NONRESIDENT
TRAINING
COURSE

April 1995

Engineering Aid 3

NAVEDTRA 14069

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

COMMANDING OFFICER
NETPMSA
6490 SAUFLEY FIELD ROAD
PENSACOLA FL 32509-5237

04 Jun 96

ERRATA # 2

Specific Instructions and Errata for
Training Manual

ENGINEERING AID BASIC

1. This errata supersedes all previous errata.

2. No attempt has been made to issue corrections for errors in typing, punctuation, and so forth, that do not affect technical accuracy or readability.

3. Make the following changes:

Page	Column	Change
2-3	1	Replace “Naval Publications and Forms Center” with “Aviation Support Office”
3-11		Replace figure 3-14 with figure 3-14 A & B
3-19	2	Replace “DOD-STD-1OOC” with “MIL-STD-1OOE”
5-7		Replace figure 5-12 with figures 5-11 and 5-12
7-17	1	Replace figure 7-22 with figures 7-21 and 7-22
14-19		Replace caption in figure 14-20 with “Sample field notes from cross-section leveling at first three stations shown in figure 14-17.”
14-28	2	Replace 1200/3.7 with 3.7/1200
14-28	2	Replace 800/-5.0 with -5.0/800

DRAWING FORMATS

Drawing format is the systematic space arrangement of required information within the drafting sheet. This information is used to identify, process, and file drawings methodically. Standard sizes and formats for military drawings are arranged according to DoD-STD-100C, *Engineering Drawing Practices,* and MIL-HDBK- 1006/1, *Policy and Procedures for Project Drawing and Specification Preparation.* With the exception of specific local command requirements, DoD-STD-1OOC and MIL-HDBK-1006/1 are your guidelines for preparing SEABEE drawings.

Most of the documents applicable to these standards have recently been revised and updated in order to gain like information and to share uniformity of form and language within the Naval Construction Force and between DoD organizations. Other influencing factors are the current widespread use of reduced-size copies of both conventional and computer-generated drawings and exchange of microfilm.

SHEET SIZES

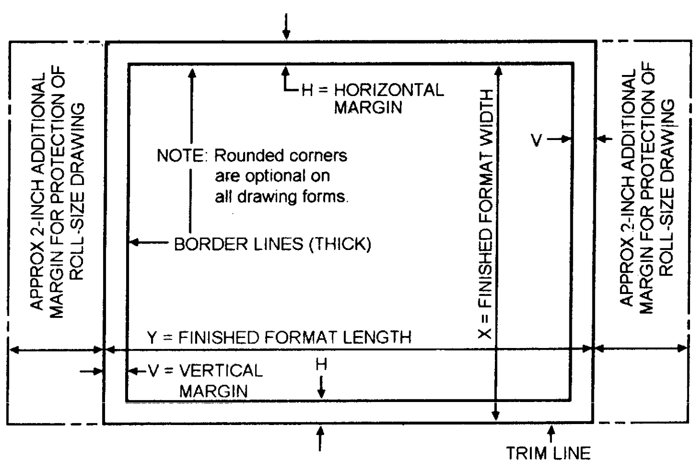
Standard drawing sheet sizes are used to facilitate readability, reproduction, handling, and uniform filing. Blueprints produced from standard size drawing sheets are easily assembled in sets for project stick files and can readily be folded for mailing and neatly filed in project letter size or legal size folders. (Filing drawings and folding blueprints will be covered later in this training manual.)

Finished format sizes for drawings shown in figure 3-14, view A, are according to ANSI Y14.1

FLAT SIZES					ROLL SIZES					
SIZE DESIGNATION LETTER	X (WIDTH)	Y (LENGTH)	MARGIN H (HORIZ)	MARGIN V (VERT)	SIZE DESIGNATION LETTER	X (WIDTH)	Y (LENGTH) MIN	Y (LENGTH) MAX	MARGIN H (HORIZ)	MARGIN V (VERT)
A(HORIZ)	8.5	11.0	0.38	0.25	G	11.0	22.5	90.0	0.38	0.50
A(VERT)	11.0	8.5	0.25	0.38	H	28.0	44.0	145.0	0.50	0.50
B	11.0	17.0	0.38	0.62	J	34.0	55.0	176.0	0.50	0.50
C	17.0	22.0	0.75	0.50	K	40.0	55.0	143.0	0.50	0.50
D	22.0	34.0	0.50	1.00						
E	34.0	44.0	1.00	0.50						
F	28.0	40.0	0.50	0.50						

NOTES: 1. ADDITIONAL PROTECTION MARGINS FOR ROLL SIZE DRAWINGS ARE NOT INCLUDED IN ABOVE DIMENSIONS.
2. ALL DIMENSIONS ARE IN INCHES.

A



B

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45.857

Figure 3-14.—Guide for preparing horizontal and vertical margins, sizes, and finished drawing format.

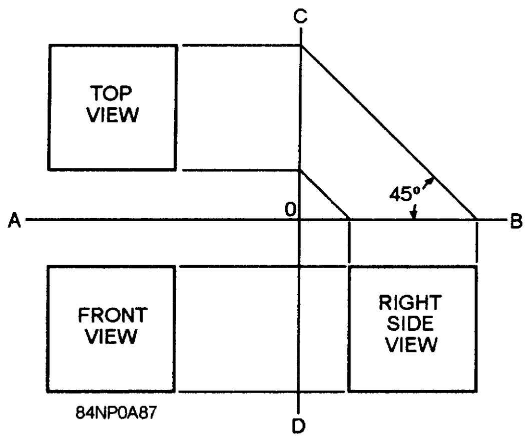

Figure 5-11.—Alternative method of extending to top view projection lines.

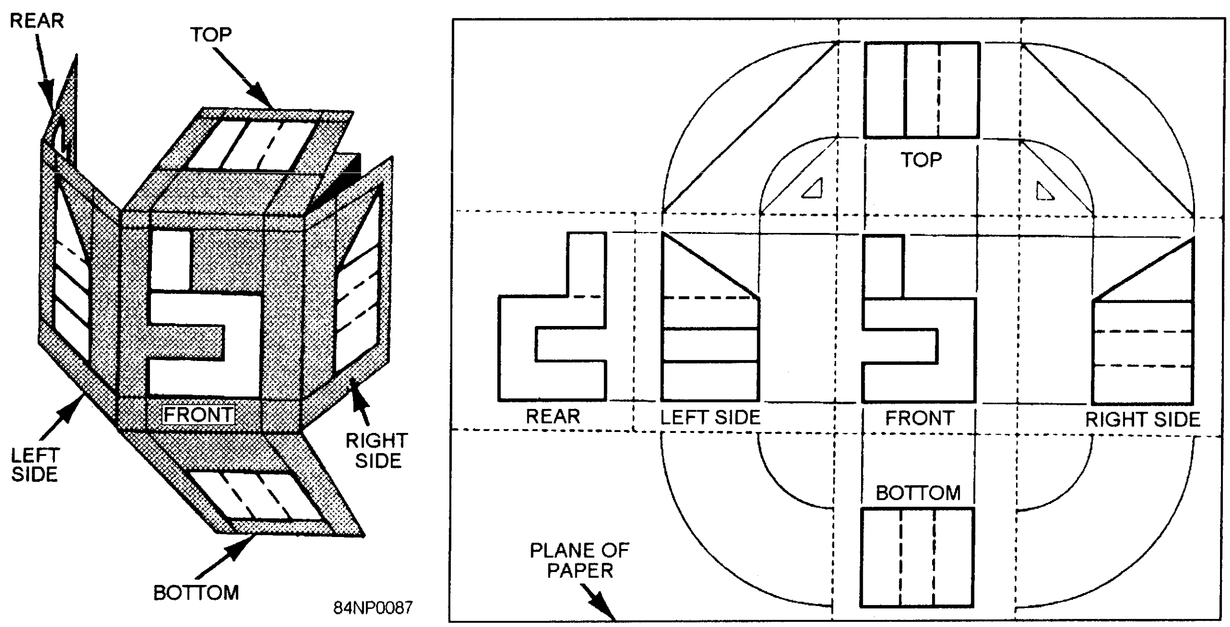

Figure 5-12.—American standard arrangement of views in a six-view third-angle multi-view projection.

view always lies in the plane of the drafting surface and does not require any rotation. Notice that the front, right side, left side, and rear views line up in direct horizontal projection.

Use the minimum number of views necessary to show an item. The three principal views are the top, front, and right-side. The TOP VIEW (also called a PLAN in architectural drawings) is projected to and drawn on an image plane above the front view of the object. The FRONT VIEW (ELEVATION) should show the most characteristic shape of the object or its most natural appearance when observed in its permanent or fixed position. The RIGHT-SIDE VIEW (ELEVATION) is located at a right angle to the front and top views, making all the views mutually perpendicular.

SPACING OF VIEWS.— Views should be spaced on the paper in such a manner as

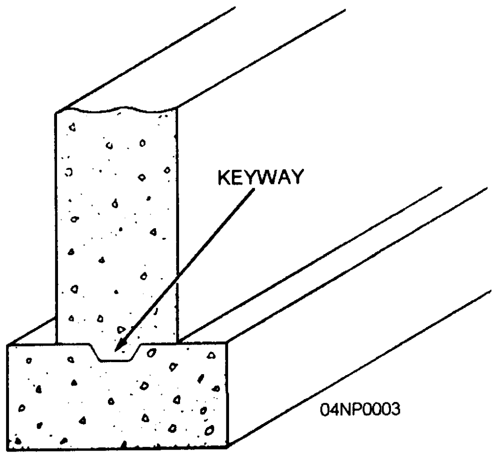

Figure7-21.—Construction joint between wall and footing with a keyway.

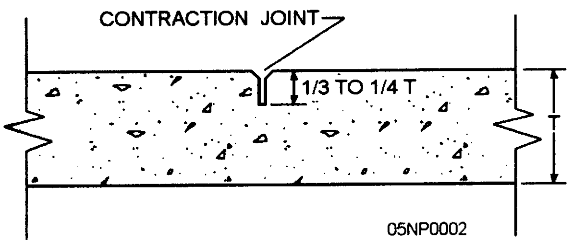

Figure 7-22.—Use of a contraction joint.

incident to shrinkage of the concrete. Atypical dummy contraction joint (fig. 7-22) is usually formed by cutting a depth of one third to one fourth the thickness of the section. Some contracting joints are made with no filler or with a thin coat of paraffin or asphalt and/or other materials to break the bond. Depending on the extent of local temperature, joints in reinforced concrete slabs may be placed at 15- to 25-ft intervals in each direction.

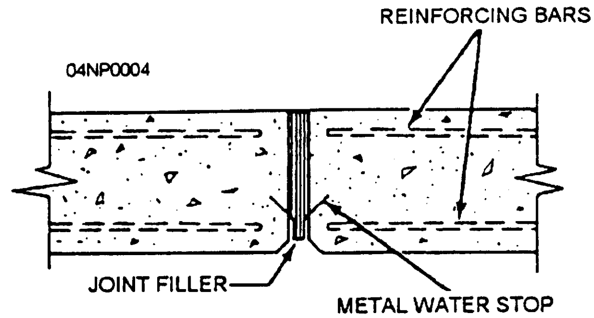

Figure 7-23.—Expansion joint for a wall.

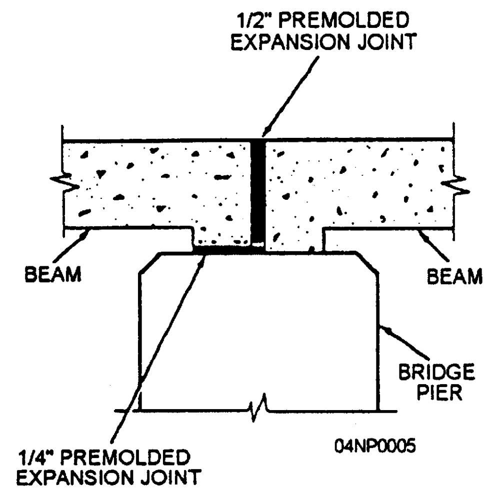

Figure 7-24.—Expansion joint for a bridge.

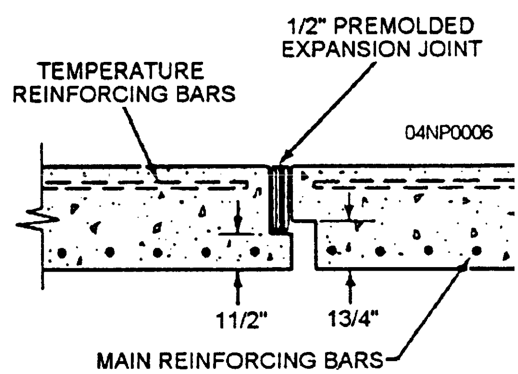

Figure 7-25.—Expansion joint for a floor slab.

Expansion Joints

Wherever expansion might cause a concrete slab to buckle because of temperature change, expansion joints (also called isolation joints) are required. An expansion joint is used with a pre-molded cork or mastic filler to separate sections from each other, thus allowing room for expansion if elongation or closing of the joint is anticipated. Figures 7-23, 7-24, and 7-25 show expansion joints for a variety of locations. Expansion joints may be installed every 20 ft.

CONCRETE FORMS

Most structural concrete is made by placing (also called CASTING) plastic concrete into

PREFACE

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

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

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

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

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1995 Revision
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Sailor's Creed

"I am a United States Sailor.

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

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

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

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

CONTENTS

CREDITS

The illustration indicated below is included in this edition of *Engineering Aid Basic* through the courtesy of the designated company. Permission to use this illustration is gratefully acknowledged.

SOURCE	FIGURE
ELE International, Inc.	15-28

INSTRUCTIONS FOR TAKING THE COURSE

ASSIGNMENTS

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

SELECTING YOUR ANSWERS

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

SUBMITTING YOUR ASSIGNMENTS

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

Grading on the Internet: Advantages to Internet grading are:

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

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

http://courses.cnet.navy.mil

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

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

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

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

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

COMPLETION TIME

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

PASS/FAIL ASSIGNMENT PROCEDURES

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

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

COMPLETION CONFIRMATION

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

ERRATA

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

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

STUDENT FEEDBACK QUESTIONS

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

For subject matter questions:

E-mail: n314.products@cnet.navy.mil
Phone: Comm: (850) 452-1001, Ext. 1754
DSN: 922-1001, Ext. 1754
FAX: (850) 452-1370
(Do not fax answer sheets.)
Address: COMMANDING OFFICER
NETPDTC (CODE N314)
6490 SAUFLEY FIELD ROAD
PENSACOLA FL 32509-5237

For enrollment, shipping, grading, or completion letter questions

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

NAVAL RESERVE RETIREMENT CREDIT

If you are a member of the Naval Reserve, you will receive retirement points if you are authorized to receive them under current directives governing retirement of Naval Reserve personnel. For Naval Reserve retirement, this course is evaluated at 20 points. These points will be credited in units as follows:

Unit 1 - 12 points upon satisfactory completion of Assignments 1 through 8

Unit 2 - 8 points upon satisfactory completion of Assignments 9 through 13

(Refer to *Administrative Procedures for Naval Reservists on Inactive Duty,* BUPERSINST 1001.39, for more information about retirement points.)

COURSE OBJECTIVES

In completing this nonresident training course, you will demonstrate a knowledge of the subject matter by correctly answering questions on the following subjects: Mathematics and Units of Measurement; Drafting Equipment; Drafting: Fundamentals and Techniques; Drafting: Geometric Construction; Drafting: Projections and Sketching; Reproduction Process; Wood and Light Frame Structures; Concrete and Masonry; Mechanical Systems and Plan; Electrical Systems and Plan; Construction Drawings; Elements of Surveying and Surveying Equipment; Direct Linear Measurements and Field Survey Safety; Horizontal Control; Direct Leveling and Basic Engineering Surveys; Materials Testing: Soil and Concrete; and Administration.

Student Comments

Course Title: *Engineering Aid 3* ______________________________

NAVEDTRA: 14069 ______________________ **Date:** ______________

We need some information about you:

Rate/Rank and Name: ______________ SSN: ________ Command/Unit ____________

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

Your comments, suggestions, etc.:

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

NETPDTC 1550/41 (Rev 4-00)

CHAPTER 1

MATHEMATICS AND UNITS OF MEASUREMENT

Mathematics is the Engineering Aid's basic tool. The use of mathematics is found in every rating in the Navy, from the simple arithmetic of counting for inventory purposes to the complicated equations encountered in computer and engineering designs. In the Occupational Field 13 ratings, the Engineering Aid is looked upon as superior in knowledge when it comes to the subject of mathematics, which generally is a correct assumption; however, to be worthy of this calling, you have the responsibility to learn more about this subject. Mathematics is a broad science that cannot be covered fully in formal service school training, so it is up to you to devote some of your own time to the study of this subject.

The EA must have the ability to compute easily, quickly, systematically, and accurately. This requires a knowledge of the fundamental properties of numbers and the ability to estimate the accuracy of computations based on field measurements or collected field data. To compute rapidly, you need constant practice and should be able to use any available device to speed up and simplify computations. In solving a mathematical problem, you should take a different approach than you would if it were simply a puzzle you were solving for fun. Guesswork has no place in its consideration, and the statement of the problem itself should be devoid of anything that might obscure its true meaning. Mathematics is not a course in memory but one in reasoning. Mathematical problems should be read and so carefully analyzed that all conditions are well fixed in mind. Avoid all unnecessary work and shorten the solution wherever possible. Always apply some proof or check to your work. Accuracy is of the greatest importance; a wrong answer is valueless.

This chapter covers various principles of mathematics. The instructions given will aid the EA in making mathematical computations in the field and the office. This chapter also covers units of measurement and the conversion from one system to the other; that is, from the English to the metric system.

FUNDAMENTALS OF MATHEMATICS

MATHEMATICS is, by broad definition, the science that deals with the relationships between quantities and operations and with methods by which these relationships can be applied to determine unknown quantities from given or measured data. The fundamentals of mathematics remain the same, no matter to what field they are applied. Various authors have attempted to classify mathematics according to its use. It has been subdivided into a number of major branches. Those with which you will be principally concerned are arithmetic, algebra, geometry, and trigonometry.

ARITHMETIC is the art of computation by the use of positive real numbers. Starting with the review of arithmetic, you will, by diligent effort, build up to a study of algebra.

ALGEBRA is the branch of mathematics that deals with the relations and properties of numbers by means of letters, signs of operation, and other symbols. Algebra includes solution of equations, polynomials, verbal problems, graphs, and so on.

GEOMETRY is the branch of mathematics that investigates the relations, properties, and measurement of solids, surfaces, lines, and angles; it also deals with the theory of space and of figures in space.

TRIGONOMETRY is the branch of mathematics that deals with certain constant relationships that exist in triangles and with methods by which they are applied to compute unknown values from known values.

STUDY GUIDES

Mathematics is an exact science, and there are many books on the subject. These numerous books are the result of the mathematicians' efforts to solve mathematical problems with ease. Methods of arriving at solutions may differ, but the end results or answers are always the same. These different approaches to mathematical problems make the study of mathematics more interesting, either by individual study or as a group.

You can supplement your study of mathematics with the following training manuals:

1. *Mathematics, Vol. 1,* NAVEDTRA 10069-D1
2. *Mathematics, Vol. 2-A,* NAVEDTRA 10062
3. *Mathematics, Vol. 2-B,* NAVEDTRA 10063
4. *Mathematics, Vol. 3,* NAVEDTRA 10073-A1

TYPES OF NUMBERS

Positive and negative numbers belong to the class called REAL NUMBERS. Real numbers and imaginary numbers make up the number system in algebra. However, in this training manual, we will deal only with real numbers unless otherwise indicated.

A real number may be rational or irrational. The word *rational* comes from the word *ratio.* A number is rational if it can be expressed as the quotient, or ratio, of two whole numbers. Rational numbers include fractions like 2/7, whole numbers (integers), and radicals if the radical is removable. Any whole number is rational because it could be expressed as a quotient with 1 as its denominator. For instance, 8 equals 8/1, which is the quotient of two integers. A number like $\sqrt{16}$ is rational since it can be expressed as the quotient of the two integers in the form 4/1. An irrational number is a real number that cannot be expressed as the ratio of two integers. The numbers

$$\sqrt{3}, \quad 5\sqrt{2}, \quad \sqrt{7+5}, \quad \frac{3}{8}\sqrt{20}, \quad \sqrt{\frac{3}{5}}$$

and 3.1416 (π) are examples of irrational numbers.

An integer may be prime or composite. A number that has factors other than itself and 1 is a composite number. For example, the number 15 is composite. It has the factors 5 and 3. A number that has no factors except itself and 1 is a prime number. Since it is advantageous to separate a composite number into prime factors, it is helpful to be able to recognize a few prime numbers. The following are examples of prime numbers: 1, 2, 3, 5, 7, 11, 13, 17, 19, and 23.

A composite number may be a multiple of two or more numbers other than itself and 1, and it may contain two or more factors other than itself and 1. Multiples and factors of numbers are as follows: Any number that is exactly divisible by a given number is a multiple of the given number. For example, 24 is a multiple of 2, 3, 4, 6, 8, and 12 since it is divisible by each of these numbers. Saying that 24 is a multiple of 3, for instance, is equivalent to saying that 3 multiplied by some whole number will give 24. Any number is a multiple of itself and also of 1.

FRACTIONS, DECIMALS, AND PERCENTAGES

The most general definition of a fraction states that "a fraction is an indicated division. " Any division may be indicated by placing the dividend over the divisor with a line between them. By the above definition, any number, even a so-called "whole" number, may be written as a common fraction. The number 20, for example, may be written as 20/1. This or any other fraction that amounts to more than 1 is an IMPROPER fraction. For example, 8/3 is an improper fraction, The accepted practice is to reduce an improper fraction to a mixed fraction (a whole number plus a proper fraction). Perform the indicated division and write the fractional part of the quotient in its lowest term. In this case, 8/3 would be 2 2/3. A fraction that amounts to less than 1 is a PROPER fraction, such as the fraction 1/4.

To refresh your memory, we are including the following rules in the solution of fractions:

1. If you multiply or divide both the numerator and denominator of a fraction by the same number, the value does not change. The resulting fraction is called an EQUIVALENT fraction.
2. You can add or subtract fractions only if the denominators are alike.
3. To multiply fractions, simply find the products of the numerators and the products of the denominators. The resulting fractional product must be reduced to the lowest term possible.

4. To divide a fraction by a fraction, invert the divisor and proceed as in multiplication.

5. The method of CANCELING can be used to advantage before multiplying fractions (using the principle of rule No. 1) to avoid operations with larger numbers.

A decimal fraction is a fraction whose denominator is 10 or some power of 10, such as 100, 1,000, and so on. For example,

$$\frac{7}{10}, \frac{23}{100}, \text{ and } \frac{87}{1,000}$$

are decimal fractions. Accordingly, they could be written as 0.7, 0.23 and 0.087 respectively. Decimal fractions have certain characteristics that make them easier to use in computations than other fractions. Chapter 5 of NAVEDTRA 10069-D1 deals entirely with decimal fractions. A thorough understanding of decimals will be useful to the Engineering Aid in making various engineering computations. Figure 1-1 shows decimal equivalents of fractions commonly used by Builders, Steelworkers, Utilitiesmen, and other trades.

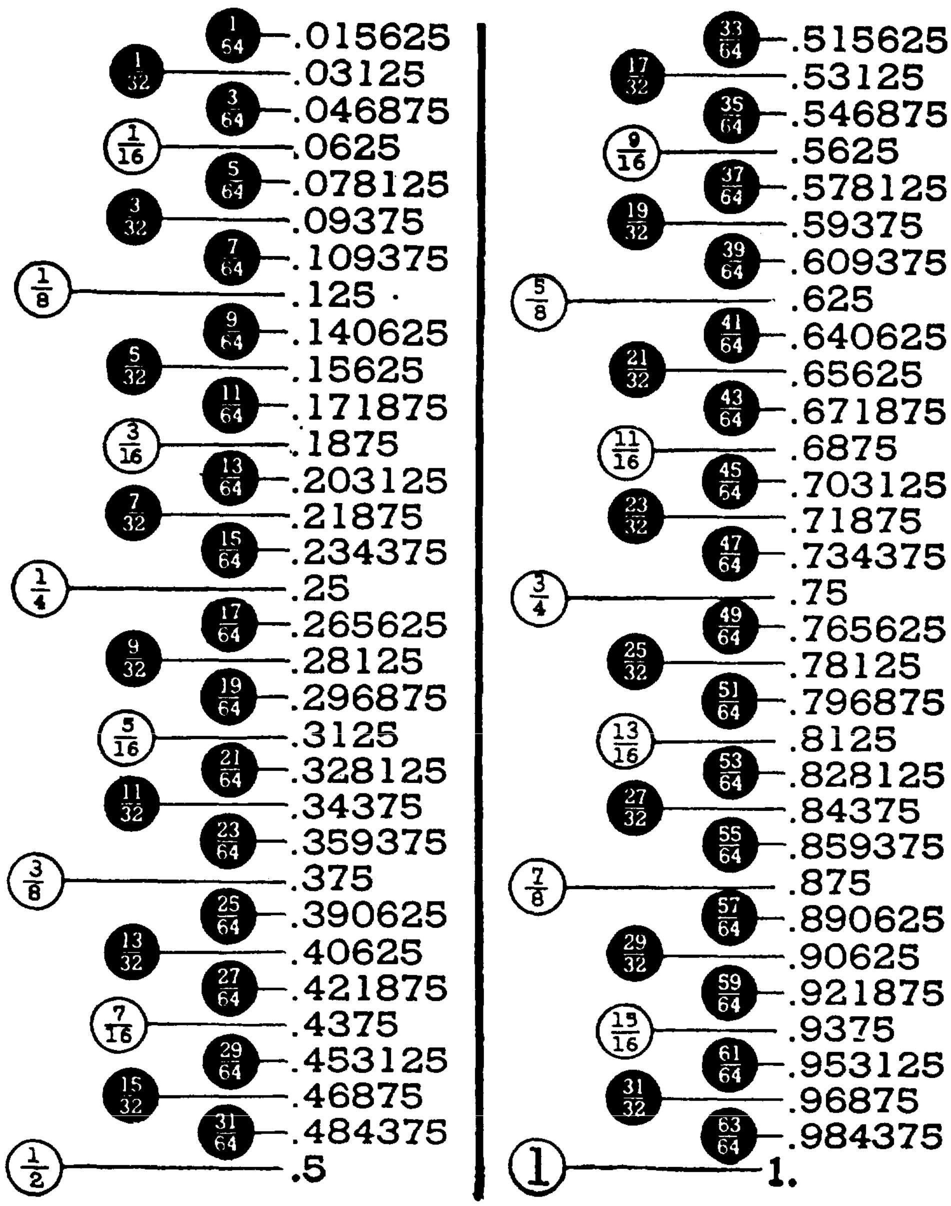

Figure 1-1. Decimal equivalents.

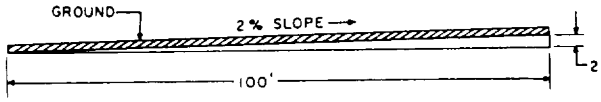

Figure 1-2.-2-percent grade.

In connection with the study of decimal fractions, businessmen as early as the fifteenth century made use of certain decimal fractions so much that they gave them the special designation PERCENT. The word *percent is* derived from Latin. It was originally *per centum,* which means "by the hundredths." In banking, interest rates are always expressed in percent; statisticians use percent; in fact, people in almost all walks of life use percent to indicate increases or decreases in production, population, cost of living, and so on. The Engineering Aid uses percent to express change in grade (slope), as shown in figure 1-2. Percent is also used in earthwork computations, progress reports, and other graphical representations. Study chapter 6 of NAVEDTRA 1-0069-D1 for a clear understanding of percentage.

POWERS, ROOTS, EXPONENTS, AND RADICALS

Any number is a higher power of a given root. To raise a number to a power means to multiply, using the number as a factor as many times as the power indicates. A particular power is indicated by a small numeral called the EXPONENT; for example, the small 2 on 3^2 is an exponent indicating the power.

Examples:

$$3^2 = 3 \times 3 = 9$$

$$3^3 = 3 \times 3 \times 3 = 27$$

$$6^2 = 6 \times 6 = 36$$

$$6^3 = 6 \times 6 \times 6 = 216$$

Many formulas require the power or roots of a number. When an exponent occurs, it must always be written unless its value is 1.

A particular ROOT is indicated by the radical sign ($\sqrt{\ }$), together with a small number called the INDEX of the root. The number under the radical sign is called the RADICAND. When the radical sign is used alone, it is generally understood to mean a square root, and $\sqrt[3]{\ }$, $\sqrt[5]{\ }$, and $\sqrt[7]{\ }$, indicate cube, fifth, and seventh roots, respectively. The square root of a number may be either + or – . The square root of 36 may be written thus: $\sqrt{36} = \pm 6$, since 36 could have been the product of (+ 6)(+ 6) or (– 6)(– 6). However, in practice, it is more convenient to disregard the double sign (±). This example is what we call the root of a perfect square. Sometimes it is easier to extract part of a root only after separation of the factors of the number, such as: $\sqrt{27} = \sqrt{9 \times 3} = 3\sqrt{3}$. As you can see, we were able to extract only the square root of 9, and 3 remains in the radical because it is an irrational factor. This simplification of the radical makes the solution easier because you will be dealing with perfect squares and smaller numbers.

Examples:

$$\sqrt{25} = \sqrt{5 \times 5} = 5$$

$$\sqrt{24} = \sqrt{4 \times 6} = 2\sqrt{6} = 2 \times 2.236 = 4.472$$

$$\sqrt[3]{40} = \sqrt[3]{8 \times 5} = 2\sqrt[3]{5} = 2 \times 1.710 = 3.420$$

Radicals are multiplied or divided directly.

Examples:

$$\sqrt{3} \times \sqrt{6} = \sqrt{18} = \sqrt{9 \times 2} = 3\sqrt{2}$$

$$\frac{\sqrt{12}}{\sqrt{3}} = \frac{\sqrt{4} \times \sqrt{3}}{\sqrt{3}} = \sqrt{4} = \pm 2$$

Like fractions, radicals can be added or subtracted only if they are similar.

Examples:

$$2\sqrt{5} + \sqrt{5} = 3\sqrt{5}$$

$$\sqrt{2 \times 4} + \sqrt{2 \times 9} = \sqrt{2}(\sqrt{4}) + \sqrt{2}(\sqrt{9})$$

$$= 2\sqrt{2} + 3\sqrt{2}$$

$$= 5\sqrt{2}$$

When you encounter a fraction under the radical, you have to RATIONALIZE the denominator before performing the indicated operation. If you multiply the numerator and denominator by the same number, you can extract the denominator, as indicated by the following example:

$$\sqrt{\frac{2}{5}} = \frac{\sqrt{2}}{\sqrt{5}} \times \frac{\sqrt{5}}{\sqrt{5}} = \frac{\sqrt{10}}{\sqrt{25}} = \frac{1}{5}\sqrt{10}$$

The same is true in the division of radicals; for example,

$$\sqrt{\frac{3}{6}} = \frac{\sqrt{3}}{\sqrt{6}} \div \frac{\sqrt{3}}{\sqrt{3}} = \frac{1}{\sqrt{2}}$$

Any radical expression has a decimal equivalent, which may be exact if the radicand is a rational number. If the radicand is not rational, the root may be expressed as a decimal approximation, but it can never be exact. A procedure similar to long division may be used for calculating square root. Cube root and higher roots may be calculated by methods based on logarithms and higher mathematics. Tables of powers and roots have been calculated for use in those scientific fields in which it is frequently necessary to work with roots. Such tables may be found in appendix I of *Mathematics, Vol. 1,* NAVEDTRA 10069-D 1, and in *Surveying Tables and Graphs,* Army TM 5-236. This method is, however, slowly being phased out and being replaced by the use of hand-held scientific calculators.

Arithmetic Extraction of Square Roots

If you do not have an electronic calculator, you may extract square roots arithmetically as follows:

Suppose you want to extract the square root of 2,034.01. First, divide the number into two-digit groups, working away from the decimal point. Thus set off, the number appears as follows:

$$\sqrt{20\ 34.01}$$

Next, find the largest number whose square can be contained in the first group, This is the number 4, whose square is 16. The 4 is the first digit of your answer. Place the 4 above the 20, and place its square (16) under the first group, thus:

```
    4
  √20 34.01
   16
```

Now perform the indicated subtraction and bring down the next group to the right, thus:

```
    4
  √20 34.01
   16
    434
```

Next, double the portion of the answer already found (4, which doubled is 8), and set the result down as the first digit of a new divisor, thus:

```
    4
  √20 34.01
   16
 8 /434
```

The second digit of the new divisor is obtained by a trial-and-error method. Divide the single digit 8 into the first two digits of the remainder 434 (that is, into 43) until you obtain the largest number that you can (1) add as another digit to the divisor and (2) use as a multiplier which, when multiplied by the increased divisor, will produce the largest result containable in the remainder 434. In this case, the first number you try is 43 + 8, or 5. Write this 5 after the 8 and you get 85. Multiply 85 by 5 and you get 425, which is containable in 434.

The second digit of your answer is therefore 5. Place the 5 above 34. Your computation will now look like this:

```
    4  5
  √20 34.01
   16
85/434
   425
```

Proceed as before to perform the indicated subtraction and bring down the next group, thus:

```
    4  5
  √20 34.01
   16
85/434
   425
     901
```

Again double the portion of the answer already found, and set the result (45 x 2, or 90) down as the first two digits of a new divisor thus:

```
    4  5
  √20 34.01
   16
85/434
   425
90/  901
```

Proceed as before to determine the largest number that can be added as a digit to the divisor 90 and used as a multiplier which, when multiplied by the increased divisor, will produce a result containable in the remainder, 901. This number is obviously 1. The increased divisor is 901, and this figure, multiplied by the 1, gives a result exactly equal to the remainder 901.

The figure 1 is therefore the third and final digit in the answer, The square root of 2,034.01 is therefore 45.1

Your completed computation appears thus:

```
        4   5. 1
     √20  34.01
       16
     85/434
        425
     901/ 901
          901
```

Fractional and Negative Exponents

In some formulas, like the velocity (V) of liquids in pipes, which you will encounter later in *Engineering Aid 1 &* C, it is more convenient to use FRACTIONAL EXPONENTS instead of radicals.

Examples:

$$\sqrt{3} = 3^{\frac{1}{2}}$$

$$\sqrt[3]{3} = 3^{\frac{1}{3}}$$

$$\sqrt[3]{3^2} = 3^{\frac{2}{3}}$$

It is readily observed that the index of the root in the above examples is the denominator of the fractional exponent. When an exponent occurs in the radicand, this exponent becomes the numerator of the fractional exponent. Roots of numbers not found in tables may be easily computed by proper treatment of the radical used.

Examples:

$$\sqrt{\frac{7}{16}} = \frac{\sqrt{7}}{\sqrt{16}} = \frac{1}{4}\sqrt{7} = \frac{2.646}{4} = 0.06615$$

$$\sqrt{8\frac{3}{4}} = \sqrt{\frac{35}{4}} = \frac{\sqrt{35}}{\sqrt{4}} = \frac{1}{2}\sqrt{35} = \frac{5.916}{2} = 2.958$$

In some work, NEGATIVE exponents are used instead of the reciprocals of numbers.

Examples:

$$3^{-1} = \frac{1}{3} \qquad 10^{-1} = \frac{1}{10}$$

$$3^{-2} = \frac{1}{3^2} = \frac{1}{9} \qquad 10^{-2} = \frac{1}{100}$$

$$\frac{1}{5^{-1}} = 5 \qquad 10^{-3} = \frac{1}{1,000}$$

Very small or very large numbers used in science are expressed in the form 5.832 **x** 10^{-4} or 8.143 **x** 10^{6} to simplify computation. To write out any of these numbers in full, just move the decimal point to either left or right, the number of places equal to the exponent, supplying a sufficient number of zeros depending upon the sign of the exponent, as shown below:

$5.832 \times 10^{-4} = 0.0005832$ (decimal moved four places to the left)

$8.143 \times 10^{6} = 8,143,000$ (decimal moved six places to the right)

RECIPROCALS

The reciprocal of a number is 1 divided by the number. The reciprocal of 2, for example, is 1/2, and the reciprocal of 2/3 is 1 divided by 2/3, which amounts to 1 x 3/2, or 3/2. The reciprocal of a whole number, then, equals 1 over the number, while the reciprocal of a fraction equals the fraction inverted.

In problems containing the power of 10, generally, it is more convenient to use reciprocals rather than write out lengthy decimals or whole numbers.

Example:

$$\frac{1}{250,000 \times 300 \times 0.02} = \frac{1}{2.5 \times 10^5 \times 3 \times \cancel{10^2} \times 2 \times \cancel{10^{-2}}}$$

$$= \frac{10^{-5}}{2.5 \times 3 \times 2} = \frac{10^{-5}}{15} = \frac{1 \times 10^{-5}}{15}$$

$$= .0667 \times 10^{-5} = 6.67 \times 10^{-2} \times 10^{-5}$$

$$= 6.67 \times 10^{-7}$$

$$= 0.000000667$$

Reciprocal is also used in problems involving trigonometric functions of angles, as you will see later in this chapter, in the solutions of problems containing identities.

RATIO AND PROPORTION

Almost every computation you will make as an EA that involves determining an unknown value from given or measured values will involve the solution of a proportional equation. A thorough understanding of ratio and proportion will greatly help you in the solution of both surveying and drafting problems.

The results of observation or measurement often must be compared to some standard value in order to have any meaning. For example, if the magnifying power of your telescope is 20 diameters and you see a telescope in the market that says 50 diameter magnifying power, then one can see that the latter has a greater magnifying power. How much more powerful? To find out, we will divide the second by the first number, which is

$$\frac{50}{20} = \frac{5}{2}.$$

The magnifying power of the second telescope is 2 1/2 times as powerful as the first. When the relationship between two numbers is shown this way, the numbers are compared as a RATIO. In mathematics, a ratio is a comparison of two quantities. Comparison by means of a ratio is limited to quantities of the same kind, For example, in order to express the ratio between 12 ft and 3 yd, both quantities must be written in terms of the same unit. Thus, the proper form of this ratio is 4 yd:3 yd, not 12 ft:3 yd. When the parts of the ratio are expressed in terms of the same unit, the units cancel each other and the ratio consists simply of two numbers. In this example, the final form of the ratio is 4:3.

Since a ratio is also a fraction, all the rules that govern fractions may be used in working with ratios. Thus, the terms may be reduced, increased, simplified, and so forth, according to the rules for fractions.

Closely allied with the study of ratio is the subject of proportion. A PROPORTION is nothing more than an equation in which the members are ratios. In other words, when two ratios are set equal to each other, a proportion is formed. The proportion may be written in three different ways, as in the following examples:

$$15:20::3:4:$$

$$15:20 = 3:4$$

$$\frac{15}{20} = \frac{3}{4}$$

The last two forms are the most common. All of these forms are read, “15 is to 20 as 3 is to 4.” In other words, 15 has the same ratio to 20 as 3 has to 4.

The whole of chapter 13, NAVEDTRA 10069-D1, is devoted to an explanation of ratio and proportion, the solution of proportional equations, and the closely related subject of variation. In addition to gaining this knowledge, you should develop the ability to recognize a computational situation as one that is available to solution by proportional equation. A very large area of surveying computations—the area that involves triangle solutions—uses the proportional equation as the principal key to the determination of unknown values on the basis of known values. Practically any problem involving the conversion of measurement expressed in one unit to the equivalent in a different unit is solvable by proportional equation. Similarly, if you know the quantity of a certain material required to produce a certain number of units of product, you can determine by proportional equation the quantity required to produce any given number of units.

In short, it is difficult to imagine any mathematical computation involving the determination of unknown values on the basis of known values that is not available to solution by proportional equation.

Your knowledge of equations need not extend beyond that required to solve linear equations; that is, equations in which the unknown appears with no exponent higher than 1. The equation

$$4x + 7 = \frac{15}{6},$$

for example, is a linear equation, because the unknown (technically known as the “variable’ ‘), x, appears to only the first power. The equation $X^2 + 2x = -1$, however, is a quadratic, not a linear, equation because the variable appears to the second power.

The whole of chapter 11 of NAVEDTRA 10069-D1 is devoted to an explanation of linear equations in one variable. The whole of chapter 12 is devoted to an explanation of linear equations in two variables.

ARITHMETIC

The common arithmetical operations are addition, subtraction, multiplication, and division. Arithmetical operations with positive whole numbers are explained in chapter 2 of NAVEDTRA 10069-D1, and arithmetical operations with signed numbers, in chapter 3. Arithmetical operations with common fractions are explained in chapter 4, and arithmetical operations with decimal fractions, in chapter 5.

ALGEBRAIC NOTATION AND ALGEBRAIC OPERATIONS

Algebraic notation—meaning generally the substitution of symbols (usually letters) for numerical values-is explained in chapter 9 of NAVEDTRA 10069-D1. Algebraic fundamentals, such as the meanings of terms; systems of groupings; and the addition, subtraction, multiplication, and division of algebraic monomials and polynomials are explained in the same chapter. The factoring of algebraic expressions is explained in chapter 10.

GEOMETRY

Since geometry is the branch of mathematics that investigates the relations, properties, and measurement of solids, surfaces, lines, and angles, it follows that just about everything a surveyor does involves geometry in some way or other. Whenever you establish a point, chain a linear distance, measure a vertical distance, turn an angle, or determine an area or a volume, you are working with geometry.

To begin with, you must know how to recognize the common types of geometrical plane and solid figures and how to compute the areas of the plane figures and the volumes of the solids.

SURFACES AND FIGURES

There is a surface on this sheet of paper. A geometrical surface has length and breadth. It has no thickness. A surface may be either a plane surface or a curved surface. When this page is held perfectly level at every point, the surface is then a plane surface. When the page is rolled to resemble a tube, the plane surface becomes a curved surface.

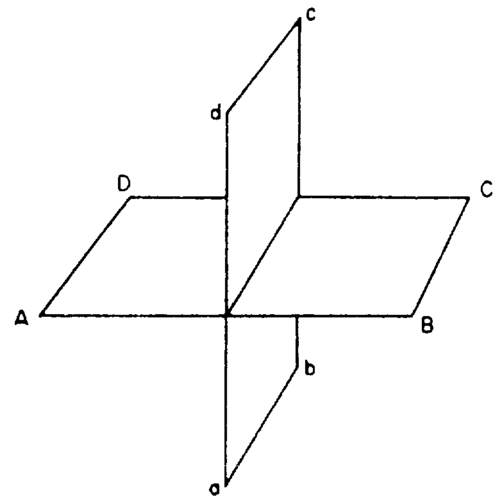

Figure 1-3.-Intersecting planes.

A plane is a real or imaginary surface in which a straight line between any two points lies wholly on that surface. Figure 1-3 shows two intersecting planes. Plane ABCD is shown to be a horizontal plane; plane abed is a vertical plane perpendicular to ABCD.

A plane surface is a surface on which every point lies in the same plane.

Plane figures are plane surfaces bounded by either straight lines or curved lines.

POLYGONS

A plane figure that is bounded by straight-line sides is called a polygon. The smallest possible number of sides for a polygon is three, and a three-sided polygon is called a triangle.

Some terms and definitions relating to polygons are as follows:

Sides	The boundary lines of a polygon
Perimeter	The sum of the sides

Triangle	A polygon bounded by three sides
Quadrilateral	A polygon bounded by four sides
Hexagon	A polygon bounded by six sides
Heptagon	A polygon bounded by seven sides
Octagon	A polygon bounded by eight sides
Equilateral	A polygon with sides of equal length
Regular	An equilateral polygon
Irregular	A nonequilateral polygon
Parallelogram	A quadrilateral with both pairs of opposite sides parallel
Rectangle	A parallelogram in which adjacent sides join at right angles
Square	An equilateral rectangle
Oblong	A nonequilateral rectangle
Trapezoid	A quadrilateral with only one pair of opposite sides parallel, the other pair being not parallel
Trapezium	A quadrilateral with no sides parallel
Rhombus	An equilateral parallelogram in which adjacent sides join at oblique (other than right) angles
Rhomboid	A nonequilateral parallelogram in which adjacent sides join at oblique angles

A triangle, quadrilateral, pentagon, hexagon, heptagon, and octagon are shown in figure 1-4. A trapezoid, trapezium, rhombus, and rhomboid are shown in figure 1-5.

DETERMINING AREAS

The area of any surface is the number of units of area measure the surface contains. A unit of area measure is a square unit. The main thing to remember when computing for areas is that the dimensions used must be of the same unit of measure—if in inches, all units must be in inches and if in feet, all must be in feet.

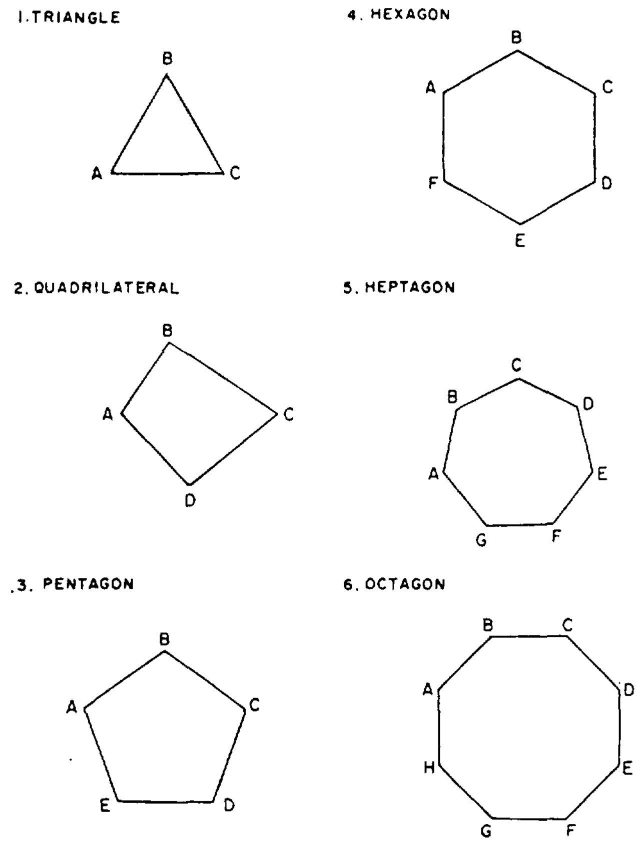

Figure 1-4.-Geometric figures of a triangle, quadrilateral, pentagon, hexagon, heptagon, and octagon.

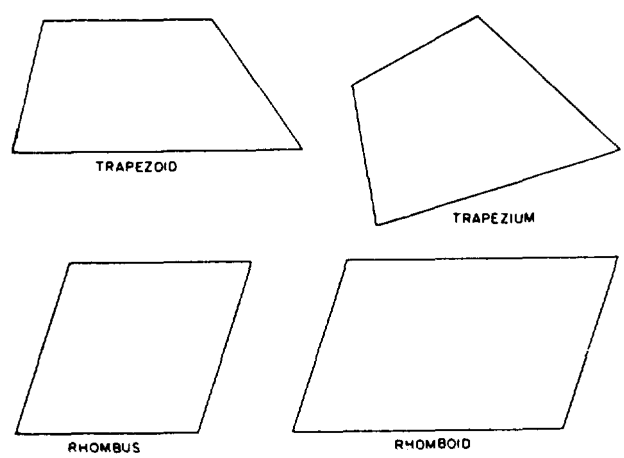

Figure 1-5.-Geometric figures of a trapezoid, trapezium, rhombus, and rhomboid.

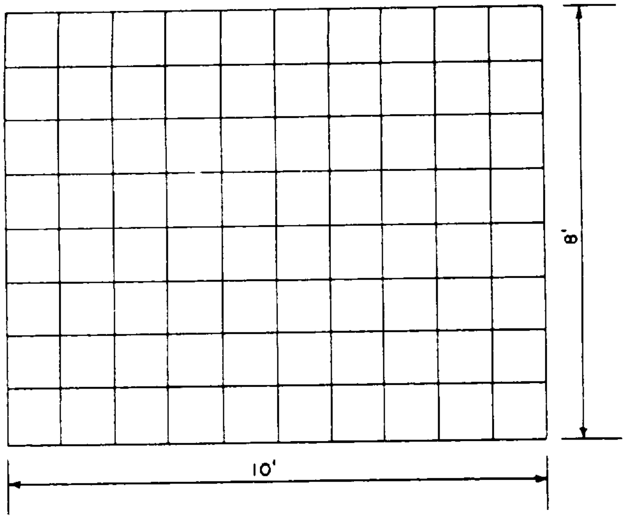

Figure 1-6.-Area of a rectangle.

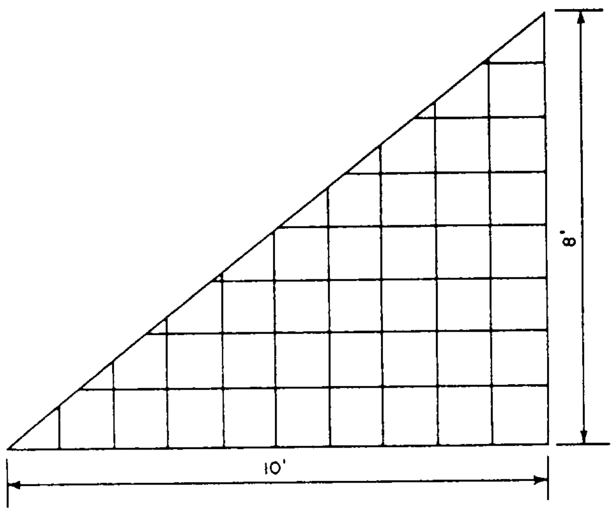

Figure 1-7.-Area of a triangle.

Area of a Rectangle

Figure 1-6 shows a rectangle measuring 10 ft by 8 ft, divided up into units of area measure, each consisting of 1 sq ft. If you were to count the units, one after the other, you would count a total of 80 units. However, you can see that there are 8 rows of 10 units, or 10 rows of 8 units. Therefore, the quickest way to count the units is simply to multiply 10 by 8, or 8 by 10.

You could call the 8-ft dimension the width and the 10-ft dimension the length, in which case you would say that the formula for determining the area of a rectangle is the width times the length, or A = w1. Or, you could call the 10-ft dimension the base and the 8-ft dimension the altitude (meaning height), in which case your formula for area of a rectangle would be A = bh.

Area of a Triangle

Figure 1-7 shows a triangle consisting of one-half of the rectangle shown in figure 1-6. It is obvious that the area of this triangle must equal one-half of the area of the corresponding rectangle, and the fact that it does can be demonstrated by geometrical proof. Therefore, since the formula for the area of the rectangle is A = bh, it follows that the formula for the triangle is A = 1/2bh.

The triangle shown in figure 1-7, because it is half of a corresponding rectangle, contains a right angle, and is therefore called a right triangle. In a right triangle the dimension h corresponds to the length of one of the sides. The triangle shown in figure 1-8, however, is a scalene triangle, so-called because no two sides are equal. Classification of triangles will be discussed later in this chapter.

Now, a perpendicular CD drawn from the apex of the triangle (from angle C) divides the triangle into two right triangles, ΔADC and ΔBDC. The area of the whole triangle equals the sum of the areas of ΔADC and ΔBDC. The area of ΔADC equals 1/2 (AD)(DC), and the area of ΔBDC equals 1/2(DB)(DC). Therefore, the area of the whole triangle equals

$$\frac{AD}{2}(DC) + \frac{DB}{2}(DC), \text{ or } DC\left(\frac{AD + DB}{2}\right).$$

But since AD + DB = AB, it follows that the area of the whole triangle equals

$$DC\left(\frac{AB}{2}\right).$$

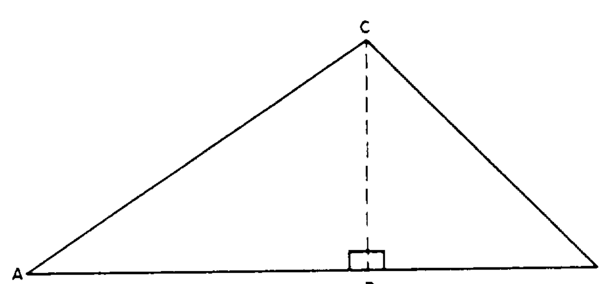

Figure 1-8.-Triangle.

The length of AB is called the base (b), and the length of DC, the altitude (h); therefore, your formula for determining the area of an oblique triangle is again A = 1/2bh.

You must remember that in a right triangle h corresponds to the length of one of the sides, while in an oblique triangle it does not. Therefore, for a right triangle with the length of the sides given, you can determine the area by the formula A = 1/2bh. For an oblique triangle with the length of the sides given, you cannot use this formula unless you can determine the value of h, Later in this chapter you will learn trigonometric methods of determining areas of various forms of triangles on the basis of the length of the sides alone.

Area of a Rhombus or Rhomboid

Figure 1-9 shows a rhomboid, ABCD. If you drop a perpendicular, CF, from $\angle$ C to AD, and project another from $\angle$A to BC, you will create two right triangles, ΔAEB and ΔCFD, and the rectangle AECF. It can be shown geometrically that the right triangles are similar and equal.

You can see that the area of the rectangle AECF equals the product of AF x FC. The area of the triangle CFD equals 1 /2(FD)(FC). Because the triangle AEB is equal and similar to CFD, the area of that triangle also equals 1/2(FD)(FC). Therefore, the total area of both triangles equals (FD)(FC). The total area of the rhomboid equals the area of the rectangle AECF + the total area of both triangles.

The total area of the rhomboid equals (AF)(FC) + (FD)(FC), or (AF + FD)(FC). But AF + FD equals AD, the base. FC equals the altitude. Therefore, the formula for the area of a rhomboid is A = bh. Here again you must remember that h in a rectangle corresponds to the length of one of the sides, but h in a rhombus or rhomboid does not.

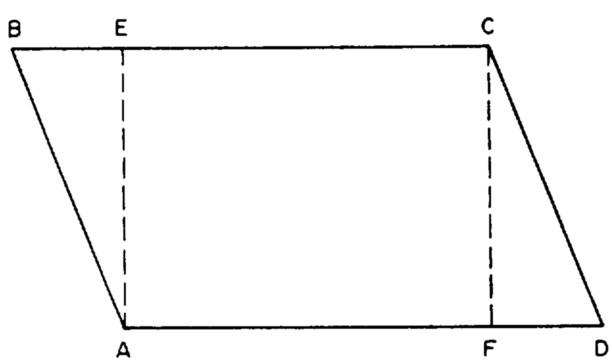

Figure 1-9.-Rhomboid.

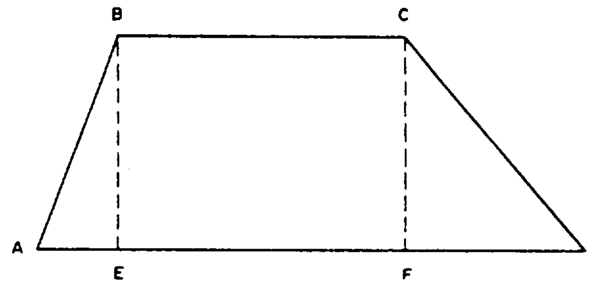

Figure 1-10.-Trapezoid.

Area of a Trapezoid

Figure 1-10 shows a trapezoid, ABCD. If you drop perpendiculars BE and CF from points B and C, respectively, you create the right triangles AEB and DFC and the rectangle EBCF between them. The area of the trapezoid obviously equals the sum of the areas of these figures.

The area of ΔAEB equals 1/2(AE)(FC), the area of ΔDFC equals 1/2(FD)(FC), and the area of EBCF equals (EF)(FC). Therefore, the area of the trapezoid ABCD equals l/2(AE)(FC) + (EF)(FC) + 1/2(FD)(FC), or

$$\frac{(AE + FD + 2EF)(FC)}{2}.$$

However, 2EF = EF + BC. Therefore, the area of the trapezoid equals

$$\frac{(AE + FD + EF + BC)(FC)}{2}.$$

But AE + FD + EF = AD. Therefore, the area of the trapezoid equals

$$\frac{(AD + BC)(FC)}{2}.$$

AD and BC are the bases of the trapezoid and are usually designated as b_1 and b_2, respectively. FC is the altitude and is generally designated as h. Therefore, the formula for the area of a trapezoid is

$$A = 1/2\ (b_1 + b_2)h.$$

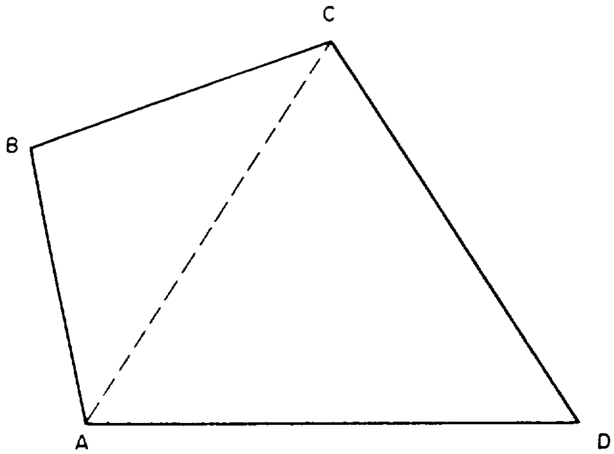

Figure 1-11.-Trapezium.

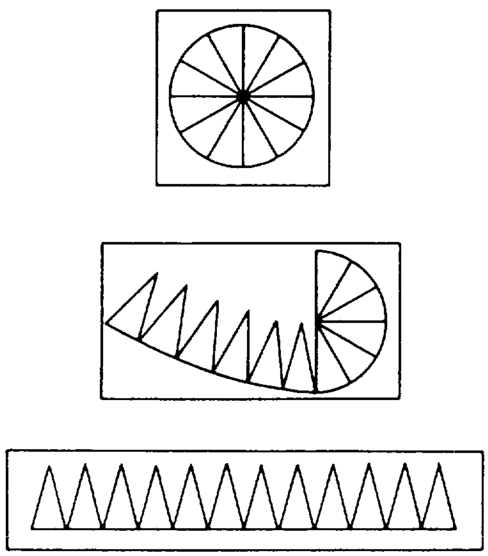

Figure 1-12.-Area of a circle.

Stated in words, the area of a trapezoid is equal to one-half the sum of its bases times its altitude.

Area by Reducing to Triangles

Figure 1-11 shows you how you can determine the area of a trapezium, or of any polygon, by reducing to triangles. The dotted line connecting A and C divides the figure into the triangles ABC and ACD. The area of the trapezium obviously equals the sum of the areas of these triangles.

Area of a Circle

Figure 1-12 shows how you could cut a disk into 12 equal sectors. Each of these sectors would constitute a triangle, except for the slight curvature of the side that was originally a segment of the circumference of the disk. If this side is considered the base, then the altitude for each triangle equals the radius (r) of the original disk. The area of each triangle, then, equals

$$\frac{br}{2},$$

and the area of the original disk equals the sum of the areas of all the triangles. The sum of the areas of all the triangles, however, equals the sum of all the b's, multiplied by r and divided by 2.

But the sum of all the b's equals the circumference (c) of the original disk. Therefore, the formula for the area of a circle can be expressed as

$$A = \frac{cr}{2}.$$

However, the circumference of a circle equals the product of the diameter times π (Greek letter, pronounced "pi"). π is equal to 3.14159. . . The diameter equals twice the radius; therefore, the circumference equals $2\pi r$. Substituting $2\pi r$ for c in the formula

$$A = \frac{cr}{2}, \text{ we have } A = \frac{(2\pi r)(r)}{2}, \text{ or } \frac{2\pi r^2}{2}, \text{ or } \pi r^2.$$

This is the most commonly used formula for the area of a circle. If we find the area of the circle in terms of circumference.

$$A = \frac{c^2}{4\pi}.$$

Area of a Segment and a Sector

A segment is a part of a circle bounded by a chord and its arc, as shown in figure 1-13. The formula for its area is

$$A = \frac{r^2}{2}\left(\frac{\pi n}{180} - \sin n\right)$$

where r = the radius and n = the central angle in degrees.

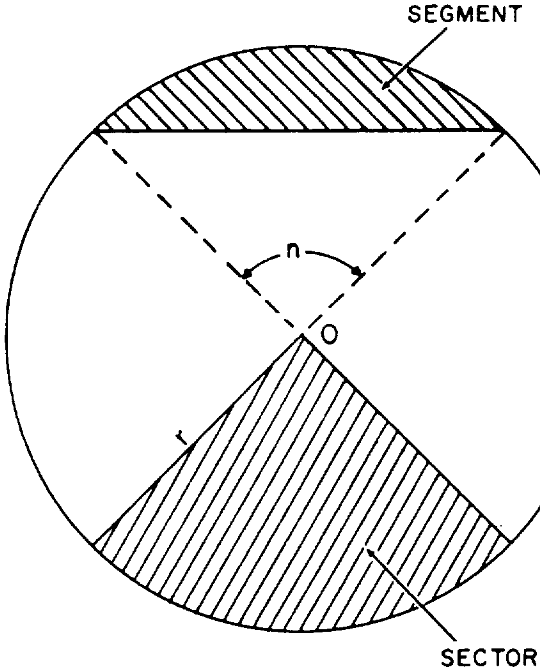

Figure 1-13.-Segment and sector of a circle,

A sector is a part of a circle bounded by two radii and their intercepted arc. The formula for its area is

$$A = \frac{\pi r^2 n}{360}$$

where r and n have the same designation as above.

Area of Regular Polygons

Figure 1-14 is a regular polygon. In any regular polygon, the area is equal to one-half the perimeter of the polygon times the radius of the inscribed circle. This is expressed in formula form as follows:

$$A = \frac{\text{perimeter} \times r}{2}$$

You can verify the above formula by dividing the polygon into equal triangles with the sides as their bases and with r as their altitudes; if you multiply the areas of the individual triangles by the number of sides in the polygon, you will arrive at the above formula.

Area of an Ellipse

The derivation of an ellipse from a conic section and methods of drawing ellipses are explained in chapter 3. An ellipse is shown in figure 1-15, The longer axis, AB, is called the major axis, and the shorter axis, CD, the minor axis. Call the length of the major axis a and that of the minor axis b. The area equals the product of half the major axis times half the minor axis times π. In formula form, it is stated as

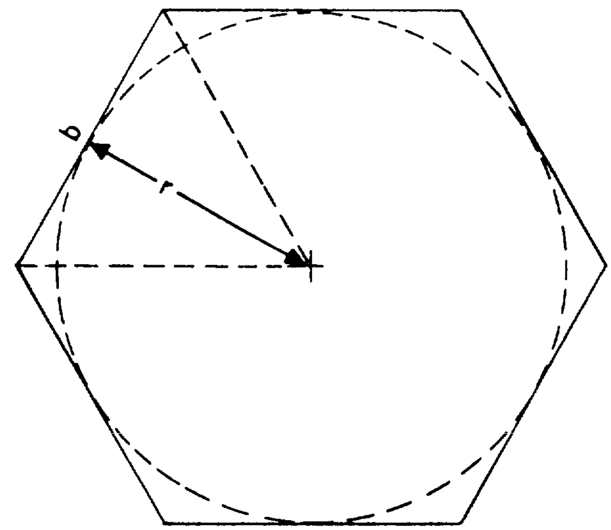

Figure 1-14.-Regular polygon.

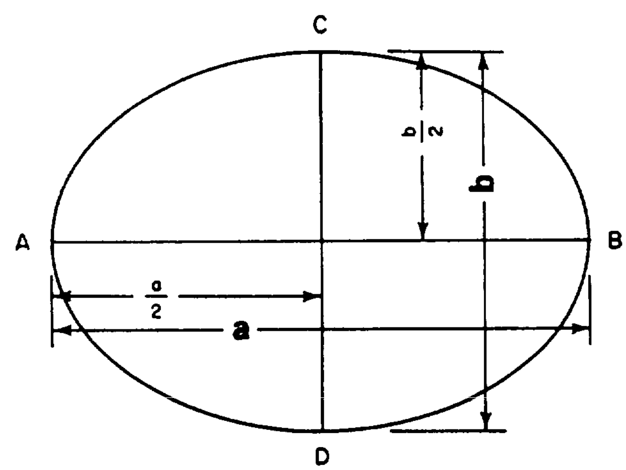

Figure 1-15.-Ellipse.

$$A = \pi\left(\frac{a}{2} \times \frac{b}{2}\right)$$

$$= \pi\left(\frac{ab}{4}\right)$$

$$= 0.7854ab$$

Irregular Areas

Irregular areas are those areas that do not fall within a definite standard shape. As you already have learned, there are formulas for computing the area of a circle, a rectangle, a triangle, and so on. However, we do not have a standard formula for computing the area of an irregular shaped plane, unless we use higher mathematics (calculus), and integrate incremental areas using lower and upper limits that define the boundaries.

As an EA, however, most areas you will be concerned with are those you will meet in plane surveying. In most surveys, the computed area is the horizontal projection of the area rather than the actual surface of the land. The fieldwork in finding areas consists of a series of angular and linear measurements, defining the outline of whatever the shape is of the area concerned, and forming a closed traverse. The following office computation methods, which you will learn as you advance in rate, are:

1. Plotting the closed traverse to scale and measuring the enclosed area directly with a polar planimeter (used only where approximate results are required, or for checking purposes).

2. Subdividing the area into a series of triangles, and taking the summation of all the areas of these triangles.

3. Computing the area using the coordinates of the individual points of the traverse (called coordinate method).

4. Computing the area by means of the balanced latitude and departure, and calculated DOUBLE MERIDIAN DISTANCES of each course (called the DMD method).

5. Computing the area by counting squares; this method is nothing but just superimposing small squares plotted on a transparent paper having the same scale as the plotted traverse (or of known graphical ratio) and counting the number of squares within the traverse. The smaller the squares, the closer to the approximate area you will get.

6. Computing an irregular area bounded by a curve and perpendicular lines, as shown in figure 1-16. Here, you can use the TRAPEZOIDAL RULE. The figure is considered as being made up of a series of trapezoids, all of them having the same base and having common distances between offsets. The formula in computing the total area is as follows:

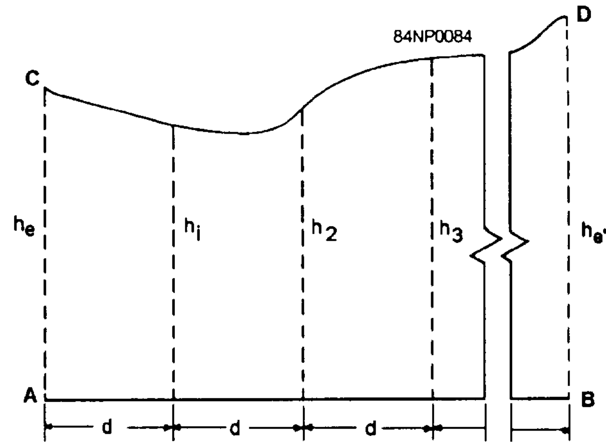

Figure 1-16.-Irregular area by trapezoidal rule.

$$A = \left(\frac{h_e}{2} + \sum h + h_{e'} \right) d$$

Where h_e and h_e = the end offsets of the series of trapezoids

$\sum h$ = the sum of the intermediate offsets ($h_1 + h_2 + h_3 + ...$)

and d = the common distance between the offsets

For the present time, try to find the areas of irregular figures by subdividing the area to series of triangles and by the method of counting the squares.

There are also areas of spherical surfaces and areas of portions of a sphere. For other figures not covered in this training manual, consult any text on plane and solid geometry.

DETERMINING VOLUMES

From the preceding section you learned the formulas for computing the areas of various plane figures. These plane areas are important in the computation of VOLUMES, as you will see later in this section.

When plane figures are combined to form a three-dimensional object, the resulting figure is

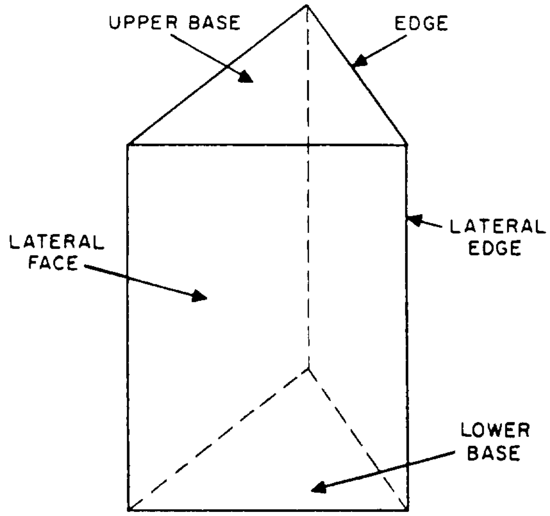

Figure 1-17.-Parts of a prism (triangular).

a solid. For example, three rectangles and two triangles may be combined as shown in figure 1-17. The flat surfaces of the solid figure are its FACES, the top and bottom faces are the BASES, and the faces forming the sides are the LATERAL FACES or SURFACES.

Some solid figures do not have any flat faces, and some have a combination of curved surfaces and flat surfaces. Examples of solids with curved surfaces include cylinders, cones, and spheres. Those solids having no flat faces include a great majority of natural objects, such as rocks, living matter, and many other objects that have irregular surfaces.

A solid figure whose bases or ends are similar, equal, and parallel polygons, and whose faces are parallelograms, is known geometrically as a PRISM. The name of a prism depends upon its base polygons. If the bases are triangles, as in figure 1-17, the figure is a TRIANGULAR PRISM. A RECTANGULAR PRISM has bases that are rectangles, as shown in figure 1-18. If the bases of a prism are perpendicular to the planes forming its lateral faces, the prism is a RIGHT prism.

A PARALLELEPIPED is a prism with parallelograms for bases. Since the bases are parallel to each other, this means that they cut the lateral faces to form parallelograms. If a parallelepipeds is a right prism and if its bases are rectangles, it is a rectangular solid. A CUBE is a rectangular solid in which all of the six rectangular faces are squares.

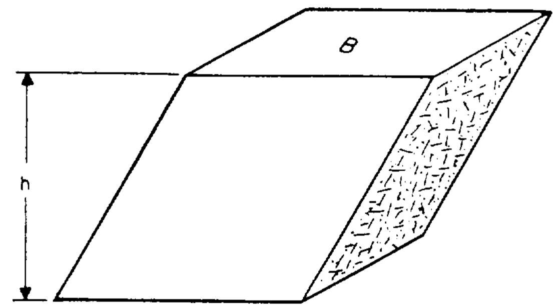

Figure 1-18.-Rectangular prism, showing its height when not a right prism.

In determining the volume of most solids, you should use the following general formula:

$$V = B h$$

Where V = the volume

B = the area of the base or end area

h = the height of the solid (the perpendicular height from its base)

Volume of a Prism

For the volume of any prism, then, you simply determine the end area or the base area by the appropriate method and multiply the end area by the length or the base area by the height.

Volume of a Cylinder

From the standpoint of volume calculation, the only difference between a cylinder and a prism lies in the fact that the end or base of a cylinder is a circle rather than a polygon. Therefore, the volume of a cylinder is equal to its end area times its length. But you determine its end area from the formula πr^2, which is the formula used for computing the area of a circular plane. Therefore, the volume of a cylinder is $\pi r^2 L$.

Volume of a Cone or Pyramid

The best way to approach the problem of determining the volume of a cone or pyramid is on the basis of the fundamental fact that the volume of a cone equals one-third of the volume of the corresponding cylinder, while the volume of a pyramid equals one-third of the volume of the corresponding prism. For any of these solids, volume equals base area times height divided by 3. Therefore, the formula for computing the volume of a cone is

$$V = \frac{1}{3}\pi r^2 h,$$

and that for a pyramid is

$$V = \frac{1}{3}Bh.$$

A pyramid may have either a rectangular or a triangular base.

Volume of Other Geometric Figures

There will be no attempt to illustrate the derivation of formulas presented in this section. The formulas for the computations of volumes and surface areas of the following geometric figures are presented here only for additional information.

A frustum is that portion of a cone or pyramid that remains after the upper part is cut off by a plane parallel to the base.

1. SPHERE

   Volume of a sphere $= \frac{4}{3}\pi r^3$

   Surface area $= 4\pi r^2$

   Where r = the radius of the sphere

2. FRUSTUM OF A CONE

   Volume of frustum = volume of large cone − volume of small cone

   $= \frac{1}{3}\pi h(r_1{}^2 + r_1 r_2 + r_2{}'^2)$ cubic units

   Lateral area $= \pi(r_1 + r_2)s$ square units

   Where h = the altitude of the frustum

   r_1 = the radius of the base

   r_2 = the radius of the top

   s = the slant height

3. FRUSTUM OF A PYRAMID

   Volume of a frustum = volume of large pyramid − volume of small pyramid

   $= \frac{1}{3}h\,(B_1 + \sqrt{B_1B_2} + B_2)$

   Where h = the altitude of frustum

   B_1 = the area of lower base

   B_2 = the area of upper base

TRIGONOMETRY

Our discussion will focus primarily on the study of plane trigonometry. It is intended only as a review of the relationships among the sides and angles of plane triangles and their ratios, called the TRIGONOMETRIC FUNCTIONS. The information presented here is based on *Mathematics, Vol. 1,* NAVEDTRA 10069-D1, chapter 19, and *Mathematics, Vol. 2-A,* NAVEDTRA 10062, chapters 3, 4, and 6.

Spherical trigonometry will be covered as you advance in rate. It is a prerequisite to the study of navigation, geodesy, and astronomy. Hence, the subject of spherical trigonometry will be introduced in the Engineering Aid class C1 school curriculum.

MEASURING ANGLES

When two straight lines intersect, an angle is formed, You can also generate an angle by rotating a line having a set direction, Figure 1-19 depicts the generation of an angle. The terminal line OB is generated from the initial point OA and forms $\angle$ AOB, which we will call θ (Greek letter, pronounced "theta"). Angle θ is generally expressed in degrees. The following paragraphs will discuss the degree and the radian systems that are generally used by Engineering Aids.

The DEGREE SYSTEM is the most common system used in angular measurement. Angular measurement by REVOLUTION is perhaps the unit you are most familiar with.

In the degree system, a complete revolution is divided into 360 equal parts called degrees (360°). Each degree is divided into 60 minutes (60′), and each minute into 60 seconds (60"). For convenience in trigonometric computations, the 360° is divided into four parts of 90° each. The

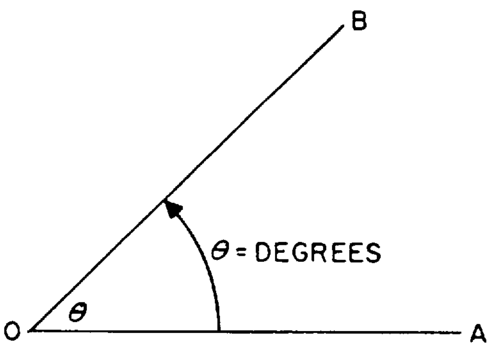

Figure 1-19.-Generation of an angle, resulting angle measured in degrees.

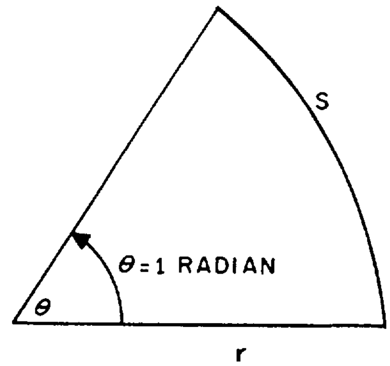

Figure 1-20.-Radian measure.

90° sectors, called QUADRANTS, are numbered counterclockwise starting at the upper right-hand sector.

When the unit radius r (the line generating the angle) has traveled less than 90° from its starting point in a counterclockwise direction (or, as conventionally referred to as, in a positive direction), the angle is in the FIRST quadrant (I). When the unit radius lies between 90° and 180°, the angle is in the SECOND quadrant (II). Angles between 180° and 270° are said to lie in the THIRD quadrant (III), and angles greater than 270° and less than 360° are in the FOURTH quadrant (IV).

When the line generating the angle passes through more than 360°, the quadrant in which the angle lies is found by subtracting from the angle the largest multiple of 360 that the angle contains and determining the quadrant in which the remainder falls.

The RADIAN SYSTEM of measuring angles is even more fundamental than the degree system. It has certain advantages over the degree system, for it relates the length of arc generated to the size of the angle and the radius. The radian measure is shown in figure 1-20. If the length of the arc (s) described by the extremity of the line segment generating the angle is equal to the length of the line (r), then it is said that the angle described is exactly equal to one radian in size; that is, for one radian, s = r.

The circumference of a circle is related to the radius by the formula, $C = 2\pi r$. This says that the circumference is 2π times the length of the radius. From the relationship of arc length, radius, and radians in the preceding paragraph, this could be extended to say that a circle

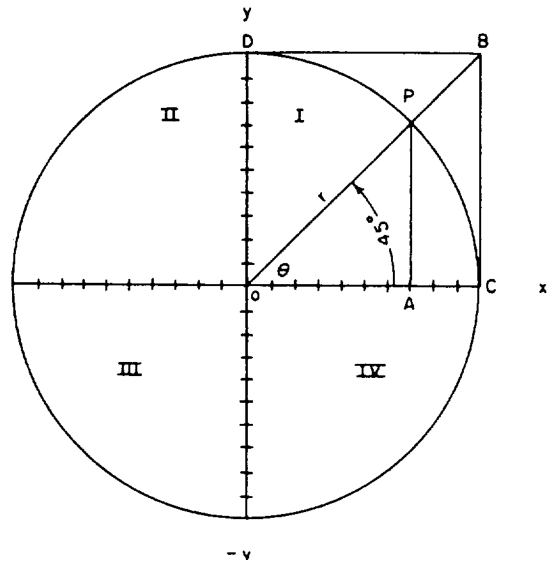

Figure 1-21.-Circle of unit radius with quadrants shown.

contains 2π radians, and the circumference encompasses 3600 of rotation. It follows that

$$2\pi \text{ radians} = 360°$$

$$\pi \text{ radians} = 180°$$

By dividing both sides of the above equation by π, we find that

$$\text{radian} = \frac{180°}{\pi} = 57.2959°, \text{ or } 57.3° \text{ (approximately)}$$

As in any other formula, you can always convert radians to degrees or vice versa by using the above relationship.

FUNCTIONS OF ANGLES

The functions of angles can best be illustrated by means of a "circle of unit radius" like the one shown in figure 1-21. A so-called "Cartesian axis" is inscribed within the circle. Coordinates measured from 0 along the x axis to thc right are positive; coordinates measured from 0 along the x axis to the left are negative. Coordinates measured along the y axis from 0 upward are positive; coordinates measured along the y axis from 0 downward are negative.

Angles are generated by the motion of a point P counterclockwise along the circumference of the circle. The initial leg of any angle is the positive leg of the x axis. The other leg is the radius r, at the end of which the point P is located; this radius always has a value of 1. The unit radius (r = OC) is subdivided into 10 equal parts, so the value of each of the 10 subdivisions shown is 0.1.

For any angle, the point P has three coordinates: the x coordinate, the y coordinate, and the r coordinate (which always has a value of 1 in this case). The functions of any angle are, collectively, various ratios that prevail between these coordinates.

The ratio between y and r (that is, y/r) is called the **sine** of an angle. In figure 1-21, AP seems to measure about 0.7 of y; therefore, the sine θ, which is equal to 45° in this case, would seem to be 0.7/1, or about 0.7. Actually, the sine of 45° is 0.70711. Graphically, the sine is indicated in figure 1-21 by the line AP, which measures 0.7 to the scale of the drawing.

The ratio between x and r (that is, x/r) is called the **cosine** of the angle. You can see that for 45°, x and y are equal, and the fact that they are can be proven geometrically. Therefore, the cosine of 45° is the same as the sine of 45°, or 0.70711. Graphically, the length of line OA represents the cosine of angle θ when the radius (r) is equal to 1.

The ratio between y and x (that is, y/x) is known as the **tangent** of an angle. Since y and x for an angle of 45° are equal, it follows that the tangent of an angle of 45° equals 1. The tangent is also indicated graphically by the line BC, drawn tangent to the circle at C and intersecting the extended r at B and DB, which is also drawn tangent at D. As you examine figure 1-21, you can deduce that BC is equal to OC. OC is equal to the unit radius, r.

The three functions shown in figure 1-21 are called the “direct” functions. For each direct function there is a corresponding “reciprocal” function–meaning a function that results when you divide 1 by the direct function. You know that the reciprocal of any fraction is simply the fraction inverted. Therefore, for the direct function sine, which is y/r, the reciprocal function (called the **cosecant)** is divided by y/r, which is r/y.

Since y at sine 45° equals about 0.7, the cosecant for 45° is r/y, which is equal to 1/0.7, or about 1.4. The cosecant is indicated graphically by the line OB in figure 1-21. If you measure this line, you will find that it measures just about 1.4 units to the scale of the drawing.

For the direct function cosine, which is x/r, the reciprocal function (called the **secant)** is r/x. Since x for cosine 45° also measures about 0.7, it follows that the secant for 45°, r/x, is the same as the cosecant, or also about 1.4. The secant is indicated graphically in figure 1-21 by the line OB also.

For the direct function tangent, which is y/x the reciprocal function (called the **cotangent)** is x/y. Since x and y at tangent 45° are equal, it follows that the value for cotangent 45° is the same as that for the tangent, or 1. The cotangent is shown graphically in figure 1-21 by the line DB, drawn tangent to the circle at D.

FUNCTIONS AND COFUNCTIONS

The functions cosine, cosecant, and cotangent are cofunctions of the functions sine, secant, and tangent, respectively. A cofunction of an angle A has the same value as the corresponding function of (90° – A); that is, the same value as the corresponding function of the complement of the angle. The sine of 30°, for example, is 0.50000. The cosine of 60° (the complement of 30°) is likewise 0.50000. The tangent of 30° is 0.57735. The cotangent of 60° (the complement of 30°) is likewise 0.57735.

Commonly used functions and cofunctions are as follows:

$$\sin A = \cos (90° - A)$$

$$\sec A = \csc (90° - A)$$

$$\tan A = \cot (90° - A)$$

FUNCTIONS OF OBTUSE ANGLES

In figure 1-22, the point P has generated an obtuse (larger than 90°) angle of 135°. This angle is the supplement of 45° (two angles are supplementary when they total 180°). We have left a dotted image of the reference angle A, which is equal to the supplementary angle of 135°. You

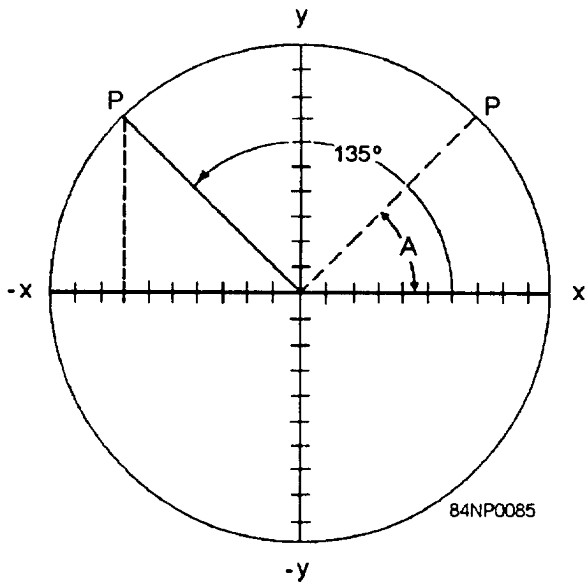

Figure 1-22.-Function of an obtuse angle.

can see that the values of x, y, and r are the same for 135° as they are for 45°, <u>except that the value of x is negative.</u> From this it follows that the functions of any obtuse angle are the same as the functions of its supplement, except that any function in which x appears has the opposite sign.

The sine of an angle is y/r. Since x does not appear in this function, it follows that sin A = sin (180° – A).

The cosine of an angle is fir. Since x appears in this function, it follows that cos A = - cos (180° – A).

The tangent of an angle is y/x. Since x appears in this function, it follows that tan A = – tan (180°- A).

The importance of knowing this lies in the fact that many tables of trigonometric functions list the functions only for angles to a maximum of 90°. Many oblique triangles, however, contain angles larger than 90°. To determine a function of an angle larger than 90° from a table that stops at 90°, you lookup the function of the supplement of the angle. If the function is a sine, you use it as is. If it is a cosine or tangent, you give it a negative sign.

The relationships of the function of <u>obtuse</u> angles are as follows:

$$\sin A = \sin (180° - A)$$

$$\cos A = -\cos (180° - A)$$

$$\tan A = -\tan (180° - A)$$

$$\cot A = -\cot (180° - A)$$

$$\sec A = -\sec (180° - A)$$

$$\csc A = \csc (180° - A)$$

The above relationships apply only when angle A is greater than 90° and less than 180°.

FUNCTIONS OF ANGLES IN A RIGHT TRIANGLE

For an acute angle in a right triangle, the length of the side opposite the angle corresponds to y and the length of the side adjacent to the angle corresponds to x, while the length of the hypotenuse corresponds to r. Therefore, the functions of an <u>acute</u> angle in a right triangle can be stated as follows:

$$\text{Sine} = \frac{\text{side opposition}}{\text{hypotenuse}} \qquad \text{Cosecant} = \frac{\text{hypotenuse}}{\text{side opposite}}$$

$$\text{Cosine} = \frac{\text{side adjacent}}{\text{hypotenuse}} \qquad \text{Secant} = \frac{\text{hypotenuse}}{\text{side adjacent}}$$

$$\text{Tangent} = \frac{\text{side opposite}}{\text{side adjacent}} \qquad \text{Cotangent} = \frac{\text{side adjacent}}{\text{side opposite}}$$

If you consider a 90° angle with respect to the “circle of unit radius” diagram, you will realize that for a 90° angle, x = 0, y = 1, and r (as always) equals 1. Since sine = y/r, it follows that the sine of 90° = 1. Since cosine = X/r, it follows that the cosine of 90° = 0/1, or 0. Since tangent= y/x, it follows that tan 90° = 1/0, or infinity (00). From one standpoint, division by 0 is a mathematical inpossibility, since it is impossible to state how many zeros there are in anything. From this standpoint, tan 90° is simply impossible. From another standpoint it can be said that there arc an “infinite” number of zeros in 1. From that standpoint, tan 90° can be said to be infinity.

In real life, the sides of a right triangle y, x, and r, or side opposite, side adjacent, and hypotenuse, are given other names according to the circumferences. In connection with a pitched roof rafter, for instance, y or side opposite is “total rise,” x or side adjacent is “total run,” and r or hypotenuse is “rafter length.” In connection with a ground slope, y or side opposite is “vertical rise,” x or side adjacent is “horizontal distance,” and r or hypotenuse is “slope distance.”

METHODS OF SOLVING TRIANGLES

To "solve" a triangle means to determine one or more unknown values (such as the length of a side or the size of an angle) from given known values. Here are some of the methods used.

Pythagorean Theorem

When you know the lengths of two sides of a right triangle, or its hypotenuse and one side, you can determine the length of the remaining side, or the length of the hypotenuse, by applying the Pythagorean theorem. The Pythagorean theorem states that the square of the length of the hypotenuse of any right triangle equals the sum of the squares of the lengths of the other two sides.

Figure 1-23 shows a right triangle with acute angles A and B and right angle C. Sides opposite A and B are designated as a and b; the hypotenuse (opposite C) is designated as c. Side a measures 3.00 ft, side b measures 4.00 ft, and the hypotenuse measures 5.00 ft. Any triangle with sides and hypotenuse in the ratio of 3:4:5 is a right triangle.

If $C^2 = a^2 + b^2$, it follows that $c = \sqrt{a^2 + b^2}$. The formulas for solving for either side, given the other side and the hypotenuse; or for the hypotenuse, given the two sides, are

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

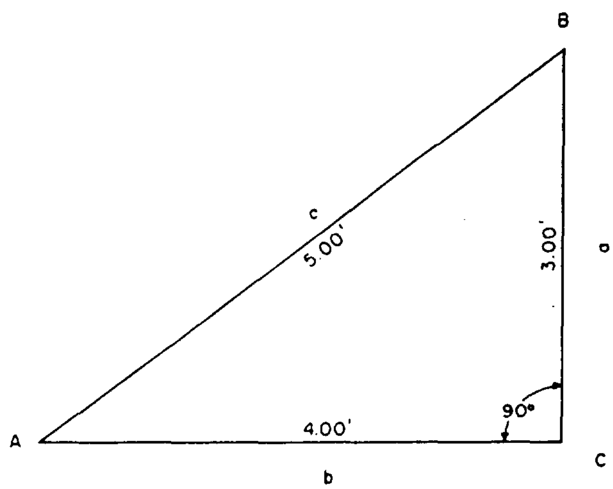

Figure 1-23.-A right triangle.

In figure 1-23, $a^2 = 9$, $b^2 = 16$, and $c^2 = 25$. Therefore, a = the square root of (25 − 16), or 3; b = the square root of (25 − 9), or 4; and c = the square root of (9 + 16), or 5.

Acute Angle of Right Triangle by Tangent

One of the angles in a right triangle always measures 900. Because the sum of the three angles in any triangle is always 180°, it follows that each of the other two angles in a right triangle must be an acute (less than 90°) angle. Also, if you know the size of one of the acute angles, you can determine the size of the other from the formulas A = (90° − B) and B = (90° − A).

In any right triangle in which you know the lengths of the sides, you can determine the size of either of the acute angles by applying the tangent of the angle. Take angle A in figure 1-23, for example. You know that

$$\tan A = \frac{a}{b}, \text{ or } \frac{3.00}{4.00}, \text{ or } 0.75.$$

Reference to a table of natural tangents shows that an angle with tangent 0.75 measures to the nearest minute, 36°52'.

Side of Right Triangle by Tangent

If you know the length of one of the sides of a right triangle and the size of one of the acute angles, you can determine the length of the other side by applying the tangent. Suppose that for the triangle shown in figure 1-23 you know that angle A measures 36°52' and that side b measures 4.00 ft. You want to determine the length of side a. Since

$$\tan A = \frac{a}{b},$$

it follows that a = b (tan A). From a table o natural tangents you find that tar 36°52′ = 0.74991. Therefore,

$$a = 4.00(0.74991), \text{ or } 3.00 \text{ ft}.$$

Side of Right Triangle by Cotangent

Suppose that for the triangle shown in figure 1-23, you know that angle B measures 53°08′ and that side a measures 3.00 ft. You want to determine the length of side b. You could do this as previously described by applying

$$\tan B = \frac{b}{a}.$$

However, the fact that side b is larger than side a means that tan B is larger than 1 (you recall that any angle larger than 45° has a tangent larger than 1).

You know that the cotangent is the reciprocal function of the tangent. Therefore, if

$$\tan B = \frac{b}{a}, \cot B = \frac{a}{b},$$

it follows that

$$b = \frac{a}{\cot B}.$$

A table of natural functions tells you that cot 53°08' = 0.74991. Therefore,

$$b = \frac{3}{0.74991}, \text{ or } 4.00.$$

Acute Angle of Right Triangle by Sine or Cosine

If you know the length of the hypotenuse and length of a side of a right triangle, you can determine the size of one of the acute angles by applying the sine or the cosine of the angle. Suppose that for the triangle shown in figure 1-23, you know that the hypotenuse, c, is 5.00 ft long and that the length of side a is 3.00 ft long. You want to determine the size of angle A. Side a is opposite angle A; therefore,

$$\sin A = \frac{a}{c}, \text{ or } \frac{3}{5}, \text{ or } 0.6.$$

A table of natural functions tells you that an angle with sine 0.6 measures (to the nearest minute) 36°52'.

Suppose that, instead of knowing the length of a, you know the length of b (4.00 ft). Side b is the side adjacent to angle A. You know that

$$\cos A = \frac{b}{c}, \text{ or } \frac{4}{5}, \text{ or } 0.8.$$

A table of natural functions tells you that an angle with cosine 0.8 measures 36°52'.

If you know the size of one of the acute angles in a right triangle and the length of the side opposite, you can determine the length of the hypotenuse from the sine of the angle. Suppose that for the triangle shown in figure 1-23, you know that angle A = 36°52' and side a = 3.00 ft.

$$\text{Sin } A = \frac{a}{c}; \text{ therefore, } c = \frac{a}{\sin A}, \text{ or } \frac{3}{0.6}, \text{ or } 5.00 \text{ ft.}$$

If you know the size of one of the acute angles in a right triangle and the length of the side adjacent, you can determine the length of the hypotenuse from the cosine of the angle. Suppose that for the triangle in figure 1-23, you know that angle A = 36°52' and side b = 4.00 ft.

$$\text{Cos } A = \frac{b}{c}; \text{ therefore, } c = \frac{b}{\cos A}.$$

Tables show that cos 36°52' = 0.80003. Therefore,

$$c = \frac{4.00}{0.80003}, \text{ or } 5.00 \text{ ft.}$$

Solution by Law of Sines

For any triangle (right or oblique), when you know the lengths of two sides and the size of the angle opposite one of them, or the sizes of two angles and the length of the side opposite one of them, you can solve the triangle by applying the law of sines. The law of sines (which is explained and proved in NAVPERS 10071-B, chapter 5) states that the lengths of the sides of any triangle are proportional to the sines of their opposite angles. It is expressed in formula form as follows:

$$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$$

In the triangle shown in figure 1-24, $\angle A$ = 41°24', a = 8.00 ft, and b = 12.00 ft. If

$$\frac{b}{\sin B} = \frac{a}{\sin A},$$

it follows that

$$\sin B = \frac{b \sin A}{a}.$$

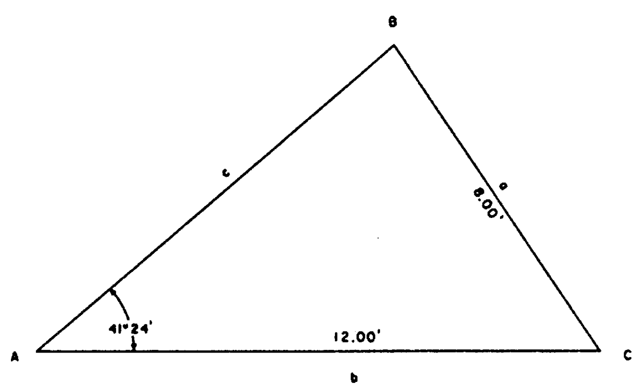

Figure 1-24.—Oblique triangle (law of sines).

The sine of 41°24′ is 0.66131; therefore,

$$\sin B = \frac{12(0.66131)}{8}, \text{ or } 0.99196.$$

Tables show that the angle with sine 0.99196 measures 82°44′. Therefore, $\angle B$ = 82°44′. $\angle C$ = 180° − (A + B), or 180° − (41°24′ + 82°44′), or 180° − 124°08, or 55°52′.

If $\frac{c}{\sin C} = \frac{a}{\sin A}$, then $c = \frac{a \sin C}{\sin A}$. The sine of 55°52′ is 0.82773. Therefore,

$$c = \frac{8(0.82773)}{9.66131}, \text{ or } 10.01 \text{ ft.}$$

Solution by Laws of Cosines

Suppose you know two sides of a triangle and the angle between the two sides. You cannot solve this triangle by the law of sines, since you do not know the length of the side opposite the known angle or the size of an angle opposite one of the known sides. In a case of this kind you must begin by solving for the third side by applying the law of cosines. The law of cosines is explained and proved in chapter 5 of NAVPERS 10071-B. If you are solving for a side on the basis of two known sides and the known included angle, the law of cosines states that in any triangle the square of one side is equal to the sum of the squares of the other two sides minus twice the product of these two sides multiplied by the cosine of the angle between them. This statement may be expressed in formula form as follows:

$$a^2 = b^2 + c^2 - 2bc \cos A$$

$$b^2 = a^2 + c^2 - 2ac \cos B$$

$$c^2 = a^2 + b^2 - 2ab \cos C$$

For the triangle shown in figure 1-25, you know that side c measures 10.01 ft; side b, 12.00 ft; and angle A (included between them), 41°24'. The cosine of 41°24' is 0.75011. The solution for side a is as follows:

$$a = \sqrt{b^2 + c^2 - 2bc \cos A}$$

$$a = \sqrt{144 + 100.20 - 2(12)(10.01)(0.75011)}$$

$$a = \sqrt{244.20 - 180.20}$$

$$a = \sqrt{64}$$

$$a = 8.00 \text{ ft}$$

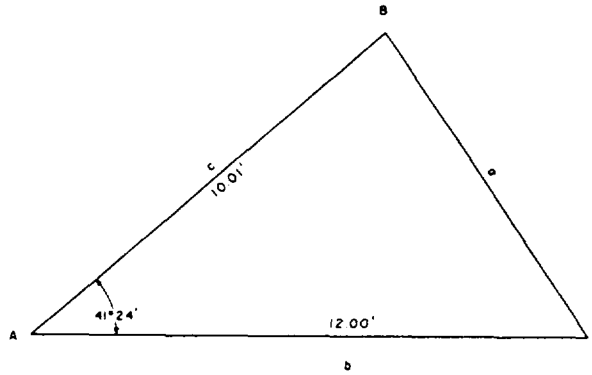

Figure 1-25.-Oblique triangle (law of cosines).

Knowing the length of this side, you can now solve for the remaining values by applying the law of sines.

If you know all three sides of a triangle, but none of the angles, you can determine the size of any angle by the law of cosines, using the following formulas:

$$\cos A = \frac{b^2 + c^2 - a^2}{2bc}$$

$$\cos B = \frac{a^2 + c^2 - b^2}{2ac}$$

$$\cos C = \frac{a^2 + b^2 - c^2}{2ab}$$

For the triangle shown in figure 1-26, you know all three sides but none of the angles. The solution for angle A is as follows:

$$\cos A = \frac{b^2 + c^2 - a^2}{2bc}$$

$$\cos A = \frac{144 + 100.20 - 64}{2(12)(10.01)}$$

$$\cos A = \frac{180.20}{240.24}$$

$$\cos A = 0.75008$$

The angle with cosine 0.75008 measures (to the nearest minute) 41°24.

Solution by Law of Tangents

The law of tangents is expressed in words as follows: In any triangle the difference between two sides is to their sum as the tangent of half the difference of the opposite angles is to the tangent of half their sum.

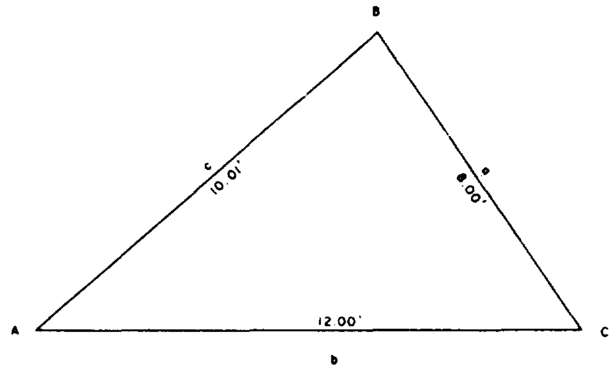

Figure 1-26.-Any triangle, three sides given.

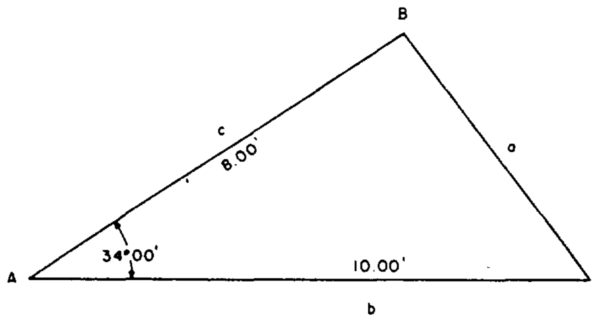

Figure 1-27.-0blique triangle (law of tangents).

For any pair of sides—as side a and side b—the law may be expressed as follows:

$$\frac{a - b}{a + b} = \frac{\tan 1/2\,(A - B)}{\tan 1/2\,(A + B)}$$

For the triangle shown in figure 1-27, you know the lengths of two sides and the size of the angle between them. You can determine the sizes of the other two angles by applying the law of tangents as follows.

First note that you can determine the value of angles (B + C), because (B + C) obviously equals 180° – A, or 180° – 34°, or 146°. Now, if you know the sum of two values and the difference between the same two, you can determine each of the values as follows:

$$\begin{aligned} x + y &= 5 \\ x - y &= 1 \\ \text{(add) } 2x &= 6 \\ x &= 3 \\ y &= 5 - x \\ y &= 2 \end{aligned}$$

Now, you know the sum of (B + C). Therefore, if you could determine the difference, or (B – C), you could determine the sizes of B and C You can determine 12(B — C) from the law of tangents, written as follows:

$$\tan \frac{1}{2}(B - C) = \frac{(b - c)\tan \frac{1}{2}(B + C)}{b + c}$$

One-half of (B + C) means one-half of 146°, or 73°. The tangent of 730 is 3.27085. The solution for 12(B – C) is therefore as follows:

$$\tan \frac{1}{2}(B - C) = \frac{(10 - 8)(3.27085)}{10 + 8}$$

$$\tan \frac{1}{2}(B - C) = \frac{6.54170}{18} = 0.36342$$

(from table of natural tangents) 1/2 (B - C) = 19°58' (B – C) = 2(19058') = 39°56'

Knowing both the sum (B + C) and the difference (B – C), you can now determine the sizes of B and C as follows:

$$\begin{aligned} B + C &= 146°00' \\ B - C &= 39°56' \\ 2B &= 185°56' \\ B &= 92°58' \\ C &= (146° - 92°58') = 53°02' \end{aligned}$$

The Ambiguous Case

When the given data for a triangle consists of two sides and the angle opposite one of them, it may be the case that there are two triangles that conform to the data. A situation in which there can be two triangles is called the ambiguous case. Figure 1-28 shows two possible triangles that

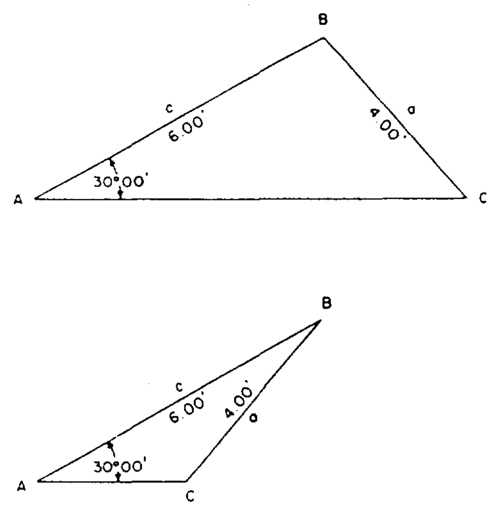

Figure 1-28.-Two ambiguous case triangles (solution of one will satisfy the other).

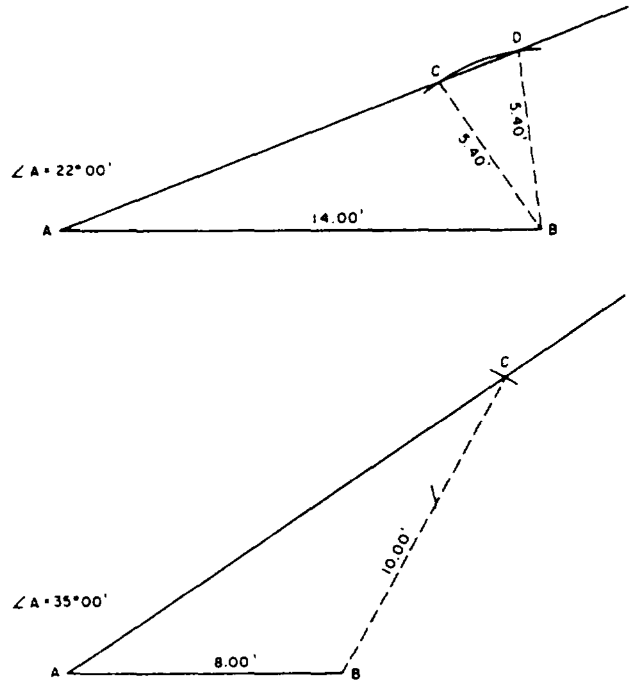

Figure 1-29.-Comparison of an ambiguous case triangle to a standard triangle.

might satisfy this situation. Both triangles shown are with given angle A = 30°00′, given side a = 4.00 ft, and given side c = 6.00 ft.

The best way to determine whether or not the given data for a triangle involves an ambiguous case is to lay out a figure to scale on the basis of the data, as shown in figure 1-29. Suppose, for example, that the data describes a triangle with angle A = 22°00'; side opposite, 5.40 ft; and other side, 14.00 ft. Lay off a line, AB, 14.00 ft long (to scale, of course), as shown in the upper triangle of figure 1-29. Use a protractor to lay off a line from A at 22°00'. Set a compass to the graphical distance of 5.40 ft (length of side opposite A) and with B as a center, strike an arc. You observe that this arc intersects the line from A at two places. Therefore, the triangle ACB and the triangle ADB both satisfy the data, and you have an ambiguous case.

Suppose now that the data describes a triangle with angle A = 35°00′; side opposite, 10.00 ft; and other side, 8.00 ft. Lay off the line AB 8.00 ft long as shown in the lower triangle of figure 1-29, and lay off a line from A at 35°00', Set a compass to 10.00 ft (length of side opposite A) and with B as a center, strike an arc. This arc will intersect the line from A at only one point. Therefore, only one triangle satisfies the data.

Determination of Angle from Three Known Sides

There are several formulas for determining the size of an angle in a triangle from three known sides. The most convenient involves the versed sine of the angle, which means (1 -cos) of the angle. The formula goes as follows:

$$1 - \cos A = \frac{2(s - b)(s - c)}{bc}$$

$$1 - \cos B = \frac{2(s - a)(s - c)}{ac}$$

$$1 - \cos C = \frac{2(s - a)(s - b)}{ab}$$

The value s means one-half the sum of sides a, b, and c, or

$$s = \frac{a + b + c}{2}.$$

For the triangle shown in figure 1-30, you would determine the size of angle A as follows:

$$s = \frac{10.00 + 12.00 + 15.00}{2} = \frac{37.00}{2} = 18.50$$

$$1 - \cos A = \frac{2(18.50 - 15)(18.50 - 10)}{(15)(10)}$$

$$= \frac{2(3.50)(8.50)}{150}$$

$$1 - \cos A = \frac{59.50}{150} = 0.39667$$

$$\cos A = 1 - 0.39667 = 0.60333$$

The angle with cosine 0.60333 measures (to the nearest minute) 52°53′.

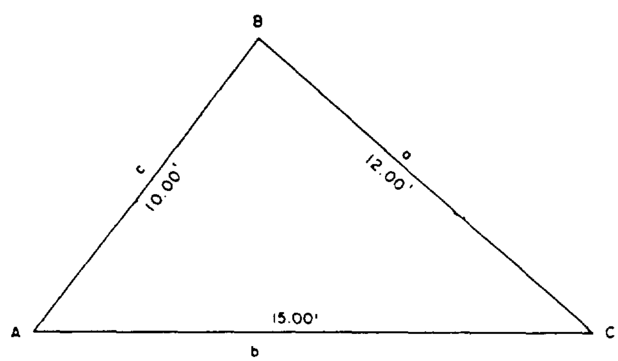

Figure 1-30.—Oblique triangle with three sides given and solved by versed sine formula.

Trigonometric Determination of Area

If you know all three sides of a triangle, you can determine the area by applying the following formula:

$$\text{area} = \sqrt{s(s-a)(s-b)(s-c)}$$

Where s = 1/2 perimeter of a triangle

For the triangle shown in figure 1-30, the area computation is

$$\text{area} = \sqrt{18.50(18.50-12.00)(18.50-15.00)(18.50-10.00}$$

$$\text{area} = \sqrt{18.50(6.50)(3.50)(8.50)}$$

$$\text{area} = \sqrt{3577.44}$$

$$\text{area} = 59.81 \text{ sq ft}$$

When you know two sides of a triangle and the angle included between them, you can determine the area by applying, appropriately, one of the following formulas:

$$\text{area} = 1/2bc \sin A$$

$$\text{area} = 1/2ac \sin B$$

$$\text{area} = 1/2ab \sin C$$

In figure 1-31, two sides, b = 13.00 ft and c = 9.00 ft, and the included angle, A = 40°00′, are given. The sine of 40°00′ is 0.64279. The area computation is as follows:

$$\text{area} = 1/2\ bc \sin A$$

$$\text{area} = 1/2(13.00)(9.00)(0.64279)$$

$$\text{area} = 58.50(0.64279)$$

$$\text{area} = 37.60 \text{ sq ft}$$

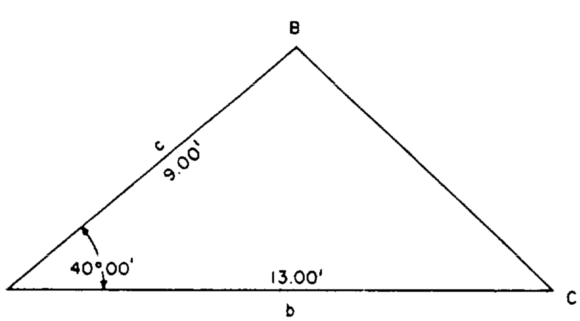

Figure 1-31.-Area of a triangle with two sides and one angle given.

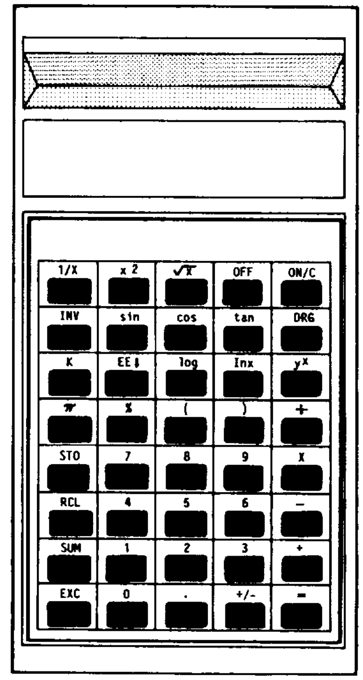

Figure 1-32.-Scientific pocket calculator.

SCIENTIFIC POCKET CALCULATOR

Figure 1-32 illustrates a typical pocket calculator that replaces the slide rule, logarithm tables, and office adding machine. This tool, packed with the latest in state-of-the-art solid-state technology, is a great asset for our trade. With it we can handle many problems quickly and accurately without having to hassle with lengthy, tedious computations. This tool should serve us faithfully for a long time if we treat it with respect and care.

Today's hand-held calculators have become an everyday part of our lives. Rugged and inexpensive, they're a practical answer to the real need we all have for quick, accurate calculations.

THE KEYBOARD

Your calculator has many features to make calculations easy and accurate. To allow you to use all of these features without crowding the keyboard, the designer has caused some of the keys to have more than one function. If you look closely at the keyboard, you'll notice that the keys in the column on the left side have two function symbols. These keys are called dual-function keys because they perform two functions. If you want to perform one of the first functions, simply press the key. To perform one of the second functions, you'll need to press the [2nd] key and then press the key for the function you wish to perform.

INSTRUCTION MANUAL

Every calculator on the market should have an instruction manual enclosed with it. Check out all the features and functions summarized in the instruction manual to become familiar with what your calculator will (and will not) do for you.

HINTS ON COMPUTING

It is a general rule that when you are expressing dimensions, you express all dimensions with the same precision. Suppose, for example, you have a triangle with sides 15.75, 19.30, and 11.20 ft long. It would be incorrect to express these as 15.75, 19.3, and 11.2 ft, even though the numerical values of 19.3 and 11.2 are the same as those of 19.30 and 11.20.

It is another general rule that it is useless to work computations to a precision that is higher than that of the values applied in the computations. Suppose, for example, you are solving a right triangle for the length of side a, using the Pythagorean theorem. Side b is given as 16.5 ft, and side c, as 20.5 ft. By the theorem you know that side a equals the square root of $(20.5^2 - 16.5^2)$, or the square root of 148.0. You could carry the square root of 148.0 to a large number of decimal places. However, any number beyond two decimal places to the right would be useless, and the second number would be determined only for the purpose of rounding off the first.

The square root of 148.0, to two decimal places, is 12.16. As the 0.16 represents more than one-half of the difference between 0.10 and 0.20, you round off at 0.2, and call the length of side a 12.2 ft. If the hundredth digit had represented less than one-half of the difference between 0.10 and 0.20, you would have rounded off at the lower tenth digit, and called the length of side a 12.1 ft.

Suppose that the hundredth digit had represented one-half of the difference betwveen 0.10 and 0.20, as in 12.15. Some computers in a case of this kind always round off at the lower figure, as, 12.1. Others round off at the higher figure, as 12.2. Better balanced results are usually obtained by rounding off at the nearest even figure. By this rule, 12.25 would round off at 12.2, but 12.35 would round off at 12.4.

UNITS OF MEASUREMENT

Engineering science would not be so precise as it is today if it did not make use of systems of measurement. In fieldwork, drafting, office computation, scheduling, and quality control, it is important to be able to measure accurately the magnitudes of the various variables necessary for engineering computations, such as directions, distances, materials, work, passage of time, and many other things.

The art of measuring is fundamental in all fields of engineering and even in our daily lives. We are familiar, for instance, with "gallons," which determines the amount of gasoline we put in our car and with "miles," which tells us the distance we have to drive to and from work. It is also interesting to note that the development of most of these standard units of measure parallels the development of civilization itself, for there has always been a need for measurement. In the early days, people used night and day and the cycle of the four seasons as their measure of time. The units of linear measure were initially adopted as comparison to the dimensions of various parts of a man's body. For example, a "digit" was at that time the width of a man's middle finger, and a "palm" was the breadth of an open hand. The same applies to most other units of linear measure that we know today—like the "foot," the "pace," and the "fathom." The only difference between today's units of measure and those of olden days is that those of today are standardized. It is with the standard types of measurements that we are concerned in this training manual.

At present, two units of measurement are used throughout the world. They are the English system and the metric system, Many nations use the metric system.

The metric system is the most practical method of measurement, for it is based on the decimal system, in which units differ in size by multiples of tens, like the U.S. monetary system in which 10 mills equal 1 cent; 100 mills or 10 cents equal 1 dime; and 1,000 mills, 100 cents, or 10 dimes equal one dollar. When we perform computations with multiples of 10, it is convenient to use an exponential method of expression as you may recall from your study of mathematics.

Table 1-1.-Linear Conversion Factors

	Inches	Feet	Yards	Statute miles	Centimeters	Meters	Kilometers
Inch	1	.083333	.0277		2.540005	.0254	
Foot	12	1	.333		30.48006	0.304801	
Yard	36	3	1	.000568	91.44018	.914402	.000914
Statute mile	63,360	5280	1760	1		1609.347	1.609347
International nautical mile		6076.10	2025.36	1.150777			
United States nautical mile		6080.20	2026.73	1.151553			
Centimeter	.3937				1	.01	
Meter	39.37	3.280833	1.093611		100	1	.001
Kilometer				0.62137		1000	1
Decimeter	3.937	.328				.1	
Decameter	393.7	32.8				10	
Hectometer		328'-1"					.1
Myriameter				6.213712			10

A unit of measurement is simply an arbitrary length, area, or volume, generally adopted and agreed upon as a standard unit of measurement. The basic standard for linear measurement, for example, is the meter, and the actual length of a meter is, in the last analysis, equal to the length of a bar of metal called the International Meter Bar, one replica of which is kept in the National Bureau of Standards, Washington, D.C.

As an EA, you will not necessarily be working with all the units described in this chapter, and therefore need not attempt to memorize them all. Many are included simply to show that units are arbitrary and that there are many different kinds of units in use.

UNITS OF LINEAR MEASUREMENT

Linear measure is used to express distances and to indicate the differences in their elevations. The standard units of linear measure are the foot and the meter. In surveying operations, both of these standard units are frequently divided into tenths, hundredths, and thousandths for measurements. When longer distances are involved, the foot is expanded into a statute or to a nautical mile and the meter into a kilometer. Table 1-1 shows the conversion factors for the common linear measurements.

English Units

In the English system, the most commonly used basic unit of linear measurement is the foot, a unit that amounts to slightly more than three-tenths of the international meter. In what is called ENGINEER'S measurement, the foot is subdivided decimally; that is, into tenths, hundredths, or thousandths of a foot. In what is called CARPENTER'S measurement, or English units, the foot is subdivided into twelfths called inches, and the inch is further subdivided into even-denominator fractional parts, as 1/2 in., 1/4 in., 1/8 in., and so on.

Fractions or multiples of the basic 1-ft unit are used to form larger units of linear measure as follows:

1 link	=	0.66 ft
1 yard	=	3.00 ft
1 rod, pole, or perch	=	16.50 ft
1 Gunter's chain	=	66.00 ft
1 engineer's chain	=	100.00 ft
1 statute mile U.S.	=	5,280.00 ft
1 nautical mile (international)	=	6,076.10 ft

A unit of linear measurement, called a VARA of Spanish and Portuguese origin, was formerly used to measure land boundaries in those areas of the United States that were at one time under Spanish control. In those areas old deeds and other land instruments still contain property descriptions in varas, which vary from state to state and country to country from 32 to 43 in.

Metric Units

In many of the non-English-speaking countries of the world, the most commonly used basic unit of linear measure is the meter. The length of a meter was originally designed to equal (and does equal very nearly) one ten-millionth part of the distance, measured along a meridian, between the earth's equator and one of the poles. A meter equals slightly more than 1.09 yd.

The big advantage of the metric system is the fact that it is a decimal system throughout; that is, the fact that the basic unit can be both subdivided into smaller units decimally and converted to larger units decimally by simply moving the decimal point in the appropriate direction. Names of units smaller than the meter are indicated by the Latin prefixes deci- (one-tenth), centi- (one-hundredth), mini- (one-thousandth), and micro- (one-millionth), as follows:

1 decimeter = 0.1 meter (1×10^{-1})

1 centimeter = 0.01 meter (1×10^{-2})

1 millimeter = 0.001 meter (1×10^{-3})

1 micrometer = 0.000001 meter (1×10^{-6})

Names of units larger than the meter are indicated by the Greek prefixes deca- (ten), hecto- (one hundred), kilo- (one thousand), myria- (ten thousand), and mega- (one million), as follows:

1 decameter = 10.00 meters (1×10)

1 hectometer = 100.00 meters (1×10^2)

1 kilometer = 1,000.00 meters (1×10^3)

1 myriameter = 10,000.00 meters (1×10^4)

1 megameter = 1,000,000.00 meters (1×10^6)

UNITS OF AREA MEASUREMENT

In the English and metric system, area is most frequently designated in units that consist of squares of linear units, as square inches, feet, yards, or miles; or square centimeters, meters, or kilometers. In the English system, the land-area measurements most commonly used are the square foot and the acre. Formerly the square rod (1 rod = 16.5 ft) and the square Gunter's chain (1 Gunters's chain = 66 ft) were used. One of the area measurements, with its equivalents, is as follows:

1 acre = 10 sq Gunter's chains

= 160 sq rods

= 43,560 sq ft

An equilateral rectangular (square) acre measures 208.71 ft on a side. There are 640 acres in a square mile.

Other area equivalents that may be of value to you are as follows:

1 square inch (sq in.) = 6.4516 + square centimeters (sq cm)

1 square foot (sq ft) = 144 sq in.

= 0.0929 + square meter (sq m)

1 square yard (sq yd) = 9 sq ft

= 0.8361 – sq m

1 square meter (sq m) = 10.7639 sq ft

= 1.1960 + sq yd

Actually, more attention should be given to linear equivalents. If you know the linear conversion factor from one unit to the other, you can always compute for any equivalent area or even volume. Just remember, area is expressed in square units and volume is expressed in cubic units.

Example: Find the area of a rectangle 2 ft by 3 ft in square inches.

Area = 2 ft x 3 ft = (2 x12)(3 x 12) = 864 sq in.

UNIT OF VOLUME MEASUREMENT

From your study of mathematics, you learned that volume is the measure of the amount of space that matter occupies. It is expressed in certain cubic units, depending upon the linear measurements or dimensions of the object.

As an EA, you will find that your interest in unit volume of measurements will be from the standpoint of earthwork, construction materials, material testing, rainfall runoff, and capacities of structures, such as, for example, a reservoir. The accuracy of your computations will depend upon your knowledge of the correct conversion factors and the units used. Remember that your dimensions must always be expressed in one kind of unit of measure; for instance, if you are using the meter, all dimensions must be in meters. The basic units of volume that you might be using are as follows:

1 cubic inch (cu in.) = 16.3872 cubic centimeters (cc)

1 cubic foot (cu ft) = 1,728 cu in. = 0.0283 cubic mete (cu m)

1 cubic yard (cu yd) = 27 cu ft = 0.7646 cubic meter

1 cubic meter (cu m) = 1,000,000 cc = 35.3145 cu ft

= 1.3079 cu yd

1 U.S. gallon = 231 cu in.

1 cu ft = 7.4805 gal

1 acre ft = 43,560 cu ft

= 1,233.49 cu m

UNITS OF WEIGHT

The units of weight most frequently used in the United States for weighing all commodities except precious stones, precious metals, and drugs are the units of the so-called AVOIRDUPOIS system. Avoirdupois units of weight are as follows:

437 1/2 grains (gr) = 1 ounce (oz)

16 ounces (oz) = 1 pound (lb)

100 pounds (lb) = 1 hundred-weight (c

1,000 pounds (lb) = 1 kip (K)

2,000 pounds (or 20 cwt) = 1 short ton (T)

2,200 pounds (lb) = 1 long ton

Precious stones and precious metals are usually weighed in the United States by the system of TROY weight, in which there are 12, rather than 16, oz in the pound. Drugs are weighed by APOTHECARIES' weight, in which there are also 12 oz in the pound.

The basic unit of the metric system of weight is the GRAM, which contains 15.432 grains. The GRAIN was originally supposed to be equal to the weight of a single grain of wheat, The gram of 15.432 grains is also used in the avoirdupois, troy, and apothecaries' system of weights.

Multiples and subdivisions of the basic unit of metric weight (the gram) are named according to the usual metric system of nomenclature, as follows:

0.000001 g = 1 microgram

0.001 g = 1 milligram

0.01 g = 1 centigram

0.10 g = 1 decigram

10.00 g = 1 decagram

100.00 g = 1 hectogram

1,000.00 g = 1 kilogram

A METRIC TON equals 1,000 kilograms, which equals 1.1 short tons.

The Engineering Aid is interested in the weight of his instruments and the pull to be applied to the ends of the tape to give correct linear measurements. The common units of weight in surveying are the OUNCE, the POUND, the GRAM, and the KILOGRAM. The following tabulation gives the relationship between these units:

1 ounce (oz) = 28.3495 grams (g)

1 pound (lb) = 453.5924 g = 0.4536 kg

1 kilogram (kg) = 2.2045 lb = 35.27 oz

UNITS OF ANGULAR MEASUREMENT

ANGULAR or CIRCULAR MEASURE is used for designating the value of horizontal and vertical angles. For general use in the measurement of angles, the circumference of the circle is divided into some even number of equal parts. The unit of angular measure is the angle at the center of the circle subtended by one of the small subdivisions of the circumference. The various units of angular measure are known as UNITS OF ARCS. In practice these units of arcs may be further expressed in decimal or fractional parts.

The Engineering Aid may encounter three systems of angular measure in the use of surveying instruments. They are the sexagesimal, the centisimal or metric, and the mil system.

Sexagesimal or North American System

In the sexagesimal or North American system, the circle is divided into 360 equal parts known as DEGREES of arc, each degree into 60 equal parts known as MINUTES of arc, and each minute into 60 equal parts known as SECONDS of arc. As an example, angles in this system are written as 263047'16".48 which is read as "two hundred sixty-three degrees, forty-seven minutes, and sixteen point four eight seconds of arc." In the United States, this is the most commonly used system of angular measurement.

Centisimal or Metric System

In the centisimal or metric system, the full circle is divided into four quadrants, and each quadrant is divided into 100 equal parts known as GRADS or GRADES. Each grad is further divided into decimal parts. As an example, angles in this system are written as $376^g.7289$, or $376^g72'89''$ which is read as "three hundred seventy-six point seven two eight nine grads," or as "three hundred seventy-six grads, seventy-two centisimal minutes, and eighty-nine centisimal seconds."

Mil System

In the mil system, the circle is divided into 6,400 equal parts known as MILS. The mil is divided into decimal parts. As an example, angles in this system are written as 1728.49 roils, which is read as "one thousand seven hundred twenty-eight point four nine mils." This system is used principally by the artillery people. The significance of this unit of angular measure is the fact that 1 mil is the angle that will subtend 1 yd at a range of 1,000 yd.

The relationship among values in the three systems of angular measure are as follows:

1 circle = 360 degrees = 400 grads = 6,400 mils

1 degree = 1.1111 grads = 17.7778 mils

1 minute = 0.2963 mils

1 grad = 0.9 degree = $0°54'00''$ = 16 mils

1 mil = 0.0562 degree = $0°03'22''.5$ or 3.3750 minutes = 0.0625 grad

MORE UNITS OF MEASUREMENT

Aside from the units of measurement discussed above, the EA must also deal with other units of measurement, such as TIME, TEMPERATURE, PRESSURE, and so forth. He must use exact time in computing problems in astronomy and some laboratory works. He must be able to apply temperature corrections to his tape readings. He must also evaluate the effect of atmospheric pressure at different elevations and get involved in some other types of measure that will be discussed in the following paragraphs.

Time Measurement

For practical purposes in everyday affairs and in surveying, the measurement of time intervals is of great concern. The time used in everyday life is known as STANDARD TIME and is based on the mean apparent revolution of the sun around the earth because of the earth's rotation on its axis. Standard time is used in surveying to regulate the normal day's operations. But, when it is necessary to observe the sun or the stars to determine the azimuth of a line or the position of a point on the earth's surface, the surveyor uses three other kinds of time. They are APPARENT (true) SOLAR TIME, CIVIL (mean solar) TIME, and SIDEREAL (star) TIME. You will learn more about these different times when you study the chapter on "Geodesy and Field Astronomy" in *Engineering Aid 1 & C.*

In all four kinds of time, the basic units of measure are the YEAR, DAY, HOUR, MINUTE, and SECOND of time. The duration of any one of these units is not the same for all kinds of time. For example, the sidereal day is approximately 4 min shorter than a standard- or civil-time day.

In the practice of surveying, it is customary to say, or write, the time of day as the number of hours, minutes, and seconds since midnight. Then the recorded time would appear, for example, as $16^h37^m52^s.71$ which is read as "sixteen hours, thirty-seven minutes, and fifty-two point seven one seconds of time."

Units of time measure are sometimes used to designate the sizes of angles. The longitude of a point on the earth's surface is often expressed in this manner. The relationship between the units of time measure and the units of angular measure in the sexagesimal system are as follows:

1 hour = 15 degrees ($1^h = 15°$)

1 minute of time = 15 minutes of arc ($1^m = 15'$)

1 second of time = 15 seconds of arc ($1^s = 15''$)

1 degree = 4 minutes of time ($1° = 4^m$)

1 minute of arc = 4 seconds of time ($1' = 4^s$)

1 second of arc = 0.0667 second of time ($1'' = 0.0667^s$

Temperature Measurement

In certain types of measurement, when the existing temperature differs from a standard temperature, the measured values will be in error and must be corrected, In each of the several temperature-measurement scales, the unit of measure is called a DEGREE, which varies for the different temperature scales, When the scale extends below zero, values below zero are identified by a minus sign. Temperatures are written, for example, as 23°F or – 5°C, the letter designating the particular temperature scale. To avoid confusion when writing or talking about temperature, we should always be sure to indicate the type of scale used, Two of the most commonly used temperature scales are the CENTIGRADE scale and the FAHRENHEIT scale.

On the Centigrade scale (also known internationally as "Celsius Scale" after Anders Celsius, a Swedish astronomer who first devised it), zero is the freezing point of water, and plus 100 is its boiling point.

On the Fahrenheit scale, the temperature of the freezing point of water is plus 32°, and its boiling point is plus 212°.

Now let us compare these scales. A Fahrenheit degree represents five-ninths of the change in heat intensity indicated by a degree on the Centigrade scale. Temperatures on either of the two scales can be converted to the other by the following formulas:

Degrees C = 5/9 (degrees F – 32°,

Degrees F = (9/5 degrees C) + 32°

Note that, when converting Fahrenheit to Centigrade, you should first subtract the 32°, then multiply by 5/9. When converting Centigrade to Fahrenheit, you should first multiply by 9/5, then add the 32°.

Pressure Measurement

Measurements of atmospheric pressure are used in surveying to determine approximate differences in elevation between points on the earth's surface and to determine the best approximate correction for the effect of atmospheric refraction. The units of measure for atmospheric pressure and their relationships are as follows:

1 atmosphere = 29.9212 inches of mercury

= 760 millimeters of mercury

= 14.6960 pounds per square inch

= 1,03323 kilograms per square centimeter

= 33.899 feet of water

= 1.01325 bars, or 1013.25 millibars

Dry Measure

Dry measure is a system of measure of volume used in the United States for dry commodities, such as grains, fruits, and certain vegetables. The basic unit in dry measure is the BUSHEL. The standard U.S. bushel contains about 77.6 lb of water. Since there are about 62.4 lb of water in a cu ft, it follows that a U.S. bushel has a volume of

$$\frac{77.6}{62.442}, \text{ or about } 1\ 1/4 \text{ cu ft.}$$

Units of dry measure are as follows:

1 bushel = 4 pecks

1 peck = 8 quarts

1 quart = 2 pints

Board Measure

Board measure is a method of measuring lumber in which the basic unit is a BOARD FOOT (bf). A board foot is an abstract volume 1 ft long by 1 ft wide by 1 inch thick. The chief practical use of board measure is in cost calculations; lumber is sold by the board foot just as sugar is sold by the pound.

There are several formulas for calculating the number of board feet in any given length of lumber of given section dimensions. Because lumber dimensions are most frequently given by length in feet and width and thickness in inches, the following formula is probably the most practical:

$$bf = \frac{\text{thickness in in.} \times \text{width in in.} \times \text{length in ft}}{12}$$

Board measure is calculated on the basis of the nominal, not the actual, section dimensions. The actual section dimensions of (for example) 2 by 4 stock, which is surfaced on all four surfaces (S4S), are about 1 5/8 in. thick by 3 5/8 in. wide. Nevertheless, the computation for the number of (for example) 300 linear ft of 2 by 4 stock would be as follows:

$$\frac{\overset{1}{\cancel{2}} \times \overset{2}{\cancel{4}} \times \overset{100}{\cancel{300}}}{\underset{\underset{\underset{1}{\cancel{3}}}{\cancel{6}}}{\cancel{12}}} = 200 \text{ bf}$$

Liquid Measure

In the United States the basic unit of liquid measure is the GALLON, which has a volume of 231 cu in. or 0.13 cu ft. The gallon is subdivided into smaller units as follows:

1 gallon = 4 quarts

1 quart = 2 pints

1 pint = 4 gills

Units larger than the gallon in liquid measure are as follows:

1 barrel = 31.5 gallons

1 hogshead = 63 gallons or 2 barrels

For petroleum products the standard barrel contains 42 gallons.

In the metric system the basic unit of liquid measure is the LITER, equal in volume to a cubic decimeter, or about 61 cu in. There are 3.785 liters in a U.S. gallon.

Following the usual metric system of nomenclature, subdivisions and multiples of the liter are as follows:

0.000001 liter = 1 microliter

0.001 liter = 1 milliliter

0.01 liter = 1 centiliter

0.10 liter = 1 deciliter

10.00 liter = 1 decaliter

100.00 liter = 1 hectoliter

1,000.00 liter = 1 kiloliter

Electrical Measure

In an electrical circuit there is a flow of electrons, roughly similar to the flow of water in a water pipe. The flow is occasioned by the production, at a generating station, battery, or other source, of an ELECTROMOTIVE FORCE (E), roughly similar to the "head" of water in a water system. The size of the electromotive force is measured in units called VOLTS.

The rate of flow of the electrons through the circuit is called the CURRENT (I). Current is measured in units called AMPERES.

The usual conductor for transporting a flow of electrons through a circuit is wire. Generally speaking, the smaller the diameter of the wire, the more will be the RESISTANCE (R) to the flow, and the larger the diameter, the less the resistance. Resistance is measured in units called OHMS.

The definitions of the units volt, ampere, and ohm are as follows:

1 volt	Electromotive force required to send a current of 1 ampere through a system in which the resistance measures 1 ohm.
1 ampere	Rate of flow of electrons in a system in which the electromotive force is 1 volt and the resistance, 1 ohm.
1 ohm	Resistance offered by a system in which the electromotive force is 1 volt and the current, 1 ampere.

The ohm is named for Georg Simon Ohm, a German scientist and early electrical pioneer, who discovered that there is a constant relationship between the electromotive force (E), the current (I), and the resistance (R) in any electrical circuit. This relationship is expressed in "Ohm's law" as follows:

$$I = \frac{E}{R}$$

From the basic law it follows that

$$E = IR$$

$$R = \frac{E}{I}$$

From Ohm's law you can (1) determine any one of the three values when you know the other two and (2) determine what happens in the circuit when a value is varied.

Suppose, for example, that the resistance (R) is increased, while the electromotive force (E) remains the same. It is obvious that the current (I) must drop proportionately. To avoid a drop in the current, it would be necessary to increase the electromotive force proportionately.

When an electrical circuit is open (that is, when there is a break in the circuit, such as an open switch), there is no flow of electrons through the circuit. When the circuit is closed, however, the current will begin to flow. With a constant electromotive force (E), the rate at which the current (1) flows will depend on the size of the resistance (R). The size of the resistance will increase with the number of electrical devices (such as lights, motors, and the like) that are placed on the circuit, and the amount of POWER each of these consumes.

Power may be defined as "electrical work per unit of time. " James Watt, another early pioneer in the electrical field, discovered that there is a constant relationship between the electromotive force (E), the current (I), and the power consumption (P) in a circuit. This relationship is expressed in the formula P = IE, from which it follows that

$$I = \frac{P}{E}, \text{ and } E = \frac{P}{I}.$$

Power is measured in units called WATTS, a watt being defined as the work done in 1 second when 1 ampere flows under an electromotive force of 1 volt.

Suppose, now, that you have a 110-volt circuit in your home. The constant E of this circuit, then, is 110 volts. In the circuit there is probably a 15-ampere fuse. A fuse is a device that will open the circuit by "burning out" if the current in the circuit exceeds 15 amperes. The reason for the existence of the fuse is the fact that the wiring in the circuit is designed to stand safely a maximum current of 15 amperes. A current in excess of this amount would cause the wiring to become red hot, eventually to "burn out, " and perhaps to start an electrical fire.

Suppose you light a 60-watt bulb on this circuit. Your E is 110 volts. By the formula

$$I = \frac{P}{E},$$

you know that the current in the circuit with the 60-watt bulb on is

$$\frac{60}{110},$$

or about 0.54 amperes, which is well within the margin of safety of 15 amperes. Dividing 15 amperes by 0.54 amperes you find that this fuse will protect a 27-lamp circuit.

But suppose now that you place on the same one-lamp circuit an electric toaster taking about 1,500 watts (electrical devices are usually marked with the number of watts they consume) and an electrical clothes dryer taking about 1,200 watts. The total P is now 60 + 1,500 + 1,200, or 2,760 watts. The current will now be

$$\frac{2{,}760}{110}$$

or 25 amperes. Theoretically, before it reaches this point, the 15-ampere fuse will burn out and open the circuit.

Mechanical Power Measure

Mechanical power (such as that supplied by a bulldozer) is measured in units called FOOT-POUNDS PER SECOND (ft-lb/sec) or FOOT-POUND PER MINUTE (ft-lb/min). A foot-pound is the amount of energy required to raise 1 lb a distance of 1 ft against the force of gravity.

One HORSEPOWER equals 33,000 ft-lb/sec or 550 ft-lb/min. One horsepower equals about 746 watts.

CONVERSION OF UNITS

To convert a measure expressed in terms of one unit to the equivalent in terms of a different unit is, when you know the ratio between the units, a simple proportional equation problem. Suppose, for example, that you want to convert a linear distance in engineer's measure (feet and decimals of feet) to the equivalent in carpenter's measure (feet and twelfths of feet) to the nearest one-eighth in. Suppose that the original distance is 12.65 ft. This means "12 ft and 65 hundredths of a foot." You want to determine first, then, how many twelfths of a foot there are in 65 hundredths of a foot. The original ratio is 12/100. The proportional equation solution is as follows:

$$\frac{x}{65} = \frac{12}{100}$$

$$x = \frac{12 \times 65}{100} = \frac{780}{100} = 7.8$$

Therefore, there are 7.8 in. (twelfths of a foot) in 0.65 ft. The next step is to determine how many eighths of an in. there are in 0.8 in.; that is, in eight-tenths of an in. The initial ratio is 8/10, and the proportional equation solution is as follows:

$$\frac{x}{8} = \frac{8}{10}$$

$$x = \frac{8 \times 8}{10} = \frac{64}{10} = 6.4$$

Therefore, there are (rounded off) 6/8 in,, or 3/4 in., in 0.8 in. In 12.65 ft, then, there are 12 ft 7 3/4 in. to the nearest 1/8 in.

Actually, the proportional method used above can be simplified by using the following solution:

Convert 12.65 ft to the nearest 1/8 in. in carpenter's measure.

12.65 ft = 12 ft + (0.65 x 12 = 7.8 in,)

= 12 ft 7.8 in.

= 12 ft 7.0 in. + (0.8 x 8 = 6.4 eighths)

= 12 ft 7.0 in. + 6/8 in. or 3/4 in. to the nearest eighth in.

= 12 ft 7 3/4 in.

In converting from engineer's to carpenter's linear measure, or vice versa, surveyors working with values to only the nearest 0.01 ft frequently use the following conversions to decimal equivalents of inches from 1 through 11 and decimal equivalents of the common carpenter's-measure subdivisions of the inch.

1 in. = 0.08 ft

2 in. = 0.17 ft

3 in. = 0.25 ft

4 in. = 0.33 ft

5 in. = 0.42 ft

6 in. = 0.50 ft

7 in. = 0.58 ft

8 in. = 0.67 ft

9 in. = 0.75 ft

10 in. = 0.83 ft

11 in, = 0.92 ft

$\frac{1}{8}$ in. = 0.01 ft

$\frac{1}{4}$ in. = 0.02 ft

$\frac{1}{2}$ in. = 0.04 ft

$\frac{3}{4}$ in. = 0.06 ft

Using these values, you can convert decimals of a foot to inches carpenter's measure, or inches carpenter's measure to decimals of a foot, very easily. To convert (for example) 0.37 ft to inches carpenter's measure, you have the following:

$$\begin{aligned} 0.33 \text{ ft} &= 4 \text{ in.} \\ 0.04 \text{ ft} &= \tfrac{1}{2} \text{ in.} \\ \hline 0.37 \text{ ft} &= 4\tfrac{1}{2} \text{ in.} \end{aligned}$$

To convert (for example) 7 3/8 in. carpenter's measure to engineer's measure, you have the following:

$$7 \text{ in.} = 0.58 \text{ ft}$$

$$\frac{3}{8} \text{ in.} = (3 \times 0.01) = \underline{0.03} \text{ ft}$$

$$7\frac{3}{8} \text{ in.} = 0.61 \text{ ft}$$

For a great many types of conversions there are tables in which you can find the desired values by inspection. Various publications contain tables for making the following conversions:

Meters to feet

Feet to meters

Degrees Centigrade to degrees Fahrenheit

Degrees Fahrenheit to degrees Centigrade

Inches and sixteenths to decimals of a foot

Sixteenths of an inch to decimals of a foot

Minutes to decimals of a degree

Degrees to roils and roils to degrees

Grads to degrees, minutes, and seconds

A conversion factor is a number that, if multiplied by a value expressed in terms of one unit, will produce the equivalent value expressed in terms of a different unit. The factor for converting linear feet to miles, for instance, is 0.00019. If you multiply 5,280 ft by 0.00019, you get 1.0032 miles, which is close enough to a mile to satisfy most practical purposes.

When you know the ratio between two different units, you can easily work out your conversion factor. For example, you know that the ratio of degrees to roils is

$$\frac{9}{160}.$$

The conversiom factor for converting degrees to roils is the number of roils in 1 degree, which is

$$\frac{160}{9}, \text{ or } 17.8.$$

The conversion factor converting roils to degrees is the number of degrees in a roil, which is

$$\frac{9}{160}, \text{ or } 0.0562.$$

Some of the common conversion factors are as follows :

Linear feet x 0.00019 = miles

Linear yards x 0.0006 = miles

Square inches x 0.007 = square feet

Square feet x 0.111 = square yards

Square yards x 0.0002067 = acres

Acres x 4840.0 = square yards

Cubic inches x 0.00058 = cubic feet

Cubic feet x 0.03704 = cubic yards

CHAPTER 2

DRAFTING EQUIPMENT

Drawing is often called the universal language. Drafting is the particular phase of drawing that engineers and designers use to convey and record ideas or information necessary for the construction of structures and machines. There are definite rules of usage to ensure that the same meaning is conveyed at all times and to enable those who learn the rules to interpret what is presented in a drawing. In contrast to pictorial drawings, such as paintings of landscapes and living things, engineering drawings use a graphical language to describe every integral part of an object. As an Engineering Aid, you will specialize in engineering drawings, whereas the Illustrator Draftsman will specialize in pictorial drawings.

In studying this chapter, you will learn that drafting is classified into types, such as technical, illustrative, mechanical, freehand, and engineering drafting. Then you will go on to learn about charts, graphs, drafting guidelines, and a variety of instruments and materials, all of which are designed to help you perform your drafting duties. This chapter also contains many pointers that will help you operate, adjust, and maintain your drafting instruments.

TYPES OF DRAFTING

Generally, drafting is classified according to its purpose or the means by which it is accomplished.

TECHNICAL AND ILLUSTRATIVE DRAFTING

A distinction is often made between technical drafting and illustrative drafting. TECHNICAL DRAFTING presents technical information in a graphic form; for example, a drawing that shows the type and proper placement of structural members in a building. ILLUSTRATIVE DRAFTING presents a pictorial image only; an example is a perspective drawing of a proposed structure. The term *illustrative drafting* is not commonly used in construction drafting.

MECHANICAL AND FREEHAND DRAFTING

MECHANICAL DRAFTING, as distinguished from freehand drafting, is any drawing in which the pencil or pen is guided by mechanical devices, such as compasses, straightedges, and french curves. In FREEHAND DRAFTING the pencil or penis guided solely by the hand of the draftsman. Sketches are the result of freehand drafting. With the exception of lettering, most technical drafting is mechanical drafting in this sense of the term.

In a different sense, the term *mechanical* applies to certain types of industrial or engineering drawings, regardless of whether the drawings are done mechanically or freehand. Some authorities confine the term, used in this sense, to the drawing of machinery details and parts. Others confine it to the drawing of plumbing, heating, air conditioning, and ventilating systems in structures. In the SEABEEs, mechanical drawing means the arrangements of machinery, utility systems, heating, air conditioning, and ventilating systems.

ENGINEERING DRAFTING

As an Engineering Aid, you will be primarily concerned with the following broad types of engineering drafting:

1. Topographic drafting, or drafting done in connection with topographic and civil engineering surveys. It may include drawings not directly related to topographic maps, such as plotted profiles and cross sections.
2. Construction drafting, or drafting of architectural, structural, electrical, and mechanical drawings related to structures.

3. Administrative drafting, or drafting done in support of the administrative and operational functions of your unit, such as technical and display charts, safety and embarkation signs, project completions, and unit readiness graphics.

In performing drafting duties, you will be working from sketches, field notes, or direct instructions from your drafting supervisor.

Engineering Charts and Graphs

Graphic presentation of engineering data means using CHARTS and GRAPHS, rather than numerical tables or word descriptions, to present statistical engineering information. Properly constructed, each form of chart or graph offers a sharp, clear, visual statement about a particular aspect or series of related facts. The visual statement either emphasizes the numerical value of the facts or shows the way these facts are related, A chart or graph that emphasizes numerical value is called **quantitative;** one that emphasizes relationships is called **qualitative.** The trend of an activity over a period of time, such as the mishaps summary report of a deployed unit rendered over a 6-mo deployment period, is more easily remembered from the shape of a curve describing the trend than from numerical statistics. Successful graphic presentation of engineering data requires as much drafting ability as the graphic representation of engineering objects. Lines must be sharp, opaque, well contrasted, and of uniform weight. Letters and figures are normally executed with the standard lettering set according to accepted conventions.

Charts and graphs are classified as **technical** or **display** charts.

TECHNICAL ENGINEERING CHARTS usually are based on a series of measurements of laboratory experiments or work activities. Such measurements examine the quantitative relationship between a set of two factors or variables. Of the two variables, one has either a controlled or regular variation and is called the independent variable. The other is called the dependent variable because its values are related to those of the independent variable. The line connecting plotted points is called a curve, although it may be broken, straight, or curved. The curve demonstrates the relationship between the variables and permits reading approximate values between plotted points.

DISPLAY CHARTS are organized primarily to convey data to nontechnical audiences. The message presents a general picture of a situation, usually comparative. There are many varieties of display charts, including bar charts, status charts, and training aids. In a SEABEE battalion, display charts are frequently used in operations and training departments. When so used, they must conform to minimum standards prescribed by the command.

Any construction job involves quantities of people, materials, and equipment. Efficient operation and completion of the job result from planning, organization, and supervision. Graphic presentation of data is important. Statistics based on the results of past jobs with similar working conditions provide a basis for predicting the amount of time that a proposed job will take. These statistics offer the best possibilities for study when presented graphically, usually in the form of a curve. The prediction of expected achievement usually is presented as a bar chart and is called a time-and-work schedule, When the scheduled work progress is compared with the actual progress (work in place), the chart is called a progress chart.

Drafting Guidelines

As stated earlier, there are definite guidelines in drafting. These guidelines provide uniform interpretation of all engineering drawings. Any drawing prepared by or for the Navy must be prepared following the latest military standard (MIL-STD), Department of Defense Standard (DOD-STD), and applicable NAVFACENGCOM design manuals. For subjects not covered by these references, you might refer to civilian publications, such as the *Architectural Graphic Standards.* Or, you may devise your own symbols, provided that any nonstandard features in your drawing are supported with adequate explanation by notes or by legend.

Many drawings continue in use for years. Therefore, you will have occasion to work with drawings that contain obsolete symbols. Look for a legend on the drawings; it should help you in reading symbols with which you are not familiar. If there is no legend, study the drawing carefully and you should be able to interpret the meaning of unfamiliar symbols and abbreviations.

DoD drawing standards, which are constantly being updated, are published by the Assistant Secretary of Defense (Supply and Logistics), Office of Standardization. Any Navy activity can obtain copies of these standards by writing to the following: Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120. All requests should state the title and identifying number and should be submitted on DD Form 1425. To ensure that you have the latest edition of a standard, check the *Department of Defense Index of Specifications and Standards,* which is issued 31 July of each year. Also check the supplements to the Index.

Current editions of the following military standards should be available to the EA:

MIL-HDBK-1006/1	*Policy and Procedures for Project Drawings and Specifications Preparation*
MIL-STD-12D	*Abbreviations for Use on Drawings and in Technical Type Publications*
MIL-STD-14A	*Architectural Symbols*
MIL-STD-17B	*Mechanical Symbols*
MIL-STD-18	*Structural Symbols*
DOD-STD-100C	*Engineering Drawing Practices*

In addition, the following civilian industry standards should be on hand in the drafting room:

ANSI Y14.1	*Drawing Sheet Size and Format*
ANSI Y14.2	*Line Conventions and Lettering*
ANSI Y14.3	*Multi and Sectional View Drawings*
ANSI Y14.5-82	*Dimensioning and Tolerancing for Engineering Drawings*
AWS A3.0-85	*Welding Terms and Definitions Standards*
ASTM E380	*Standard for Metric Use*

DRAFTING EQUIPMENT

To be a proficient draftsman, you must be familiar with the tools of your trade and the proper techniques of using them. Great care must be given to the proper choice of drafting equipment and accessories. To have a few good pieces of equipment is much better than to have a large stock of undependable and shoddy equipment.

NAVAL MOBILE CONSTRUCTION BATTALION'S STANDARD DRAFTSMAN KIT

As a means of ensuring that every Naval Mobile Construction Battalion's (NMCB's) drafting section is properly outfitted with adequate drafting equipment and accessories, standard draftsman kits are provided in each NMCB's allowance. The drafting equipment and supplies contained in the draftsman kit #0011 are listed in the NMCB's TABLE OF ALLOWANCE (Assembly 80011). For this reason, no attempt will be made here to list all equipment and supplies currently carried in the standard draftsman kit. One complete NMCB's draftsman kit is designed to be used by three draftsmen. Normally, two complete draftsman kits will be carried in a battalion allowance, available for checkout to the drafting section supervisor or engineering chief. It is the responsibility of each crew leader to make sure that the kits assigned to him are complete. The kits are continuously reviewed and updated according to current battalion requirements.

Most of the consumable items contained in the kit, such as pencils, pencil leads, lead holders, masking tape, and ink, are stocked in the battalion supply department for kit replenishment. Additional drafting equipment and supplies, such as pointers and dust brushes, are also stocked in most battalion drafting rooms to supplement the drafting kits.

To avoid losing any equipment and supplies not included in the draftsman kit, personnel should not pack them with the kit when the kit is turned in to the supply department at the end of a deployment or homeport period.

The following sections will acquaint you with general drafting equipment and supplies, with emphasis being placed on items used by SEABEE draftsmen.

DRAFTING MEDIA

Materials used to draw on are referred to as DRAFTING MEDIA. Generally there are three types: paper, cloth, and film. For all practical purposes, you, as a SEABEE draftsman, will use tracing paper, profile paper, plan/profile paper, and cross-section paper. Although it is not found in the draftsman kit, illustration board is used for preparing signs and charts. Tracing cloth and film are rarely used by SEABEE draftsmen, and hence will not be described here.

TRACING PAPER (also called TRACING VELLUM) is a high-grade white (or slightly tinted) transparent paper that takes pencil well, and from which pencil lines can be easily erased. Also, reproductions can be made directly from pencil drawings on tracing paper; however, for better results in reproduction, a pencil drawing on tracing paper is usually inked over.

PROFILE, PLAN/PROFILE, and CROSS-SECTION PAPER are referred to as GRIDDED MEDIA. Each type of gridded media is designed for a specific purpose. Most gridded media used by EAs are suitable for reproduction.

PROFILE PAPER is normally available in two grid patterns: 4 by 20 lines (4 lines vertical and 20 lines horizontal) per inch and 4 by 30 lines per inch with the vertical lines accented every 10th line. Horizontal lines on the 4 by 20 are accented medium-weight every 5th line and heavyweight every 50th line. Horizontal lines on the 4 by 30 have heavyweight accent lines every 25th line. Profile paper is generally used for road design profiles.

PLAN/PROFILE PAPER has rulings and grid accents similar to those of 4 by 20 and 4 by 30 profile paper, except that the grid patterns occupy only the lower half of the paper. The upper half is plain paper, used to draw the plan view in relation to the profile or to add explanatory notes to the profile. Plan/profile paper is also used for road design.

CROSS-SECTION PAPER, sometimes referred to as graph paper, is available in a variety of grid patterns. Generally, graph paper used by the EA has a grid scale of 10 by 10 lines per square inch. It is used for drawing road cross sections, rough design sketching, preparing schedules, plotting graphs, and many other uses.

Most drafting media are available in three styles: plain sheets or rolls, preprinted sheets with borders and title blocks, and sheets with non-reproducible grids. For further information on the many varieties of drafting media available, refer to suppliers' catalogs, such as those published by Keuffel & Esser Co. and Eugene Dietzgen Co.

ILLUSTRATION BOARD is a drawing paper with a high rag content mounted on cardboard backing. The type normally found in a SEABEE drafting section has a smooth white drawing surface that takes ink readily. Normally, the board is 30 in. by 40 in. and comes in 50-sheet packages. Illustration board is used by the EA for making signs and for large unmounted charts and for mounting maps, photos, and drawings that require a strong backing. A thinner board, called BRISTOL BOARD, is also used for making small signs and charts. The thickness of bristol board is about the same thickness as an ordinary index card. Unlike illustration board, bristol board has two white smooth sides that take ink very well. Bristol board is less expensive than illustration board and is easily cut, to size with a paper trimmer. It is available in many sizes; the most popular size is 20 in. by 30 in. in 50- or 100-sheet packages.

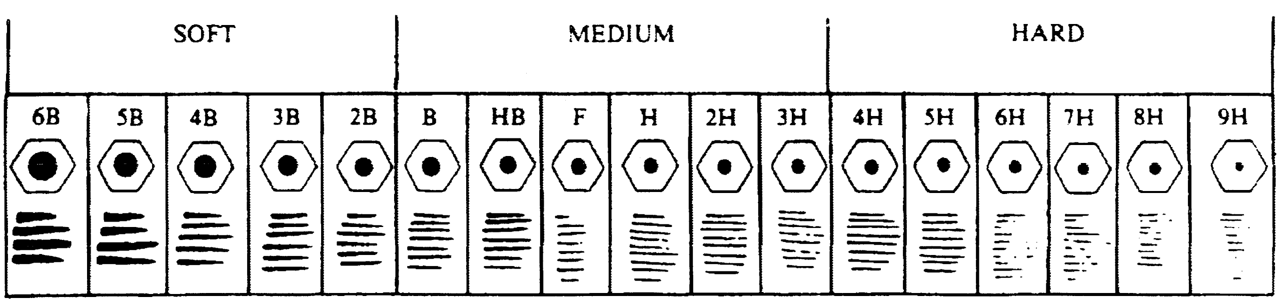

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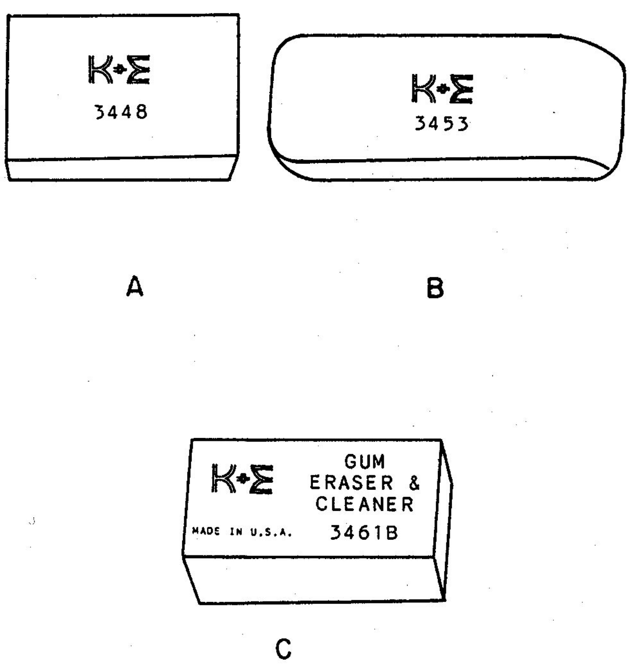
Figure 2-1.—Grades of drafting pencils.

DRAFTING PENCILS

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

Drafting pencils are graded according to the relative hardness of their graphite lead. A pencil that is considered soft is designated by the letter *B*. On the other hand, a hard pencil is designated by the letter *H*. Figure 2-1 shows 17 common grades of drafting pencils from 6B (the softest and the one that produces the thickest line) to 9H (the hardest and one that produces a thin, gray line).

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



Courtesy of Keuffel & Esser Company, Rockaway, NJ

45.672X

Figure 2-2.-Types of erasers.

ERASERS AND ERASING ACCESSORIES

You must be very careful in selecting an eraser that will remove pencil or ink lines without damaging the surface of the drawing sheet.

A vinyl eraser (fig. 2-2, view A) is ideal for erasing lines drawn on tracing cloth and films. An ordinary double-beveled pencil eraser generally comes in red or in pink color (sometimes called a PINK PEARL). A harder eraser (sometimes called a RUBY RED) (fig. 2-2, view B) is designed for erasing lines in ink. The ART GUM eraser (fig. 2-2, view C), made of soft pliable gum, will not mar or scratch. It is ideally suited for removing pencil or finger marks and smudges.

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

The so-called STEEL ERASER, shown in figure 2-3, is, of course, actually a scraper. It is used principally for scraping off erroneous ink lines, especially from tracing cloth. The figure shows a short-bladed steel eraser; long-bladed steel erasers are also available. A steel eraser is not generally recommended for use by beginners because it has a tendency to damage the surface of the drawing sheet.

Figure 2-4 shows an ELECTRIC ERASER. The control switch is directly under the fingertip;

45.673

Figure 2-3.-Steel eraser.

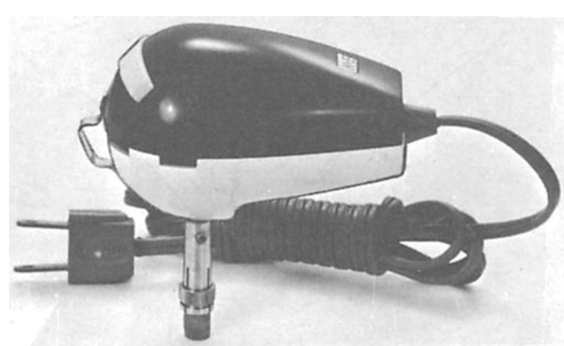


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Figure 2-4.-Electric eraser.

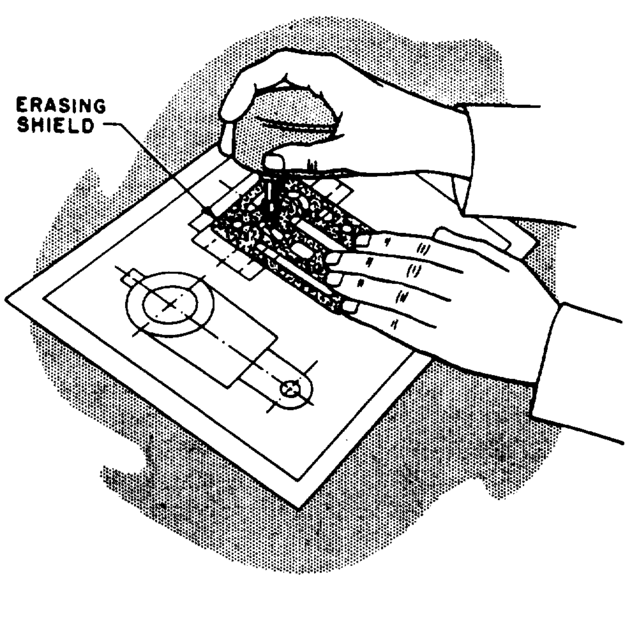
the body of the machine fits comfortably in the palm of the hand, and the rotating eraser can be directed as accurately as a pencil point. Refills for either ink or pencil erasing are available.

CAUTION: Do not hold the electric eraser steady in one spot, or you may easily wear a hole or damage the surface of the material being erased.

When there are many lines close together and only one needs to be removed or changed, the desired lines may be protected by an erasing shield, as shown in figure 2-5.

Finely pulverized gum eraser particles are available in squeeze bottles or in DRY CLEAN PADS for keeping a drawing clean while you work on it. If a drawing or tracing is sprinkled occasionally with gum eraser particles, triangles, T squares, scales, french curves, and the like, not only tend to stay clean themselves, but also tend to clean the drawing or tracing as they are moved over the surface.

Before a drawing is inked, it is usually prepared by sprinkling on POUNCE (a very fine bone dust) and then rubbing in the pounce with a felt pad on the container. Pounce helps to prevent a freshly inked line from spreading. A draftsman's DUST BRUSH should be used for brushing dust and erasure particles off a drawing.



29.273

Figure 2-5.-Use of an erasing shield.

DRAFTING TABLES WITH BOARDS

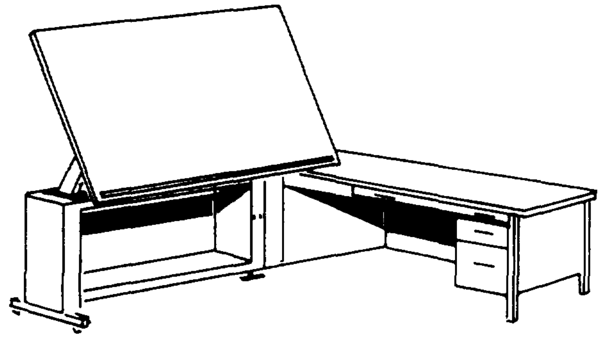
Most EA shops are furnished with standard drafting tables with drafting boards, as shown in figure 2-6. The majority of this furniture is easily adjustable to the users' needs. The height of the table should be such that if you desire to work in a standing position, you can do so without stooping or holding your arms in a raised position. Hinged attachments for the drafting board are provided to adjust the incline so that your line of sight will be approximately perpendicular to the drafting surface. Your drafting stool should be high enough in relation to the table for you to see the whole drafting board but not so high that you are uncomfortably seated.

The drafting boards contained in the draftsman kit are constructed of joined strips of softwood, usually clear white pine or basswood. They are equipped with hinged attachments for securing the board to a table or fabricated base. If suitable bases are not available, table bases may be constructed at the unit carpenter shop.

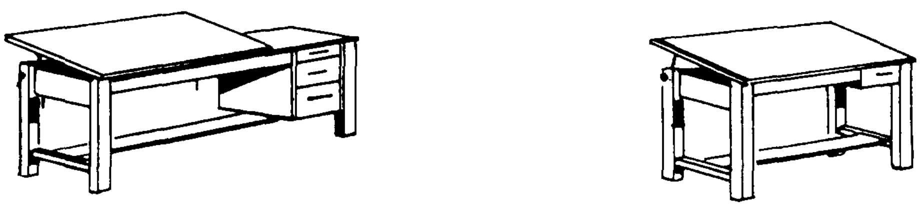
You should consider only the left-hand vertical edge as a working edge for the T square if you are right-handed (the right-hand edge if you are left-handed). The T square should never be used with the head set against the upper or lower edge of the board, as the drafting board may not be perfectly square.

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

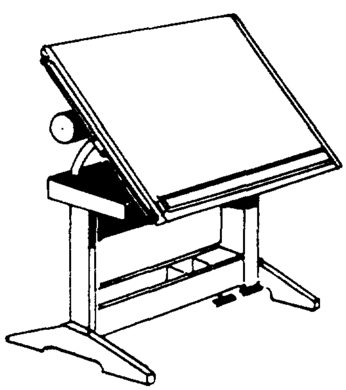
Since you will be constantly using your eyes, it is important that your working area be well lighted. Natural light is best, if available and ample, although in the majority of cases acceptable natural light will be the exception rather than the rule. Drafting rooms are usually lighted with overhead fluorescent fixtures. Ordinarily, these fixtures are inadequate in quality and intensity of light. Adjustable lamps will improve the lighting conditions. The most popular type of adjustable lamp is the floating-arm fluorescent fixture that clamps onto the drafting



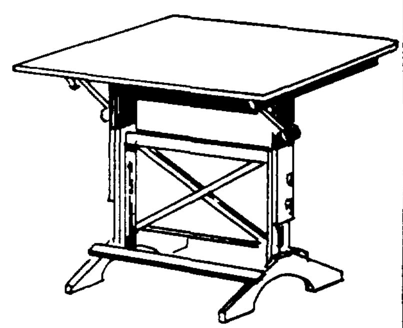
L-SHAPED DRAFTING TABLE AND REFERENCE DESK. THE DRAWING BOARD IS ADJUSTABLE TO ANY ANGLE.



DRAFTING TABLES WITH ADJUSTABLE DRAWING BOARDS THAT MAY BE TILTED UP TO A MAXIMUM OF 45°. TABLE SHOWN ON THE LEFT ALSO HAS A FLAT SURFACE FOR TOOLS OR REFERENCE MATERIAL.



FRENCH TABLE; ADJUSTABLE TO ANY ANGLE FROM HORIZONTAL TO VERTICAL.



PEDESTAL DRAFTING TABLE; SPACE SAVER AND ADJUSTABLE.

142.21

Figure 2-6.-Drafting tables with boards.

table. Arrange your lighting to come from the front-left, if you are right-handed; from the front-right, if you are left-handed. This minimizes shadows cast by drawing instruments and your hands.

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

T SQUARES

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

The T square shown in figure 2-7 is typical of the ones used by an EA. The head is made of hardwood and the blade, usually of maple with a natural or mahogany finish. The edges of the blade are normally transparent plastic strips glued into grooves on both edges of the blade, as shown in the cross section in figure 2-7. This allows the edge of the T square to ride above the drawing as the blade is moved up or down the board. This arrangement is a great advantage when you are drawing with ink. Since the tip of the ruling pen does not come in contact with the blade, but is below it, ink cannot be drawn under the blade to blot the drawing.

The T square is used for drawing horizontal lines only. Always draw lines along the upper edge of the blade. The T square also serves as a base for the triangle when vertical and inclined lines are drawn. Some T squares are designed with adjustable heads to allow angular adjustments of the blade.

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

Before beginning a new job, you should test the top edge of your T square for warp or nicks by drawing a sharp line along the top of the blade.

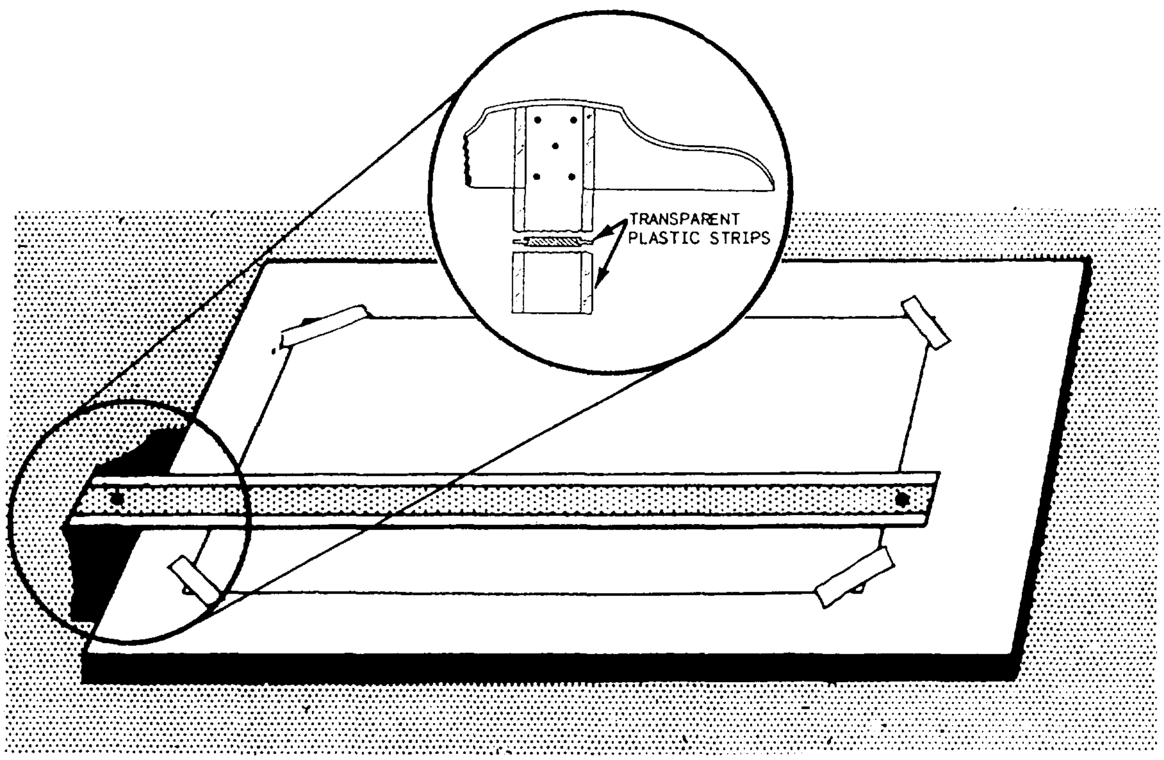


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Figure 2-7.-Drafting board with T square and drafting paper in place.

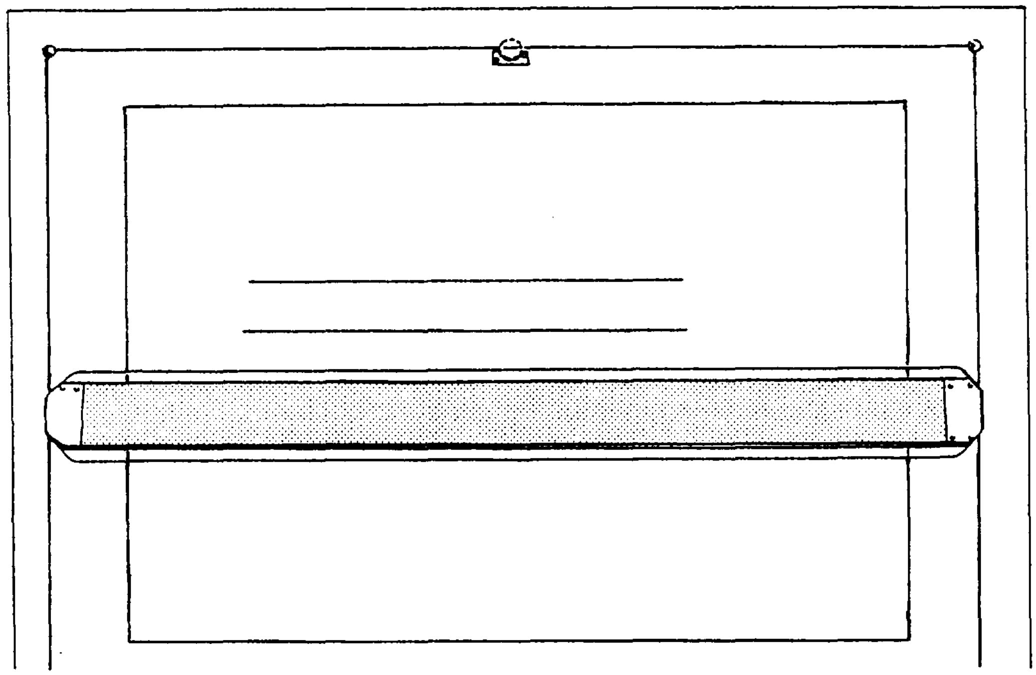

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Figure 2-8.-Parallel straightedge.

Turn the T square over and redraw the line with the same edge. If the blade is warped, the lines will not coincide.

If the blade swings when the head is held firmly against the edge of the drawing board, the blade may be loose where it is joined to the head, or the edge of the T square head may be warped. You can usually tighten a loose blade by adjusting the screws that connect it to the head, but if it is out of square, warped, or in bad condition, you should select a new T square.

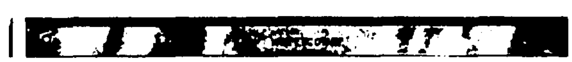
PARALLEL STRAIGHTEDGE

Many draftsmen prefer to use a PARALLEL STRAIGHTEDGE (fig. 2-8) rather than a T square. The primary purpose of the parallel straightedge is the same as the T square.

The parallel straightedge is a laminated maple blade with transparent plastic edges similar to those on the T square. The parallel straightedge uses a system of cords and pulleys so that it is supported at both ends by a cord tacked to the drawing board. You can move the straightedge up or down the board with pressure at any point along its length and maintain parallel motion automatically. It comes complete with cord, tacks, cord tension adjuster, and mounting instructions. Some straightedges, like the one shown in figure 2-8, are equipped with a cord lock on one end of the blade. The straightedge is locked into place by turning the cord lock clockwise. This permits use of the straightedge on an inclined board. It also prevents accidental movement when you are inking or using mechanical lettering devices. The advantages of the parallel straightedge become particularly significant when you are working on large drawings. While the T square works well for small work, it becomes unwieldy and inaccurate when you are working on the far right-hand side of large drawings.

STEEL STRAIGHTEDGE

When drawing long, straight lines, you should use a STEEL STRAIGHTEDGE (fig. 2-9) because its heavy weight helps keep the straightedge exactly in position. The steel



Courtesy of Keuffel & Esser Company, Rockaway, NJ

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Figure 2-9.-Steel straightedge.

straightedge is also excellent for trimming blueprints and cutting heavy illustration board.

Steel straightedges are usually made of stainless steel and are available in lengths of 15 in. to 72 in. The one included in the draftsman kit is 42 in. long. Some have a beveled edge, like the one shown in figure 2-9.

TRIANGLES

TRIANGLES are used in combination with the T square or straightedge to draw vertical and inclined lines. They are usually made of transparent plastic, which allows you to see your work underneath the triangles.

Triangles are referred to by the size of their acute angles. Figure 2-10 shows two basic drafting triangles: the 45° (each acute angle measures 45°, and the 30°/60° (one acute angle measures 30°; the other, 60°). The size of a 45° triangle is designated by the length of the sides that form the right angle (the sides are equal). The size of a 30°/60° triangle is designated by the length of the longest side that forms the right angle. Sizes of both types of triangles range from 4 in. through 18 in. in 2-in. increments.

Like all other drafting equipment, triangles must be kept in good condition. If plastic triangles are dropped, their tips may be damaged. Also, triangles may warp so that they do not lie flat on the drawing surface, or the edge may deviate from true straightness. To prevent warping or chipping, you should always lay them flat or hang them up when they are not in use. Since there is seldom enough drawer space available to permit laying triangles flat, it is best to develop the habit of hanging them up. If the tips are bent, use a sharp knife to cut off the damaged part. If the triangle is warped, you may be able to bend it back by hand. If this does not straighten it, leave the triangle lying on a flat surface with weights on it or hold the triangle to the opposite curvature with weights. If the triangle becomes permanently warped so that the drawing edges are curved or the angles are no longer true, throw it away and get another.

To test the straightness of a triangle, place it against the T square and draw a vertical line, as shown in figure 2-11. Then reverse the triangle and draw another line along the same edge. If the triangle is straight, the two lines will coincide; if they don't coincide, the error is half the resulting space.

PROTRACTORS

PROTRACTORS are used for measuring and laying off angles other than those that may be drawn with the triangle or a combination of triangles. Most of the work you will do involving the use of the protractor will involve plotting information obtained from field surveys.

Like the triangle, most protractors are made of transparent plastic. They are available in 6-, 8-, and 10-in. sizes and are either circular or semicircular in shape, as shown in figure 2-12.

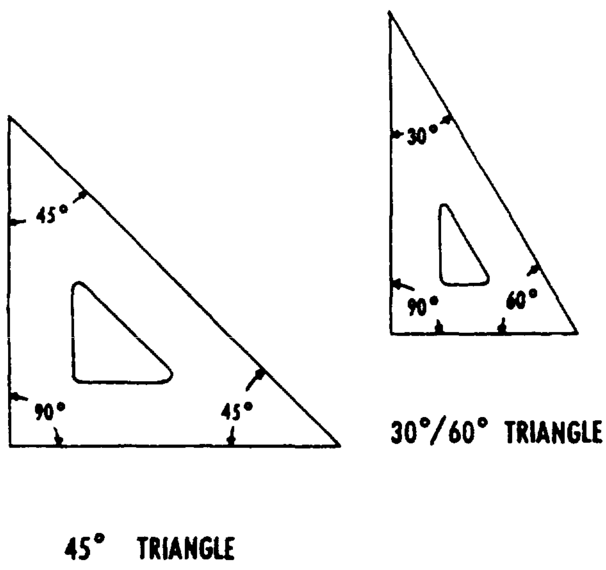

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Figure 2-10.-45° and 30°/60° drafting triangles.

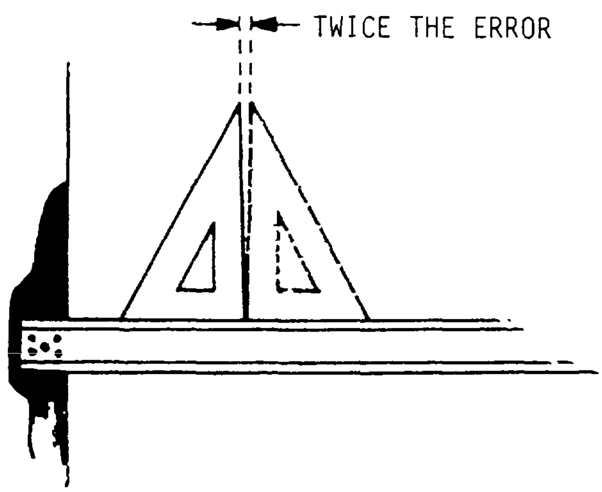

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Figure 2-11.-Testing a triangle for straightness.

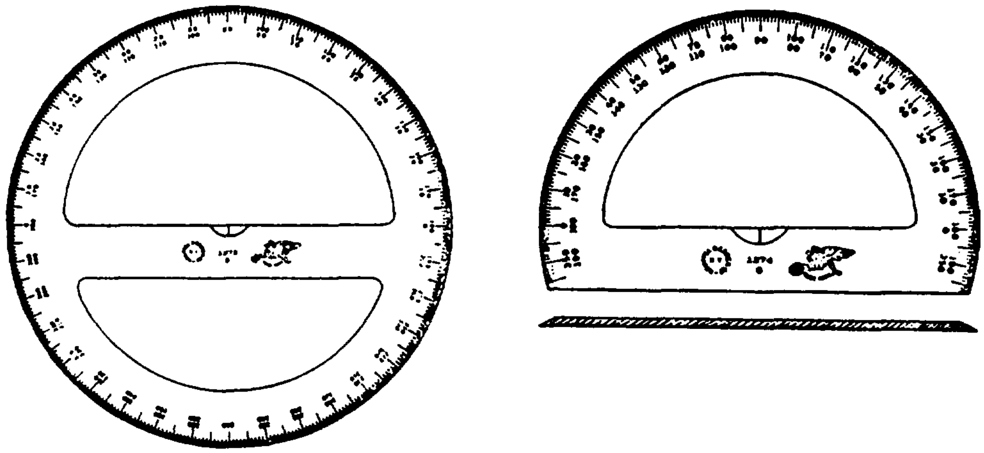

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Figure 2-12.-Types of protractors.

Protractors used by the EA are usually graduated in increments of 1/2°. By careful estimation, angles of 1/4° may be obtained. Protractor numbering arrangement varies. Semicircular protractors are generally labeled from 0° to 180° in both directions. Circular protractors may be labeled from 0° to 360° (both clockwise and counterclockwise), or they may be labeled from 0° to 90° in four quadrants.

Protractors should be stowed and cared for in the same manner as triangles.

ADJUSTABLE TRIANGLES

The ADJUSTABLE TRIANGLE, shown in figure 2-13, combines the functions of the triangle and the protractor. When it is used as a right triangle, the hypotenuse can be set and locked at any desired angle to one of the bases. The transparent protractor portion is equivalent to a protractor graduated in 1/2° increments. The upper row of numbers indicates angles from 0° to 45° to the longer base; the lower row indicates angles from 45° to 90° to the shorter base. By holding either base against a T square or straightedge, you can measure or draw any angle between 0° and 90°.

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

FRENCH CURVES

Irregular curves (called FRENCH CURVES) are used for drawing smooth curved lines that are not arcs or circles, such as ellipses, parabolas, and spirals. Transparent plastic french curves come in a variety of shapes and sizes.

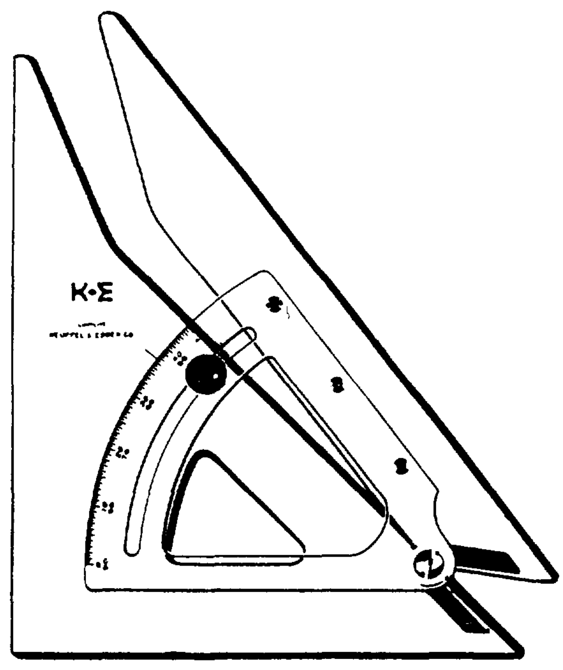

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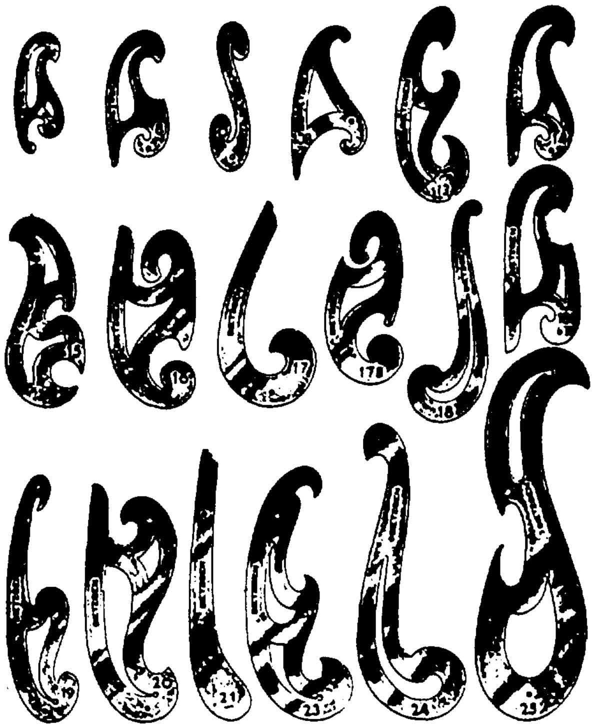
Figure 2-13.-Adjustable triangle.



