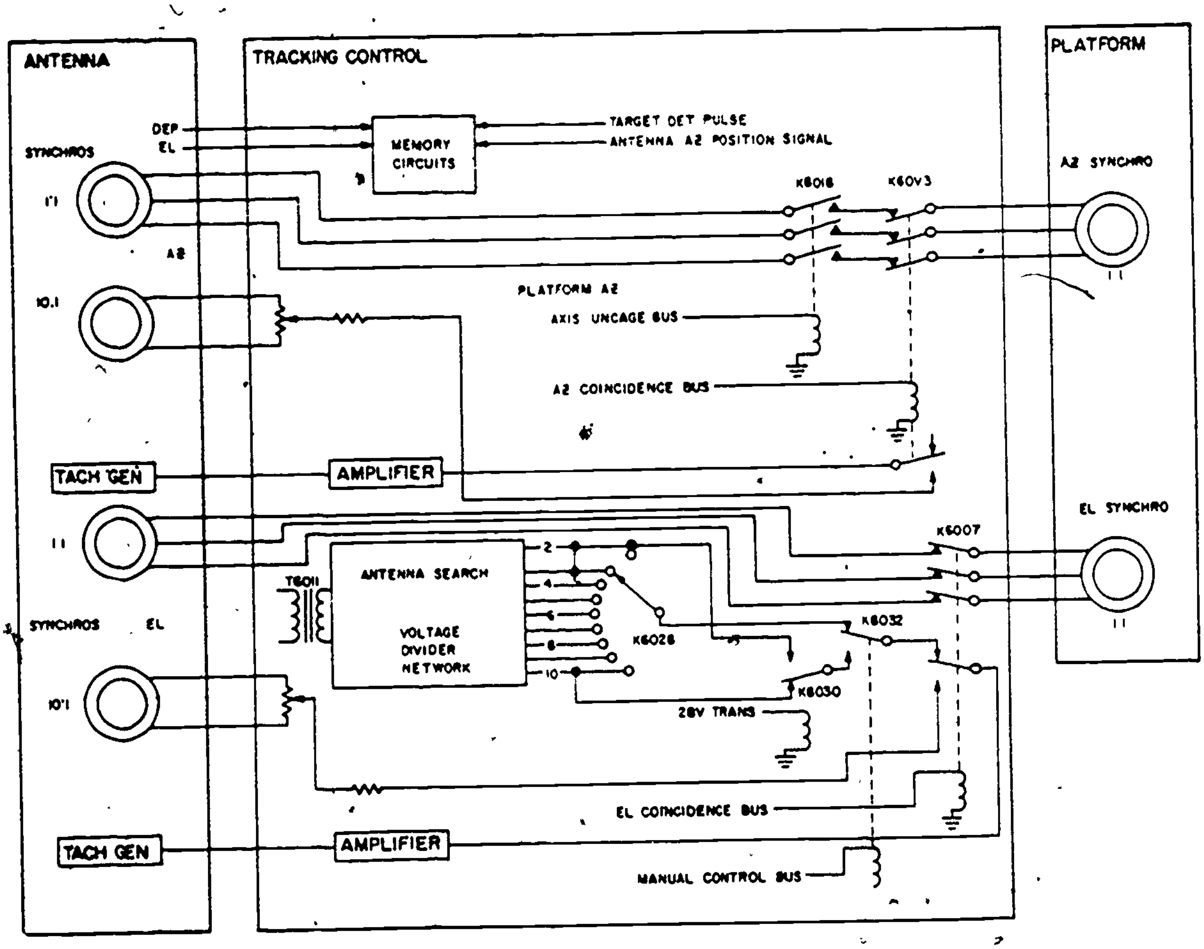


Figure 2-18. Objective 811, exercise 1.

2-4. Principles of Illustrating for Television

Television is a medium appealing to two of the human senses—sight and hearing. Therefore, this audiovisual medium is ideally suited for instruction by showing while telling. Of course, the success of this medium as a teaching device depends greatly on the preparation that is made before the TV camera starts shooting. One of the area of preparation is graphic aids—the visual aids that form a large part of the props necessary to put on a program. Here is where you, as an illustrator, get into the act.

Graphic materials are used effectively in the presentation of concrete and abstract ideas in educational and informational television. Graphics include all the visual materials used to reinforce, speed, and clarify the communication of ideas, concepts, and theories.

Visual materials for television should be simple and direct so that new ideas to be presented are not lost in unnecessary detail. This last factor, closely related to legibility, is of prime importance since, without legibility, communication is lost.

In many respects, visual aids prepared for use on television require different standards of preparation than do visual aids for use in the conventional briefing room, classroom, or auditorium. Therefore, a knowledge and an appreciation of the peculiarities of television visual aids are essential for an illustrator and must be included in your training.

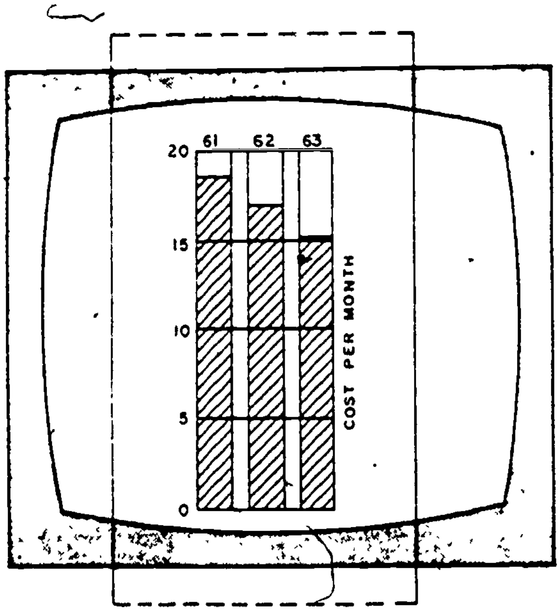
Since the standards of preparing artwork used to produce slides and transparencies for overhead projection are similar to those for television artwork, we have included the preparation of slides and transparencies in this chapter.

Before constructing any graphic aid, you must consider certain factors that will influence your design of the aid. Regardless of the technical excellence or informational value of the aid, if you do not adhere to certain standards of design, the aid may not be of any value, or at least its potential value may be greatly limited. This is due to the peculiarities of presentation by television. The factors you must consider are:

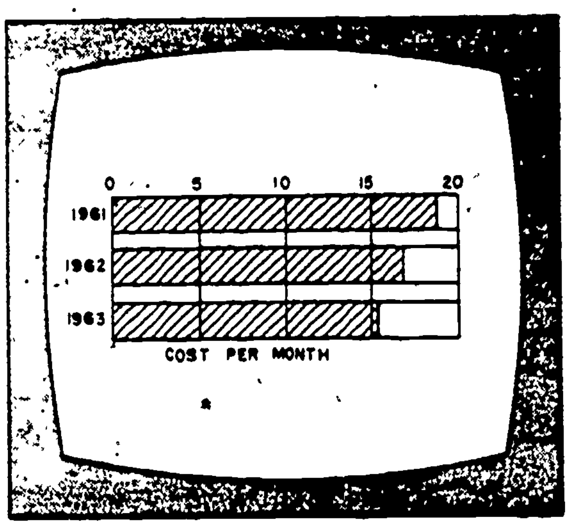
- Aspect ratio.
- Edge loss and safety field.
- Lettering size and styles.
- Size of graphic aids.
- The method of checking for clarity.
- Use of black and white.
- Use of grays.
- Use of color.

812. Solve two given problems, one using the aspect ratio, the other using the one-sixth rule.

Aspect Ratio. Artwork for television must



A. WRONG ASPECT RATIO



B. CORRECTED ASPECT RATIO

Figure 2-19. Aspect ratio.

conform to the shape of the screen area of the television picture tube. The relationship of height to width, which approximates the proportion of the TV monitor (receiver), is called the aspect ratio. This ratio is 3 by 4 (3 units high by 4 units wide) and includes all components of a TV visual presentation, such as the graphic, the camera viewfinder, and all monitors. All visuals constructed for TV should have this aspect ratio to insure that all of the necessary visual material is seen on the monitor. Part A of figure 2-19 shows a visual aid with the wrong aspect ratio. Notice that in framing the aid from top to bottom, considerable blank space is left on each side. Framing the aid from side to side cuts off material at the top and bottom. Part B of figure 2-19 shows the same aid revised to the proper 3 by 4 aspect ratio. Notice that now the entire aid is on the monitor screen with no blank spaces on any of the sides and that no material is cut off.

The 3 by 4 aspect ratio has a number of merits. Probably the most important reason for using this ratio is that it is the same as employed by the motion picture industry. Thus, a televised motion picture is usually not appreciably cropped (cut off at the top, bottom, or sides). Many years ago this aspect ratio was determined to be artistically sound since it approximates the dimensions of the normal range of vision, our horizontal range of vision being about one-third greater than our vertical range.

In view of the fact that still photographs are often printed in a vertical format, one might think that much will be lost when such photographs are confined to the horizontal. There is, however, very little loss in compositional effects. In general, there is usually more interest in the horizontal direction and most motion is horizontal rather than vertical. Any graphic artwork is designed to fit within this 3 by 4 shape for maximum utilization of the picture area and correct framing by the cameraman.

Edge loss and safety field. A problem closely related to the TV aspect ratio is the edge loss and safety field. The television system tends to crop the edges of all picture material. With slides, film, and artwork prepared for opaque projection, the first cropping is done by the projector. The film pickup camera and the studio camera crop more area, and finally the receiver or monitor itself make an additional cropping. Artwork material must be prepared to keep the important subject matter within a safety field so that all of the information will appear on

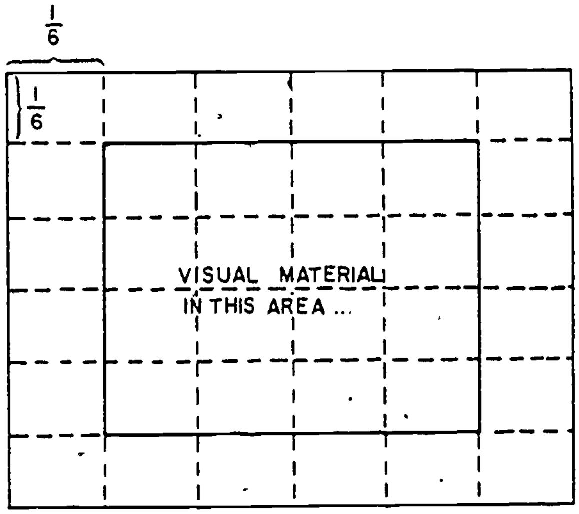


Figure 2-20. Safety field (one-sixth rule).

the receiver. Artwork prepared for studio coverage is not quite so critical since the cameraman can allow for an additional safety margin.

The one-sixth rule for determining the safe area is useful and easy to understand. As shown in figure 2-20, you divide the camera field, which is the total area of the picture, into six equal subdivisions both vertically and horizontally. The area covered by the 16 central rectangles is the safe area. A mask, corresponding to the overall size of the visual with the safe area cut out, is useful in making visual aids. You just place the mask, which can be made from paper or cardboard, on the card you plan to use to make your visual and print or draw within the cutout area.

As you can see in figure 2-20, the safety margin is quite large. This safety margin is particularly important when the camera is equipped with an image orthicon tube. The image orthicon is equipped with a safety device called an electronic orbiter that causes the picture to slowly and imperceptibly rotate. The rotation prevents the semipermanent impression of the picture on the tube, especially when bright subjects are encountered. While the rotation (1 to 2 rotations per minute) is imperceptible to the average viewer, it actually shifts the framing of a graphic when the graphic is on camera for 20 or 30 seconds. The result, in the case of an inadequate margin, is that the shot could be initially framed when it first appears and be misframed after the orbiter shifts it.

Commercial television illustrators have to make an additional allowance for monitor misalignment as to size, centering, focus, etc.

In commercial television, the monitor (that is, the viewing equipment) is not under the control of station personnel since it belongs to the viewer. However, in most noncommercial TV stations the monitor is owned and controlled by the same personnel that are producing the television production. Under these circumstances, there is no reason why test patterns cannot be periodically and frequently transmitted, monitors aligned, and graphics checked out for adequacy. Thus, an extra amount of safety field need not be provided, as in commercial TV.

It is desirable that some framing arrangement be worked out between the graphic section, the cameraman, and the producers. Sometimes a graphic is confined and entirely visible within the transmitted picture. On other occasions, it is desirable to have the graphic bleed off and out of the picture area. Not necessarily knowing the intent of the particular graphic, the cameraman and often the director are not sure whether the entire graphic display is displayed to the viewer or whether it is intended that part of the graphic be cropped by camera framing. For this reason, a format can be established by means of sample masks to be placed over graphics, whereby the mask indicates (1) the total area to be seen and (2) the important content area. This mask is helpful to both the cameraman and to you. The cameraman sets up this mask on a stand and frames his camera so that he sees the entire display area. From this point on, if he does not move his camera either toward or away from the graphic, he will have the correct framing through an entire series of graphics. Since you prepare your graphics to the same mask you can rely upon the cameraman showing the entire display area as indicated on the mask. It is common for the display area to represent the total scan of the monitor, while the graphic content area is confined to the areas of good resolution. In other words, the difference between the outer limits of the mask and the inner area of the mask excludes that area of poor edge and corner resolution. When you use this system, there is no misunderstanding between the cameraman and the illustrator as to how much of the picture to show, and there is a virtual guarantee that important and crucial graphic information will not fall into the areas of poor pictorial resolution.

Exercises (812):

1. What is the size of a full page (regular) illustration if the 3 to 4 ratio is maintained?

2. If the illustrating surface is 9 by 13 inches, using the one-sixth rule, what is the size of the drawing?

813. State the criterion that determines the adequacy of lettering size and styles, and apply the formula for selecting maximum letter height.

Lettering Size and Styles. Lettering size, styles, and general graphic techniques are best developed as a result of experience in your own installation. The criterion is: "if the graphic can be seen on the monitor with sufficient clarity to illustrate its point, your sizes and styles are appropriate." If the graphic is not clear, the letter style, size, and/or the medium must be changed. No hard and fast rules can be stated. Each graphic organization will have to work out its own standards based upon the pictorial resolution ability of its transmission system, the basic artwork size chosen as a standard, etc. From these considerations, certain letter sizes and style will develop.

It is important that minimum letter sizes be used only when necessary in order to portray a maximum of information in a limited space. The minimum should be just that—minimum. Do not use the minimum as a standard. Whenever possible, use a larger and more clearly perceivable size of letter.

For maximum visibility, lettering for television should be simple in style. The individual type characters should be consistent and clear. Complicated letter styles such as ornate and Old English should not be used because they are difficult to read at a glance. Extremely thin letters should not be used because of the possibility of losing portions of the lettering in transmission.

A rule to determine letter height has been established based upon legibility at 20 feet from a 21-inch receiver. The rule for maximum visibility at this distance is this: "The height of the lettering should be a minimum of 1/15 of the graphic height." For example, a graphic having a vertical copy layout area of 15 inches should have letters at

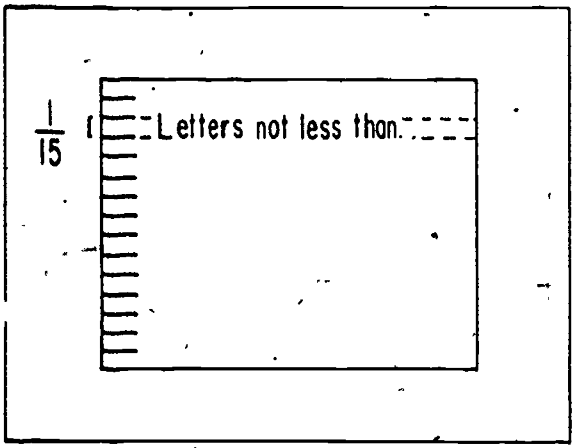


Figure 2-21. Minimum lettering height.

least 1 inch high. This minimum height rule is illustrated in figure 2-21.

Additional rules of good spacing must also be considered in television graphics. For television, the distance between individual letters should never be less than the thickness of the letter itself. Television scanning tends to cause the lettering to appear to be closer together; thus wider-than-usual spacing is necessary.

The thickness of a line, or line weight, is another important factor to consider when designing TV graphics. Based upon the above legibility standard, line weight should be a minimum of 1/75 the width of the copy layout area. The nature of the illustration and the importance of each line of copy govern the weight of the lines.

Size of Graphic Aids. We previously discussed the aspect ratio of graphic aids. However, no mention was made of the actual size. Considering an aspect ratio of 3 to 4, the graphic can be made in any size as long as this ratio is maintained. Thus, the graphic can be 3 by 4 inches, or such dimension as 30 by 40 inches, or even 9 by 12 feet. Notice that the ratio in all of the above sizes is the same. Even though the ratio is correct, you must use an appropriate size. Your problem is to provide a graphic in the 3 by 4 ratio that when displayed at monitor size (whether this involves enlargement or reduction) is clearly visible to the viewer at the mean viewing distance.

Most TV installations select the actual size of their graphics based on such considerations as the standard stock size of illustration board, the need to file and to store, the size of the storage area, and complexity of the graphic. Naturally, you want to use a size that is comfortable to work with. Let's see why these other considerations are important.

Television gray board comes in the standard size of 30 by 40 inches. This is in our 3 by 4 ratio. Therefore, the board can be used as it is, if the illustration requires this much material and you have adequate storage room. If you use this large size, do not be misled into thinking your work is more legible than it actually is. A 30- by 40-inch illustration that is perfectly clear to you when you hold it at arm length will not necessarily be as clear to the TV viewer when he is looking at a 21-inch monitor at a mean viewing distance of 9 feet.

Suppose we cut the 30- by 40-inch sheet into smaller pieces for purposes of economy. By cutting the stock sheet 10 times on each edge, we obtain 100 pieces which are 3 by 4 inches, still in a 3 by 4 ratio. Obviously, this is impractical for illustrating, since much of your work would have to be almost microscopic. When the small graphic is enlarged enough to fill a TV screen, minor mistakes, bobbles, and trembles are also enlarged and are quite disconcerting to the viewer. The appropriate size, then, lies somewhere in between our two extremes.

A good comfortable size is obtained by cutting the stock material into 9 pieces, each approximately 10 by 13⅓ inches. This size is a convenient one for you to work on; it is a convenient size for storing in standard file cabinets, and it is a convenient size for handling by personnel during the presentation of the TV production. Remember, however, that this is the size of the card stock and that the viewing area is somewhat smaller when the one-sixth rule is applied. When possible, all graphics should be made in a single size since camera framing and focusing need to be done only once for an entire series of graphics.

Graphic art techniques, as used in television illustration, are limited by television transmission and visibility. In general, we can say that poster techniques are best suited for television illustrations. As with poster design, details and tones are so accomplished as to be understandable at a distance. Simplification of line, tone, and lettering is essential for maximum legibility.

Method of checking clarity. Now, let's find out how we can tell if your artwork has adequate clarity from the standpoint of the TV viewer. Assume that the size of the basic graphic is 10 by 13⅓ inches. You are working on this graphic with your eyes about 20 inches from your work. However, this distance tells you little about how the graphic looks from the distance at which a TV viewer sees it. At what distance then should you examine your work to get the same impression as the viewer? The graphic is 10 inches high but after taking off a 1½-inch border at the top and at the bottom, the space left for the actual artwork is 7 inches. If you assume that the monitor screen is 14 inches high and that it will be viewed at a mean distance of 9 feet, you can find the distance from which you must look at your illustration by the following calculations. Since 7 inches (the height of your illustration) is 1/2 of 14 inches (the height of the TV screen), you must view your illustration from a distance of 1/2 the mean viewing distance. Therefore, you should view your work from a distance of 1/2 of 9 feet which is 4½ feet.

The principle discussed in the previous paragraph pertains to all graphics and monitors; however, our example pertains only to the specific sizes and dimentions mentioned. It is important that you remember at all times that your working distance is not the proper viewing distance. No matter what size stock material you use, no matter what monitor size is used, you should continually check your work by standing back at the viewers relative viewpoint. In this way you can make sure that the information imparted by the graphic will be clearly visible.

Exercises (813):

1. If a TV graphic is 10 inches high and 13⅓ inches wide, what is the smallest possible height that lettering can be? How thin can the line weight of the letters be?

2. If you have a strip of prepared lettering that is 1/3 inch high that you want to sue in a graphic illustration for TV, what is the maximum height that you can draw the illustration?

3. State the general criterion for testing style and size of letters.

814. Specify the advantages and disadvantages of using black and white as compared to color; explain the general rule you apply to decide whether or not the illustration has adequate resolution; and explain restrictions concerning gray tones.

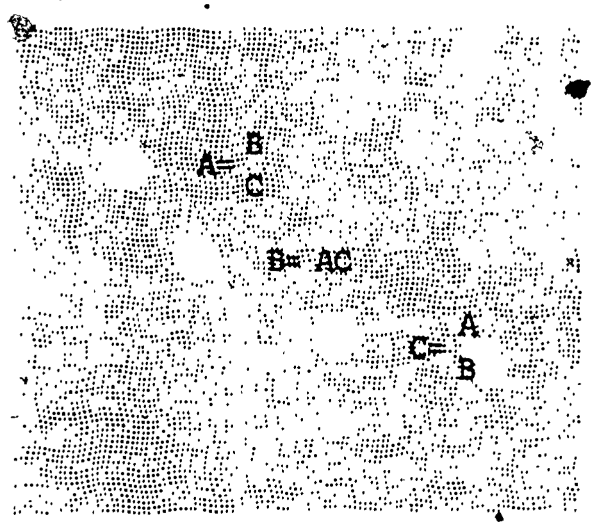


Figure 2-22. Graphic with three shades.

Use of Black and White. At first thought, it would seem that the use of black and white would be very appropriate for many graphics. For example, the presentation of a mathematical formula in black and white seems to be a good idea since an extreme contrast range is desirable in most illustrative work. This is not so when presented on TV. Too much contrast can cause halo and horizontal streaking when the two extremes are used adjacent to each other. Rather than black letters on a white background, a graphic having three tones such as shown in figure 2-22 would be preferable.

In general, the use of black and white in each illustration is essential. Although using black and white in every illustration may not always be appropriate from your view point as an illustrator, the video engineer finds it most desirable. The video engineer sets his video levels on a black-white basis. He must have black and white present in the illustration in order to establish his basic video setup. Generally speaking, the difference in black and white to the video engineer is a 1-volt peak-to-peak signal. He does not consider the intermediate grays—he sets the black and white levels correctly, and the grays automatically fall into their proper place. If he is provided with an illustration that lacks either black or white or both, he has no basis for adequate video setup, and the result will likely be a poor or marginal transmission. There are cases where the deliberate inclusion of black and white, even though inappropriate to the pictorial content of the graphic, is a strained but necessary technique for the illustrator. However, this is one of the ground rules of television with which the TV illustrator must learn to live.

Use of grays. Presuming that the television system is properly adjusted, a maximum of about eight distinct shades of gray plus black and white are discernible in black and white TV reproduction. Because of transmission restrictions, you must be careful how you use your gray tones. If you place two only slightly different gray tones side by side, they will probably look alike when they are reproduced on the screen. You should compensate for this by spreading your grays when making tonal illustrations. Graphics should be restricted to about three or four shades of gray (if this many are necessary) plus black and white. If you limit yourself to three shades of gray, you can use every other shade in the gray scale.

Using color. You can use color in preparing graphics for black and white TV but you must use them with caution and only in terms of their gray scale equivalents. Two colors in a graphic show considerable contrast to the eye, but on television they may actually appear as identical shades of gray. A similar situation could develop on live TV where red chalk is used on a blackboard. If you are in doubt about any color contrast, check the colors out on camera before you go into production. Do not be misled by thinking that color somehow contributes to the graphic. It may not do so.

If you must use colors for some reason, prepare a gray response chart such as the one we discussed in the chapter on color. Relate the various colors to their gray scale values. Place the various colors and hues in columns or rows corresponding to the shade of gray in which the hue will appear on TV. Not all hues will have the same exact gray value as the steps in the gray scale, but you can construct the columns to accommodate slightly lighter and darker readings. To construct a gray response chart, first lay out the gray scale and then make on-camera comparisons of the samples of color. Remember that the gray

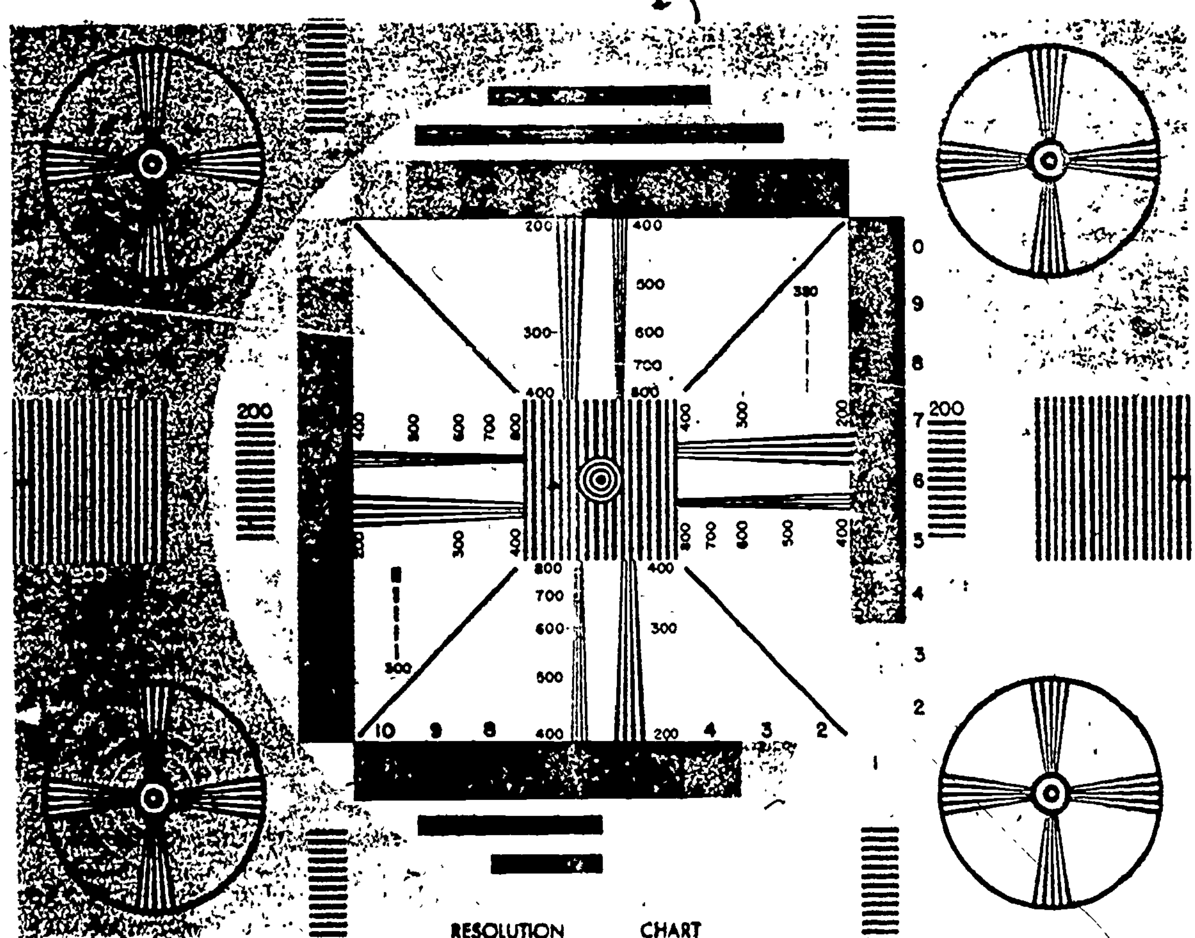


Figure 2-23 RETMA resolution target.

responses are not absolute and will vary with factors such as lighting and camera tube life.

Fine detail and resolution. To an experienced photographer, photographing the RETMA resolution target (test pattern), which is shown in figure, 2-23, would be a fairly straightforward job. He could make an exacting reproduction that would show every line and every shade of gray on the target. Television reproduction does not permit a level of resolution comparable to photography. Resolution is the ability of the system to reproduce fine detail. A resolution number may be assigned by noting the maximum ability of the system to distinguish between lines of the illustrated target.

For example, using figure 2-23, note that the central portion shows a number of lines that taper in to a closer spacing as they approach the center of the target. One band goes from 200 to 400, and the band next to it goes from 400 to 800. By watching the monitor, you may readily distinguish a point where the lines are just barely separated. Let us suppose that the lines just barely appear separated at the point marked "350." This then, is the resolution of the system at this point on the screen. This resolution would be quite acceptable in broadcast television. At the same time, you can check out the resolution at any point on the monitor by viewing the appropriate parallel bars, tapered lines, or circles. You can also check out the system with this same target by viewing the gray scale rendition.

Although closed circuit television systems have a considerably greater capability than broadcast systems because they employ a greater number of vertically spaced scanning lines and many more video pulses per scan line, much of any fine detail in an illustration will be lost. Therefore, when you prepare an illustration for television, you should visualize it as though it were being presented on a monitor. We have already discussed the practice of stepping back to get the same viewing ratio as the viewer. Now, here is how you can tell what your illustration will look like after loss due to the TV system's poor resolution factor. Lay a sheet of wax paper over your illustration and step back to the appropriate viewing distance. The net result is very similar to what the TV system does to your illustration. You can save a great deal of time and effort by not including those details which cannot penetrate the TV system. A good rule to follow in designing your illustration for television is BIG, BOLD, and SIMPLE. Where details are important to the content and concept of the illustration, you will often have to develop specific TV methods.

Exercises (814):

1. What are the advantages and disadvantages of using black and white (as opposed to color) in all illustrations that are to be reproduced on television?

2. Why should you restrict your use of gray tones when designing a graphic for television reproduction?

3. If you use color in preparing your graphics for black and white television, to what factor must you pay particular attention?

4. State the general rule that determines adequacy of resolution.

2-5. Television Techniques

Since the type of illustration will depend on the particular television technique used to present it, you must learn something about these different techniques. Therefore, let's discuss several of the most important techniques—studio cards, rear projection, slides, the phantom, animation, and illustrating for color TV.

815. Given a list of descriptive statements concerning TV production, select, then match the appropriate terms.

Studio Cards. Considering the total number of visual aids used on television, most graphics are in the category of studio cards; that is, small cards placed on an easel, mounted on a pegboard, or stuck on the wall with tape, and shot by a studio camera. Since the cards are used for static presentations, they permit careful framing, lighting, and camera portrayal. In addition, they allow the narrator to point to and discuss various aspects of the graphic.

Media used in constructing studio cards are tempera, retouch grays, airbrush, grease pencil, pencil, pen and ink, felt point pens, and pastels. Matte finish texture sheets and matte finish tapes are also very effective for making studio cards. Photographs that are not glossy make excellent studio cards when mounted on a cardboard backing.

It is possible to subdue a portion of the graphic, where three or more ideas are presented at the same moment, by using a tracing paper overlay with a cutout revealing the area in which you are interested. The areas under tracing paper are subdued, but visible. The most clearly visible area and the one that the viewer will focus on is the area not obscured by the tracing paper. As the concepts develop, the original tracing paper can be modified or removed entirely. Studio cards have the main advantage (as compared with slides) of being in the studio with the narrator and under the direct and immediate control of the cameraman, the floor manager, etc.

Rear projection. In studio production, transparencies are often projected on the backside of a translucent screen and picked up by the studio camera. The transparencies normally used are the 2- by 2-inch slide and by the 4- by 5-inch cell.

There are three important advantages to rear projection. First, a projector with its associated cables does not clutter up the studio set and inhibit camera movement. Second, the studio light falling on the screen does not deteriorate or wash out the projected picture from the rear projection as it does with front projection. Third, the performer may work close to the projected picture with no worry about blocking the light from projector to screen.

The artwork for rear view transparencies can be produced in a number of ways. For TV use, the photographic negative or positive is satisfactory. The original artwork is constructed keeping the standards of legibility in mind; then the artwork is photographed and reduced to a 2- by 2-inch or 4- by 5-inch transparency. Next the film is mounted in a frame and made ready for rear projection.

Another type of rear projection uses no screen. A large acetate transparency such as the ones used in overhead projectors is placed on a transparency box and is lighted from behind. The camera actually shoots the rear-lighted transparency.

Slides. One of the most versatile ways of displaying visual material on television is by the film-camera chain. This piece of equipment projects transparent visuals, slides, and movie film directly into a camera. By use of the multiplexer most studios can handle several sizes of slides as well as 16-mm sound films. The most important display feature of the film chain multiplexer arrangement is the ability to switch quickly from slide to slide regardless of size.

The slide is presented in either positive or negative form. In the positive form it functions as a studio card; however, the narrator cannot point since he would interfere with the projection of the image. The slide used in the negative form can be used as a superimposition (super). The information on the slide is superimposed over a live scene. The lettering plus the live scene appear together. Supers usually are presented on the lower one-third of the TV screen; however, they may be planned to be inserted in any area of the picture.

The original graphic can be used directly on camera just as easily as a slide; however, using a slide has certain advantages and permits certain specific applications. One advantage (for the director) is that the use of the graphic in slide form involves a film chain and does not tie up one of his studio cameras. However, to use a slide when a studio camera is readily available introduces an unnecessary photographic step into the process and a correspondingly unnecessary expense. The use of slides rather than the graphic itself on the studio camera is justified if the graphic is repeatedly used during the program. In live programming, cards suffer studio damage and loss, and they are a filing and storage problem. The use of slides in these cases will protect the graphic through repeated use and simplify storage and filing procedures. In a single instance of recorded programming, the principal justification for the use of slides is to free a studio camera for other use.

The Phantom. The principle of the phantom is based on color values. To use this technique, you draw the illustration on a medium gray background in colored media, preferably pencil. You must use a color that has the same value on the gray scale as the background material. As a result, while your basic drawing is visible to the narrator or instructor, it is, in effect, invisible to the TV camera. The narrator or instructor, using a felt tipped pen or grease pencil, traces over the colored drawing visible to him. To the TV camera, he appears to be making a completely new drawing on a blank background. This approach has several uses and advantages. For example, when it becomes necessary or desirable to develop a complex graphic on camera, the drawing problems involved are vastly simplified for the "on-camera artist." He merely has to trace. This technique gives the impression that the on-camera performer is not only a competent instructor but that he is also a good illustrator. This phantom technique can also be used in the development of mathematical problems as a convenient means of preventing innocent errors that sometimes occur regardless of the on-camera performer's competence.

The phantom can also be used as a deliberate slow-down device. That is, it provides "on-air" development of a graphic that would otherwise have to be shown instantly in total form. A slowdown is desirable since it is entirely possible to present so much material at one time that the viewer can neither absorb nor comprehend.

Since the phantom is used in the studio on the set and is frequently shown along with the narrator, it should be fairly large. A convenient size is 15 by 20 inches, but it can be larger than this. For studio utilization, the phantom is placed in a frame. For live, single instance programming, the phantom can be used directly; but in repeated or recorded programming, it is best to place it behind a sheet of nonglare glass. This procedure is wise in any event because it is possible to make an error in rehearsal.

Animation. Special techniques of presentation have been developed to create interest on the part of the viewer. One of these is animation. Since moving objects attract, hold, and lead the eye, movement or animation can be a very useful tool in aiding the learning process. Animation techniques range from the simplest movement, such as exposing a line of lettering to the most complex animation used by the television and motion picture industry. Full animation techniques are complex and require a great deal of time and expense. Since it is expensive, it is usually confined to instances of absolute need for ideal portrayal.

In 16-mm motion pictures every second of animation requires 24 separate drawings since this is the frame rate of 16-mm film. In television the frame rate is 30 per second. Since it is difficult and expensive to match the quality of animation produced by the motion picture industry, in television the term "animation" is generally understood to mean a limited form of animation with jerky motion and adrupt movements.

Slide card. For limited budgets, animation techniques have been devised that can be constructed quickly and inexpensively. The simplest animation technique is the slide card. It can be used to develop such things as a line on a graph, expose a waveshape, or progressively show lines of lettering. The slide card is basically composed of three layers. The top and bottom layers are stationary, and the center layer is movable. Information to be exposed is placed on the bottom layer and is covered by the center movable layer. The top layer has cutouts through which the information on the bottom layer is exposed when the center layer is removed.

Pop in. From a practical viewpoint, animation in television is probably best limited to the step-by-step development of specific graphics by means of the "pop-in" technique. Using this system, an illustration will be shot in an incomplete form, up to a selected point. From this point on, the illustration with an addition will be edited to the previous segment. The use of either physical or electronic editing gives the viewer the impression that the additional item has just "popped in" to the basic graphic. This system can be used successfully and repeatedly—that is, a 5- or 6-segment graphic can be built up in steps by pop-ins.

Technamation. This is a technical method of limited animation that uses polarized graphic materials in conjunction with polarized light. The graphic materials for technamation have a pressure sensitive adhesive backing and are available in various forms and shapes that produce a variety of effects. A typical use of a technamation graphic can be seen on some news and weather shows on TV. By using the appropriate technamation material in an area where movement is desired, the illusion of directional, circular, or concentric motion is obtained. In addition, a blinking effect is also obtainable.

When polarized light from some source strikes a graphic, the light is reflected as unpolarized light from all areas except where the technamation material is placed. Here, it is reflected as polarized light. If this reflected light, both polarized and unpolarized, enters the camera lens, there is no effect. However, if a transparent disk is slowly rotated, the reflected (or transmitted as the case may be) light from the technamation material selectively goes from matched polarization to cross polarization. At the cross polarization position, no light enters the camera. Then gradually as the disk approaches the position where polarization matches, more light enters the lens. The net effect is a blinking area where the technamation material is located. There is no blinking from the rest of the graphic because it did not reflect polarized light.

The technamation process can be used with considerable effectiveness in many instances where action is purely repetitive. There is no long-range effect. Whether the motion is band motion, circle expansion, flashing, etc., it is cyclic according to the rate at which the polarizing disk is turned.

Technamation material may be lighted from either the front or the rear. In the case of rear lighting, the graphic must be cut in the areas of the technamation material. Depending on the application, the polarizing disk may be placed over the light source if a single source is used or it may be placed in front of the television camera lens. The technamation principle may also be applied to fade-ins, fade-outs, color changes, or other effects, usually through manual operation of the disk.

Crawls. Another animation technique is accomplished by the use of crawl devices. A crawl device can show a great deal of information progressively without losing continuity. Information is made to crawl or to move either in the horizontal or vertical direction across the screen. Vertical crawls are used far more often than horizontal ones.