Courtesy of Dietzgen Corporation

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Figure 2-14.-French curves.

Figure 2-14 shows an assortment of french curves. In such an assortment you can find edge segments that can be fitted to any curved line that you need to draw.

French curves should be cared for and stowed in the same manner as triangles.

DRAWING INSTRUMENT SETS

So far we have discussed only those instruments and materials that you will need for drawing straight lines (with the exception of french curves). Many drawings that you will prepare will require circles and circular arcs. For this purpose, instruments contained in a drawing instrument set are used. Many types of drawing instrument sets are available; however, it is sometimes difficult to judge the quality of drafting instruments by appearance alone. Often their characteristics become evident only after they are used.

The drawing instrument set shown in figure 2-15 is typical of those sets found in the standard draftsman kit. The following sections describe these instruments. Some special-purpose instruments not found in the set will also be described. They may be purchased separately or found in other instrument sets.

Compasses

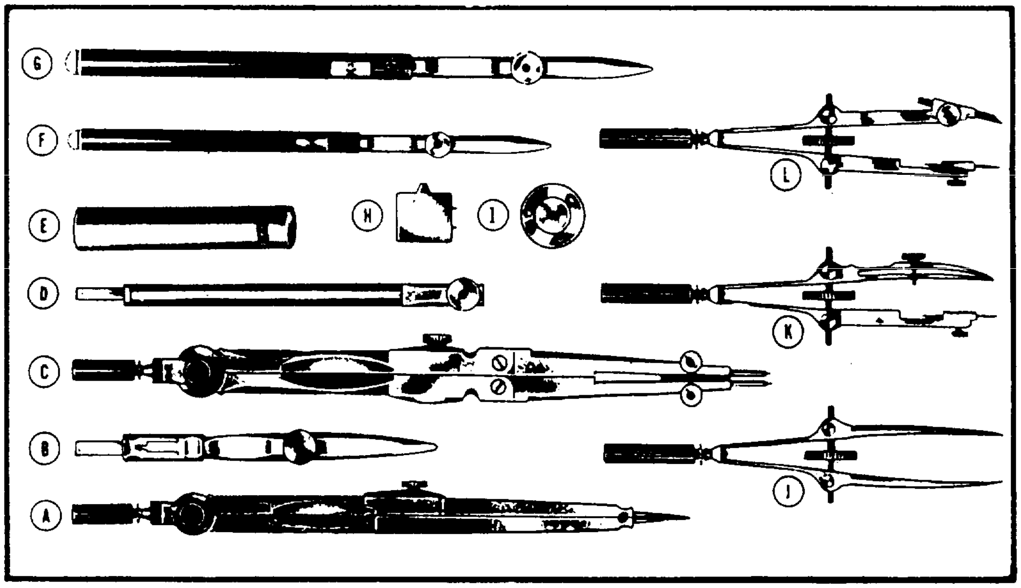
Circles and circular curves of relatively short radius are drawn with COMPASSES. The large **pivot joint compass** (fig. 2-15C) is satisfactory for drawing circles of 1 in. to about 12 in. in diameter without an extension bar. The pivot joint provides enough friction to hold the legs of the compass in a set position. One of the legs is equipped with a setscrew for mounting either a pen (fig. 2- 15B) or a pencil attachment on the compass. There is also an extension bar (fig. 2-15D), which can be inserted to increase the radius of the circle drawn.

The other type of compass found in the drawing instrument set is the **bow compass** (fig. 2-15K and 2- 15L). Many experienced draftsmen prefer the bow compass over the pivot joint compass. The bow compass is much sturdier and is capable of taking the heavy pressure necessary to produce opaque pencil lines without losing the radius setting.

There are two types of bow compasses. The location of the adjustment screw determines the type. The bow pen (fig. 2-15K) and bow pencil (fig. 2-15L) are the **center adjustment type,** whereas the bow instruments shown in figure 2-16 are the **side adjustment type.** Each type comes in two sizes: large and small. Large bow compasses are usually of the center adjustment type, although the side adjustment type is available. The large bow compasses are usually about 6 in. long; the small, approximately 4 in. long. Extension bars are available for large bow compasses. Bow compasses are available as separate instruments, as shown in figures 2-15 and 2-16, or as combination instruments with pen and pencil attachments.

Most compasses have interchangeable needlepoints. The conical or plain needlepoint is used when the compass is used as dividers. The shoulder-end needlepoint is used with pen or pencil attachments.

When many circles are drawn using the same center, the compass needle may tend to bore an oversized hole in the drawing. To prevent these holes, use a device called a **horn center** or **center disk** (fig. 2-151). This disk is placed over the center point. The point of the compass needle is then placed into the hole in its center.



INSTRUMENT SET CONTENTS

(A)	HAIRSPRING DIVIDERS, 6"	(H)	KEY-SCREWDRIVER COMBINATION
(B)	COMPASS PEN ATTACHMENT	(I)	HORN CENTER, 1/2" DIAMETER
(C)	FRICTION HEAD PIVOT JOINT COMPASS, 6 1/2"	(J)	CENTRAL THUMBSCREW BOW DIVIDERS, 3 3/4"
(D)	COMPASS EXTENSION BAR	(K)	CENTRAL THUMBSCREW BOW PEN, 3 3/4"
(E)	CONTAINER W/PENCIL LEADS	(L)	CENTRAL THUMBSCREW BOW PENCIL, 3 3/4"
(F)	RULING PEN, 4 1/2"		
(G)	RULING PEN, 5 1/2"		

Courtesy of Keuffel & Esser Company, Rockaway, NJ

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Figure 2-15.-Typical drawing instrument set.

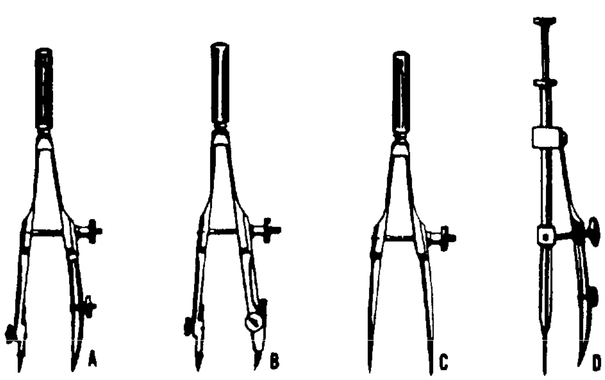

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Figure 2-16.-Bow instruments: (A) Bow pen; (B) Bow pencil; (C) Bow dividers; (D) Drop bow pen.

Dividers

DIVIDERS are similar to compasses, except that both legs are provided with needlepoints. The instrument set (fig. 2-15) contains two different types and sizes of dividers: **large 6-in. hairspring dividers** (fig. 2-15A) and **small center adjustment bow dividers** (fig. 2- 15J). The large pivot joint compass (fig. 2-15C) may also be used as dividers. As with compasses, dividers are available in large and small sizes, and in pivot joint, center adjustment bow, and side adjustment bow types. Figure 2-16C shows small side adjustment bow dividers. Pivot joint dividers are used for measurements of approximately 1 in. or more. For measurements of less than 1 in., bow dividers should be used. Dividers are used to transfer measurements, to step off a series of equal distances, and to divide lines into a number of equal parts.

Drop Bow Pen

The DROP BOW PEN (fig. 2-16D) is not one of the standard instruments. However, for some jobs it is essential. It is used to ink small circles with diameters of less than a quarter of an inch. As the name indicates, the pen assembly is free to move up and down and to rotate around the main shaft. When using this instrument, hold the pen in the raised position, adjust the setscrew to give the desired radius, and then gently lower the pen to the paper surface and draw the circle by rotating the pen around the shaft.

Maintenance of Compasses and Dividers

Figure 2-17 shows the three shapes in which compasses and dividers are made: round, flat, and bevel. Figure 2-18 shows two types of pivot joints commonly found on compasses and dividers. When you select compasses and dividers, test them for alignment by bending the joints and bringing the points together. New instruments are factory adjusted for correct friction setting. They rarely require adjustment. A small jeweler's screwdriver or the screwdriver found in some instrument sets (fig. 2-15H) is used for adjusting most pivot joint instruments. Instruments that require a special tool should be adjusted by skilled instrument repairmen.

Pivot joint compasses and dividers should be adjusted so that they may be set without undue friction. They should not be so rigid that their manipulation is difficult, nor so loose that they will not retain their setting.

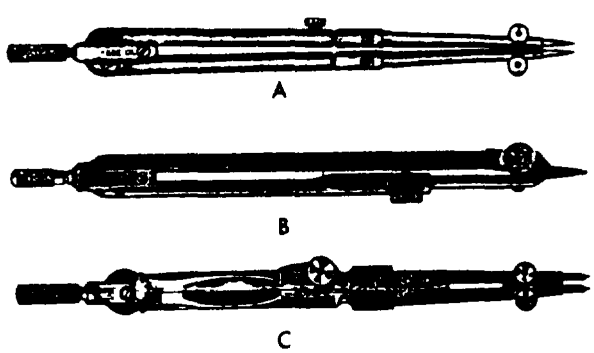

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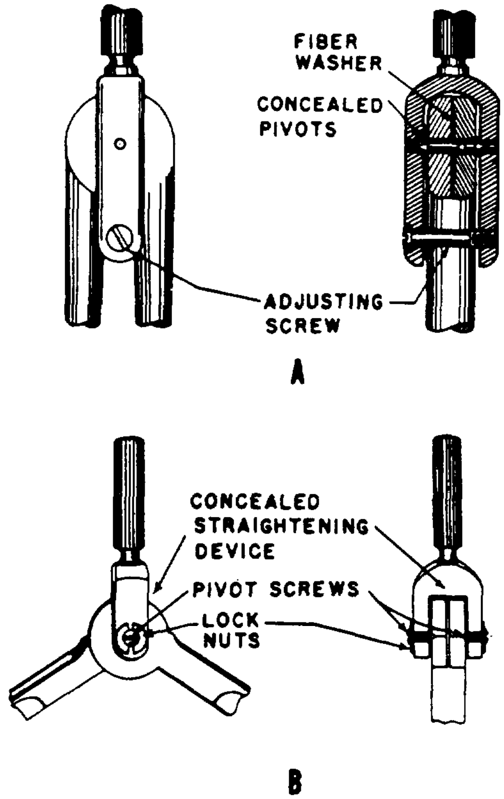
Figure 2-17.-Shapes of compasses and dividers: (A) Round; (B) Flat; (C) Bevel.



Courtesy of Keuffel & Esser Company, Rockaway, NJ

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Figure 2-18.-Sections of pivot joints.

Divider points should be straight and free from burrs. When the dividers are not in use, the points may be protected by sticking them into a small piece of soft rubber eraser or cork. When points become dull or minutely uneven in length, make them even by holding the dividers vertically, placing the legs together, and grinding them lightly back and forth against a whetstone. (See fig. 2-19, view A.) Then hold the dividers horizontally and sharpen each point by whetting the outside of it back and forth on the stone, while rolling it from side to side with your fingers (fig. 2-19, view B). The inside of the leg should remain flat and should not be ground on the stone. The outside of the point should not be ground so that a flat surface results. In shaping the point, be careful to avoid shortening the leg.

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

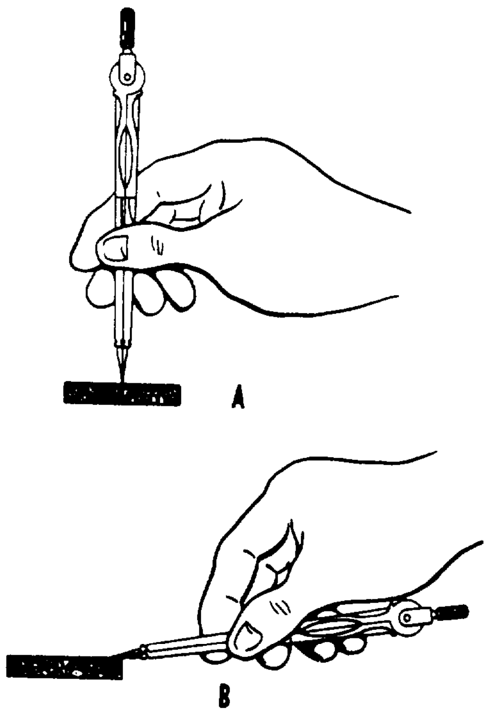

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Figure 2-19.-Divider maintenance: (A) Evening the legs of dividers; (B) Sharpening divider needlepoints.

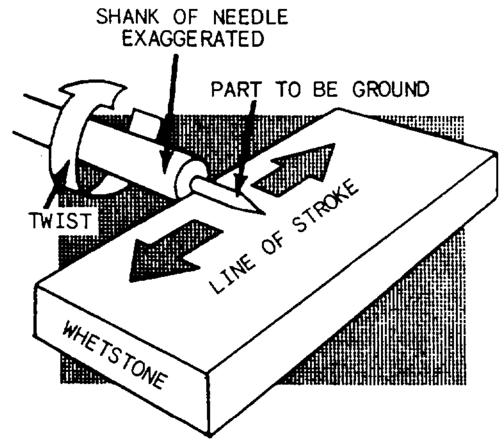

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Figure 2-20.-Shaping a compass needle.

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

To make a compass needle smaller, wet one side of the whetstone and place the needle with its shoulder against this edge. Then grind it against the whetstone, twirling it between your thumb and forefinger (fig. 2-20). Test it for size by inserting it in a hole made by another needle of the correct size. When it is pushed as far as the shoulder, it should not enlarge the hole.

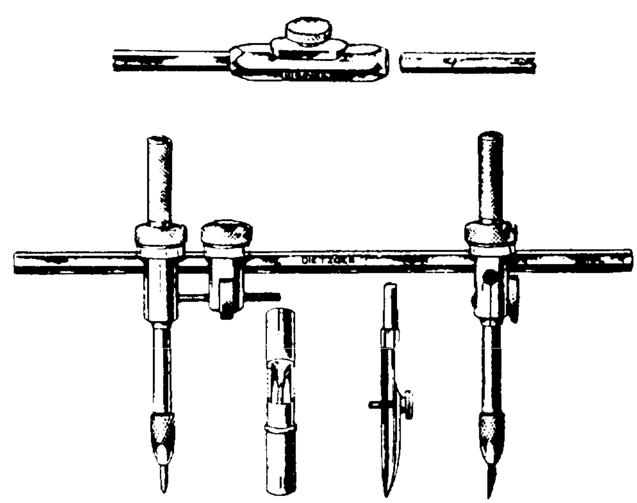
The screw threads on bow instruments are delicate. Because of this, you should take care never to force the adjusting nut. Threads must be kept free from rust or dirt.

If possible, it is best to keep drawing instruments in a case, since the case protects them from damage from falls or unnecessary pressures. Then, too, the lining of the case is usually treated with a chemical that helps prevent the instruments from tarnishing or corroding.

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

Beam Compass

The BEAM COMPASS (fig. 2-21) is used for drawing circles with radii larger than can be set on a pivot joint or bow compass. Both the needle-point attachment and the pen or pencil attachment on a beam compass are slide-mounted on a metal



Courtesy of Dietzgen Corporation

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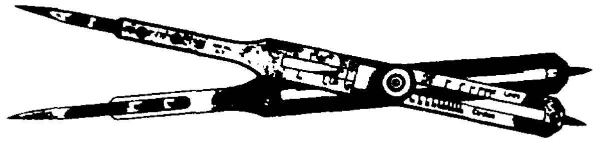
Figure 2-21.-Beam compass.



Courtesy of Keuffel & Esser Company, Rockaway, NJ

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Figure 2-22.-Proportional dividers.

bar called a beam. The slide-mounted attachments can be locked in any desired position on the beam. Thus, a beam compass can be used to draw circles of any radius up to the length of the beam. With one or more beam extensions, the length of the radius of a beam compass ranges from about 18 in. to 70 in.

PROPORTIONAL DIVIDERS

PROPORTIONAL DIVIDERS (fig. 2-22) are used for transferring measurements from one scale to another. This capability is necessary when drawings are to be made to a larger or smaller scale. They can also be used to divide lines or circles into equal parts.

Proportional dividers consist of two legs of equal length, pointed at each end, and held together by a movable pivot. By varying the position of the pivot, you can adjust the lengths of the legs on opposite sides of the pivot so that the ratio between them is equal to the ratio between two scales. Therefore, a distance spanned by the points of one set of legs has the same relation to the distance spanned by the points of the other set as one scale has to the other.

On the proportional dividers, a thumb nut moves the pivot in a rack-and-gear arrangement. When the desired setting is reached, a thumb-nut clamp on the opposite side of the instrument locks the pivot in place. A scale and vernier are provided on one leg to facilitate accurate setting. On less expensive models, the movable pivot is not on a rack and gear, and there is no vernier. The dividers may be set by reference to the table of settings that is furnished with each pair; they will accommodate varying ranges of scales from 1:1 to 1:10. However, it is better not to depend entirely on the table of settings. You can check the adjustment by drawing lines representing the desired proportionate lengths, and then applying the points of the instrument to them in turn until, by trial and error, the correct adjustment is reached.

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

Some proportional dividers have an extra scale for use in getting circular proportions. The scale marked Circle indicates the setting for dividing the circumference into equal parts.

The points of the dividers are of hardened steel, and if they are handled carefully, these points will retain their sharpness during long use. If they are damaged, they may be sharpened and the table of settings will still be usable, but the scale on the instrument will no longer be accurate.

SCALES

In one sense, the term scale means the succession of graduations on any graduated standard of linear measurement, such as the graduations on a steel tape or a thermometer. In another sense, when we refer to the “scale of a drawing,” the term means the ratio between the dimensions of the graphic representation of an object and the corresponding dimensions of the object itself.

Suppose, for example, that the top of a rectangular box measures 6 in. by 12 in. If you draw a 6-in. by 12-in. rectangle on the paper, the dimensions of the drawing would be the same as those of the object. The drawing would, therefore, be a full-scale drawing. This scale could be expressed fractionally as 1/1, or it could be given as 1 in. = 1 in.

Suppose that instead of making a full-scale drawing, you decided to make a half-scale drawing. You should then draw a 3-in. by 6-in. rectangle on the paper. This scale could be expressed fractionally as 1/2, or it could be given as 1 in. = 2 in., or as 6 in. = 1 ft.

In this case, you made a drawing on a smaller scale than the scale of the original object, the scale of an original object being always 1/1, or unity. The relative size of a scale is indicated by the fractional representation of the scale. A scale whose fractional representation equals less than unity is a less-than-full scale. One whose fractional representation is greater than unity (such as a scale of 200/1) is a larger-than-full scale. A scale of 1/10,000 is, of course, smaller than a scale of 1/100.

A scale expressed as an equation can always be expressed as a fraction. For example, the scale of 1 in. = 100 ft, expressed fractionally, comes to 1 over (100 x 12), or 1/1,200.

It is obvious that any object that is larger than the drawing paper on which it is to be represented must be “scaled down” (that is, reduced to less-than-full scale) for graphic representation. Conversely, it is often desirable to represent a very small object on a scale larger than full scale for the purpose of clarity and to show small details. Because the drawings prepared by an EA frequently require scaling down, the following discussion refers mostly to that procedure. However, scaling up rather than down simply means selecting a larger-than-full scale rather than a smaller-than-full scale for your drawing.

You could, if necessary, determine the dimensions of your drawing by arithmetical calculation; for example, on a half-scale drawing, you divide each of the actual dimensions of the object by 2. However, this might be a time-consuming process if you were drawing a map of a certain area to a scale of 1 in. = 1,000 mi, or 1/6,335,000 ft.

Consequently, you will usually scale a drawing up or down by the use of one or another of a variety of scales. This sense of the term scales refers to a graduated, rulerlike instrument on which scale dimensions for a drawing can be determined by inspection.

Scales vary in types of material, shapes, style of division, and scale graduations. Good quality scales are made of high-grade boxwood or plastic, while inexpensive scales are sometimes made of yellow hardwood. The boxwood scales have white plastic scale faces that are permanently bonded to the boxwood. The graduation lines on the boxwood scales are cut by a highly accurate machine. Plastic scales, while less expensive than boxwood scales, have clear graduations and are reasonably accurate.

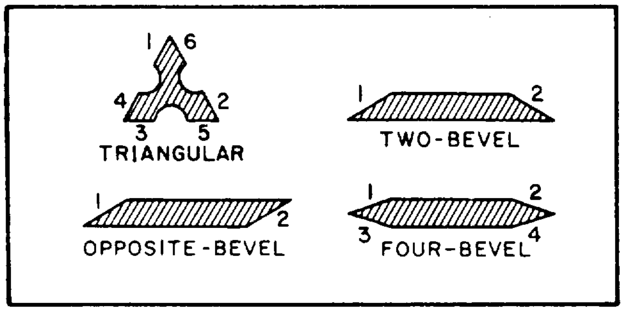

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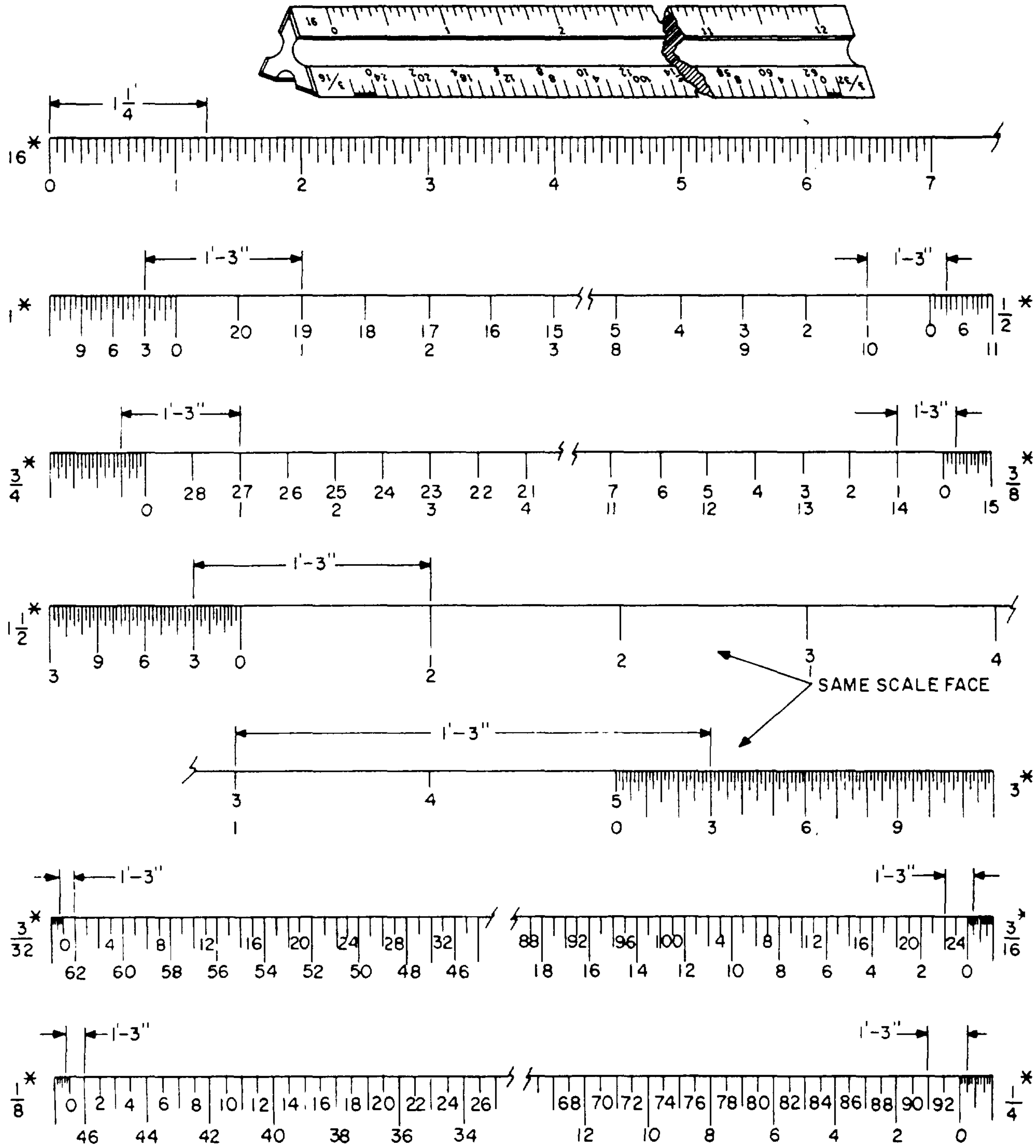
Figure 2-23.-Types of scales in cross section.

Scales are generally available in four different shapes, as shown in figure 2-23. The numbers in the figure indicate the location of the scale face. The triangular scale provides six scale faces on one rule. The two-bevel flat scale provides two scale faces on one side of the rule only. The opposite-bevel flat scale provides two scale faces, one on each side of the rule. And the four-bevel flat scale provides four scale faces, two on each side of the rule. The most common types of scales are the architect’s, the engineer’s, the mechanical engineer’s, and the metric. All of these scales are found in the EA’s draftsman kit with the exception of the mechanical engineer’s scale, which is primarily used by machine draftsmen.

To gain a better understanding of the architect’s and engineer’s scale, which will be described in the following sections, it may be helpful to have the actual scales at hand as you study.

Architect’s Scale

ARCHITECT’S SCALES are usually triangular in shape and are used wherever dimensions are measured in feet and inches. Major divisions on the scale represent feet which, in turn, are subdivided into 12ths or 16ths, depending on the individual scale.



NOTE:
16 SCALE IS SUBDIVIDED INTO SIXTEENTHS.
ALL OTHERS ARE SUBDIVIDED INTO TWELFTHS.
* SCALE DESIGNATION NUMBERS.

142.320

Figure 2-24.-Architect's scale.

Figure 2-24 shows the triangular architect's scale. Also shown are segments of each of the eleven scales found on this particular type of scale. Notice that all scales except the 16th scale are actually two scales that read from either left to right or right to left. When reading a scale numbered from left to right, notice that the numerals are located closer to the outside edge. On scales that are numbered from right to left, notice that the numerals are located closer to the inside edge.

Architect's scales are "open" divided (only the main divisions are marked throughout the length) with the only subdivided interval being an extra interval below the 0-ft mark. These extra intervals are divided into 12ths. To make a scale measurement in feet and inches, lay off the number of feet on the main scale and add the inches on the subdivided extra interval. However, notice that the 16th scale is fully divided with its divisions being divided into 16ths.

Now let's measure off a distance of 1 ft 3 in. to see how each scale is read and how the scales compare to one another. (Refer to fig. 2-24.) Since the graduations on the 16th scale are subdivided into 16ths, we will have to figure out that 3 in. actually is 3/12 or 1/4 of a foot. Changing this to 16ths, we now see we must measure off 4/16ths to equal the 3-in. measurement. Note carefully the value of the graduations on the extra interval, which varies with different scales. On the 3 in. = 1 ft scale, for example, the space between adjacent graduations represents one-eighth in. On the 3/32 in. = 1 ft scale, however, each space between adjacent graduations represents 2 in.

The scale 3/32 in. = 1 ft, expressed fractionally, comes to 3/32 = 12, or 1/128. This is the smallest scale provided on an architect's scale. The scales on the architect's scale, with their fractional equivalents, are as follows:

3 in. = 1 ft . . . . 1/4 scale

1 1/2 in. = 1 ft . . . . 1/8 scale

1 in. = 1 ft . . . . 1/12 scale

3/4 in. = 1 ft . . . . 1/16 scale

1/2 in. = 1 ft . . . . 1/24 scale

3/8 in. = 1 ft . . . . 1/32 scale

1/4 in. = 1 ft . . . . 1/48 scale

1/16 in. = 1 ft . . . . 1/64 scale

1/8 in. = 1 ft . . . . 1/96 scale

3/32 in. = 1 ft . . . . 1/128 scale

Engineer's Scale

The chain, or civil engineer's, scale, commonly referred to as the ENGINEER'S SCALE, is usually a triangular scale, containing six fully divided scales that are subdivided decimally, each major interval on a scale being subdivided into 10ths. Figure 2-25 shows the engineer's scale and

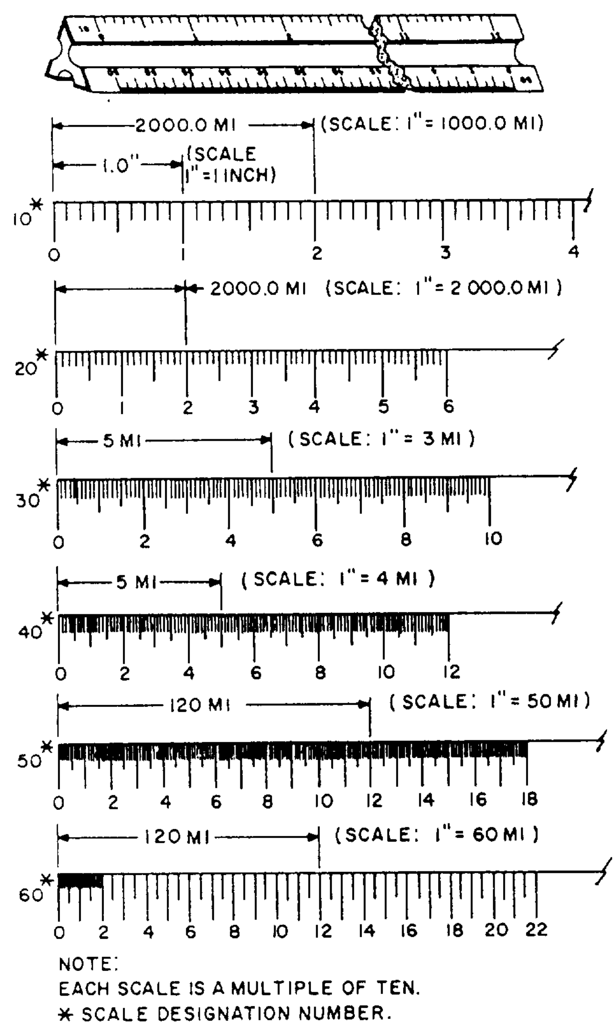


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Figure 2-25.-Engineer's scale.

segments of each of the six scales. Each of the six scales is designated by a number representing the number of graduations that particular scale has to the linear inch. On the 10 scale, for example, there are 10 graduations to the inch; on the 50 scale there are 50. You can see that the 50 scale has 50 graduations in the same space occupied by 10 on the 10 scale. This space is 1 linear inch.

To determine the actual number of graduations represented by a numeral on the engineer's scale, multiply the numeral by 10. On the 50 scale, for instance, the numeral 2 indicates 2 x 10, or 20 graduations from the 0. On the 10 scale, the numeral 11 indicates 11 x 10, or 110 graduations from the 0. Note that the 10 scale is numbered every major graduation, while the 50 scale is numbered every other graduation. Other scales on the engineer's scale are the 20, 30, 40, and 60.

Because it is decimally divided, the engineer's scale can be used to scale dimensions down to any scale in which the first figure in the ratio is 1 in. and the other is 10, or a multiple of 10.

Suppose, for example, that you wanted to scale a dimension of 150 mi down to a scale of 1 in. = 60 mi. You would use the 60 scale, allowing the interval between adjacent graduations to represent 1 mi. To measure off 150 mi to scale on the 60 scale, you would measure off 2.5 in., which falls on the 15th major graduation.

Suppose now that you want to scale a dimension of 6,500 ft down to a scale of 1 in. = 1,000 ft. The second figure in the ratio is a multiple of 10 times a multiple of 10. You would therefore use the 10 scale, allowing the interval between adjacent graduations on the scale to represent 100 ft, in which case the interval between adjacent numerals on the scale would indicate 1,000 ft. To measure off 6,500 ft, you would simply lay off from 0 to 6.5 on the scale.

To use the engineer's scale for scaling to scales that are expressed fractionally, you must be able to determine the fractional equivalent of each of the scales. For any scale, this equivalent is simply 1 over the total number of graduations on the scale, or 1 over the product of the scale number times 12, which comes to the same thing. Applying this rule, the fractional expressions of each of the scales is as follows:

10 scale = 1/120

20 scale = 1/240

30 scale = 1/360

40 scale = 1/480

50 scale = 1/600

60 scale = 1/720

Suppose you wanted to scale 50 ft down to a scale of 1/120. The 10 scale gives you this scale; you would therefore use the 10 scale, allowing the space between graduations to represent 1 ft, and measuring off 5 (for 50 ft). The line on your paper would be 5 in. long, representing a line on the object itself that is 120 in. x 5 in., or 600 in., or 50 ft long.

Similarly, if you wanted to scale 50 ft down to a scale of 1/600, you would use the 50 scale and measure off 5 for 50 ft. In this case, the line on your paper would be 1 in. long, representing a line on the object itself that is 1 x 600, or 600 in., or 50 ft long.

When it is not required that the drawing be made to a specified scale—that is, when the dimensions of lines on the drawing are not required to bear a specified ratio to the dimensions of lines on the object itself—the most convenient scale on the engineer's scale is used. Suppose, for example, that you want to draw the outline of a 360-ft by 800-ft rectangular field on an 8-in, by 10 1/2-in. sheet of paper with no specific scale prescribed. All you want to do is reduce the representation of the object to one that will fit the dimensions of the paper. You could use the 10 scale, allowing the interval between adjacent graduations to represent 10 ft. In this case, the numerals on the scale, instead of representing 10, 20, and so on, will represent 100, 200, and so on. To measure off 360 ft to scale, you should measure from 0 to the 6th graduation beyond the numeral 3. For 800 ft you should measure from 0 to the numeral 8.

Because you allowed the interval between adjacent graduations to represent 10 ft, and because the 10 scale has 10 graduations to the in., the scale of your drawing would be 1 in. = 100 ft, or 1/1,200.

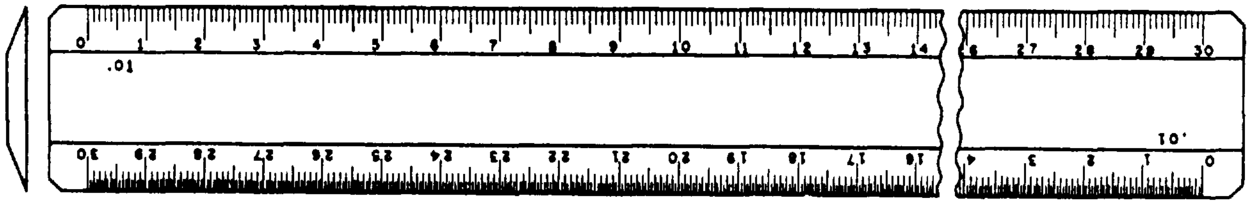

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Figure 2-26.-Flat metric scale.

Metric Scale

The METRIC SCALE is used in the place of the architect's and the engineer's scale when measurements and dimensions are in meters and centimeters. Metric scales are available in flat and triangular shapes. The flat 30-cm metric scale is shown in figure 2-26. The top scale is calibrated in millimeters and the bottom scale in half millimeters. The triangular metric scale has six fully divided scales, which are 1:20, 1:33 1/3, 1:40, 1:50, 1:80, and 1:100.

When you are using scales on a drawing, do not confuse the engineer's scale with the metric scale. They are very similar in appearance. Whenever conversions are made between the metric and English system, remember that 2.54 cm equals 1 in.

Triangular Scale Clip

For use with a triangular scale, a scale clip or scale guard, such as the one shown in figure 2-27, is very helpful. The clip makes it easy for you to identify what scale you are using. Large spring-type paper clips will serve the same purpose when scale clips are not available.

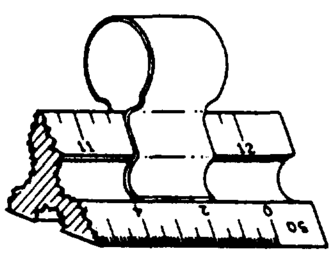

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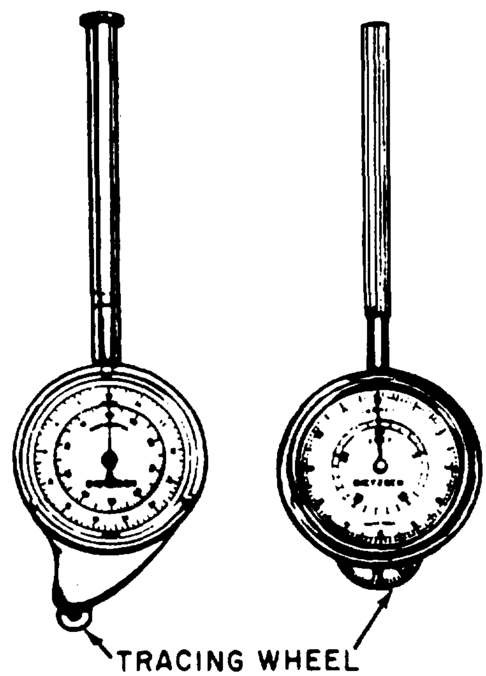
Figure 2-27.-Use of triangular scale clip.

MAP MEASURES AND SCALE INDICATORS

MAP MEASURES are precision instruments for measuring the lengths of roads, pipelines, and other irregular outlines on maps and drawings. Distances are measured by first setting the instrument to zero, then tracing the line to be measured with the small, projecting tracing wheel, like that on the map measures shown in figure 2-28.

In using map measures, do not depend entirely on the indicated numerical scale. Always check it against the graphical scale on the map or drawing. Verify if, for example, 1 in. traversed



Courtesy of Dietzgen Corporation

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Figure 2-28.-Types of map measures.

on the graphical scale really registers 1 in. on the dial; if not, make the proper correction to the distance measured. Actually, a map measure is just another odometer. Odometers are used to measure actual distances, while the map measures are used to measure scaled distances.

There are many ways of indicating the scale on a drawing. Among these are the fractional method, the equation method, and the graphic method.

In the fractional method, the scale is indicated as a fraction or a ratio. A full-size scale is indicated as 1/1; enlarged scale, as 10/1, 4/1, 2/1, etc.; and reduced scale, as 1/2, 1/4, 1/10, etc. Notice that the drawing unit is always given as the numerator of the fraction and the object unit as the denominator. On maps, the reduced scale fraction may be very large (for example, 1/50,000), as compared with the typical scales on machine drawings. On maps, the scale is frequently expressed as a ratio, such as 1:50,000.

In the equation method, a certain number of inches on the drawing is set equal to a certain length on the object. Symbols are used for feet (') and inches ("). On architectural drawings, a certain number of inches on the drawing is set to equal to 1 foot on the object. A full-size scale is entered as 12" = 1' – 0"; an enlarged scale, as 24" = 1'–0"; and a reduced scale, as 1/8" = 1' – 0". On civil engineering drawings, 1 in. on the drawing is set to equal to a certain measurement on the object: 1" = 5', 1" = 100', 1" = 1 mi.

In the graphic method, an actual measuring scale is shown on the drawing. Typical graphic scales are shown in figure 2-29. Note that in each case, the primary scale lies to the **right** of the 0; a subdivided primary scale unit lies to the **left** of the 0.

DRAFTING TEMPLATES

DRAFTING TEMPLATES are timesaving devices that are used for drawing various shapes and standard symbols. They are especially useful when shapes and symbols must appear on the drawing a number of times. Templates are usually made of transparent green or clear plastic. They are available in a wide variety of shapes, including circles, ellipses, hexagons, triangles, rectangles, and arcs. Special templates are available for symbols used on architectural drawings, mechanical drawings, and maps. Templates for almost every purpose are available from the well-known drafting supply companies. Figure 2-30 shows only a few of the more common types of drafting templates. One set of commonly used drafting templates is included in the EA's draftsman kit.

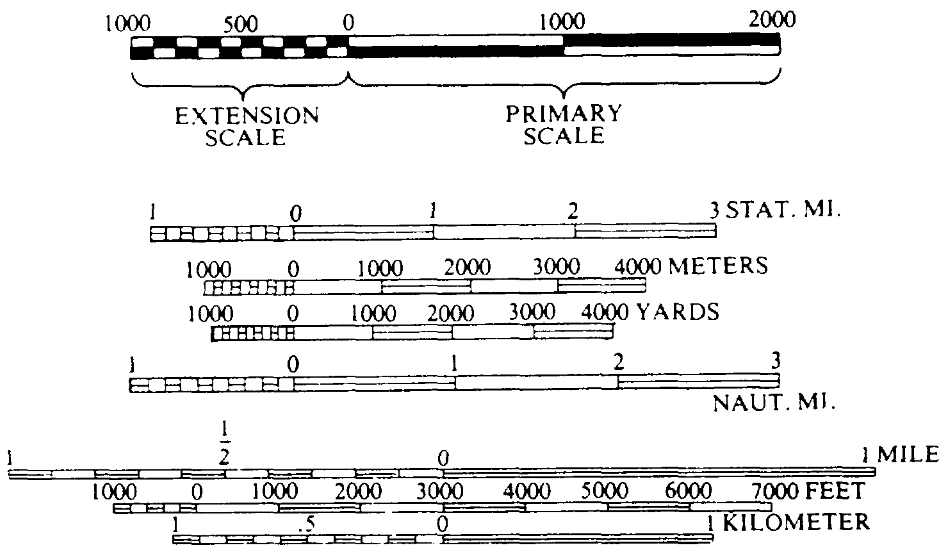

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Figure 2-29.-Typical graphic scales.

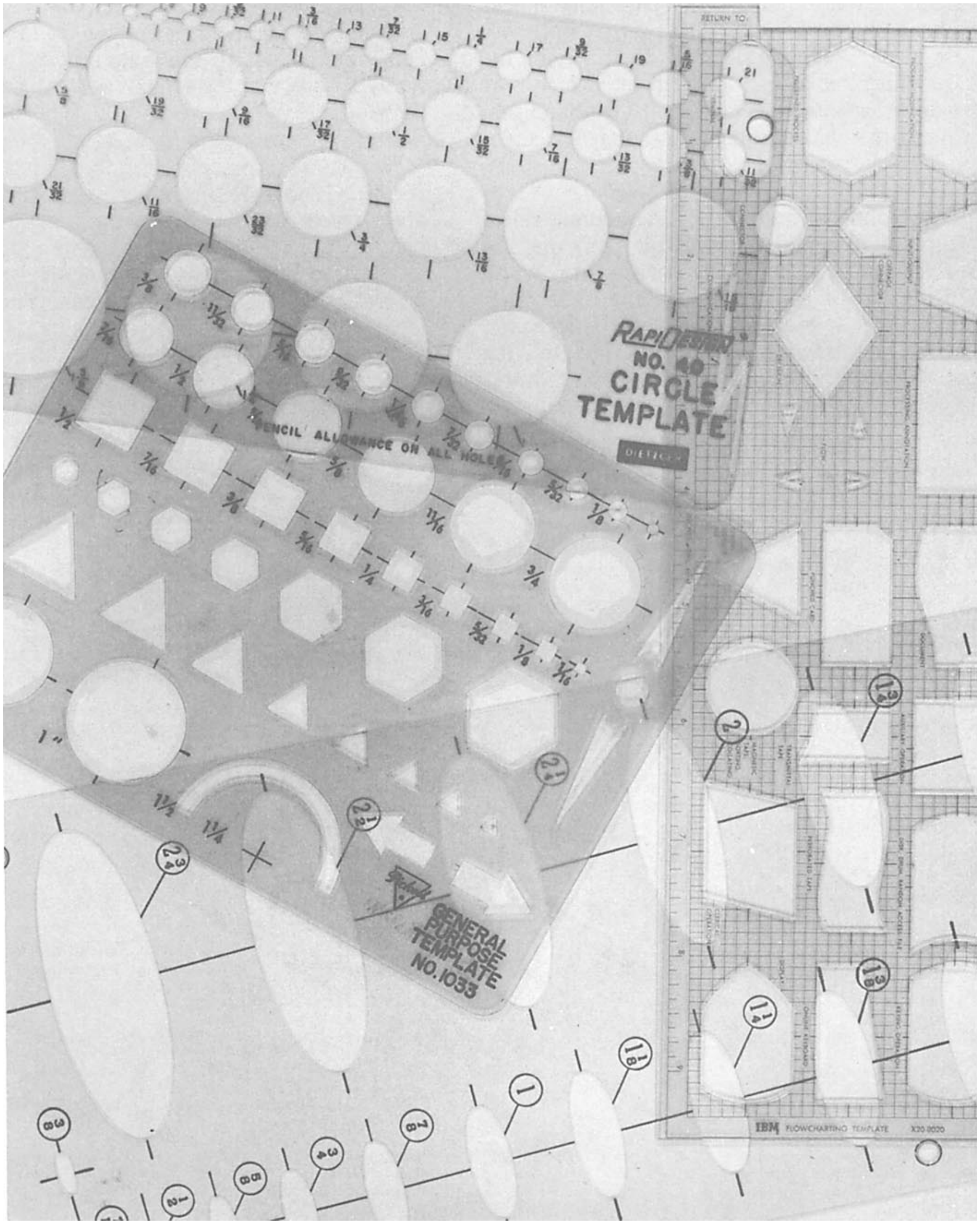

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Figure 2-30.—Drafting templates.

FREEHAND LETTERING PENS

Frequently, you will prepare inked drawings, maps, or charts that require freehand lines and lettering. There are many types of freehand pens available. But here we will be concerned only with those pens used by the EA. Included in the draftsman kit is a reservoir pen set, which may be used either with a penholder, as a freehand pen, or fitted into a mechanical lettering device for template lettering.

The technical fountain pen (sometimes called a Rapidograph pen or reservoir pen) may be used for ruling straight lines of uniform width with the aid of a T square, triangle, or other straightedge. It may also be used for freehand lettering and drawing and with various drawing and lettering templates. One of the best features of the technical fountain pen is its ink reservoir. The reservoir, depending on the style of pen, is either built into the barrel of the pen or is a translucent plastic ink cartridge attached to the body of the pen. The large ink capacity of the reservoir saves time because you do not have to constantly replenish the ink supply. Therefore, many EAs prefer the technical fountain pen to the ruling pen.

A typical technical fountain pen is shown in figure 2-31. Variations in pen style and line size are offered from various manufacturers. Some pens are labeled by the metric system according to the line weight they make. Other pens are labeled with a code that indicates line width measured in inches. For instance, a No. 2 pen draws a line .026 in. in width. Most technical fountain pens are color-coded for easy

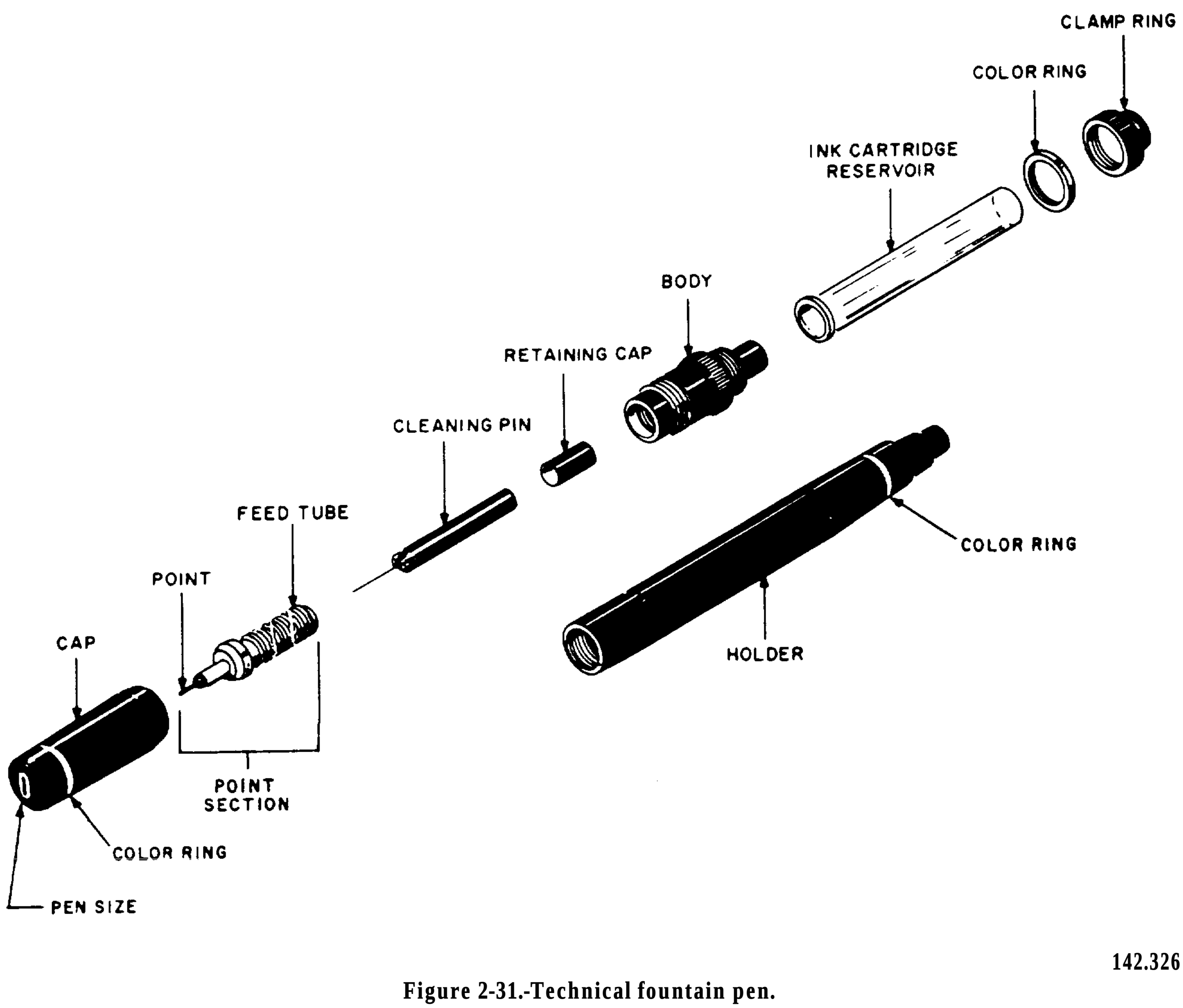

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Figure 2-31.-Technical fountain pen.

identification of pen size. These pens are available either as individual fountain pen units, resembling a typical fountain pen, or as a set, having a common handle and interchangeable pen units. The pen shown in figure 2-31 is a part of a set of technical fountain pens.

Some reservoir pens for lettering are made so the point section will fit in a Leroy scriber. (The Leroy letter set will be discussed in chapter 3.) These pens may also be used for any work that a regular technical fountain pen is used for.

Processes of Using the Technical Fountain Pen

As shown in figure 2-32, you must hold the technical fountain pen so that it is perpendicular to the drawing surface at all times. If you don't hold the pen in the correct manner, the point will bevel or wear unevenly and eventually form an elliptical point. With the point in this condition, the pen will produce lines of inconsistent widths.

To fill the reservoir of a fountain pen, use the knob located on the barrel opposite the point. When you turn the knob counterclockwise, a plunger is forced down into the barrel forcing out any ink remaining in the reservoir. Place the point end of the pen into the ink and turn the knob clockwise to pull the plunger up. As the plunger is pulled up, ink is drawn through the point, filling the reservoir.

To fill the ink cartridge type of pen shown in figure 2-31, remove the cartridge from the body and insert the ink bottle dropper all the way into the reservoir cartridge. Place the dropper in contact with the bottom of the reservoir cartridge to prevent the ink from forming air bubbles. Fill the cartridge to approximately three-eighths of an inch from the top, then replace the cartridge and clamp ring.

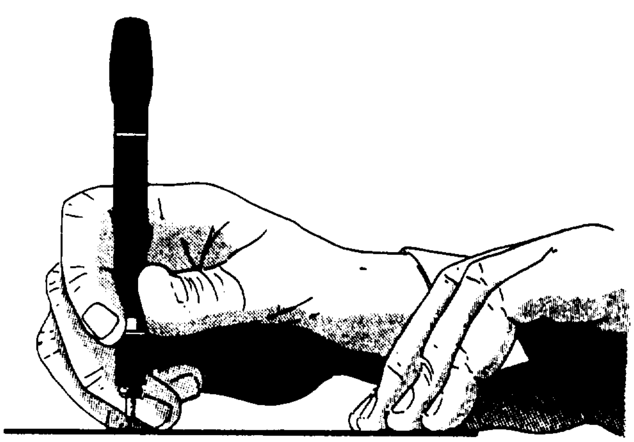

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Figure 2-32.-Drawing with a technical fountain pen.

Care and Cleaning of the Technical Fountain Pen

The feed tube of the pen point is threaded (fig. 2-3 1). Along this threaded portion is an inclined channel that allows air to enter the ink reservoir. This channel must be free of dried ink or foreign particles to ensure correct ink flow. When cleaning the pen, scrub the threads and channel with a brush, such as a toothbrush, wetted with a cleaning solution of soap and water. A cleaning pin (a tiny weighted needle) is made so that it fits into the feed tube and point (fig, 2-31). This cleaning pin assures a clear passage of ink from the reservoir to the point. Usually, a light shake of the pen will set the cleaning pin in motion, removing any particles that settle in the tube when not in use. (Do not shake the pen over your drawing board.)

If the pen is not used frequently, the ink will dry, clogging the point and feed tube. When the pen becomes clogged, soak the pen in pen cleaner or ammonia water until it will unscrew with little or no resistance. A better practice is to clean the pen before you put it away if you know in advance that you will not be using it for several days.

The cleaning pin must be handled with care, especially the smaller sizes. A bent or damaged cleaning pin will never fit properly into the feed tube and point.

DRAWING INK

A draftsman's drawing ink is commonly called INDIA INK. Drawing ink consists of a pigment (usually powdered carbon) suspended in an ammonia-water solution. Ink that has thickened by age or evaporation maybe thinned slightly by adding a few drops of solution of four parts aqua ammonia to one part distilled water. After the ink dries on paper, it is waterproof. Drawing ink is available in many different colors, but for construction and engineering drawings, black ink is preferred for reproduction and clarity. Small

3/4- or 1-oz bottles of black, red, and green ink are found in the standard draftsman kit. Larger bottles are available for refilling the small bottles. The stopper for a small ink bottle is equipped with either a squeeze dropper or a curved pipette for filling pens.

When you are working with ink, always keep the stopper on the ink bottle when you are not filling the pen, and keep the bottle far away from your drawing. Nothing is more frustrating for a draftsman than to spill a bottle of ink on a finished drawing. Special bottle holders are available to minimize this hazard. If you do not have a bottle holder, it would be to your advantage to devise your own.

OTHER TOOLS

Many tools other than the ones already presented in this chapter are currently used to help create technical drawings. A variety of drafting machines (not in the draftsman kit) are available at several shore-based support activities. Dependent upon the requirements of that particular activity, an EA assigned to staff or independent duty may also be exposed to a more advanced and sophisticated computer-assisted drafting method.

The standard drafting machine combines the functions of a parallel ruler, protractor, scales, and triangles. Various drafting operations requiring straight and parallel lines may be performed advantageously with a drafting machine.

The majority of drafting machines are constructed so that the protractor head may be moved over the surface of a drafting table without change in orientation by means of a parallel-motion linkage consisting of two sets of double bars. Figure 2-33 shows a rigid metal connecting link or arms, commonly called pin-joint linkage.

Another type of drafting machine has two steel bands enclosed in tubes working against one another (fig. 2-34) (although this type may also

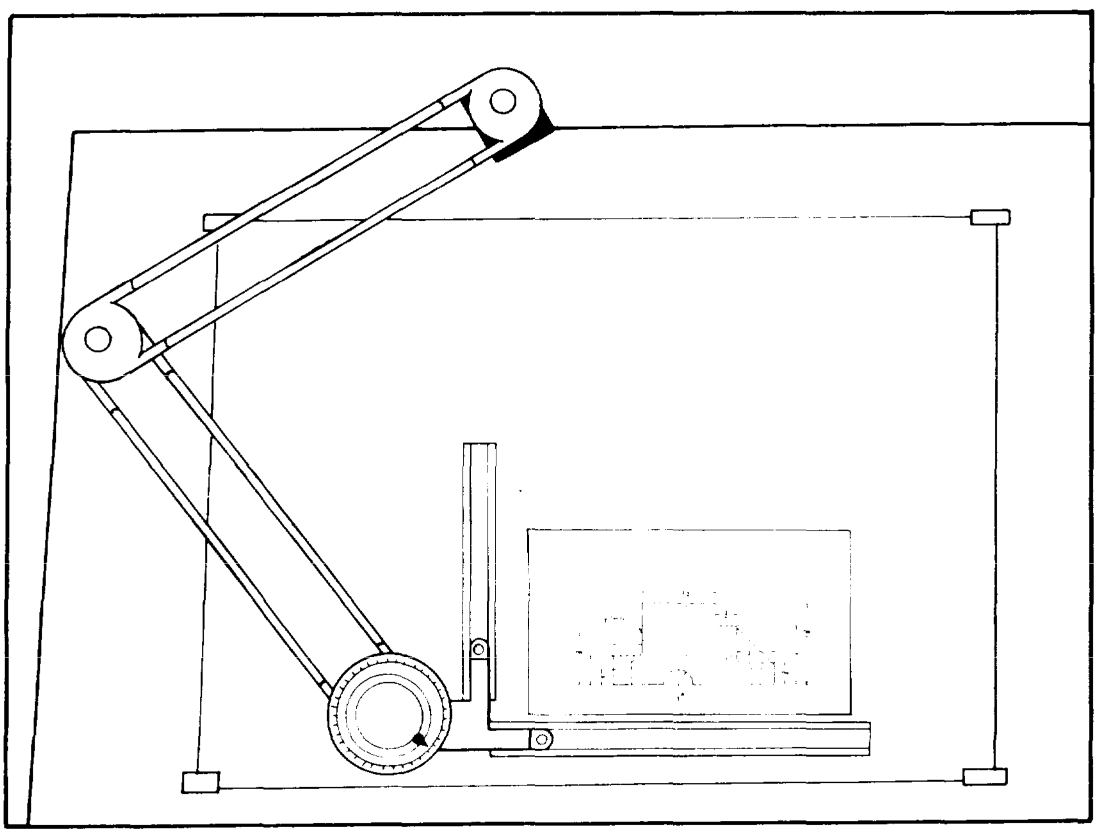

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Figure 2-33.-Drafting machine with rigid arms.

have the bands without the tubes). If these bands become loose through wear or expansion, the tension can be increased on them. This type of drafting machine is superior to that with pin-point linkage because there is less lost motion.

To learn more about other tools and their uses, refer to chapter 1 of the field manual FM 5-553, General Drafting, published by the Headquarters, Department of the Army, and other civilian publications.

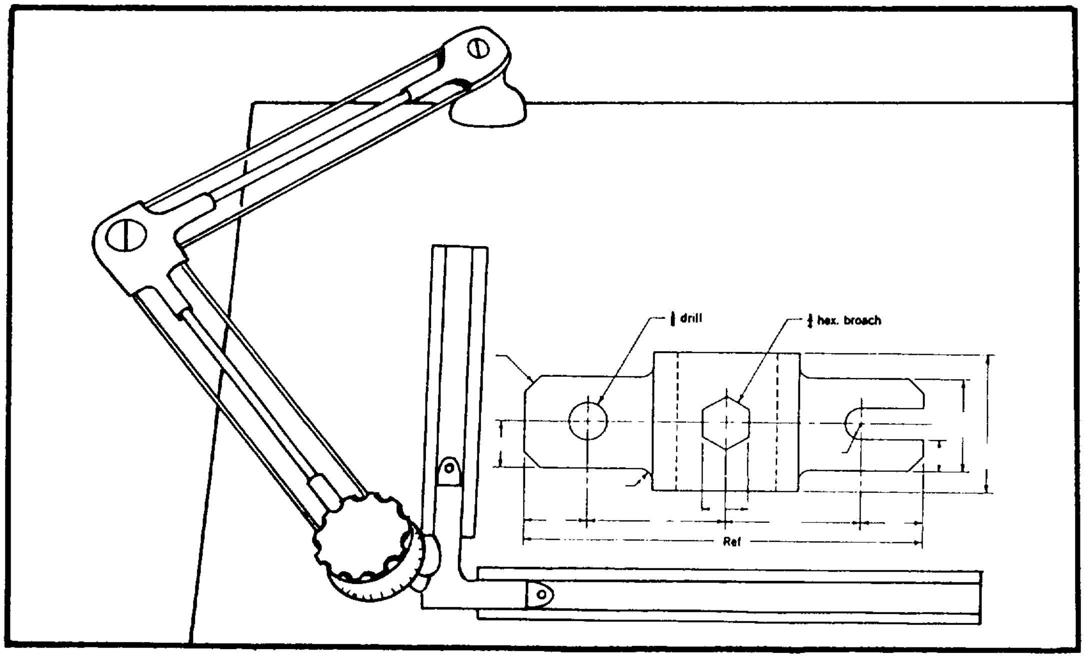

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Figure 2-34.-Drafting machine with enclosed steel bands.

CHAPTER 3

DRAFTING: FUNDAMENTALS AND TECHNIQUES; REPRODUCTION PROCESS

In this chapter you will learn the fundamental and basic techniques associated with the use of drafting equipment and accessories commonly used by the EA in preparing drawings and charts. The techniques are applied using standard drawing format, line conventions, and lettering described in detail in two of the publications you will use most often: DoD-STD-100C, *Engineering Drawing Practices*, and MIL-HDBK-1006/1, *Policy and Procedures for Project Drawing and Specification Preparation*. It is your responsibility to keep up to date on these publications and other applicable reference materials to ensure that your drawings are prepared according to the latest revisions.

This chapter also covers the procedures related to the safe use and maintenance of the typical reproduction equipment and discusses the different methods of reproducing drawings and the types of drawing paper used.

This training manual will not cover specific reproduction responsibilities since each command may have different reproduction equipment depending on its mission and the size of its engineering department. When you are assigned this responsibility, you will be given additional on-the-job training.

WORK PREPARATION

Before you begin to work, you should devote some time and thought to organizing your working area. Drafting furniture should be arranged so you can work comfortable y without fatigue or eyestrain. Be sure to check the lighting before you set up your drafting table. You can devise a system of stowing your equipment and supplies so that they are handy and in order.

WORK AREA

Your immediate work area should be large enough to allow sufficient freedom of movement, but not so large that you waste time reaching for equipment, supplies, and reference publications. An ideal working area allows each draftsman approximately 90 sq ft of space, although you may actually have more or less depending on the total area of the drafting room and the number of draftsmen who will work there.

If you are easily distracted, do not butt your drafting table up against and facing another draftsman's table.

Ensure that you have adequate lighting. The best light for drafting is natural light coming over the left shoulder and from the front left to avoid shadows cast by your hands, T square or parallel ruling straightedge, and triangles. Avoid a glaring light as it will cause eyestrain. Use the drafting lamp that was described in chapter 2. Your drafting table height should be from 36 to 40 in. above floor level. Your drafting chair or stool should be high enough that you can see the whole drawing board, but not so high that you have to lean over uncomfortably to draw. As mentioned in chapter 2, the board may be inclined or left flat according to your preference. A slope of 1 to 8 works well for the inclined position. By shifting your body or head slightly, you should be able to look directly at any point on an average-sized drawing sheet; that is, your line of sight should be approximately perpendicular to the drawing surface.

Before you begin to draw, arrange your equipment in an orderly manner. Place each article so that you can reach it easily, and keep it in place when you are not using it. A systematic arrangement is timesaving and efficient. You decrease the likelihood of accidentally dropping your tools or pushing them off the table if you keep them in order. You will find it very convenient to have a small worktable adjacent to your drafting board. Placing your drafting tools and reference publications on the worktable leaves you with an uncluttered drawing board surface. When you use the drafting board in the inclined position, a separate worktable becomes a necessity.

YOUR EQUIPMENT AND MATERIALS

Selection of drafting equipment and materials will depend largely upon each of your drafting assignments. Let your good judgment and common sense guide you in their selection. After some experience, you will automatically select proper equipment and materials as they are required. Until you become proficient, don't hesitate to seek the advice of your drafting supervisor or an experienced draftsman. Assignments to staff and support billets within the Naval Construction Force (NCF) will expose you to modern drafting equipment and materials, such as the adjustable drafting board with a drafting machine attached.

Drafting Board

As a SEABEE draftsman, you will probably not be able to select your drafting board. Unless the board is new, it will probably be marred and full of small pinholes. To obtain a smooth drawing surface, you should cover the board with a vinyl material or heavy manila paper. Laminated vinyl covering minimizes pencil scoring, is non-glaring, and is easily kept clean by wiping with a damp cloth. Heavy manila paper will serve the same purpose, but must be replaced when it becomes soiled or marked with use.

Drafting Paper

Most of the drawings that you will prepare will be drawn on tracing paper, which was described in chapter 2. You will use tracing paper to copy or trace drawings either in pencil or in ink. You will also prepare most of your original pencil drawings on tracing paper. This type of paper is especially suited for reproduction of blueprints. However, it tears easily and becomes soiled after repeated handling.

When making a drawing directly on tracing paper, you should place a smooth sheet of white paper below it (detail paper works well). The whiteness of this sheet (called a platen sheet) gives better line visibility, and its hard surface makes it possible to draw good pencil lines without grooving the tracing paper.

Do not usc gritty erasers on tracing paper, especially when ink is to be applied. If erasures must be made, use a green or red ruby eraser, which is only slightly abrasive. Abrasive erasers wear away the surface. Erase carefully so you don't tear the drawing. A light back-and-forth motion works best. If the surface of the drawing becomes scratched by erasing, it can be partially smoothed by burnishing the damaged area with a hard, smooth object or your thumbnail. Avoid using the electric eraser on tracing paper, as it will quickly "burn" a hole through the paper. To clean up smudges and dust, use a soft art gum eraser or sprinkle pounce on the drawing and rub lightly with your hand or a triangle.

Water, perspiration, or graphite from your pencil will ruin drawing paper. In order to keep moist hands or arms from marring the drawing, use a clean sheet of paper as a mask to protect the drawing surface next to the work area. Between drawing sessions you should protect unfinished drawings by covering them.

Tracing paper must not be folded. The crease marks will damage the lines on the drawing and cause blurred prints when the drawing is reproduced. For that matter, no drawing should ever be folded. Drawings and tracings should be either stored flat or rolled and placed in cylindrical containers. Prints or drawings larger than 8 1/2 in. by 11 in. may be folded so that they can be filed in standard filing cabinets.

Besides tracing paper, you will select other types of paper for special uses. You will be mainly concerned with the gridded papers described in chapter 2. The quality of the gridded paper that you will use is similar to that of tracing paper and should be used in the same manner.

As you gain experience, you will learn which type of paper to use for each drafting assignment. Of course, you will be limited by the types of paper available and the guidelines given to you by your drafting supervisor.

Drafting Pencils

For the average drafting assignment, three or four pencils are usually sufficient. A hard pencil, 4H or 5H, should be used to lay out the drawing in light construction and projection lines. A medium pencil, H or F, is then used to darken the required lines and to make arrowheads and lettering. The grade of drawing paper you use will also determine which pencil you choose for making a drawing. A soft, rough-textured paper usually requires a softer pencil for layout work, since a hard pencil would leave indentations in the paper and thus spoil the appearance of the drawing.

One way to find out if you are using the proper pencils on a drawing is to make a blueprint (reproduction) of the drawing. If the reproduced lines do not appear, or appear too light, use a softer pencil. If, on the other hand, lines appear too dark in relation to other lines, use a harder pencil. You may be able to vary the weight of lines by the amount of pressure exerted on the pencil, but this should not be attempted without experience. Bearing down on a hard pencil to produce darker lines may cause grooves in the paper.

Another way to find out if you are using the proper pencil is to hold your drawing up to a light and view it from the back side. Pencil adjustment is the same as in the previous method. Of course, both methods apply only when transparent drawing paper is used.

To sharpen a pencil, cut the wood away from the unlettered end (fig. 3-1, view A) with a draftsman's pencil sharpener or a penknife. The lettered end should be left intact so that the grade of pencil can always be identified. The cut should be started about 1 1/2 in. from the end, leaving a half inch of lead exposed. To produce a conical or needlepoint (fig. 3-1, view B), which is best for general use, rotate the pencil between the fingers at the same time as the exposed lead is rubbed back and forth across the full length of the sandpaper pad (fig. 3-1, view C). Many draftsmen prefer to use a mechanical lead pointer instead of the sandpaper pad. The mechanical pointer quickly produces a uniform conical or needlepoint. However, the sandpaper pad must still be used to produce other types of points. The resulting needlepoint should be dulled slightly by drawing it lightly across a piece of scrap paper several times. Avoid sharpening pencils near your drawing. Graphite particles will cause smudges that are difficult to erase. A cloth or tissue should be used to wipe away graphite particles that cling to the pencil after it is sharpened. A wedge point (fig. 3-1, view D) will aid an experienced draftsman in the extensive drawing of straight lines. This point is produced by sharpening a pencil to the conical point just described, then flattening both sides on the sandpaper pad. For an elliptical point, hold the pencil firmly with thumb and fingers and cut the lead on the sandpaper pad by a back-and-forth motion, keeping the pencil at an angle of about 25 degrees to the pad. Continue until a flat ellipse is formed, as shown in figure 3-1, view E. A good draftsman never uses a dull pencil.

Some draftsmen prefer to use mechanical drafting pencils instead of wooden pencils. The lead of a mechanical pencil is sharpened in the same manner as the lead of a wooden pencil. However, the length of the mechanical pencil is not depleted as the lead is sharpened. This is an advantage over wooden pencils that become difficult to use when they are less than 3 in. in length. When leads for the mechanical pencil are exchanged, ensure that the changeable lead grade designator on the mechanical pencil corresponds to that of the lead used.

BASIC DRAFTING TECHNIQUES

You should practice handling and using drafting instruments before attempting complex drawing problems. Developing correct drawing habits will enable you to make continuous improvement in the quality of your drawings. The

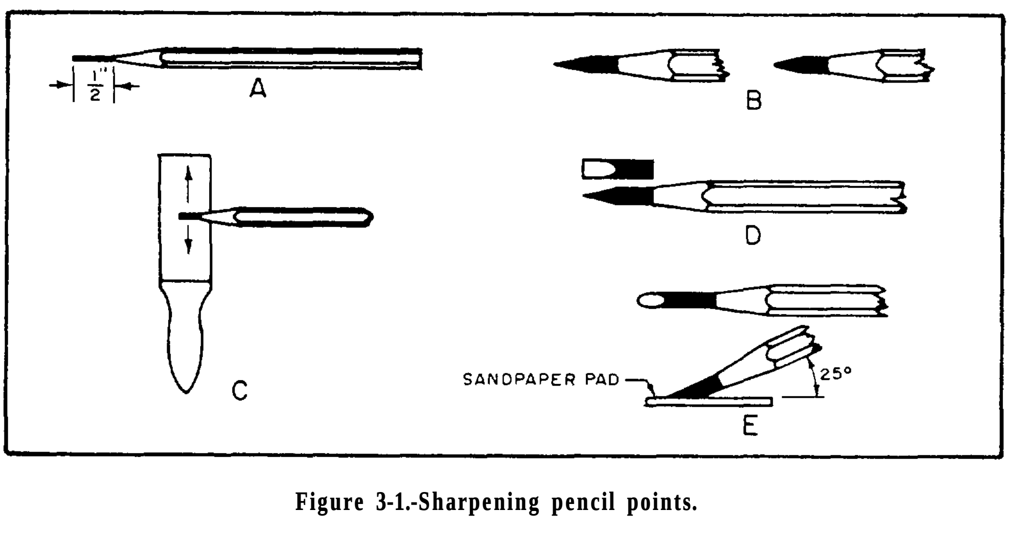

Figure 3-1.-Sharpening pencil points.

main purpose of making your first drawings is to learn to use instruments. Each drawing will offer an opportunity for practice. Later on, good form in the use of instruments will become a natural habit.

Accurate pencil drawings are of first importance since all inked drawings and tracings are made from finished pencil drawings. It is a mistake to believe that a poor pencil drawing can be corrected when you make the ink tracing. Any drawing important enough to be inked or traced in ink must be accurate, legible, and neat. Because most military and commercial blueprints are made from pencil drawings, ambitious trainees will work to acquire skill in pencil drawing as they perfect their technique. Good technique and skillful pencil drawing are basic to proficiency in drafting.

The following sections will guide you in attaching your drawing paper to the board and in drawing basic lines with the T square, triangles, and pencil.

ATTACHMENT OF PAPER TO THE BOARD

Now that you have become relatively familiar with your equipment and materials, it is time to get started by attaching your drafting paper to the board. The sheet should be placed close to the left edge of the drafting board. Working in this area makes the T square easier to handle and reduces the likelihood of error because of T square "swing." The drafting sheet should be far enough from the bottom of the board (about 3 in.) to ensure firm support for the head of the T square when you are drawing at the lower part of the sheet. A drawing sheet properly attached to the board on which a T square is used is shown in figure 3-2. After aligning the drawing sheet, smooth out any wrinkles and fasten the four corners with short strips of drafting tape. If you are attaching large sheets, you should place additional strips of tape at the top and bottom edges of the sheet. Drafting tape has a lighter coating of adhesive than does masking tape. Consequently, it will hold the drawing firmly, yet can be removed without tearing or marring the drawing. If you use masking tape or transparent tape, leave a large margin in the event you tear the paper when removing the tape. When placed diagonally across the corners of the sheet, as shown in figure 3-2, the drafting tape offers little obstruction to movement of the T square and triangles. Avoid the use of thumbtacks; they will eventually ruin the drafting board.

If you are using a parallel straightedge or drafting machine instead of a T square, the procedure just described is the same with one exception. Instead of placing the paper close to the left edge of the board, you should place it approximately at the midpoint of the length of the parallel straightedge or in the center of the drawing board surface when you are using a drafting machine.

HORIZONTAL LINES

The draftsman's horizontal line is constructed by drawing from left to right along the working

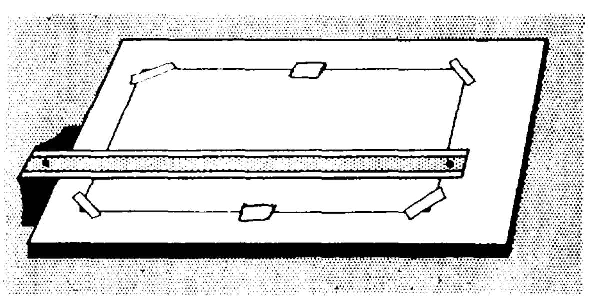

Figure 3-2.-Attaching drafting paper to the board.

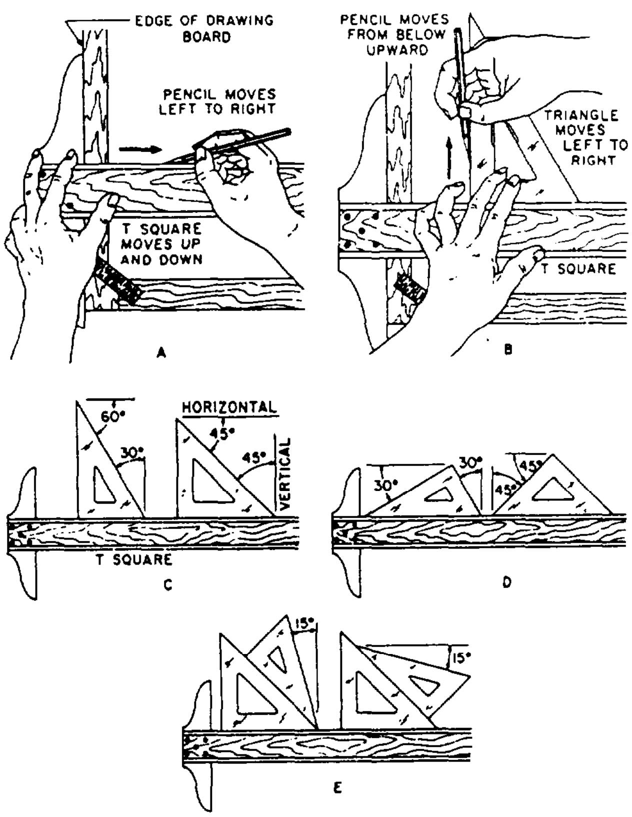

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Figure 3-3.-Construction of basic lines.

edge of a T square, as shown in figure 3-3, view A. This working edge, when true, is perpendicular to the working edge of the drafting board. When you draw horizontal lines, keep the working edge of the T square head in firm contact with the working edge of the drafting board. The pencil should be inclined to the right at an angle of about 60 degrees, with the point close to the junction of the working edge and the paper. Hold the pencil lightly and, if it was sharpened with a conical point, rotate it slowly while drawing the line to achieve a uniform line width and preserve the shape of the point. Normally, when a series of horizontal lines is being drawn, the sequence of drawing is from the top down.

VERTICAL LINES

Vertical lines are produced parallel to the working edge of the drafting board by using triangles in combination with a T square. One leg of a triangle is placed against the working edge of the blade and the other faces the working edge of the board to prevent the draftsman from casting a shadow over his work. Lines are drawn from the bottom up, as shown in figure 3-3, view B. The pencil is inclined toward the top of the working sheet at an angle of approximately 60 degrees, with the point as close as possible to the junction of the triangle and the drafting paper. Sequence in drawing a series of vertical lines is from left to right. At no time should the lower edge of the T square blade be used as a base for triangles.

INCLINED LINES

The direction or angle of inclination of an inclined line on a drafting sheet is measured by reference to the base line from which it is drawn. Inclined lines at standard angles are constructed with the T square as a base for triangles used either singly, as shown in views C and D of figure 3-3, or in combination, as shown in view E of figure 3-3.

Used in combination with the T square as a base, the triangles serve as guides for producing lines at intervals of 15 degrees, as shown in figure 3-4. Used singly, the 45-degree triangle will divide a circle into 8 equal parts; the 30°/60° triangle will divide a circle into 12 equal parts. For drawing lines at angles other than those described above, you should use a protractor.

PROTRACTION OF ANGLES

To measure an angle, place the center mark of the protractor at the vertex of the angle, with the 0-degree line along one side. Then note the degree mark that falls on the side. To lay off an angle, position the protractor as above and use a needlepoint or a sharp-pointed pencil to mark the desired values. Then project lines from the vertex to these marks.

Using only the three points on the protractor, as described above, may result in considerable inaccuracy, particularly if the lines of an angle are to be extended for some distance beyond the protractor. A refinement of the procedure is indicated in figure 3-5. Suppose angle BOA is to

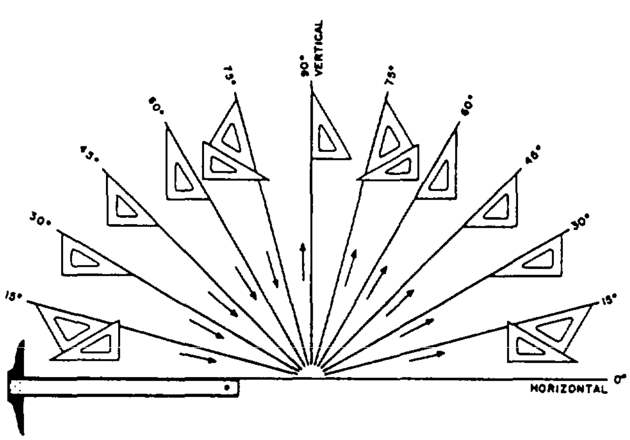

Figure 3-4.-Using T square (or parallel straightedge) and triangles to draw lines at different angles to the horizontal. Arrows indicate the direction in which the lines should be drawn.

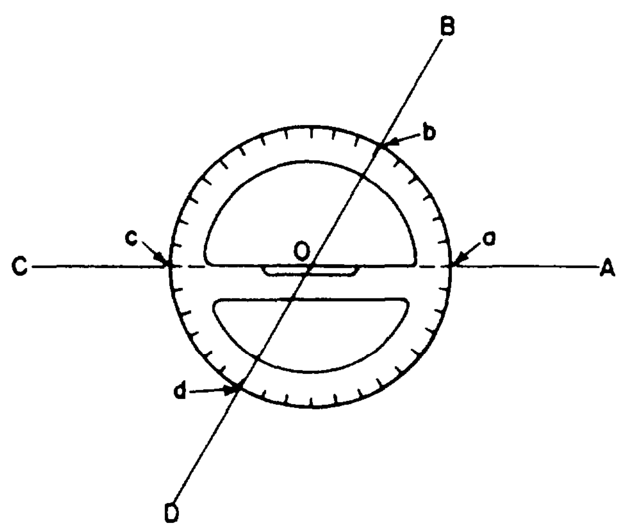

Figure 3-5.-Protracting an angle.

be measured. Extend line AO on to C; extend line BO on to D. When you set the center of the protractor at O, make sure that both points c and a are on line AC. Take your reading at point d as well as at point b when you measure the angle. If you are laying off the angle BOA, protract and mark point d as well as point b; this gives you three points (d, O, and b) for establishing line DB. If you are using a semicircular protractor, you can't, of course, locate point d; but your accuracy will be improved by lining up c, O, and a before you measure or lay off the single angle BOA.

PARALLEL AND PERPENDICULAR LINES

To draw a line parallel to a given line (fig. 3-6, view A), adjust the hypotenuse of a triangle in combination with a straightedge (T square or triangle) to the given line; then, holding the straightedge firmly in position, slip the triangle to the desired position and draw the parallel line along the hypotenuse.

To construct a line perpendicular to an existing line, use the triangle and straightedge in combination, with the hypotenuse of the triangle resting against the upper edge of the straightedge (fig. 3-6, view B). Adjust one leg of the triangle to a given line. Then slide the triangle along the supporting straightedge to the desired position and draw the line along the leg, perpendicular to the leg that was adjusted to the given line. In the same manner, angles with multiples of 15 degrees may be drawn, using the triangle combinations shown in figure 3-4.

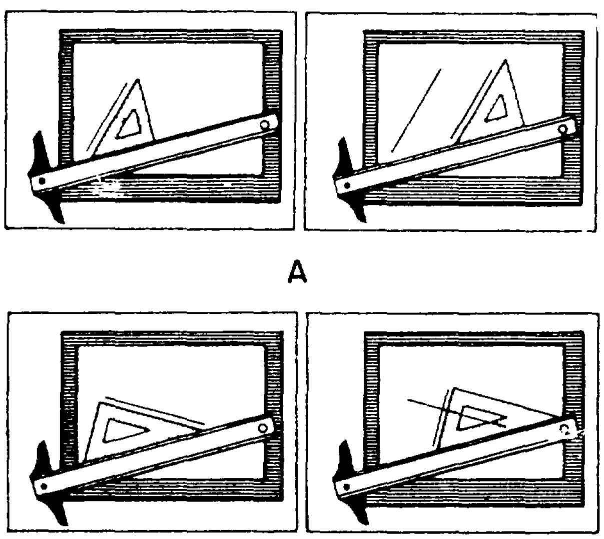

Figure 3-6.-Drawing parallel and perpendicular lines.

CURVED LINES

Many drawings that you will prepare require the construct ion of various curved lines. Basically there are two types of curved lines: circles and segments of circles, called arcs, which are drawn with a compass; and noncircular curves, which are usually drawn with french curves. In this chapter we will discuss only techniques for using the compass and the french curve. Application of compass techniques in geometric construction will be covered in chapter 4.

Use of the Compass

When you are drawing circles and arcs, it is important that the lines produced with the compass are the same weight as corresponding pencil lines. Since you cannot exert as much pressure on the compass as you can with pencils, you should use a compass lead that is

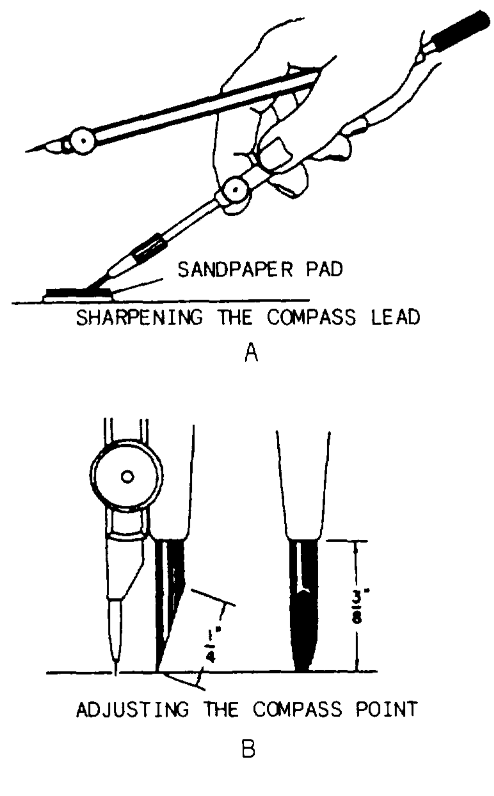

Figure 3-7.-Sharpening the compass lead and adjusting the point.

about one grade softer than the pencil used for corresponding line work. For dim construction lines, use 4H to 6H leads. Avoid using leads that are too short.

The compass lead should be sharpened with a single elliptical face, as shown in figure 3-7, view A. A sandpaper pad works best for sharpening compass leads. The elliptical face of the lead is normally placed in the compass so that it faces outward from the other compass leg. Adjust the shoulder-end needlepoint so that the point extends slightly farther than the lead (fig. 3-7, view B). With the needlepoint pressed lightly in the paper, the compass should be centered vertically when the legs are brought together.

Bow compasses and pivot joint compasses are used in the same manner. To draw a circle with a compass, lightly press the needlepoint into the drawing paper and rotate the marking leg around it. Always rotate the compass clockwise. As you rotate, lean the compass slightly forward. With a little practice, you will find that you can easily draw smooth circles using only the thumb and forefinger of one hand. It is important that you use an even pressure as you rotate the compass. You may find it necessary to rotate the compass several times to produce a circle with a uniform dense black line.

When you wish to set the compass to draw a circle of a given diameter, use a piece of scratch paper and follow the steps listed below, referring to figure 3-8.

1. Draw a horizontal line with a straightedge.

2. With the straightedge as a base, use a triangle and draw a vertical line intersecting the horizontal line (fig. 3-8, view A).

3. Measure the radius of the circle with a scale, as shown in figure 3-8, view B, and draw a second vertical line from this point.

4. Set the needlepoint at the intersection of the first vertical line and the horizontal line (fig. 3-8, view C). This is the center of the circle.

5. Set the marking leg to fall on the intersection of the second vertical line and the horizontal line (fig. 3-8, view D).

6. Draw a half circle with the compass fig. 3-8, view E).

7. Check your work by measuring the diameter established by this half circle with a scale (fig. 3-8, view F).

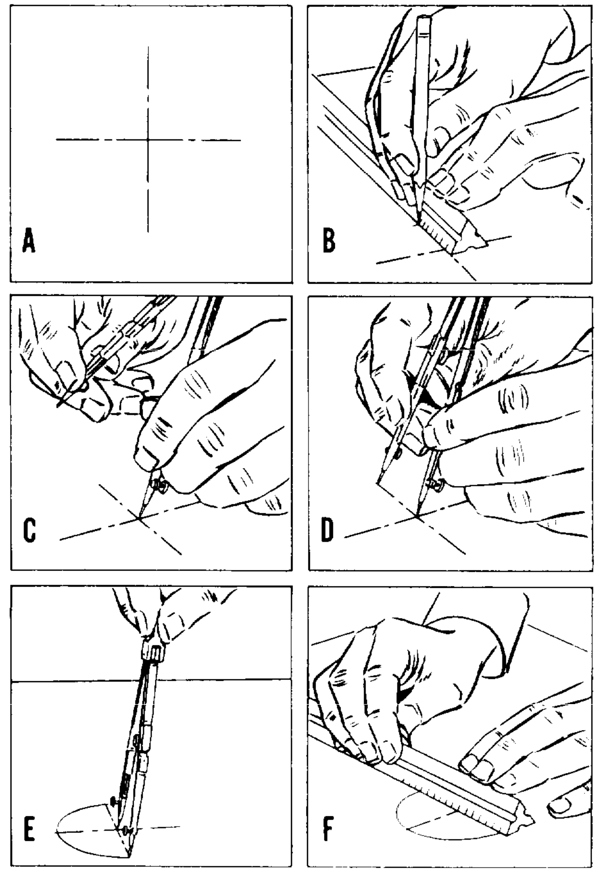

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Figure 3-8.-Drawing a circle of a given radius.

Once You have set the compass to the exact radius of the circle, handle it very carefully so that you don't disturb the setting. Set the needlepoint at the center of the circle and carefully rotate the compass to draw a line describing the circumference of the circle. Do not apply too much pressure on the needlepoint or it will bore a hole in the paper and you will lose the accurate center mark. To keep the diameter of the hole to a minimum, you may set the needlepoint of the compass on a small strip of paper or thin cardboard over the drafting sheet at the center of the circle.

When you are using the pencil leg to draw circles smaller than 1 in. in radius, keep the adjustable pencil and needle legs straight. For larger circles, both legs should be adjusted so that they are perpendicular to the paper. On the other hand, when you are using the compass with the pen leg, you MUST adjust it at the hinge joint to keep it perpendicular to the paper for all size

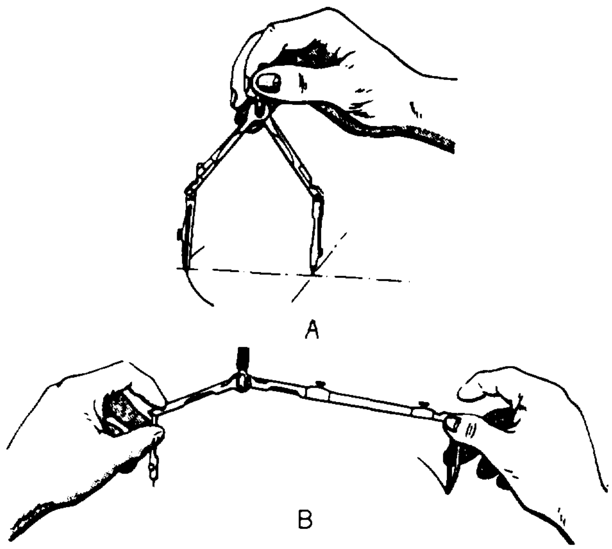

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Figure 3-9.-Drawing a circle in ink.

circles. (See fig. 3-9, view A.) If the pen is not perpendicular to the paper, ink will not flow properly. To draw large circles, insert the extension bar in the pen or pencil leg, as shown in figure 3-9, view B. When the extension bar is used to draw large circles, the process of using the compass with only one hand becomes awkward. You should use both hands, as shown in figure 3-9, view B.

Use of the French Curve

The french 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 in a smooth flowing line. To draw the finished line over the freehand line, match the various parts of the french curve to various segments of the freehand curve. Avoid abrupt changes in curvature by placing the short radius of the french curve toward the short radius portion of the line to be drawn. Change your position around the drawing board when necessary so that you can work on the side of the french curve that is away from you. You should avoid working on the “under” side of the french curve. Place the french curve so that it intersects at least two points of the line. When drawing the line along the edge of the french curve, stop short of the last point intersected. Then move the french curve along to intersect two or three more points and make sure that the edge of the curve connects smoothly with the line already drawn. When using the irregular curve, you can draw a perfectly smooth curved line by plotting enough points (the

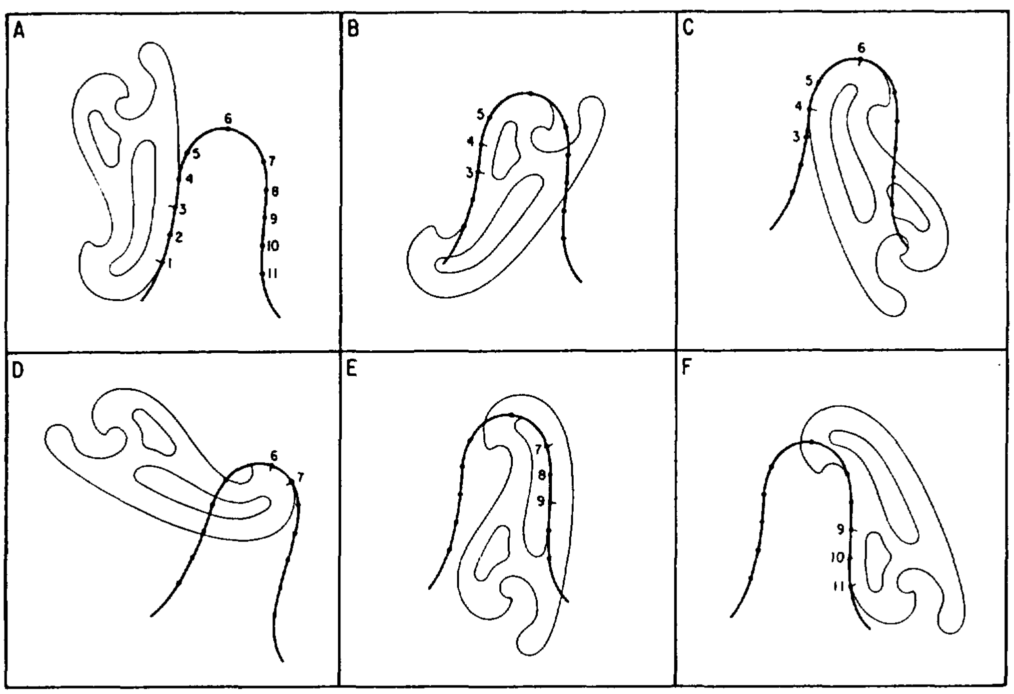

Figure 3-10.-Use of the french curve.

sharper the curve, the more points you need) and by drawing in shorts steps.

Figure 3-10 shows how a smooth line is drawn through a series of plotted points. The french curve in view A matches points 1, 2, 3, and 4. Draw a line from 1 to 3 only (not to 4).

At B, the curve matches points 3 to beyond 4. Draw a line from 3 to 4 only (not to 5).

At C, it matches points 4, 5, and 6. Draw a line from 4 to just short of 6.

At D, it matches a point short of 6 to beyond 7. Draw a line from 6 to 7.

At E, it matches a point short of 7 to beyond 9. Draw a line from 7 to 9.

At F, it matches a point short of 9 to beyond 11. Draw a line from 9 to 11.

You will probably notice how the french curve is turned over and reversed to find portions that fit the points on the line with increasing or decreasing changes in curvature.

When you are drawing a curved line that extends into a straight line, the curve should be drawn first, and the straight line joined to it.

USE OF DRAFTING TEMPLATES

Drafting templates should be used only when accuracy can be sacrificed for speed. Circles or arcs, for example, can be drawn more quickly with a template than with a compass. Templates must be used properly to be effective.

To draw a circle with the circle template (fig. 3-11), lay out center lines on the drawing where the circle is to be drawn. Then place the correct circle opening over the center line so that the quadrant lines on the template coincide with the center lines on the paper. Draw the circle, using a sharp, conical point on the pencil. Allowance must always be made for the width of the pencil line in placing the template opening in the right position on the drawing.

To draw an arc, lay out tangent lines on the drawing. Then place the correct size circle of the template on the paper so that the template quadrant lines coincide with the tangent lines, and draw the arc.

When using a template, you must hold it down firmly to keep it from slipping out of position. Figures or circles from the template must be drawn with the correct line weight on the first setting as it is difficult to reset the template in the exact position.

USE OF THE DIVIDERS

As we stated in chapter 2, dividers are used to transfer measurements, to step off a series of equal distances, and to divide lines into a number of equal parts. Dividers are manipulated with one hand. In setting dividers (fig. 3-12, view A), hold

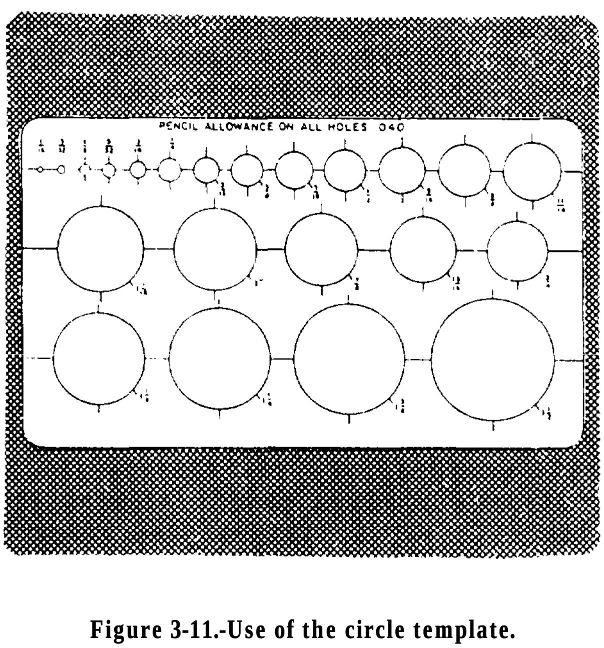

Figure 3-11.-Use of the circle template.

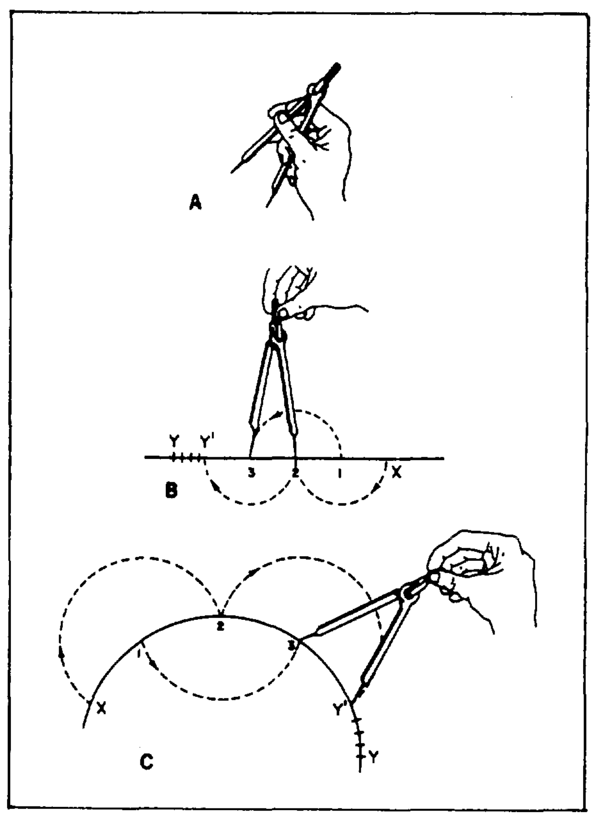

Figure 3-12.-Use of the dividers.

one leg between the thumb and the first and second fingers, and hold the other leg between the third and fourth fingers. Place the second and third fingers on the inside of the legs; the dividers are opened by spreading these fingers apart. Dividers are closed by squeezing the thumb and first finger toward the fourth finger while gradually slipping out the other two fingers.

To transfer measurements on a drawing, set the dividers to the correct distance, then transfer the measurements to the drawing by pricking the drawing surface very lightly with the points of the dividers.

To measure off a series of equal distances on the line, set the dividers to the given distance. Then step off this distance as many times as desired by swinging the dividers from one leg to the other along the line, first swinging clockwise 180 degrees, then counterclockwise 180 degrees, and so on.

In dividing either a straight line (fig. 3-12, view B) or a curved line (fig. 3-12, view C) into a given number of equal parts (for example, four) by trial, open the dividers to a rough approximation of the first division (in this case, one quarter of the line length) and step off the distance lightly, holding the dividers by the handle and pivoting the instrument on alternate sides of the line at each step. If the dividers fall short of the end of the line after the fourth step, hold the back leg in place and advance the forward leg, by guess, one quarter of the remaining distance. Repeat the procedure until the last step falls at the end of the line. Be careful during this process not to punch holes in the paper, but just barely mark the surface for future reference. To identify prick marks made with small dividers for future reference, circle the marks lightly with a pencil.

USE OF THE DRAFTING SCALE

Accuracy in drawing depends to a great extent upon correct use of the scale in marking off distances. You should place the edge of the scale parallel to the line being measured (fig. 3-13). To eliminate shadows cast by your body or hands, point the desired scale face away from you for horizontal measurements and toward your left for vertical measurements. With a sharp pencil, mark off short dashes at right angles to the scale at the correct distances, aligning the mark carefully with the scale graduation. Have your eye approximately over the point being measured,

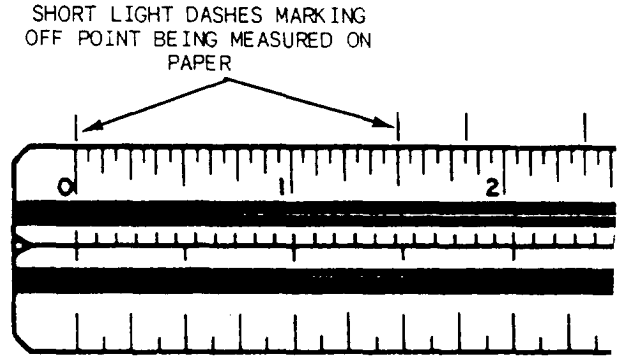

Figure 3-13.-Use of the drafting scale.

and make light marks to denote the point of measurement.

When setting the compass to a given radius or when setting divider points, never place the sharp points of these instruments on the scale. Lay out the desired radius or distance on a straight pencil line by using the scale in the manner described above. Then adjust the compass or dividers to the indicated length by using the measured line. A scale surface marred by pinpricks is difficult to read and is unsuitable for accurate work.

In making successive measurements along the same line, make as many measurements as possible without moving the scale. If a number of distances are to be laid out end to end, hold the scale in one position and add each successive measurement to the preceding one. If the scale is moved to a new position each time, slight errors in measurement may accumulate. For example, four successive measurements of 1 5/8 in. each should give an overall length of 6 1/2 in., not 6 9/16 in. Therefore, make as many measurements as you can without changing the reference point. This will avoid cumulative errors in the use of the scale.

Note that your pencil touches the scale only for the purpose of marking a point on the paper. Never use a scale as a straightedge for drawing lines. A typical office ruler has a metal edge; it is a scale and straightedge combined. But a draftsman's measuring scale is for measuring only; it is not a ruler. A scale properly used will last for decades, but a scale used as a straightedge will soon have the graduations worn away.

DRAWING FORMATS

Drawing format is the systematic space arrangement of required information within the drafting sheet. This information is used to identify, process, and file drawings methodicaly. Standard sizes and formats for military drawings are arranged according to DoD-STD-100C, *Engineering Drawing Practices,* and MIL-HDBK-1006/1, *Policy and Procedures for Project Drawing and Specification Preparation.* With the exception of specific local command requirements, DoD-STD-100C and MIL-HDBK-1006/1 are your guidelines for preparing SEABEE drawings.

Most of the documents applicable to these standards have recently been revised and updated in order to gain like information and to share uniformity of form and language within the Naval Construction Force and between DoD organizations. Other influencing factors are the current widespread use of reduced-size copies of both conventional and computer-generated drawings and exchange of microfilm.

SHEET SIZES

Standard drawing sheet sizes are used to facilitate readability, reproduction, handling, and uniform filing. Blueprints produced from standard size drawing sheets are easily assembled in sets for project stick files and can readily be folded for mailing and neatly filed in project letter size or legal size folders. (Filing drawings and folding blueprints will be covered later in this training manual.)

Finished format sizes for drawings shown in figure 3-14, view A, are according to ANSI Y14.1

FLAT SIZES					ROLL SIZES					
SIZE DESIGNATION LETTER	X (WIDTH)	Y (LENGTH)	MARGIN		SIZE DESIGNATION LETTER	X (WIDTH)	Y (LENGTH)		MARGIN	
			H (HORIZ)	V (VERT)			MIN	MAX	H (HORIZ)	V (VERT)
A(HORIZ)	8.5	11.0	0.38	0.25	G	11.0	22.5	90.0	0.38	0.50
A(VERT)	11.0	8.5	0.25	0.38	H	28.0	44.0	145.0	0.50	0.50
B	11.0	17.0	0.38	0.62	J	34.0	55.0	176.0	0.50	0.50
C	17.0	22.0	0.75	0.50	K	40.0	55.0	143.0	0.50	0.50
D	22.0	34.0	0.50	1.00						
E	34.0	44.0	1.00	0.50						
F	28.0	40.0	0.50	0.50						

NOTES: 1. ADDITIONAL PROTECTION MARGINS FOR ROLL SIZE DRAWINGS ARE NOT INCLUDED IN ABOVE DIMENSIONS.
2. ALL DIMENSIONS ARE IN INCHES.

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Figure 3-14.-Guide for preparing horizontal and vertical margins, sizes, and finished drawing format.

(1980), approved and adopted for use under DoD-STD-100C. Flat size refers to drawings that, because of their relatively small size, should be stored or filed flat. Roll size refers to drawings that, because of their lengths, are filed in rolls. Finished format sizes for a drawing refer to the dimensions between trim lines (X and Y in figure 3-14, view A). The TRIM LINE is the outside line of either the vertical or horizontal margin. The inside lines of the margins are called BORDERLINES. Width (X) is always PARALLEL to the working edge of the drawing board; length (Y) is always PERPENDICULAR to the working edge of the drawing board.

Notice, in figure 3-14, view B, that 2 in. should be added to the left margin and to the right margin for protection of roll-size drawings. The edge of a drawing prepared on tracing paper will tear easily after it is rolled and unrolled several times.

SHEET LAYOUT

Sheets of drafting or tracing paper are cut slightly larger than their required finished sizes and are fastened to the drafting board as previously described. Using a hard (4H to 6H) pencil and a T square (or parallel straightedge), draw a horizontal trim line near the lower edge of the paper. Then draw a vertical trim line near the left edge of the paper with a T square (or parallel straightedge), pencil, and triangle, as previously described. Dimensions establishing the finished length of the sheet (distance between vertical trim lines) and the location of the vertical borderlines are marked off on the horizontal trim lines. A full-size scale should be used when you are laying off a series of measurements along a line. Dimensions establishing the finished width of the sheet (distance between horizontal trim

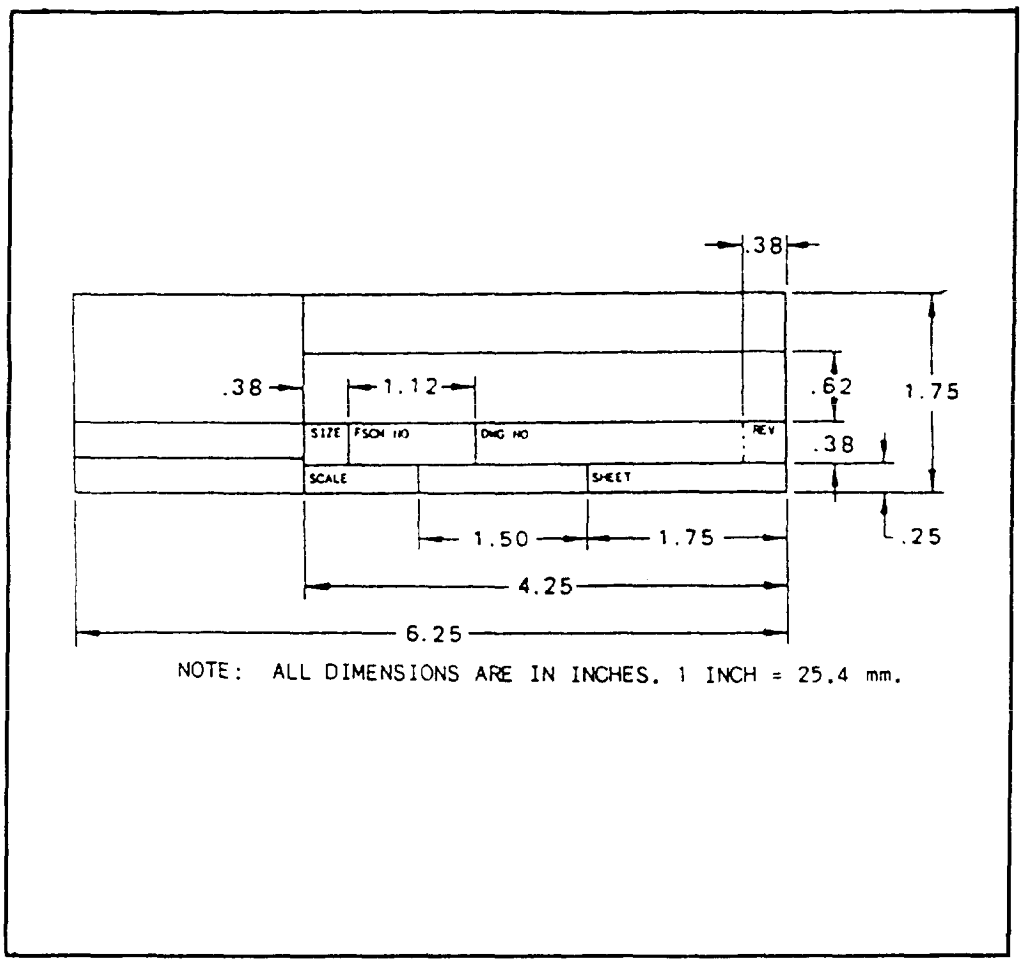


Figure 3-15.-Preparing title block for A-, B-, C-, and G-size drawings.

lines) and the location of the horizontal borderlines are marked off on the vertical trim lines. Dimensions may be scaled along the borderlines.

After the drawing is completed, borderlines are given the required weight. After the completed drawing has been removed from the board, it is cut to its finished size along the trim line. If blueprints are to be made on paper that is not precut to the standard drawing size, you may find it necessary to leave an extra margin outside the trim lines. By leaving an extra margin, you can darken the trim lines. The darkened trim lines, when reproduced, will provide a visible line for trimming the blueprints to size. The extra margin will also help protect the drawing when it is repeatedly handled or attached to the drawing board later for revisions.

BASIC FORMAT

The following discussion deals with the basic drafting format. By basic format, we mean the title block, revision block, list of materials, and other information that must be placed on applicable size drafting sheets. Although you may find slight variations on local-command-prepared drawings, the basic format specified in MIL-HDBK-1006/1 is required on all NAVFACENGCOM drawings.

Title Block

The primary purpose of a drawing title block is to identify a drawing. Title blocks must be uniform in size and easy to read. They may be mechanically lettered, neatly lettered freehand, or preprinted commercially on standard size drafting sheets.

Generally, the title block is placed in the lower right-hand corner of the drawing sheet, regardless of the size of the drawing (except for vertical title block). There are three sizes of title blocks: a block used for A-, B-, C-, and G-size drawings (fig. 3-15), a slightly larger block for D-, E-, F-, H-, J-, and K-size drawings (fig. 3-16), and a

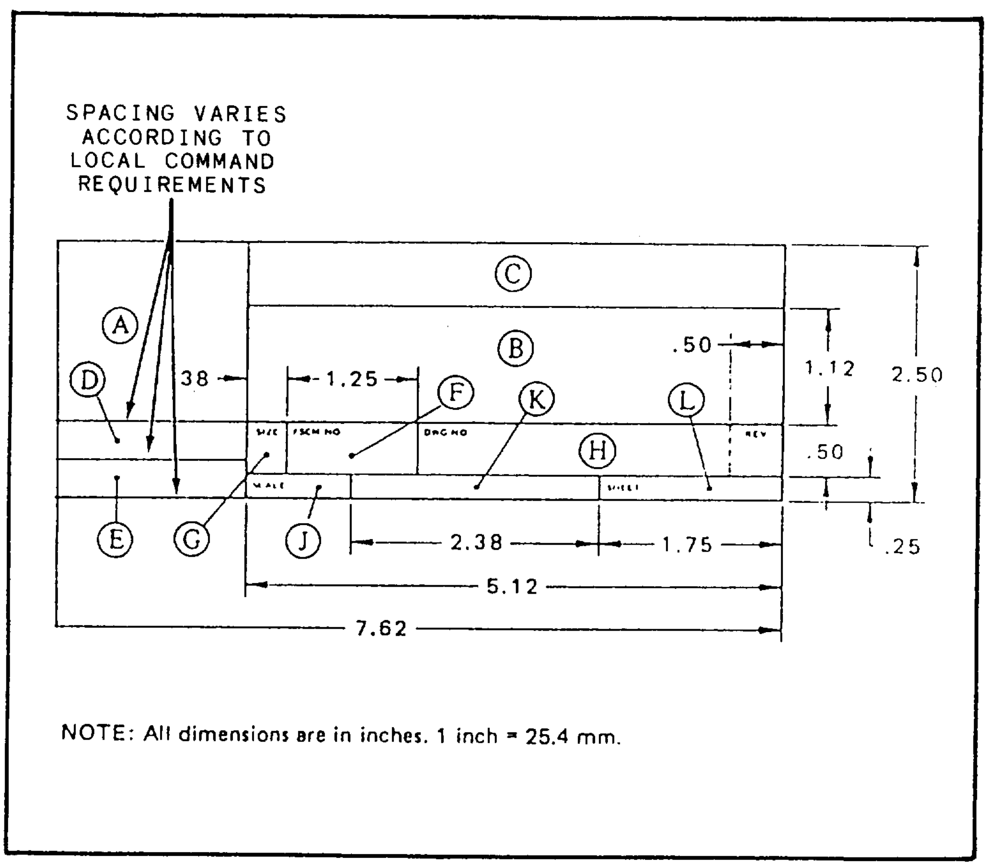


Figure 3-16.-Preparing title block for D-, E-, F-, H-, J-, and K-size drawings.

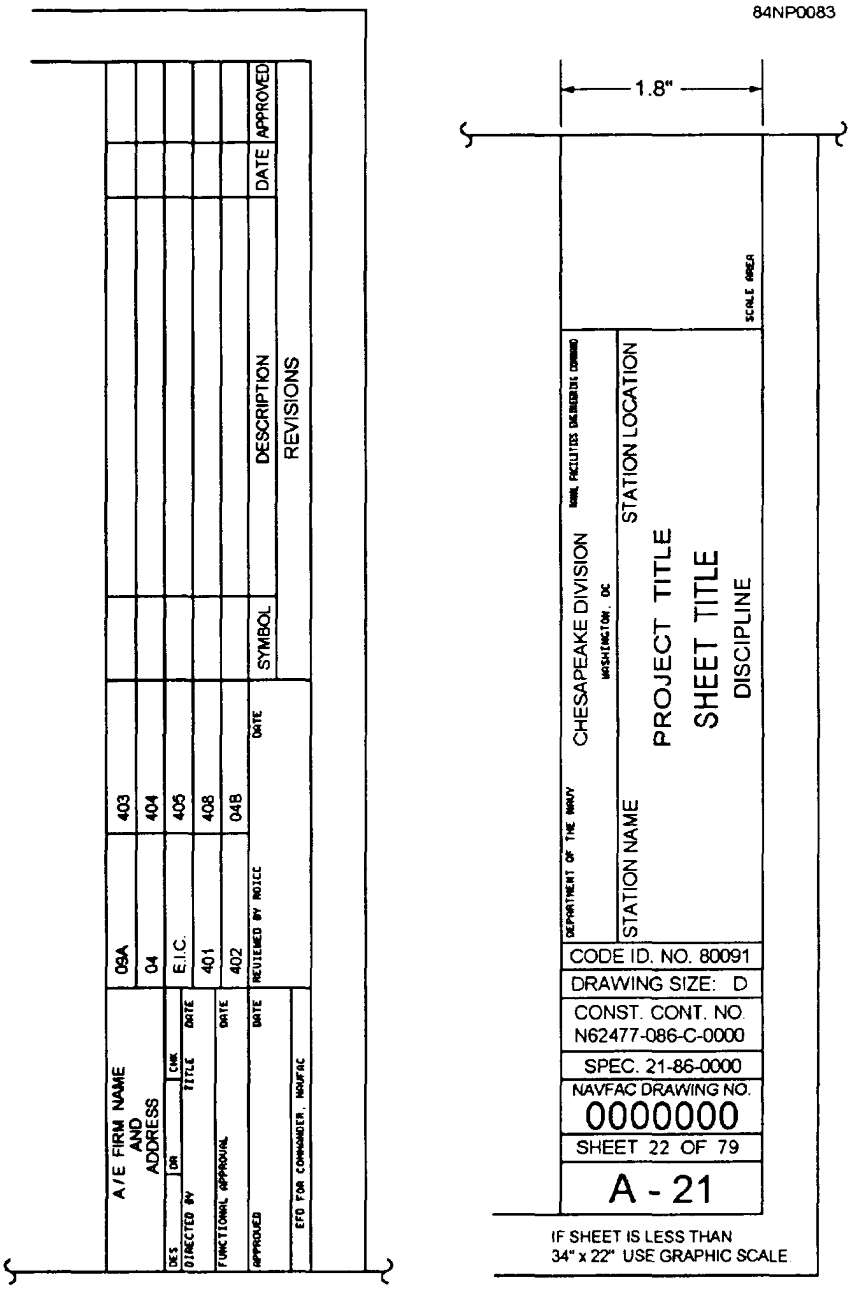


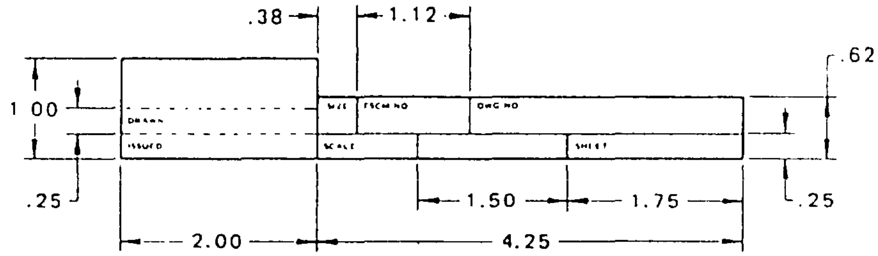
Figure 3-17.-Example of vertical title block prepared by NAVFACENGCOM.

vertical title block (fig. 3-17). The vertical title block format must be used for all 22-in. by 34-in. (D-size) drawings and is optional for 28-in. by 40-in. (F-size) drawings.

In a multiple-sheet drawing, either the basic title block or a “continuation sheet title block” format (fig. 3-18) may be used for second and subsequent sheets provided all sheets are of the same size. Certain information common to all drawings in the basic title block is optional in the continuation sheet title block.

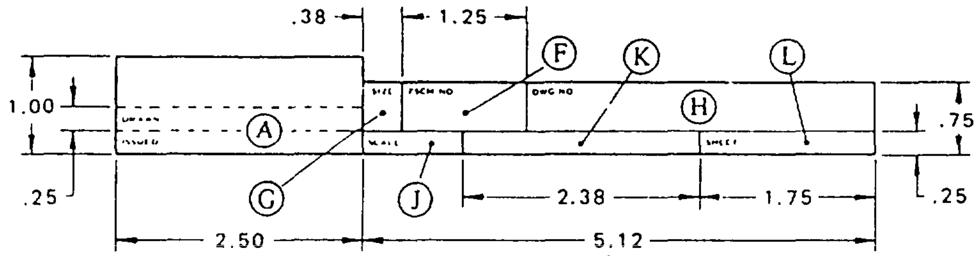
The letter designations shown in figure 3-16 are used to locate the following title block information:

(A) Record of preparation. This information will vary with each command or activity, but will normally include the dates and the surnames of the persons concerned with the preparation of the drawing. The applicable work request number or locally assigned drawing number may also be placed in the upper prtion of this space. This block is optional for continuation sheets.



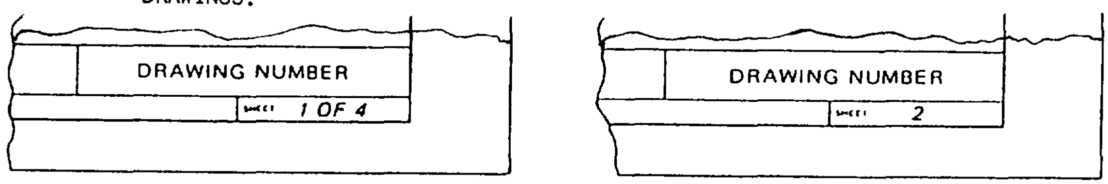
NOTE: All dimensions are in inches. 1 inch = 25.4 mm.

A.-CONTINUATION SHEET TITLE BLOCK FOR A-, B-, C-, AND G- SIZE DRAWINGS.



NOTE: All dimensions are in inches. 1 inch = 25.4 mm.

B.-CONTINUATION SHEET TITLE BLOCK FOR D-, E-, F-, H-, J-, AND K- SIZE DRAWINGS.



(SHEET 1) (SECOND OR SUBSEQUENT SHEET)

C.-EXAMPLE OF MULTIPLE SHEET NUMBERING

Figure 3-18.-Use of continuation sheet title block and multiple sheet numbering.

(B) Drawing title. In the space provided for the drawing title, the general project and the specific features shown on the drawing should be included.

Example 1:

RESTROOM FACILITIES
SEABEE PARK

ARCHITECTURAL

PLANS, ELEVATIONS, SECTIONS, DETAILS

Example 2:

DEFINITIVE DRAWING

BERTHING PIER

The general project (RESTROOM FACILITIES, SEABEE PARK, in example 1) once entered in the title block of sheet 1, is not to be repeated on each sheet of a set of multiple-project drawings. Example 2 is the title taken from the title block of a drawing contained in NAVFAC P-272, *Definitive Designs for Naval Shore Facilities.* In this example the general project or common title, DEFINITIVE DRAWING, appears as the top line title on all drawings in NAVFAC P-272. This block is optional for continuation sheets.

(C) Preparing activity. This space is reserved for the name and location of the activity preparing the drawing. In addition, the words DEPARTMENT OF THE NAVY are placed in this space. This block is optional for continuation sheets.

The information placed in spaces (D) and (E) (fig 3-16) varies with each command and the

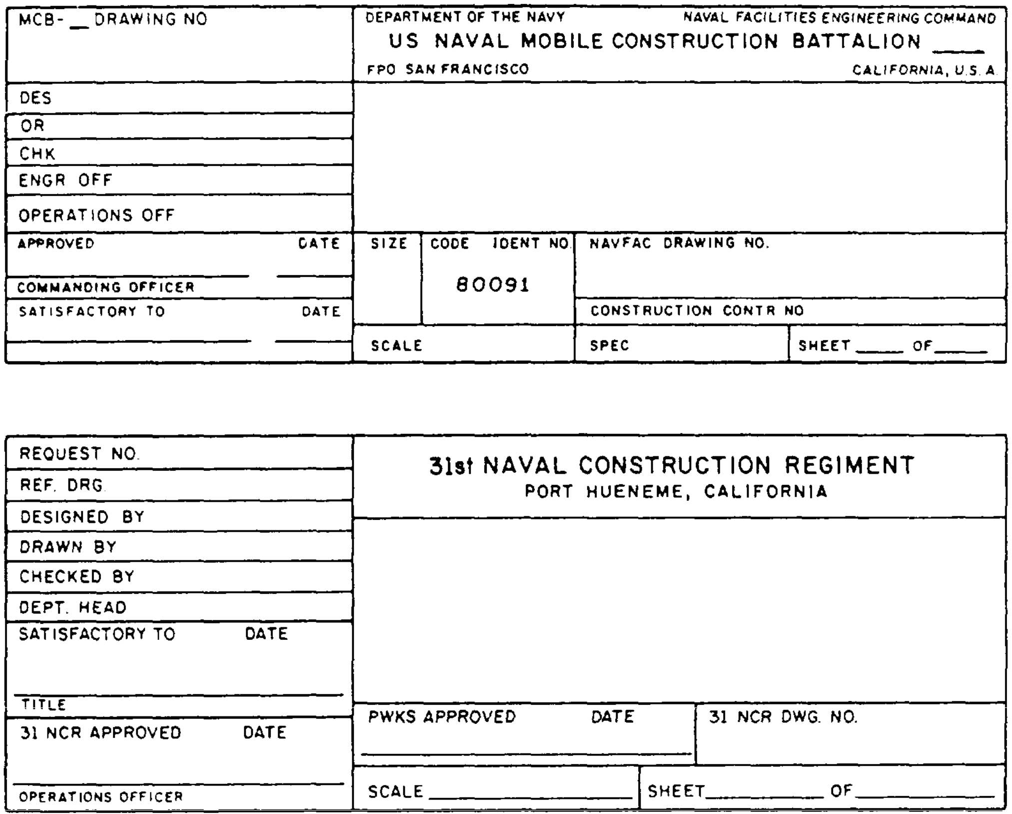


Figure 3-19.-Examples of title blocks used on drawings prepared by Naval Construction Battalion and Naval Construction Regiment.

purpose of the drawing (fig. 3-19). One space is usually reserved for the signature of (APPROVED BY) your commanding officer or officer in charge, and the other space is for the signature of the commander of the activity or command requiring the drawing (SATISFACTORY TO). As shown in the examples in figure 3-19, these two spaces may be used interchangeably. This is acceptable as long as consistency is maintained. It is also acceptable to use only space (E) when a SATISFACTORY TO space is not required for the drawing, as shown on the NAVFAC title blocks in figures 3-20 and 3-21. In this case the (E) space is extended upward or the (A) space may be extended downward if additional space is required. These blocks, if not required, may be absorbed into block (A) far continuation sheets or used for other purposes.

(F) Code identification number. The federal supply code for manufacturers (FSCM) is a five-digit number used to identify the government design activity; that is, the activity having responsibility for the design of an item. For most of your drawings, NAVFAC has the ultimate design responsibility. Therefore, the identification number "80091" is to appear in the title block of all NAVFACENGCOM drawings. You may choose to use either "FSCM" or "Code 10" (the terms are interchangeable) in the title block.

(G) Drawing size. This space is reserved for the letter designating the drawing format size.

(H) Drawing number. If the drawing is prepared for or by NAVFACENGCOM, a NAVFAC drawing number will be assigned. Assignment of NAVFAC drawing numbers is covered in MIL-HDBK 1006/1, *Policy and Procedures for Project Drawing and Specification Preparation.* If the drawing does not require a NAVFAC drawing number, this space will be left blank, and a local command drawing number will be placed in space (A). Occasionally, local title blocks require the drawing number to be placed in space (H). (Refer to fig. 3-19.)

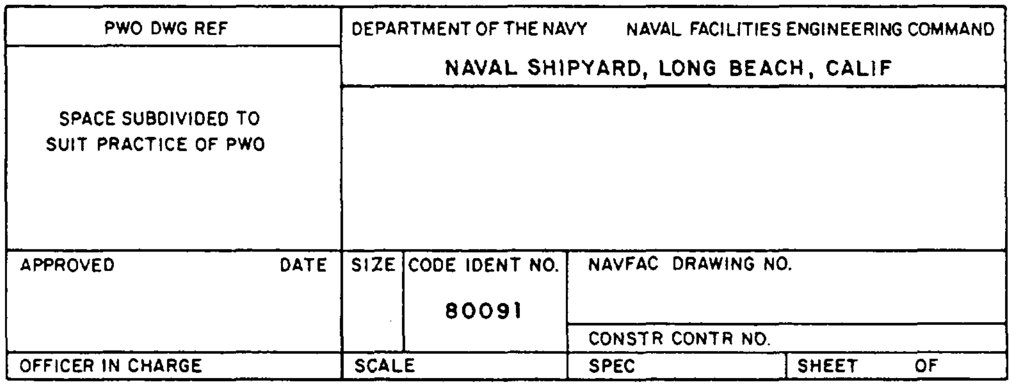


Figure 3-20.-Example of a title block prepared by an activity not requiring NAVFACENGCOM approval.

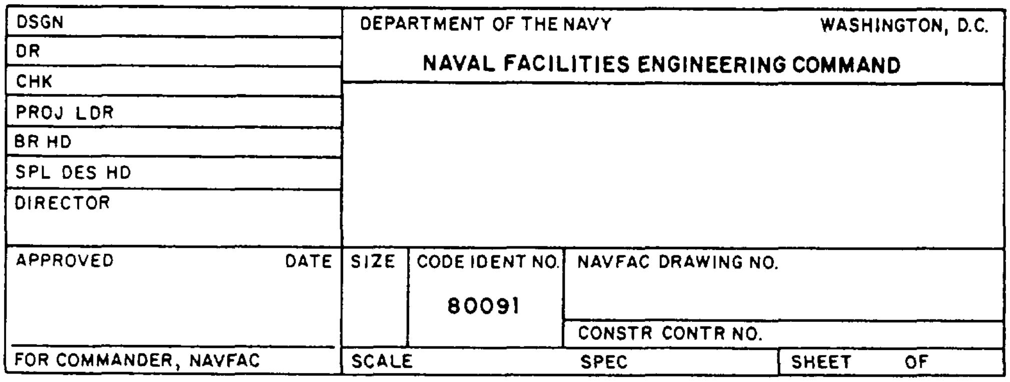


Figure 3-21.-Example of a title block used on drawings prepared by NAVFACENGCOM.

Ⓙ Scale. This space is reserved for the scale to which the drawing is prepared. When more than one scale is used on the drawing, the words AS SHOWN or AS NOTED are entered after the word SCALE in the space Ⓙ. If the drawing was not to scale, the word NONE is entered.

Ⓚ Specification number. On drawings that are prepared for or by NAVFACENGCOM, this space is reserved for the project specification or contract number. If the drawing does not pertain to a particular project specification or contract, this space will normally be left blank.

Ⓛ Sheet number. On a single construction drawing, SHEET 1 of 1 will be entered in this space. For numbering of second and subsequent sheets in a multiple-sheet drawing (fig. 3-18, view C), similar drawing numbers appear in both basic and continuation sheet title blocks; however, the total sheet number is entered on sheet 1 while the specific sheet number is entered on each subsequent sheet.

Satisfactory To Block

In addition to spaces Ⓓ and Ⓔ on the title block, which are provided for approval signatures, a second SATISFACTORY TO block may be required when an outside activity requests a drawing. The extra SATISFACTORY TO block is identical to the SATISFACTORY TO space in the title block but is located adjacent to title block space Ⓔ.

Revision Block

A REVISION block contains a list of all revisions made to the drawing. On construction drawings, the revision block is placed in the upper right-hand corner. Basically, all revision blocks provide the same information; only the

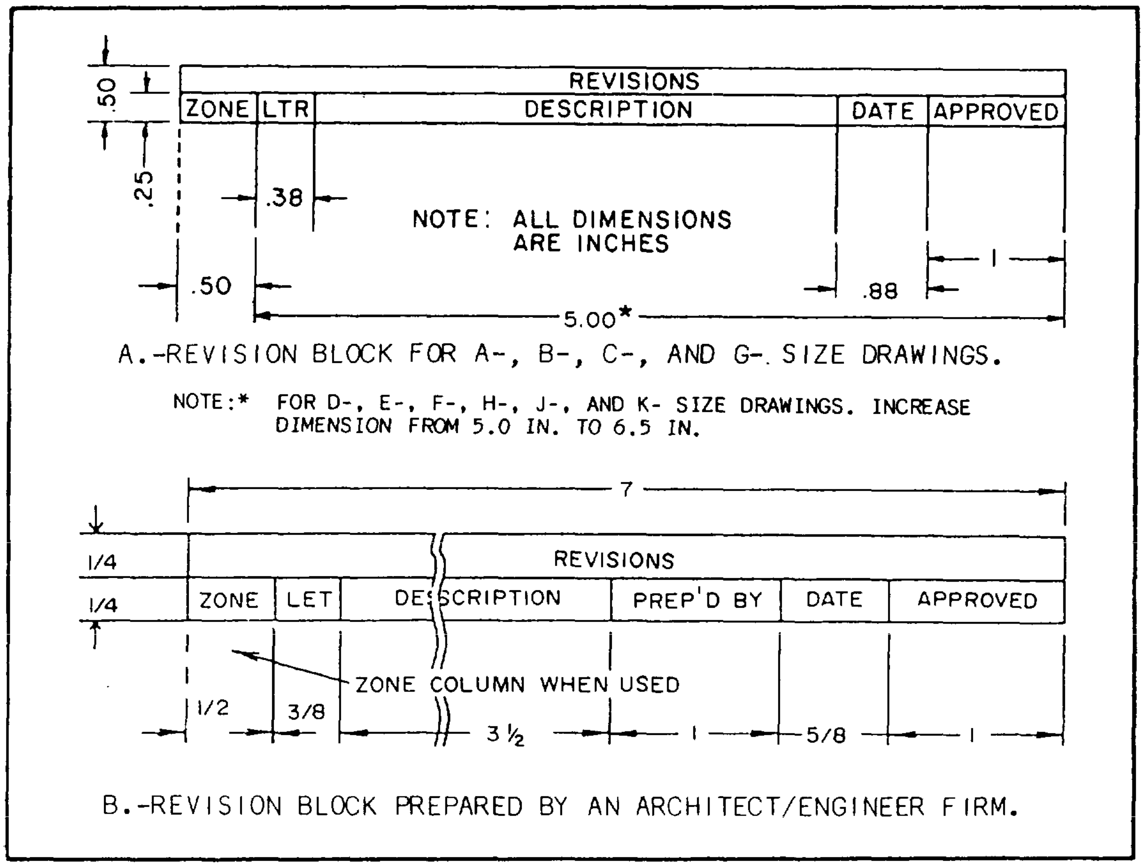


Figure 3-22.-Format used in preparing revision blocks.

sizes of the blocks differ (fig. 3-22). Revision information is entered chronologically starting at the top of the revision block.

Revision letters are used to identify a change or revision to a drawing. Uppercase letters are used in alphabetical sequence, omitting the letters *I*, *O*, *Q*, *S*, *X*, and *Z*. The first revision to a drawing is assigned the *A*. On a drawing, all changes that are incorporated at one time are identified by the same revision letter. The changes may be numbered sequentially to permit ready identification of a specific change. In this case, the appropriate serial number will appear as a suffix to the revision letter (for example, A1, A2, A3, etc.). Whenever possible the revision letter will be placed near the actual change on the drawing. It should be placed so it is not confused with other symbols on the drawing. Usually, the revision letter is placed inside of a circle or triangle (Ⓐ or △A). If a circle or triangle is used on the drawing, it should also be used in the revision block.

A brief description of each change is made in the description column, adjacent to its revision letter, in the revision block. The approval signature and date of revision are also entered in the appropriate columns. For all drawings prepared by Architect/Engineer (A/E) firms, the revision block should include a separate PREPARED BY column (fig. 3-22, view B).

The zone column on the standard revision block is normally omitted on construction drawings but may be used in reviewing maps. Zones are indicated by alphabetical or numerical entries and are evenly spaced in the margin for locating an object on the drawing or map. Use of zoning is described in DoD-STD-100C.

Like title blocks, revision blocks may vary with each command, and you will be required to follow command guidelines. The procedure for making revisions to drawings is covered in DoD-STD-100C.

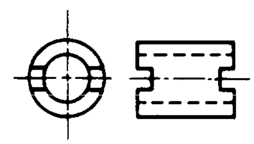
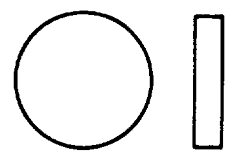
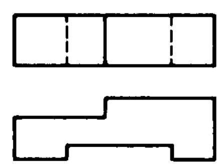
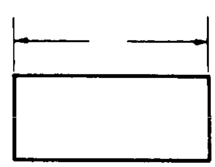
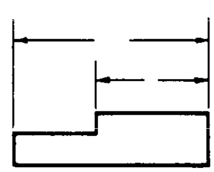
Bill of Materials

When a BILL OF MATERIALS block is used on a construction drawing, it is placed directly above the title block against the right-hand margin. A bill of materials is a tabulated list of material requirements for a given project. The size of the BILL OF MATERIALS block will depend on the size of the drawing and the number of material items listed. On most construction projects, it is impossible to list all items in a single BILL OF MATERIALS block; therefore, it is omitted from the drawings, and a separate list of materials is prepared by an estimator.

LINE CONVENTIONS

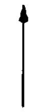
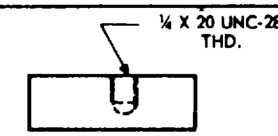
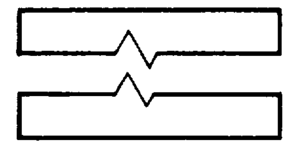
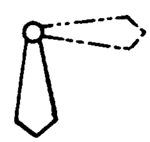
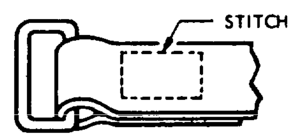
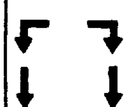
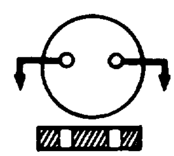
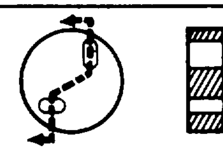
When you are preparing drawings, you will use different types of lines to convey information. Line characteristics, such as widths, breaks in the line, and zigzags, all have definite meanings. Figure 3-23, taken from DoD-STD-100C, shows the different types of lines that should be used on your drawings.

LINE STANDARDS

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

142.46.1

Figure 3-23.-Use of line characteristics and conventions.

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

142.46.2

Figure 3-23.-Use of line characteristics and conventions–Continued.

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

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

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

CONSTRUCTION LINES

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

CENTER LINES

Center lines are used to indicate the center of a circle, arc, or any symmetrical object. (See fig. 3-24.) Center lines are composed of long and short dashes, alternately and evenly spaced, with a long dash at each end. They should extend at least one-fourth in. outside the object. At intersecting points, center lines should be drawn as short dashes.

A very short center line may be drawn as a single dash if there is no possibility of confusing it with other lines. Center lines may also be used to indicate the travel of a moving center, as shown in figure 3-24.

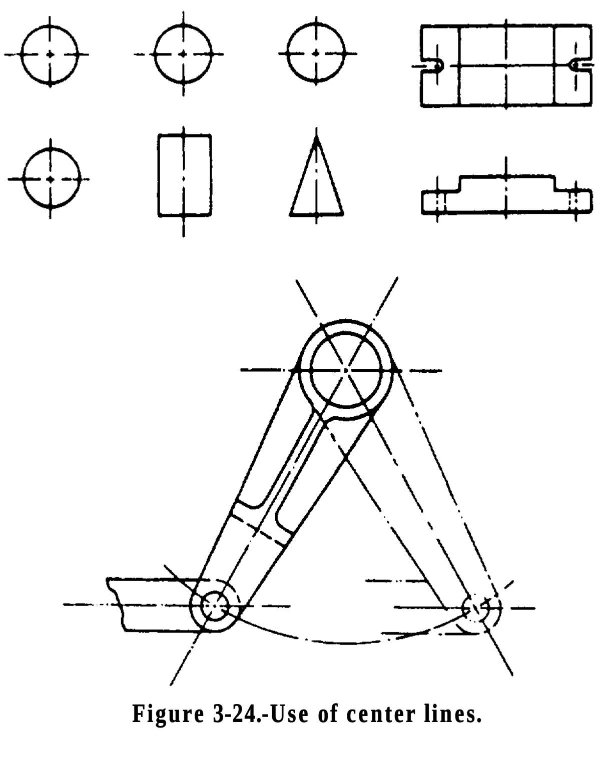


Figure 3-24.-Use of center lines.

VISIBLE LINES

The visible edge lines of the view are drawn as solid, thick lines. These include not only the outlines of the view, but lines defining edges that are visible within the view. (See fig. 3-25.)

HIDDEN LINES

Hidden edge lines are drawn with short dashes and are used to show hidden features of an object. A hidden line should begin with a dash in contact with the line from which it starts, except when it is the continuation of an unbroken line. (See fig. 3-26.)

To prevent confusion in the interpretation of hidden edge lines, you must apply certain standard techniques in drawing these lines. A hidden edge line that is supposed to join a visible or another hidden line must actually contact the line, as shown in the upper views of figure 3-27;

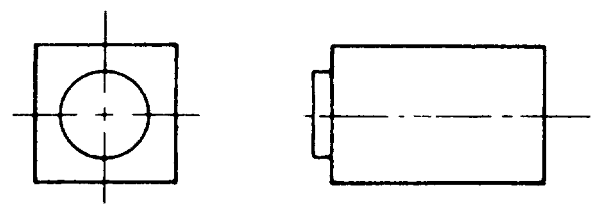


Figure 3-25.-Use of visible edge lines.

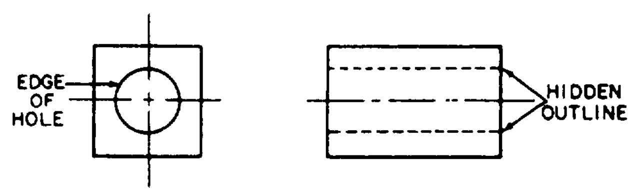


Figure 3-26.-Use of hidden edge lines.

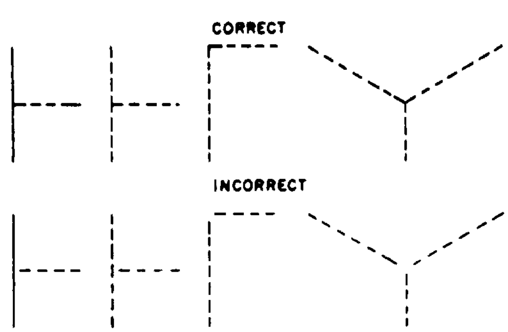


Figure 3-27.-Correct and incorrect procedures for drawing adjoining bidden lines.

the incorrect procedure is shown in the lower views.

Figure 3-28 shows an intersection between a hidden edge line and a visible edge line. Obviously, on the object itself the hidden edge line must be below the visible edge line. You indicate this face by drawing the hidden edge line as shown in the upper view of figure 3-28. If you drew it as indicated in the lower view, the hidden edge line would appear to be above, rather than beneath, the visible edge line.

Figure 3-29 shows an intersection between two hidden edge lines, one of which is beneath the other on the object itself. You indicate this fact by drawing the lines as indicated in the upper view of figure 3-29. If you drew them as indicated in the lower view, the wrong line would appear to be uppermost.

EXTENSION LINES

Extension lines are used to extend dimensions beyond the outline of a view so that they can be read easily. These thin, unbroken lines are started about one sixteenth of an inch from the outline of the object and extend about one eighth of an inch beyond the outermost dimension line. They are drawn parallel to each other and perpendicular

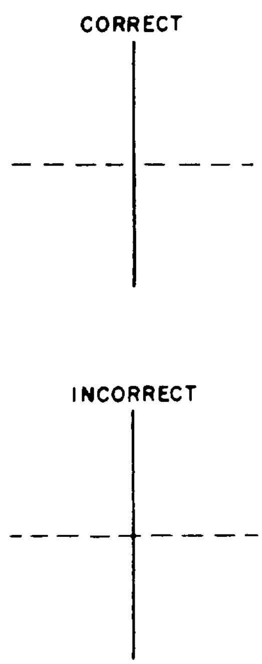


Figure 3-28.-Correct and incorrect procedures for drawing a hidden edge line that intersects a visible edge line.

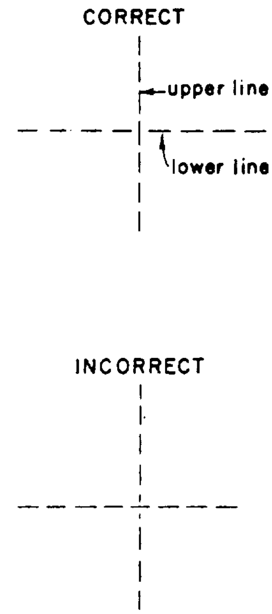


Figure 3-29.-Correct and incorrect procedures for drawing intersecting hidden edge lines that are on different levels.

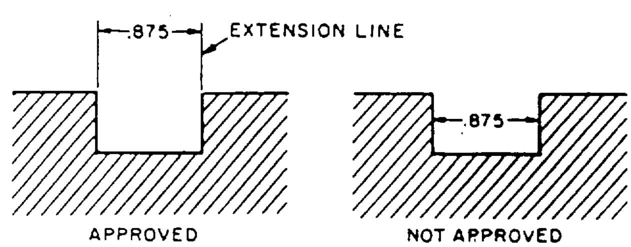


Figure 3-30.-Use of extension lines.

to the distance to be shown. (See fig. 3-30.) In unusual cases, extension lines may be drawn at other angles if their meaning is clear.

As far as practical, avoid drawing extension lines directly to the outline of an object. When it is necessary for extension lines to cross each other, they should be broken, as shown in figure 3-31.

DIMENSION LINES

A dimension line, terminating at either end in a long, pointed arrowhead, is inserted between each pair of extension lines. It is a thin line, and, except in architectural and structural drafting, it is usually broken to provide a space for the dimension numerals. Occasionally, when the

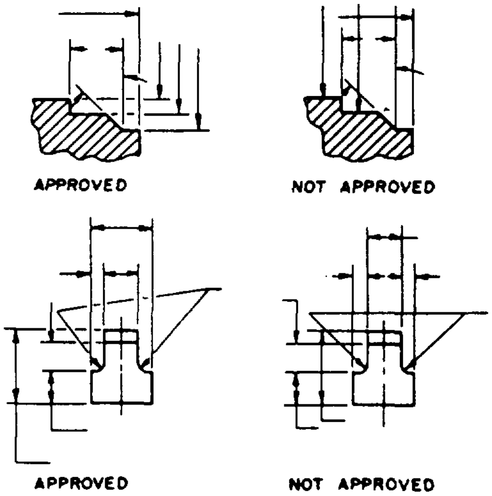


Figure 3-31.-Breaking extension lines and leaders at points of intersection.

radius of an arc is to be indicated, there is an arrow at only the end of the line that touches the arc. The other end, without an arrow, terminates at the point used as the center in drawing the arc.

The arrowhead on a dimension or leader line is an important detail of a drawing. If these arrowheads are sloppily drawn and vary in size, the drawing will not look finished and professional. The size of the arrowhead used on a drawing may vary with the size of the drawing, but all arrowheads on a single drawing should be the same size, except occasionally when space is very restricted.

The arrowheads used on Navy drawings are usually solid, or filled in, and are between one eighth and one fourth of an inch long, with the length about three times the spread. (See fig. 3-32.)

With a little practice, you can learn to make good arrowheads freehand, Referring to figure 3-32, first define the length of the arrowhead with a short stroke as shown at A. Then draw the sides of the arrowhead as indicated at B and C. Finally, fill in the area enclosed by the lines, as shown at D.

LEADERS

Leaders are used to connect numbers, references, or notes to the appropriate surfaces

Figure 3-32.-Method of drawing an arrowhead.

or lines on the drawing. From any suitable portion of the reference, note, or number, a short line is drawn parallel to the lettering. From this line the remainder of the leader is drawn at an angle (dog leg) to an arrowhead or dot. In this way, the leader will not be confused with other lines of the drawing. If the reference is to a line, the leader is always terminated at this line with an arrowhead, as shown in figure 3-33. However, a reference to a surface terminates with a dot within the outline of that surface.

BREAK LINES

The size of the graphic representation of an object is often reduced (usually for the purpose of economizing on paper space) by the use of a device called a break. Suppose, for example, you want to make a drawing of a rectangle 1 ft wide by 100 ft long to the scale of 1/12, or 1 in. = 1 ft. If you drew in the full length of the rectangle, you would need a sheet of paper 100 in. long. By using a break, you can reduce the length of the figure to a feasible length, as shown in figure 3-34.

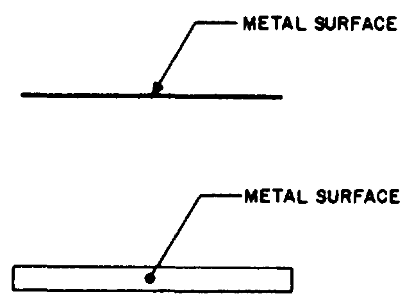


Figure 3-33.-Use of a leader.

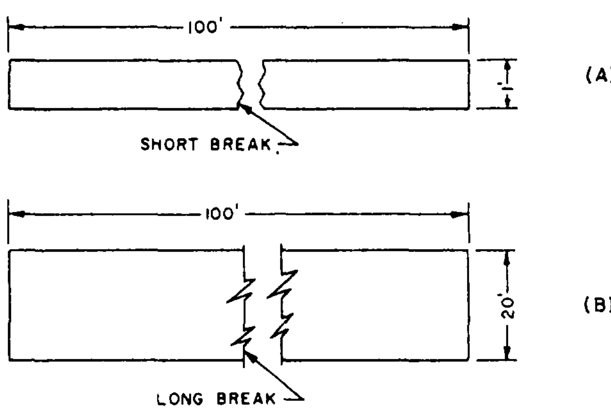


Figure 3-34.-Use of proper line conventions for (A) short break, and (B) long break.

On the original object, the ratio of width to length is 1:100. You can see that on the drawing the ratio is much larger (roughly about 1:8). However, the break tells you that a considerable amount of the central part of the figure is presumed to be removed.

The thick, wavy lines shown in view (A), figure 3-34, are used for a short break. A short break is indicated by solid, freehand lines, and is generally used for rectangular sections. For wooden rectangular sections, the breaks are made sharper (serrated appearance) rather than wavy.

For long breaks, full, ruled lines with freehand zigzags are used, as shown in view (B), figure 3-34. For wider objects, a long break might have more than one pair of zigzag lines.

For drawings made to a large scale, special conventions are used that apply to drawing breaks in such things as metal rods, tubes, or bars. The methods of drawing these breaks are shown in figure 3-35.

PHANTOM LINES

Phantom lines are used most frequently to indicate an alternate position of a moving part, as shown in the left-hand view of figure 3-36. The part in one position is drawn in full lines, while in the alternate position it is drawn in phantom lines.

Phantom lines are also used to indicate a break when the nature of the object makes the use of the conventional type of break unfeasible. An example of this use of phantom lines is shown in the right-hand view of figure 3-36.

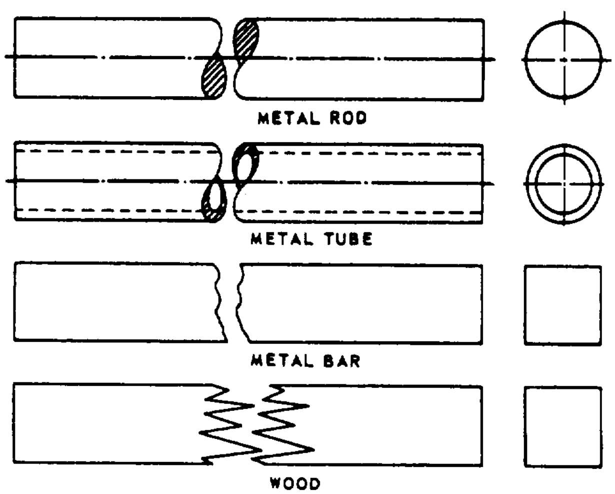


Figure 3-35.-Use of special breaks.

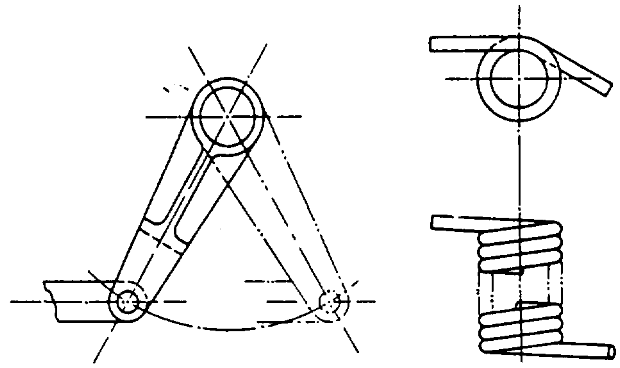


Figure 3-36.-Use of phantom lines.

SECTION LINES

Sometimes the technical information conveyed by a drawing can best be shown by a view that represents the object as it would look if part of it were cut away. A view of this kind is called a section.

The upper view of figure 3-37 shows a plan view of a pipe sleeve. The lower view is a section,

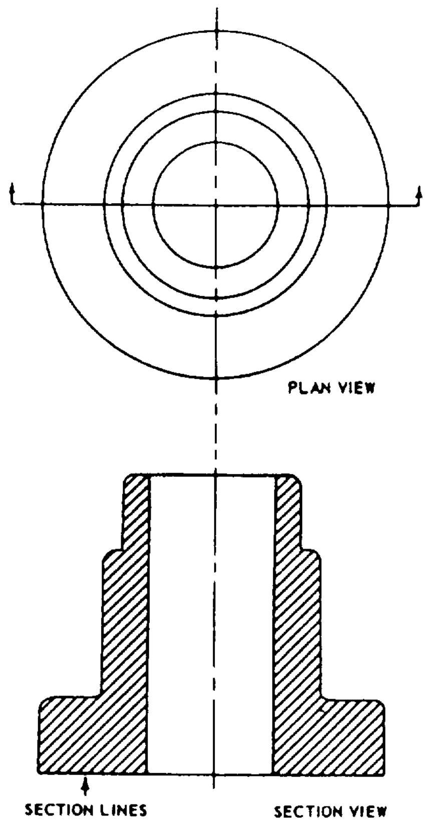


Figure 3-37.-Drawing of a plan view and a full section.

showing the pipe sleeve as it would look, viewed from one side, if it were cut exactly in half vertically. The surface of the imaginary cut is crosshatched with lines called section lines. According to DoD-STD-100C, "section lining shall be composed of uniformly spaced lines at an angle of 45 degrees to the baseline of the section. On adjacent parts, the lines shall be drawn in opposite directions. On a third part, adjacent to two other parts, the section lining shall be drawn at an angle of 30 to 60 degrees."

The cross-hatching shown in figure 3-37 could be used on any drawing of parts made of only one material (like machine parts, for example, which are generally made of metal). The cross-hatching is the symbol for metals and may be used for a section drawing of any type of material.

A section like the one shown in figure 3-37, which goes all the way through and divides the object into halves, is called a full section. If the section showed the sleeve as it would look if cut vertically into unequal parts, or cut only part way through, it would be a partial section. If the cut followed one vertical line part of the way down and then was offset to a different line, it would be an offset section.

VIEWING OR CUTTING PLANE LINES

VIEWING PLANE LINES are used to indicate the plane or planes from which a surface or several surfaces are viewed.

CUTTING PLANE LINES are used to indicate a plane or planes in which a sectional view is taken.

Section views are used to give a clearer view of the interior or hidden feature of an object that normally cannot be clearly observed in conventional outside views.

A section view is obtained by cutting away part of an object to show the shape and construction at the cutting plane.

Notice the CUTTING PLANE LINE AA in figure 3-38, view A. It shows where the imaginary cut has been made. The single view in figure 3-38, view B, helps you to visualize the cutting plane. The arrows point in the direction in which you are to look at the sectional view.

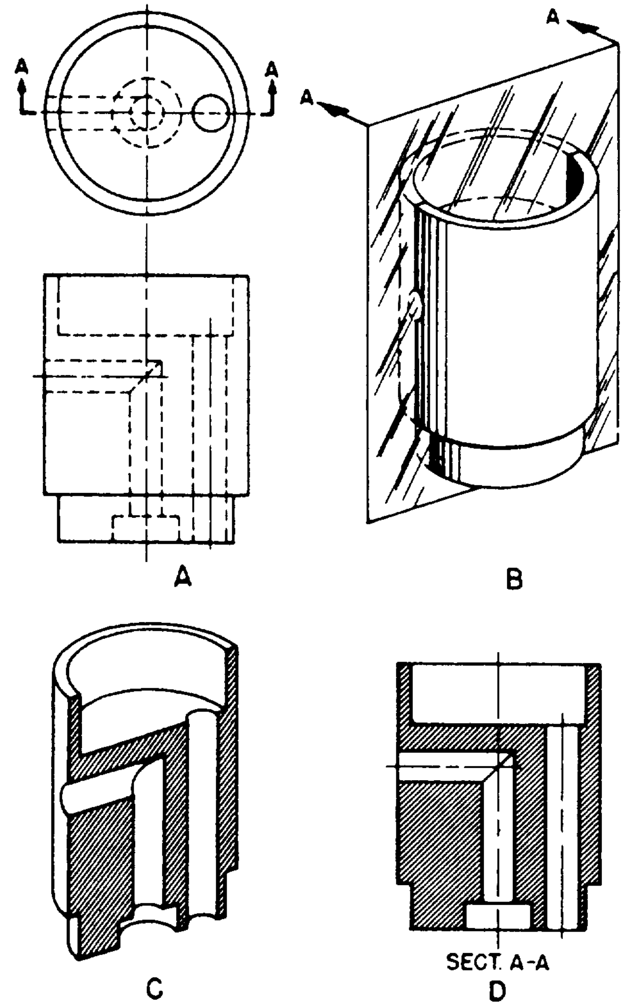


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Figure 3-38.-Action of a cutting plane.

Figure 3-38, view C, is a front view showing how the object would look if it were cut in half.

The orthographic section view of section A-A, figure 3-38, view D, instead of the confusing front view in figure 3-38, view A, is placed on the drawing. Notice how much easier it is to read and understand.

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

Cutting plane lines, together with arrows and letters, make up the cutting plane indications. The arrows at the end of the cutting plane lines are used to indicate the direction in which the sections are viewed. The cutting plane may be a single continuous plane, or it may be offset if the detail can be shown to better advantage. On simple views, the cutting plane should be indicated as shown in figure 3-38, view A. On large, complex views or when the cutting planes are offset, they should be shown as in figure 3-39.

All cutting plane indications should be identified by use of reference letters placed at the point of the arrowheads. Where a change in direction of the cutting plane is not clear, reference letters may also be placed at each change of direction. Where more than one sectional view appears on a drawing, the cutting plane indications should be lettered alphabetically.

The letters that are part of the cutting plane indication should always appear as part of the title; for example, SECTION A-A, SECTION B-B, If the single alphabet is exhausted, multiples of letters maybe used. The word *SECTION* may be abbreviated, if desired. Place the title directly under the section drawing.

DATUM LINES

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

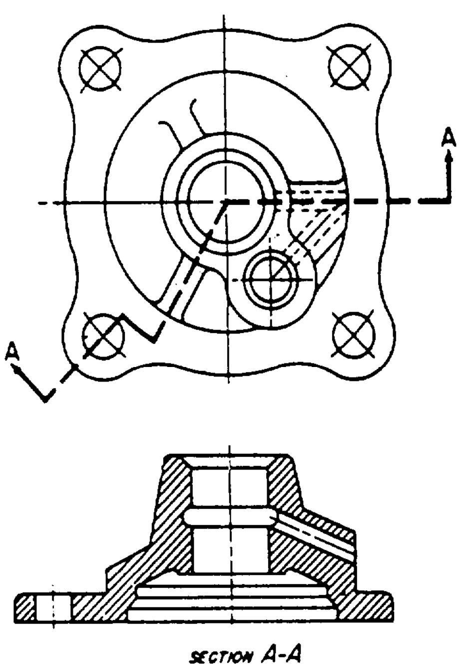

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Figure 3-39.-Use of an offset section.

STITCH LINES

Stitch lines are used to indicate the stitching or sewing lines on an article. They consist of a series of very short dashes (medium thickness), approximately half the length of the dash of hidden lines, evenly spaced. Long lines of stitching may be indicated by a series of stitch lines connected by phantom lines.

MATCH LINES

Match lines are used when an object is too large to fit on a single drawing sheet and must be continued on another sheet. The points where the object stops on one sheet and continues on the next sheet must be identified with corresponding match lines. They are medium weight lines indicated with the words *MATCH LINE* and referenced to the sheet that has the corresponding match line. Examples of construction drawings that may require match lines are maps and road plans where the length is much greater than the width and it is impractical to reduce the size of the drawing to fit a single sheet.

ORDER OF PENCILING

Experience has shown that a drawing can be made far more efficiently and rapidly if all the lines in a particular category are drawn at the same time, and if the various categories of lines are drawn in a specific order or succession. Figure 3-40 shows the order in which the lines of the completed drawing (shown in the last view) were drawn. This order followed the recommended step-by-step procedures, which is as follows:

1. Draw all center lines.
2. Draw the principal circles, arcs, fillets, rounds, and other compass-drawn lines. A fillet is a small arc that indicates a rounded concave joint between two surfaces. A round is a small arc that indicates a rounded convex joint between two surfaces.

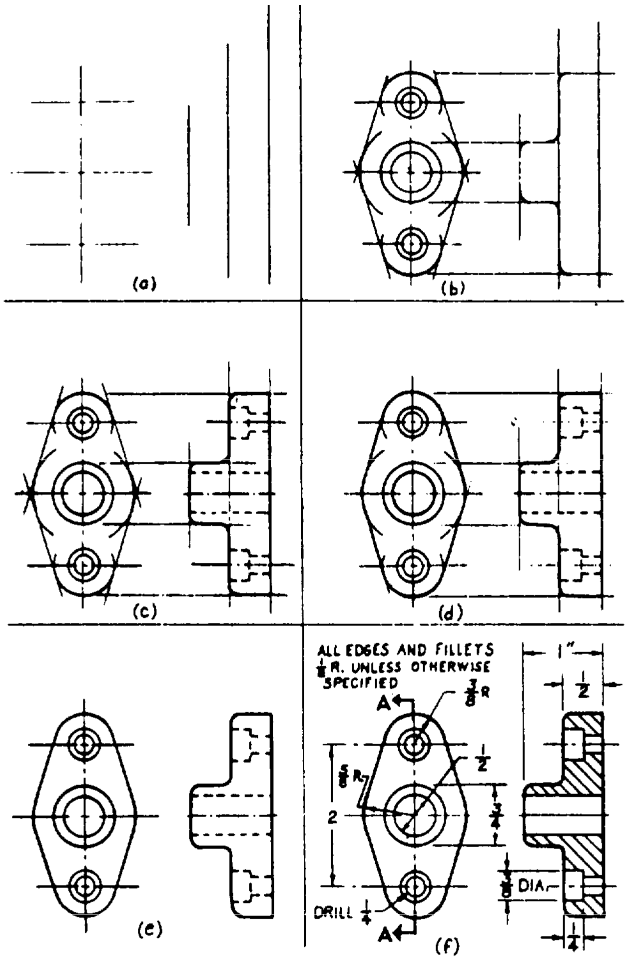

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Figure 3-40.-Order of penciling a drawing.

3. Draw the horizontal and vertical outlines, visible lines, and hidden lines.
4. Draw the nonhorizontal and nonvertical outlines, visible lines, and hidden lines.
5. Clean up the drawing, erasing all excess lines and construction lines. A construction line is a light line used as a drawing guide only.
6. Draw extension lines, dimension lines, section lines, and any other lines required.
7. Inscribe the dimensions and lettering.

To a limited extent you can vary the thickness of a pencil line by varying the extent to which you bear down on the pencil. However, you can't bear down very hard without troughing the paper. Therefore, you can't get much variety in line weight with a pencil. For a drawing that will be inked over, this doesn't make any difference. However, for one that will not be reproduced, or which will be reproduced directly from the pencil original, you must follow, as nearly as you can, the line conventions.

ORDER OF INKING

The beginner is usually frightened at the prospect of trying to ink a drawing without spoiling it. Once you have learned how to use drawing instruments and to follow a definite order of inking, you will have greatly reduced the danger of spoiling a drawing. Nowadays, draftsmen prefer the reservoir pen or rapidograph to the ruling pen for inking straight and curved lines and even for lettering. On the other hand, the ruling pen should NEVER be used to ink freehand lines.

One good way to avoid smeared ink lines is by using SPACE BLOCKS. These strips of tape or thin pieces of plastic, when fastened to both faces of the triangles, french curves, or templates (fig. 3-41), raise their edges from the surface of the drafting paper and prevent ink from running under the edge.

When you use a rapidograph or reservoir pen with a T square or parallel straightedge, make long lines with a whole arm movement and short lines with a finger movement.

Draw horizontal lines from left to right, starting at the top of the drawing and working down. (If you are left-handed, you will, of course, draw these lines from right to left, and similarly reverse many of the directions given in this training manual.)

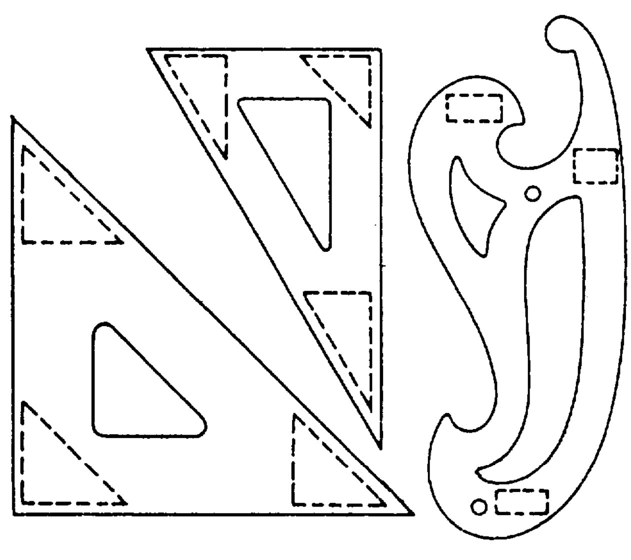

Figure 3-41.-Use of space blocks.

Vertical lines are usually drawn in an upward direction, moving from left to right across the drawing. However, when you have to draw a number of vertical lines or lines slanted in the same direction, the way you draw them will be governed by the source of your light and the way you have found that you can draw vertical lines with greatest control.

Let the first lines dry before starting to draw any intersecting lines. Watch carefully when you draw one line across another line. You vary the thickness of ink lines by selecting a pen unit that matches your desired application and/or line convention.

The order generally recommended for inking is as follows:

1. Inking of a drawing must start from the top of the paper and progress toward the bottom.
2. Start inking all arcs of circles, fillets, rounds, small circles, large circles, and other compass-drawn lines.
3. Ink all irregular curves, using a french curve or a spline as a guide.
4. Ink all thick horizontal lines, then all medium and thin lines.
5. Start at the left edge and ink the thick first, the medium next, and finally the thin vertical lines from left to right.
6. Follow the same procedure described in (4) and (5) for slanting.
7. Ink section lines, dimensions, and arrowheads.
8. Ink notes and title, meridian symbol, and graphic scales.
9. Ink borders and check inked drawing for completeness.
10. Use an art gum or a kneaded eraser to erase pencil marks or for final cleanup of the drawing.

LETTERING

The information that a drawing must present cannot be revealed by graphic shapes and lines alone. To make a drawing informative and complete, you must include lettering in the form of dimensions, notes, legends, and titles. Lettering can either enhance your drawing by making it simple to interpret and pleasant to look at, or it can ruin your drawing by making it difficult to read and unsightly in appearance. Therefore, it is essential that you master the techniques and skills required for neat, legible lettering.

FREEHAND LETTERING

As you work with experienced draftsmen, you will notice that their freehand lettering adds style and individuality to their work. They take great pride in their freehand lettering ability. By learning basic letter forms and with constant practice, you will soon be able to do a creditable job of lettering and acquire your own style and individuality. Anyone who can write can learn to letter. As you practice you will steadily improve both your style and the speed with which you can letter neatly. Don't give up if your first attempts do not produce neat lettering. Don't be afraid to ask your supervisor for a few pointers.

An understanding of the letter shapes and the ability to visualize them can be accomplished by drawing them until the muscles of your hand are accustomed to the pattern of the strokes that make up the letters. You should be able to draw good letters without consciously thinking of this pattern.

Your position and how you hold your pencil will greatly affect your lettering. You should sit up straight and rest your forearm on the drawing board or table. Hold the pencil between the thumb, forefinger, and second finger; the third and fourth fingers and the ball of the palm rest on the drawing sheet. Do not grip the pencil tightly. A tight grip will cramp the muscles in your fingers, causing you to lose control. If you get "writer's cramp" easily, you are probably holding your pencil too tightly. The pencil should be kept sharpened to produce uniform line weights. A conical-shaped pencil point works best for most lettering. Usually, an F or H pencil is used for lettering. A pencil that is too hard may cut into the paper, or it may produce lettering that will not reproduce easily. A pencil that is too soft will require frequent sharpening, and it will produce lettering that may smear easily on a drawing.

GUIDELINES

Figure 3-42, view A, shows the use of light pencil lines called guidelines. Guidelines ensure consistency in the size of the letter characters. If your lettering consists of capitals, draw only the cap line and base line. If lowercase letters are included as well, draw the waist line and drop line.

The waist line indicates the upper limit of the lowercase letters. The ascender is the part of the lowercase letter that extends above the body of the letter; for example, the dot portion of the

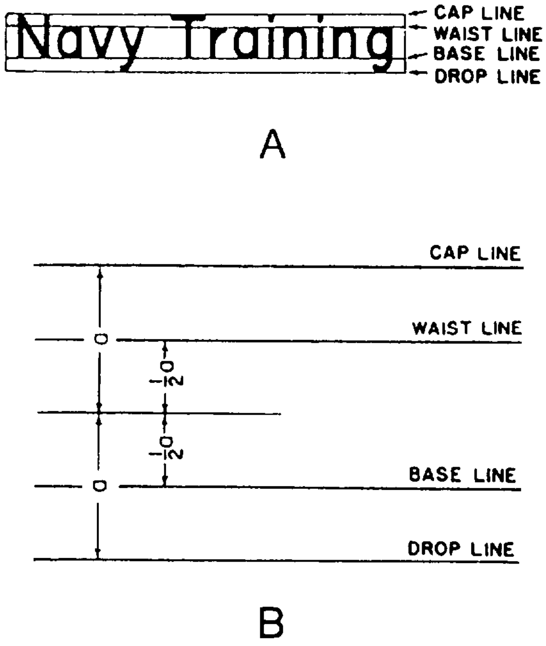

Figure 3-42.-Laying off guidelines.

character *i* in figure 3-42, view A. All ascenders are as high as the caps.

The drop line indicates the lower limit of the lowercase letters. The descender is the part of the lowercase letter that extends below the body of the letter, an example being the tail of the character g in figure 3-42, view A. The vertical distance from the drop line to the base line is the same as the vertical distance from the waist line to the cap line. It is about one third of the vertical distance between the base line and the cap line, or about one half of the vertical distance between the base line and the waist line.

Figure 3-42, view B, shows an easy way to lay out guidelines for caps and lowercase. Let the height of a capital be 1 1/2 times the distance "a." Set a compass or dividers to distance "a," and lay off distance "a" above and below the midline selected for the guidelines, The method locates the cap line and the drop line. Then set the compass or dividers to one half of "a," and lay off this distance above and below the midline. This method locates the waist line and the base line.

To help you keep your lettering vertical, it is a good idea to construct vertical guidelines, spaced at random along the horizontal guidelines. For inclined lettering, lay off lines inclined at the angle you wish your lettering to be slanted. (See fig. 3-43, view A.) Inclined lines are known as

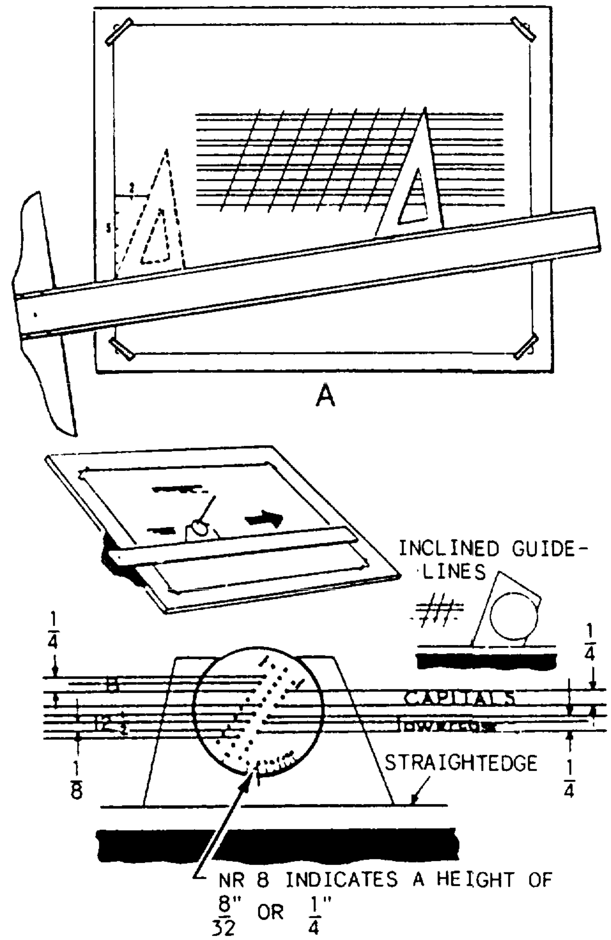

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Figure 3-43.-Laying off lines for lettering.

direction lines and are normally slanted at a maximum of 68 degrees.

Ames Lettering Instrument

If you have many lines of lettering to do, you will find a lettering instrument, such as the Ames lettering instrument, shown in figure 3-43, view B, quite useful and timesaving. The top-left section of figure 3-43, view B, 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 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 the Ames lettering instrument permits you to use it for lettering ranging in height from 1/16 to 5/16 in. 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 the instrument for a particular letter height. A number aligned with the index line on the outer section of the instrument indicates the height of the lettering in 32ds of an inch. In figure 3-43, view B, the number 8 is aligned with the index; therefore, the distance between the capital letter guides produced by this setting is 8/32 in. or 1/4 in.

By standing the Ames lettering instrument on its greater sloping side, you can use it for drawing guidelines for inclined lettering that slope at an angle of 67 1/2 degrees with the horizontal. (See the upper-right portion of fig. 3-43, view B.)

Spacing Between Guidelines

The spacing between two lines of capitals may vary from one half of the height to the full height of a capital. Two thirds of the height is customarily used.

The spacing commonly used between lines of lowercase letters is shown in figure 3-44. The space indicated by the letter *S* equals the vertical distance between the waist line and the cap line.

VERTICAL SINGLE-STROKE GOTHIC LETTERING

The generally accepted style of lettering for SEABEE drawings is the single-stroke Gothic

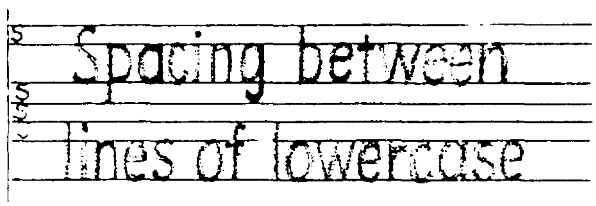

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Figure 3-44.-Spacing between lines of lowercase letters.

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Figure 3-45.-Vertical single-stroke Gothic capitals and numerals.

vertical (fig. 3-45) or inclined lettering. The term *Gothic* refers to the style of letters. Gothic lettering is the simplest style to make and the easiest to read on a drawing. Single-stroke means that each stroke of the letter is made by one stroke of the pencil. Figure 3-46 shows the basic strokes required for single-stroke lettering. Vertical strokes are drawn from the top down with an even finger movement. (Inclined strokes are drawn in the same manner.) Horizontal strokes are drawn from left to right with a complete hand movement, pivoting at the wrist. Curved strokes proceed from above downward, using a combined finger and wrist motion. Lettering strokes are drawn, not sketched. It is important that you use the correct direction and sequence of strokes recommended for each letter.

The required shapes of vertical single-stroke Gothic letters and numerals will be shown and discussed in the next several figures and paragraphs. To emphasize the proportions of the letters and numerals, each character is shown in a grid, six units high. The grid serves as a reference for comparing the height of the various characters in proportion to their width as well as locating the individual strokes that compose the characters.

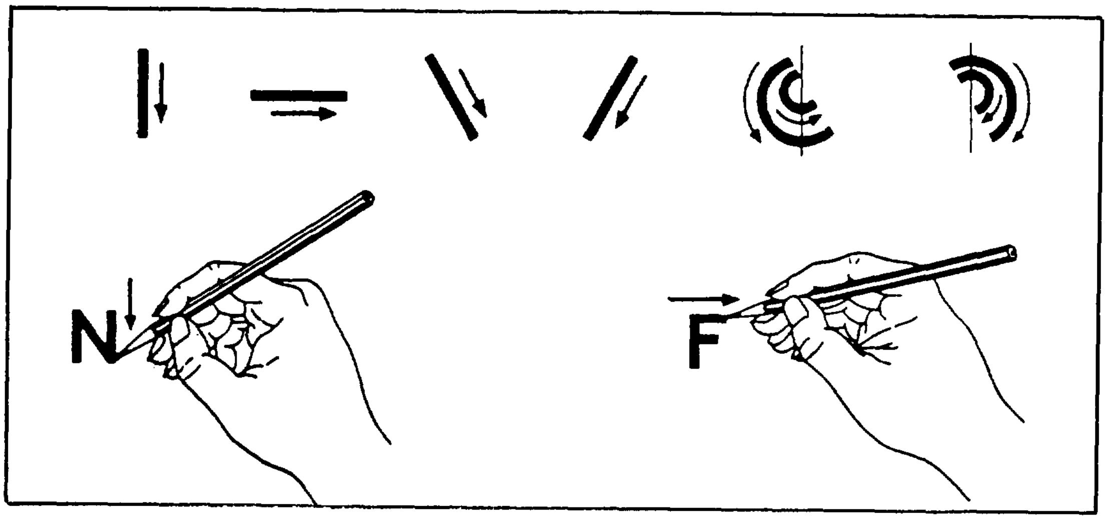

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Figure 3-46.-Basic lettering strokes.

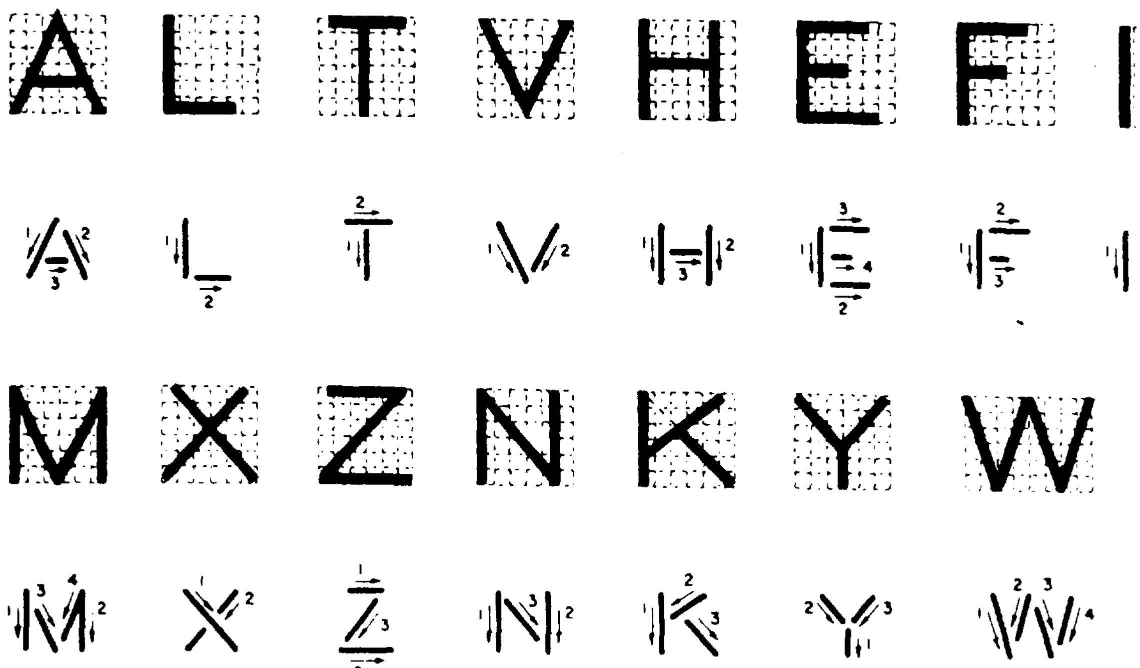

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Figure 3-47.-Lettering vertical straight-line capitals.

For learning purposes, the characters are grouped by the type of strokes required to form each character.

Straight-Line Capitals

The capital letters shown in figure 3-47 are formed with only straight-line strokes.

Z, X, Y, K. Stroke 2 of the *Z* is longer than stroke 1. The inclined strokes of the *X* are closer together at their starting than at their finishing points. The three strokes of the *Y* intersect slightly below the center of the square. Stroke 2 of the *K* intersects stroke 1 at a point one third of the distance up from the base line. Stroke 3, if extended, would intersect stroke 1 at the top.

I, A, L, T. The letter 1 is the basic vertical stroke. Inclined strokes 1 and 2 of the *A* intersect just above the cap line; stroke 3 is located one third of the distance up from the base line. The horizontal stroke of the *T is* drawn first; the vertical stroke or stem is drawn from the center. With both *L* and *T,* the horizontal stroke maybe lengthened or shortened to balance the letters in a word. If, for example, *L* precedes *A,* its horizontal stroke is reduced slightly; if *T* precedes *A,* its horizontal stroke is extended slightly.

H, F, E. In *H, F,* and *E,* the central horizontal bar is placed slightly above the center for stability. In both *E* and *F,* the cap line stroke is four units long and the central stroke is three-fifths of this length. The base line of *E* is one-half unit longer than its cap line.

V, W, M, N. The two inclined strokes of the *V* intersect just below the base line. The *W* is 1 1/3 times the width of a normal letter; note that it is wider than *M.* Strokes 1, 2, 3, and 4 of the *W* intersect below the base line. Strokes 3 and 4 of the *M* and 2 and 3 of the *N* intersect on the base line. Note that the outside strokes of the *M* and *N* are drawn first.

Curved- and Straight-Line Combinations

The capital letters shown in figure 3-48 are formed by either curved line strokes or by a combination of curved- and straight-line strokes.

O, Q, C, G. The *O* and *Q* are complete circles; *C* and *G* are not the full width of the square because they are not full circles. The tail of *Q,* if extended, would intersect the center of the circle. Stroke 4 of *G* begins at the center of the circle.

U, J, D. Stroke 3 of *U* is elliptical and connects two parallel vertical lines a third of the distance above the base line. Stroke 2 of *J* is similar but not so broad. Stroke 4 of *D* is circular, joining two horizontal segments.

P, R, B. The horizontal midstrokes of *P* and *R* lie just below the midpoint, and the horizontal midstroke of *B* lies just above the midpoint. Horizontal stroke 4 in *B* is slightly longer than strokes 2 and 3, which are the same length.

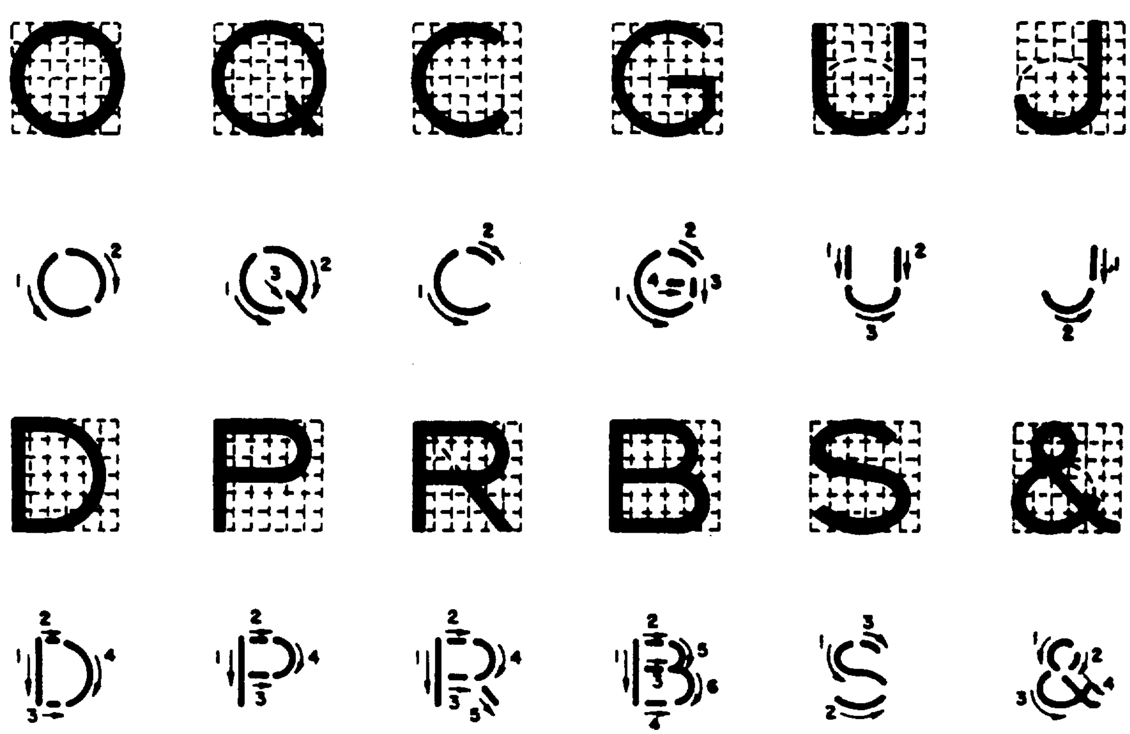

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Figure 3-48.-Lettering vertical capitals, curved- and straight-line combinations.

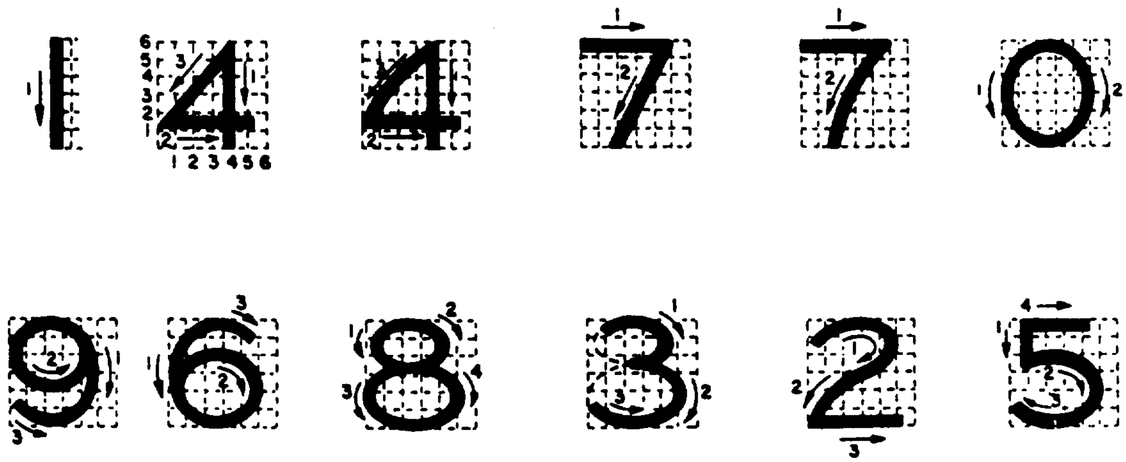

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Figure 3-49.-Lettering vertical numerals.

S and *&*. The upper and lower portions of *S* are ellipses, the upper slightly smaller than the lower. The ampersand *(&)* is basically similar despite a greater difference in the sizes of the ellipses.

Numerals and Fractions

The need for extreme care in drawing numerals cannot be overstressed, particularly in the preparation of construction drawings in which a poorly drawn numeral can cause costly errors and delays.

Numerals are drawn using the same size guidelines as the capital letters on a drawing. Vertical guidelines are spaced at random. Numerals should not be made so small or be crowded so closely as to impair their legibility.

In figure 3-49 the vertical stroke of the numeral 4 is placed two units from the right side. The horizontal bar is one quarter the height of the number above the base line. Note that the closed curves of *0, 6,* and *9* are elliptical, not circular. The *6* is an inverted *9*. The *8* is composed of two ellipses tangent slightly above the center point. The top ellipse also is narrower. The *3* is the same as the *8* with the left portions of the loops cut off. The curved lines of *2* follow the elliptical contours of *8*. The top portion of the *5* is slightly narrower than the bottom.

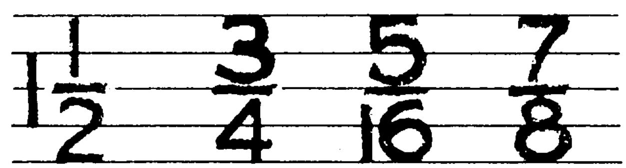

Figure 3-50.-Vertical fractions.

The bottom ellipse is two thirds of the height of the figure from the base line.

The division bar between the numerator and denominator of the fractions is always drawn parallel to the guidelines, as shown in figure 3-50. The complete height of a fraction is twice that of a whole number. The division bar is centered midway between the base line and cap line. The top guideline of the numerator and the bottom guideline of the denominator are spaced a full number height from the division bar. The numbers composing a fraction are three quarters of the height of a full number. The clear space on either side of the division bar is one quarter of a full number. Numbers in a fraction are centered about a vertical guideline that cuts the fraction bar in half.

Lowercase Letters

Lowercase letters are never used on construction drawings, although it is acceptable to use them for notes on maps or similar drawings.

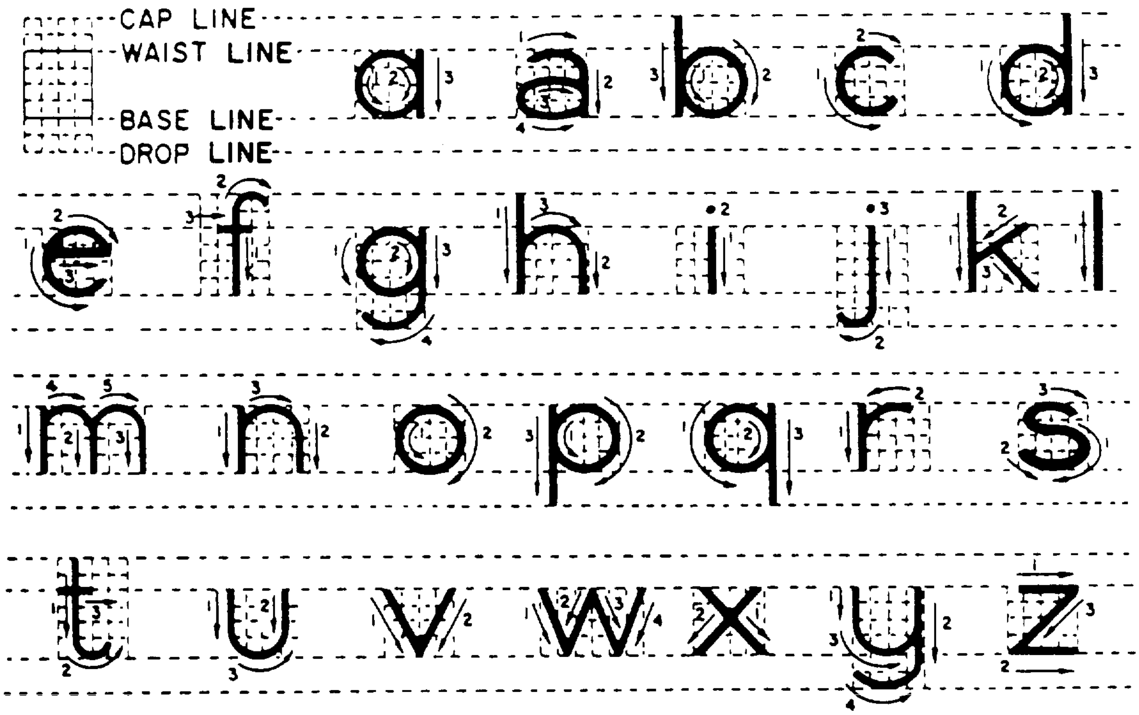

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Figure 3-51.-Lettering vertical lowercase letters.

Lowercase letters should NEVER be used on drawing title blocks. Figure 3-51 shows lowercase letters along with guidelines and strokes used to form each letter.

The crosses of *f* and *t* are on the waist line and extend the same distance on either side of stroke 1. The horizontal stroke of e is just above midheight. The bodies of *a, b, g, p,* and *q* are circular and vertical strokes of these letters do not increase their width at the points of tangency. The vertical strokes of *p* and *q* terminate at the drop line. The vertical strokes of *g, j,* and *y* terminate in curves that are tangent to the drop line.

INCLINED LETTERING

Inclined single-stroke Gothic lettering is also acceptable on SEABEE drawings, although it is not recommended for the beginner and should not be attempted until you have mastered vertical lettering techniques. Inclined and vertical lettering should never appear on the same drawing. The lettering style used must always be consistent.

Figures 3-52 and 3-53 show the required formation of inclined letters. The angle of

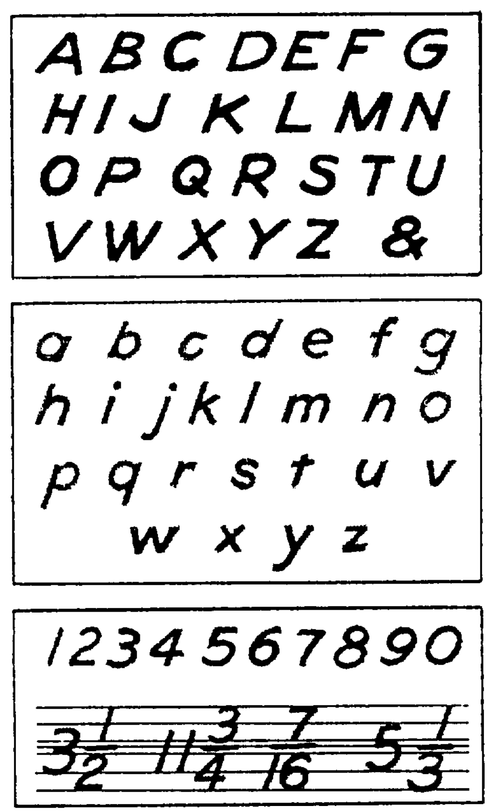

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Figure 3-52.-Inclined single-stroke Gothic.

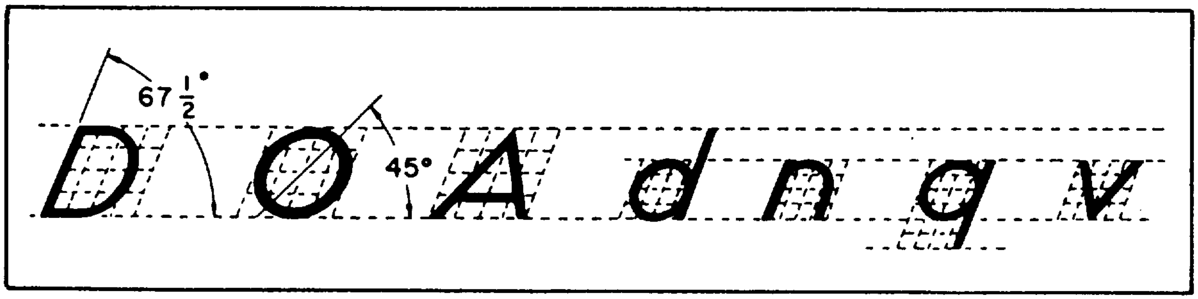

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Figure 5-53.-inclined letter formation.

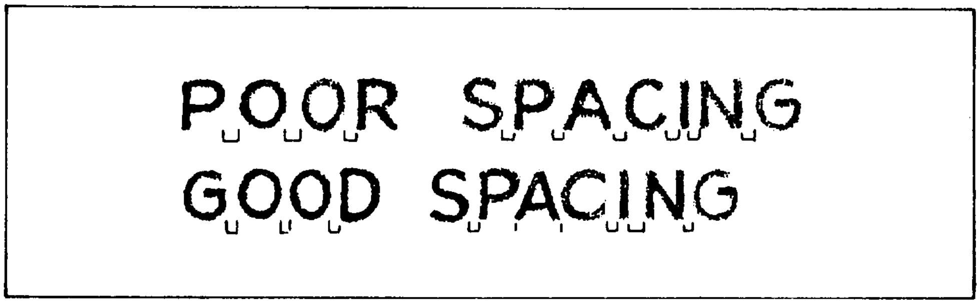

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Figure 3-54.-Letterspacing.

inclination is 67 1/2 degrees from the horizontal. Inclined guidelines may be drawn with the lettering triangle as described, or a line at the proper angle may be laid off with the protractor and parallel lines constructed from it. Horizontal guidelines and sequence of strokes are the same as for vertical letters. Rules of stability, proportion, and balance are similar. The circles and circular arcs used in vertical letters become elliptical in inclined letters, their major axes making angles of 45 degrees with the horizontal. Letters such as *A, M, V,* and *Y* should be made symmetrically about a guideline. Inclined lowercase letters follow the same principles as inclined capitals.

COMPOSITION OF LETTERING

Once you have learned the proper shapes and strokes required to form each letter and numeral, you should concentrate on practicing the composition of words and sentences. Proper spacing of letters and words does more for the appearance of a block of lettering than the forms of the letters themselves. But this does not mean that you should discontinue further practice of correctly forming each letter.

LETTERSPACING

In straight-line lettering, determine the spacing between letters by eye after making the first letter and before making each succeeding letter. To give a word the appearance of having uniformly spaced letters, make the areas between the letters nearly equal, as shown in figure 3-54. The areas between adjacent letters in a word vary with respect to whether the letters have straight sides *(H, I, M, N)* or slanted sides *(A, V, W)* and whether the letters are round *(O, Q, C, G)* or open *(L, J)*. Adjacent straight-sided letters are drawn farther apart than are adjacent round letters. Adjacent slant-sided and open letters are drawn nearer together than are adjacent round letters. Where letters *L* and *T, L* and *V, A* and *V,* and other pairs of like shape come together in a word, the top of one may have to be drawn above the bottom of the other to avoid having the word appear as two or more words. In letterspacing, the six problems listed below are the hardest to solve. The first five problems are solved by moving the letters closer together; the sixth by moving the letters farther apart.

1. Round next to round. (Increasing area at top and bottom where letters curve away from each other, as in figure 3-55A).

2. Round next to slant. (Increasing area at top or bottom where letters move away from each other, as in figure 3-55B).

3. Vertical next to slant. (Increasing area at top or bottom where one letter slants away from the other, as in figure 3-55C).

4. Slant next to slant. (Increasing area at top or bottom where letters slant in opposite directions, as in figure 3-55D).

5. Round next to vertical. (Increasing area at top and bottom where round letter curves away, as in figure 3-55E).

6. Vertical next to vertical. (Decreasing area at top and bottom where stems move together, as in figure 3-55F.)

A good way to evaluate the spacing of letters is to hold the lettering away from you and squint your eyes, observing the gray tone throughout the lettering. If the tone appears spotty or varies too much, the letters are poorly spaced.

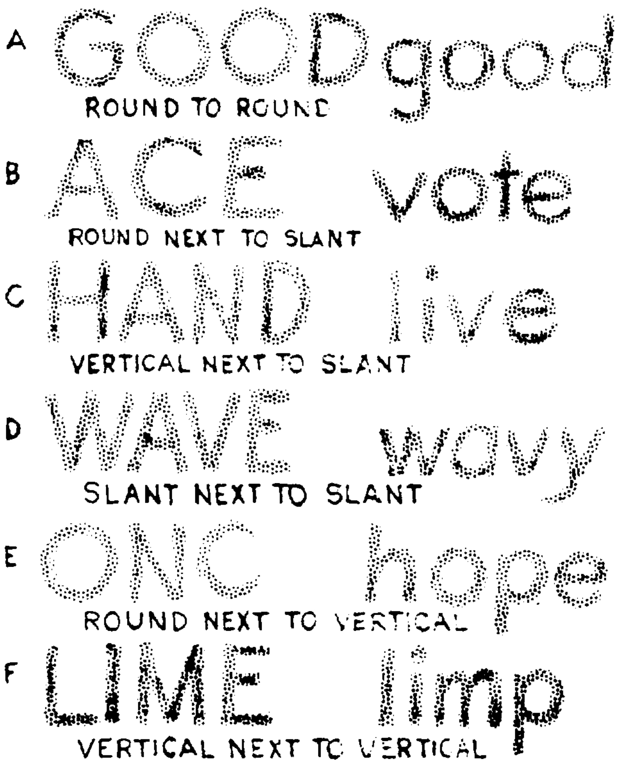

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Figure 3-55.-Common spacing problems.

WORD SPACING

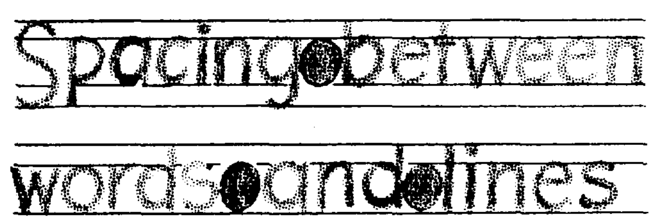
Proper spacing between words is an important factor in making them easy to read. Allow enough space between words and sentences to keep them from running together, but not so much as to cause words to be read one at a time. A good practice to follow is making spaces between words equal to the space that the letter *O* occupies as shown in figure 3-56. If you prefer, you can use the letter *N* or a correctly spaced letter *I* instead.

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, use the lowercase *o* to determine the width of the space. If one letter is full height and the other is lowercase height, such as the words *bid now or on him*, the space would be equal to half a capital *O* and half a lowercase *o*.

LINE SPACING

In addition to the spacing between letters and words, the spacing between lines of lettering adds to the readability of the lettering. Again your eye and your artistic ability must be your guide. Except when you are trying for a special effect, you should have enough space between the lines to make it easy for the reader to see what he is reading.

The distance between lines may vary from 1/2 to 1 1/2 times the height of the letter, but for the sake of appearance, it should not be exactly



45.207A

Figure 3-56.-Spacing between words and lines.

the same as the letter height. As a general rule, two thirds of the letter height is a good distance between lines. This spacing allows room for descenders of lowercase letters and still maintains a clear space of one third of the letter height between the descenders and capital letters, or ascenders of lowercase letters of the following line. Figure 3-56 shows proper word and line spacing.

CENTERING

Since the letters of the alphabet vary in width, it is rather difficult to center a line of lettering. Figure 3-57 shows one way of solving this problem. First, take a piece of scratch paper and letter in the required line. Then, place this 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.

Ending a line of lettering at a given point is equally difficult. As in centering, first, letter the line on a piece of scratch paper in order to achieve the proper line length.

To make lines of lettering come out to a specified length, you must adjust the word and/or letterspacing. This adjustment in spacing is called JUSTIFYING. A good example of justifying is found in the columns of this manual. Notice how all full lines start and stop on the right- and left-hand margins. Usually, you will only find justified lettering typeset or typewritten by mechanical means. However, if you do have an occasion to justify your lettering, you should try to keep the spacing between the words as uniform as possible. Uneven spacing detracts from the appearance of the job. When it is impossible to divide the spacing evenly, insert wider spacing at points where one word ends and the next begins with tall letters, like *d*, *b*, and *l*.

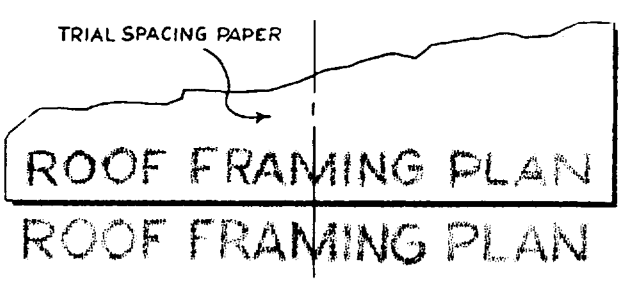


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Figure 3-57.-Centering with trial spacing paper.

If you use too much space between the words, the paragraph will tend to fall apart because it is filled with rivers of white space that will disturb the eye.

When a line is so short that it calls for an undue amount of space between words to lengthen the line, allow more space between the letters in each word. This is known as letterspacing. When words are letterspaced, always allow extra space between words so that they will not seem to run together when they are read.

Letterspacing makes short words in titles or headings appear longer. Though it frequently improves the appearance of words in caps, letter-spacing reduces the legibility of words in lowercase, Therefore, the process must be used with caution.

MECHANICAL LETTERING

In chapter 2 we discussed pens that are used primarily for freehand lettering. At times, however, you will be tasked with preparing drawings, charts, maps, or signs that require the use of mechanical lettering. When we refer to mechanical lettering, we mean standard uniform characters that are executed with a special pen held in a scriber and guided by a template. Mechanical lettering does not normally require the use of lettering guidelines. You will use mechanical lettering principally for title blocks and notes on drawings, marginal data for special maps, briefing charts, display charts, graphs, titles on photographs, signs, and any other time that clear, legible, standardized lettering is required. It should be noted that freehand lettering is the required lettering on most of your drawings; mechanical lettering should be confined to special uses similar to those described above. The availability of mechanical lettering devices should not deter you from the daily practice required to execute freehand lettering. With continuous practice you will become proficient with both mechanical and freehand lettering.

One of the most popular types of mechanical lettering sets is the LEROY lettering set. A

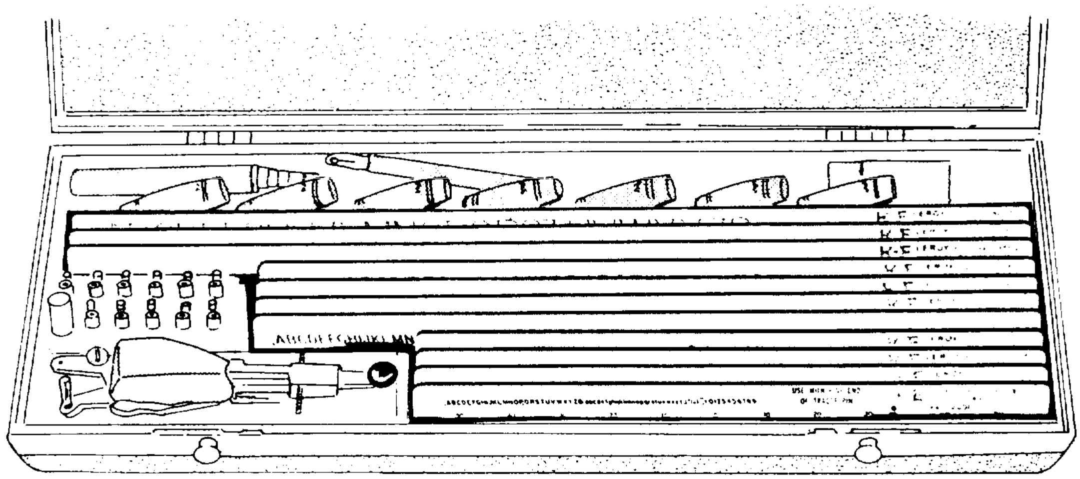

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Figure 3-58.-Leroy lettering set.

standard Leroy lettering set consists of a set of templates, a scriber, and a set of pens. (See fig. 3-58.)

TEMPLATES

Templates are made of laminated plastic with the characters engraved in the face so that the lines serve as guide grooves for the scriber. The height of the characters, in thousandths of an inch, is given by a number on the upper right-hand side of the template. For example, 3240-500CL indicates a No. 500 template. The entire number and letter designation identifies the template in the manufacturer's catalog. The range of character heights offered by a standard set of templates is from 80 (0.08 in. or 5/64 in.) to 500 (0.5 in. or 1/2 in.). 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 each scale division represents the center-to-center distance of normal-width letters.

PENS

A standard set of pens for producing various line weights consists of 11 sizes ranging from 000, the finest, to 8. Each pen is composed of two parts: the ink reservoir and the cleaning pin. The reservoir is a series of connected tubes of decreasing diameters, the smallest establishing line thickness. The cleaning pin acts as a valve, protruding beyond the edge of the bottom tube when the pen is not touching the drawing surface. In this position, no ink flows. When the pen is resting 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.

NOTE: As stated in chapter 2, some reservoir pens are made so the point section will fit in a Leroy scriber. They have become popular with the SEABEEs (and widely used over the standard pens contained in the Leroy lettering set), especially for long hours of uninterrupted lettering.

A SCRIBER holds the pen in alignment and controls its motion as the tracing pin is guided through the character grooves of the template. Two types of scribes are available: adjustable and

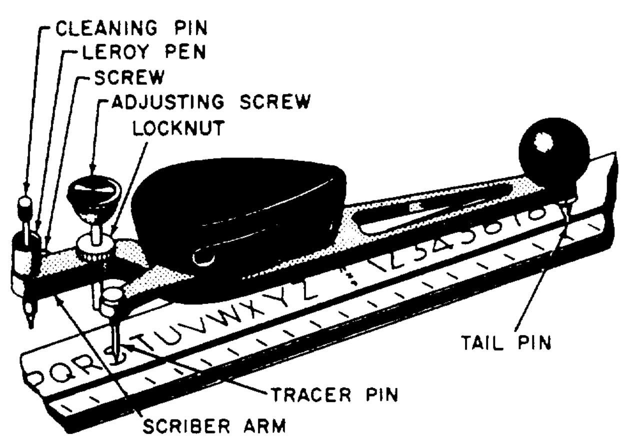

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Figure 3-59.-Leroy scriber and template.

fixed. An adjustable scriber produces letters with any slant from vertical to 22 1/2 degrees forward from a single template; a fixed scriber produces only vertical letters. Both scribers consist of a tracing pin, pen socket, socket screw, and a tail pin. Figure 3-59 shows a fixed scriber. The tracing pin on most Leroy scribers is reversible, One point is used with fine groove templates (Nos. 060, 080, and 100), and the other point is for wider groove templates (No. 120 to No. 500).

LINE WEIGHTS

Recommended combinations of template and pen for best proportion between line thickness and letter size are shown below.

Template No.	Pen No.
060	000
080	000 or 00
100	00
120	0
140	1
175	2
200	3
240	3
290	4
350	4
425	5
500	6

This list is also found inside the lid of the Leroy lettering set case.

OPERATING PROCEDURES

A certain technique is required to manipulate the Leroy scriber with the template and, at the same time, hold the template against the working edge of the T square or straightedge without slipping.

The T square or straightedge must be held in position with the ball of your left hand resting on the blade, while the fingers of the left hand hold the template against the working edge and change the position of the template when necessary. The scriber is held between the thumb and first three fingers of your right hand. The little finger of the right hand presses the right side of the template against the working edge, preventing the tracing pin from slipping out of the character grooves of the template. Care must be taken to keep the tail pin in the straight-guide groove at the bottom of each template. When you are making long lines of large lettering, you may find it helpful to secure the T square or straightedge at both ends of the drawing board with drafting tape.

Using the above techniques to manipulate the scriber and template, follow the steps listed below to form uniform letters, words, and sentences. As you follow the steps, refer to figure 3-59.

1. Select the template with letters of the desired height. The distance between each graduation at the bottom of the template is equal to the height of the letter that can be made with the template. The numbers in a fraction are made by using a template one size smaller than that used for whole numbers.
2. Lay the template along the top edge of a T square or straightedge.
3. Using the table of recommended template and pen sizes previously mentioned, select the proper pen to give a well-proportioned letter.

NOTE: On drawings with a great deal of lettering, the recommended combinations may be altered by one pen size, either under or over the recommended size, for variation and appearance. Never use a pen size more than two over the recommended size.

4. Insert the selected pen into the socket of the scriber arm until the shoulder of the pen rests on the scriber arm.
5. Tighten the screw on the side of the scriber arm.
6. Loosen the locknut on the adjusting screw in the scriber arm.
7. Set the tail pin of the scriber in the straight-guide groove of the template.
8. Set the tracer pin of the scriber in the groove of a character.
9. Lower the pen gently to the drawing surface.
10. Raise or lower the scriber arm by turning the adjusting screw until the tip of the cleaning

pin within the pen just touches the drawing surface. Tighten the locknut when the desired height is reached. To prevent blotting, you should make this rough adjustment before you put ink into the pen.

11. Remove the scriber from the template.

12. Remove the cleaning pin from the pen.

NOTE: To prevent the ink from flowing straight through the pen, you should not remove the cleaning pin of a Leroy pen No. 4 or larger from the pen.

13. Fill the reservoir of the pen with drawing ink. The Leroy pen should be filled with ink in the same manner as any common drafting inking instrument. The reservoir should be kept from one-fourth to three-fourths full; too low an ink level results in irregular lines.

14. If the cleaning pin was removed, reinsert it into the pen.

15. Wipe the lower tip of the pen with a cloth to remove any excess ink that may have been pushed through by the cleaning pin.

16. Draw a test line on a piece of scratch paper to ensure that the ink will flow smoothly.

17. Gently lower the pen to the drawing surface after inserting the tail and tracer pins in their proper grooves.

18. Proceed with the lettering by moving the tracer pin in the grooves of the characters, keeping the tail pin in the straight-guide groove.

If the ink does not flow properly, turn the cleaning pin inside the pen and wipe the tip with a cloth; also, make any necessary minor adjustments to the adjusting screw to allow the ink to flow properly. Tighten the locknut. When you will not be lettering for short periods of time, place the tip of the pen, still in the socket of the scriber arm, on a piece of moist cotton. This will prevent the ink from drying around the opening of the pen and will help the ink to flow properly when you begin lettering again.

SPACING AND CENTERING

The rules for freehand letterspacing and word spacing also apply to mechanical lettering. Guidelines are not necessary for mechanical lettering; however, when you are making more than one line of lettering, you may draw horizontal base lines at intervals to help you maintain the proper spacing between the lines. Spacing between lines of mechanical lettering is the same as for freehand lettering.

When lettering must be centered above a certain part of a drawing, or within a certain space, use the scales along the bottom edges of the templates. Each space on the scale represents the center-to-center distance of normal-width letters. For example, to center the words *LEROY LETTERING* about a certain line, proceed as follows:

1. Count the letters in each word and the spaces between words. Result: 15.

2. Considering the letter *I* and the space between the words as half value for each, reduce the total by one. Result: 14.

3. Divide the result of No. 2 above by two. Result: 7.

NOTE: If there had been an odd number of half values, you would use the next lower number and allow more space between words than normally required.

4. Set the zero of the scale at the vertical line about which the lettering is to be centered and mark off seven spaces to the left and right of zero.

5. Start the *L* of the word *LEROY* in the title at the left mark and continue to the end. The right edge of the *G* should fall on the mark to the right.

MAINTENANCE OF MECHANICAL LETTERING EQUIPMENT

Pens should be cleaned thoroughly with water after use and stored properly in the lettering set case. Never wash them under running water in a sink. The pen and cleaning pin may accidentally be washed down the drain. If water does not clean a pen satisfactorily, a diluted solution of ammonia may be used. Commercial pen cleaning solutions and pen cleaning kits are available. Caked or dried ink can be removed by soaking the pens overnight in a cleaning solution; however, the pens may corrode if soaked longer. Cleaning pins should be handled with care because they are fragile and easily bent, especially the smaller ones.

The screw that holds the pen in the scriber should never be screwed too tightly, as the fine threads tend to strip very easily.

Templates should be cleaned after every use. Dirt and dried-on ink are very easily transferred onto an otherwise clean drawing. You must ensure that the template grooves are kept free from all foreign matter and that the tracer pin does not cut into the sides of the grooves. In order to form perfect letters every time, you must make sure that the tracer pin slides along the grooves smoothly. When small templates are used, a small sharp tracing pin must be inserted in the scriber. If a sharp tracing pin is used in the larger templates, the grooves of the templates will be damaged.

LETTERING SYSTEM

Today's operating units, training commands, and shore establishments within the Naval Construction Force (NCF) have a great demand for quality graphics to enhance command presentations during management and readiness inspections and during execution and completion reports.

The bulk of the job is commonly handled by the engineering department or branch. As an EA, you will be tasked with producing a variety of quality signs, labels, lettering, tags, and other miscellaneous requests.

It is likely that your office may already have one of the lettering machines used for this job. The pressure lettering machine (fig. 3-60) is just one of the typical tools that produces high-quality lettering faster than press-on type letters and the mechanical letters. This machine uses a pressure process to transfer dry carbon impressions onto a variety of tapes that are used for producing letters, numbers, and symbols. The impressions are made from raised characters on an interchangeable type of disc available in different styles, ranging in size from 8 points to 36 points (table 3-1). Overall, this machine is easy to use. Daily operation and on-the-job training will enhance your efficiency.

Table 3-1.-Size Range of Impressions Made from Characters Used on a Lettering-System Type of Disc

POINT SIZE	≈	INCHES (mm)
8	≈	1/16" (2 mm)
10	≈	3/32" (2.5 mm)
12	≈	1/8" (3 mm)
14	≈	9/64" (3.5 mm)
18	≈	3/16" (4.5 mm)
24	≈	1/4" (6.5 mm)
30	≈	5/16" (7.5 mm)
36	≈	3/8" (9 mm)

RECOMMENDED TYPE SIZE USES:

8 TO 14	POINT-SUBHEADLINES
18 TO 24	POINT-UPPER AND LOWERCASE HEADLINE
30 TO 36	POINT-LARGE, BOLD ALL UPPERCASE HEADLINES

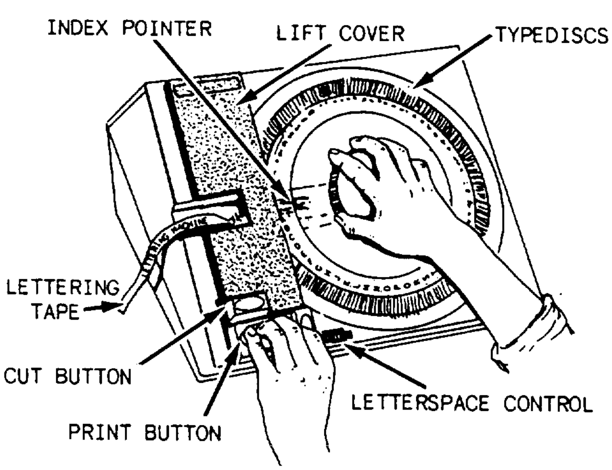

Figure 3-60.-Typical pressure lettering machine.

DRAWING REPRODUCTION

One of the most important skills an EA needs to learn besides drafting is operating reproduction equipment or machines. The quality of a reproduced copy (usually called BLUEPRINT) measures the accuracy, completeness, and conformance to applicable standards of an original or traced drawing. All EAs therefore should be familiar with the aspects of performing this skill and should develop competency through practice and experience. This section discusses the various aspects of the reproduction process and maintenance of a typical reproduction machine.

REPRODUCTION ROOM

Regardless of the type of reproduction machine used, it should be positioned in a room in such a manner as to ensure the best possible ventilation. The machine should be set against an outside wall and an exhaust tube or an exhaust vent provided with a fan should be installed since ammonia is used in the developing process.

If possible, less light is preferable because light-sensitive paper is used. All supplies of sensitized paper and other materials for reproduction should be kept in a dehumidified, cool, and dark storage area. It is good practice to date the supplies so as to use the oldest stock first. Heat is a major factor to consider, no matter what machine is used.

Ventilation should be sufficient throughout the room, since the prints, even after they emerge from the machine, are saturated with ammonia fumes. The fumes from ammonia are very powerful, and personnel should avoid excessive inhalation. Chemicals used in developing solutions that come in powder form should be stored the same as sensitized materials. Ammonia should be stored in shatterproof bottles.

CAUTION

Ammonia fumes are extremely toxic! Burns, as well as temporary blindness, can result if you are careless while handling the solution.

Since reproduction machines are energized with electricity, you need a firm understanding of electrical safety. NEVER touch an energized electrical plug, switch, or any part of electrically operated equipment with wet hands or while standing in water or on a wet floor. If the machine should become wet or be in contact with water while in use, you should disconnect the electrical power source before attempting to clean up the area. It is also important for qualified and certified personnel to inspect electrical outlets and connections frequently for obvious signs of damage.

REPRODUCTION MACHINES

The process most commonly used for reproducing construction drawings by the Navy is the DIAZO or AMMONIA VAPOR PROCESS. Basically, this process produces prints with a white background and blue or black lines after exposure to light. These prints are then dry developed with ammonia vapor. This process uses aqueous ammonia as a developing agent with water vapor as the carrying agent, causing the paper exiting from the chamber to carry residual ammonia vapor with it. In the diazo process, the ammonia chest is saturated with water vapor at all times to help eliminate the toxic ammonia vapors.

Diazo process reproduction machines are made by several manufacturers, such as Blu-Ray Inc. and General Analine Film Corp. (GAF). Machines formerly made by GAF were called Ozalid. The machines presently made are no longer called Ozalid, only labeled GAF. However, old Ozalid equipment is still serviced and repaired by the GAF Corporation.

The basic difference between the various types of diazo machines is the size of paper that they can accommodate. Paper that is 9 in. wide can be used on the smallest machine, and paper that is 54 in. wide can be used on the largest machine.

Blu-Ray Model 842 Whiteprinter

The Blu-Ray Model 842 Whiteprinter, shown in figure 3-61, has most of the capabilities of larger diazo process machines. It is ideally suited for use in battalion engineering offices, because it is easy to set up and is easily moved. It is very simple to operate and easy to maintain.

It is important that all EAs thoroughly understand the manufacturer's instructions covering the operation and maintenance of the Blu-Ray reproduction machine before attempting to use it. Keep a current file for all reference material available for use by the operators. The machine should be located as close as possible to an electrical outlet that supplies adequate power. (Electrical specifications are given in the operation manual.)

After the machine has been assembled and set up according to the manufacturer's instructions, the machine must be placed on a level surface, such as a table or a desk. This is very important for proper ammonia drainage and adequate support for the feet on the bottom of the machine.

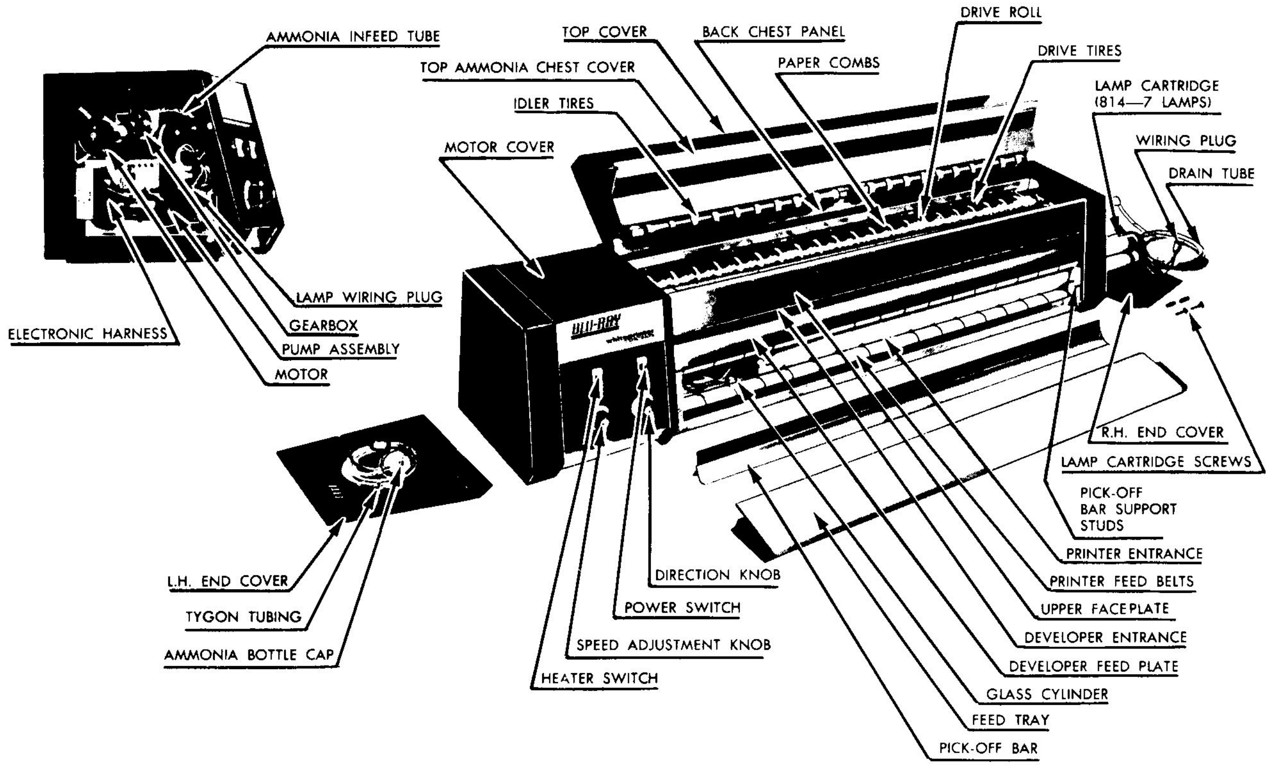

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Figure 3-61.-Exploded view of the Blu-Ray Model 842 Whiteprinter.

The ammonia supply bottle must be placed below the machine so that there will be a short, direct, and unkinked run of the large ammonia discharge tube.

Only the proper aqueous ammonia, as recommended in the operation manual, should be used. Use only fresh ammonia and change it at least once a month for best operation. NEVER reuse the discharged ammonia.

Room temperature is important. Blu-Ray manufacturers recommended a room temperature of 70°F be maintained. A drop in room temperature will cause condensation in the chest, giving wet prints and may, if excessive, jam the developer.

The Blu-Ray is equipped with an ammonia chest heater, which has an independent heater switch. The heater is used to activate the ammonia vapor to improve development when it is necessary. This may be true especially with long, continuous machine operation.

The machine must be kept dust-free and clean. Dust is an abrasive material that can wear out the Teflon gate strips in the developer section, as well as other moving parts.

OPERATION.— A pilot-lighted switch marked POWER on the instrument panel turns the Blu-Ray machine on and off. When it turns the machine on, it actuates the main drive motor and the ammonia pump motor and fan, and it lights the fluorescent tubes.

A pilot-lighted switch marked HEATER on the instrument panel manually turns the heater on and off.

Two knobs on the instrument panel marked SPEED and DIRECTION manually will give a stepless speed range from 0 to 12 ft per min in both directions.

To select the desired speed of operation, manually turn the knob marked SPEED to a number that experience has shown to be proper for the type of paper being printed.

The knob marked DIRECTION has a forward and reverse setting. Keep this knob at forward setting at all times. Use the reverse setting only when the paper is jamming and must be instantly removed. This knob can be snapped from forward to reverse while the machine is running. The Blu-Ray may be turned on and off AT ANY TIME. THERE IS NO WARM-UP OR

COOL-DOWN PERIOD REQUIRED FOR THIS MACHINE. Just turn on the power switch, make your print, and turn the machine off. This is recommended for longer machine and lamp life.

Making prints is extremely simple. Place your original tracing or transparency, face up, on the sensitized reproducing paper, chemical (yellow) side up. Adjust the leading edges of both papers so they are even, uncurled, and uncreased. THIS IS IMPORTANT! Place the two adjusted sheets on the feed table and gently feed them evenly into the printer entrance WITH THE GRAIN of the sensitized paper (see package for grain indication) until they are engaged between the rubber belts and the glass cylinder.

If for any reason the above described entrance of the paper to the printer is erratic, creased, wrinkled, or uneven, turn the direction knob to reverse and the papers will come out of the printer.

As the original and printed sensitized paper exits from the printer over the top of the glass cylinder, manually separate the sensitized paper from the original tracing.

Turn the sensitized paper up and into the entrance of the ammonia developing chest. The finished print will exit from the top of the machine.

If your print is too light, turn the speed knob to a higher number; if too dark, turn to a lower number.

The interior of the ammonia chest of the Blu-Ray machine is readily accessible for inspection or removal of jammed paper. Using finger catches on the top of the machine, lift up the top cover, and the upper chest panel will be exposed. (Before opening, SEE WARNING below.) Two sliding door latch-type fasteners hold the upper chest panel in its closed position. Slide these door latches toward the center of the machine, and open the upper chest panel up and back, exposing the interior of the ammonia chest.

WARNING

DO NOT OPEN THE AMMONIA CHEST WHILE THE MACHINE IS RUNNING. Be sure that all ammonia has drained from the machine. Stand back from the machine when the chest is open. There is a heavy charge of ammonia in the chamber. Be sure to provide ventilation at all times when the ammonia chest is open.

When removing jammed paper from the ammonia chest, do not bend or scratch any of the mechanical parts in the chest.

Because of described qualities of the aqueous ammonia, it is important that a NITE-SHEET be run in the developer section when the machine is not in operation for a period of time (nights, weekends, etc.). This nite-sheet can be a wide sheet of sensitized paper long enough to extend from both the entrance and exit of the developer section. Stop the machine when this is accomplished, allowing the sheet to remain. This sheet will absorb the excess vapor and condensation, leaving a dry chamber when the machine is started again.

MAINTENANCE.— Periodic maintenance and inspection of the Blu-Ray machine are essential. Major maintenance and repairs should be performed only by skilled service personnel.

For maximum light exposure, it is very important that the exterior and interior of the glass cylinder be cleaned frequently. When the glass cylinder needs to be cleaned, follow the steps given below.

1. Disconnect the electrical cord from its power source.
2. Remove both end panels from the machine by removing the panel-holding screws.
3. Back off the locking screw and open the drive-section cover.
4. Disconnect the lamp cartridge wiring. DO NOT PULL THE WIRES; grasp the plug.
5. Unfasten the lamp cartridge by removing the screws at the right-hand end of the lamp cartridge frame. Gently remove the lamp cartridge, ensuring that the wires at the left-hand end of the cartridge do not snag.
6. Thoroughly clean the glass-printing cylinder and lamps. Use the manufacturer's recommended glass cleaner or an ammonia-water solution. NEVER use an abrasive cleaner on the glass cylinder.

It is inherent in the nature of fluorescent lamps to lose brilliancy after months of usage. This requires the machine to be slowed down to produce the desired prints. When this occurs, the lamps should be replaced, Since the lamp cartridge must be removed when the glass-printing cylinder interior is being cleaned, burned out or weak lamps should be replaced at the same time. Lamps, as well as any other parts needed, should be obtained through your supply system.

It is recommended that the lamp starters be replaced when the lamps are being replaced. The lamp starters are located in the ballast panel in the back of the machine. For ease of removal and replacement, a portion of the ballast panel cover must be removed to expose the starters.

Printer feed belts may become slack over a period of time, causing slippage and blurred prints. A simple adjustment may be made as follows:

1. Pull the small Tygon tube out of the ammonia supply bottle cap.
2. Run the machine until the tube is pumped dry and no longer feeding the ammonia tank in the machine.
3. Raise the motor end of the machine a few inches for a moment for complete drainage.
4. Shut off the machine.
5. Tip the machine on its back carefully so the ammonia tubes and power cord that project from the back will not be crushed or kinked. This will expose the two slotted idler take-up brackets.
6. Loosen the two screws in both brackets, and press down approximately one-fourth in, beyond the previous setting to give proper tension to the belts, and re-secure. Make sure that both brackets are set at the same position.

The components in the ammonia chest are readily accessible and easily removed. The top cover is removed by sliding a door-catch type of pivot and then lifting it off of the machine. The back chest panel can be removed independently for internal inspection by removing four screws and sliding the panel out of the machine. Both the upper and lower paper combs are attached to the back chest panel, allowing for inspection and replacement of their combs when the panel is removed. Take out the ammonia tank first. The ammonia tank is independently removed from the ammonia chest by removing the two wing screws on the right-hand end of the machine where the tank drains. Disconnect the Tygon ammonia in-feed tube in the motor end of the machine, and slide the tank out to the right. The grid and drive roll assemblies are easily removed as a unit by unscrewing the plastic drive-roll plug at the right end of the drive roll. Slide the drive roll off of a pin slot connector to the drive shaft, and lift the assembly up and out of the chest.

After 600 hr of operation, the plastic Tygon tube in the ammonia pump will need to be replaced. Extra tubing is supplied with the machine for this purpose. To replace a tube, remove the left-hand end panel by removing the screws holding down the drive-section top cover. This will expose the pump with its motor and all the tube connections. Study how the tube is placed so that after it is removed you can place the new tube properly.

There is a tube coupling on the tube support bracket. Pull the tube lead to the pump from the coupling.

Jog the machine by snapping the power switch ON and OFF. The old tube will move out of the pump by normal rotating pump action. Pull this tube off of the ammonia feed pipe leading into the machine.

Take a piece of replacement tubing and cut the end on a bias (slant) so it will feed through the pump smoothly. Feed the tubing into the coupling end of the pump and jog the machine (as before) so the tube will be pulled through the pump.

When this tube is completely in the pump, cut it to length and reattach as before to the ammonia coupling and ammonia feed pipe.

The upper faceplate and the developer feed plate extrusions are removed by removing two screws from each and lifting them off of the machine. This will expose the lower slider gasket. The lower slider gasket is attached to the gasket retainer angle and is removed as a unit by removing the fastening screws. A replacement gasket unit can then be inserted.

TROUBLESHOOTING.— If the Blu-Ray machine is to operate at peak efficiency, it must be kept in proper working order. In trouble-shooting the machine, use the following summary as a guide:

Loss of printing speed:

1. Glass cylinder dirty.
2. Voltage too low.
3. Fluorescent lamps dirty or past useful life.
4. Overage sensitized paper.
5. Machine not level, causing binding.
6. Printer drive belts loose.
7. Air entrance blocked, causing lamp heating.
8. Flickering or burnt-out lamp, check starters.

Starting or stalling difficulties:

1. Voltage too low.
2. Machine not level, causing binding.
3. Wiring loosened or disconnected. Call dealer.

Ammonia leakage:

1. Developer chamber top not properly latched after inspection.
2. Ammonia drain tube locked.
3. Machine not level, preventing proper drainage.
4. Ammonia bottle improperly capped.
5. Ruptured pump tubing.

Wrinkled prints from developer jamming:

1. Condensation in ammonia chest.
2. Did not use nite-sheet.
3. Sensitized paper damp before using, because of humid storage.
4. Paper placed in developer chamber against the grain.
5. Foreign material in developer chamber.
6. Exit not clear.

Lamps burn out prematurely:

1. Improper voltage.
2. Air entrance blocked causing hot lamps.
3. Improper or defective starters.
4. Shorting in wiring.

Prints do not develop:

1. Weak or exhausted ammonia—replace.
2. Sensitized paper old or exposed.
3. Ammonia pump not operating properly—infeed tube kinked or pinched.
4. Cold ammonia in supply bottle.

Ozalid

Every EA should have a basic understanding of the various functions of the Ozalid (fig. 3-62); therefore, in this section we will discuss printing and developing, as well as the operating principles of the cooling and exhaust system. Information is also given on machine operation, adjustments, and maintenance.

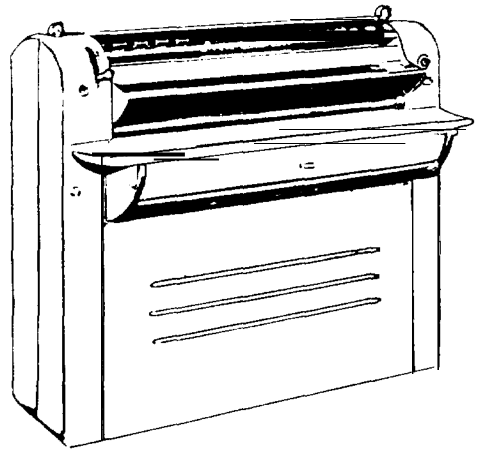

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Figure 3-62.-Ozalid machine.

PRINTING SECTION.— Figure 3-63 shows the principles of operation of the printing and developing sections. Of particular interest at this point is the printing section. This section is divided into four basic units: light source, reflector assembly, printing cylinder, and feed belts.

During the reproduction process, the original and a piece of material, such as paper that has been sensitized (coated with a light, sensitive dye), are inserted into the machine. Sensitized material is placed with the emulsion side up on the feed-board, and the original is placed on top. Originals should be of a transparent or translucent nature with an opaque image on one side only. Feed belts carry this material around the revolving printing cylinder where the dye of the treated paper that is NOT covered by the opaque image of the original is desensitized by the ultraviolet light rays emitted from the mercury-vapor lamp. After exposure, the original and print are picked off of the printing cylinder by the pick-off assembly, and directed towards the developing section.

After pick-off, the guide roller directs the original and print between a printer and tracing separator belt. These belts cause the print and the original to be delivered to two separator tank assemblies where the original and print are separated from each other.

The process of separation is unique and is therefore worthy of further discussion. Critical to the operation of separation are perforations in the walls of the two separator tanks. During

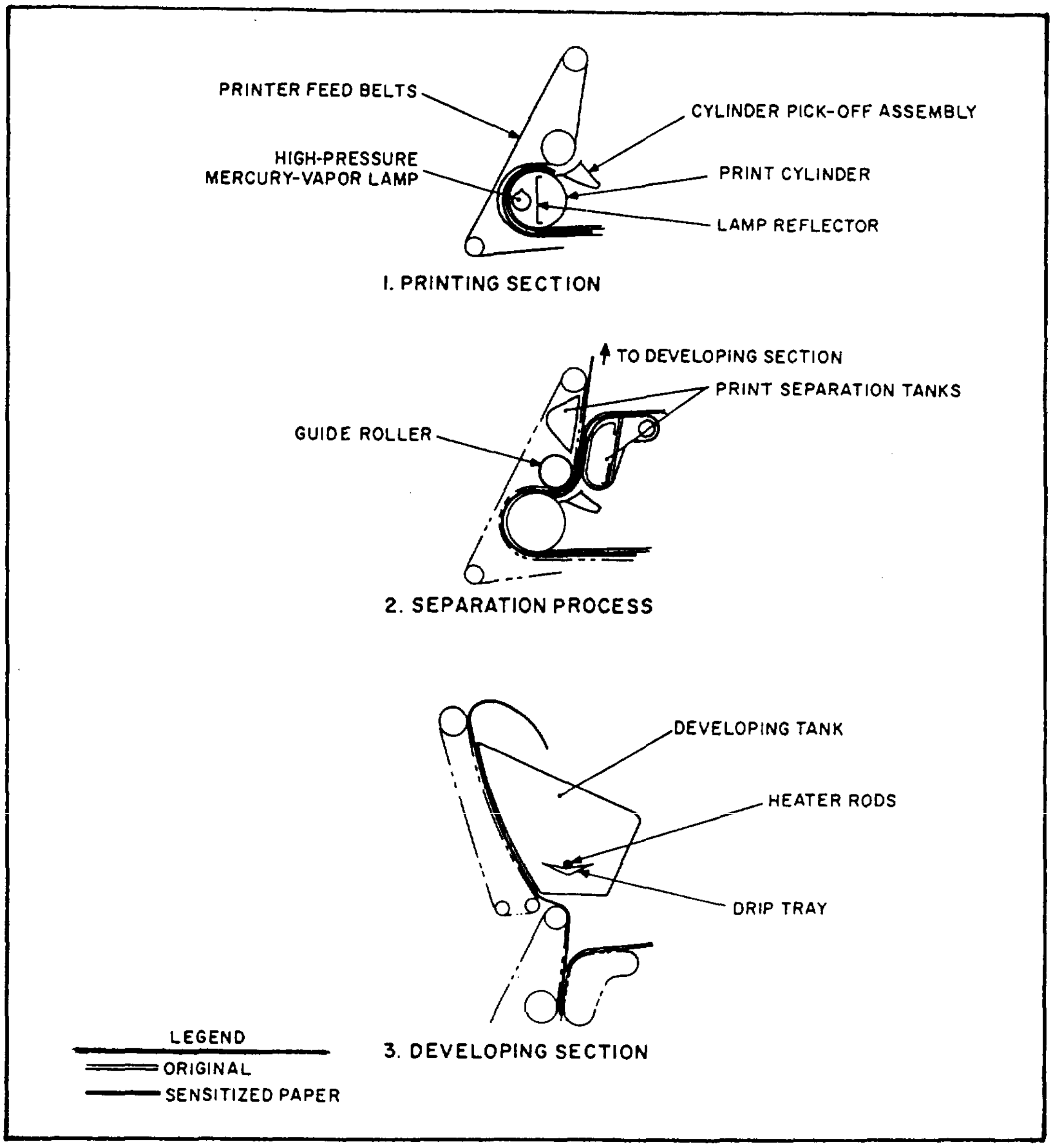


Figure 3-63.-Principles of operation.

operation, air that is drawn through these holes causes a difference in pressure that causes the original to follow the tracing belt and the print to follow the printer belt. Thus, the original and print are separated and directed in different directions. The original moves out of the machine, and the print moves into the developing section where ammonia vapors develop those areas that were not desensitized. It should be noted that it is possible, should the need arise, to direct both the original and the print out of the machine before they go to the developing section. All that is necessary to accomplish this is to operate a lever. When the lever is operated, a group of fingers is extended. These fingers cause the print to be directed out of the machine, along with the original. One instance in which it is desirable to remove the print is when the sensitized paper is coated on both sides. In this instance, the second side will be exposed before any developing takes place.

DEVELOPING SECTION.— The developing section consists of a perforated stainless steel developing tank. This tank is continuously supplied with ammonia from an ammonia supply

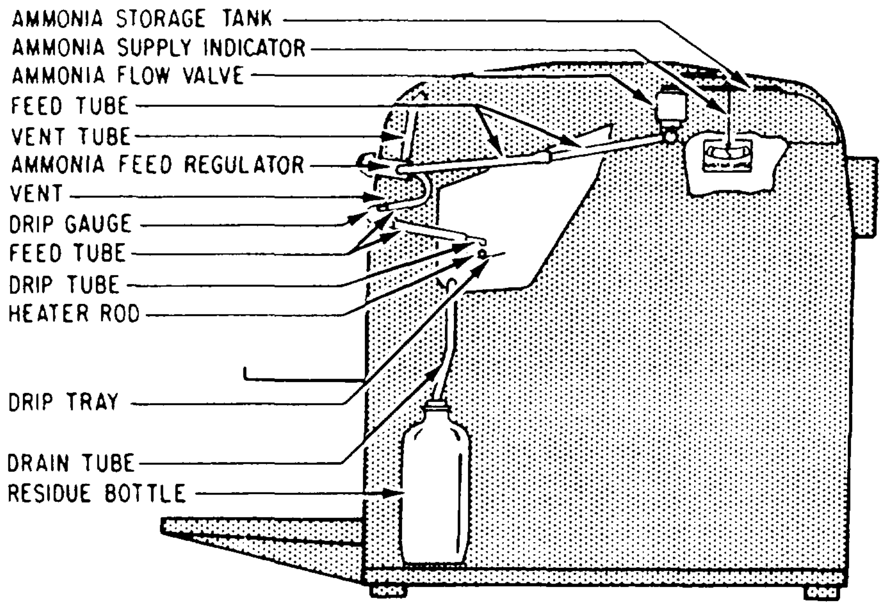


Figure 3-64.-Ammonia flow system.

tank through a gravity-feed system (fig. 3-64). This feed system permits a smooth, even flow of ammonia, thus minimizing the possibility of air or vapor locking of the feed tubing. The amount of ammonia fed into the developer is controlled by a feed regulator at a rate of approximately 50 to 60 drops per minute. The ammonia is directed into evaporating drip trays that are suspended in the developer tank. Fastened to these trays are electric heater rods. These rods, in conjunction with a second thermo-switch controlled heater in the developing tank, serve to heat the ammonia and thereby accelerate the formation of ammonia vapors. These vapors activate the image on the print as they escape through the holes in the upper part of the developer tank. Thus, a semi-permanent image of those areas that were NOT desensitized in the printing section is developed on the print as it passes across the vapors.

To protect the machine from flooding with ammonia when the machine is secured, an automatic shutoff valve is located in the ammonia feedline. This value shuts automatically when the machine is secured and opens automatically when the machine is turned on, thereby remitting ammonia to the feed tray.

A second ammonia supply system being used in some machines is called the anhydrous ammonia system. Cylinders filled with anhydrous ammonia supply the developing section with an ammonia vapor. This vapor is directed into the developer tank where it is distributed with the aid of distilled water that is fed into the drip trays.

For safety reasons, cylinders should be stored away from heat and sunlight. Do not allow the temperature of the cylinders to reach a temperature above 125°F. Position the cylinders upright, and firmly attach them with a chain or strap to a rigid supporting member, such as a wall.

Cylinders are attached to the developing tank through a system of piping and fittings, When changing a cylinder, close the valve on the expended cylinder tightly by turning it clockwise. Bleed off all pressure remaining in the feed line by turning on the ammonia flow in the machine. Disconnect the fitting or yoke cylinder connection. Replace the cylinder and remove the protecting valve cap. Ensure that a Teflon washer is in place. Connect the fitting or yoke cylinder connection. Make sure all connections are tight. Open the cylinder valve. Check for possible leaks on all connections by holding a piece of unexposed and undeveloped diazo paper close to the connections. If the diazo paper discolors, retighten the connections.

A uniform flow of ammonia is maintained by a pressure gauge located between the cylinder and the developing section. In addition, the pressure gauge indicates the amount of available ammonia left in the cylinder. A new cylinder will have a gauge reading of 150, while an empty cylinder will indicate a reading of 50.

After passing through the pressure gauge, the ammonia travels through a flowmeter. The flowmeter is located on the front of the machine, which is within easy reach of the operator. With this meter, the operator is able to turn on or off the ammonia flow. Additionally, the operator is able to adjust the flow obtaining maximum development with a minimum amount of ammonia. Using this type of development system, the operator is able to turn the ammonia supply on only when developing, thus saving ammonia during warm-up and periods of idling or nonuse.

A water supply is used to aid in the distribution of the ammonia vapor within the developing tank. Water is fed into the evaporating drip trays, creating additional vapor, which increases the ammonia's effectiveness. This water supply is controlled by a feed regulator (located on the front of the machine). Also the amount of water being supplied is visible through a tube above the feed regulator. Adjust the water flow to 60 drops per minute, and ensure that a constant dripping of water is reaching the machine, or the drip trays may be damaged.

COOLING AND EXHAUST SYSTEM.— Excessive amounts of heat or ammonia vapors should NOT reach the room in which the machine is located because of the installed exhaust and cooling system. The system consists of twin blowers, driven by a motor that exhausts fumes and hot air from the machine enclosure through a vent to the outside atmosphere. Therefore, a partial vacuum is created within the machine covers, thereby causing air to flow into the machine rather than the counterflow that would otherwise exist. A blower time switch operates the blower motor independently of the rest of the machine thereby ensuring the removal of vapors and hot air after the mercury-vapor lamp is turned off. The switch may be adjusted to operate for any given length of time up to 30 minutes.

MACHINE OPERATION.— A short warm-up period is required before material can be fed into the machine. Always follow the manufacturer's instructions during machine operation. When starting the machine, make sure that the developer drain tube is inserted in the residue bottle (fig. 3-64). Then, fill the storage tank with ammonia. If bubbles are encountered in the feed system because of increased temperature or high altitude, dilute the ammonia with cold water. Usually, a one-eighth to one-fourth dilution is sufficient.

After the ammonia storage tank has been filled, turn on the main switch, and adjust the ammonia feed to 50 to 60 drops per minute. At high speeds (30 ft per minute and above), the rate of drops per minute can be increased. On virtually all modern, large-size diazo machines, ammonia feed is automatically increased and decreased to correspond with variation of machine speed.

CAUTION

During machine operation, the ammonia feed regulator should NEVER be turned completely off. If the machine is left running and no moisture is entering the developer section, the evaporation tray and heater rods are likely to be warped because of excessive heat.

After a short warm-up period, the machine is ready for operation. The machine should be run for approximately 20 min or until the operating temperature is between 180°F and 210°F. Time and temperature may vary; therefore, always follow the manufacturer's instructions. Feed the material into the machine with the original on top, adjusting the speed of the machine so that a clear print is obtained.

Printing speed is dependent on the translucency of the original, the density of the opaque image, and type of sensitized material used.

Running the machine at speeds that are too fast will result in a background on the print.

Running the machine too slowly will cause the image to be weak or missing from the print altogether. The only positive method for obtaining the correct speed for your machine is by running a test because each machine's light intensity changes with age.

When stopping the machine, turn the ammonia flow off, then feed a sheet of porous wrapping paper, 16 in. wide, into the machine. Stop the machine with the paper in position around the printing cylinder and between the sealing sleeve and the perforated tank. This will prevent the sleeve from sticking to the perforated tank top and will also protect the belts from the heat of the cylinder while it is cooling.

ADJUSTMENTS AND MAINTENANCE.— Normally, when the machine is first installed, no adjustments are required. Occasionally, however, some readjustment may be necessary because of atmospheric changes, which may cause shrinkage or expansion of some of the belts. These adjustments should be performed according to the manufacturer's instructions and only then by qualified personnel.

Maintenance is required on a daily, weekly, monthly, semiannually, annually, and whenever necessary basis. The following guide should be followed:

1. Daily requirements:

a. Empty the residue bottle after at least every 8 hours of operation. Never reuse residue water.

b. Replenish the ammonia supply.

c. Clean the outside of the cylinder with glass cleaner. (Operate the machine at slow speed while cleaning the cylinder.)

d. Clean the feedboard, tracing receiving tray, and print receiving tray. Keep them free of foreign objects.

2. Weekly requirements:

Clean the inside of the cylinder when the machine is COLD, using the following procedure:

a. Open the door at each end of the lamp housing.

b. Remove the lamp connector from each end.

c. Swing the triangular stop aside and withdraw the lamp assembly.

d. Clean the inside of the cylinder—wrap a damp, clean cloth around a swab and wipe the cylinder while it is in slow motion. Repeat the procedure with a dry cloth wrapped around the swab until the cylinder is thoroughly clean.

e. Wipe the lamp assembly with a DAMP cloth.

f. Reinstall the lamp assembly.

IMPORTANT: Handle the lamp assembly with great care, as it is fragile and expensive. DO NOT ATTEMPT TO REMOVE THE LAMP FROM THE MACHINE UNTIL IT HAS COOLED. Always rest the lamp assembly flat on a table; never stand it on end.

3. Monthly requirements:

Lubricate the bearings and drive chain assembly sparingly with No. 10 motor oil.

4. Semiannual requirements:

Clean all suction holes of the rotating tracing separation drum with pipe stem cleaners.

5. Annual requirements:

a. Lubricate the bearings and drive chain sparingly with No. 10 motor oil.

b. Remove all hoses of the airflow system and clean out dust and dirt.

6. Whenever necessary:

a. If the developer sealing sleeve becomes tacky, remove it from the machine; wash both the inside and the outside thoroughly with soap and water and dry well. NEVER attempt to wash the sealing sleeve while it is in the machine.

b. It is advisable to clean the perforated side of the developing tank at the same time. Use any commercial cleaning fluid. This will prevent any smudging of prints because of dirt accumulations on the perforated side.

REPRODUCTION MATERIALS

Diazo materials are available from various sources under different trade names and designations, such as K&E, 3M, and GAF. Basically, all diazo reproduction materials have been coated with a light-sensitive dye. The two types commonly used for reproduction of original drawings are standard weight blueprint paper and sepia line intermediates.

Blueprint Paper

Standard weight paper (commonly called blueprint paper) provides a black or blue image on a white background. The printing speed for paper is described as rapid. Paper is available in sheet sizes that range from 8 by 10 in. to 34 by 44 in., or in rolls that range in widths from 11 to 42 in. with lengths of 50 or 100 yd.

Colored paper provides black or blue images on blue, green, pink, or yellow stock.

Plastic-coated papers are now available that give a slightly glossy print with better line density than the standard paper.

Sepia Line Intermediates

Sepia line intermediates are used as duplicate originals. These intermediates are prints from which additional prints can be made, saving wear on the original. When you use the sepia intermediate, it is possible to keep emulsion-to-emulsion contact in each generation, resulting in a sharper image. In addition, sepia has a greater density and is capable of delivering a darker image than the original, particularly when the original is in pencil. Sepia has a rich, mahogany image color that blocks the ultraviolet light rays. Base materials may be a vellum base treated with a plastic transparentizer that allows the passage of the light rays. Sheet and roll sizes are similar to those of the standard paper. You can make corrections on the sepia prints by using a solution of intermediate corrector to remove the image, then adding the pencil or ink correction.

CHAPTER 4

DRAFTING: GEOMETRIC CONSTRUCTION

Knowledge of the principles of geometric construction and its applications are essential to an Engineering Aid, As a draftsman, you must be able to "construct" or draw any of the various types of lines. In a line drawing, a line may be a straight line, a circle, an arc of a circle or a fillet, a circular curve, a noncircular curve, or a combination of these basic types of lines.

You must also be able to construct line drawings at specified angles to each other, various plane figures, and other graphic representations consisting exclusively of lines. This chapter provides information that will aid you in drawing different types of geometric constructions.

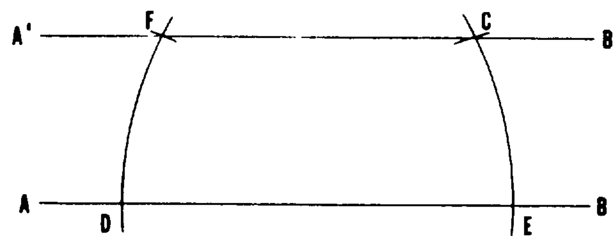


Figure 4-1.-Drawing a line through a given point, parallel to another line.

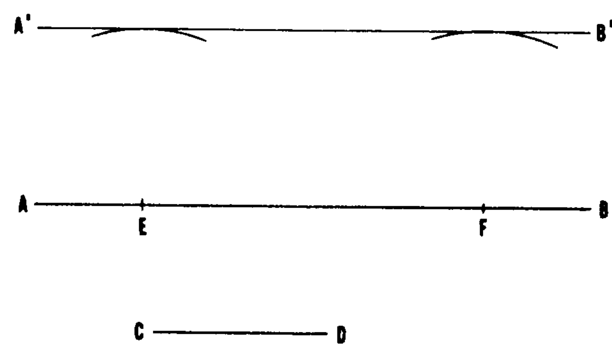


Figure 4-2.-Drawing a parallel line at a given distance from another line.

STRAIGHT LINES

One method of drawing horizontal and vertical lines, perpendicular and parallel lines, and inclined lines is by using a straightedge (or a T square) with a triangle. Another practical method of constructing straight lines is by using a drafting compass.

Figure 4-1 shows a method of drawing a line parallel to another line. Here, the line is to be drawn through given point C. To draw a line through C parallel to AB, place the needlepoint of the compass on any point D on AB, and strike arc CE. Shift the needlepoint to E, maintaining the same radius, and strike arc DF. Set a compass to a chord of arc CE, and lay off the chord DF from D, thus locating point F. A line drawn through F and C is parallel to AB.

Figure 4-2 shows another method of drawing one line parallel to another, this one being used when the second line is to be drawn at a given distance from the first. To draw a line parallel to AB at a distance from AB equal to CD, set a compass to the length of CD, and, from any points E and F on AB, strike two arcs. A line A'B' drawn tangent to (barely touching) the arcs is parallel to AB, and located CD distance from AB.

In the preceding chapter, you learned how to draw a line perpendicular to another by the use of a straightedge and a triangle. Two other methods of solving this problem are explained below.

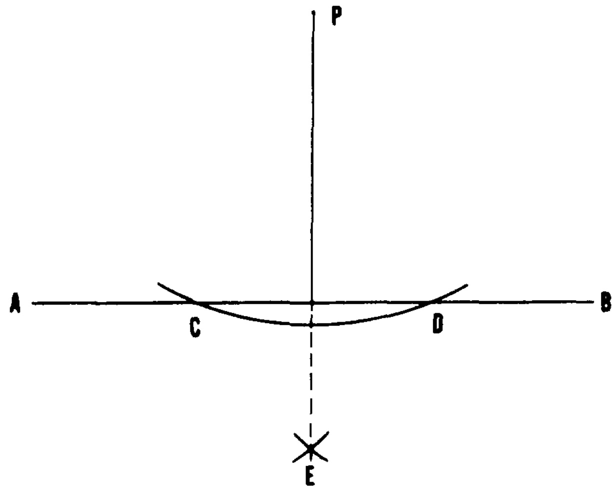


Figure 4-3.-Dropping a perpendicular from a given point to a line.

Figure 4-3 shows a method of dropping a perpendicular from a given point to a line, using a compass. To drop a perpendicular from point P to AB, set the needlepoint of the compass at P and strike an arc intersecting AB at C and D. With C and D as centers and any radius larger than one-half of CD, strike arcs intersecting at E. A line from P through E is perpendicular to AB.

Figure 4-4 shows a method of erecting a perpendicular from a given point on a line. To erect a perpendicular from point P on AB, set a compass to any convenient radius, and, with P as a center, strike arcs intersecting AB at C and D. With C and D as centers and any radius larger than one-half of CD, strike arcs intersecting at E. A line from P through E is perpendicular to AB.

BISECTION OF A LINE

A line can be bisected by trial and error with dividers; that is, by setting the dividers to various spreads until you find one that correctly measures one-half the length of the line.

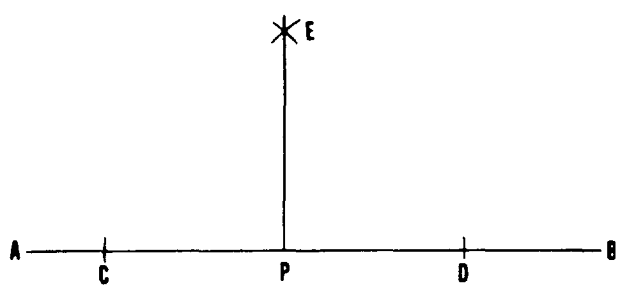


Figure 4-4.-Erecting a perpendicular from a given point on a line.

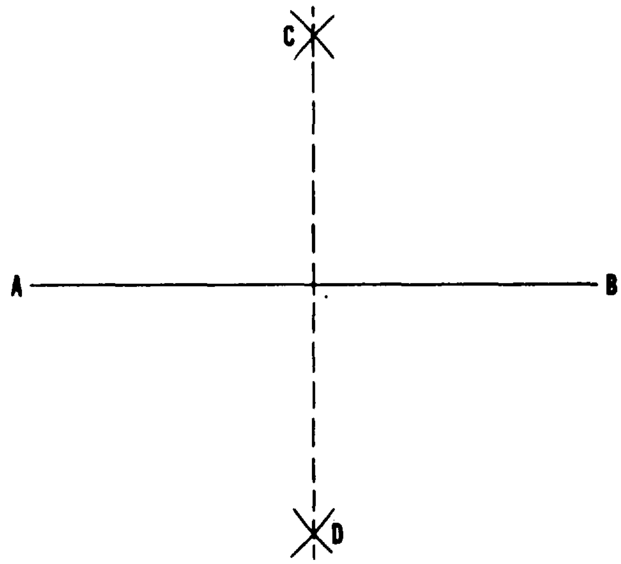


Figure 4-5.-Bisecting a line.

Geometric construction for bisecting a line is shown in figure 4-5. To bisect the line AB, use the ends of the line, A and B, as centers; set a compass to a radius greater than one-half the length of AB; and strike arcs intersecting at C and D. A line drawn from C through D bisects AB.

DIVISION INTO ANY NUMBER OF EQUAL PARTS

A line may be divided into more than two equal parts by trial and error with the dividers. Geometric construction for dividing a line into any number of equal parts is shown in figure 4-6. To divide AB into 10 equal parts, draw a ray line CB from B at a convenient acute angle to AB. Set a compass to spread less than one-tenth of the length of CB, and lay off this interval 10 times from B on CB. Draw a line from the 10th interval

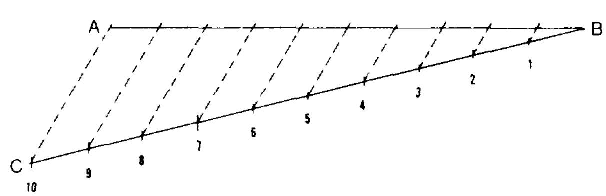


Figure 4-6.-Dividing a line into any number of equal parts.

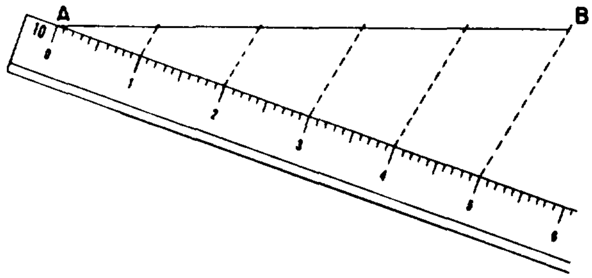


Figure 4-7.-Using a scale to lay off equal intervals on a random line.

to A, and project the other points of intersection from CB to AB by lines parallel to the first one. The projected points of intersection divide AB into 10 equal parts.

Figure 4-7 shows how you can use a scale to lay off equal intervals on the ray line.

DIVISION INTO PROPORTIONAL PARTS

Figure 4-8 show's a method of dividing a line into given proportional parts. The problem here is to divide the line AB into parts that are proportional as 2:3:4. Lay off ray line CB from B at a convenient acute angle to AB. Set a compass to a convenient spread, and lay off this interval from B on CB the number of times that is equal to the sum of the figures in the proportion (2 + 3 + 4 = 9). Draw a line from the point of intersection of the last interval to A, and use a straightedge and triangle to project the second and fifth intercepts on CB to AB by lines parallel to the first one. The projected intercepts divide AB into segments that are proportional as 2:3:4.

Here again, you could use a scale to lay off nine equal intervals on CB.

DIVISION ACCORDING TO A GIVEN RATIO

You may be required to divide a line into parts so that the ratio between the whole line and one of the parts is the same as that between two other lines. A method

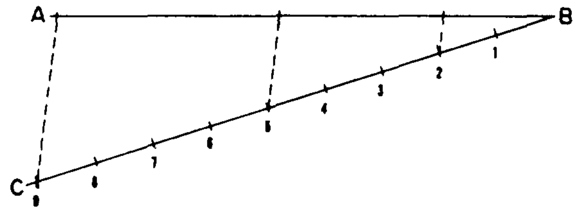


Figure 4-8.-Dividing a line into proportional parts.

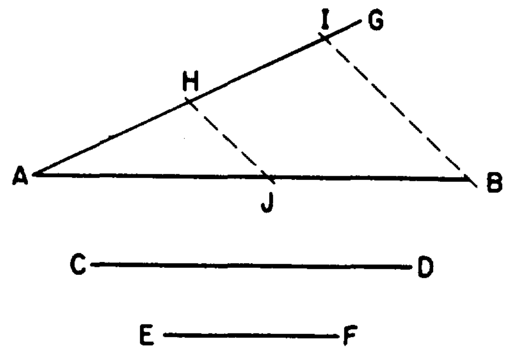


Figure 4-9.-Dividing a line into parts according to a given ratio.

of doing this is shown in figure 4-9. Here, it is required that AB be divided so that the ratio between AB and a part of AB is the same as the ratio between CD and EF. From A, draw a ray line AG at a convenient acute angle from AB. On AG, lay off AH equal to EF and AI equal to CD. Draw a line from I to B, and use a straightedge and triangle to project H to J on a line parallel to IB. The ratio of AB to AJ is the same as that of CD to EF.

ANGLES

You already know how to lay off an angle of given size with a protractor, or trigonometrically by the use of the tangent or the chord method.

TRANSFER OF AN ANGLE

There is a geometric construction for laying off, on another part of the same drawing or on a different drawing, an angle

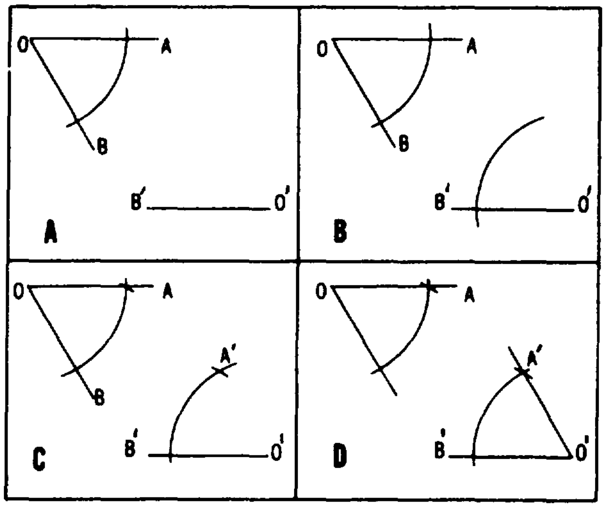


Figure 4-10.-Transferring an angle.

equal in size to one that is already drawn. This procedure, called transferring an angle, is shown in figure 4-10. Here, the draftsman desired to lay off from O′ a line that would make an angle with B′O′ equal to angle BOA. To do this, draw an arc through OB and OA, with O as a center, as shown in figure 4-10, view A. Then, draw an arc of the same radius from B′O′, with O′ as a center, as shown in figure 4-10, view B. Next, measure the length of the chord of the arc between OB and OA and lay off the same length on the arc from B′O′, as shown in figure 4-10, view C. A line drawn from O′ through A′ makes an angle with B′O′ equal to angle BOA, as shown in figure 4-10, view D.

BISECTION OF AN ANGLE

To bisect an angle means to divide it in half. If you know the size of the angle, you can bisect it by simply dividing the size by 2 and laying off the result with a protractor.

Geometric construction for bisecting an angle is shown in figure 4-11, To bisect the angle AOB, first lay off equal intervals from O on OA and OB. With the ends of these intervals as centers, strike intersecting arcs of equal radius at P. Draw a line from O through the point of intersection of the arcs, P. The line OP bisects angle AOB.

PLANE FIGURES

This section explains how to construct certain plane figures, such as the triangle, rectangle, square, and regular polygon. You must understand the geometrical construction of plane figures because they appear in engineering drawings.

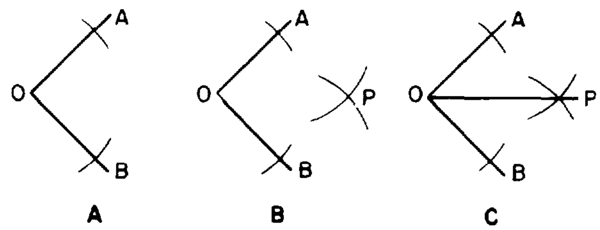


Figure 4-11.-Bisecting an angle.

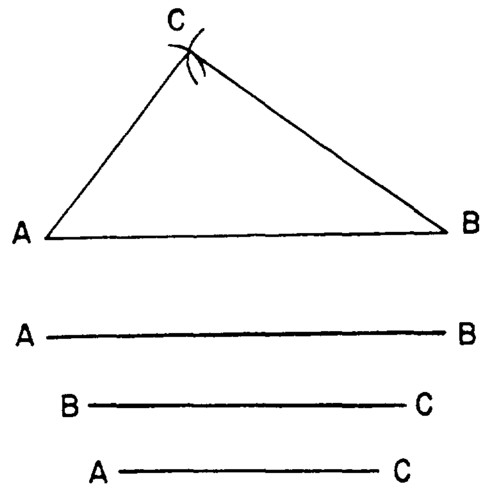


Figure 4-12.-Constructing a triangle with three sides given.

TRIANGLE: THREE SIDES GIVEN

To draw a triangle with three sides given, first draw a straight line AB, equal in length to one of the given sides (fig. 4-12). With A as a center, strike an arc with a radius equal to the given length of the second side. With B as a center, strike an intersecting arc with a radius equal to the length of the third side. Draw lines from A and B to the point of intersection of the arcs.

RIGHT TRIANGLE: HYPOTENUSE AND ONE SIDE GIVEN

Figure 4-13 shows a method of drawing a right triangle when the hypotenuse and one side are given. The line H is the given hypotenuse; the line S is the given side. Draw AB equal to H. Locate the center of AB (by bisection), and, with the midpoint as a center and a radius equal to one-half of AB, draw the semicircle from A to B as shown. Set a compass or dividers to the length of S, and, with A as a center, strike an arc intersecting the semicircle at C. Draw AC and BC.

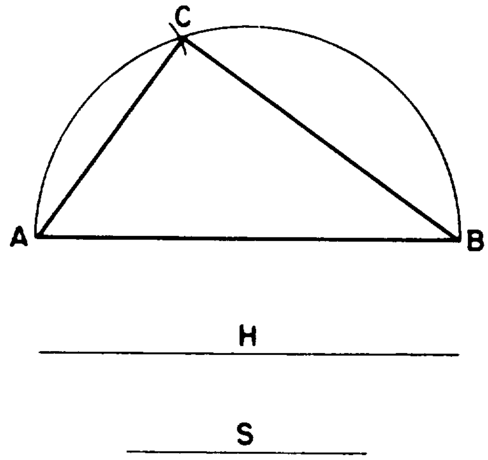


Figure 4-13.-Constructing a right triangle with hypotenuse and one side given.

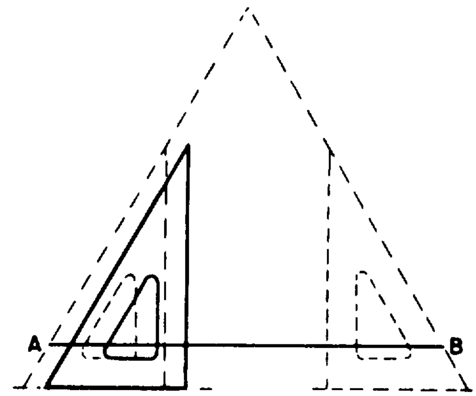


Figure 4-14.-Equilateral triangle with a given length of side AB.

EQUILATERAL TRIANGLE: LENGTH OF SIDE GIVEN

To construct an equilateral triangle when the length of a side is given, you can follow the method previously described for constructing a triangle when the length of each side is given. The sides of an equilateral triangle are equal in length.

Each angle in an equilateral triangle measures 60°. This fact is applied in the method of constructing an equilateral triangle with given length of side, such as the one shown in figure 4-14. Simply use a 30°/60° triangle and a T square or straightedge to erect lines from A and B at 60° to AB.

EQUILATERAL TRIANGLE IN A GIVEN CIRCUMSCRIBED CIRCLE

A circumscribed plane figure is one that encloses another figure, the circumscribed figure being tangent to the extremities of the enclosed figure. An inscribed plane figure is one that is enclosed by a circumscribed figure.

Figure 4-15 shows you how to inscribe an equilateral triangle within a given circumscribed circle. Draw a vertical center line intersecting the given circle at A and B. With B as a center and a radius equal to the radius of the circle, strike arcs intersecting the circle at C and D. Lines connecting A, C, and D form an equilateral triangle.

EQUILATERAL TRIANGLE ON A GIVEN INSCRIBED CIRCLE

Figure 4-16 shows one method of circumscribing an equilateral triangle on a given inscribed

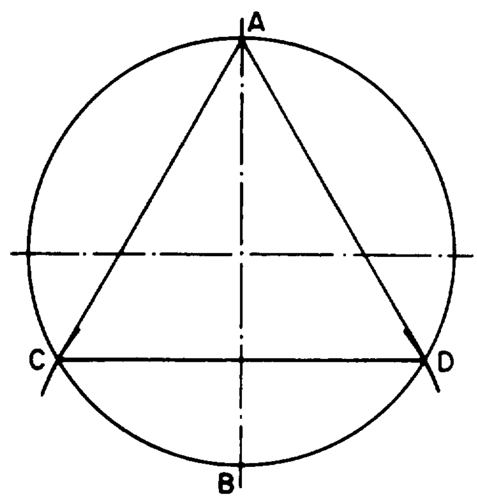


Figure 4-15.-Equilateral triangle in a given circumscribed circle.

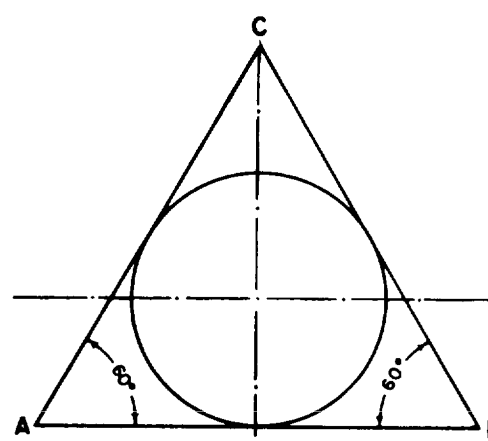


Figure 4-16.-Equilateral triangle on a given inscribed circle: one method.

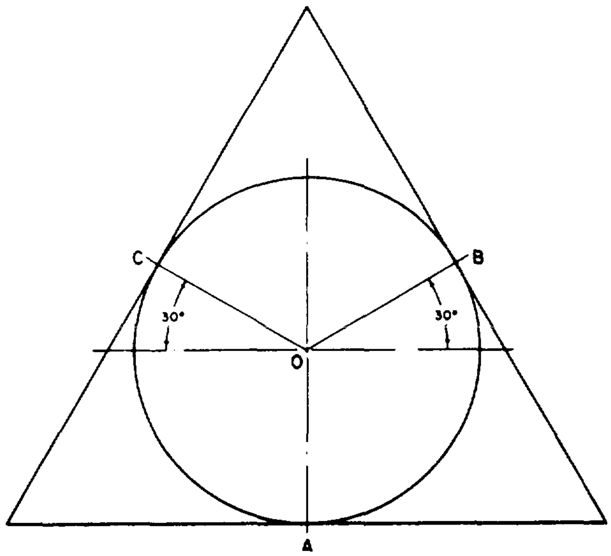


Figure 4-17.-Equilateral triangle on a given inscribed circle: another method.

circle. Draw AB parallel to the horizontal center line of the circle and tangent to the circumference. Then use a 30°/60° triangle to draw AC and BC at 60° to AB and tangent to the circle.

Another method of accomplishing this construction is shown in figure 4-17. Draw radii at 30° to the horizontal center line of the circle, intersecting the circumference at C and B. There is a third point of intersection at A, so you now have three radii: OA, OB, and OC. Draw the sides of the triangle at A, B, and C, tangent to the circle and perpendicular to the relevant radius.

RECTANGLE: GIVEN LENGTH AND WIDTH

To construct a rectangle with a given length and width, draw a horizontal line AB, equal to the given length. With a straightedge and triangle, erect perpendiculars from A and B, each equal to the given width. Connect the ends of the perpendiculars.

SQUARE: GIVEN LENGTH OF SIDE

You can construct a square with a given length of side by the method described for constructing a rectangle. Another method is shown in figure 4-18. With a T square, draw horizontal line AB equal to the given length of side. With a T square and a 45° triangle, draw diagonals from A and B at 45° to AB. Erect perpendiculars from A and B, intersecting the diagonals. Then connect the points of intersection.

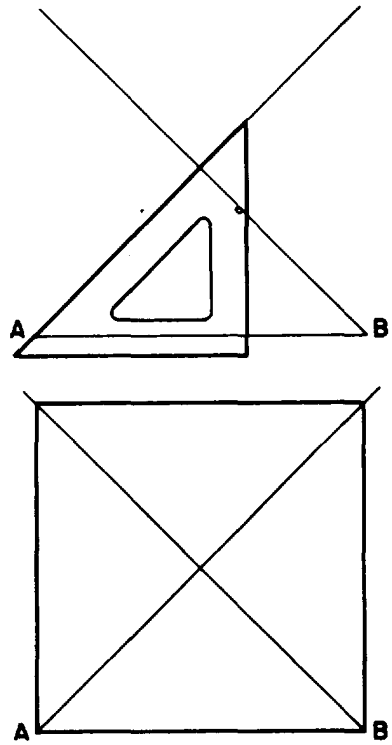


Figure 4-18.-Square with a given length of side.

SQUARE: GIVEN LENGTH OF DIAGONAL

Figure 4-19 shows a method of constructing a square with a given length of diagonal. Draw horizontal line AB, equal to the given length of the diagonal. Locate O at the center of AB, and lay off CD through O, perpendicular to and

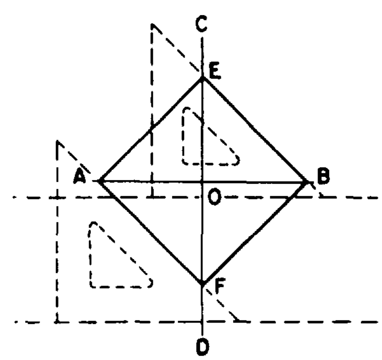


Figure 4-19.-Square with a given length of diagonal.

slightly longer than AB. Use a T square and a 45° triangle to draw AF and EB at 45° to AB and CD, Connect AE and FB.

SQUARE IN A GIVEN CIRCUMSCRIBED CIRCLE

Figure 4-20 shows a method of drawing a square in a given circumscribed circle. Draw the diameters AB and CD at right angles to each other, and connect the points where the diameters intersect the circumference of the circle.

SQUARE CIRCUMSCRIBED ON A GIVEN INSCRIBED CIRCLE

Figure 4-21 shows a method of circumscribing a square on a given inscribed circle, Draw diameters AB and CD at right angles to each other. Then draw each side of the square tangent to the point where a diameter intersects the circumference of the circle and perpendicular to the diameter.

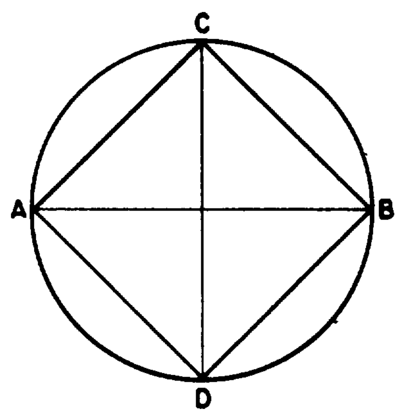


Figure 4-20.-Square in a given circumscribed circle.

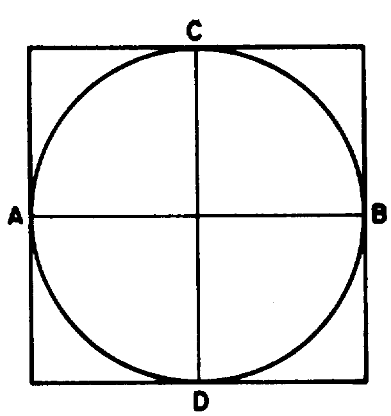


Figure 4-21.-Square on a given inscribed circle.

ANY REGULAR POLYGON IN A GIVEN CIRCUMSCRIBED CIRCLE

You can construct any regular polygon in a given circumscribed circle by trial and error with a drafting compass or dividers as shown in figure 4-22. To draw a nine-sided regular polygon in the circle shown, divide the circumference by trial and error with a compass or dividers into nine equal segments, and connect the points of intersection. To get a trial spread for a compass or dividers, divide the central angle subtended by the entire circle (360) by the number of sides of the polygon, in this case, by nine. Then, lay off the central angle quotient from the center of the circle to the circumference with a protractor.

ANY REGULAR POLYGON ON A GIVEN INSCRIBED CIRCLE

The same method (dividing the circumference into equal segments) can be used to construct a regular polygon on a given inscribed circle. In this case, however, instead of connecting the points of intersection on the circumference, you draw each side tangent to the circumference and

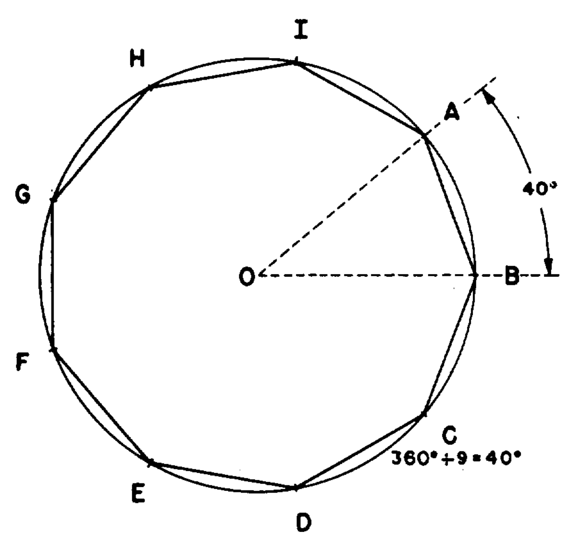


Figure 4-22.-Regular polygon in a given circumscribed circle.

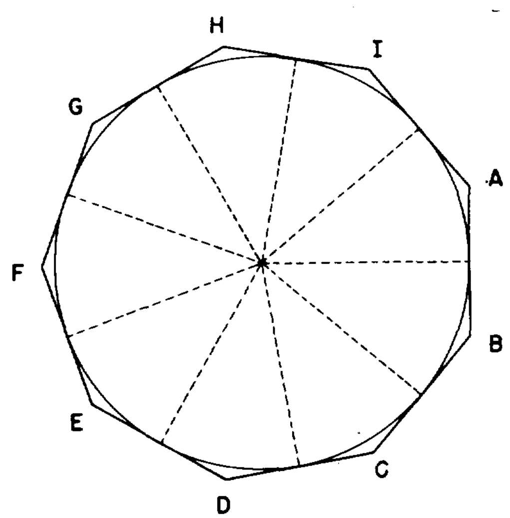


Figure 4-23.-Regular polygon on a given inscribed circle.

perpendicular to the radius at each point of intersection, as shown in figure 4-23.

ANY REGULAR POLYGON WITH A GIVEN LENGTH OF SIDE

Figure 4-24 shows a method of drawing any regular polygon with a given length of side. To draw a nine-sided regular polygon with length of side equal to AB, first extend AB to C, making CA equal to AB. With A as a center and AB (or CA) as a radius, draw a semicircle as shown. Divide the semicircle into nine equal segments from C to B, and draw radii from A to the points of intersection. The radius A2 is always the second side of the polygon.

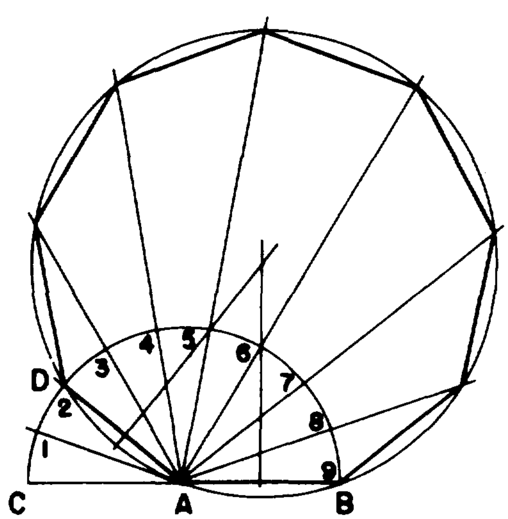


Figure 4-24.-Any regular polygon with a given length of side.

Draw a circle through points A, B, and D. To do this, first erect perpendicular bisectors from DA and AB. The point of intersection of the bisectors is the center of the circle. The circle is the circumscribed circle of the polygon. To draw the remaining sides, extend the radii from the semicircle as shown, and connect the points where they intersect the circumscribed circle.

Besides the methods described for constructing any regular polygon, there are particular methods for constructing a regular pentagon, hexagon, or octagon.

REGULAR PENTAGON IN A GIVEN CIRCUMSCRIBED CIRCLE

Figure 4-25 shows a method of constructing a regular pentagon in a given circumscribed circle. Draw a horizontal diameter AB and a vertical diameter CD. Locate E, the midpoint of the radius OB. Set a compass to the spread between E and C, and, with E as a center, strike the arc CF. Set a compass to the spread between C and F, and, with C as a center, strike the arc GF. A line from G to C forms one side of the pentagon. Set a compass to GC and lay off this interval from C around the circle. Connect the points of intersection.

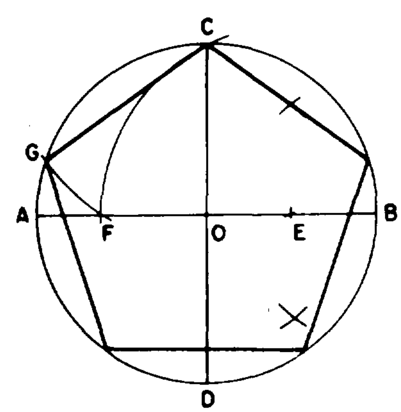


Figure 4-25.-Regular pentagon in a given circumscribed circle.

REGULAR PENTAGON ON A GIVEN INSCRIBED CIRCLE

To construct a regular pentagon on a given inscribed circle, determine the five equal intervals on the circle in the same manner. However, instead of connecting these points, draw each side of the figure tangent to the circle at a point of intersection.

REGULAR HEXAGON IN A GIVEN CIRCUMSCRIBED CIRCLE

Many bolt heads and nuts are hexagonal (six-sided) in shape. Figure 4-26 shows a method of constructing a regular hexagon in a given circumscribed circle. The diameter of the circumscribed circle has the same length as the long diameter of the hexagon. The radius of the circumscribed circle (which equals one-half the long diameter of the hexagon) is equal in length to the length of a side. Lay off the horizontal diameter AB and vertical diameter CD. OB is the radius of the circle. From C, draw a line CE equal to OB; then lay off this interval around the circle, and connect the points of intersection.

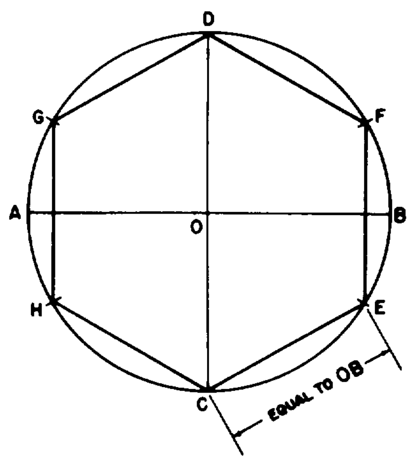


Figure 4-26.-Regular hexagon in a given circumscribed circle: one method.

Figure 4-27 shows another method of constructing a regular hexagon in a given circumscribed circle. Draw vertical diameter AB, and use a T square and a 30°/60° triangle to draw BC from B at 30° to the horizontal. Set a compass to BC, lay off this interval around the circumference, and connect the points of intersection.

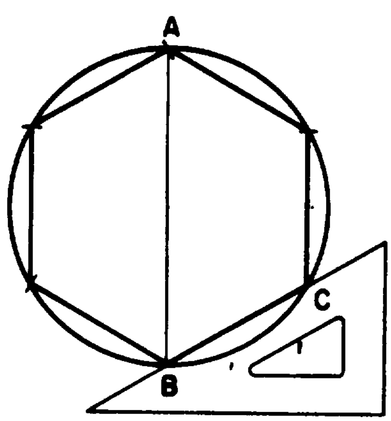


Figure 4-27.-Regular hexagon in a given circumscribed circle: another method.

REGULAR HEXAGON ON A GIVEN INSCRIBED CIRCLE

Figure 4-28 shows a method of constructing a regular hexagon on a given inscribed circle. Draw horizontal diameter AB and vertical center line. Draw lines tangent to the circle and perpendicular to AB at A and B. Use a T square and a 30°/60° triangle to draw the remaining sides of the figure tangent to the circle and at 30° to the horizontal.

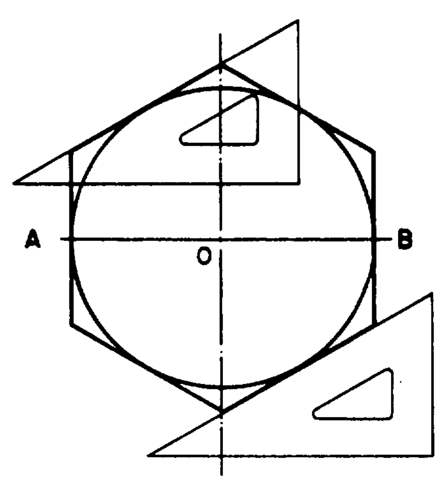


Figure 4-28.-Regular hexagon on a given inscribed circle.

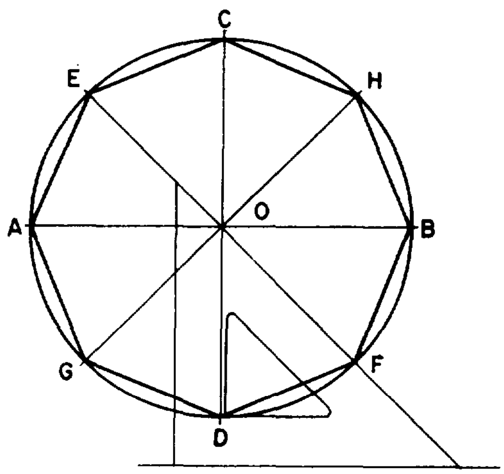


Figure 4-29.-Regular octagon in a given circumscribed circle.

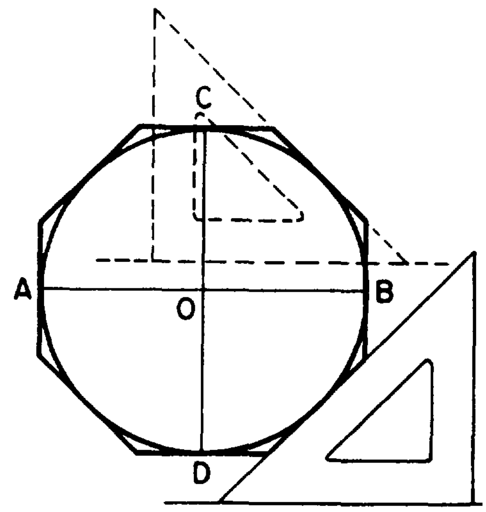


Figure 4-30.-Regular octagon around a given inscribed circle.

REGULAR OCTAGON IN A GIVEN CIRCUMSCRIBED CIRCLE

Figure 4-29 shows a method of constructing a regular octagon in a given circumscribed circle. Draw horizontal diameter AB and vertical diameter CD. Use a T square and a 45° triangle to draw additional diameters EF and GH at 45° to the horizontal. Connect the points where the diameters intersect the circle.

REGULAR OCTAGON AROUND A GIVEN INSCRIBED CIRCLE

Figure 4-30 shows a method of constructing a regular octagon around a given inscribed circle. Draw horizontal diameter AB and vertical diameter CD. Draw tangents at A, B, C, and D perpendicular to the diameters. Draw the remaining sides of the figure tangent to the circle at 45° to the horizontal.

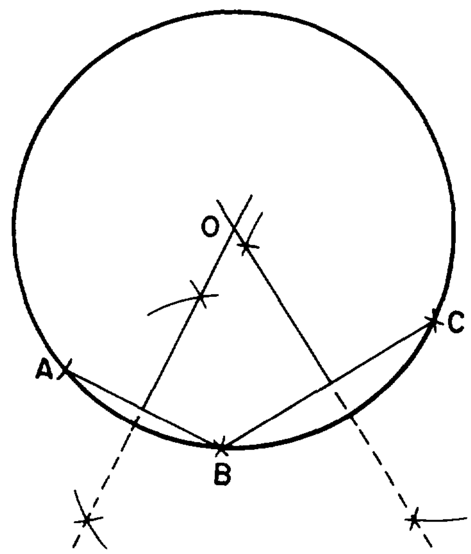


Figure 4-31.-Circle or arc through three points.

CIRCULAR CURVES

Many of the common geometrical constructions occurring in the drafting room are those involving circular curves. This section explains how to construct circular curves that may be required to satisfy varying conditions.

CIRCLE THROUGH THREE POINTS

In figure 4-31 the problem is to draw a circle (or a circular arc) that passes through points A, B, and C. Connect the points by lines and erect perpendicular bisectors as shown. The point of intersection of the perpendicular bisectors (O) is the center of the circle or arc passing through all three points.

LINE TANGENT TO A CIRCLE AT A GIVEN POINT

A line that is tangent to a circle at a given point is perpendicular to the radius that intersects the point. It follows that one method of drawing a line tangent to a circle at a given point is to draw the radius that intersects the point, and then draw the line tangent at the point of intersection and perpendicular to the radius.

Another method is shown in figure 4-32. To draw a line tangent to the circle at P, set a compass to the radius of the circle, and, with P as a center, strike an arc that intersects the circle at A. With the compass still set to the radius of the circle, use A as a center and strike an arc that intersects the first arc at B. With B as a center and the compass still set to the radius of the circle, strike another arc. A line through the point of intersection (0) of the last drawn arc and through P is tangent to the circle at P.

CIRCULAR ARC OF A GIVEN RADIUS TANGENT TO TWO STRAIGHT LINES

Drawing a fillet or round comprises the problem of drawing a circular arc of a given radius tangent to two nonparallel lines.

Figure 4-33 shows a method that can be used when the two nonparallel lines form a right angle. AB is the given radius of the arc. Set a compass to this radius, and, with the point of intersection of the lines as a center, strike an arc intersecting the lines at C and D. With C and D as centers and the same radius, strike intersecting arcs as shown. The point of intersection of these arcs (0) is the center of the circle of which an arc of the given radius is tangent to the lines.

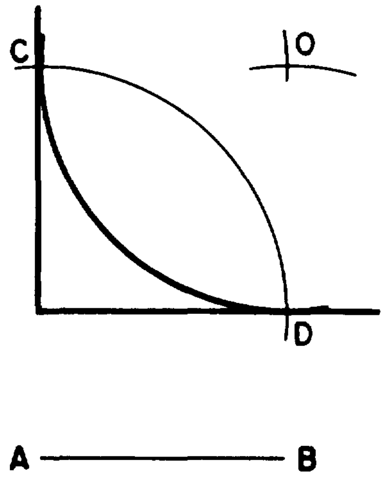


Figure 4-33.-Circular arc tangent to two lines that form a right angle.

Figure 4-34 shows a method that can be used regardless of the size of the angle formed by the lines. Again AB equals the given radius of the arc, and the problem is to draw an arc with radius equal to AB, tangent to CD and EF. Draw GH parallel to CD and at a distance from CD equal to the given radius of the arc. Draw IJ parallel to EF and also at a distance equal to the given radius of the arc. The point of intersection between GH and IJ (P) is the center of the circle of which an arc of the given radius is tangent to CD and EF.

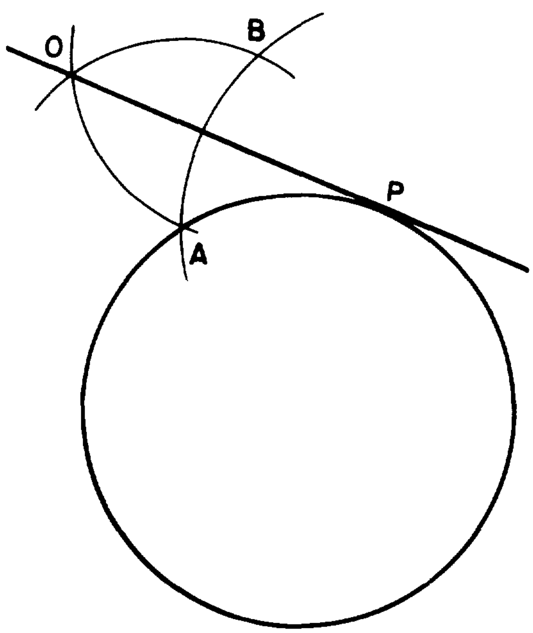


Figure 4-32.-Line tangent to a given point on a circle.

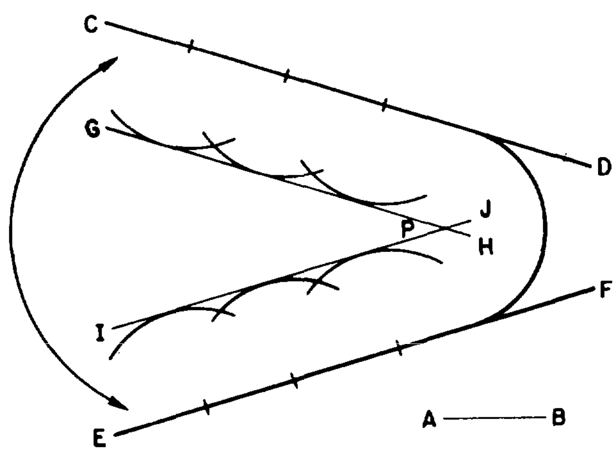


Figure 4-34.-Circular arc tangent to two lines that form any angle.

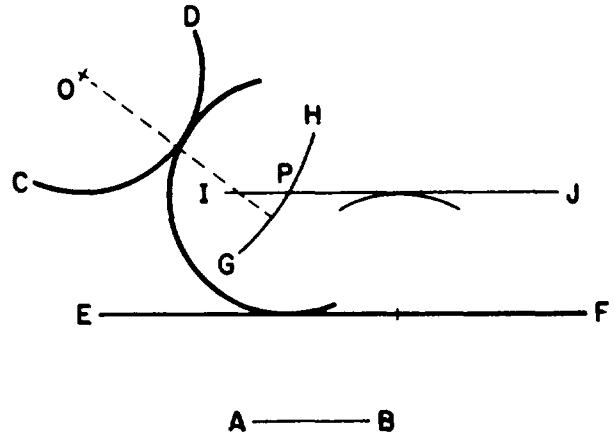


Figure 4-35.-Circular arc tangent to a straight line and another circular arc.

CIRCULAR ARC OF A GIVEN RADIUS TANGENT TO A STRAIGHT LINE AND TO ANOTHER CIRCULAR ARC

The problem in figure 4-35 is to draw a circular arc with a radius equal to AB, tangent to the circular arc CD and to the straight line EF. Set a compass to a radius equal to the radius of the circular arc CD plus the given radius AB (which is indicated by the dashed line shown), and, with O as a center, strike the arc GH. Draw a line IJ parallel to EF at a distance from EF equal to AB. The point of intersection (P) between GH and IJ is the center of the circle of which an arc of the given radius is tangent to CD and EF.

CIRCULAR ARC OF A GIVEN RADIUS TANGENT TO TWO OTHER CIRCULAR ARCS

The problem in figure 4-36 is to draw an arc with a radius equal to AB, tangent to the circular arcs CD and EF. Set a compass to a spread equal to the radius of arc CD plus AB (indicated by the left-hand dashed line), and, with O as a center, strike an arc. Set the compass to a spread equal to the radius of arc EF plus AB (indicated by the right-hand dashed line), and, with O´ as a center, strike an intersecting arc. The point of intersection between the two arcs (P) is the center of the circle of which an arc of given radius is tangent to arcs CD and EF.

In figure 4-36 the circular arcs CD and EF curve in **opposite** directions. In figure 4-37 the problem is to draw an arc with radius equal to AB, tangent to two circular arcs, CD and EF, that curve in the **same** direction.

Set a compass to a radius equal to the radius of EF less AB, and, with O´ as a center, strike an arc. Then, set a compass to a radius equal to the radius of arc CD plus line AB, and, with O as center, strike an intersecting arc at P. The point of intersection of these two arcs is the center of the circle of which an arc of the given radius is tangent to CD and EF.

When a circular arc is tangent to another, it is commonly the case that the two arcs curve in opposite directions. However, an arc may be drawn tangent to another with both curving in the same direction. In a case of this kind, the tangent arc is said to enclose the other.

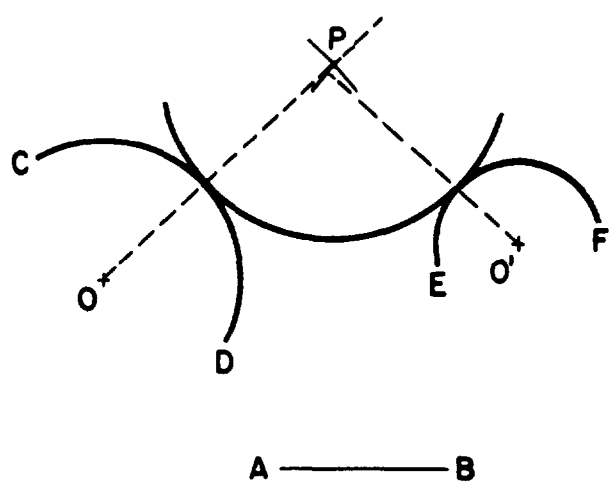


Figure 4-36.-Circular arc tangent to two other circular arcs.

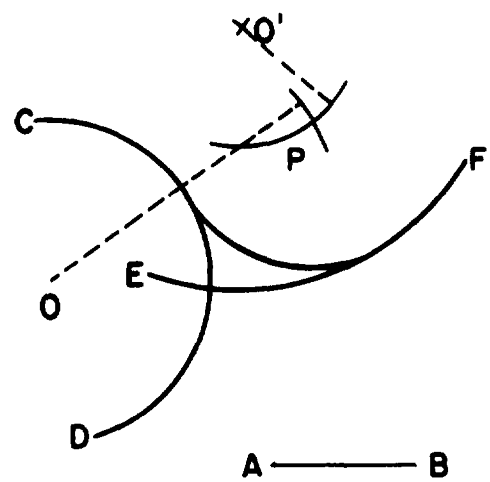


Figure 4-37.-Circular arc tangent to arcs that curve in the same direction.

An arc tangent to two others may enclose both, or it may enclose only one and not the other. In figure 4-38 the problem is to draw a circular arc with a radius equal to AB, tangent to and enclosing both arcs CD and EF. Set a compass to a radius equal to AB less the radius of CD (indicated by the dashed line from O), and, with O as a center, strike an arc. Set the compass to a radius equal to AB less the radius of EF (indicated by the dashed line from O′), and, with O′ as a center, strike an intersecting arc at P. The point of intersection of these two arcs is the center of a circle of which an arc of given radius is tangent to, and encloses, both arcs CD and EF.

In figure 4-39 the problem is to draw a circular arc with a radius equal to AB, tangent to, and enclosing, CD, and tangent to, but NOT enclosing, EF. Set a compass to a radius equal to AB less the radius of arc CD (indicated by the dashed line from 0), and, with O as a center, strike an arc, Set the compass to AB plus the radius of EF (as indicated by the dashed line from O′), and, with O′ as a center, strike an intersecting arc at P. The point of intersection of the two arcs is the center of a circle of which an arc of the given radius is tangent to and encloses arc CD and also is tangent to, but does not enclose, arc EF.

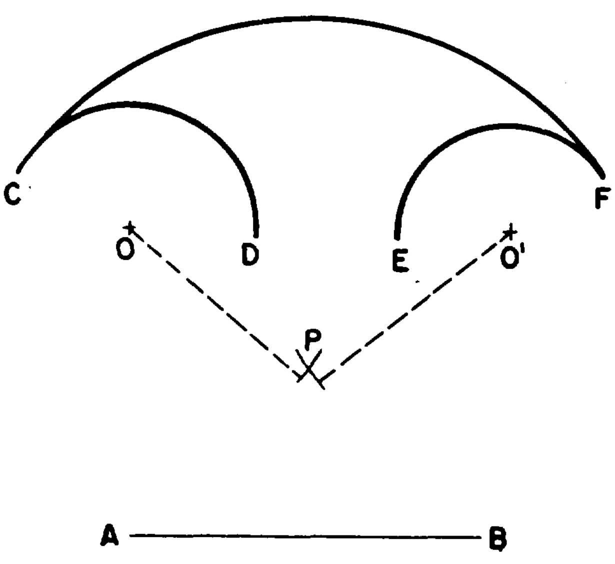


Figure 4-38.-Circular arc tangent to and enclosing two other circular arcs.

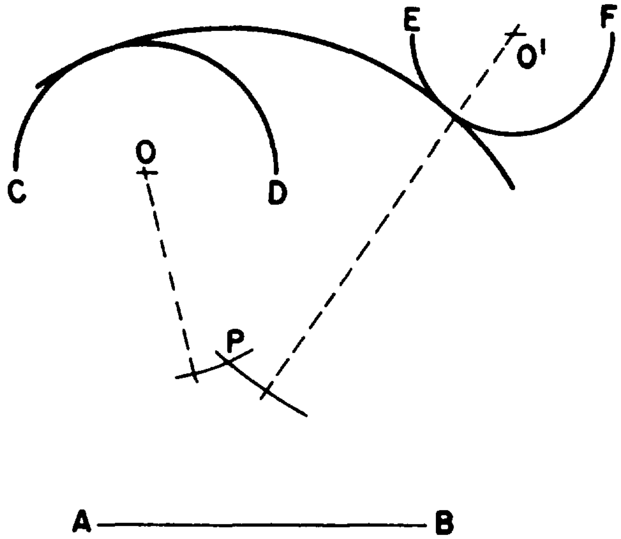


Figure 4-39.-Circular arc tangent to and enclosing one arc and tangent to, but not enclosing, another.

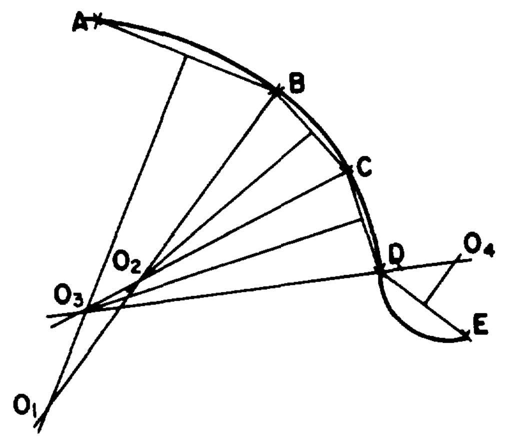


Figure 4-40.-Curve composed of a series of consecutive tangent circular arcs.

COMPOUND CURVES

A curve that is made up of a series of successive tangent circular arcs is called a compound curve. In figure 4-40 the problem is to construct a compound curve passing through given points A, B, C, D, and E. First, connect the points by straight lines. The straight line between each pair of points constitutes the chord of the arc through the points.

Erect a perpendicular bisector from AB. Select an appropriate point O_1 on the bisector as a center, and draw the arc AB. From O_1, draw the radius O_1B. From BC, erect a perpendicular bisector. The point of intersection O_2 between this bisector and the radius O_1B is the center for the arc BC. Draw the radius O_2C, and erect a perpendicular bisector from CD. The point of intersection O_3 of this bisector and the extension of O_2C is the center for the arc CD.

To continue the curve from D to E, you must reverse the direction of curvature. Draw the radius O_3D, and erect a perpendicular bisector from DE on the opposite side of the curve from those previously erected. The point of intersection of this bisector and the extension of O_3D is the center of the arc DE.

REVERSE, OR OGEE, CURVE

A reverse, or ogee, curve is composed of two consecutive tangent circular arcs that curve in opposite directions,

Figure 4-41 shows a method of connecting two parallel lines by a reverse curve tangent to the lines. The problem is to construct a reverse curve tangent to the upper line at A and to the lower line at B.

Connect A and B by a straight line AB. Select on AB point C where you want to have the reverse curve change direction. Erect perpendicular bisectors from BC and CA, and erect perpendiculars from B and A. The points of intersection between the perpendiculars (O_1 and O_2) are the centers for the arcs BC and CA.

Figure 4-42 shows a method of constructing a reverse curve tangent to three intersecting straight lines. The problem is to draw a reverse

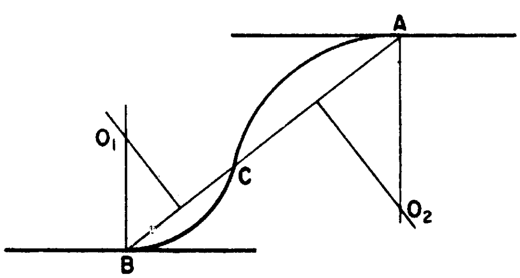


Figure 4-41.—Reverse curve connecting and tangent to two parallel lines.

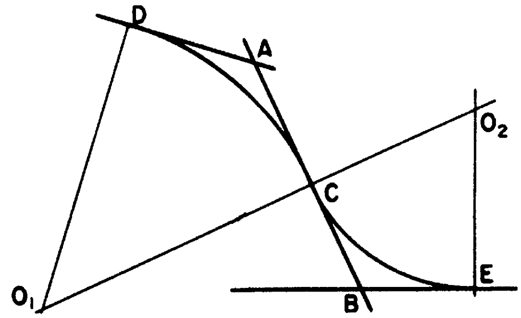


Figure 4-42.—Reverse curve tangent to three intersecting straight lines.

curve tangent to the three lines that intersect at points A and B. Select on AB point C where you want the reverse curve to change direction. Lay off from A a distance equal to AC to establish point D. Erect a perpendicular from D and another from C. The point of intersection of these perpendiculars (O_1) is the center of the arc DC.

Lay off from B a distance equal to CB to establish point E. Erect a perpendicular from E, and extend O_1C to intersect it. The point of intersection (O_2) is the center of the arc CE.

NONCIRCULAR CURVES

The basic uniform noncircular curves are the ellipse, the parabola, and the hyperbola. These curves are derived from conic sections as shown in figure 4-43. The circle itself (not shown, but a curve formed by a plane passed through a cone perpendicular to the vertical axis) is also derived from a conic section.

This section describes methods of constructing the ellipse only. Methods of constructing the hyperbola are given in *Engineering Drawing* by French and Vierck and in *Architectural Graphic Standards.*

Of the many different ways to construct an ellispe, the three most common are as follows: the pin-and-string method, the four-center method, and the concentric-circle method. The method you should use will depend on the size of the ellipse and where it is to be used.

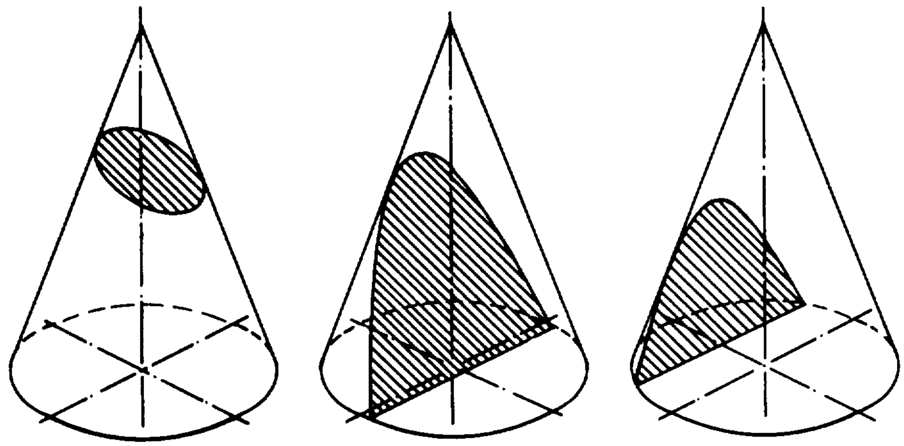


Figure 4-43.-Conic sections: ellipse, parabola, and hyperbula (left to right).

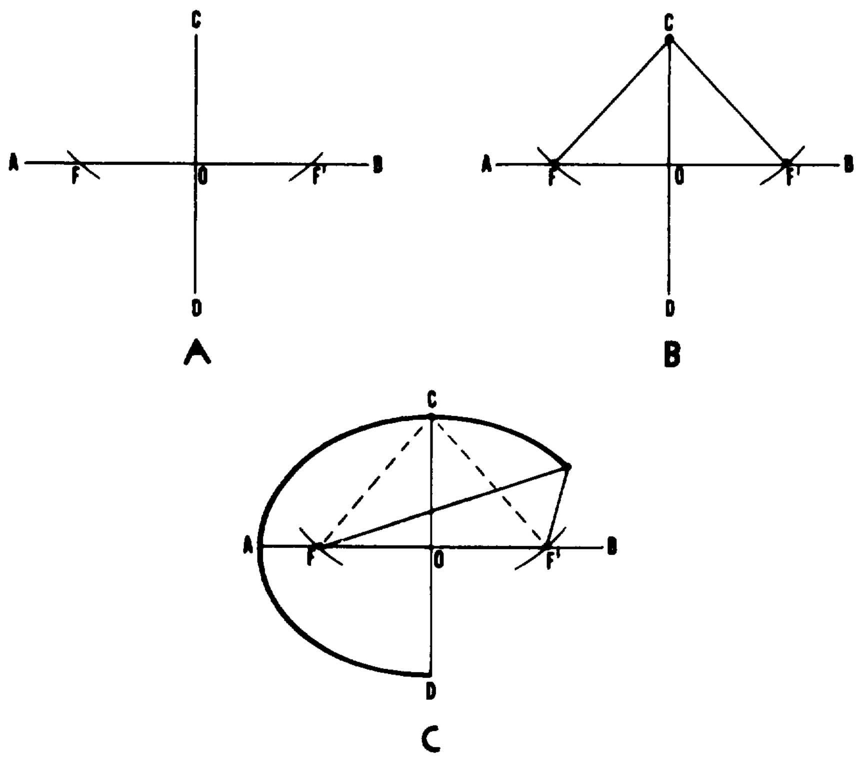


Figure 4-44.-Ellipse by pin-and-string method.

ELLIPSE BY PIN-AND-STRING METHOD

The dimensions of an ellipse are given in terms of the lengths of the major (longer) and minor (shorter) axes. Figure 4-44 shows a method of constructing an ellipse that is called the pin-and-string method. The problem is to construct an ellipse with a major axis, AB, and a minor axis, CD. Set a compass to one-half the length of AB, and, with C as a center, strike arcs intersecting AB at F and F´. The points F and F´ are called the foci of the ellipse. Set a pin at point C, another at F, and a third at F´. Tie the end of a piece of string to the pin at F, pass the string around the pin at C, draw it taut, and fasten it to the pin at F´. Remove the pin at C, place the pencil point in the bight of the string, and draw the ellipse as shown in view C, keeping the string taut all the way around.

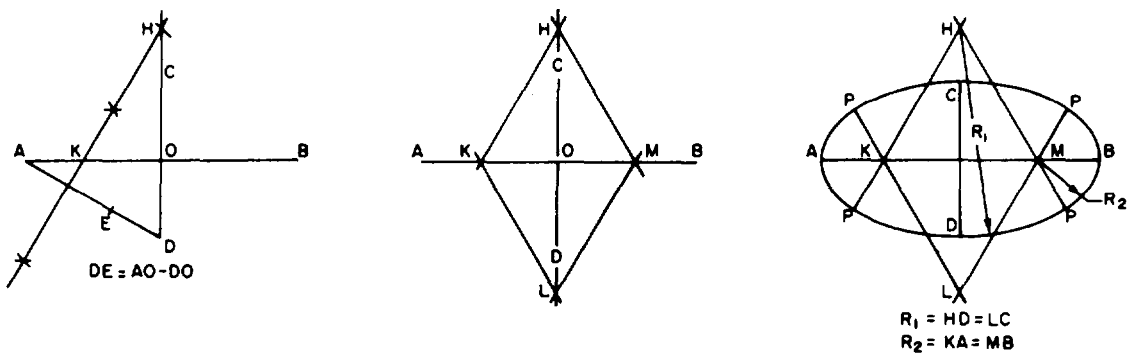


Figure 4-45.-Ellipse by four-center method.

ELLIPSE BY FOUR-CENTER METHOD

The four-center method is used for small ellipses. Given major axis, AB, and minor axis, CD, mutually perpendicular at their midpoint, O, as shown in figure 4-45, draw AD, connecting the end points of the two axes. With the dividers set to DO, measure DO along AO and reset the dividers on the remaining distance to O. With the difference of semiaxes thus set on the dividers, mark off DE equal to AO minus DO. Draw perpendicular bisector AE, and extend it to intersect the major axis at K and the minor axis extended at H. With the dividers, mark off OM equal to OK, and OL equal to OH. With H as a center and radius R_1 equal to HD, draw the bottom arc. With L as a center and the same radius as R_1, draw the top arc. With M as a center and the radius R_2 equal to MB draw the end arc. With K as a center and the same radius, R_2, draw the end arc. The four circular arcs thus drawn meet, in common points of tangency, P, at the ends of their radii in their lines of centers.

ELLIPSE BY CONCENTRIC-CIRCLE METHOD

Figure 4-46 shows the concentric-circle method of drawing an ellipse. With the point of intersection between the axes as a center, draw two concentric circles (circles with a common center), one with a diameter equal to the major axis and the other with a diameter equal to the minor axis, as shown in figure 4-46, view A. Draw a number of diameters as shown in figure 4-46, view B. From the point of intersection of each diameter with the larger circle, draw a vertical line; and from the point of intersection of each diameter with the smaller circle, draw an intersecting horizontal line, as shown in figure 4-46, view C. Draw the ellipse through the points of intersection, as shown in figure 4-46, view D, with a french curve.

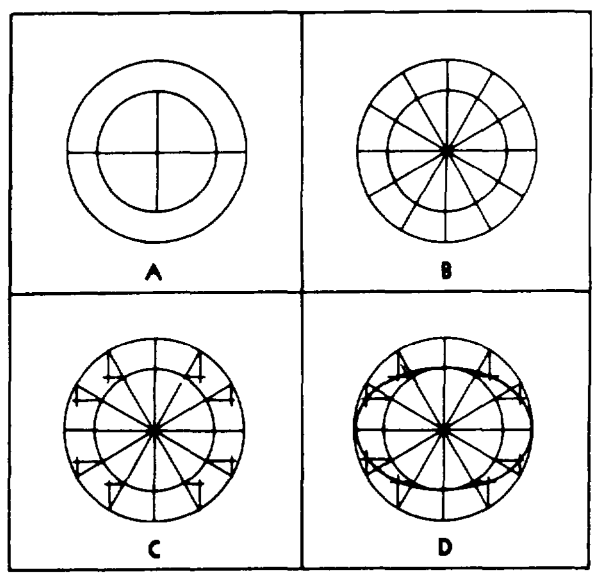


Figure 4-46.-Ellipse by concentric-circle method.

CHAPTER 5

DRAFTING: PROJECTIONS AND SKETCHING

This chapter deals with the theory of projections and methods of preparing projection drawings. By applying basic geometric construction (described in the preceding chapter) to the various projection methods, you should be able to clearly represent any given object or structure on paper. Although the methods discussed here are basic to all drawings, they are easily adapted to construction drawings. This chapter also covers various techniques of freehand sketching. You will learn how to prepare quick sketches to convey or develop your ideas.

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

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

PARALLEL PROJECTION

To satisfy requirements for preparing single- or multi-view drawings, you may use two main types of projection: PARALLEL and PERSPECTIVE (fig. 5-1). PARALLEL projection

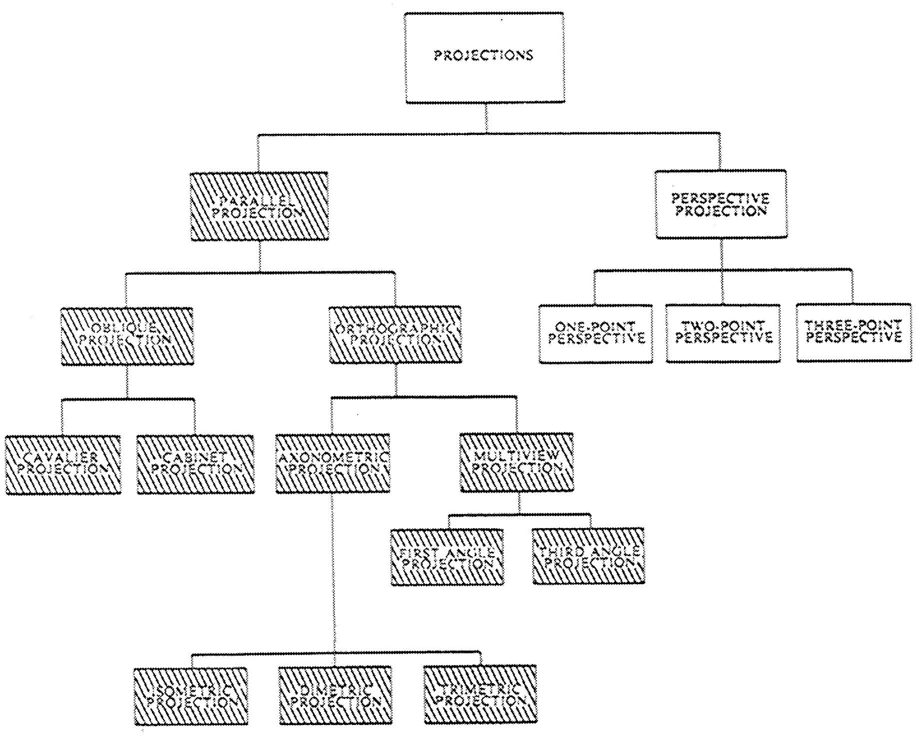


Figure 5-1.—Classification of major projections.

(fig. 5-2) is further classified into subtypes according to the direction of its projection lines relative to the plane of projection. If the projection lines, in addition to being parallel to each other, are perpendicular (normal) to the plane of projection, the result is an **orthographic** projection. If they are parallel to each other but oblique to the plane of projection, the result is an **oblique** projection.

To better understand the theory of projection, you must become familiar with certain elements that are common to each type of projection. Some of these elements are defined below.

The POINT OF SIGHT (or STATION POINT) is the position of the observer in relation to the object and the plane of projection (fig. 5-2). It is from this point that the view of the object is taken. The point of sight is changed to give different views of the same object; hence, there must be a different point of sight for each view. Imagine yourself looking first at the front of an object, then down at the top, and then at the right or left side, as the case may be. Each additional view requires a new point of sight.

The observer views the features of the object through an imaginary PLANE OF PROJECTION (or IMAGE PLANE). In parallel projection, this theoretical transparent plane is placed between the point of sight and the object, as shown in figure 5-2. For perspective pictorials, it

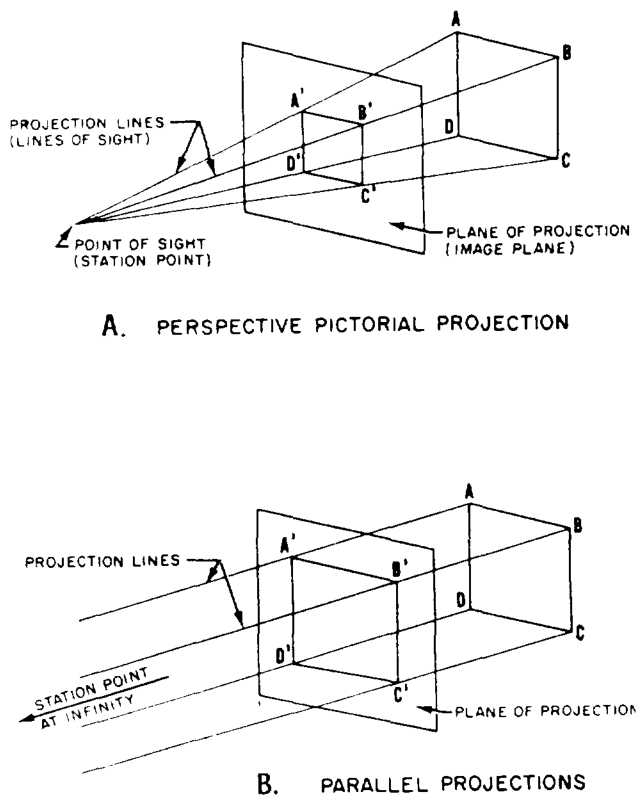


Figure 5-2.-Types of projections.

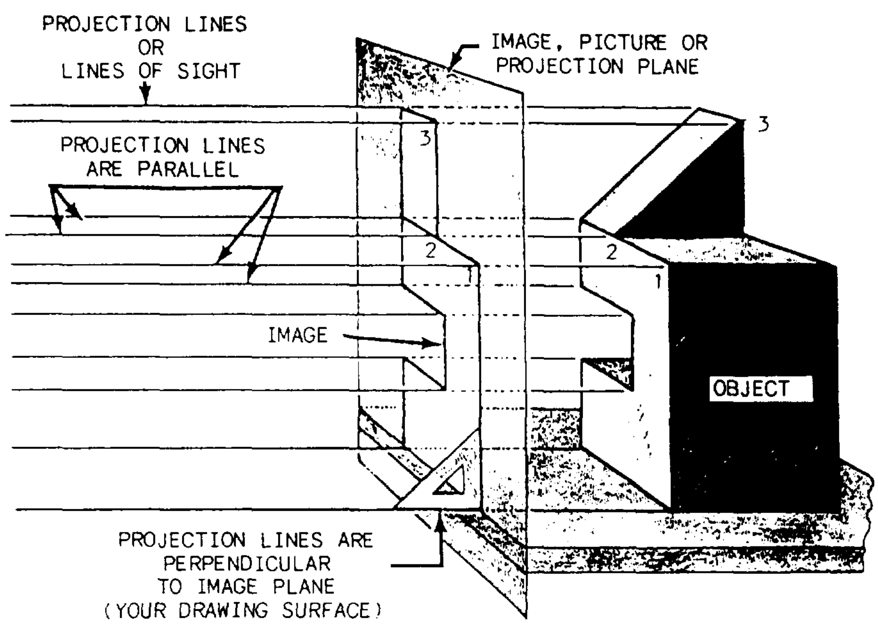


Figure 5-3.-Basic orthographic projection.

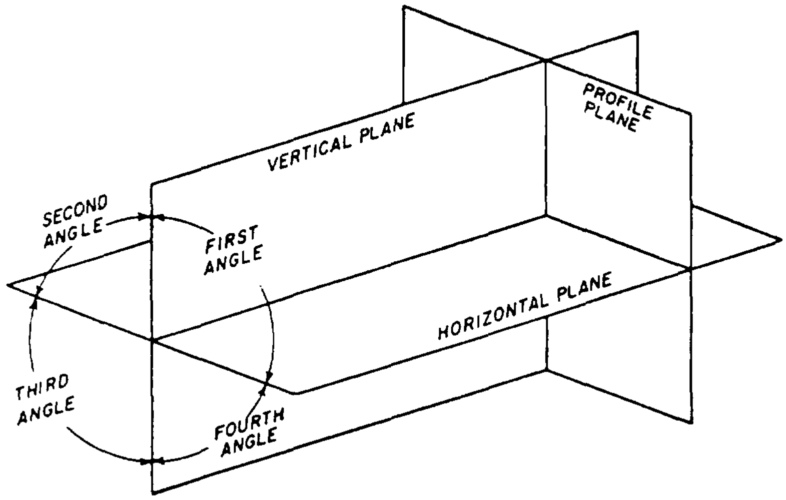


Figure 5-4.-Primary (principal) planes of projections.

is normally placed between the point of sight and the object. For the purpose of studying any type of projection, it must be assumed that the planes of projection are in fixed positions. Once the object is placed in a definite imagined position, it should never be changed. If a different view of the object is desired, the location of the point of sight is changed.

The PROJECTION LINES (or LINES OF SIGHT) are the imaginary lines from the eye of the viewer (point of sight) to points on the object (fig. 5-2). By the use of projection lines, points on the object are projected on the image plane. These points are the points at which the projection lines appear to pierce the image plane. By the projection of the prominent points, lines, and surfaces of an object, a complete view of that object can be projected on the plane of projection.

The relationship between the point of sight (station point), the plane of projection (image plane), the projection lines (lines of sight), and the manner in which they are used for each individual type of projection will be discussed in the following sections.

ORTHOGRAPHIC PROJECTION

When you are called upon to draw a three-dimensional object or figure, it is customary to represent the parts and forms on the flat plane of the drafting paper in such a manner that all features are shown in their true dimensions and in their true relationship with other features on that part of the object. To do this, you must draw a number of views of the object from different angles. Projecting these essential views into a single plane is known as ORTHOGRAPHIC PROJECTION. The term *orthographic is* derived from the word *orthos* meaning perpendicular or right-angular.

Multi-view Projection

When an object is viewed through a plane of projection from a point at infinity, an accurate outline of the visible face of the object is obtained (fig. 5-3). However, the projection of one face usually will not provide an overall description of the object; other planes of projection must be used. Establishing an object's true height, width, and depth requires front, top, and side views, which are called the PRINCIPAL PLANES OF PROJECTION. Figure 5-4 shows the three principal (or primary) planes of projection, known as the VERTICAL, HORIZONTAL, and PROFILE PLANES. The angles formed between the horizontal and the vertical planes are called the FIRST, SECOND, THIRD, and FOURTH ANGLES, as indicated in the figure. Currently, however, for technical reasons, only the use of first- and third-angle projection is practical.

FIRST-ANGLE PROJECTION.— A fine example of first-angle projection using a cube is

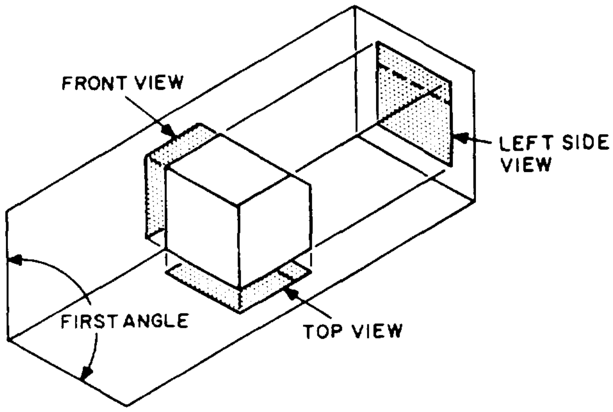


Figure 5-5.-Elample of a first-angle projection.

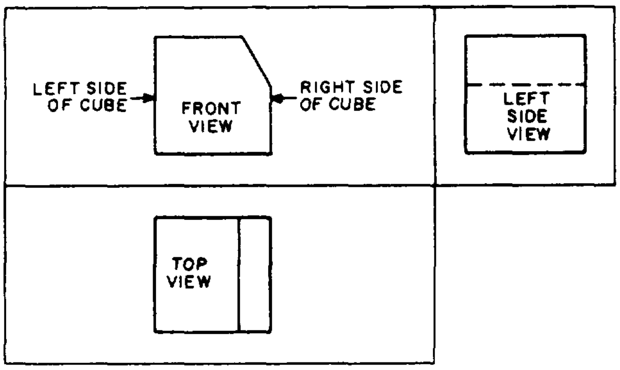


Figure 5-6.-Firsl-angle projection brought into a single plane.

shown in figure 5-5. The cube is supposed to be fronting toward the vertical plane of projection. As you can see, you get a front view on the vertical plane, a left side view on the profile plane, and a top view on the horizontal plane.

Now, to put these views on a sheet of drafting paper, you must get them all into the same plane. You presume that the vertical plane of projection is already in the plane of the paper. To get the other two views into the same plane, you rotate the profile plane counterclockwise and the horizontal plane clockwise. The projection now appears as shown in figure 5-6.

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

THIRD-ANGLE PROJECTION.— Figure 5-7 shows a third-angle projection of a cube. As you can see, you get a front view on the vertical plane, a top view on the horizontal plane, and a right side view on the profile plane.

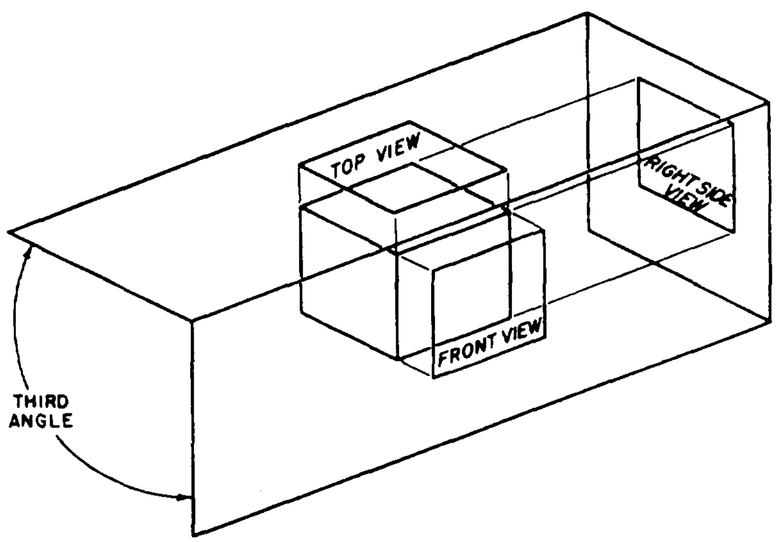


Figure 5-7.-Example of a third-angle projection.

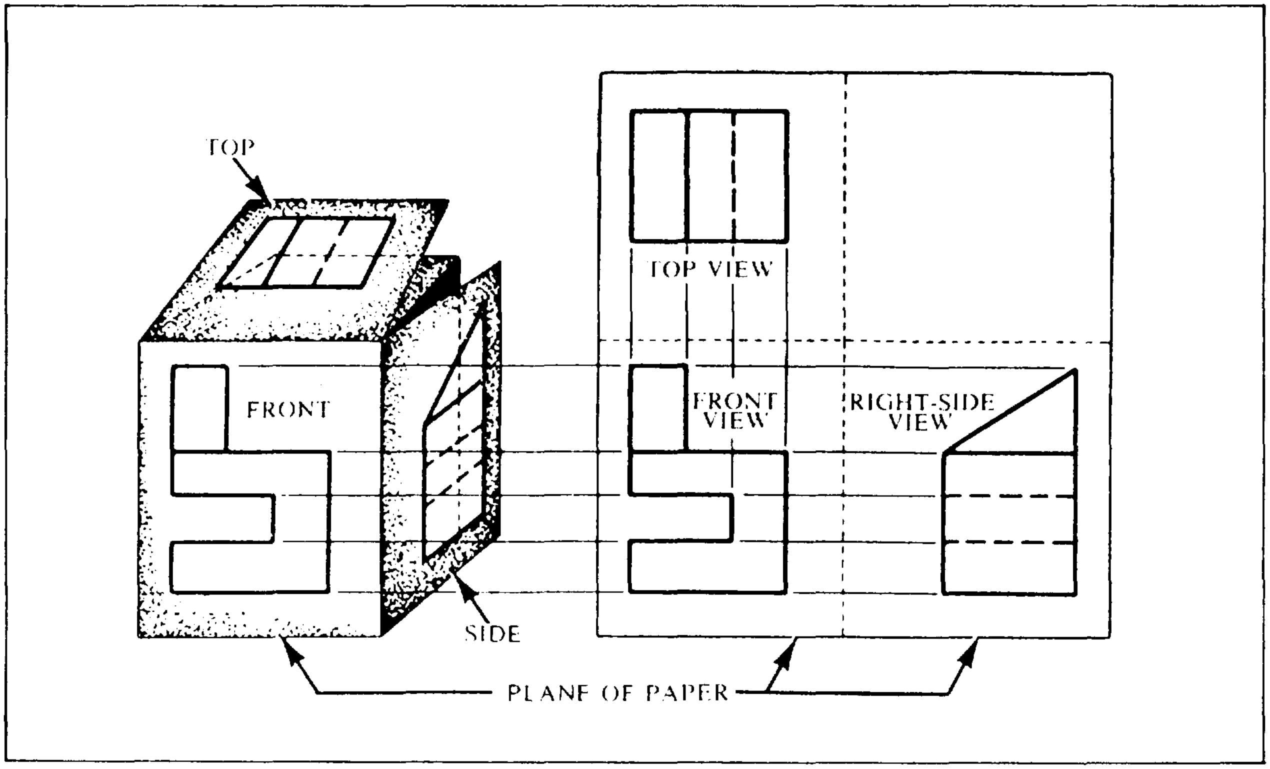


Figure 5-8.-A third-angle projection brought into a single plane.

Again you assume that the vertical plane is already in the plane of your drawing paper. To get the other two views into the same plane, you rotate them both clockwise.

Figure 5-8 shows a third-angle projection of an object brought into a single plane. The top view is above the front view; the right side of the object, as shown in the front view, is toward the right side view; and the top, as shown in the front view, is toward the top view.

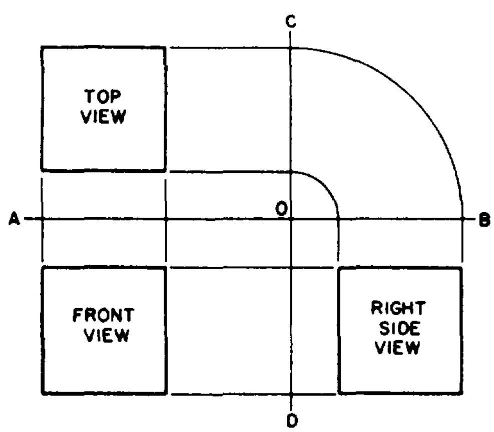


Figure 5-9.-Method of making a third-angle projection.

Figure 5-9 shows the basic principles of the method by which you would actually make the projection shown in figure 5-8. Draw a horizontal line AB and a vertical line CD, intersecting at O. AB represents the joint between the horizontal and the vertical plane; CD represents the joint between these two and the profile plane. Any one of the three views could be drawn first, and the other two projected from it. Assume that the front view is drawn first on the basis of given dimensions of the front face. Draw the front view, and project it upward with vertical projection lines to draw the top view. Project the top view to CD with horizontal projection lines. With O as a center, use a compass to extend these projection lines to AB. Draw the right side view by extending the projection lines from AB vertically downward and by projecting the right side of the front view horizontally to the right.

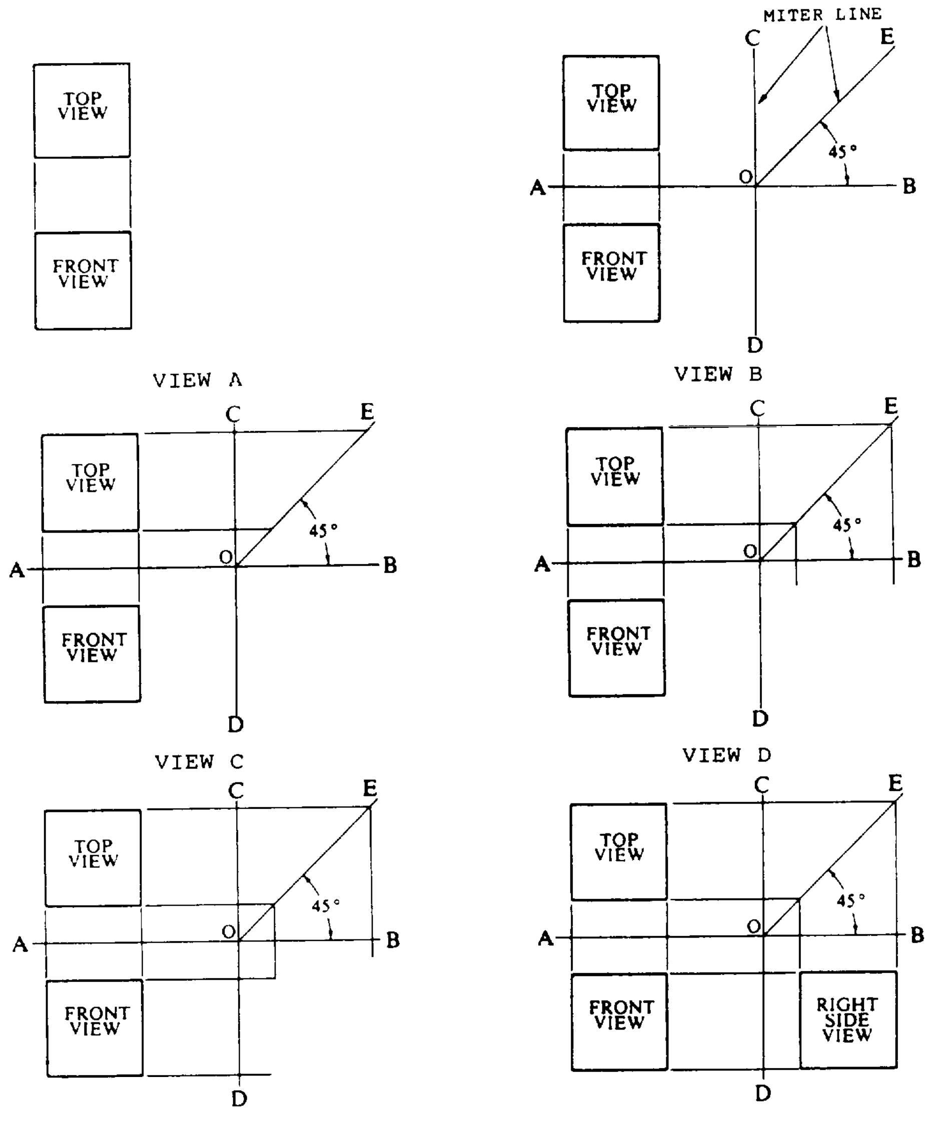


Figure 5-10.-Use of a miter line.

USE OF A MITER LINE.— A miter line (fig. 5-10) offers a convenient method of laying out a third view while you are in the process of drawing two views. Place the miter line (fig. 5-10, view B) to the right of the top view at a convenient distance, keeping the appearance of a balanced drawing. Draw light projection lines from the top view to the miter line (fig. 5-10, view C), then vertically downward (fig. 5-10, view D). Using the front view, draw horizontal projection lines (fig. 5-10, view E) to the right, intersecting the vertical projection lines. The result of this procedure is the outline and placement of the right side view (fig. 5-10, view F).

Some EAs prefer to extend the top view projection lines to the right side view using the alternate method shown in figure 5-11.

ARRANGEMENT OF VIEWS.— The six principal views of an object drawn in a third-angle projection are arranged according to the American standard arrangement of views. This arrangement (practiced since the late 1800s) depicts the relative position of the six principal views and their relationship to each other on a drafting plane.

As shown in figure 5-12, all views (except the front view) are rotated toward the observer as though they are hinged. REMEMBER, the front

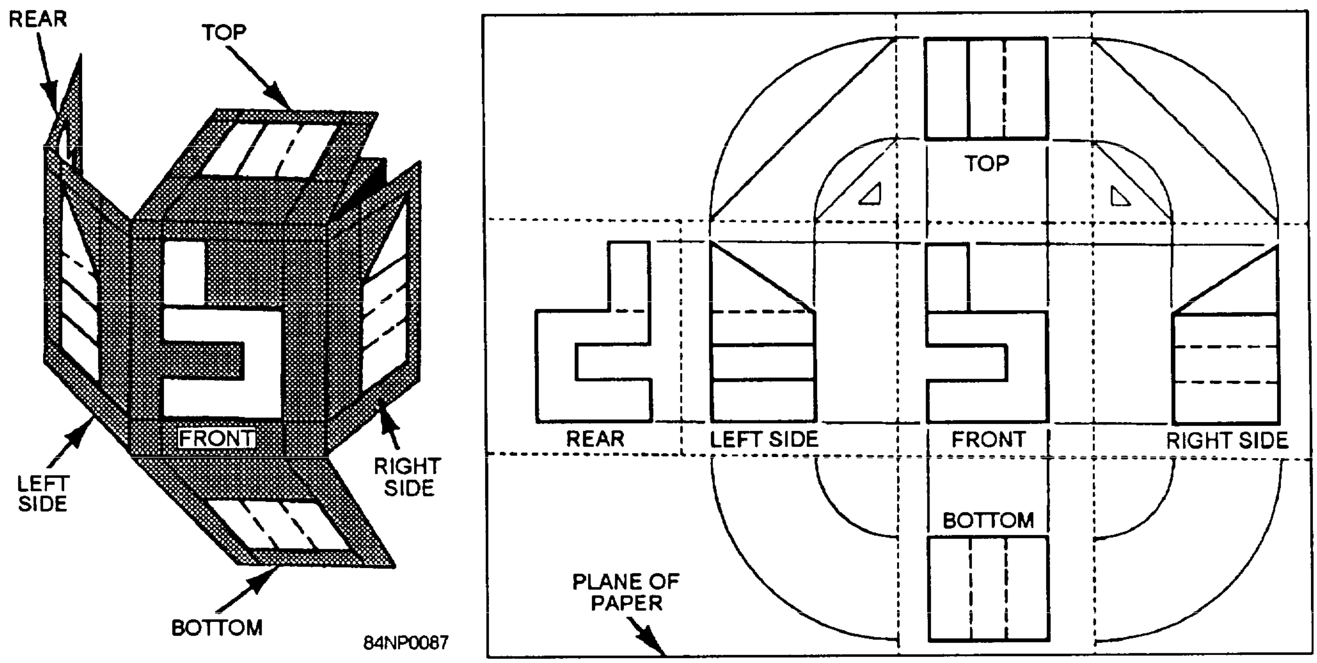


Figure 5-12.-American standard arrangement of views in a six-view third-angle multi-view projection.

view always lies in the plane of the drafting surface and does not require any rotation. Notice that the front, right side, left side, and rear views lineup in direct horizontal projection.

Use the minimum number of views necessary to show an item. The three principal views are the top, front, and right-side. The TOP VIEW (also called a PLAN in architectural drawings) is projected to and drawn on an image plane above the front view of the object. The FRONT VIEW (ELEVATION) should show the most characteristic shape of the object or its most natural appearance when observed in its permanent or fixed position. The RIGHT-SIDE VIEW (ELEVATION) is located at a right angle to the front and top views, making all the views mutually perpendicular.

SPACING OF VIEWS.— Views should be spaced on the paper in such a manner as

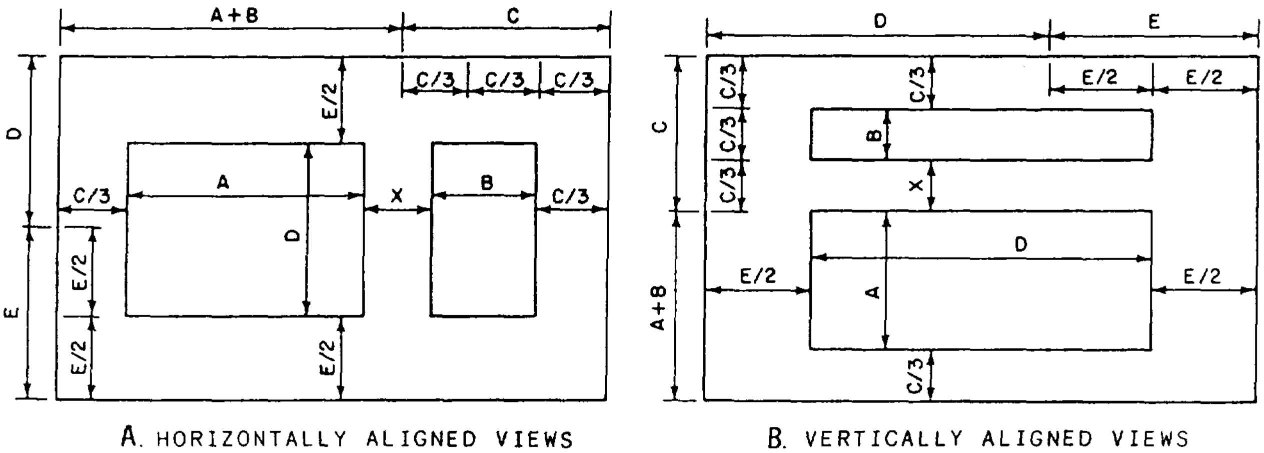


Figure 5-13.-Proper spacing of views.

give the appearance of a balanced drawing. An easy way to locate horizontally aligned views on a standard size drawing sheet is shown in figure 5-13, view A. With a compass or scale, lay off the length plus the width of the object (A + B) from one end of the horizontal margin. Divide the remaining distance, C, into three equal parts (C/3). This will be the approximate distance from either view to the vertical margin. The two views should be equidistant from the vertical margin. The spacing between views should be adjusted so that the apparent area is close to the apparent area between either view and the vertical margin. Basically, the shape of the object will determine the space between views. Generally, the distance from the views to the vertical margins and the distance between views (X) will be approximately equal. To locate the views vertically on the paper, lay off the depth of the object (D) on the vertical margin. Divide the remaining distance (E) into two equal parts (E/2). This will be the approximate distance from the top or bottom of the view to the horizontal margins.

The same method also applies to vertically aligned views on a standard size drawing sheet, as shown in figure 5-13, view B.

Proper spacing of a three-view drawing is shown in figure 5-14. As you can see, the principle is the same as that applied in spacing a two-view drawing. Distances are again equal as indicated, with distance B equal to, or slightly less than, distance A, and distance D equal to, or slightly less than, distance C.

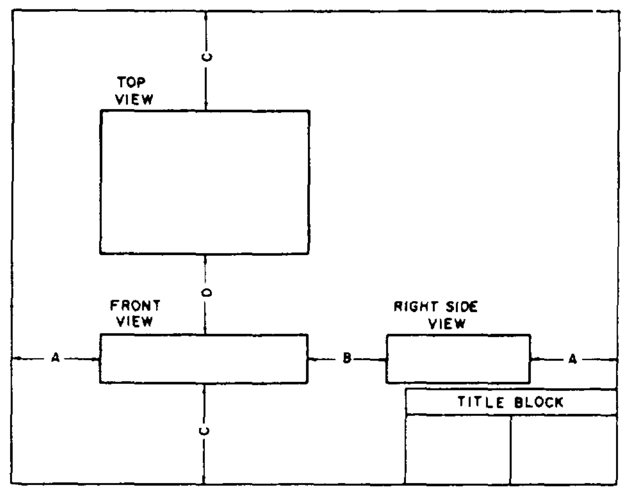


Figure 5-14.-Proper spacing of views on a three-view projection.

While the spacing of views in figure 5-14 is technically correct, the drawing has an unbalanced appearance because of the large area of empty space in the upper right corner and because the right side view crowds the title block. If the drawing will contain a sizeable bill of materials in the upper right corner, this spacing will be satisfactory. If not, it should be improved, if possible.

If the object is one that allows an arbitrary choice with regard to the designation of surfaces as top, front, and so on, the spacing can be improved by changing the designation shown in figure 5-14 and projecting the object as shown in figure 5-15. That which appears as the top in

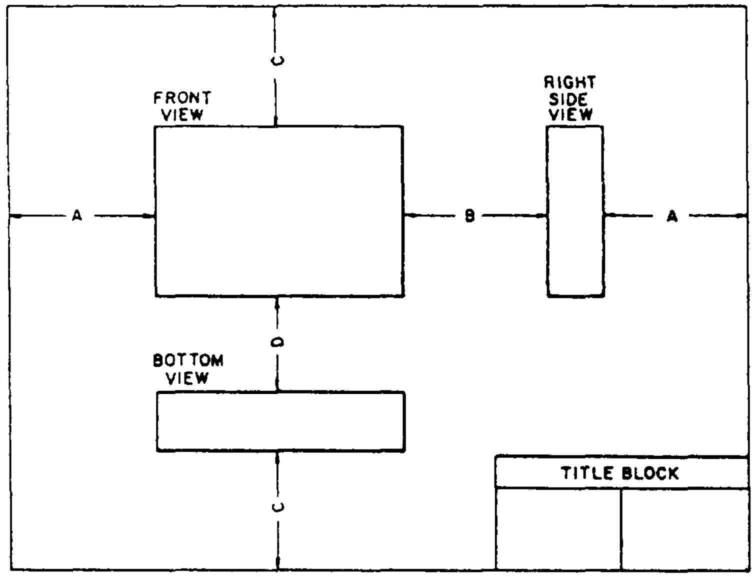


Figure 5-15.-Improved spacing for three-view projection of object shown in figure 5-18.

figure 5-14, you can now call the front; it follows that which appears as the front in figure 5-14 appears as the bottom in figure 5-15. Again the right side view appears, but it now appears in the upper, rather than the lower, right corner and vertically rather than horizontally.

Spacing views in a drawing of a circular object is like spacing letters; you try to equalize the areas of the spaces around and between the views. Figure 5-16 shows properly spaced two-view drawings of a perforated disk. For the views that are horizontally in line, you locate the horizontal center line midway between the horizontal margins; for the views that are vertically in line, you locate it midway between the vertical margins. The other spacing is as indicated. To determine the lengths of distances A and 2/3 A, set a compass to the diameter plus the thickness of the disk, and lay off this distance on the margin. Then divide the remaining segment of the margin into three intervals, two of them being equal, and the third one being 1 1/2 times as long as each of the others.

VIEW ANALYSIS.— You must be able to analyze a multi-view projection or, in other words, to determine what each line in a particular view represents. In this connection, it is helpful to remember that in a third-angle projection, the plane of projection is always presumed to be between the object and the observer, regardless

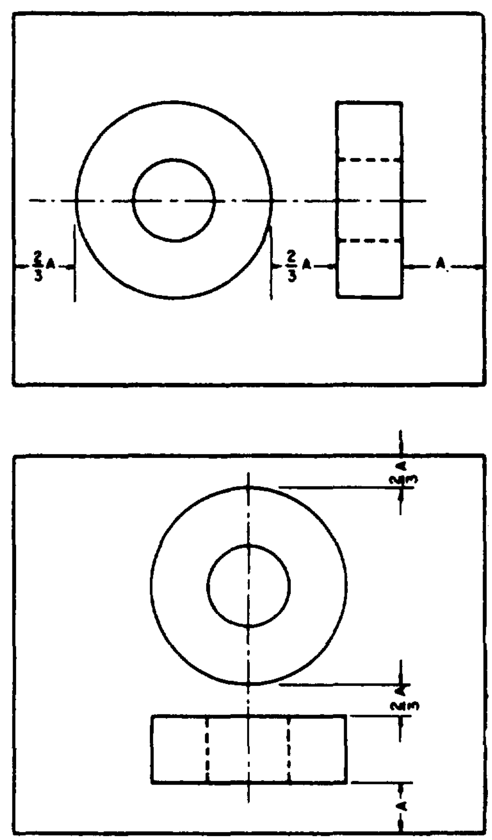


Figure 5-16.-Spacing of views of a circular object,

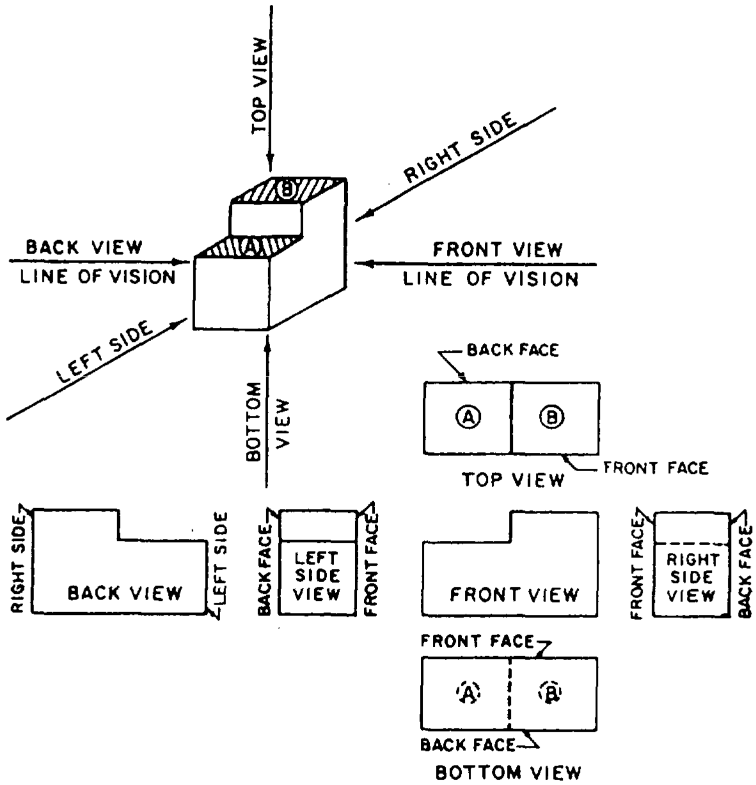


Figure 5-17.-Multi-view analysis of a third-angle orthographic projection.

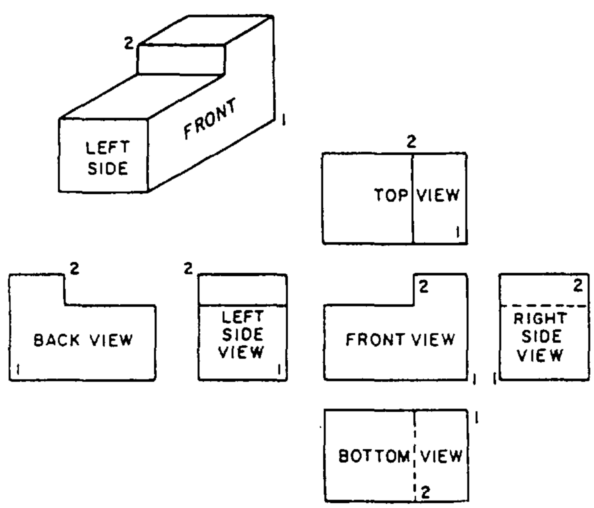


Figure 5-18.-Procedure for numbering hidden and visible corner points.

of which view you are considering. This means that, in a third-angle projection, each view of a surface of an object is a view of that surface as it would appear to an observer looking directly at it.

Figure 5-17 shows a six-view multi-view third-angle projection of the block shown in a single-view projection in the upper left corner of the figure. You should not have any trouble analyzing the front view; you know that the top is up, the bottom is down, the left side is to the left, and the right side is to the right.

In the top and bottom views, it's easy to see that the right-hand vertical line represents the right side and the left-hand vertical line, the left side. But you might have to think a minute to realize that the upper horizontal line in the top view represents the back face of the block, while the upper horizontal line in the bottom view represents the front face of the block. Note, also, that there is a line that appears as a visible line in the top view and as a hidden line in the bottom view.

In the right side and left side views, you can readily see that the upper horizontal line represents the top of the block and the lower horizontal line, the bottom. But you may have to think a minute to realize that the left-hand vertical line in the right side view represents the front face of the block, while the left-hand vertical line in the left side view represents the back face. Again, there is a line that appears as a visible line in the right side view and as a hidden line in the left side view.

In the back view, the block is shown reversed, so that the cutaway part, which appears to the right in the front view, appears to the left in the back view. Similarly, the right-hand vertical line in the front view represents the right side of the block, while the right-hand vertical line in the back view represents the left side.

As a general observation, it is helpful in view analysis to note that in the top, bottom, and side views, the line that represents the front face of the block faces toward the front view of the block. Similarly, in the back view, the line that represents the left side faces toward the left side view of the block. This applies to third-angle projection only.

A point that constitutes a corner on an object is sometimes numbered for purposes of identification in various views of the object. In a particular view of an object, a corner point number may be visible, or it may be hidden, as shown in figure 5-18. In the upper left corner of the figure, there is an oblique projection of a block, with a corner numbered 2. You can see that this corner is visible in top, back, and left side views, but hidden in bottom, front, and right side views.

The rule for numbering is that for a hidden corner point, the number is placed within the outline, and for a visible corner point, outside the outline. You can see how the rule has been followed in figure 5-18.

A multi-view projection should contain only as many views as are required to describe the object fully. If you refer back to figure 5-17, you can see at once that the back view does not convey any information that is not available in the front view; the back view is therefore superfluous and should be omitted. The same applies to the bottom view, which conveys no information not available in the top view. Likewise, the left side view conveys no information not available in the right side view.

You have the choice of omitting either the top or bottom view and either the right side or left side view. One general rule in this instance is that a top view is preferable to a bottom view and a right side view, to a left side view; another rule is that a view with a visible line is preferable to a view with the same line shown as a hidden line. Both rules apply here to eliminate the bottom and the left side views. All you need here is a three-view projection showing the top, front, and right side views.

It is often the case that a two-view projection is all that is required. The view at the top of figure 5-19 shows a single-view projection of an object. It is obvious that a top view of this object tells you everything you need to know except the thickness; a right side view tells you everything you need to know except the length; and a front view tells you everything you need to know except the width. All you need to do, then, is to select a particular view and couple it with another view that gives you the dimension that is missing in the first view.

There are three possible two-dimensional projections of the object shown in A, B, and C. In the selection of one of these three, everything else being equal, the balance of the drawing would be the deciding factor. Either A or B appears better balanced than C, and between A and B, A would look better on a long oblong sheet of paper, and B, better on a shorter oblong sheet.

The object shown in figure 5-19 has a definitely designated top and front; it follows that the right and left sides are also definitely designated. This is the case with many objects; you have no choice, for example, with regard to the top, bottom, front, and back of a house.

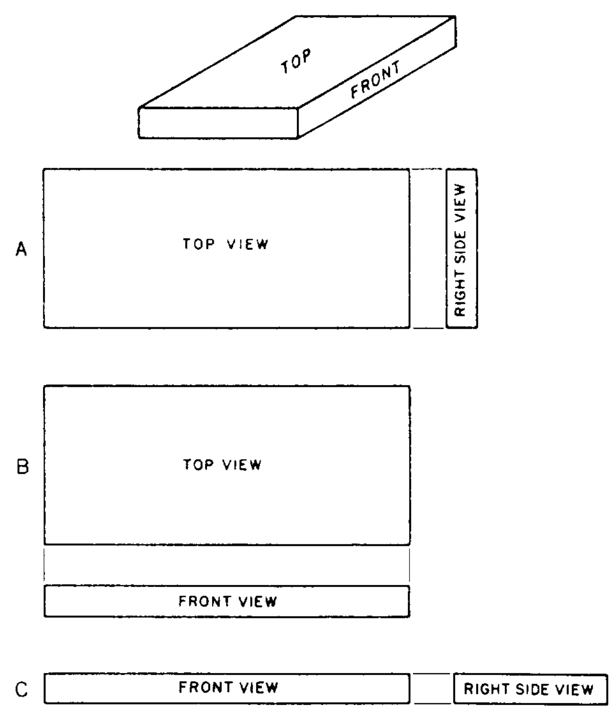


Figure 5-19.-Two-view multi-view projections.

Many objects, however, have no definite top, bottom, front, or back—as many types of machine parts, for example. With an object of this kind, you can select a surface and call it the front, and select another and call it the top, according to convenience. However, it is a general rule that an object should be shown in the position it customarily occupies.

One-view drawings are permissible for objects for which one view and such features as thickness or length, stated as a dimension or note, can completely define the object.

NORMAL AND NON-NORMAL LINES.— In a multi-view orthographic projection, a NORMAL line is one that is parallel to two of the planes of projection and perpendicular to the third. A line that is parallel to a plane of projection will appear on that plane in its true length (to the scale of the drawing). A line that is perpendicular to a plane of projection will appear on that plane as a point.

A line that is perpendicular to one plane of projection must of necessity be parallel to the other two. But a line that is parallel to one plane of projection may be oblique (neither parallel nor perpendicular) to one or both of the others. A line that is oblique to one or more of the planes of projection is called a NON-NORMAL LINE.

If a non-normal line is parallel to a plane of projection, it will appear on that plane in its true length. However, it will appear foreshortened in a view on a plane to which it is oblique. A non-normal line may, of course, be oblique to all three planes of projection, in which case it will appear foreshortened in all regular views of the object. A REGULAR VIEW is a view on one of the three regular planes of projection (horizontal, vertical, or profile). Views on planes other than the regular planes are called AUXILIARY VIEWS. Auxiliary views will be discussed later in this chapter.

A single-view projection of a block is shown in the upper left corner of figure 5-20. This block is presumed to be placed for multi-view projection with the front parallel to the vertical plane, the bottom parallel to the horizontal plane, and the right side parallel to the profile plane. The line AB, then, is parallel to the vertical plane, but oblique to both the horizontal and the profile planes.

In the multi-view projections, you can see that it is only in the views on the vertical plane (the front and back views) that the line AB appears in its true length. In the views on the horizontal

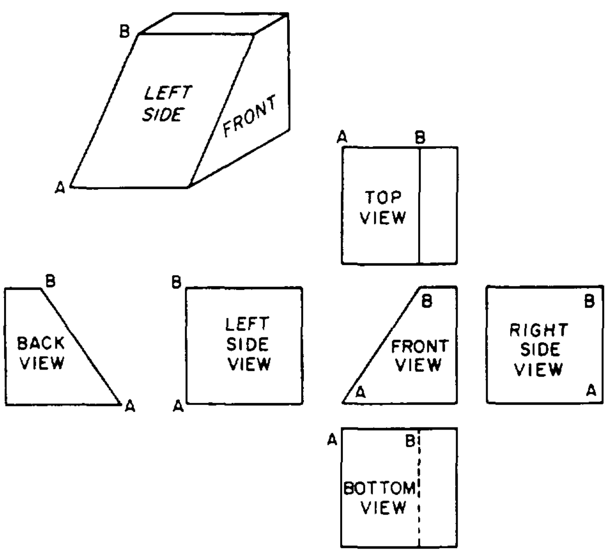


Figure 5-20.-Foreshortening of a line in a multi-view projection.