There are a number of devices used to achieve crawl movement. One such device is the drum crawl, which is composed of a large cylinder approximately 48 inches in circumference and mounted on a rod. Information is attached to the circumference of the drum. As the device is turned, the information moves. On the TV screen the information comes into view on the bottom and disappears at the top. Because of the curvature of the drum the copy represented has the illusion of rolling in and out. The center line of copy is distinct while the lines of copy above and below the distinct line are foreshortened and slightly out of focus.

Another crawl device is the roller crawl. It is composed of two rollers separated by a distance of approximately 36 inches. One end of a roll of paper is attached to the top roller and the other end is attached to the bottom roller. In the upright position, the information on the paper moves from the bottom of the screen to the top of the screen and is often presented as a superimposition at the beginning or end of a program. When the device is laid on its side, the information can be moved from the right side to the left side of the screen or from the left to the right, creating some interesting effects.

Gobo. A "gobo" is a graphic used in conjunction with the crawl device. The gobo is a two-dimensional cutout that is part of a complete graphic. It is mounted in front of the crawl device, and the cutout area of the gobo is registered with the information on the crawl. As the crawl information moves, it appears in the cutout window. A cartoon character holding a picture frame and information moving within the frame is an example of a crawl and gobo combination.

Illustrating for Color TV. As color TV becomes more prominent and monochrome TV gives way to some extent, your job will be lightened considerably. One of the greatest burdens for monochrome TV graphics is the limitation of an absolute range of 10 shades of gray and a practical range of 4 or 5 shades of gray. Many of the most challenging problems can be easily solved when you are permitted to use color. With color, however, the use of the phantom becomes impractical as a graphic form.

Exercise (815):

1. Match the items in the left column with the most appropriate descriptive statement in right column.

___1. Slide card.
___2. Animation.
___3. Studio cards.
___4. Pop in.
___5. Technamation.
___6. Rear projection.
___7. Phantom.
___8. Slides.

a. Most used form of graphics media used are tempera, retouch grays, airbrush, grease pencil, pencil, pen and ink, felt point pens, and pastels . . . advantage of being in the studio with the narrator and, under the direct and immediate control of the cameraman, the floor manager, etc.

b. Transparencies normally used are 2- by 2-inch slide and by the 4- by 5-inch cell . . does not clutter up the studio set and inhibit camera movement . . . light falling on the screen does not deteriorate or wash out the picture . performer may work close to projected picture with no worry about blocking the light . . one type uses no screen.

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c. Most versatile of visual display methods . . . presents in either positive or negative form . . . original graphic can be used directly on camera.
d. Principle is based on color values . . . narrator traces over the colored drawing . . . used as a deliberate slow-down device . . . used on set, frequently shown along with narrator, should be fairly large . . . 15 to 20 inches.
e. One technique developed to create interest on part of viewer . . . requires great deal of time and expense.
f. Simplest animation technique . . . basically composed of three layers.
g. Use of either physical or electronic editing gives the viewer the impression that additional item has suddenly just been added to the basic graphic.
h. Method of limited animation that uses polarized graphic materials in conjunction with polarized light . . . seen on some news and weather shows on TV . . . in the cross polarization position, no light enters the camera . . . may be lighted from either front or rear . . . may be applied to fade-ins, fade-outs, color changes, or other effects through manual operation of the disk.

2-6. Illustrating for Overhead Projection Devices

Illustrating for transparencies and slides is governed by the same, or similar, standards that govern the preparation of illustrations for television. Here are some additional facts to remember.

If your slide is to be truly effective, it must be visually fluent. It must convey your ideas clearly and simply. Simplicity should be your watchword in making slides.

Restrict your slide to one idea, avoid clutter, and don't try to put too much on one slide for it will only tend to confuse the viewers. Make sure that the artwork is functional and not ornate. Remember that the purpose of a slide is to inform and not to dazzle or impress the audience.

Don't attack the task of preparing slides in a helterskelter fashion. Plan for the job. Do your layout on a piece of paper first; this will save you time and material. Check it for balance, clarity, and simplicity. Ask yourself, "Will it achieve my objective?"

816. Name the materials used to make slides; explain why photographic slides are the most popular.

Glass Slides. Some of the many types of glass slides, the materials used, and the methods of preparing them are discussed briefly in the following paragraphs.

Clear glass slides. The following procedure is recommended for preparing a clear glass slide. First, determine exactly what you want on the slide. Gather all the materials you will need. Then work out your design or lettering on a piece of paper. Make sure that the dimensions of your basic layout will fit the glass slide. Your next step is to tape the slide to the paper and trace your design or lettering on the glass. The specific type of writing implement that you use for the tracking job will vary with the type of slide being made.

Enamel spray slides. Only India and transparent colored inks may be used on enamel spray slides. Line definition is excellent, and it is easy to prepare. This slide is made ready for use by spraying a light film of clear enamel on the glass. Make sure that the coating of enamel is light and even or there may be distortion when the slide is projected. The enamel comes packaged in an aerosol-type container and can be obtained through normal supply channels or purchases locally at almost any paint store. Letter or draw the desired information on the glass and your slide is ready to use.

Etched glass slides. These slides are also known as *frosted glass slides.* The glass is treated with acid that gives it a frosted appearance. In addition, the surface of the glass becomes somewhat roughened, which permits a wide latitude in the choice of drawing implements. You can use lead pencils, colored inks, and colored pencils on these slides. Take particular care when tracing your design on the etched glass. Erasures and corrections should be avoided because they will show up as smudges when projected. When you have finished your slide, apply a light coat of plastic spray to it. This will prevent smudging. In addition, the slide will become clear and the frosted effect will be removed, resulting in better projection qualities.

Sandwich slides. As the name implies, this type of slide is a sandwich, consisting of two pieces of glass with some kind of transparent material between them. Any transparent material can be used, such as acetate, diazo foil, or positive film.

Cut your transparent material to fit the glass. Now you can draw on the material or even type on it, but you must use a carbon sheet with it. When typing, place the transparent material between two pieces of carbon paper with the carbon sides facing the material. Insert the material and carbons into the typewriter and set the machine for stencil work. Type through the carbon. This will produce lettering on both sides of the transparent material, resulting in a better projected image. Remove the transparency from the typewriter and bind it between two pieces of glass. To bind the slide, you place the transparency between two pieces of glass, making sure that the message is properly centered. Then unroll sufficient transparent tape to go around the perimeter of the slide, and starting at the point farthest from the roll of tape, place the edge of your sandwich in the center of the tape. Press the overlapping tape down onto the sides of the glass. Then roll the slide on its corner, along the tape, and press down the overlapping tape once again. Repeat the process until the four sides of the slide are taped. Cut the tape and press the remaining tape into place. If Polaroid frames are available, they are easier and faster to mount, more economical, and may be used over and over. However, for permanent slides, glass mounting is better, since Polaroid frames provide no surface protection.

Photographic Slides. There are several good reasons that make photographic slides the most popular type of slide. They can be made in any size to fit any projector. They provide excellent definition of detail. You don't have to worry about smudging the picture as you do with enamel spray slides. You do, however, have to plan your production well in advance. It often takes considerable time to get your slides back from the photo lab. The period involved will usually vary according to your priority and the workload of the lab.

Acetate Slides. There are several types of acetate slides. These include the clear acetate slide, carbon slide, and etched acetate slide.

Clear acetate slides. This is the simplest form of the acetate family. It is a clear, transparent piece of plastic. You can write on it with a grease pencil, India ink, or a felt-tipped pen. Grease pencil, regardless of color, shows black on your projected image because the mark is opaque.

In constructing the clear acetate slide, you follow the same procedures as those outlined under glass slides. Plan your layout, put it on paper and then trace it on the acetate. You can also type on the clear acetate if you use pencil carbon or ditto carbon in the same way as previously discussed.

When making slides, be sure you keep the acetate clean. If oil from your hands or any kind of grease gets on the acetate, the grease pencil will skip when you write. Inks will not stick to the acetate if the acetate is greasy. You can remove the oil and grease with lighter fluid or other cleaning fluid. Mistakes can be erased with a clean cloth. The grease pencil and ink will rub off quite easily. To make permanent slides when using grease pencil and ink, protect them by placing another piece of clear acetate on top of your slide and taping it firmly in place.

Carbon slides. A carbon slide consists of a light sheet of acetate coated with a black carbon baking. It is a commercially prepared product to be used with the overhead projector. It provides the same flexibility as the clear acetate slide. You can type on a carbon slide or use an ordinary lead pencil to write on a carbon slide. The projected image appears as a white line on a black background. This occurs because the carbon is scraped away from the acetate as you write. The result is a very vivid and dramatic effect.

Etched acetate slides. This type of slide possess all the properties of etched glass slides. The only difference, as compared to glass, is that you can type on the frosted acetate.

Exercises (816):

1. Name the three materials used in making slides.

2. Why are photographic slides most popular?

817. List two advantages of diazo transparencies, restate the steps for preparing multicolored projectual, and tell what resource to use when calculating minimum letter height.

Diazo Transparencies. The diazo process is a method of reproducing copy material on acetate foil. To make a projectual transparency using this process, you must first put your basic drawing on translucent paper, such as tracing paper. Drawings should be prepared with black drawing ink or a dark, soft pencil. You can also type on the paper, using carbon paper so that the type will register on both sides of the tracing paper.

Since the size of your basic artwork is quite large, 7½ inches by 10 inches, it is easier to work with than smaller slide drawings. You can get more detail on the drawing and you can work with bolder stroke. Another advantage in making diazo transparencies is that you can literally cut out mistakes. If you make a mistake on the tracing paper, you can simply cut out the incorrect path and tape a new section in its place.

After your basic artwork is finished, your job is practically done. You merely have to place your master on top of a piece of sensitized foil and run it through the diazo dry developer machine. The diazo machine exposes the master and foil to ultraviolet light and then bathes the foil in ammonia fumes. The developing process is all done automatically. Lacking a machine, you can achieve the same result with a sunlamp and an ammonia vapor bath, using a gallon jar with a sponge saturated with ammonia in the bottom and covered with a grid to keep the foil from contacting the ammonia.

The same diazo process is adaptable to the production of color slides. By producing separate slides of appropriate colors and assembling them in an overlay, you can create a full color transparency.

To keep the diazo transparencies from warping, you should mount them in frames. Commercially prepared frames are available or you can make them very easily out of manila folders or heavier cardboard. If your transparencies are on 8- by 10-inch foil, you should cut a 7¼- by 9¼-inch opening in the cardboard. This will permit the foil to extend beyond the edges of the frame opening. Then use masking tape to secure the foil to the frame. Do not use staples as they can cause

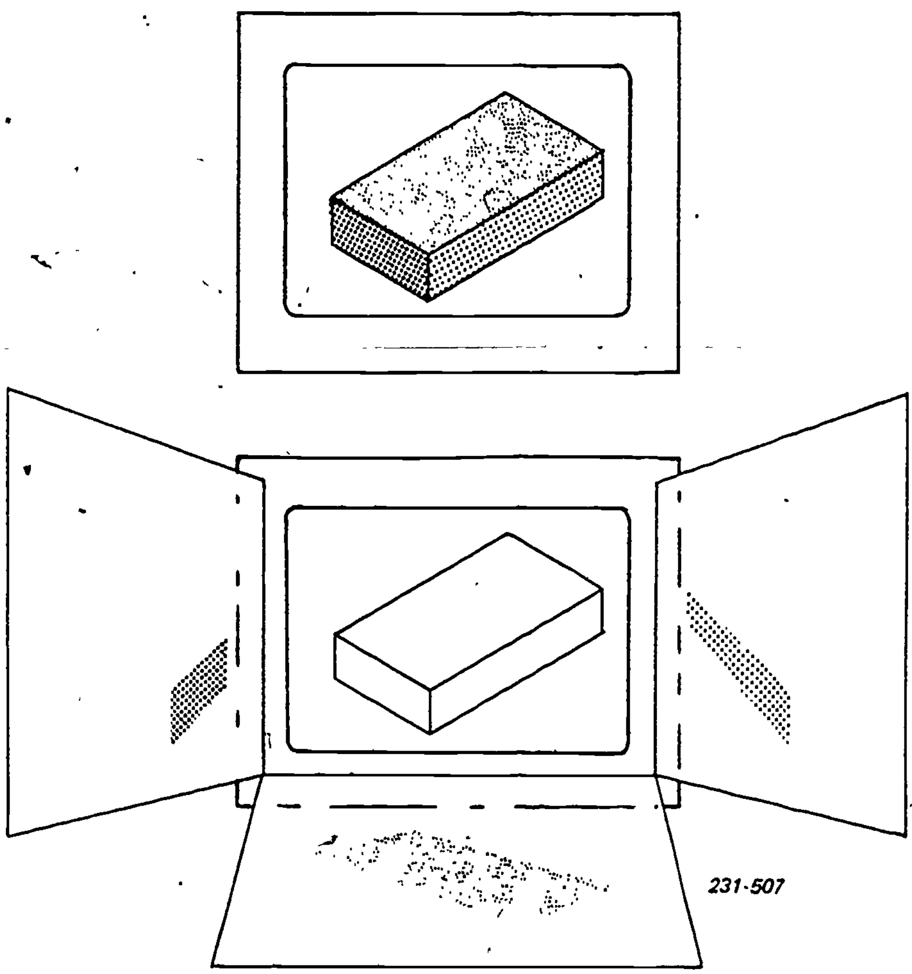


Figure 2-24. Static projectual.

damage to the projectual transparency during handling and filing. Trim the frame so that the slides will fit in a standard filing cabinet but leave at least a 1-inch margin all the way around the projectual to provide a desired rigidity. This type of projectual is shown at the upper portion of figure 2-24, and is sometimes called a *static projectual.*

When a single graphic unit is too complicated to be represented by a single projectual, it can be broken down into simplier components by means of the overlay technique. You process each overlay sheet separately, starting with the basic transparency. Then tape the mount of the first overlay to the basic mount so that it is hinged on one side and can be folded back away from the basic or will lay directly on top of the basic. Continue the process until all overlays are in place. If the sequence with which the total graphic unit is built up is always the same, the overlays should be hinged on the same side of the basic mount. If the sequence varies, then you must hinge them at different sides, top or bottom of the basic projectual as shown in the lower portion of figure 2-24. This type of projectual is sometimes called a dynamic projectual.

One of the most important factors to consider when combining two or more transparencies to form a single projectual is registration. All of the transparencies must be perfectly aligned. This alignment must be obtained in the artwork as well as in the finished product. For this reason you will find that using a commercial process such as the Technifax Slidemaster System will give better results. Let's see how this system works.

The Technifax Slidemaster System is an integrated process for the production of Diazochrome (a product of the Technifax Corporation) multicolored projectuals. It is based on a mechanical registration system, adapted from the pin registration technique used in the animated motion-picture cartoon industry. This system utilizes three pins, machined and aligned to a tolerance of .001 inch. All masters and sensitized materials are punched as follows: the center hole is round (3/16 inch); the end holes are elongated (1/4 inch by 3/16 inch), and are equidistant from the center hole (1 7/8 inch).

When the punched material is mounted on the pins, the elongated shape of the holes permits distortions to be distributed toward the edges of the projectual where they are less critical. You may punch your own materials with the Technipunch (another Technifax product), or you may purchase prepunched tracing paper, Diazochromes, Texray, and other diazo materials employed in projectual making.

Two basic pieces of equipment are used in the Slidemaster System: an exposure unit (Proto-Printer) and a developing unit (Pickle Jar Developer or Proto-Coupler). You use the system in the following manner:

a. Punch the original, or master.

b. Punch as many sheets of tracing paper, or Texray (a translucent diazo paper that yields a nonreproducible blue image of the original, which serves as a guide for opaquing and tracing) as are required for color-separation masters. If Texray is used, several prints are reproduced from the original, using the exposure unit and the developing unit.

c. For each section of the original to be reproduced in any given color, superimpose a piece of tracing paper over the original by placing it over the pins of the Tecniboard (a component of the Proto-Printer). The pins hold the original and tracing in perfect registration. You can use a Texray print in place of the tracing paper.

d. Punch each sheet of Diazochrome.

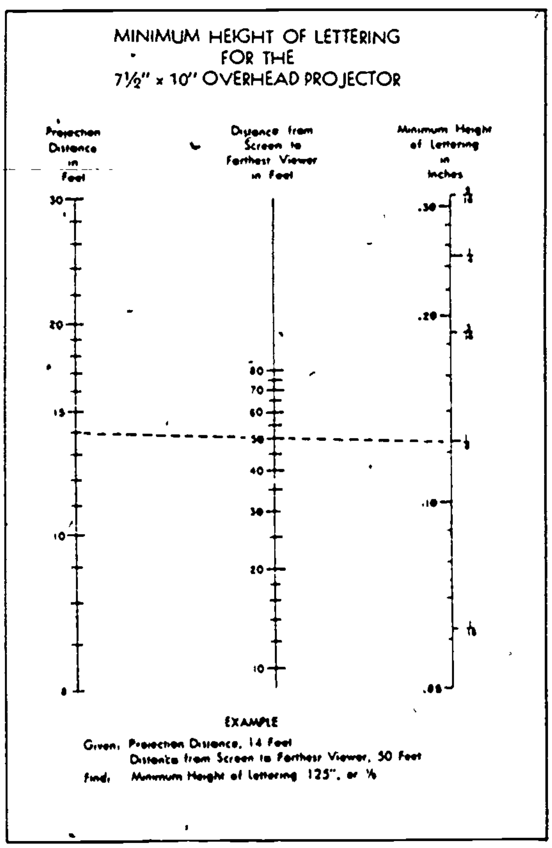


Figure 2-25. Height of lettering.

e. Mount a sheet of Diazochrome on the pins of the Tecniboard, superimpose the appropriate color-separation master (opaqued Texray or tracing), and place the assembly in the exposure unit. After the exposure, develop the Diazochrome in the developing unit. Repeat this procedure until you have the required number of Diazochrome prints.

f. Register and assemble each projectual Diazochrome over a Tecnifax projectual mount by placing both mount and Diazochrome over the pins of the Tecniboard. Registration is automatic. Affix the elements of a projectual to the mount with pressure-sensitive tape. If the projectual consists of hinged overlays, attach three Techinges to each film overlay, and then staple each series of Techinges to the projectual mount.

Determining Minimum Lettering Height for Overhead Projectuals. The minimum height that you can use for lettering on overhead projectuals depends on the distance of projection and the distance between the screen and farthest viewer. Calculating this minimum height is a complex mathematical operation. You have to consider such factors as 20/20 vision and how much the projected image will be enlarged. Therefore, the operating instructions of most projectors include charts such as the one shown in figure 2-25 that does the calculating for you. All you need to use the chart is a straightedge. Let's see how the chart works.

To design the lettering on a projectual you must know the distance between the projector and the screen and the distance between the screen and the farthest viewer. Let us suppose that these distances are 14 feet and 50 feet respectively. To find the correct height, you align your straightedge on point 14 on the left scale and on point 50 on the center scale. The straightedge will then intersect the scale on the right between the point .12 and point .14, and as you can see it intersects the scale closer to point .12 than .14. Notice that the right scale is also marked off in fractions of an inch and that our point of intersection is marked 1/8. This 1/8 inch is the minimum height that lettering on the projectual should be. Now, you try one, using 30 feet for the projection distance and 60 feet for the distance of the farthest viewer. If you got 1/16 inch for the minimum lettering height, you've got the idea. If you didn't, try it again.

Exercises (817):

1. What are two advantages of diazo transparencies?

2. What are the basic steps used in making a diazo multicolored, single-unit projectual?

3. To what do you refer to calculate the minimum height of lettering to be used on overhead projectual?

Reproduction Methods and Processes

WHEN THE ORIGINAL illustration is to aid communication, the illustration may be produced in any medium and with any technique that is effective for the presentation. For example, if a chart is to be used by a commander to present information to his staff, it can be produced in the most suitable medium and by the techniques that effect the desired results. Since there are few restrictions on the media and techniques that may be used, there is a large selection from which to choose the appropriate media and techniques for the occasion.

When more than one copy of the illustration is required, the method of reproducing the needed copies must also be considered in selecting the media and technique used to produce the original illustration. The method and process of reproduction may limit the number of media and techniques that can be used to produce the original illustration. Therefore, you must know something about the various methods and processes of reproduction to be able to select the most appropriate medium and technique for any illustration that must be reproduced. The information on printing processes and on the most important methods of reproduction presented in this chapter should give you this basic knowledge.

3-1. Printing Processes

The art of printing is based on a very simple principle. If you ink the tip of your finger, and then press it on a piece of white paper, you will make a fingerprint—a printed image of the pattern of lines on your finger. Printing can be that simple or it can be as complex as producing hundreds of copies of a multipage technical order; of course, printing is usually somewhere between these extremes.

But simple or complex, there must always be something to print from, something to serve as a pattern of the thing to be printed. You cannot make a fingerprint without a fingertip, nor can anything else be printed with printer's ink on paper unless there are forms of type, engraved plates, blocks, cylinders, or something to print from.

Typesetting, engraving, and platemaking are not mechanical in the same sense that printing is. They are processes and methods for creating printing patterns that can be used by the printing presses to reproduce words, designs, or pictures in small or large quantities. They are extremely flexible and versatile, for they make it possible to put in print any combination of words, characters, and figures in any language; or to reproduce any design, picture, or other graphic form in either black and white or in color.

There are three basic methods of printing, and each has its own peculiar requirements as to the way its printing plates are made. These three printing methods are letterpress, gravure, and lithography.

818. Given a list of printing methods, match the type; and calculate the average word count—given necessary requirements.

Letterpress Process. Letterpress printing is accomplished from relief printing surfaces. A relief printing surface is like the lines on the fingertip, like a rubber stamp, or like type as shown in figure 3-1.

When a printing surface is in relief, the spaces between the printing elements are lower and consequently do not print (even though they may have ink in them) because they do not come in contact with the paper.

There are numerous methods for lowering the nonprinting areas of relief printing plates. The principles most generally used are either to cut or engrave them by hand or machine or to etch them with acid. Each method is a form of engraving.

When photography is employed to affix the image to the surface of a sheet or metal

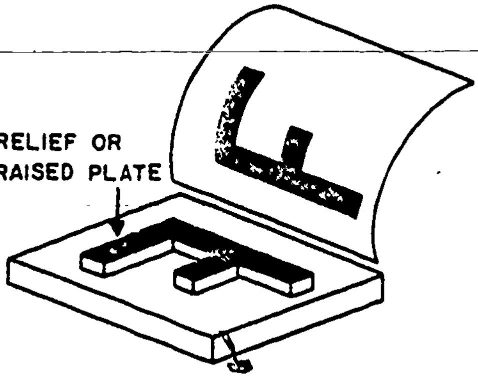


Figure 3-1. Relief printing.

preparatory to etching, the process of platemaking is called photoengraving. This is the process that makes reproduction possible. Photography copies the subjects to be reproduced with accuracy to any desired size.

A special photographic printing method applies the image to the surface of the metal plate to be etched. When this print is complete, it is an acidproof protective covering on all printing areas of the image. All of the nonprinting areas, such as the spaces between lines, dots, or other elements of the image, are left with no protective covering. Consequently, the etching acid bites into the unprotected areas and gives them enough depth to prevent contact with the paper when the higher areas are inked and printed.

Type. One of the important aspects of letterpress printing is its use of type. Printers' type is an assortment of pieces of metal of various sizes on which separate letters or characters are cast. These pieces of type are arranged by the compositor to make up the words and sentences he wishes to print.

Originally, each piece of type had to be picked up and set into place by hand. Now machines do most of this work. The old hand method of setting type is employed largely in advertising where a great deal of detail and large type sizes are used.

Early printers found it difficult to apply the common measuring devices to type and spacing material and developed their own system of linear measurements known as the point system. Since this system is still used, you should know a little bit about it so that you can when necessary request the appropriate type size.

In the point system of measuring type, the unit of measurement is the point, which is 0.013837 inch or slightly less than 1/72 inch. Thus, in 6-point type, the body of the type is 6/72 inch or 1/12 inch in height. Twelve-point type is 12/72 inch and can be set 6 lines to the inch. The actual printing face of the type is always slightly less than the surface of the body, which allows for a small clearance between lines.

The *em* and *en* are common terms in measuring type. It so happens that the type letter "m" is used as a unit of surface measurement in type. It is a square of the body of type. For example, an em in 72-point type is 1 inch square. An em in 12-point type is 12 points in width and 12 points in height. An en is half as wide as an em.

One of the principle type calculations that an illustrator is called upon to make is to determine how much copy, set in a given size type, will go into a given space. Or stated in reverse, what size of type can be used to set a given amount of copy in a given space. The following table gives the approximate number of words that can be set in a square inch according to type size:

Type Size	*Set Solid*	*1-Point Leaded*
5½	57	42
6	47	34
8	32	23
10	21	16
12	14	11
14	10	8
18	7	5

Line cut. In early printing, the plate used for printing in the letterpress was made by hand. In this process, the illustration to be printed is redrawn in reverse or traced onto a block of wood and the surface of the block not to be printed is cut away; this operation leaves the printing surface in relief. Today, this process is done by photoengraving.

Line cuts are the simplest and least expensive method of making plates by photoengraving. The subject to be reproduced by line etching must consist of black and white only. Pen and ink sketches, printed words, or any subject made up of solid lines or masses can be reproduced by this process. Shadows and shades will not show up in a line etching; therefore, portraits, photographs, or any illustration that contains grays cannot be reproduced by this method.

The subject or drawing is first photographed. Then a negative is developed, fixed, and dried. The printing plate is exposed to light through the negative, developed, fixed, and washed in the same manner as the photographic print. The plate is then brushed with dragon's blood, a resinous powder that adheres only to the printed parts of the plate. The image is burnt in by heating the plate. Next the plate is placed in a bath of weak nitric acid that acts on the unprotected portion of the plate, biting into it and leaving only the black portion of the original in relief.

Halftone. Making halftones is the same as making line cuts, with the exception that the negative is made through a screen. The halftone reproduces shades of gray as well as the white and black portions of an illustration. Therefore, photographs, paintings, and most drawings and designs can be reproduced by this process.

The halftone screen is the key to the entire process. It is made of two pieces of plate glass bearing engraved parallel lines. These lines are filled with black pigment, and the plates are cemented together with the sets of lines at right angles so that they form a pattern of squares. Screens are made in various degrees of fineness. A 60-line screen has 60 parallel lines to the inch in each direction.

The negative for halftone work is produced in the same manner as the negative for a line cut, except that the image is photographed through the screen that is placed in the camera just in front of the plate. The light from the image passes through the squares in the screen to the sensitized plate, resulting in the image on the finished negative being broken up into many graduations of fine and heavy dots.

The negative must be stripped before making the print. After coating the film to give it strength, the film is stripped off the celluloid or glass base and is placed on a piece of clear plate glass. The film is laid over a highly polished plate of copper that is covered with a sensitized solution. When the plate is exposed to a strong light, the sensitive chemical solution under the spaces between the dots becomes hard, while the area under the dots washes off, exposing the bare metal.

The process of etching the halftone plate is somewhat different from that of etching a line cut. The image is first burned to the plate. Then the border, edges, back of the plate, and the parts that are to print solid black are covered with a protective acid resistant. The plate is then placed in a chloride of iron bath. During the bath, the acid dissolves out the metal between the dots and lines of the print on the plate. The first bite etches only slightly to bring out the shadows. The plate is then taken from the bath, the acid washed off, and the etching continued by applying acid with a brush on different parts of the plate to bring out the contrast. Each etch serves to lighten the part where it is applied. The plate is again placed in the acid bath for final etching to the desired depth. The plate is then removed, washed, and trimmed. After the plate has been mounted, cleaned, and touched up, it is ready for printing.

Gravure Process. The second printing method is identified by the general term "gravure." Technically, gravure is an intaglio process. The printing elements are all below the plate surface, as shown in figure 3-2, having been cut, scratched, engraved, or etched into the metal. Thus, they form ink-retaining grooves or cups. Surplus ink on the surface must be wiped or scraped off after each inking and before each printing impression. Wiping or scraping to remove surface ink to establish the necessary nonprinting areas leaves a proper amount of ink in the grooves and cups of the low areas. Printing is done with considerable pressure that forces the paper into the recesses of the plate. When the paper comes out of these recesses, it brings the printed ink impression along with it.

Lithographic Process. "Lithography" is the term most generally used to designate the third method of printing. The term is an inheritance from the early days when all lithography was done from flat stone slabs. The word "lithos" means stone. In modern practice, thin metal sheets are nearly always used.

The lithographic process utilizes the principle that grease and water have no affinity for each other. In lithographic platemaking, the image eventually to be printed is affixed to the surface of the thin metal plate in the form of a thin film of greasy ink. In other words, all printing elements have a greasy surface. The spaces between are dampened with water. The ink used in this process is also somewhat greasy. When the ink is applied to the finished printing form, it sticks to the grease image but is rejected by the water.

The nonprinting areas of a lithographic plate have no ink on them (because they have been dampened with water and consequently refuse to accept ink). The water on the plate, as well as the ink, must be replenished after each impression. Lithographic presses therefore have two sets of rollers, one for the ink and the other for water.

The grease image on the printing plates can be hand drawn, applied photographically, or made by transfers from a master plate or stone.

When lithographic stones are used, the process is true lithography. If metal plates are used, the process technically becomes planography. However, the original descriptive, "lithography," still persists.

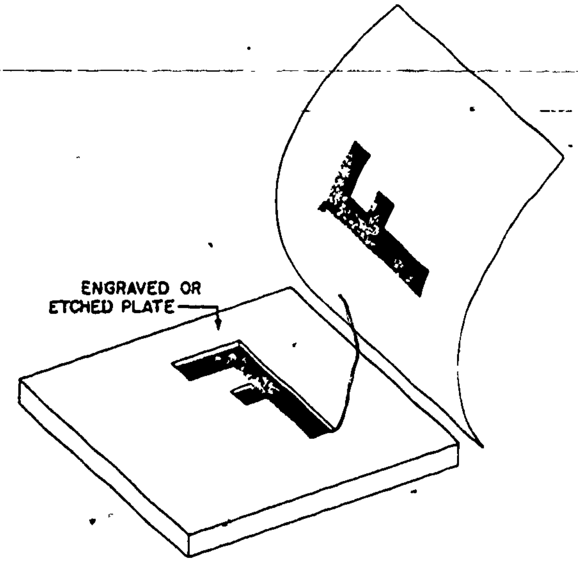


Figure 3-2. Intaglio printing.

Most modern lithography is done by the offset process. A simple illustration of the process is shown in figure 3-3. The original thin metal plate is wrapped around a plate cylinder on the press, and the printed impression from this plate is transferred onto a rubber blanket wrapped around another cylinder (offset roller). This blanket, in turn, makes contact with the paper, and the ink image on the rubber offsets onto the paper.

Exercises (818):

1. Match the methods of printing with the basic type of printing.

___1. Letterpress.	a. Relief.
___2. Gravure.	b. Gothic.
___3. Lithography.	c. Intaglio.
	d. Roman.
	e. Planography.

2. Using 8-point type set solid, the average number of words that can be printed in a space 2 by 3 inches is ________ ________.

3-2. Silk Screen Printing

There are many useful printing processes that incorporate certain features of letterpress, gravure, and lithography, yet differ from these three basic processes. One of these you are likely to use in your job as an illustrator is the silk screen process. This process can be used for printing on surfaces that are difficult to print on by any other method. Printing can be applied to fabrics, posters, glass, china, wood, cork, felt, metals, and cellophane, as well as many other materials.

The silk screen process is a stencil process. Three types of stencils are used—hand-cut stencils made from special film or lacquered paper, stencils prepared with brush and shellac called tusche, and stencils prepared by the photographic process on a sensitized silk screen.

819. Given a list of terms and procedures relating to silk screening, match the terms with the appropriate statement.

Materials. The materials needed to reproduce a design by the silk screen process are listed below:

- Medium mesh silk (48 meshes per lineal inch).
- Adhering liquid.
- Stencil material (Profilm, Nu-film).
- Stencil knife.
- Screen process paint.
- Reducing varnish.
- Squeegee.
- Paper masking tape.
- Wooden frame.
- Liquid tusche.
- Lithograph pencils.
- Removing liquid.

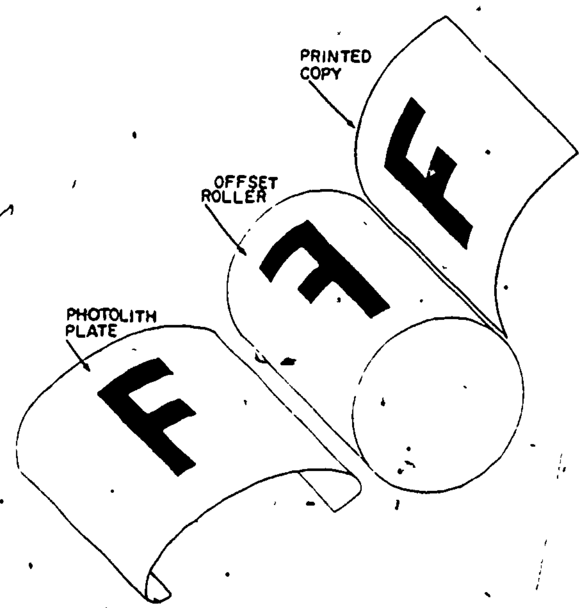


Figure 3-3. Planographic printing.

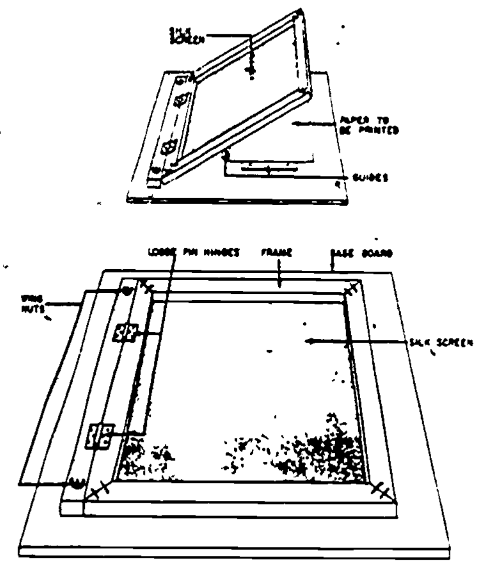


Figure 3-4. Silk screen.

Printing Procedure. The first step in printing by the silk screen method is to construct the frame if one is not already available to hold the screen. The frame should be built of lightweight, well-seasoned lumber, with strong joints at the corners. The frame should be fastened to a table or board with hinges, as shown in figure 3-4. The silk should be so laid that the threads are parallel to the sides of the frame. The silk is held in place by a strip of twisted fibrous material which presses the silk tightly into a groove in the frame. It can also be stretched and tacked to the frame in a manner similar to stretching watercolor paper.

Master copy. The master copy is made by making a layout of the design or illustration on drawing paper or bristol board the same size as the desired prints.

Cutting the film. The film is a thin transparent material attached to a layer of translucent paper. A piece of film just large enough to cover the actual drawing is fastened over the master copy with the film side up. Thumbtacks or adhesive tape are used to fasten the film to the board over the master copy. A sharp stencil knife is used to cut the design in the film, cutting through only the film and not the backing paper. As an area is outlined with the knife, the film covering the design to be printed is lifted carefully and stripped from the backing paper.

Attaching the stencil to the screen. The stencil, backing paper and all, is placed film side up under the screen in a position that will permit the correct application of the ink on the material to be printed. Newspaper or other scrap paper is placed under the film to force it into contact with the silk. A small soft cloth saturated with adhering liquid is rubbed quickly over a small area of the silk covering the film. A large soft cloth is wiped over this portion at once to absorb any excess liquid since too much liquid will spoil the film. A darkening of the film usually indicates that the film has adhered.

When the entire surface has been attached, allow it to dry for about 15 minutes, then raise a corner of the paper backing to detach the backing from the film. If the film is raised from the silk at any point, it must be replaced, the screen turned over, and adhering liquid used until it is firmly fastened.

The open spaces around the stencil are blocked out with adhesive paper or masking tape to prevent any unnecessary parts from printing. Tape is also applied on the inside of the screen around the edges of the silk to prevent ink from working under the frame. The squeegee, which is a blade of rubber about 1/4 inch thick and which fits lengthwise into a slot of wooden handle, should be nearly as wide as the inside of the frame. The squeegee is placed at the top of the frame.

Printing. A special paint is used. It is mixed to the consistency of thick cream. The paper or cloth to be printed is fed against register guides (see the top illustration of fig. 3-4) on the board under the silk, and the screen is lowered over it. The paint is then poured upon the screen at one end and pulled across the screen with an even pressure stroke of the squeegee. This action forces the paint through the open portion of the stencil. This operation is repeated in the opposite direction for the next print. The entire procedure is repeated until the required number of copies are printed.

Cleaning the silk. The film or paper stencil should be removed from the screen after the run has been completed. This is done by brushing a small amount of the film remover on the silk. After it stands for a few minutes, the paper stencil may be peeled off. If film is used, it must be rubbed with cloth and removing liquid. The silk should be finally cleaned with the same liquid, by scrubbing it between two wads of cloth dampened with the removing liquid.

Methods of Producing Stencils. Besides the film method, there are several other ways of producing stencils. Some of the important other types of stencils are shellac, lacquer, tusche, and direct photography.

Shellac stencils. The paper cut stencil is a simple and easy way to prepare the image for the silk. A sheet of thin tracing paper is first coated with two coats of orange shellac. The original drawing, made on drawing paper or bristol stock, is then covered with rubber cement. The shellac-coated paper is placed over the original drawing, shellac side up. When it is smoothed out, the cement will hold the tracing paper in place. The design is then cut through the tracing paper, and the parts that are to show up in the print are removed, while the centers remain in place. The screen is placed over the shellac-coated paper, and the paper is adhered to the silk by moving a warm iron over the silk on the inside of the screen. The iron should be just warm enough to heat the shellac and cause the stencil to adhere to the silk. A cloth with a few drops of alcohol on it may also be used to dissolve the shellac and make it adhere to the silk. The original drawing is stripped off after the stencil has been attached to the screen; then the rubber cement is removed by rubbing. The mesh of the silk must be cleaned with benzine or naphtha in order that a clear print will result. The screen is then ready for mounting and printing.