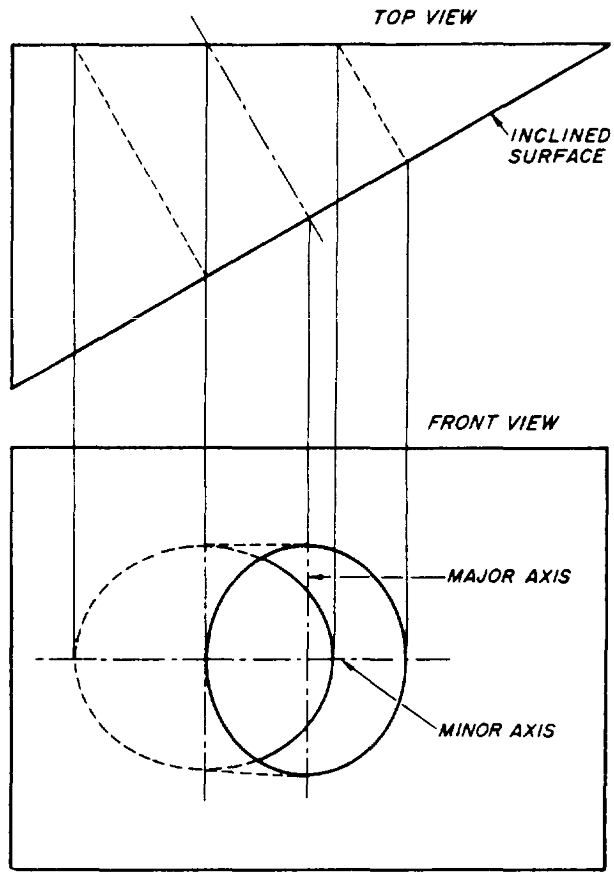


Figure 5-21.-A circle on a surface oblique to the plane of projection projected as an ellipse.

plane (top and bottom views) and in the views on the profile plane (right and left side views), the line appears foreshortened. Note, however, that you don't need to calculate the amount of the foreshortening, since it works itself out as you project the various views.

CIRCLES IN MULTI-VIEW ORTHOGRAPHIC PROJECTION.— A circle on a surface that is parallel to the plane of projection will project as a circle. A circle on a surface that is oblique to the plane of projection, however, will project as an ellipse, as shown in figure 5-21. The upper view in this figure is a top view of a wedge, the wedge having a hole bored through it perpendicular to the inclined face. The outline of this hole on the front face of the wedge projects as an ellipse in the front view. You get the minor axis of the ellipse by projecting downward as shown. The length of the major axis is equal to the diameter of the hole.

Another ellipse is shown in the front view. This is the partly hidden and partly visible outline of the hole as it emerges through the back of the wedge. The back of the wedge is parallel to the front view plane of projection; therefore, this ellipse is the true outline of the hole on the back of the wedge. The outline is elliptical because the hole, though it is circular, is bored obliquely to the back face of the wedge.

To draw these ellipses, you could use any of the methods of drawing an accurate ellipse explained in the previous chapter on geometric construction, or you could use an ellipse template.

AUXILIARY VIEWS.— In theory, there are only three regular planes of projection: the vertical, the horizonal, and the profile. Actually, it is presumed that each of these is, as it were, double; there is, for example, one vertical plane for a front view and another for a back view.

We assume, then, a total of six regular planes of projection. A projection on any one of the six is a regular view. A projection NOT on one of the regular six is an AUXILIARY VIEW.

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

In the upper left of figure 5-22, there is a single-view projection of a triangular block, the base of which is a rectangle. This block is presumed to be placed for multi-view projection

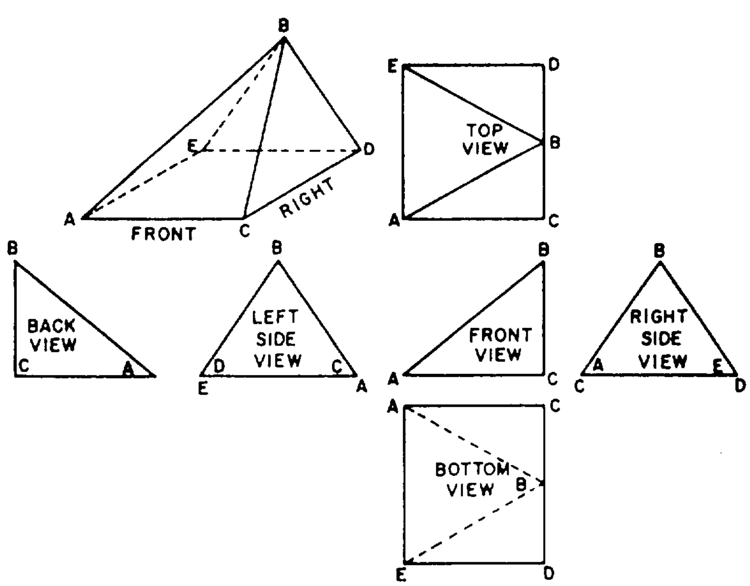


Figure 5-22.-A line oblique to all planes of projection is foreshortened in all views.

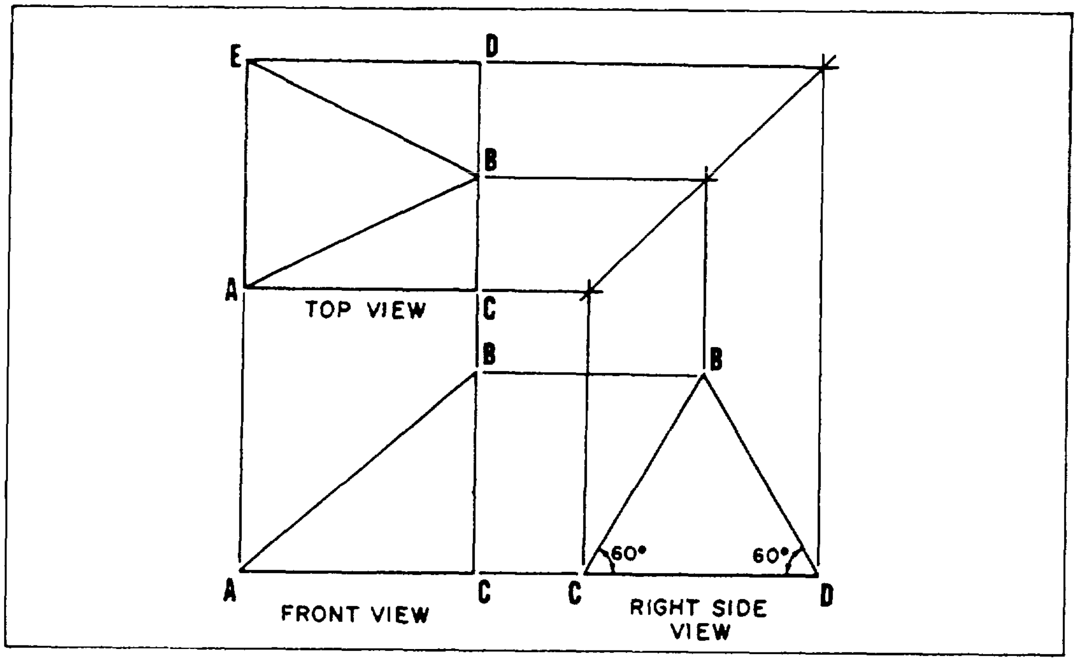


Figure 5-23.-Normal multi-view projection.

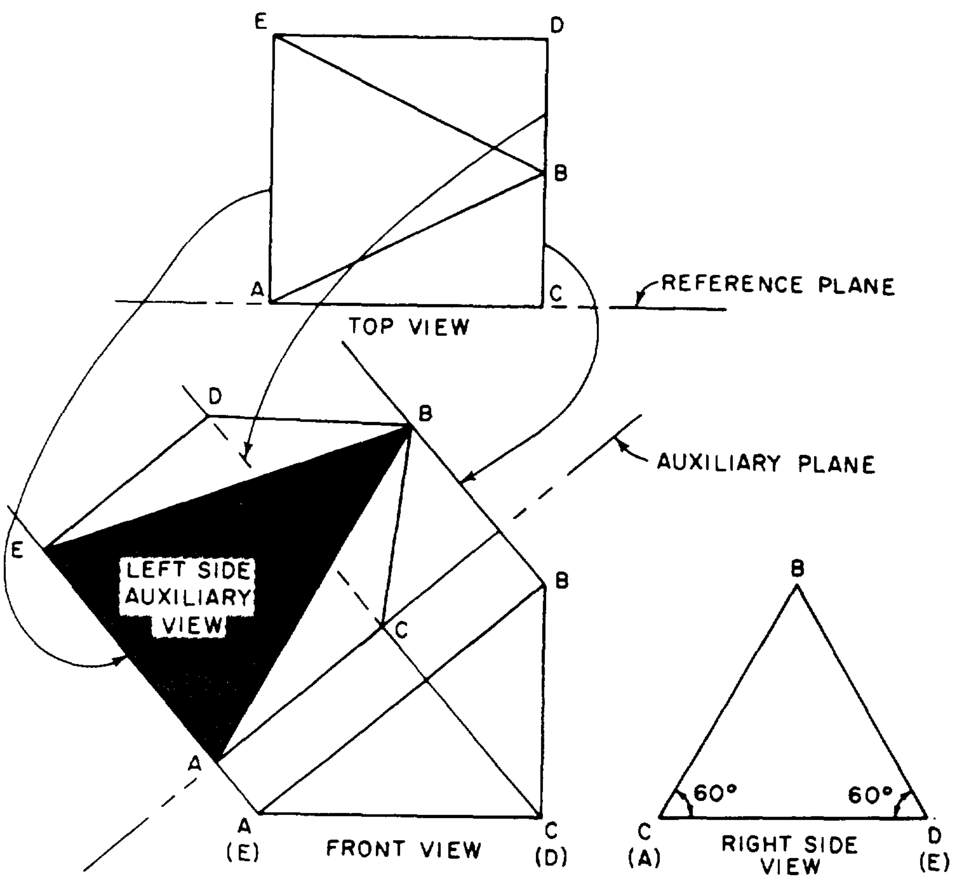


Figure 5-24.-Projection of left side auxiliary view.

with the right side parallel to the profile plane. The block is then drawn, using all six views of multi-view projection.

By careful examination of figure 5-22, you will see that the lines AB, AE, BD and BC and the surfaces ABC, ABE, and BDE are oblique to three regular planes of projection. The lines are foreshortened and the surfaces are not shown in their true shape in any of the six normal views.

The first step in the drawing of any auxiliary view is to draw the object in normal multi-view projection, as shown in figure 5-23. A minimum of two orthographic views is necessary. The space between these views is generally greater than normal. The reason for this will become apparent. Notice in figure 5-23, in the front view, that A is the end point of line AE (top view) and C is the end point of CD.

The second step is to decide which line or surface is to be shown in an auxiliary view and which orthographic view it will be projected from. The following facts must be considered when rendering this decision:

1. Front or rear auxiliary views are always projected from a side view.
2. Right or left auxiliary views are always projected from a front view.
3. An elevation auxiliary view is always projected from the top view.

The third step is to select the auxiliary and reference planes. The auxiliary plane is simply a plane parallel to the desired line or lines representing an edge view of the desired surface. In figure 5-24, the true length of line AB and the true shape of surface ABE are desired. A left side auxiliary view is needed. The auxiliary plane is drawn parallel to line AB in the front view. Line AB actually represents an edge view of surface ABE. The reference plane (top view) represents an edge view of the orthographic view (front view) from which the auxiliary view will be projected. Therefore, when front, rear, or side auxiliary views are desired, the reference plane will always be in the top view. When elevation auxiliary views are drawn, the reference plane may be in any view in which the top view is represented by a straight line. The reference plane in figure 5-24 is the edge of the top view that represents the front view. Remember that, although these planes are represented by lines, they are actually planes running perpendicular to the views.

Step four is to project and locate the points describing the desired line or surface. Draw the projection lines from the orthographic view perpendicular to the auxiliary plane. Then take the distances from the reference plane, whether by scaling or with a compass. The distances are the perpendicular distances from the reference plane to the desired point. In figure 5-24, the projection lines are drawn from points A, B, and C in the front view, perpendicular to the auxiliary plane. The projection line from point A indicates the line on which point E will also be located. The projection line from point C designates the line of both C and D, and that from B locates B only. To transfer the appropriate distances, first, look for any points lying on the reference plane. These points will also lie on the auxiliary plane where their projection lines intersect it (points A and C). To locate points B, D, and E, measure the perpendicular distances they are from the reference plane in the top view and transfer these distances along their respective projection lines in the auxiliary view. The points are equidistant from both the reference and auxiliary planes. Therefore, any line parallel to the reference plane is also parallel to the auxiliary plane and equidistant from it.

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

Those points and lines lying furthest away from the auxiliary plane in the orthographic view being projected from are always beneath any point or line that is closer. In figure 5-24, point C (representing line CD) in the front view is further from the auxiliary plane than any line or surface it will cross in the auxiliary view. Therefore, it will appear as a hidden line.

The final step is to label and dimension the auxiliary view. The labeling must include an adequate description. The term AUXILIARY must be included along with the location of the view in relation to the normal orthographic views (LEFT SIDE AUXILIARY VIEW, REAR ELEVATION AUXILIARY VIEW, and so forth). Dimensions are given only to those lines appearing in their true length. In figure 5-24, only lines AB, AE, and BE on the auxiliary view should be dimensioned.

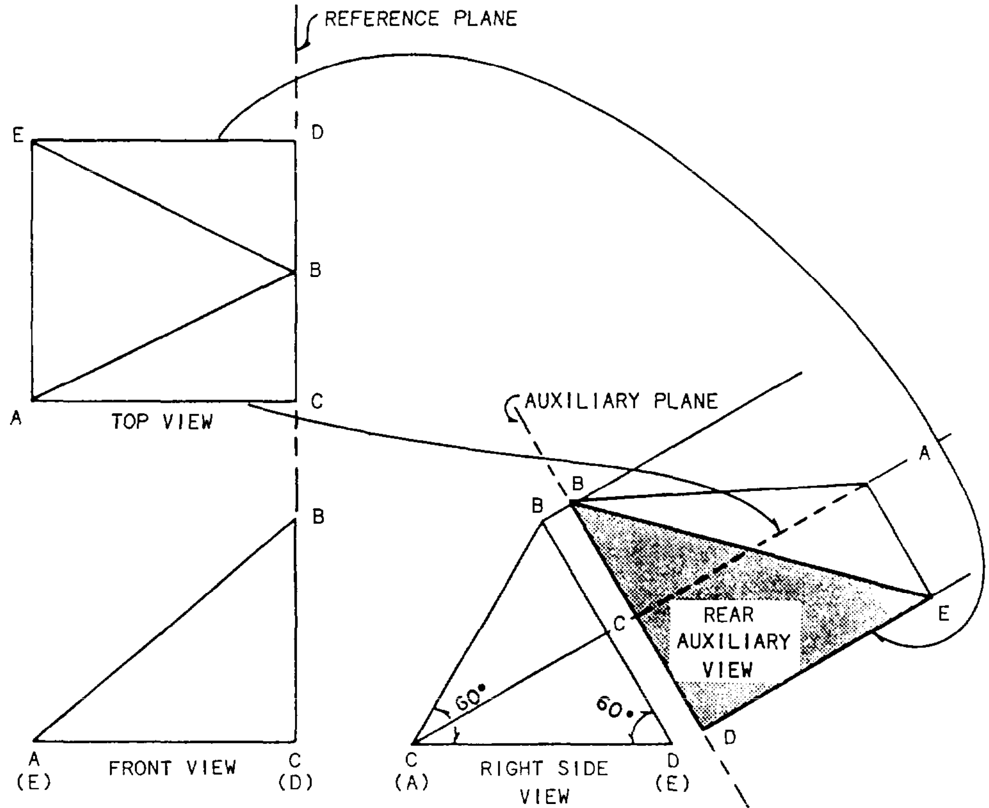


Figure 5-25.-Projection of rear auxiliary view.

Using the procedures previously described, follow the steps taken to project and draw the rear auxiliary view in figure 5-25.

Sometimes the total auxiliary view is not needed. Such a view could possibly even make the drawing confusing. In this case, a PARTIAL AUXILIARY VIEW is used. Only the points or lines needed to project the line or surface desired are used. This reduces the number of projection lines and greatly enhances the clarity of the view. If a partial auxiliary view is used, then it must be labeled PARTIAL to avoid confusion. In figure 5-24, if only the true length of line AB is desired, the points A and B would be projected and connected. The view would be complete after it was labeled and dimensioned.

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

AUXILIARY SECTION.— An auxiliary view maybe a sectional, rather than a surface, view. In the upper left part of figure 5-26, there is a single-view projection of a block. It is desired to show the right side of the block as it would appear if the block were cut away on the plane indicated by the dotted line, the angle of observation to be perpendicular to this plane. The desired view of the right side is shown in the auxiliary section, which is projected from a front view as shown. Because the auxiliary plane of projection is parallel to the cutaway surfaces, these surfaces appear in true dimensions in the auxiliary section.

A regular multi-view of an orthographic drawing is one that is projected on one of the

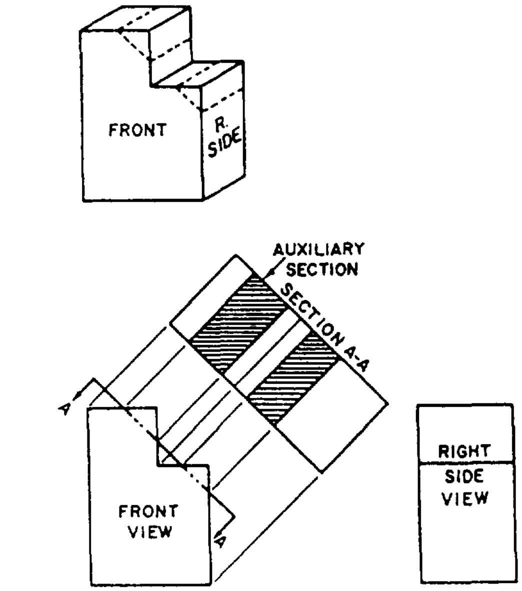


Figure 5-26.-Use of an auxiliary section.

regular planes of projection. An auxiliary view is one that is projected on a plane other than one of the regular planes.

A rectangular object is in normal position for regular multi-view orthographic projection when each of its faces is parallel to one regular plane of projection and perpendicular to the other two. This is the case with the object shown in figure 5-27, view A.

USE OF REVOLUTIONS.— In a REVOLUTION, the object is projected on one or more of the regular planes of projection. However, instead of being placed in normal position, the object is revolved on an axis perpendicular to one of the regular planes.

Figure 5-27, view B, is a three-view multi-view projection showing the block in 5-27, view A, as it would appear if it were revolved 30 degrees on an axis perpendicular to the profile plane of projection. Figure 5-28, view A, shows how the

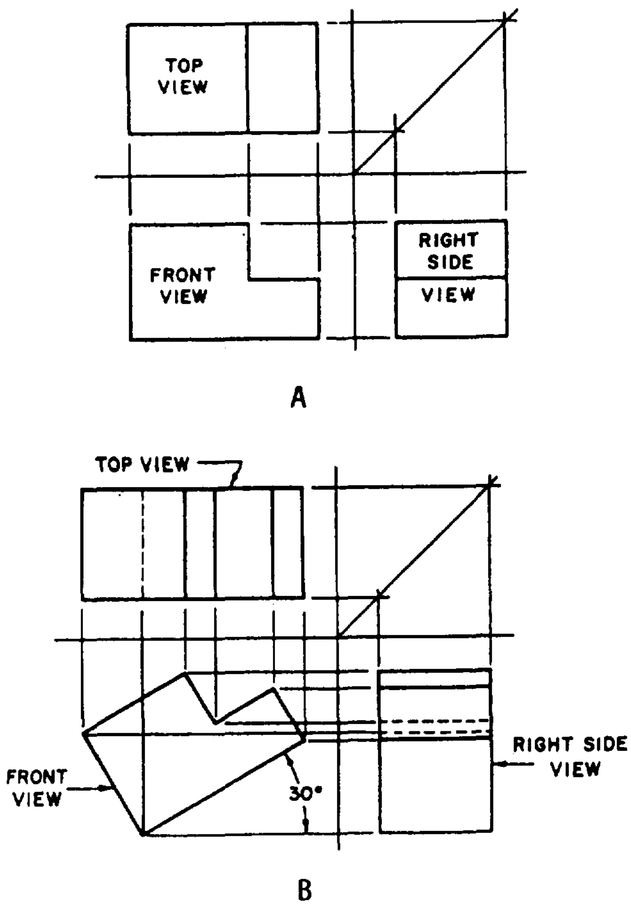


Figure 5-27.-A. Multi-view view of block in normal position; B. Multi-view view of block revolved 30 degrees on axis perpendicular to vertical plane.

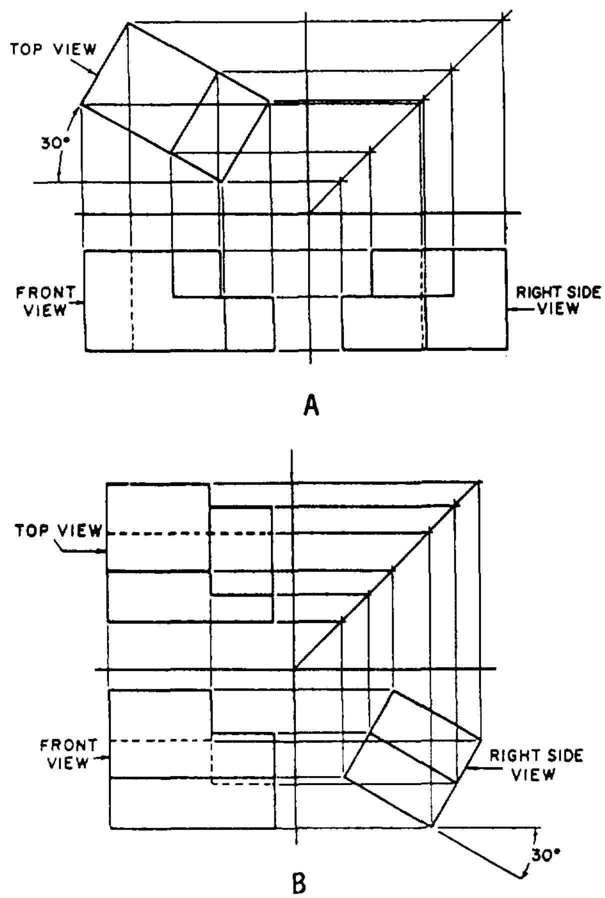


Figure 5-28.-Use of revolution on axis perpendicular to (A) horizontal plane and (B) vertical plane.

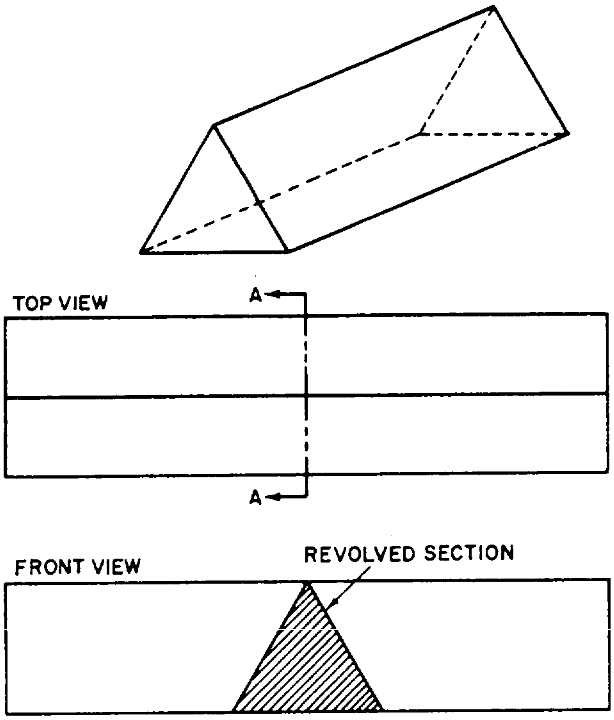


Figure 5-29.-Use of a revolved section (A-A).

block would look if it were revolved 30 degrees on an axis perpendicular to the horizontal plane. Figure 5-28, view B, shows the block as it would appear if it were revolved 30 degrees on an axis perpendicular to the vertical plane.

REVOLVED SECTIONS.— A common use of the revolution is the revolved section, shown in figure 5-29. At the top of this figure, there is a single projection of a triangular block. You can show all required information about this block in a two-view projection by including a revolved section in the front view as shown. You first assume that the block is cut by a plane perpendicular to the longitudinal axis. You then revolve the resulting section 90 degrees on an axis perpendicular to the horizontal plane of projection.

SECTIONING TECHNIQUES.— A sectional view is called for when the internal structure of an object can be better shown in such a view than it can by hidden lines. In the upperpart of figure 5-30, there is a single-view projection of a pulley. The same object is shown below in a two-view multi-view projection. The internal structure of the pulley is shown by the hidden lines in the top view.

In figure 5-31, the internal structure of the pulley is much more clearly shown by a sectional view. Note that hidden lines behind the plane of projection of the section are omitted in the

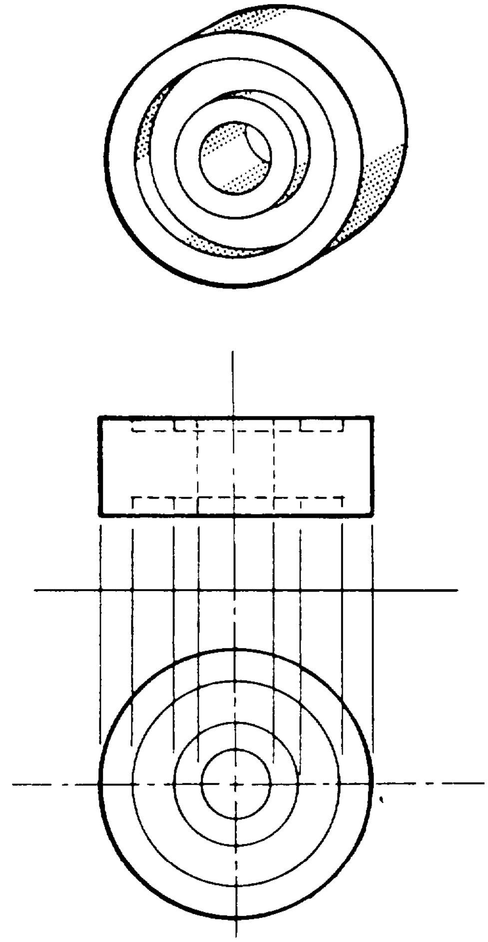


Figure 5-30.-Internal structure of an object shown by hidden lines.

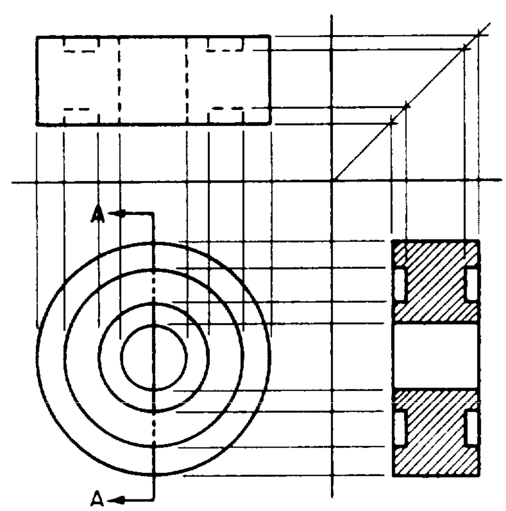


Figure 5-31.-Internal structure of an object more clearly shown by sectional view.

sectional view. These lines are omitted by general custom, the custom being based on the fact that the elimination of hidden lines is the fundamental reason for making a sectional view. However, any lines that would be VISIBLE behind the sectional plane of projection must be included in the sectional view.

The section shown in figure 5-31 is called a FULL SECTION because the cutting plane passes entirely through the object and divides it into two equal parts. Also, the object shown in figure 5-31 is a symmetrical object—meaning, in general, that the shape of one half is identical to the shape of the other. This being the case, you could have used a HALF SECTION like the one shown in figure 5-32. This half section constitutes one half of the full section. Because the other half of the full section would be identical with the half shown, it need not be drawn.

Note that a center line, rather than a visible line, is used to indicate the division between the sectioned and the unsectioned part of the sectional view. A visible line would imply a line that is actually nonexistent on the object. Another term used in place of center line is LINE OF SYMMETRY.

A section consisting of less than half a section is called a PARTIAL SECTION. (See fig. 5-33.) Note that here you use a break line to indicate the division between the sectioned and unsectioned part. For this reason, a partial section is often called a BROKEN SECTION.

The section lines drawn on a sectional surface always serve the basic purpose of indicating the limits of the sectional or cutaway surface. They may also indicate the type of material of which

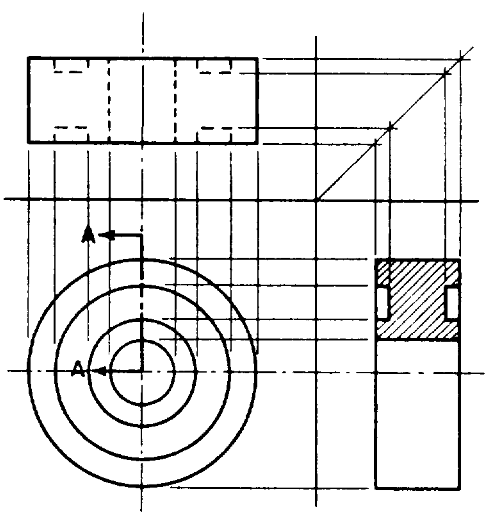


Figure 5-32.-Use of half section.

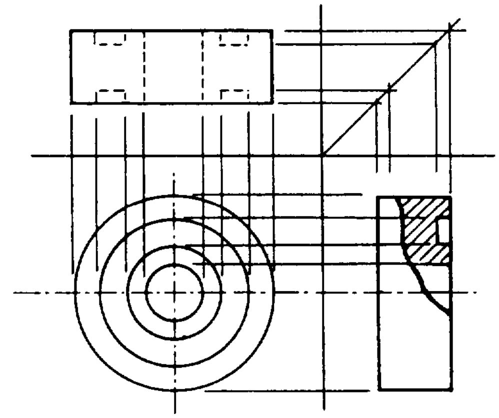


Figure 5-33.-Use of partial or broken section.

the sectioned surface consists. For example, in figure 5-34, view A shows section lining for an object made of cast iron. View B shows two matching parts made of steel, and view C shows three adjacent parts made of brass, bronze, or copper. For other symbolic section lining symbols, refer to ANSI Standard Y14.2.

In view of the vast numbers of different materials, and since drawings must always identify materials by lettered form, such as notes, it is usually more desirable, and it is common practice, to use a general purpose symbol for section lining. The general purpose symbol is the cast iron symbol shown in figure 5-34, view A. The use of other symbols, then, should be limited to those situations when it is truly desirable, or conventional, to graphically differentiate between materials. For example, in an assembly drawing (a drawing showing different papers fitted together), it is often desirable to differentiate materials.

On a regular multi-view section, section lining (sometimes called diagonal hatching or cross-hatching) should be drawn at 45° to the horizontal, as shown in figure 5-34, view A. However, if section liners drawn at 45° to the

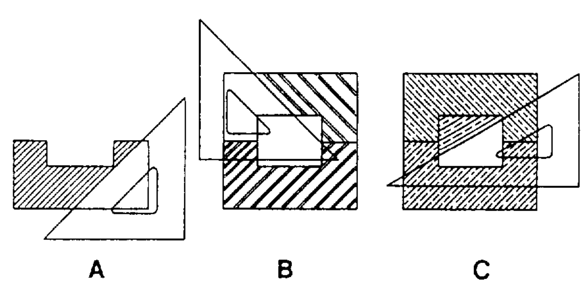


Figure 5-34.-Diagonal hatching on separate sectional surfaces shown in normal position.

horizontal would be parallel or perpendicular (or nearly so) to a prominent visible outline, the angle should be changed to 30°, to 60°, or some other angle. If two adjacent sectioned surfaces are shown, the hatching should be in opposite directions, as shown in figure 5-34, view B. If still a third surface is included, it should be hatched at another suitable angle to make the surface clearly stand out separately from the other surfaces (figure 5-34, view C). Note that the hatching lines on one surface are not permitted to meet those on an adjacent surface.

In drawing section lining, use a sharp, medium-grade pencil (H or 2H). Space the lines as uniformly as possible by eye. As a rule, spacing of the lines should be as generous as possible, yet close enough to distinguish the sectioned surface clearly. For average drawings, space the lines about 3/32 in. or more apart.

Diagonal hatching on an auxiliary section should be drawn at 45 degrees to the horizontal, with respect to the section. Figure 5-35 shows this rule.

In a revolution or other view of an object in other than the normal position, the diagonal hatching on a section should be drawn at 45 degrees to the horizontal or vertical axis of the object as it appears in the revolution. Figure 5-36 shows this rule.

Axonometric Projection

Axonometric single-plane projection is another way of showing an object in all three dimensions in a single view. Theoretically, axonometric projection is orthographic projection in that only one plane is used and the projection lines are perpendicular to the plane of projections. It is the object itself, rather than the projection lines, that is inclined to the plane of projection.

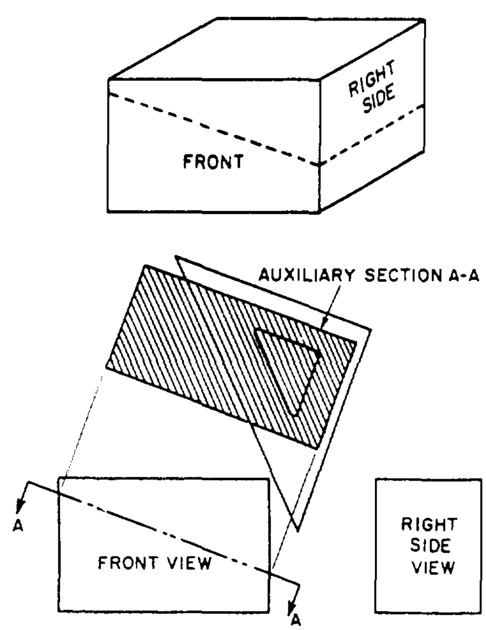


Figure 5-35.-Diagonal hatching on an auxiliary section.

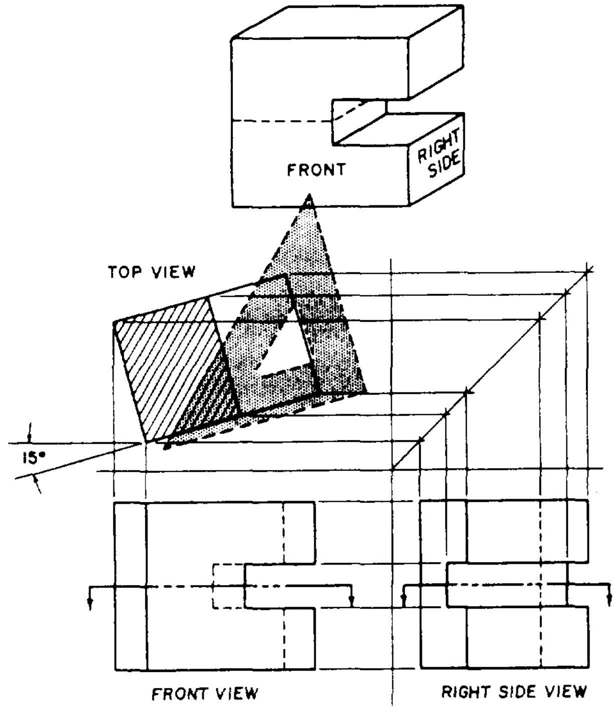


Figure 5-36.-Diagonal hatching on a revolution.

ISOMETRIC PROJECTION AND ISOMETRIC DRAWING.— Figure 5-37 shows a cube projected by ISOMETRIC PROJECTION, the most frequently used type of axonometric projection. The cube is inclined so that all of its surfaces make the same angle (35°16′) with the plane of projection. As a result of this inclination, the length of each of the edges shown in the projection is somewhat shorter than the actual length of the edge on the object itself. This reduction is called FORESHORTENING. The degree of reduction amounts to the ratio of 1 to the cosine of 35°16′, or 1/0.8165. This means that if an edge on the cube is 1 in, long, the projected edge will be 0.8165 in. long. As all of the surfaces make the same angle with the plane of projection, the edges all foreshorten in the same ratio. Therefore, one scale can be used for the entire layout; hence the term *isometric,* which literally means "one-scale."

Figure 5-38 shows an isometric projection as it would look to an observer whose line of sight was perpendicular to the plane of projection. Note

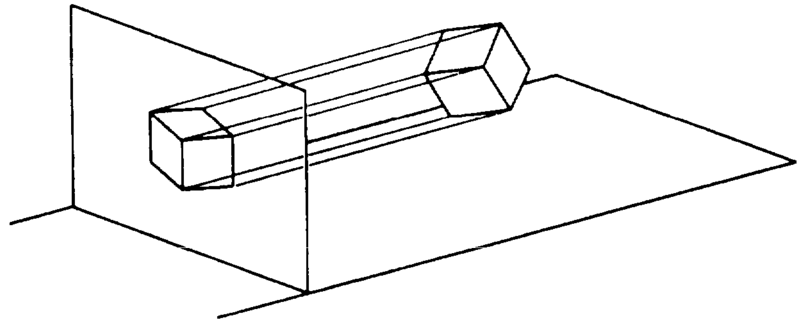


Figure 5-37.-Isometric projection of a cube.

that the figure has a central axis, formed by the lines OA, OB, and OC. The existence of this axis is the origin of the term *axonometric projection*. In an isometric projection, each line in the axis forms a 120-degree angle with the adjacent line, as shown. A quick way to draw the axis is to draw the perpendicular OC, then use a T square and 30°/60° triangle to draw OA and OB at 30 degrees to the horizontal. Since the projections of parallel lines are parallel, the projections of the other edges of the cube will be, respectively, parallel to these axes.

A rectangular object can be easily drawn in isometric by the procedure known as box construction. In the upperpart of figure 5-39, there is a two-view normal multi-view projection of a rectangular block. An isometric drawing of the block is shown below. You can see how you build the figure on the isometric axis and how you lay out the dimensions of the object on the isometric drawing. Because you lay out the identical dimensions, it is an isometric drawing rather than an isometric projection.

Non-isometric Lines.— If you examine the isometric drawing shown in figure 5-39, you will note that each line in the drawing is parallel to one or another of the legs of the isometric axis. You will also notice that each line is a normal line in the multi-view projection. Recall that a normal line is a line that, in a normal multi-view projection, is parallel to two of the planes of projection and perpendicular to the third. Thus,

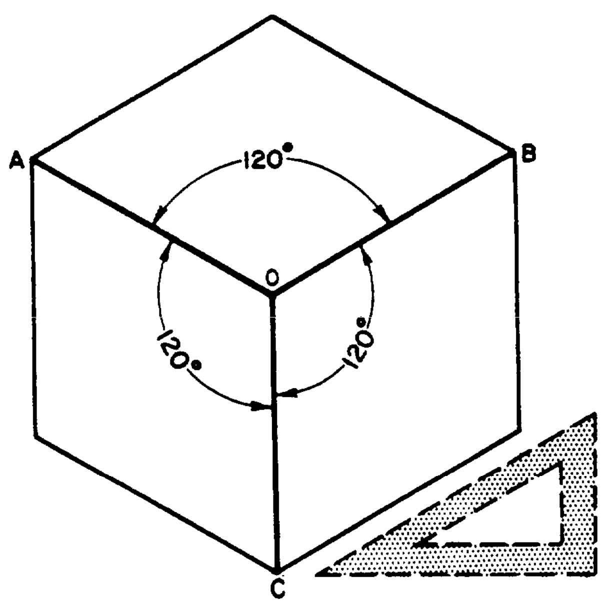


Figure 5-38.-Use of an isometric axis.

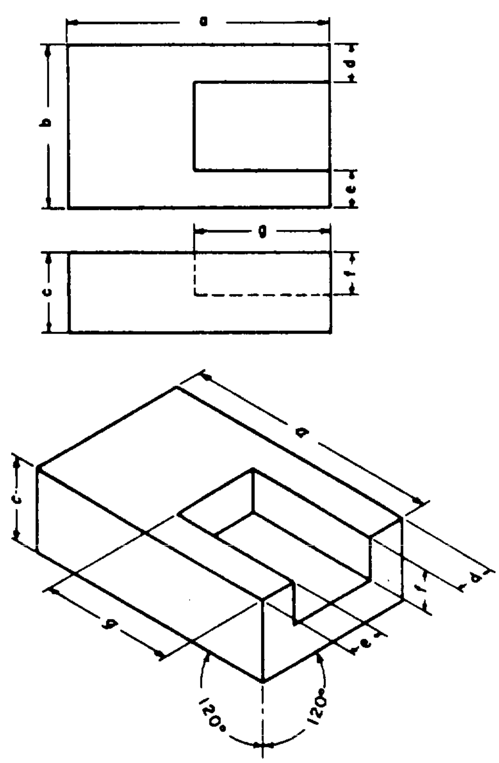


Figure 5-39.-Use of "box construction" in isometric drawing.

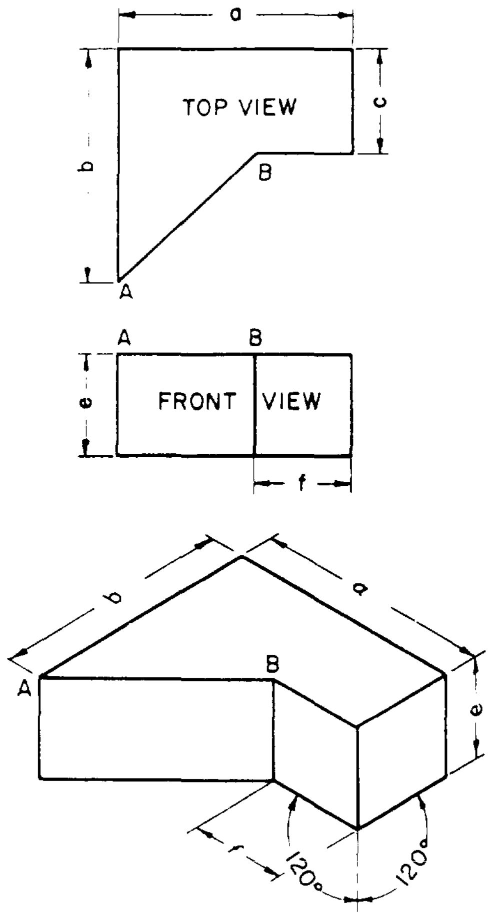


Figure 5-40.-A non-isometric line (AB) in an isometric projection.

a NON-ISOMETRIC LINE is a line that is not parallel to any one of the three legs of the isometric axis. It is not a normal line in a normal multi-view projection of the object.

The upperpart of figure 5-40 shows a two-view normal multi-view projection of a block. Though the line AB is parallel to the horizontal plane of projection, it is oblique to both the vertical and the profile planes. It is therefore not a normal, but an oblique, line in the multi-view projection, and it will be a non-isometric line in an isometric projection or drawing of the same object.

The line AB appears in its true length in the top multi-view view because it is parallel to the plane of the view (the horizontal plane); but it will appear as a non-isometric line, and therefore not in its true length, in an isometric drawing, as shown in the bottom part of figure 5-40. It follows that you cannot transfer AB directly from the multi-view projection to the isometric drawing. You can, however, transfer directly all the normal lines in the multi-view projection, which will be isometric lines appearing in their true lengths in the isometric drawing. When you have done this, you will have constructed the entire isometric drawing, exclusive of line AB and of its counterpart on the bottom face of the block. The end points of AB and of its counterpart will be located, however, and it will only be necessary to connect them by straight lines.

Angles in Isometric.—In a normal multi-view view of an object, an angle will appear in its true size. In an isometric projection or drawing, an angle never appears in its true size, Even an angle formed by normal lines, such as each of the 90-degree corner angles of the block shown in the bottom part of figure 5-41, appears distorted in isometric.

The same principle used in transferring a non-isometric line is used to transfer an angle in isometric. The upperpart of figure 5-41 shows a two-view multi-view projection of a block. On the top face of the block, the line AB makes a 40-degree angle with the front edge. The line AB is an oblique (that is, not normal) line, which will appear as a non-isometric line in the isometric drawing. You locate the end points of AB on the isometric drawing by

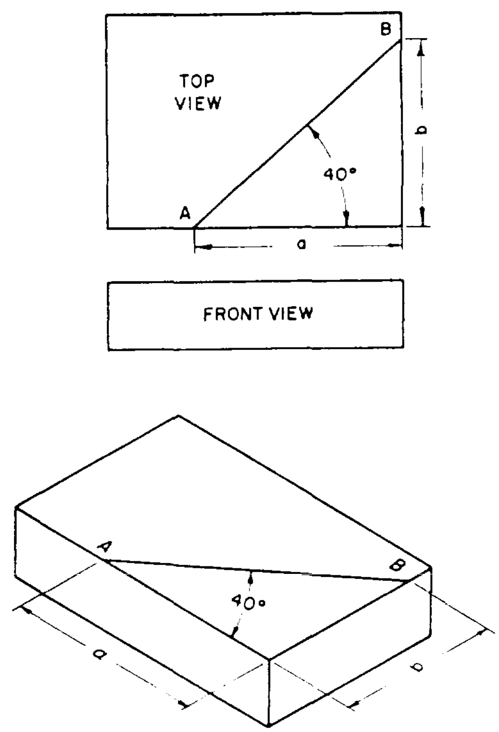


Figure 5-41.-Drawing an angle in isometric.

measuring distances along normal lines on the multi-view projection and laying them off along the corresponding isometric lines on the isometric drawing. The angle that measures 40 degrees on the top multi-view view measures only about 32 degrees on the isometric drawing. Note, however, that it is labeled 40 degrees on the isometric drawing. This is because it actually is a 40-degree angle as it would look on a surface plane at the isometric angle of inclination.

Circles in Isometric.— A circle in a normal multi-view view will appear as an ellipse in an isometric drawing. This is shown in figure 5-42, view A.

A procedure that maybe used to construct an isometric circle is shown in figure 5-42, view B. The steps of that procedure are as follows:

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

If the above discussion seems familiar, it should. It is simply an approximation of the four-point method you studied in the previous chapter. However, it can be used only when drawing isometric circles on an isometric drawing.

Noncircular Curves in Isometric.— A line that appears as a noncircular curve in a normal multi-view view of an object appears as a non-isometric

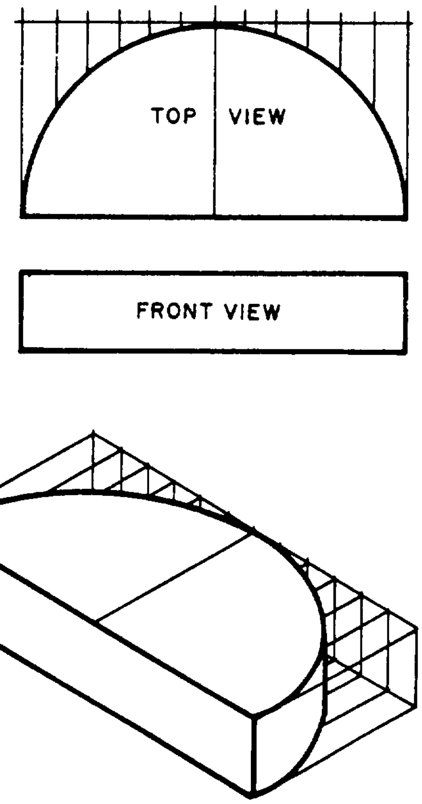


Figure 5-43.-Method of drawing a noncircular curve in isometric.

line in an isometric drawing. To transfer such a line to an isometric drawing, you must plot a series of points by measuring along normal lines in the multi-view view and transferring these measurements to corresponding isometric lines in the isometric drawing.

The upperpart of figure 5-43 shows a two-view multi-view projection of a block with

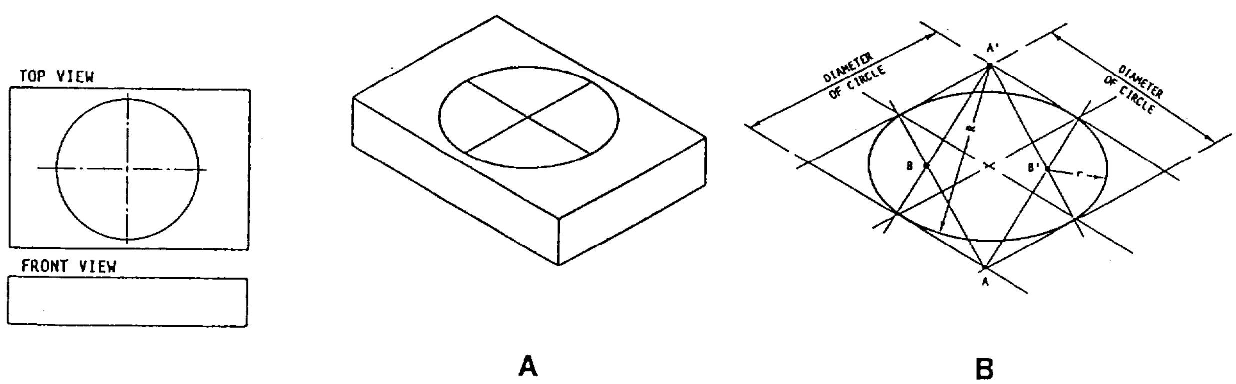


Figure 5-42.-A circle on a normal multi-view view appears as an ellipse in an isometric drawing.

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

Alternate Positions of Isometric Axis.— Up to this point, the isometric axis has been used with the lower leg vertical. The axis may, however, be used in any position, provided the angle between adjacent legs is always 120 degrees. Figure 5-44 shows how varying the position of the axis varies the view of the object.

Diagonal Hatching in Isometric.— Diagonal hatching on a sectional surface shown in isometric should have the appearance of making a 45-degree angle with the horizontal or vertical axis of the surface. If the surface is an isometric surface (one that makes an angle of 35°16' with the plane of projection), lines drawn at an angle of 60 degrees to the horizontal margin of the paper, as shown in figure 5-45, present the required appearance. To show diagonal hatching on a non-isometric surface, you must experiment to determine the angle that presents the required appearance.

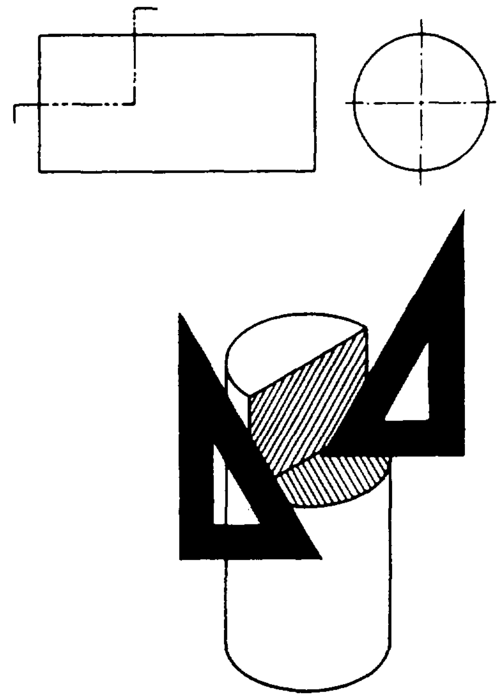


Figure 5-45.-An example of diagonal hatching in isometric.

DIMETRIC AND TRIMETRIC PROJECTION.— TWO other subclassifications of the axonometric projection category are dimetric and trimetric projections; however, these types are used less frequently than isometric projections and will not be discussed further in this training manual.

OBLIQUE SINGLE-PLANE PROJECTION

We have seen that an object may be drawn showing length and width on a single plane. Depth

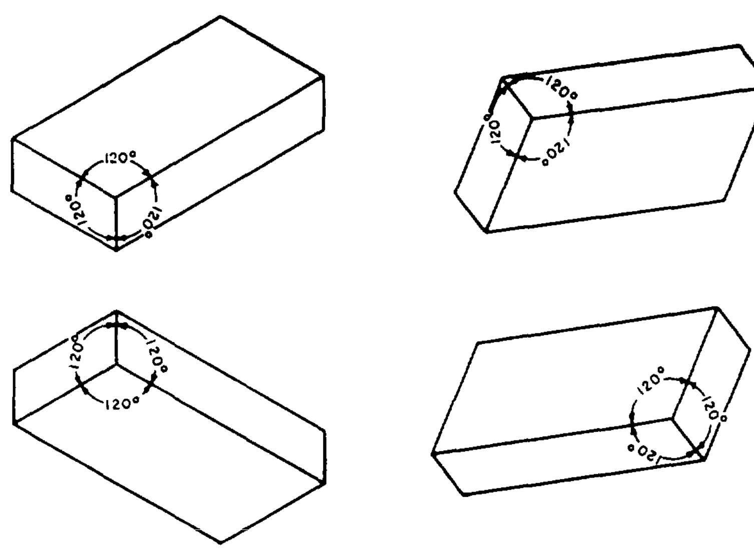


Figure 5-44.-Various positions of isometric axes.

may also be shown on this single plane by constructing the receding projection lines of the object at an angle other than perpendicular to the plane of projection.

Figure 5-46 shows the same object by both orthographic and oblique projection. The block is placed so that its front surface (the surface toward the plane of projection) is parallel to the plane of projection. You can see that the orthographic projection shows only this surface of the block. The oblique projection, on the other hand, shows the front surface and also the top and side surfaces. The orthographic projection shows only two dimensions: length and width. The oblique projection shows three: length, width, and thickness. Oblique projection, then, is one method by which an object can be shown, in a single view, in all three dimensions.

There are two types of oblique single-plane projections: CAVALIER and CABINET.

Cavalier Projection

CAVALIER PROJECTION is a form of oblique projection in which the projection lines are presumed to make a 45-degree vertical and a 45-degree horizontal angle with the plane of projection. Assume that in figure 5-47 the line XX' represents a side-edge view of the plane of projection, and that the square ABCD represents a side of a cube, placed with its front face parallel to, and its top face perpendicular to, the plane of projection. You can see that the projected lengths of AB and AD are the same as the actual lengths.

Now assume that the line XX' in figure 5-47 represents a top-edge view of the plane of

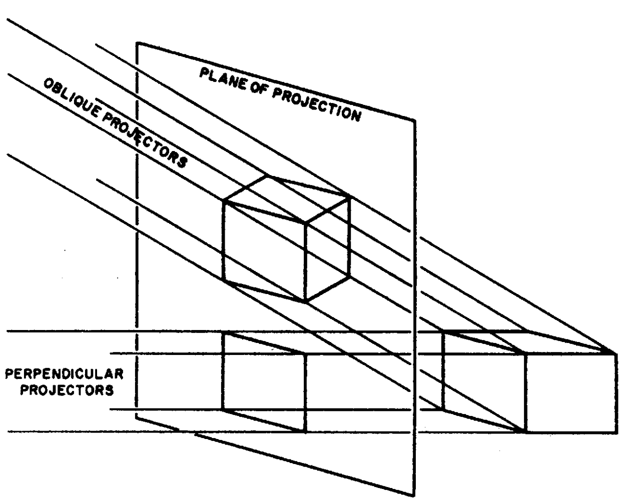


Figure 5-46.—Oblique and orthographic projections of the same object.

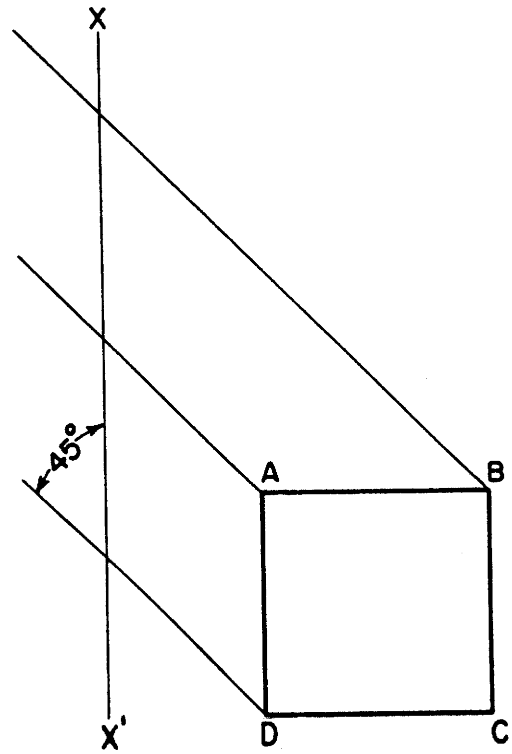


Figure 5-47.—Angle of projection lines in a cavalier projection.

projection, and that the square ABCD represents the top of the cube. You can see again that the projected lengths of AB and AD are the same as the actual lengths of AB and AD.

In a cavalier projection, then, any line parallel to or perpendicular to the plane of projection is projected in its true length. Figure 5-48 shows a cavalier projection of the cube shown in figure 5-47. You start by drawing the axis, which consists of the front axes OA and OB and the receding axis OC. The front axes are always perpendicular to each other; the receding axis

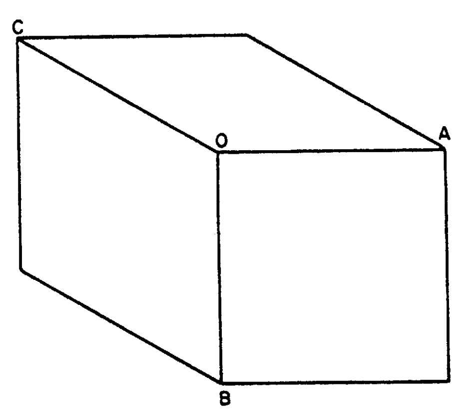


Figure 5-48.—Cavalier projection of a cube.

may be drawn from O at any convenient angle. All three are equal in length, the length being the length of an edge of the original cube (which may be scaled down or up if the drawing is made other than full scale). After you draw the axis, complete the projection by drawing the required parallel lines. All the edges shown in the projection are, like the edges on the original cube, equal in length.

Cabinet Projection

The first thing you notice about the cube shown in figure 5-48 is the fact that it doesn't look like a cube because the depth dimension appears to be longer than the height and width dimensions. The reason for this is the fact that a cavalier projection corrects a human optical illusion—the one that causes an object to appear to become smaller as its distance from the eye increases. This illusion. in turn. causes receding parallel lines to appear to the eye to be shorter-than they really are, and also to be converging toward a point in the distance. But receding parallel lines on a cavalier projection appear in their true lengths, and they remain constantly parallel. Also, the far edges of the cube shown in figure 5-48 are equal in length to the near edges.

The distortion in figure 5-48 is only apparent. It is sometimes desirable to reduce this appearance of distortion. This can be done by reducing the length of the receding axis (OC in fig. 5-39). This axis can be reduced by any desired amount, but it is customary to reduce it by one half.

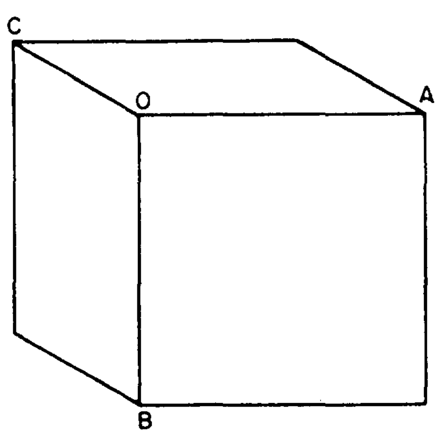


Figure 5-49.-Cabinet projection of the cube in figure 5-48. (Note receding axis OC reduced by one half its length.)

When the receding axis is reduced by one half, the projection is called a CABINET PROJECTION. Figure 5-49 shows a cabinet projection of a cube. The length of the receding axis OC has been reduced by one half. As you can see, this representation looks more like a cube.

Cavalier and cabinet projections are compared in figures 5-50 and 5-51.

Oblique Drawing Techniques

In an oblique projection drawing of a rectangular object, one face (usually the most prominent or most important) is parallel to the plane of projection. All features appearing on this plane, such as circles or oblique lines, are in their true dimension. However, in the side or top views, these same features are somewhat distorted because of the receding axis angle. When drawing these features, you can use various techniques to aid you in their construction.

For convenience, the angles chosen for the receding axis are either 30 degrees, 45 degrees, or

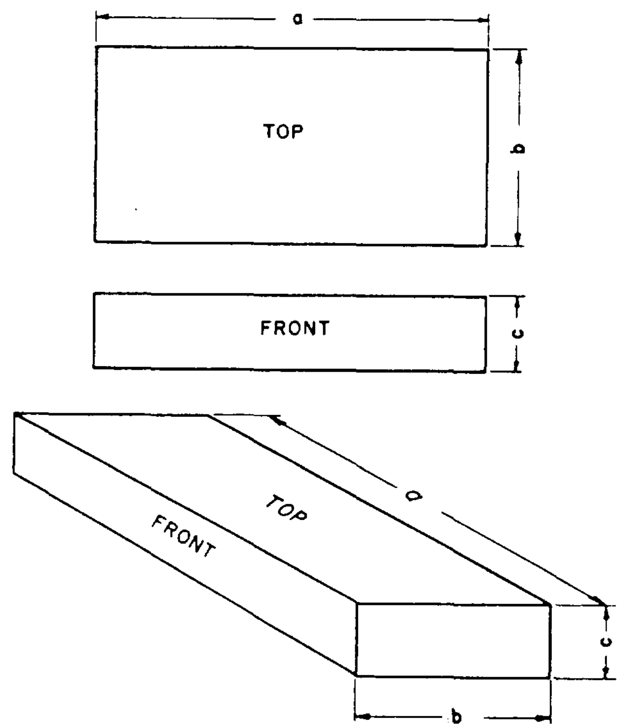


Figure 5-50.-Cavalier projection. Distances along front axis and along receding axis are all true.

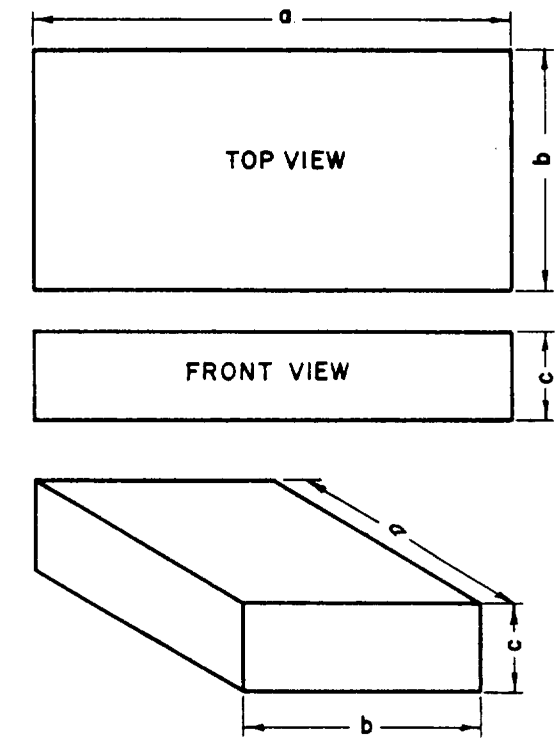


Figure 5-51.-Cabinet projection. Distances along front axis are true; distances along receding axis are reduced by one half.

60 degrees because they are easily constructed with triangles (fig. 5-52).

IRREGULAR LINES.— An irregular line in an oblique drawing is a line that would be an oblique line in a normal multi-view projection. In the upperpart of figure 5-53, there is a

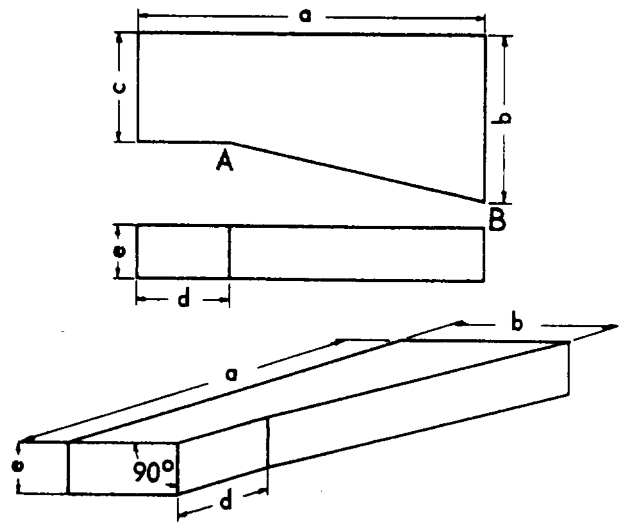


Figure 5-53.-Cavalier projection of an object with irregular lines.

two-view multi-view projection of a block; the line AB is an irregular line and will not appear in its true length in an oblique projection. To transfer the line, you draw the projection by transferring measurements taken along regular lines; these measurements locate the end points of the irregular line. Figure 5-53 shows the cavalier projection of an irregular line. The procedure for cabinet projection would be the same except that all measurements along the receding axis would be reduced by one half.

ANGLES IN OBLIQUE.— In an oblique projection, an angle on the surface that is parallel to the plane of projection will appear in its true

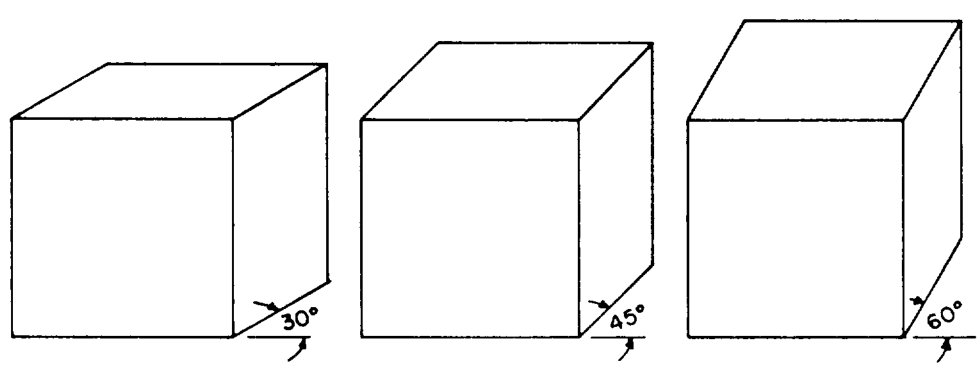


Figure 5-52.-Angles of 30 degrees, 45 degrees, and 60 degrees are normally chosen for the receding axis in oblique projection because they are easily drawn with triangles.

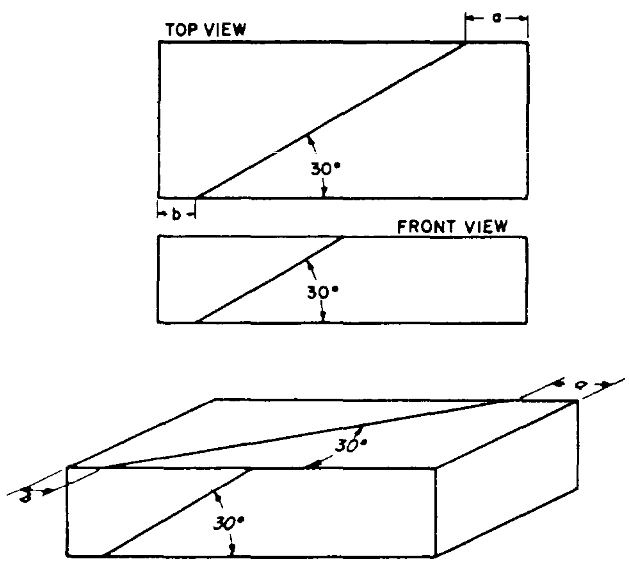


Figure 5-54.-Transferring an angle in oblique projection.

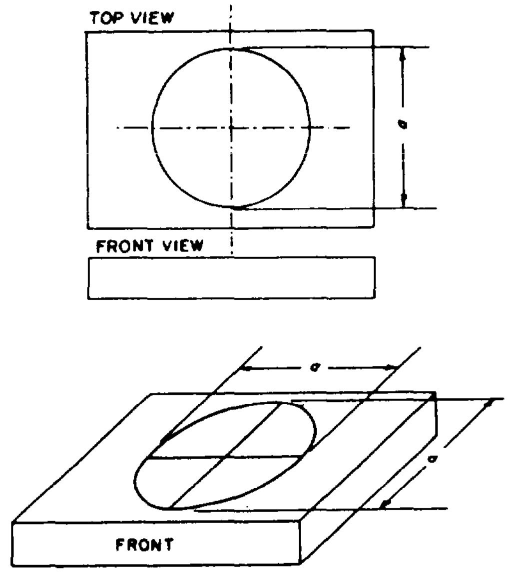


Figure 5-55.-Cavalier projection of a circle on a receding surface.

size; an angle on any other surface will not. The upperpart of figure 5-54 shows a two-view multi-view projection of a block. It has a 30-degree angle on the top face and another on the front face. In the cavalier projection below, the angle on the front face still measures 30 degrees; that on the top face measures only about 9 degrees. You transfer the top face angle by locating the end points of the line by measurements along regular lines.

CIRCLES IN OBLIQUE.— In an oblique projection, a circle on the surface parallel to the plane of projection will appear as a circle. A circle on any other surface will appear as an ellipse, as shown in figure 5-55. The upperpart of this figure shows a two-view multi-view projection of a block with a circle on its upper face. The lower part of this figure shows a cavalier projection in which the circle appears as an ellipse. Each of the conjugate (joined together) diameters of the ellipse is equal to the diameter of the circle.

PERSPECTIVE PROJECTION AND PERSPECTIVE DRAWING

PERSPECTIVE PROJECTION (fig. 5-2) is obtained when the projection lines converge to a point that is at a finite distance from the plane of projection. Each projection line forms a different angle with the plane of projection, giving the viewer a three-dimensional picture of the object. This type of projection, however, cannot accurately convey the structural features of a building; hence, it is not adequate for working drawings.

On the other hand, of all the three-dimensional single-plane drawings, PERSPECTIVE DRAWINGS are the ones that look the most natural. At the same time, they are also the ones that contain the most errors. Lines that have the same length on the object have different lengths on the drawing. No single line or angle on the drawing has a length or size that has any known relationship to its true length or size when projected through perspective projections.

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

If you are required to prepare perspective drawings, refer to *Illustrator Draftsman*, NAVEDTRA 10472, or civilian publications, such as *Architectural Drawing and Light Construction* and *Architectural Graphic Standards.*

SKETCHING

The EA who is able to make quick, accurate SKETCHES will find this ability a valuable asset when it comes to conveying technical information or ideas. Without this ability you are handicapped in many of your day-to-day situations. Almost every drawing or graphic problem originates with a sketch. The sketch becomes an important thinking instrument, as well as a means of conversing effectively with technically trained people. Sketching is not just another trick of the trade; it is a skill that is essential and should be an important part of your training. To gain proficiency in freehand sketching, invite situations entailing sketching at every opportunity. Do not worry about your first attempts at sketching; appearance will improve with experience.

A sketch is usually thought of as being made freehand, although in practice you may use graph paper or a small triangle for a straightedge. A sketch may be of an object or an idea or a combination of both. Sketches are used to solve graphic problems before an object or structure is put in final form on a drawing. Preliminary sketches are used to plan and organize intelligently the sheet layout of a complete set of drawings for a construction project, which often includes many views and details. There are no set standards for technical freehand sketching; however, you should use standard line conventions for clarity.

A sketch may be drawn pictorially so that it actually looks like the object, or it can be an orthographic sketch of the object showing different views. The degree of perfection required for any sketch will depend upon its intended use.

SKETCHING MATERIALS

One of the main advantages of sketching is that few materials are required. Basically, you need only a pencil and paper. However, the type of sketch prepared and your personal preference will determine the materials used.

You should use a soft pencil in the grade range from F to 3H, with H being a good grade for most sketching. The pencil should be long enough to permit a relaxed but stable grip. As you gain experience, you may even prefer to use fine tip felt pens. (Dark- or bright-colored pens should be used.) Felt tip pens work very well on overlay sketches (discussed later).

Most of your sketches will be done on scratch paper, which can be any type or size of paper. An experienced draftsman will keep a pad of 3 in. by 5 in. or 5 in. by 8 in. scratch paper handy at all times. For planning the layout of a drawing, you will find tracing paper to be convenient. The advantage of sketching on tracing paper is the ease with which sketches can be modified or redeveloped simply by placing transparent paper over previous sketches or existing drawings. Sketches prepared in this manner are referred to as OVERLAY SKETCHES. Cross-section or graph paper may be used to save time when you are required to draw sketches to scale. (See fig. 5-56.) Isometric sketches are easily done on specially ruled isometric paper. (See fig. 5-57.)

An eraser maybe used, but you will probably do very little erasing. Sketches usually can be

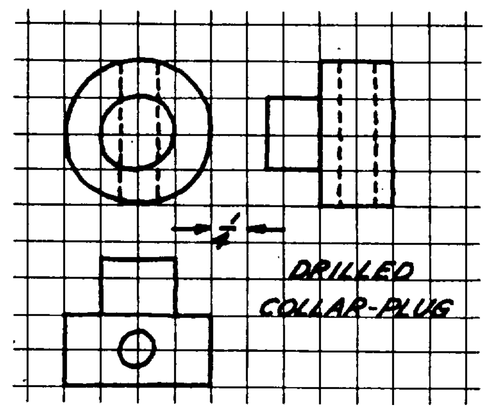


Figure 5-56.-Use of cross-sectional paper in technical sketching.

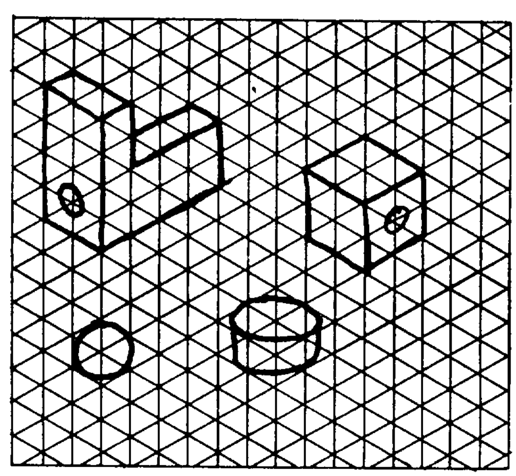


Figure 5-57.-Use of specially ruled isometric paper in technical sketching.

redrawn more quickly than mistakes can be erased.

For making dimensioned sketches in the field, you will need some sort of measuring tape—either a pocket rule or a surveyor's tape, depending on the extent of the measurements taken. If you are required to collect extensive field data, it would be to your benefit to maintain a sketch notebook. A surveyor's field notebook works well for this purpose.

TECHNIQUES OF SKETCHING

The sketch should conform to one of the standard types of projection discussed in this chapter. You must apply correct proportion whenever possible. When you use cross-section paper, its grid will provide a ready scale that will aid you in sketching proportionally. You do this by counting the squares within the object to be drawn. The size of your sketch depends upon the complexity of the object and the size of paper you are using.

Sketching Straight Lines

In sketching lines, place a dot where you want a line to begin and one where you want it to end. In sketching long lines, place one or more dots between the end dots. Then swing your hand in the direction your line should go, and back again a couple of times before you touch your pencil to the paper. In this way you get the feel of the line. Then use these dots to guide your eye and your hand as you draw the line. Draw each line with a series of short strokes instead of with one stroke. Using short strokes, you can better control the direction of your line and the pressure of your pencil on the paper. Hold the pencil about three quarters of an inch to an inch from the point so that you can see what you are doing. Strive for a free and easy movement rather than a cramped finger and wrist movement.

Another useful technique in drawing straight lines is to use the side of the paper, pad, or table as a guide for your hand. Hold the pencil at the desired starting point of the line and place the heel of your hand and one finger on the guide, as shown in figure 5-58. Move the pencil, in this case, with one uniform stroke to complete the line. Try drawing several light horizontal lines and, after each one is drawn, examine it for straightness, weight, and neatness. If it is too light, use either a softer pencil or a little more pressure.

Vertical lines are usually sketched downward on the paper. The same suggestions for using locator dots, free movement of the entire arm, and guides apply to vertical lines as they do to horizontal lines.

Slanting lines may be drawn from either end toward the other. For better control, you might find it helpful to rotate the paper, thus placing the desired slanting line in either the horizontal or vertical position.

To keep your sketch neat, first sketch your lines lightly. Lines not essential to the drawing can be sketched so lightly that you need not erase them. Darken essential lines by running your pencil over them with more pressure. Figure 5-59 shows line conventions drawn with various types of pencil points.

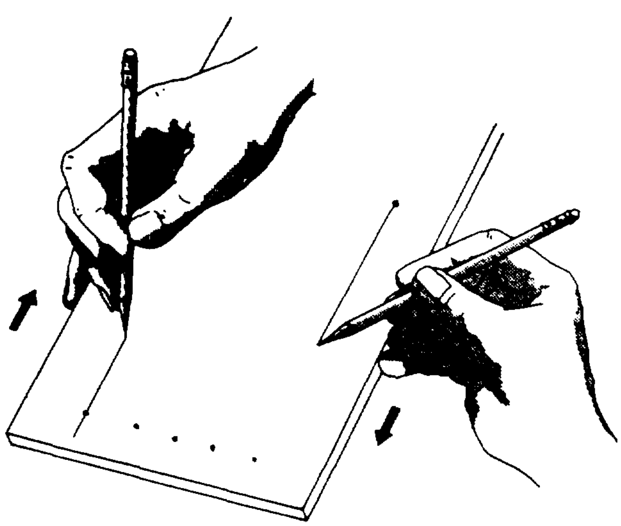


Figure 5-58.-Use of paper, pad, or table as a guide when drawing straight lines.

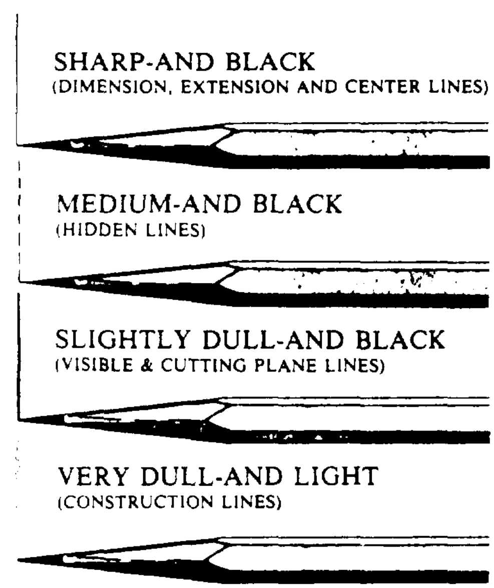


Figure 5-59.-Line conventions drawn with various types of pencil points.

Dividing Lines and Areas Equally

Your ability to divide lines and areas into equal parts is necessary in arriving at many of the common geometric forms required in sketching. The simplest method of bisecting lines is by visual comparison, as shown in figure 5-60. The entire line is first observed and weighed optically to determine its fulcrum or point of balance. Each half is compared visually before the bisecting point is placed. This procedure can be repeated any number of times to divide a line into any number of equal divisions, merely by dividing and redividing its line segments.

Centers of rectangular areas are easily determined by drawing their diagonals. If necessary the halves can be divided with diagonals for smaller divisions, as shown in figure 5-61.

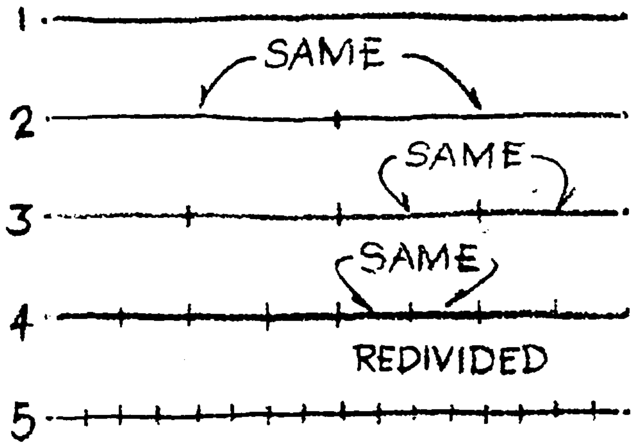


Figure 5-60.-Bisecting a line by visual comparison.

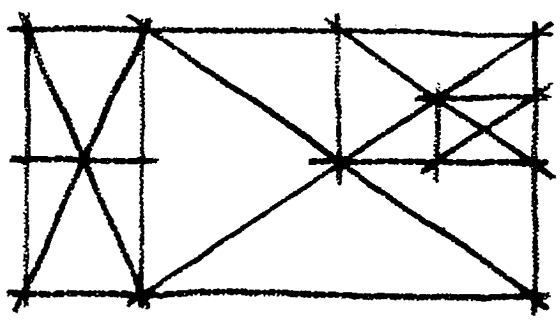


Figure 5-61.-Locating centers by sketching diagonals.

Sketching Angles

The 90-degree angle is predominant in the majority of your sketches. Thus it is important that you learn to sketch right angles accurately, even if it entails checking them with the triangle occasionally. Frequently, the perpendicular edges of your paper can serve as a visual guide for comparison. It is also helpful to turn your sketch upside down; non-perpendicular tendencies of horizontal and vertical lines will become evident. Shaping right angles correctly will give your sketch stability, without which effectiveness is lost.

A 45-degree angle is made by dividing a right angle by visual comparison; and a 30-degree or 60-degree angle, by dividing the right angle into three equal parts. The 30-degree or 45-degree angle may be divided into equal parts in the same manner. (See fig. 5-62.) Always start with the right angle for the most accurate estimation of angle shape.

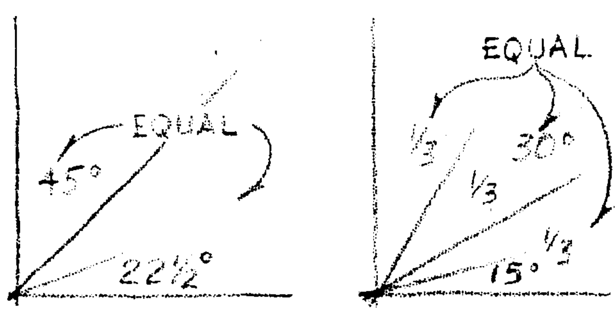


Figure 5-62.-Sketching angles by visual comparison.

Sketching Circles and Arcs

Perfectly round circles are the most difficult to draw freehand. Figure 5-63 shows methods of

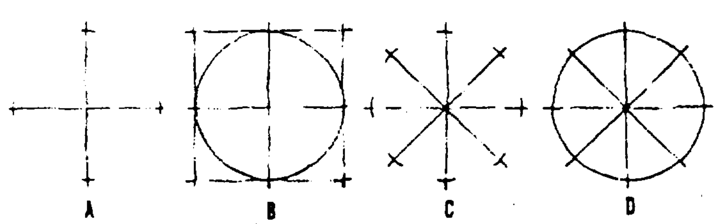


Figure 5-63.-Methods of sketching circles.

drawing circles and curves using straight lines as construction lines. First, draw two straight lines crossing each other at right angles, as in figure 5-63, view A. The point at which they cross will serve as the center of the circle. The four lines radiating from this center will serve as the radii of the circle. You can use a piece of marked scrap paper to measure an equal distance on each radius from the center. Sketch a square, with the center of each side passing through the mark defining a radius. (See fig. 5-63, view B.) Now sketch in your circle, using the angles of the square as a guide for each arc. When larger circles are required, you can add 45-degree angles to the square to form an octagon. This will provide four additional points of tangency for the inscribed circle.

In figure 5-63, view C and view D, four lines, instead of two, are sketched crossing each other. The radii are measured as in constructing the other circle, but a square is not drawn. For this method, you will find it helpful to rotate the paper and sketch the circle in one direction.

For drawing large circles, you can make a substitute for a compass with a pencil, a piece of string, and a thumbtack. Tie one end of the string to your pencil near the tip. Measure the radius of the circle you are drawing on the string, and insert your tack at this point. Now swing your pencil in a circle, taking care to keep it vertical to the paper.

Another technique for drawing circles is shown in figure 5-64. In view A of figure 5-64, observe how the pencil is held beneath the four fingers with the thumb. This grip tends to produce a soft or easy motion for sketching large circles or curves and also makes it possible to sketch small circles, as shown in figure 5-64, views B and C. You notice in figure 5-64, view B, that the second finger rests at the center of the circle

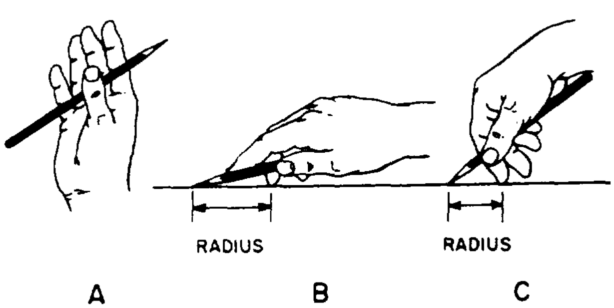


Figure 5-64.-Proper pencil grip in sketching circles and arcs.

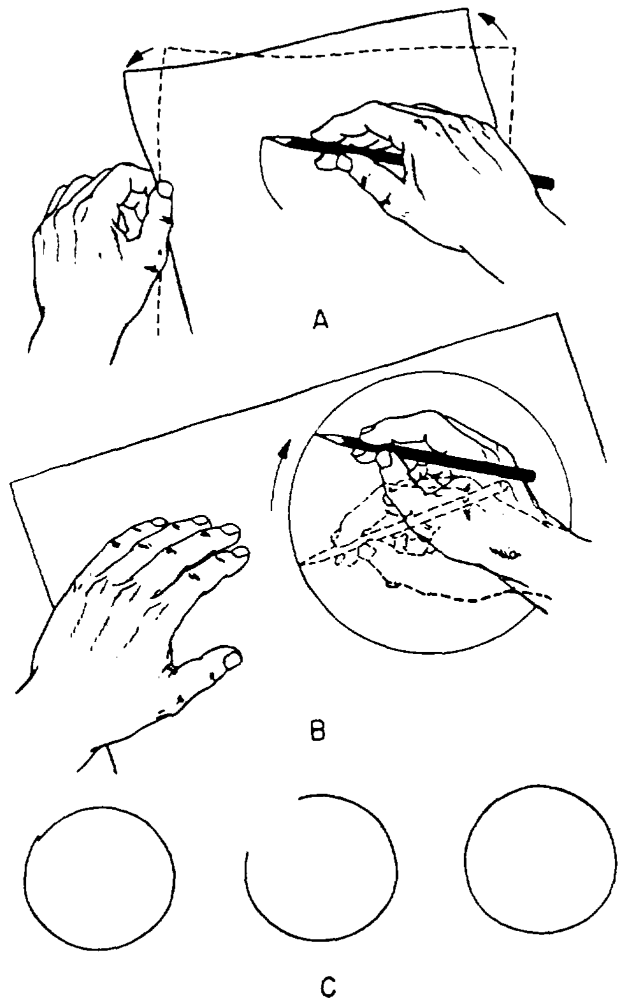


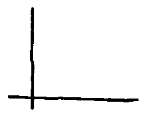
Figure 5-65.-Steps in sketching a circle.

and forms the pivot about which the pencil lead can swing. The distance from the fingertip to the pencil lead determines the radius of the circle. To draw smaller circles, you need to assume a somewhat different grip on the pencil, as shown in view C of figure 5-64, but the principle is the same.

As shown in view A of figure 5-65, the first step in sketching either large or small circles with the grips shown in the previous figure is placing the second finger on the paper at the center of the proposed circle. Then, with the pencil lightly touching the paper, use the other hand to rotate the paper to give you a circle that may look like the one in figure 5-65, view B. To correct the slight error of closure shown in view C, erase a substantial section of the circle and correct it by eye, as shown at the right. You now have a complete and round circle, but with only a very light line, which must be made heavier. Do this as shown in view B. Notice that you DO NOT PIVOT on the second finger during this step. You rest your hand on its side and, keeping it within the circle, trace over the light line with your hand pivoting naturally at the wrist. As you work around the circle in this way, rotate the paper counter-clockwise so that your hand can work in its most natural and easy position. Of course with smaller circles you cannot work with your hand within the circle, but the same general approach can be used with success.

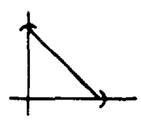
Probably one of the best methods to sketch curves connected to straight lines is the six-step method illustrated and explained below.

1. Intersect a vertical and horizontal line, lightly.

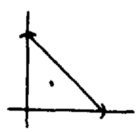


2. Mark off on the horizontal and vertical lines the same distance from the intersection.

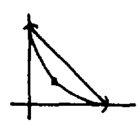
3. Draw a light diagonal line through the two points marked.



4. Place an x or a dot in the exact center of the triangle formed.



5. Start your curve from one point of the triangle preferably on the vertical line) touching the x or dot and ending at the other point of the triangle.



6. Erase all unnecessary guidelines and darken the curve and necessary adjoining straight lines.

A little practice with this method should enable you to improve your ability to sketch curves properly.

Figure 5-66 shows a convenient way to sketch arcs and curves by lightly drawing construction boxes (or blocks).

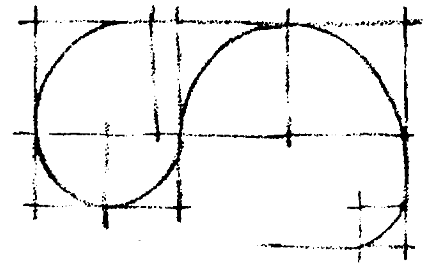


Figure 5-66.-Sketchirrg curves using construction boxes.

Construction Lines

When you are sketching an object, such as that shown in figure 5-67, don't start at one corner and draw it detail by detail and expect it come out with the various elements in correct proportion. It is better to block in the overall size of the object first, (See fig. 5-67, view A.) Then draw light guidelines at the correct angles for the various outlines of the object. (See fig. 5-67, views B and C.)

Finish the sketch by first making an outline of the object and then drawing in the details, as shown in figure 5-67, view D.

Order of Sketching

To make a working sketch, first choose a clean sheet of paper, either plain or ruled. Estimate the size the sketch should be, and select the views that will give the best picture of the object. Then draw the ORTHOGRAPHIC PROJECTIONS of these views, leaving adequate space between them for

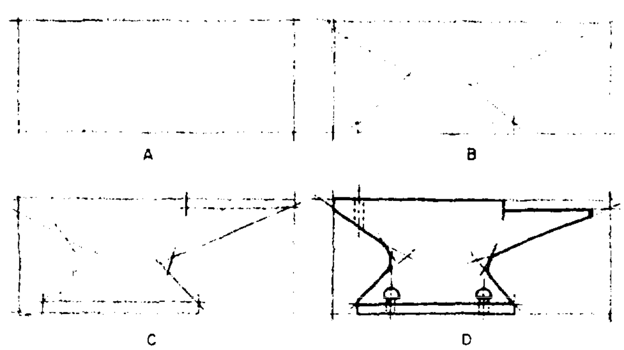


Figure 5-67.-The use of construction lines in sketching an object.

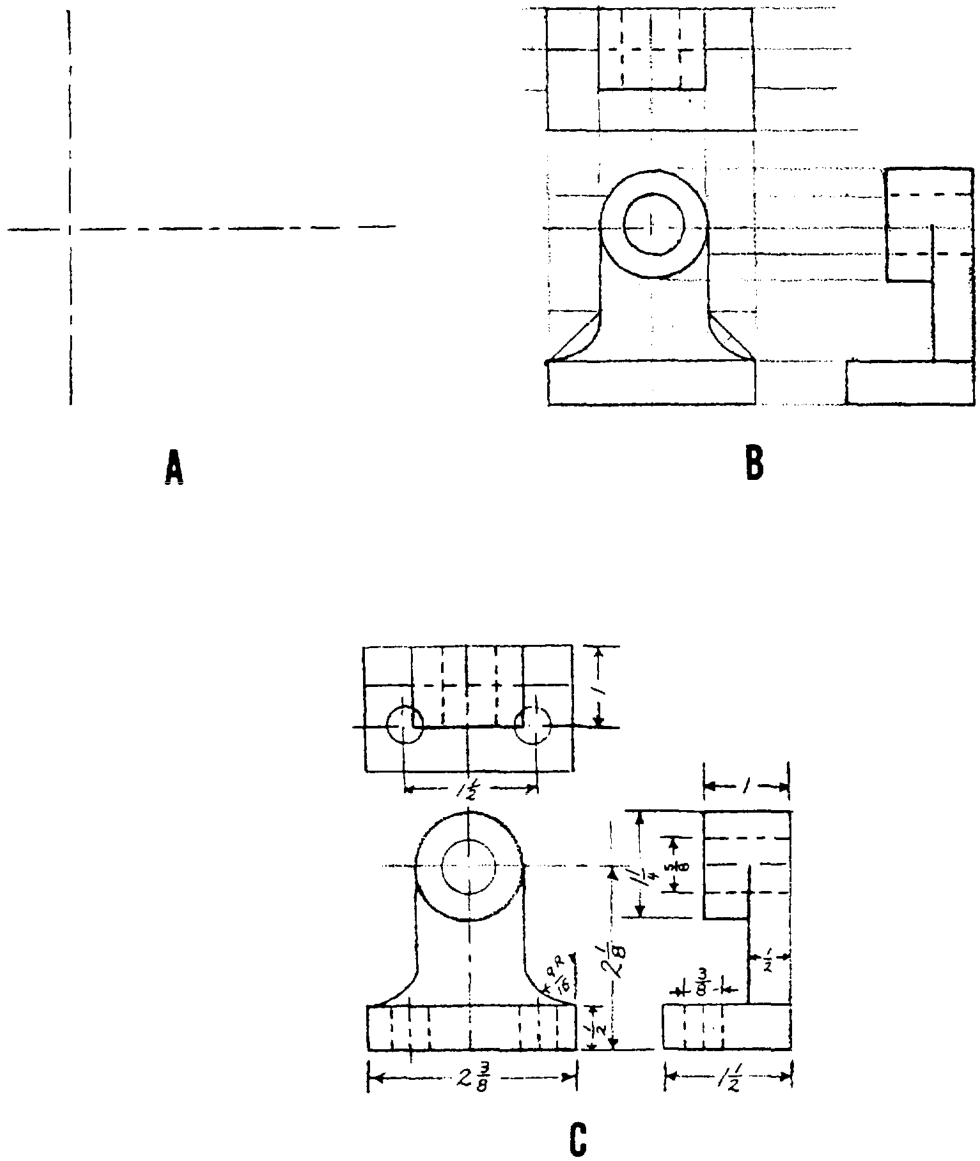


Figure 5-68.-Progress of a working sketch.

dimensions. (Refer to the working sketch in fig. 5-68.) In sketching, progress as follows:

1. Draw the center lines, as shown in figure 5-68, view A.
2. Block in the views.
3. Draw the outlines, aligning them as in figure 5-68, view B.
4. Add the details on the surface of the views.
5. Darken the lines of the finished sketch.
6. Use an art gum or a kneaded eraser to erase the construction lines, which are no longer needed. If necessary, touch up the lines you may have inadvertently erased.
7. Draw all necessary extension and dimension lines.
8. Letter in the dimensions. (See fig. 5-68, view C.)

You can see that a working sketch such as the one shown in figure 5-68 could easily be followed in preparing a finished drawing of the object. The sketch provides you with all the necessary information needed on the finished drawing.

Pictorial Sketches

Often it will be more convenient, or even necessary, to prepare isometric or oblique

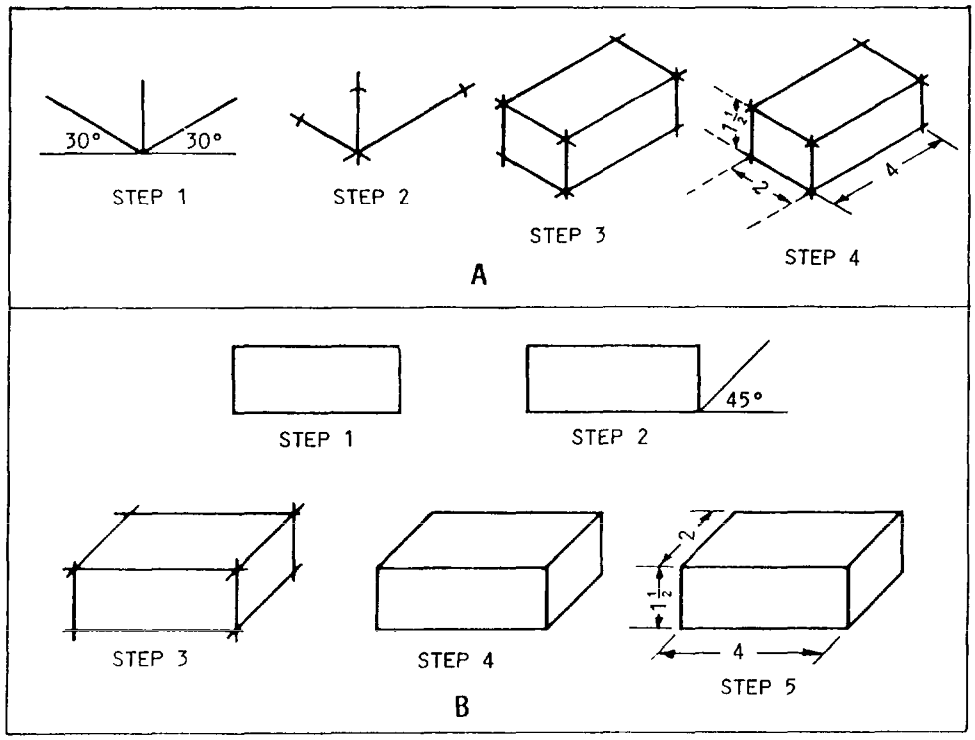


Figure 5-69.-Sketching a rectangular block: A. Isometric; B. Oblique.

PICTORIAL SKETCHES instead of multi-view orthographic sketches. Pictorial sketches provide you with a quick method of examining tentative construction details. A quick pictorial sketch will also help you in the layout of isometric and oblique drawings.

The principles of pictorial and orthographic sketching are similar, except that in pictorial sketching you will be dealing with volumes rather than flat planes. Basically, pictorial sketches and pictorial drawings are practically the same except for the drawing materials used in their development and the fact that pictorial sketches are not normally drawn to scale. By following a few simple steps, based on pictorial drawing construction principles, you should be able to prepare meaningful pictorial sketches.

ISOMETRIC SKETCHES.— Select a position (view) that will show the object to the best advantage. You will know what you want included in your sketch, so move either the object or yourself until you can actually see everything you want to show. If the object is something you have in mind or if you intend to sketch an isometric view from an orthographic drawing, you will have to visualize the object and assume a viewing position. In making your isometric sketch, remember that you start by sketching three isometric axes 120 degrees apart, using two angles of 30 degrees and a vertical axis of 90 degrees. Figure 5-69, view A, shows a step-by-step procedure that can be used in making an isometric sketch of a wooden rectangular block measuring 1 1/2 in. by 2 in. by 4 in.

The first step is to sketch the three isometric axes, as mentioned earlier. The second step is to mark off the 1 1/2 in. for height on the vertical axis, the 2-in. width along the left axis, and the 4-in. length along the right axis. The third step is to draw two vertical lines 1 1/2 in. high (starting with the marks on the right and left axis), then sketch parallel lines from each of the marks on the sketch. Note that the lines that are parallel on the object are parallel on the sketch. The fourth step is to dimension the sketch. The dimensions on an isometric sketch are placed parallel to the ends or edges. The final step is to check the sketch for completeness and accuracy.

OBLIQUE SKETCHES.— The front face or view of an OBLIQUE SKETCH is drawn the same way as an orthographic front view. Using the same wooden block that was sketched

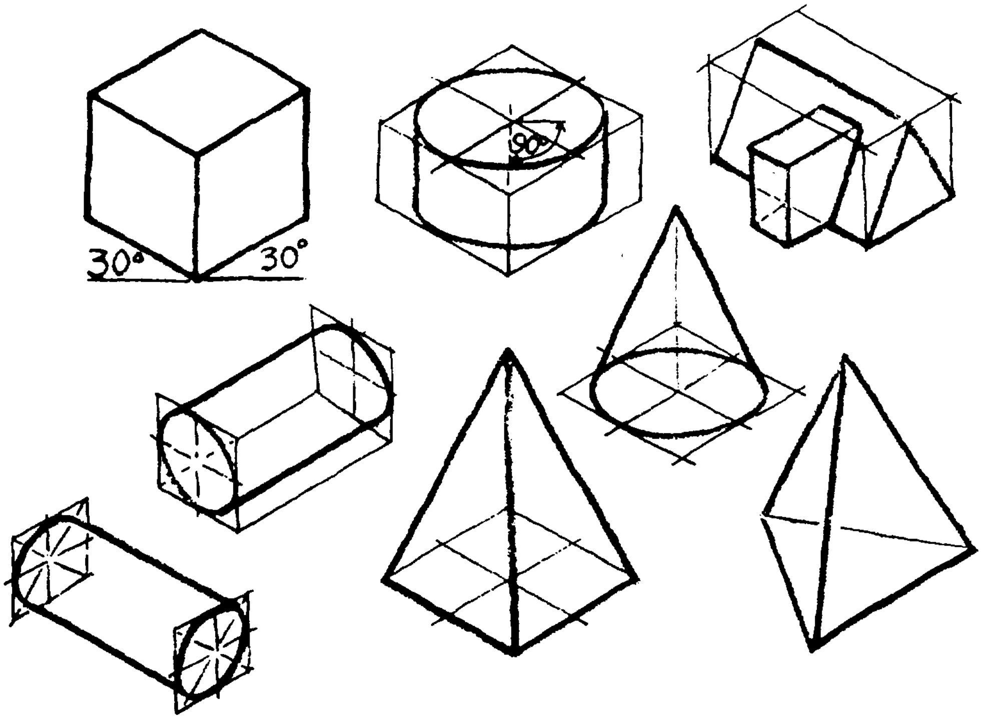


Figure 5-70.-Basic isometric forms.

isometrically for a model, you should draw an oblique sketch following the basic steps shown in figure 5-69, view B.

The first step is to draw a rectangle of the front view (using light lines). Then, second, draw an oblique base line at a 45-degree angle starting at the corner (intersection) of the horizontal and vertical base lines. Third, sketch the remaining horizontal and vertical lines parallel to the other base lines. Fourth, erase any unnecessary lines, and fifth, dimension and darken the completed drawing for easier reading. Remember, place the dimensions so they are parallel to the axis lines. The final step is to check the sketch for completeness and accuracy.

In the above procedures for development of pictorial sketches, a simple rectangular form was used. All objects may be simplified to their basic geometric forms. These forms are the first consideration in the pictorial sketch. Basic volumetric forms are shown in figure 5-70. By carefully analyzing any object you sketch, you will see one or more of the forms shown in figure 5-70. However, at times only a part of a form is present.

Before attempting detailed sketches, practice sketching the basic forms. Then look for these forms in the object you are about to sketch, and concentrate on the basic form representation. Enclose the object in a basic form, or build it up with a series of different forms, depending on the nature of the object. Details are added or "carved" from these forms after shape and proportion have been determined.

Overlay Sketches

To make OVERLAY SKETCHES, sketch freehand on transparent paper placed over existing drawings or other sketches. Sometimes when you make overlay sketches, you merely trace, freehand, objects or lines from another drawing or sketch. But more often you will prepare overlay sketches by tracing and then adding supplementary sketched lines or objects.

Usually, when this type of sketch is prepared, only the prominent or desired features are traced. Overlay sketches are primarily used for planning purposes.

A suggested procedure for using overlay sketches as a tool for planning is explained in the following example:

The drafting room is being relocated. You are tasked with developing a proposed furniture and equipment layout. You have the latest prints of the floor plan and an electrical plan, and you know what furniture and equipment will be moved to the new area. The steps you take to develop the proposed layout are as follows:

1. Check the floor plan and electrical plan against the actual room layout. If necessary, check the dimensions. Correct any discrepancies with a dark-colored fine tip felt pen or colored pencil.

2. Place a piece of tracing paper over the floor plan on the print and secure it with small strips of drafting tape.

3. Trace the outline of the walls with single freehand lines (preferably with a dark-colored felt tip pen). Terminate the lines, where applicable, to indicate windows and door openings.

4. Remove the tracing paper from the floor plan and place it over the electrical plan, lining the traced wall outlines up with the corresponding walls on the electrical plan. Using appropriate symbols, locate, on the traced floor plan, all electrical outlet locations.

5. You now have a clear overlay sketch of the existing floor plan without the unnecessary dimensions and information that are on the original print of the floor plan. This is your basic planning overlay. Check your overlay with the original prints to make sure that relevant lines were not omitted.

6. Place another sheet of tracing paper over the basic planning overlay. This becomes your second overlay. On this second overlay, sketch in your desired location of all the furniture and equipment. Use simple shapes for each and estimate sizes. Use letters or symbols for identification. Repeating the outline of the walls is not necessary because you can still see the outline from the basic planning overlay.

7. If this first location sketch on the second overlay does not suit you or does not provide an adequate layout, lay another piece of tracing paper over the second layout and sketch another layout. Repeat this procedure with additional overlays until you have developed a good layout.

8. Once you have a good layout, trace the wall outlines from the basic planning overlay. This final overlay sketch is your proposed furniture and equipment layout for the new location of the drafting room.

CHAPTER 6

WOOD AND LIGHT FRAME STRUCTURES

When you prepare an engineering drawing, regardless of type, you are required to apply knowledge of the materials and methods of construction. This chapter describes the uses, kinds, sizes, grades, and other classifications of wood as they apply to light frame building construction; the various structural members and their functions; and the different types of finishing hardwares and fasteners used.

WOOD

Of the different construction materials, wood is probably the most often used and perhaps the most important. The variety of uses of wood is practically unlimited. Few SEABEE construction projects, whether involving permanent or temporary structures, are built without using wood. Temporary uses of wood include scaffolding, shoring, bracing, and miscellaneous concrete forms.

There are several types or species of wood. Each type has its own characteristics and its recommended uses. For most large projects, the types and classifications of wood are given in the project specifications. For smaller projects that DO NOT have written specifications, the types and classifications of wood are included in the drawings. The types, sources, uses, and characteristics of common woods are given in table 6-1. In addition, the species, size classification, and design values of common structural woods are also listed in the *Architectural Graphic Standards.*

LUMBER

In construction, the terms *wood, lumber,* and *timber* have distinct, separate meanings. WOOD is the hard, fibrous substance that forms the major part of the trunk and branches of a tree. LUMBER is wood that has been cut and surfaced for construction use. TIMBER is lumber whose smallest dimension is NOT less than 5 in. Another term, *MILLWORK*, refers to manufactured lumber products, such as doors, window frames, window casings, shutters, interior trim, cabinets, and moldings.

Sizes

Standard lumber sizes have been established in the United States to permit uniformity in planning structures and in ordering materials. Lumber is identified by NOMINAL SIZES. The nominal size of a piece of lumber is larger than the actual DRESSED dimensions. Dressed lumber has been SURFACED (planed smooth) on two or more sides. It is designated according to the number of sides or edges surfaced. If it has been surfaced on two sides only, the designation is S2S (surfaced 2 sides); if surfaced on all four sides, S4S (surfaced 4 sides); or if surfaced on two sides and two edges, S2S2E. Lumber is ordered and designated on drawings by its nominal size rather than by its dressed dimensions. Common widths and thicknesses of lumber in nominal and dressed dimensions are shown in table 6-2.

Classification

Lumber is classified according to its USE, SIZE, and EXTENT OF MANUFACTURE. When classified according to use, lumber falls into three categories:

1. YARD LUMBER—grades, sizes, and patterns generally intended for ordinary construction and general building purposes
2. STRUCTURAL LUMBER—2 or more in. in thickness and width for use where working stresses are required
3. FACTORY AND SHOP LUMBER—produced or selected mainly for manufacture of furniture, doors, cabinets, and other millwork

Table 6-1.-Common Woods

Type	Sources	Uses	Characteristics
Ash	East of Rockies . .	Oars, boat thwarts, benches, gratings, hammer handles, cabinets, ball bats, wagon construction farm implements.	Strong, heavy, hard, tough, elastic, close straight grain, shrinks very little, takes excellent finish, lasts well.
Balsa	Ecuador.	Rafts, food boxes, linings of refrigerators, life preservers, loud speakers, sound-proofing, air-conditioning devices, model airplane construction.	Lightest of all woods, very soft, strong for its weight, good heat insulating qualities, odorless.
Basswood .	Eastern half of U.S. with exception of coastal regions.	Low-grade furniture, cheaply constructed buildings, interior finish, shelving, drawers, boxes, drainboards, woodenware, novelties, excelsior, general millwork.	Soft, very light, weak, brittle, not durable, shrinks considerably, inferior to poplar, but very uniform, works easily, takes screws and nails well and does not twist or warp.
Beech. . . .	East of Mississippi, Southeastern Canada.	Cabinetwork, imitation mahogany furniture, wood dowels, capping, boat trim, interior finish, tool handles, turnery, shoe lasts, carving, flooring.	Similar to birch but not so durable when exposed to weather, shrinks and checks considerably, close grain, light or dark red color.
Birch	East of Mississippi River and North of Gulf Coast States, Southeast Canada, Newfoundland.	Cabinetwork, imitation mahogany furniture, wood dowels, capping, boat trim, interior finish, tool handles, turnery, carving.	Hard, durable, fine grain, even texture, heavy, stiff, strong, tough, takes high polish, works easily, forms excellent base for white enamel finish, but not durable when exposed. Heartwood is light to dark reddish brown in color.
Butternut	Southern Canada, Minnesota, Eastern U. S. as far south as Alabama and Florida.	Toys, altars, woodenware, millwork, interior trim, furniture, boats, scientific instruments.	Very much like walnut in color but softer, not so soft as white pine and basswood, easy to work, coarse grained, fairly strong.

Table 6-1.-Common Woods—Continued

Type	Sources	Uses	Characteristics
Cypress. . . .	Maryland to Texas, along Mississippi valley to Illinois.	Small boat planking, siding, shingles, sash, doors, tanks, silos, railway ties.	Many characteristics similar to white cedar. Water resistant qualities make it excellent for use as boat planking.
Douglas Fir. .	Pacific Coast, British Columbia.	Deck planking on large ships, shores, strongbacks, plugs, filling pieces and bulkheads of small boats, building construction, dimension timber, plywood.	Excellent structural lumber, strong, easy to work, clear straight grained, soft, but brittle. Heartwood is durable in contact with ground, best structural timber of northwest.
Elm.	States east of Colorado.	Agricultural implements, wheel-stock, boats, furniture, crossties, posts, poles.	Slippery, heavy, hard, tough, durable, difficult to split, not resistant to decay.
Hickory.	Arkansas, Tennessee, Ohio, Kentucky.	Tools, handles, wagon stock, hoops, baskets, vehicles, wagon spokes.	Very heavy, hard, stronger and tougher than other native woods, but checks, shrinks, difficult to work, subject to decay and insect attack.
Lignum Vitae	Central America.	Block sheaves and pulleys, waterexposed shaft bearings of small boats and ships, tool handles, small turned articles, and mallet heads.	Dark greenish brown, unusually hard, close grained, very heavy, resinous, difficult to split and work, has soapy feeling.
Live Oak . . .	Southern Atlantic and Gulf Coasts of U.S., Oregon, California.	Implements, wagons, ship building.	Very heavy, hard, tough, strong, durable, difficult to work, light brown or yellow sap wood nearly white.
Mahogany . . .	Honduras, Mexico, Central America, Florida, West Indies, Central Africa, other tropical sections.	Furniture, boats, decks, fixtures, interior trim in expensive homes, musical instruments.	Brown to red color, one of most useful of cabinet woods, hard, durable, does not split badly, open grained, takes beautiful finish when grain is filled but checks, swells, shrinks, warps slightly.

Table 6-1.-Common Woods—Continued

Type	Sources	Uses	Characteristics
Maple.	All states east of Colorado, Southern Canada.	Excellent furniture, high-grade floors, tool handles, ship construction crossties, counter tops, bowling pins.	Fine grained, grain often curly or "Bird's Eyes," heavy, tough, hard, strong, rather easy to work, but not durable. Heartwood is light brown, sap wood is nearly white.
Norway Pine	States bordering Great Lakes.	Dimension timber, masts, spars, piling, interior trim.	Light, fairly hard, strong, not durable in contact with ground.
Philippine Mahogany. .	Philippine Islands	Pleasure boats, medium-grade furniture, interior trim.	Not a true mahogany, shrinks, expands, splits, warps, but available in long, wide, clear boards.
Poplar	Virginias, Tennessee, Kentucky, Mississippi Valley.	Low-grade furniture cheaply constructed buildings, interior finish, shelving, drawers, boxes.	Soft, cheap, obtainable in wide boards, warps, shrinks, rots easily, light, brittle, weak, but works easily and holds nails well, fine-textured.
Red Cedar. .	East of Colorado and north of Florida.	Mothproof chests, lining for linen closets, sills, and other uses similar to white cedar.	Very light, soft, weak, brittle, low shrinkage, great durability, fragrant scent, generally knotty, beautiful when finished in natural color, easily worked.
Red Oak. . .	Virginias, Tennessee, Arkansas, Kentucky, Ohio, Missouri, Maryland.	Interior finish, furniture, cabinets, millwork, crossties when preserved.	Tends to warp, coarse grain, does not last well when exposed to weather, porous, easily impregnated with preservative, heavy, tough, strong.
Redwood . .	California.	General construction, tanks, paneling.	Inferior to yellow pine and fir in strength, shrinks and splits little, extremely soft, light, straight grained, very durable, exceptionally decay resistant.

Table 6-1.-Common Woods—Continued

Type	Sources	Uses	Characteristics
Spruce	New York, New England, West Virginia, Central Canada, Great Lakes States, Idaho, Washington, Oregon.	Railway ties, resonance wood, piles, airplanes, oars, masts, spars, baskets.	Light, soft, low strength, fair durability, close grain, yellowish, sap wood indistinct.
Sugar Pine	California, Oregon.	Same as white pine.	Very light, soft, resembles white pine.
Teak	India, Burma, Siam, Java.	Deck planking, shaft logs for small boats.	Light brown color, strong, easily worked, durable, resistant to damage by moisture.
Walnut	Eastern half of U.S. except Southern Atlantic and Gulf Coasts, some in New Mexico, Arizona, California.	Expensive furniture, cabinets, interior woodwork, gun stocks, tool handles, airplane propellers, fine boats, musical instruments.	Fine cabinet wood, coarse grained but takes beautiful finish when pores closed with woodfiller, medium weight, hard, strong, easily worked, dark chocolate color, does not warp or check, brittle.
White Cedar. . . .	Eastern Coast of U.S., and around Great Lakes.	Boat planking, railroad ties, shingles, siding, posts, poles.	Soft, light weight, close grained, exceptionally durable when exposed to water, not strong enough for building construction, brittle, low shrinkage, fragment, generally knotty.
White Oak . .	Virginias, Tennessee, Arkansas, Kentucky, Ohio, Missouri, Maryland, Indiana.	Boat and ship stems, sternposts, knees, sheer strakes, fenders, capping, transoms, shaft logs, framing for buildings, strong furniture, tool handles, crossties, agricultural implements, fence posts.	Heavy, hard, strong, medium coarse grain, tough, dense, most durable of hardwoods, elastic, rather easy to work, but shrinks and likely to check. Light brownish grey in color with reddish tinge, medullary rays are large and outstanding and present beautiful figures when quarter sawed, receives high polish.

Table 6-1.-Common Woods—Continued

Type	Sources	Uses	Characteristics
White Pine.	Minnesota, Wisconsin, Maine, Michigan, Idaho, Montana, Washington, Oregon, California	Patterns, any interior job or exterior job that doesn't require maximum strength, window sash, interior trim, millwork, cabinets, cornices.	Easy to work, fine grain, free of knots, takes excellent finish, durable when exposed to water, expands when wet, shrinks when dry, soft, white, nails without splitting, not very strong, straight grained.
Yellow Pine.	Virginia to Texas.	Most important lumber for heavy construction and exterior work, keelsons, risings, filling pieces, clamps, floors, bulkheads of small boats, shores, wedges, plugs, strongbacks, staging, joists, posts, piling, ties, paving blocks.	Hard, strong, heartwood is durable in the ground, grain varies, heavy, tough, reddish brown in color, resinous, medullary rays well marked.

Nominal, rough, green lumber has three general classifications, according to size, as follows:

1. BOARDS—less than 2 in. thick and 1 **or** more in. wide. If less than 6 in. wide, they may be classified as strips.

2. DIMENSION—at least 2 in. thick, but less than 5 in. thick, and 2 or more in. wide. It may be classified as framing, joists, planks, rafters, studs, and small timbers.

3. TIMBERS—smallest dimension is 5 or more in. They may be classified as beams, stringers, posts, caps, sills, girders, and purlins.

Lumber classified by extent of manufacture consists of three types as follows:

1. ROUGH LUMBER is not dressed (surfaced) but sawed, edged, and trimmed to the extent that saw marks show in the wood on the four longitudinal surfaces of each piece for its overall length.

2. DRESSED LUMBER is surfaced by a planing machine to attain a smooth surface and uniform size.

3. WORKED LUMBER is dressed and also matched, shiplapped, or patterned.

Grading

According to the American Lumber Standards set by the National Bureau of Standards for the U.S. Department of Commerce, lumber is graded for quality. The major grades of yard lumber, in descending order of quality, are SELECT LUMBER and COMMON LUMBER. Each of these grades is subdivided, also in descending order of quality.

SELECT LUMBER has a good appearance and good qualities for finishing. One kind of select lumber is suitable for natural finishes; another kind, for painted finishes. Select lumber for natural finishes is graded A or B. Grade A is nearly free of defects and blemishes, but Grade B contains a few minor blemishes. Select lumber for painted finishes is Grade C or D. The blemishes in Grade C are more numerous and significant than those in Grade B. Grade D has even more blemishes than Grade C does. Either grade, C or D, presents a satisfactory appearance when painted.

COMMON LUMBER is suitable for general construction and utility purposes. It, also, is subdivided by grade in descending order of quality. No. 1 common is sound, tight-knotted stock, containing only a few minor defects. It must be suitable for use as watertight lumber.

Table 6-2.-Nominal and Dressed Sizes of Lumber

Item	Thickness (Inches)		Face Width (Inches)	
	Nominal	Dressed	Nominal	Dressed
			2	1 1/2
			3	2 1/2
			4	3 1/2
			5	4 1/2
	1	3/4	6	5 1/2
			7	6 1/2
Boards	1 1/4	1	8	7 1/4
			9	8 1/4
	1 1/2	1 1/4	10	9 1/4
			11	10 1/4
			12	11 1/4
			14	13 1/4
			16	15 1/4
			2	1 1/2
			3	2 1/2
			4	3 1/2
	2	1 1/2	5	4 1/2
Dimension	2 1/2	2	6	5 1/2
Lumber	3	2 1/2	8	7 1/4
	3 1/2	3	10	9 1/4
			12	11 1/4
			14	13 1/4
			16	15 1/4
			2	1 1/2
			3	2 1/2
			4	3 1/2
			5	4 1/2
Dimension	4	3 1/2	6	5 1/2
Lumber	4 1/2	4	8	7 1/4
			10	9 1/4
			12	11 1/4
Timbers	5 & Thicker		5 & Wider	

No. 2 common contains a limited number of significant defects but no knotholes or other serious defects. It must be suitable for use as grain-tight lumber. No. 3 common contains a few defects, larger and coarser than those in No. 2; for example, occasional knotholes. No. 4 is low-quality material, contains serious defects like knotholes, checks, shakes, and decay. No. 5 common holds together only under ordinary handling.

STRUCTURAL LUMBER is graded according to allowable stresses that determine its safe load-carrying capacity. This capacity is based on various factors, such as species of the wood, density, moisture content, and other characteristics that affect the strength of the lumber. Factory and shop lumber is generally graded by its intended use; the grades vary greatly from use to use.

Board Measure

The basic unit of quantity for lumber is called a BOARD FOOT. It is defined as the volume of

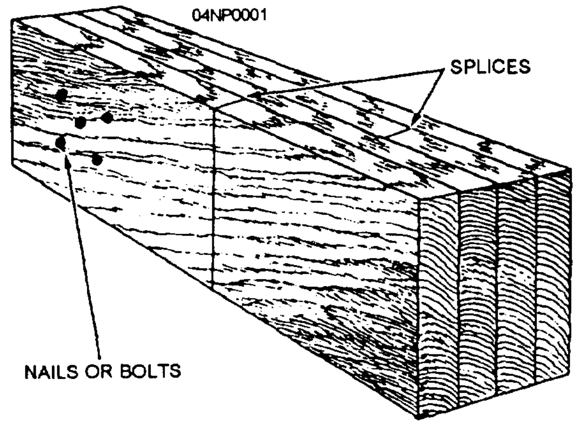


Figure 6-1.-Example of a laminated lumber.

a board 1 ft long by 1 ft wide by 1 in. thick. Since the length of lumber is usually measured in feet, the width in inches, and the thickness in inches, the formula for the quantity of lumber in board feet becomes the following:

$$\frac{\text{Thickness (inches)} \times \text{width (inches)} \times \text{length (feet)}}{12} = \text{board measure (board feet)}$$

Example: Calculate the board measure of a 14-ft length of a 2 by 4. Applying the formula, you get

$$\frac{2 \times 4 \times 14}{12} = 9\ 1/3$$

Lumber less than 1 in. thick is presumed to be 1 in. thick for board measure purposes. Board measure is calculated on the basis of the nominal, not the dressed, dimensions of lumber. The symbol for board feet is bm, and the symbol for a unit of 1,000 is M. If 10,000 board feet of lumber were needed, for example, the quantity would be 10Mbm.

LAMINATED LUMBER

Laminated lumber is commonly used when increased wood load-carrying capacity and rigidity are required. Usually made of several pieces of 1 1/2-in. -thick lumber, called laminations, the pieces are nailed, bolted, or glued together with the grain of all pieces running parallel (fig. 6-1). When extra length is needed, the pieces are spliced with the splices staggered so that no two adjacent laminations are spliced at the same point. Built-up beams and girders are examples of laminated lumber.

Laminations may be used independently or with other materials in the construction of a structural unit. Trusses can be made with laminations for the chords and sawed lumber for the web members (fig. 6-2). Special beams (fig. 6-3) may be constructed with laminations for the flanges and sawed lumber for the webs.

Probably the greatest use of laminations is in the fabrication of large beams and arches. Beams with spans larger than 100 ft and depths of 8 1/2 ft have been constructed with 2-in. boards. Laminations this large are factory-produced. They are glued together under pressure. Most laminations are spliced using scarf joints (fig. 6-4), and the entire piece is dressed to ensure uniform thickness and width.

PLYWOOD

Plywood is a panel product made from thin sheets of wood called veneers. An odd number of veneers, such as three, five, or seven, is generally used so the grains on the face and back of the panel run in the same direction. Cross-lamination (fig. 6-5) distributes the grain strength in both directions, creating a panel that resists splitting and, pound for pound, one of the strongest building materials available.

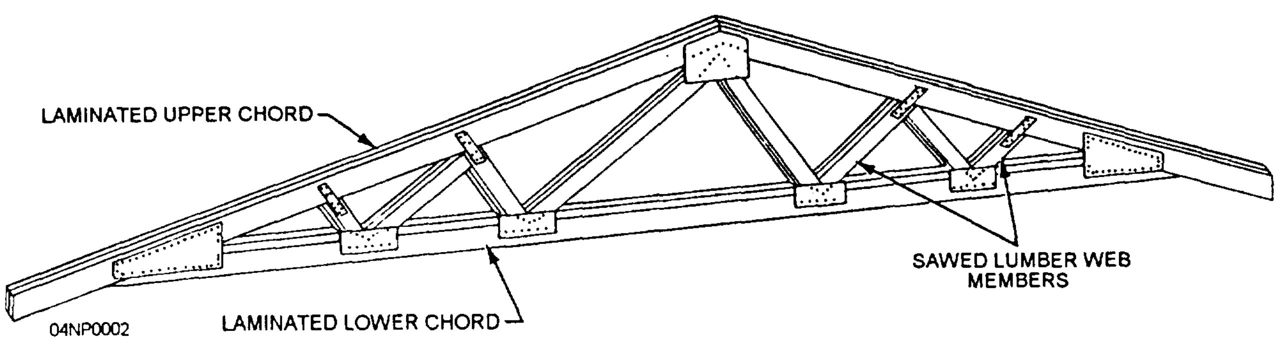


Figure 6-2.-Truss using laminated and sawed lumber.

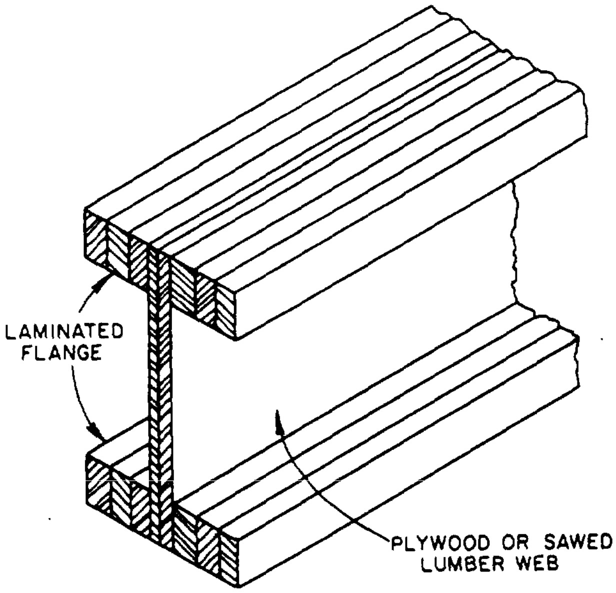


Figure 6-3.-Laminated and sawed lumber or plywood beam.

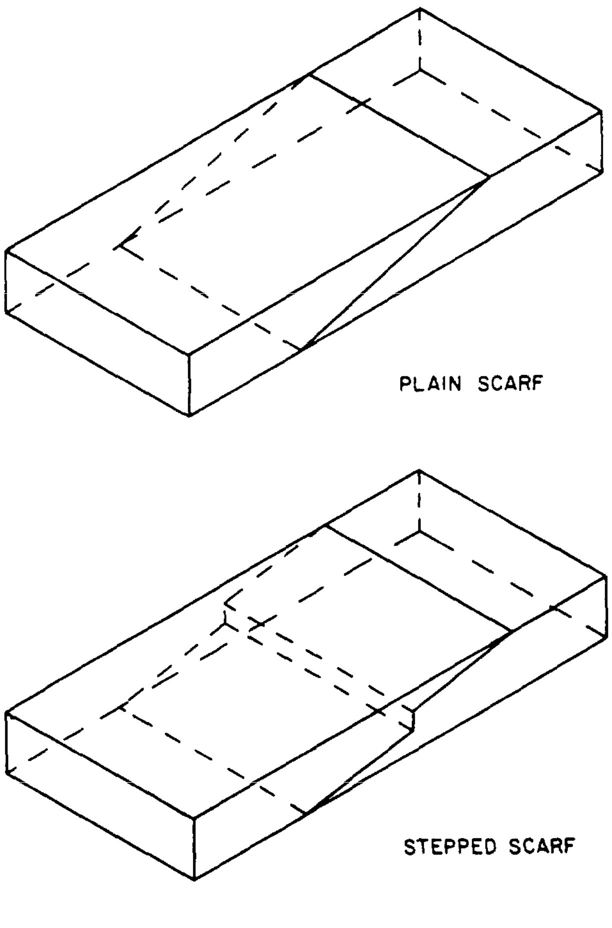


Figure 6-4.-Scarf joints.

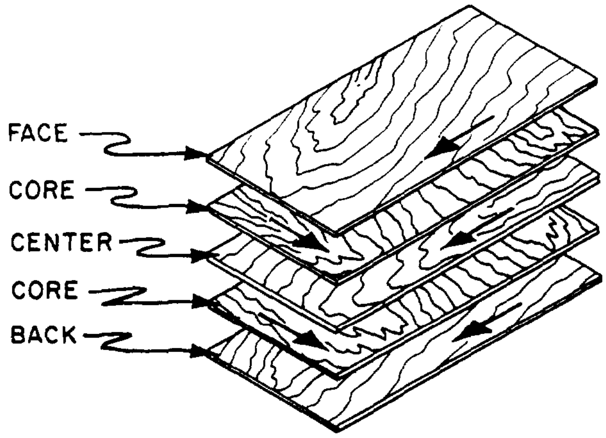


Figure 6-5.-Grain direction in a sheet of plywood.

Dry from the mill, plywood is never "green." From ovendry to complete moisture saturation, a plywood panel swells across or along the grain only about 0.2 of 1 percent and considerably less with normal exposures.

There is probably no building material as versatile as plywood. It is used for concrete forms, wall and roof sheathing, flooring, box beams, soffits, stressed-skin panels, paneling, partitions, doors, furniture, shelving, cabinets, crates, signs, and many other purposes.

Sizes

Plywood is generally available in panel widths of 36, 48, and 60 in. and in panel lengths ranging from 60 to 144 in. in 12-in. increments. Other sizes are also available on special order. Panels 48 in. wide by 96 in. long (4 by 8 ft), and 48 in. wide by 120 in. long (4 by 10 ft), are most commonly available. The 4 by 8 ft and larger sizes simplify construction, saving time and labor.

Nominal thicknesses of sanded panels range from 1/4 to 1 1/4 in. or greater, generally in 1/8-in. increments. Unsanded panels are available in nominal thicknesses of 5/16 to 1 1/4 in. or greater, in increments of 1/8 in. for thicknesses over 3/8 in. Under 3/8 in., thicknesses are in 1/16-in, increments.

Types

Plywood is classified by type as INTERIOR or EXTERIOR. Made of high-quality veneers and more durable adhesives, exterior plywood is better than interior at withstanding exposure to the elements. Even when wetted and dried

N—Special order natural finish veneer. Select all heartwood or all sapwood. Free of open defects. Allows some repairs.

A—Smooth and paintable. Neatly made repairs permissible. Also used for natural finish in less demanding applications.

B—Solid surface veneer. Circular repair plugs and tight knots permitted.

C—Knotholes to 1 in. Occasional knotholes 1/2 in. larger permitted providing total width of all knots and knotholes within a specified section does not exceed certain limits. Limited splits permitted. Minimum veneer permitted in exterior-type plywood.

C [Plgd]—Improved C veneer with splits limited to 1/8 in. in width and knotholes and borer holes limited to 1/4 in. by 1/2 in.

D—Permits knots and knotholes to 2 1/2 in. width and 1/2 in. larger under certain specified limits. Limited splits permitted.

Figure 6-6.-Plywood veneer grades.

repeatedly or otherwise subjected to the weather, exterior plywood retains its glue bond and withstands exposure to the elements. Interior plywood can withstand an occasional wetting but not permanent exposure to the elements.

Grades

The several grades within each type of plywood are determined by the grade of the veneer (N, A, B, C, or D) used for the face and back of the panel (fig. 6-6). Panel grades are generally designated by the kind of glue and by the veneer grade on the back and face. Grading is based on the number of defects, such as knotholes, pitch pockets, splits, discolorations, and patches, in each face of the plywood panel.

Identification Stamps

Stamps are placed on the edges and back of each sheet of plywood so it can be properly identified. Figure 6-7 shows typical back-stamps and edge-marks found on a standard sheet of plywood. It shows all information needed about the sheet, except its actual size.

Figure 6-8 shows the stamps found on the backs of structural and standard sheathing panels. They vary somewhat from the standard stamps.

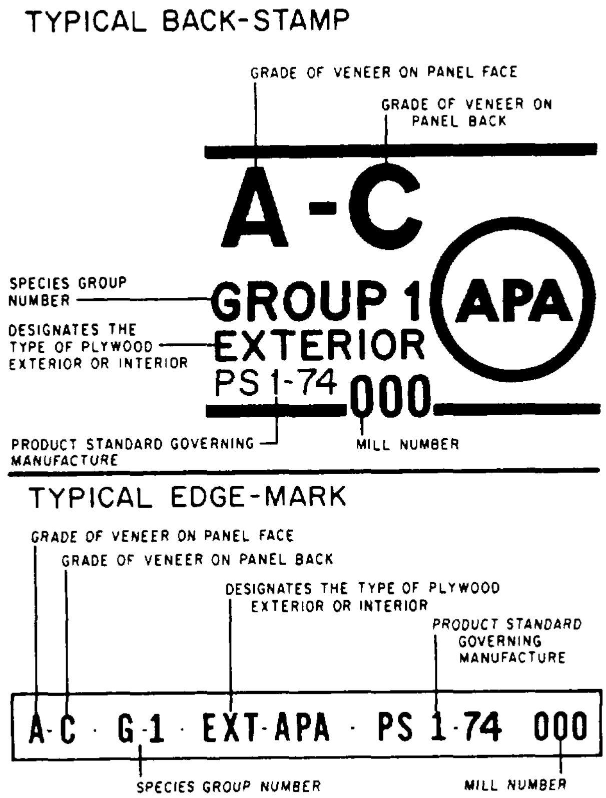


Figure 6-7.-Standard plywood identification symbols.

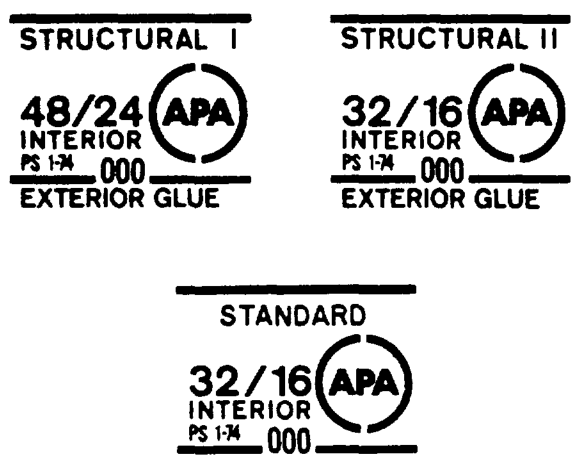


Figure 6-8.-Structural and standard sheathing identification symbols.

The actual grade is NOT given, NOR is the species group. The index numbers 48/24 and 32/ 16 give the maximum spacing in inches of supports. The number to the left of the slash is the maximum O.C. (on-center) spacing of supports for roof decking. The number to the right of the slash is the maximum O.C. spacing of supports for subfloors. A number 0 on the right of the slash indicates that the panel should NOT be used for subflooring. No reference to the index number is needed when the panel is to be used for wall sheathing.

Detailed information on specific types and grades and their uses can be found in commercial standards for the manufacture of plywoods established by the U.S. Department of Commerce. General plywood characteristics and architectural information can be found in the following publications: *American Plywood Association, National Lumber Manufacturing Association*, or the *Architectural Graphic Standards*. The latter book can be found in your unit's technical library.

SPECIAL-PURPOSE PLYWOOD

Other types of plywood are manufactured for specific purposes. Among these types are the structural, sheathing, overlaid panels, decorative panels, and concrete form panels. Table 6-3 lists some of the various types of plywood with their suggested uses.

Structural plywood is recommended for heavy-load application where strength properties are of great importance. Likewise, for box beams, gusset plates, and stressed-skin panels, unsanded grades of C-D plywood are recommended.

Standard plywood sheathing is used for subfloors, roof decks, and wall sheathing. It is

Table 6-3.-Uses of Plywood

SOFTWOOD PLYWOOD GRADES FOR EXTERIOR USES				
GRADE (EXTERIOR)	FACE	BACK	INNER PLYS	USES
A-A	A	A	C	Outdoor where appearance of both sides is important.
A-B	A	B	C	Alternate for A-A, where appearance of one side is less important.
A-C	A	C	C	Siding, soffits, fences. Face is finish grade.
B-C	B	C	C	For utility uses such as farm buildings, some kinds of fences, etc.
C-C (Plugged)	C Plugged	C	C	Excellent base for tile and linoleum, backing for wall coverings.
C-C	C	C	C	Unsanded, for backing and rough construction exposed to weather.
B-B Concrete Forms	B	B	C	Concrete forms. Re-use until wood literally wears out.
MDO	B	B or C	C or C-Plugged	Medium Density Overlay. Ideal base for paint: for siding, built-ins, signs, displays.
HDO	A or B	A or B	C-Plugged	High Density Overlay. Hard surface; no paint; needed. For concrete forms, cabinets, counter tops, tanks.

SOFTWOOD PLYWOOD GRADES FOR INTERIOR USES				
GRADE (INTERIOR)	FACE	BACK	INNER PLYS	USES
A-A	A	A	D	Cabinet doors, built-ins, furniture where both sides will show.
A-B	A	B	D	Alternate of A-A. Face is finish grade, back is solid and smooth.
A-D	A	D	D	Finish grade face for paneling, built-ins, backing.
B-D	B	D	D	Utility grade. One paintable side. For backing, cabinet sides, etc.
STANDARD	C	D	D	Sheathing and structural uses such as temporary enclosures, subfloor. Unsanded.

recommended for use in spaces that may be exposed to moisture during construction, but will be covered when construction is complete.

Overlaid panels have a resin-treated fiber-surfacing material, on one or both sides, to hold paint and finishes more readily. These exterior or interior types of plywood are recommended for use in furniture, cabinets, millwork, and exterior trims.

Decorative panels are used basically for exterior and interior wall sheathing. Both types are manufactured in a multitude of designs and patterns and can be painted, stained, or left to weather naturally.

A concrete form panel has a coating over its exterior face to make it moisture-resistant and nonadhesive to concrete when used as forming material. The exterior coating reduces the number of times the form must be oiled and allows the panel to be reused several times.

COMMON WOOD SUBSTITUTE

For various reasons, many common construction materials are used as wood or plywood substitutes. Some are significantly less expensive than plywood; others are more suitable because of their decorative appearance and weather-resistant qualities.

Particleboard

Particleboard, commonly referred to as chipboard or flakeboard, is produced by mixing a resin-bonding agent with wood particles and bonding them together by means of heat and pressure. The use of particleboard is limited to nonstructural use because of its low strength qualities. The most common size sheets are 4 ft by 8 ft and vary from 1/4 in. to 1 1/2 in. thick.

Hardboard

Hardboard is made of compressed wood fibers subjected to heat and heavy pressure. The finish may be obtained in a plain, smooth surface or in any number of glossy finishes, some of which imitate tile or stone. Its strength is about equal in all directions, and it can be bent into various shapes. Hardboard is available in thicknesses from 1/8 in. to 3/8 in. The most common size sheets are 4 ft by 8 ft.

Fiberboard

Fiberboard is made of wood or vegetable fiber that has been compressed to form sheets or boards. They are comparatively soft and provide good insulation and sound-absorbing qualities. Fiberboard is available in sizes from 1/2 in. to 1 in. thick, 2 ft to 4 ft wide, and 8 ft to 12 ft long.

Gypsum Wallboard

Gypsum wallboard is composed of gypsum between two layers of heavy paper. Some types have unfinished surfaces, while others have finishes that represent wood grain or tile. The most common thickness is 1/2 in. Its width is usually 4 ft, and its length varies from 4 to 14 ft.

Another type of gypsum wallboard has depressed or tapered edges. The joints are filled with special cement and are then taped so that the joints do not show. They can then be painted. This procedure is commonly known as DRY WALL. Dry walls are particularly useful in areas and spaces where sound-deadening and fire-resistant materials are desired.

TREATMENT

When not properly treated and installed, wood can be destroyed by decay, fungi, boring insects, weathering, or fire. Although designed for the specific use of the wood, treatment varies from project to project and from one geographical area to another. The kind and amount of treatment is usually given by the project specifications. Where no written specifications exist, the drawings should indicate the kind and amount of wood treatment.

Manufacturers' commercial standards contain information on wood pretreated by the manufacturer. NAVFAC publications and specifications provide technical information and design requirements for the treatment of wood used in buildings and structures.

WOOD FRAME STRUCTURES

In a wood frame building or structure, the framework consists mostly of wood load-bearing members that are joined together to form an internal supporting structure, much like the skeleton of a human body.

When a complete set of drawings is made for a certain building, large-scale details are usually shown for typical sections, joints, and other unusual construction features. Understanding the different functions of the structural members of a frame building will enable you to make these drawings correctly and promptly.

THEORY OF FRAMING

Generally, a building has two main parts: the FOUNDATION and that part above the foundation, called the SUPERSTRUCTURE. The framework of a wooden superstructure is called the FRAMING of the building. It is subdivided into floor framing, wall framing, and roof framing. FLOOR FRAMING consists, for the most part, of horizontal structural members called joists, and the WALL FRAMING, for the most part, of vertical members called studs. ROOF FRAMING consists of both horizontal and vertical structural members.

The most common framing and construction methods are the PLATFORM (also called WESTERN and STORY-BY-STORY framing) (fig. 6-9) and the BALLOON FRAMING (fig. 6-10). The striking difference between these two methods is

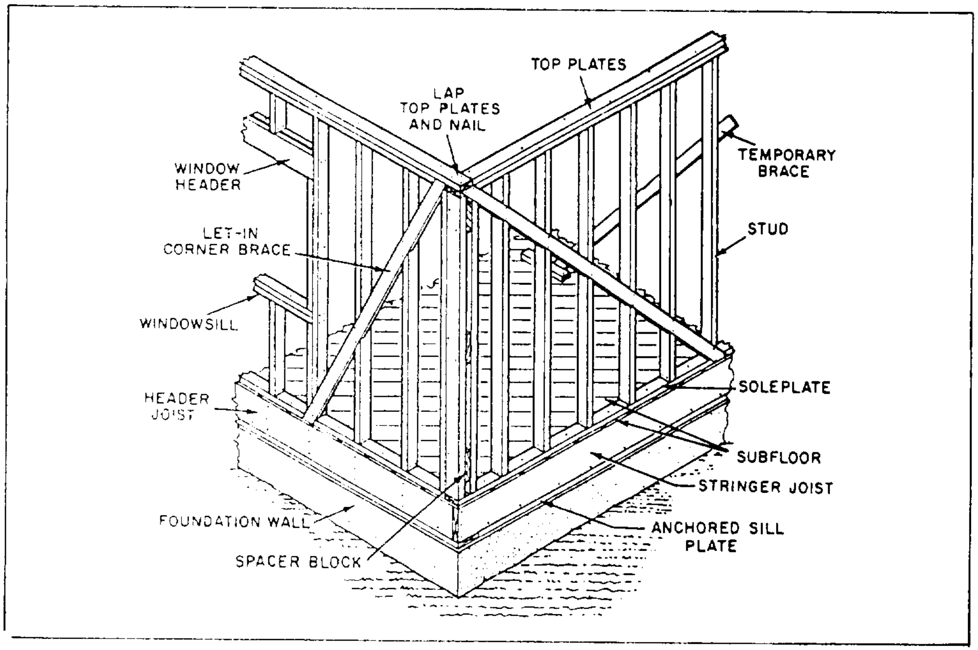


Figure 6-9.-Wall framing used in platform construction.

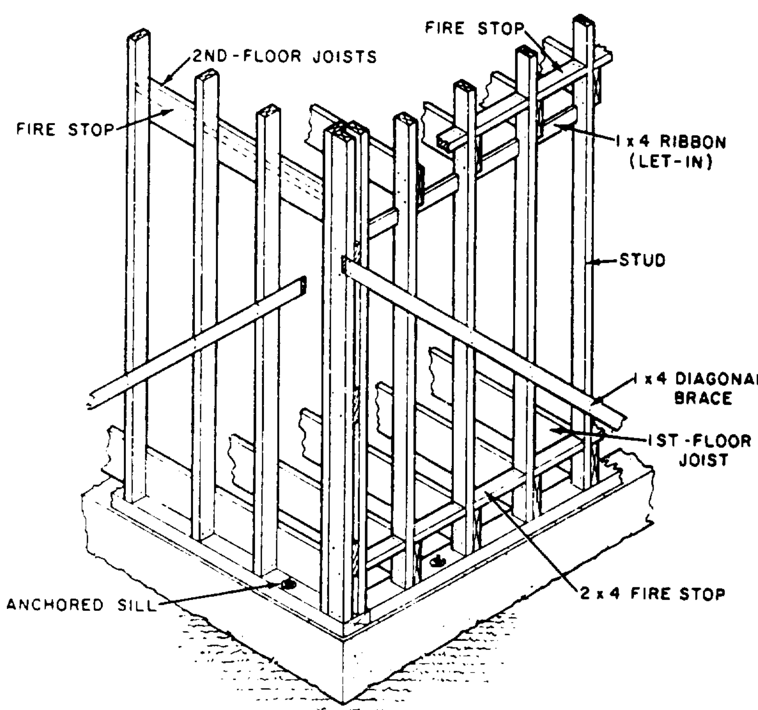


Figure 6-10.-Wall framing used in balloon construction.

that in balloon framing, the studs extend from the sill of the first floor to the top of the soleplate or end rafter of the second floor; whereas the platform framing has separate studs for each floor anchored on the soleplate.

SILL FRAMING AND LAYOUT

The lowest horizontal wood frame structural member is the SILL, a piece of dimensional lumber laid flat and bolted down to the top of the foundation pier or wall. It is the first part of the frame to be set in place and provides a nailing base for the other adjoining members. It may extend all around the building, joined at the corners and spliced when necessary.

The type of sill assembly selected depends upon the general type of construction methods used in the framework. The method of framing

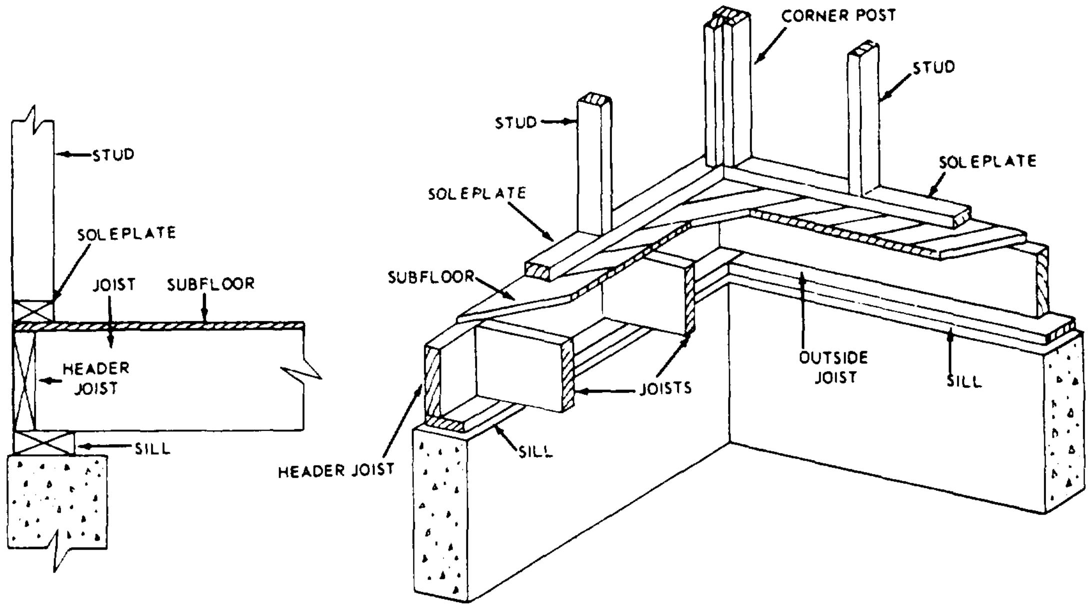


Figure 6-11.-Box-sill assembly for platform framing.

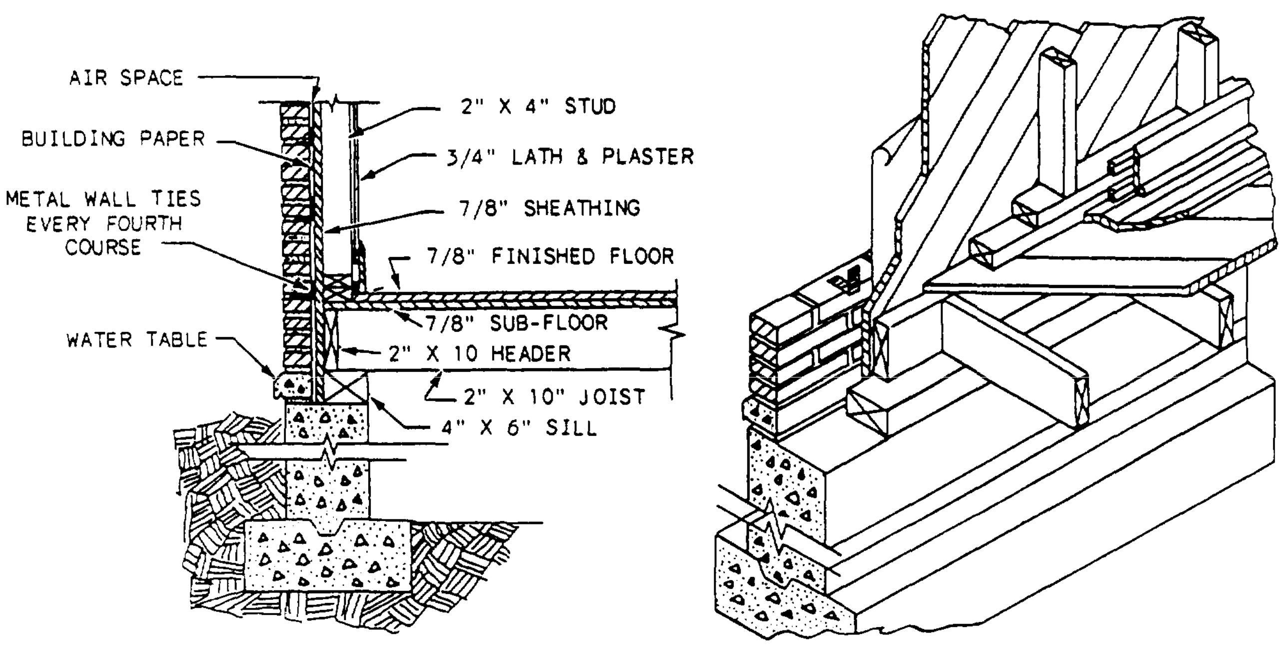


Figure 6-12.-Sill assembly in brick veneer construction.

the studs to the sill is called SILL ASSEMBLY. The BOX-SILL assembly shown in figure 6-11 is the type most frequently used in platform-frame construction. In this type, the ends of the joists are framed against a header-joist, which is set flush with the outer edge of the sill. The construction method for a sill assembly in which brick veneer is used as exterior siding (fig. 6-12) is similar to the box-sill assembly except that the sill is set in the foundation wall to allow enough space for the brick to rest directly on the wall.

Balloon-frame construction uses the T-SILL (fig. 6-13) and EASTERN (fig. 6-14) assemblies. Here, the studs are anchored on the sill and are continuous; that is, in one piece from sill to roof line.

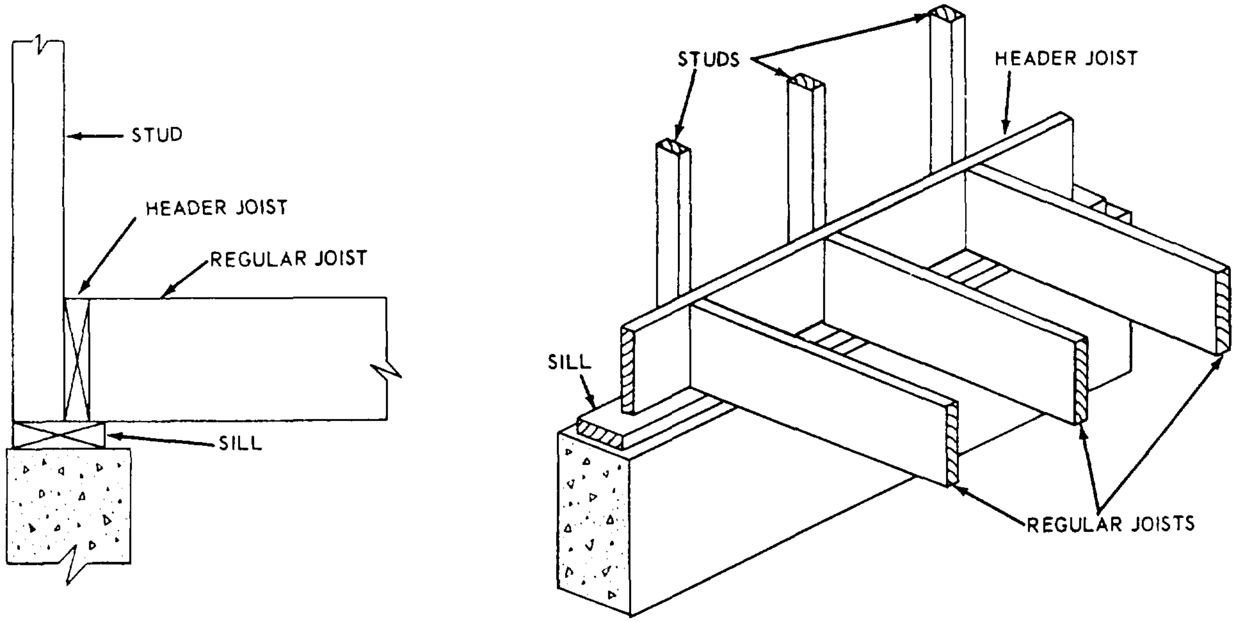


Figure 6-13-T-sill assembly.

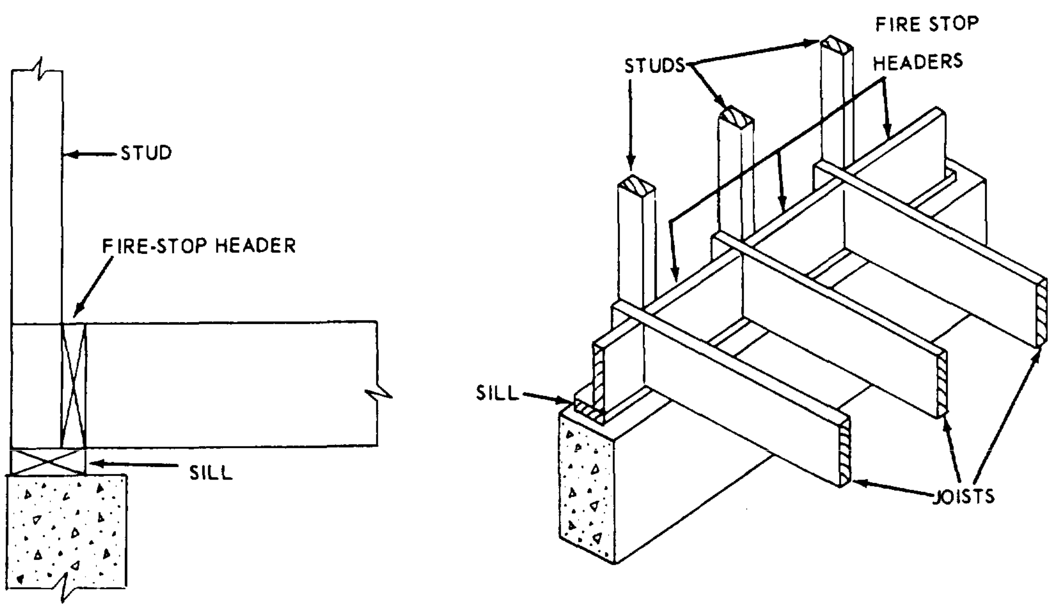


Figure 6-14.-Eastern sill assembly.

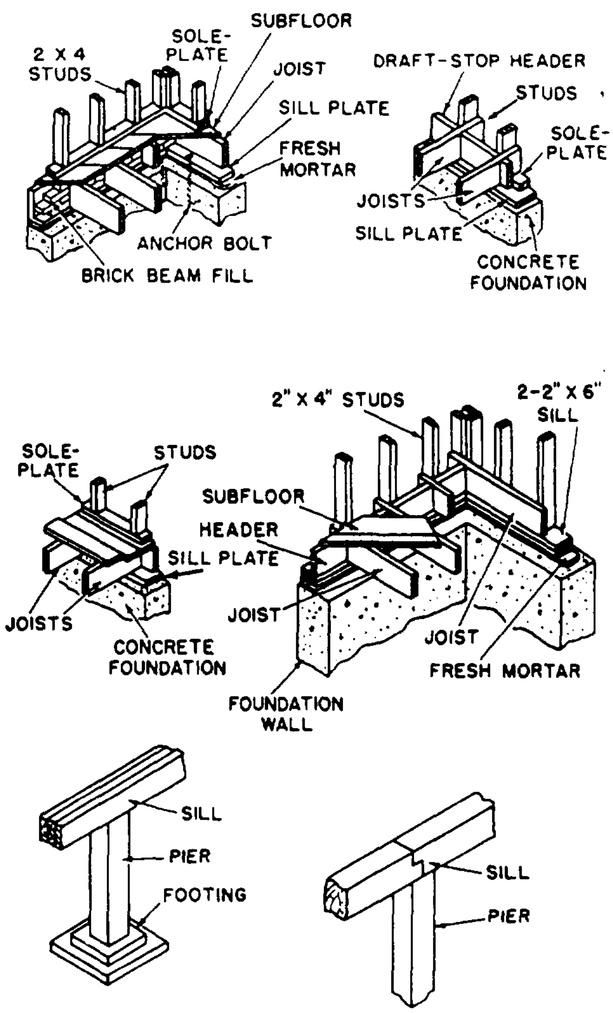


Figure 6-15.-Types of sills.

Other types of sill framing and layout are shown in figure 6-15.

FLOOR FRAMING

Horizontal members that support the floors in wood frame structures are called JOISTS or BEAMS, depending upon the length of the SPAN (distance between the end supports). Members less than 4 ft apart are called joists; members 4 ft or more apart are called beams. The usual spacing for wood frame floor members is either 16 in. or 24 in. O.C. Joists are usually 2 by 8, 2 by 10, or 2 by 12. A COMMON JOIST is a full-length joist that spans from wall to wall or from wall to girder. A CRIPPLE JOIST is similar to a common joist with the exception that it does not

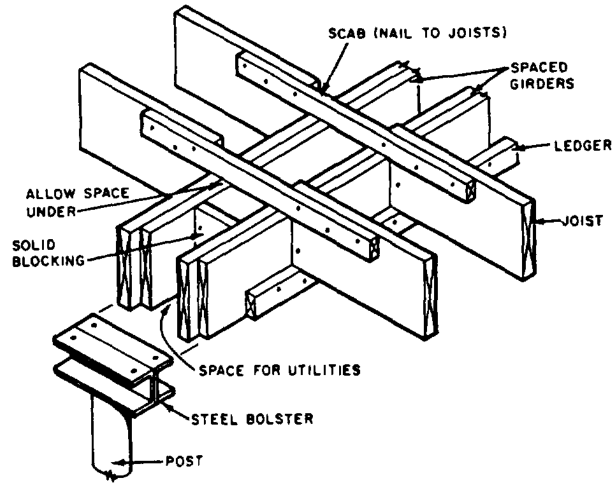


Figure 6-16.-Spaced wood girder.

extend the full span. Cripples are normally interrupted by floor openings.

Girders (fig. 6-16) are horizontal members that support joists at points other than along the outer wall lines. When the span is longer than can be covered by a single joist, a girder must be placed as an intermediate support for joist ends. Ground-floor girders are commonly supported by concrete or masonry pillars and pilasters. A PILLAR is a girder support that is clear of the foundation walls. A PILASTER is set against a foundation wall and supports the end of a girder. Both pillars and pilasters are themselves supported by concrete footings. Upper-floor girders are supported by columns. GIRTS are horizontal wood framing members that help to support the outer-wall ends of upper-floor joists in balloon framing.

Framing Around Floor Openings

A common joist must be cut away to give way for floor openings, such as stairways. The wall-opening ends of cripple joists are framed against HEADERS, as shown in figure 6-17. Specifications usually require that headers be doubled—sometimes tripled. Headers are framed bet ween the full-length joists, also called TRIMMERS, on either side of the floor opening. Headers up to 6 ft in length are fastened with nails, whereas those longer than 6 ft are fastened with joist hangers.

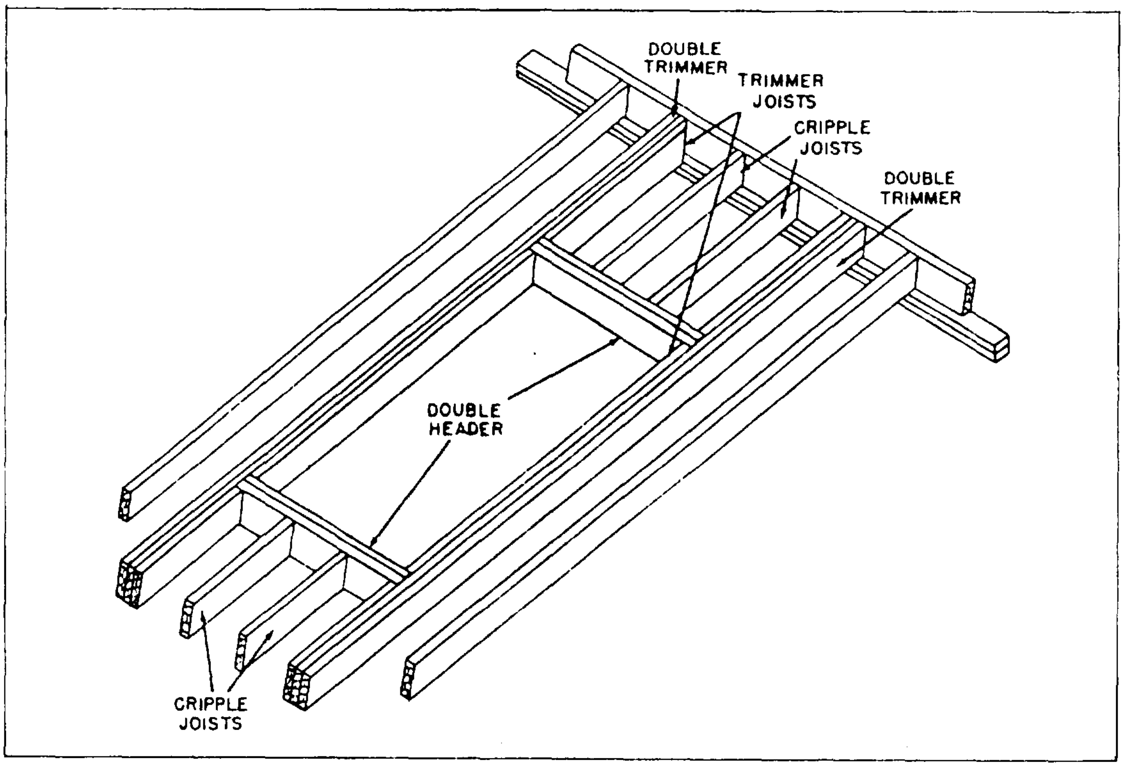


Figure 6-17.-Framing around floor openings.

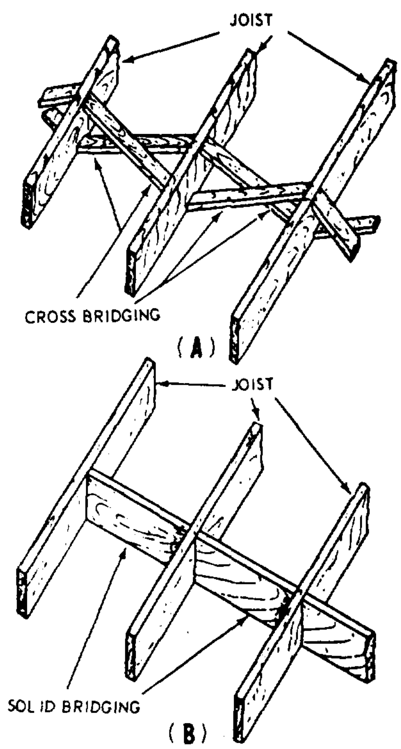


Figure 6-18.-Cross bridging and solid bridging.

Bridging

Bridging is the system of bracing the joists to each other to hold them plumb and aligned. It also serves to distribute part of a concentrated load over several joists next to those directly under the load. There are two types of bridging: CROSS BRIDGING (fig. 6-18, view A) and SOLID BRIDGING (fig, 6-18, view B). Cross bridging consists of pairs of STRUTS set diagonally between the joists. The strut stock comes in sizes of 1 by 3, 1 by 4, 2 by 2, and 2 by 4. Solid bridging consists of pieces of joist-size stock set at right angles to the joists. They can be staggered for easier installation. Cross bridging is more rigid than solid bridging and is more frequently used in construction. Bridging should be provided for all spans greater than 6 ft.

Subflooring

Joists are covered by a layer (or double layer) of boards called SUBFLOORING. It usually consists of square-edge or tongue-and-grooved boards or plywood 1/2 to 3/4 in. thick that serve

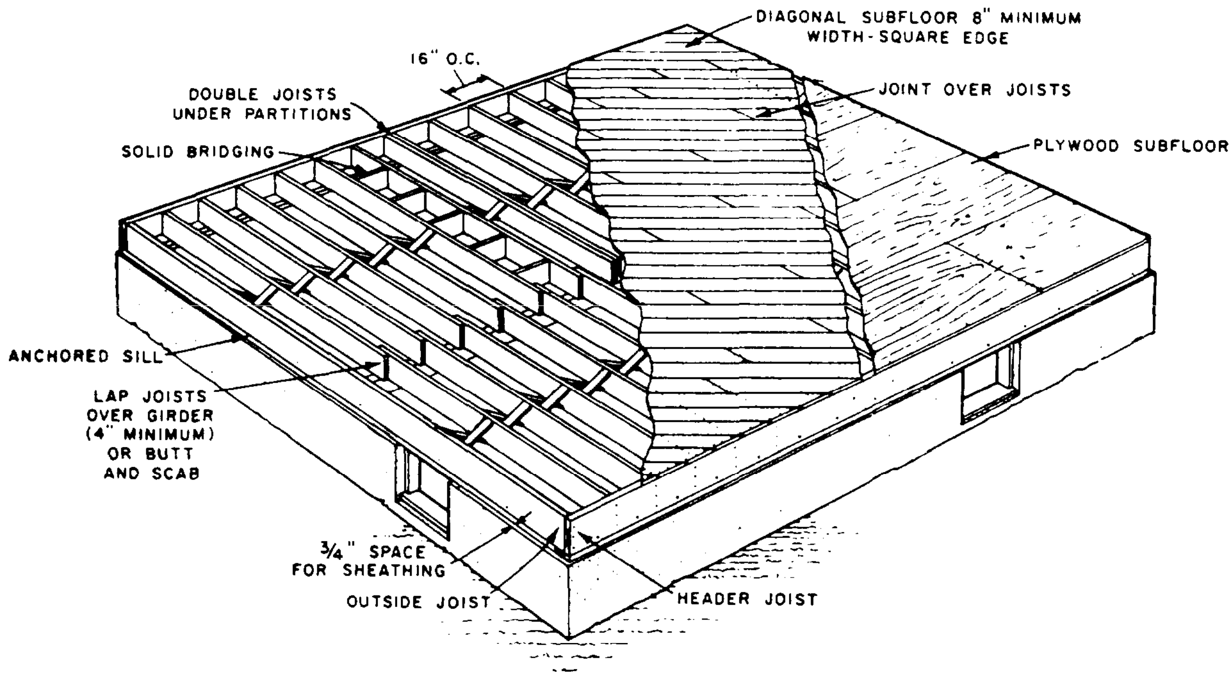


Figure 6-19.-Typical floor framing with subflooring.

as a working platform and base for finish flooring (fig. 6-19). Sub flooring may be applied either diagonally (most common) or at right angles to the joists. Diagonal subflooring permits finish flooring to be laid either parallel to, or, more commonly, at right angles to, the joists. The joist spacing should not exceed 16 in. O.C. when finish flooring is laid parallel to the joists or when parquet finish flooring is used.

WALL FRAMING

As with floor construction, two general types of wall framing are commonly used: platform construction and balloon-frame construction. The platform method shown in figure 6-9 is more often used because of its simplicity.

A typical wall frame (fig. 6-20) is composed of regular studs, cripples, trimmers, headers, and fire stops (fig. 6-10) and is supported by the floor soleplate, The wall framing members used in conventional construction are generally nominal 2 by 4 in. in size. The requirements are good stiffness, good nail-holding ability, freedom from warp, reasonable dryness (about 15-percent moisture content), and ease of working. The closely spaced and slender vertical members of the wall framing are called the STUDS. They support the top plates and provide the framework to which the wall sheathing is nailed on the outside and which supports the lath, plaster, and insulation on the inside. TOP PLATES (or CAPS) are horizontal wood framing members that are nailed to the tops of the wall or partition studs. SOLEPLATES are horizontal wood framing members that serve as nailing bases for studs in platform-framing construction. HEADERS form the upper members of a rough doorframe, or upper or lower members of a rough window frame. Similar members that form the ends of a rough floor or roof opening (as a skylight) are also called headers.

Partition

The inside space of a building is divided by partition walls. In most cases, these walls are framed as part of the building. There are two types of partition walls: BEARING and NONBEARING. Partition walls of the bearing type support the ceiling joists and all other loads imposed upon them; those of the nonbearing type support only themselves and are usually installed after the other framework is put in. Partition walls are framed in the same manner as outside walls, and door openings are framed as outside openings. CORNER POSTS or T-POSTS are used at corners or where one partition wall joins another. They provide nailing surfaces for the inside wall finish (fig. 6-21).

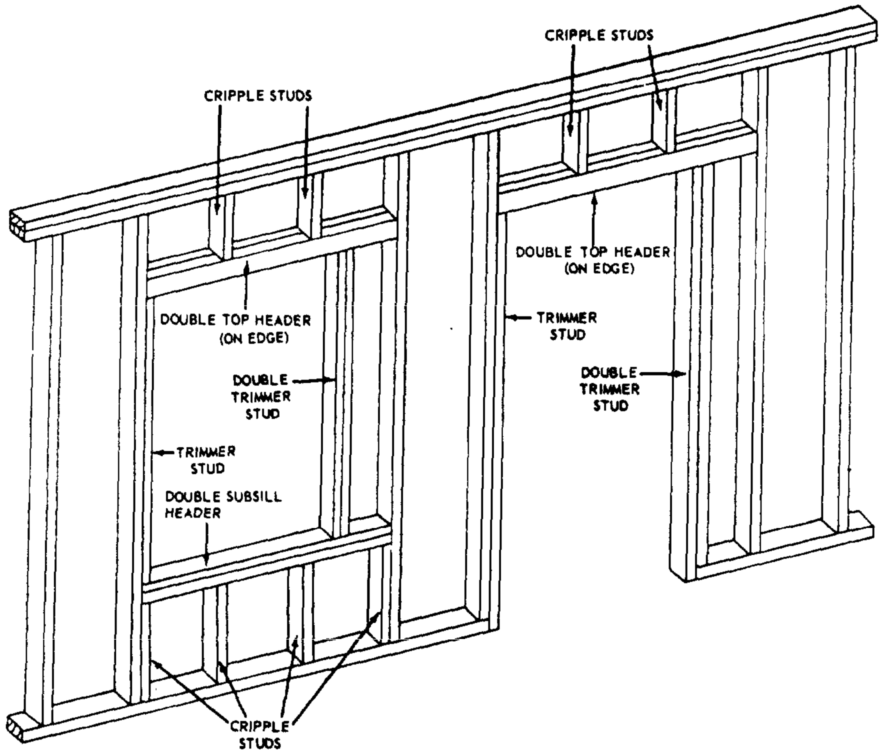


Figure 6-20.-Parts of a wall frame, showing headers.

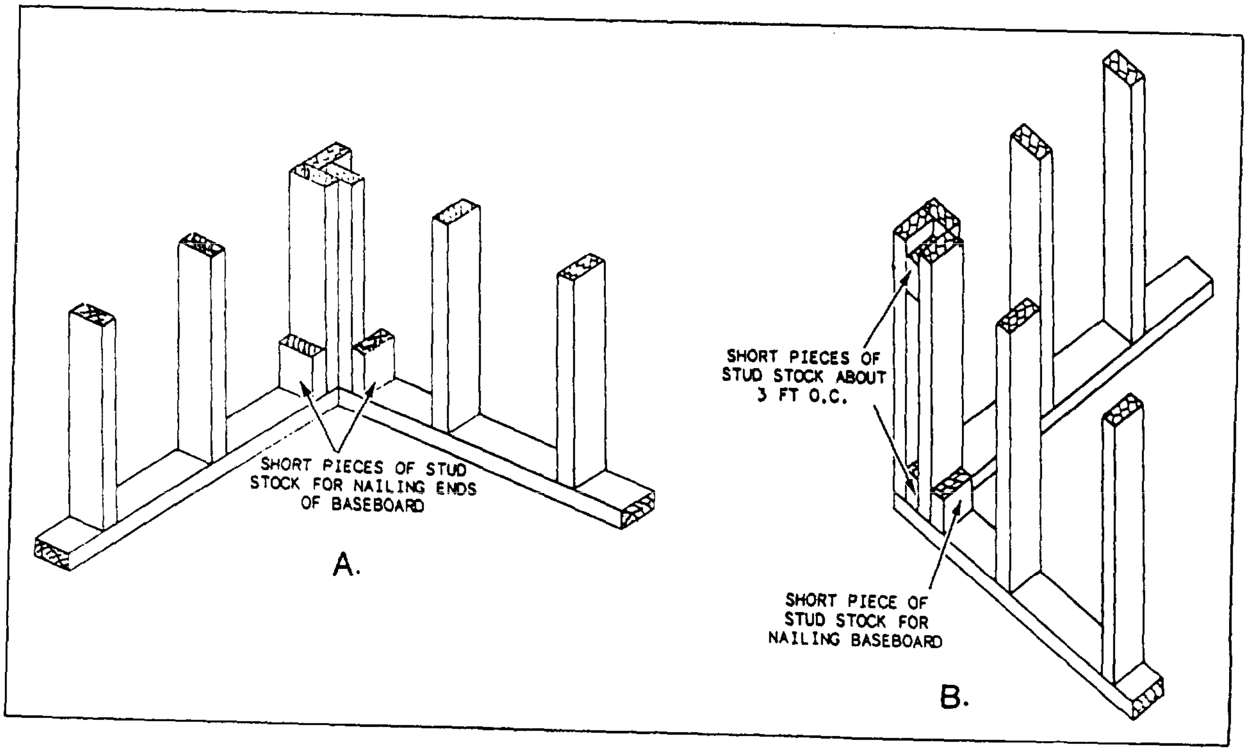


Figure 6-21.-Typical examples of corner posts: A. Simplest type; B. More solid type.

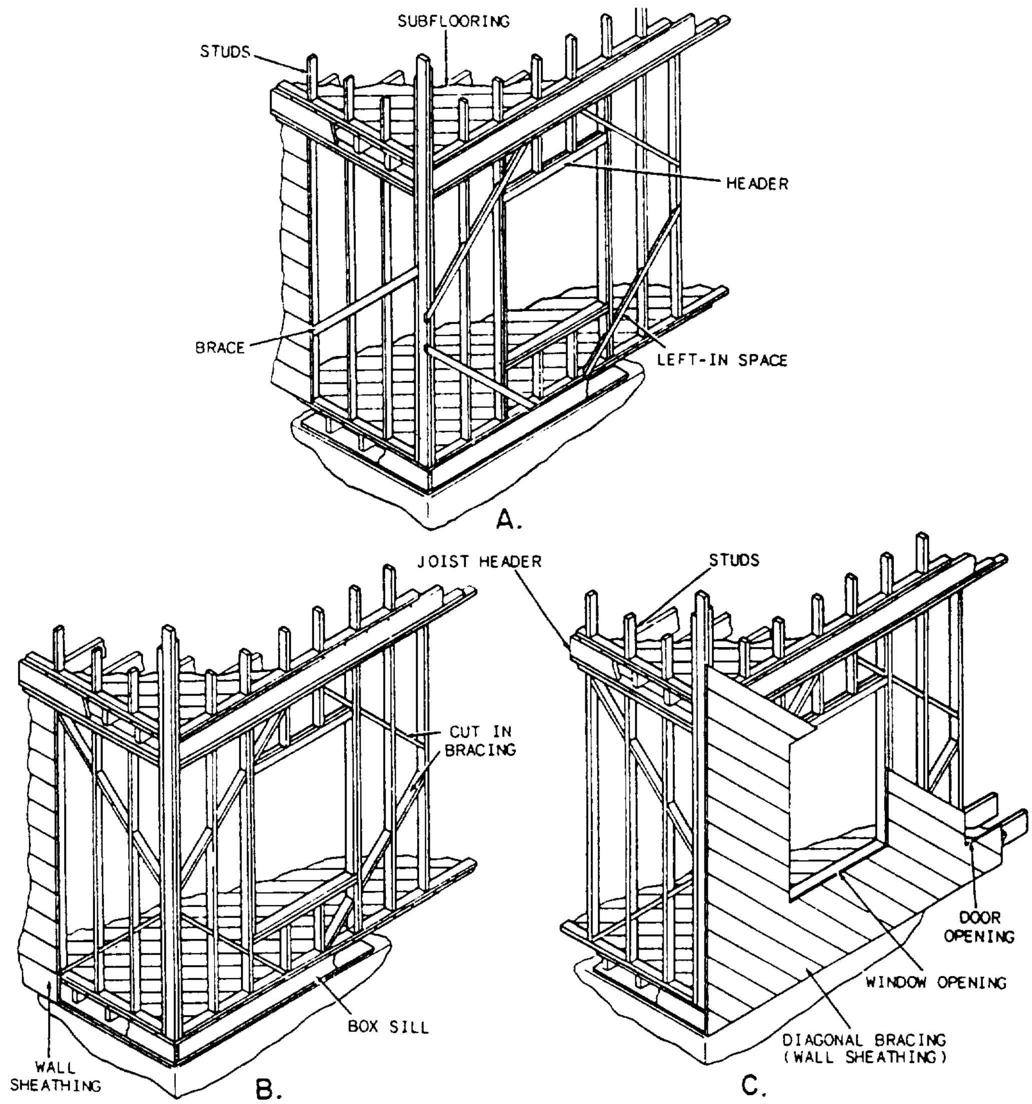


Figure 6-22.-Common types of bracing: A. Let-in bracing; B. Cut-in bracing; C. Diagonal bracing.

Braces

Braces are used to stiffen framed construction and help buildings resist the twisting or straining effects of wind or storm. Good bracing keeps corners square and plumb and prevents warping, sagging, and shifts resulting from lateral and external forces that would otherwise tend to distort the frame. Figure 6-22 shows three common methods of bracing frame structures: (A) let-in bracing, (B) cut-in bracing, and (C) diagonal bracing.

ROOF FRAMING

Roofs must be sloped so that they will shed water. The most common types of roof construction include the intersecting, the shed, the gable, and the hip (fig. 6-23). An INTERSECTING ROOF consists of a gable and valley or hip and valley intersecting each other at right angles. A SHED ROOF has a single surface that slopes downward from a ridge on one side of the structure. A GABLE ROOF has two surfaces sloping downward from a ridge located between the sides of the structure—usually midway between them. A HIP ROOF is pitched on the sides like a gable roof and also is pitched on one or both ends.

Roof Pitch

The PITCH (amount of slope) of a roof is expressed as a FRACTION in which the

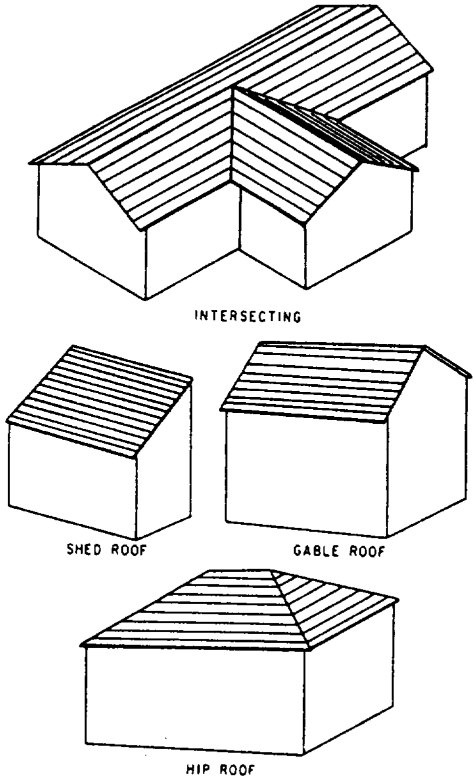


Figure 6-23.-Most common types of pitched roofs.

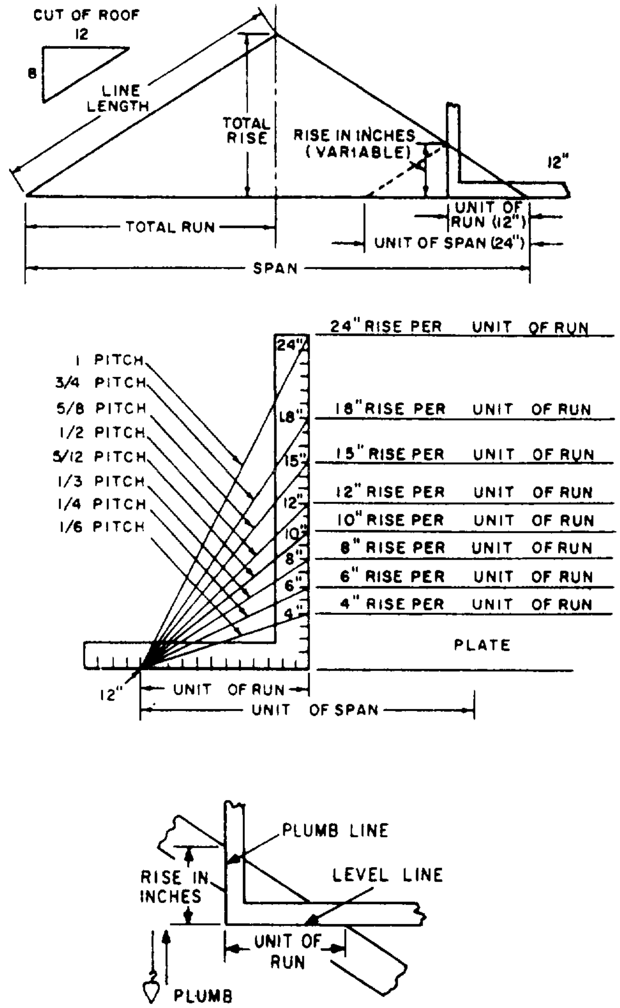


Figure 6-24.-Roof pitch diagram.

numerator is the UNIT RISE and the denominator is the UNIT SPAN. By common practice, unit run is always given as 12. See the roof pitch diagram in figure 6-24. Expressed in equation form,

$$\text{Pitch} = \frac{\text{Unit Rise}}{\text{Unit Span}}$$

$$= \frac{\text{Unit Rise}}{2 \times \text{Unit Run}}$$

Suppose that a roof rises 8 units for every 12 units of run—meaning that unit rise is 8 and unit run is 12. Since the unit span is 24, the pitch of the roof is 8/24, or 1/3. This value is also indicated in the center view of the roof pitch diagram in figure 6-24.

On construction drawings, the pitch of a roof is indicated by a small ROOF TRIANGLE like the one in the upper view of figure 6-24. The triangle is drawn to scale so that the length of the horizontal side equals the unit run (which is always 12), and the length of the vertical side equals the unit rise.

Rafter Layout

RAFTERS are framing members that support a roof. They do for the roof what joists do for the floor and what the studs do for the wall. They are generally inclined members spaced from 16 to 48 in, apart that vary in size, depending on their length and the distance they are spaced.

The tops of the inclined rafters are fastened in one of the various common ways, which is determined by the type of roof. The bottoms of the rafters rest on the plate member, which provides a connecting link between the wall and the roof and is really a functional part of both.

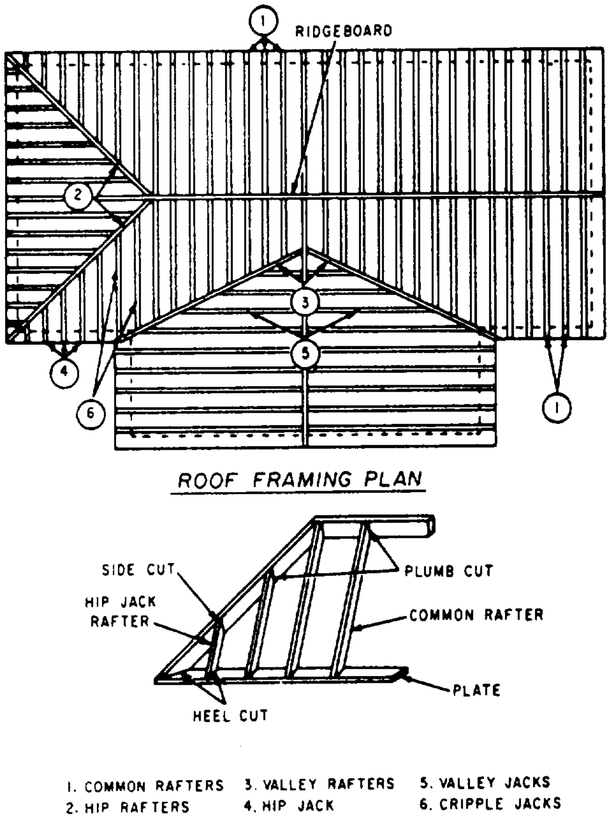


Figure 6-25.-Rafter terms.

The structural relationship between the rafters and the wall is the same in all types of roofs. The rafters are NOT framed into the plate, but simply nailed to it. Some are cut to fit the plate. In hasty construction, rafters are merely laid on top of the plate and nailed in place. Rafters may extend a short distance beyond the wall to form the eaves and protect the sides of the building.

Figure 6-25 shows a typical roof framing plan. The following rafter terms and definitions supplement the notes in the drawing:

COMMON RAFTERS—Rafters that extend from the plates to the ridgeboard at right angles to both.

HIP RAFTERS—Rafters that extend diagonally from the corners formed by perpendicular plates to the ridgeboard.

VALLEY RAFTERS—Rafters that extend from the plates to the ridgeboard along the lines where two roofs intersect.

HIP JACKS—Rafters whose lower ends rest on the plate and whose upper ends rest against the hip rafter.

VALLEY JACKS—Rafters whose lower ends rest against the valley rafters and whose upper ends rest against the ridgeboard.

CRIPPLE JACKS—Rafters that are nailed between hip and valley rafters.

JACK RAFTERS-Hip jacks, valley jacks, or cripple jacks.

TOP OR PLUMB CUT—The cut made at the end of the rafter to be placed against the

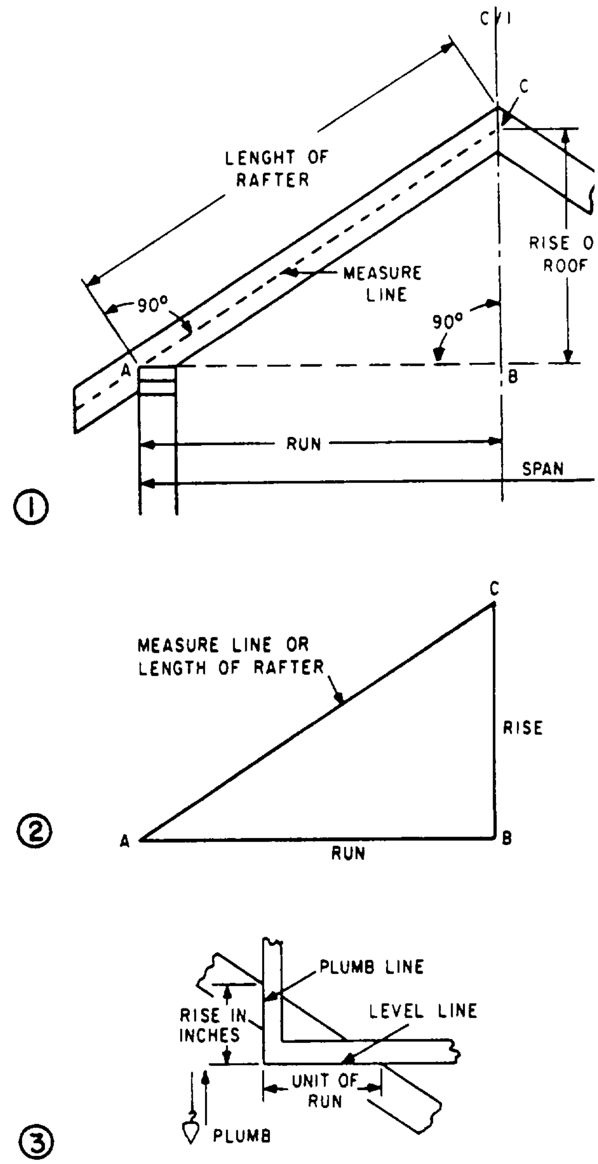


Figure 6-26.-Additional terms used in rafter layout.

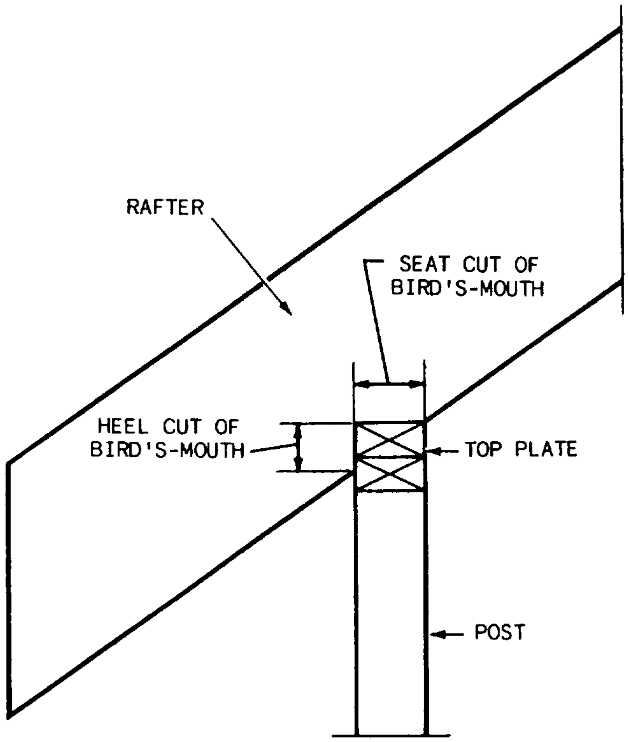


Figure 6-27.-Bird's-mouth on a rafter with projection.

ridgeboard or, if the ridgeboard is omitted, against the opposite rafters (fig. 6-25).

SEAT, BOTTOM, OR HEEL CUT—The cut made at the end of the rafter that is to rest on the plate.

SIDE, OR CHEEK, CUT—A bevel cut on the side of a rafter to fit against another frame member.

EAVE OR TAIL—The portion of the rafter extending beyond the outer edge of the plate.

Figure 6-26 shows additional terms used in connection with rafter layout.

RAFTER LENGTH is the shortest distance between the outer edge of the plate and the center of the ridgeline.

MEASURE LINE is an imaginary reference line laid out down the middle face of the rafter.

PLUMB LINE is any line that is vertical when the rafter is in its proper position.

LEVEL LINE is any line that is horizontal when the rafter is in its proper position.

A rafter with a projection often has a notch in it called a BIRD' S-MOUTH (fig. 6-27). The plumb cut of the bird's-mouth that bears against the side of the rafter plate is called the HEEL CUT, whereas the SEAT CUT bears on top of the bird's-mouth. COLLAR TIES (fig. 6-28) are horizontal members used as reinforcement in gable or double-pitch roof rafters. In a finished attic, these ties may function as ceiling joists.

When the rafters are placed farther apart, horizontal members called PURLINS are placed across them to serve as the nailing or connecting members for the roofing. Purlins are generally used with standard metal roofing sheets, such as galvanized iron or aluminum sheets.

Several methods of roof framing and types of rafter arrangement are further shown in figures 6-29 through 6-36.

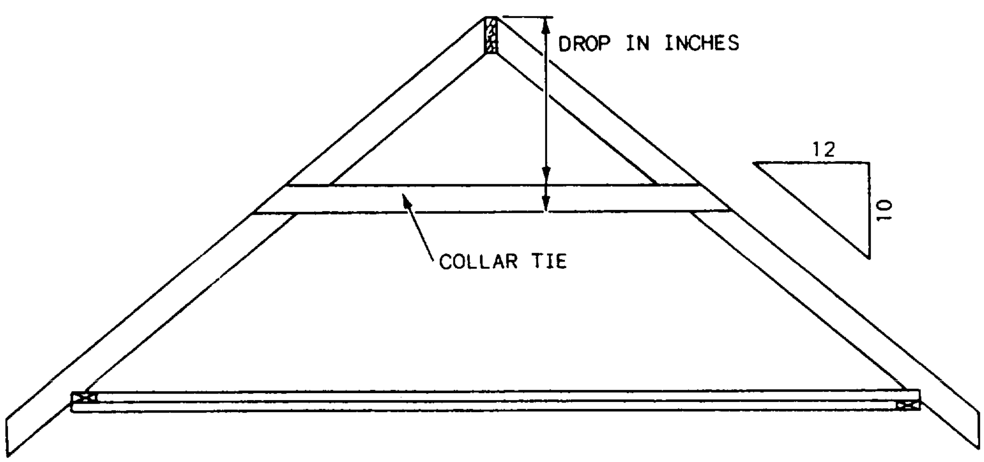


Figure 6-28.-Layout of a collar tie.

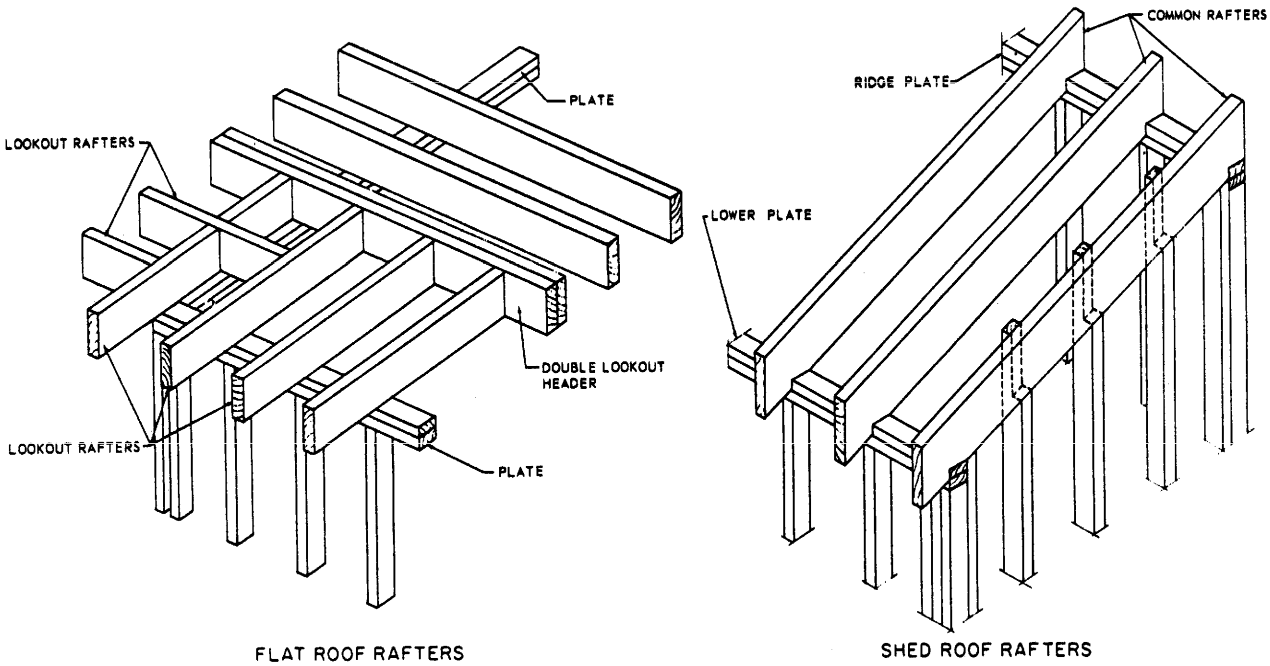


Figure 6-29.—Flat and shed roof framings.

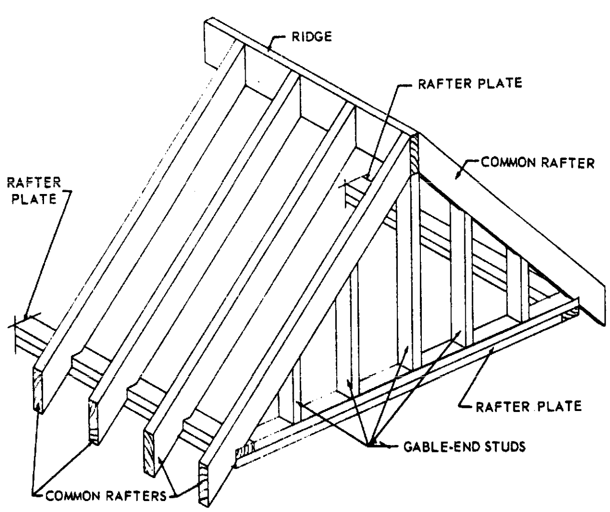


Figure 6-30.—Gable roof framing.

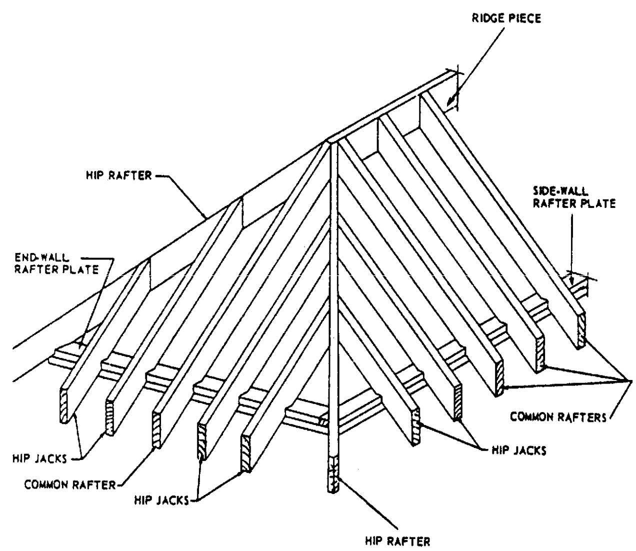


Figure 6-31.—Equal-pitch roof

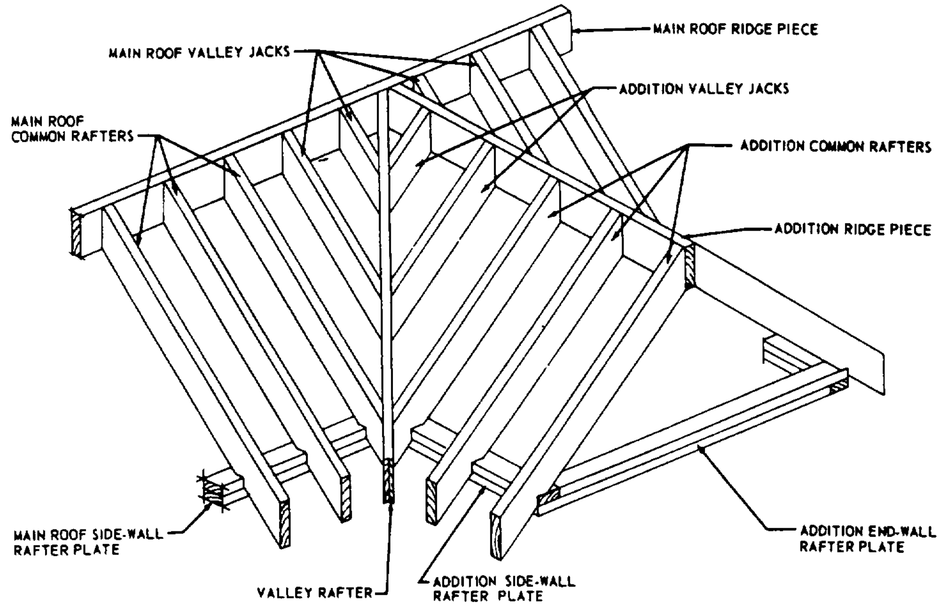


Figure 6-32.-Addition roof framing.

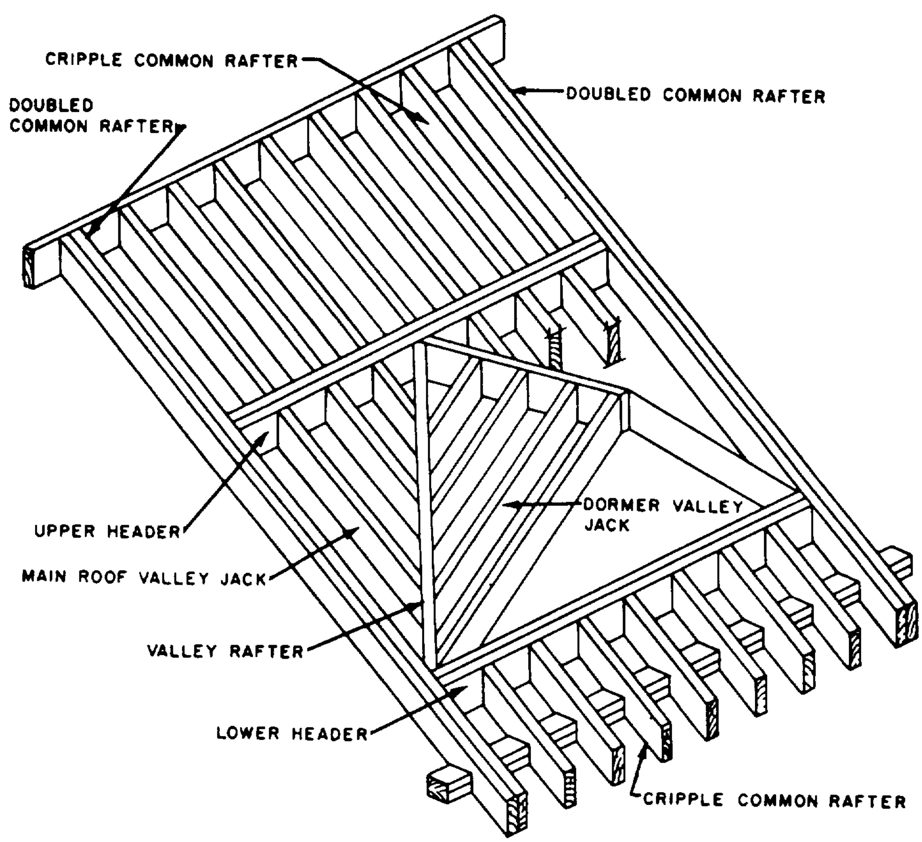


Figure 6-33.-Framing of gable dormer without sidewalls.

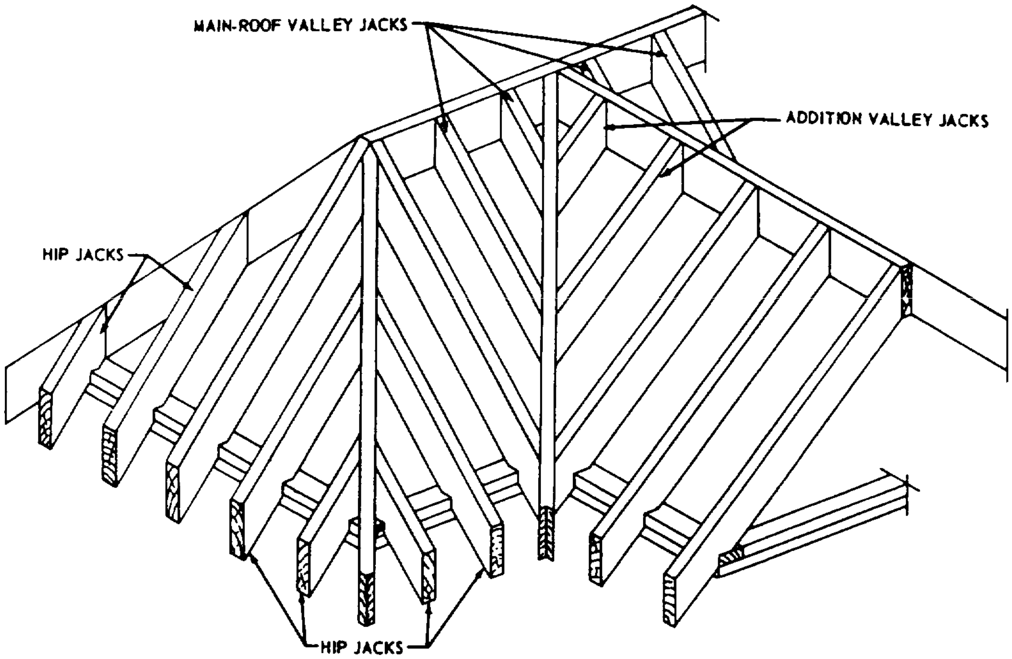


Figure 6-34.-Types of jack rafters.

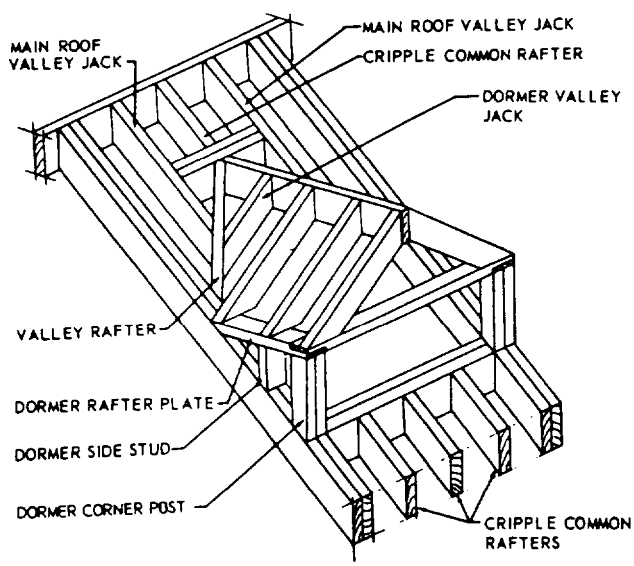


Figure 6-35.-Framing of gable dormer with sidewalls.

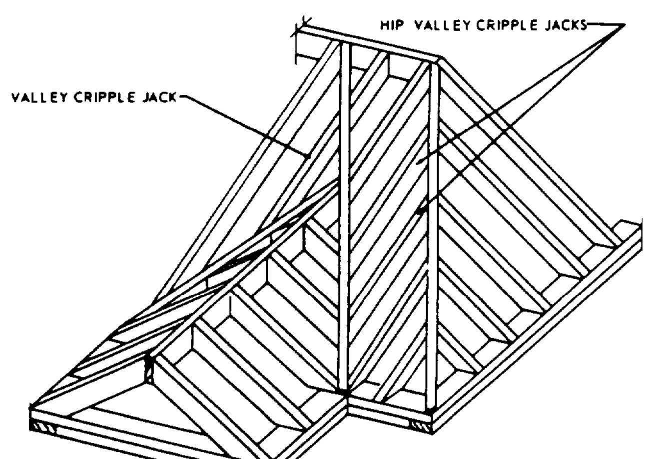


Figure 6-36.-Cripple jacks.

Roof Trusses

A TRUSS is an engineered structural frame that is used to span distances that are too great for single-piece members without intermediate supports. Figure 6-37 shows a roof truss or rafter truss assembly. Chords and webs are connected to one another by GUSSET PLATES—metal plates or plywood pieces that are nailed, glued, or bolted in place. The load that the roof must carry is the important factor to be considered in selecting the type of truss. These loads may consist of the roof itself, forces caused by wind, and the weight of snowfall or ice.

Some of the most common types of light wood trusses are shown in figure 6-38. The W-truss (fig. 6-38, view A) is perhaps the most widely used. It uses four web members assembled in the

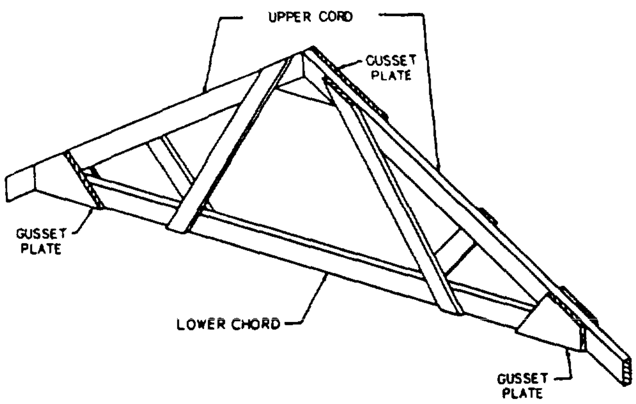


Figure 6-37-Roof or rafter truss.

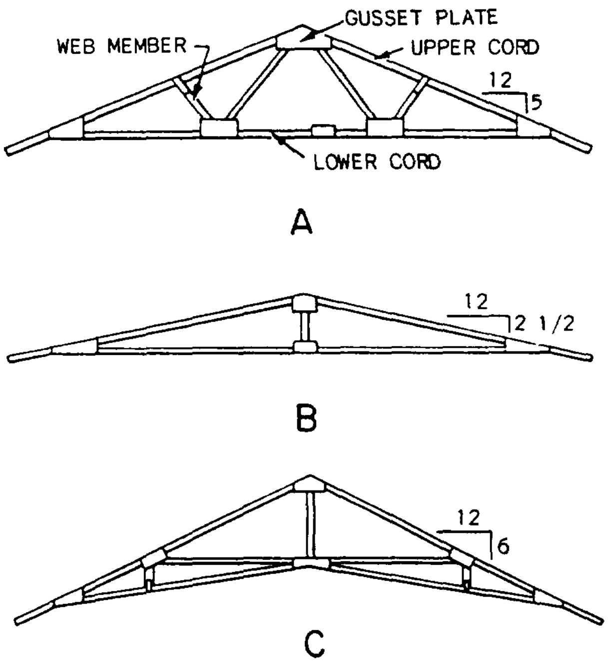


Figure 6-38.-Light wood trusses: A. W-type; B. King post; C. Scissors.

shape of the letter *W* instead of a center post. The KING POST truss is the simplest type of structure. It consists of an upper and lower chord with a vertical center post (fig. 6-38, view B). The SCISSORS truss (fig. 6-38, view C) is used for structures with sloped ceiling room, such as a vaulted ceiling.

BUILDING FINISH

Perhaps the best way to define building finish is to say that it comprises those nonstructural parts of the building. The finish is divided into EXTERIOR finish (located principally on the outside of the structure) and INTERIOR finish (located inside). The work involved in the installation of nonstructural members on the structure is called FINISH CARPENTRY.

EXTERIOR FINISH

The principal items of the exterior finish are the ROOF SHEATHING and COVERING, EXTERIOR TRIM, and WALL SHEATHING. The order in which these items are erected may vary slightly, although in some cases two or more items may be installed at the same time. Normally, roof sheathing is installed as soon as possible to allow work inside a structure to progress during inclement weather.

Roof Sheathing and Roof Covering

Roof sheathing is the covering over the rafters or trusses and usually consists of nominal 1-in. lumber or plywood. In some types of flat or low-pitched roofs, wood roof planking or fiberboard roof decking might be used. Sheathing should be thick enough to span the supports and provide a solid base for fastening the roofing materials. Generally, third grade species of lumber, such as pines, redwoods, and hemlocks, are used as roof sheathing boards.

Board roof sheathing (fig. 6-39) used under asphalt shingles, metal sheet roofing, or other

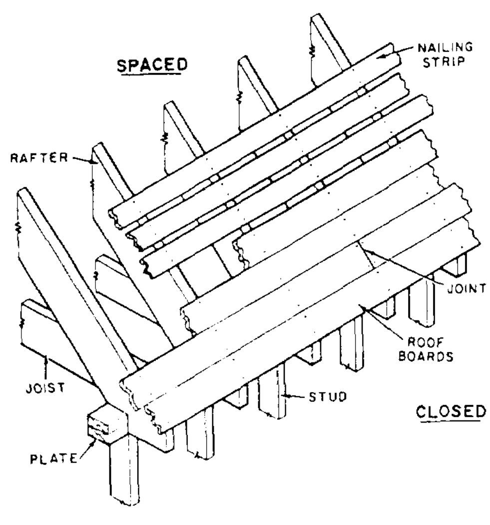


Figure 6-39.-Typical board roof sheathing, showing both closed and spaced types.

roofing materials that require continuous support should be laid closed (without spacing); however, when wood shingles or shakes are used in damp climates, it is common to have spaced roof boards (fig. 6-39). When plywood roof sheathing is used, it should be laid with the grain perpendicular to the rafter (fig. 6-40).

Roof covering materials used for pitched roofs are wood, asphalt shingles, tiles and slate, galvanized iron (GI) sheets, and several other sheet materials. For flat or low-pitched roofs, a built-up construction is also used. An asphalt-saturated felt underpayment called ROOFING FELT is applied over the roof sheathing before the roof covering is installed. The roofing felt serves three basic purposes: It keeps the roof sheathing dry until the shingles can be applied, it acts as a secondary barrier against wind-driven rain and snow, and it protects the shingles from any resinous substance that may be released from the sheathing.

The method of laying an asphalt-shingle roof is shown in figure 6-41. The roofing rolls are usually 36 in. wide with a 2 in. to 4 in. overlap. The shingles are usually laid with 5 in. exposed to the weather. Figure 6-42 shows installation of wood shingles. Wood shingles are available in

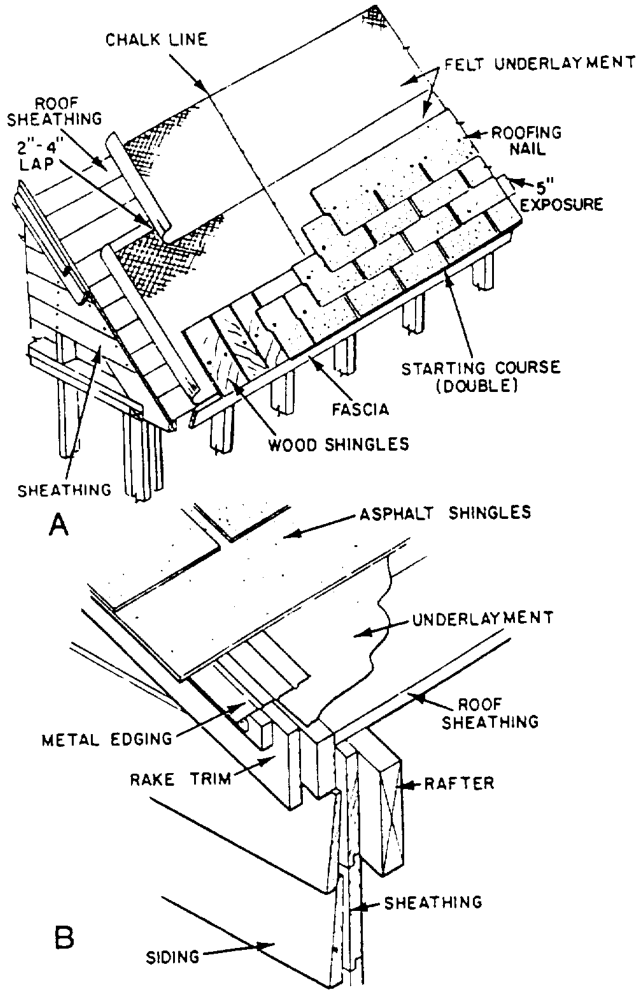


Figure 6-41.-Application of asphalt shingles: A. Common method with strip shingles; B. Metal edging at gable end.

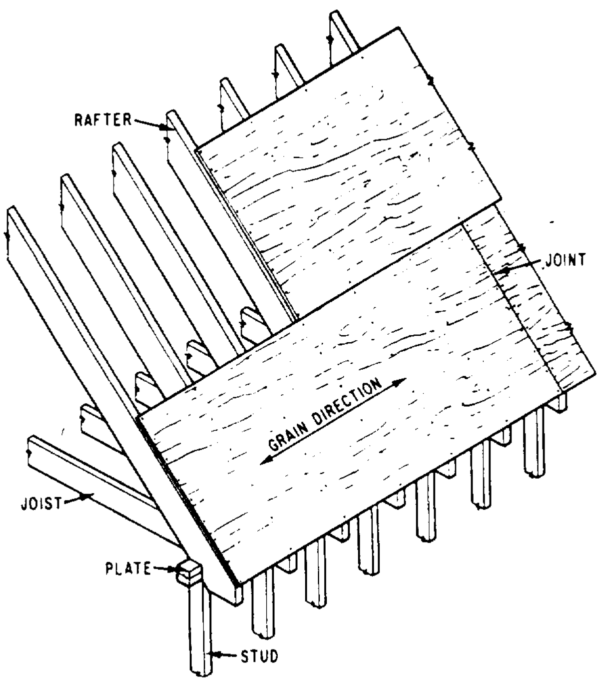


Figure 6-40.-Application of plywood roof sheathing.

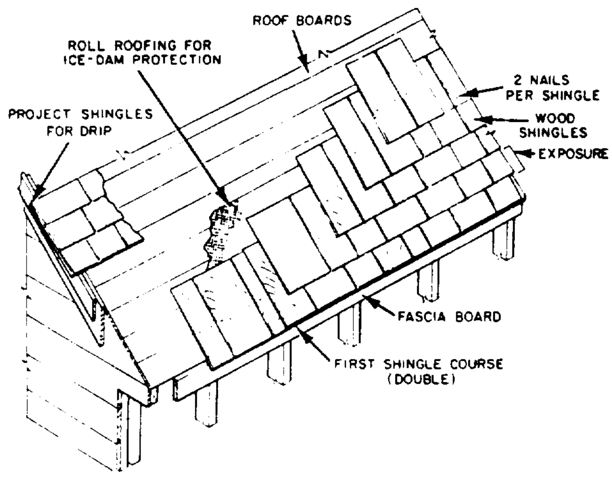


Figure 6-42.-Installation of wood shingles.

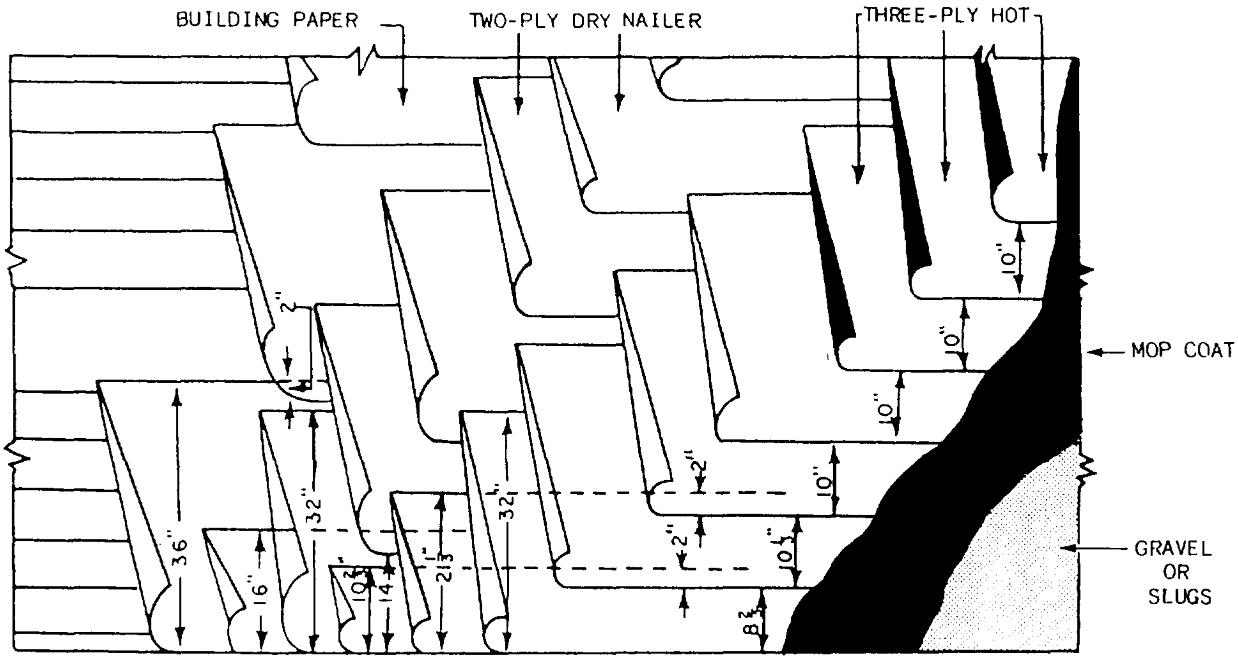


Figure 6-43-A typical building paper and felt on five-ply built-up roof.

three standard lengths: 16, 18, and 24 in. The 16-in. length is perhaps the most popular. Wood shakes are applied in much the same manner as wood shingles.

On flat roofs, the roof covering is usually built up. BUILT-UP ROOFING consists of several layers (plies) of felt, set in a hot binder of melted pitch or asphalt. Built-up roofs are always designated by the number of plies they contain. A five-ply built-up roof is shown in figure 6-43, Notice that aggregate surfacing materials, such as gravel, slag, marble, and other suitable materials, are used in built-up roofing to provide a good weathering surface and protect the bitumens from sunlight and external heat.

Exterior Trim

Before the installation of the roof sheathing is completed, the exterior finish at and just below the eaves of the roof, called CORNICE, can be constructed. The practical purpose of a cornice is to seal the joint between wall and roof against weather penetration. Purely ornamental parts of a cornice are called trim. Figure 6-44 shows a simple type of cornice, used on a roof with no rafter overhang. A roof with a rafter overhang may have the “open” cornice shown in

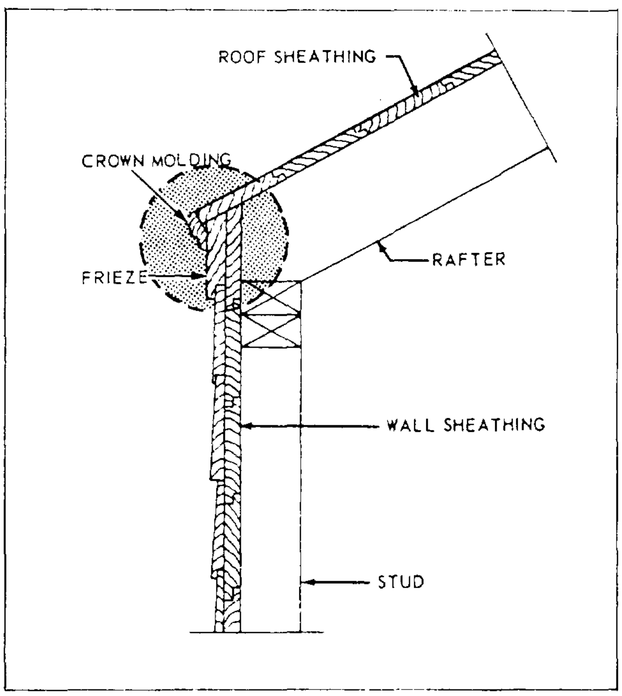


Figure 6-44.-Simple cornice.

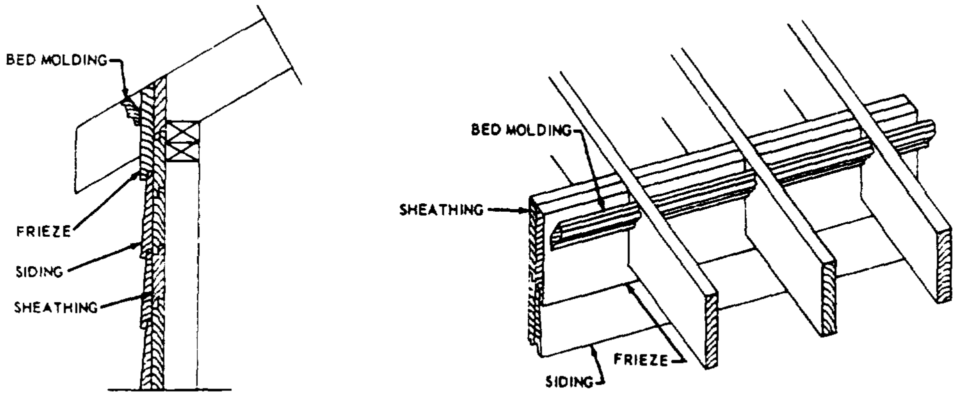


Figure 6-45.-Open cornice without a fascia board.

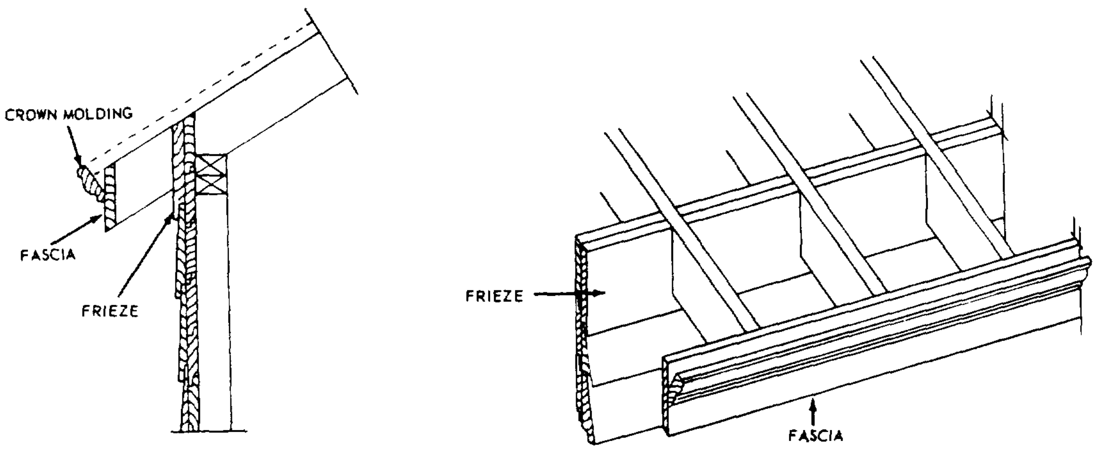


Figure 6-46.-Open cornice with a fascia board.

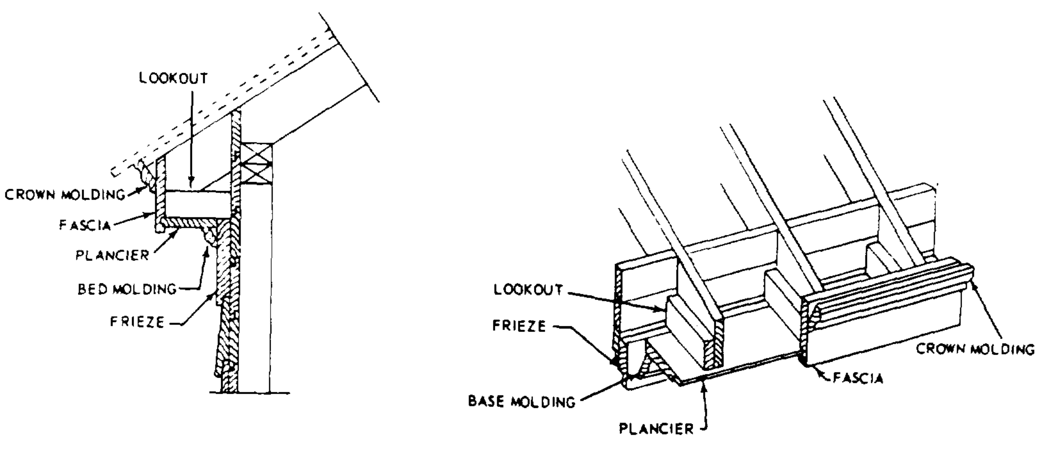


Figure 6-47.-Closed or boxed cornice.

figures 6-45 and 6-46, or the "closed" or "boxed cornice" shown in figure 6-47. A short extension of a cornice along the gable-end wall of a gable-roof structure is called cornice return (fig. 6-48). Finish along the rakes of a gable roof is called the gable cornice trim (fig. 6-49). The rafter-end edges of a roof are called EAVES. A hip roof has eaves all the way around. A gable roof has only two eaves; the gable-end or end-wall edges of a gable roof are called RAKES.

Wall Sheathing

The outside wall sheathing or covering on a frame structure consists of either wood siding or paneling, wood shingles, plywood, fiberboard, hardboard, and/or other types of materials. Masonry, veneers, metal or plastic siding, and other non-wood materials are additional choices. There are two general types of wooden board siding: drop siding and common siding. DROP SIDING (fig. 6-50) is joined edge to edge (rather than overlapping). COMMON SIDING consists of boards that overlap each other single-wise. Boards not more than 4 ft long are called clapboard; boards in longer lengths but not more than 8 in. wide are called bevel siding. A number of drop board and common sidings can be used horizontally or vertically (fig. 6-51), and some

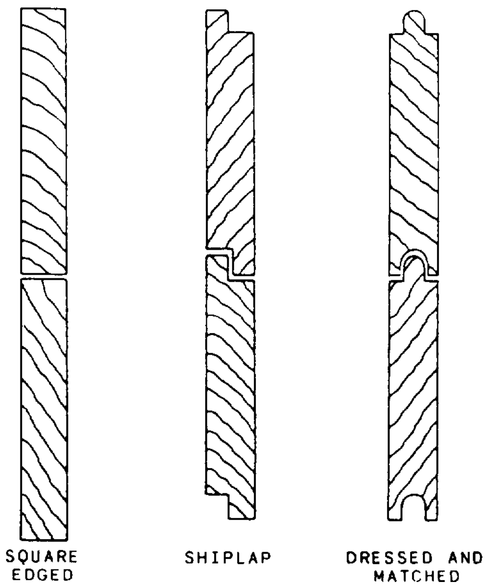


Figure 6-50.-Types of drop siding.

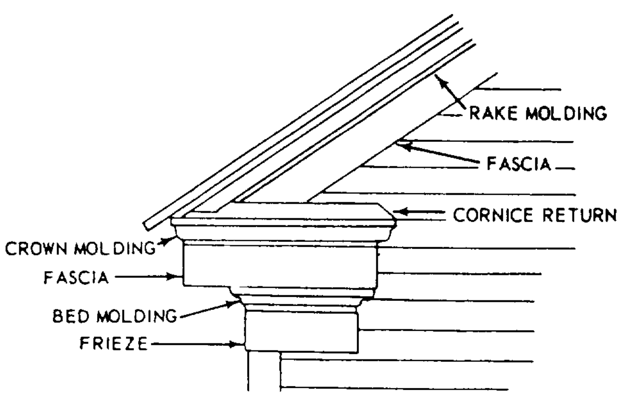


Figure 6-48.-Cornice return.

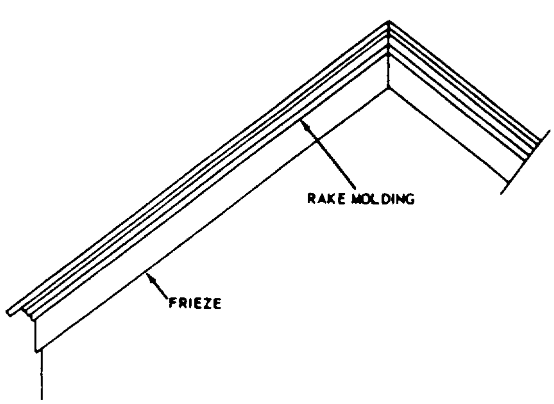


Figure 6-49.-Gable cornice trim.

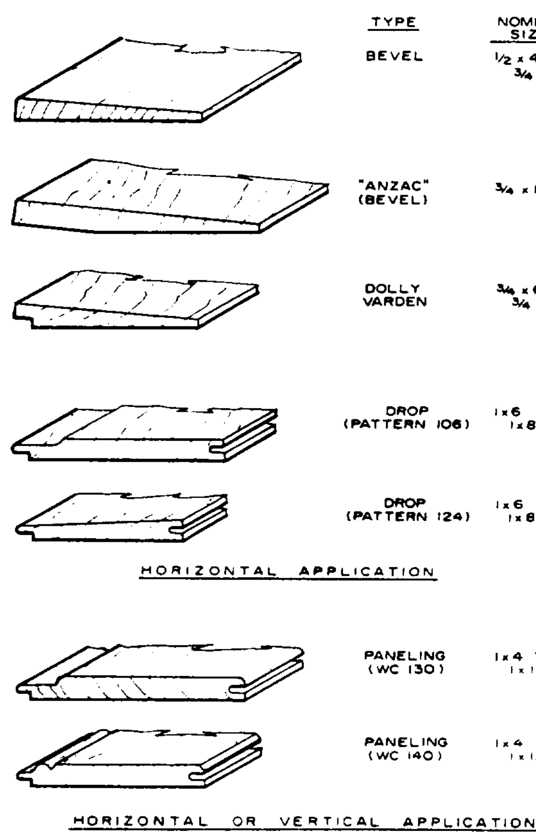


Figure 6-51.-Wood siding types.

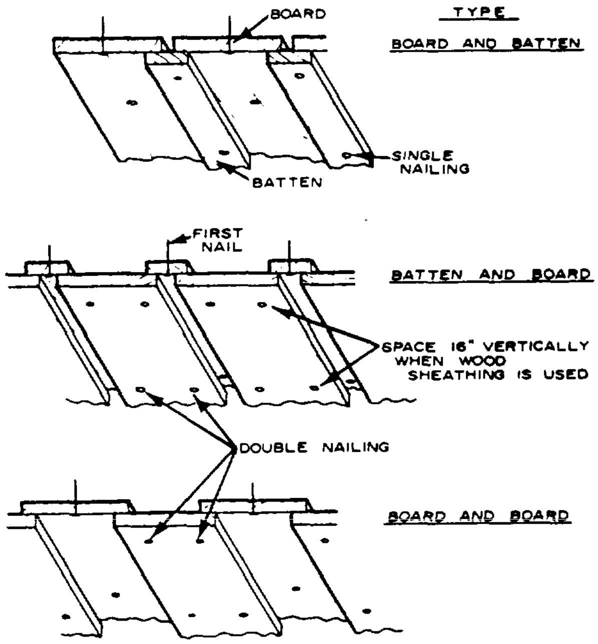


Figure 6-52.-Vertical board siding.

may be used in either manner if adequate nailing areas are provided. Figure 6-52 shows a method of vertical siding application.

Masonry veneers are used effectively with wood sidings in various exterior finishes to enhance the aesthetic appearance of the structure. Other non-wood materials, such as stucco or a cement plaster finish, are favored for an exterior cover because they require a minimum of maintenance. Plastic films on wood sidings or plywood are also used because little or no refinishing is necessary for the life of the building.

Flashing

FLASHING is specially constructed pieces of corrosion-resistant metal or other materials used to protect buildings from water seepage. Flashing should be installed to prevent penetration of water and other moisture in the form of rain or melted snow at the junction of material changes, chimneys, and roof-wall intersection. Flashing should also be used over exposed doors, windows, and roof ridges. Figures 6-53 through 6-57 show areas or locations in which some type of flashing is required.

Flashing materials used on roofs may be asphalt-saturated felt, metal, or plastic. Felt flashing is generally used at ridges, hips, and valleys. However, metal flashing made of aluminum, galvanized steel, or copper, is considered superior to felt.

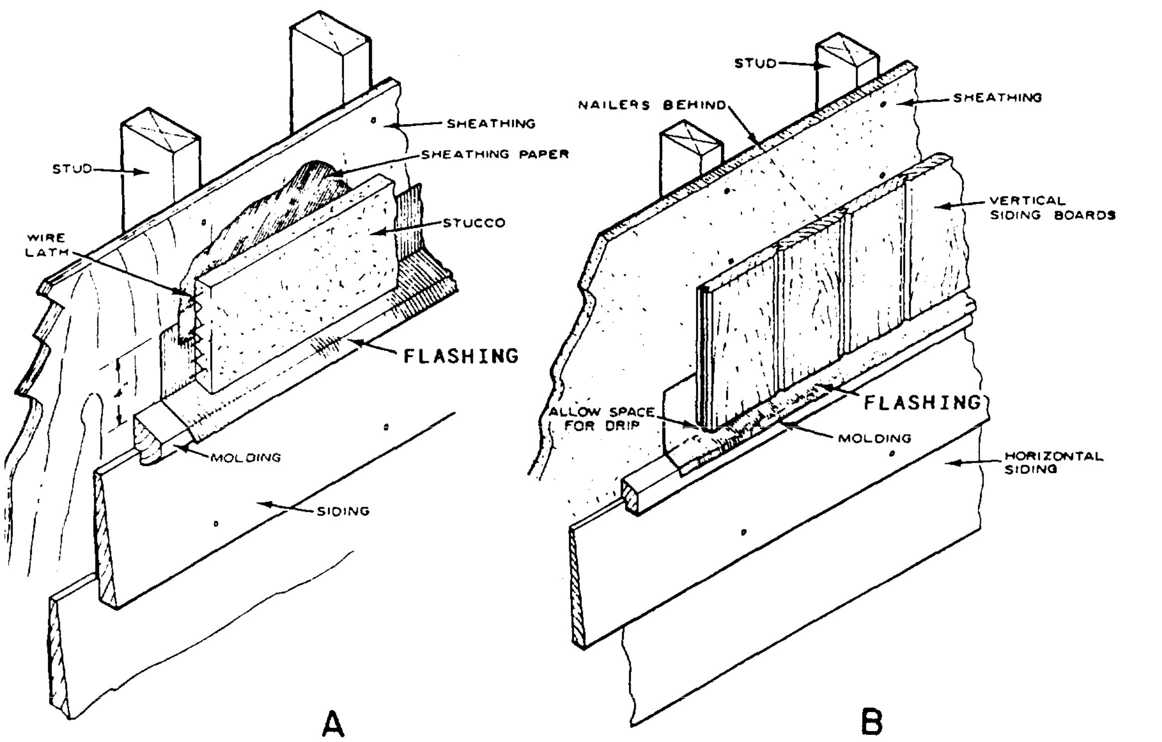


Figure 6-53.-Use of flashing at material changes: A. Stucco above, siding below; B. Vertical siding above, horizontal below,

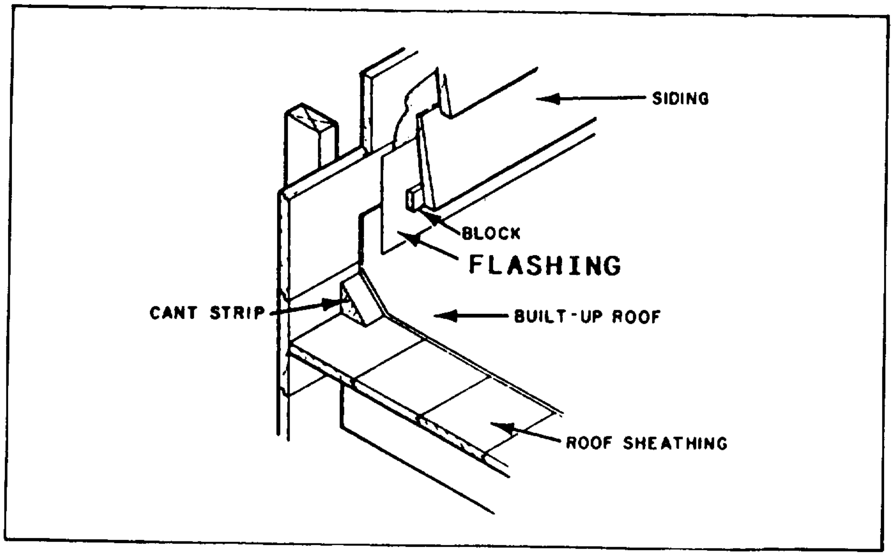


Figure 6-54.-Use of flashing at building line on built-up roof.

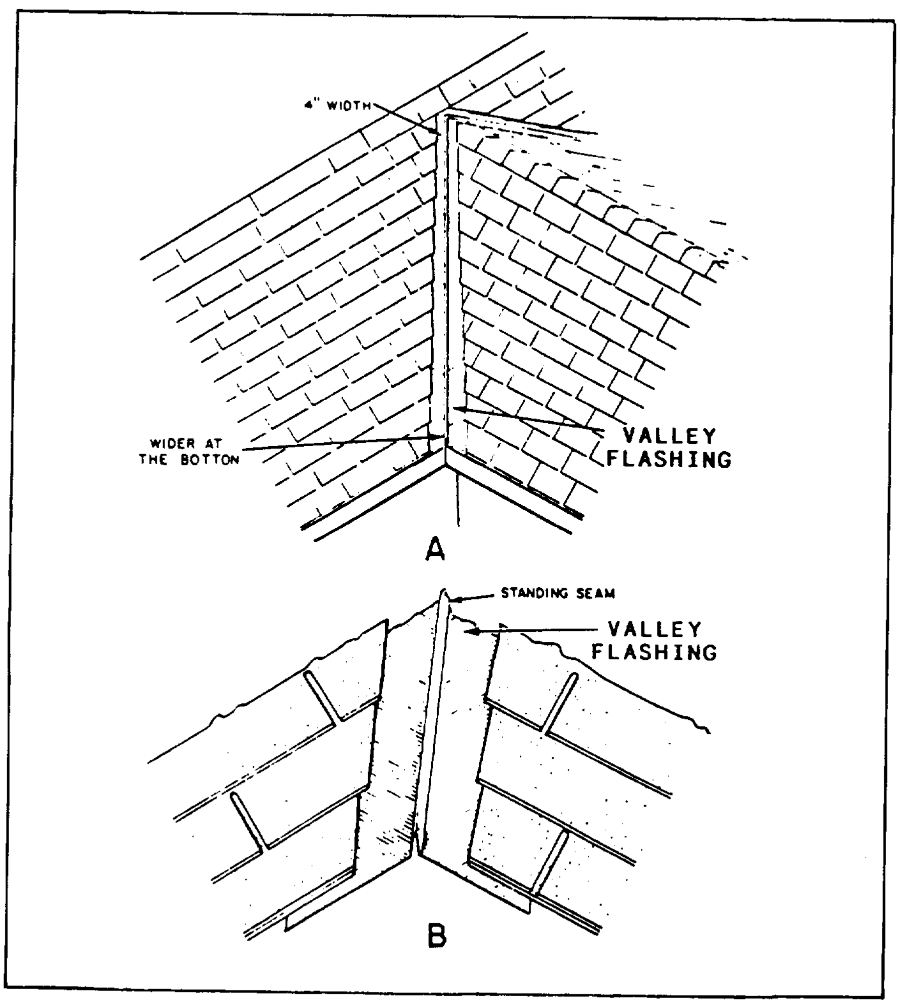


Figure 6-55.-Valley flashing: A. Valley; B. Standing seam.

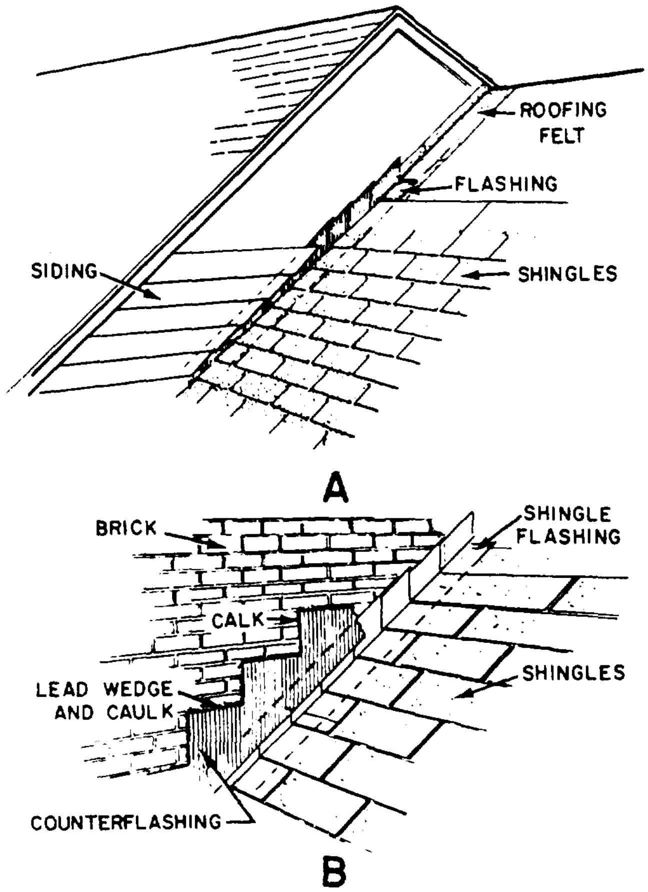


Figure 6-56-Flashing at roof and wall intersection: A. Wood siding wall; B. Brick wall.

Gutters and Downspouts

GUTTERS and DOWNSPOUTS should be installed to keep rainwater away from the foundation of the building (fig. 6-58). Some gutters are built in the cornice and connected to the downspouts (fig. 6-59). The most common types of gutters used are shown in figure 6-60. Gutters and downspouts may be made of galvanized metal, copper, or aluminum. Some have a factory-applied enamel finish. Plastic gutters and downspouts are also available.

INTERIOR FINISH

The INTERIOR FINISH consists mainly of the coverings applied to the rough inside walls, ceiling, and subfloors. Other interior finish items are ceiling and wall coverings, doorframes and window frames, stairs, floor covering, and wood trims. When required, installation of kitchen and built-in cabinets are considered part of the interior finish.

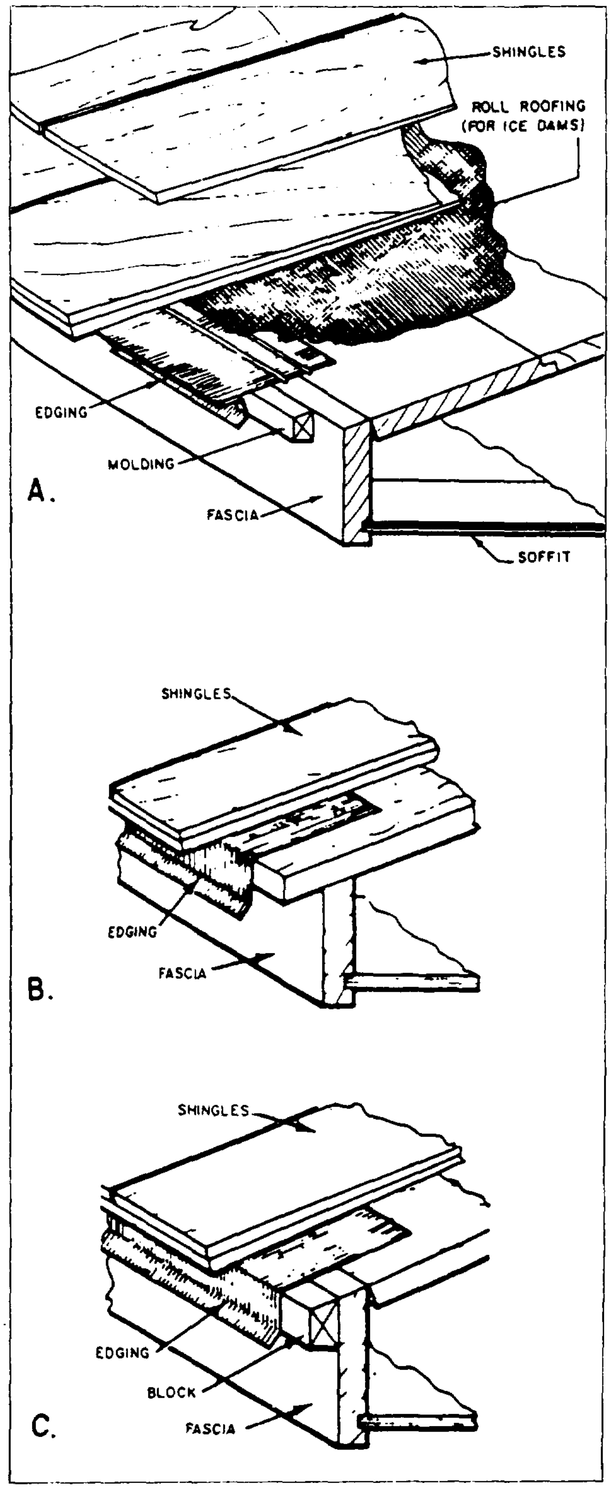


Figure 6-57.-Cornice flashing: A. Formed flashing; B. Flashing without wood blocking; C. Flashing with wood blocking.

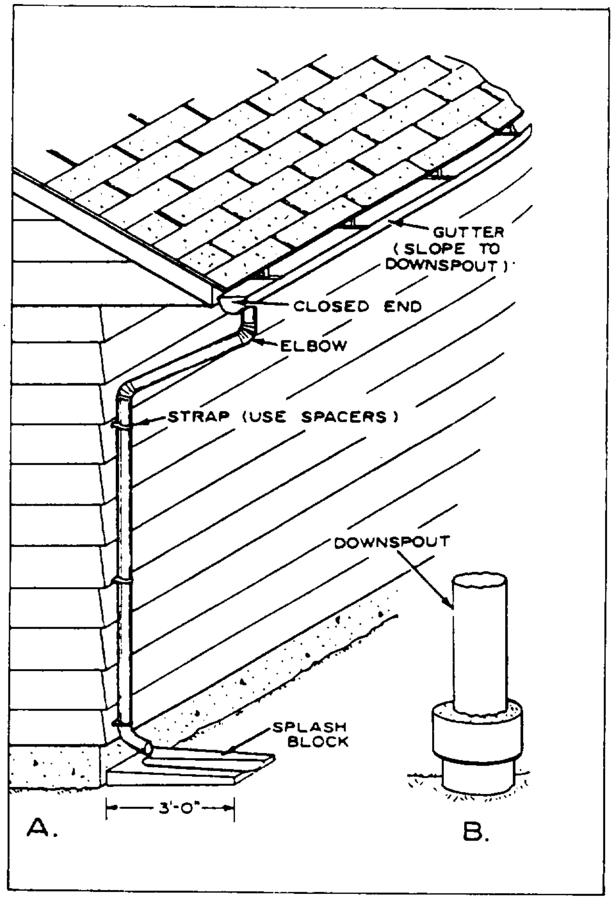


Figure 6-58-Use of gutter and downspout: A. Downspout with splash block; B. Drain to storm sewer.

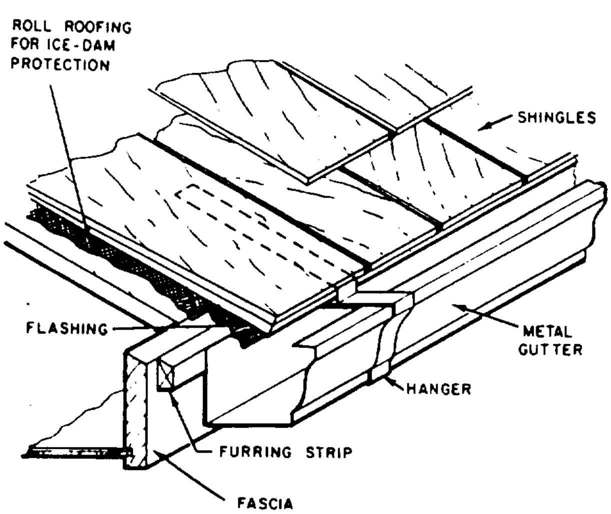


Figure 6-59.-Formed metal gutters.

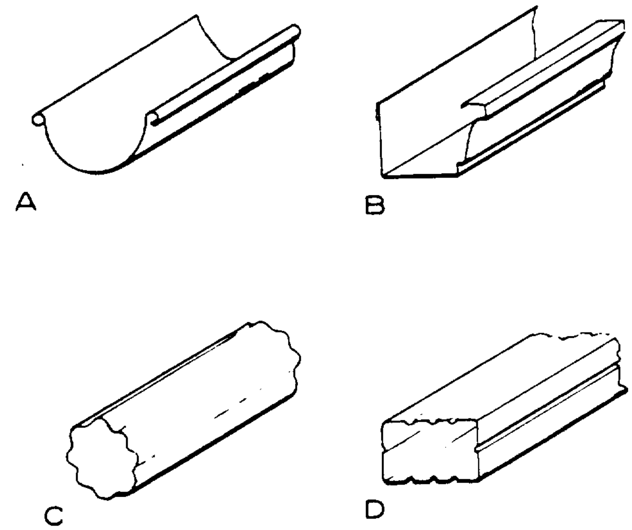


Figure 6-60.-Gutters and downspouts: A. Half-round gutter; B. Formed gutter; C. Round downspout; D. Rectangular downspout.

Ceiling and Wall Covering

Ceiling and wall covering may be broadly divided into PLASTER and DRY-WALL covering. Dry-wall covering is a general term applied to sheets or panels of wood, plywood, gypsum, fiberboard, and the like. A plaster and/or ceiling covering requires a "plaster base" and a "plaster ground" before it is installed. The plaster base, such as gypsum, fiberboard, or metal lath, provides a plane-surface base to which the plaster can be applied. Wooden strips of the same thickness as the combined thickness of the lath and plaster, called plaster ground, are installed before the lath is applied to serve as guides for the plasterers to ensure uniform plaster thickness around doorframes and window frames and behind casings.

The use of dry wall over the lath-and-plaster finish is rapidly increasing. Installation or construction time is faster with the application of dry wall. Being wet, plaster requires drying time before other interior work can be started. Gypsum is one of the most widely used types of dry-wall finishes. It is made up of a gypsum filler faced with paper or with a foil back that serves as a vapor barrier on exterior walls. It is also available with vinyl or other prefinished surfaces. It comes in 4- by 8-ft sheets and in lengths of up to 16 ft for horizontal application. Notice in

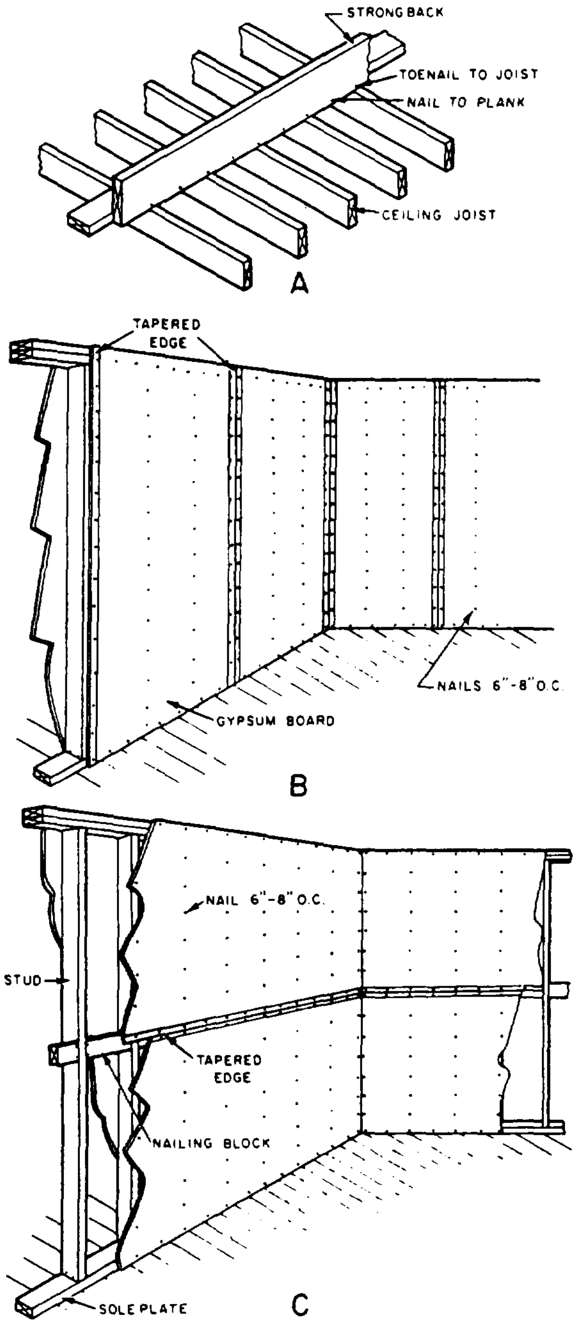


Figure 6-61—Application of gypsum board finish: A. Strongback B. Vertical application; C. Horizontal application.

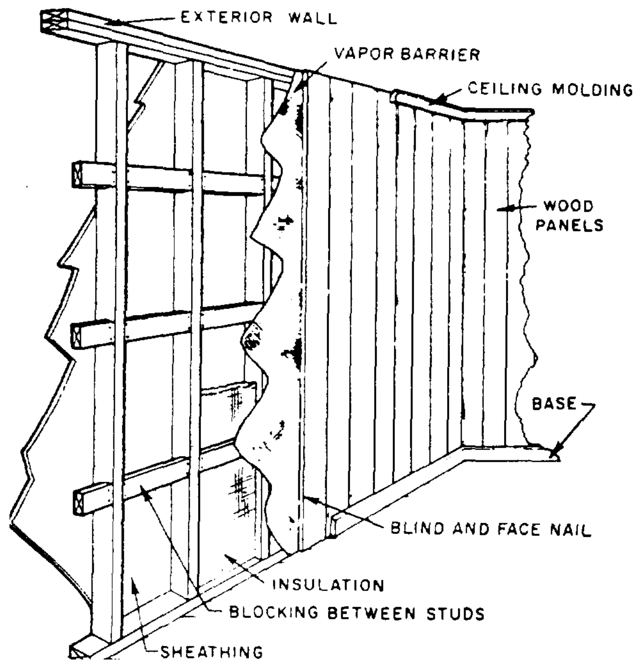


Figure 6-62.-Application of vertical paneling.

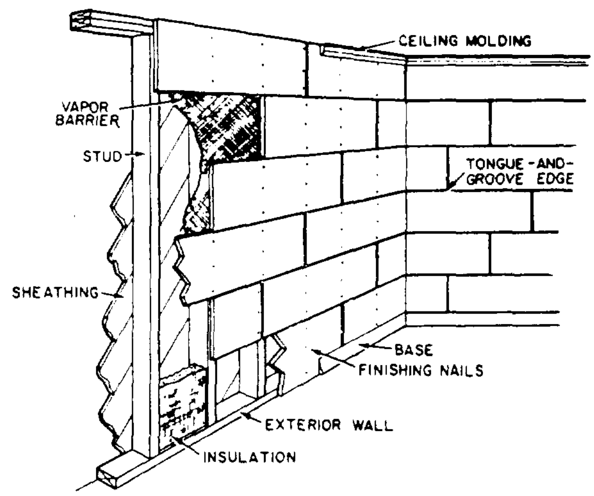


Figure 6-63.-Application of tongued-and-grooved paneling over studs.

figure 6-61, view A, a "strongback" is usually used for aligning ceiling joists or studs to provide a smooth, even surface. Figures 6-62 and 6-63 show typical application of paneling using other types of dry-wall finishes.

A variety of ceiling systems can also be used to change the appearance of a room, lower a ceiling, finish off exposed joints, or provide acoustical control. Suspended acoustical ceiling systems are designed to integrate the functions of lighting, air distribution, and fire protection. Acoustical tiles, available in 12-to 30-in. widths, 12- to 60-in. lengths, and 3/16- to 3/4-in. thicknesses, are used with the other grid system components (fig. 6-64). Depending on the type of ceiling or roof construction, ceiling tiles may be installed in various ways, such as with the use of wood strips nailed across the ceiling joists or roof trusses (fig. 6-65).

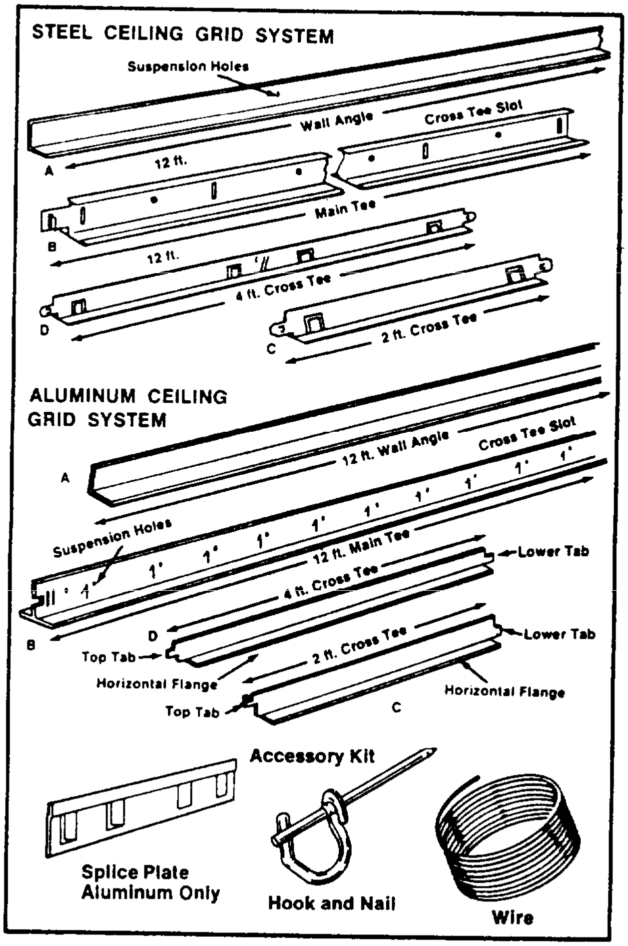


Figure 6-64.-Grid system components.

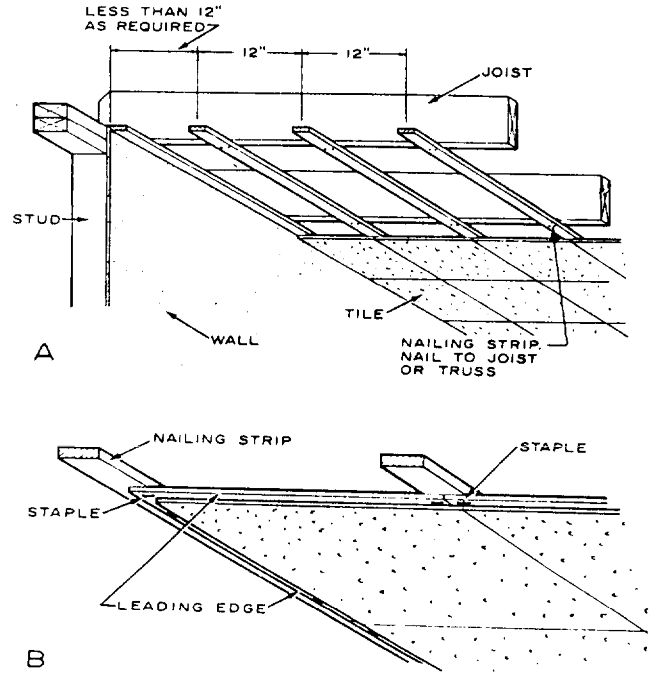


Figure 6-65.-Ceiling tile assembly: A. Nailing strip location; B. Stapling.

Insulation and Vapor Barriers

Heat inflow or outflow has important effects upon the occupants of a building. The use of insulation improves comfort conditions and savings in fuel. The materials commonly used for insulation may be classified as blanket, batt, loose-fill, reflective, and rigid. These materials are manufactured in a variety of forms and types, and their insulating values vary with the type of construction, kinds of construction materials used, and thickness of insulation. Figure 6-66 shows different types of insulation commonly used in construction.

Vapor barriers should be used to keep moisture from seeping through walls, floors, and ceiling materials. Among the effective vapor-barrier materials are asphalt laminated papers, aluminum foil, and plastic film. Most blanket and batt insulations (fig. 6-66) have paper-backed aluminum foil on one side to serve as a vapor

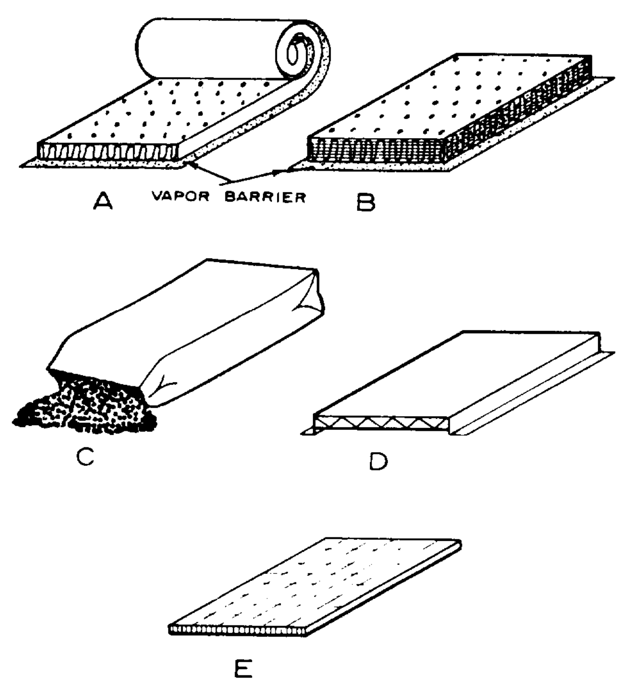


Figure 6-66.-Types of insulation: A. Blanket; B. Batt; C. Fill; D. Reflective (one type); E. Rigid.

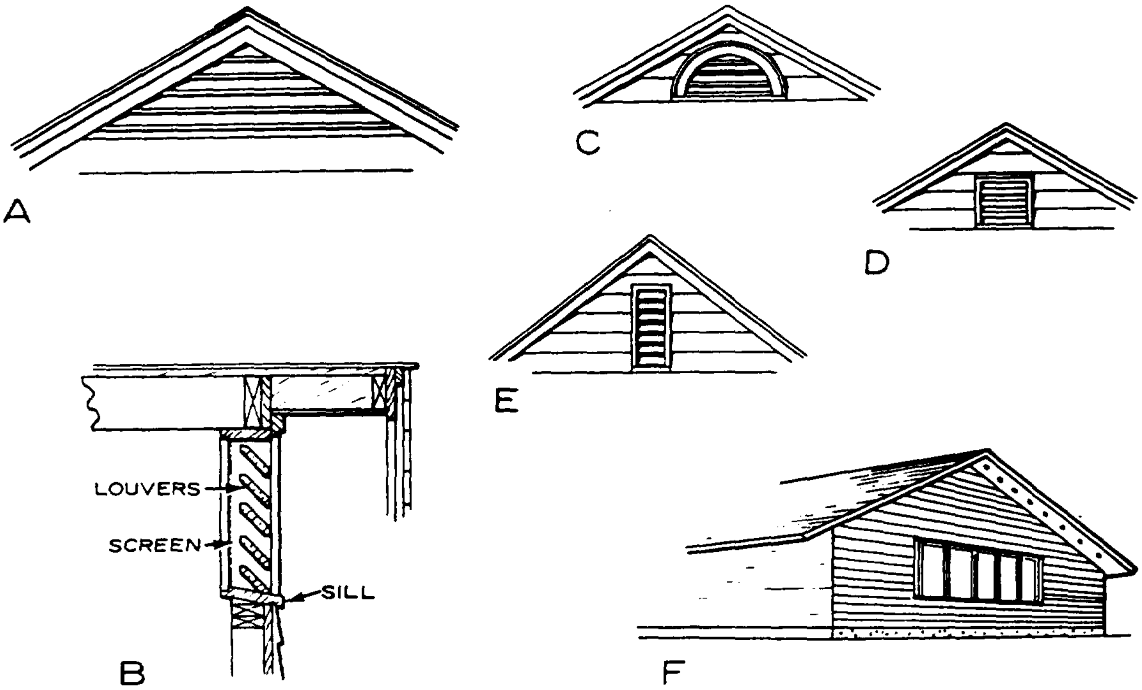


Figure 6-67.-Outlet ventilators: A. Triangular; B. Typical cross section; C. Half-circle; D. Square; E. Vertical; F. Soffit.

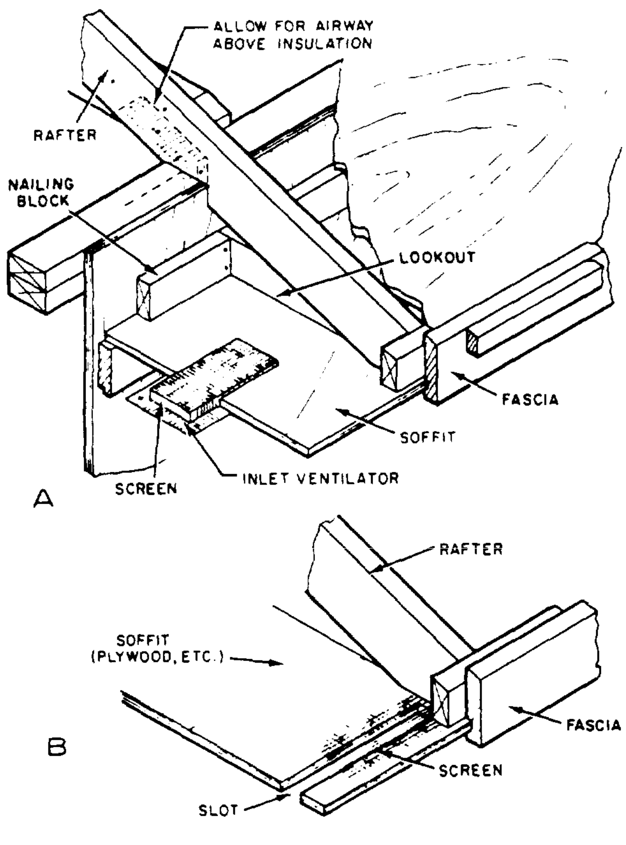


Figure 6-68.-Inlet ventilators: A. Small insert ventilator; B. Slot ventilator.

barrier. Foil-backed gypsum lath or gyspum boards are also available and serve as excellent vapor barriers. Where other types of membrane vapor barriers were not installed during construction, several coats of paint do provide some protection. Aluminum primer and then several coats of flat wall or oil paint are effective in retarding vapor transmission.

Even where vapor barriers are used, condensation of moisture vapor may occur in the attic, in roof spaces, and in crawl spaces, if any, under the building or porch. In such spaces, VENTILATION is the most practical method of removing condensed or hot air that may otherwise facilitate decay to the structure. It is common practice to install ventilators, several types of which are shown in figures 6-67 and 6-68.

Stairs

The two principal elements in a stairway are the TREADS, which people walk on, and the STRINGERS (also called springing trees, strings, horses, and carriages), which support the treads. The simplest type of stairway, shown at the left in figure 6-69, consists of these two elements alone.

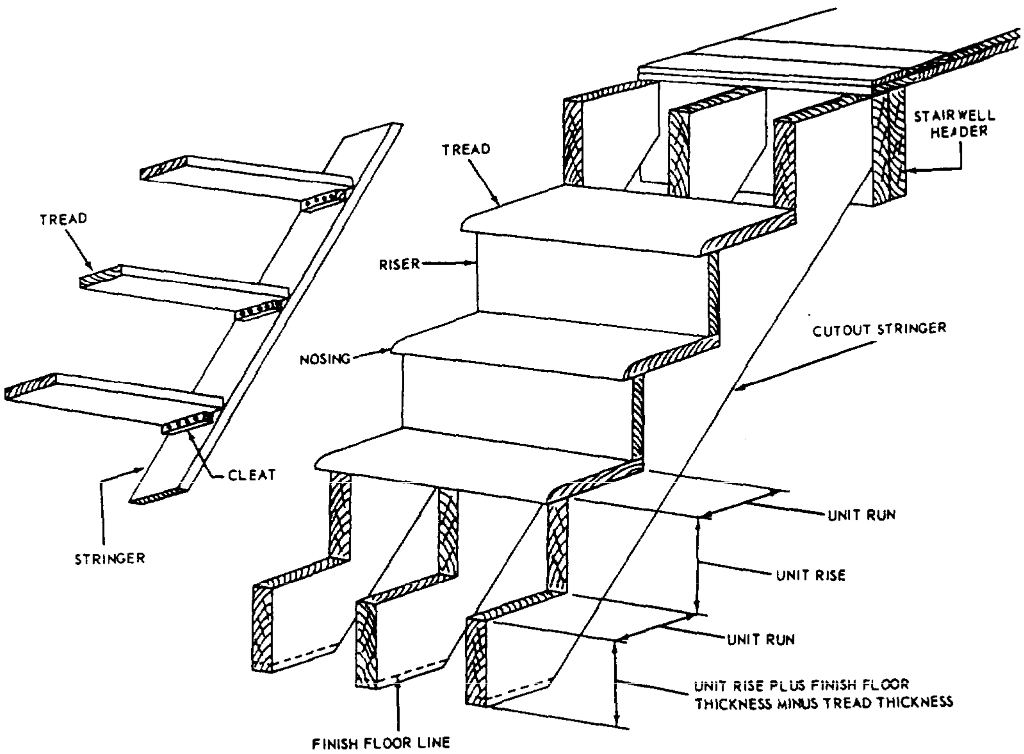


Figure 6-69.-Parts of a stairway.

Additional parts commonly used in a finished stairway are shown at the right in figure 6-69. The stairway shown here has three stringers, each of which is sawed out of a single timber. For this reason, a stringer of this type is commonly called a CUTOUT or SAWED stringer. On some stairways, the treads and risers are nailed to triangular stair blocks attached to straight-edged stringers.

A stairway that continues in the same straight line from one floor to the next is called a STRAIGHT-FLIGHT stairway. When space does NOT permit the construction of one of these, a CHANGE stairway (one that changes direction one or more times between floors) is installed. A change stairway in which there are platforms between sections is called a PLATFORM stairway.

Stairs in a structure are divided into PRINCIPAL STAIRS and SERVICE STAIRS. Principal stairs are those extending between floors above the basement and below the attic floor. Porch, basement, and attic stairs are service stairs. The lower ends of the stringers on porch, basement, and other stairs anchored on concrete are fastened with a kickplate (fig. 6-70).

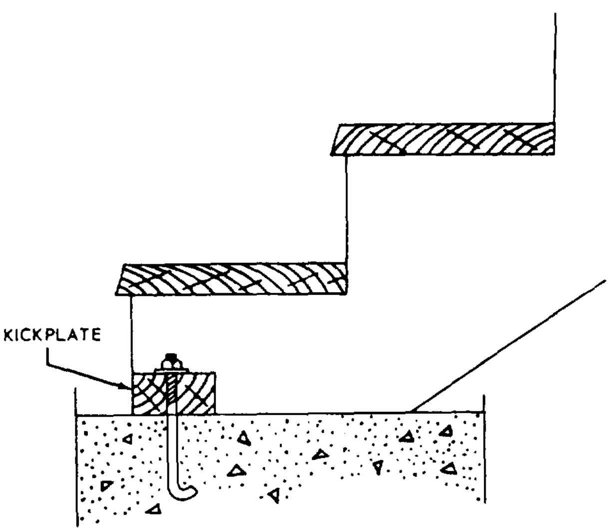


Figure 6-70.-Kickplate for anchoring stairs to concrete.

Finish Flooring

Finish flooring is broadly divided into wood finish flooring and resilient finish flooring. Most wood finish flooring comes in strips that are

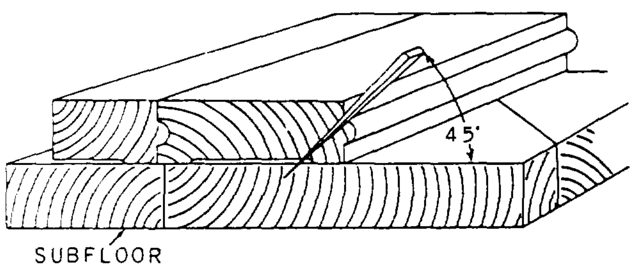


Figure 6-71.-Toenailing wood finish flooring.

side-matched; that is, tongue-and-grooved for edge-joining; some is end-matched as well. Wood flooring strips are usually recessed on the lower face and toenailed through the subflooring into joists, as shown in figure 6-71.

In Navy structures, wood finish flooring has been largely supplanted by various types of resilient flooring, most of which is applied in the form of 6 by 6, 9 by 9, or 12 by 12 floor tiles. Materials commonly used are asphalt, linoleum, cork, rubber, and vinyl. With each type of tile, the manufacturer recommends an appropriate type of adhesive for attaching the tile to the subflooring.

On other areas subject to a high degree of dampness, ceramic or glazed interior tile is most commonly used. Ceramic tiles are used to cover all or part of the bathrooms, shower rooms, and some kitchen floors.

Doors

Standard doors and combination doors (storm and screen) are millwork items that are usually fully assembled at the factory and ready for use in the building. All wood components are treated with a water-repellent preservative to provide protection against the elements. Doors are manufactured in different styles, as shown in figure 6-72.

Exterior doors, outside combination doors, and storm doors may be obtained in a number of designs to fit the style of almost any building. Doors in the traditional pattern are usually of the panel type (fig. 6-72, view A). A PANEL DOOR consists of stiles (solid vertical members), rails (solid cross members), and filler panels in a number of designs. Exterior FLUSH DOORS use a solid-core, rather than hollow-core type to minimize warping. (Warping is caused by a difference in moisture content on the exposed and unexposed faces of the door.) Weatherstripping should be installed on exterior doors to reduce both air infiltration and frosting of the glass on the storm door during cold weather. Flush doors consist of thin plywood faces over a framework of wood with a wood block or particleboard core.

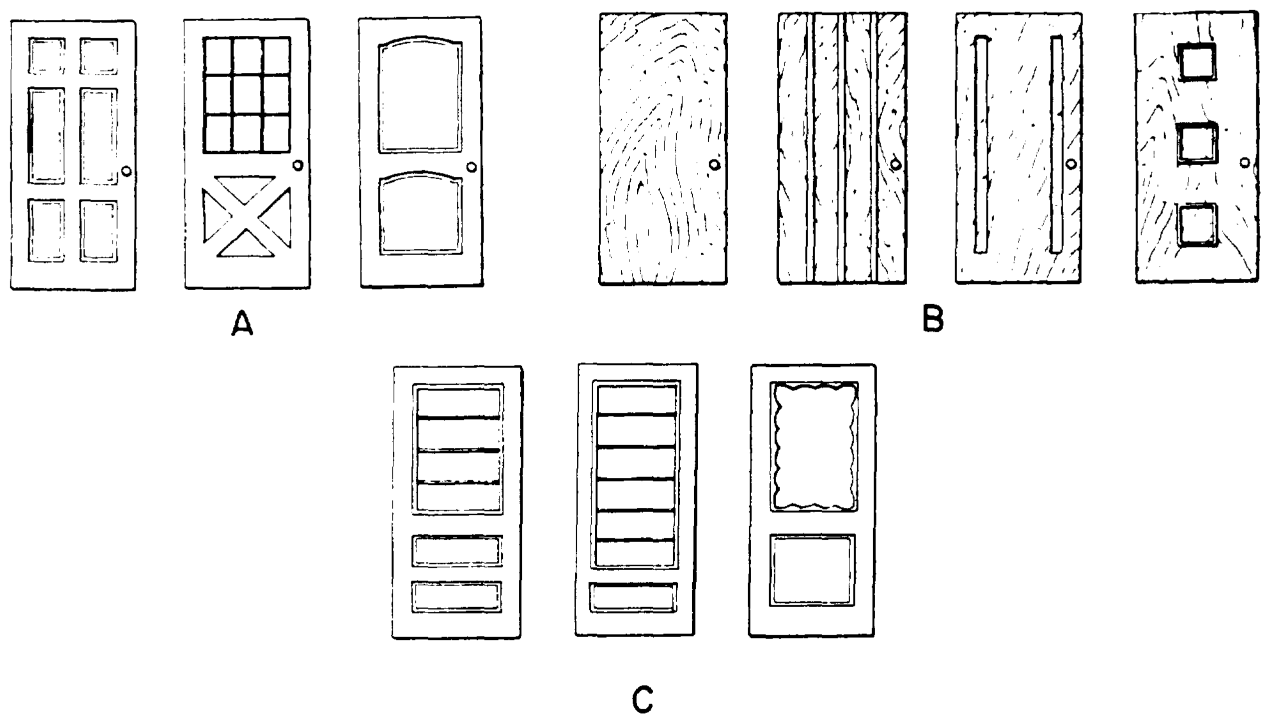


Figure 6-72.-Exterior doors: A. Traditional panel; B. Flush; C. Combination.

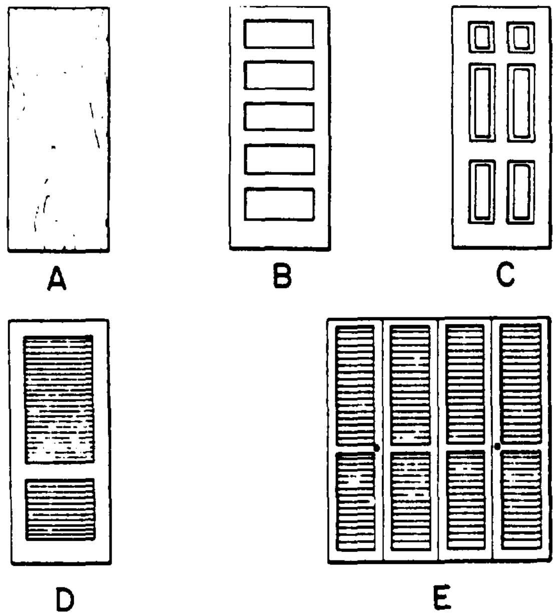


Figure 6-73-Interior doors: A. Flush; B. Panel (five-cross); C. Panel (colonial); D. Louvered; E. Folding (louvered).

Exterior doors are usually 1 3/4 in. thick and not less than 6 ft 8 in. high. The main entrance door is 3 ft wide, and the side or rear door is normally 2 ft 8 in. wide. The exterior trim used can vary from a simple CASING (the trim used around the edges of door openings and also as a finishing trim on the room side of windows and exterior doorframes) to a molded or plain pilaster.

Similarly, interior doors also come in many styles (fig. 6-73). The two principal types are flush and panel doors. Interior panel doors (colonial and five-cross type) are manufactured to be similar to the exterior doors, Novelty doors, such as the folding door unit, are commonly used for closets because they provide ventilation. The interior flush door is usually made up with a hollow core of light framework covered with thin plywood or hardboard. Most standard interior doors are 1 3/8 in. thick.

Hinged doors should open or swing in the direction of natural entry, against a blank wall, and should not be obstructed by other swinging doors. Doors should NEVER be hinged to swing into a hallway.

Figure 6-74 shows the principal parts of a finish doorframe. On an outside door, the frame

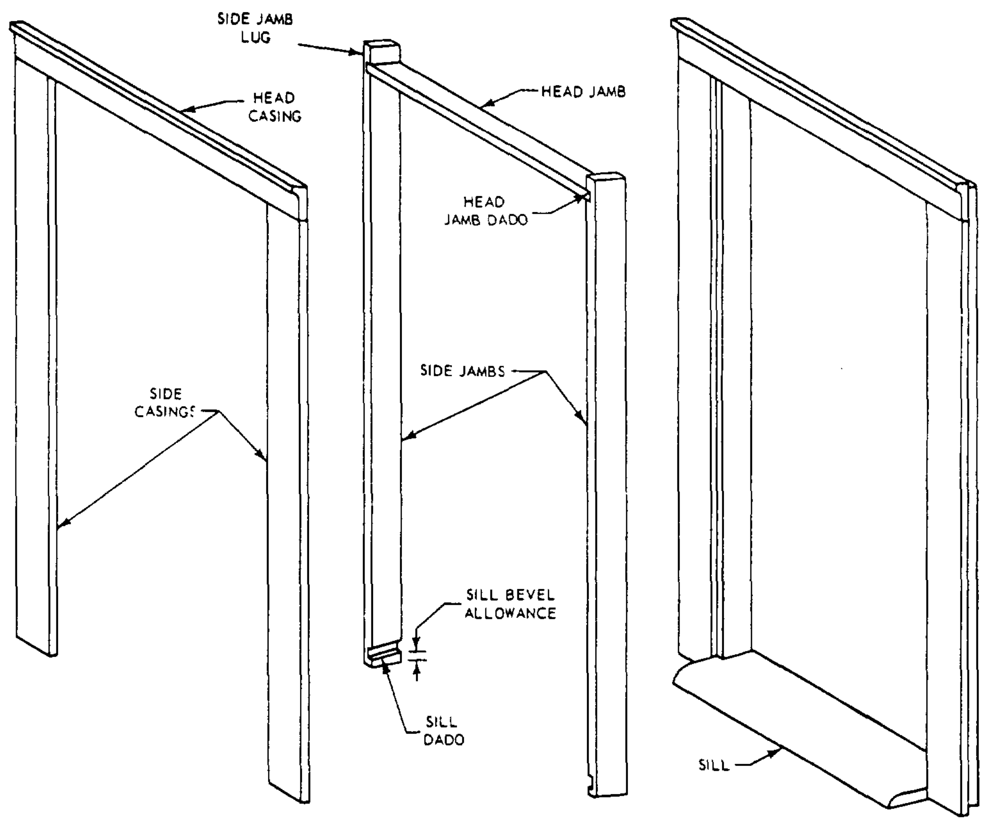


Figure 6-74.-Principal parts of a finish doorframe.

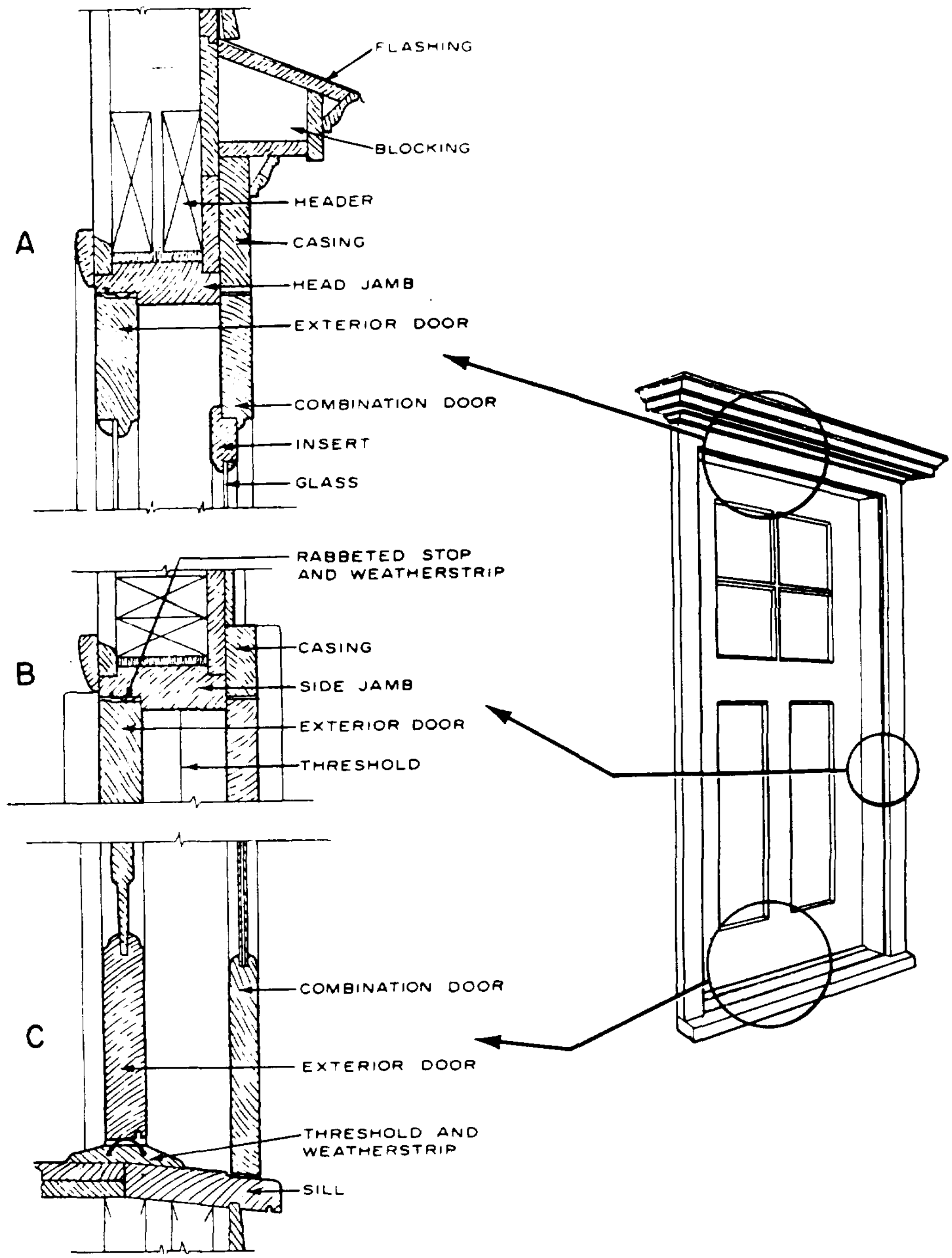


Figure 6-75.-Exterior door and frame. Exterior door and combination door (screen and storm) cross sections: A. Head jamb; B. Side jamb; C. Sill.

includes the side and head casings. On an inside door. the frame consists only of the side and head jambs; the casings are considered part of the inside-wall covering.

Figure 6-75 shows section drawings of exterior doorframe details.

Windows

The part of a window that forms a frame for the glass is called sash, and window sash is considered part of the interior, not the exterior, finish. However, a window with a sash that is

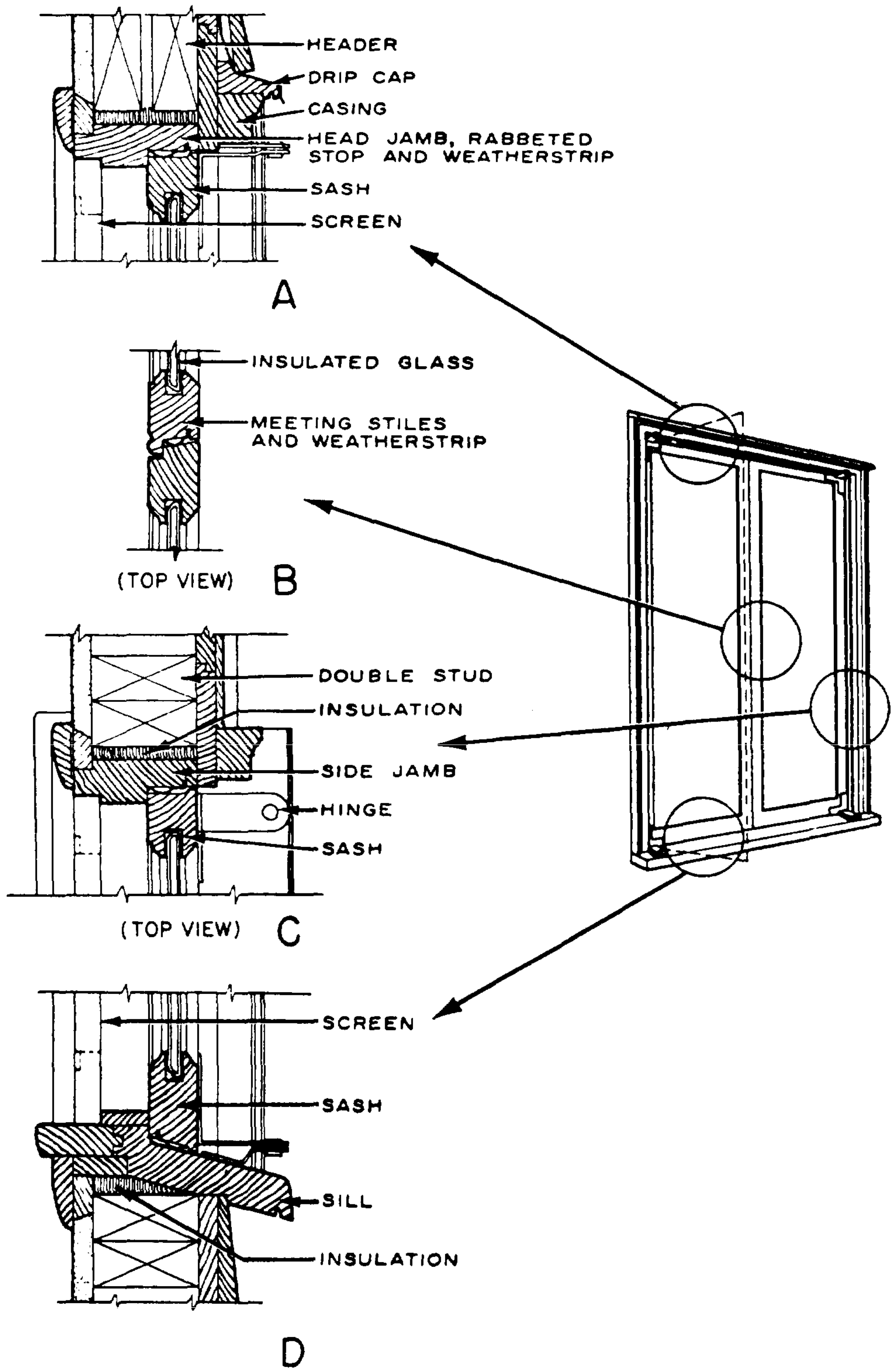


Figure 6-76.-Outswinging casement sash. Cross sections: A. Head jamb; B. Meeting stiles; C. Side jambs; D. Sill.

hinged at the side is called a casement window (fig. 6-76)—single casement if there is only one sash, double casement if there are two. A window that is hinged at the top or bottom is called a transom window. One with a number of horizontally hinged sashes that open and close together like the slats in a venetian blind is a jalousie window. A window having two sashes that slide vertically past each other is a double-hung window.

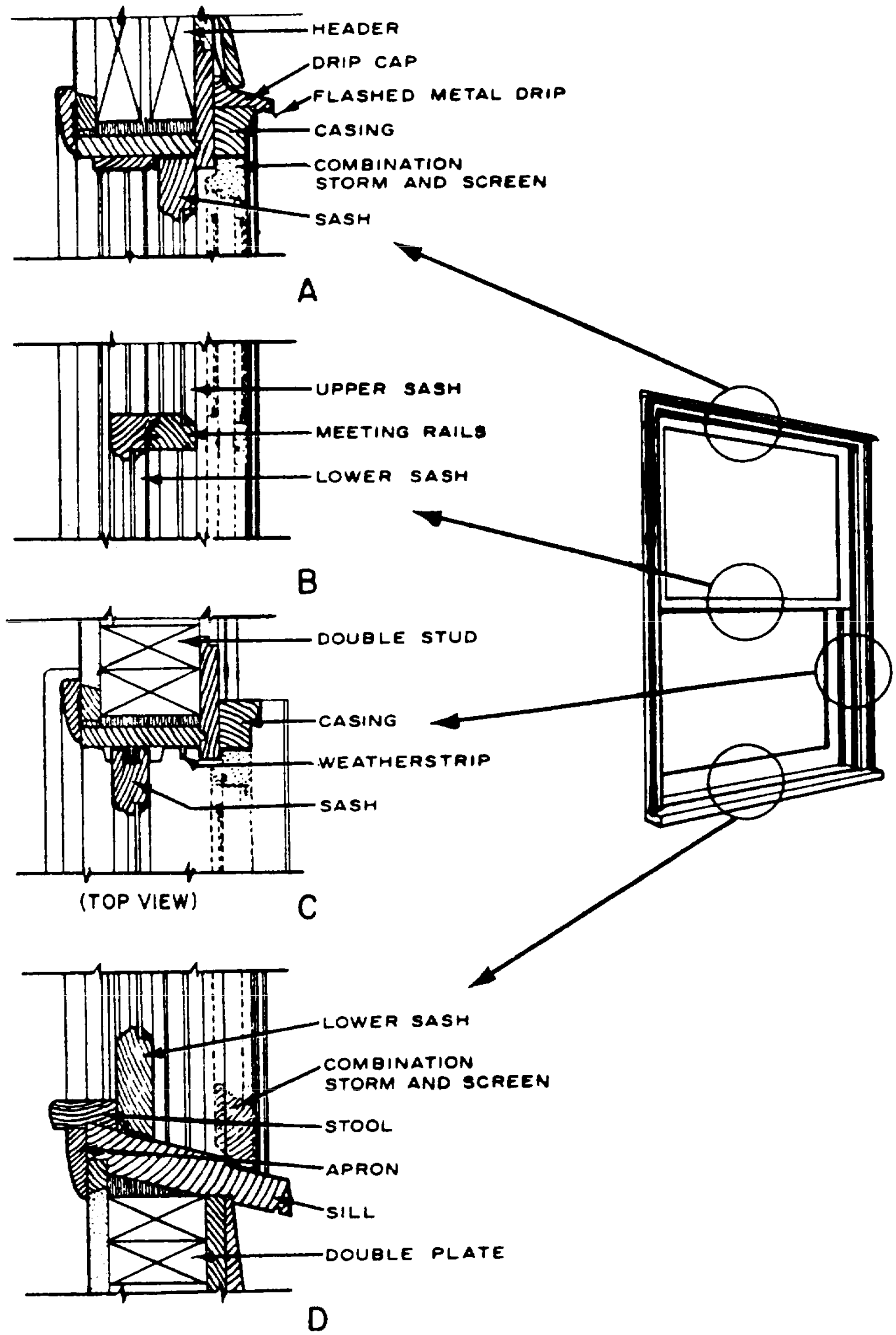


Figure 6-77.-Double-hung windows. Cross sections: A. Head jamb; B. Meeting rails; C. Side jambs; D. Sill.

Basically, the finish frames for all of these are much alike, consisting principally, like a finish doorframe, of side jambs, head jamb, sill, and outside casing (the inside casing being considered part of the inside-wall covering). However, a double-hung window frame contains some items that are NOT used on frames for other types of windows. Section drawings showing head- and side-jamb details for a double-hung window are shown in figure 6-77. Sill details are shown in figure 6-78.

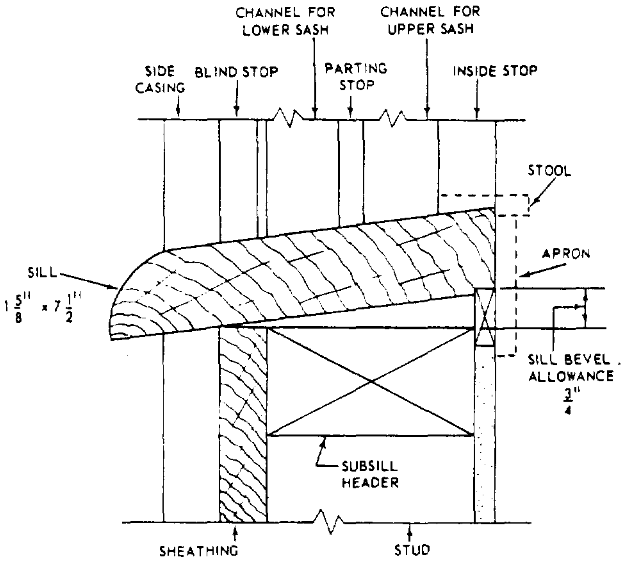


Figure 6-78.-Sill detail for a double-hung window.

A window schedule on the construction drawings gives the dimensions, type, such as casement, double-hung, and so forth, and the number of lights (panes of glass) for each window in the structure. A window might be listed on the schedule as, for example, No. 3, DH, 2 ft 4 in. by 3 ft 10 in, 12 LTS. This means that window No. 3 (it will have this number on any drawing in which it is shown) is a double-hung window with a finished opening, measuring 2 ft 4 in. by 3 ft 10 in. and having 12 lights of glass. In any view in which the window appears, the arrangement of the lights will be shown. On one of the lights, a figure such as 8/10 will appear. This means that each light of glass has nominal dimensions of 8 by 10 in.

Figure 6-79 shows a double-hung window sash and the names of its parts.

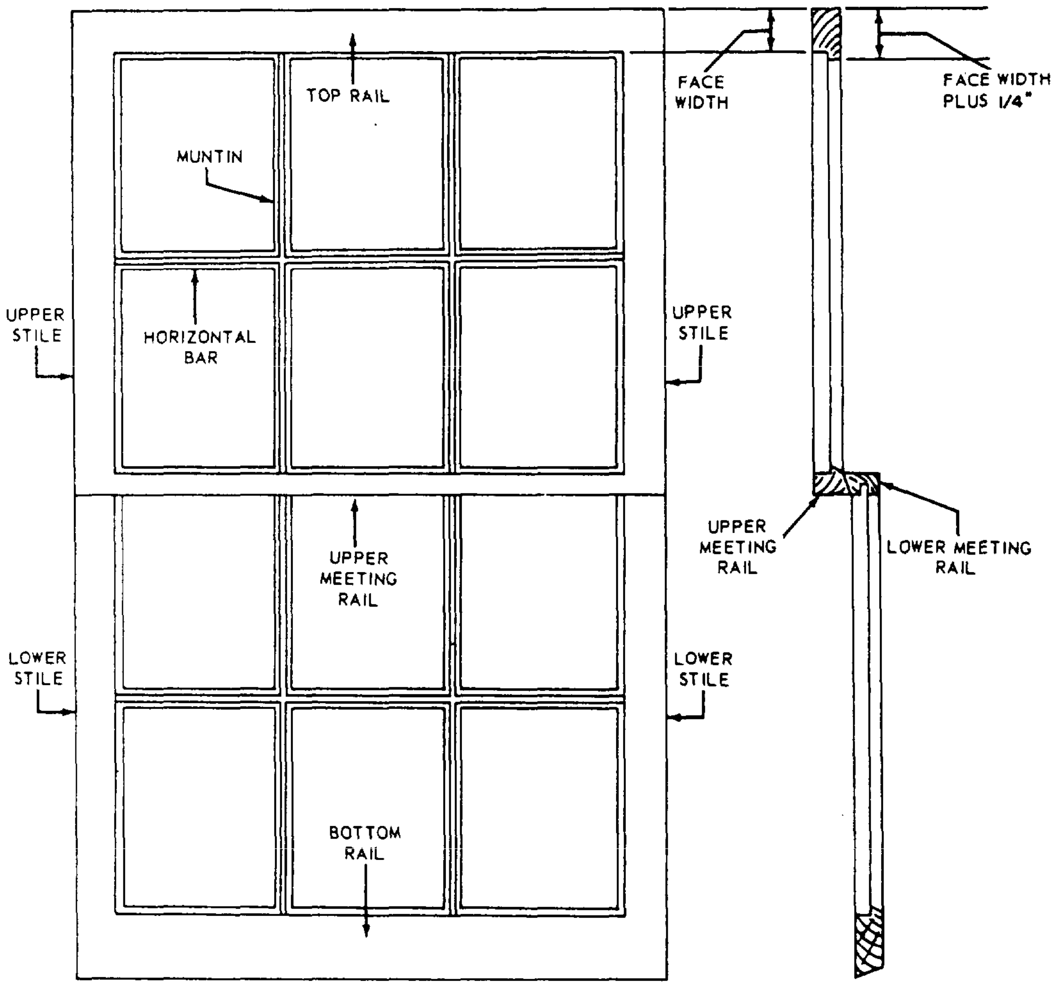


Figure 6-79.-Parts of a double-hung window sash.

Wood Trims

The most prominent items in the interior trim are the inside door and the window casings, which may be plain-faced or ornamentally molded in various ways. Another item is the baseboard, which covers the joint between an inside wall and finish floor (fig. 6-80). Baseboards or base molding are available in several widths and forms. Figures 6-81 and 6-82 show areas where some types of molding are desirable.

HARDWARE

HARDWARE is a general term covering a wide variety of accessories that are usually made of metal or plastic and ordinarily used in building construction. Hardware includes both finishing and rough hardware.

FINISHING HARDWARE consists of items that are made in attractive shapes and finishes and are usually visible as an integral part of the finished structure. Included are locks, hinges, door pulls, cabinet hardware, window fastenings, door closers and checks, door holders, and automatic exit devices. In addition, there are the lock-operating trim, such as knobs and handles, escutcheon plates, strike plates, and knob rosettes. There are also push plates, push bars, kickplates, doorstops, and flush bolts.

ROUGH HARDWARE consists of items that are NOT usually finished for an attractive appearance. These items include casement and special window hardware, sliding and folding door supports, and fastenings for screens, storm windows, shades, venetian blinds, and awnings.

Other items may be considered hardware. If you are not sure whether an item is hardware or what its function is, refer to a commercial text, such as the *Architectural Graphic Standards.*

FASTENERS

The devices used in fastening or connecting members together to form structures depend on the kinds of material the members are made of.

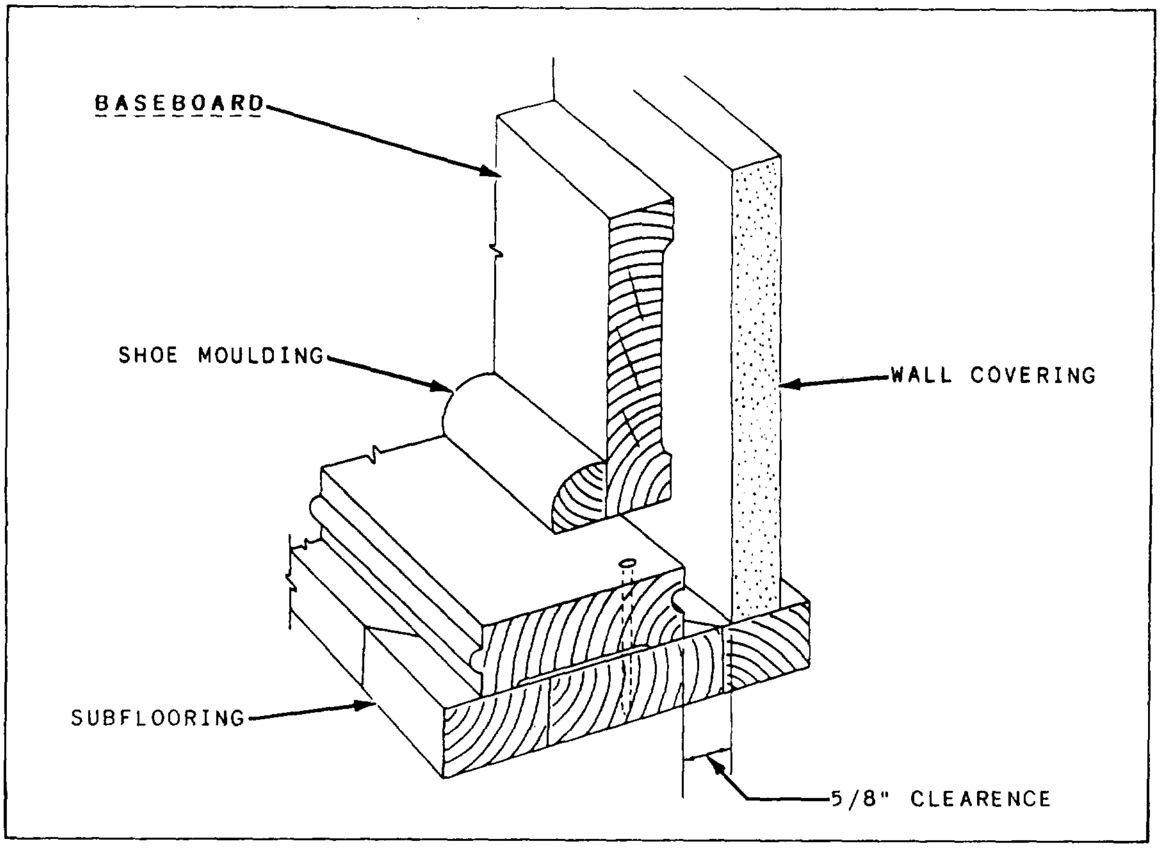


Figure 6-80.-Baseboard.

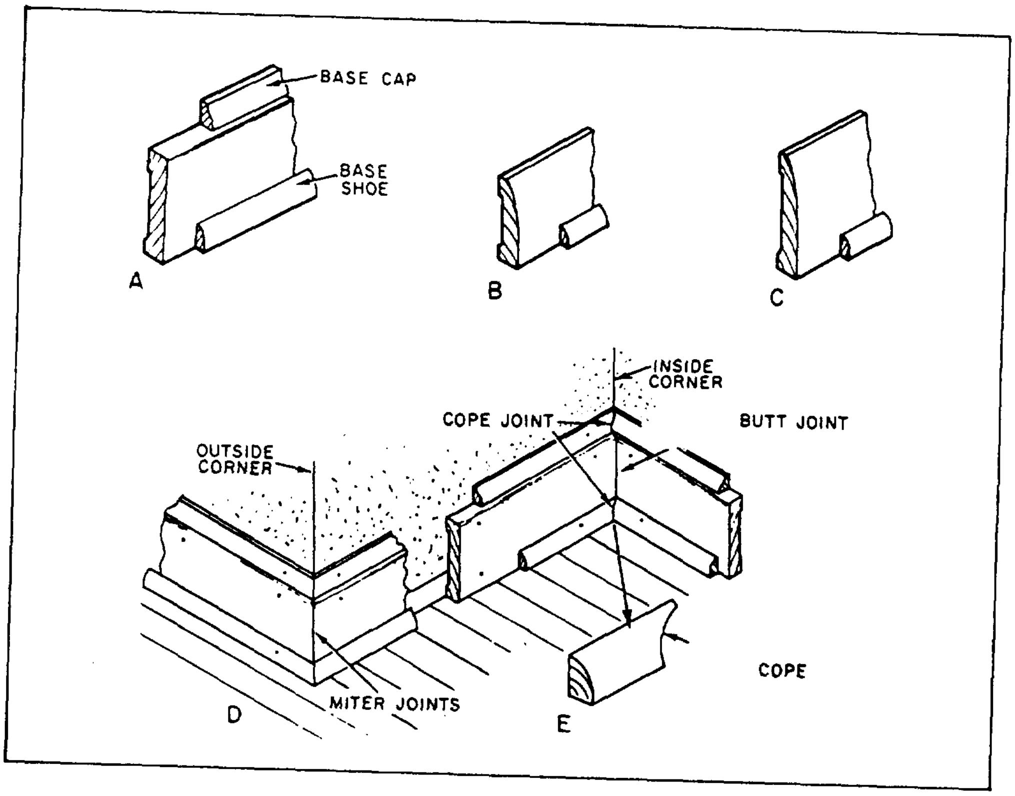


Figure 6-81.-Base moldings: A. Square-edge base; B. Narrow ranch base; C. Wide ranch base; D. Installation; E. Cope.

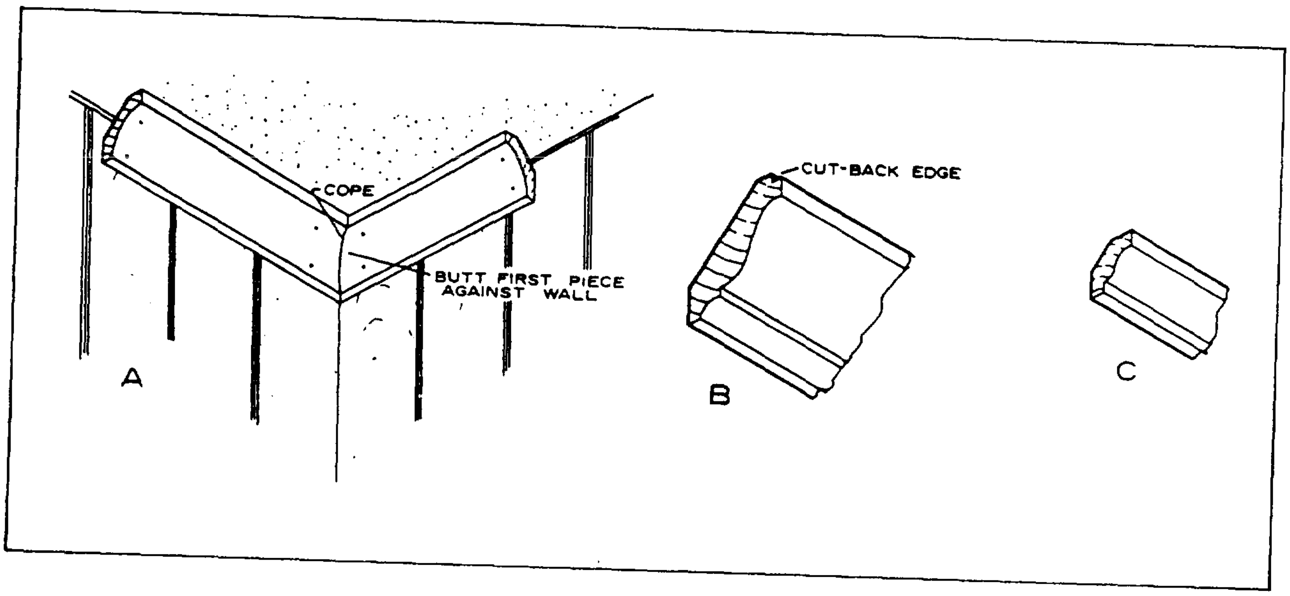
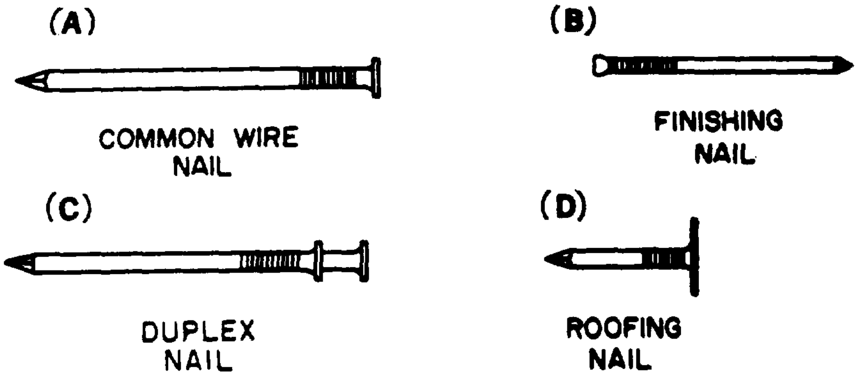
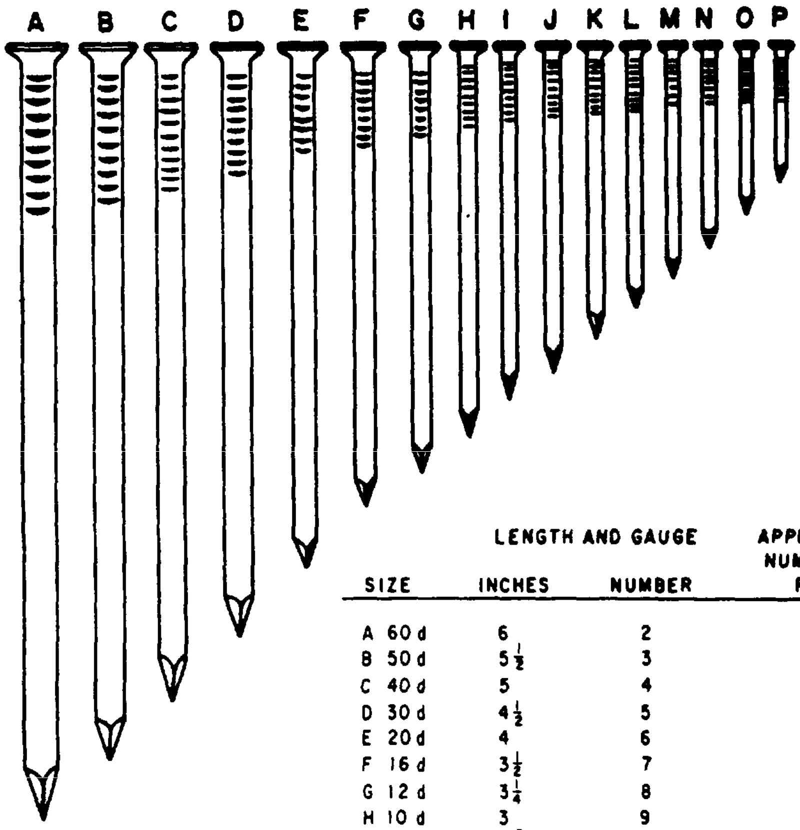


Figure 6-82.-Ceiling moldings: A. Installation (inside corner); B. Crown molding; C. Small crown molding.





SIZE		LENGTH AND GAUGE INCHES	LENGTH AND GAUGE NUMBER	APPROXIMATE NUMBER TO POUND
A	60 d	6	2	11
B	50 d	5½	3	14
C	40 d	5	4	18
D	30 d	4½	5	24
E	20 d	4	6	31
F	16 d	3½	7	49
G	12 d	3¼	8	63
H	10 d	3	9	69
I	9 d	2¾	10¼	96
J	8 d	2½	10¼	106
K	7 d	2¼	11½	161
L	6 d	2	11½	181
M	5 d	1¾	12½	271
N	4 d	1½	12½	316
O	3 d	1¼	14	568
P	2 d	1	15	876

Figure 6-83.-Types and sizes of common wire nails and other nails.

The most common fastening devices are nails, screws, and bolts.

Nails

There are many types of nails—all of which are classified according-to their use and form. The standard nail is made of steel wire. The wire nail is round-shafted, straight, pointed, and may vary in size, weight, size and shape of head, type of point, and finish. The holding power of nails is. less than that of screws or bolts.

The COMMON WIRE nail and BOX nail (fig. 6-83, view A) are the same, except that the wire sizes are one or two numbers smaller for a given length of the box nail than they are for the common nail. The FINISHING nail (fig. 6-83, view B) is made from finer wire and has a smaller head than the common nail, Its head may be driven below the surface of the wood, which leaves only a small hole that is easily puttied. The DUPLEX nail (fig, 6-83, view C) seems to have two heads. Actually one serves as a shoulder to give maximum holding power while the other projects above the surface of the wood to make withdrawal simple. The ROOFING NAIL (fig. 6-83, view D) is round-shafted and galvanized. It has a relatively short body and comparatively large head. Like the common wire, finishing, or duplex nail, it has a diamond point.

Besides the general-purpose nails shown in figure 6-83, there are special-purpose nails. Examples include wire brads, plasterboard nails, concrete nails, and masonry nails. The wire brad has a needlepoint; the plasterboard nail has a large-diameter flathead. The concrete nail is specially hardened for driving in concrete. So is the masonry nail, although its body is usually grooved or spiraled.

Lengths of wire nails NOT more than 6 in. long are designated by the penny system, where the letter *d* is the symbol for a penny. Thus, a 6d nail means a sixpenny nail. The thickness of a wire nail is expressed by the number, which relates to standard wire gauge. Nail sizes (penny and length in inches), gauges, and approximate number of nails per pound are given in figure 6-83. Nails longer than 6 in. (called SPIKES) are not designated by the penny. The general size and type of nail preferable for specific applications are shown in table 6-4.

Table 6-4.-Size, Type, and Use of Nails

SIZE	LGTH (IN.)[1]	DIAM (IN.)	REMARKS	WHERE USED
2d	1	.072	SMALL HEAD	FINISH WORK, SHOP WORK.
2d	1	.072	LARGE FLATHEAD	SMALL TIMBER, WOOD SHINGLES, LATHES.
3d	1¼	.08	SMALL HEAD	FINISH WORK, SHOP WORK.
3d	1¼	.08	LARGE FLATHEAD	SMALL TIMBER, WOOD SHINGLES, LATHES.
4d	1½	.098	SMALL HEAD	FINISH WORK, SHOP WORK.
4d	1½	.098	LARGE FLATHEAD	SMALL TIMBER, LATHES, SHOP WORK.
5d	1¾	.098	SMALL HEAD	FINISH WORK, SHOP WORK.
5d	1¾	.098	LARGE FLATHEAD	SMALL TIMBER, LATHES, SHOP WORK.
6d	2	.113	SMALL HEAD	FINISH WORK, CASING, STOPS, ETC., SHOP WORK.
6d	2	.113	LARGE FLATHEAD	SMALL TIMBER, SIDING, SHEATHING, ETC., SHOP WORK.
7d	2¼	.113	SMALL HEAD	CASING, BASE, CEILING, STOPS, ETC.
7d	2¼	.113	LARGE FLATHEAD	SHEATHING, SIDING, SUBFLOORING, LIGHT FRAMING.
8d	2½	.131	SMALL HEAD	CASING, BASE, CEILING, WAINSCOT, ETC., SHOP WORK.
8d	2½	.131	LARGE FLATHEAD	SHEATHING, SIDING, SUBFLOORING, LIGHT FRAMING, SHOP WORK.
8d	1¼	.131	EXTRA-LARGE FLATHEAD	ROLL ROOFING, COMPOSITION SHINGLES.
9d	2¾	.131	SMALL HEAD	CASING, BASE, CEILING, ETC.
9d	2¾	.131	LARGE FLATHEAD	SHEATHING, SIDING, SUBFLOORING, FRAMING, SHOP WORK.
10d	3	.148	SMALL HEAD	CASING, BASE, CEILING, ETC., SHOP WORK.
10d	3	.148	LARGE FLATHEAD	SHEATHING, SIDING, SUBFLOORING, FRAMING, SHOP WORK.
12d	3¼	.148	LARGE FLATHEAD	SHEATHING, SUBFLOORING, FRAMING.
16d	3½	.162	LARGE FLATHEAD	FRAMING, BRIDGES, ETC.
20d	4	.192	LARGE FLATHEAD	FRAMING, BRIDGES, ETC.
30d	4½	.207	LARGE FLATHEAD	HEAVY FRAMING, BRIDGES, ETC.
40d	5	.225	LARGE FLATHEAD	HEAVY FRAMING, BRIDGES, ETC.
50d	5½	.244	LARGE FLATHEAD	EXTRA-HEAVY FRAMING, BRIDGES, ETC.
60d	6	.262	LARGE FLATHEAD	EXTRA-HEAVY FRAMING, BRIDGES, ETC.

[1]THIS CHART APPLIES TO WIRE NAILS, ALTHOUGH IT MAY BE USED TO DETERMINE THE LENGTH OF CUT NAILS.

Screws

A wood screw is a fastener that is threaded into the wood. Wood screws are designated by the type of head (fig. 6-84) and the material from which they are made; for example, flathead brass or round-head steel. The size of a wood screw is designated by its length in inches and a number relating to its body diameter—meaning the diameter of the unthreaded part. This number runs from 0 (about 1/15-in. diameter) to 24 (about 3/8-in. diameter).

Lag screws, called LAG BOLTS (fig. 6-84), are often required where ordinary wood screws are too short or too light, or where spikes do not hold securely. They are available in lengths of 1 to 16 in. and in body diameters of 1/4 to 1 in. Their heads are either square or hexagonal.

Sheet metal, sheet aluminum, and other thin metal parts are assembled with SHEET METAL screws and THREAD-CUTTING screws (fig. 6-84). Sheet metal screws are self-tapping; they can fasten metals up to about 28 gauge. Thread-cutting screws are used to fasten metals that are 1/4 in. thick or less.

Bolts and Driftpins

A steel bolt is a fastener having a head at one end and threads at the other, as shown in figure 6-85. Instead of threading into wood like a screw, it goes through a bored hole and is held by a nut. Stove bolts range in length from 3/8 to 4 in. and in body diameter from 1/8 to 3/8 in. Not especially strong, they are used only for fastening light pieces. CARRIAGE and MACHINE bolts are strong enough to fasten load-bearing members, such as trusses. In length, they range from 3/4 to 20 in.; in diameter, from 3/16 to 3/4 in. The carriage bolt has a square section below its head which embeds in the wood as the nut is set up, keeping the bolt from turning. An expansion bolt is used in conjunction with an expansion shield to provide anchorage in a position in which a threaded fastener alone is useless,

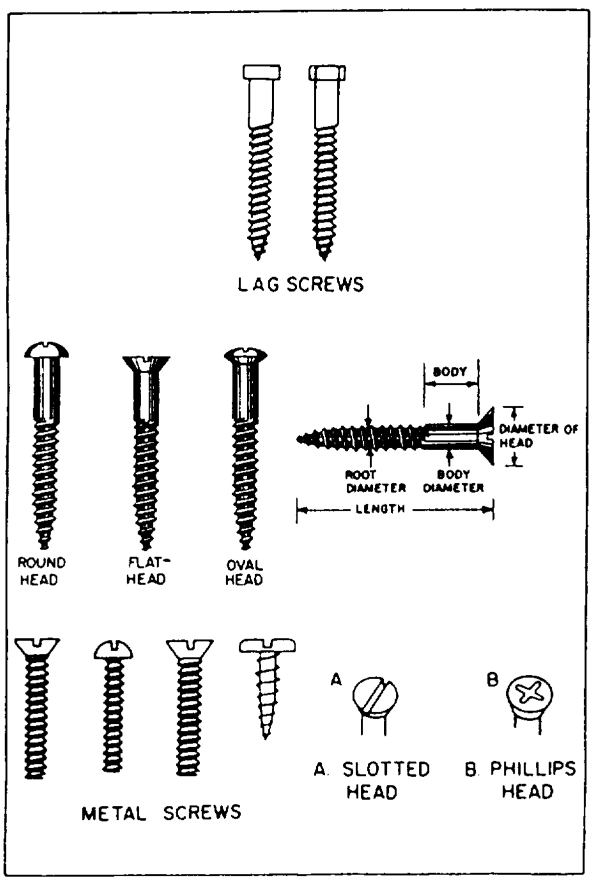


Figure 6-84.-Types of screws.

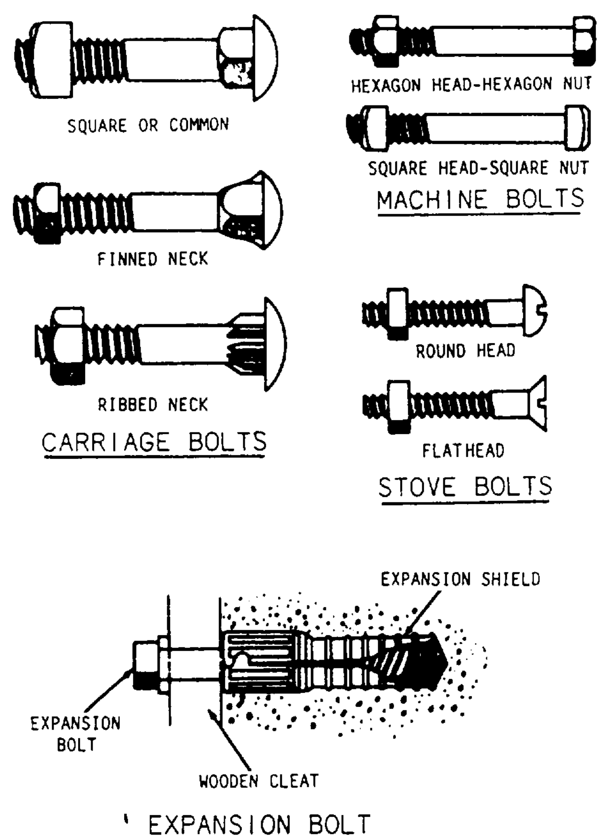


Figure 6-85.-Types of bolts.

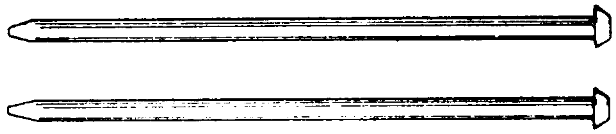


Figure 6-86.-Driftpins (driftbolts).

Driftpins (driftbolts) (fig. 6-86) are long, heavy, threadless bolts used to hold heavy pieces of timber together. Corrugated fasteners (fig.. 6-87) are used in a number of ways; for example, to fasten joints (miter) and splices together and as a substitute for nails where nails may split the timber.

Glue

Glue, one of the oldest materials for fastening, if applied properly, will form a joint that is stronger than the wood itself. Probably one of the best types of glue for joint work and furniture construction is animal glue, made from hides. Other types of glue are extracted from fish, vegetables, casein, plastic resin, and blood albumin. Glue can be obtained commercially in a variety of forms—liquid, ground, chipped, flaked, powdered, or formed into sticks.

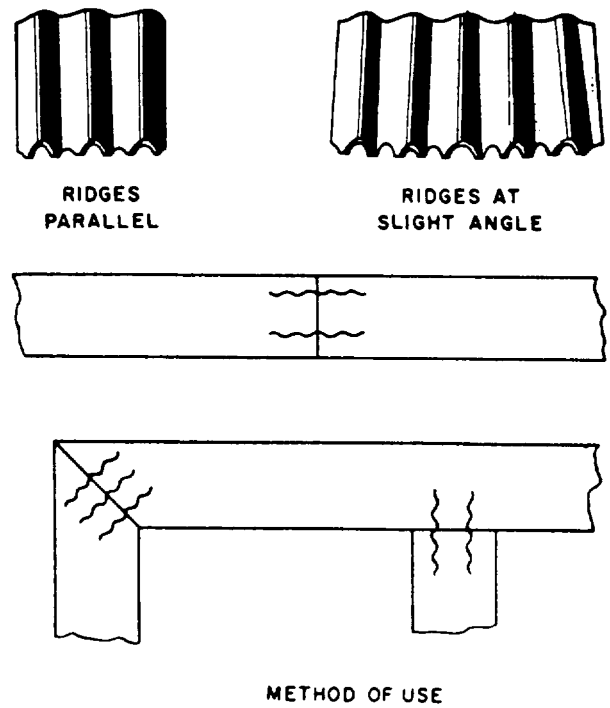


Figure 6-87.-Use of corrugated fasteners.

CHAPTER 7

CONCRETE AND MASONRY

This chapter provides information and guidance for the Engineering Aid engaged in or responsible for drawing structural and architectural layouts from existing plans, engineering sketches, or specifications, It includes information on basic materials commonly used in concrete and masonry construction.

Basic principles and procedures associated with the construction of reinforced, precast, and prestressed concrete and tilt-up construction are also discussed in this chapter. Terminology as it applies to masonry units is used to acquaint the Engineering Aid with the various terms used in this type of construction.

CONCRETE

CONCRETE is a synthetic construction material made by mixing CEMENT, FINE AGGREGATE (usually sand), COARSE AGGREGATE (usually gravel or crushed stone), and WATER together in proper proportions; the product is not concrete unless all four of these ingredients are present. A mixture of cement, sand, lime, and water, without coarse aggregate, is NOT concrete, but MORTAR or GROUT.

Mortar is used mainly for bonding masonry units together. The term grout refers to a water-cement mixture (called neat-cement grout) or water-sand-cement mixture (called sand-cement grout) used to plug holes or cracks in concrete, to seal joints, and for similar plugging or sealing purposes.

The fine and coarse aggregates in a concrete mix are called the INERT ingredients; the cement and water are the ACTIVE ingredients. The inert ingredients and the cement are thoroughly mixed together first. As soon as the water is added, a chemical reaction between the water and the cement begins, and it is this reaction (which is called HYDRATION) that causes the concrete to harden.

Always remember that the hardening process is caused by hydration of the cement by the water, not by a DRYING OUT of the mix. Instead of being dried out, the concrete must be kept as moist as possible during the initial hydration process. Drying out would cause a drop in water content below the amount required for satisfactory hydration of the cement.

The fact that the hardening process has nothing whatever to do with a drying out of the concrete is clearly shown by the fact that concrete will harden just as well under water as it will in the air.

Concrete may be cast into bricks, blocks, and other relatively small building units that are used in concrete MASONRY construction.

The proportion of concrete to other materials used in building construction has greatly increased in recent years to the point where large, multistory modern building are constructed entirely of concrete, with concrete footings, foundations, columns, walls, girders, beams, joists, floors, and roofs.

REQUIREMENTS FOR GOOD CONCRETE

The first requirement for good concrete is a supply of good cement of a type suitable for the work at hand. Next is a supply of satisfactory sand, coarse aggregate, and water; all of which must be carefully weighed and measured. Everything else being equal, the mix with the best graded, strongest, best shaped, and cleanest aggregate will make the strongest and most durable concrete.

The best designed, best graded, and highest quality mix in the world will NOT make good concrete if it is not WORKABLE enough to fill the form spaces thoroughly. On the other hand, too much fluidity will result in certain defects. Improper handling during the whole concrete-making process (from the initial aggregate handling to the final placement of the mix) will cause segregation of aggregate particles by sizes, resulting in nonuniform, poor concrete.

Finally, the best designed, best graded, highest quality, and best placed mix in the world will not produce good concrete if it is not properly CURED—meaning, properly protected against loss of moisture during the earlier stages of setting.

As you can see, the important properties of concrete are its strength, durability, and watertightness. These factors are controlled by the WATER-CEMENT RATIO or the proportion of water to cement in the mix.

Strength

The COMPRESSIVE strength of concrete is very high, but its TENSILE strength (meaning its ability to resist stretching, bending, or twisting) is relatively low. Consequently, concrete that must resist a good deal of stretching, bending, or twisting, such as concrete in beams, girders, walls, columns, and the like, must be REINFORCED with steel. Concrete that must resist compression only may not require reinforcement.

Durability

The DURABILITY of concrete means the extent to which the material is capable of resisting the deterioration caused by exposure to service conditions. Ordinary structural concrete that is to be exposed to the elements must be watertight and weather resistant. Concrete that is subject to wear, such as floor slabs and pavements, must be capable of resisting abrasion. It has been found that the major factor controlling durability is strength—in other words, the stronger the concrete is, the more durable it will be. As mentioned previously, the chief factor controlling strength is the water-cement ratio, but the character, size, and grading (distribution of particle sizes between the largest permissible coarse and the smallest permissible fine) of the aggregate also have important effects on both strength and durability. Given a water-cement ratio that will produce maximum strength consistent with workability requirements, maximum strength and durability will still not be attained unless the sand and coarse aggregate consist of well-graded, clean, hard, and durable particles, free from undesirable substances (fig. 7-1).

Watertightness

The ideal concrete mix would be one made with just the amount of water required for complete hydration of the cement. This would be a DRY mix, however, too stiff to pour in the forms. A mix that is fluid enough to be poured into forms always contains a certain amount of water over and above the amount that will combine wit h the cement, and this water will eventually evaporate, leaving voids or pores in the concrete.

Even so, penetration of the concrete by water would still be impossible if these voids were not interconnected. They are interconnected, however, as a result of a slight sinking of solid particles in the mix during the hardening period. As these particles sink, they leave water-filled channels, which become voids when the water evaporates.

The larger and more numerous these voids are, the more the watertightness of the concrete will be impaired. Since the size and number of the voids vary directly with the amount of water used in excess of the amount required to hydrate the cement, it follows that to keep the concrete as watertight as possible, you must not use more water than the minimum amount required to attain the necessary degree of workability.

PLAIN CONCRETE

Plain concrete is defined as concrete with no reinforcement, This type of concrete is most often used where strength is not essential and stresses are minimal, such as sidewalks or driveways and floors where heavy loads are not anticipated.

REINFORCED CONCRETE

Reinforced concrete refers to concrete containing steel (bars, rods, strands, wire, and mesh) as reinforcement and designed to absorb tensile and shearing stresses, Concrete structural members, such as footings, columns and piers, beams, floor slabs, and walls, must be reinforced to attain the necessary strength in tension.

Reinforced Concrete Structural Members

A reinforced concrete structure is made up of many types of reinforced structural members, including footings, columns, beams, slabs, walls, and so forth. Their basic functions are briefly described below.

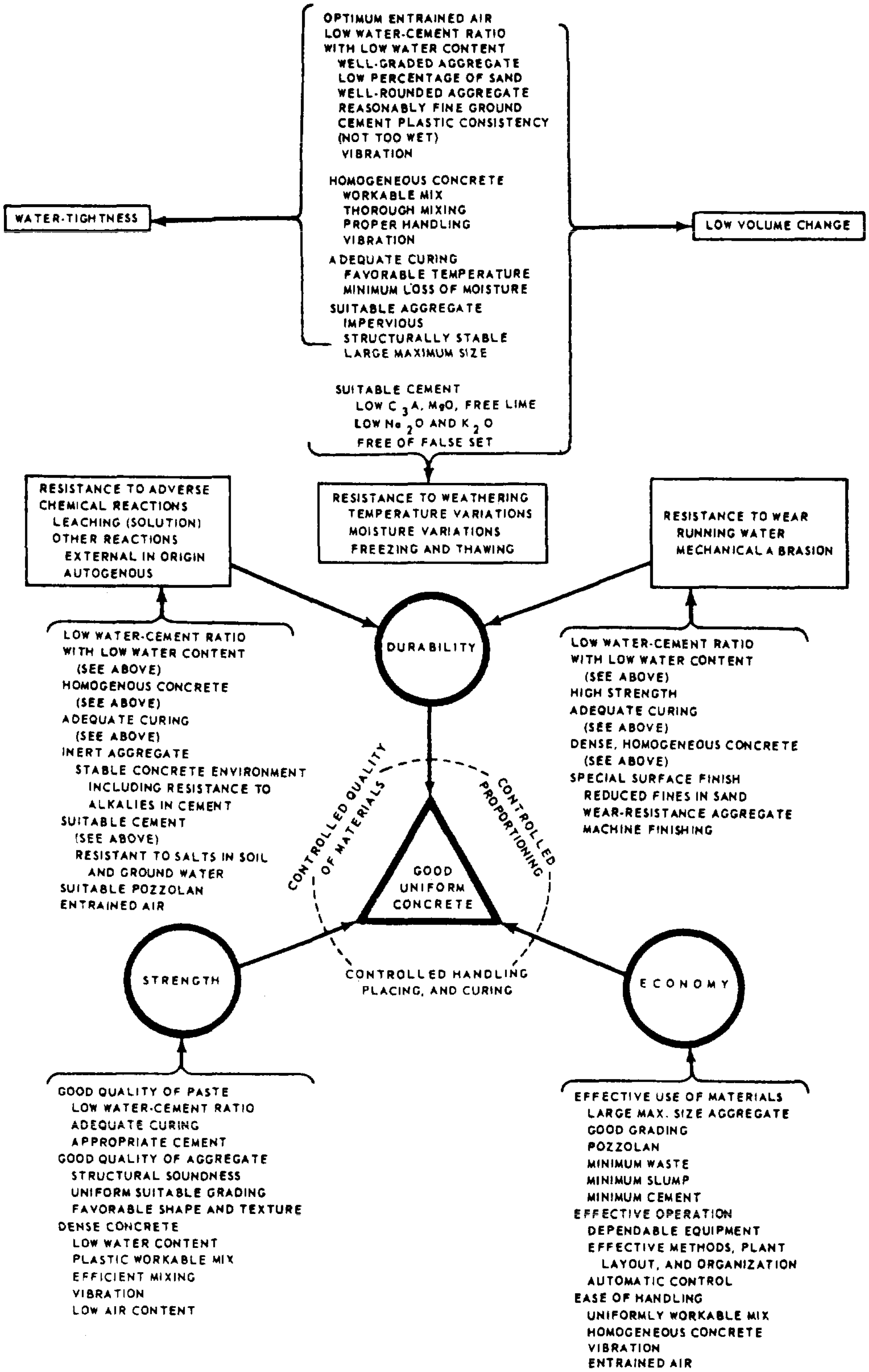


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Figure 7-1.-The principal properties of good concrete.

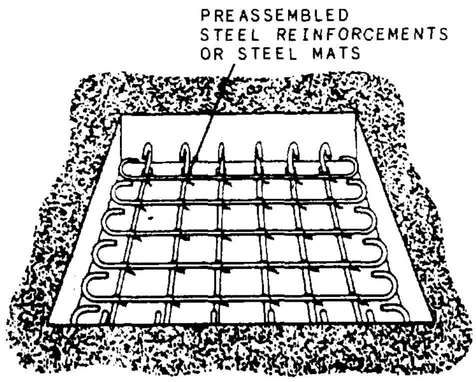


Figure 7-2.-Typical small footing.

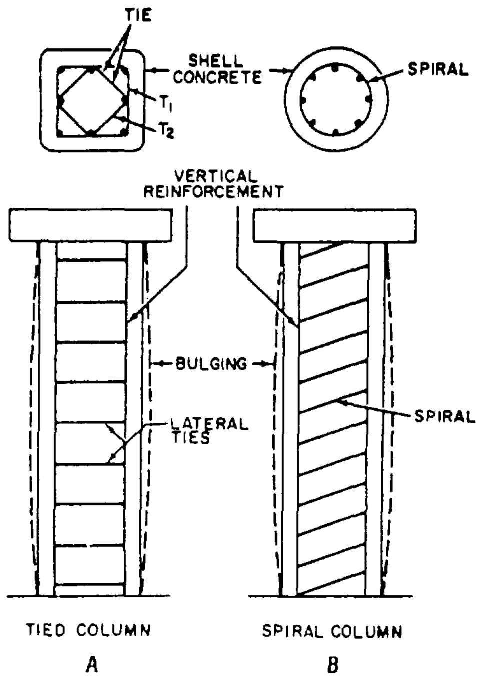


Figure 7-3.-Reinforced concrete columns.

FOOTING AND FOOTING REINFORCEMENT.— Footings support the entire structure and distribute the load to the ground. The size and shape of a footing depend upon the design of the structure. In a small footing (fig. 7-2), "steel mats" or reinforcements are generally preassembled and placed after the forms have been set. In large or continuous footings, such as those found under bearing walls, steel mats are constructed in place.

COLUMN AND COLUMN REINFORCEMENT.— A column is a slender, vertical member that carries a superimposed load. Concrete columns, especially those subjected to bending stresses, must always be reinforced with steel. A PIER or PEDESTAL is a compressive member that is short (usually the height is less than three times the least lateral dimension) in relation to its cross-sectional area and carries no bending stress.

In concrete columns, vertical reinforcement is the principal reinforcement. However, a loaded column shortens vertically and expands laterally; hence, lateral reinforcements in the form of lateral ties are used to restrain the expansion. Columns reinforced in this manner are called tied columns (fig. 7-3, view A). If the restraining reinforcement is a continuous winding spiral that encircles the core and longitudinal steel, the column is called a spiral column (fig, 7-3, view B).

BEAM AND BEAM REINFORCEMENT.— Beams are the principal load-carrying horizontal members. They take the load directly from the floor and carry it to the columns. Concrete beams can either be cast in place or precast and transported to the jobsite. Figure 7-4 shows several common types of beam reinforcing steel shapes. Both straight and bent-up principal

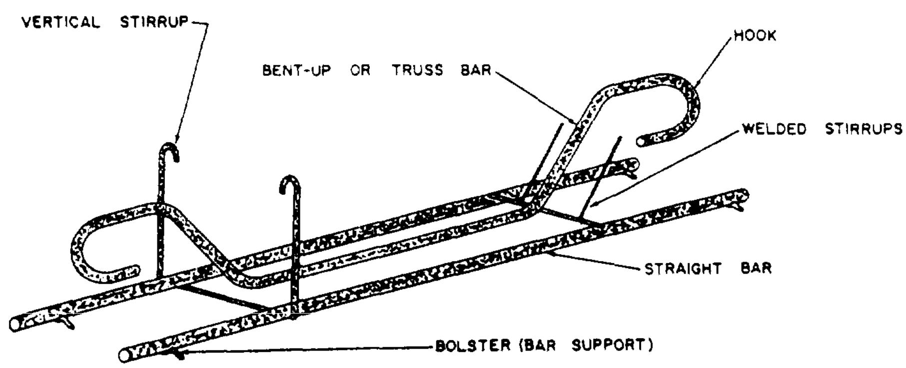


Figure 7-4.-Typica1 shapes of reinforcing steel.

reinforcing bars are needed to resist the bending tension in the bottom over the central portion of the span. Fewer bars are necessary on the bottom near the ends of the span where the bending moment is small. For this reason, some bars may be bent so that the inclined portion can be used to resist diagonal tension. The reinforcing bars of continuous beams are continued across the supports to resist tension in the top in that area.

SLAB AND SLAB REINFORCEMENT.— Concrete slabs come in a variety of forms depending on their locations. Ground slabs take the load directly to the ground. Plain slabs (similar in shape to ground slabs) take the load directly from the floor and transmit it to the beams. In other cases, joists, poured as part of plain slabs, carry the loads to the beams. Joists are used to strengthen the middle portion of the slab.

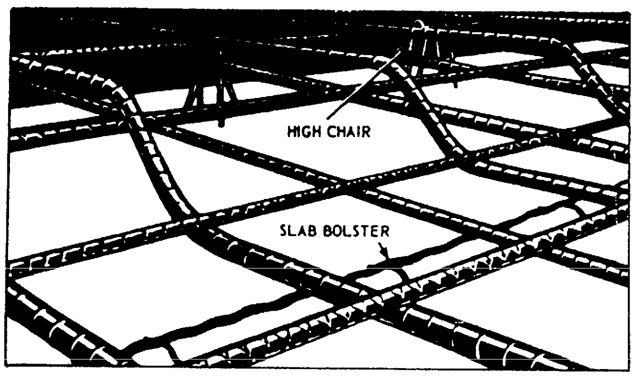


Figure 7-5.—Reinforcing steel for a floor slab.

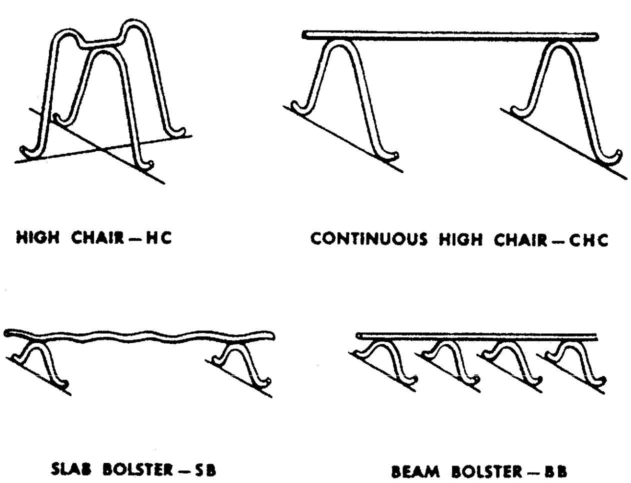


Figure 7-6.—Devices used to support horizontal reinforcing bars.

Concrete slab reinforcements (fig. 7-5) are supported by reinforcing steel in configurations called slab bolster and high chair. Concrete blocks made of sand-cement mortar can be used in place of the slab bolster. The height of the slab bolster is determined by the concrete protective cover required. If the concrete surface is to be in contact with the ground or exposed to the weather after removal of the forms, the protective covering of concrete over the steel should be 2 in. Other devices used to support horizontal reinforcing bars are shown in figures 7-6, 7-7, and 7-8. Wood blocks should be

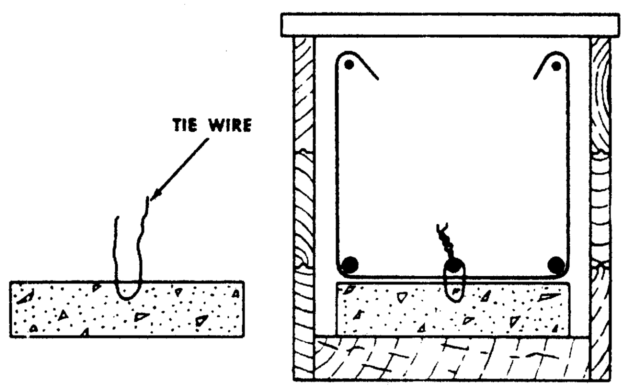


Figure 7-7.—Precast concrete block used for reinforcing steel support.

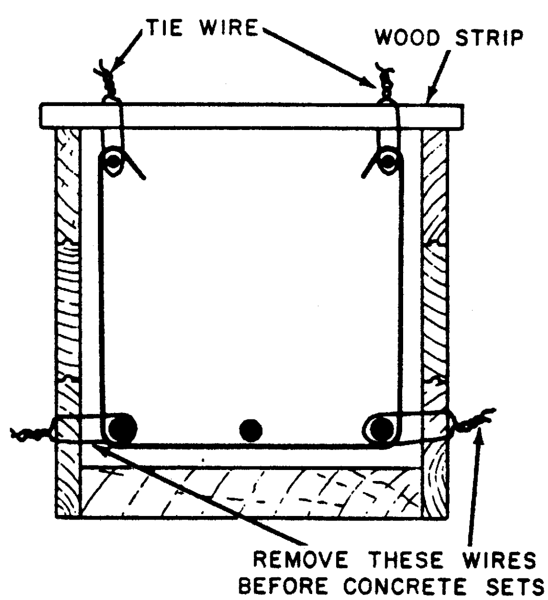


Figure 7-8.—Beam-reinforcing steel hung in place.

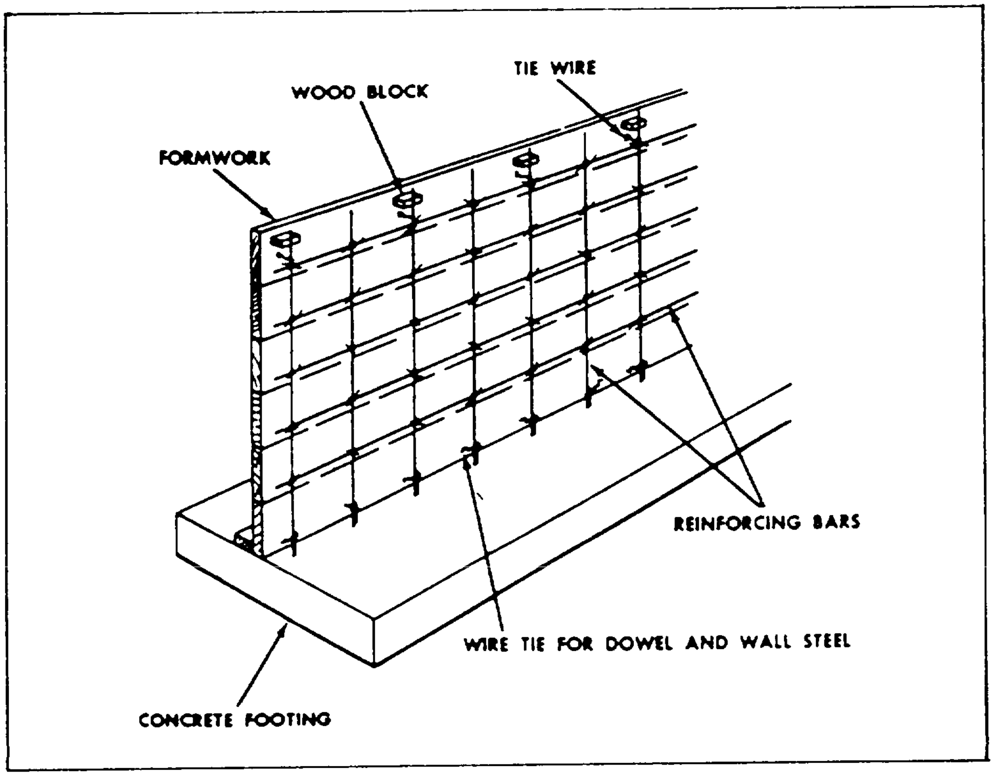


Figure 7-9.-Steel in place in a wall.

substituted for the metal supports only if there is no possibility of the concrete becoming wet or if the construction is known to be temporary.

WALL REINFORCEMENT.— Placement of steel reinforcement in load-bearing walls is the same as for columns except that the steel is erected in place and not preassembled. Horizontal steel is tied to vertical steel at least three times in any bar length. The wood block is removed when the form has been filled up to the level of the block, as shown in figure 7-9.

Reinforcing Steel

Steel is the best material for reinforcing concrete because the coefficients of expansion of the steel and the concrete are considered almost the same; that is, at a normal temperature, they will expand and contract at an almost equal rate. (At very high temperatures, steel will expand more rapidly than the concrete, and the two materials will separate.)

Steel also works well as a reinforcement for concrete because it makes a good bond with the concrete. This bond strength is proportional to the contact area surface of the steel to the concrete. In other words, the greater the surface of steel exposed to the adherence of the concrete, the stronger the bond. A deformed reinforcing bar

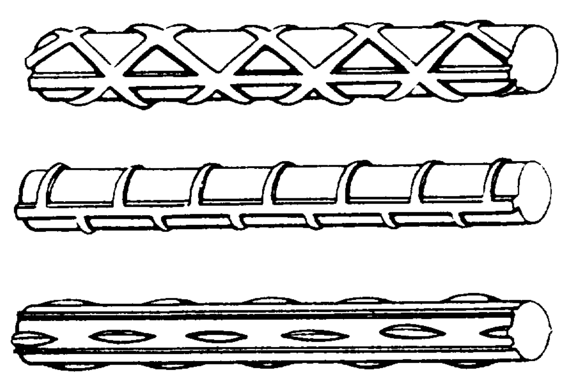


Figure 7- 10.-Types of deformed reinforcing bars.

is better than a plain round or square one. In fact, when plain bars of a given diameter are used instead of deformed bars, approximately 40 percent more plain bars must be used.

The adherence of the concrete depends on the roughness of the steel surface: the rougher the steel, the better the adherence. Thus, steel with alight, firm layer of rust is superior to clean steel, but steel with loose or scaly rust is inferior. Loose or scaly rust may be removed from the steel by rubbing the steel with burlap.

The requirements for reinforcing steel are that it be strong in tension and, at the same time, ductile enough to be shaped or bent cold.

Reinforcing steel may be used in the form of bars or rods that are either PLAIN or DEFORMED or in the form of expanded metal, wire, wire fabric, or sheet metal. Each type is useful for a different purpose, and engineers design structures with these purposes in mind.

Plain reinforcing bars are usually round in cross section. They are used as main tension reinforcement for concrete structures. They are the least used of the rod type of reinforcement because they offer only smooth, even surfaces for the adherence of concrete. Reinforcing bars or rods are commonly referred to as rebars.

Deformed bars are like the plain bars except that they have either indentations in them or ridges on them, or both, in a regular pattern. The twisted bar, for example, is made by twisting a plain square bar cold. The spiral ridges along the surface of the deformed bar increase its bond strength with concrete. Other forms used are the round- and square-corrugate d bars. These bars are formed with projections around the surface that extend into the surrounding concrete and prevent slippage. Another type is formed with longitudinal fins projecting from the surface to prevent twisting. Figure 7-10 shows a few of the various types of deformed bars available. In the United States, deformed bars are used almost exclusively, while in Europe, both deformed and plain bars are used.

There are 11 standard sizes of reinforcing bars. Table 7-1 lists the bar numbers, weight, and nominal diameters of the 11 standard sizes. Bars No. 3 through No. 18, inclusive, are deformed bars. Remember that bar numbers are based on the nearest number of 1/8 in. (3. 175 mm) included in the nominal diameter of the bar. To measure rebar, you must measure across the roundsquare portion where there is no deformation.

Table 7-1.-Standard Reinforcing Bars

BAR NUMBERS	WEIGHT	NOMINAL DIAMETER	
	POUNDS PER FOOT	INCHES	MILLI-METERS
#3	0.376	0.375	9.5
#4	0.668	0.500	12.7
#5	1.043	0.625	15.8
#6	1.502	0.750	19.0
#7	2.044	0.875	22.2
#8	2.670	1.000	25.4
#9	3.400	1.128	28.5
#10	4.303	1.270	31.7
#11	5.313	1.410	35.9
#14	7.650	1.693	43.0
#18	13.600	2.257	57.3

05NP0001

The raised portion of the deformation is not considered in measuring the rebar diameter.

BENDS.— Frequently, it is required that reinforcing bars be bent into various shapes. There are several reasons for this. First, let us go back to the reason for using reinforcing steel in concrete—to increase the tensile and compressive strength of concrete. You might compare the hidden action within abeam from live and dead loads to breaking a stick over your knee. You have seen how the splinters next to your knee push toward the middle of the stick when you apply force, while the splinters from the middle to the opposite side pull away from the middle. This is similar to what happens inside the beam.

For instance, take a simple beam (a beam resting freely on two supports near its ends). The dead load (weight of the beam) causes the beam to bend or sag. Now, from the center of the beam to the bottom, the forces tend to stretch or lengthen the bottom portion of the beam. This part is said to be in tension, and that is where the steel reinforcing bars are needed. As a result of the combination of the concrete and steel, the tensile strength in the beam resists the force of the load and keeps the beam from breaking apart. At the exact center of the beam, between the compressive stress and the tensile stress, there is no stress at all—it is neutral.

In the case of a continuous beam, it is a little different. The top of the beam may be in compression along part of its length and in tension along another part. This is because a continuous beam rests on more than two supports. Thus, the bending of the beam is NOT all in one direction but is reversed as it goes over intermediate supports.

To help the concrete resist these stresses, engineers design the bends of reinforcing steel so that the steel will set into the concrete just where the tensile stresses take place. That is why some reinforcing rods are bent in almost a zigzag pattern. The joining of each bar with the next, the anchoring of the bar ends with concrete, and the anchoring by overlapping two bar ends together are some of the important ways to increase and keep bond strength. Some of the bends you will encounter are shown in figure 7-11.

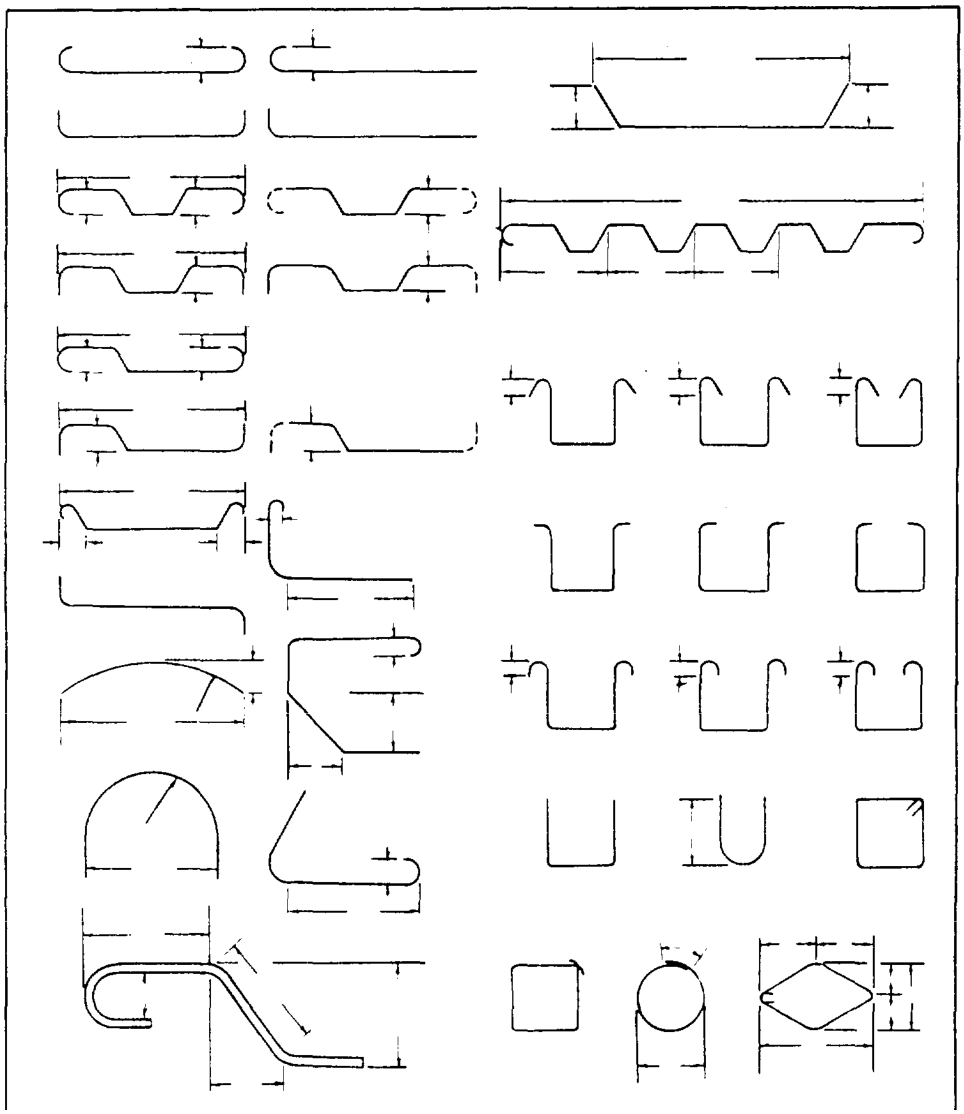
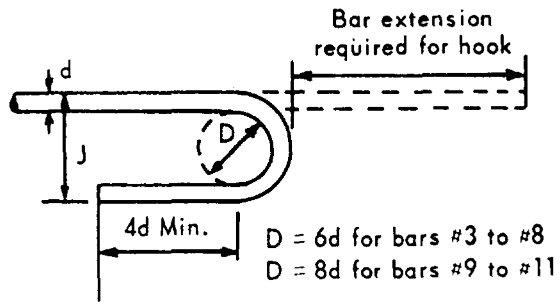


Figure 7-11.-Typical reinforcement bar bends.

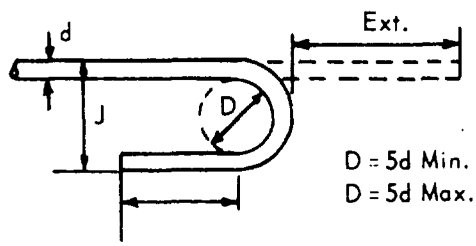
When reinforcing bars are bent, caution must be exercised to ensure the bends are not too sharp. If too sharp a bend is put into the bars, they may crack or be weakened. Therefore, certain minimum bend diameters have been established for the different bar sizes and for the various types of hooks. These bending details are shown in figure 7-12. There are many different types of bends, depending on where the rods are to be placed. For example, there are bends on heavy

Recommended sizes - 180° hook



Bar size d	Bar exten.	J
#2	4	2
3	5	3
4	6	4
5	7	5
6	8	6
7	10	7
8	11	8
9	1-3	11¼
10	1-5	1-0¾
11	1-7	1-2¼

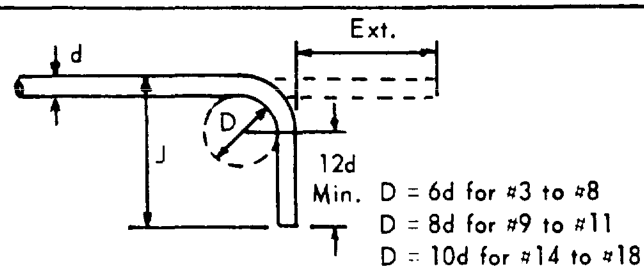
Minimum sizes - 180° hook



Note: Minimum size hooks to be used only for special conditions.