Lacquer stencils. A stencil similar to the shellac stencil can be made with lacquer. The paper is first coated with lacquer, the design cut out and placed lacquer side up against the silk. It is attached by wiping over the silk with a cloth moistened with lacquer thinner, softening the lacquer and causing the stencil to adhere to the silk. The silk should be wiped with a dry cloth after it has been wiped with the thinner to take up the excess thinner and allow the lacquer to stick.

Glue may also be used as an adhesive to mount the stencil onto the silk. It is applied in the same manner as the lacquer or shellac, using a damp cloth and a warm iron.

Tusche method. Lettering and drawing may be applied to the screen by the use of liquid tusche. The silk screen is placed over the preliminary drawing, and the tusche is painted on the silk over the elements of the drawing.

Although the tusche can be thinned out with distilled water, it is insoluble after it dries. Fish glue, thinned with water, is brushed over the entire screen on the inside, allowed to dry, and brushed on a second time. When this dries, the tusche is washed out by rubbing both sides of the silk with soft cloths soaked in turpentine. The dissolving tusche carries away the glue over it, leaving the clean screen open at all points where the tusche is applied.

Masking paper is attached to the underside of the screen over all areas not opened, and scotch tape is fastened around the frame on the inside.

Direct photographic method. Another method of preparing the screen is by photography. Designs that are too intricate to produce on paper or film stencils are done by this method. Pictorial designs, pen and ink sketches, halftones, and other types of complicated subjects can be produced on the sensitized screen.

The screen for the direct photographic method is coated with a bichromated solution of glue or gelatin. The coating is allowed to dry and the plate is placed with the film or ink side against the sensitized silk. It is locked in a contact frame and exposed to a strong light. The amount of exposure depends on the solution used and the intensity of the light. The screen is etched out in warm water after it has been removed from the contact frame. It must be kept under subdued light until it has been dampened on both sides. Enlarged or reduced prints may also be made.

Exercises (819):

1. Pair the characterizing statements in the right column with the most appropriate item listed in the left column.

___ 1. Direct photographic method.
___ 2. Film.
___ 3. Medium mesh.
___ 4. Printing.
___ 5. Lacquered stencil.
___ 6. Cleaning silk.
___ 7. Master copy.
___ 8. Attaching stencil to screen.
___ 9. Shellac stencil.
___ 10. Tusche method.

a. 48 per lineal inch.
b. Made by making layout of design on drawing paper or bristol board.
c. Attached to layer of translucent paper . . . thumbtacks (or adhesive tape) used to fasten to the board over master copy.
d. Cloth saturated with adhering liquid rubbed over small area . . . large cloth wiped over portion to absorb excess liquid. . .open spaces are blocked out with adhesive . . . squeegee is placed at top of frame.
e. Special solution as thick as ice cream is used. . .poured upon screen at one end . . .operation is repeated in other direction.
f. Uses film remover. . .let stand few minutes, peel off paper stencil. . .between wads dampened with liquid.
g. Original drawing covered with rubber cement . . .coated paper placed over drawing. . .paper is adhered to silk by moving warm iron over silk on inside of screen.

h. Attach by wiping over the silk with a cloth moistened with thinner. . .or glue may be used.
i. 56 per lineal inch.
j. Can be thinned with distilled water. . .insoluble after dry. . . masking paper attached to underside of screen over areas not opened. . .scotch tape fastened around frame on the inside.
k. Used for intricate designs . . .pictorial designs, pen and ink sketches, halftones, and other types of complicated subjects . . .screen is coated with bichromated solution of glue or gelatin. . .screen is etched out in warm water.

3-3. Photo Composing Machine

Most Air Force graphic sections are equipped with a photo composing machine capable of producing black-type copy ready to be pasted down on layouts or finished artwork that is to be reproduced. Although you should learn to operate the particular machine in your section by using the operating instructions that come with the machine, we should discuss the operating principles that are basic to all photo composing machines.

The typed copy from photo composing machines is printed on photo-sensitized paper or on film. Paper comes in rolls of 100 and 75 feet, film in rolls of 50 and 35 feet. The 75 feet paper rolls and the 35 feet film rolls both have adhesive backs. The film copy is a positive transparency—black letters on a transparent background. Such copy is ideally suited for silk screen, gravure, and visual aid processes.

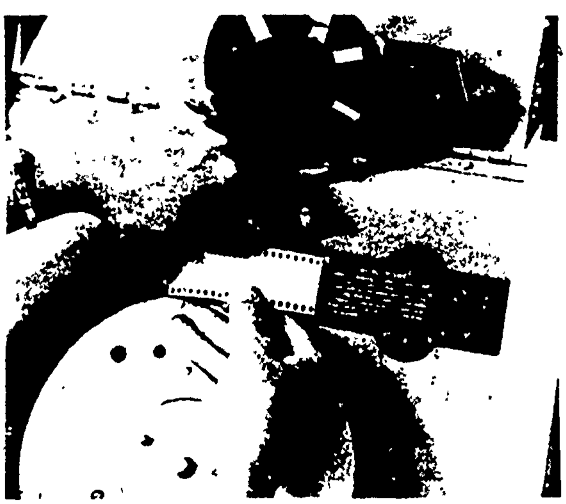


Figure 3-5. Inserting film.

820. Sort out correct from incorrect procedures for preparing the photo composing machine and for composing.

Preparation for Operation. The following acceptable steps are used to prepare a typical photo composing machine for operation:

- Mix the developer and fixer solutions.
- Fill and insert the development tank.
- Load the machine with paper or film.
- Insert the typemaster.
- Set the lighthouse opening.
- Set wordspacing dial.
- Set letterspacing dial.
- Set line position selector knob.
- Set front switch.
- Set exposurminder.
- Set line length dial.

The chemical for the solutions used with the photo composing machine comes in powder form to be dissolved in water according to the instructions printed on the packages. These powders form liquid concentrates that are mixed 1 to 3 parts water to form the solutions used in the developing tank. A mark on the tank indicates the level to which you fill the separate compartment with developer, fixer, and water.

To prepare a box of paper for insertion into the machine, loosen the outer bond and pull out the lead strip until the inner bond is broken. Then insert the rounded end of the backup strip, bent tip pointing down, into the paper box slot between the top of the box and the paper, feeding the entire length of the strip into the box until the opposite end hooks over the top edge of the paper box slot.

To insert the paper in the machine, raise the front cover and the lighthouse. Pull out the paper feed clutch knob. Insert the paper into the paper well. Raise the paper roller, as shown in figure 3-5, and feed the paper underneath the first guide, along the paper channel, underneath the second guide, and into the machine. Lower the lighthouse and front cover, leaving the bottom half of the front cover raised.

To insert a typemaster, raise the lighthouse and the front cover slightly. Insert the typemaster as shown in figure 3-6, positioning it so that the drive plate's center locating pin enters the large locating hole in the center of the typemaster.

Figure 3-6. Inserting typemaster.

To set the lighthouse opening, move the lighthouse opening control lever to the setting indicated on the typemaster. Make sure that the lever snaps into position.

The wordspacing dial should be set, using the large numbers on the right side of the dial and turning the wordspacing knob until the number on the dial that corresponds to the point size of the typemaster being used is aligned with the indicator mark. To obtain correct letter spacing, turn the letterspacing knob until zero on the letterspacing dial is aligned with the indicator mark.

The line position selector knob has six setting positions: N, A, B, C, D, and E. The N setting is used for all 1-line typemasters and for the composition of repetitive copy with multiline typemasters. The A and B settings are for top and bottom lines, respectively, on 2-line typemasters. The C, D, and E settings are for top, middle, and bottom lines, respectively, on 3-line typemasters. Correct settings are indicated on all multiline typemasters.

The exposurminder is set by pressing the read button and turning the adjust knob until the meter needle is at 5 on the dial. This setting is normal for all composition.

In multiline composition, all lines must start from the same starting point. To assure accuracy of left margins, indentions, and centered lines, zero (starting point) must be brought to the indicator from the left. To make the setting manually, turn the dial to 6; then turn the paper feed knob clockwise until zero is aligned with the indicator hairline.

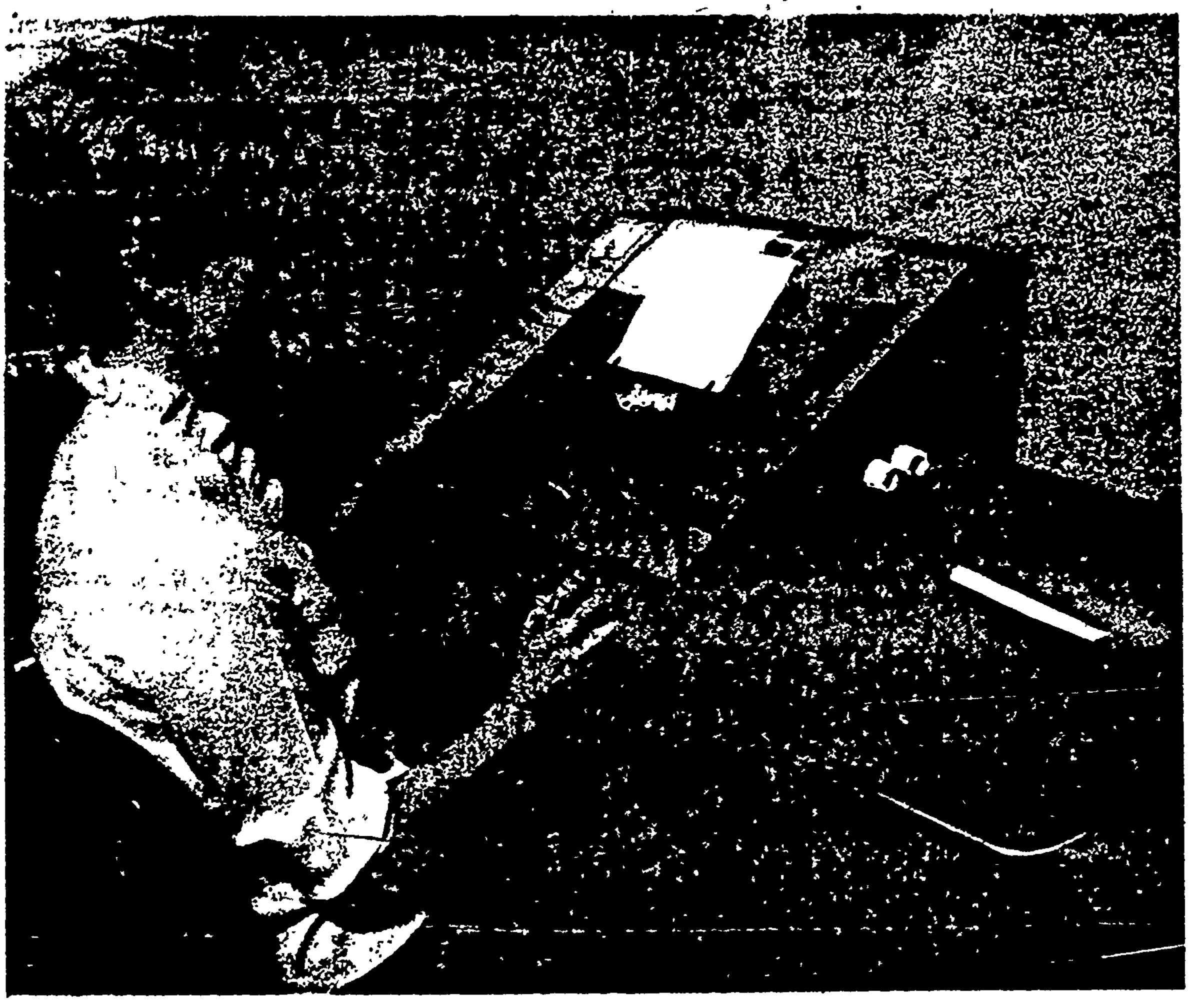


Figure 3-7. Operating photo composing machine.

Composing copy. The following steps are used to compose copy:

- Turn the print-space lever to the PRINT position and release it immediately.
- Repeat the same procedure for each letter in the word.
- Move the print-space lever to the SPACE position for spacing between words.
- After composition has been completed, turn the paper feed knob until 7 inches of paper is fed into the machine to advance the last character printed beyond the cutting knife mechanism.
- Raise the cutoff and feed lever and hold it up until the red develop light goes on; then release the lever. The developing process will start and is completely automatic.

Figure 3-7 shows an operator at the photo composing machine. Notice that she has the printing copy directly in front of her where it is easy to read as she operates the machine.

Exercises (820):

1. Sort out the incorrect from the correct preparatory procedures for operating a typical photo composing machine, then correct the faulty procedures. (Note that these steps are not intended to be put into a sequential order.) List (by letter) the incorrect, then make the corrections.

   a. Mix the developer and fixer solutions using a 1 to 4 ratio of powder to water.
   b. Set the exposurminder by turning the read knob until the meter needle is at 5 on the dial (for normal composition).
   c. Fill and insert the development tank.
   d. To insert paper, loosen outer bond, but do not pull out the lead strip until the inner bond is broken.
   e. To insert the typemaster, raise the lighthouse and front cover as much as possible.
   f. Set the lighthouse operating control

lever to the setting indicated on the letterspacing dial.
g. Set wordspacing dial.
h. Set the wordspacing knob until "1" on the letterspacing dial is aligned with the indicator mark.
i. Set front switch.
j. Set line length dial.

2. Do the same for steps used to compose copy.
   a. Turn the print-space lever to the PRINT position and release it immediately.
   b. Repeat the same procedure for each letter in the word.
   c. Move the print-space lever to the SPACE position for spacing between words.
   d. After composition has been completed, turn the paper feed knob until 7 inches of paper is fed into the machine to advance the last character printed beyond the cutting knife mechanism.
   e. Raise the cutoff and feed lever and hold it up until the red develop light goes on; then release the lever. The developing process will now start when you manually initiate it.

3-4. Methods of Reproduction

Copies of illustrations or drawings are often needed for work copies, samples, information, and file copies. In many cases you will be the one who makes these reproductions, using available reproducing machines. The two most common reproduction methods are diazotype and dry electrostatic transfer.

821. Name the two common methods, compare these methods of reproduction, and state the advantage(s) of the dry process over the moist process.

Diazotype. Diazotype reproduction is possibly the most versatile and effective nonphotographic reproduction process. The process is simply a contact exposure of a light-sensitive paper to ultraviolet light through a translucent original (master). Development is a one-step alkalizing process that takes place in a single automatic machine; it exposes the light-sensitive paper, ejects the original or master, and develops and dries the reproduction copy. The resulting print (reproduction copy) is positive; that is, light and dark areas correspond to the master. (In a negative print, light areas become dark and the dark areas become light.)

When you make a drawing that is to be reproduced by diazotype reproduction, the paper you use (the master) must be translucent or transparent. Generally, the drawing is not inked; however, inking may be done if a particular situation requires it.

Basic techniques of producing diazotype images. There are two basic techniques of producing diazotype images, each requiring specialized processing equipment and noninterchangeable sensitized materials. The systems are called dry-developing, or ammonia developing, process and semidry, or moist developing process. The ingredients or chemical makeup of both processes are basically the same. They consist of a diazonium salt and a coupler. The diazonium salt, commonly called diazo, and the coupler are coal tar or petroleum derivatives that combine to form a dye. The formula of the coupler determines the color of the dye image. The diazo is the light-sensitive component of the formula. The large variety of compounds that fall into the diazonium salt and coupler groups allows a wide span of exposure and reaction times and variety of dye images.

Developing processes. The process is simple for developing both dry and moist diazotype reproductions. The reproduction cycles for both processes are shown in figure 3-8. When ultraviolet light strikes the diazo through the translucent portion of the master, the normally yellowish diazonium salt undergoes a chemical change and becomes a new, colorless, inactive compound. In the ammonia (dry) developing process, both the diazo and the coupler are included in the sensitizing formula that is stabilized by a mild acid to prevent premature coupling. In the moist developing process the diazo is on the paper, and the coupler is in the developing solution.

After exposure through the translucent master to ultraviolet light, the master is ejected from the machine and the exposed paper conveyed to the developing portion. In the ammonia (dry) process the exposed material (diazo and coupler on the paper) is passed through an aqua ammonia vapor where the stabilizer is counteracted by the alkalinity of the ammonia. The diazo that has not been exposed then combines with the coupler to form a dye image. In the moist developing process, the exposed paper is moistened by

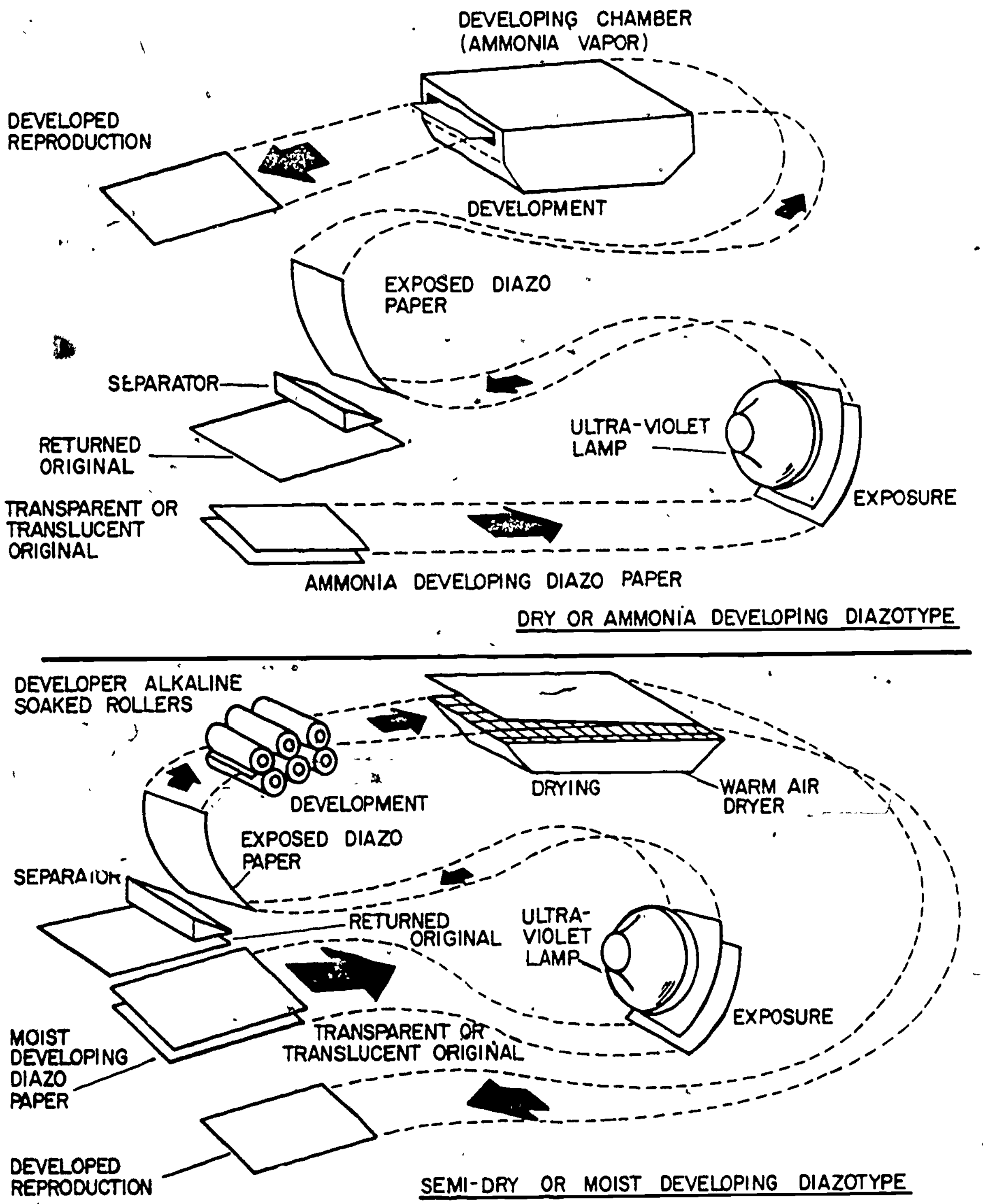


Figure 3-8. Diazo reproduction process.

the alkaline developer solution that contains the coupler. Where the diazo was unaffected by the light, a dye image is formed.