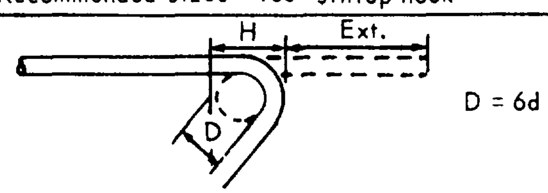
Bar size d	Bar exten.	J
#2	4	1¾
3	5	2¾
4	5	3½
5	6	4¼
6	7	5¼
7	9	6
8	10	7
9	11	8
10	13	9
11	14	10

Recommended minimum sizes - 90° hook



Bar size d	Bar exten.
# 2	3½
3	6
4	8
5	10
6	1-0
7	1-2
8	1-4
9	1-7
10	1-10
11	2-0

Recommended sizes - 135° stirrup hook



Bar size d	Bar exten.
# 2	3½
3	4
4	4½
5	5½

Note: Stirrup hooks may be bent to the diameter of the supporting bars.

Figure 7-12.-Standard hook details.

beam and girder bars, bends for reinforcement of vertical columns at or near floor levels, stirrup and column ties, slab reinforcement, and bars or wire for column spiral reinforcement.

SPLICES.— Where splices in reinforcing steel are not dimensioned on the drawings, the bars should be lapped not less than 30 times the bar diameter, nor less than 12 in. The stress in a tension bar can be transmitted through the concrete and into another adjoining bar by a lap splice of proper length. The "lap" is expressed as the number of bar diameters. If using the No. 2 bar, make the lap at least 12 in.

EXPANDED METAL AND WELDED WIRE FABRIC.— Expanded metal or wire mesh is also used for reinforcing concrete. Expanded metal is made by partly shearing a sheet of steel, as shown in figure 7-13, view A. The sheet steel has been sheared in parallel lines and then pulled out or expanded to form a diamond shape between each parallel cut. Another type is square rather than diamond shaped, as shown in figure 7-13, view B. Expanded metal is frequently used during plastering operations.

Welded wire fabric is available both in rolls (fig. 7-14) for light building construction and sheets for highways and use in buildings when roll sizes will not give ample reinforcement. Wire fabric is furnished in both square and rectangular patterns, welded at each intersection. The rectangular sizes range from 2 by 4 in. to 6 by 12 in. The square patterns are available in 2 by 2 in., 3 by 3 in., 4 by 4 in., and 6 by 6 in. Both are furnished in a wide variety of wire gauges. The square pattern has the same gauge in both directions, while the rectangular type may have the same gauge in both directions or the larger gauge running longitudinally. Specifications and designs are usually used when wire fabric (mesh) is being lapped; however, a minimum of 2 in. between laps is usually sufficient.

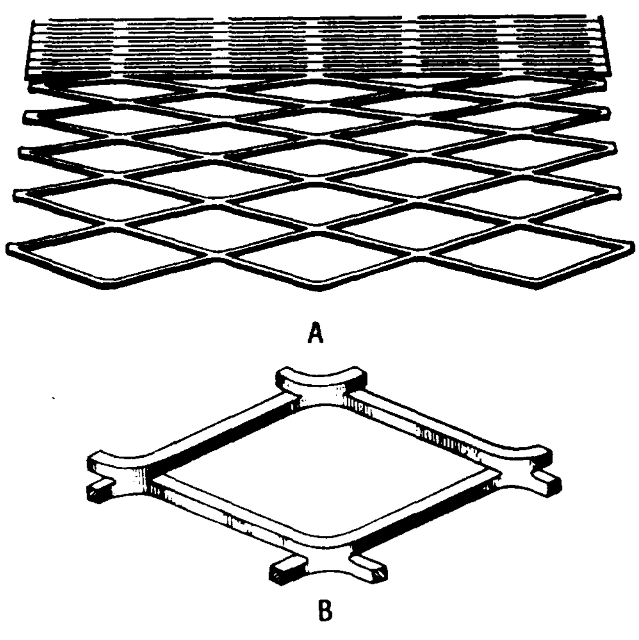


Figure 7-13.-Expanded or diamond mesh steel reinforcement.

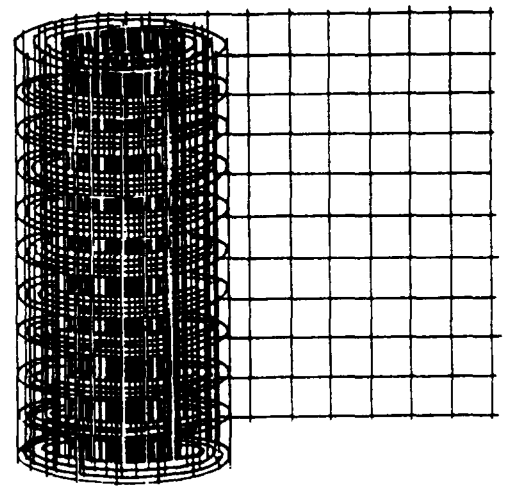


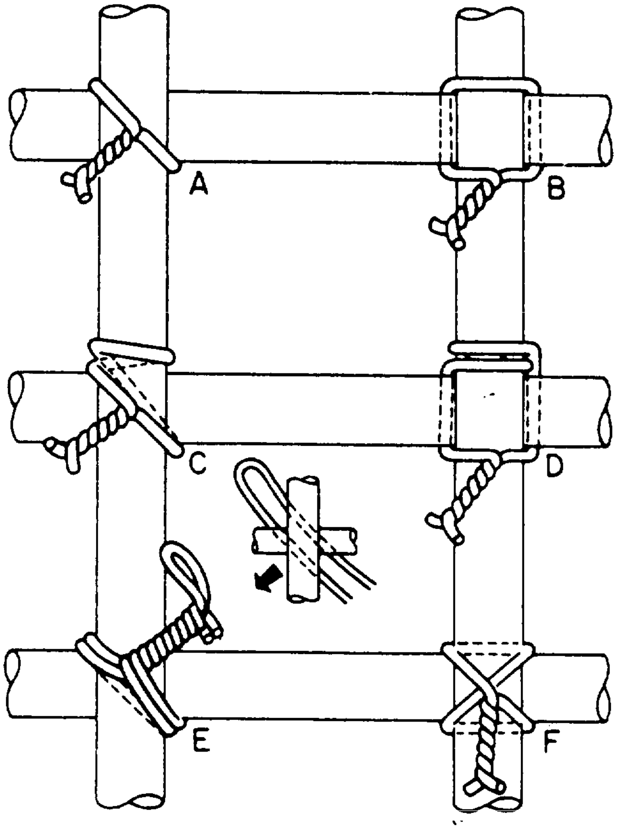
Figure 7-14.-Welded wire fabric.

Reinforcing bars can be joined together by different types of ties. Figure 7-15 shows six types used by the SEABEEs.

PRECAST CONCRETE

Precasting is the fabrication of a structural member at a place other than its final position of use. It can be done anywhere, although this procedure is best adapted to a factory or yard. Jobsite precasting is not uncommon for large projects. Precast concrete can be produced in several different shapes and sizes, including piles, girders, and roof members. Prestressed concrete is especially well adapted to precasting techniques.

Generally, structural members including standard highway girders, poles, electric poles, masts, and building members are precast by factory methods unless the difficulty or



A. Snap or simple tie.
B. Saddle tie.
C. Wall tie.
D. Saddle tie with twist.
E. Double-strand single-tie.
F. Cross tie.

Figure 7-15.-Types of ties.

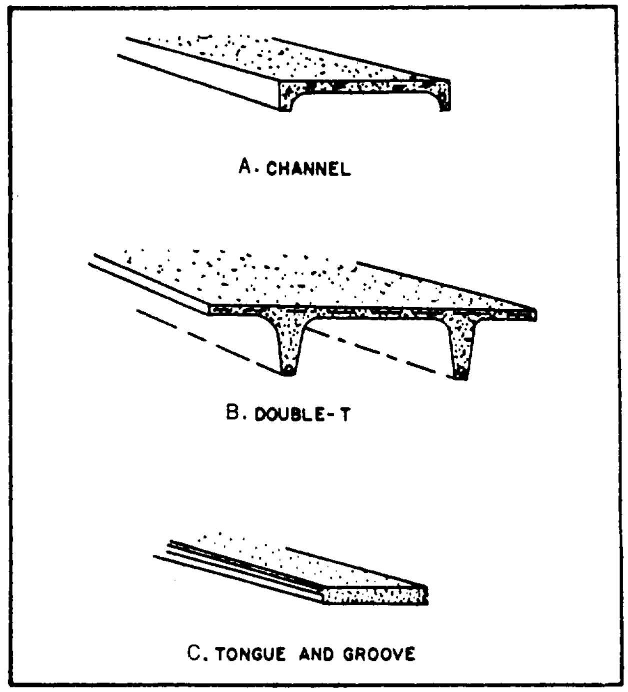


Figure 7-16.-Typical precast panels.

impracticability of transportation makes jobsite casting more desirable. On the other hand, concrete that is cast in the position that it is to occupy in the finished structure is called cast-in-place concrete.

Precast Concrete Floors, Roof Slabs, Walls, and Partitions

The most commonly used precast slabs or panels for FLOOR and ROOF DECKS are the channel and double-T types (fig. 7-16, views A and B).

The channel slabs vary in size with a depth ranging from 9 to 12 in., width 2 to 5 ft, and a thickness of 1 to 2 in. They have been used in spans up to 50 ft. If desired or needed, the legs of the channels may be extended across the ends and, if used in combination with the top slabs. may be stiffened with occasional cross ribs. Wire mesh may be used in the top slabs for reinforcement. The longitudinal grooves located along the top of the channel legs may be grouted to form keys between adjacent slabs.

The double-T slabs vary in size from 4 to 6 ft in width and 9 to 16 ft in depth. They have been used in spans as long as 50 ft. When the top-slab size ranges from 1 1/2 to 2 in. in thickness, it should be reinforced with wire mesh.

The tongue-and-groove panel (fig. 7-16, view C) could vary extensively in size, according to the design requirement. They are placed in position much like tongue-and-groove lumber; that is, the tongue of one panel is placed inside the groove of an adjacent panel. They are often used as decking panels in large pier construction.

Matching plates are ordinarily welded and used to connect the supporting members to the floor and roof slabs.

Panels precast in a horizontal position, in a casting yard, or on the floor of the building, are ordinarily used in the makeup of bearing and nonbearing WALLS and PARTITIONS. These panels are placed in their vertical positions by cranes or by the tilt-up procedure, as shown in figures 7-17 and 7-18.

Usually, these panels are solid, reinforced slabs, 5 to 8 in. in thickness, with the length varying according to the distances between columns or other supporting members. When windows and door openings are cast in the slabs, extra reinforcements should be installed around the openings.

A concrete floor slab with a smooth, regular surface can be used as a "casting surface." When this smooth surface is used for casting, it should be covered with some form of liquid or sheet material to prevent bonding between the surface and the wall panel. The upper surface of the panel may be finished as regular concrete is finished by troweling, floating, or brooming.

SANDWICH PANELS are panels that consist of two thin, dense, reinforced concrete-face slabs separated by a core of insulating material, such as lightweight concrete, cellular glass, plastic foam, or some rigid insulating material.

These panels are sometimes used for exterior walls to provide additional heat insulation. The thickness of the sandwich panels varies from 5 to 8 in., and the face slabs are tied together with wire, small rods, or in some other manner. Welded or bolted matching plates are also used to connect the wall panels to the building frame, top and bottom. Caulking on the outside and grouting on the inside should be used to make the points between the wall panels watertight.

Precast Concrete Joists, Beams, Girders, and Columns

Small, closely spaced beams used in floor construction are usually called JOISTS; however, these same beams when used in roof construction

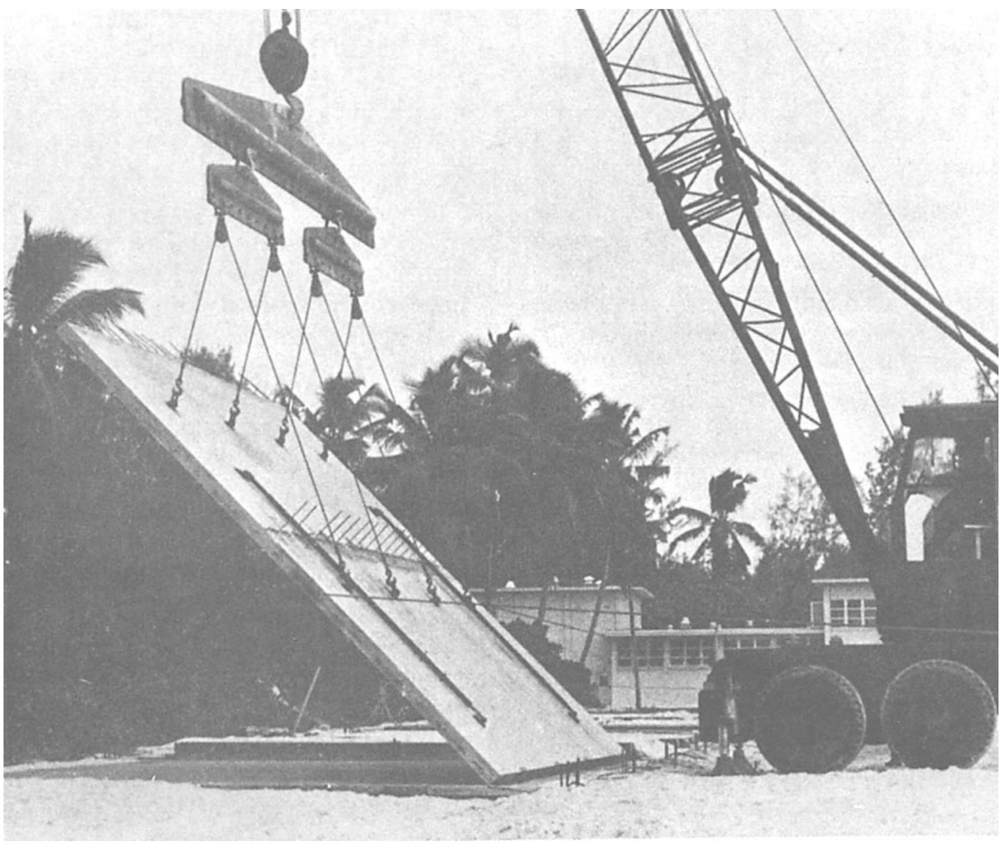


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Figure 7-17.-Precast panels being erected by use of crane and spreader bars.

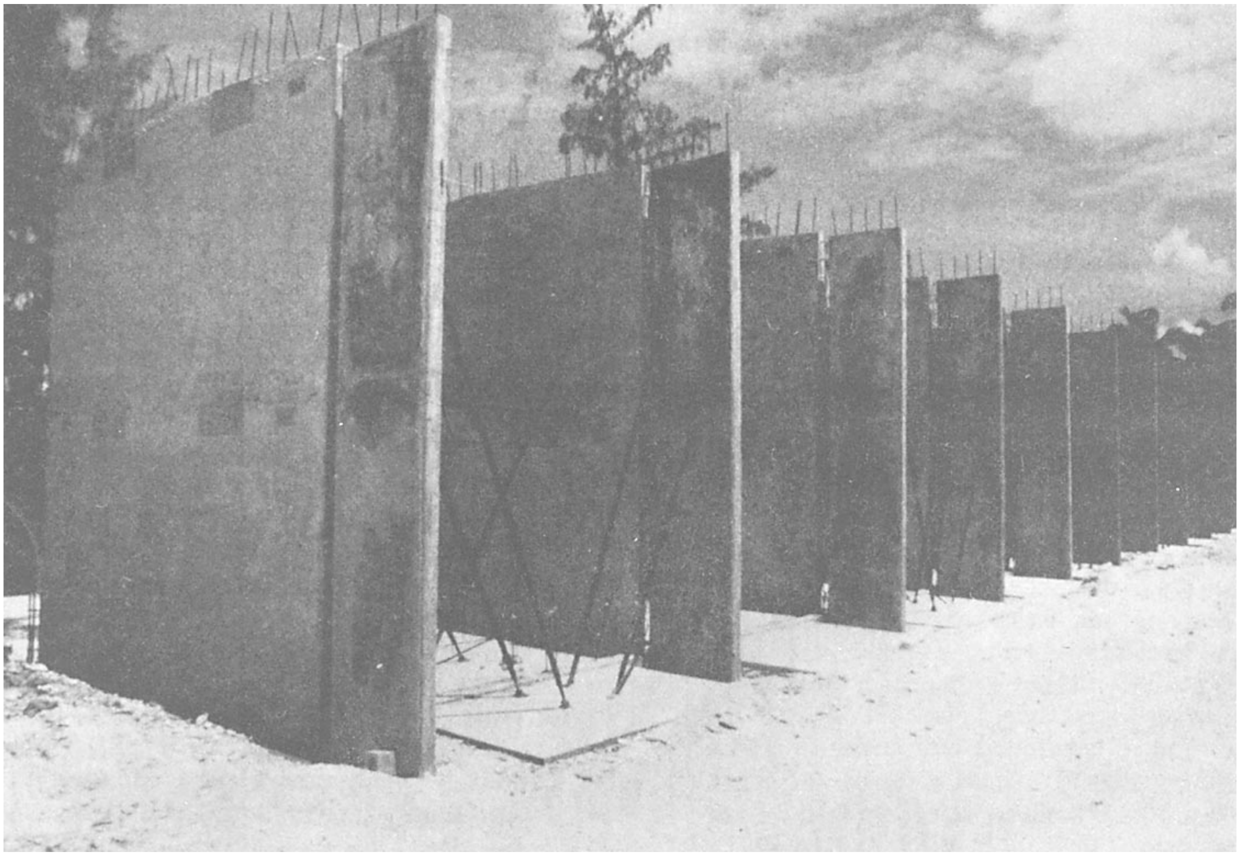

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Figure 7-18.-Precast panels in position.

are called PURLINS. The cross sections of these beams are shaped like a T or an I. The ones with the inverted T-sections are usually used in composite construction where they support cast-in- place floor or roof slabs.

BEAMS and GIRDERS are terms usually applied to the same members, but the one with the longer span should be referred to as the girder. Beams and girders may be conventional precast design or prestressed. Most of the beams will be I-shaped unless the ends are rectangular. The T-shaped ones can also be used.

Precast concrete COLUMNS may be solid or hollow. If the hollow type is desired, heavy card-board tubing should be used to form the core. A looped rod is cast in the column footing and projects upward into the hollow core to help hold the column upright. An opening should be left in the side of the column so that the column core can be filled with grout. This causes the looped rod to become embedded to form an anchor. The opening is dry packed.

Advantages of Precast Concrete

Precast concrete has the greatest advantage when identical members are to be cast because the same forms can be used several times. Some other advantages are listed below.

Control of the quality of concrete.

Smoother surfaces, and plastering is not necessary.

Less storage space is needed.

Concrete member can be cast under all weather conditions.

Better protection for curing.

Weather conditions do not affect erection.

Faster erection time.

PRESTRESSED CONCRETE

A prestressed concrete unit is one in which engineered stresses have been placed before it has been subjected to a load. When PRETENSIONING is used, the reinforcement (high-tensile-strength steel strands) is stretched through the form between the two end abutments or anchors. A predetermined amount of stress is applied to the steel strands. The concrete is then poured, encasing the reinforcement. As the concrete sets, it bonds to the pretensioned steel. When it has reached a specified strength, the tension on the reinforcement is released. This prestresses the concrete, putting it under compression, thus creating a built-in tensile strength.

POST-TENSIONING involves a precast member that contains normal reinforcing in addition to a number of channels through which the prestressing cables or rods maybe passed. The channels are usually formed by suspending inflated tubes through the form and casting the concrete around them. When the concrete has set, the tubes are deflated and removed. Once the concrete has reached a specified strength, prestressing steel strands or TENDONS are pulled into the channels and secured at one end. They are then stressed from the opposite end with a portable hydraulic jack and anchored by one of several automatic gripping devices.

Post-tensioning may be done where the member is poured or at the jobsite. Each member may be tensioned, or two or more members may be tensioned together after erection. In general, post-tensioning is used if the unit is over 45 ft long or over 7 tons in weight. However, some types of pretensioned roof slabs will be considerably longer and heavier than this.

When a beam is prestressed, either by pretensioning or post-tensioning, the tensioned steel produces a high compression in the lower part of the beam. This compression creates an upward bow or camber in the beam (fig. 7-19). When a load is placed on the beam, the camber is forced out, creating a level beam with no deflection.

Those members that are relatively small or that can be readily precast are normally pretensioned. These include precast roof slabs, T-slabs, floor slabs, and roof joists.

SPECIAL TYPES OF CONCRETE

Special types of concrete are essentially those with unique physical properties or those produced with unusual techniques and/or reproduction processes. Many special types of concrete are made with portland cement as a binding medium; some use binders other than portland cement.

Lightweight Concrete

Conventional concrete weighs approximately 150 lb per cubic foot. Lightweight concrete weighs 20 to 130 lb per cubic foot, depending on its intended use. Lightweight concrete can be made by using either gas-generating chemicals or

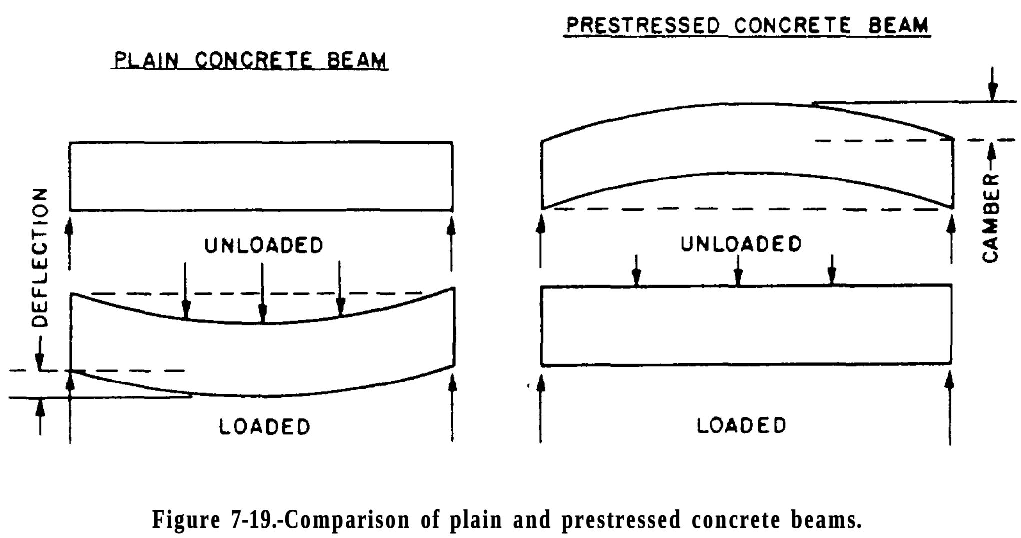


Figure 7-19.-Comparison of plain and prestressed concrete beams.

lightweight aggregates, such as expanded shale, clay, or slag. Concrete containing aggregates like perlite or vermiculite is very light in weight and is primarily used as insulating material. Lightweight concrete is usually classified according to its weight per cubic foot.

Semi-lightweight concrete has a unit weight of 115 to 130 lb per cubic foot and an ultimate compressive strength comparable to normal concrete. Sand of normal weight is substituted partially or completely for the lightweight fine aggregate.

Insulating lightweight concrete has a unit weight ranging from 20 to 70 lb per cubic foot, and its compressive strength seldom exceeds 1,000 psi. This type of concrete is generally used for insulating applications, such as fireproofing.

Structural lightweight concrete has a unit weight up to 115 lb per cubic foot and a 28-day compressive strength in excess of 2,000 psi. This type is used primarily to reduce the dead-load weight in concrete structural members, such as floors, walls, and the roof section in high-rise structures.

Heavyweight Concrete

Heavyweight concrete is produced with special heavy aggregates and has a density of up to 400 lb per cubic foot. This type is used principally for radiation shielding, for counterweights, and for other applications where higher density is desired. Except for density, the physical properties of heavyweight concrete are similar to those of normal- or conventional-weight concrete.

TILT-UP CONSTRUCTION

Tilt-up concrete construction is a special form of precast concrete building. This method consists basically of jobsite prefabrication, in which the walls are cast in a horizontal position, tilted to a vertical position, and then secured in place. Tilt-up construction is best suited for large one-story buildings, but it can be used in multistory structures. Usually, multistory structures are built by setting the walls for the first story, placing the floor above, then repeating the procedure for each succeeding floor. An alternate method is to cast two- to four-story panels.

The wall panels are usually cast on the floor slab of the structure. Care must be exercised to ensure the floor slab is smooth and level and that all openings for pipes and other utilities are temporarily plugged. The casting surface is treated with a good bond-breaking agent to ensure the panel does not adhere when it is lifted.

Reinforcement of Tilt-Up Panels

The steel in a tilt-up panel is set in the same manner as it is in a floor slab. Mats of reinforcement are placed on chairs and tied as needed. Reinforcement should be as near the center of the panel as possible. Reinforcing bars are run through the side forms of the panel. When welded wire fabric or expanded wire mesh is used, dowel bars are used to tie the panels and their vertical supports together. Additional reinforcement is generally needed around openings.

The panel is picked up or tilted by the use of PICKUP INSERTS. These inserts are tied into the reinforcement. As the panel is raised into its vertical position, the maximum stress will occur; therefore, the location and number of pickup inserts is extremely important. Some engineering manuals provide information on inserts, their locations, and capacities.

Tilt-Up Panel Foundations

An economical and widely used method to support tilt-up panels is a simple pad footing. The floor slab, which is constructed first, is NOT poured to the perimeter of the building to permit excavating and pouring the footings. After the panel is placed on the footing, the floor slab is completed. It may be connected directly to the outside wall panel, or a trench may be left to run mechanical, electrical, or plumbing lines.

Another method that is commonly used, as an alternative, is to set the panels on a grade beam or foundation wall at floor level. Regardless of the type of footing, the panel should be set into a mortar bed to ensure a good bond between the foundation wall and the panel.

Panel Connections

The panels may be tied together in a variety of ways. The location and use of the structure will dictate what method can or can NOT be used. The strongest method is a cast-in-place column with the panel-reinforcing steel tied into the column. However, this does NOT allow for expansion and contraction. It may be preferable to tie only the corner panels to the columns and allow the remaining panels to move.

A variety of other methods of connecting the panels are also used. A BUTTED connection, using grout or a gasket, can be used if the wall does NOT contribute any structural strength to the structure. Steel columns are welded to steel angles or plates secured in the wall panel. Precast columns can also be used. Steel angles or plates are secured in both the columns and plate and welded together to secure the panel.

When panel connections that do not actually hold the panels in place are used, the panels are generally welded to the foundation and to the roof by using steel angles or plates. All connections must provide waterproof joints. This is accomplished by the use of expansion joint material.

Finishes

Tilt-up panels may be finished in a variety of ways similar to any other concrete floor or wall. Some finishes may require the panel to be poured face up; others will require face-down pouring. This may affect the manner in which the panels are raised and set.

CONCRETE CONSTRUCTION JOINTS AND CONNECTIONS

Construction joints are divisions between concrete work done at intervals spaced widely enough to allow partial hardening. They are used between the units of structure and placed where they will cause the minimum amount of weakness to the structure. It is safe to assume that construction joints are located where the shearing stresses and bending moments are relatively small or where the joints will be supported by other structural members. For horizontal work, such as floor slabs, construction joints should be in a vertical plane; whereas, for vertical work, such as columns, the joints should lie in a horizontal plane (fig. 7-20).

Foundation walls are bonded to footings with vertical reinforcing steel called “dowels, ” which are placed in footings and extend about 3 to 4 ft up into the wall. A wedge-shaped through, called a keyway, is built into the footing to strengthen the bond between footings and walls (fig. 7-21).

Contraction Joints

The purpose of contraction joints is to control cracking caused by temperature changes

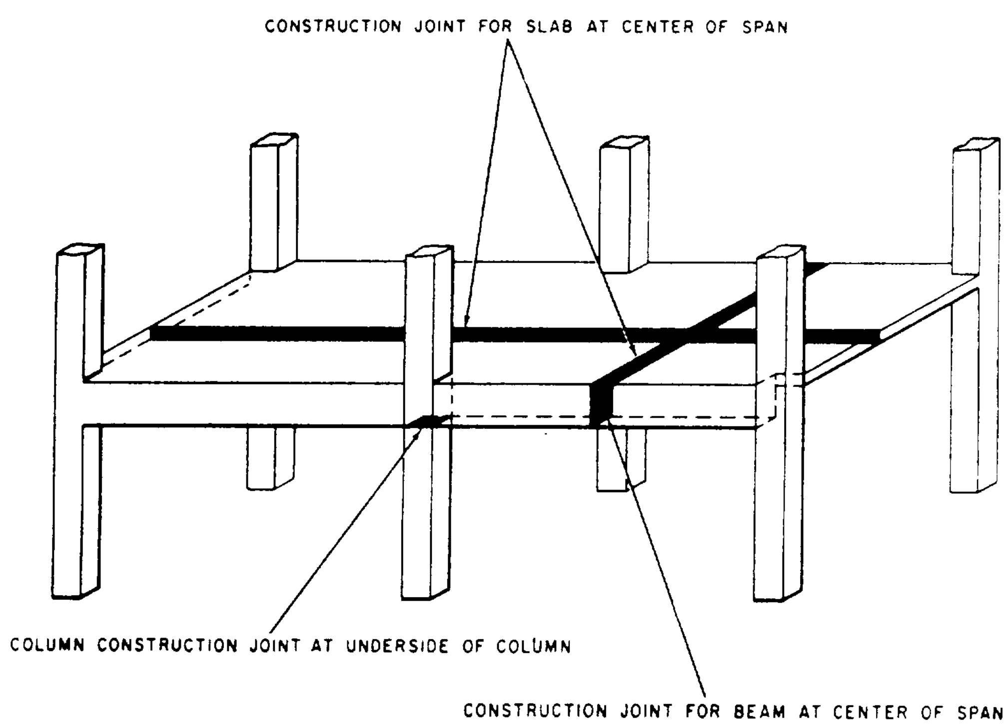


Figure 7-20-Location of construction joints in beams, columns, and floor slabs.

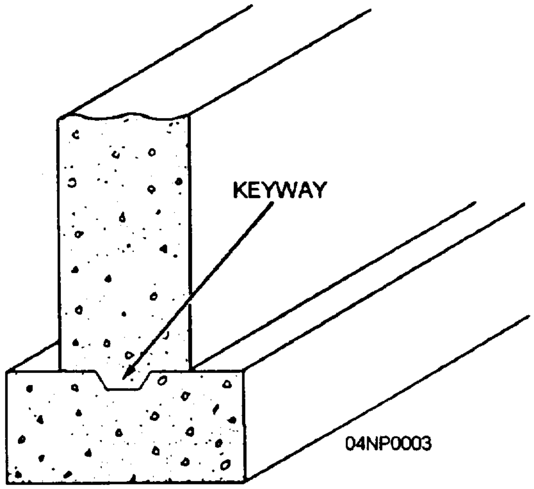


Figure 7-22.-Use of a contraction Joint.

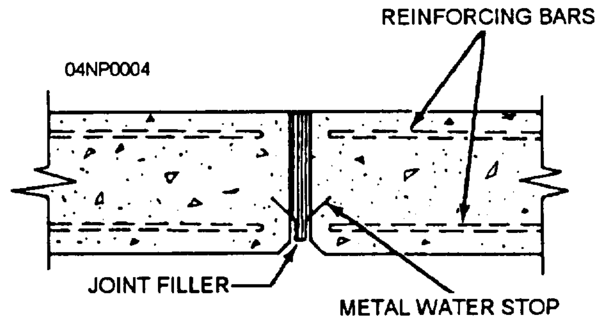


Figure 7-23.-Expansion joint for a wall.

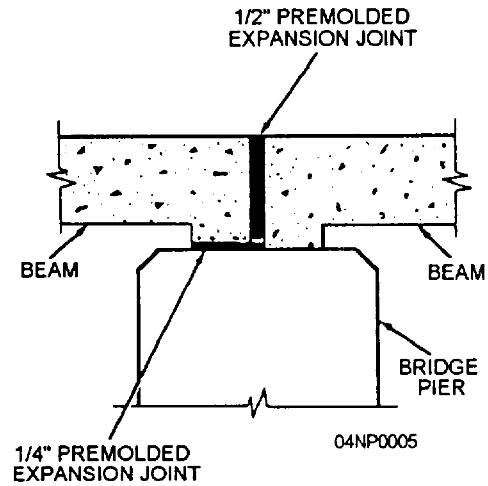


Figure 7-24.-Expansion joint for a bridge.

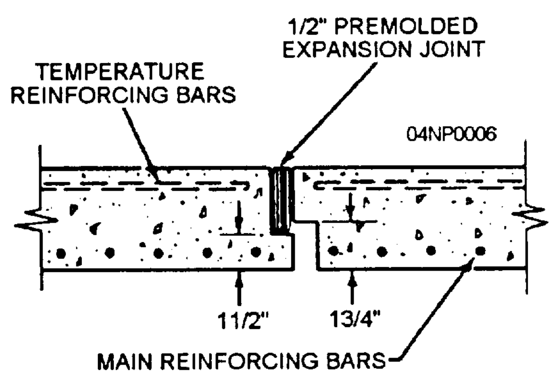


Figure 7-25.-Expansion joint for a floor slab.

incident to shrinkage of the concrete. A typical dummy contraction joint (fig. 7-22) is usually formed by cutting a depth of one third to one fourth the thickness of the section. Some contracting joints are made with no filler or with a thin coat of paraffii or asphalt and/or other materials to break the bond. Depending on the extent of local temperature, joints in reinforced concrete slabs may be placed at 15-to 25-ft intervals in each direction.

Expansion Joints

Wherever expansion might cause a concrete slab to buckle because of temperature change, expansion joints (also called isolation joints) are required. An expansion joint is used with a pre-molded cork or mastic filler to separate sections from each other, thus allowing room for expansion if elongation or closing of the joint is anticipated. Figures 7-23, 7-24, and 7-25 show expansion joints for a variety of locations. Expansion joints may be installed every 20 ft.

CONCRETE FORMS

Most structural concrete is made by placing (also called CASTING) plastic concrete into

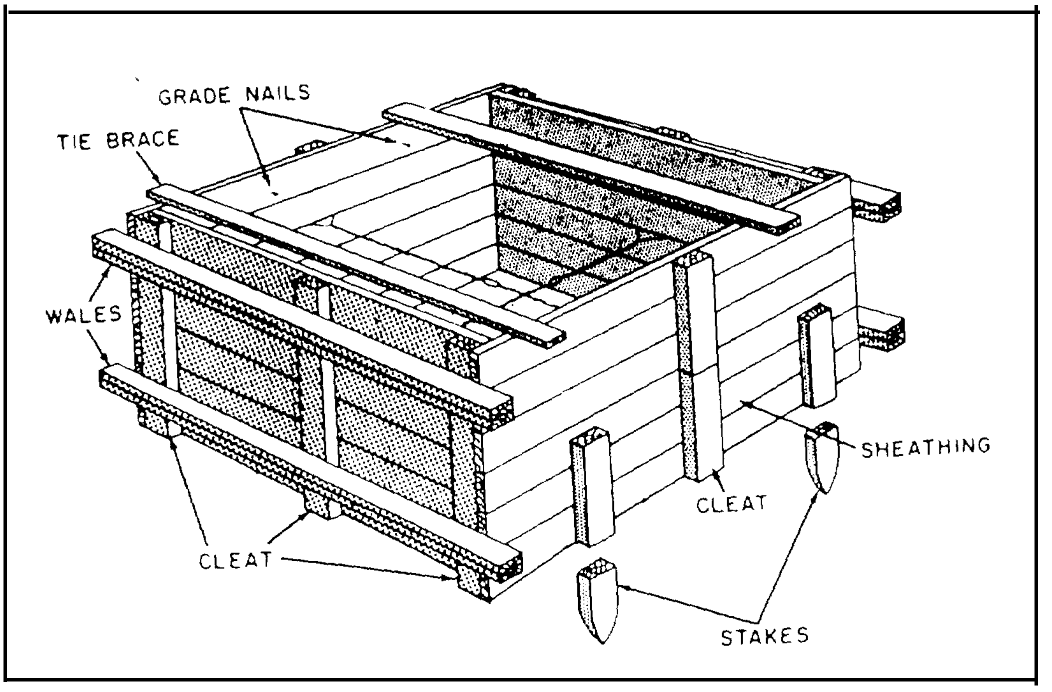


Figure 7-26. Typical large footing form.

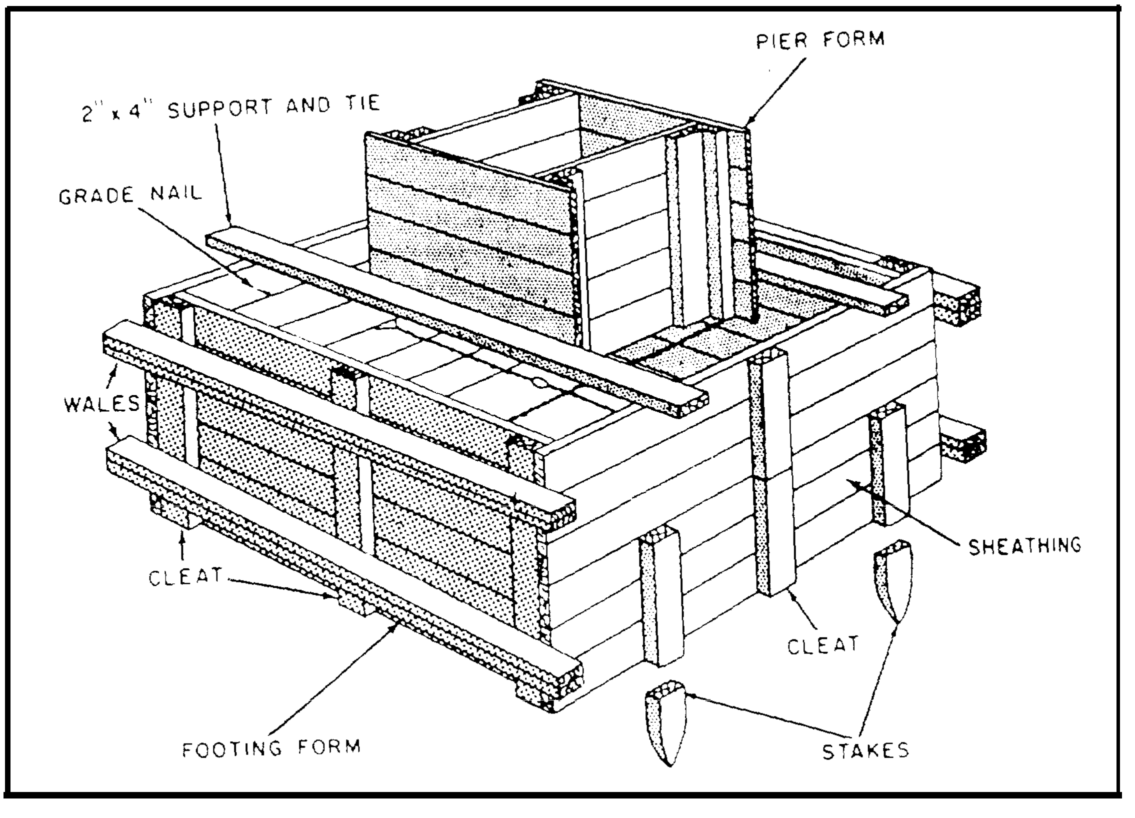


Figure 7-27.-Typical footing and pier form.

spaces enclosed by previously constructed FORMS. These forms are usually removed once the plastic concrete hardens into the shape outlined by the forms.

Forms for concrete structures must be tight, rigid, and strong. If the forms are NOT tight, loss of water and paste may cause sand streaking as well as weakness to the concrete. The forms must be strong enough to resist the high pressure exerted by the concrete.

Form Materials

Undisturbed soil or clay, if sufficiently rigid and excavated to proper dimensions, maybe used as EARTH FORMS. Design, specifications, and construction methods, however, dictate what kind of form materials are to be used on certain structures. Wood, plywood, steel, fiber glass, and other approved materials are commonly used as form materials. Forms for concrete pavement and curves should be metal; surfaces exposed to view in the finished structure and those requiring special finishes should be wood, plywood, or other approved material.

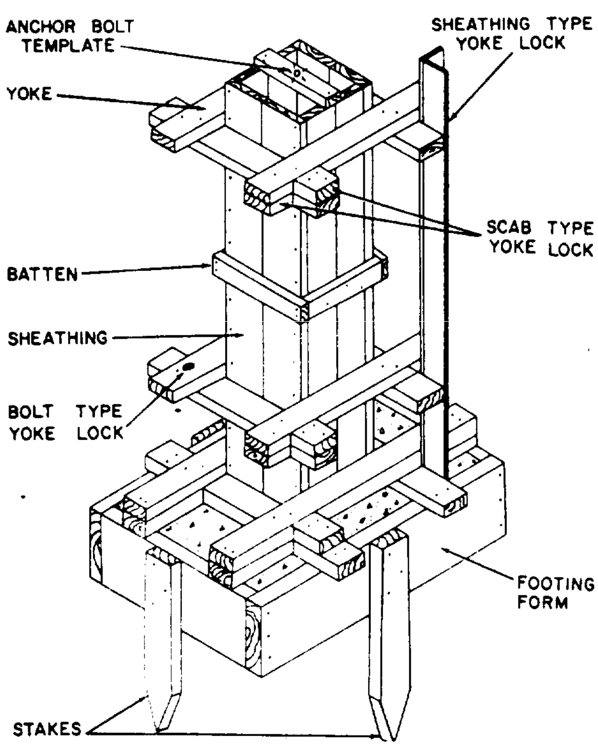


Figure 7-28.-Form for concrete column.

Foundation Forms

Foundation forms may include forms or parts of forms for column footings, pier footings, and wall footings. Whenever possible, the earth should be excavated and the hole used to contain the foundation of footing forms. In most cases, FOOTINGS are cast directly against the earth, and only the sides are molded in forms. In some cases where there is a firm natural earth surface that is capable of supporting and molding the concrete, parts of forms are often omitted. Figure 7-26 shows a typical large footing form. Figures 7-27 and 7-28 show typical footing forms for a concrete pier and a concrete column, respectively.

Wall Forms

Wall forms are made up of five basic parts. They are as follows: (1) sheathing, to shape and retain the concrete until it sets; (2) studs, to form a framework and support the sheathing; (3) wales, to keep the form aligned and support the studs; (4) braces, to hold the forms erect under lateral pressure; and (5) ties and spreaders or tie-spreader units, to hold the sides of the forms at the correct spacing (fig. 7-29).

Wall forms may be built in place or prefabricated, depending on the shape and the desirability for reuse.

Wall forms are usually reinforced against displacement by the use of TIES. Two types of

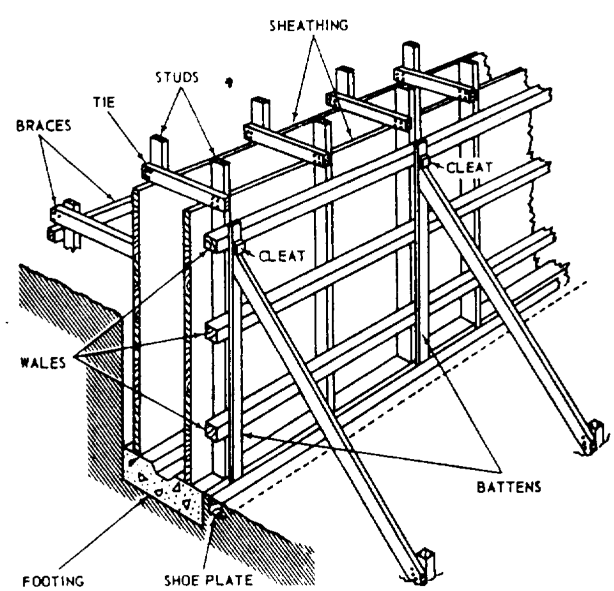


Figure 7-29.-Parts of a typical wall form.

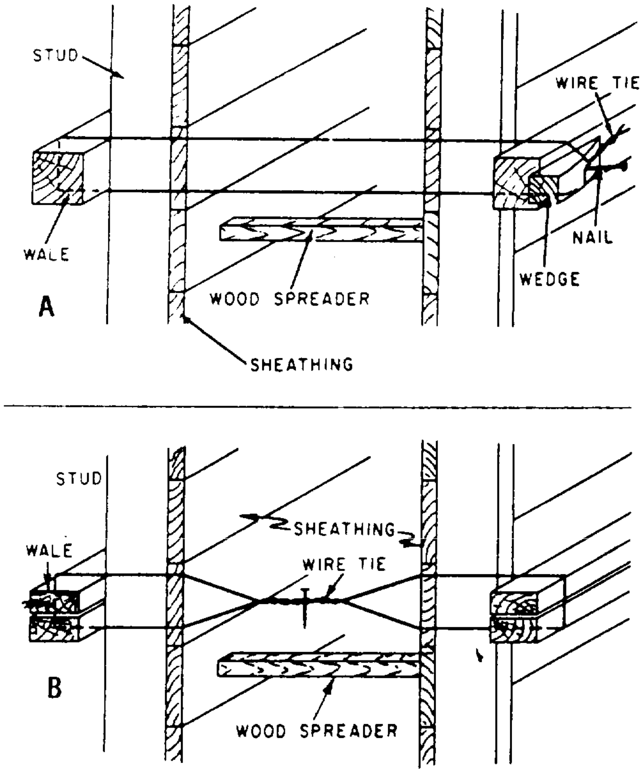


Figure 7-30.-Wire ties for wall forms.

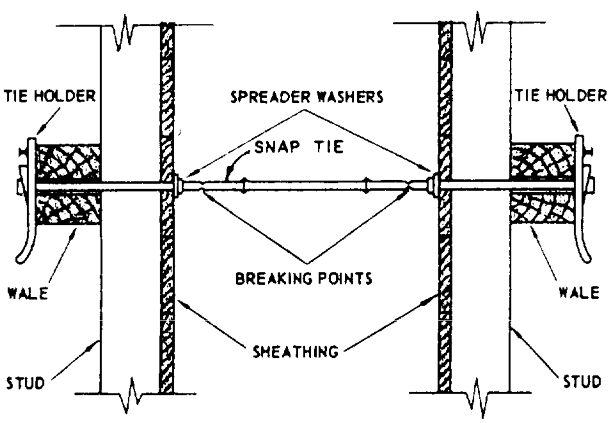


Figure 7-31.-Snap tie.

simple wire ties, used with wood SPREADERS, are shown in figure 7-30. The wire is passed around the studs and wales and through small holes bored in the sheathing. The spreader is placed as close as possible to the studs, and the tie is set taut by the wedge shown in the upper view or by twisting with a small toggle, as shown in the lower view. When the concrete reaches the level of the spreader, the spreader is knocked out and removed. The parts of the wire that are inside the forms remain in the concrete; the outside surplus is cut off after the forms are removed.

Wire ties and wooden spreaders have been largely replaced by various manufactured devices that combine the functions of the tie and spreader. Figure 7-31 shows one of these, called a SNAP TIE. These ties are made in various sizes to fit various wall thicknesses. The tie holders can be removed from the tie rod. The rod goes through small holes bored in the sheathing and also through the wales, which are usually doubled for that purpose. Tapping the tie holders down on the ends of the rod brings the sheathing to bear solidly against the spreader washers. After the concrete has hardened, the tie holders can be detached to strip the forms. After the forms are stripped, a special wrench is used to break off the outer sections of rod; they break off at the breaking points, located about 1 in. inside the surface of the concrete. Small surface holes remain, which can be plugged with grout, if necessary.

Another type of wall form tie is the TIE ROD, as shown in figure 7-32. The rod in this type consists of three sections: an inner section, which is threaded on both ends, and two threaded outer sections. The inner section, with the cones set to the thickness of the wall, is placed between the forms, and the outer sections are passed through the wales and sheathing and threaded into the cone nuts. The clamps are then threaded up on the outer sections to bring the forms to bear against the cone nuts. After the concrete hardens, the clamps are loosened, and the outer sections of rod are removed by threading them out of the cone nuts. After the forms are stripped, the cone nuts are removed from the concrete by threading

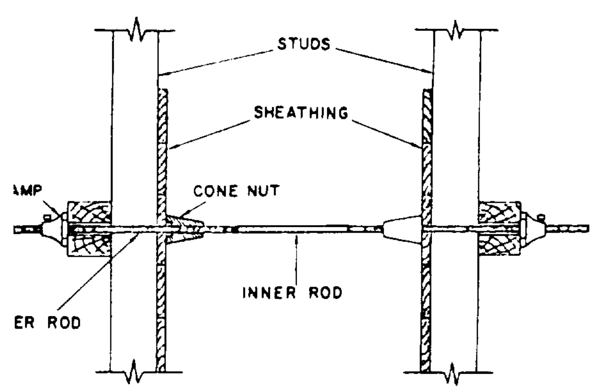


Figure 7-32.-Tie rod.

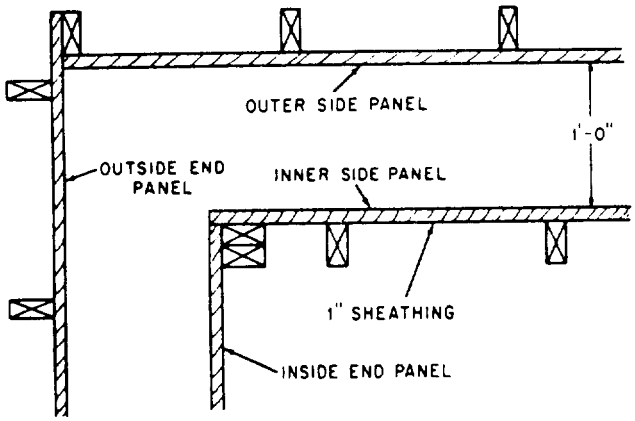


Figure 7-33.-Method of joining wall form panels at a corner.

them off the inner sections of rod with a special wrench leaving the cone-shaped surface holes. The outer sections and the cone nuts may be reused indefinitely.

The use of prefabricated panels for formwork has recently been on the increase. These panels can be reused many times, thus reducing the time and labor required for erecting forms on the site.

Many types of prefabricated form panels are in use. Contractors sometimes build their own panels from wood framing covered with plywood sheathing (fig. 7-33). The standard size is 2 ft by 8 ft, but panels can be sized to suit any particular situation.

Panels made with a metal frame and plywood sheathing are also in common use and are available in a variety of sizes. Special sections are produced to form inside corners, pilasters, and so forth. Panels are held together by patented panel clamps. Flat bar ties, which lock into place between panels, eliminate the need for spreaders. Forms are aligned by using one or more doubled rows of 2 by 4's, secured to the forms by a special device that is attached to the bar ties.

Form panels made completely of steel are also available. The standard size is 24 by 48 in., but various other sizes are also manufactured. Inside and outside corner sections are standard, and insert angles allow odd-sized panels to be made up as desired.

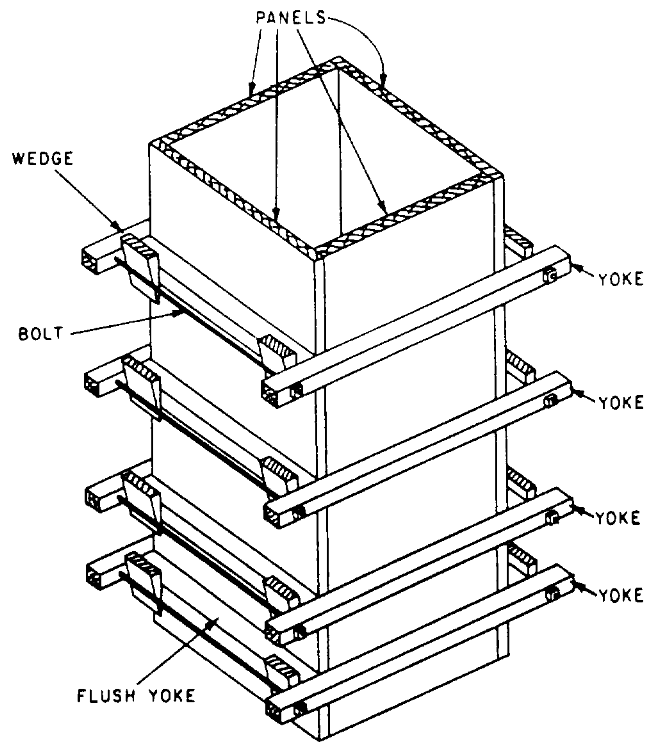


Figure 7-34.-Column form.

Large projects requiring mass concrete placement are often formed by the use of giant panels or ganged, prefabricated forms. Cranes usually raise and place these large sections, so their size is limited only by the available equipment. These large forms are built or assembled on the ground, and their only basic difference from regular forms is the extra bracing required to withstand handling.

Special attention must be given to corners when forms are being erected. These are weak points because the continuity of sheathing and wales is broken. Forms must be pulled tightly together at these points to prevent leakage of concrete.

Column Forms

A typical concrete column form (fig. 7-34) is securely braced by YOKES to hold the sheathing together against the bursting pressure exerted on the form by the plastic concrete. Since the bursting pressure is greater at the bottom than the top, the yokes are placed closer together at the bottom. Notice, in figure 7-34, that on two panels, the

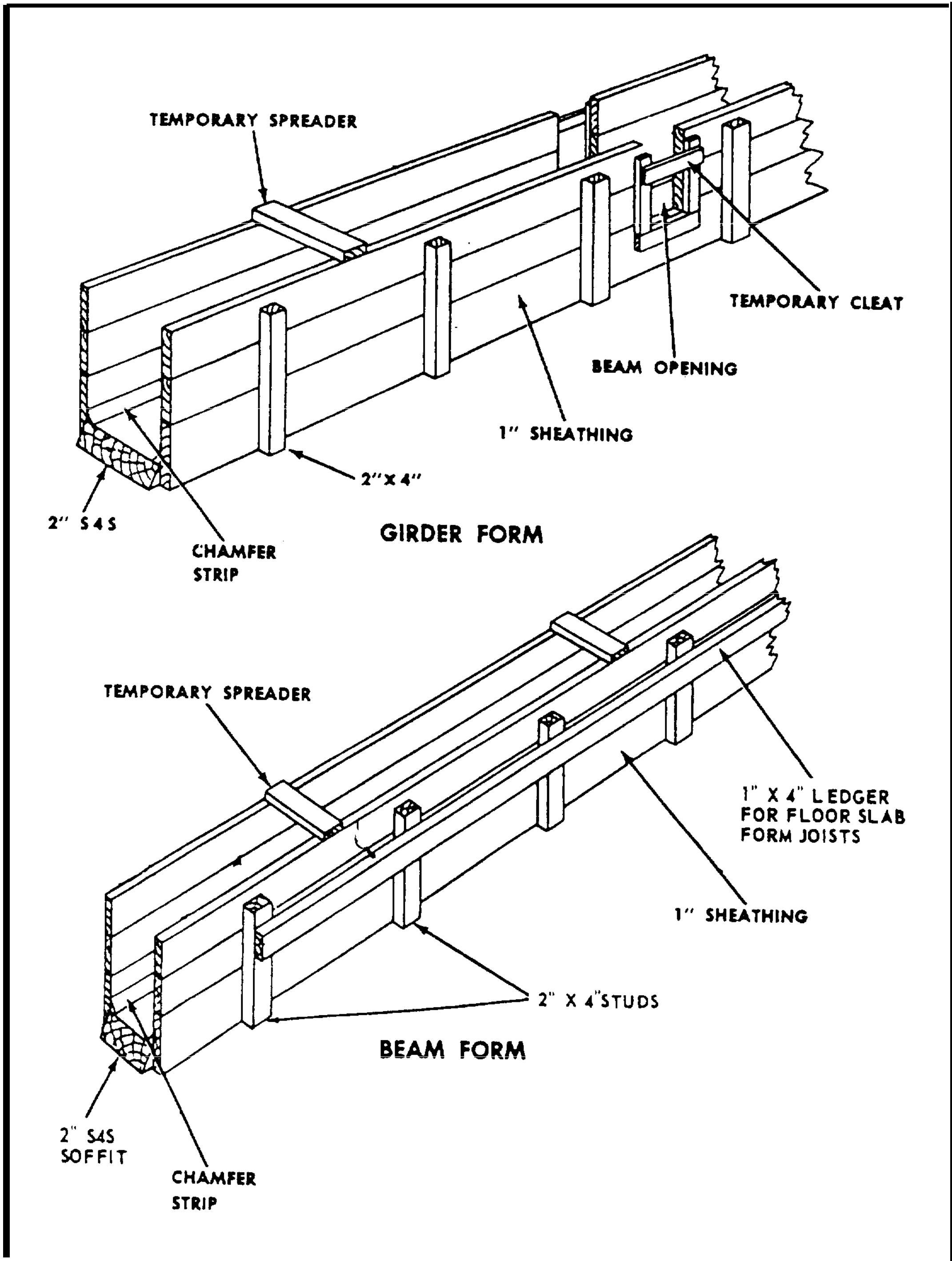


Figure 7-35.-Typical beam and girder forms.

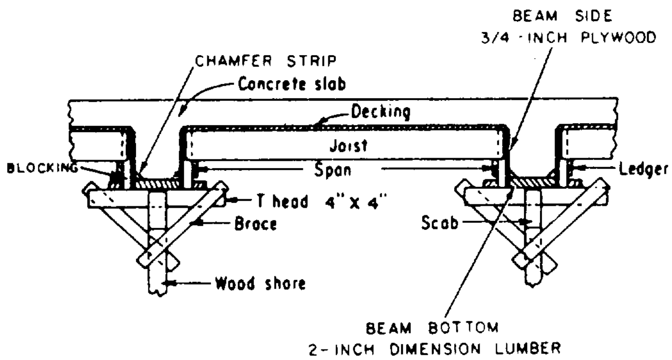


Figure 7-36.-Typical components of beam formwork with slab framing in.

yoke members come flush with the edges of the sheathing; on the other two, they project beyond the edges. Bolt holes are bored in these projections, and bolts are inserted to backup the wedges that are driven to tighten the yokes.

Beam and Girder Forms

The type of construction to be used for beam forms depends upon whether the form is to be removed in one piece or whether the sides are to be stripped and the bottom left in place until such time as the concrete has developed enough strength to permit removal of the shoring. The latter type of beam form is preferred, and details for this type are shown in figure 7-35. Beam forms are subjected to very little bursting pressure but must be shored up at frequent intervals to prevent sagging under the weight of the fresh concrete.

Figure 7-36 shows atypical interior beam form with slab forms supported on the beam sides. This drawing indicates that 3/4-in. plywood serves as the beam sides and that the beam bottom is a solid piece of 2-in. dimensioned lumber supported on the bottom by 4- by 4-in. T-head shores. The vertical side members, referred to in the figure as blocking, are placed to assist in transmitting slab loads to the supporting shores.

MASONRY

MASONRY is that form of construction composed of stone, concrete, brick, gypsum, hollow clay tile, concrete brick, tile, or other similar building units or materials or a combination of these materials, laid up unit by unit and set in mortar. This section will discuss the basic masonry materials commonly used in construction.

CONCRETE MASONRY

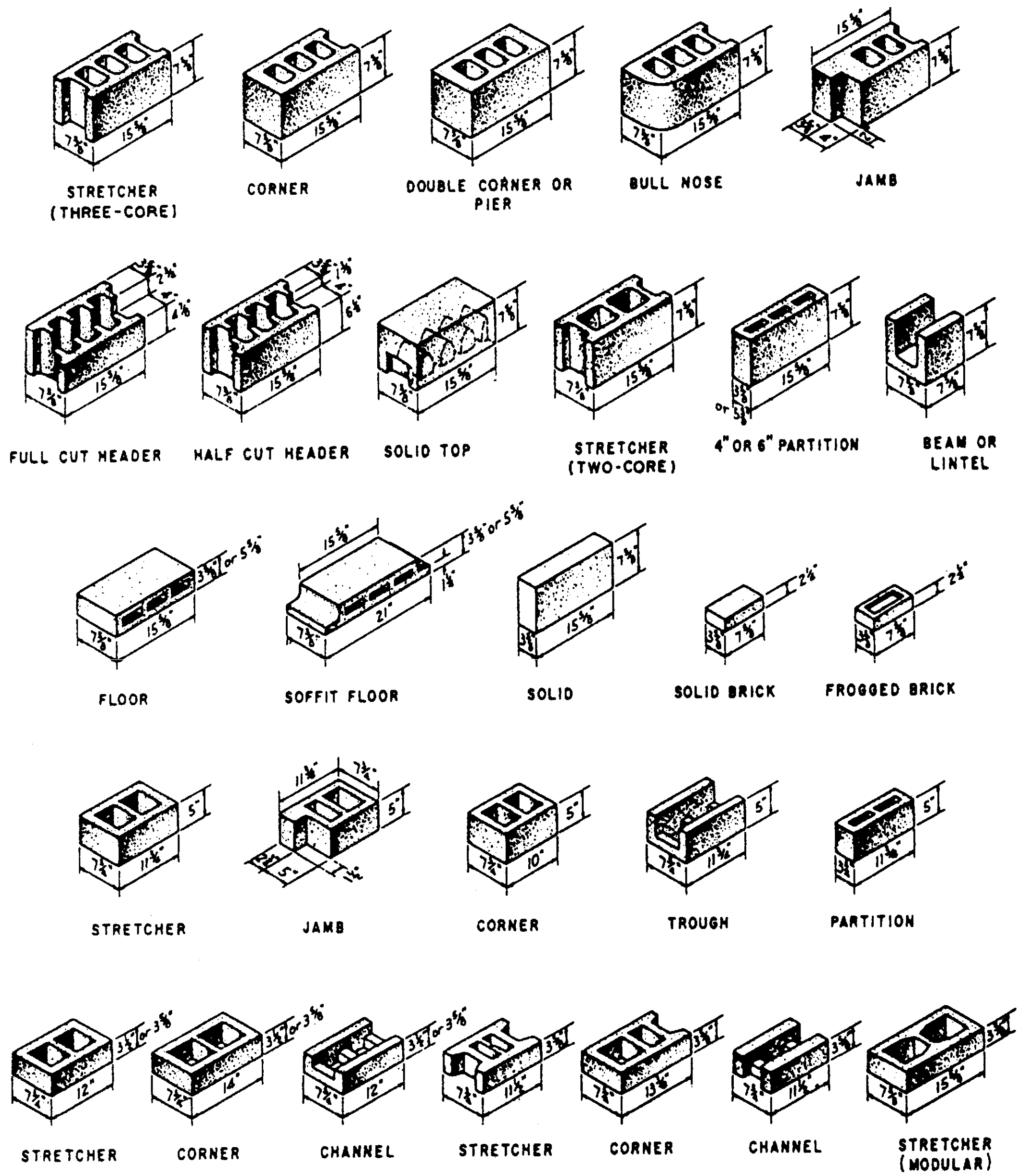
Concrete masonry has become increasingly important as a construction material. Important technological developments in the manufacture and utilization of the units have accompanied the rapid increase in the use of concrete masonry. Concrete masonry walls properly designed and constructed will satisfy various building requirements including fire, safety, durability, economy, appearance, utility, comfort, and good acoustics.

The most common concrete masonry unit is the CONCRETE BLOCK. It is manufactured from both normal and lightweight aggregates. There are two types of concrete block: heavyweight and lightweight. The heavyweight block is manufactured from cement, water, and aggregates, such as sand, gravel, and crushed limestone. The lightweight blocks use a combination of cement, water, and a lightweight aggregate. Cinders, pumice, expanded shale, and vermiculite are a few of the aggregates used in lightweight block production. The lightweight units weigh about 30 percent less than the heavyweight units.

Concrete blocks are made to comply with certain requirements, notably compressive strength, absorption, and moisture content. Compressive strength requirements provide a measure of the blocks' ability to carry loads and withstand structural stresses. Absorption requirements provide a measure of the density of the concrete while moisture content requirements indicate if the unit is sufficiently dry for use in wall construction.

Block Sizes and Shapes

Concrete block units are made in sizes and shapes to fit different construction needs. Units are made in full- and half-length sizes, as shown



(Dimensions shown are actual unit sizes. A 7⅝" x 7⅝" x 15⅝" unit is commonly known as an 8" x 8" x 16" block.)

Figure 7-37.—Typical sizes and shapes of concrete masonry units.

in figure 7-37. Concrete unit sizes are usually referred to by their nominal dimensions. A unit measuring 7 5/8 in. wide, 7 5/8 in. high, and 15 5/8 in. long is referred to as an 8- by 8- by 16-in. unit. When it is laid in a wall with 3/8-in. mortar joints, the unit will occupy a space 16 in. long and 8 in. high. Besides the basic 8- by 8- by 16-in. units, the illustration shows a smaller partition unit and other units that are used much as cut brick are in brick masonry.

The corner unit is laid at a corner or at some similar point where a smooth, rather than a recessed, end is required. The header unit is used in a backing course placed behind a brick face tier header course. Part of the block is cut away to admit the brick headers. The uses of the other shapes shown are self-evident. Besides the shapes shown in figure 7-37, a number of smaller shapes for various special purposes are available. Units may be cut to the desired shapes with a bolster or, more conveniently and accurately, with a power-driven masonry saw.

The sides and the recessed ends of a concrete block are called the SHELL (fig. 7-38). The

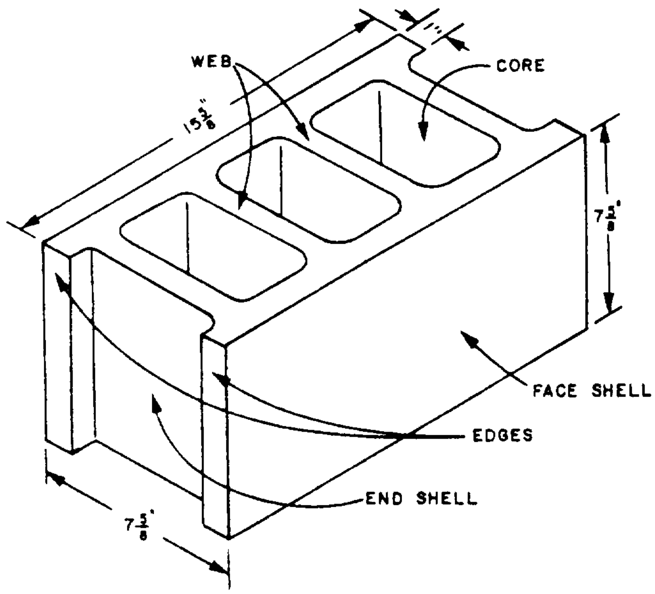


Figure 7-38.-Concrete block.

material that forms the partitions between the cores is called the WEB, and the holes between the webs are called CORES. Each of the long sides of a block is called a FACE SHELL, and each of the recessed ends is called an END SHELL. The vertical ends of the face shells, on either side of the end shells, are called the EDGES.

Wall Patterns

The large number of shapes and sizes of concrete blocks lend themselves to a great many uses. Figure 7-39 shows only a few of the wall patterns that can be developed using various pattern bonds and block sizes. Commercial publications from the Portland Cement Association show many more. Figure 7-40 shows some of the styles of SCREEN BLOCKS (blocks with patterned holes). This type of block is used to

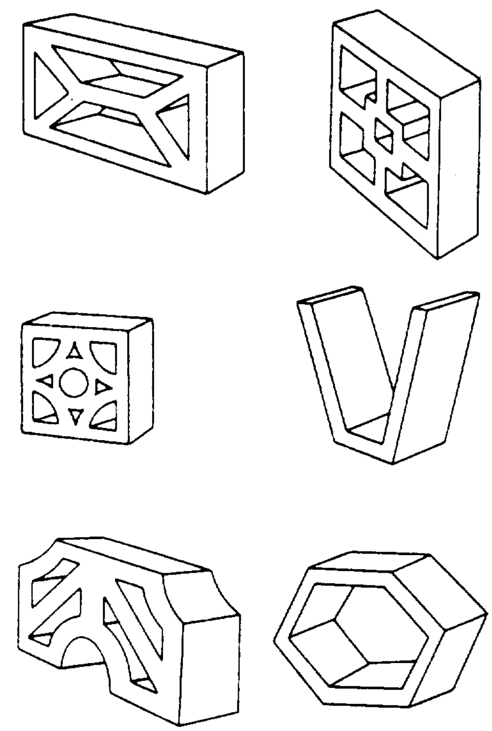


Figure 7-40.-Screen block designs.

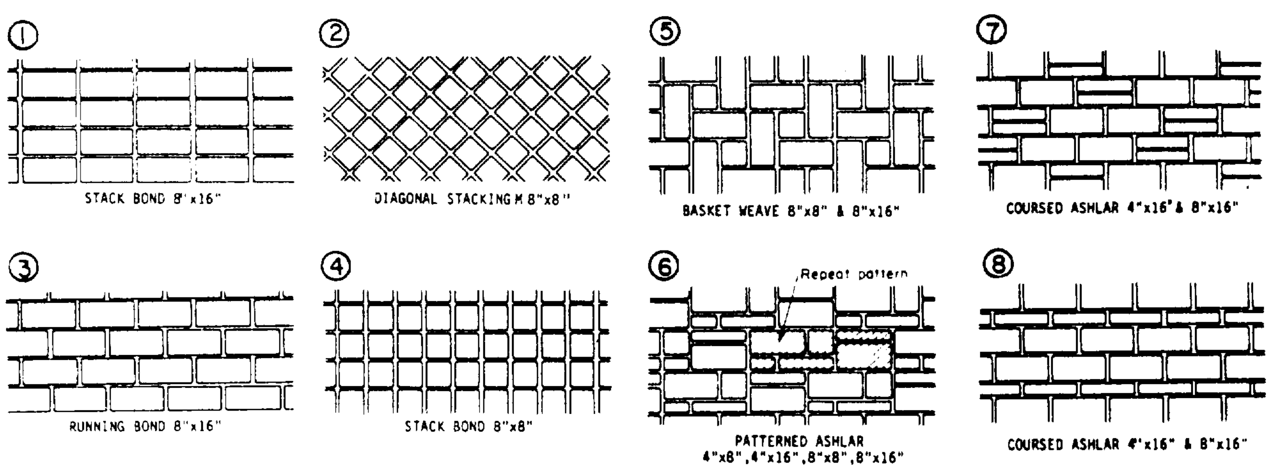


Figure 7-39.-Wall patterns.

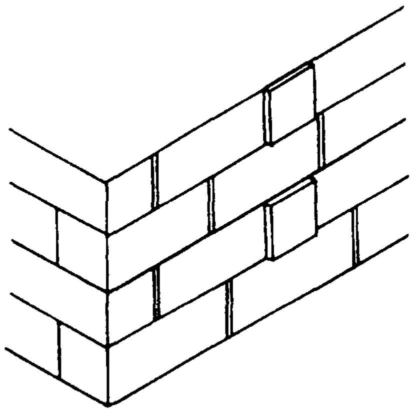


Figure 7-41.-Blocks laid in relief.

make a decorative wall called a PIERCED or SCREEN wall. Other architectural effects can be achieved by laying some block in relief (fig. 7-41) or by varying the type of mortar joint.

Modular Planning

Concrete masonry walls should be laid out to make maximum use of full- and half-length units, thus minimizing cutting and fitting of units on the job. Length and height of walls, width and height of openings, and wall areas between doors, windows, and corners should be planned to use full-size and half-size units, which are usually available (fig. 7-42). This procedure assumes that window frames and doorframes are of modular dimensions that fit modular full- and half-size units. Then, all horizontal dimensions should be in multiples of nominal full-length masonry units, and both horizontal and vertical dimensions should be designed to be in multiples of 8 in. Table 7-2 lists nominal lengths of concrete masonry walls by stretchers, and table 7-3 lists nominal heights of concrete masonry walls by courses. When units 8 by 4 by 16 are used, the horizontal dimension should be planned in multiples of 8 in. (half-length units), and the vertical dimensions, in multiples of 4 in. If the thickness of the wall is greater or less than the length of a half unit, a special length unit is required at each corner in each course.

STRUCTURAL CLAY TILE MASONRY

Hollow masonry units made of burned clay or shale are called, variously, structural tiles,

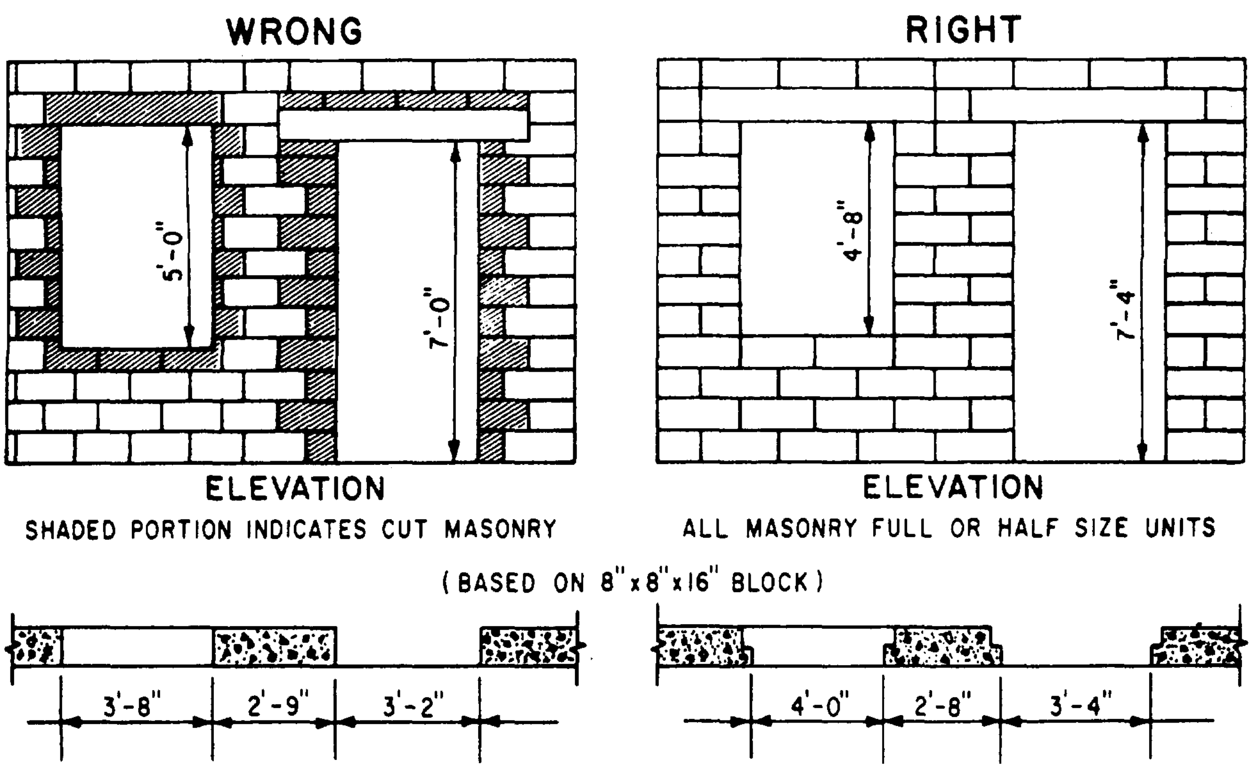


Figure 7-42.-Use of modular dimensions in concrete masonry wall openings.

Table 7-2.-Nominal Length of Concrete Masonry Walls by Stretchers

(Actual length of wall is measured from outside edge to outside edge of units and is equal to the nominal length minus ⅜" (one mortar joint).)

No. of stretchers	Nominal length of concrete masonry walls	
	Units 15⅝" long and half units 7⅝" long with ⅜" thick head joints.	Units 11⅝" long and half units 5⅝" long with ⅜" thick head joints.
1	1′ 4″	1′ 0″.
1½	2′ 0″	1′ 6″.
2	2′ 8″	2′ 0″.
2½	3′ 4″	2′ 6″.
3	4′ 0″	3′ 0″.
3½	4′ 8″	3′ 6″.
4	5′ 4″	4′ 0″.
4½	6′ 0″	4′ 6″.
5	6′ 8″	5′ 0″.
5½	7′ 4″	5′ 6″.
6	8′ 0″	6′ 0″.
6½	8′ 8″	6′ 6″.
7	9′ 4″	7′ 0″.
7½	10′ 0″	7′ 6″.
8	10′ 8″	8′ 0″.
8½	11′ 4″	8′ 6″.
9	12′ 0″	9′ 0″.
9½	12′ 8″	9′ 6″.
10	13′ 4″	10′ 0″.
10½	14′ 0″	10′ 6″.
11	14′ 8″	11′ 0″.
11½	15′ 4″	11′ 6″.
12	16′ 0″	12′ 0″.
12½	16′ 8″	12′ 6″.
13	17′ 4″	13′ 0″.
13½	18′ 0″	13′ 6″.
14	18′ 8″	14′ 0″.
14½	19′ 4″	14′ 6″.
15	20′ 0″	15′ 0″.
20	26′ 8″	20′ 0″.

Table 7-3.-Nominal Height of Concrete Masonry Walls by Courses

(For concrete masonry units 7⅝" and 3⅝" in height laid with ⅜" mortar joints. Height is measured from center to center of mortar joints.)

No. of courses	Nominal height of concrete masonry walls	
	Units 7⅝" high and ⅜" thick bed joint	Units 3⅝" high and ⅜" thick bed joint
1	8″	4″.
2	1′ 4″	8″.
3	2′ 0″	1′ 0″.
4	2′ 8″	1′ 4″.
5	3′ 4″	1′ 8″.
6	4′ 0″	2′ 0″.
7	4′ 8″	2′ 4″.
8	5′ 4″	2′ 8″.
9	6′ 0″	3′ 0″.
10	6′ 8″	3′ 4″.
15	10′ 0″	5′ 0″.
20	13′ 4″	6′ 8″.
25	16′ 8″	8′ 4″.
30	20′ 0″	10′ 0″.
35	23′ 4″	11′ 8″.
40	26′ 8″	13′ 4″.
45	30′ 0″	15′ 0″.
50	33′ 4″	16′ 8″.

hollow tiles, structural clay tiles, structural clay hollow tiles, and structural clay hollow building tiles, but most commonly called building tile. In building tile manufacture, plastic clay is pugged through a die, and the shape that emerges is cut off into units. The units are then burned much as bricks are burned.

The apertures in a building tile, which correspond to the cores in a brick or a concrete block, are called CELLS. The solid sides of a tile are called the SHELL and the perforated material enclosed by the shell is called the WEB. A tile that is laid on one of its shell faces is called a SIDE-CONSTRUCTION tile; one that

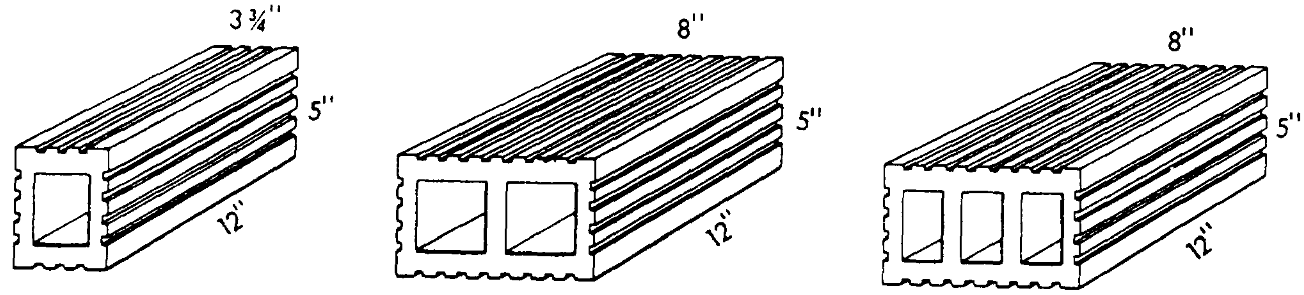


Figure 7-43.-Standard shapes of side-construction building tiles.

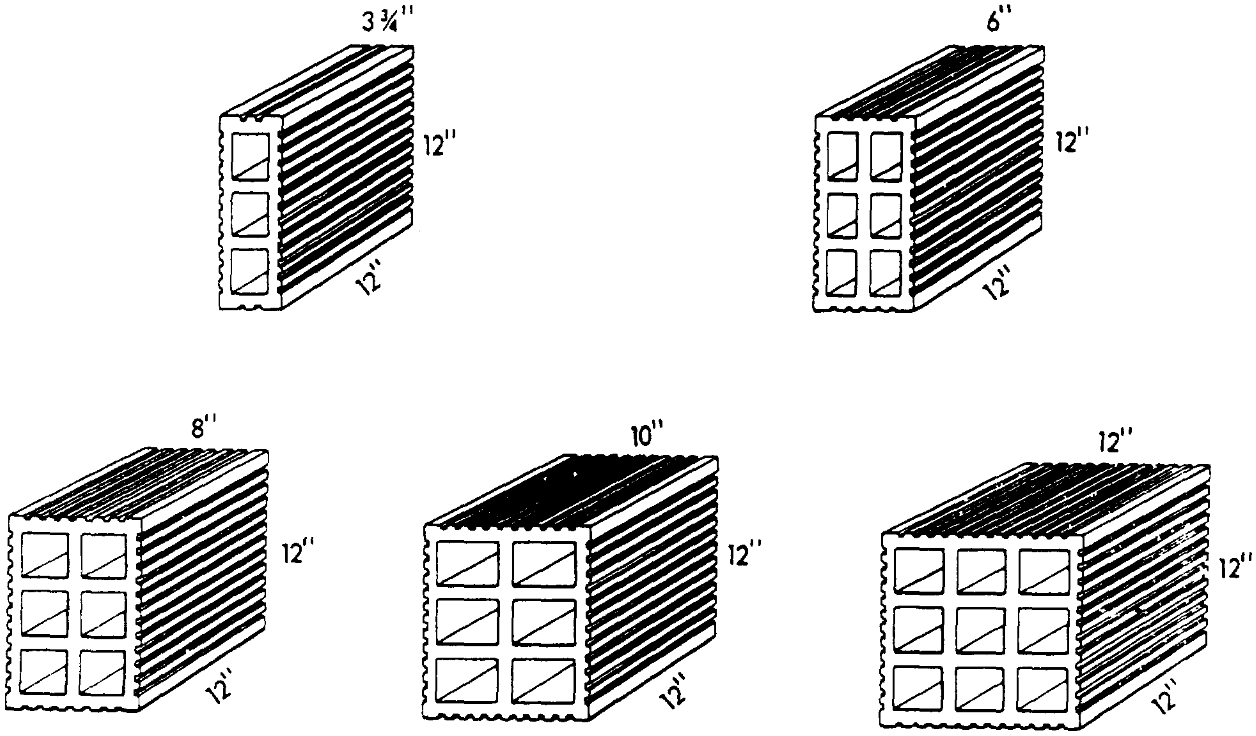


Figure 7-44.-Standard shapes of end-construction building tiles.

is laid on one of its web faces is called an END-CONSTRUCTION tile. Figures 7-43 and 7-44 show the sizes and shapes of basic side- and end-construction building units. Special shapes for use at corners and openings, or for use as closures, are also available.

Physical Characteristics

The compressive strength of the individual tile depends upon the materials used and upon the method of manufacture, in addition to the thickness of the shells and webs. A minimum compressive strength of tile masonry of 300 lb per square in, based on the gross section may be expected. The tensile strength of structural clay tile masonry is small. In most cases, it is less than 10 percent of the compressive strength.

The abrasion resistance of clay tile depends primarily upon its compressive strength. The stronger the tile, the greater its resistance to wearing. The abrasion resistance decreases as the amount of water absorbed increases.

Structural clay facing tile has excellent resistance to weathering. Freezing and thawing action produces almost no deterioration. Tile that will absorb no more than 16 percent of its weight of water have never given unsatisfactory performance in resisting the effect of freezing and thawing action. Only portland cement-lime mortar or mortar prepared from masonry cement should be used if the masonry is exposed to the weather.

Walls containing structural clay tile have better heat-insulating qualities than walls composed of solid units because of the dead air space that exists in tile walls. The resistance to sound penetration of this type of masonry compares favorably with the resistance of solid masonry walls, but it is somewhat less.

The fire resistance of tile walls is considerably less than the fire resistance of solid masonry walls. It can be improved by applying a coat of plaster to the surface of the wall. Partition walls of structural clay tile 6 in, thick will resist a fire for 1 hr provided the fire produces a temperature of not more than 1700°F.

The solid material in structural clay tile weighs about 125 lb per cubic foot. Since the tile contains hollow cells of various sizes, the weight of the tile varies, depending upon the manufacturer and type. A 6-in. tile wall weighs approximately 30 lb per square foot, while a 12-in. tile weighs approximately 45 lb per square foot.

Uses for Structural Clay Tile

Structural clay tile may be used for exterior walls of either the load-bearing or nonload-bearing type. It is suitable for both below-grade and above-grade construction.

Structural load-bearing tile is made from 4- to 12-in. thicknesses with various face dimensions. The use of these tiles is restricted by building codes and specifications, so consult the project specification.

Nonload-bearing partition walls from the 4- to 12-in. thicknesses are frequently made of structural clay tile. These walls are easily built, light in weight, and have good heat- and sound-insulating properties.

Figure 7-45 shows the use of structural clay tile as a back unit for a brick wall.

Figure 7-46 shows the use of 8- by 5- by 12-in. tile in wall construction. Exposure of the open end of the tile can be avoided by the application of a thin tile called a SOAP at the corner.

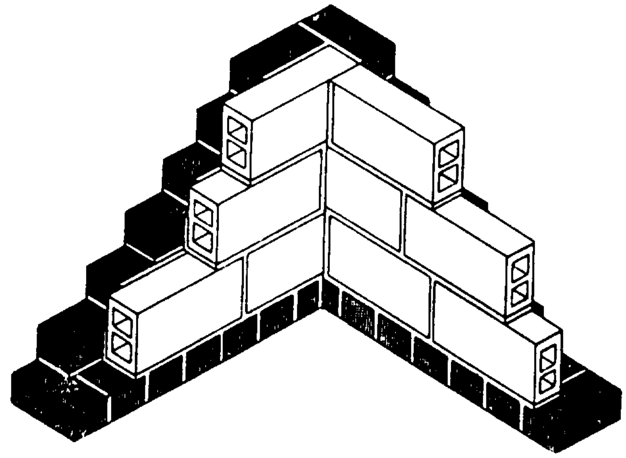


Figure 7-45.-Structural tile used as a backing for bricks.

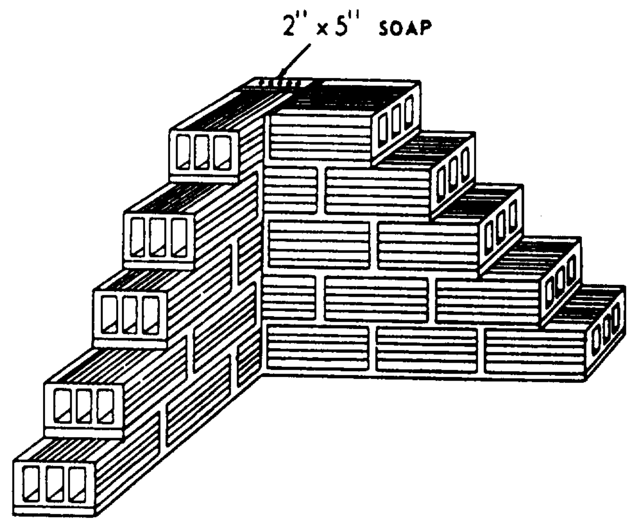


Figure 7-46.-Eight-inch structural clay tile wall.

STONE MASONRY

Stone masonry is masonry is which the units consist of natural stone. In RUBBLE stone masonry, the stones are left in their natural state, without any kind of shaping. In ASHLAR masonry, the faces of stones that are to be placed in surface positions are squared so that the surfaces of the finished structure will be more or less continuous plane surfaces. Both rubble and ashlar work may be either RANDOM or COURSED.

Random rubble is the crudest of all types of stonework. Little attention is paid to laying the

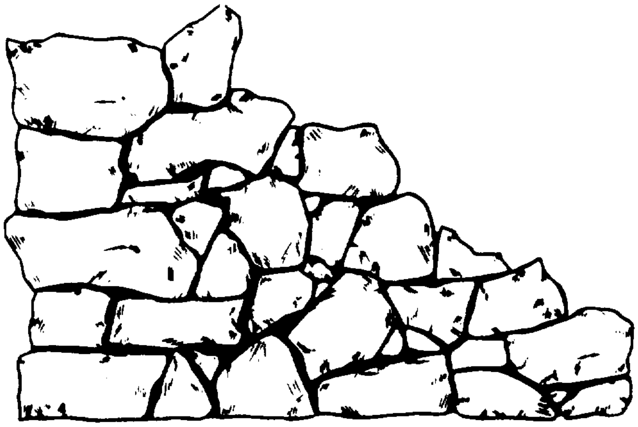


Figure 7-47.-Random rubble stone masonry.

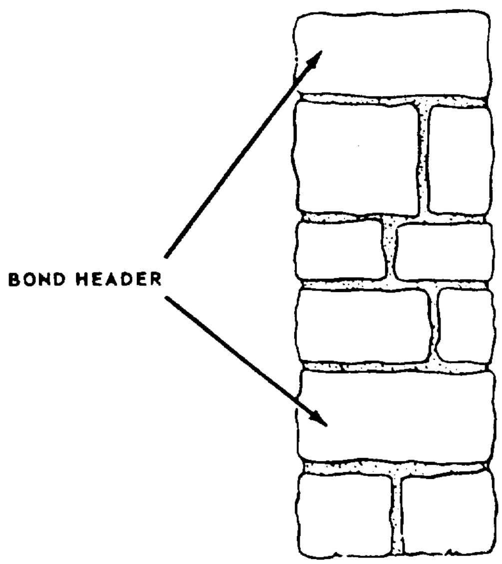


Figure 7-48.-Layers of bond stones in random stone masonry.

stones in courses, as shown in figure 7-47. Each layer must contain bonding stones that extend through the wall, as shown in figure 7-48. This produces a wall that is well tied together. The bed joints should be horizontal for stability, but the "builds" or head joints may run in any direction.

Coursed rubble consists of roughly squared stones assembled in such a manner as to produce approximately continuous horizontal bed joints, as shown in figure 7-49.

The stone for use in stone masonry should be strong, durable, and cheap. Durability and strength depend upon the chemical composition and physical structure of the stone. Some of the

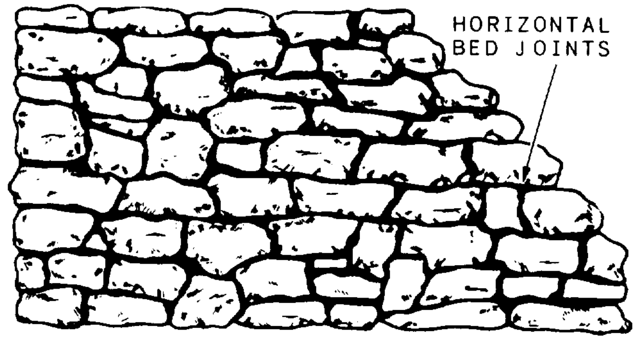


Figure 7-49.-Coursed rubble masonry.

more commonly found stones that are suitable are limestone, sandstone, granite, and slate. Unsquared stones obtained from nearby ledges or quarries or even fieldstone maybe used. The size of the stone should be such that two people can easily handle it. A variety of sizes is necessary to avoid using large quantities of mortar.

The mortar for use in stone masonry may be composed of portland cement and sand in the proportions of one part cement to three parts sand by volume. Such mortar shrinks excessively and does not work well with the trowel. A better mortar to use is portland cement-lime mortar. Mortar made with ordinary portland cement will stain most types of stone. If staining must be prevented, nonstaining white portland cement should be used in making the mortar. Lime does not usually stain the stone.

BRICK MASONRY

In brick masonry construction, units of baked clay or shale of uniform size are laid in courses with mortar joints to form walls of virtually unlimited length and height. These units are small enough to be placed with one hand. Bricks are kiln-baked from various clay and shale mixtures. The chemical and physical characteristics of the ingredients vary considerably; these and the kiln temperatures combine to produce brick in a variety of colors and harnesses. In some regions, pits are opened and found to yield clay or shale that, when ground and moistened, can be formed and baked into durable brick; in other regions, clays or shales from several pits must be mixed.

The dimensions of a U.S. standard building brick are 2 1/4 by 3 3/4 by 8. The actual dimensions of brick may vary a little because of shrinkage during burning.

Brick Nomenclature

Frequently, the Builder must cut the brick into various shapes. The most common shapes are shown in figure 7-50. They are called half or bat, three-quarter closure, quarter closure, king closure, queen closure, and split. They are used to fill in the spaces at corners and such other places where a full brick will not fit.

The six surfaces of a brick are called the cull, the beds, the side, the end, and the face, as shown in figure 7-51.

Brick Classification

A finished brick structure contains FACE brick (brick placed on the exposed face of the structure) and BACKUP brick (brick placed behind the face brick). The face brick is often of higher quality than the backup brick; however, the entire wall may be built of COMMON brick.

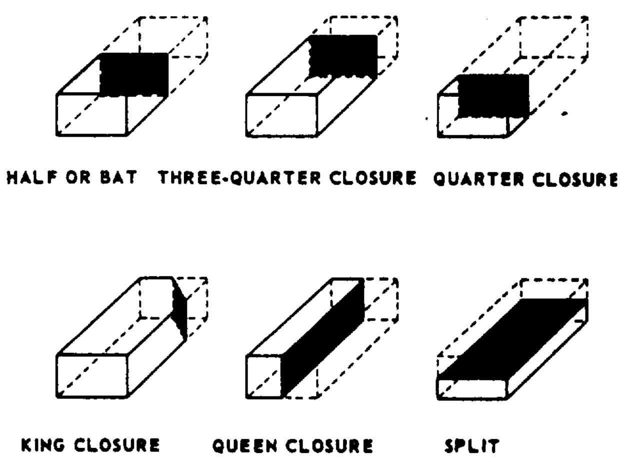


Figure 7-50.-Nomenclature of common shapes of cut brick.

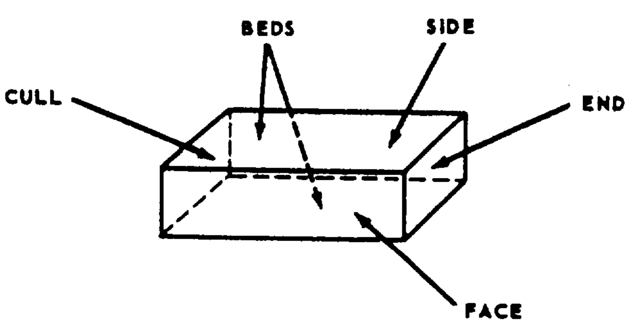


Figure 7-51.-Brick surfaces nomenclature.

Common brick is brick that is made from pit-run clay, with no attempt at color control and no special surface treatment like glazing or enameling. Most common brick is red.

Although any surface brick is a face brick as distinguished from a backup brick, the term *face brick* is also used to distinguish high-quality brick from brick that is of common-brick quality or less. Applying this criterion, face brick is more uniform in color than common brick, and it may be obtained in a variety of colors as well. It may be specifically finished on the surface, and in any case, it has a better surface appearance than common brick. It may also be more durable, as a result of the use of select clay and other materials, or as a result of special manufacturing methods.

Backup brick may consist of brick that is inferior in quality even to common brick. Brick that has been underburned or overburned, or brick made with inferior clay or by inferior methods, is often used for backup brick.

Still another type of classification divides brick into grades according to the probable climatic conditions to which it is to be exposed. These are as follows:

GRADE SW is brick designed to withstand exposure to below-freezing temperatures in a moist climate like that of the northern regions of the United States.

GRADE MW is brick designed to withstand exposure to below-freezing temperatures in a drier climate than that mentioned in the previous paragraph.

GRADE NW is brick primarily intended for interior or backup brick. It maybe used exposed, however, in a region where no frost action occurs, or in a region where frost action occurs, but the annual rainfall is less than 15 in.

Types of Bricks

There are many types of brick. Some are different in formation and composition while others vary according to their use. Some commonly used types of brick are described in the following paragraphs.

COMMON brick is made of ordinary clays or shales and burned in the usual manner in the kilns. These bricks do not have special scorings or markings and are not produced in any special color or surface texture. Common brick is also known as hard- and kiln-run brick. It is used generally for backing courses in solid or cavity brick walls. The harder and more durable kinds are preferred for this purpose.

FACE bricks are used in the exposed face of a wall and are higher quality units than backup brick. They have better durability and appearance. The most common colors of face brick are various shades of brown, red, gray, yellow, and white.

CLINKER bricks are bricks that have been overburned in the kilns. This type of brick is usually hard and durable and may be irregular in shape. Rough hard corresponds to the clinker classification.

PRESS bricks are made by the dry press process. This class of brick has regular smooth faces, sharp edges, and perfectly square corners. Ordinarily, all press brick are used as face brick.

GLAZED bricks have one surface of each brick glazed in white or other colors. The ceramic glazing consists of mineral ingredients that fuse together in a glass-like coating during burning. This type of brick is particularly suited for walls or partitions in hospitals, dairies, laboratories, or other buildings where cleanliness and ease of cleaning are necessary.

FIREBRICK is made of a special type of fire clay that will withstand the high temperatures of fireplaces, boilers, and similar usages without cracking or decomposing. Firebrick is larger than regular structural brick, and often, it is hand molded.

CORED BRICK are made with two rows of five holes extending through their beds to reduce weight. There is no significant difference between

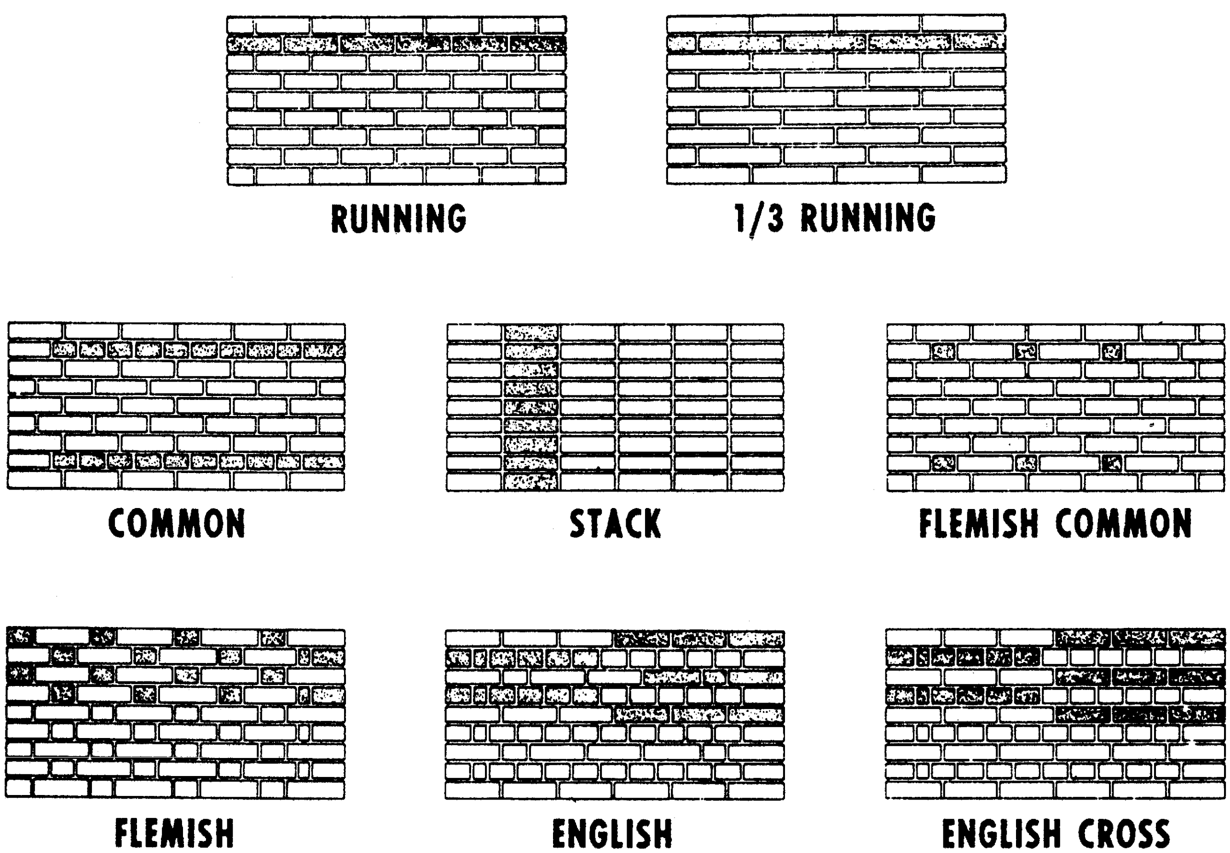


Figure 7-52.—Types of brick masonry bond.

the strength of walls constructed with cored brick and those constructed with solid brick. Resistance to moisture penetration is about the same for both types of walls. The most easily available brick that will meet the requirements should be used whether the brick is cored or solid.

SAND-LIME bricks are made from a lean mixture of slaked lime and fine silicious sand, molded under mechanical pressure and hardened under steam pressure.

Types of Bonds

When the word *bond* is used in reference to masonry, it may have three different meanings:

STRUCTURAL BOND is a method of interlocking or tying individual masonry units together so that the entire assembly acts as a single structural unit. Structural bonding of brick and tile walls may be accomplished in three ways: first, by overlapping (interlocking) the masonry units; second, by the use of metal ties embedded in connecting joints; and third, by the adhesion of grout to adjacent wythes of masonry.

MORTAR BOND is the adhesion of the joint mortar to the masonry units or to the reinforcing steel.

PATTERN BOND is the pattern formed by the masonry units and the mortar joints on the face of a wall. The pattern may result from the type of structural bond used or may be purely a decorative one in no way related to the structural bond. Five basic pattern bonds are in common use today, as shown in figure 7-52. These are running bond, common bond, stack bond, Flemish bond, and English bond.

RUNNING BOND is the simplest of the basic pattern bonds; the running bond consists of all stretchers. Since there are no headers used in this bond, metal ties are usually used. Running bond is used largely in cavity wall construction and veneered walls of brick and often in facing tile walls where the bonding may be accomplished by extra width stretcher tile.

COMMON or AMERICAN BOND is a variation of running bond with a course of full-length headers at regular intervals. These headers provide structural bonding, as well as pattern. Header courses usually appear at every fifth, sixth, or seventh course, depending on the structural bonding requirements. In laying out any bond pattern, it is important that the corners be started correctly. For common bond, a three-quarter brick must start each header course at the corner. Common bond may be varied by using a Flemish header course.

STACK BOND is purely a pattern bond. There is no overlapping of the units, all vertical joints being aligned. Usually, this pattern is bonded to the backing with rigid steel ties, but when 8-in.-thick stretcher units are available, they may be used. In large wall areas and in load-bearing construction, it is advisable to reinforce the wall with steel pencil rods placed in the horizontal mortar joints. The vertical alignment requires dimensionally accurate units, or carefully prematched units, for each vertical joint alignment. Variety in pattern may be achieved by numerous combinations and modifications of the basic patterns shown.

FLEMISH BOND is made up of alternate stretchers and headers, with the headers in alternate courses centered over the stretchers in the intervening courses. Where the headers are not used for structural bonding, they may be obtained by using half brick, called blind-headers. Two methods are used in starting the corners. Figure 7-52 shows the so-called FLEMISH corner in which a three-quarter brick is used to start each course and the ENGLISH corner in which 2-in. or quarter-brick closures must be used.

ENGLISH BOND is composed of alternate courses of headers and stretchers. The headers are centered on the stretchers and joints between stretchers. The vertical (head) joints between stretchers in all courses line up vertically. Blind headers are used in courses that are not structural bonding courses. The English cross bond is a variation of English bond and differs only in that vertical joints between the stretchers in alternate courses do NOT line up vertically. These joints center on the stretchers themselves in the courses above and below.

Masonry Terms

Specific terms are used to describe the various positions of masonry units and mortar

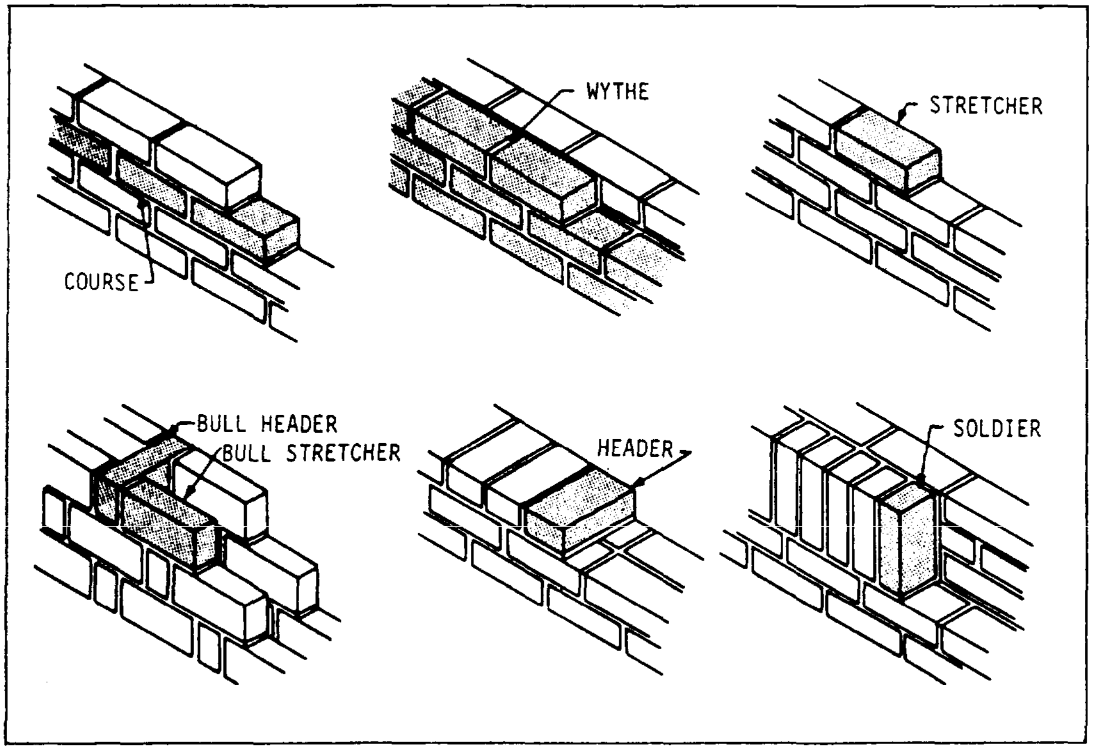


Figure 7-53.-Various positions of wall masonry units and mortar joints.

joints in a wall (fig. 7-53). These are as follows:

Course. One of the continuous horizontal layers (or rows) of masonry that, bonded together, form the masonry structure.

Wythe. A continuous single vertical wall of brick

Stretcher. A masonry unit laid flat with its longest dimension parallel to the face of the wall.

Bull-Stretcher. A rowlock brick laid with its longest dimension parallel to the face of the wall.

Bull-Header. A rowlock brick laid with its longest dimension perpendicular to the face of the wall.

Header. A masonry unit laid flat with its longest dimension perpendicular to the face of the wall. It is generally used to tie two wythes of masonry together.

Rowlock. A brick laid on its edge (face).

Soldier. A brick laid on its end so that its longest dimension is parallel to the vertical axis of the face of the wall.

CHAPTER 8

MECHANICAL SYSTEMS AND PLAN

To be able to prepare workable construction. drawings, EAs should have the ability to recognize and describe the materials used in mechanical systems, to understand their uses and functions, and to discuss the purpose and the development of a mechanical plan in the context of plumbing for water distribution and drainage systems.

This chapter will discuss only the plumbing and drainage portions of the mechanical systems and the various materials used. You will not be expected to design the system; however, as an EA, you may be called upon to prepare construction drawings from sketches and specifications.

MECHANICAL SYSTEMS (PLUMBING)

In general, plumbing refers to the system of pipes, fixtures, and other appurtenances used inside a building for supplying water and removing liquid and waterborne wastes. In practice, the term also includes storm water or roof drainage and exterior system components connecting to a source, such as a water main, and a point of disposal, such as a domestic septic tank or cesspool.

The purpose of plumbing systems is, basically, to bring a supply of safe water into a building for drinking, washing, and cooking, distribute the water within the building, and carry off the discharge of waste material from various receptacles on the premises to sewers, leech basins, and so forth, without causing a hazard to the health of the occupants. Codes, regulations, and trade practices define the plumbing specifications, which vary from one location or place of application to another. Although the National Plumbing Code is widely accepted as a guideline for the minimum requirements for plumbing designs, you must also be familiar with applicable local codes, especially when working with mechanical drawings and plans.

WATER DISTRIBUTION SYSTEM

The purpose of a water distribution system is to carry potable COLD and HOT WATER throughout a building for domestic or industrial use. A typical water supply system (fig. 8-1) consists of service pipe, distribution pipe, connecting pipe, fittings, and control valves. The water service pipe begins at the WATER MAIN. The water distribution pipe starts at the end of the service pipe and supplies the water throughout the building.

Piping Materials

Several types of pipe are used in water distribution systems, but only the most common types used by the SEABEEs will be discussed. These piping materials include copper, plastic, galvanized steel, and cast iron. Some of the main characteristics of pipes made from these materials are presented below.

COPPER PIPE AND TUBING.— Copper is one of the most widely used materials for tubing. This is because it does not rust and is highly resistant to any accumulation of scale particles in the pipe. This tubing is available in three different

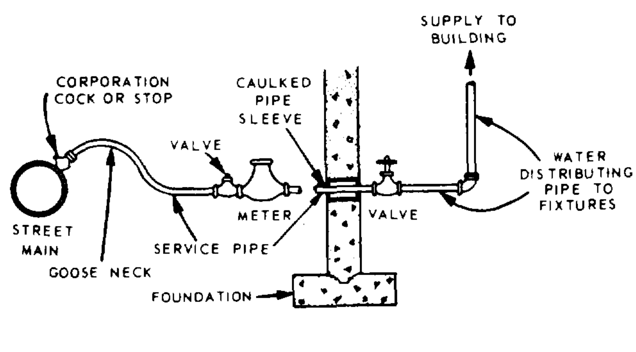


Figure 8-1.-Cross-sectional diagram of a water supply and distribution system.

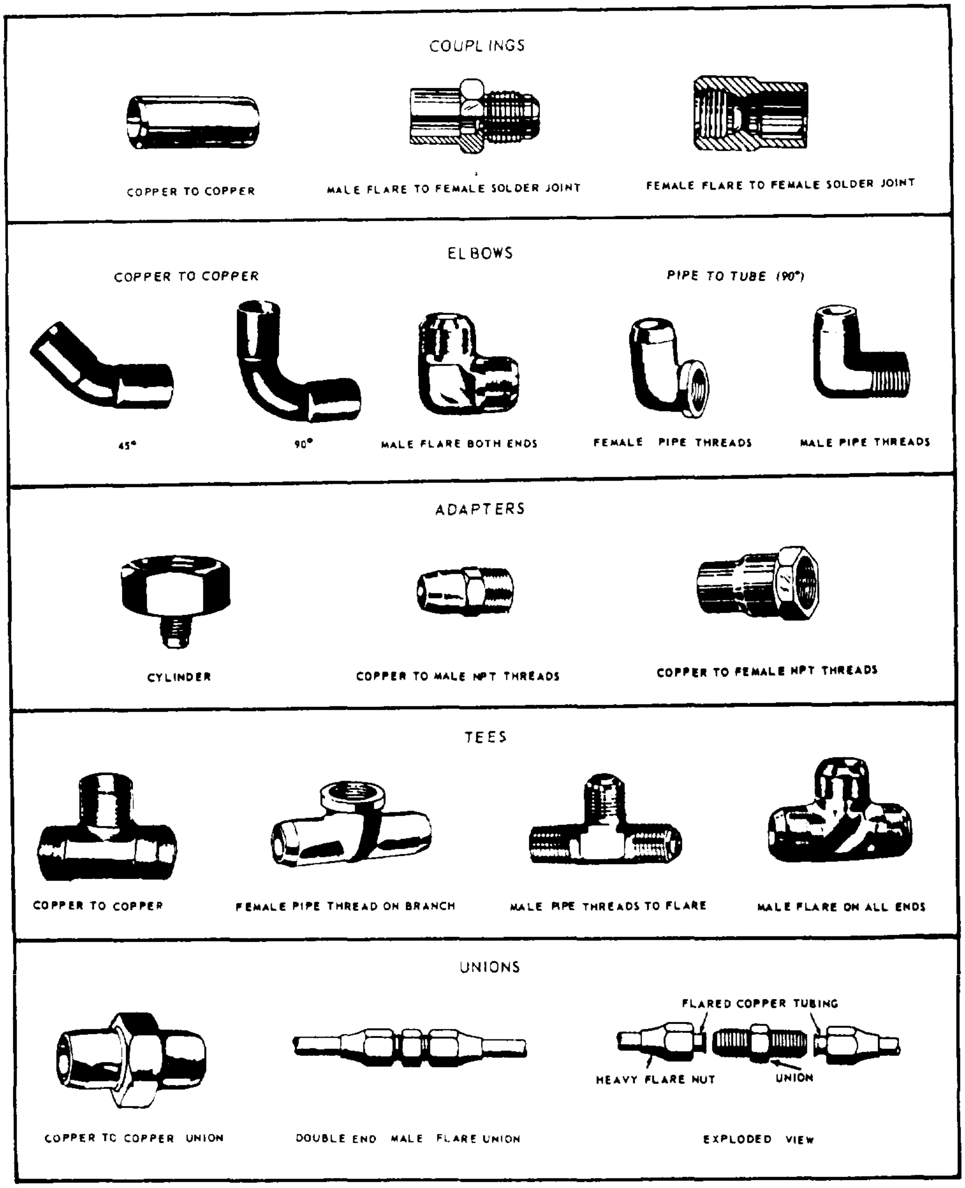


Figure 8-2.-Typical copper fittings.

types: K, L, and M. K has the thickest walls, and M, the thinnest walls, with L's thickness in between the other two. The thin walls of copper tubing are soldered to copper fittings. Soldering allows all the tubing and fittings to be set in place before the joints are finished. Generally, faster installation will be the result.

Type K copper tubing is available in either rigid (hard temper) or flexible (soft temper) and is primarily used for underground service in the water distribution systems. Soft temper tubing is available in 40- or 60-ft coils, while hard temper tubing comes in 12- and 20-ft straight lengths.

Type L copper tubing is also available in either hard or soft temper and either in coils or in straight lengths. The soft temper tubing is often used as replacement plumbing because of the tube's flexibility, which allows easier installation. Type L copper tubing is widely used in water distribution systems.

Type M copper tubing is made in hard temper only and is available in straight lengths of 12 and 20 ft. It has a thin wall and is used for branch supplies where water pressure is low, but it is NOT used for mains and risers. It is also used for chilled water systems, for exposed lines in hot-water heating systems, and for drainage piping.

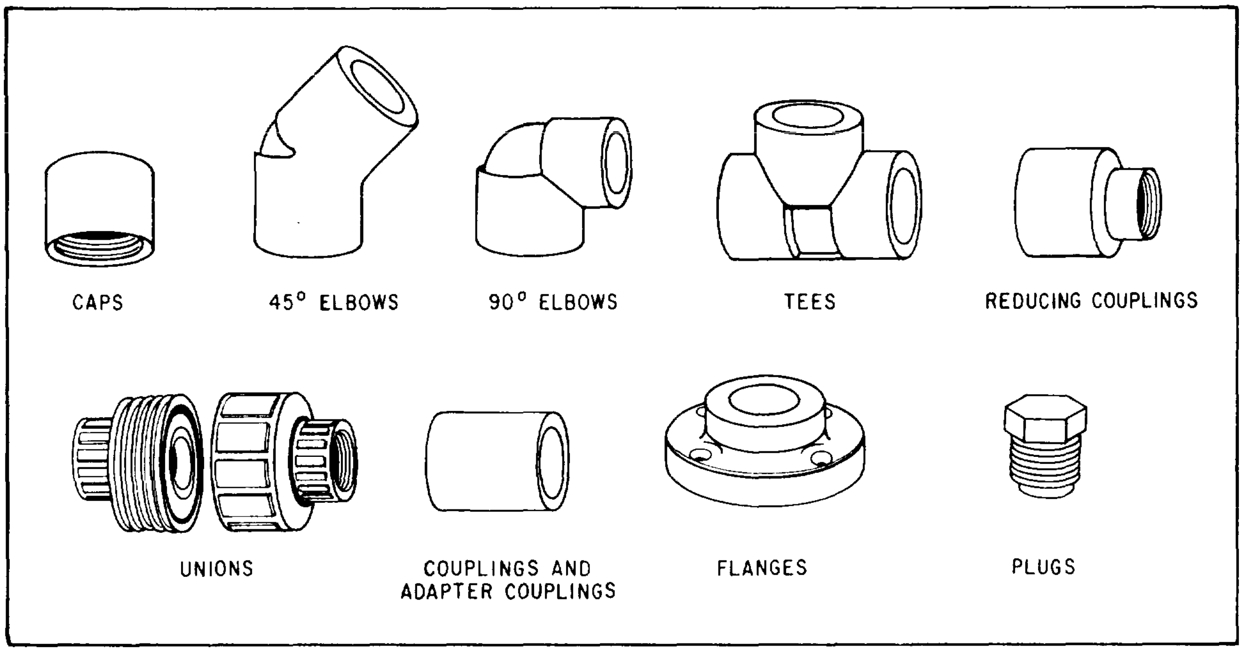


Figure 8-3.-Plastic pipe fittings.

PLASTIC PIPE.— Plastic pipe has seen extensive use in current Navy construction. Available in different lengths and sizes, it is lighter than steel or copper and requires no special tools to install. Plastic pipe has several advantages over metal pipe: it is flexible; it has superior resistance to rupture from freezing; it has complete resistance to corrosion; and, in addition, it can be installed aboveground or belowground.

One of the most versatile plastic and polyvinyl resin pipes is the polyvinyl chloride (PVC). PVC pipes are made of tough, strong thermoplastic material that has an excellent combination of physical and chemical properties. Its chemical resistance and design strength make it an excellent material for application in various mechanical systems. Sometimes polyvinyl chloride is further chlorinated to obtain a stiffer design, a higher level of impact resistance, and a greater resistance to extremes of temperature. A CPVC pipe (a chlorinated blend of PVC) can be used not only in cold-water systems, but also in hot-water systems with temperatures up to 210°F.

Economy and ease of installation make plastic pipe popular for use in either water distribution and supply systems or sewer drainage systems.

GALVANIZED PIPE.— Galvanized pipe is commonly used for the water distributing pipes inside a building to supply hot and cold water to the fixtures. This type of pipe is manufactured in 21-ft lengths. It is GALVANIZED (coated with zinc) both inside and outside at the factory to resist corrosion. Pipe sizes are based on nominal INSIDE diameters. Inside diameters vary with the thickness of the pipe. Outside diameters remain constant so that pipe can be threaded for standard fittings.

CAST-IRON WATER PIPE.— Cast-iron pipe, sometimes called cast-iron pressure pipe, is used for water mains and frequently for service pipe up to a building. Unlike cast-iron soil pipe, cast-iron water pipe is manufactured in 20-ft lengths rather than 5-ft lengths. Besides bell-and-spigot joints, cast-iron water pipes and fittings are made with either flanged, mechanical, or screwed joints. The screwed joints are used only on small-diameter pipe.

Fittings

Fittings vary according to the type of piping material used. The major types commonly used in water service include elbows, tees, unions, couplings, caps, plugs, nipples, reducers, and adapters. Some typical copper pipe fittings are shown in figure 8-2. Plastic pipe fittings (fig. 8-3) that are similar in appearance to those used with metal piping are available. Some plastic pipes can

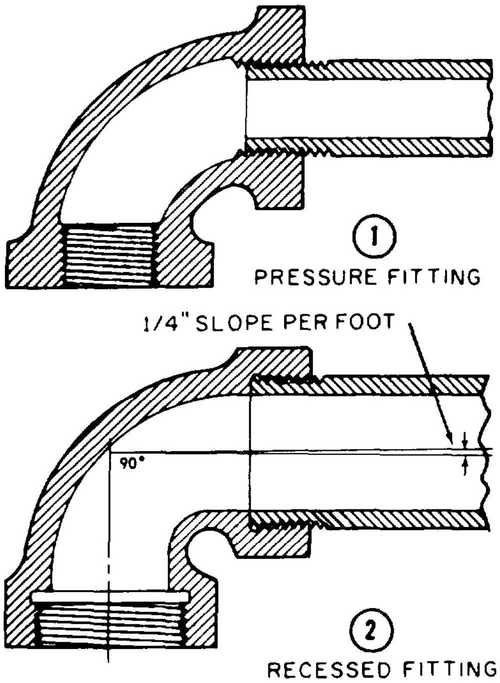


Figure 8-4.-Comparison of pressure and recessed (Durham) types of fittings.

also be adapted to metal pipe fittings. The fittings used on either steel pipe or wrought iron are generally made of malleable iron or cast iron. There are two types of iron pipe fittings used: the PRESSURE type and the RECESSED type (fig. 8-4).

The pressure type of fitting is the standard fitting used on water pipe. The recessed type of fitting, also known as a cast-iron drainage or Durham fitting, is generally required on all drainage lines. The recessed type is most suitable for a smooth joint; it reduces the probability of grease or foreign material remaining in the joint and causing a stoppage in the line. Recessed fittings are designed so that horizontal lines entering them will have a slope of one-fourth in. per foot.

ELBOWS (OR ELLS) 90° AND 45°.— These fittings (fig. 8-5, close to middle of figure) are used to change the direction of the pipe either 90 or 45 degrees. REGULAR elbows have female threads at both outlets. STREET elbows change the direction of a pipe in a close space where it would be impossible or impractical to use an elbow and nipple. Both 45- and 90-degree street elbows are available with one female and one male threaded end. The REDUCING elbow is similar to the 90-degree elbow except that one opening is smaller than the other.

TEES.— A tee is used for connecting pipes of different diameters or for changing the direction of pipe runs. A common type of pipe tee is the STRAIGHT tee, which has a straight-through portion and a 90-degree takeoff on one side. All three openings of the straight tee are of the same size. Another common type is the REDUCING tee, similar to the straight tee just described, except that one of the threaded openings is of a different size than the other.

UNIONS.— There are two types of pipe unions. The GROUND JOINT UNION consists of three pieces, and the FLANGE UNION is made in two parts. Both types are used for joining two pipes together and are designed so that they can be disconnected easily.

COUPLINGS.— The three common types of couplings are straight coupling, reducer, and eccentric reducer. The STRAIGHT COUPLING is for joining two lengths of pipe in a straight run that does not require additional fittings. A run is that portion of a pipe or fitting continuing in a straight line in the direction of flow. A REDUCER is used to join two pipes of different sizes. The ECCENTRIC REDUCER (also called a BELL REDUCER) has two female (inside) threads of different sizes with centers so designed that when they are joined, the two pieces of pipe will not be in line with each other, but they can be installed so as to provide optimum drainage of the line.

CAPS.— A pipe cap is a fitting with a female (inside) thread. It is used like a plug, except that the pipe cap screws on the male thread of a pipe or nipple.

PLUGS.— Pipe plugs are fittings with male (outside) threads. They are screwed into other fittings to close openings. Pipe plugs have various types of heads, such as square, slotted, and hexagonal sockets.

NIPPLES.— A nipple is a short length of pipe (12 in. or less) with a male thread on each end. It is used for extension from a fitting.

At times, you may use the DIELECTRIC or INSULATING TYPE of fittings. These fittings connect underground tanks or hot-water tanks. They are also used when pipes of dissimilar metals

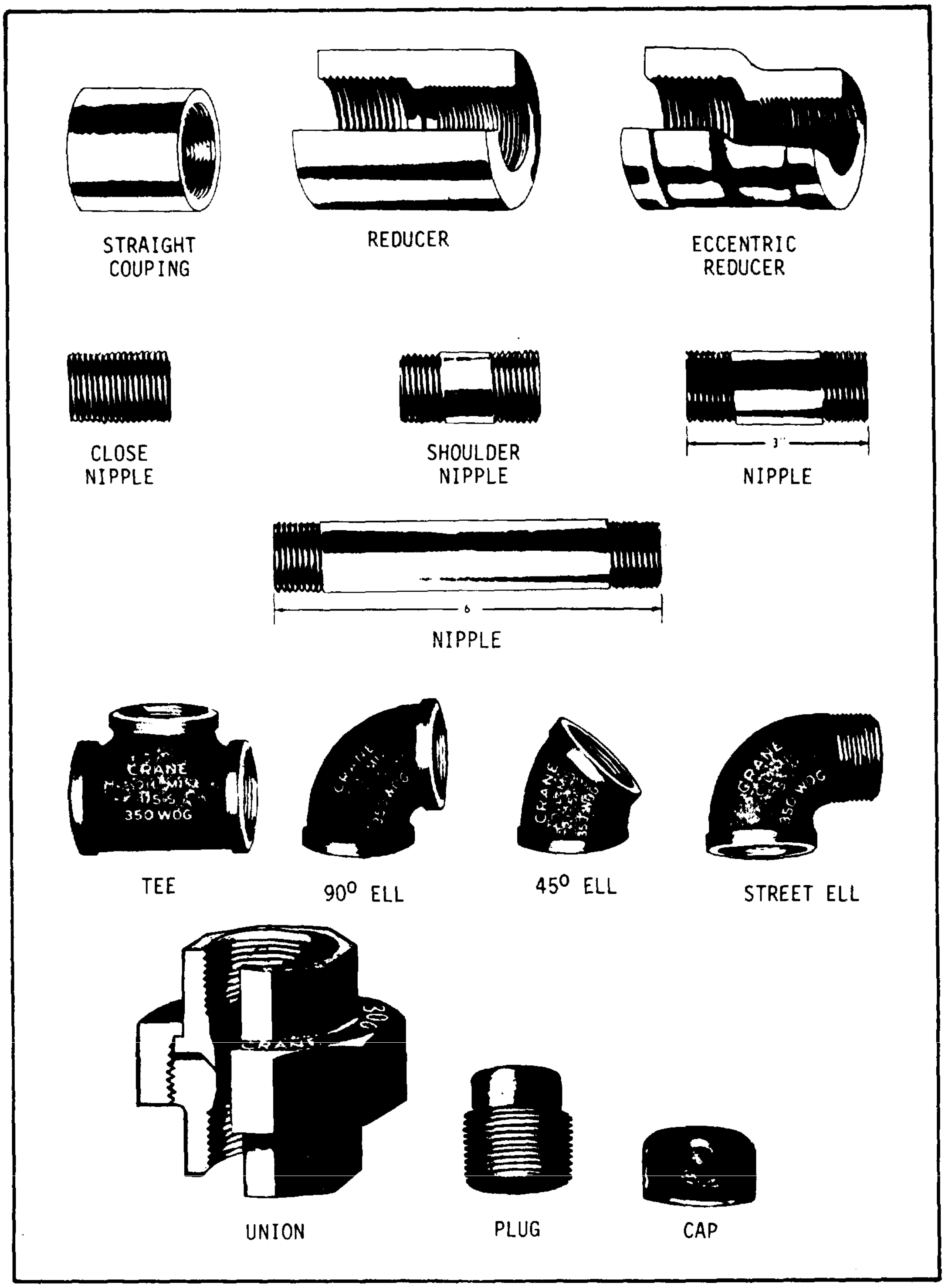


Figure 8-5.-Types of pipe fittings.

are to be joined. The purpose of dielectric fittings is to curtail galvanic or electrolytic action. The most common dielectric fittings are the union, coupling, and bushing.

Fittings are identified by the sizes of pipe that are connected to their openings. For example, a 3- by 3- by 1 1/2-in. tee is one that has two openings for a 3-in. run of pipe and a 1 1/2-in. reduced outlet. If all openings are the same size, only one nominal diameter is designated. For example, a 3-in. tee is one that has three 3-in. openings.

Joints and Connections

There are various methods of joining pipes for water distribution systems. Each method used is designed to withstand internal (hydrostatic) pressure in the pipe and normal soil loads if joints and connections are belowground. Some of these methods produce the types of joints and connections described below.

FLARED AND SWEATED JOINTS.— These joints are generally used with copper pipe and tubing. The end of a copper pipe is formed into a funnellike shape so that it can be held in a threaded fitting when a line joint is being made. This method is called FLARING, and the result is called a FLARED JOINT. A SWEATED JOINT is made with soft solder instead of threads or flares. In plumbing, copper pipe or tubing is occasionally fused by heating with a gas flame and silver-aIloy filler metal called SILVER BLAZING (also called HARD SOLDERING).

SOLVENT WELDED, FUSION WELDED, FILLET WELDED, THREADED, AND FLANGED JOINTS.— These types of joints are common to plastic pipes. In the production of a SOLVENT WELDED JOINT, a solvent cement with a primer is used. Before solvent is applied, the pipe and fitting must be thermally balanced (caused to have similar temperatures). This process should not be undertaken when the temperature is below 40°F or above 90°F or when the pipes are exposed to direct sunlight.

FUSION WELDED JOINTS are produced by the use of a gas- or an electric-heated welding tool. The process consists of simultaneously heating the meeting surfaces of the pipe and fitting to a uniform plastic state, joining the components together, and then allowing the two surfaces to fuse into a homogeneous bond as the materials cool to room temperature.

FILLET WELDED JOINTS are made by the use of a uniform heat and pressure on the welding rod during application of the bead. This process can also be applied to repair leaks in thermoplastics.

In plastic pipes, THREADED JOINTS are commonly used for temporary and low-pressure piping since threading reduces the pipe wall thickness. Only certain heavy pipes can be threaded with a special strap wrench. Teflon tape is often used for pipe joint compound when this method of joining pipes is used.

FLANGED JOINTS are extensively used for process lines that are dismantled frequently. Plastic pipes are joined together by the use of plastic flanges with soft rubber gaskets.

BELL-AND-SPIGOT AND MECHANICAL JOINTS.— These types of joints are most commonly used with cast-iron pressure pipe and fittings for water mains. These service lines are joined by the use of lead, lead wool, or sometimes a sulfur compound. Mechanical joints are made with rubber sealing rings held in place by metal follower rings that are bolted to the pipe. These are designed to permit expansion and contraction of the pipe without injury to the joints.

THREADED PIPE JOINTS are commonly used on galvanized steel, galvanized wrought iron, and black-iron pipe. The process includes connecting threaded male and female ends. Nontoxic compounds are used for t bread lubricant on water pipes, while powdered graphite and oil are used for steam pipes.

Valves

Valves are devices that are used to stop, start, or regulate the flow of water into, through, or from pipes. Essentially, valves consist of a body containing an opening and a means of closing the opening with a valve disk or plug that can be tightly pressed against a seating surface around or within the opening. Many different valve designs are available; however, only the three most common types of valves will be discussed here. They are the gate, check, and globe valves.

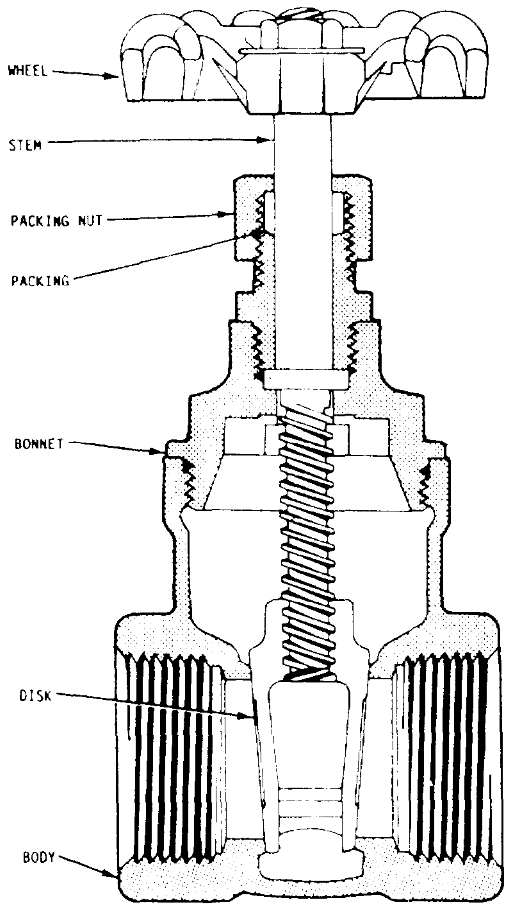


Figure 8-6.-Crow section of a gate valve.

GATE VALVE.— The gate valve (fig. 8-6) has a wedge-shaped, movable plug, called a gate, that fits tightly against the seat when the valve is closed. When the gate is opened, an unrestricted flow passage is provided. It allows fluid to flow through in a straight line with little resistance and less friction and pressure drop, provided the valve gate or disk is kept fully opened. The gate valve releases a variable amount with each turn of the gate.

Gate valves must always be operated in either their fully opened or fully closed position, never in any position to adjust the rate of flow. A partly closed gate will cause vibration and chattering, damaging the seating surfaces.

CHECK VALVE.— The check valve is used principally to prevent backflow in pipelines automatically. The valves are entirely automatic and are used where flow of liquids, vapors, or

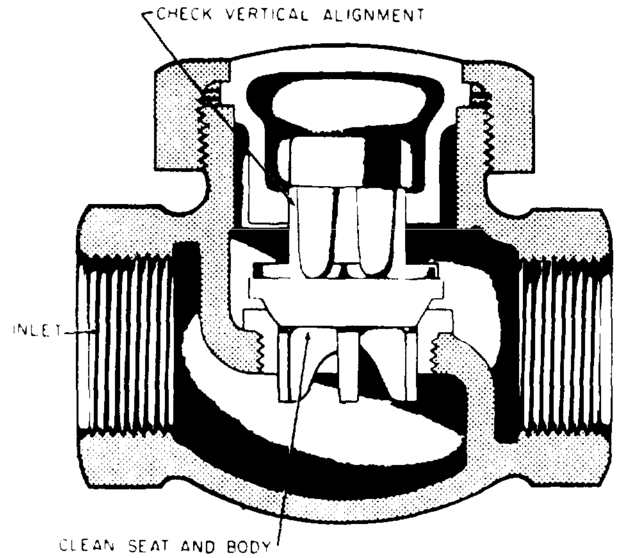


Figure 8-7.-Cross section of a swing check valve.

gases in one direction only is required. Check valves fall into two main groups: swing check valves and lift check valves. A SWING CHECK VALVE, shown in figure 8-7, is used where an unrestricted flow is desired. A LIFT CHECK VALVE is usually used for air or gases or when operation of the check valve is frequent (fig. 8-8).

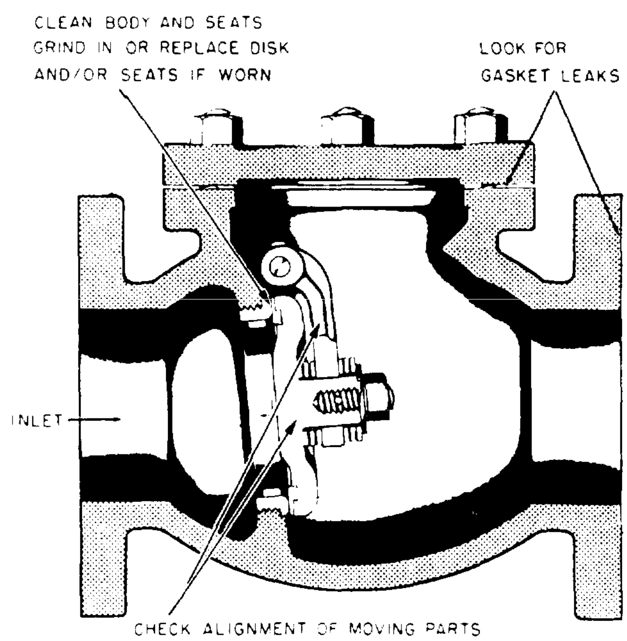


Figure 8-8.-Lift check valve.

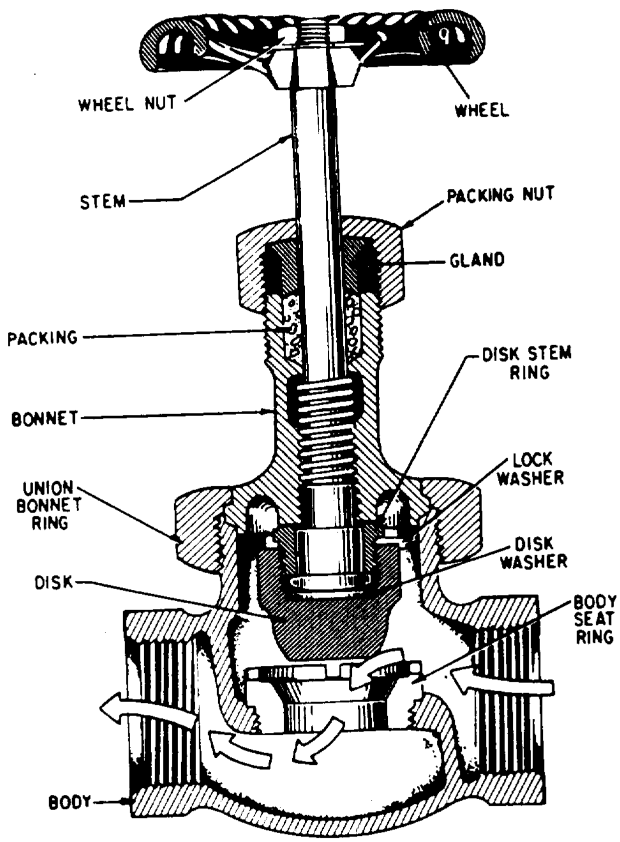


Figure 8-9.-Cross section of a globe valve.

GLOBE VALVE.— The globe valve (fig. 8-9), so-called because of its globular-shaped body, is used for regulating liquids, gases, and vapor flow by means of throttling (adjusting rate of flow). They are well suited for services requiring regulated flow and/or frequent valve settings (throttling).

Pipe Supports

Pipes are designed to be used for structural applications only to the extent of withstanding normal soil loads and internal pressures up to their hydrostatic pressure rating. Therefore, any pipe supplying air, water, or steam, when exposed aboveground and in the interior of buildings must be supported adequately to prevent sagging.

The weight of the pipes plus the weight of fluid contained in them may produce strained joints and breaks that can cause leaks in the valves. Figure 8-10 shows several methods of supporting pipe in both horizontal and vertical positions. On

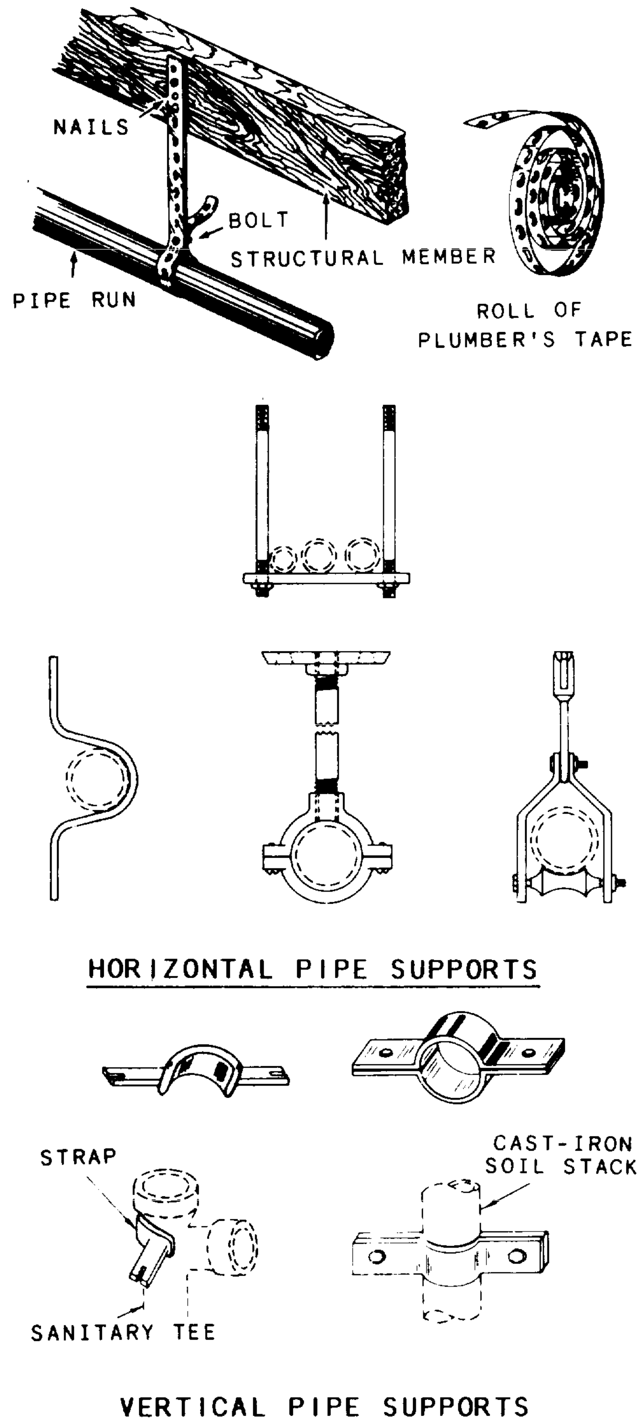
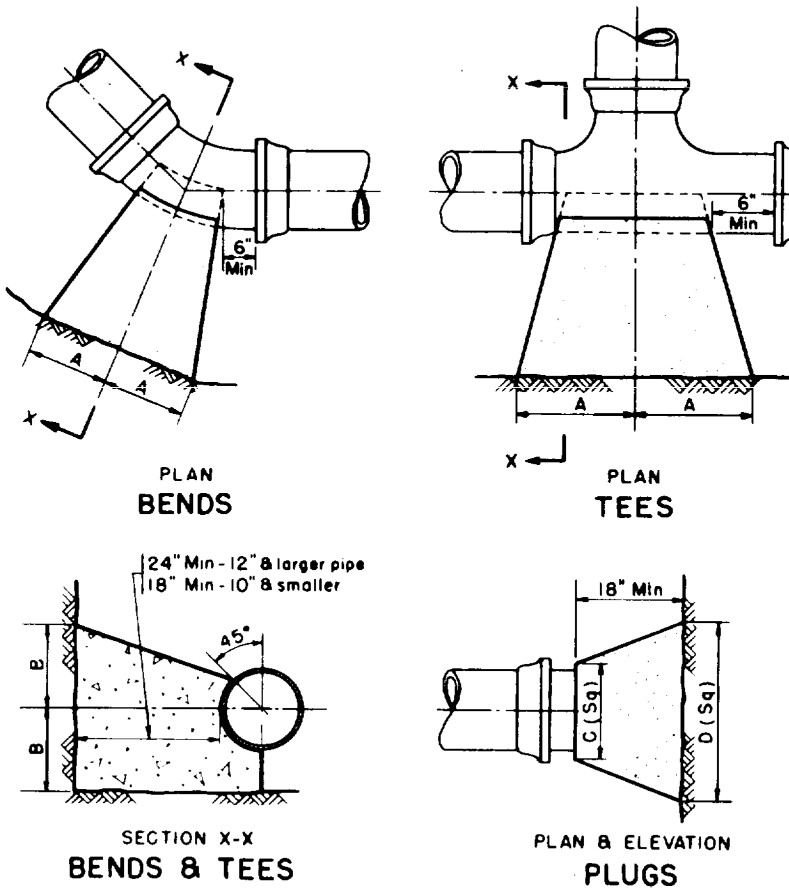


Figure 8-10.-Methods of supporting pipe.

water mains, standard thrust blocks (fig. 8-11), made of concrete or other applicable materials, are installed at all changes of direction to prevent pipe displacement caused by high water pressure.



TYPE	SIZE	1/4 BENDS		1/8 BENDS		1/16 BENDS		TEES		PLUGS	
		A	B	A	B	A	B	A	B	C	D
TYPE I 4000 PSF SOIL	6"	8"	10"	6"	8"	3"	8"	8"	8"	10"	15"
	8"	12"	12"	8"	10"	5"	9"	9"	12"	12"	20"
	10"	16"	14"	10"	12"	6"	10"	11"	14"	14"	25"
	12"	19"	16"	12"	14"	8"	11"	14"	16"	16"	30"
	14"	23"	18"	14"	16"	10"	12"	16"	18"	18"	34"
	16"	26"	20"	16"	18"	11"	13"	18"	20"	20"	38"
TYPE II 2000 PSF SOIL	6"	16"	10"	9"	10"	6"	8"	10"	12"	10"	21"
	8"	22"	13"	12"	13"	8"	10"	13"	16"	12"	29"
	10"	26"	17"	14"	17"	10"	13"	16"	20"	14"	36"
	12"	29"	21"	16"	21"	11"	16"	18"	24"	16"	41"
	14"	35"	24"	19"	24"	12"	20"	22"	27"	18"	48"
	16"	38"	27"	21"	27"	12"	24"	24"	30"	20"	54"

NOTE: Based on 100 p.s.i. static pressure plus A.W.W.A. water hammer
All bearing surfaces to be carried to undisturbed ground

STANDARD THRUST BLOCKS
FOR WATER MAINS

Figure 8-11.-Uses of thrust blocks.

Pipe Insulation

The main purpose of insulating pipelines is to prevent heat passage from steam or hot-water pipes to the surrounding air or from the surrounding air to cold-water lines. In some cold regions, insulation also prevents water from freezing in a pipe, especially when the pipe runs outside a building. Thus, hot-water lines are insulated to prevent loss of heat from the hot water, while potable waterlines are insulated to prevent absorption of heat in drinking water. Insulation also subdues noise made by the flow of water inside pipes, such as water closet discharges. Common types of pipe insulating materials are shown in figure 8-12.

SANITARY DRAINAGE SYSTEM

The purpose of a drainage system is to carry sewage, rainwater, or other liquid wastes to a point of disposal. Although there are three types of drainage systems—storm, industrial, and sanitary—only the latter, which is the most common drainage system installed by the SEABEEs, will be discussed.

The SANITARY DRAINAGE SYSTEM carries sanitary and domestic wastes from a source (or collection system) to a sewage treatment plant or facility. Surface waters and groundwaters must be excluded from this system to prevent overload of the sewage treatment facilities.

Piping Materials

The types of materials actually used will depend upon whether the installation is underground, outside buildings, underground within buildings, or aboveground within buildings. The availability of certain types of desired piping materials and fittings may also govern the type of pipe actually used.

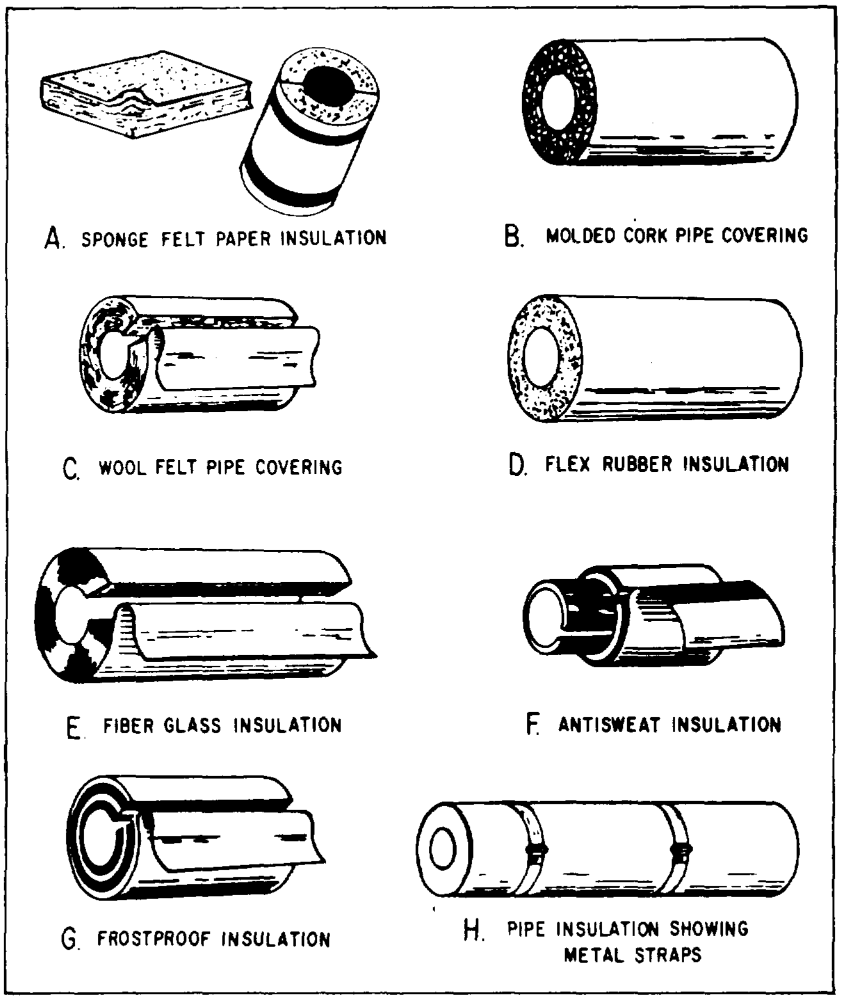


Figure 8-12.-Types of pipe insulation.

Underground piping outside of buildings may be cast-iron soil pipe, vitrified clay or concrete, or plastic polyvinyl chloride (PVC) pipe, but PVC pipes are the most common. Underground piping within buildings may also be of cast iron, galvanized steel, lead, or PVC; however, cast iron and PVC are the most popular materials used.

Aboveground sewage piping within buildings consists of either one or a combination of the following: brass or copper pipe, cast iron or galvanized wrought iron, galvanized steel or lead, and PVC pipe. Again, the reason for the growing popularity of plastic PVC piping is the unique combination of chemical and physical properties it has, ease of installation, and cost effectiveness. Descriptions and characteristics of some of the most common piping materials used in a sanitary drainage system follow.

CAST-IRON SOIL PIPE (CISP).— This type of pipe is composed of gray cast iron made of compact, close-grained pig iron; scrap iron and steel; metallurgical coke; or limestone. Cast-iron soil pipe is normally used in or under buildings, protruding at least 5 ft from the building. Here, it connects into a concrete or clay sewer line. Cast-iron soil pipe is also used under roads or other places of heavy traffic. If the soil is unstable or contains cinder and ashes, vitrified clay pipe is used instead of cast-iron soil pipe.

Cast-iron soil pipe comes in 5-ft and 10-ft lengths, with nominal inside diameters of 2, 3, 4, 5, 6, 8, 10, 12, and 15 in. It is available as single-hub or double-hub in design, as indicated in figure 8-13. Note that single-hub pipe has a hub at one end and a spigot at the other, while a double-hub pipe has a hub on each end. Hubs or bells of cast-iron soil pipe are enlarged sleevelike fittings that are cast as a part of the pipe to make watertight and pressure-tight joints with oakum and lead.

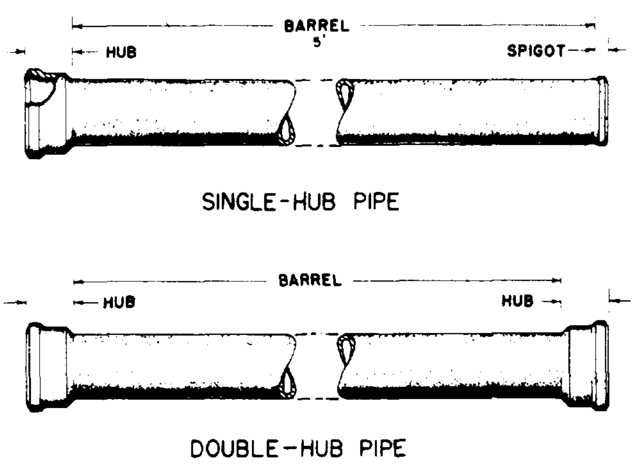


Figure 8-13.-Single-hub and double-hub cast-iron soil pipe.

VITRIFIED CLAY AND CONCRETE PIPE.— Vitrified clay pipe is made of moistened, powdered clay. It is available in laying lengths of 2, 2 1/2, and 3 ft and in diameters ranging from 4 to 42 in. Like cast-iron soil pipe, it has a bell end and a spigot end to facilitate joining. Vitrified clay pipe is used for house sewer lines, sanitary sewer mains, and storm drains.

Precast concrete pipe may be used for sewers in the smaller sizes—those less than 24 in. This pipe is not reinforced with steel. Dimensions of concrete pipe are similar to those of vitrified clay pipe.

PLASTIC PIPE.— The use of rigid plastic pipe has expanded greatly over the years. Years ago, plastic piping was used extensively for farm water systems, lawn sprinklers, and some other domestic and industrial uses. Now, plastic pipe is used for all kinds of water and drainage applications.

Plastic piping has outstanding resistance to nearly all acids, caustics, salt solutions, and other corrosive liquids and gases. It does not rust, corrode, scale, or pit inside or outside. It is also nontoxic, nonconductive, and not subject to electrolytic corrosion—a major cause of failure when metal pipe is installed underground. Another important advantage of plastic pipe is low resistance to abrasion because of its smooth inner wall, resulting in maximum flow rate and minimum buildup of sludge and slime.

Fittings

The types of fittings, joints, and connections used by water distribution are strikingly similar to those used by waste drainage systems. In sanitary or waste drainage systems, fittings also vary according to the type of piping materials used; however, special mechanical seal adapters are available for joining different types of pipes, such as cast-iron soil pipes to vitrified clay, or vice versa. Some of the fittings commonly

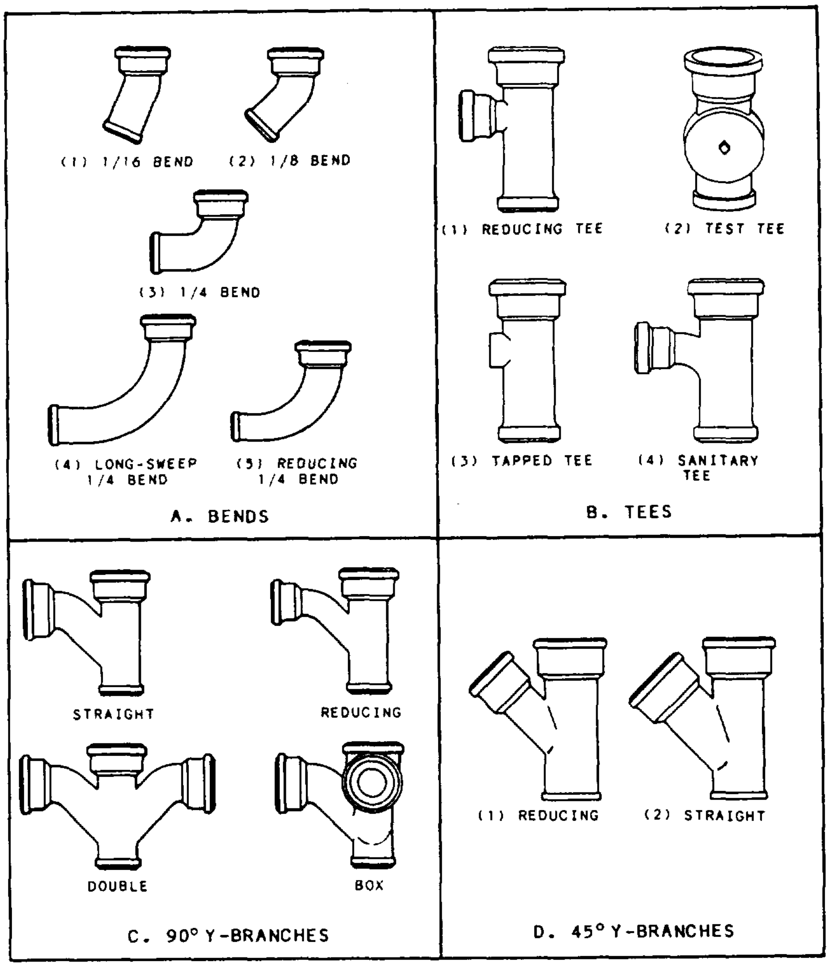


Figure 8-14.-Common cast-iron soil pipe fittings.

used are shown in figure 8-14 and described below.

BENDS.— The 1/16 bend (fig. 8-14, view A) is used to change the direction of cast-iron soil pipe 22 1/2°. A 1/8 bend changes the direction 450. The direction is changed 90° in a close space when the SHORT-SWEEP 1/4 bend is used. The LONG-SWEEP 1/4 bend is used to change the direction 90° more gradually than a quarter bend. The REDUCING 1/4 bend changes the direction of the pipe gradually 90°, and in the sweep portion, it reduces nearly one size.

TEES.— Tees (fig. 8-14, view B) are used to connect branches to continuous lines. For connecting lines of different sizes, REDUCING tees are often used. The TEST tee is used in stack and waste installations where the vertical stack joins the horizontal sanitary sewer. It is installed at this point to allow the plumber to insert a test tee and fill the system with water while testing for leakage. The TAPPED tee is frequently used in the venting system where it is called the main vent tee. The SANITARY tee is commonly used in a main stack to allow the takeoff of a cast-iron pipe branch.

NINETY-DEGREE Y-BRANCHES.— Four types of cast-iron soil pipe 90° Y-branches generally used are shown in figure 8-14, view C. These are normally referred to as COMBINATION Y AND 1/8 BENDS. The STRAIGHT type of 90° Y-branch is used in sanitary sewer systems where a branch feeds into a main, and it is desirable to have the incoming branch feeding into the main as nearly as possible in a line parallel to the main flow. The REDUCING 90° Y-branch is the same as the straight type, except that the branch coming into the main is a smaller size pipe than the main. The DOUBLE 90° Y-branch (or DOUBLE

COMBINATION Y and 1/8 BEND) is easy to recognize since there is a 450 takeoff bending into a 90° takeoff on both sides of the fitting. It is especially useful as an individual vent. The BOX type 90° Y-branch has two takeoffs. It is designed so that each takeoff forms a 90° angle with the main pipe. The two takeoffs are spaced 900 from each other.

FORTY-FIVE-DEGREE Y-BRANCHES.— The two types of 45° Y-branches (fig. 8-14, view D) are the reducing and straight types. They are used to join two sanitary sewer branches at a 45° angle. The REDUCING type is a straight section of pipe with a 45° takeoff of a smaller size branching off one side. The STRAIGHT type of 45° Y-branch, or true Y, is the same as the reducing type except that both bells are the same size.

Figure 8-15 shows some common fittings used with vitrified clay and concrete pipes. It should be noted that these types of pipes are used outside the building, which greatly reduces the number of different types of fittings. Joints on vitrified clay and concrete pipe are made of cement or bituminous compounds. Cement joints might be made of grout—a mixture of cement, sand, and water.

Plastic pipe fittings for waste drainage are shown in figure 8-16.

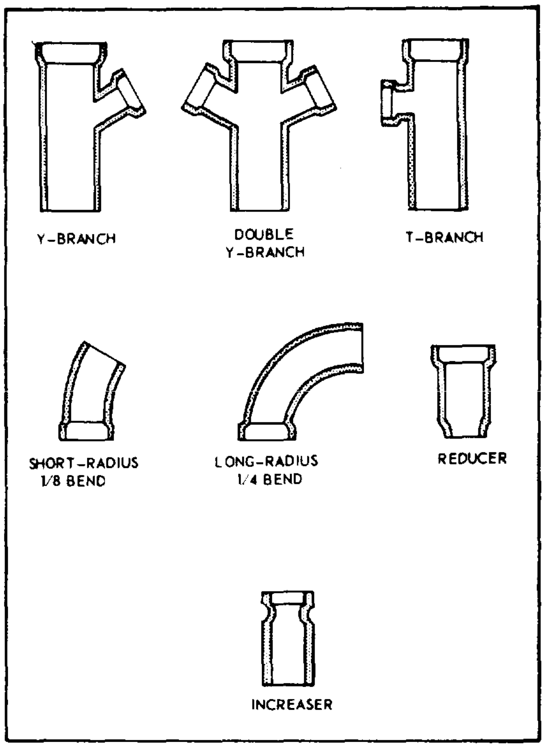


Figure 8-15.-Cross section of vitrified clay or concrete pipe fittings.

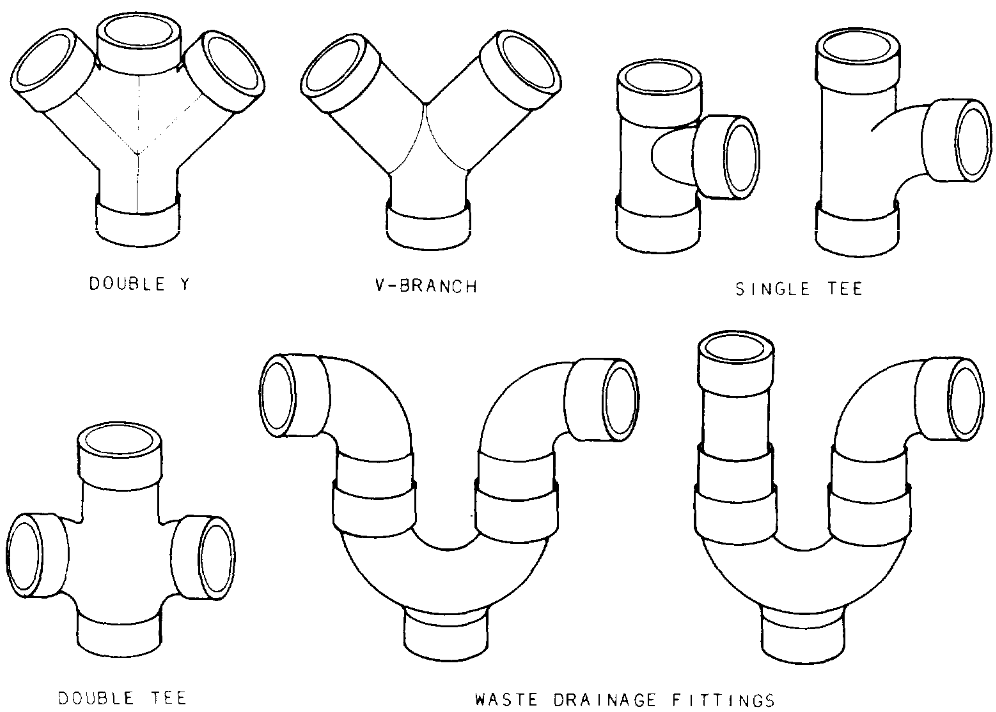


Figure 8-16.-Typical plastic pipe fittings.

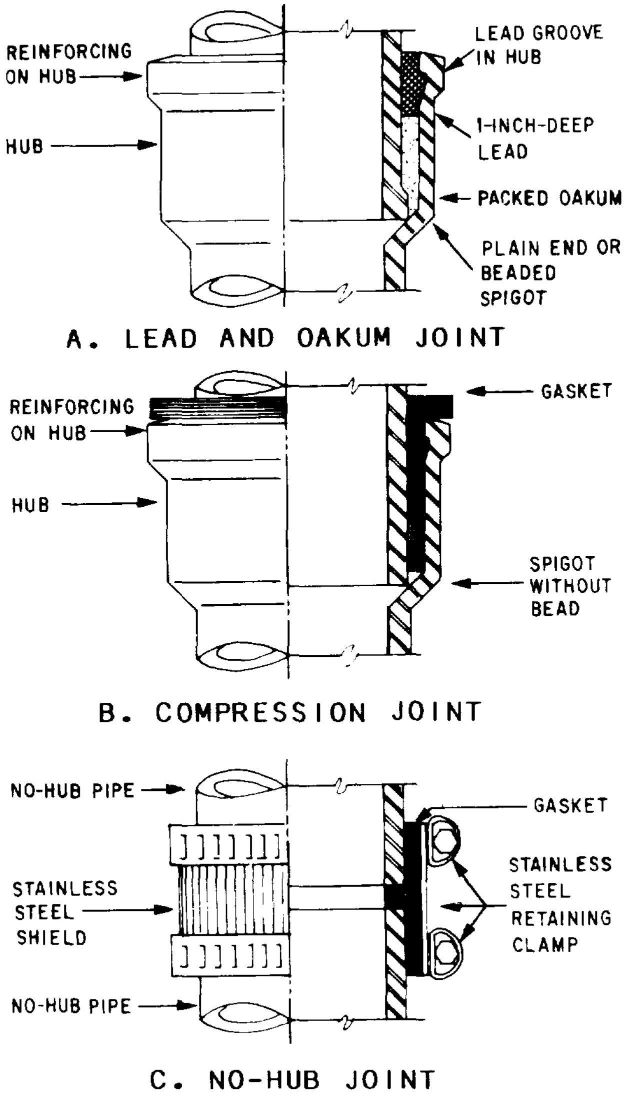


Figure 8-17.-Various joints currently used to connect CISP and fittings.

Joints and Connections

Various types of joints and connections used in waste drainage systems are described below.

LEAD AND OAKUM JOINT, COMPRESSION JOINT, AND NO-HUB JOINT.— These types of joints (fig. 8-17) are used to connect cast-iron soil pipes (CISP) and fittings. In lead and oakum joints, oakum (made of hemp impregnated with bituminous compound and loosely twisted or spun into a rope or yarn) is packed into the hub completely around the joint, and melted lead is poured over it (fig. 8-17, view A).

In compression joints, an assembly tool is used to force the spigot end of the pipe or fitting into the lubricated gasket inside the hub (fig. 8-17, view B). A no-hub joint uses a gasket on the end of one pipe and a stainless steel shield and clamp assembly on the end of the other pipe (fig. 8-17, view C).

MORTAR OR BITUMINOUS JOINTS.— This type of joint is common to vitrified clay and concrete pipes and fittings. Mortar joints may be made of grout (a mixture of cement, sand, and water).

The use of SPEED SEAL JOINTS (rubber rings) in joining vitrified clay pipe has become widespread. Speed seal joints eliminate the use of oakum and mortar joints for sewer mains. This type of seal is made a part of the vitrified pipe joint when manufactured. It is made of polyvinyl chloride and is called a plastisol joint connection.

Traps

A trap is a device that catches and holds a quantity of water, thus forming a seal that prevents the gases resulting from sewage decomposition from entering the building through the pipe. A number of different types of traps are available; however, the trap mainly used with plumbing fixtures is the P-TRAP (fig. 8-18). It comes in sizes from 1 1/4 in. to 6 in. in diameter. P-traps are usually made of nickel or chrome-plated brass, malleable galvanized or wrought iron, copper, other metal alloys, and plastic.

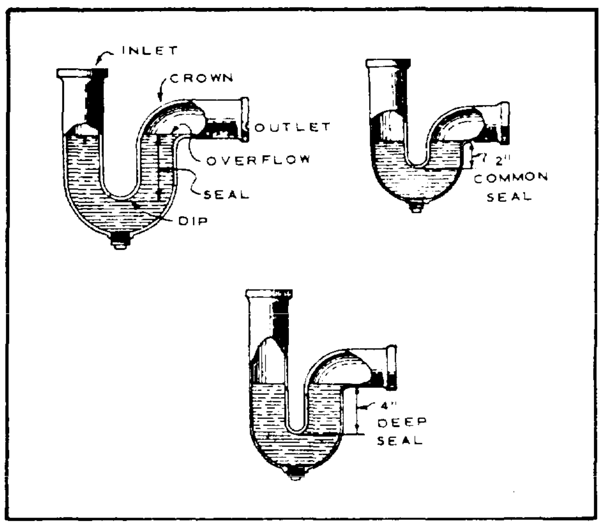


Figure 8-18.-P-traps.

Traps are commonly installed on fixtures, such as lavatories, sinks, and urinals. At times, the P-trap may also be suitable in shower baths and other installations that do not require wasting of large amounts of water.

Vents

A VENT (pipe) allows gases in the sewage drainage system to discharge to the outside. It also allows sufficient air to enter, reducing the air turbulence in the system. Without a vent, once the water is discharged from the fixture, the moving waste tends to siphon the water from the other fixture traps as it goes through the pipes. This means that the vent piping must serve the various fixtures, as well as the rest of the sewage drainage system. The vent from a fixture or group of fixtures ties in with the main vent. A MAIN VENT is the principal artery of the venting system to which vent branches maybe connected and run undiminished in size as directly as possible from the building drain to the open air above (fig. 8-19).

The MAIN SOIL AND WASTE VENT or VENT STACK, installed in a vertical position, refers to the portion of the stack that extends above the highest fixture branch, through the roof, and to the exterior of the building.

Various types of vents are used in the ventilation of fixtures. The selection of a particular type depends largely on the manner in which the plumbing fixtures are to be located and grouped.

An INDIVIDUAL VENT, also known as a BACK VENT, connects the main vent with the individual trap underneath or behind a fixture. This method of venting is shown in figure 8-19.

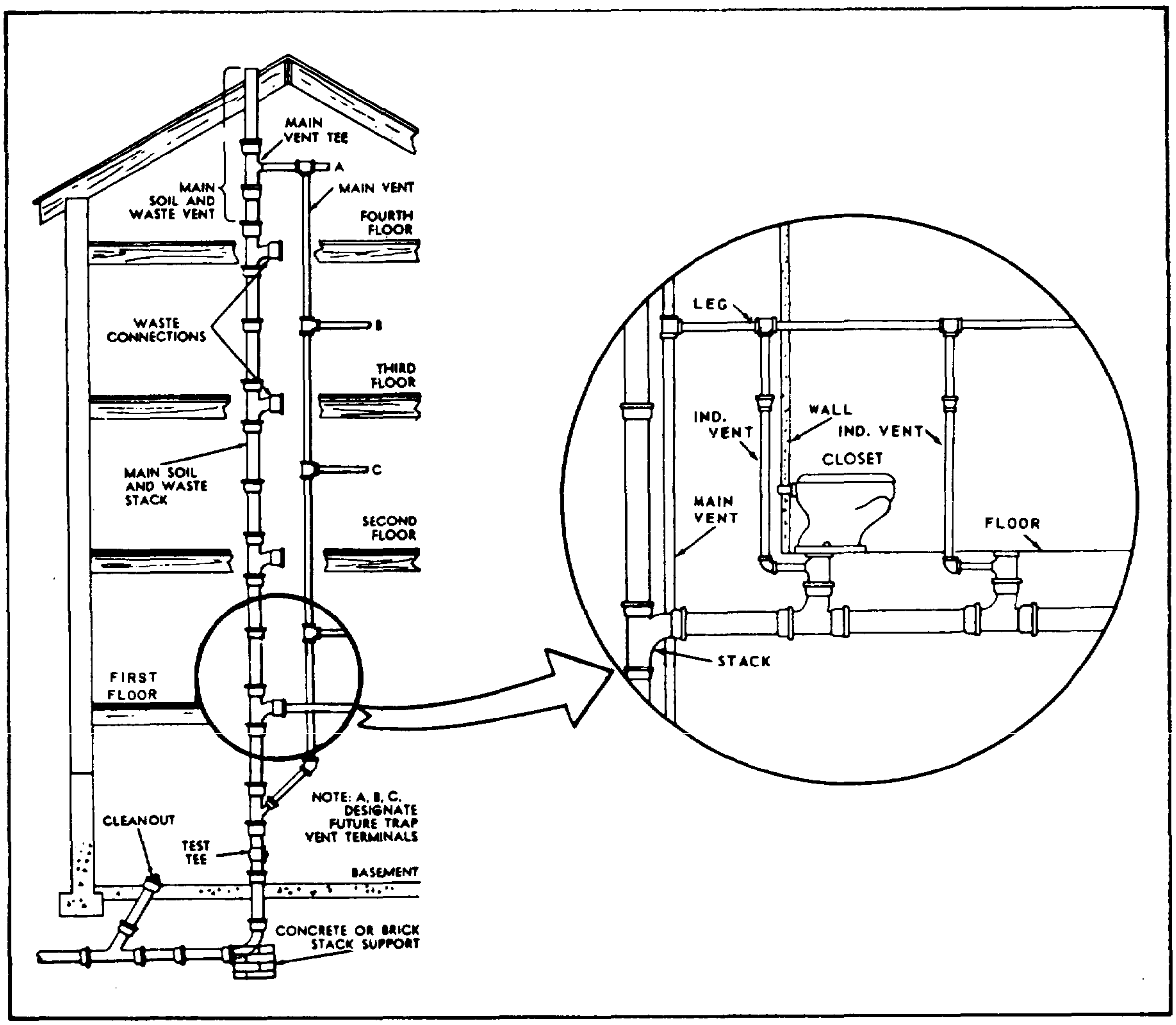


Figure 8-19.-Typical stack and vent installation.

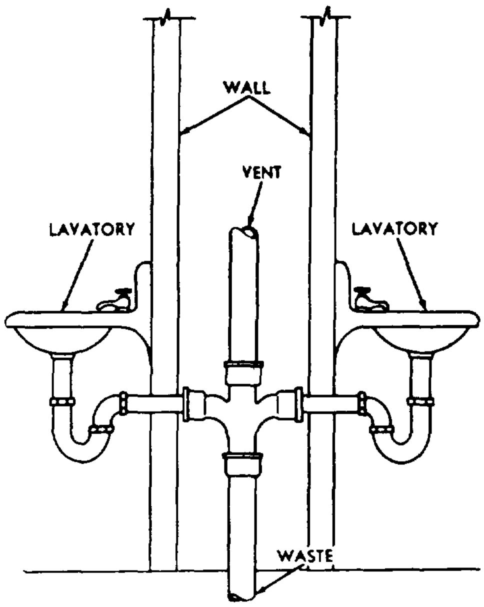


Figure 8-20.-Two fixture units sharing a common vent.

A COMMON VENT vents two traps to a single vent pipe, as shown in figure 8-20. The unit vent can be used when a pair of lavatories is installed side by side, as well as when they are hung back to back on either side of a partition (as shown in the figure). A point to note is that the waste from both fixtures discharges into a double sanitary tee.

A CIRCUIT VENT serves a group of fixtures. As shown in figure 8-21, a circuit vent extends from the main vent to a position on the horizontal branch between the last two fixture connections. If more than eight fixtures are to be vented, an additional circuit vent is to be installed. In this type of vent, water and waste discharged by the last fixture tend to scour the vents of other fixtures on the line.

When liquid wastes flow through a portion of a vent pipe, the pipe is known as a WET VENT. A LOOP VENT is the same, except that it connects into the stack unit to form a loop. This type may be used on a small group of bathroom fixtures, such as a lavatory, water closet, and shower, as shown in figure 8-22. The pipe for a wet vent installation should be sized to take care of the lavatory, water closet, and shower.

NOTE: The pipe for a wet vent installation should never be under 2 in. in diameter when it will be draining more than four fixture units. A water closet should not drain into a wet vent.

As shown in figure 8-22, the lavatory should be individually vented. This is necessary to prevent loss of the trap seal through indirect siphonage. Another point to note is that the relatively clean water discharged from the lavatory will tend to scour the wet vent, preventing an excessive buildup of waste material in the vent.

Materials used in vent piping ordinarily include galvanized pipe, cast-iron soil pipe, and, at times, brass, copper, and plastic piping.

In all phases of the venting system, it is best to use proper-sized piping. Remember that the diameter of the vent stack or main vent must be no less than 2 in. The actual diameter depends on the developed length of the vent stack and on the number of fixture units installed on the soil or waste stack. The diameter of a vent stack should be at least as large as that of the soil or waste stack.

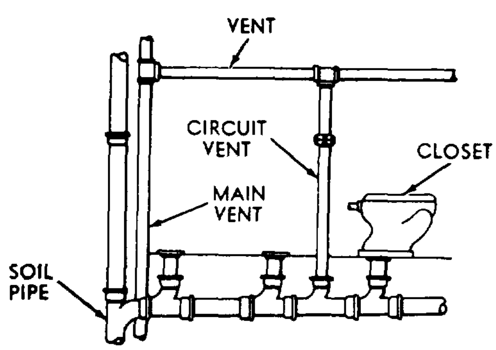


Figure 8-21.-Use of a circuit vent.

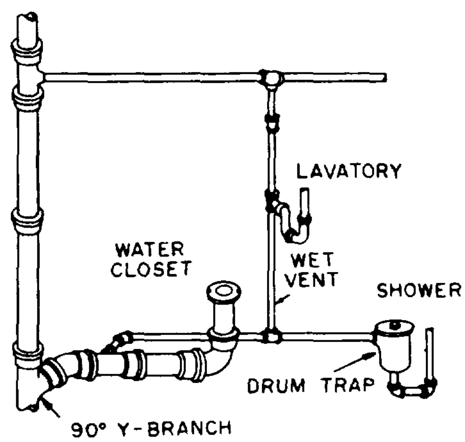


Figure 8-22.-Use of a wet vent.

Branches

Solid and waste pipe BRANCHES are horizontal branch takeoffs that connect various fixtures and the vertical stack (fig. 8-19). One method of installing a branch takeoff from the vertical stack is to use a Y-branch with a 1/8 bend caulked into it. Another method is to use a sanitary tee, which is an extra-short-pattern 900 Y-branch. Of these two methods, the sanitary tee is better because you eliminate one fitting and an extra caulked joint, both of which arc required for the 1/8 bend takeoff.

In some cases, however, the combination Y and 1/8 bend is used more often than the sanitary tee when local codes allow more fixture units to be connected to a stack of a given size.

Generally, waste pipes are graded downward to ensure complete drainage. Horizontal vents are also pitched slightly to facilitate discharge of condensation.

MECHANICAL PLAN

A mechanical plan, as used in this chapter, includes drawings, layouts, diagrams, and notes that refer only to water distribution and sanitary drainage systems. Heating and air conditioning, refrigeration, and other like systems will not be discussed in this section. In the Navy, mechanical systems vary, depending on whether these systems are aboard ship or shore-based. As an EA, you will be mainly concerned with the shore-based systems, which may be permanent installations with the most modern fixtures, equipment, and appurtenances, or temporary installations at advanced bases. For temporary installations, the most economical materials that will serve the purpose are normally used.

WATER SUPPLY AND DISTRIBUTION DIAGRAM

The water supply system for a building starts from a single source—the water main. Water is tapped from this source with a self-tapping machine (fig. 8-23, view B), and a corporation stop (fig. 8-23, view A) is installed. Cold water enters the building through a cold-water service

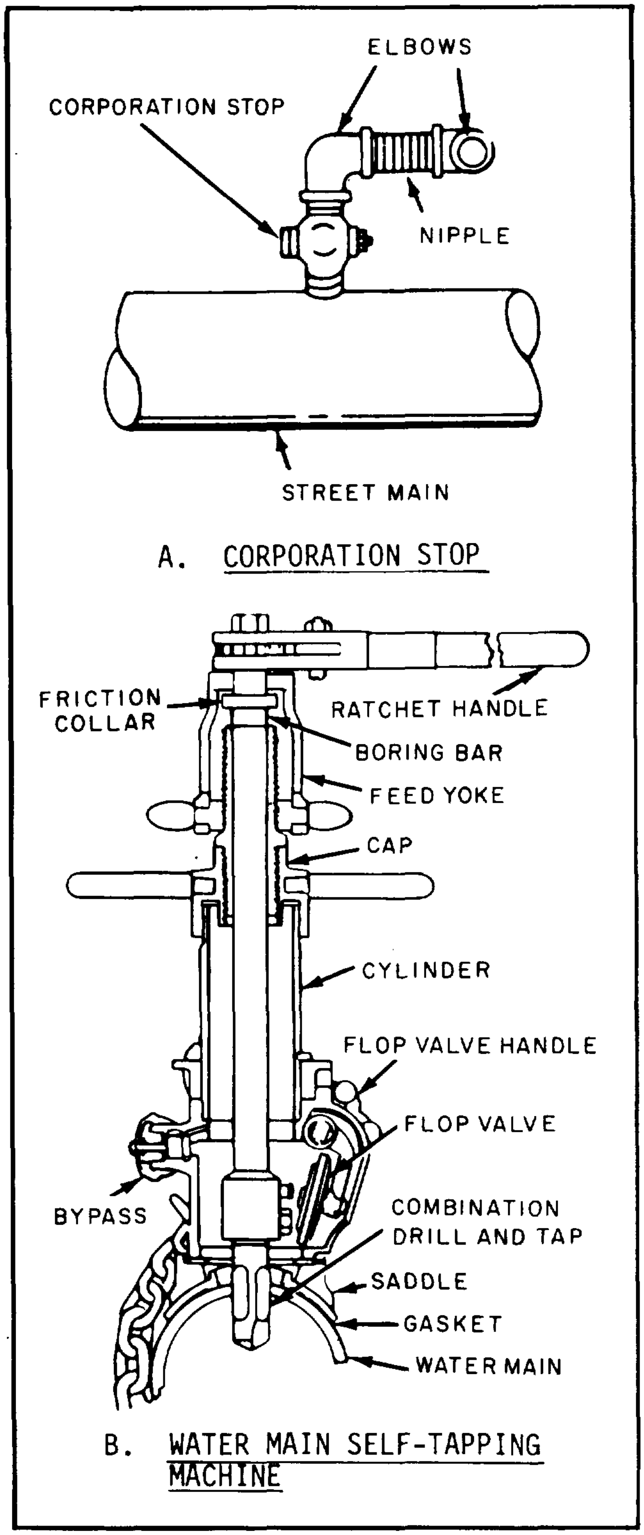


Figure 8-23.-Use of corporation stop and self-tapping machine.

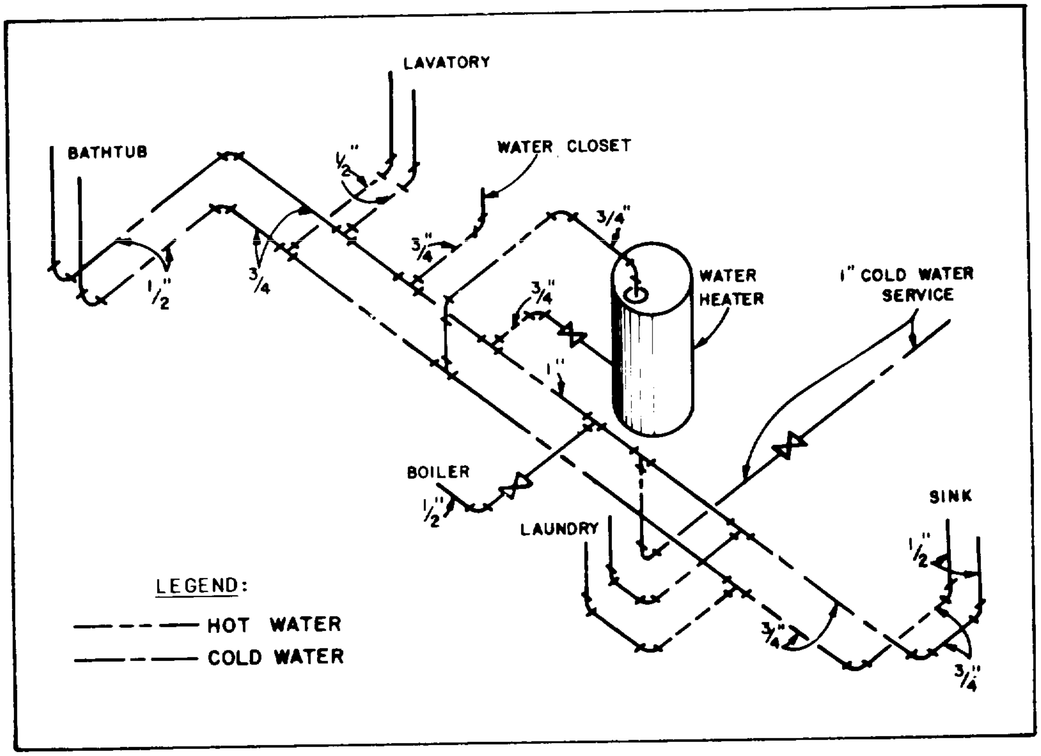


Figure 8-24.-Typical hot and cold water risers diagram.

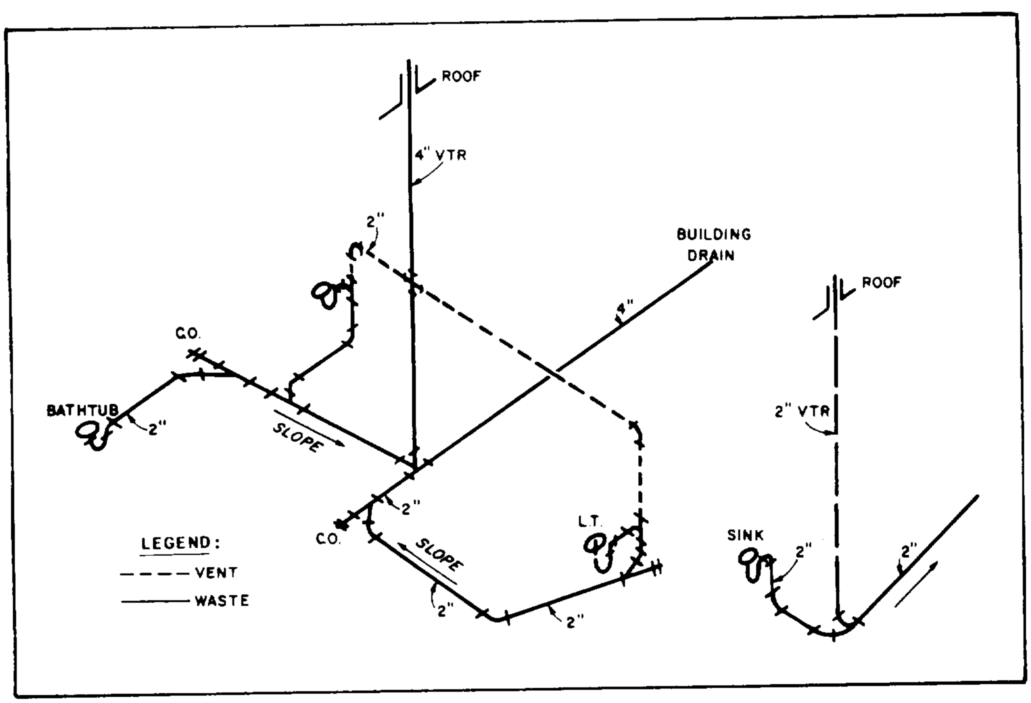


Figure 8-25.-Example of a waste and soil risers diagram.

line. Figure 8-24 shows typical hot- and cold-water service lines for a single-story residential building and how they are connected to feed the fixtures. This type of layout is often called a RISER DIAGRAM. This diagram, in isometric, is a method of visualizing or showing a three-dimensional picture of the pipes in one drawing.

WASTE AND SOIL DRAINAGE DIAGRAM

Figure 8-25 shows the waste and soil pipes and. associated fitting symbols in a riser diagram. The arrow represents the direction of flow. If you notice, all the pipes are sloping towards the building drain. Figure 8-26 further shows the basic layout of a drainage system. The function of each part is as follows:

- FIXTURE BRANCHES are horizontal drainpipes connecting several fixtures to the stack.

- A FIXTURE DRAIN extends from the P-trap of a fixture to the junction of that drain with any other drainpipe.

- SOIL AND WASTE FIXTURE BRANCHES feed into a vertical pipe, referred to as a stack. If the waste carried by the fixture branch includes human waste (coming from water closets or from a fixture with similar functions), the stack is called a SOIL STACK. If a stack carries waste that does not include human waste, it is referred to as a WASTE STACK. These stacks service all the fixture branches beginning at the top branch and go vertically to the building drain.

- A BUILDING DRAIN (also referred to as a house drain) is the lowest piping part of the drainage system. It receives the discharge from the soil, waste, and other drainage pipes inside the building and extends to a point 3 ft outside the building wall. (Most local codes require that the house drain extend at least 3 ft beyond the building wall, but a few local requirements range from 2 to 10 ft.)

- A BUILDING SEWER is that part of the horizontal piping of a drainage system that extends from the end of the building drain. It

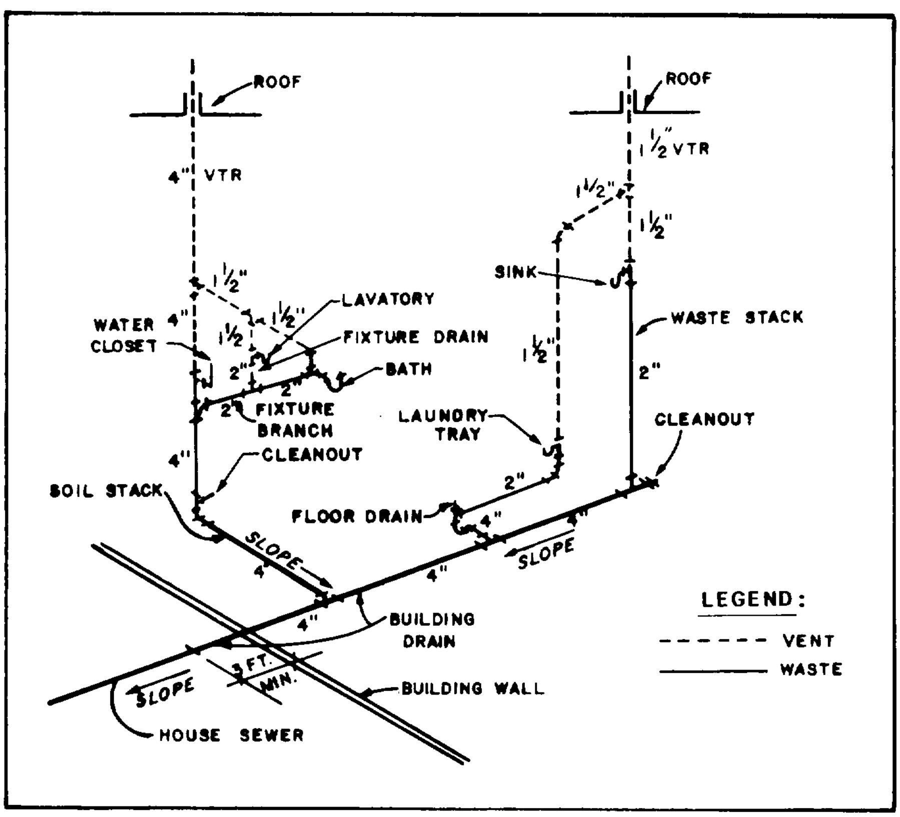


Figure 8-26.-Basic layout of a drainage system.

conveys the waste to the community sewer or an independent disposal unit.

● A FLOOR DRAIN is a receptacle used to receive water to be drained from the floors into the drainage system. Floor drains are usually located near the heating equipment and in the vicinity of the laundry equipment or any unit subject to overflow or leakage.

● A CLEANOUT is a unit with a removable plate or plug that provides access into plumbing or other drainage pipes for cleaning out extraneous material.

PLUMBING LAYOUT

In construction drafting, a mechanical (or utility) plan normally includes both water

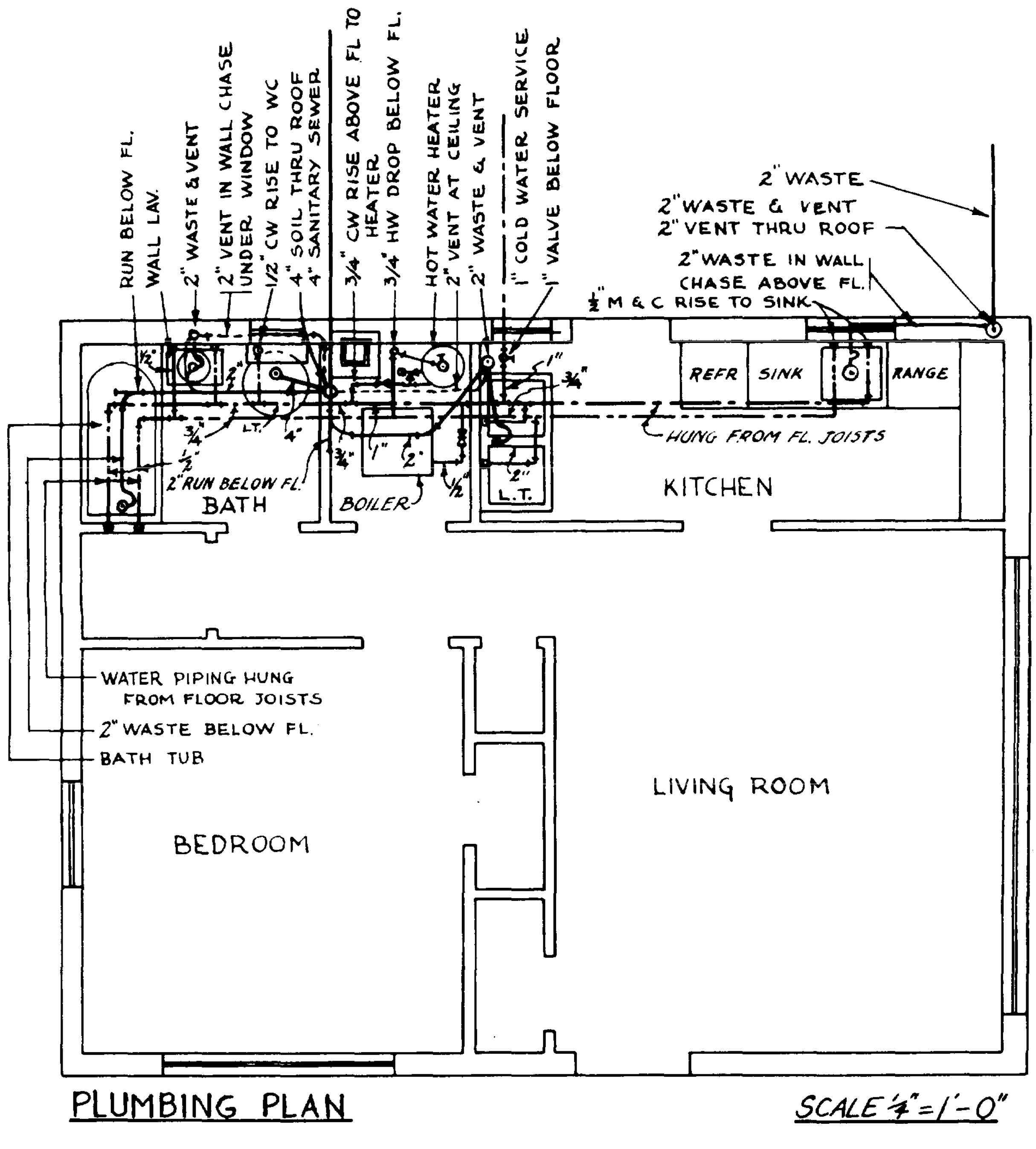


Figure 8-27.-Typical plumbing layout for a small residential building.

distribution and sanitary drainage systems combined, especially on smaller buildings or houses. The plumbing layout is usually drawn into a copy of the floor plan for proper orientation with existing plumbing fixtures, walls and partition outlines, and other utility features. Figure 8-27 shows a typical plumbing layout. The reproduction is, unfortunately, too small to be easily studied, but you can see that it uses the mechanical symbols. Refer to ANSI Y32.4-1977, *Graphic Symbols Used in Architectural and Building Construction* and MIL- STD-17-1, *Mechanical Symbols.*

As shown in figure 8-27, the cold-water service line, which enters the building near the laundry trays, is indicated by a broken dash-and-single-dot line, while the waste pipes are indicated by solid lines. If you follow the cold-water service line, you will see how it passes, first, a 1-in. main shutoff valve below the floor and just inside the building wall. From here, it proceeds to a long pipe running parallel to the building wall and hung under the floor joists, which services, beginning at the right-hand end, the cold-water spigot in the sink, the cold-water spigot in the laundry, the hot-water heater, the boiler for the house heating system, the flushing system in the water closet (W.C.), the cold-water spigot in the bathroom washbasin, and the cold-water spigot in the bathtub. The below-the-floor line is connected to the spigots by vertical RISERS. Valves at the hot-water heater and boilers are indicated by appropriate symbols.

From the hot-water heater, you can trace the hot-water line (broken dash-and-double-dot line) to the hot-water spigots in the sink, laundry, bathroom washbasin, and bathtub. This line is also hung below the floor joists and connected to the spigots by risers.

You can see the waste line (solid line) for the bathtub, washbasin, and W.C. (with traps indicated by bends) running under the floor from the bathtub by way of the washbasin and W.C. to the 4-in. sanitary sewer. Similarly, you can see the waste line from the laundry running to the same outlet. However, the kitchen sink has its own, separate waste line. The bathroom utilities waste lines vent through a 4-in. pipe running through the roof; the sink waste line vents through a 2-in. pipe running up through the roof.

MECHANICAL SYMBOLS

As stated earlier in this chapter, the Engineering Aid is not expected to design the system, but the main objective is to draw a workable plumbing plan for use by the plumbing crew or any other interested parties. In order to accomplish this, the EA must be familiar with the terms, symbols, definitions, and the basic concepts of the plumbing trade.

As a rule, plumbing plans should show the location of the fixtures and fittings to be installed and the size and the route of the piping. The basic details are left to the plumber (UT), who is responsible for installing a properly connected system according to applicable codes, specifications, and good plumbing and construction practices. Generally, plumbing plans consist of four types of symbols: piping, fittings, valves, and fixtures.

Piping Symbols

The line symbols for piping shown in figure 8-28 are composed of solid or dashed lines that indicate the type and location of that particular

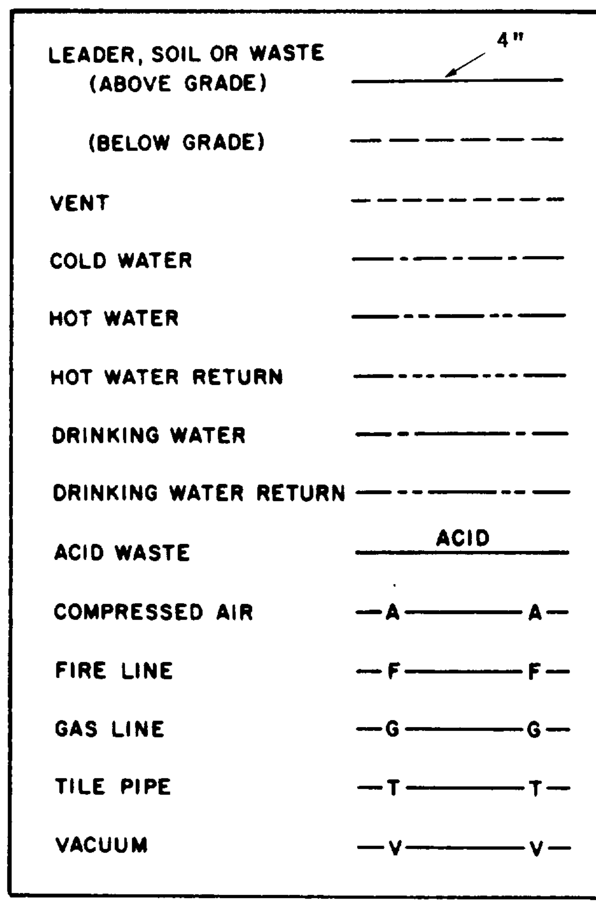
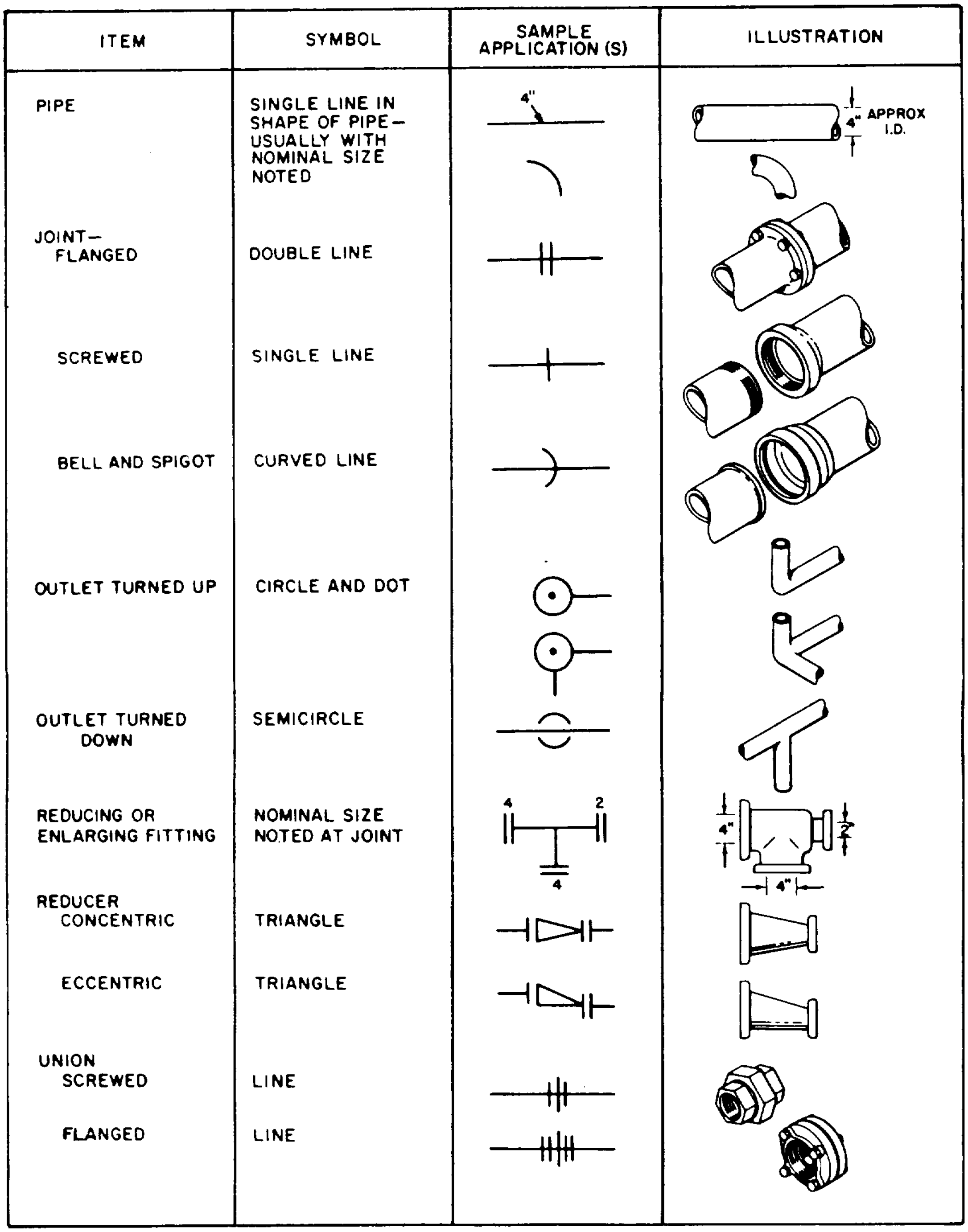


Figure 8-28.-Line symbols for piping.

pipe on the plan. Other line symbols identify the proposed use of the pipes. The size of the required piping should also be noted alongside each route of the plan. Piping up to 12 in. in diameter is referred to by its nominal size, which is approximately equal to the inside diameter (I.D.). The exact inside diameter depends on the classification of the pipe. Heavy types of piping have smaller inside diameters because their wall thickness is greater. Piping over 12 in. in diameter is referred to by its outside diameter (O.D.).

Fitting Symbols

The pipe-fitting symbols shown in figure 8-29 are the basic line symbols used for pipes, in



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

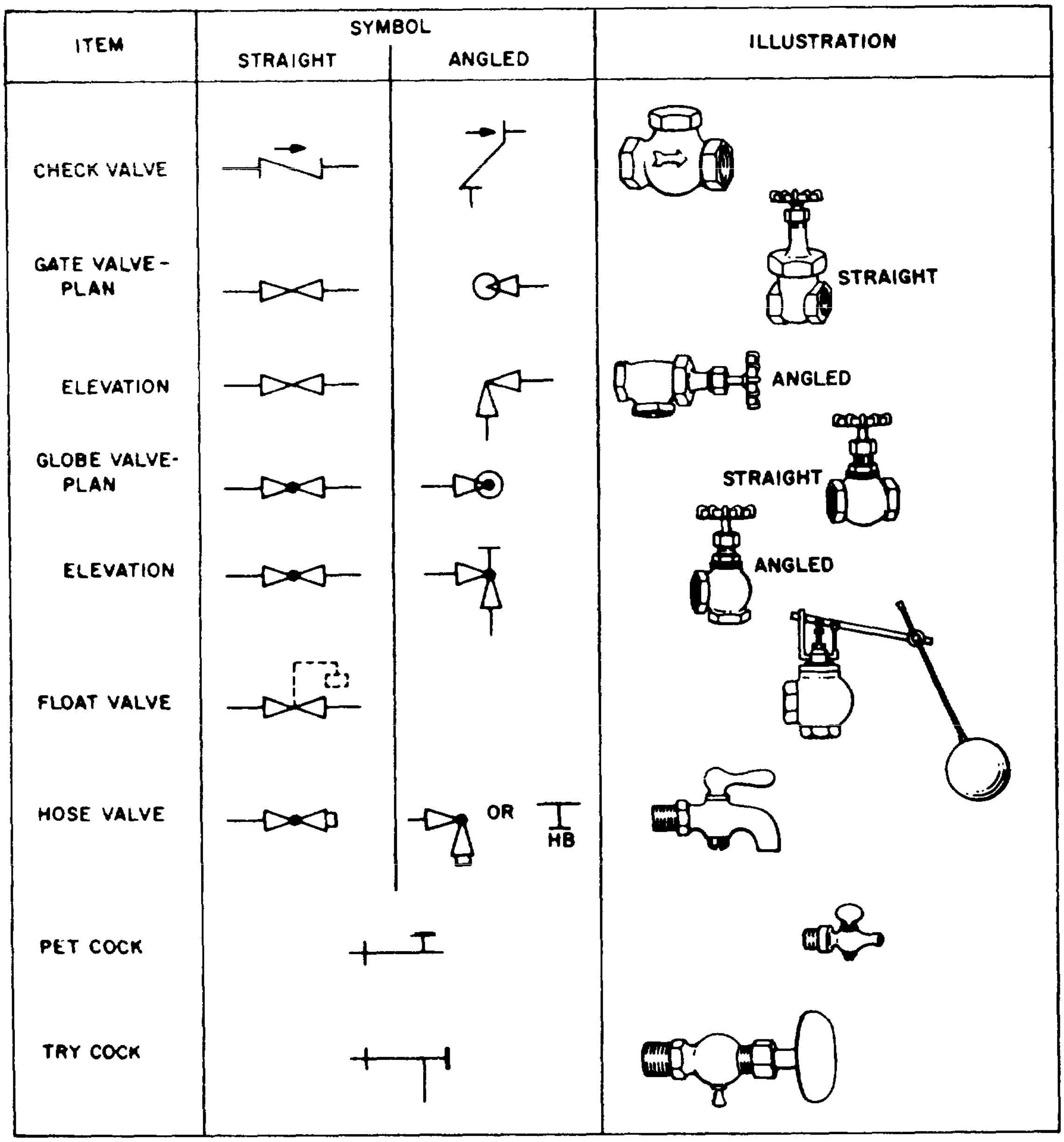
Figure 8-29.-Pipe-fitting symbols.

conjunction with the symbology of pipe fittings or valves. They define not only the size of the pipe and the method of branching and coupling, but also the purpose for which the pipe will be used. This is important because the type of material from which the pipe is made deter-mines how the pipe should be used.

Figure 8-29 covers only a few of the symbols for fittings, joints, and connections used in the plumbing system. For additional symbols on welded and soldered joints, refer to the appendices on plumbing symbols found in the back of this book .

Valve Symbols

Figure 8-30 shows the symbols used for the most frequently encountered valves. The type of material and size of valves are normally not noted on mechanical drawings but must be assumed from the size and material of the connected pipe.



NOTE: SYMBOLS ARE SHOWN FOR SCREWED FITTINGS – SYMBOLS FOR JOINTS ARE ADDED FOR OTHER TYPES

Figure 8-30.-Valve symbols.

However, when specified on the lists of materials or plumbing takeoff, valves are called out by size, type of material, and working pressure; for example, 2-in. gate valve, PVC, 175-lb working pressure.

Fixture Symbols

The symbols shown in figure 8-31 are for general appurtenances, such as drains and sumps, but other fixtures, such as sinks, water closets, and shower stalls, are shown on the plans by pictorial or block symbols. The extent to which the symbols are used depends on the nature of the drawing. In many cases, the fixtures will be specified on a bill of materials or other schedules keyed to the plumbing plan. When the fixtures are described on the schedule, the EA can use symbols that closely resemble the actual fixtures or obtain mechanical symbol templates that are available commercially.

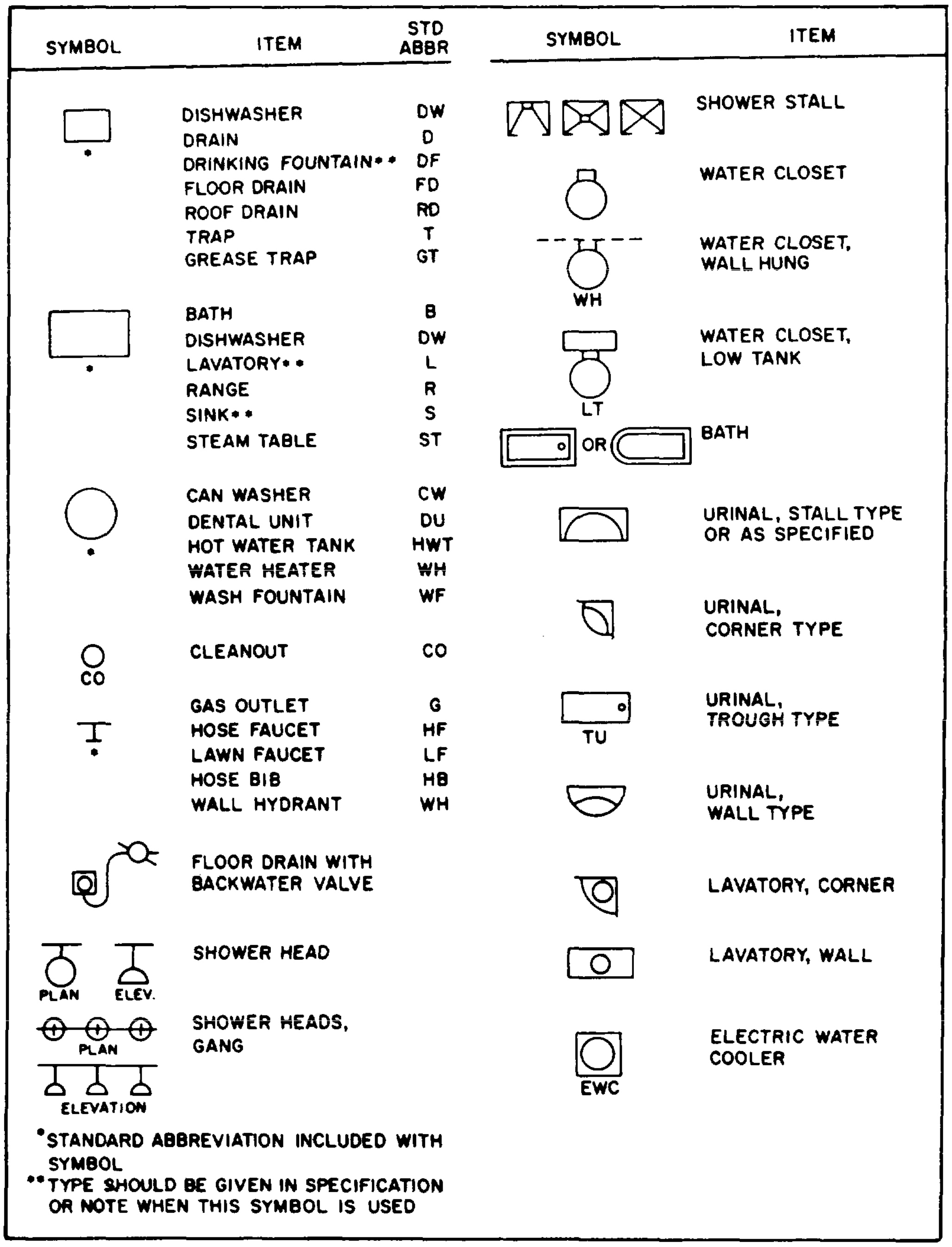


Figure 8-31.-Symbols for plumbing fixtures.

CHAPTER 9

ELECTRICAL SYSTEMS AND PLAN

It is important for an EA working on a set of drawings or plans to convey his ideas (or instructions) effectively to a skilled craftsman (CE) who is to install the electrical system. It is also equally important for you, as an EA, to understand and be thoroughly familiar with the methods and basic functions associated with the different materials and fixtures used in the installation of an electrical system.

This chapter, when used in conjunction with the previous chapters on wood, concrete and masonry, and mechanical systems and plan, will enable you to prepare construction drawings (discussed in the next chapter), revise as-built drawings in the field, and incorporate minor design changes with ease.

ELECTRICAL SYSTEM

Each building requires an electrical system to provide power for the lights and to run various appliances and equipment. At Navy bases, the electrical (or power) system consists of three main parts: the power plant that supplies the electrical power, the electrical distribution system (external) that carries the electrical current from the generating station to the various buildings, and the interior electrical wiring system that illuminates the building and feeds the interior electrical power to the appliances and equipment within the building.

In this section, we will discuss only the external power distribution and the various materials and fittings used in the installation of an electrical system. For more information, refer to the latest edition of *Construction Electrician 3 & 2*, NAVEDTRA 10636, *National Electrical Code*®(NEC®), and Army Technical Manuals (TMs).

ELECTRICAL (POWER) DISTRIBUTION SYSTEM

Electrical distribution is defined as the delivery of power to building premises, on poles or placed underground, from the power plant or substation through feeders and mains.

The power system is generally considered to be a combination of two sections: the transmission and the distribution. The difference between the two sections depends on the function of each at that particular time.

At times, in a small power system, the difference tends to disappear, and the transmission section merges with the distribution section. The delivery network, as a whole, is referred to as the distribution section and is normally used to designate the outside lines and frequently continues inside the building to include power outlets.

Most land-based power systems use alternating current (ac) rather than direct current (dc), principally because transformers can be used only with ac. An ac distribution system usually contains one or more generators (technically known as ALTERNATORS in an ac system); a wiring system of FEEDERS, which carry the generated power to a distribution center; and the DISTRIBUTION CENTER, which distributes the power to wiring systems called PRIMARY MAINS and SECONDARY MAINS. A representative transmission and distribution system is shown in figure 9-1.

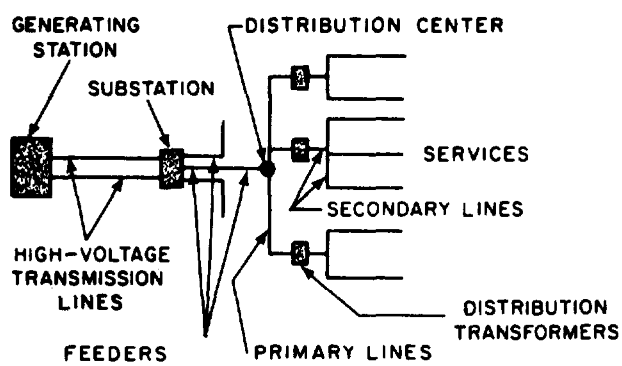


Figure 9-1.-Electrical transmission and distribution system.

Power from the generating station may be carried to the various points of consumption by overhead transmission and distribution lines, by underground cable, or by a combination of both. At most advanced bases, OVERHEAD feeder lines are commonly used because such lines are cheaper to build, simpler to inspect, and easier to maintain than UNDERGROUND cables. Obviously, the use of underground cables is preferred at airports and runways to prevent hazardous flight conditions.

Overhead Power Distribution

Figure 9-2 shows a three-phase, three-wire OVERHEAD power distribution system. Assume that the system has an alternator generating 220 V (fig. 9-3). From the generating station, three-phase, three-wire feeders carry the power overhead to the distribution points (or centers), from which two primary mains branch off. One of these mains carries power to a lighting system and a single-phase motor in a motor pool, each of which is designed to operate on 110 V, and to a three-phase motor designed to operate on 220 V. The 220-V, three-phase motor is connected directly to the 220-V, three-phase primary main. However, for the lighting system and 110-V motor, two wires in the primary main are tapped off to a transformer, which reduces the 220-V primary main voltage to 110 V. The use of two wires creates a single-phase voltage in the secondary main to the motor pool. Similarly, power to secondary mains running to the operational headquarters, living quarters, and the mess hall is reduced to 110 V and converted to single phase.

A system may be a THREE-WIRE or a FOUR-WIRE system, depending upon whether the alternators are connected DELTA (A) or WYE (Y). Figure 9-4 is a schematic diagram showing a delta connection. The coil marked

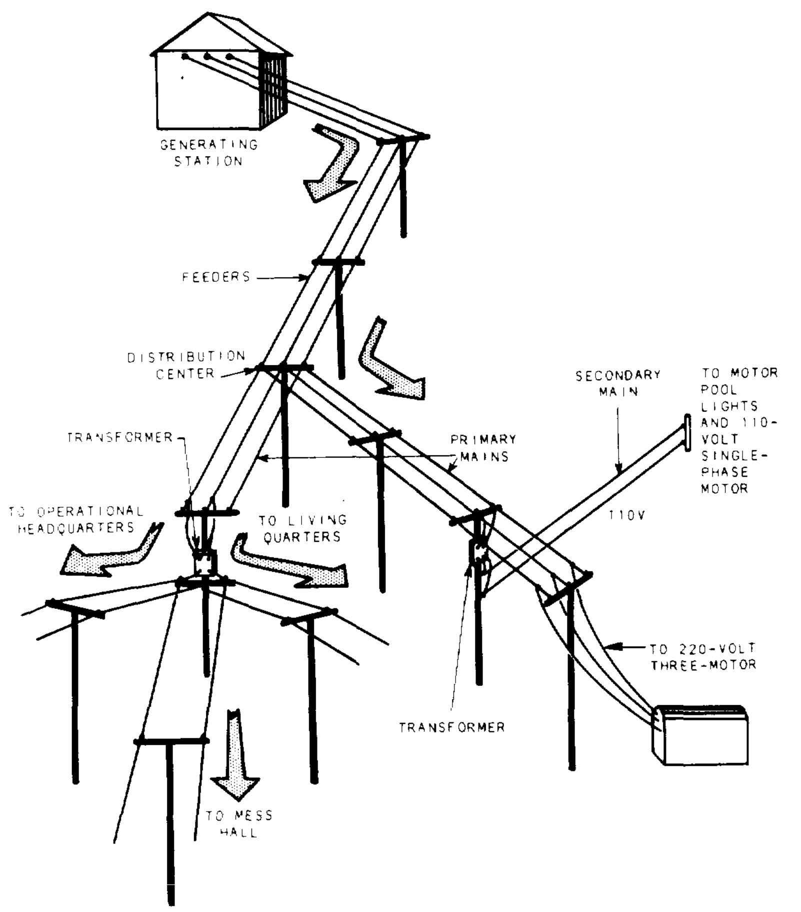


Figure 9-2.-A typical overhead power distribution system.

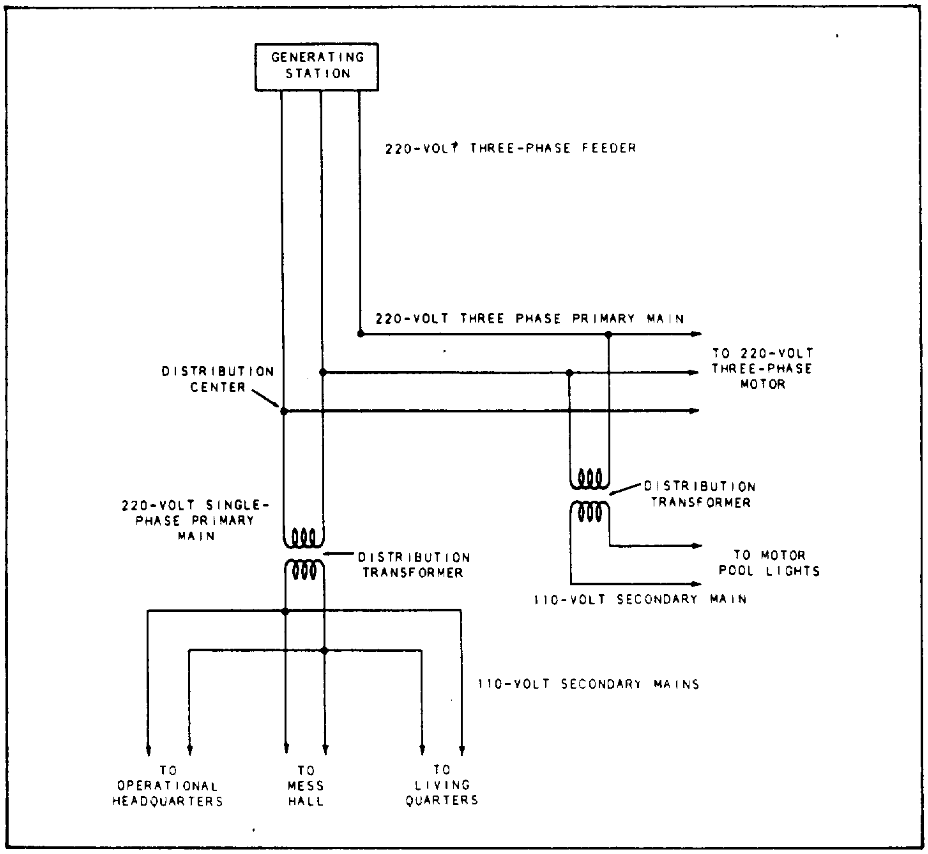


Figure 9-3.-Wiring diagram of the three-phase, three-wire distribution system in figure 9-2.

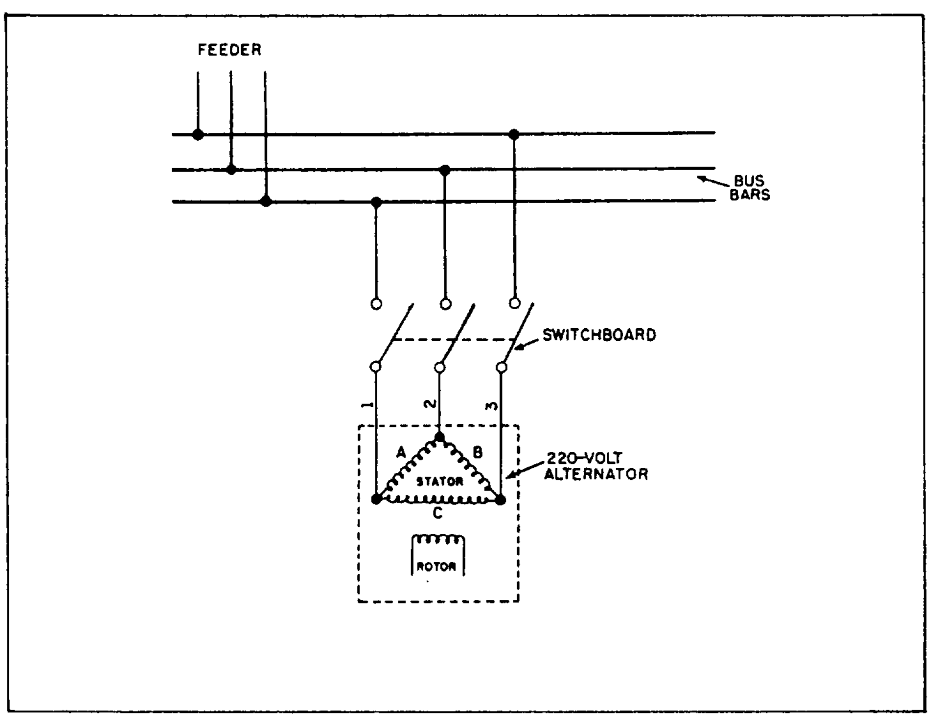


Figure 9-4.-Schematic diagram of a delta-connected alternator.

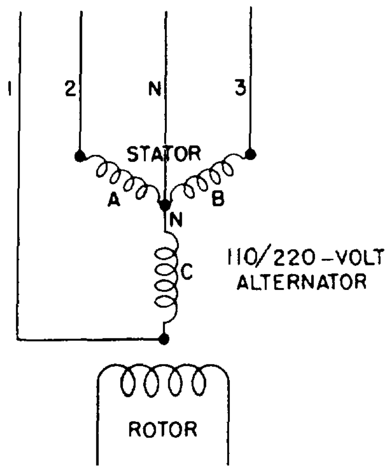


Figure 9-5.-Y-connected alternator (three-phase, four-wire).

STATOR represents the stationary coils of wire in the alternator; the one marked ROTOR represents the coils, which rotate on the armature. You can see that the power is taken off the stator from three connections, which in the drawing form a triangle or delta. All three wires are live (called HOT) wires.

Figure 9-5 shows a Y-connected alternator (three-phase, four-wire). N represents a common or NEUTRAL point to which the stator coils are all connected. The current is taken off the stator by the three lines (wires), 1, 2, and 3, connected to the stator coil ends; and also by a fourth line, N, connected to the neutral point. Lines 1, 2, and 3 are hot wires; line N is NEUTRAL.

The voltage developed in any pair of wires, or in all three wires, in a delta-connected alternator is always the same; therefore, a

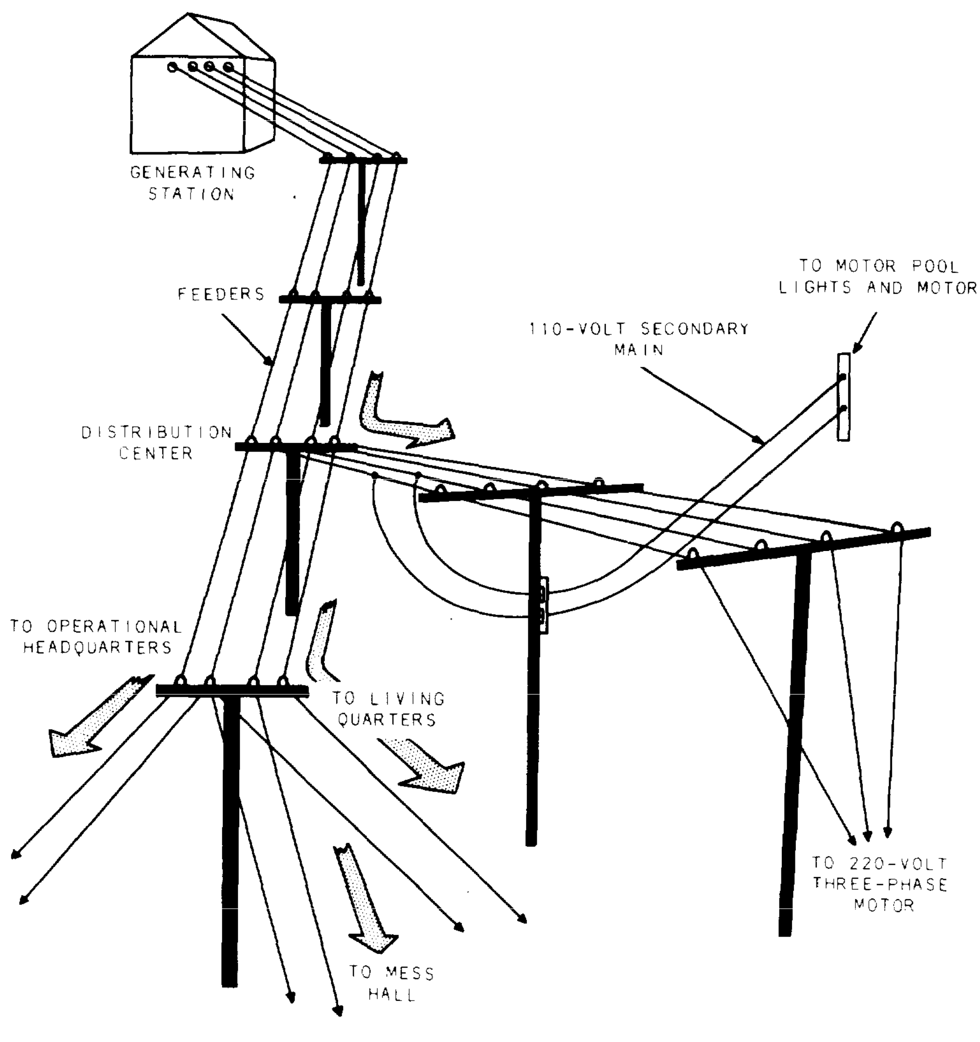


Figure 9-6.-A pictorial view of a four-wire overhead distribution system.

delta-connected system has only a single voltage rating (220 V in fig. 9-4). However, in a Y-connected system, the voltage developed in different combinations of wires is different. In figure 9-5, you can see that lines 1 and 2 take power from two stator coils (A and C). The same applies to lines 1 and 3 (power from coils C and B) and lines 2 and 3 (power from coils A and B). However, the neutral (N) and line 2 take power from coil A only; neutral (N) and line 1, from coil C only; and neutral (N) and line 3, from coil B only.

It follows from this that a Y-connected alternator can produce two different voltages: a higher voltage in any pair of hot wires, or in all three hot wires, and a lower voltage in any hot wire paired with the neutral wire.

Output taken from a pair of wires is SINGLE-PHASE voltage; output from three wires is THREE-PHASE voltage. The practical significance of this lies in the fact that some electrical equipment is designed to operate only on single-phase voltage, while other equipment is designed to operate only on three-phase voltage. This equipment includes the alternators themselves, and a system with a three-phase alternator is called a three-phase system. However, even in such a system, single-phase voltage can be obtained by tapping only two of the wires.

Figure 9-6 shows a four-wire system serving the same facilities. Here there is a Y-connected alternator rated at 110/220 V. You can see that to get 110 V single phase for the secondary mains, no transformers are necessary. These mains are simply tapped into pairs of wires, one of each pair being a hot wire and the other, the neutral wire. The 220-V, three phase motor is tapped into the three hot wires that develop 220 V, three-phase. You can see that the neutral wire in a four-wire system exists to make it possible for a lower voltage to be used in the system.

Figure 9-7 shows a wiring diagram for the system shown in figure 9-6.

Now, let's discuss the device called a DISTRIBUTION TRANSFORMER. A transformer is simply a device for increasing or reducing the voltage in an electrical circuit. It ranges in size from one that is portable (those used for appliances inside the building) to heavy ones that are mounted permanently on platforms or

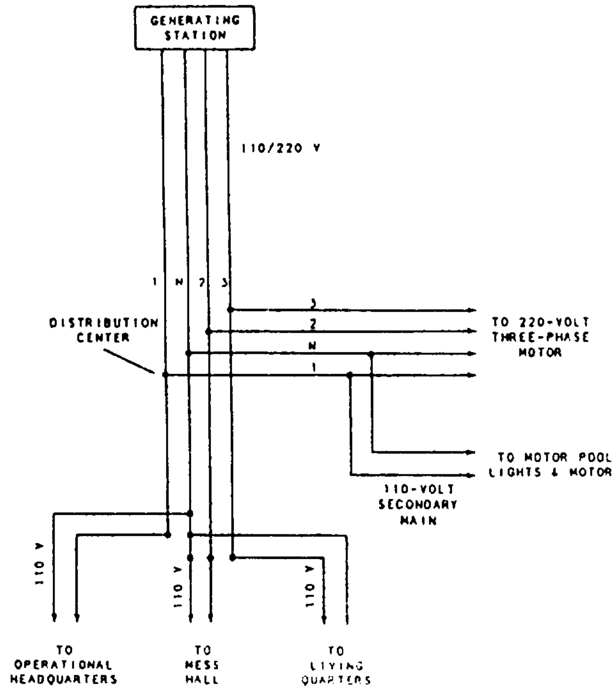


Figure 9-7.-Wiring diagram of the four-wire system in figure 9-6.

hung with crossarm brackets attached to an electric pole. Ask one of the CES to show you a transformer. It is very probable that one is nearby.

Now, for long-distance power transmission, a voltage higher than that normally generated is required. A transformer is used to step the voltage up to that required for transmission. Then at the service distribution end, the voltage must be reduced to that required for lights and equipment. Again a transformer is used; but this time it is to step down the voltage.

The reason for stepping up the voltage in a line lies in the fact that the greater the distance, the more resistance there will be to the current flow; and a much greater force will be required to push the current through the conductor. Perhaps you can best understand this reasoning if you examine Ohm's Law.

$$I = \frac{E}{R}.$$

(Refer to chapter 1 of this book.)

You can see from the formula above that the CURRENT (I) varies inversely to the RESISTANCE (R). To maintain the required current flow as the resistance increases, one must increase the VOLTAGE, or ELECTROMOTIVE FORCE (E), accordingly. The increase in voltage makes it possible to use smaller wires or cables, thus minimizing the support for aboveground transmission lines, and consequently minimizing the cost of the system.

Underground Distribution

The Navy uses UNDERGROUND power distribution systems on most shore facilities for several reasons: underground lines are secure against damage that high winds and storms inflict on overhead lines in some areas; underground lines leave clear areas and open spaces for the operations of heavy mobile equipment; and underground lines are much more secure against enemy attack than overhead lines.

There are three principal categories of underground lines: duct lines, cables buried directly, and conduits located in tunnels. The system most frequently installed by construction battalions is the underground duct system, which consists of manholes, handholes, duct lines, and cables. In general, a representation of the system layout and a list of materials needed to install the system can be found in a standard set of drawings.

INTERIOR ELECTRICAL WIRING SYSTEM

In general, the term *service* means the electrical system that brings the power from the pole or other point on the exterior power distribution line to the point on or inside the building from which it is distributed to the building circuits. Service for a building consists of two parts: the service conductors and the service equipment.

The SERVICE CONDUCTORS supply power from the pole or other point on the exterior distribution system to the building. These conductors may be SERVICE DROP conductors for overhead service, or they may be SERVICE LATERAL conductors for underground service. From the service conductors, electrical power is brought into the building through a SERVICE ENTRANCE to the SERVICE EQUIPMENT on or inside the building. The service equipment is the necessary equipment, usually consisting of a circuit breaker or switch or fuses, that is located near the entry point of the supply conductors to the building. This equipment is the main control and means of cutting off the power supply to the building.

Service Conductors

The SERIVCE DROP CONDUCTORS (fig. 9-8) run from the pole to the building. These conductors may consist of an approved multi-conductor cable or individual (single) conductor. In either case, they must have thermoplastic, rubber, or other weatherproof insulation. The current-carrying capacity of the service drop conductors must be sufficient to ensure that ample current for the prospective maximum load may be conducted without a temperature rise to a point high enough to damage the insulation. The NEC® specifies the minimum size conductors that may be used for different load (amperage) requirements.

Figure 9-9 shows an UNDERGROUND SERVICE that brings power into a building. the conductors, corresponding to the service drop that

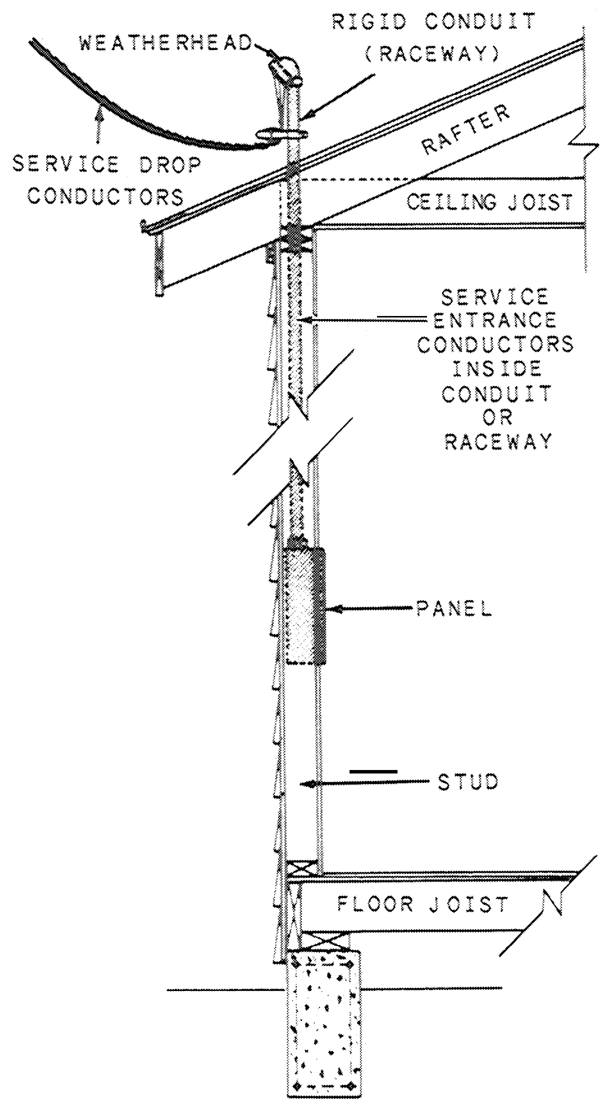


Figure 9-8.—Overhead service entrance.

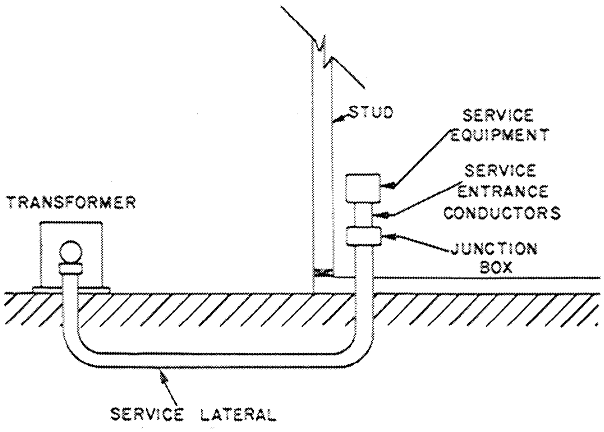


Figure 9-9.—Underground service to building.

brings the power to the building, are called the service lateral. Sometimes these conductors are tied to an overhead distribution system, and they run down the pole into the ground before they are run to the building. In other cases, the entire distribution system, except for the transformers, is underground. The service lateral may be connected to a secondary main, or, if the building is served by separate transformers, it is connected to the transformers.

The service lateral may be installed in rigid conduit, either metallic or nonmetallic, or it can be installed with underground service entrance (USE) cable. The figure shows the layout of an underground service lateral run from the transformer to the junction box and to the service equipment.

Service Entrance

The starting point for interior wiring is the SERVICE ENTRANCE, which brings power from the service conductors to the service equipment. Refer again to figure 9-8. As shown in this figure, the service entrance conductors are connected to the service drop at a point just outside the building. These conductors may be approved single conductors run through a protective raceway, such as rigid metallic or nonmetallic conduit. The service entrance conductor may also be an approved type of service entrance cable that does not need raceway protection unless it is likely to be damaged by abrasions or from being struck by passing equipment. Where single conductors are used, they must be insulated as require by the NEC®. The NEC® also specifies the size wire that may be used as service entrance cable.

Also shown in figure 9-8 is a SERVICE HEAD. A service head, frequently called a WEATHERHEAD, is used with a raceway to provide an entrance for the conductors into the building. The weatherhead is designed to prevent the entrance of rain into the raceway. It is also designed to reduce abrasion to the insulation.

A SERVICE ENTRANCE SWITCH (left-hand side of fig. 9-10) provides a means of

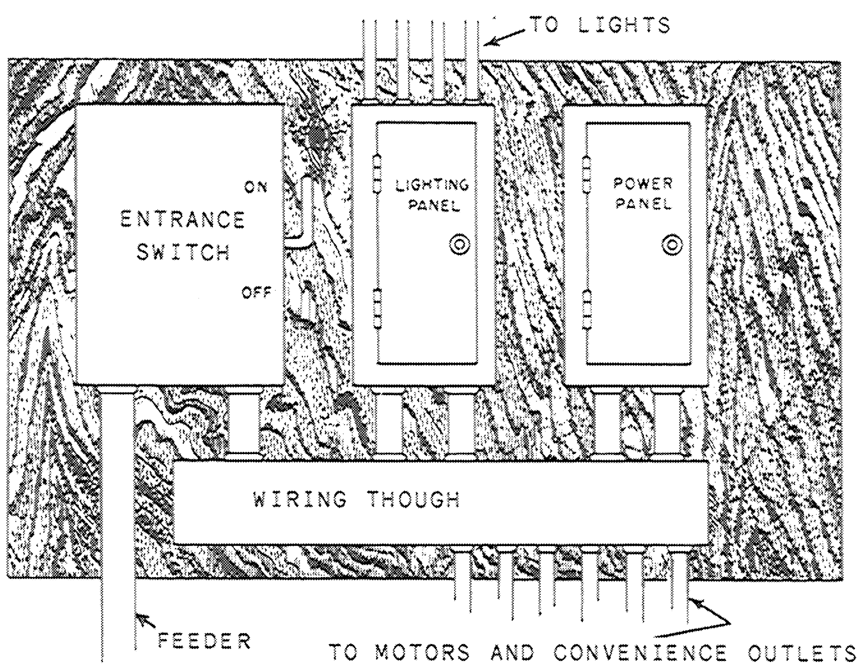


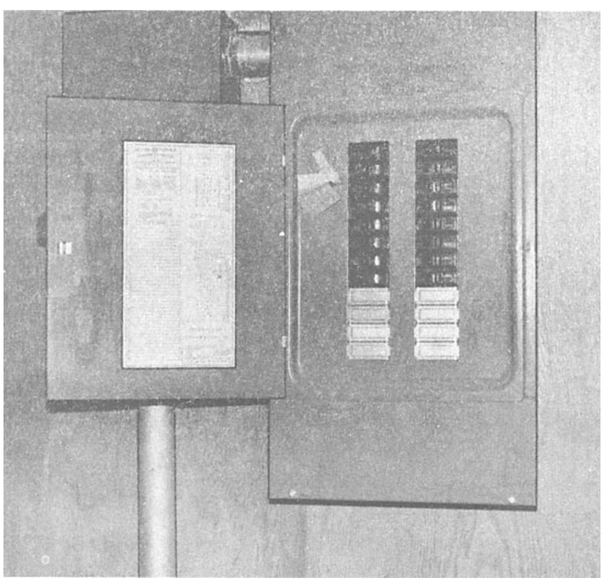
Figure 9-10.—Typical layout for entrance switch, lighting panel, and power panel.

disconnecting the service conductors from the supply source. It may consist of a single manually operated switch or a circuit breaker. The NEC® sets a minimum size for entrance switches at 60 A for the fuse type and 50A for the circuit breaker type. A CIRCUIT BREAKER is a protective device that automatically opens the circuit, rather than burning out like a fuse, when the amperage exceeds that rated for the circuit breaker. The NEC® recommends a minimum size of 100-A service for individual residences. However, when not more than two two-wire branch circuits are installed, a 30-A entrance switch may be used.

Panelboard

A PANELBOARD (fig. 9-10) is defined by the NEC® as a single panel, or a group of panel units designated for assembly in the form of a single panel, including buses. It comes with or without switches and/or automatic overcurrent protective devices for the control of light, heat, or power circuits of small individual as well as aggregate capacity; it is designed to be placed in a cabinet or a cutout box and placed in or against a wall or partition and is only accessible from the front.

A BREAKER PANEL uses a thermal unit built into the switch with the breaker being preset at the factory to open automatically at a predetermined



73.11

Figure 9-11.-Lighting panel.

ampere setting. It maybe reset to the ON position after a short cooling-off period.

LIGHTING PANELS (fig. 9-11) are normally equipped with 15-A single-pole automatic circuit breakers, while the power panels may have one-, two-, or three-pole automatic circuit breakers with a capacity to handle the designated load. In most buildings, the entrance switch and panelboards can be mounted close to each other; however, they must be placed where service and maintenance can be easily performed. They should not block any passage that is supposed to be open, and they should not be in a place where exposure to corrosive fumes and dampness is imminent. Panelboards should be located as near as possible to the center of the electrical load.

Conductors

ELECTRICAL CONDUCTORS generally consist of drawn copper or aluminum formed into wire. They provide paths for the flow of electrical current. Conductors are usually covered with insulating materials (fig. 9-12) to minimize the

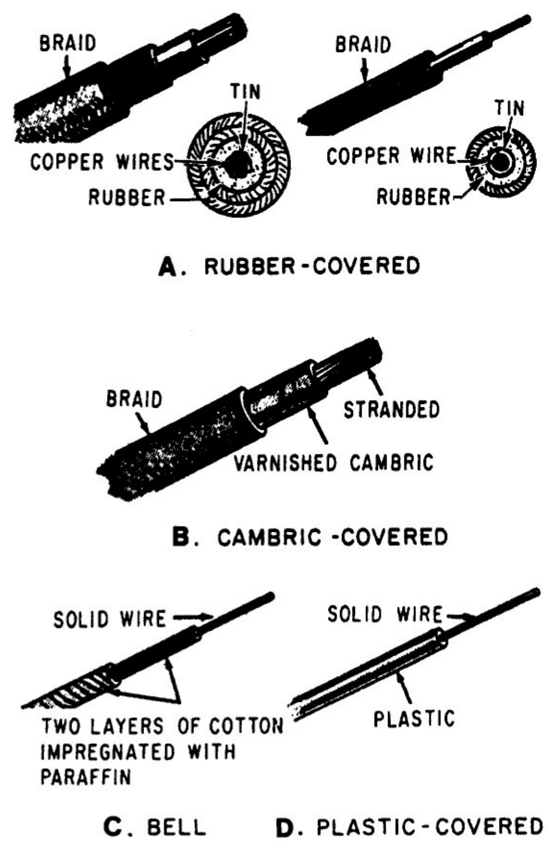


Figure 9-12.-Types of single insulated conductors.

chances for short circuits and to protect personnel. Atmospheric conditions, voltage requirements, and environmental and operating temperatures are factors to consider in selecting the type of insulating material for a particular job.

SINGLE CONDUCTORS.— A single conductor may consist of one solid wire or a number of stranded, uncovered, solid wires that share in carrying the total current. A stranded conductor has the advantage of being more flexible than a solid conductor, making it more adaptable for pulling through any bends in a conduit. Common types of single conductors are shown in figure 9-12.

Conductors vary in diameter. Wire manufacturers have established a numerical system, called the American Wire Gage (AWG) Standard, to eliminate the necessity for cumbersome circular mil or fractional-inch diameters in describing wire sizes. Figure 9-13 shows a comparison of one-half actual wire diameters to their AWG numerical designations. Notice that the wire gauge number increases as the diameter of the wire decreases.

The wire size most frequently used for interior wiring is No. 12 AWG and is a solid conductor. No. 8 and larger wires are normally used for heavy power circuits or as service entrance leads to buildings.

The type of wire used to conduct current from outlet boxes to sockets in the lighting fixtures is called "fixture wire." It is stranded for flexibility and is usually size 16 or 18 AWG.

AWG NUMBER	½ ACTUAL SIZE	DIAMETER (INCHES)
18	●	.0403
16	●	.0508
14	●	.0640
12	●	.0808
10	●	.1018
8	●	.1284
6	●	.184
4	●	.232
2	●	.292
1	●	.332
1/0	●	.373
2/0	●	.419
3/0	●	.470
4/0	●	.528

Figure 9-13.—Comparison of standard wire gauge number to wire diameters.

MULTIWIRE (CABLE) CONDUCTORS.— A multiwire conductor, called a CABLE, is an assembly of two or more conductors insulated from each other with additional insulation or a protective shield formed or wound around the group of conductors. The covering or insulation for individual wires is color coded for proper identification. Figure 9-14 shows common types of multiwire conductors.

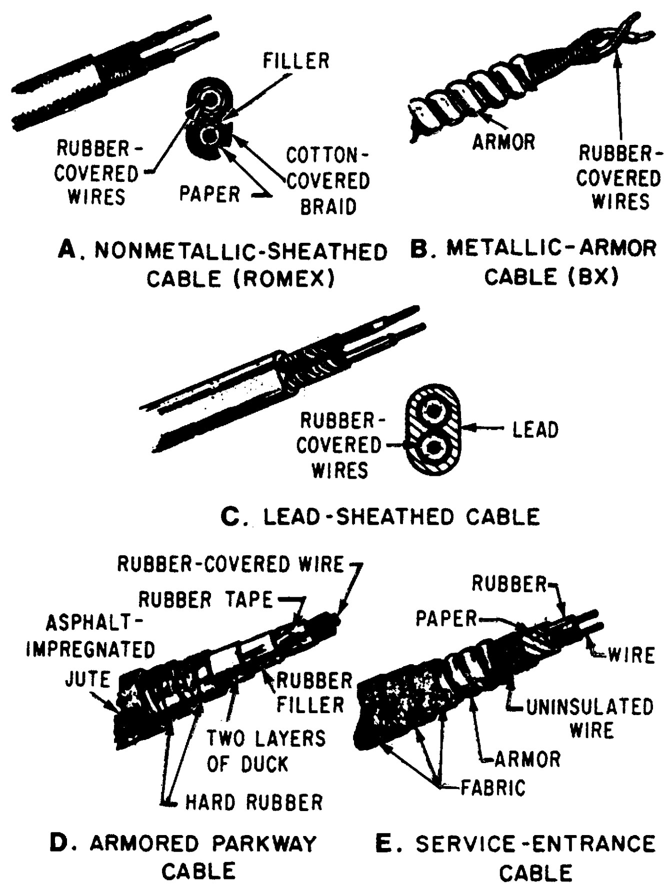


Figure 9-14.—Types of multiwire insulated conductors (cables).

Nonmetallic-sheathed cable (NMC) (fig. 9-14, view A) is more commonly called by the trade name "ROMEX," ROMEX (NMC) comes in sizes No. 14 through 2 for copper conductors and No. 12 through 2 for aluminum or copper-clad aluminum conductors. This type of cable comes with a bare (uninsulated) ground wire. The ground wire is laid in the interstices (intervals) between the circuit conductors and under the outside braid. The ground wire is used to ensure the grounding of all metal boxes in the circuit, and also to furnish the ground for the grounded type of convenience outlets that are required in Navy installations. Nonmetallic-sheathed cable is used for temporary wiring in locations where the use of conduit would be unfeasible. The use of Romex as service entrance cable, in garages, in storage battery rooms, imbedded in poured concrete, or in any hazardous area is NOT authorized.

Metallic-armored cable (fig. 9-14, view B), also called BX cable, is used in naval installations for temporary wiring, but unlike Romex, its use in commercial installation is restricted. Most city building codes restrict the use of BX cables to oil burner control circuits and the like. A difficulty with BX is the fact that it tends to ground after installation. Small metal burrs on, the armor can, because of vibration, penetrate the insulation and cause a ground.

BX cables come in sizes from No. 14 to 2 AWG, and each cable may contain one, two, three, or four conductors. The armor on the cable furnishes a continuous ground between boxes.

Insulation

As mentioned earlier, electrical conductors are available with various kinds of insulating materials. Some of these are rubber, thermoplastic, and varnished cambric. Special types of paper, glass, silk, and enamel are also used to insulate conductors, but with less frequency than those previously mentioned. The NEC® recommends insulation of certain kinds for use in dry, damp, and wet locations. Underground installations, those in concrete slabs and masonry, those in direct contact with the earth, and those subject to saturation with water or other liquids are considered wet-location installations.

Another factor to consider in the choice of insulation is temperature. Different insulations have different maximum temperature ratings. Check the NEC® and applicable LOCAL CODES to be sure you are using the appropriate insulation for the location and temperature considered in the plans. Some examples of the composition of insulation, the location that applies, and their maximum temperature rating follow:

Type RH is a heat-resistant compound, that will stand higher temperature than Type R. This type is commonly used in dry locations. The maximum temperature rating is 167°F.

Type RHW is a moisture-resistant rubber compound for use where the wire may be subject to wet conditions. This type is used in both wet and dry locations. The maximum temperature rating is 167°F.

Type RUH is a high grade rubber compound, consisting of 90-percent latex. This type is often used for direct burial in dry locations. The maximum temperature rating is 140°F.

Thermoplastic insulation has the advantage of long life, toughness, and a dielectric strength (that is, a capacity for insulating) equal to that of rubber. It requires no protective covering over the insulation. Common types of thermoplastic insulation are Types T, TW, and TA. Type T is suitable only for dry locations with a maximum temperature rating of 140°F. Type TW is moisture-resistant, and again, with a temperature rating of 140°F. Type TA is a thermoplastic-asbestos compound that combines the characteristics of Types T and TW. This type has a maximum temperature rating of 194°F. Its use is restricted to switchboard wiring.

Varnished cambric insulation has an insulating quality midway between that of rubber and paper. It is more flexible than paper; its dielectric strength is greater than that of rubber. This type is not adversely affected by ordinary oil and grease. It is manufactured in either standard type (black finish), or in the heat-resistant type with a yellow finish. Varnished insulation is restricted to dry locations in areas such as motor leads, transformer leads, and high-voltage cables.

Conduits and Fittings

An electrical conduit is a pipe, tube, or other means in which electrical wires are installed for protection from accidental damage or from the elements. If pipes or tubing is used, the fittings depend upon the pipe or tubing material. The conduit used in Navy construction is generally classified as RIGID, THIN-WALL, or FLEXIBLE conduit. The three types of conduit and their associated fittings are shown in figure 9-15.

RIGID CONDUIT.— Rigid galvanized steel or aluminum conduit is made in 10-ft lengths. It is threaded on both ends and comes with a coupling on one end. It comes in sizes from 1/2 in. to 6 in. in diameter. Various fittings used

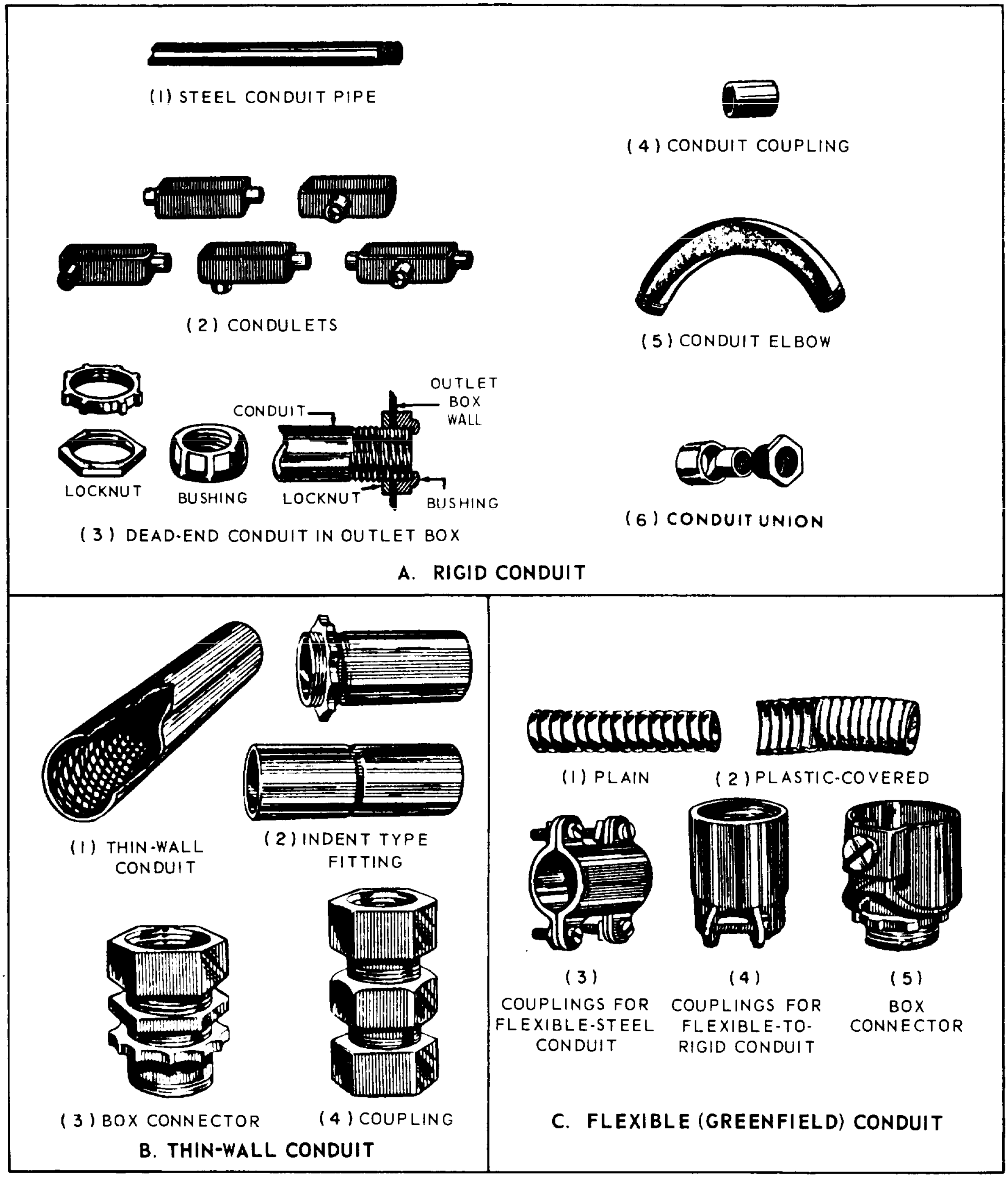


Figure 9-15.-Types of conduit and their associated fittings.

for connecting rigid metal conduit are shown in figure 9-15, view A. The use of rigid conduit involves a good deal of cutting, bending, and threading of lengths. An ordinary hacksaw or special wheel pipe cutter is used for cutting, while a ratchet type of mechanical die is used for thread-cutting conduit pipes. Bending of pipes can be undertaken both manually, using a bending tool commonly called a hickey, and hydraulically. A hydraulic bender is recommended for making smooth and accurate bends.

CONDULETS (fig. 9-15, view A (2)) are a convenient way of making bends, especially in conduit that will be exposed to the elements. They are heavily used on sharp corners and also to reduce the number of bends made in a run of conduit.

Another type of rigid conduit approved for use by NAVFAC is the polyvinyl chloride (PVC) pipe. This now popular plastic conduit is specially suitable for use in areas where corrosion of metal conduits has been a problem. Some of the advantages of PVC conduit are as follows: light handling weight, ease of installation, and leakproof joints. This conduit is primarily intended for underground wire and cable raceway use and is made in two forms. Type I is designed for concrete encasement, and Type II is designed for direct earth burial. Rigid plastic conduit and fittings are joined together by a solvent-type adhesive welding process. It also comes in sizes of 1/2 to 6 in. in diameter. PVC fittings are also available from the manufacturer. (For more information on PVC fittings, refer to Article 370 of the NEC®.)

THIN-WALL CONDUIT.— Electric metallic tubing (EMT) or thin-wall conduit, as it is better known, is a type of conduit with a wall thickness quite a bit less than the rigid conduit. It is made in sizes from 1/2 to 2 in. in diameter. Thin-wall conduit cannot be threaded; therefore, special types of fittings (fig. 9-15, view B) must be used for connecting pipe to pipe to boxes.

FLEXIBLE CONDUIT.— Flexible conduit (fig. 9-15, view C), also called Greenfield, is a spirally wrapped metal band wound upon itself and interlocking in such a manner as to provide a round cross section of high mechanical strength and flexibility. It is used where rigid conduit would not be feasible to install and requires no elbow fittings. It is made in sizes from 1/2 to 3 in. in diameter. Greenfield is available in two types: the plain or standard unfinished-metal type and a moisture-resistant type called sealtite, which has a plastic or latex jacket. The moisture-resistant type is not intended for general use but only for connecting motors or portable equipment in damp or wet locations and where flexibility of connections is desired.

Wire Connectors

Figure 9-16 shows various types of connectors that are used to join or splice conductors. The type used will depend on the type of installation and the wire size. Most connectors operate on the same principle, that of gripping or pressing the conductors together. WIRE NUTS are used extensively for connecting insulated single conductors installed inside of buildings.

Outlet Boxes

OUTLET BOXES bind together the elements of a conduit or cable system in a continuous

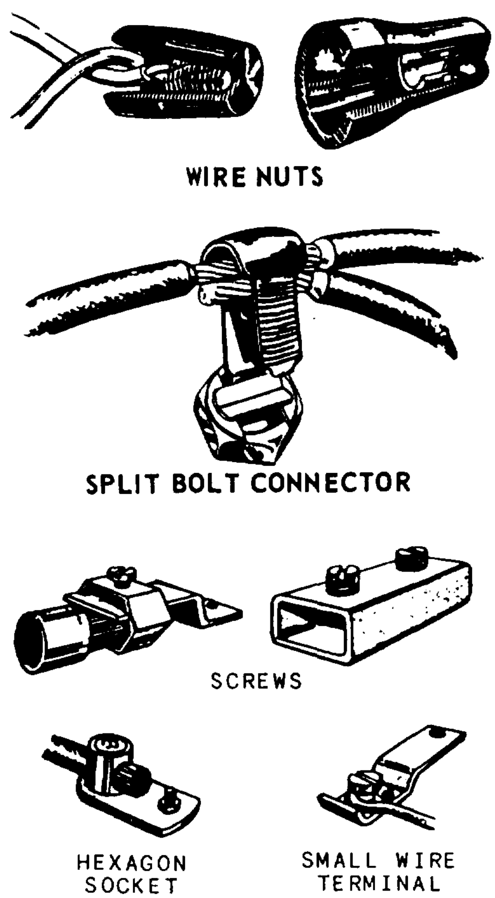


Figure 9-16.-Types of cable and wire connectors.

grounded system. They provide a means of holding the conduit in position, space for mounting such devices as switches and receptacles, protection for these devices, and space for making splices and connections. Outlet boxes used in Navy construction are usually made of galvanized steel; however, nonmetallic boxes, such as rigid plastic compounds, are being used for approved installation. Boxes are either round, octagonal, square, or rectangular in shape. Commonly used outlet boxes are shown in figure 9-17.

An outlet box is simply a metal container, set flush or nearly flush with the wall, floor, or ceiling, into which the outlet receptacle or switch will be inserted and fastened. Figure 9-17, view A, is a 4-in. octagon box used for ceiling outlets. This box is made with 1/2- or 3/4-in. KNOCKOUTS—indentations that can be knocked out to make holes for the admission of conductors and connectors. Figure 9-17, view B, shows a 4 11/16-in. square box used for heavy duty, such as for a range or dryer receptacle. It is made with knockouts up to 1 in. in diameter. Figure 9-17, view C, is a sectional or GEM BOX used for switches or receptacles. By loosening a screw, you can remove the side panel on the gem box so that two or more boxes can be GANGED (combined) to install more than one switch or receptacle at a location. Figure 9-17, view D, is a UTILITY BOX, called a handy box, made with 1/2- or 3/4-in. knockouts and used principally for open-type work. Figure 9-17, view E, is a 4-in. square box with 1/2- or 3/4-in. knockouts, used quite often for switch or receptacle installation. It is equipped with plastic rings having flanges of various depths so that the box may be set in plaster walls of various thicknesses.

Besides the boxes shown, there are special boxes for switches when more than two switches at one location are required. These are called CONDUIT GANG BOXES, and they are made to accommodate three, four, five, or six switches. Each size box has a cover to fit.

The NEC® requires that outlet boxes be 1 1/2 in. deep except when the use of a box of this depth will result in injury to the building structure or is impractical, in which case a box not less than 1/2 in. deep may be used. For switch boxes, the 2 1/2-in. depth is the most widely

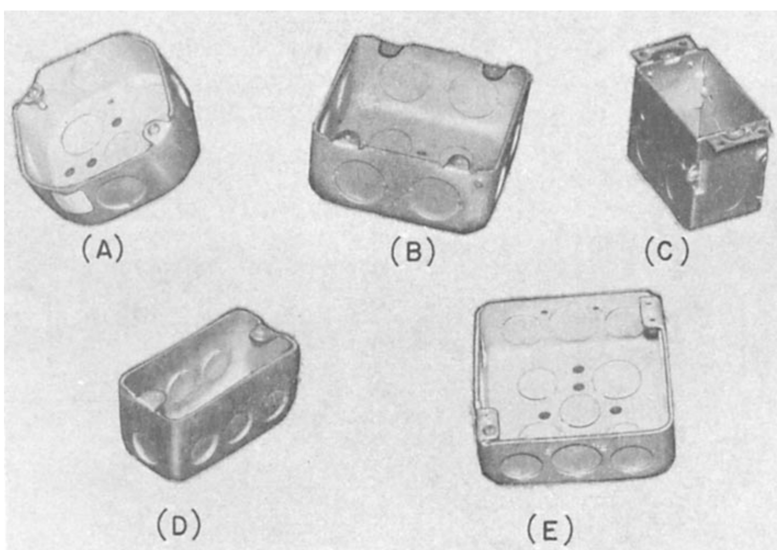


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Figure 9-17.-Types of outlet boxes.

used. The NEC® also requires that the outside edges of outlet and switch boxes without flush plates NOT be recessed more than 1/4 in. below the surface of the finished wall.

Receptacles

RECEPTACLES are used to plug in lights and appliances around the building. Some of the types of receptacle commonly used in interior wiring are discussed in the following paragraphs in the order of their frequency of use.

A CONVENIENCE OUTLET (fig. 9-18) is a duplex receptacle with two vertical or T-slots and a round contact for the ground. This ground is connected to the frame of the receptacle and is grounded to the box by way of screws that secure the receptacle to the box.

A RANGE RECEPTACLE (fig. 9-19) maybe either a surface type or a flush type. It has two slanted contacts and one vertical contact and is rated at 50 A. Receptacles for clothes dryers are similar but are rated at 30 A. Range and dryer receptacles are rated at 250 V and are used with three-wire, 115/230 V, two hot wires and a neutral. A receptacle for use with an air-conditioner taking 230 V is made with two horizontal slots and one round contact for the ground.

Also used in the Navy are strips that allow movement of the receptacle to any desired location. These strips are available in 3-ft and 6-ft lengths and may even be used around the entire room. This type of outlet is particularly desirable in rooms where portable equipment or fixtures, such as drafting tables and audio-visual equipments, are used. Specialty outlets (weather-proof are used in all exterior locations because they resist weather damage.

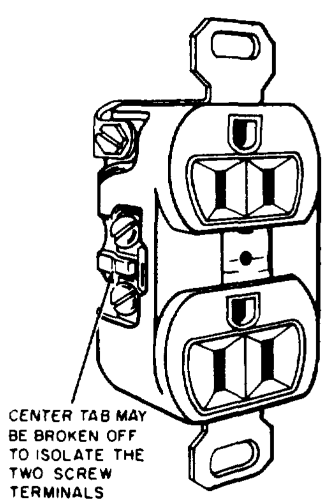

Figure 9-18.-A typical duplex convenience outlet.

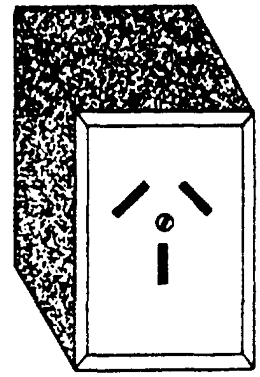

Figure 9-19.-Range receptacle.

Switches

For interior wiring, single-pole, three- or four-way toggle switches are used. Most of the switches will be single-pole, but occasionally a three-way system is installed, and on rare occasions, a four-way system.

A single-pole switch (fig. 9-20) is a one-blade, on-and-off switch that may be installed singly or in multiples of two or more in the same metal box.

In a three-way switch circuit (fig. 9-21), there are two positions, either of which may be used to turn a light ON or OFF. The typical situation is one in which one switch is at the head of a stairway and the other at the foot.

A four-way switch (fig. 9-22) is an extension of a three-way circuit by the addition of a four-way switch series.

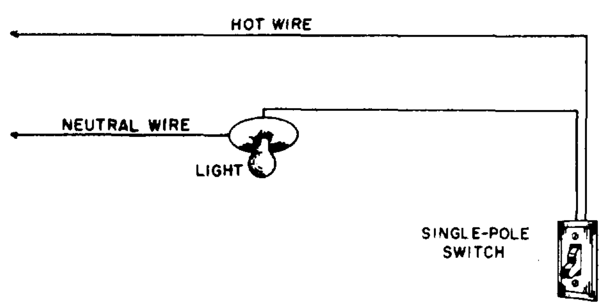

Figure 9-20.-Single-pole switch circuit.

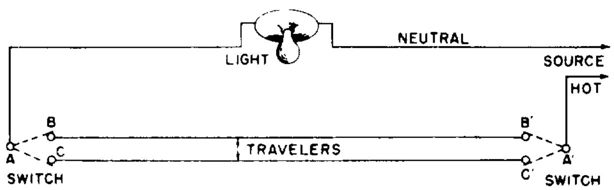

Figure 9-21.-Three-way switch circuit.

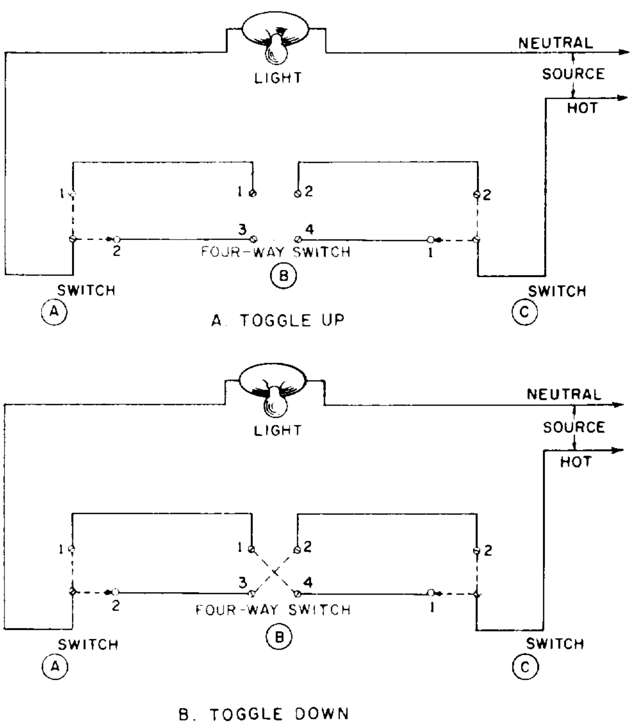

Figure 9-22.-Four-way switch circuit.

Note that three- and four-way switches can be used as single-pole switches, and four-way switches can be used as three-way switches. Some activities may install all small-wattage, four-way switches for all lighting circuits to reduce their inventories. However, three- and four-way switches are usually larger than single-pole switches and take up more box room. The size of a switch depends on its ampacity (related maximum amperage). The ampacity and maximum allowable voltage are stamped on the switch.

ELECTRICAL PLAN

The electrical information and layouts in construction drawings, just as the mechanical plan, are generally superimposed on the building plan and the plot plan.

In this chapter, we will address electrical plans as those drawings that pertain to the ELECTRICAL (POWER) DISTRIBUTION SYSTEM, which indicate outside power lines and appurtenances for multibuilding installations, and the INTERIOR ELECTRICAL WIRING SYSTEM.

As an EA3, the electrical layout for both light and power is your main concern. You will be required to draw electrical drawings and layouts from notes, sketches, and specifications provided by the designing engineer. Although you are not required to design the electrical wiring system, you must be familiar with the methods, the symbols, and the nomenclature, as well as the basic functions of the components associated with the electrical systems, its transmission and distribution, and the circuits hookup. In addition, you must also be familiar with the codes (both NEC® and local) and standards and specifications, and be able to apply that knowledge in drawing electrical plans.

STANDARDS AND SPECIFICATIONS REQUIREMENTS

Because the safety of the electrical system is of prime importance, it is imperative that all Navy electrical installations ashore conform to rigid standards and specifications. When preparing construction drawings, the EAs, like the CES, are required to follow the specifications issued by the Naval Facilities Engineering Command (NAVFACENGCOM). In particular, an EA working on electrical wiring and layout diagrams for electrical plans should refer to the latest edition of ANSI Y32.9 and ANSI Y14.15.

Codes

Code requirements and installation procedures offer protection for the consumer against unskilled electrical labor. Among other functions, the NEC® serves as a basis for limiting the type and wiring to be used, the circuit size, the outlet spacings, the conduit requirements, and the like. In addition, local codes are also used when separate electrical sections are applicable to the locale in which the building will be built. Be certain that you always have a copy of the latest edition of the NEC® available for your use.

Similarly, all of the types of electrical devices and fixtures included in the materials list prepared for electrical plans are to meet certain specifications and minimum requirements. An independent organization called Underwriters

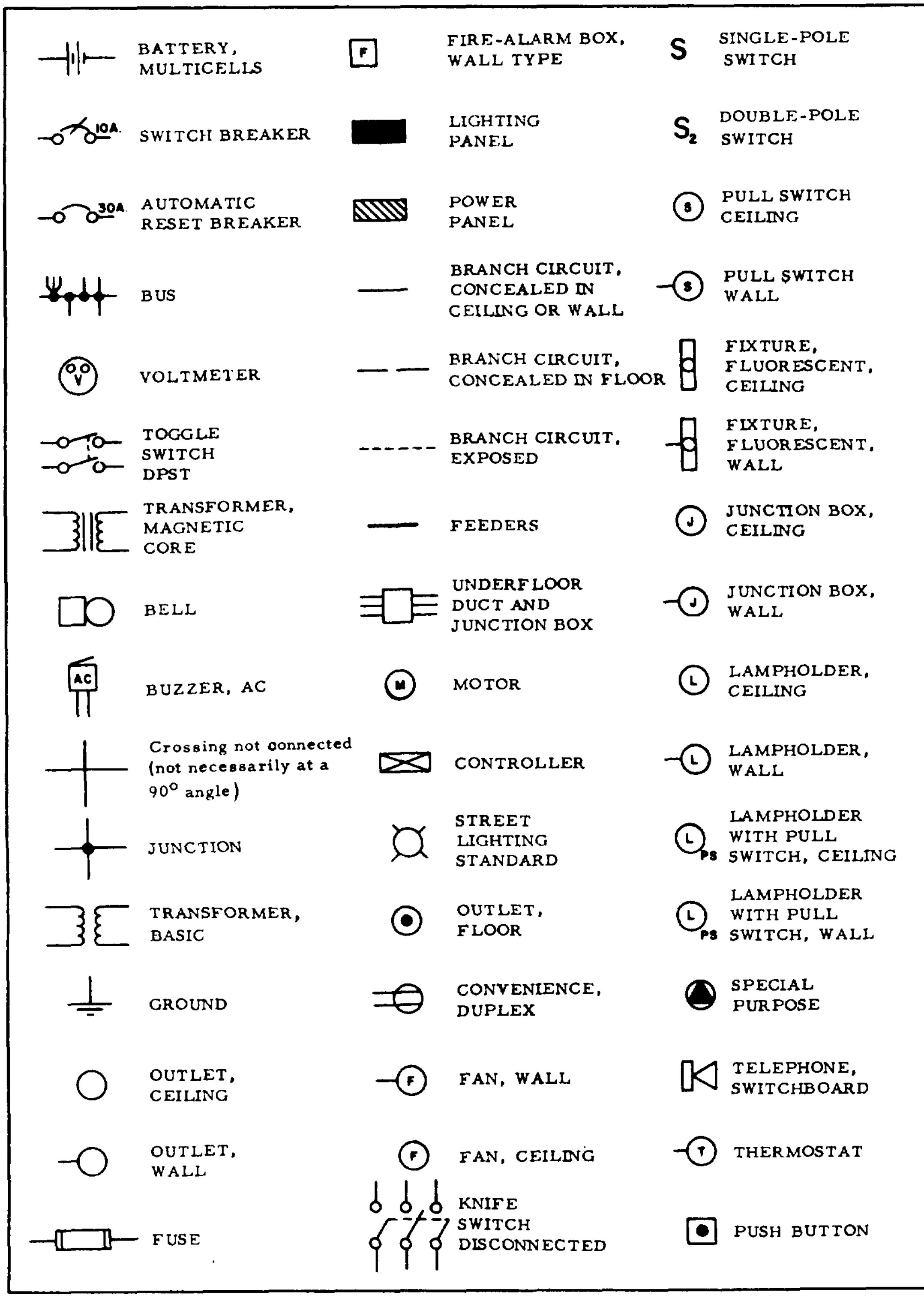

Figure 9-23.-Common types of electrical symbols.

Laboratories (UL) tests various electrical fixtures and devices to determine if they meet minimum specification and safety requirements as set up by UL. Those fixtures and devices that are approved may then bear UL labels.

Permit

In the SEABEEs, utility drawings (both mechanical and electrical) are thoroughly reviewed before an excavation (or digging) permit is granted and issued to the project subcontractor. Such action minimizes the hazards to personnel and underground structures during the construction process. All of the minor design changes and field adjustments must be noted and reflected on as-built and working drawings. Therefore, close coordination and cooperation must develop within and among all of the parties involved in the project to maintain periodic checks on red-lined prints so that information can be compared and verified as up to date.

ELECTRICAL SYMBOLS

The conventions used on the electrical plan are SYMBOLS that indicate the general layout, units, related equipment, fixtures and fittings, and routing and interconnection of various electrical wiring. The most common types of symbols used in electrical drawings are shown in figure 9-23. To see additional or special symbols, refer to the appendix section of this book and/or to ANSI Y32.9.

To draw in electrical symbols in an electrical drawing, as in drawing a mechanical plan, it is best to use templates. For example, a wiring symbol is generally drawn as a single line but with slanting "tick marks" to indicate the number of wires in an electrical circuit.

EXTERIOR ELECTRICAL LAYOUT (PLAN)

Exterior distribution lines (or network) deliver electrical power from the source (generating station or transmission substation) to various points of use. Figure 9-24 shows a typical layout, extracted from NAVFAC P-437, *Facilities Harming Guide,* of an exterior electrical network of buildings for a 100-man camp. This layout, in condensed form, shows a site plan of the camp area with facilities and the location of the electrical component system. Included in the electrical plan is a list of facilities (upper right-hand corner of fig. 9-24) that describes the corresponding item symbol, facility number, and quantity. An electrical load data table is also included in the drawing.

As an EA, you will be called upon to trace, modify, revise, and even review the workability of the drawing. It is therefore to your advantage not only to study and become familiar with the electrical plans, but also to gain a working knowledge of how the system works. NAVFAC P-437 offers a wide variety of plans, drawings, and applications for the Advanced Base Functional Component (ABFC) System for use in SEABEE construction.

INTERIOR ELECTRICAL LAYOUT (PLAN)

As we mentioned earlier, the electrical information on exterior electrical distribution is generally shown in the regular site or plot plan. The INTERIOR ELECTRICAL LAYOUT, however, is, for small buildings, drawn into a print made from the floor plan. On larger projects, additional separate drawing sheets are necessary to accommodate detailed information needed to meet construction requirements.

Figure 9-25 shows an electrical layout of a typical public works shop. Once again, note that the electrical information is superimposed on an outline taken from an architectural floor plan. In addition to the list of assemblies and electrical load table, a wiring diagram and panel schedule of a 225-A, three-phase circuit breaker is drawn. The underground service entrance (item 10 on the list of assemblies) delivers a four-wire, 120/208-V power into the building. Lighting circuits use a three-wire, No. 12 AWG (TW).

The following basic steps are suggested to guide you in the development of an interior electrical plan:

1. Show the location of the service panel and its rating in amps.
2. Show all of the wall and ceiling outlets.
3. Show all of the special-purpose outlets, such as telephones, communications, doorbells, and so forth.
4. Show all of the switches and their outlet connections.
5. Show convenience outlets.
6. If required, complete a schedule of electrical fixtures, symbols, legends, and notes necessary to clarify any special requirements in the drawing that are not stipulated in the specifications.

The steps suggested above can be put to practice in the next chapter following mastery of civil and architectural drawings.

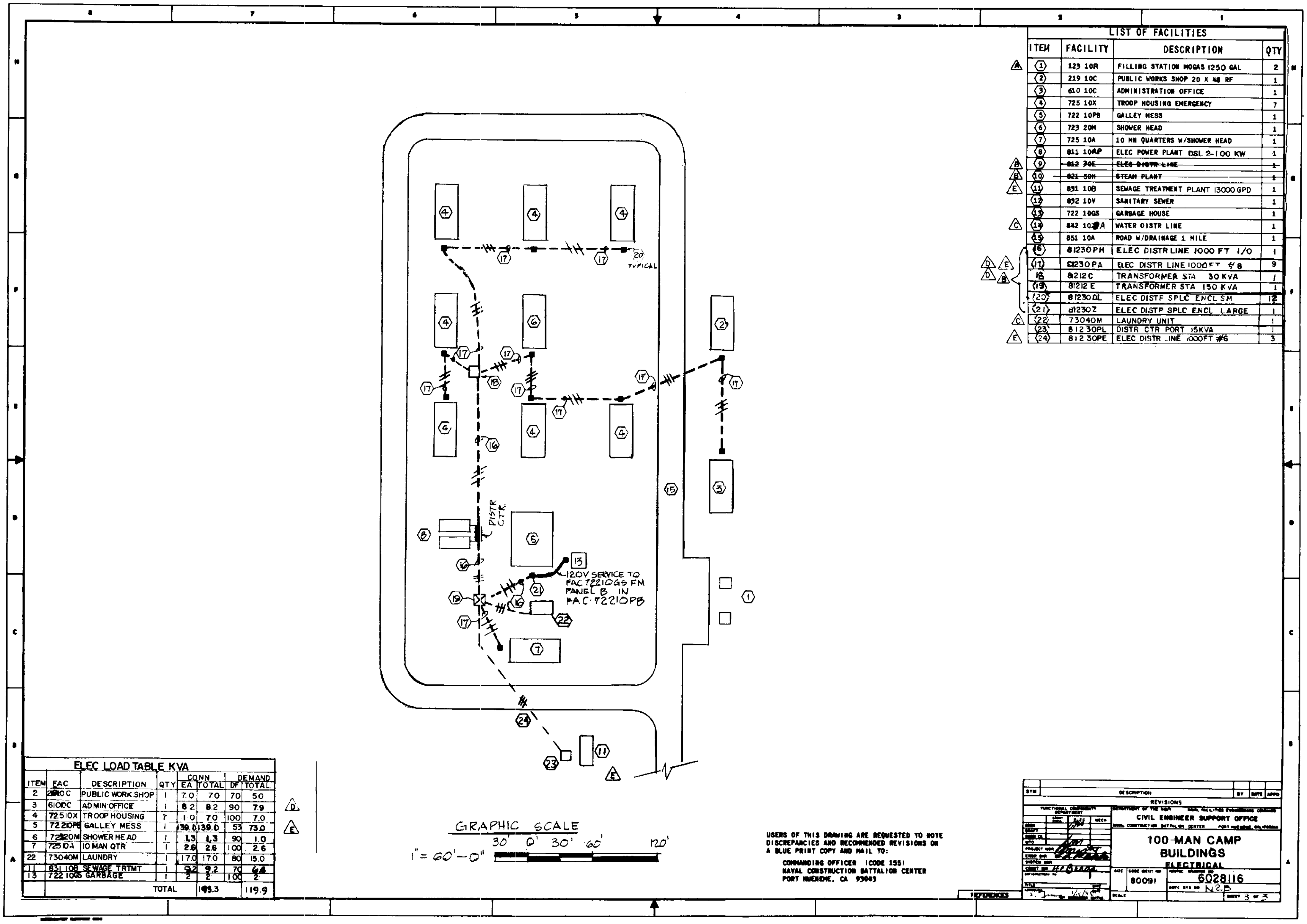

Figure 9-24.—Example of an exterior electrical plan.

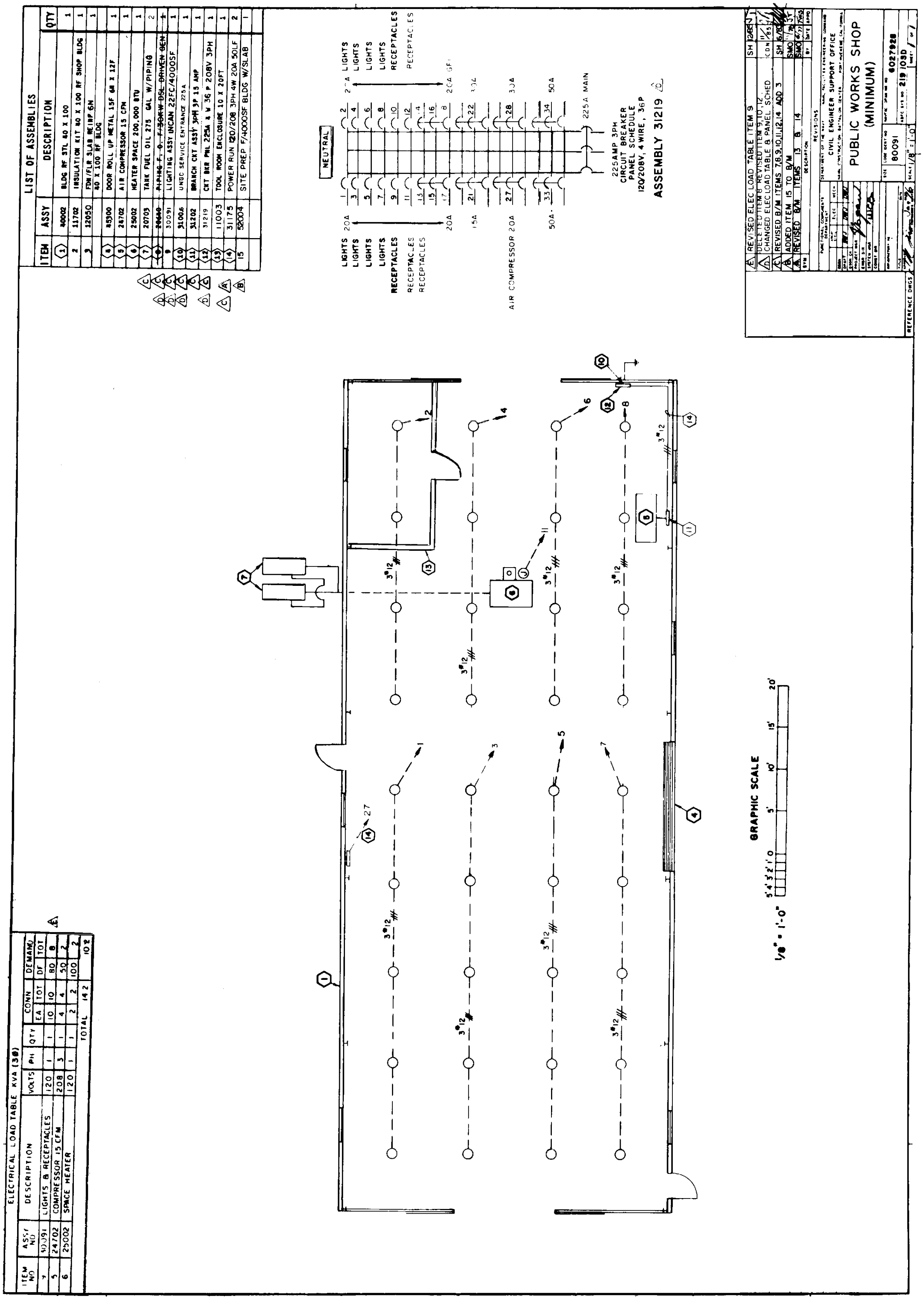

Figure 9-25.—Example of an interior electrical plan.

CHAPTER 10

CONSTRUCTION DRAWINGS

The construction of any structure or facility is described by a set of related drawings that give the SEABEEs a complete sequential graphic description of each phase of the construction process. In most cases, a set of drawings shows the location of the project, boundaries, contours, and outstanding physical features of the construction site and its adjoining areas. Succeeding drawings give further graphic and printed instructions for each phase of construction.

TYPES OF CONSTRUCTION DRAWINGS

Generally, construction drawings are categorized according to their intended purpose. Some of the types commonly used in military construction are discussed in this chapter.

PRESENTATION DRAWINGS

The purpose of the PRESENTATION DRAWINGS is to present the proposed building or facility in an attractive setting in its natural surrounding at the proposed site. They often consist of perspective views complete with colors and shading. Since presentation drawings are actually used to “sell” an idea or design concept, an EA assigned to the drafting section is rarely required to develop them.

SHOP DRAWINGS

SHOP DRAWINGS are drawings, schedules, diagrams, and other related data to illustrate a material, a product, or a system for some portion of the work prepared by the construction contractor, subcontractor, manufacturer, distributor, or supplier. Product data include brochures, illustrations, performance charts, and other information by which the work will be judged. As an EA, you will be required to draft shop drawings for minor shop and field projects. You may draw shop items, such as doors, cabinets, and small portable structures (prefabricated berthing quarters, and modifications of existing buildings), or perhaps you may be drawing from portions of design drawings, specifications, or from freehand sketches given by the design engineer.

MASTER PLAN DRAWINGS

MASTER PLAN DRAWINGS are commonly used in the architectural, topographical, and construction fields. They show sufficient features to be used as guides in long-range area development. They usually contain section boundary lines, horizontal and vertical control data, acreage, locations and descriptions of existing and proposed structures, existing and proposed surfaced and unsurfaced roads and sidewalks, streams, rights-of-way and appurtenances, existing utilities, north point indicator (arrow), contour lines, and profiles. Master plan and general development drawings on existing and proposed Navy installations are maintained and constantly upgraded by the resident officer in charge of construction (ROICC) and by the public works department (PWD).

WORKING DRAWINGS

A WORKING DRAWING (also called project drawing) is any drawing that furnishes the information required by the craftsmen to manufacture a machine part or by a builder crew to erect a structure; it is prepared from a freehand sketch or a design drawing. Complete information is presented in a set of working drawings, complete enough that the user will require no further information. Project drawings include all the drawings necessary for the different SEABEE ratings to complete the project. These are the drawings that show the size, quantity, location, and relationship of the building components.

A complete set of project drawings consists of general drawings, detail drawings, assembly drawings, and always a bill of materials. GENERAL DRAWINGS consist of "plans" (views from above) and elevations (side or front views) drawn on a relatively small defined scale, such as 1/8 in. = 1 ft or 1/4 in. = 1 ft. Most of the general drawings are drawn in orthographic projections, though sometimes details may be shown in isometric or cavalier projections. A DETAIL DRAWING shows a particular item on a larger scale than that of the general drawing in which the item appears, or it may show an item too small to appear at all on a general drawing. An ASSEMBLY DRAWING is either an exterior or a sectional view of an object showing the details in the proper relationship to one another. Usually, assembly drawings are drawn to a smaller scale than are detail drawings. This procedure provides a check on the accuracy of the design and detail drawings and often discloses errors.

Depending on the space available on the drafting sheet, you may incorporate the BILL OF MATERIALS in the drawing; otherwise, you are to list it on a separate sheet. The bill of materials contains a list of the quantities, types, sizes, and units of the materials required to construct the object presented in the drawing.

In a typical military construction, working (project) drawings go through stages of review and evaluation for design and technical adequacy by NAVFACENGCOM to ensure good quality, consistency, and cost effectiveness of the design. Special terms discussed in the following paragraphs describe these stages, from the initial development of the project to the final phase of construction.

Preliminary Drawings

PRELIMINARY DRAWINGS are the initial plans for projects prepared by the designer or architects and engineers (A/E) firm during the early planning or promotional stage of the building development. They provide a means of communication between the designer and the user (customer). These drawings are NOT intended to be used for construction, but they are used for exploring design concepts, material selection, preliminary cost estimates, approval by the customer, and a basis for the preparation of finished working drawings.

You will notice that most of the design work incorporated into the preliminary drawings at the 35-percent stage of completion contain, as a minimum, the following information: site plans, architectural floor plans, elevations, building sections, preliminary finish schedule and furniture layouts, interior and exterior mechanical and electrical data, and civil and structural details. All of the preliminary project drawings scheduled for use by the SEABEEs are reviewed by the COMCBPAC or COMCBLANT, as appropriate, for construction methods or procedures, whereas preliminary contract drawings are reviewed by ROICC.

Final Drawings

FINAL DRAWINGS are 100 percent complete, signed by the contracting officer, and used forbidding purposes. This set of plans becomes official contract drawings once the contract is awarded. Final drawings are often revised to show changes made by a scope change or by a change order with the concurrence of both the contractor and contracting officer. At this stage of completion, no further functional input may be introduced into the final drawings because of time constraints. In general, final drawings, together with project specifications, cost estimates, and all of the calculations, comprise the final stages of design requirements.

Red-lined Drawings

These are the official contract drawings that you will mark up during construction to show as-built conditions. RED-LINED DRAWINGS are marked in color "red" to indicate either a minor design change or a field adjustment.

As-built Drawings

These are the original contract drawings (or sepia copies) that you will change to show the AS-BUILT conditions from the red-lined drawings. Upon completion of facilities, the construction contractor or the military construction force (NMCB) is required to provide the ROICC with as-built drawings indicating construction deviations from the contract drawings. All of the as-built marked-up prints must reflect exact as-built conditions and show all features of the project as constructed. After completion of the project, as-built marked-up prints are transmitted by the ROICC to the engineering field division (EFD).

Record Drawings

The original contract drawings, corrected according to the marked prints, provide a permanent record of as-built conditions upon completion of the instruction work on a project. The original RECORD DRAWINGS may be retained in the custody of the EFD or they may be transferred to stations with public works.

CONCEPTUAL DEFINITIVE DESIGNS

These are prepared designs or drawings defining various functional, engineering, and logistical requirements for structures and facilities needed on a repetitive basis. These drawings are intended to provide a uniform basis for planning and design. CONCEPTUAL DESIGNS commonly used in the Navy include both definitive and standard designs.

Definitive Designs

DEFINITIVE DESIGNS are drawings of typical buildings and structures you will find in NAVFAC P-272, *Definitive Designs for Naval Shore Facilities, Part 1.* These drawings contain floor plan arrangements, building sections and elevations, and utility requirements for general guidance to A/E contractors or in-house staff who prepare project drawings and specifications. Part 2 of P-272 contains advance designs of more complex facilities that may include equipment layouts, piping diagrams, electrical schematics, and other critical requirements for specific guidance in preparing project designs. Both parts, however, are used in conjunction with NAVFACENGCOM criteria manuals, handbooks, and guide specifications listed in P-34, *Engineering and Design Criteria for Navy Facilities.*

Included in the facility type of designs are single-line schematics, bubble diagrams, or graphics based on definitive drawings called FACILITY PLATES. These plates (fig. 10-1) are used to show functional relationships or building layouts, such as detailed information concerning the design of individual rooms within a specific type of facility. Facility plates may show the location of all of the equipment and furnishings within a room, the location of utilities serving the room, the location and size of doors and windows, a ceiling plan reflecting the location of lighting fixtures, and other technical design information about the room. Facility plates are used instead of the definitive design whenever the plates effectively convey the necessary design data or whenever definitive are scheduled to be revised, developed, or validated. You will find most of the facility plates within the pages of criteria or design manuals (DMs).

Standard Designs

These designs are detailed working drawings of predominantly specialized structures for unique naval facilities, such as waterfront structures, aircraft operations and maintenance facilities, ammunition storage facilities, and fleet moorings. STANDARD DESIGNS form a part of the construction documents requiring only supplemental drawings for adapting the facility to the specific site. You can modify these drawings (except for ammunition facilities) as necessary to meet on-site requirements. Ammunition and explosive design standards may NOT be modified without the approval of the Naval Facilities Engineering Command (NAVFACENGCOM). When standard designs are used for a construction project, with or without modifications, a new title block and drawing number are required. The cognizant EFD assigns these numbers.

Another source of detailed construction drawings, NOT definitive, is found in NAVFAC P-437, *Facilities Planning Guide, Vol. 1.* These facility and assembly drawings contain reproducible drawings of pre-engineered structures used to satisfy the Naval Construction Force (NCF) at advanced bases in peacetime and during contingency operations. Thus, if a facility is required to meet tactical and strategic situations, construction planners can easily and readily identify and determine specific requirements and provide support. Other useful information for SEABEE planners, such as crew size, man-hours by skill, land area, and fuel necessary to make a component, facility, or assembly operational, is contained within the guide. As an EA, you should realize the importance of becoming familiar with the contents of NAVFAC P-437.

PROJECT DRAWING PREPARATION

All NAVFACENGCOM project drawings are prepared according to DOD-STD-100. The policy and procedures for preparing and developing these drawings are outlined in the military handbook MIL-HDBK-1006/1. Project drawings must be complete, accurate, and explicit since they (together with the design specifications) form the basic ingredients used in contracts for the construction of naval facilities. EAs and in-house planners also benefit from clear and consistent project drawings, especially when revising project drawings.

POLICY AND STANDARDS

The design criteria for project drawings are set by NAVFACENGCOM. These criteria also

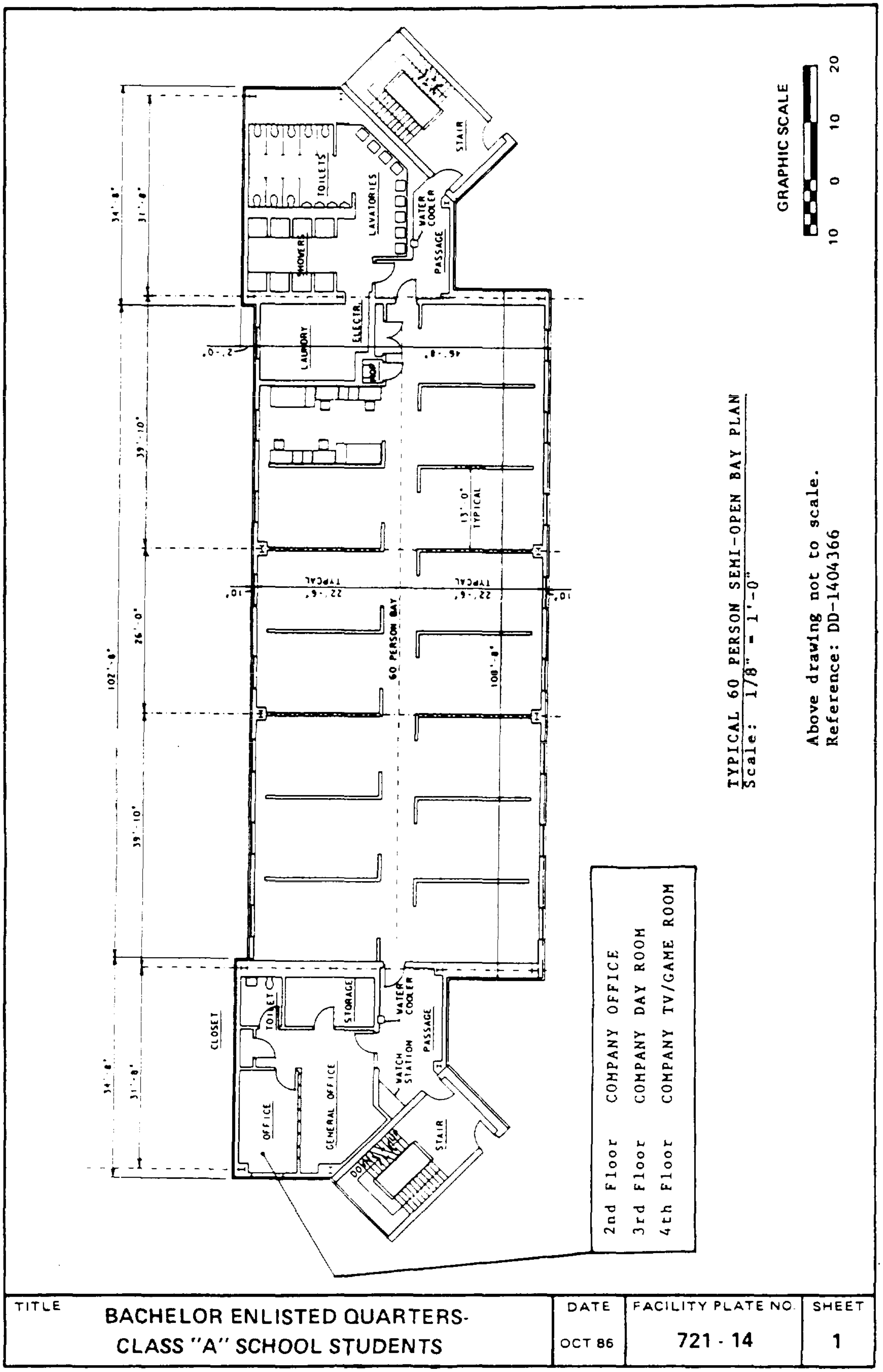

Figure 10-1.—Example of a facility plate (based on Definitive Design 1404366).

apply to definitive designs and standard drawings and also to project specifications. EFDs and A/Es are allowed latitude in new concepts, creative thinking, and the use of new materials; however, when deviations from mandatory criteria are considered, they need to obtain prior clearance from NAVFACENGCOM headquarters.

For dimensions on project drawings, you may use customary U.S. dimensions unless the project is in an area in which System International (SI) is normally used. The International System of Units is the internationally accepted "metric" system. Use of the word metric is no longer an accepted practice. For details of the proper use of SI units, refer to ASTM E380-82, *Standard for Metric Practice,* for generic conversions, and ASTM E621-79, *Recommended Practice for the Use of Metric (SI) Units in Building Design and Construction,* for conversions in engineering and design.

ORDER OF DRAWINGS

Project drawings for buildings and structures are arranged in the following order:

1. TITLE SHEET AND INDEX—Contains specific project title and an index of drawings. (Used only for projects containing 60 or more drawings).
2. PLOT OR VICINITY PLANS—Contain either plot or vicinity plans or both, as well as civil and utility plans. For small projects, this sheet should include an index of the drawings.
3. LANDSCAPE AND IRRIGATION (if applicable).
4. ARCHITECTURAL (including interior design as applicable).
5. STRUCTURAL.
6. MECHANICAL (heating, ventilation, and air conditioning).
7. PLUMBING.
8. ELECTRICAL.
9. FIRE PROTECTION.

DRAWING SHEET SIZE AND FORMAT

The following should be used for NAVFACENGCOM drawings:

TYPE	SIZE (IN INCHES)
Flat	17 x 22 (C size) - When small sheets are required
Flat	22 x 34 (D size) - for project and other drawings
Flat	28 x 40 (F size) - option to 22 x 34

Refer to chapter 3, figure 3-14 for finished drawing and format and margins.

Title Blocks

The title block indicates the name and location of the activity preparing the drawing, drawing title and number, approval within the activity and by an activity other or different than the source preparing the drawing, and other information relative to preparation of the drawing, such as the predominant scale used, drawing size letter designation, and sheet number for multiple sheet drawings. The code identification number or Federal Supply Code for Manufacturers (FSCM) "80091" is required in the title block of all NAVFACENGCOM drawings. Vertical title block format is used for all 22- by 34-in. (D-size) drawings; whereas, use of vertical title block is optional for 28- by 40-in. (F-size) drawings. The layout and format for title blocks are shown in chapter 3, figures 3-15 to 3-21, and in ANSI Y14.1-1980.

Drawing Numbers

NAVFACENGCOM drawing numbers issued to individual engineering field divisions are within the following limits:

NORTHERN DIVISION . . . . . .2 000 000 to 2 999 999

CHESAPEAKE DIVISION . . .3 000 000 to 3 999 999

ATLANTIC DIVISION . . . . .4 000 000 to 4 999 999

SOUTHERN DIVISION . . . . . . .5 000 000 to 5 999 999

WESTERN DIVISION . . . . .6 000 000 to 6 999 999

PACIFIC DIVISION . . . . .7 000 000 to 7 999 999

NAVFACENGCOM headquarters retains custody of all of the numbers up to and including 1 999 999 and all other drawing numbers not assigned. Each cognizant EFD is responsible for the control of assigned numbers for issuing, assigning, and recording these numbers for its own use or the use of activities within its geographical area. Each activity maintains an assignment record including locations and drawing titles of drawing numbers assigned to it.

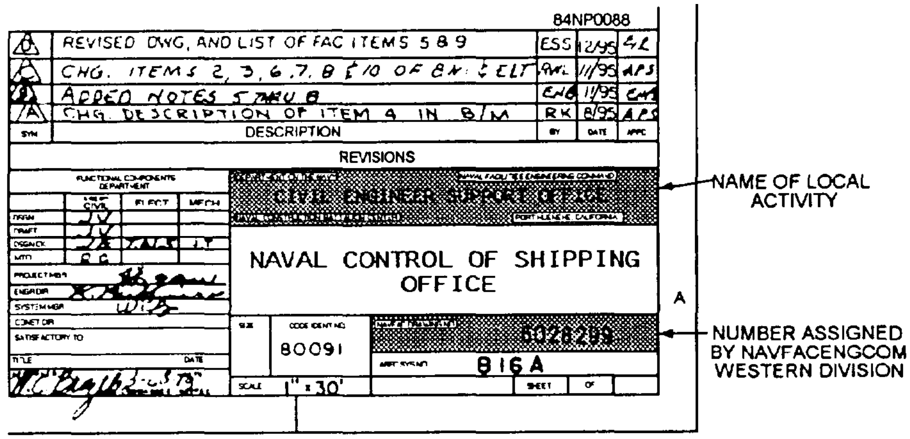

Figure 10-2.-A title block showing a drawing number assigned by NAVFACENGCOM.

(Figure 10-2 is an example of a local activity, such as the Civil Engineering Support Office (CESO), using a drawing number assigned by the Western Division (WESTDIV).)

Figure 10-2.A title block showing a drawing number assigned by NAVFACENGCOM.

You may not use a NAVFACENGCOM assigned number for any other drawing, even though the drawing to which it has been assigned is not being used. Sometimes, because of extensive revision on a particular drawing, it becomes necessary to prepare a new drawing and to assign a new NAVFACENGCOM drawing number. A cross-reference note to be placed directly above or adjacent to the title block is shown below.

Old Drawing Note:	New Drawing Note:
THIS DRAWING SUPER- SEDED BY DRAWING NO. ________________	THIS DRAWING SUPER- SEDES DRAWING NO. ________________

Drawing Revisions

Revisions to NAVFACENGCOM project drawings are to be made according to DOD-STD-100C. The revision block may include a separate "PREPARED BY" column to indicate the organization, such as an A/E firm, that prepared the revision. The layout of the modified revision block is to be as shown in chapter 3, figure 3-22, views A and B.

Graphic Scales

Graphic scales are located in the lower right-hand corner of each drawing sheet, with the words Graphic Scales directly over them. The correct graphic scales must be shown prominently on each drawing because, as drawings are reduced in size, the reductions are often NOT to scaled proportions.

Line Conventions and Lettering

You should pay close attention to the opaqueness and uniform weight of lines. To provide contrasting division and use of thick and thin lines, refer to chapter 3, figure 3-23, and ANSI Y14.2M, *Line Conventions and Lettering, Engineering Drawing and Related Documentation Practices.* Uppercase lettering is to be used except for notes on maps and similar drawings, where lowercase lettering may be used. The minimum allowable height of freehand letters is 5/32 (0.156) in., and of mechanical or computer graphics is 0.150 in. For abbreviations on drawings, use MIL-STD-12, *Abbreviations.*

DIMENSIONING AND TOLERANCING

All dimensions and tolerances are to clearly define engineering intent and be prepared according to ANSI Y14.5M, *Dimensioning and Tolerancing for Engineering Drawings.* Some of the fundamental rules that apply to dimensioning and tolerancing drawings are as follows:

1. A dimension having a tolerance may have it applied directly to the dimension or indicated by a general note on the drawing sheet.

2. Dimensioning for size, form, and location of features are to be complete; however, no more dimensions than those necessary for complete definition should be given. Neither the use of "sealing" (measuring the size of a feature directly from an engineering drawing) nor assumption of a distance or size is permitted. The use of a reference dimension on a drawing should also be minimized.

3. Dimensions should be arranged to provide optimum readability to obtain required

information. Dimensions should be selected to suit the function and should not be subject to more than one interpretation.

Detailed dimensioning format and standards will be discussed freely in this chapter to meet specific requirements. You will notice that dimensioning construction or project drawings differs in some applications from dimensioning general technical drawings. This occurs primarily because of the materials and methods of construction.

Units of Measure

As we stated earlier, the unit of measurement selected should be according to the policy of the user and the geographical area in which the project plans will be used. The U.S. linear unit commonly used on project drawings is the inch, while that of SI (metric) linear units is the millimeter. On drawings where all dimensions are either in millimeters or inches, individual linear unit identification is NOT required. However, when this is the case, your drawing should contain a note stating "UNLESS OTHERWISE SPECIFIED, ALL DIMENSIONS ARE IN INCHES" (or "IN MILLIMETERS," as applicable). Millimeter dimension values shown on an inch-dimensioned drawing must be followed by the symbol mm, while inch dimension values shown on a millimeter-dimensioned drawing will be followed by the abbreviation IN.

Similarly, dimensions for angular units are expressed in either degrees and decimal parts of a degree or in degrees, minutes, and seconds. Refer to figure 10-3 for guidance, as applicable.

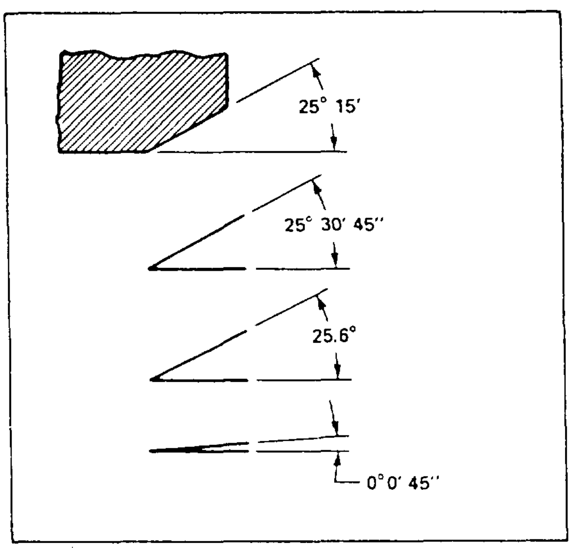

Figure 10-3.-Dimensioning angular units.

Application of Dimensions

Dimensions are applied by means of dimension lines, extension lines, or a leader from a dimension, note, or specification directed to the appropriate feature. Some of the standard rules to be followed when you are drawing DIMENSION LINES are as follows:

1. The breaking of dimension lines for insertion of numerals, as shown in figure 10-4,

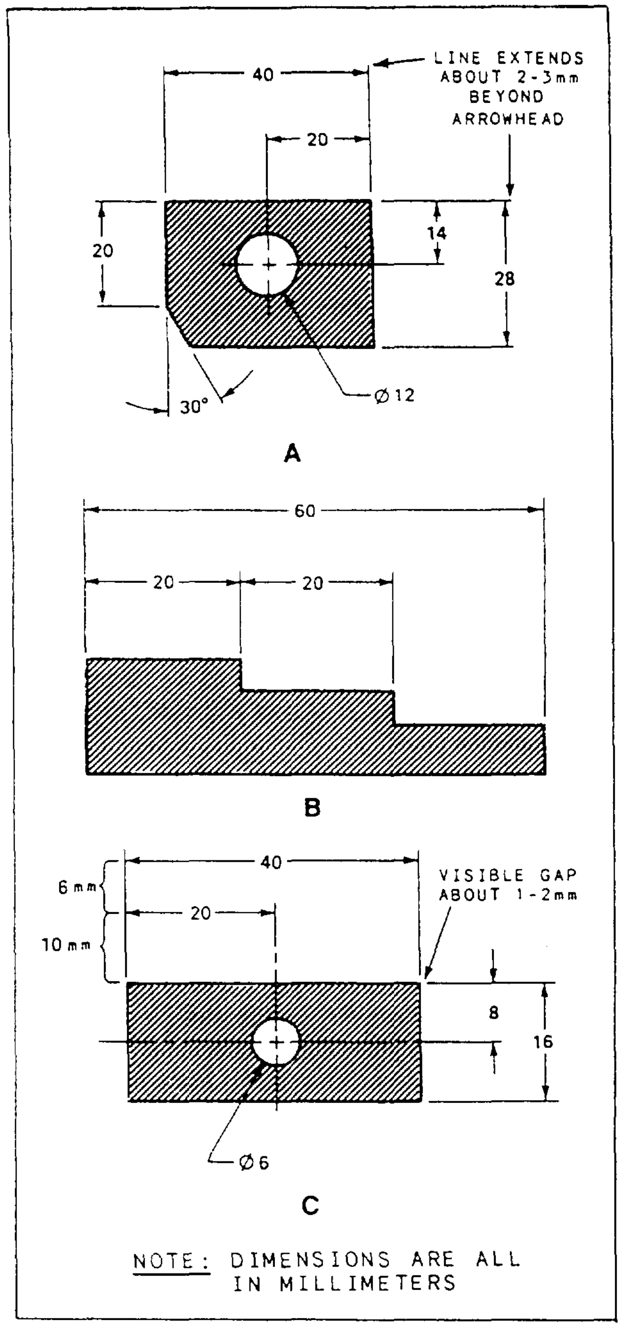

Figure 10-4.-Applications of dimensions and dimension lines: A. Breaking dimension lines for insertion of numerals; B. Grouping lines for uniform appearance; C. Proper spacing of dimension lines from object.

view A, is the preferred method of drawing dimension lines in many forms of drafting. However, for construction drawings, it is permissible, and in fact customary, to draw dimension lines from one extension line to another without breaking them. The numerals are then placed above the dimension line and parallel to the direction of measurement. This method is easier and saves considerable time.

2. Dimension lines are to be aligned if practical and grouped for uniform appearance, as shown in figure 10-4, view B. The space between the first dimension line and the object line should be not less than 10 mm, minimum; the space between succeeding parallel dimension lines should be not less than 6 mm, minimum, as shown in figure 10-4, view C. Where there are several parallel dimension lines, you may stagger the numerals for easier reading.

When using U.S. standards, you should ensure that the minimum space between the first dimension line and the object line is 3/8 in., and the succeeding parallel dimension lines are spaced at least 1/4 in. apart.

3. An angle is to be dimensioned with an arc drawn so that its center is at the apex of the angle and the arrowheads terminate at the extension of the two sides, as shown in figure 10-3.

4. Crossing dimension lines should be avoided insofar as possible. If crossing them is unavoidable, dimension lines are to be unbroken. Figure 3-23, chapter 3, shows the characteristics of dimension lines.

As explained in chapter 3, extension lines (also called projection lines) are used to indicate the extension of a surface or point to a location outside the outline of the object (or view). They are usually drawn perpendicular to dimension lines. Where space is limited, you may draw extension lines at an oblique angle. Figure 10-5, view A, clearly shows this application. You should also minimize the crossing of extension lines over one another and over dimension lines by placing the shortest dimension line closest to the outline of the object, as shown in figure 10-5, view B. Where extension lines cross arrowheads or dimension lines close to arrowheads (fig. 10-5, view C), a break in the extension line is advisable. For examples in the proper use of extension lines, refer to chapter 3, figures 3-30 and 3-31. LEADERS (or leader lines), also explained in chapter 3, direct dimensions, notes, or symbols to the intended place on the drawing.

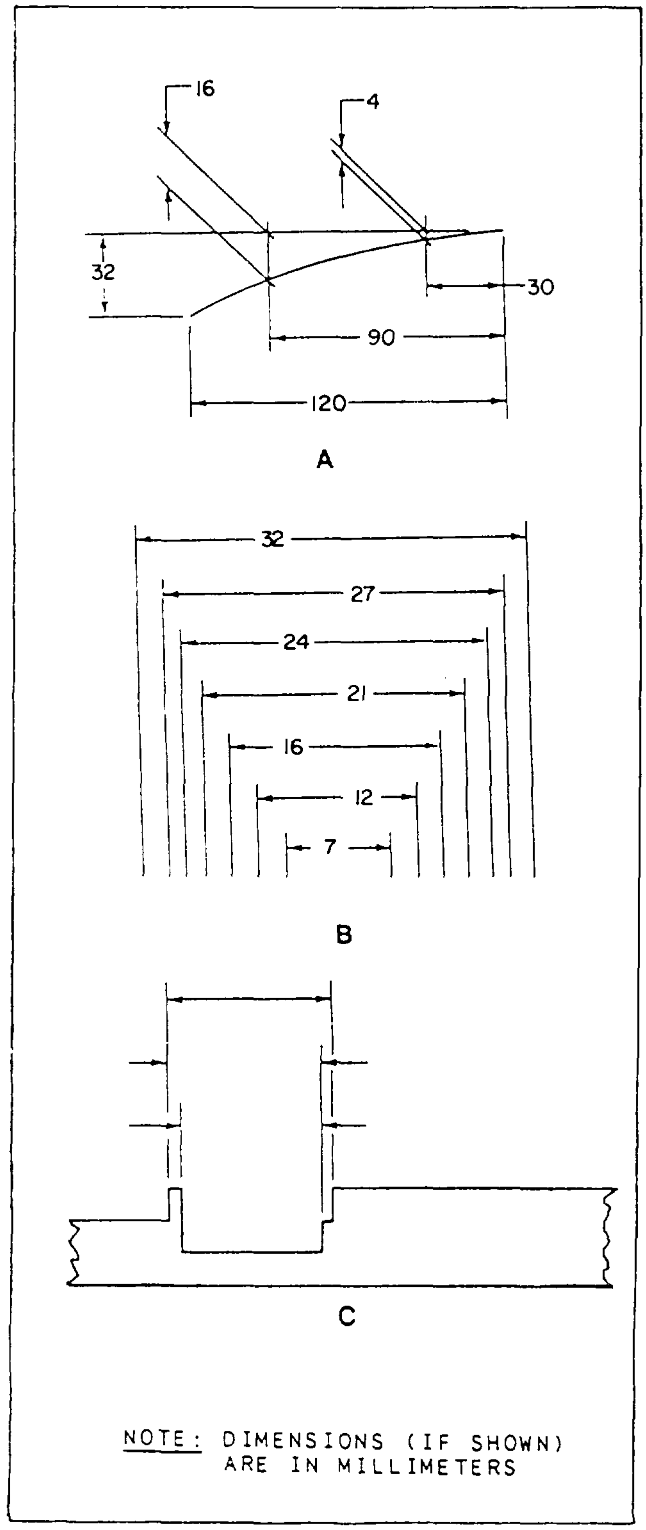

Figure 10-5.-Applications of extension lines: A. Where space is limited; B. Minimizing crossing of extension lines; C. Where extension lines break.

DRAWING SYMBOLS

Because of the small scale used in most drawings, standard graphic symbols are used to present complete information concerning construction items and materials. These typical symbols are used so frequently in construction drawings that their meanings must be familiar not only to the preparer, but to the user as well. The main information sources for a particular symbol are the Military (Drawing) Standards (MIL-STD) and the American National Standards Institute (ANSI). Refer to these standards before you use other references. Listed below are some of the most commonly used military standards and the particular symbols they carry.

Standard	Description
MIL-STD-14	Architectural Symbols (latest revision)
MIL-STD-17-1	Mechanical Symbols (latest revision)
MIL-STD-18	Structural Symbols (latest revision)
ANSI Y32.9-1972	Graphic Symbols for Electrical Wiring and Layout Diagrams Used in Architecture and Building Construction
ANSI Y32.4-1977	Graphic Symbols for Plumbing Fixtures for Diagrams Used in Architecture and Building Construction
ANSI/AWS A2.4-1986	Symbols for Welding

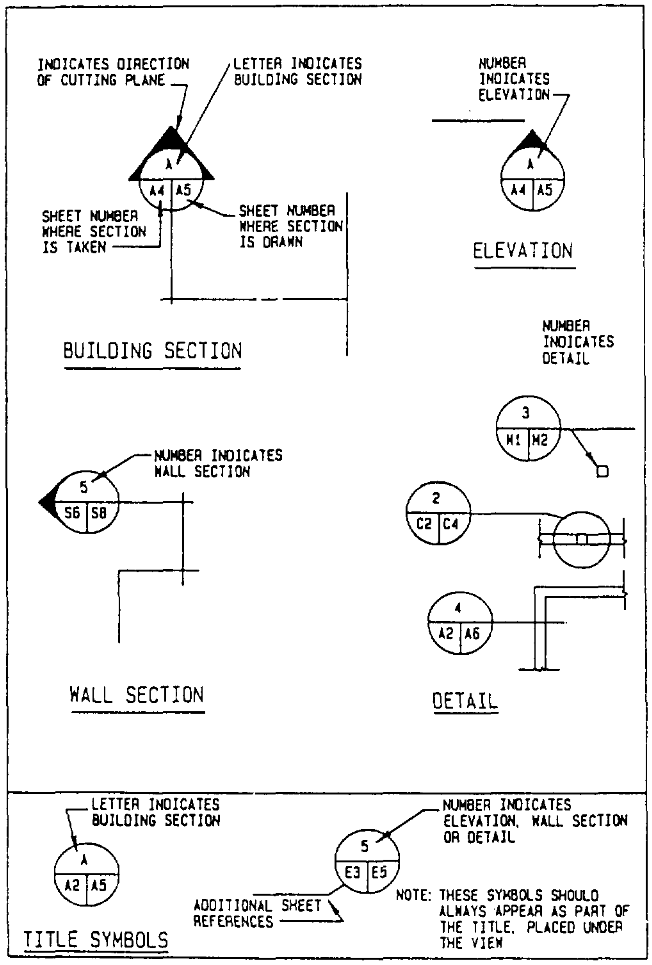

Figure 10-6.-Symbols used to identjfy sections, elevations, and details.

Sometimes you may notice that other symbols are not included in any of the standards mentioned earlier. These symbols, like the ones shown in figure 10-6, can be found in one of the military handbooks developed by NAVFACENGCOM for project drawings. As an EA, you will find that your knowledge of applicable symbols will greatly assist you in accomplishing the job correctly and promptly, and, above all, with confidence. Some of the basic architectural and welding symbols are shown in figures 10-7 through 10-10. Other types of symbols are shown in the appendix section of this book.

DRAWING NOTES

NOTES are brief, clear, and explicit statements regarding material use and finish and construction methods. Notes in a construction drawing are classified as specific and general.

SPECIFIC notes are used either to reflect dimensioning information on the drawing or to be explanatory. As a means of saving space, many of the terms used in this type of notes are often expressed as abbreviations.

GENERAL notes refer to all of the notes on the drawing not accompanied by a leader and an arrowhead. As used in this book, general notes for a set of drawings covering one particular type of work are placed on the first sheet of the set. They should be placed a minimum of 3 in. below the space provided for the revision block when the conventional horizontal title block is used. When the vertical title block is used, you may place the general notes on the right side of the drawing. General notes for architectural and structural drawings may include, when applicable,

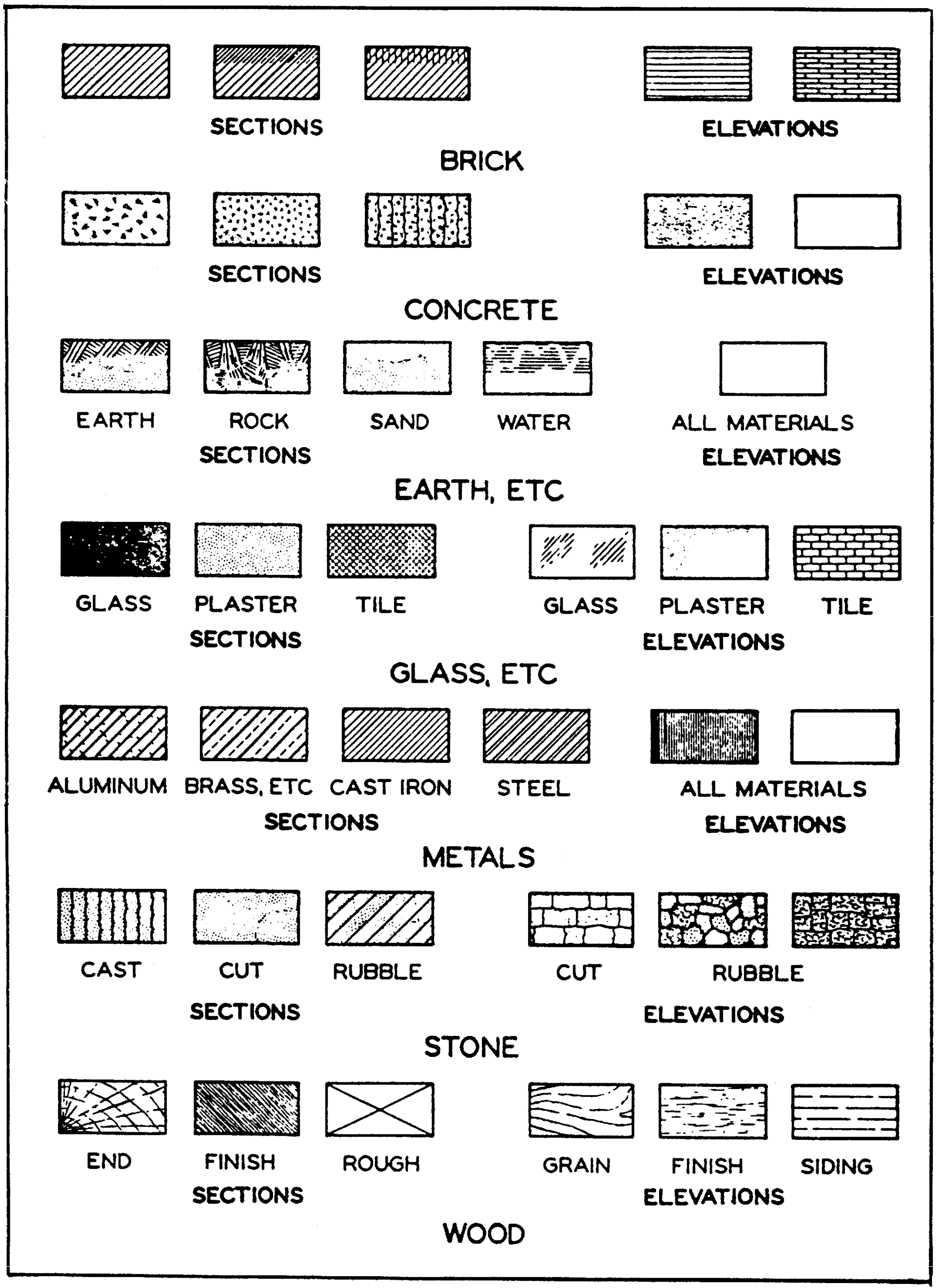

Figure 10-7.—Common architectural symbols (for various materials) used in drawing sections and elevations.

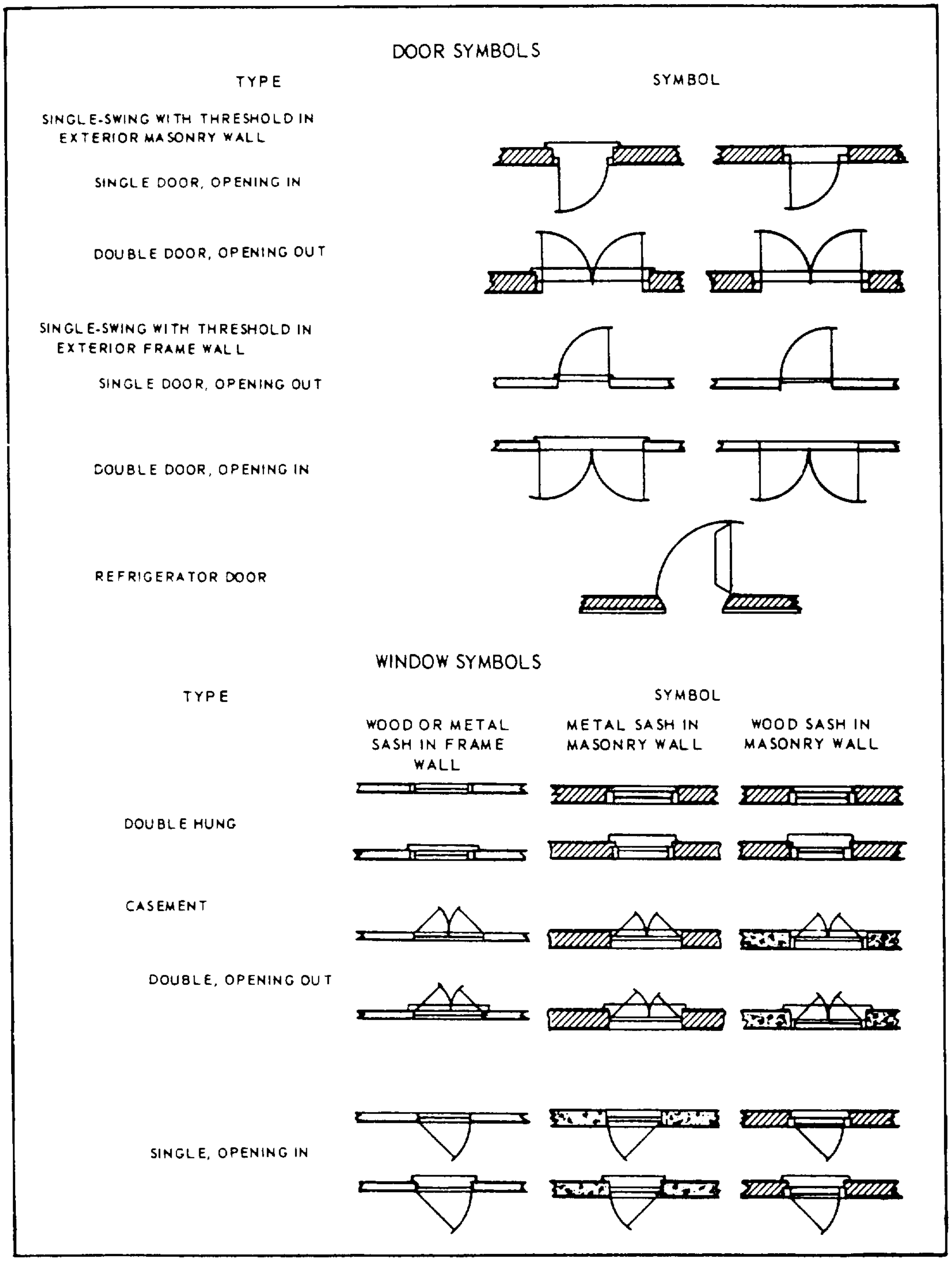

Figure 10-8.-Architectural symbols (doors and windows).

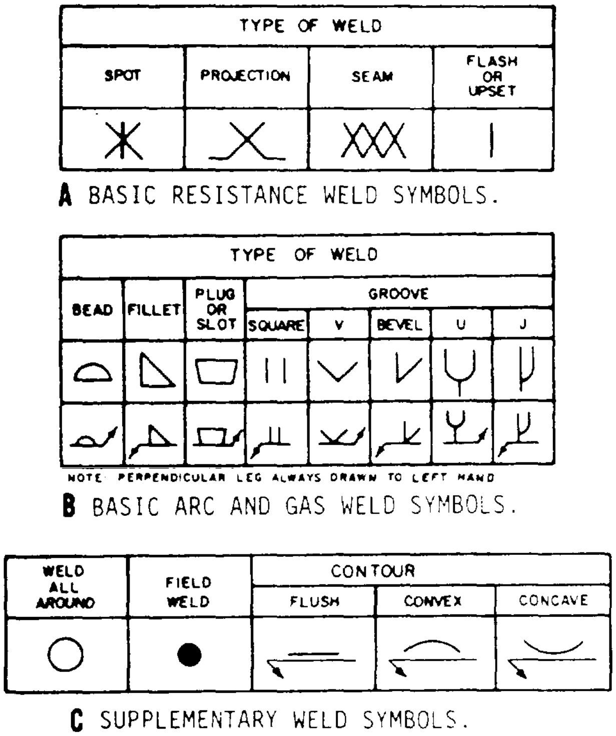

Figure 10-9.-Weld symbols.

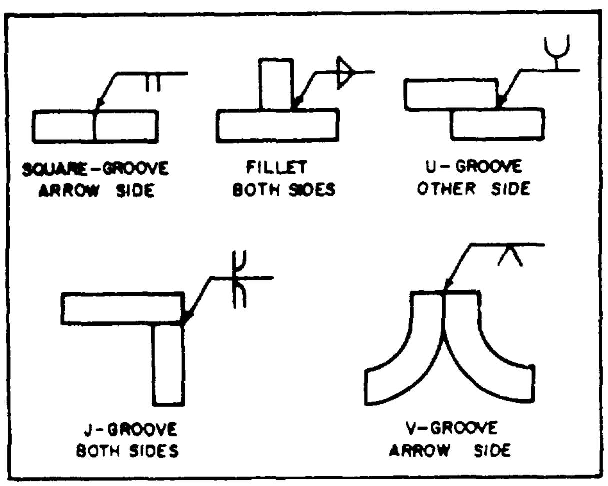

Figure 10-10.-Application of weld symbols.

roof, floor, wind, seismic, and other loads, allowable soil pressure or pile-bearing capacity, and allowable unit stresses of all the construction materials used in the design. Notes for civil, mechanical, electrical, sanitary, plumbing, and similar drawings of a set may include, when applicable, references for vertical and horizontal control (including soundings) and basic specific design data.

General notes may also refer to all of the notes grouped according to materials of construction in a tabular form called a SCHEDULE. Schedules for items like doors, windows, rooms, and footings are somewhat more detailed. Their formats will be presented later in this chapter.

MAIN DIVISIONS OF PROJECT DRAWING

Generally, working or project drawings may be divided into the following major categories: civil, architectural, structural, mechanical, electrical, and fire protection. In SEABEE construction, however, the major categories most commonly used are as follows: CIVIL, ARCHITECTURAL, STRUCTURAL, MECHANICAL, and ELECTRICAL sets of drawings.

Regardless of the category, working drawings serve the following functions:

- They provide a basis for making material, labor, and equipment estimates before construction begins.
- They give instructions for construction, showing the sizes and locations of the various parts.
- They provide a means of coordination between the different ratings.
- They complement the specifications; one source of information is incomplete without the others.

CIVIL DRAWINGS

Civil working drawings encompass a variety of plans and information to include the following:

- Site preparation and site development
- Fencing
- Rigid and flexible pavements for roads and walkways
- Environmental pollution control
- Water supply units (that is, pumps and wells)

Depending on the size of the construction project, the number of sheets in a set of civil drawings may vary from a bare minimum to several sheets of related drawings. Generally, on an average-size project, the first sheet has a location map, soil boring log, legends, and sometimes site plans and small civil detail drawings. (Soil boring tests are conducted to determine the water table of the construction site and classify the existing soil.) Civil drawings are often identified with the designating letter C on their title blocks.

A SITE PLAN (fig. 10-11) furnishes the essential data for laying out the proposed building lines. It is drawn from notes and sketches based upon a survey. It shows the contours, boundaries,

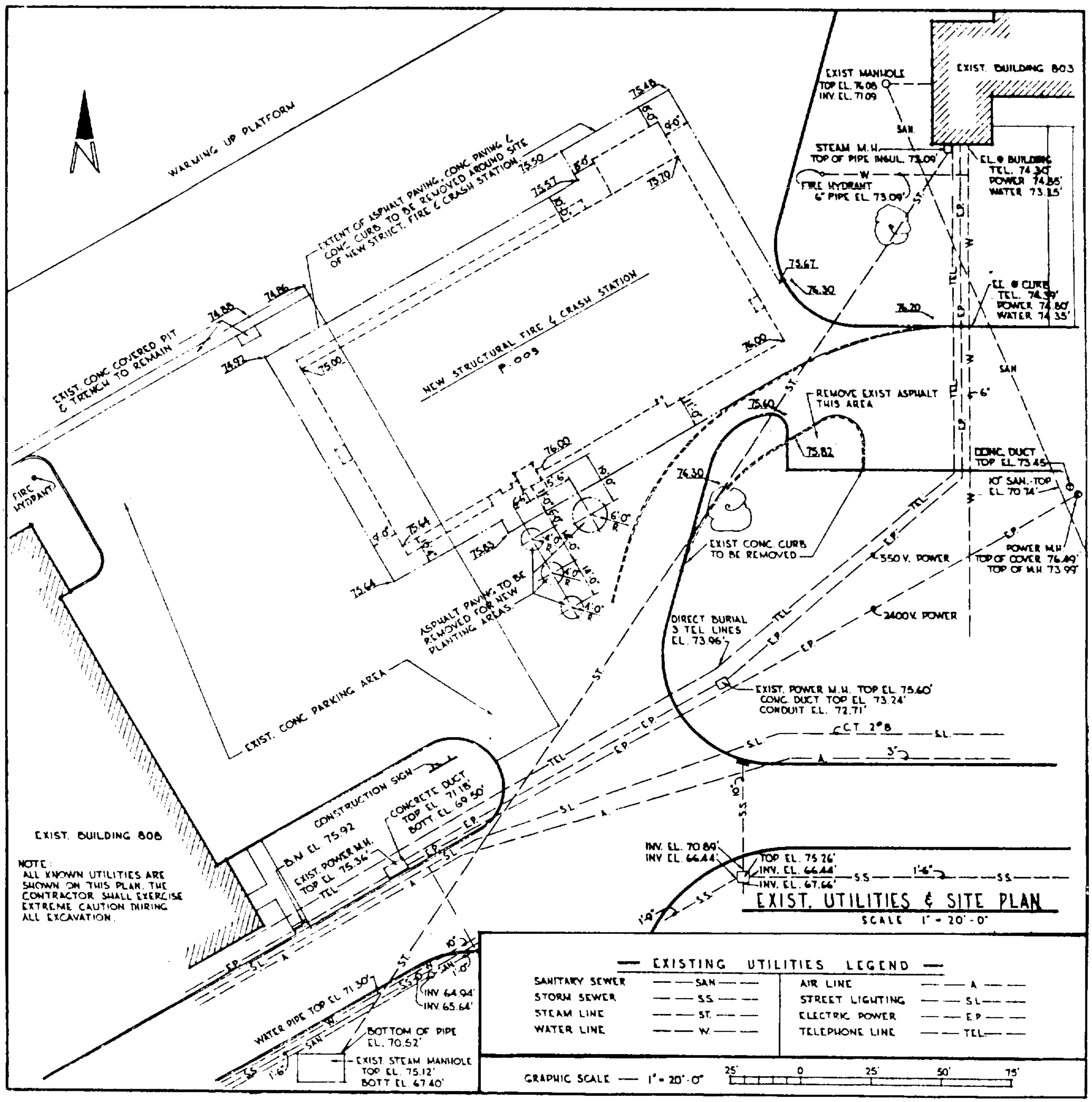

Figure 10-11.-Example of a site plan with existing utilities.

roads, utilities, trees, structures, references, and other significant physical features on or near the construction site. By showing both existing and finished contours, the field crew (Equipment Operators) is able to estimate and prepare the site for construction and to finish the site (including landscaping) upon completion of construction. As an EA, you should be familiar with the methods and symbols used on maps and topographic drawings.

Site plans are drawn to scale. In most instances, the engineer's scale is used rather than the architect's scale. For buildings on small lots, the scales normally used are 1 in. = 10 ft or 1 in. = 20 ft. This means that 1 in. on the drawing is equal to 10 or 20 ft, whichever the case may be, on the ground. Since the engineer's scale is the principal means of making scaled site plans, you, as an EA, should be thoroughly familiar with its uses.

On a set of project drawings prepared by an A/E firm, the physical information given on the site plan is taken from surveyor-prepared field notes or sketches. Other information contained on the site plan may also be used by the planners and estimators when figuring quantities of materials required, labor needed, and areas available for staging of equipment and materials.

As an EA, you may be tasked with drawing a site plan or revising one. Outlines of some of the basic procedures in the development of a site plan follow.

1. Lay out the site plan from the surveyor's drawing, showing boundary lines or limits of construction and existing trees and construction. Also note any existing features that must be removed.

2. Draw contour lines with dashed lines. Notice that if contour lines are placed on the reverse side of the drafting sheet, they make future changes or revisions easier.

3. Draw the proposed building and all surrounding construction, such as sidewalks and parking areas. Show the outline of the building wall with solid lines and the outline of the roof overhang with dashed lines.

4. Give the finished floor elevations of the building or buildings, garages (if any), and finished elevations desired on sidewalks and parking areas.

5. Review the existing contour lines. It is important that surface water not run into the buildings and other constructions, but rather towards a storm drainage system.

6. Place the dimensions. Locate the building and other constructions by a minimum of two location dimensions. If the building is not positioned parallel with the property line, more than two dimensions are required. Dimensions should be from the property line to the exterior wall of the building, not the overhang. Other dimensions necessary to be included are distances to road center lines, utility lines, easements, and any restrictions or obstructions to the site, such as utility poles and hydrants.

7. Double-check your drawing, taking a second look at the finish grade elevations, datum point, and other related information. A good technique is keeping a site plan checklist handy to make sure information given is complete and accurate.

ARCHITECTURAL DRAWINGS

ARCHITECTURAL WORKING DRAWINGS (sometimes identified with the designating letter *A* on their title blocks, as shown in chapter 3, figure 3-17) consist of all the drawings that describe the architectural design and composition of the building. A set of architectural drawings includes floor plans, building sections, exterior and interior elevations, millwork, door and window details and schedules, interior and exterior finish schedules, and special architectural treatments. For small, uncomplicated buildings, the architectural drawings might also include foundation and framing plans, which are generally included as part of the structural drawings.

Floor Plan

A FLOOR PLAN is a horizontal section through a building, showing the outline or arrangement of the floor. An offset cutting plane is often required to pass through low and high features on the wall in order to reveal doors, windows, fireplaces, stair openings, and other features located in the building.

The floor plan is usually the first drawing worked on by the EA. It is considered the key drawing in a set of project drawings—the drawing that all of the construction personnel will look at. Hence, the purpose of the floor plan is to show information about the location and type of construction, location and size of doors, windows, built-in fireplaces, stairs, rooms, and exterior and interior features.

Figure 10-12 shows the manner in which a floor plan is developed. Imagine that after the

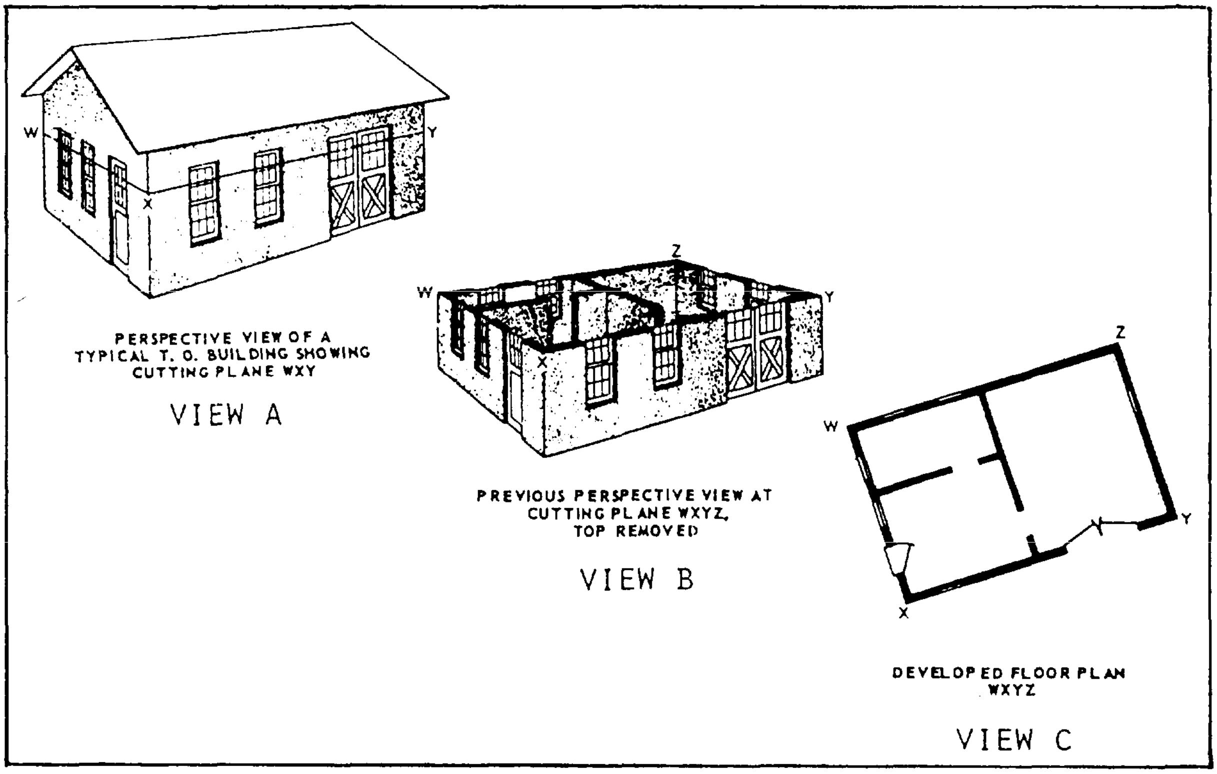

Figure 10-12.-Development of a floor plan.

building has been constructed, a cutting plane is used and cuts through the structure passing through the plane WXYZ (view A) and that the upper portion has been removed (view B). You would then be able to look down on the floor from above, and the drawing of what you see would be the floor plan (view C).

Figure 10-13 shows a floor plan of a concrete-masonry construction. It gives the lengths, thicknesses, and character of the outside walls and partitions at the particular floor level. It also shows the dimensions and arrangement of the rooms, the widths and locations of the doors and windows, and the locations and character of the rest rooms and other utility features. Study figure 10-13 carefully!

DRAWING A FLOOR PLAN.— Proper scale selection and sheet layout should be done to achieve the best results on the drawing. Before doing the actual drawing, you should draw up preliminary sketches to include the approximate size of the building, room dimensions, wall thicknesses, corridor widths, and so forth. Ideally, a scale of 1/4 in. = 1 ft should be used for easy readability. Smaller scales, such as 3/16 in. = 1 ft and 1/8 in. = 1 ft, are sometimes used for large buildings and in cases in which the size of the sheet is limited.

After you have selected the proper scale and sheet layout, you should follow the procedures outlined below.

1. Lay out construction lines (after taping the sheet to the drafting board surface) for borders, title block, and exterior limits of the building at any one side. Lay out the rooms and walls from left to right, with the exterior wall thickness being drawn first. Since the wall thickness varies with the materials used, it is impossible to accurately draw actual dimensions of each material selected. An EA would use a “nominal” wall thickness dimension of 6 in. for a wall frame exterior wall that has no brick or stone veneer. In a wall, a VENEER is a thin covering of material, such as brick, placed over a backing material of wood frame or block. Nominal wall thicknesses found in the *Architectural Graphics Standards* (AGS) should be used as a guide. Lay out the interior walls across the building,

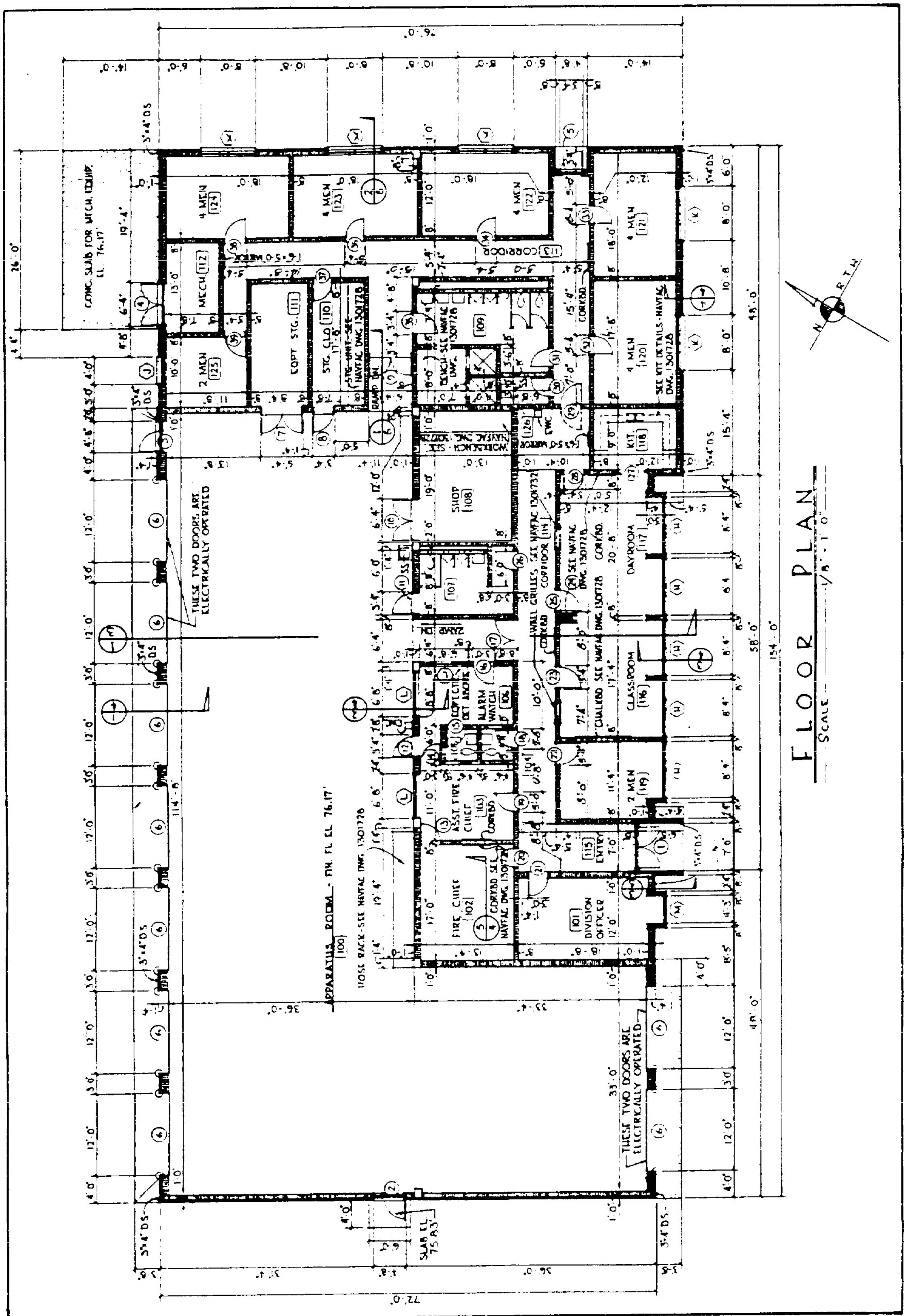

Figure 10-13.—Example of a floor plan for a concrete-masonry construction.

checking rooms, closets, bathrooms, corridors, and so on, as you proceed. Notice that a wider wall is required to allow room for a plumbing pipe to be contained within the wall.

2. Locate all doors. Both exterior and interior doors can be drawn easily if you use an architectural template. Notice that exterior doors in residential houses generally swing inward, whereas those of commercial buildings are often required by building or fire codes to swing outward. Some people prefer a full or 90-degree door swing over the 30-degree swing because they can check to be certain that it will not interfere with any equipment, walls, or appurtenances in the room.

3. Draw in and locate all windows, using proper window symbols and conventions. Next, draw the stairs (and handrails, if any) and other exterior and interior features, fixtures, equipments, appliances, and cabinets, using their proper symbols.

4. Lay out the guidelines for dimensions and the dimension lines. Now that the building basic floor plan is lightly laid out, double-check and review the accuracy and completeness of the information drawn in. You are now ready to darken in the plan. Remember that, other than the construction lines (which need not be erased), all of the lines must be drawn darkly and will vary only in the width of their lines. As an EA, you must develop a systematic approach in pursuing a fast and orderly darkening of lines. Darkening from left to right and then from top to bottom is common practice. To help keep the drawings clean, EAs often cover a partial section of their finished drawing with a clean sheet of paper while darkening the exposed section.

5. Draw in section markings on the floor plan and indicate where the wall sections have been taken. If at this point neither the section nor detail markings have been decided upon, they may be placed on the plan later. Complete the drawing by adding all the material symbols, title, graphic scale, and other relative information. Go over your floor-plan checklist for completeness.

One of your challenges as an EA (and a measure of drafting competency) is to apply your dimensioning technique to the various types of materials and construction methods used on the building. Although the principles of dimensioning and general locations of dimensions are the same, a difference exists in which dimensions are shown, and how the walls, openings, and partitions are dimensioned.

DIMENSIONING A FLOOR PLAN.— Generally, dimensions should be laid out on sketch paper before they are placed on the drawing. Besides dimensions for interior partitions, as many dimensions as possible are placed outside the plan to avoid overcrowding. Moreover, exterior dimensions are kept far enough away from the plan to avoid interfering with roof overhangs, notes, porches, or other features. In DIMENSIONING FLOOR PLANS, proceed as follows:

1. For wood-frame construction, locate the extension line of the exterior wall dimension at the outside face of the studs or stud line (fig. 10-14, view A). Partitions are measured from the

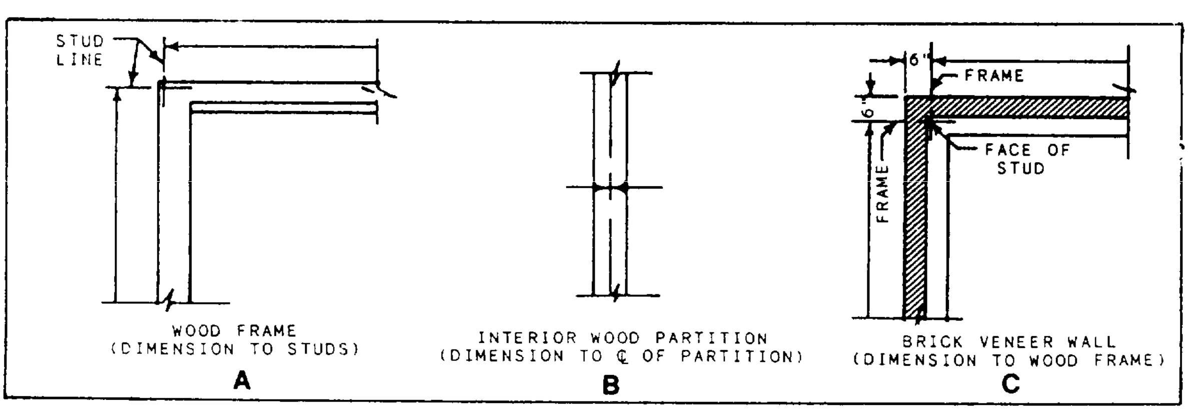

Figure 10-14.-Dimensioning wood-frame and veneer construction.

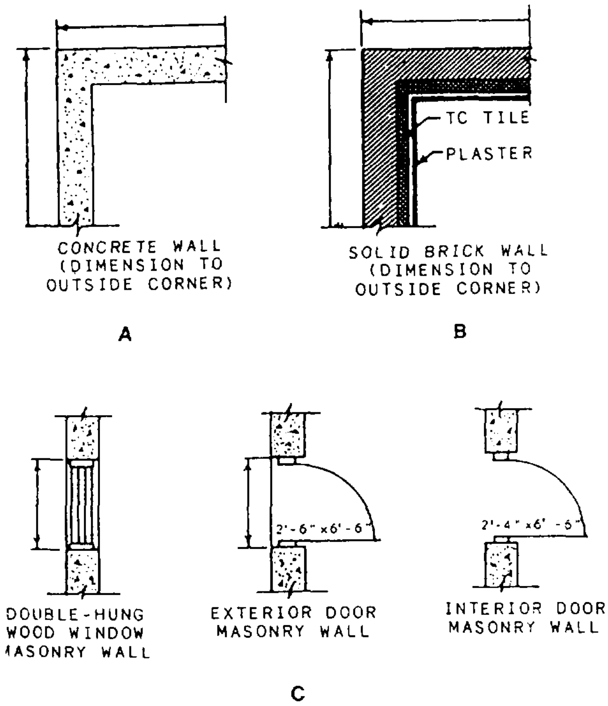

Figure 10-15.-Dimensioning concrete-masonry construction; window and door openings.

outside face of the studs to the center line of the partition (fig. 10-14, view B). In some cases, partitions are measured from the outside face of the studs to the face of the interior stud walls. The important thing is to be consistent. You must take extra care to see that all of the partition measurements are referenced from the same exterior wall. In wood frame with veneer construction, dimensioning is the same as wood frame without veneer (fig. 10-14, view C). The only difference is in the overall dimension showing the total size of the house when the veneer is added. In concrete-masonry constructions, the dimensions are all given to the face of the walls and not to the center lines, as shown in figure 10-15, views A and B.

2. In wood frame construction, doors and windows are dimensioned to their center lines. This is not the case in concrete or masonry construction, as shown in figure 10-13. Notice in this figure that the rough openings of the doors and windows and the distance between the rough openings are dimensioned. This is the correct procedure for concrete or masonry construction. Also see figure 10-15, view C, for dimensioning doors and windows in masonry construction.

3. Throughout your dimensioning of the floor plan, and then again when finished, take time to check your dimensions for legibility and accuracy. Make sure, also, that the cumulative total of all short dimensions add up to their corresponding overall dimension.

Elevations

ELEVATIONS are orthographic projections showing the finished interior and exterior appearance of the structure. Interior elevations are required for important features, such as built-in cabinets and shelves, but it is not uncommon for elevations to be drawn for all interior walls in each room of a building. Cabinet elevations show the cabinet lengths and heights, distance between base cabinets and wall cabinets, shelf arrangements, doors and direction of door swings, and materials used. Interior wall elevations show wall lengths, finished floor-to-ceiling heights, doors, windows, other openings, and types of finish materials used.

Exterior elevations show the types of materials used on the exterior, where the materials are used, the finished grade around the structure, the roof slope, the basement or foundation walls, footings, and all of the vertical dimensions.

Basically, four elevations are needed in a set of drawings to complete the exterior description: the front, the rear, and two sides of a structure, as they would appear projected on vertical planes. A typical elevation is drawn at the same scale as the floor plan, either 1/4 in. = 1 ft or 1/8 in. = 1 ft, but occasionally a smaller scale may be used because of space limitations, or a larger scale, to show more detail.

There are several methods used to identify each elevation as it relates to the floor plan. The method most commonly used by SEABEEs is to label the elevations with the same terminology used in multi-view and orthographic projection; that is, FRONT, REAR, RIGHT-SIDE, and LEFT-SIDE ELEVATIONS (fig. 10-16). On

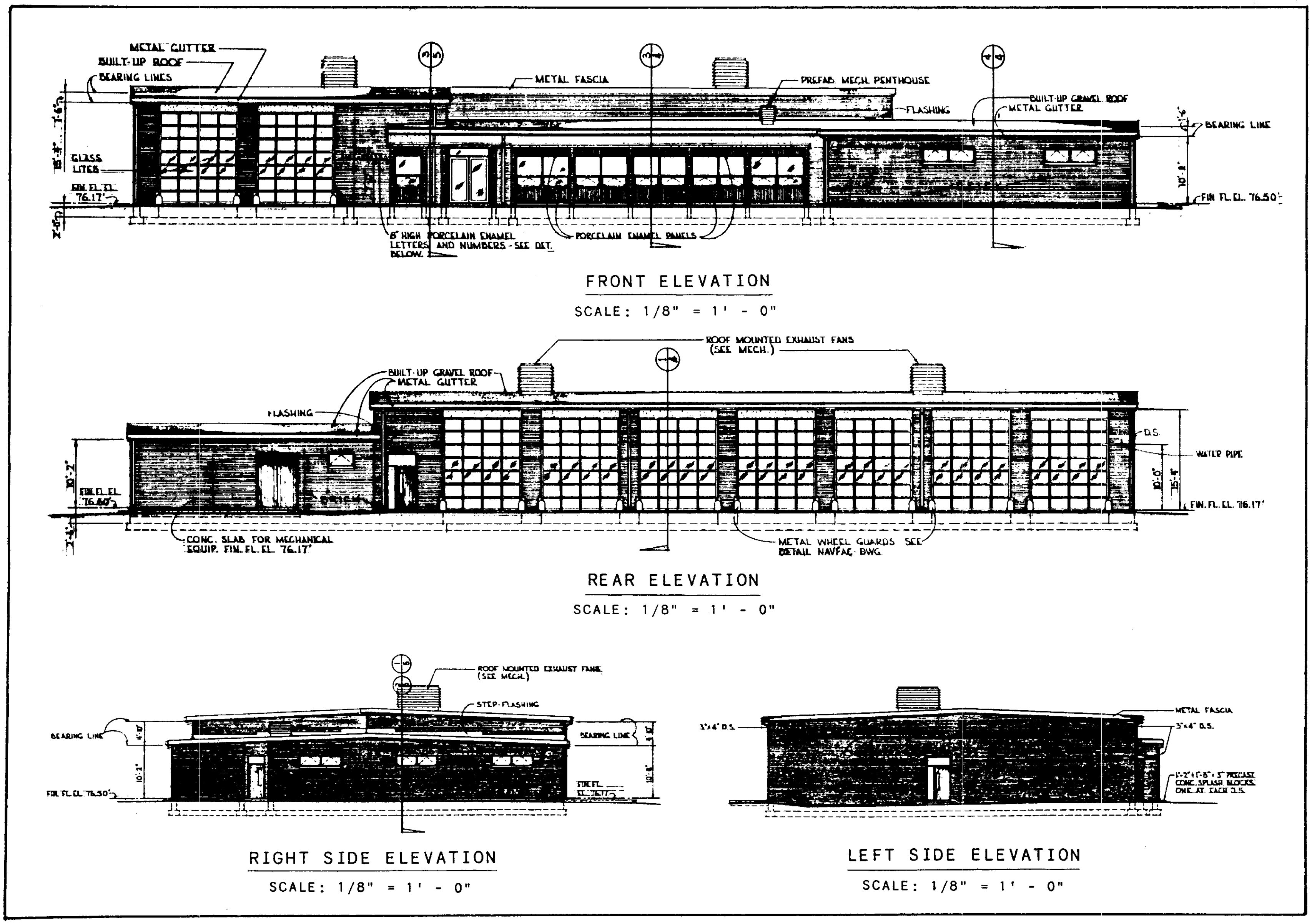

Figure 10-16.—Labeling elevations for the plan shown in figure 10-14.