At this time, the dry (ammonia) process is used more extensively. The ammonia process has a larger variety of compounds and is somewhat more versatile than the moist process. However, the moist developing process has the advantage of not emitting ammonia odors. Both processes are capable of producing high-quality prints.

Second originals. Since the translucent paper on which the original (master) drawing is drawn wears out after a few reproduction copies are made, a "second original" is often made. This second copy is made on special foils or acetate (both translucent) coated with the same substance as that used on the light-sensitive reproduction copy paper. Because the material used for the second original is much more durable than the paper of the original, many more reproductions can be made by using the second original as the master.

Diazotype reproduction in general. Diazotype reproduction produces a positive print that is quite stable on hard-finish papers, plastic-coated papers, and acetate sheets. There is a tendency for the print on the cheaper, softer papers to oxidize slowly. Long storage or exposure to heat or sunlight can cause these cheaper papers to discolor, and to become brittle, and also cause the image to fade slightly.

The speed at which the ammonia process diazo runs is generally faster than the moist developing process. There is wide variation in the running speeds depending upon the sensitizing compound on the paper. Diazotype reproduction paper is available in either sheets or rolls of various dimensions. Generally, the color of the image is blue, sepia, or red.

Dry Electrostatic Transfer. This Xerox method of reproduction is a fast, dry, electrostatic copying process that uses ordinary paper. It has inherent advantages that make it a flexible, versatile, and economic means of reproduction.

While the preparation of paper offset masters is the most popular use of the dry electrostatic transfer process, it is equally easy to prepare transparencies, single or multiple copies on ordinary paper, chemical resist images, and others.

Here is how the dry electrostatic transfer process works:

- The surface of the selenium-coated plate is electrically charged as it passes under wires.
- The original document is projected through a camera lens. The charge on the plate is drained away in areas that are exposed to light.
- Negatively charged powder is cascaded over the plate and it adheres to the positive image. The latent image now becomes visible.
- A sheet of paper (or paper offset master) is placed over the plate, and the paper is given a positive charge.
- The positively charged paper attracts the powder from the plate, forming a direct positive image.
- The print or offset master is fused by heat for permanency.

The Xerox process has limitations in that the equipment is rather delicate (the plates are quite easily damaged). The copy produced is generally good but considerable loss is experienced in all but the sharpest line copy.

The Xerox process is of considerable value in intermediate publication work, especially in preparing masters for other duplicating processes. The process is fast, usually requiring less than 5 minutes for the entire process. Although the reproduction is permanent and is comparatively economical, copy for copy, the plates, powders, and equipment are somewhat expensive.

Exercises (821):

1. What are the two most common reproduction methods?

2. What are the two basic techniques used in producing images by the diazotype process?

3. What advantage does the dry electrostatic method have over the moist diazotype?

4. Given statements that descriptively relate to graphics reproduction, specify which statements appropriately refer to diazotype and which to electrostatic.

Diazotype (use D).
Electrostatic (use E).

a. Most versatile and effective nonphotographic process.
b. After exposure through translucent master to ultraviolet light, master is ejected from machine and exposed paper is conveyed to the developing portion.
c. Equipment is rather delicate and expensive (plates are easily damaged).
d. Print or offset master is fused by heat for permanency.
e. A contact exposure of a light-sensitive paper to ultraviolet light through a translucent original.
f. Surface of the selenium-coated plate is electrically charged as it passes under wires.
g. Second copy is made on special foils with the same substance as that used on the light-sensitive reproduction copy paper.

Figure 3-9. Photo before retouching.

h. Preparation of paper offset masters is most popular use.
i. Method is fast, dry, and uses ordinary paper.

So far in this volume, we have been interested mainly in the techniques of producing original artwork. We have discussed the techniques of black and white media, color media, and various types of illustrations. We also have discussed various types of reproduction processes. It is obvious that an illustration to be reproduced by some reproduction process must be developed with the end product in mind. It is also obvious that, if the reproduction is to satisfy the need, there must be some type of communication between the illustrator and the printer. In other words, you must use some means of telling the printer how you want your illustration reproduced, what size it should be, and any other information required to reproduce it satisfactorily.

The purpose of this chapter is to familiarize you with some of the intercommunication techniques used between illustrator and printer. As typical examples, we have presented the techniques of preparing photographs and colored illustrations for reproduction.

3-5. Photo Techniques

The use of photographic illustrations in technical publications is widespread, and for good reason. The photograph is often the best representation of the illustrated subject, and the reader is inclined to trust the accuracy of a photo more than he does a drawing. In order to be worthy of this trust, photographs must conform to and be prepared according to certain standards. The photo must present its subject free from distortion, well lighted, properly composed, and in its natural or most effective position.

Every effort made by the photographer to decrease the amount of work you must do on the photograph results in a time saving and, generally, in a better product. The photograph should give its subject good contrast, separate the planes in the subject, and avoid distracting and extraneous background; such a photo requires little further work from you. A skillful photographer can obtain a great deal of expression in a photograph. He can create impressions of action, balance, and emphasis. If the photograph is to be effective, the photographer must know, before he shoots, what he expects from the finished print. His main considerations must be quality, accuracy, and a print suitable for illustration with minimum retouching.

822. State the purpose of photo retouching, cropping, scaling, and the way phantom effects are produced.

Retouching. If the photographer fails to get all of the qualities that are necessary to make a photograph suitable for reproduction, you, as an illustrator, must add the missing qualities by retouching the photograph.

For example, let's look at figure 3-9. At the first glance, it appears that the photographer did his job exceptionally well; and he did, except for some things that were unavoidable or unintentionally overlooked. If the purpose of this photograph is to show how the machine pictured in the photo is operated, the reader would have to overcome some distracting influences to focus his full attention on the subject of the photograph. For instance, he might be distracted by the conglomeration of waste paper and excess film strips in the lower right corner of the photo. The background too might prove distracting. It certainly doesn't add anything to the subject of the picture—the operation of the machine. Let's see how we can improve the photo by retouching it.

Look back at figure 3-7. This figure shows how the photo appears after retouching. Notice that the distracting influences have been removed—the waste paper and film are gone, and the background has been subdued by placing a piece of translucent material over it. Now, let's see how this phantom effect was accomplished.

The technique that was used to subdue the background in figure 3-7 is shown in figure 3-10. The process involves the use of Bourges Solotone sheets. These sheets are specially prepared acetate sheets covered with transparent, uniformly light or dark tones that are removable. The photograph shown in figure 3-10 is covered with a white Solotone sheet. The illustration shows the covering material being scraped from the area over the part of the photograph which is to stand out clearly in the final print.

The use of Solotone is a simple process. Here are the steps you use:

- Select the sheet that will provide the desired opacity by placing test sheets over the artwork or photo. You may want to lighten or darken a particular area.
- Place the selected sheet (dull side up) over the artwork or photo and attach it to one side of the copy, using either Scotch tape or masking tape.
- Remove the tone where it is not wanted. This is done either by scraping with either a plastic stylus or by applying liquid color remover.
- Slip a sheet of black paper (or white paper if you are using dark Solotone) under the Solotone sheet to check for any areas that may not have been removed completely from the sheet.
- After you have completed the scraping, place a protective cover sheet over the entire copy.

Cropping. When the photographer takes a picture, he usually includes more than just the subject. He purposely includes some of the area around the subject because he knows that it is almost impossible to get perfect picture balance and arrangement at the time he takes the picture. He knows that the added area will allow him to select the part of the total picture best showing the subject in a well balanced and interestingly arranged print.

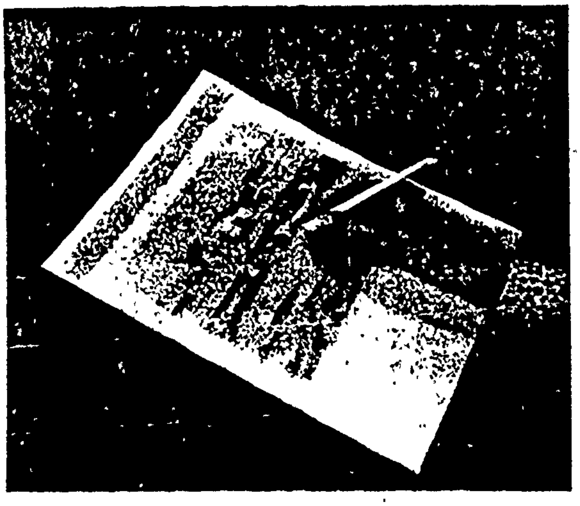


Figure 3-10. Bourges Solotone.

Figure 3-11. Cropping techniques.

This technique also allows illustrators to select the part of a photograph that will best portray a particular subject. This technique is called cropping. Let's make a typical example of how this technique is used.

Figure 3-11 shows how a photograph was cropped by the illustrator of this CDC volume. Notice that in cropping the copy to be reproduced he retouched the background around the subject, outlined the desired area with white opaqué paint, and made crop mark and dimension line notations in the margin of the copy. If the print is to be the same size as the original copy, the term "1 to 1" is written in the open space of the dimension line. If the print is to be reduced (or enlarged), the instructions and the desired dimensions in inches are placed, accordingly, in the open space of the dimension line.

Figure 3-12 shows the result achieved by the cropping process. Notice that the crop marks and other instructions have been eliminated and that the print now appears in the desired size.

Scaling method. Since the parts of photographs used for illustrations are seldom the same size as the final print and since illustrations are usually drawn 1/3 or 1/2 larger than the final print, knowing a simple method for scaling down or scaling up the original is desirable. Such a method is shown in figure 3-13. The steps in the procedure are also given in the illustration.

Overlay. When lettering or line work is done on any kind of tone drawing, the final product must be produced in a combination copy. The line work of a combination copy can be applied either directly on the surface of the tone drawing or on a transparent acetate overlay placed over the tone drawing. For example, suppose that callouts were used in the illustration shown in figure 3-13 to identify the important parts of the airplane. The lettering and line work can be drawn, pasted, or applied on the tone copy or on an acetate sheet placed over the tone copy.

Applying the line work directly on the tone copy and reproducing the entire illustration as a halftone is the more economical method. However, the line work of an illustration reproduced in this manner is likely to be fuzzy or indistinct, and the shadow around pasteup areas is likely to be reproduced in the finished print.

If clear cut line work is desired in the print, the line work must be drawn on a transparent overlay. When the illustration is processed, the two parts are photographed separately to produce the two negative films needed in

Figure 3-12. Results of cropping.

making the printing plate. The two negatives are used together to produce a combination line and halftone plate.

It is obvious that the two parts of the illustration must register perfectly if they are to combine properly. Therefore, register marks must be placed on both the tone copy and the transparent overlay. The registration marks usually consist of three small circles with crossed lines through the centers or they may consist of the crosses only. In either case, they are widely spaced in the border of the copy.

Exercises (822):

1. What is the purpose of photo retouching?

2. How can the background of a photograph be given a faded out or phantom effect?

3. What does cropping affect?

4. What is the reason for scaling?

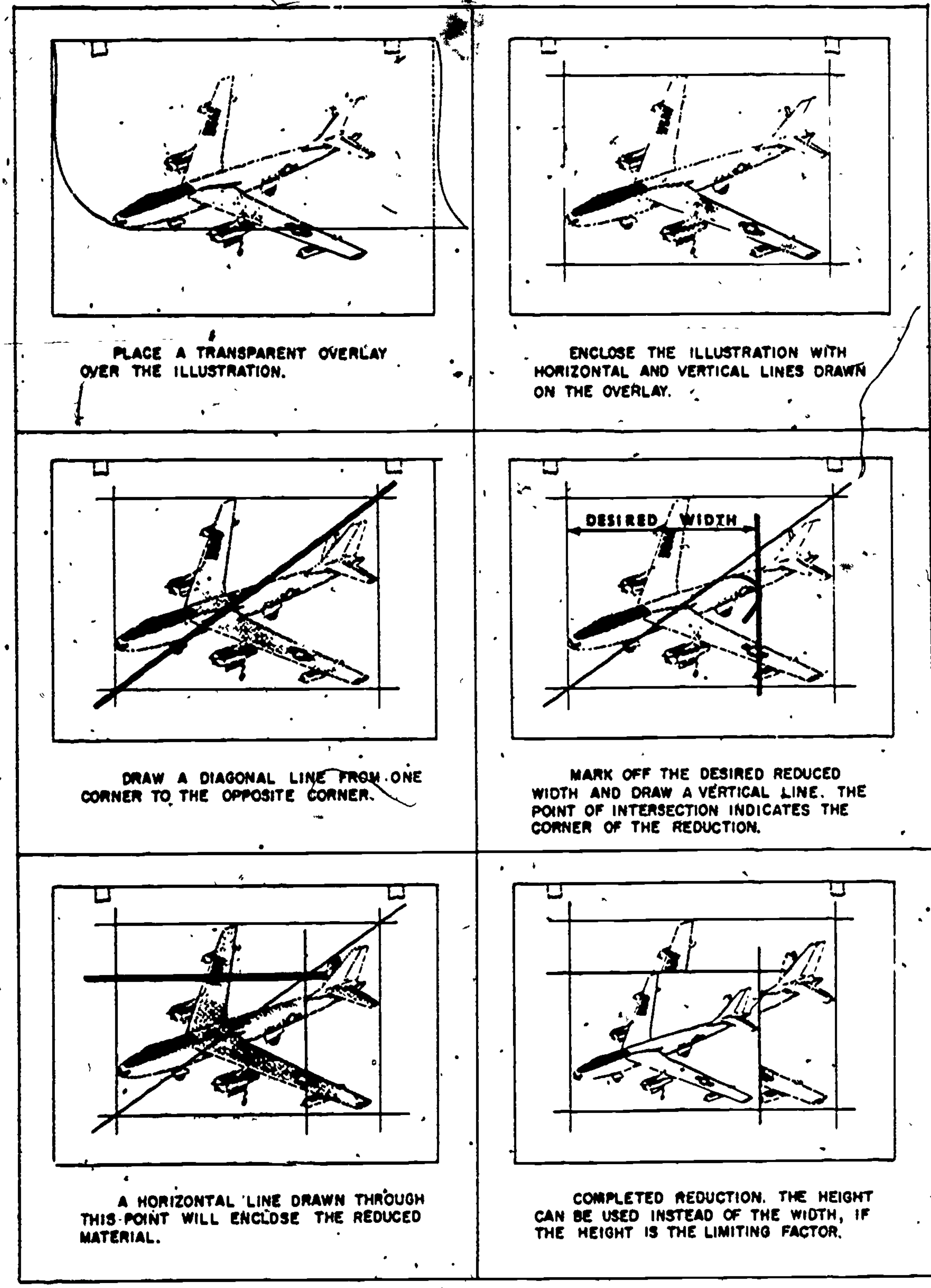


Figure 3-13. Reducing or enlarging method.

3-6. Color Separation Processes

When an illustration is to be reproduced in full color, four separate printing plates are required—a plate for each basic color. The four basic colors are red, yellow, blue, and black. This process of separating the colors—the final topic in this CDC—may be done by the illustrator, photoengraver, or lithographer.

823. Explain why black is used in color reproduction; then given a list of qualifying statements concerning photoengraving processes, match the appropriate terms.

Photoengraving Processes. The photoengraver uses filters and sensitized emulsions to eliminate the three colors not desired on the negative being made. For instance, if there is green in the subject being reproduced, the photoengraver uses a filter that allows the desired amount of yellow and blue through to those negatives and holds to a minimum the red and black in the green areas.

Indirect method. There are two basic methods that the photoengraver uses to make separation negatives. One is the indirect method of color separation, wherein continuous tone separation negatives are made; then contact positives are made from these negatives, retouched, and rephotographed as halftones. This method is of particular advantage with difficult copy having very dense areas that would be almost impossible for the finisher to open up when furnished with an ordinary set of prints.

Direct method. The second method of color separation is the direct method. This method is used when, in the opinion of the photographer, it is possible to make halftone color separation negatives directly from the copy. The direct method operates as follows: The photoengraver makes screen negatives direct from the artwork by using filters. The screen negatives are then printed on metal, and the color etcher not only etches the picture into the metal but also color corrects by etching as he sees fit to obtain as near a reasonable facsimile of the artwork as possible.

Filter principle. Color separating is subtractive and utilizes filters that are complementary to the color eventually to be used for printing. Thus, a blue-violet filter transmits blue-violet but stops yellow. This is the filter that is used to produce the yellow printer. It works as follows.

The colors transmitted by this filter are red and blue (note that these are two of the three colors that ultimately will be used in the printing), and these are the only colors that will affect the photographic plate. When developed, these areas in the negative will be the most dense. When a print is made from this negative, the values will be reversed, the result being that the dense negative values of red and blue will be the lightest values in the print. This is the reason that it is most appropriate to refer to this as the subtractive process.

While all this is going on, the yellow of the original is being absorbed by the filter; so all yellow areas will be most transparent in the negative (consequently, most dense in the print). By subtracting the red and blue, the image of all the yellow becomes isolated or separated. When such a print is in the proper yellow, complementary to the filter color, it will represent all of the yellow in the original no matter whether it be a yellow alone or a yellow that is part of another color, such as green.

The red printer is made by following the same procedure except that a green (yellow-blue) filter is used; the blue printer is made by using the orange (yellow-red) filter.

The fourth color. It is impossible to match or duplicate a brilliant color approximating the printing ink itself, since in each case the ink absorbs such a large percentage of its own color, instead of reflecting it completely. The superimposition of all the inks full strength will not generally give a dense neutral black, but rather a greenish or reddish black, depending on whether the red or blue-green ink has the greater absorption deficiency. Hence the need for the fourth impression to give a neutral black rendering.

Illustrator considerations. The copy for process plates should be prepared with the limitations of the color process in mind. If your copy features metallic objects that are painted with metallic colors instead of ordinary pigments, you cannot expect the engraver to match this effect with process color alone. If some parts of your copy are prepared with a brilliant chrome yellow and other areas with a pale lemon yellow, the engraver will have to try to approximate these with process colors.

Bear in mind the difference between the texture of the drawing surface and the pages on which the print is made. Do not expect color printed on glossy stock to have the same soft feeling of watercolor painted on watercolor paper. Also, the whites of a copy cannot be reproduced faithfully when printing is done on cream-colored stock.

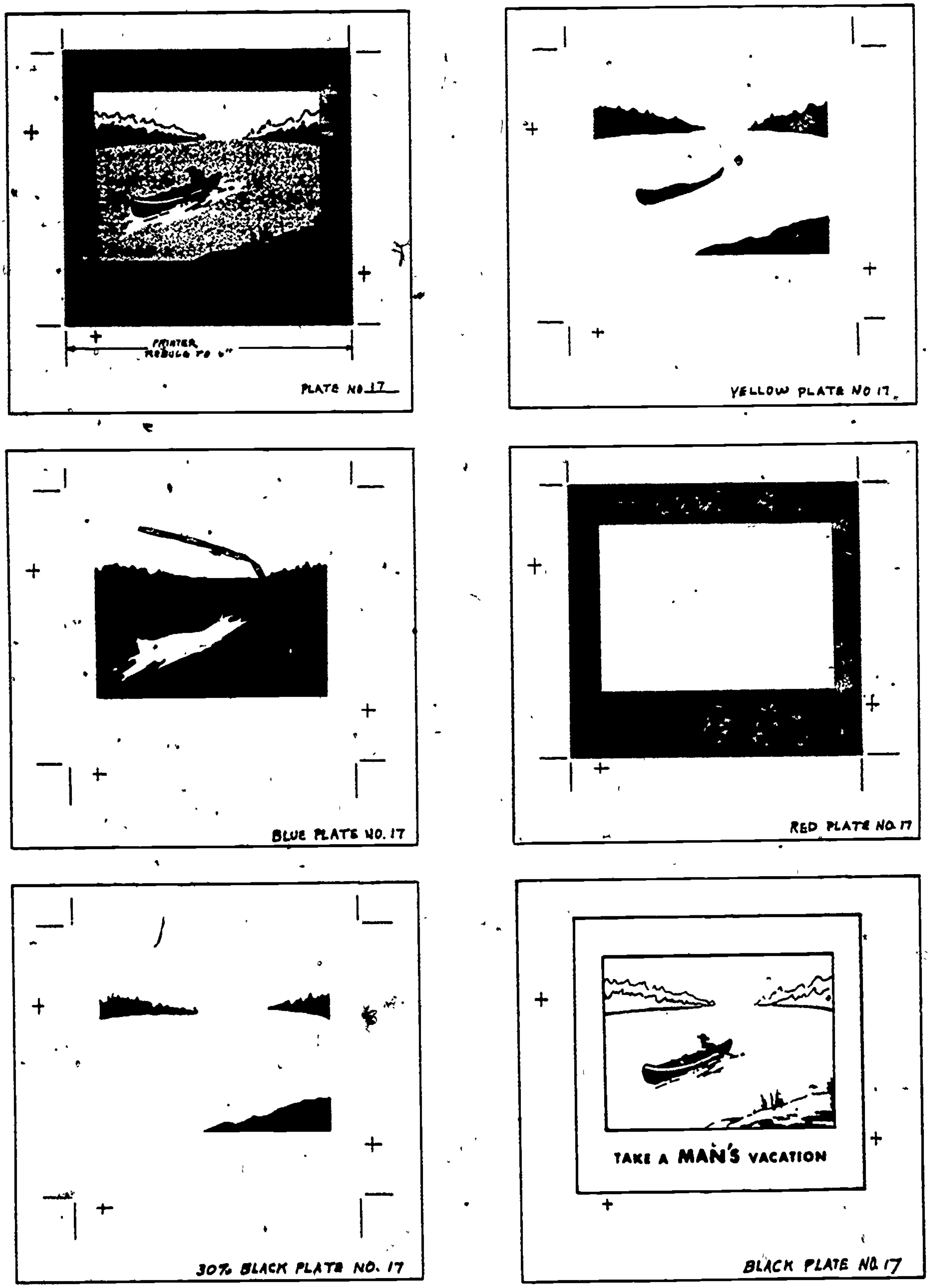


Figure 3-14. Color separation technique.

When you reduce a color by adding white to it, you must bear in mind that the resulting color becomes a false color photographically and cannot be reproduced faithfully. The only way that the engraver can approximate a whited out or reduced color is to lighten the dot tone value on the inking surface of the printing plate, allowing more white paper to come through.

Color Separation Drawings. An illustrator is often called on to make color separation drawings that the engraver or lithographer uses to make the printing plates. These drawings may be simple instructions the lithographer uses in separating the colors, or they may be the work of a skilled artist who does the job of color separation that color filters do automatically.

Tissue overlay. Perhaps the easiest method for the artist to use to indicate color separation is the tissue overlay. In its simplest form this method consists of a sheet of tissue (tracing paper) laid over the artwork, with the color areas blocked in with crayon or pencil. This overlay is used by the lithographer who does the actual registering of the separate pieces by adding the lap on his film with opaque paint. This tissue method can also be used to indicate a perfect register.

Key line. This method is often used for color work with large masses. First, an outline of the color lap is drawn with a ruling pen. Then the area on the inside and the outside of this line is filled in with black, up to within 1/16 inch from the line. This leaves a thin white area on both sides of the design line. A tissue overlay is used to indicate the areas of color.

The lithographer makes a negative and a positive of this drawing. On one, he finishes filling in the center and takes out the background; on the other he finishes filling in the background and takes out the center. Since the line is common to each, it forms the width of the overlap. The weight of the line depends upon the colors to be used. A set of light and dark colors can have more overlap than a set of two light colors or a set of two dark colors.

Acetate overlay. In this method the artist draws separate artwork for each color, judging, for instance, the value that must be provided on the red artwork and on the blue artwork to give the correct shade of violet when the job is printed. A typical example of the work that must be done is shown in figure 3-14.

The plate at the upper left in figure 3-14 represents the colored illustration that is to be reproduced. This plate is sent along with the others to be used by the lithographer as a guide for the finished print. Notice that it also includes three register marks, crop marks, and dimension instructions.

An acetate sheet is placed over the original drawing, frosted side up. Then the crop marks and register marks are made exactly over the original marks. Next, the areas containing the color which this plate will be used to produce are outlined and filled in with black India ink. This procedure is used for the plates of all three primary colors and for the black plate. In this particular example, a 30-percent black, halftone screen plate is also made, which will be used to gray some of the areas of color. This plate will be combined with the black plate in the process of making the black printing plate.

To achieve lap register, the design in each plate is made a little larger than its background to insure a slight overlap. The element to appear in the lighter color should overlap into the darker color.

Exercises (823):

1. Explain why black is used in color reproduction.

2. Match the most appropriate term with the descriptive statement(s) (right column) that characterize(s) it.

Indirect method.
Direct method.
Blue-violet filter.
Lap register.
Green filter.
Red printer.
Blue printer.
Yellow-red filter.
Neutral black rendering.
Tissue overlay.
Key line.
Acetate overlay.

a. Continuous tone separation negatives are made.
b. Used for color work with large areas.
c. Stops yellow.
d. Color areas are blocked in with crayon or pencil.
e. Placed over original drawing, frosted side up.
f. Green filter used.
g. Screen negatives made from artwork by using filters.
h. Advantageous with difficult copy (that having dense areas that would be almost impossible for finisher to open up with ordinary set of prints).
i. Artist draws separate artwork for each color, judging the values to be produced.

j. Design in each plate is made a little larger than its background.
k. Used when it is possible to make halftone color separation negatives from copy.
l. Screen negatives are printed on metal, the color etcher etches the picture and color corrects.
m. Yellow-blue.
n. Orange filter.
o. Fourth impression.
p. Easiest method for artist to indicate color separation.

550

ANSWERS FOR EXERCISES

CHAPTER 1

References:
800 - 1.

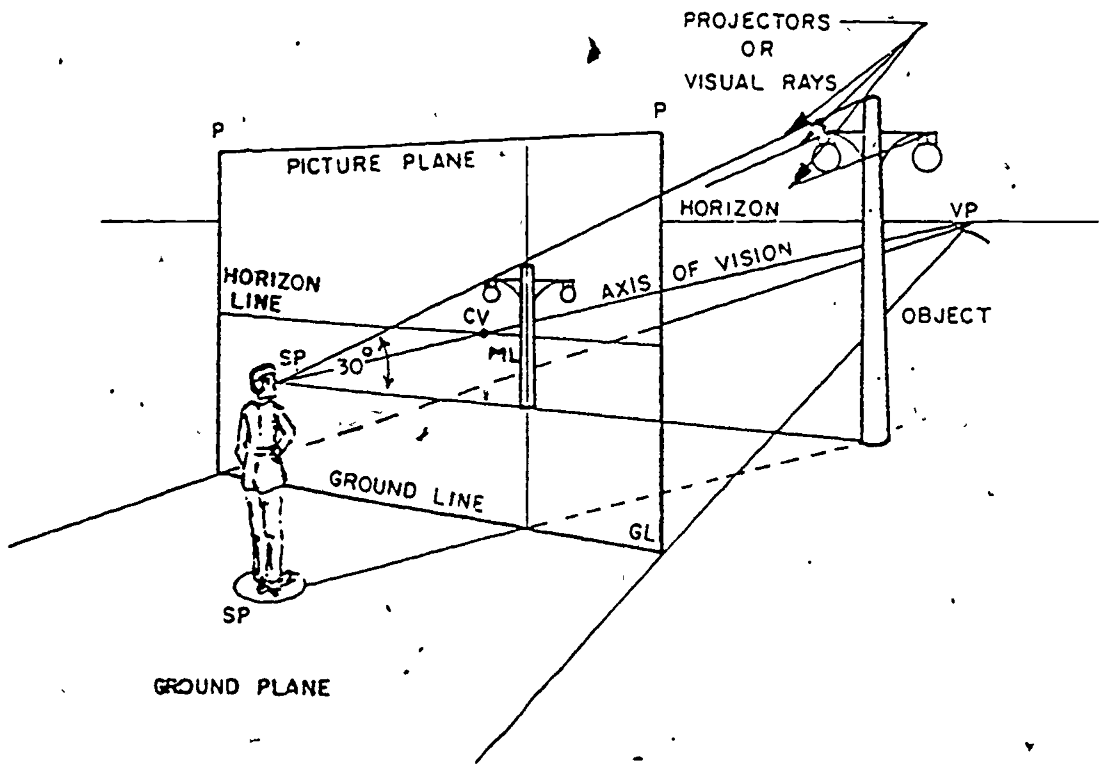


Figure 1. Nomenclature applied (answer for objective 800, exercise 1).

800 - 2. Definitions:
- a. Horizon is a visible or invisible line that represents the actual horizon and eye level of the observer.
- b. Vanishing point (VP) is the point on the horizon where all lines representing parallel horizontal edges converge.
- c. Ground line represents the intersection of the ground plane and the picture plane.
- d. Picture plane represents the rectangular outline (real or imaginary).
- e. Station point is the point through which all converging light rays go; position of observer's eyes in relation to object.
- f. Visual rays are converging light rays.
- g. Center (line) of vision (CV) (axis of vision) is the observer's line of sight. It is the point at which this line intersects the picture plane.
- h. Object plane is any vertical surface of the object.
- i. Horizon plane is an invisible plane passing through the station point and the Earth's horizon.
- j. Measuring line (ML) is the part of the object that touches the picture plane.

800 - 3. Due to the fact that the SP is in relation to

the object, if the point shifts, the perspective also shifts accordingly.

800 - 4. By changing (augmenting or decreasing) the perspective; if the picture plane moves closer to the object, the perspective becomes larger. The converse is true, as well.

801 - 1. Three types of perspective are:
a. One-point (parallel) exists when two dimensions are parallel to an imaginary plane of reference (picture plane).
b. Two-point (angular): object is considered sitting at an angle to the picture plane. There are two sets of horizontal edges converging toward two different vanishing points on the eye level or horizon line.
c. With three-point (oblique) perspective none of the object's surfaces are parallel to the picture plane.

801 - 2. A is one-point.
B is two-point.
C is three-point.

802 - 1.

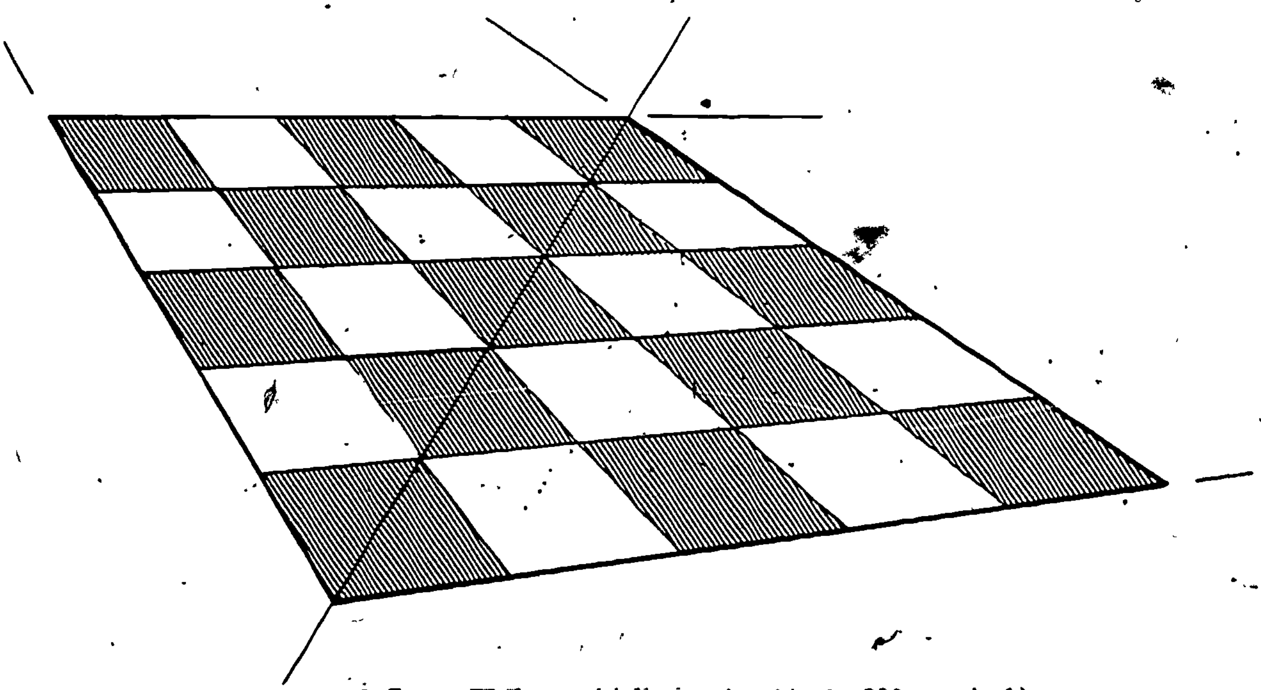


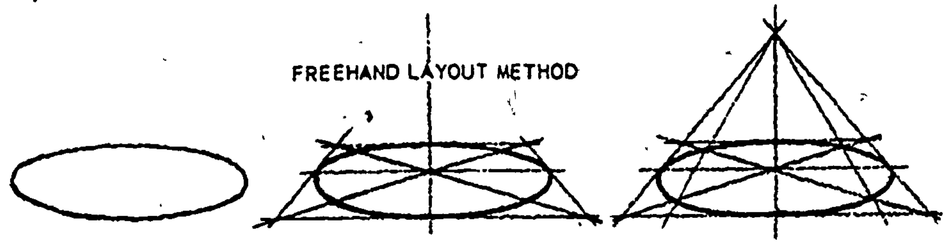
Figure 2. Division of rectangular area (answer for objective 802, exercise 1).

802 - 2. To establish the needed station point and vanishing point(s).

552

803 - 1.

a.



b.

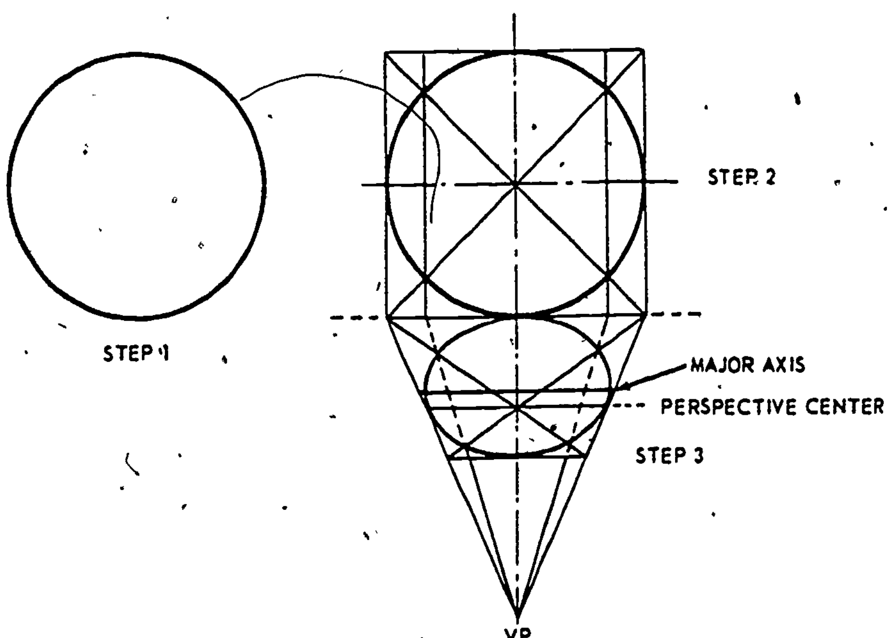


Figure 3. Freehand and mechanical tool layout methods (answer for objective 803, exercise 1).

804 - 1. The horizon, the station point, and the vanishing point(s).

805 - 1. a. Step one is to draw a line to represent the picture plane.
b. Step two is to select the station point (approximately the center of the plan view at a 30° overall angle).

805 - 2. Line (A) *actually* touches the picture plane; it, thus, is not foreshortened (to be discussed further in the next increment). In fact, line (A) is important because it can be used for measuring.

806 - 1. Foreshortening is the illusion created that makes an irregular (free) form appear to go

toward or recede from the viewer.

806 - 2. Main consideration:
  a. Proper use of vanishing point.
  b. Eye level of observer.
  c. Light source.

CHAPTER 2

807 - 1, 1, I; 2, B; 3, H; 4, A; 5, D; 6, F; 7, E; 8, G; 9, C.

808 - 1. General steps:
  a. Understand purpose and scope of illustration then familiarize yourself with the request.
  b. Research if necessary to be sure illustration is technically correct.
  c. Visualize to produce a rough layout (decide how it is to be presented, what it is to look like, and the medium to be used).
  d. Produce the comprehensive layout—an accurate drawing and instructions for rendering or finishing the illustration.

808 - 2. a, c, e, h, and i.

809 - 1. As shown from top to bottom of left column, then from top to bottom of right column.

Orthographic quarter section.	Short break.
Perspective full section.	Long break.
Phantom view.	Cylindrical objects.
Irregular cutaway.	Wood or plastic.
Three-quarter cutaway.	Metal bar.
	Centerline.
	Hidden line.
	Phantom line.
	Sectioning extension line.
	Leader line.
	Dimension line.
	Visible form line.

810 - 1. Block diagrams, which do not actually show motion or function, display a theoretical arrangement of components and symbolic interconnection. Whereas, schematic diagrams use symbols in the form of color (not words), line, line patterns, tones and the like to show motion (function). Wiring diagrams, the last main type of symbolic illustration, is concerned with the lines representing the path that actual wires take in a specific, *real* system component. (Schematic is most concerned with signal flow.)

810 - 2. (From top) Equipment, component, shield, inclosures (mechanical equipment), chassis outline, signal path (or base lines), envelope filament grids cathode, vacuum tubes plate, and lead or circuit lines (and graphic symbols).

811 - 1. Check your work against figure 2-15.

812 - 1. 6⅝ by 8½ inches.

812 - 2. 6 by 12 inches.

813 - 1. The lettering must be 1/15 of the height of the graphic. In this case it must be 2/3 (10:15 - 2/3). The line weight must be at least 1/75 of 13⅓ inches. Therefore, it must be at least 1/6 inch thick.

813 - 2. Since the minimum height for lettering is 1/15 of the graphic height, the largest that the graphic can be is 15 times the height of the lettering which is 5 inches (15 × 1/3 = 5).

813 - 3. If the graphic can be seen on the monitor with sufficient clarity to illustrate its point, your sizes and styles are appropriate.

814 - 1. The advantage of using black and white in all TV illustrations is that it gives the video engineer a reference on which he can set up his basic video levels. Besides the fact that black and white may not fit well into the design of an illustration, using black and white next to each other may cause a halo or horizontal streaking.

814 - 2. The TV system is not as effective in distinguishing tone as is the human eye. If you did not restrict your use of gray to 3 or 4 separated tones, some of the different tones might appear to be the same tone.

814 - 3. Value. You should compare the value of colors with the values of gray.

814 - 4. Lay a sheet of wax paper over your illustration and step back to the appropriate viewing distance. The net result is very similar to what the TV system does to your illustration. BIG, BOLD, and SIMPLE is the criterion to apply.

815 - 1. 1, f; 2, e; 3, a; 4, g; 5, h; 6, b; 7, d; and 8, c.

816 - 1. Glass, photographic film, and acetate.

816 - 2. Because they can be made in any size to fit any projector, provide excellent definition of detail, and they do not easily smudge.

817 - 1. Diazo transparencies are larger than most slides, thus (in terms of drawing) more detailed and easier to cut out mistakes.

817 - 2. The steps for a diazo multicolored projectual are:
  a. Draw the original artwork and punch for pin registration.
  b. Punch as many sheets of tracing paper and Diazochrome as colors to be used. Also punch the number of mounting frames needed.
  c. Place a sheet of tracing paper over the original and registration pins, and opaque areas to be printed in one color. Repeat for each color.
  d. Place appropriate Diazochrome and tracing paper over registration pins and expose in exposure unit. Repeat for each color.
  e. Develop each Diazochrome in the developing unit.
  f. Assemble the projectual by placing a mounting frame and the Diazochrome films over the registration pins.
  g. Tape the assembled projectual to the mount.

817 - 3. Refer to a monograph chart such as shown in figure 2-25.

CHAPTER 3

818 - 1. 1, a; 2, c; and 3, e.

818 - 2. 6 lines.

819 - 1. 1, k; 2, c; 3, a; 4, e; 5, h; 6, f; 7, b; 8, d; 9, g; and 10, j.

820 - 1. a (ratio is 1 to 3), b (turn adjust dial), d (pull lead strip to break inner bond), e (raise only slightly), f (indicated on the typemaster), h (zero on dial).
820 - 2. e (developing process will start automatically).

821 - 1. Diazotype and by electrostatic.
821 - 2. Dry-developing and semi-dry developing.
821 - 3. No special paper is needed.
821 - 4. D (a), D (b), E (c), E (d), D (e), E (f), D (g), E (h), E (i).

822 - 1. Retouching adds the qualities to a photograph that the photographer failed or could not obtain.
822 - 2. The phantom effect is obtained by laying a sheet of Solotone over the photograph and scraping away the surface over the subject.
822 - 3. Cropping indicates the exact part of a photo that should be reproduced (also indicates what part of the photo is not needed).
822 - 4. Since photos used for illustrations are seldom the same size as the final print, scaling up or down (depending on the task at hand) is a necessary process.

823 - 1. Black is used in color reproduction because the mixture of the three primaries does not produce a neutral black. It is also used to give tone and body to other colors.
823 - 2. Indirect method: a, h.
Direct method: k, g, l.
Blue-violet filter: c.
Lap register: j.
Green filter: m.
Red printer: f.
Blue printer: n.
Yellow-red filter: n.
Neutral black rendering: o.
Tissue overlay: p, d.
Key line: b.
Acetate overlay; i, e.

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6-1 550

STOP– 1. MATCH ANSWER SHEET TO THIS EXERCISE NUMBER. 2. USE NUMBER 1 OR NUMBER 2 PENCIL.

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EXTENSION COURSE INSTITUTE
VOLUME REVIEW EXERCISE
DRAWING AND PRODUCTION

Carefully read the following:

DO'S:

1. Check the "course," "volume," and "form" numbers from the answer sheet address tab against the "VRE answer sheet identification number" in the righthand column of the shipping list. If numbers do not match, take action to return the answer sheet and the shipping list to ECI immediately with a note of explanation.
2. Note that numerical sequence on answer sheet alternates across from column to column.
3. Use a medium sharp #1 or #2 black lead pencil for marking answer sheet.
4. Circle the correct answer in this test booklet. After you are sure of your answers, transfer them to the answer sheet. If you *have* to change an answer on the answer sheet, be sure that the erasure is complete. Use a clean eraser. But try to avoid any erasure on the answer sheet if at all possible.
5. Take action to return entire answer sheet to ECI.
6. Keep Volume Review Exercise booklet for review and reference.
7. If *mandatorily* enrolled student, process questions or comments through your unit trainer or OJT supervisor.
   If *voluntarily* enrolled student, send questions or comments to ECI on ECI Form 17.

DON'TS:

1. Don't use answer sheets other than one furnished specifically for each review exercise.
2. Don't mark on the answer sheet except to fill in marking blocks. Double marks or excessive markings which overflow marking blocks will register as errors.
3. Don't fold, spindle, staple, tape, or mutilate the answer sheet.
4. Don't use ink or any marking other than a #1 or #2 black lead pencil.

NOTE: NUMBERED LEARNING OBJECTIVE REFERENCES ARE USED ON THE VOLUME REVIEW EXERCISE. In parenthesis after each item number on the VRE is the *Learning Objective Number* where the answer to that item can be located. When answering the items on the VRE, refer to the *Learning Objectives* indicated by these *Numbers.* The VRE results will be sent to you on a postcard which will list the *actual* VRE *items you missed.* Go to the VRE booklet and locate the *Learning Objective Numbers* for the items missed. Go to the text and carefully review the areas covered by these references. Review the entire VRE again before you take the closed-book Course Examination.

Multiple Choice

1. (800) What is the point on the horizon where all horizontal, parallel receding lines converge?

   a. Vanishing point.
   b. Station point.
   c. Ground line.
   d. Picture plane.

2. (800) Which of the following can be used as a measuring line for establishing the relationship between parts of a picture?

   a. Horizon.
   b. Ground line.
   c. Vanishing point.
   d. Vertical plane point.

3. (800) The point through which all converging light rays pass is called the

   a. picture plane.
   b. vanishing point.
   c. station point.
   d. axis of vision.

4. (800) What does the object plane represent?

   a. Any vertical surface of the object.
   b. Any horizontal surface of the object.
   c. Any line parallel with the axis of vision.
   d. Any vertical or horizontal surface of the object.

5. (800) To draw a three-dimensional object on a two-dimensional surface, you must know the

   a. shape and dimensions of the object.
   b. purpose for which the drawing is to be used.
   c. number of lines required to complete the drawing.
   d. number of thumbnail sketches required to complete the project.

6. (800) Select the correct statement.

   a. Moving the picture plane closer to the station point increases the perspective.
   b. Positioning the picture plane at an angle with the object simplifies the perspective drawing.
   c. The closer you place the station point to the object, the more lifelike the perspective will appear.
   d. A good rule is to place the station point so that the largest angle between any two visual rays is 30°.

7. (801) When does parallel or one-point perspective occur?

   a. When the height and width are oblique to the picture plane.
   b. When the height and width are parallel to the picture plane.
   c. When the horizon line is above the object.
   d. When the horizon line is below the object.

8. (801) What is another name for angular perspective?

   a. Four-point perspective.
   b. Three-point perspective.
   c. Two-point perspective.
   d. One-point perspective.

9. (801) What is the only dimension parallel to the picture plane in an angular perspective?

   a. Station point.
   b. Width.
   c. Height.
   d. Depth.

10. (802) What should be established before any measurements are made?

a. The horizon line.
b. The size of the object.
c. The needed vanishing points and horizon line.
d. The needed vanishing points and station point.

11. (802) Where is the ruler used in perspective drawing to divide an area into a number of parts?

a. On a line parallel to the picture plane, either horizontal or vertical.
b. On a line parallel to the station point, either horizontal or vertical.
c. On a line parallel to the vanishing point lines.
d. A ruler is not necessary in perspective drawing.

12. (803) What is the function of a circle in relation to perspective in a two-dimensional drawing?

a. It serves the same function as that of the cube.
b. The circle is the guide for drawing all three-dimensional illustrations.
c. The circle is most often used to control vertical and horizontal format.
d. The circle is the guide for drawing all two-dimensional curves, ellipses and ovals in perspective.

13. (804) What are the major things to remember in perspective drawing?

a. The horizon, measurements, and the station point.
b. Visual rays, the centerline of vision, and the horizon.
c. The picture plane, the ground line, and the object plane.
d. The horizon, the station point, and the vanishing points.

14. (805) What is the purpose of a plan and elevation view in perspective?

a. To permit drawing an object approximately as it would be seen by the human eye.
b. To show that all lines in perspective are foreshortened.
c. To show that perspective is a very limited method.
d. To show that a picture plane is not necessary.

15. (806) An irregular form appearing to recede from or come toward the viewer causes a phenomenon known as

a. free form.
b. foreshortening.
c. refraction.
d. perspective.

16. (806) From an established light source, shadows

a. are not shown in perspective.
b. never follow any contour plane.
c. recede to different vanishing points.
d. follow the contour of the plane upon which they fall.

17. (807) A narrative presentation may be either written or oral and is normally presented in

a. slide form.
b. story form.
c. data form.
d. graphic form.

18. (808) Translating the basic composition of the rough layout into an accurate, well-drawn, or projected outline drawing is a step for

a. a rough layout.
b. a thumbnail layout.
c. the finished layout.
d. a comprehensive layout.

19. (808) Which of the following is a step in the rendering procedure?

   a. Familiarize yourself with the request for the illustration.
   b. Make a rough sketch of the illustration.
   c. Mount the illustration as needed.
   d. Establish firmly what to show.

20. (809) Which choice is correct concerning the comprehensive pictorial?

   a. May be a phantom view.
   b. May be an exploded view.
   c. May be an orientation view.
   d. May not be an operational illustration.

21. (809) A phantom view is drawn to show portions of a subject as if it were

   a. transparent.
   b. translucent.
   c. solid.
   d. opaque.

22. (809) When you want to show internal parts and external surface, you should use

   a. a side view.
   b. a plan view.
   c. a phantom view.
   d. an exploded view.

23. (809) "A line that consists of a series of short, evenly spaced dashes" defines a

   a. hidden line.
   b. centerline.
   c. leader line.
   d. phantom line.

24. (810) An illustration that uses lines, colors, graphic symbols, and words is

   a. a pictorial illustration.
   b. a symbolic illustration.
   c. a finished illustration.
   d. an orthographic illustration.

25. (810) What kind of diagrams are primarily concerned with data flow?

   a. Schematic diagrams.
   b. Wiring diagrams.
   c. Block diagrams.
   d. Mechanical diagrams.

26. (810) In a circuit diagram, which of the following is used to indicate an electrical shield?

   a. Solid lines.
   b. A series of long dashes.
   c. A series of short dashes.
   d. Alternate long and short dashes.

27. (811) What does the dashed line of an electrical relay indicate?

   a. That all relay contacts open at the same time.
   b. That all relay contacts close at the same time.
   c. That relay contacts are closed only when the relay is energized.
   d. That all relay contacts move simultaneously when the relay is energized.

28. (811) What are dog legs?

   a. Zigzag lines.
   b. Callout lines.
   c. Dimension lines.
   d. Break lines.

29. (811) The primary purpose of a wiring diagram is to

   a. show signal flow.
   b. illustrate theory.
   c. show wiring connections between components.
   d. show the location of auxiliary power sources.

30. (812) Concerning visual materials for television, aspect ratio refers to the

a. width of the TV screen.
b. height of the TV screen.
c. number of lines on a TV screen.
d. relation between the height and width of the TV screen.

31. (812) The rule that allows for edge loss and establishes a safety field is called the

a. one-eighth rule.
b. one-sixth rule.
c. one-fourth rule.
d. one-half rule.

32. (813) The minimum line weight for a TV graphic is

a. 1/75 the width of the copy layout.
b. 1/50 the width of the copy layout.
c. 1/25 the width of the copy layout.
d. 1/15 the width of the copy layout.

33. (813) You must make nine graphic TV illustrations having a basic size of 10 by 13 1/3 inches. How many sheets of 30- by 40-inch television gray board will be required?

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

34. (814) For television, using black and white next to each other may cause

a. a fade out.
b. a grayed blending.
c. an all-black presentation.
d. halo and horizontal streaking.

35. (814) To allow the TV video engineer to set up the video levels, what must you include in each TV graphic?

a. Both black and white.
b. Either black or white.
c. Three or four tones of gray.
d. Black, white, and a medium gray.

36. (814) On black and white TV, when an object's color has the same gray scale value as the background, the

a. background is grayed.
b. object appears invisible to the TV camera.
c. object's color is visible only to the TV camera.
d. object will appear more clearly on the monitor screen.

37. (814) The resolution of a TV system tells the illustrator how

a. to apply ink by hand.
b. to use registration marks.
c. a mistake can be corrected.
d. much detail he can put into an illustration.

38. (815) The original artwork for rear view projection is photographed and normally reduced to a

a. 2- by 4-inch transparency.
b. 5- by 7-inch transparency.
c. 8- by 10-inch transparency.
d. 2- by 2-inch or 4- by 5-inch transparency.

39. (815) The principle of the phantom is based on

a. color values.
b. line construction.
c. drawing an illustration on a gray background using charcoal sticks.
d. drawing an illustration on a white background using a number B1 pencil.

40. (815) The simplest method of presenting animation on television is by

a. technamation.
b. crawl.
c. slide cards.
d. pop-ins.

41. (815) Information appearing in a cutout window or picture frame type setting is an example of a

a. gobo.
b. crawl.
c. pop-in.
d. slide card.

42. (816) India ink and transparent color inks can only be used on

a. enamel spray slides.
b. etched glass slides.
c. clear glass slides.
d. sandwich slides.

43. (816) What type of glass slide must you use if lettering produced on a typewriter is to be shown?

a. Enamel spray slide.
b. Etched glass slide.
c. Sandwich slide.
d. Clear glass slide.

44. (816) Which of the following types of acetate slides is capable of producing the most unusual effect?

a. Etched.
b. Frosted.
c. Carbon.
d. Clear.

45. (816; 817) The basic artwork used to produce diazo transparencies is easier to work on than artwork used to produce glass slides because

a. it is larger.
b. it can be more detailed.
c. you can use bolder strokes.
d. mistakes can be more easily corrected.

46. (817) A multicolored diazo projectual is made by

a. offset printing.
b. four-color printing.
c. coloring a single transparency.
d. assembling separate Diazochromes.

47. (817) What is the single most important factor when combining two or more transparencies to form one projectual?

a. Color.
b. Registration.
c. Tape mounts.
d. The first overlay.

48. (817) What is the minimum height for lettering on an overhead projectual if the projection distance is 15 feet and the farthest viewer is 43 feet?

a. .05 inch.
b. .10 inch.
c. .15 inch.
d. .20 inch.

49. (818) The printing process that uses type is

a. letterpress.
b. lithography.
c. gravure.
d. silk screen.

50. (818) Type is measured in points, and a point is 0.013837 inch. Which of the following corresponds approximately to this measurement?

a. 1/72 inch.
b. 1/64 inch.
c. 1/32 inch.
d. 1/16 inch.

51. (818) How many lines of 18-point type can be printed in a space 3 inches high?

a. 3.
b. 6.
c. 8.
d. 12.

52. (818) What size type set solid must be used to print copy of 192 words in a space 2 by 3 inches?

a. 6.
b. 8.
c. 10.
d. 12.

53. (818) What principle applies to the lithograph process?

a. That like electrical charges repel.
b. That unlike electrical charges attract.
c. That grease and water have no affinity for each other.
d. That printing ink is retained in grooves and wiped from the surface.

54. (819) The process of printing which allows the greatest selection of printing surfaces is the

a. silk screen.
b. lithography.
c. letterpress.
d. gravure.

55. (819) What is the most important precaution to observe when cutting a film stencil for the silk screen process?

a. Do not cut the silk.
b. Do not cut the backing paper.
c. Do not remove any of the film.
d. Do not apply too much lacquer thinner.

56. (819) When preparing the silk screen for printing, the film stencil is attached to the silk by applying

a. an adhering liquid.
b. a warm iron.
c. paper tape.
d. turpentine.

57. (819) What type of stencil can be adhered to the silk by heating it with a warm iron?

a. Lacquer.
b. Shellac.
c. Film.
d. Tusche.

58. (819) In making a stencil for the silk screen using the tusche method, what is used to block out the areas of the design which are not printed?

a. Rubber cement.
b. Masking tape.
c. Fish glue.
d. Mucilage.

59. (820) What office machine is capable of producing type-like lettering?

a. Xerox.
b. Thermofax.
c. Photo composing.
d. Lithograph.

60. (820) What is the normal setting for the exposurminder?

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

61. (820) How much paper should be fed into the photo composing machine after composition has been completed?

a. 3 inches.
b. 7 inches.
c. 10 inches.
d. 15 inches.

62. (821) Concerning diazotype reproduction, the ammonia developing process is a

a. wet process.
b. dry process.
c. semimoist process.
d. semidry process.

63. (821) If you are allergic to ammonia, the type of diazotype process which you should avoid using is the

a. moist process.
b. semidry process.
c. dry process.
d. ultraviolet process.

64. (821) The Xerox process is based on the principle of

a. repellency of water and oil.
b. electrostatic transfer.
c. lithographic printing.
d. diazotype printing.

65. (822) What is the simplest technique for subduing the background of a photograph?

a. Apply a light transparent wash over the background.
b. Use an airbrush and opaque paint to retouch the area.
c. Stipple the area using a large bristle brush, and retouch grays.
d. Use a Solotone sheet over the photograph and scrape away the surface over the subject.

66. (822) When lettering or line work is done on any kind of tone drawing, the final product must be produced

a. photographically.
b. in a combination copy.
c. using the silk screen method.
d. using the double overlay method.

67. (823) How is color achieved in halftone color separation negatives made directly from the original color illustration?

a. By photographing the original artwork in full color.
b. By using a subtractive color separation process and monochrome filters.
c. By making screen negatives directly from the artwork by using filters.
d. By using an additive color separation process and complementary filters.

68. (823) A red printer uses

a. a yellow-red filter.
b. an orange filter.
c. a green (yellow-blue) filter.
d. a blue-violet filter.

69. (823) What simple method can an illustrator use to indicate to the lithographer the desired color separation of a finished product?

a. Key line method.
b. Tissue overlay method.
c. Acetate overlay method.
d. Color strip method.

70. (823) With the acetate overlay method,

a. color work with large masses may be treated.
b. the sheet is placed on the original drawing, frosted side up.
c. the sheet is placed on the original drawing, frosted side down.
d. the areas containing color are outlined and filled in with pencil.