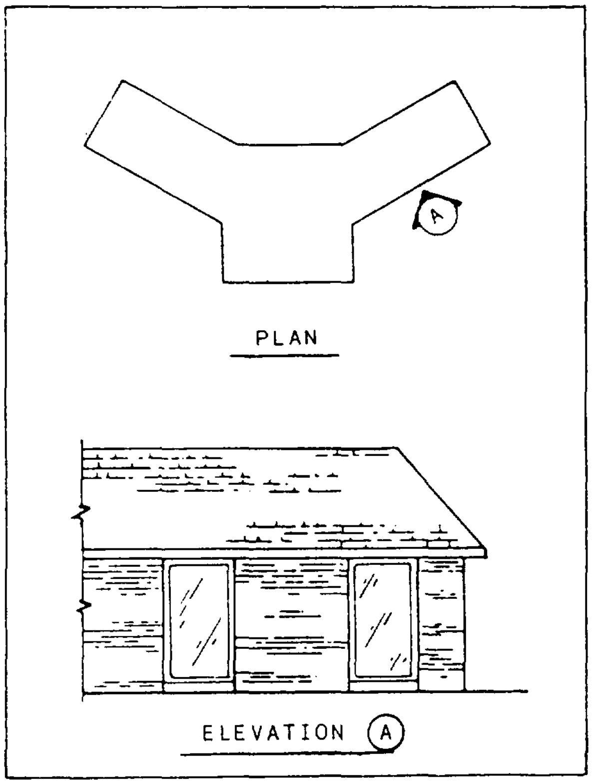

Figure 10-17.-Use of a letter to identify elevation on irregular floor plans.

irregular plans, such as shown in figure 10-17, the elevations may be identified by a letter or a number.

The following basic procedures will serve as a guide in the development and drawing of elevations:

1. Use the same sheet size as that of the floor plan. Determine the overall height and length of the elevation from the floor plan and wall section (predetermined by prior computation or a sketch). We assume that you are using the same scale for elevations as for the floor plan. Block in the views with construction lines placed in a logical order, such as starting with the front view and working around the building. Generally, the front and right-side elevations are next to each other, and the rear (if necessary) and the left-side elevations are shown below. Whenever possible, show all of the elevations on one sheet.

2. Draw the exterior limits of the elevations. The floor plan may be placed underneath the drafting sheet on which the elevations will be drawn. Vertical projections determine and define the length of exterior walls, any breaks or corners along the wall, windows, roof overhang, doors, and other elements, such as chimney location. Horizontal projections from a wall section locate the height of the doors and windows, the cave line, the bottom of fascia, the top and bottom of the footing, and the top of the roof to the space in which the elevation is to be drawn.

3. Repeat this process until all of the elevations are lightly laid out and final changes are incorporated into the exterior design. Darken the drawing, following the same procedures used in the floor plan: from left to right, top to bottom, until completed. You must remember that all of the portions drawn below the grade line are shown with a dark hidden line, and the grade line is the darkest line on the elevation drawing (disregarding the border lines).

4. Add the dimensions. Show only vertical dimensions to include the following: the bottom of the footing, all of the finished floor lines, finished ceiling lines, finished grade, height of features, chimney height, and freestanding walls. Refer to chapter 3 of this book for additional information on drafting format, conventions, and techniques.

5. Add all notes and pertinent information on exterior materials and finishes, title, scale, window identification marks, and roof pitch. Section symbols (fig. 10-6) may be shown on the elevation to indicate where the sections have been taken (fig. 10-16).

6. Finish up the elevations by adding the material symbols (fig. 10-7). Notice that symbols do not take the place of the material notations; they just supplement them. Go over your elevation checklist for completeness and accuracy of information.

STRUCTURAL DRAWINGS

STRUCTURAL DRAWINGS (sometimes identified with the designating letter *S* on their title blocks) consist of all the drawings that describe the structural members of the building and their relationship to each other. A set of structural drawings includes foundation plans and details, framing plans and details, wall sections, column and beam details, and other plans, sections, details, and schedules necessary to describe the structural components of the building or structure. The general notes in the structural drawings should also include, when applicable, roof, floor, wind, seismic, and other loads, allowable soil pressure or pile bearing capacity, and allowable stresses of all material used in the design.

Foundation Plan

A FOUNDATION PLAN is a top view of the footings or foundation walls, showing their area and their location by distances between center lines and by distances from reference lines or boundary lines. Actually, it is a horizontal section view cut through the walls of the foundation showing beams, girders, piers or columns, and openings, along with dimensions and internal composition.

The foundation plan is used primarily by the building crew who will construct the foundation of the proposed structure. In most SEABEE construction, foundations are built with concrete-masonry units and cast-in-place concrete. Figure 10-18 shows a plan view of a structure as it would look if projected into a horizontal plane that passes through the structure slightly below the level of the top of the foundation wall. The plan shows that the main foundation will consist of 12-in. concrete-masonry unit (CMU) walls measuring 28 ft lengthwise and 22 ft crosswise. In this plan, the CMU walls are identified by the standard symbol for concrete block. Ideally, a specific note should be added to call out the material.

A girder running through the center of the building will be supported at the ends by two 4-by 12-in. concrete pilasters that will butt against the end foundation walls. Intermediate support for the girder will be provided by two 12-by 12-in. concrete piers, each supported on 18- by 18-in. spread footings, 10 in. deep. The dotted lines around the foundation walls indicate that these walls will also rest on spread footings.

You need relative information about the total concept of the structure before you can draw the foundation plan. You must make a careful study of the materials and construction methods used, observe the type of foundation used, and analyze the relative position of the framing and the foundation wall or footing. You must also make reference to all of the applicable wall sections and typical sill details found in your texts and reference materials, such as the Architectural *Graphics Standards* before you start the foundation plan.

In most drafting practices, it is customary to use the ground floor plan to develop the

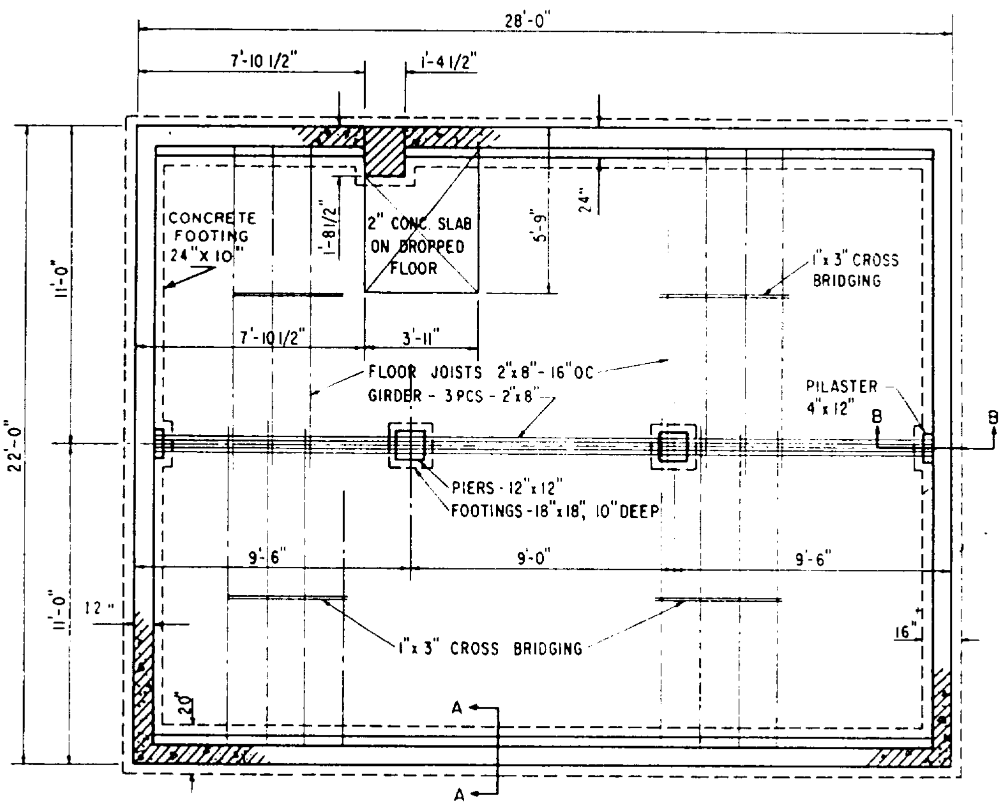

Figure 10-18.-Example of a foundation plan.

foundation plan because the floor plan readily offers the information you need for the foundation plan, such as the general shape of the building, openings, dimensions, and so forth. Some of the basic procedures in the proper development of a foundation plan are outlined below.

1. Prepare and organize your drafting needs. Since the foundation plan is usually drawn at the same scale as the floor plan (1/4 in. = 1 ft), use the same sheet size and layout. A smaller scale (1/8 in. = 1 ft) may be used for the foundation plan when it is necessary to save space and provided that the amount of information given on this plan is limited. From an EA's point of view, drawing the foundation plan at the same scale as the floor plan is easier because you can use the floor plan to trace the outline and other features, thus saving time and effort. Ideally, centering the plan would provide more space for notes and details on footings.

2. Lay out the drafting sheet lightly, beginning with the borders and title block. Tape the original, or preferably a print of the floor plan, under the sheet for the foundation plan if the same scale is being used. Draw the exterior outline of the foundation wall (usually the outside line of the exterior lines of the building), and also locate any retaining walls, steps, porches, and fireplaces. Again, be careful to notice what type of frame construction is used. The extent of using the floor plan in laying out the foundation plan varies among wood-frame, masonry, and steel-frame construction. Study these differences closely. Most often, dimensions are modified on the foundation plan, depending on the materials used. If the foundation is not drawn to the same scale as the floor plan, first determine the size of the foundation plan to be drawn, and lay it out on the sheet. Follow up by transferring all of the dimensions from the floor plan to the foundation plan. Locate other features accurately.

3. Draw the inside wall of the foundation wall once the wall thickness is scaled and the outside foundation line is located. Along the wall, locate other features, such as access doors, vents, and pilasters. Also, draw the foundation for piers, columns, chimney, and retaining wall, if required.

4. Lay out the footings. Check the standards for typical details on different types of footing and the minimum allowable footing size. Now, draw and note any additional structural information required. In wood-frame construction, the structural information for the first-floor construction is commonly shown on the foundation plan. If required, locate and lay in the supporting beam or girder and the size, spacing, and direction of floor joists.

5. Lay out the dimensions. As in all of the EA work, be sure to double-check all of the dimensions to be certain they are correct and complete and that all of the features required are located in the drawing. Apply the principals and correct drafting techniques learned from chapter 3 of this book. Add all of the notes, materials, appropriate plan symbols, and other pertinent information required to complete the plan.

6. Draw in the scale to the plan and the title of the drawing. Go over your foundation-plan checklist, and make sure the entire drawing is darkened in and labeled.

Framing Plan

FRAMING PLANS show the size, number, and location of the structural members (steel or wood) in the building framework. Separate framing plans may be drawn for the floors, the walls, and the roof.

The FLOOR FRAMING PLAN must specify the sizes and spacing of joists, girders, and columns used to support the floor. Detail drawings must be added, if necessary, to show the methods of anchoring joists and girders to the columns and foundation walls or footings.

The floor framing plan is basically a plan view showing the layout of the girders and joists. Figure 10-19 shows the manner of presenting floor framing plans. The unbroken double-line symbol indicates joists. Joist symbols are drawn in the position they will occupy in the completed building. Double framing around openings and beneath bathroom fixtures is shown where used. Bridging is also shown by a double-line symbol that runs perpendicularly to the joist. In the figure, the number of rows of cross bridging is controlled by the span of the joist; the rows should not be placed more than 7 or 8 ft apart. Hence, a 14-ft span may need only one row of bridging, but a 16-ft span needs two rows.

Dimensions need not be given between joists. Such information is given along with notes. For example, "2" by 8" joists @ 2' – 0" O.C." indicates that the joists are to be spaced at intervals of 2 ft 0 in. on center (O.C.). Lengths may not be indicated in framing plans; the overall building dimensions and the dimensions for each bay or distances between columns or posts provide such data. Notes also identify floor openings, bridging, and girts or plates.

The WALL FRAMING PLANS show the location and method of framing openings and ceiling heights so that studs and posts can be cut.

The ROOF FRAMING PLANS show the construction of the rafters used to span the building and support the roof. The size, spacing, roof slope, and all of the details are also shown in the plan. The roof framing plan is drawn in the same manner as the floor framing plan; rafters are shown in the same manner as joists. Figure 10-20 is an example of a roof framing plan for a wood-frame roof.

In a precast or cast-in-place concrete floor and roof framing, a structural plan should indicate, with symbols, the location of bearing walls, beams, and columns, and the direction and size of steel reinforcing bars, the direction of the span, and the size and thickness of required structural members. Figure 10-21 shows an example of a structural roof framing with schedules and general notes included.

When preparing framing plans, follow the procedures outlined below.

1. For wood-frame construction, trace or transfer the dimensions of the location of the exterior stud wall, and lay out the limits of the roof overhang. Next, lay out the roof framing by locating the ridgeboard first and then all of the required intersecting pieces.

2. When the floor framing plans are required, proceed to transfer dimensions of the foundation walls or footings. Lay out supporting girders and joists in their proper spacing. Notice any bearing wails, stairwells, and other openings when you are developing a second-floor framing plan.

3. For concrete framing, take a similar approach. Lay out the dimensions of the bearing walls below the floor (or roof) being framed. Hence, you will need the foundation plan to draw the first-floor framing, and you will need the first-floor plan to draw the second-floor framing. Next, add the locations of the beams and columns and the direction of the span and size of the precast concrete or the reinforcing steel for the poured-in-place concrete.

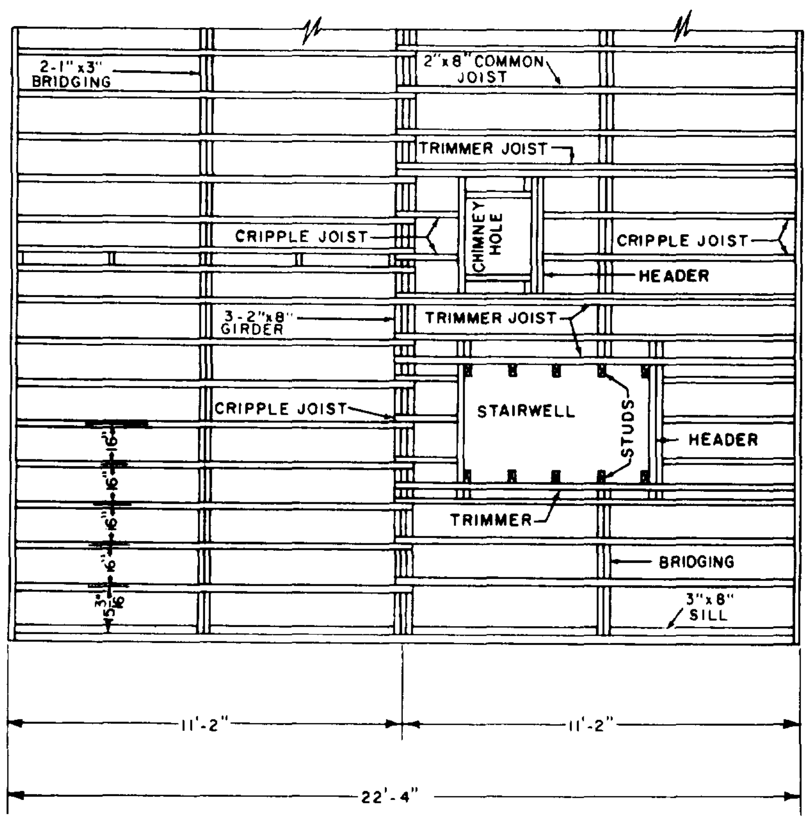

Figure 10-19.-Example of a structural floor framing plan for a wood-frame construction.

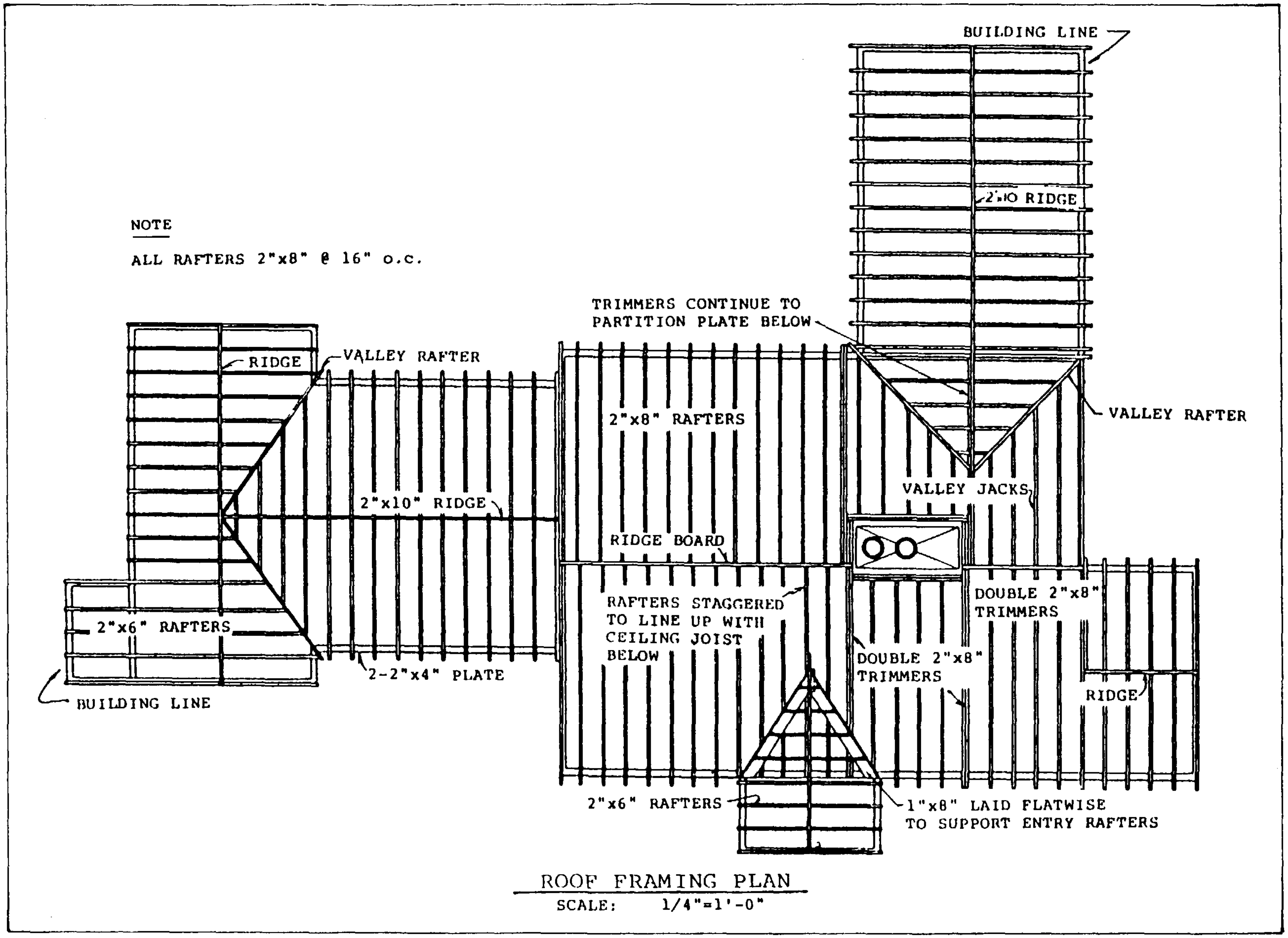

Figure 10-20.—Typical structural roof framing plan for a wood-frame construction.

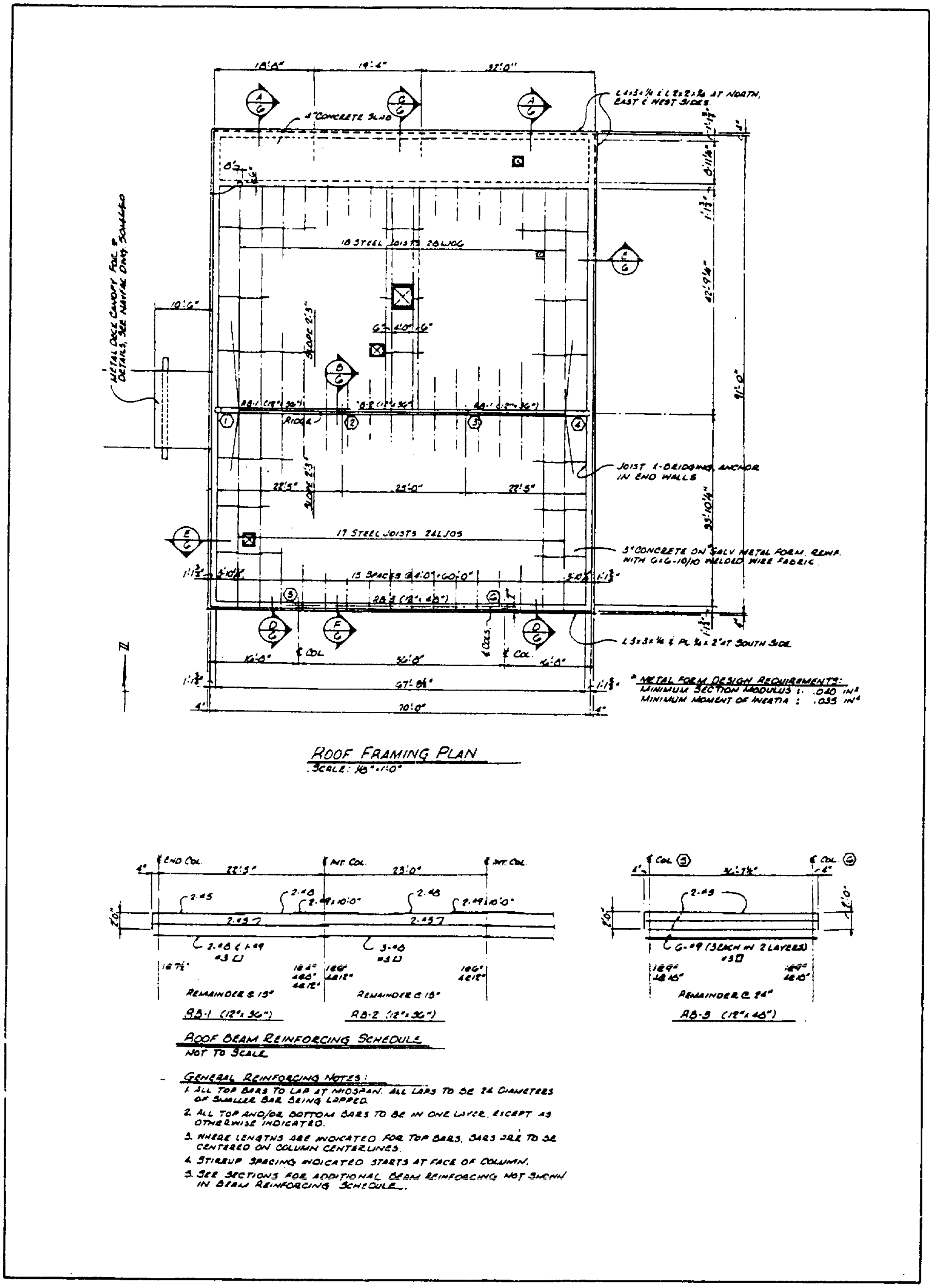

Figure 10-21.-Example of a structural roof framing plan for a precast or a cast-in-place concrete construction.

4. For steel framing, trace off or transfer the dimensions of all of the bearing walls, columns, and beams below the floor (or roof) being framed. Lay out the steel framing, using the grid system (a common setup used in steel framing).

5. Lay out guidelines for dimensions, notes, and labels. Darken in all of the framing and fill in the notes and dimensions. Draw in the section and detail marks. Go over your structural plans checklist and check the dimensions against those traced from the floor plan.

MECHANICAL DRAWINGS

Refer to chapter 8 of this book to review the basic functions of the components associated with the mechanical systems and the methods used in the development of a mechanical plan. This section will focus on the procedures applicable in drawing plumbing plans for residential and commercial buildings.

In some residences and commercial structures, a separate mechanical plan is drawn to show fixtures, water supply and waste disposal lines, equipment, and other supply and disposal sources. In drawing a plumbing plan, the following procedures apply:

1. Trace the floor plan, showing all exterior and interior walls, major appliances, and plumbing fixtures. Orient your drawing so that enough space is left for fixture schedules, legends, details, or other related information. Note that the outline of the building is drawn in thin but visible lines.

2. Draw the water-supply line from the source into the house, and then, one by one, to all of the fixtures. Use the appropriate line thickness and symbols for drawing valves, fittings, and pipe sizes. Next, draw the disposal system. Start the layout with the house or building drain from just outside the building. Also, locate the waste and vent stack at this time.

3. Add a symbol legend, drawing title, notes, and scales, and fill in the title block. Go over and double-check the dimensions and the checklist.

As you can readily tell from figure 8-27 in chapter 8, plumbing plans alone can become extremely difficult to read and fully comprehend. For this reason, it is general practice to prepare and include riser diagrams, such as those shown in chapter 8, figures 8-24 through 8-26. These isometric drawings are much easier to understand and are invaluable to those responsible for preparing material estimates and to the craftsmen (UTs) responsible for installing plumbing systems.

As alluded to in chapter 8, the mechanical division of a set of construction drawings will include, in addition to plumbing plans and details, drawings for any heating, ventilation, and air-conditioning systems that a building might contain. Frequently, the drawing sheets in the mechanical division are identified by the designating letter *M* in the title block. However, remember that in the order of drawings, these sheets containing heating, ventilation, and air-conditioning drawings will precede those for plumbing.

ELECTRICAL DRAWINGS

The electrical systems and plans, as described in chapter 9, consist of the basic functions of the components associated with electrical distribution and interior wiring and the methods used in the development of an electrical plan. This section, however, emphasizes the procedures used in preparing an electrical drawing or plan. It is important for an EA not only to understand the symbols and drafting methods used here, but also to learn a great deal about how the system works, the safety of the system, and the minimum requirements of local and national codes included in the drawing. The drawing sheets in the electrical division of construction drawings are frequently identified by the letter *E* in their title blocks.

In drawing the electrical plan, follow the same approach used in the mechanical drawing, such as using the correct line thickness and proper orientation. To the fullest extent possible, be sure, also, to use the standard electrical symbols discussed previously in the text.

1. After the floor plan is traced, locate the meter and service panel, noting the voltage rating and the amperage. Locate all of the convenience outlets, ceiling and wall fixtures, and other electrical devices required with the appropriate symbols.

2. Locate all of the switches; connect the switches to the fixtures or convenience outlets,

using a template or a french curve. The curved lines may be solid or dashed, and should be included in the symbols list. Add the circuits, the circuit numbers, and the circuit notations.

3. Next, add a symbol legend and a fixture legend (if required). Place the drawing title, note the scale, and fill in the title block. Again, go over your drawing for completeness and accuracy.

SECTIONS

As necessary, SECTIONS are used in each of the main divisions of construction drawings to show the types of construction required, the types of materials used, their locations, and the method of assembling the building parts. Although they may be used in each of the divisions, the most common sections are generally located in the architectural and structural divisions.

All properly prepared sections are important to those responsible for constructing a building. Perhaps the most important of all are WALL SECTIONS, such as those shown in figure 10-22. These sections, commonly drawn at a scale of 3/4 in. = 1 ft, and normally located in the structural division, provide a wealth of information that is necessary to understand the structural

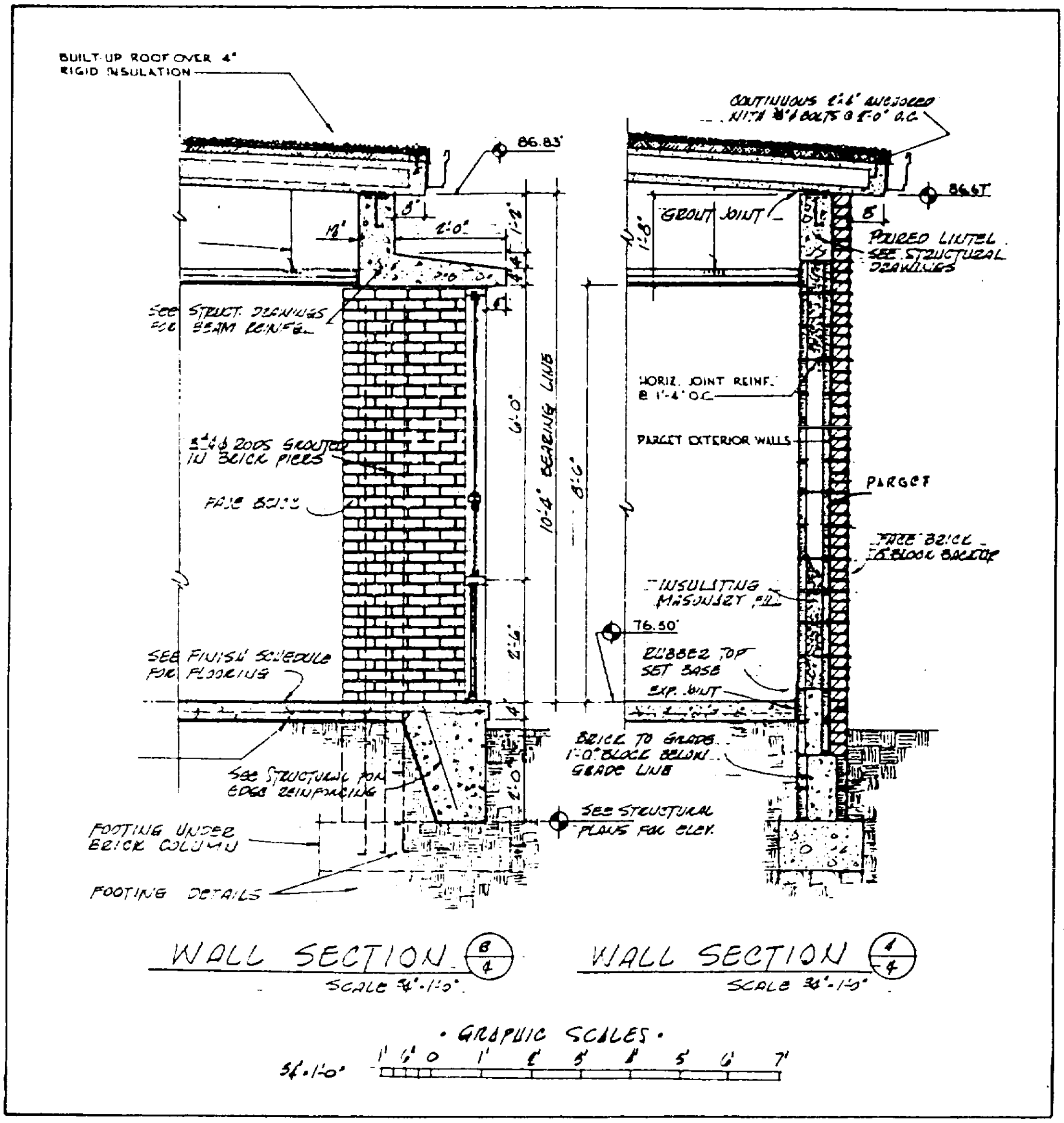

Figure 10-22.-Examples of wall sections.

Figure 10-23.—Development of a sectional view.

arrangement, construction methods, and material composition of the walls of the building.

When a cutting plane is passed through the narrow width of a building, as shown in figure 10-23, a TRANSVERSE, or CROSSSECTION, is developed. Similarly, passing the cutting plane through the length of a building results in a LONGITUDINAL SECTION. These section, usually located in the architectural division, are used to clarify the building design and total construction process. Another example of a building section is shown in figure 10-24, view A. Often, transverse and longitudinal sections are drawn at the same scale as the floor plan. To show as much construction information as possible, it is not uncommon for staggered (offset) cutting planes to be used in developing these sections.

If the time and effort were spent to draw a separate section for each and every wall and part of a building, it would soon become apparent that many of these sections are completely identical. To reduce the time and effort required for drafting and to simplify the construction drawings, it is common practice to use typical sections where exact duplications would otherwise occur. An example of a typical section is shown in figure 10-24, view B.

For best results and to save time, you should make a sketch of the section before beginning the actual drawing. Always have your sketch checked by your leading petty officer or another experienced EA to make sure that your work is compatible with their concept of the design of the building.

When more than one section is placed on the drafting sheet, arrange the sections so that the first one is through the front of the building, the other sections, excluding the last, move progressively through the interior, and the last one is through the back. This way, when the sections are finished, they give the user an orderly construction "tour" through the building. The following procedures will guide you in the development of a section:

1. After having selected the appropriate scale, lay out the first section lightly. Next, lay out all the other sections, allowing enough space between them for notes and dimensions. Align the sections so that the same elevation is maintained and the sections relate to one another, as shown in figure 10-22. Again, maintain enough clearance for subtitles and scale and enough room for your title block.

2. Lay out the guidelines for the material labels, leaders, and vertical dimensions.

3. Darken the section drawings, using a system such as starting at the top of the sheet and working down, then starting at the left and

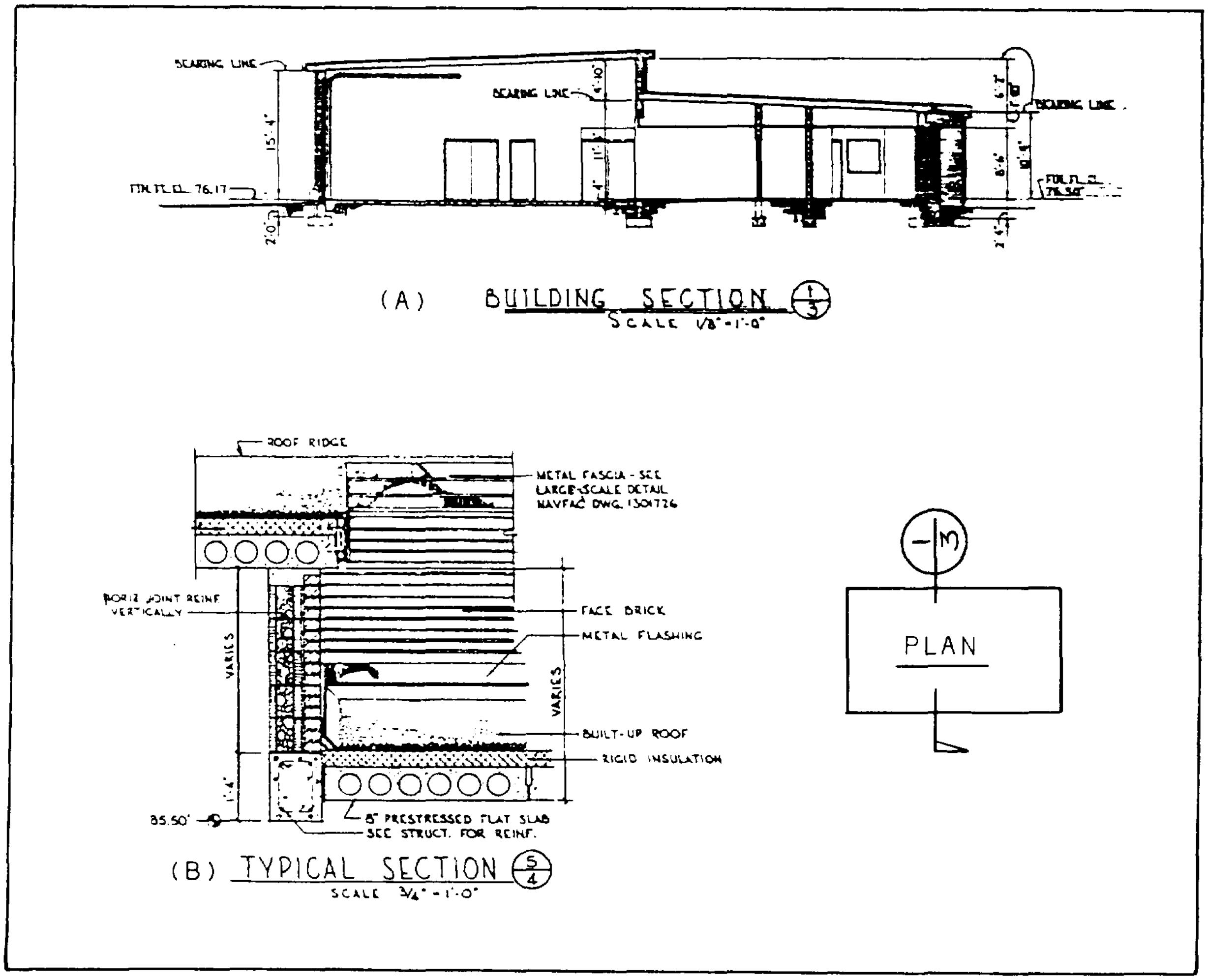

Figure 10-24.-Types of sections.

working to the right until completed. Next, put in all of the labels, notes, and dimensions. You may add detail markings, if any, at this time.

4. Add material symbols. Some EAs prefer to place the symbols at the back of the sheet rather than in the front for neatness and fast access for erasure when a minor change or revision affects them. Place the title and scale below to complete the section drawing. Remember to go over your section checklist for accuracy and completeness.

DETAILS

DETAILS are large-scale drawings of the construction assemblies and installation that were not clearly shown in the sections. These enlarged drawings show the user how the various parts of the structure are to be connected and placed. The construction of specific types of foundations, doors, windows, cornices, and so forth, are customarily shown in detail drawings located within their applicable main division of the construction drawings. Details are usually

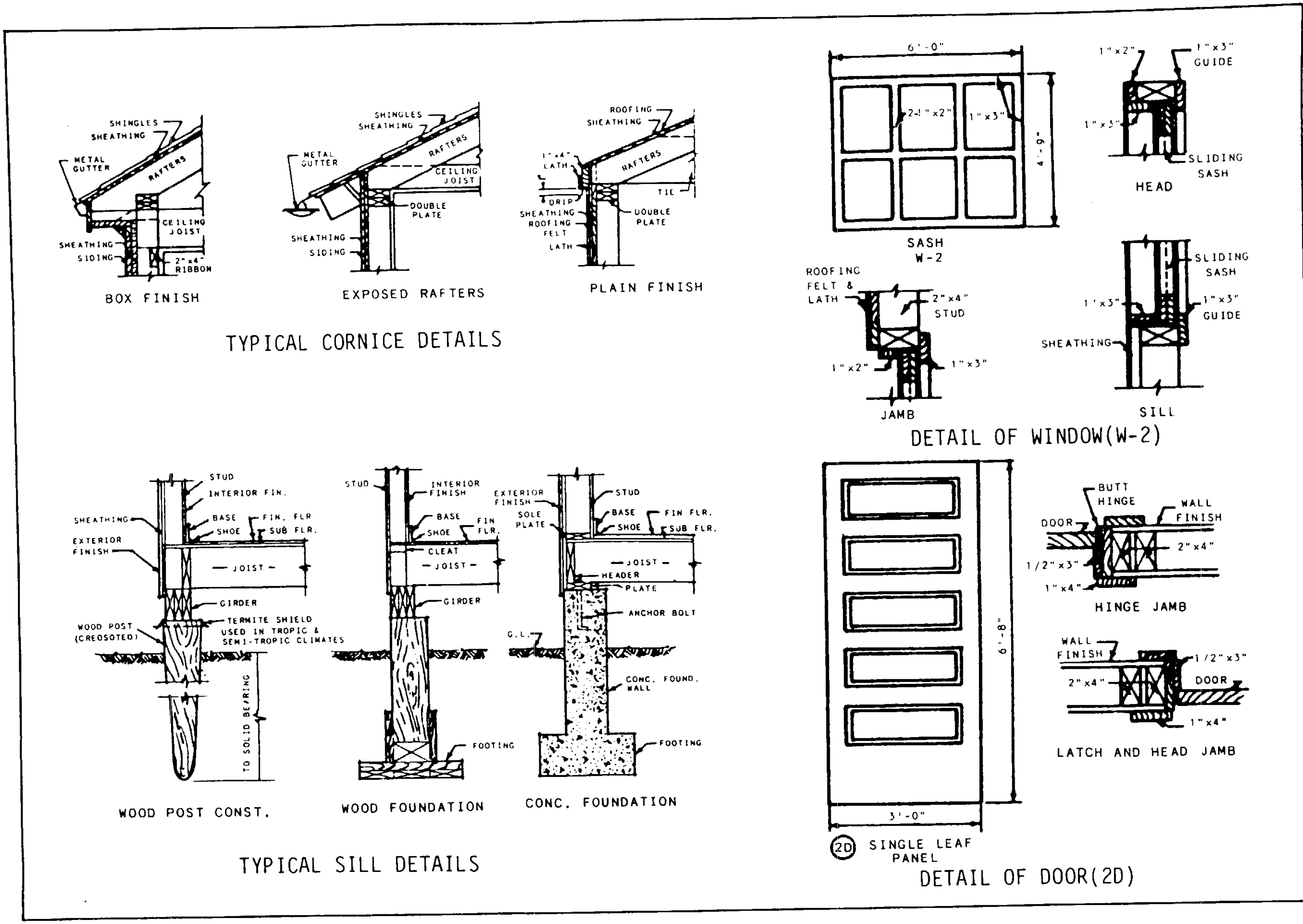

Figure 10-25.—Examples of detail groupings.

grouped (fig. 10-25) so that references may be made more easily from the general drawing.

The scale selected for details depends on how large it needs to be drawn to clearly explain the required information. Details are usually drawn at a larger scale than the sections, generally 1 in., 1 1/2 in., or 3 in. = 1 ft.

Details commonly used for installation of items such as doorframes and window frames, fireproofing, and material connections are readily available in the *Graphic Standards* and Sweet's catalogs. These typical details, however, are to be adapted to the particular building being drawn. You may avoid the use of "typical" details when different conditions actually exist. It is important for an EA to understand construction well enough to make an accurate detail drawing.

Selecting the particular sheet to draw the detail is important. Details that relate to the drawing are placed on that sheet; if space is limited, all other details should be placed with the section or schedules or on a separate sheet set aside for details. Likewise, door details should be placed on the sheet with the floor plans, on the sheet with the door schedule, on a sheet with sections, or on a sheet set aside for details.

The following procedures are given to guide you in the development and drawing of details:

1. Lay out the details on the particular sheet. Draw extension lines, dimensions lines, and guidelines for all of the dimensions lightly.

2. Darken in the details, one at a time, using a system similar to that used in drawing sections. Add labels, notes, and dimensions. Remember to show all of the sizes and thicknesses of materials required.

3. Add material symbols and place title and scale below the detail to complete the drawing.

SCHEDULES

SCHEDULES are tabular or graphic arrangements of extensive information or notes related to construction materials. The use of schedules presents a quick and easy way for planners, estimators, contractors, and suppliers to share similar data, hence reducing construction errors and saving time. In the SEABEEs, the success of the planners and estimators (P&E) in accurately preparing takeoff, of the supply department (S-4) in properly ordering construction materials, and of the construction crew (line companies and detachments) in installing the materials in their proper locations depends greatly upon the efficiency with which the relative information is conveyed on the drawing (plans).

The material information most commonly placed in schedules relates to doors, windows, room finishes, lintels, and other structural elements. The information required on a DOOR SCHEDULE varies from a bare minimum (for small jobs) to extensive (for large projects). A door schedule may include the following: door number, quantity, mark or code number, type, size, material description, lintel, and remarks.

An example of a tabular door schedule is shown in figure 10-26. Doors are commonly

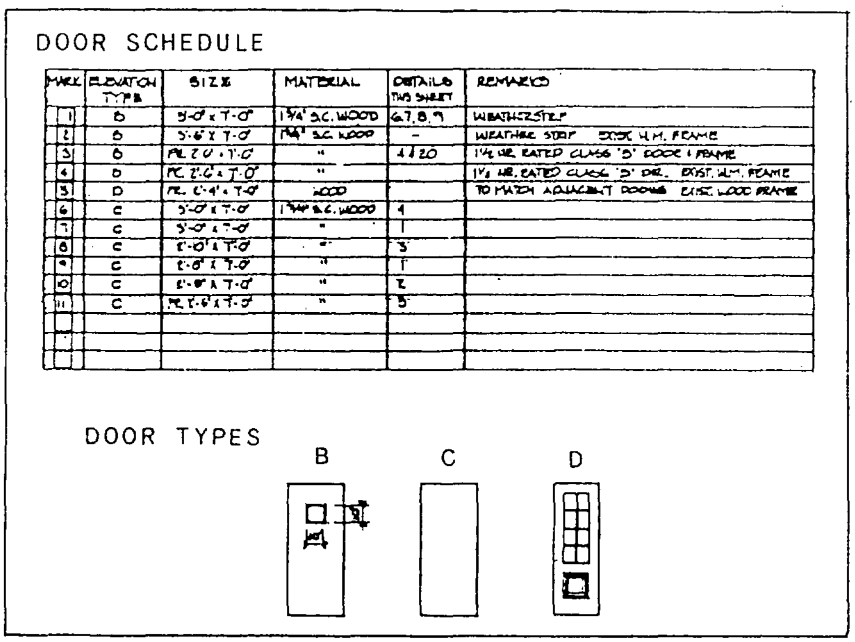

Figure 10-26.-Example of a door schedule.

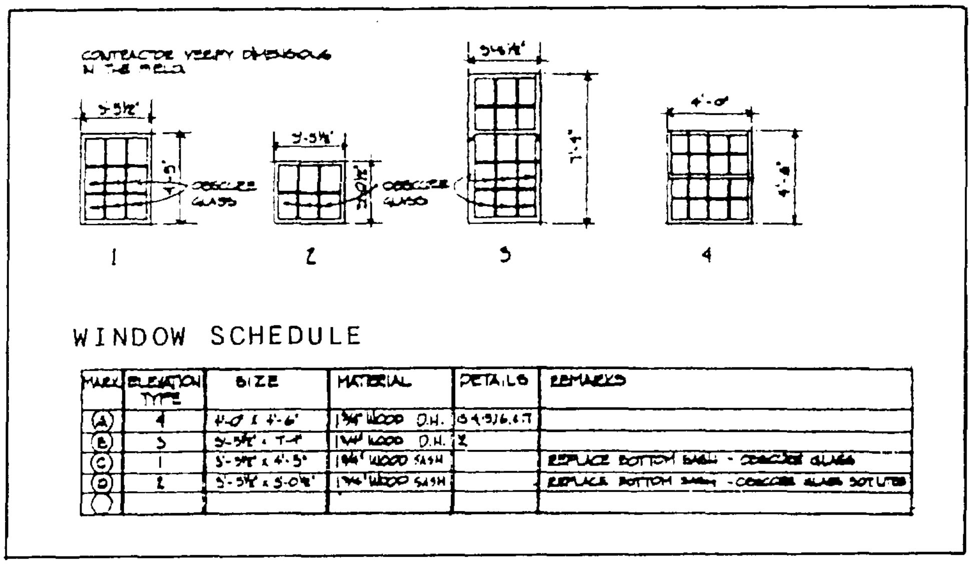

Figure 10-27.-Example of a window schedule.

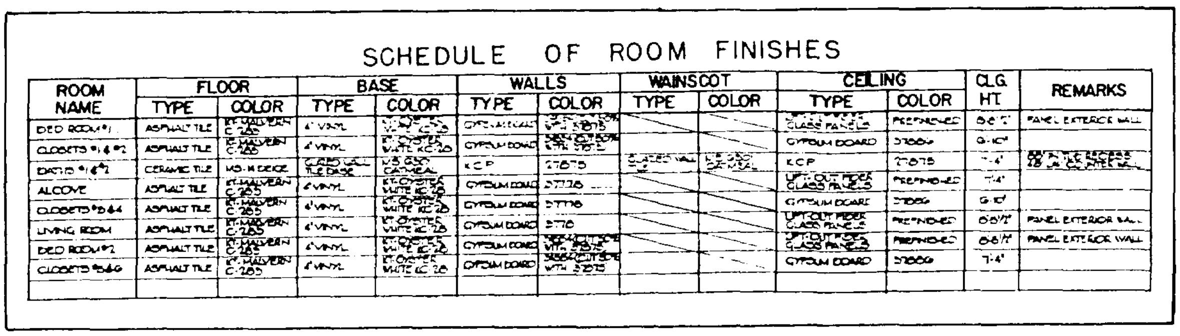

Figure 10-28.-Example of a material finish schedule.

marked with a number or numbers and letters. Letter *D* is a common designation used for doors (sometimes enclosed in a circle or other shape). A WINDOW SCHEDULE (fig. 10-27) provides an organized presentation of the significant window characteristics. Information often includes the following: mark, window type, size, required opening size, material type, lintels, and remarks. Windows are often marked with letters or letters with numbers. Letter *W* is used most commonly for window schedules. A MATERIAL FINISH SCHEDULE (fig. 10-28) may include the following: room number, material finish for floors, walls, base, and remarks. Where several rooms in a row have identical finish, a common practice is to use the ditto mark (´´) or initials DO. It is essential that you take care when making changes in the material finish used in a particular room, as changes you make will greatly affect other rooms below it. Errors are less likely to occur and revisions will be easier to handle when each space in the schedule is lettered individually. Remember, whenever possible, place all of the schedules on the same sheet as their respective drawings on the building.

BILL OF MATERIALS

A BILL OF MATERIALS (BM) is a tabular statement of material requirements for a given project. It contains information, such as stock numbers, unit of issue, quantity, line item number, description, vendor, and cost. Sometimes the bill of materials will be submitted on material estimate sheets or material takeoff sheets, but all will contain similar information. Actually, a bill of materials is a grouped compilation based on takeoffs and estimates of all of the material needed to complete a structure. The takeoff sheet usually is an actual tally and checkoff of the items shown, noted, or specified on the construction drawings and specifications.

In most cases, each NAVFACENGCOM drawing contains a separate BM; however, sometimes an in-house project prepared by local commands may contain a BM incorporated within the set of drawings. Figure 10-29 shows an example of a completed BM.

BILL OF MATERIAL
11ND-CBC-4013/2 (2-75)
0900-LL-P81-3020

PROJECT: INTERIM WATER SYSTEM REINDEER STATION (CANTONMENT AREA) — SHIP APRIL 19- — BM NO. DIW 112

AUTHORITY — PAGE — OF

ROUT IDENT	M&S	SERV & REQNR	DMD	SERV & SUPP ADDRESS	SIG	FUND CODE		PROJECT	PRI	RDD	JOB ORDER	ACCOUNTING DATA	ROS
P96	2	N62583	N	Y1W112	A	TN	W	ZM9	05	094	4K6404		

DOC IDENT	STOCK NUMBER FSC NIIN	UNIT OF ISSUE	QUANTITY	DOCUMENT NUMBER DATE SERIAL	COG	ADV	L/I	CNT FLAG	DESCRIPTION/SPECIFICATION/VENDORS	UNIT COST	TOTAL COST	LOCATION	QTY/DATE RECD	QTY/DATE ISSUED
AOE		SH	69	40817903			1		PLYWOOD, 3/4"X4'X8' BB EXTERIOR TYPE. SUGGESTED VENDOR: THOMPSON LUMBER CO.	12.00	828.00			
		BF	30	7904			2		LUMBER, SOFTWOOD, 1"X6"X12' STANDARD CONSTRUCTION GRADE 2 OR BETTER. SUGGESTED VENDOR: THOMPSON LUMBER CO.	.18	5.40			
		BF	2422	7905			3		LUMBER, SOFTWOOD, 2"X4"X16' STANDARD CONSTRUCTION GRADE 2 OR BETTER. SUGGESTED VENDOR: THOMPSON LUMBER CO.	.28	678.16			
		BF	144	7906			4		LUMBER, SOFTWOOD, 2"X6"X16' STANDARD CONSTRUCTION GRADE 2 OR BETTER. SUGGESTED VENDOR: THOMPSON LUMBER CO.	.28	40.32			
		BF	1173	7907			5		LUMBER, SOFTWOOD, 4"X 4"X 16' STANDARD CONSTRUCTION GRADE 2 OR BETTER. SUGGESTED VENDOR: THOMPSON LUMBER CO.	.33	387.09			

SUBMITTED BY	DATE	APPROVED BY	DATE	TARGET APPROVED BY	DATE	BM TOTAL LINE ITEMS	PAGE TOTAL $	BM TOTAL $
E.B. JASON	20 MAR	T. J. ABERNATHY	3-25-				1938.97	

Figure 10-29.-Example of a bill of materials prepared locally.

CHAPTER 11

ELEMENTS OF SURVEYING AND SURVEYING EQUIPMENT

This chapter provides an overview of surveying in general with emphasis on the principles and procedures of basic surveying and the use of various surveying equipments, instruments, and accessories. As an EA, you should realize that accuracy in surveying is essential because other factors affecting sound decisions in engineering practice are dependent upon the results of your survey.

Surveying is a science that deals with the determination of the relative positions of points on or near the earth's surface. These points may be needed to locate or lay out roads, airfields, and structures of all kinds; they may be needed for cultural, hydrographic, or terrain features for mapping; and, in the military, these points may be targets for artillery and mortar fires. The relative horizontal positions of these points are determined from distances and directions measured in the field, while their vertical positions are computed from the differences in elevations, which are measured directly or indirectly from an established point of reference or datum.

The earliest applications of surveying were for the purpose of establishing the boundaries of land. Although many surveyors are still preoccupied with establishing or subdividing boundaries of landed properties, the purposes of surveys have branched out to many areas that parallel the advancement of various engineering fields and other areas of civilization. Surveyors may be called upon in court to substantiate definite locations of various objects, such as those involving major traffic accidents, maritime disasters, or even murder cases, in which direction and distance have a bearing.

Surveying continues to play an extremely important role in many branches of engineering. The results of today's surveys are being used to map the earth above and below; for navigational charts for use in the air, on land, and at sea; and for other major survey operations for related tasks in geology, forestry, archeology, and landscape architecture. As a surveyor in the Naval Construction Force, you will be required to submit survey results before, during, and after planning and construction of advanced base structures, bridges, roads, drainage works, pipelines, and other types of conventional ground systems. In addition, an EA assigned to an oceanographic unit may be involved in hydrography to a great extent, establishing an offshore triangulation network, depth sounding, and mapping.

Again, though these surveys are for various purposes, still the basic operations are the same—they involve measurements and computations or, basically, fieldwork and office work.

CLASSIFICATION OF SURVEYING

Generally, surveying is divided into two major categories: plane and geodetic surveying.

PLANE SURVEYING

PLANE SURVEYING is a process of surveying in which the portion of the earth being surveyed is considered a plane. The term is used to designate survey work in which the distances or areas involved are small enough that the curvature of the earth can be disregarded without significant error. In general, the term *plane surveying* is applied to surveys of land areas and boundaries (land surveying) in which the areas are of limited extent. For small areas, precise results may be obtained with plane surveying methods, but the accuracy and precision of such results will decrease as the area surveyed increases in size. To make computations in plane surveying, you will use formulas of plane trigonometry, algebra, and analytical geometry.

A great number of surveys are of the plane surveying type. Surveys for the location and construction of highways and roads, canals, landing fields, and railroads are classified under plane surveying. When it is realized that an arc of 10 mi is only 0.04 greater that its subtended chord; that a plane surface tangent to the spherical arc has departed only about 8 in. at 1 mi from the point of tangency; and that the sum of the angles of a spherical triangle is only 1 sec greater than the sum of the angles of a plane triangle for a triangle having an area of approximately 75 sq mi on the earth's surface, it is just reasonable that the errors caused by the earth's curvature be considered only in precise surveys of large areas.

In this training manual, we will discuss primarily the methods used in plane surveying rather than those used in geodetic surveying.

GEODETIC SURVEYING

GEODETIC SURVEYING is a process of surveying in which the shape and size of the earth are considered. This type of survey is suited for large areas and long lines and is used to find the precise location of basic points needed for establishing control for other surveys. In geodetic surveys, the stations are normally long distances apart, and more precise instruments and surveying methods are required for this type of surveying than for plane surveying.

The shape of the earth is thought of as a spheroid, although in a technical sense, it is not really a spheroid. In 1924, the convention of the International Geodetic and Geophysical Union adopted 41,852,960 ft as the diameter of the earth at the equator and 41,711,940 ft as the diameter at its polar axis. The equatorial diameter was computed on the assumption that the flattening of the earth caused by gravitational attraction is exactly 1/297. Therefore, distances measured on or near the surface of the earth are not along straight lines or planes, but on a curved surface. Hence, in the computation of distances in geodetic surveys, allowances are made for the earth's minor and major diameters from which a spheroid of reference is developed. The position of each geodetic station is related to this spheroid. The positions are expressed as latitudes (angles north or south of the Equator) and longitudes (angles east or west of a prime meridian) or as northings and castings on a rectangular grid.

The methods used in geodetic surveying are beyond the scope of this training manual.

TYPES OF SURVEYS

Generally, surveys can be classified by names descriptive of their functions. Functionally, surveys are classed as construction, topographic, route, and special. Special surveys, such as photogrammetry, hydrography, and property surveys, are conducted either with special equipment or for a special purpose. Some of the types of surveys that you may perform as an EA are discussed in the following paragraphs.

CONSTRUCTION SURVEYS

CONSTRUCTION SURVEYS (sometimes called engineering surveys) are conducted to obtain data essential for planning, estimating, locating, and layout for the various phases of construction activities or projects. This type of survey includes reconnaissance, preliminary, location, and layout surveys.

The objectives of engineering or construction surveying include the following:

1. The obtaining of reconnaissance information and preliminary data required by engineers for selecting suitable routes and sites and for preparing structural designs
2. The defining of selected locations by establishing a system of reference points
3. The guidance of construction forces by setting stakes or otherwise marking lines, grades, and principal points and by giving technical assistance
4. The measuring of construction items in place for the purpose of preparing progress reports
5. The dimensioning of structures for preparation of as-built plans

All of the above objectives are called engineering surveys by the American Society of Civil Engineers (ASCE), and the term *construction surveys* is applied to the last three objectives only, The Army Corps of Engineers, on the other hand, generally applies the term *construction surveying* to all of the objectives listed above.

Engineering and/or construction surveys, then, form part of a series of activities leading to the construction of a man-made structure. The term *structure* is usually confined to something that is built of structural members, such as a building or a bridge. It is used here in a broader sense, however, to include all man-made features, such as graded areas; sewer, power, and water lines; roads and highways; and waterfront structures.

Construction surveys normally cover areas considered small enough to use the plane surveying methods and techniques.

TOPOGRAPHIC SURVEYS

The purpose of a TOPOGRAPHIC SURVEY is to gather survey data about the natural and man-made features of the land, as well as its elevations. From this information a three-dimensional map may be prepared. You may prepare the topographic map in the office after collecting the field data or prepare it right away in the field by plane table. The work usually consists of the following:

1. Establishing horizontal and vertical control that will serve as the framework of the survey
2. Determining enough horizontal location and elevation (usually called side shots) of ground points to provide enough data for plotting when the map is prepared
3. Locating natural and man-made features that may be required by the purpose of the survey
4. Computing distances, angles, and elevations
5. Drawing the topographic map

Topographic surveys are commonly identified with horizontal and/or vertical control of third- and lower-order accuracies.

ROUTE SURVEYS

The term *route survey* refers to surveys necessary for the location and construction of lines of transportation or communication that continue across country for some distance, such as highways, railroads, open-conduit systems, pipelines, and power lines. Generally, the preliminary survey for this work takes the form of a topographic survey. In the final stage, the work may consist of the following:

1. Locating the center line, usually marked by stakes at 100-ft intervals called stations
2. Determining elevations along and across the center line for plotting profile and cross sections
3. Plotting the profile and cross sections and fixing the grades
4. Computing the volumes of earthwork and preparing a mass diagram
5. Staking out the extremities for cuts and fills
6. Determining drainage areas to be used in the design of ditches and culverts
7. Laying out structures, such as bridges and culverts
8. Locating right-of-way boundaries, as well as staking out fence lines, if necessary

SPECIAL SURVEYS

As mentioned earlier in this chapter, SPECIAL SURVEYS are conducted for a specific purpose and with a special type of surveying equipment and methods. A brief discussion of some of the special surveys familiar to you follows.

Land Surveys

LAND SURVEYS (sometimes called cadastral or property surveys) are conducted to establish the exact location, boundaries, or subdivision of a tract of land in any specified area. This type of survey requires professional registration in all states. Presently, land surveys generally consist of the following chores:

1. Establishing markers or monuments to define and thereby preserve the boundaries of land belonging to a private concern, a corporation, or the government.
2. Relocating markers or monuments legally established by original surveys. This requires examining previous survey records and retracing what was done. When some markers or monuments are missing, they are reestablished following recognized procedures, using whatever information is available.
3. Rerunning old land survey lines to determine their lengths and directions. As a result of the high cost of land, old lines are remeasured to get more precise measurements.
4. Subdividing landed estates into parcels of predetermined sizes and shapes.
5. Calculating areas, distances, and directions and preparing the land map to portray the survey data so that it can be used as a permanent record.
6. Writing a technical description for deeds.

Control Surveys

CONTROL SURVEYS provide “basic control” or horizontal and vertical positions of points to which supplementary surveys are adjusted. These types of surveys (sometimes termed *geodetic surveys)* are conducted to provide geographic positions and plane coordinates of triangulation and traverse stations and the elevations of bench marks. These control points are further used as references for hydrographic surveys of the coastal waters; for topographic control; and for the control of many state, city, and private surveys.

Horizontal and vertical controls generated by land (geodetic) surveys provide coordinated position data for all surveyors. It is therefore necessary that these types of surveys use first-order and second-order accuracies.

Hydrographic Surveys

HYDROGRAPHIC SURVEYS are made to acquire data required to chart and/or map shorelines and bottom depths of streams, rivers, lakes, reservoirs, and other larger bodies of water. This type of survey is also of general importance to navigation and to development of water resources for flood control, irrigation, electrical power, and water supply.

As in other special surveys, several different types of electronic and radio-acoustical instruments are used in hydrographic surveys. These special devices are commonly used in determining water depths and location of objects on the bottom by a method called taking SOUNDINGS. Soundings are taken by measuring the time required for sound to travel downward and be reflected back to a receiver aboard a vessel.

TYPES OF SURVEYING OPERATIONS

The practice of surveying actually boils down to fieldwork and office work. The FIELDWORK consists of taking measurements, collecting engineering data, and testing materials. The OFFICE WORK includes taking care of the computation and drawing the necessary information for the purpose of the survey.

FIELDWORK

FIELDWORK is of primary importance in all types of surveys. To be a skilled surveyor, you must spend a certain amount of time in the field to acquire needed experience. The study of this training manual will enable you to understand the underlying theory of surveying, the instruments and their uses, and the surveying methods. However, a high degree of proficiency in actual surveying, as in other professions, depends largely upon the duration, extent, and variation of your actual experience.

You should develop the habit of STUDYING the problem thoroughly before going into the field, You should know exactly what is to be done; how you will do it; why you prefer a certain approach over other possible solutions; and what instruments and materials you will need to accomplish the project.

It is essential that you develop SPEED and CONSISTENT ACCURACY in all your fieldwork. This means that you will need practice in handling the instruments, taking observations and keeping field notes, and planning systematic moves.

It is important that you also develop the habit of CORRECTNESS. You should not accept any measurement as correct without verification. Verification, as much as possible, should be different from the original method used in measurement. The precision of measurement must be consistent with the accepted standard for a particular purpose of the survey.

Fieldwork also includes adjusting the instruments and caring for field equipment. Do not attempt to adjust any instrument unless you understand the workings or functions of its parts. Adjustment of instruments in the early stages of your career requires close supervision from a senior EA.

Collection of Engineering Data

The collection of ENGINEERING DATA is a part of SEABEE surveying. Engineering data is actually any information that is essential for efficient construction. Most of your fieldwork, such as running a traverse, leveling, and determining cuts and fills, may be classified under this category. However, compiling these field measurements and converting them into a common medium that will be of value to the engineer requires skill that can only be attained through long experience. Although the planning and organization will generally be handled by the engineering officer or by a senior EA, the actual collection of engineering data will generally be delegated to you; hence, it is to your advantage to understand the procedures early in your career. This job may take a combination of fieldwork and office work. If the same quality of the desired information can be found from sources other than actual fieldwork, do not hesitate to use them; if necessary, use spot checks to verify certain points, depending upon the source.

Each project requires the study of a different set of engineering data, so it is up to the engineering officer or the senior EAs to devise a workable method of compilation that will suit each particular project. It is essential that the compiled data be complete in all respects as required by the purpose of the project and that the compilation be completed with sufficient lead time. Generally, a separate folder for each project is maintained and labeled.

Some of the engineering data that may be considered for SEABEE projects are as follows:

- Vicinity maps, topographic maps, or aerial photographs of the site

- Geographic factors, accessibility, real estate, and so forth

- Geographic location: latitude and longitude; control points (both horizontal and vertical)

- Tide information

- Weather and climatic conditions: rainfall, wind velocity (including direction and duration), flood, and perhaps typhoon or hurricane seasons

- Current velocity and discharge of a river or stream and perhaps an estimate of the watershed area

- Types of soils and their natural conditions (samples may be collected for testing)

- Availability of construction materials, such as rocks, gravel, sand, borrow pits, and timber, near the site

- Availability and suitability of local labor and existing facilities, such as sources of power, water, and other utilities

- Other factors affecting construction, military operations, and logistics support

Factors Affecting Fieldwork

The surveyor must constantly be alert to the different conditions encountered in the field. Physical factors, such as TERRAIN AND WEATHER CONDITIONS, affect each field survey in varying degrees. Measurements using telescopes can be stopped by fog or mist. Swamps and flood plains under high water can impede taping surveys. Sights over open water or fields of flat, unbroken terrain create ambiguities in measurements using microwave equipment. The lengths of light-wave distance in measurements are reduced in bright sunlight. Generally, reconnaissance will predetermine the conditions and alert the survey party to the best method to use and the rate of progress to expect.

The STATE OF PERSONNEL TECHNICAL READINESS is another factor affecting fieldwork. As you gain experience in handling various surveying instruments, you can shorten survey time and avoid errors that would require resurvey.

The PURPOSE AND TYPE OF SURVEY are primary factors in determining the accuracy requirements. First-order triangulation, which becomes the basis or "control" of future surveys, is made to high-accuracy standards. At the other extreme, cuts and fills for a highway survey carry accuracy standards of a much lower degree. In some construction surveys, normally inaccessible distances must be computed. The distance is computed by means of trigonometry, using the angles and the one distance that can be measured. The measurements must be made to a high degree of precision to maintain accuracy in the computed distance.

So, then, the purpose of the survey determines the accuracy requirements. The required accuracy, in turn, influences the selection of instruments and procedures. For instance, comparatively rough procedures can be used in measuring for earthmoving, but grade and alignment of a highway have to be much more precise, and they, therefore, require more accurate measurements. Each increase in precision also increases the time required to make the measurement, since greater care and more observations will be taken.

Each survey measurement will be in error to the extent that no measurement is ever exact. The errors are classified as systematic and accidental and are explained in the latter part of this text. Besides errors, survey measurements are subject to mistakes or blunders. These arise from misunderstanding of the problem, poor judgment, confusion on the part of the surveyor, or simply from an oversight. By working out a systematic procedure, the surveyor will often detect a mistake when some operation seems out of place. The procedure will be an advantage in setting up the equipment, in making observations, in recording field notes, and in making computations.

Survey speed is not the result of hurrying; it is the result of saving time through the following factors:

1. The skill of the surveyor in handling the instruments
2. The intelligent planning and preparation of the work

3. The process of making only those measurements that are consistent with the accuracy requirements

Experience is of great value, but in the final analysis, it is the exercise of a good, mature, and competent degree of common sense that makes the difference between a good surveyor and an exceptional surveyor.

Field Survey Parties

The size of a field survey party depends upon the survey requirements, the equipment available, the method of survey, and the number of personnel needed for performing the different functions. Four typical field survey parties commonly used in the SEABEEs are briefly described in this section: a level party, a transit party, a stadia party, and a plane table party.

LEVEL PARTY.— The smallest leveling party consists of two persons: an instrumentman and a rodman. This type of organization requires the instrumentman to act as note keeper. The party may need another recorder and one or more extra rodmen to improve the efficiency of the different leveling operations. The addition of the rodmen eliminates the waiting periods while one person moves from point to point, and the addition of a recorder allows the instrumentman to take readings as soon as the rodmen are in position.

When leveling operations are run along with other control surveys, the leveling party may be organized as part of a combined party with personnel assuming dual duties, as required by the work load and as designated by the party chief.

TRANSIT PARTY.— A transit party consists of at least three people: an instrumentman, a head chainman, and a party chief. The party chief is usually the note keeper and may double as rear chainman, or there may be an additional rear chainman. The instrumentman operates the transit; the head chainman measures the horizontal distances; and the party chief directs the survey and keeps the notes.

STADIA PARTY.— A stadia party should consist of three people: an instrumentman, a note keeper, and a rodman. However, two rodmen should be used if there are long distances between observed points so that one can proceed to a new point, while the other is holding the rod on a point being observed. The note keeper records the data called off by the instrumentman and makes the sketches required.

PLANE TABLE PARTY.— The plane table party consists of three people: a topographer or plane table operator, a rodman, and a computer.

The topographer is the chief of the party who sets up, levels, and orients the plane table; makes the necessary readings for the determination of horizontal distances and elevations; plots the details on the plane table sheet as the work proceeds; and directs the other members of the party.

The rodman carries a stadia rod and holds it vertically at detail points and at critical terrain points in the plotting of the map. An inexperienced rodman must be directed by the topographer to each point at which the rod is to be held. An experienced rodman will expedite the work of the party by selecting the proper rod positions and by returning at times to the plane table to draw in special details that he may have noticed.

The computer reduces stadia readings to horizontal and vertical distances and computes the ground elevation for rod observations. He carries and positions the umbrella to shade the plane table and performs other duties as directed by the topographer. At times, the computer may be used as a second rodman, especially when the terrain is relatively flat and computations are mostly for leveling alone.

Field Notes

Field notes are the only record that is left after the field survey party departs the survey site. If these notes are not clear and complete, the field survey was of little value. It is therefore necessary that your field notes contain a complete record of all of the measurements made during the survey and that they include, where necessary, sketches and narrations to clarify the notes. The following guidelines apply.

LETTERING.— All field notes should be lettered legibly. The lettering should be in freehand, vertical or slanted Gothic style, as illustrated in basic drafting. A fairly hard pencil or a mechanical lead holder with a 3H or 4H lead is recommended. Numerals and decimal points should be legible and should permit only one interpretation.

FORMAT.— Notes must be kept in the regular field notebook and not on scraps of paper for later transcription. Separate surveys should be recorded on separate pages or in different books. The front cover of the field notebook should be marked with the name of the project, its general location, the types of measurements recorded, the designation of the survey unit, and other pertinent information. The inside front cover should contain instructions for the return of the notebook, if lost. The right-hand pages should be reserved as an index of the field notes, a list of party personnel and their duties, a list of the instruments used, dates and reasons for any instrument changes during the course of the survey, and a sketch and description of the project.

Throughout the remainder of the notebook, the beginning and ending of each day's work should be clearly indicated. Where pertinent, the weather, including temperature and wind velocities, should also be recorded. To minimize recording errors, someone other than the recorder should check and initial all data entered in the notebook.

RECORDING.— Field note recording takes three general forms: tabulation, sketches, and descriptions. Two, or even all three, forms may be combined, when necessary, to make a complete record.

In TABULATION, the numerical measurements are recorded in columns according to a prescribed plan. Spaces are also reserved to permit necessary computations.

SKETCHES add much to clarify field notes and should be used liberally when applicable. They may be drawn to an approximate scale, or important details may be exaggerated for clarity. A small ruler or triangle is an aid in making sketches. Measurements should be added directly on the sketch or keyed in some way to the tabular data. An important requirement of a sketch is legibility. See that the sketch is drawn clearly and large enough to be understandable.

Tabulation, with or without added sketches, can also be supplemented with DESCRIPTIONS. The description may be only one or two words to clarify t he recorded measurements. It may also be quite a narration if it is to be used at some future time, possibly years later, to locate a survey monument.

ERASURES ARE NOT PERMITTED IN FIELD NOTEBOOKS. Individual numbers or lines recorded incorrectly are to be lined out and the correct values inserted. Pages that are to be rejected are crossed out neatly and referenced to the substituted pages. THIS PROCEDURE IS MANDATORY since the field notebook is the book of record and is often used as legal evidence.

Standard abbreviations, signs, and symbols are used in field notebooks. If there is any doubt as to their meaning, an explanation must be given in the form of notes or legends.

OFFICE WORK

OFFICE WORK in surveying consists of converting the field measurements into a usable format. The conversion of computed, often mathematical, values may be required immediately to continue the work, or it may be delayed until a series of field measurements is completed. Although these operations are performed in the field during lapses between measurements, they can also be considered office work. Such operations are normally done to save time. Special equipment, such as calculators, conversion tables, and some drafting equipment, are used in most office work.

In office work, converting field measurements (also called reducing) involves the process of computing, adjusting, and applying a standard rule to numerical values.

Computation

In any field survey operation, measurements are derived by the application of some form of mathematical computation. It may be simple addition of several full lengths and a partial tape length to record a total linear distance between two points. It maybe the addition or subtraction of differences in elevation to determine the height of instrument or the elevation during leveling. Then again, it maybe checking of angles to ensure that the allowable error is not exceeded.

Office computing converts these distances, elevations, and angles into a more usable form. The finished measurements may end up as a computed volume of dirt to be moved for a highway cut or fill, an area of land needed for a SEABEE construction project, or a new position of a point from which other measurements can be made.

In general, office computing reduces the field notes to either a tabular or graphic form for a permanent record or for continuation of fieldwork.

Adjustment

Some survey processes are not complete until measurements are within usable limits or until corrections have been applied to these measurements to distribute accumulated errors. Small errors that are not apparent in individual measurements can accumulate to a sizeable amount. Adjusting is the process used to distribute these errors among the many points or stations until the effect on each point has been reduced to the degree that all measurements are within usable limits.

For example, assume that 100 measurements were made to the nearest unit for the accuracy required. This requires estimating the nearest one-half unit during measurement. At the end of the course, an error of + 4 units results. Adjusting this means each measurement is reduced 0.04 unit. Since the measurements were read only to the nearest unit, this adjustment would not be measurable at any point, and the adjusted result would be correct.

SIGNIFICANT FIGURES.— The term *significant figures* refers to those digits in a number that have meaning; that is, whose values are definitely known to be exact.

In a measured quantity, the number of significant figures is determined by the accuracy of the measurement. For example, a roughly measured distance of 193 ft has three significant figures. More carefully measured, the same distance, 192.7 ft, has four significant figures. If measured still more accurately, 192.68 ft has five significant figures.

In surveying, the significant figures should reflect the allowable error or tolerance in the measurements. For example, suppose a measurement of 941.26 units is made with a probable error of ± 0.03 unit. The ± 0.03 casts some doubt on the fifth digit which can vary from 3 to 9, but the fourth digit will still remain 2. We can say that 941.26 has five significant figures; and from the allowable error, we know the fifth digit is doubtful. However, if the probable error were ±0.07, the fourth digit could be affected. The number could vary from 941.19 to 941.33, and the fourth digit could be read 1, 2, or 3. The fifth digit in this measurement is meaningless. The number has only four significant figures and should be written as such.

The number of significant figures in a number ending in one or more zeros is unknown unless more information is given. The zeros may have been added to show the location of the decimal point; for example, 73200 may have three, four, or five significant figures, depending on whether the true value is accurate to 100, 10, or 1 unit(s). If the number is written 73200.0, it indicates accuracy is carried to the tenth of a unit and is considered to have six significant figures.

When decimals are used, the number of significant figures is not always the number of digits. A zero may or may not be significant, depending on its position with respect to the decimal and the digits. As mentioned above, zeros may have been added to show the position of the decimal point. Study the following examples:

0.000047 . . . . two significant figures

0.0100470 . . . . six significant figures

0.1000470 . . . . seven significant figures

2.0100470 . . . . eight significant figures

In long computations, the values are carried out to one more digit than required in the result. The number is rounded off to the required numbers of digits as a final step.

ROUNDING OFF NUMBERS.— Rounding off is the process of dropping one or more digits and replacing them with zeros, if necessary, to indicate the number of significant figures. Numbers used in surveying are rounded off according to the following rules:

1. When the digit to be dropped is less than 5, the number is written without the digit or any others that follow it. (Example: 0.054 becomes 0.05.)

2. When the digit is equal to 5, the nearest EVEN number is substituted for the preceding digit. (Examples: 0.055 becomes 0.06; 0.045 becomes 0.04.)

3. When the digit to be dropped is greater than 5, the preceding digit is increased by one. (Example: 0.047 becomes 0.05.)

4. Dropped digits to the left of the decimal point are replaced by zeros.

5. Dropped digits to the right of the decimal points are never replaced.

EXAMPLES:

2738.649	to five significant figures equals	2738.6
792.850	to four significant figures equals	792.8
792.750	to four significant figures equals	792.8
675823.	to four significant figures equals	675800
675863.	to four significant figures equals	675900
4896.3	to four significant figures equals	4896
4896.7	to four significant figures equals	4897

CHECKING COMPUTATIONS.— Most mathematical problems can be solved by more than one method. To check a set of computations, you should use a method that differs from the original method, if possible. An inverse solution, starting with the computed value and solving for the field data, is one possibility. The planimeter and the protractor are also used for approximate checking. A graphical solution can be used, when feasible, especially if it takes less time than a mathematical or logarithmic solution. Each step that cannot be checked by any other method must be recomputed; and, if possible, another EA should recompute the problem. When an error or mistake is found, the computation should be rechecked before the correction is accepted.

Drafting Used In Surveying

The general concept of drafting and the use of drafting instruments were discussed in chapters 2 through 5. By this time, you should be familiar with the use of various drafting instruments and with the elements of mechanical drawing. Drafting used in surveying, except for some freehand sketches, is generally performed by mechanical means; for example, the drawing of lines and surveying symbols is generally done with the aid of a straightedge, spline, template, and so on.

The drawings you make that are directly related to surveying will consist of maps, profiles, cross sections, mass diagrams, and, to some extent, other graphical calculations. Their usefulness depends upon how accurately you plot the points and lines representing the field measurements. It is important that you adhere to the requirements of standard drawing practices. Correctness, neatness, legibility, and well-proportioned drawing arrangement are signs of professionalism.

In drawing a PROPERTY map, for example, the following general information must be included:

1. The length of each line, either indicated on the line itself or in a tabulated form, with the distances keyed to the line designation.
2. The bearing of each line or the angles between lines.
3. The location of the mapped area as referenced to an established coordinate system.
4. The location and kind of each established monument indicating distances from reference marks.
5. The name of each road, stream, landmark, and so on.
6. The names of all property owners, including those whose lots are adjacent to the mapped area.
7. The direction of the true or magnetic meridian, or both.
8. A graphical scale showing the corresponding numerical equivalent.
9. A legend to the symbols shown on the map, if those shown are not standard signs.
10. A title block that distinctly identifies the tract mapped or the owner's name. (It is required to contain the name of the surveyor, the name of the draftsman, and the date of the survey.)

Besides the above information, there are some other items that may be required if the map is to become a public record. When this is the case, consult the local office of the Bureau of Land Management or the local surveyors' society for the correct general information requirements to be included in the map to be drawn.

In drawing maps that will be used as a basis for studies, such as those to be used in roads, structures, or waterfront construction, you are required to include the following general information:

1. Information that will graphically represent the features in the plan, such as streams, lakes, boundaries, roads, fences, and condition and culture of the land.
2. The relief or contour of the land.
3. The graphical scale.
4. The direction of the meridian.
5. The legend to symbols used, if they are not conventional signs.
6. A standard title block with a neat and appropriate title that states the kind or purpose of the map. Again, the surveyor's name and that

of the draftsman, as well as the date of survey, are to be included in the title block.

Maps developed as a basis for studies are so varied in purpose that the above information may be adequate for some but inadequate for others. The Engineering Aid, when in doubt, should consult the senior EA, the engineering officer, or the operations officer as to the information desired in the proposed map. The senior EA or the chief of the field survey party is required to know all these requirements before actual fieldwork is started.

A map with too much information is as bad as a map with too little information on it. It is not surprising to find a map that is so crowded with information and other details that it is hard to comprehend. If this happens, draw the map to a larger scale or reduce the information or details on it. Then, provide separate notes or descriptions for other information that will not fit well and thus will cause the appearance of overcrowding. Studying the features and quality of existing maps developed by NAVFACENGCOM and civilian architects and engineers (A & E) agencies will aid you a great deal in your own map drawing.

Orientation Symbol

Every map you draw has to have an ORIENTATION SYMBOL (sometimes called meridian arrows) on it. The symbol that represents the direction of the meridian is indicated by a needle or feathered arrow pointing north. It must be drawn long enough that it could be transferred accurately to any part of the map. The FULL-HEAD ARROW represents the true meridian; the HALF-HEAD ARROW, the magnetic meridian. If both are drawn, as shown in figure 11-1, the angle between them must be indicated. The general tendency is to draw the symbol in an artistic way; however, the simple design shown in figure 11-1 is adequate for most purposes. If possible, the top of a map must always be oriented north; however, the shape of the mapped area or the most important features of the project may alter this preference.

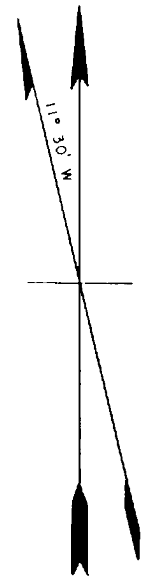

Figure 11-1.-An orientation symbol or meridian arrows.

Kinds of Maps

Maps are classified according to purpose, scale, or type. Maps classified according to purpose include strategic, tactical, and artillery maps; communications, utilities, or soil maps; and maps pertaining to special studies. When maps are classified according to scale, you have large-scale, medium-scale, and small-scale. Some of the more common types, such as geographic, planimetric, topographic, hydrographic, special-purpose, and photomaps or mosaics, are briefly described in the next several paragraphs.

GEOGRAPHIC MAPS.— A geographic map is a map of a large area, such as that of a state or country, that shows the location of towns, counties, cities, rivers or streams, lakes, roads, and principal civil boundaries, such as county and state lines. Maps showing the general location of the works of people, such as the Railroad Map of the United States, the Irrigation Map of Arizona, and the Panama Canal Zone Map, are classified as geographical maps.

PLANIMETRIC MAPS.— These maps show natural or man-made features in a horizontal plane only. Relief in a measurable form is omitted. A few examples of planimetric maps are property, maps for city layout, site plan, communications, route and distance, and isogonic maps of the magnetic variation lines.

TOPOGRAPHIC MAPS.— Maps that depict the natural and man-made features of the earth's surface in a measurable form, showing both horizontal and vertical positions are called topographical maps. Vertical positions, or relief, are normally represented by contours. A precise topographic map shows surface features so perfectly that it can be used for making an exact three-dimensional model of the area. Such a model is called a RELIEF MAP. Your work in the SEABEEs will generally concern topographic maps for use in construction.

HYDROGRAPHIC MAPS.— A hydrographic map shows the shorelines, the location and depth of soundings, and often the topographic and other features of lands adjacent to the shorelines. It also shows the locations of both horizontal and vertical control in the area.

SPECIAL-PURPOSE MAPS.— These are maps developed for specific purposes. A PRELIMINARY MAP developed from a preliminary survey of a highway, a LOCATION MAP showing the alignment of the located line, and a RIGHT-OF-WAY MAP showing the boundaries of the right-of-way and the adjacent lands all come under the heading of special-purpose maps.

MOSAIC AND OVERLAYS.— The aerial photographic mosaic is constructed from two or more overlapping prints joined so that they form a single picture. Usually, vertical photographs are used and a maplike result is obtained; however, oblique photographs may be used, in which case the result is a panorama. The mosaic has become increasingly useful in cartography and related fields since World War I. Large geographic areas may be represented in this manner with each feature of terrain assuming its natural appearance and approximating its proportionate size. The U.S. Army Topographic Command has a vari-colored map of the entire United States and other countries that was developed from mosaics. The Army calls it a PICTOMAP; this is the type of map that is generally used in a war zone.

Aerial photographs may be converted into line maps by the use of overlays. Usually, these are made by tracing the details from the photograph on transparent paper or vellum and adding such marginal data as desired. This line map may then be reproduced quickly by blueprinting or by lithography. Figure 11-2 shows a vertical aerial

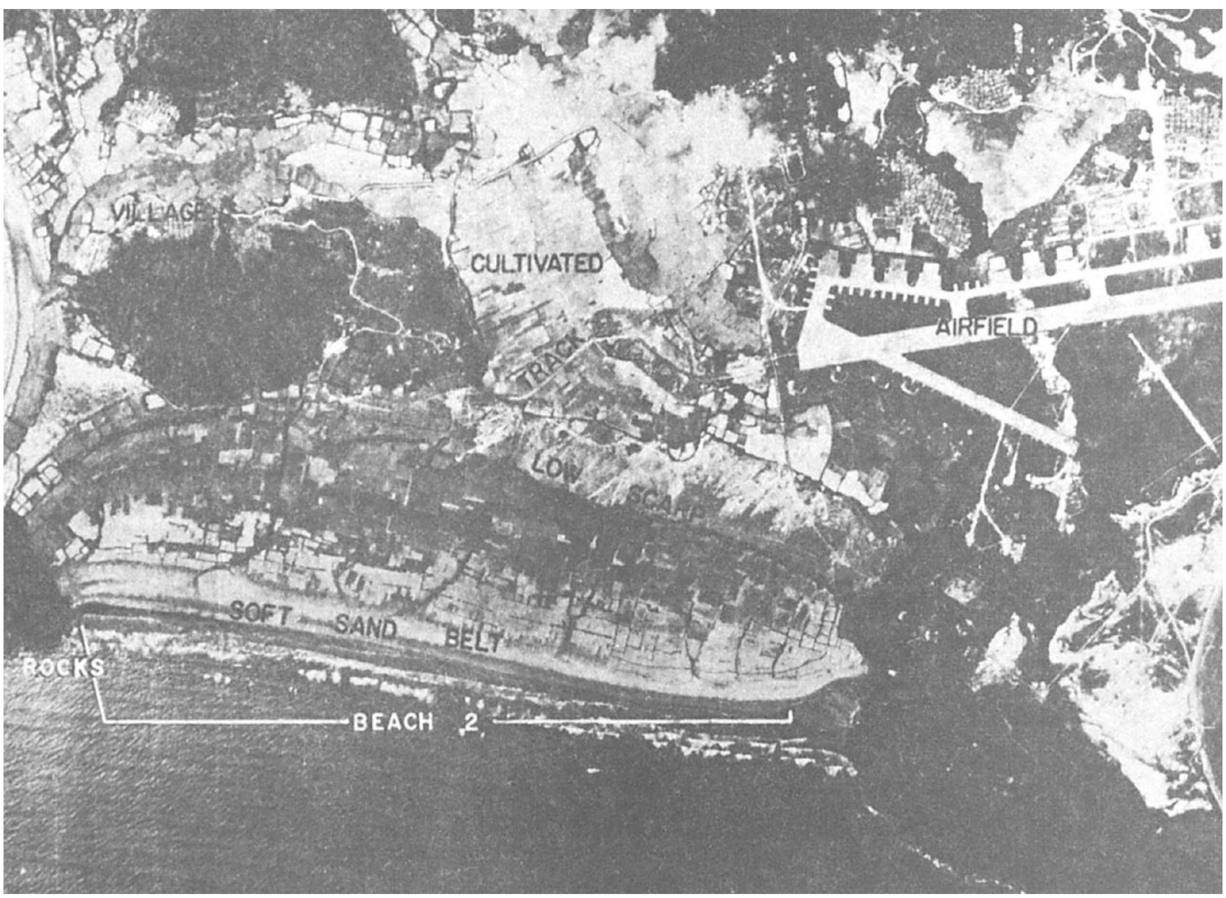

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Figure 11-2.-Example of an aerial photograph.

photograph, and figure 11-3 shows the line map made by the use of overlays.

BASIC SURVEYING INSTRUMENTS

Most fieldwork done by an Engineering Aid (especially at the third- and second-class levels) is likely to consist of field measurements and/or computations that involve plane surveying of ordinary precision. This section describes the basic instruments, tools, and other equipment used for this type of surveying. Other instruments used for more precise surveys will also be described briefly.

Surveying instruments come in various forms, yet their basic functions are similar; that is, they are all used for measuring unknown angles and distances and/or for laying off known angles and distances.

MAGNETIC COMPASS

A magnetic compass is a device consisting principally of a circular compass card, usually graduated in degrees, and a magnetic needle, mounted and free to rotate on a pivot located at the center of the card. The needle, when free from any local attraction (caused by metal), lines itself up with the local magnetic meridian as a result of the attraction of the earth's magnetic North Pole.

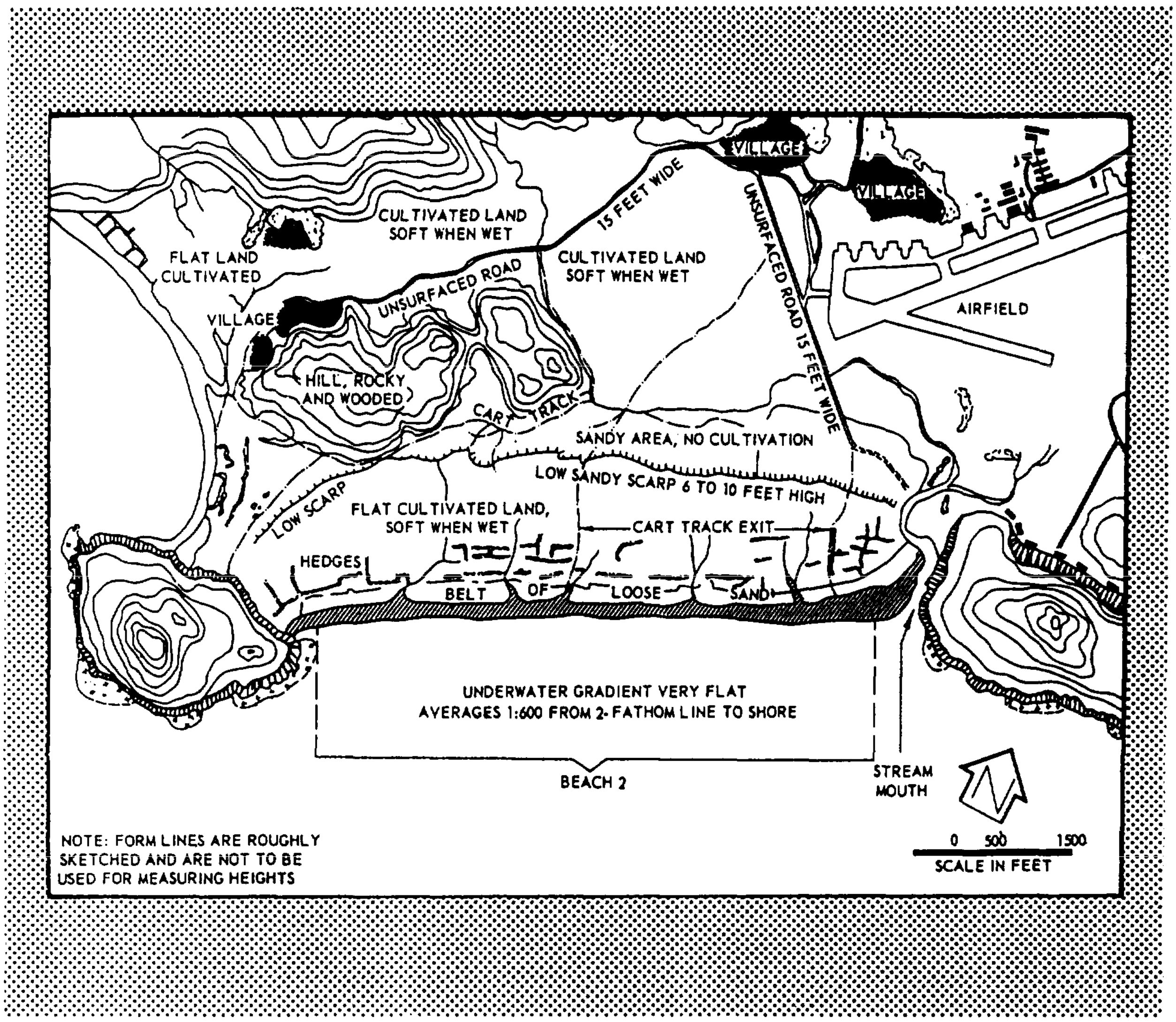

Figure 11-3.-Line map made by overlays from the aerial photograph in figure 11-2.

The magnetic compass is the most commonly used and simplest instrument for measuring directions and angles in the field. This instrument has a variety of both civilian and military applications. The LENSATIC COMPASS (available in your Table of Allowance) is most commonly used for SEABEE compass courses, for map orientation, and for angle direction during mortar and field artillery fires.

In addition to this type of compass, there are several others used exclusively for field surveys. The ENGINEER'S TRANSIT COMPASS, located between the standards on the upper plate, is graduated from 0° through 360° for measuring azimuths, and in quadrants of 90° for measuring bearings (fig. 11-4). Notice in figure 11-4 that the east and west markings are reversed. This permits direct reading of the magnetic direction.

The compass shown in figure 11-5 is commonly called the BRUNTON POCKET TRANSIT. This instrument is a combination compass and clinometer. It can be mounted on a light tripod or staff, or it may be cradled in the palm of the hand.

Other types of compasses can also be found in some surveying instruments, such as the theodolite and plane table.

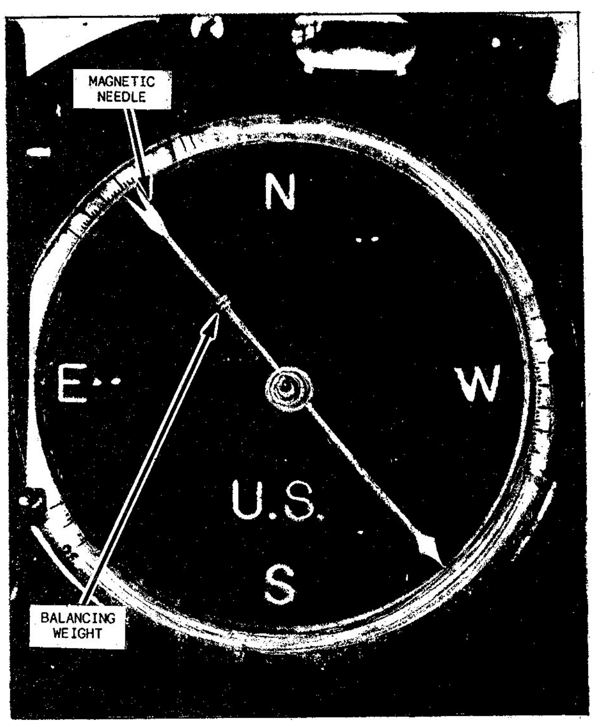

Figure 11-4.-Engineer's transit compass.

ENGINEER'S TRANSIT

A primary survey fieldwork consists of measuring horizontal and vertical angles or directions and extending straight lines. The instruments that can perform these functions have additional refinements (built-in) that can be used for other survey operations, such as leveling. Two types of instruments that fall into this category are the engineer's transit and the theodolite. In recent years, manufacturing improvements have permitted construction of direct-reading theodolites that are soon to replace the vernier-reading transits. However, in most SEABEE construction, the engineer's transit is still the major surveying instrument.

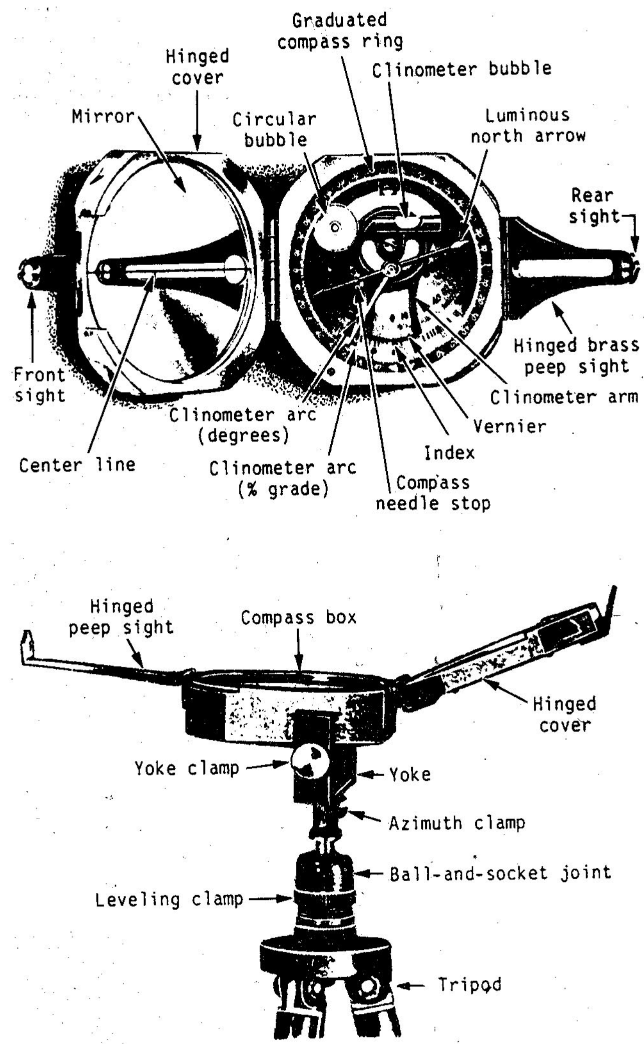

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Figure 11-5.-A Brunton pocket transit.

The transit (fig. 11-6) is often called the universal survey instrument because of its uses. It may be used for measuring horizontal angles and directions, vertical angles, and differences in elevations; for prolonging straight lines; and for measuring distances by stadia. Although transits of various manufacturers differ in appearance, they are alike in their essential parts and operations.

The engineer's transit contains several hundred parts. For-descriptive purposes, these parts may be grouped into three assemblies: the leveling head assembly, the lower plate assembly, and the upper many plate or alidade assembly (fig. 11-7).

Leveling Head Assembly

The leveling head of the transit normally is the four-screw type, constructed so the instrument can be shifted on the foot plate for centering over a marked point on the ground.

Lower Plate Assembly

The lower plate assembly of the transit consists of a hollow spindle that is perpendicular to the

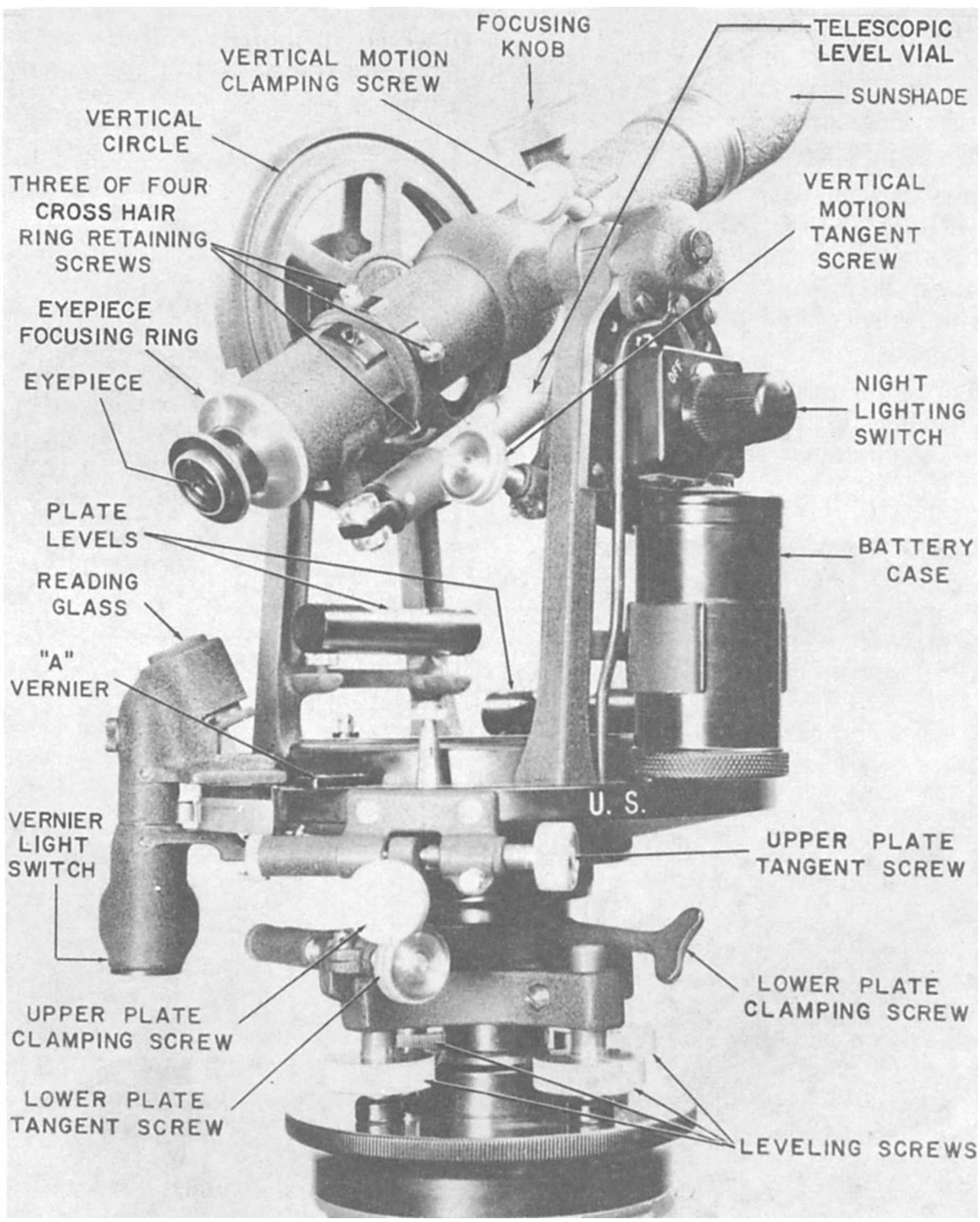

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Figure 11-6.-An engineer's transit.

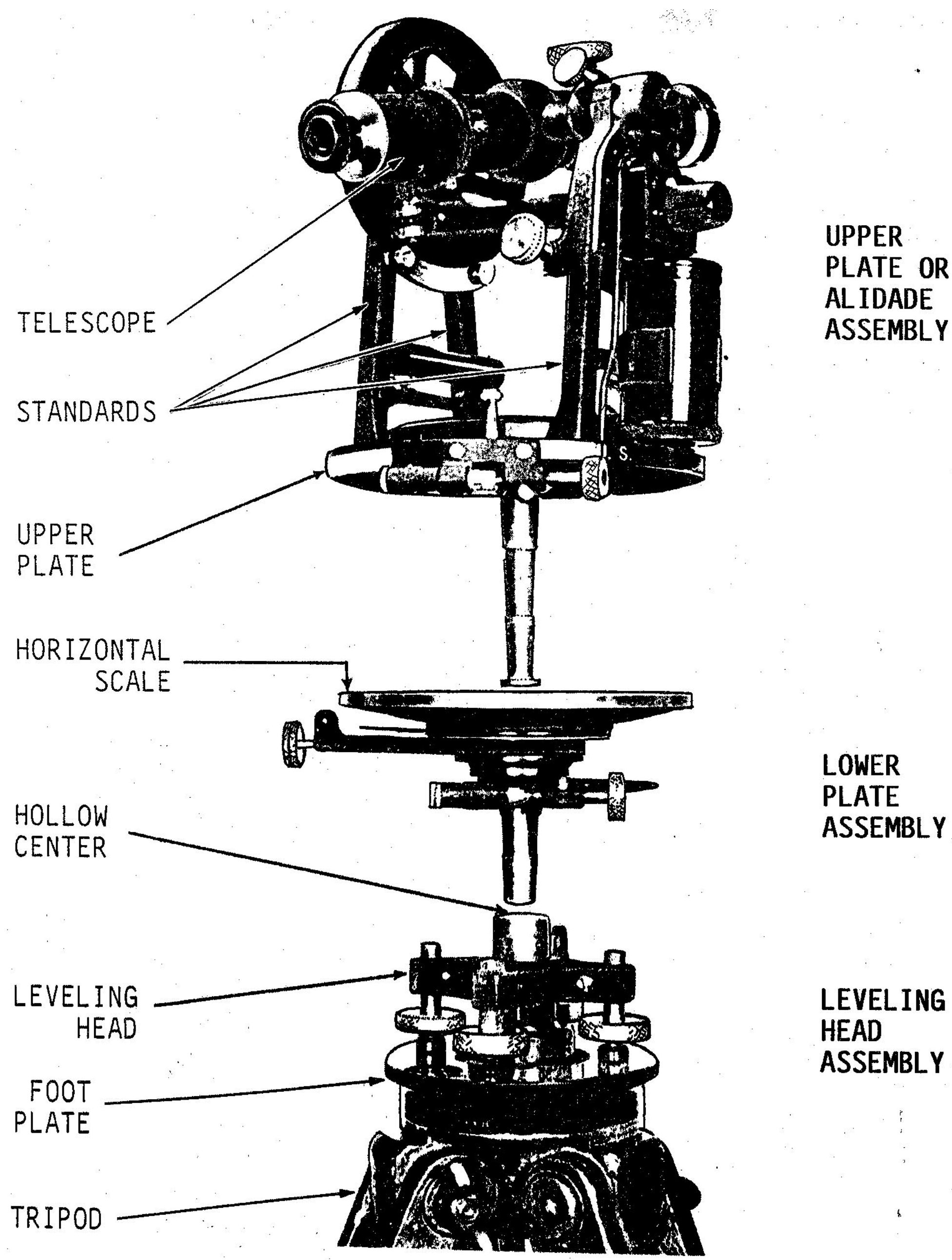

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Figure 11-7.-An engineer's transit, exploded view.

center of a circular plate and accurately fitted the socket in the leveling head. The lower plate contains the graduated horizontal circle on which the values of horizontal angles are read with the aid of two verniers, A and B, set on the opposite sides of the circle. A clamp controls the rotation of the lower plate and provides a means for locking it in place. A slow-motion tangent screw is used to rotate the lower plate a small amount to relative to the leveling head. The rotation accomplished by the use of the lower clamp and tangent screw is known as the LOWER MOTION.

Upper Plate or Alidade Assembly

The upper plate, alidade, or vernier assembly consists of a spindle attached plate to a circular plate carrying verniers, telescope standards, plate-level vials, and a magnetic compass. The spindle is accurately fitted to coincide with the socket in the lower plate spindle. A clamp is tightened to hold the two plates together or loosened to permit the upper plate to rotate relative to the lower plate. A tangent screw permits the upper plate to be moved a small amount and is known as the UPPER MOTION. The standards support two pivots with adjustable bearings that hold the horizontal axis and permit the telescope to move on a vertical plane. The vertical circle moves with the telescope. A clamp and tangent screw are provided to control this vertical movement. The vernier for the vertical circle is attached to the left standard. The telescope is an erecting type and magnifies the image about 18 to 25 times. The reticle contains stadia hairs in addition to the cross hairs. A magnetic compass is mounted on the upper plate between the two standards and consists of a magnetized needle pivoted on a jeweled bearing at the center of a graduated circle. A means is provided for lifting the needle off the pivot to protect the bearing when the compass is not in use.

LEVEL VIALS.— Two plate level vials (fig. 11-6) are placed at right angles to each other. On many transits, one plate level vial is mounted on the left side, attached to the standard, under the

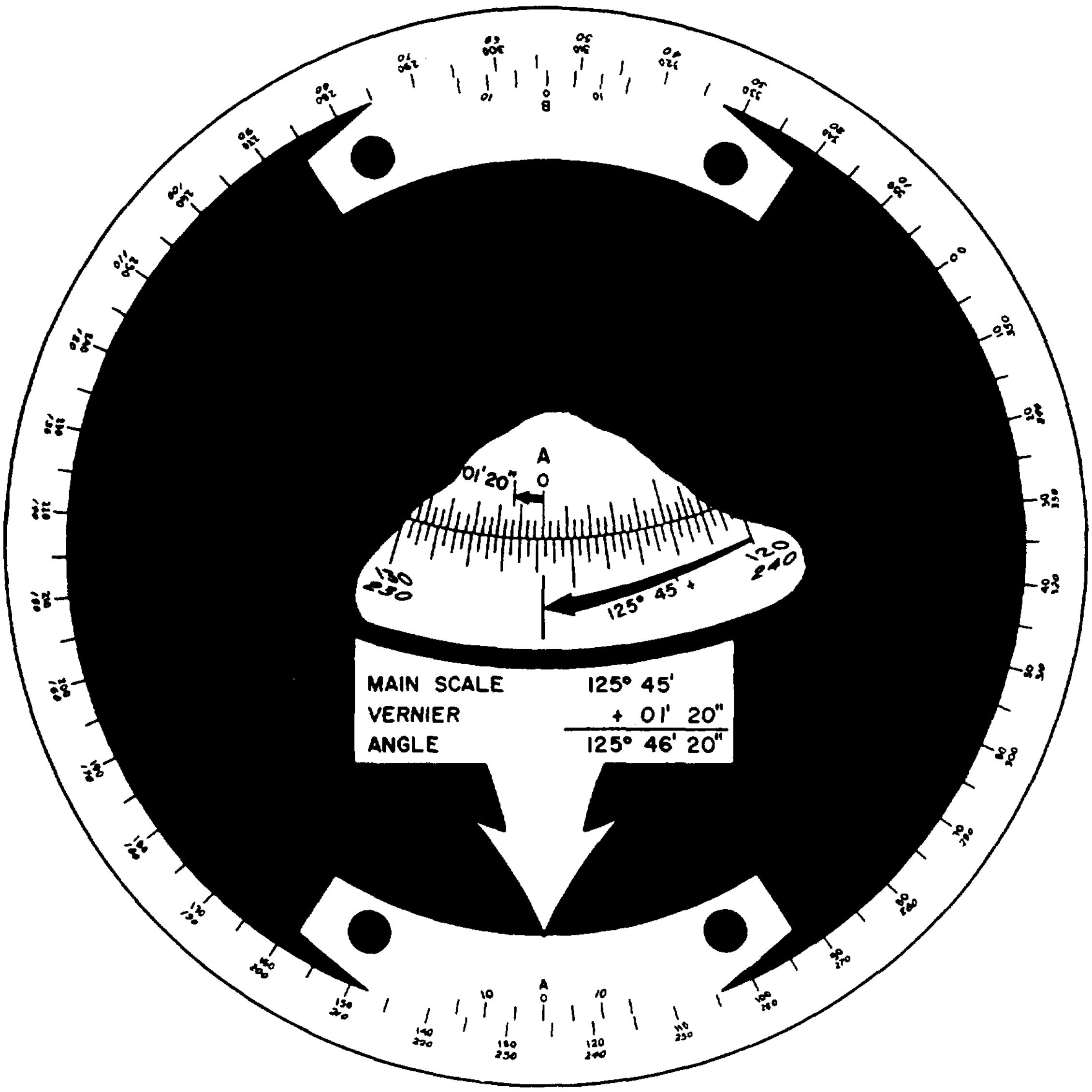

Figure 11-8.-Horizontal scales, 20 second transit.

vertical circle vernier. The other vial is then parallel to the axis of rotation for the vertical motion. The sensitivity of the plate level vial bubbles is about 70 sec of movement for 2 mm of tilt. Most engineer's transits have a level vial mounted on the telescope to level it. The sensitivity of this bubble is about 30 sec per 2-mm tilt.

CIRCLES AND VERNIERS.— The horizontal and vertical circles and their verniers are the parts of the engineer's transit by which the values of horizontal and vertical angles are determined. A stadia arc is also included with the vertical circle on some transits.

The horizontal circle and verniers of the transit that are issued to SEABEE units are graduated to give least readings of either 1 min or 20 sec of arc. The horizontal circle is mounted on the lower plate. It is graduated to 15 min for the 20-sec transit (fig. 11-8) and 30 min for the 1-min transit (fig. 11-9). The plates are numbered from 0° to 360°, starting with a common point and running both ways around the circle. Two double verniers, known as the A and B verniers, are mounted on the upper plate with their indexes at circle readings 180° apart. A double vernier is one that can be read in both directions from the index line. The verniers reduce the circle graduations to the final reading of either 20 sec or 1 min.

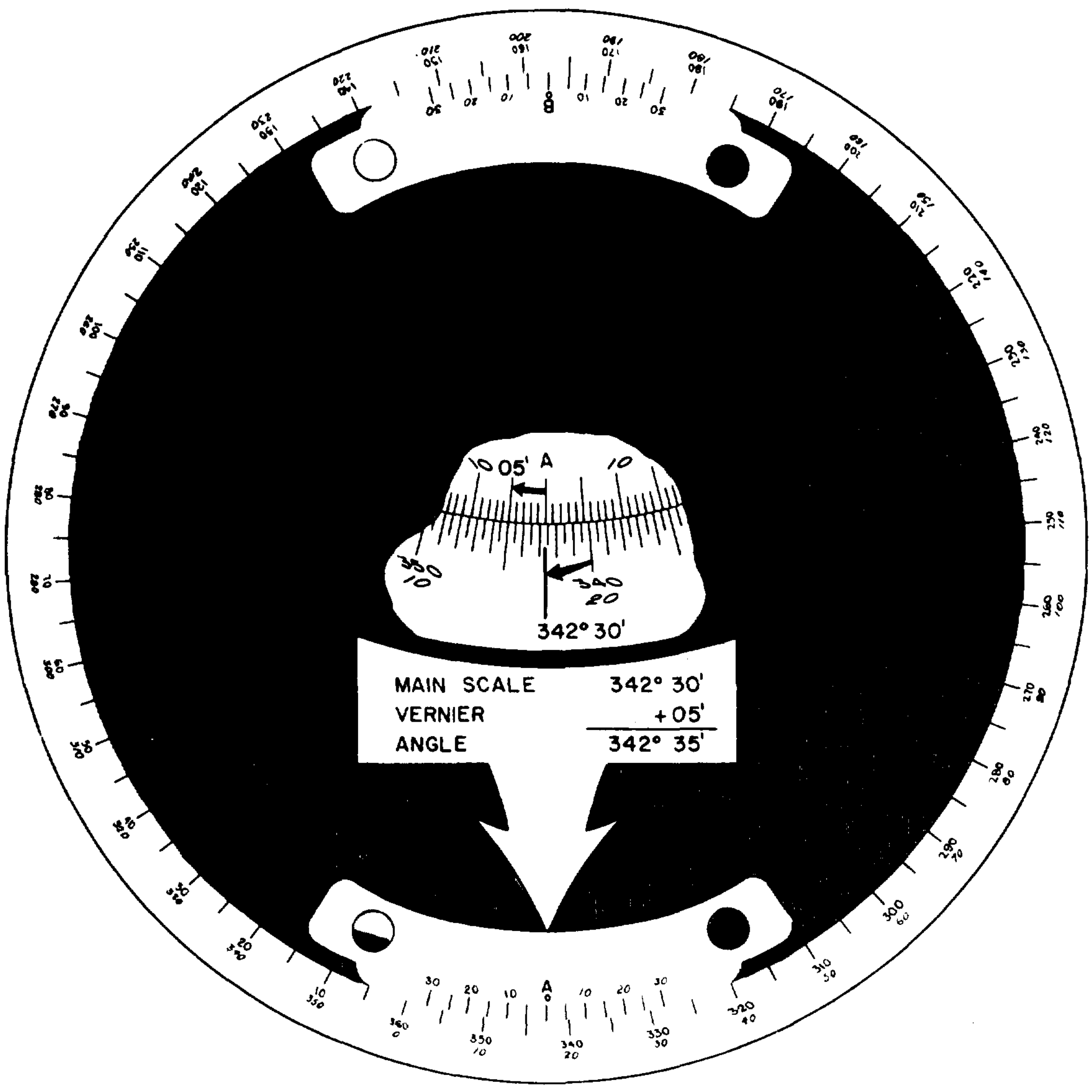

Figure 11-9.-Horizontal scales, 1-minute transit.

The A vernier is used when the telescope is in its normal position, and the B vernier is used when the telescope is plunged.

The VERTICAL CIRCLE of the transit (fig. 11-10) is fixed to the horizontal axis so it will rotate with the telescope. The vertical circle normally is graduated to 30´ with 10° numbering. Each quadrant is numbered from 0° to 90°; the 00 graduations define a horizontal plane, and the 90° graduations lie in the vertical plane of the instrument. The double vernier used with the circle is attached to the left standard of the transit, and its least reading is 1´. The left half of the double vernier is used for reading angles of depression, and the right half of this vernier is used for reading angles of elevation. Care must be taken to read the vernier in the direction that applies to the angle observed.

In addition to the vernier, the vertical circle may have an H and V (or HOR and VERT) series of graduations, called the STADIA ARC (fig. 11-10). The H scale is adjusted to read 100 when the line of sight is level, and the graduations decrease in both directions from the level line. The other scale, V, is graduated with 50 at level, to 10 as the telescope is depressed, and to 90 as it is elevated.

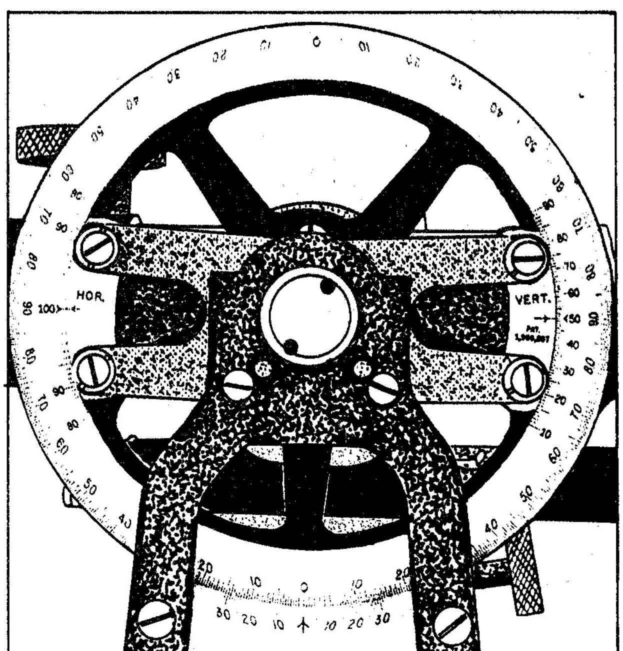

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Figure 11-10.-Vertical circle with verniers, scales, and stadia arc.

The VERNIER, or vernier scale, is an auxiliary device by which a uniformly graduated main scale can be accurately read to a fractional part of a division. Both scales may be straight as on a leveling rod or curved as on the circles of a transit. The vernier is uniformly divided, but each division is either slightly smaller (direct vernier) or slightly larger (retrograde vernier) than a division of the main scale (fig. 11-11). The amount a vernier division differs from a division of the main scale determines the smallest reading of the scale that can be made with the particular vernier. This smallest reading is called the LEAST COUNT of the vernier. It is determined by dividing the value of the smallest division on the scale by the number of divisions on the vernier.

Direct Vernier.— A scale graduated in hundredths of a unit is shown in figure 11-11, view A, and a direct vernier for reading it to thousandths of a unit. The length of 10 divisions on the vernier is equal to the length of 9 divisions on the main scale. The index, or zero of the vernier, is set at 0.340 unit. If the vernier were moved 0.001 unit toward the 0.400 reading, the Number 1 graduation of the vernier shown in figure 11-11, view A, would coincide with 0.35 on the scale, and the index would be at 0.341 unit. The vernier, moved to where graduation Number 7 coincides with 0.41 on the scale, is shown in figure 11-11, view B. In this position, the correct scale reading is 0.347 unit (0.340 + 0.007). The index with the zero can be seen to point to this reading.

Retrograde Vernier.— A retrograde vernier on which each division is 0.001 unit longer than the 0.01 unit divisions on the main scale is shown in figure 11-11, view C. The length of the 10 divisions on the vernier equals the length of the 11 divisions of the scale. The retrograde vernier extends from the index, backward along the scale. Figure 11-11, view D, shows a scale reading of 0.347 unit, as read with the retrograde vernier.

Vernier for Circles. — Views E and F of figure 11-11 represent part of the horizontal circle of a transit and the direct vernier for reading the circle. The main circle graduations are numbered both clockwise and counterclockwise. A double vernier that extends to the right and to the left of the index makes it possible to read the main circle in either direction. The vernier to the left of the index is used for reading clockwise angles, and the vernier to the right of the index is used for reading

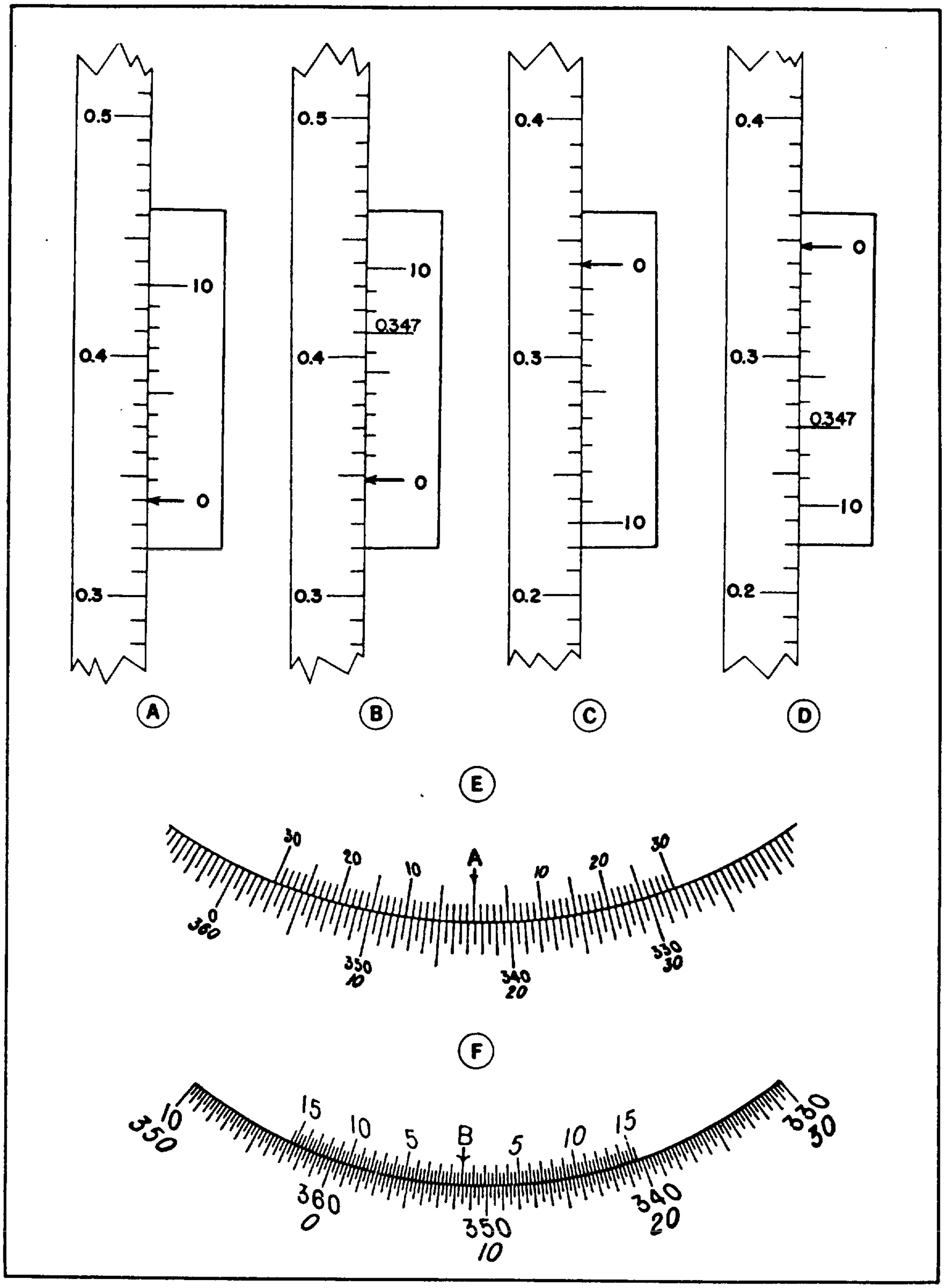


Figure 11-11.-Types of verniers.

counterclockwise angles. The slope of the numerals in the vernier to be used corresponds to the slope of the numerals in the circle being read. Care must be taken to use the correct vernier. In figure 11-11, view E, the circle is graduated to half degrees, or 30 min. On this vernier, 30 divisions are equal in length to 29 divisions on the circle. The least reading of this vernier is 30 min divided by 30 divisions, or 1 min. The index (fig. 11-11, view E) is seen to lie between 342°30´ and 343°. In the left vernier, graduation Number 5 is seen to coincide with a circle graduation. Then, the clockwise reading of this circle is 342°30´ plus 05´, or 342°35´. When the right vernier is used in the same way, the counterclockwise reading of the circle is 17°00´ plus 25´, or 17°25´. In figure 11-11, view F, the circle is graduated in 15-min divisions and each half of the double vernier contains 45 divisions. The least reading on this vernier is 20 sec. The clockwise reading of the circle and vernier is 351°30´plus 05´40" or 351°35´40". The counterclockwise reading is 8°15´ plus 9´20", or 8°24´20".

THEODOLITE

A theodolite is essentially a transit of high precision. Theodolites come in different sizes and weights and from different manufacturers. Although theodolites may differ in appearance, they are basically alike in their essential parts and operation. Some of the models currently available for use in the military are WILD (Herrbrugg), BRUNSON, K&E, (Keuffel & Esser), and PATH theodolites.

To give you an idea of how a theodolite differs from a transit, we will discuss some of the most commonly used theodolites in the U.S. Armed Forces.

One-Minute Theodolite

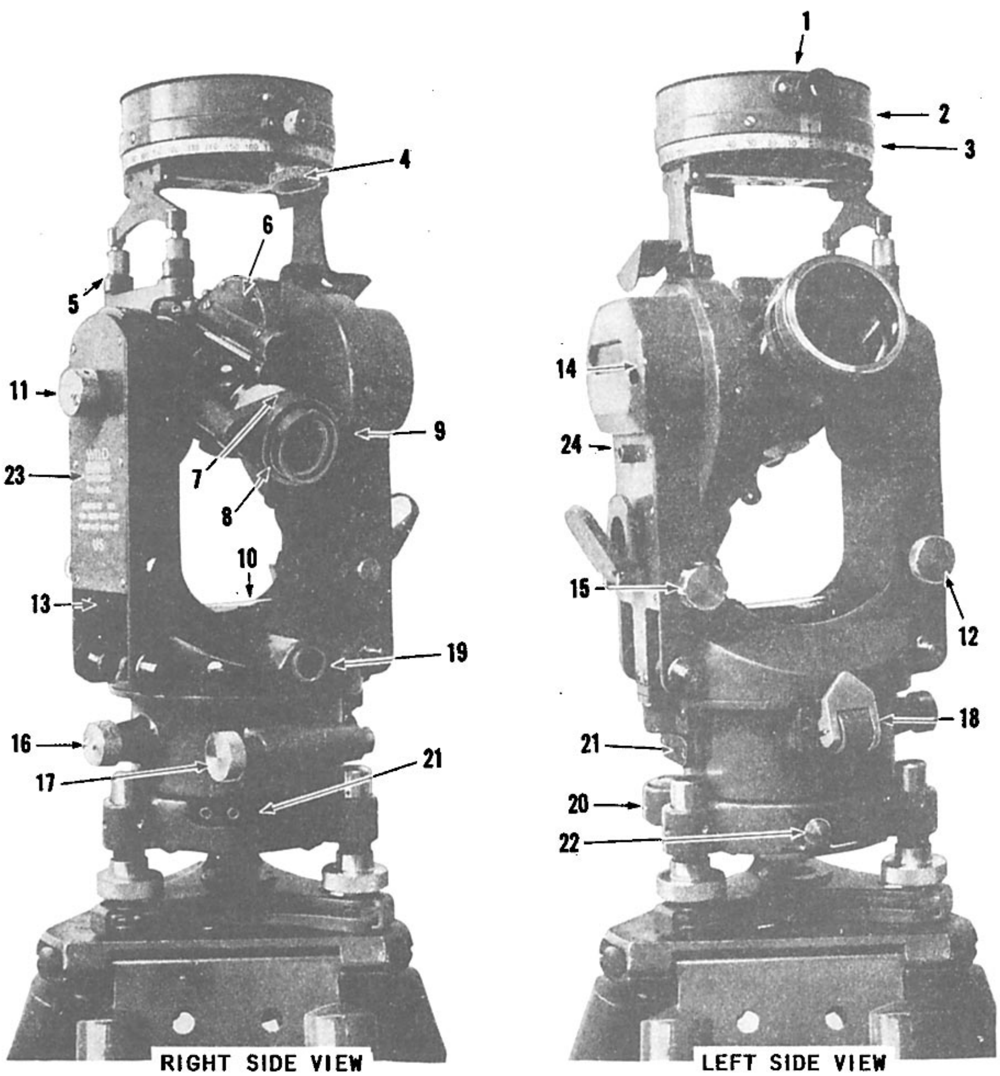
The 1-min directional theodolite is essentially a directional type of instrument. This type of instrument can be used, however, to observe horizontal and vertical angles, as a transit does.

The theodolite shown in figure 11-12 is a compact, lightweight, dustproof, optical reading instrument. The scales read directly to the nearest minute or 0.2 mil and are illuminated by either natural or artificial light. The main or essential parts of this type of theodolite are discussed in the next several paragraphs.

HORIZONTAL MOTION.— Located on the lower portion of the alidade, and adjacent to each other, are the horizontal motion clamp and tangent screw used for moving the theodolite in azimuth. Located on the horizontal circle casting is a horizontal circle clamp that fastens the circle to the alidade. When this horizontal (repeating) circle clamp is in the lever-down position, the horizontal circle turns with the telescope. With the circle clamp in the lever-up position, the circle is unclamped and the telescope turns independently. This combination permits use of the theodolite as a REPEATING INSTRUMENT. To use the theodolite as a DIRECTIONAL TYPE OF INSTRUMENT, you should use the circle clamp only to set the initial reading. You should set an initial reading of 0°30´ on the plates when a direct and reverse (D/R) pointing is required. This will minimize the possibility of ending the D/R pointing with a negative value.

VERTICAL MOTION.— Located on the standard opposite the vertical circle are the vertical motion clamp and tangent screw. The tangent screw is located on the lower left and at right angles to the clamp. The telescope can be rotated in the vertical plane completely around the axis (360°).

LEVELS.— The level vials on a theodolite are the circular, the plate, the vertical circle, and the telescope level. The CIRCULAR LEVEL is located on the tribrach of the instrument and is used to roughly level the instrument. The PLATE LEVEL, located between the two standards, is used for leveling the instrument in the horizontal plane. The VERTICAL CIRCLE LEVEL (vertical collimation) vial is often referred to as a split bubble. This level vial is completely built in, adjacent to the vertical circle, and viewed through a prism and 45° mirror system from the eyepiece end of the telescope. This results in the viewing of one-half of each end of the bubble at the same time. Leveling consists of bringing the two halves together into exact coincidence, as



1 Compass eyepiece
2 Compass
3 Circle ring
4 Caging knob
5 Compass leveling screw
6 Telescope level
7 Focus drive
8 Microscope eyepiece
9 Telescope eyepiece
10 Plate level
11 Vertical clamp
12 Vertical slow-motion screw
13 Vertical slow-motion adjusting screw
14 Collimation level
15 Collimation slow-motion screw
16 Horizontal clamp
17 Horizontal slow-motion screw
18 Horizontal circle clamp
19 Optical plumb eyepiece
20 Circular level
21 Electric plugs
22 Tribrach clamp lever
23 Right cover
24 Left cover

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Figure 11-12.—One-minute theodolite.

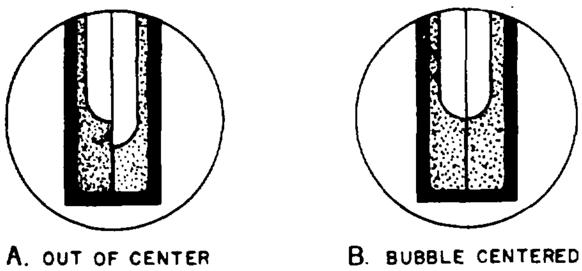

Figure 11-13.-Coincidence- type level.

shown in figure 11-13. The TELESCOPE LEVEL, mounted below the telescope, uses a prism system and a 45° mirror for leveling operations. When the telescope is plunged to the reverse position, the level assembly is brought to the top.

TELESCOPE.— The telescope of a theodolite can be rotated around the horizontal axis for direct and reverse readings. It is a 28-power instrument with the shortest focusing distance of about 1.4 meters. The cross wires are focused by turning the eyepiece; the image, by turning the focusing ring. The reticle (fig. 11-14) has horizontal and vertical cross wires, a set of vertical and horizontal ticks (at a stadia ratio of 1:100), and a solar circle on the reticle for making solar observations. This circle covers 31 min of arc and can be imposed on the sun's image (32 min of arc) to make the pointing refer to the sun's center. One-half of the vertical line is split for finer centering on small distant objects.

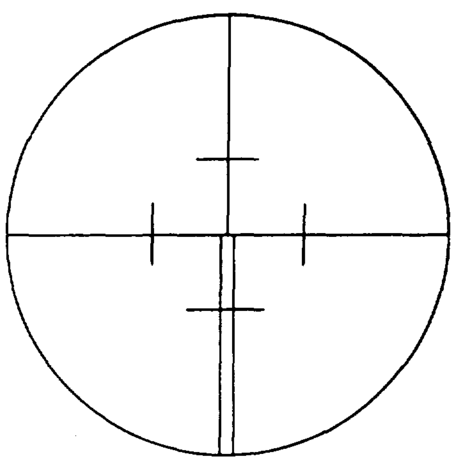

Figure 11-14.-Theodolite reticle.

The telescope of the theodolite is an inverted image type. Its cross wires can be illuminated by either sunlight reflected by mirrors or by battery source. The amount of illumination for the telescope can be adjusted by changing the position of the illumination mirror.

TRIBRACH.— The tribrach assembly (fig. 11-15), found on most makes and models, is a detachable part of the theodolite that contains the leveling screw, the circular level, and the optical plumbing device. A locking device holds the alidade and the tribrach together and permits interchanging of instruments without moving the tripod. In a "leapfrog" method, the instrument (alidade) is detached after observations are completed. It is then moved to the next station and another tribrach. This procedure reduces the amount of instrument setup time by half.

CIRCLES.— The theodolite circles are read through an optical microscope. The eyepiece is located to the right of the telescope in the direct position, and to the left, in the reverse. The microscope consists of a series of lenses and prisms that bring both the horizontal and the

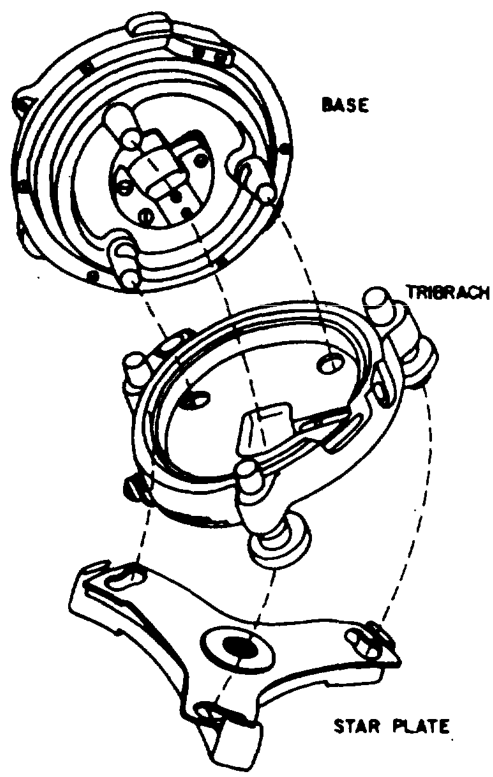

Figure 11-15.-Three-screw leveling head.

vertical circle images into a single field of view. In the DEGREE-GRADUATED SCALES (fig. 11-16), the images of both circles are shown as they would appear through the microscope of the 1-min theodolite. Both circles are graduated from 0° to 360° with an index graduation for each degree on the main scales. This scale's graduation appears to be superimposed over an auxiliary that is graduated in minutes to cover a span of 60 min (1°). The position of the degree mark on the auxiliary scale is used as an index to get a direct reading in degrees and minutes. If necessary, these scales can be interpolated to the nearest 0.2 min of arc.

The vertical circle reads 0° when the theodolite's telescope is pointed at the zenith, and 180° when it is pointed straight down. A level line reads 90° in the direct position and 270° in the reverse. The values read from the vertical circle are referred to as ZENITH DISTANCES and not vertical angles. Figure 11-17 shows how these zenith distances can be converted into vertical angles.

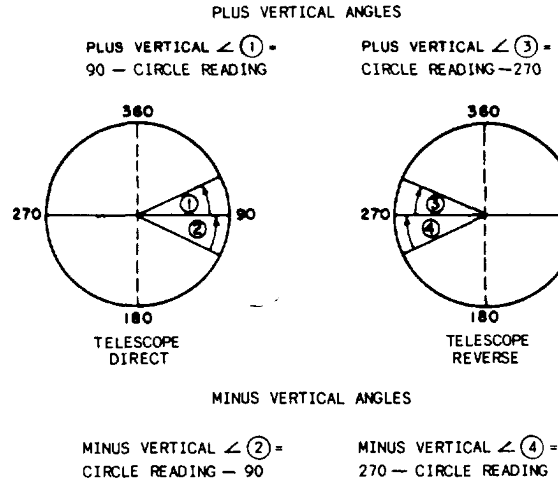

Figure 11-17.-Converting zenith distances into vertical angles (degrees).

In the MIL-GRADUATED SCALES (fig. 11-18), the images of both circles are shown as they would appear through the reading microscope of the 0.2-mil theodolite. Both circles are graduated from 0 to 6,400 mils. The main scales are marked and numbered every 10 mils, with the

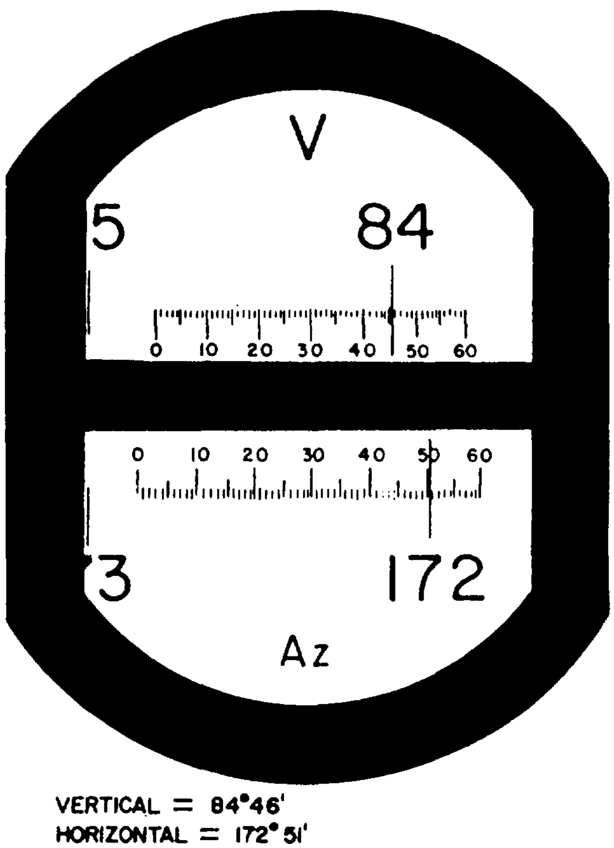

Figure 11-16.-Degree-graduated scales.

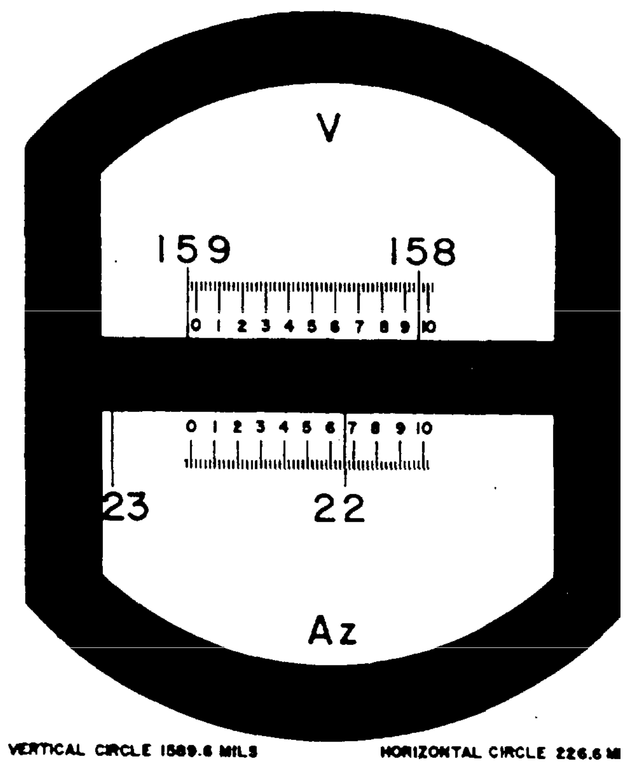

Figure 11-18.-Mil-graduated scales.

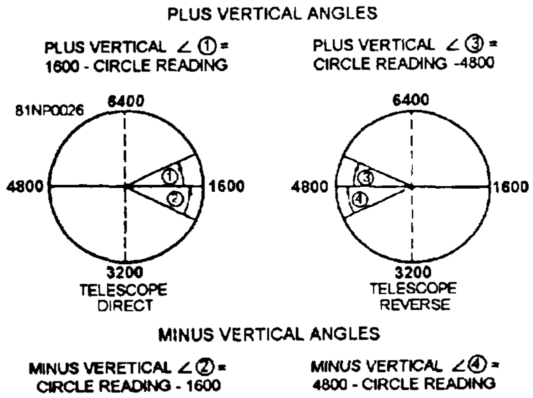

Figure 11-19.-Vertical angles from zenith distances (mils).

last zero dropped. The auxiliary scales are graduated from 0 to 10 roils in 0.2-mil increments. Readings on the auxiliary scale can be interpolated to 0.1 mil.

The vertical circle reads 0 mil when the telescope is pointed at the zenith, and 3,200 mils when it is pointed straight down. A level line reads 1,600 roils in the direct position and 4,800 roils in the reverse. The values read are zenith distances. These zenith distances can be converted into vertical angles as shown in figure 11-19.

One-Second Theodolite

The 1-sec theodolite is a precision direction type of instrument for observing horizontal and vertical directions. This instrument is similar to,

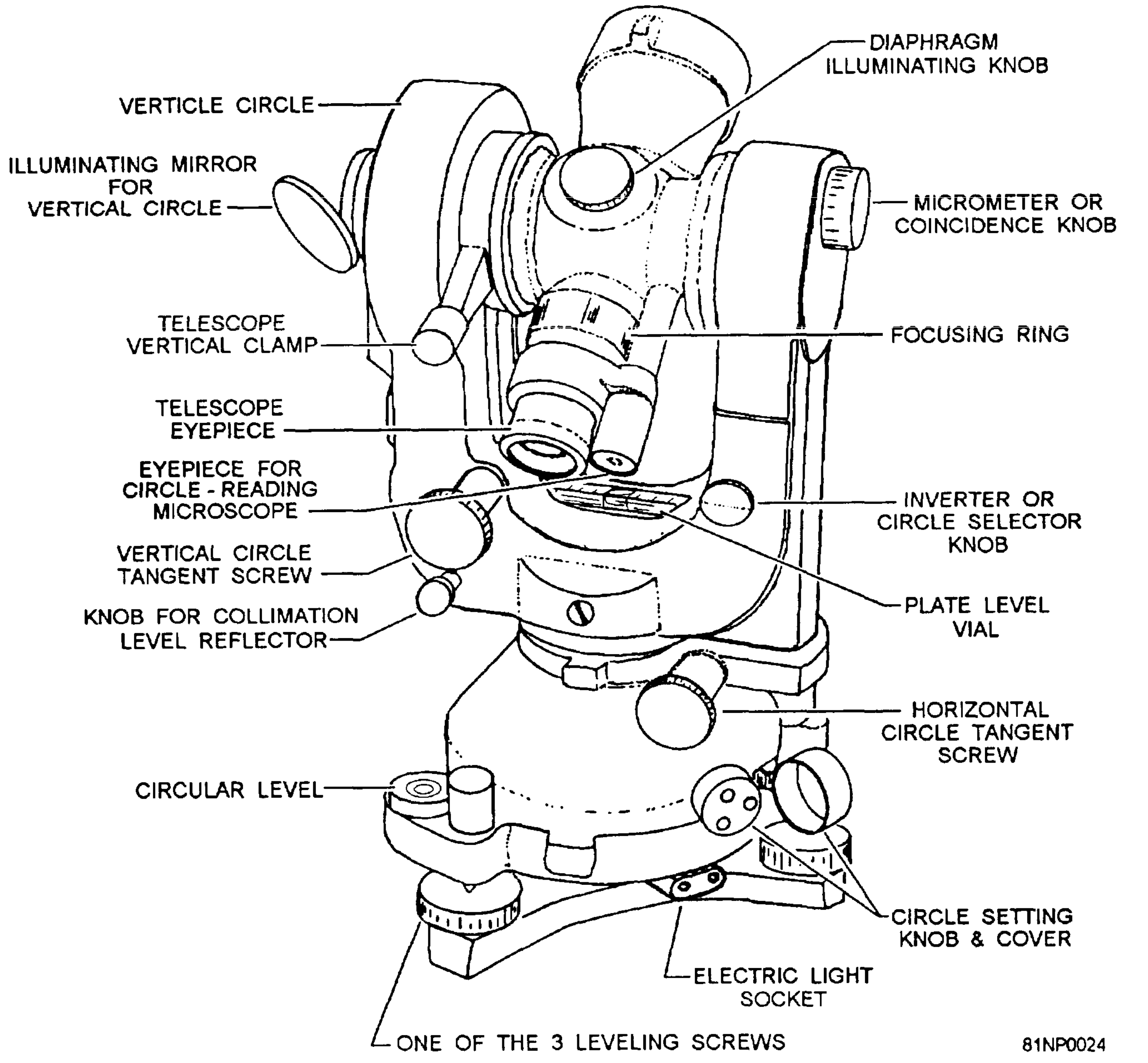

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Figure 11-20.-A 1-second theodolite.

but slightly larger than, the 1-min theodolite. The WILD theodolite shown in figure 11-20 is compact, lightweight, dustproof, optical reading, and tripod-mounted. It is one spindle, one plate level, a circular level, horizontal and vertical circles read by an optical microscope directly to 1 sec (0.002 roil), clamping and tangent screws for controlling the motion, and a leveling head with three foot screws. The circles are read using the coincidence method rather than the direct method. There is an inverter knob for reading the horizontal and vertical circles independently. The essential parts of a l-see theodolite are very similar to that of the 1-min theodolite, including the horizontal and vertical motions, the levels, the telescope, the tribrach, and the optical system shown in figure 11-21. The main difference between the two types, besides precision, is the manner in which the circles are read.

The CIRCLE to be viewed in the 1-see theodolite is selected by turning the inverter knob on the right standard. The field of the circle-reading microscope shows the image of the

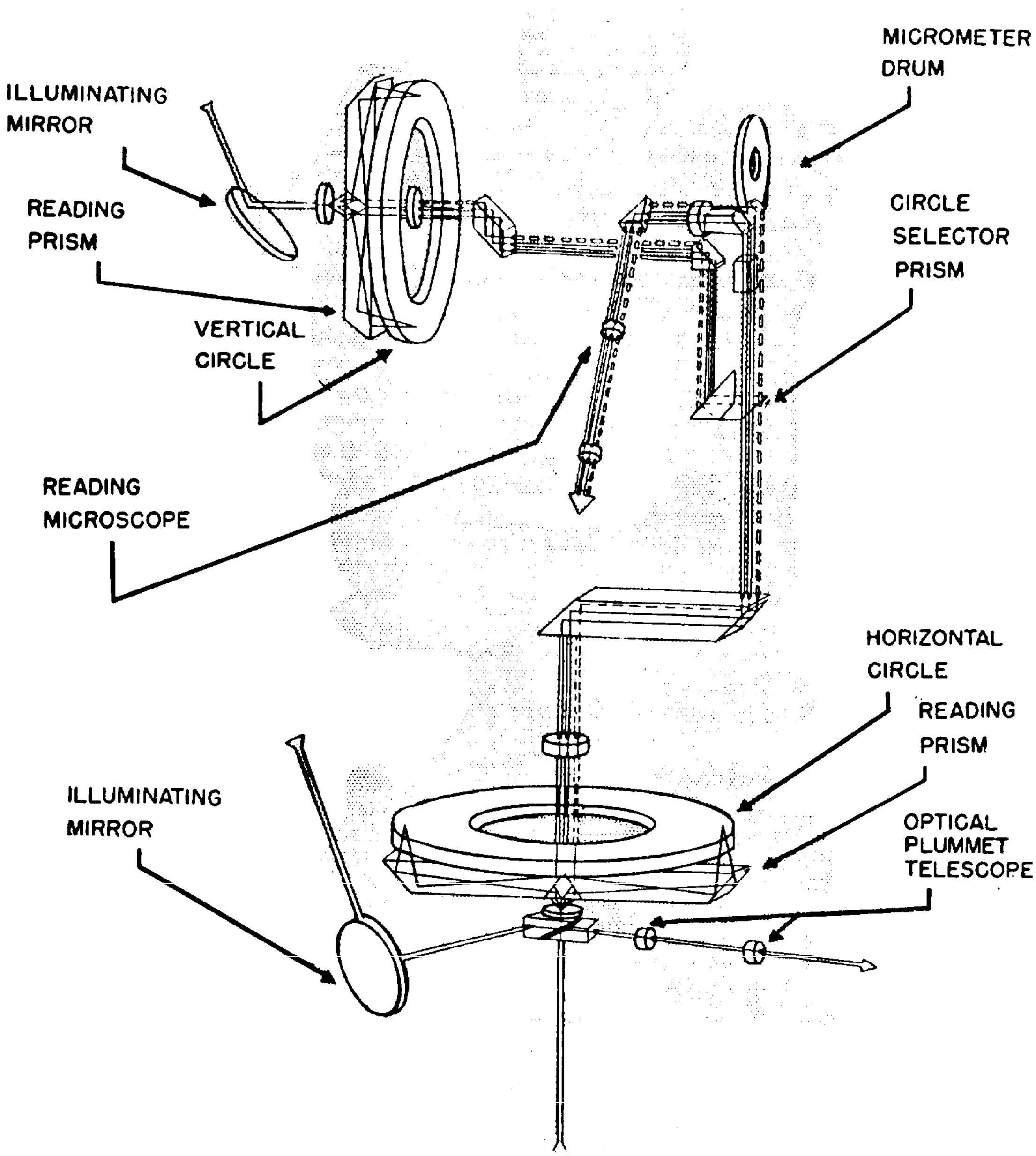

Figure 11-21.-Circle-reading optical system.

circle (fig. 11-22) with lines spaced at 20-min intervals, every third line numbered to indicate a degree, and the image of the micrometer scale on which the unit minutes and seconds are read. The numbers increase in value ($0^\circ$to 360°, clockwise around the circle. The coincidence knob on the side of, and near the top of, the right standard is used in reading either of the circles. The collimation level and its tangent screw are used when the vertical circle is read.

The circles of the theodolite are read by the COINCIDENCE METHOD in which optical coincidence is obtained between diametrically opposite graduations of the circle by turning the MICROMETER or COINCIDENCE KNOB. When this knob is turned, the images of the opposite sides of the circle appear to move in opposite directions across the field of the CIRCLE-READING MICROSCOPE. The graduations can be brought into optical coincidence and appear to form continuous lines crossing the dividing line. An index mark indicates the circle graduations that are to be used in making the coincidence. The index mark will be either in line with a circle graduation or midway between two graduations. The final coincidence adjustment should be made between the graduations in line with the index mark or when this index mark is halfway between the two closest graduations.

HORIZONTAL CIRCLE.— To read the HORIZONTAL CIRCLE, turn the INVERTER or CIRCLE-SELECTOR KNOB until its black line is horizontal. Adjust the illuminating mirror to give uniform lighting to both sections of the horizontal circle; the micrometer scale is viewed through the circle-reading microscope. Focus the microscope eyepiece so that the graduations are sharply defined. The view through the microscope should then be similar to figure 11-22, view A. From this point, continue in the following way:

1. Turn the coincidence knob until the images of the opposite sides of the circle are moved into coincidence. Turning this knob also moves the micrometer scale. The view through the microscope now appears as shown in figure 11-22, view B.
2. Read the degrees and tens of minutes from the image of the circle. The nearest upright number to the left of the index mark is the number of degrees (105). The diametrically opposite number (the number $\pm 180^\circ$) is 285. The number of divisions of the circle between the upright 105 and inverted 285 gives the number of tens of minutes. In figure 11-22, view B, there are five divisions between 105 and 285; and the reading, therefore, is $105^\circ 50'$. The index may also be used for direct reading of the tens of minutes. Each graduation is treated as 20 min. Thus, the number of graduations from the degree value to the index mark multiplied by 20 min is the value. If the index falls between graduations, another 10 min is added when the tens of minutes is read directly.
3. Read the unit minutes and seconds below from the image of the micrometer scale. This scale has two rows of numbers below the graduations; the bottom row is the unit minutes and the top row, seconds. In figure 11-22, view B, the unit minutes and seconds are read as 7'23.5"
4. Add the values determined in Steps 2 and 3 above. This gives $105^\circ 57' 23.5''$as the final reading.

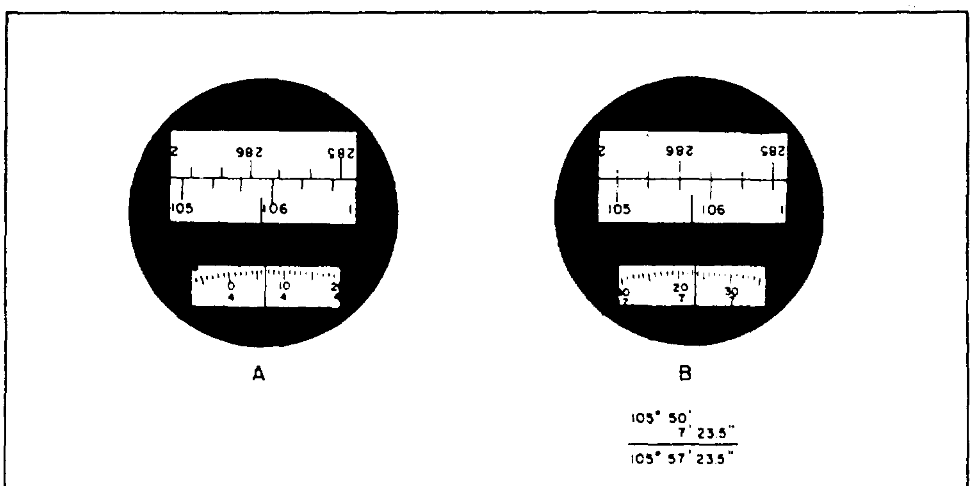

Figure 11-22.-View of a 1-second theodolite circle.

VERTICAL CIRCLE.— When reading the VERTICAL CIRCLE, turn the circle-selector knob until its black line is vertical. Adjust the mirror on the left standard and focus the microscope eyepiece. You then go on in the following way:

1. Use the vertical circle tangent screw to move the collimation level until the ends of its bubble appear in coincidence (fig. 11-23) in the collimation level viewer on the left standard.
2. Read the vertical circle and micrometer scale as described before. Be sure to have proper coincidence before you take the reading.
3. The vertical circle graduations are numbered to give a 0° reading with the telescope pointing to the zenith. Consequently, the vertical circle reading will be 90° for a horizontal sight with the telescope direct and 270° for a horizontal sight with the telescope reversed. Figure 11-23 shows the view in the circle-reading microscope for direct and reversed pointings on a target. These readings are converted to vertical angles as follows:

	Telescope Direct	Telescope Reversed
Circle Reading	86°17'43.5"	273°42'21.5"
Zenith Distance	86°17'43.5"	86°17'38.5"
Mean Zenith Distance...	86°17'41.0"	
Mean Vertical Angle	+3°42'19.0"	

There are two separate occasions for setting the horizontal circle of the theodolite. In the first case, the circle is set to read a given value with the telescope pointed at a target. With the theodolite pointed at the target and with the azimuth clamp tightened, the circle is set as follows: Set the micrometer scale to read the unit minutes and the seconds of the given values. Then, with the circle-setting knob, you turn the circle until coincidence is obtained at the degree and tens of minutes value of the given reading. This setting normally can be made accurately to plus or minus 5 sec. After the circle is set in this manner, the actual reading should be determined.

In the second case, the circle is set to a value of a given angle. When a predetermined angle is measured, you first point the instrument along the initial line from which the angle is to be measured and read the circle. Add the value of the angle to the circle reading to determine the circle reading for the second pointing. Set the micrometer scale to read the unit minutes and the seconds of the value to be set on the circle. Then, you turn the instrument in azimuth and make coincidence at the degrees and tens of minutes value that is to be set. The predetermined value can usually be set on the circle in this way to plus or minus 2 sec.

ENGINEER'S LEVEL

The engineer's level is a widely used instrument for leveling operations. Its sighting device is a 30 ± 3 variable power telescope, with a maximum length of 18 in. and with an erecting eyepiece. Some models use internal focusing, while others use external focusing objective

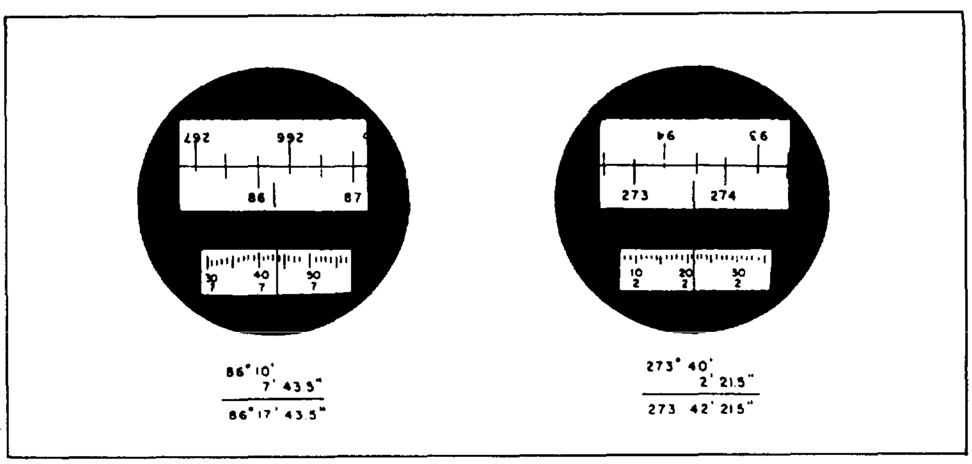

Figure 11-23.-View of a vertical circle for direct and reversal pointings.

assemblies. The reticle has two cross hairs at right angles to each other, and some models have stadia hairs. The telescope and level bar assembly is mounted on a spindle that permits the unit to be revolved only in a horizontal plane. It cannot be elevated or depressed. A clamp and tangent screw acts on this spindle for small motions to permit accurate centering. The spindle mounts in a four-screw leveling head that rests on a foot plate. The foot plate screws onto the threads on the tripod. When the instrument is properly leveled and adjusted, the line of sight, defined by the horizontal cross hair, will describe a horizontal plane.

The two distinct types of engineer's levels, classified according to their support, are the wye level and the dumpy level. The WYE LEVEL (fig. 11-24) is so called because its telescope is supported by a pair of wye rings. These rings can be opened for the purpose of turning the telescope or rotating it around its horizontal axis. The bubble tube (vial) can be adjusted, either vertically or laterally, by means of adjusting nuts at the ends of the bubble tube. All these features are provided for the purpose of making fine adjustments. The DUMPY LEVEL (fig. 11-25) has its telescope rigidly attached to the level bar, which supports an adjustable, highly sensitive level vial. During visual leveling operations and observations, both types handle similar basic operations. Their cross hairs are brought into focus by rotation of the eyepiece, and their target, into clear focus by rotation of the focusing knob. Their telescope can be exactly trained on targets by lightly tightening the azimuth clamp and manipulating the azimuth tangent screw.

PRECISION LEVEL

Other types of leveling instruments have been incorporated into the SEABEE units. In fact, the self-leveling level has now become standard

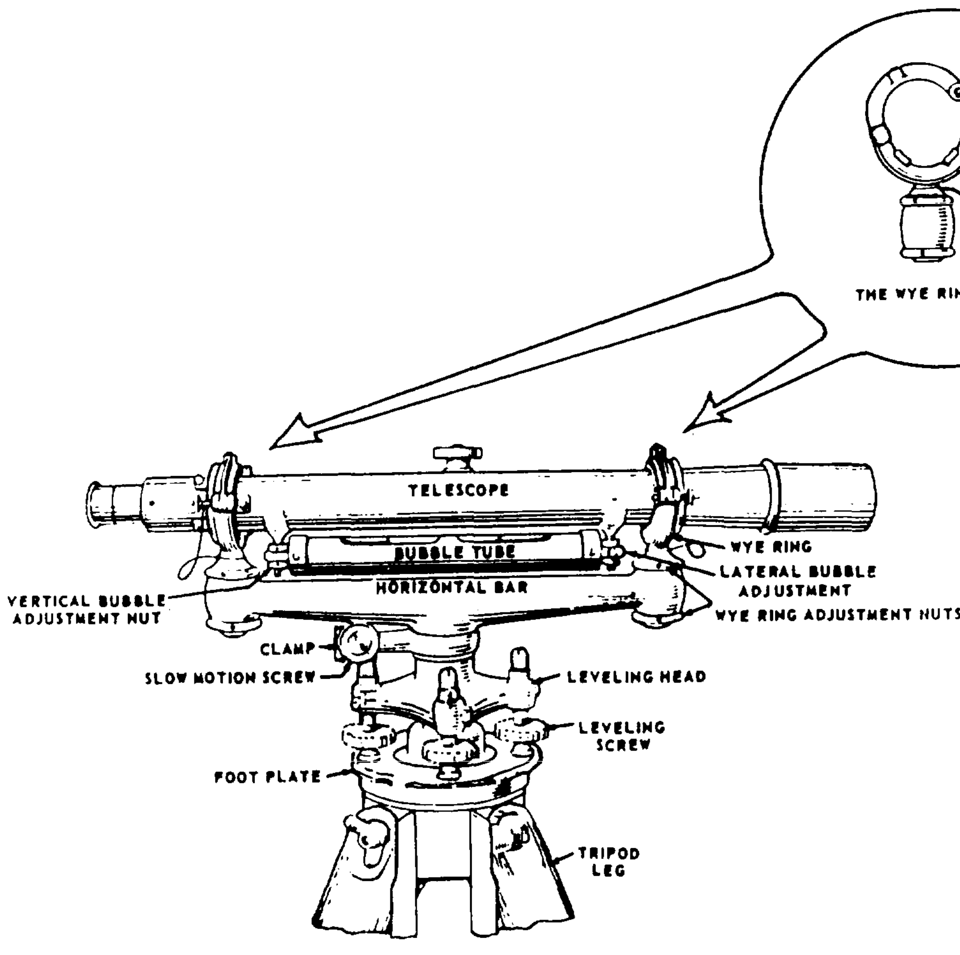

Figure 11-24.-A wye level.

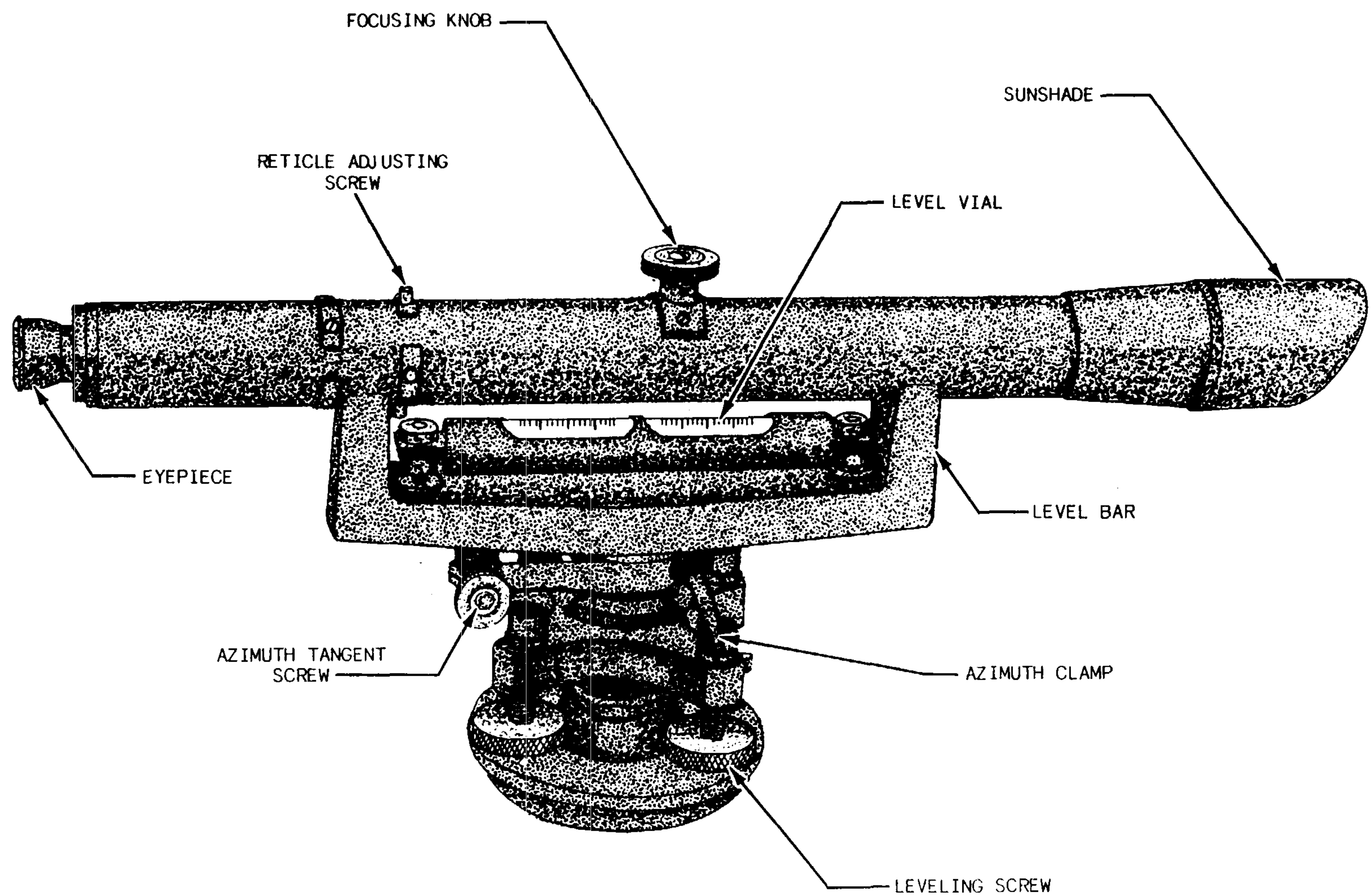

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Figure 11-25.—A dumpy level.

equipment in the Naval Construction Force Table of Allowance (TOA). These precision instruments are essentially like the conventional levels except for added features.

A precision level is one that is equipped with an extra-sensitive level vial. The sensitivity of a level vial is usually expressed in terms of the size of the vertical angle the telescope must be moved to cause the bubble in the level vial to move from one graduation to the next.

The sensitivity of the level vial on an ordinary level is about 20 sec. On a precise level, it is about 2 sec. The telescope level vial on an ordinary transit has a sensitivity of about 30 sec.

The more sensitive the level vial is, the more difficult it is to center the bubble. If the level vial on an ordinary level had a sensitivity as high as 2 sec, the smallest possible movement of the level screw would cause a large motion of the bubble.

For this reason, a precise level is usually also a tilting level. On a tilting level, the telescope is hinged at the objective end so the eyepiece end can be raised or lowered. The eyepiece end rests on a finely threaded micrometer screw that can be turned to raise or lower the eyepiece end in small increments. The instrument is first leveled, as nearly as possible, in the usual manner. The bubble is then brought to exact center by the use of the micrometer screw.

Military Level

The military level (fig. 11-26) is a semi-precise level designed for a more precise work than the engineer's level. The telescope is a 30-power, 10-in.-long, interior-focusing type with an inverting eyepiece and an enclosed fixed reticle. The reticle is mounted internally and cannot be adjusted as in other instruments. It contains cross wires and a set of stadia hairs. The objective is focused by an internal field lens through a rack and pinion, controlled by a knob on the upper right-hand side of the telescope. The telescope and level vial can be tilted through a small angle in the vertical plane to make the line of sight exactly horizontal just before the rod reading is made. The tilting is done by a screw with a graduated drum located below the telescope eyepiece. A cam is provided to raise the telescope off of the tilting device and to hold it firmly when the instrument is being moved and during the preliminary

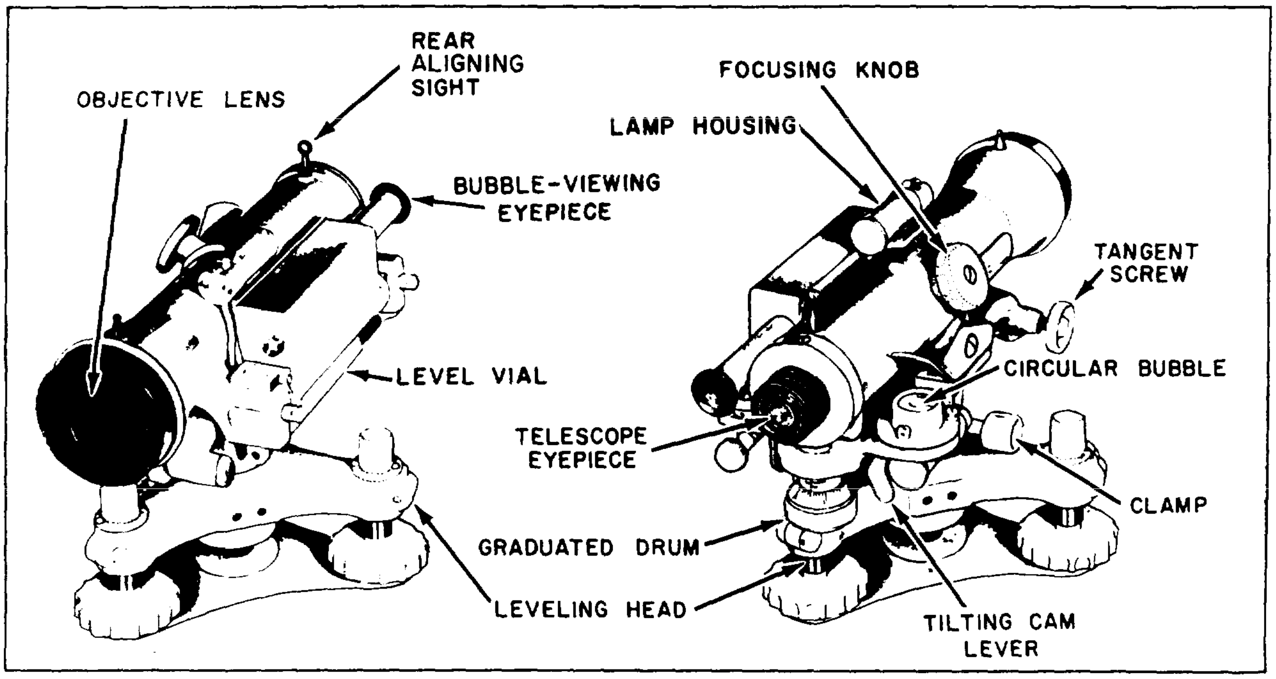

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Figure 11-26.-A military level.

leveling. An eyepiece, located to the left of the telescope, is used for viewing the bubble through the prism system that brings both ends of the bubble (fig. 11-13) into coincidence.

The level vial is located directly under the telescope, but to the left and below, directly in line with the capstan screws under the bubble-viewing eyepiece. The level vial's sensitivity is given as 30 sec per 2-mm spacing. A circular bubble that is viewed through a 45° mirror is provided for the first approximate leveling before the long level vial is used. For night work, battery-powered electric illumination lights the long bubble, the reticle, and the circular level. The clamping screw and the horizontal motion tangent screw are located on the right-hand side; the former near the spindle and the latter below the objective lens. The instrument has a three-screw leveling head. The tripod for this level has a non-extension leg to add rigidity and stability to the setup.

Self-Leveling Level

The self-leveling level (also called automatic level) shown in figure 11-27 is a precise, time-saving development in leveling instruments. It did away with the tubular spirit level, whose bubble takes time in centering as well as in resetting its correct position from time to time during operation.

The self-leveling level is equipped with a small bull' s-eye level and three leveling screws. The leveling screws, which are on a triangular foot plate, are used to center the bubble of the bull's-eye level approximately. The line of sight automatically becomes horizontal and remains horizontal as long as the bubble remains approximately centered. A prismatic device called a compensator makes this possible. The compensator is suspended on fine, nonmagnetic wires. The action of gravity on the compensator causes the optical system to swing into the position that

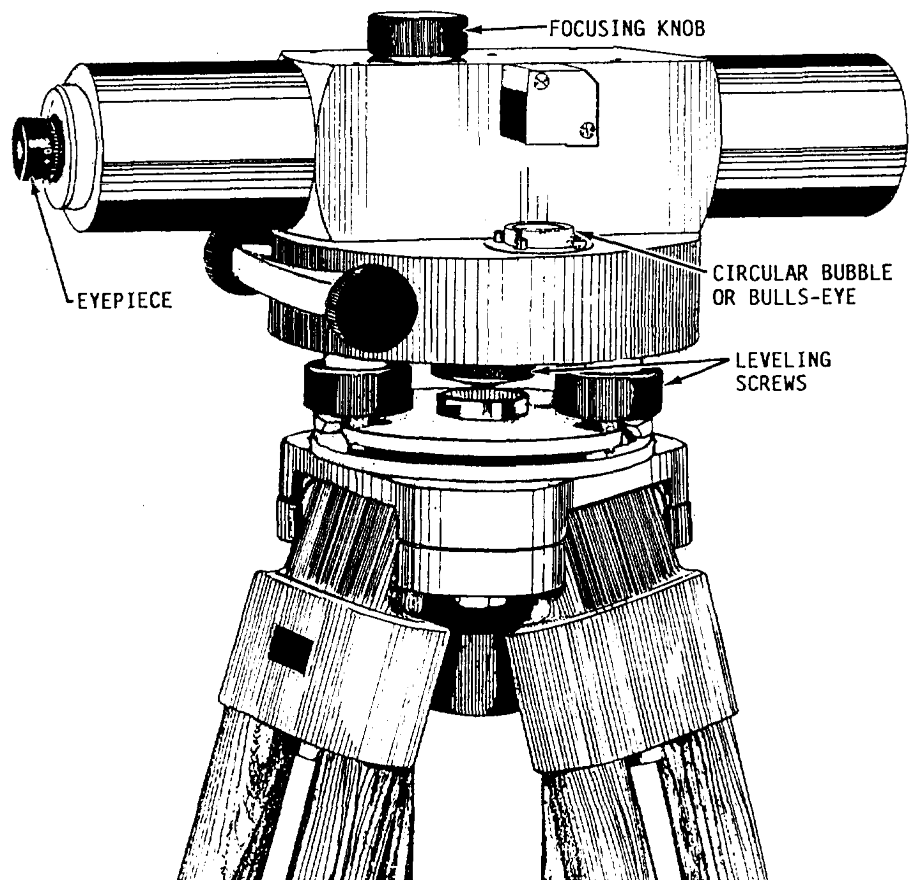

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Figure 11-27.-An automatic level.

defines a horizontal sight. This horizontal line of sight is maintained despite a slight out of level of the telescope or even when a slight disturbance occurs on the instrument.

HAND LEVEL

The hand level, like all surveying levels, is an instrument that combines a level vial and a sighting device. It is generally used for rough leveling work. In a cross-sectional work, for example, terrain irregularities may cause elevations to go beyond the instrument range from a setup. A hand level is useful for extending approximate elevations off the control survey line beyond the limits of the instruments.

Figure 11-28, view A, shows a LOCKE HAND LEVEL; view B shows an ABNEY HAND LEVEL. For greater stability, both hand levels may be rested against a tree, rod, range pole, or on top of a staff. A horizontal line, called an index line, is provided in the sight tube as a reference line. The level vial is mounted atop a slot in the sight tube in which a reflector is set at a 45° angle. This permits the observer, while sighting through the tube, to see the landscape or object, the position of the bubble in the vial, and the index line at the same time.

The distances over which a hand level is sighted are comparatively short; therefore, no magnification is provided for the sighting.

The Abney hand level is more specialized than the Locke type. It has a clinometer for measuring the vertical angle and the percent of grade. The clinometer has a reversible graduated arc assembly mounted on one side. The lower side of the arc is graduated in degrees, and the upper side, in percent of slope. The level vial is attached to the axis of rotation at the index arm.

When the index arm is set at zero, the clinometer is used like a plain hand level. The bubble is centered by moving the arc and not the sighting tube as is the case in the plain hand level. Thus, the difference between the line of sight and the level bubble axis can be read in degrees or percent of slope from the position of the index arm of the arc. The 45° reflector and the sighting principle with its view of the landscape, bubble, and index line are the same as in the plain hand level.

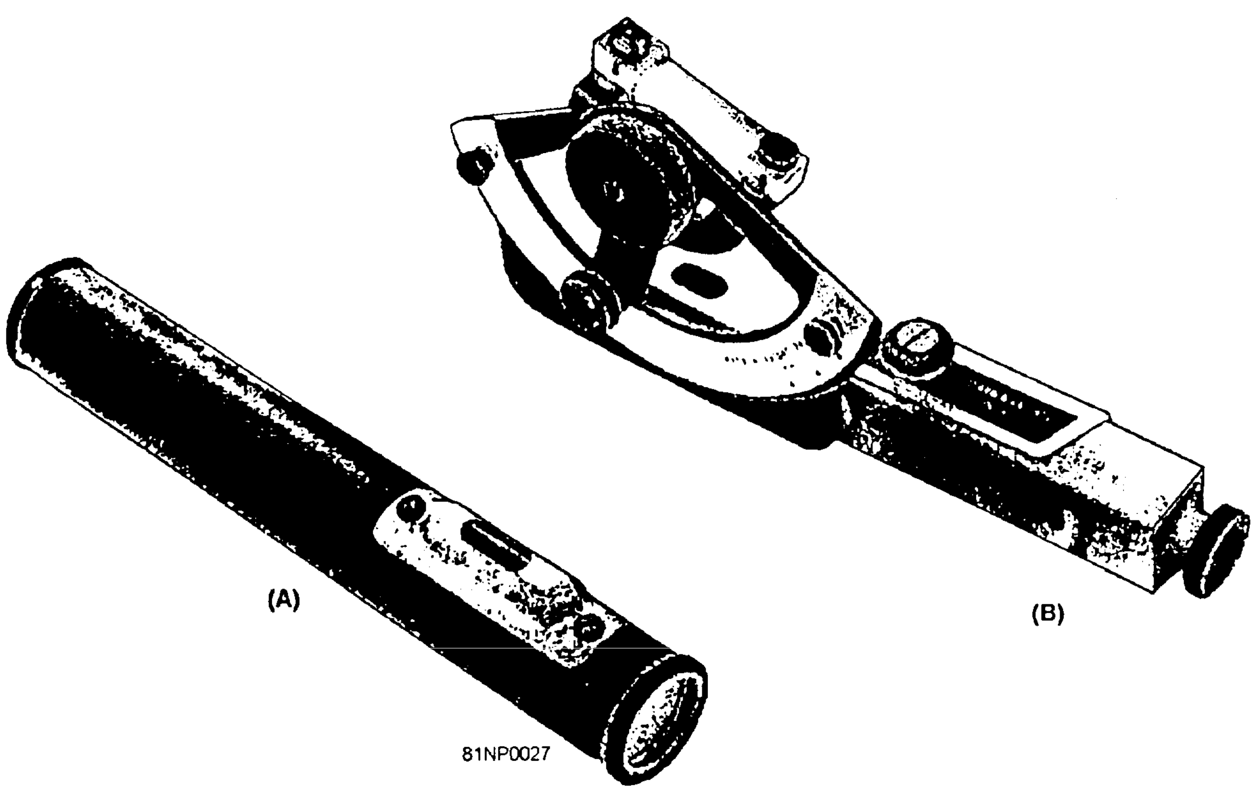

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Figure 11-28.-Types of hand levels.

PLANE TABLE

When combined with the stadia board or Philadelphia rod, the plane table are used in what is generally known as plane table surveys. Which these instruments, the direction, the distance, and the difference in elevation can be measured and plotted directly in the field. The plane table opration produces a completed sketch or map manuscript without the need for further plotting or computing.

A plane table (fig. 11-29) consists of a drawing board mounted on a tripod with a leveling device designed as part of the board and tripod. The commonly used leveling head is the ball-and-socket type. The cross section of a plane table with the tripod head is shown in figure 11-30. The board (G) usually is either 18 by 24 in. or 24 by 31 in. and has an attached recessed fitting that screws onto the top of the spindle (A). A wingnut (B) controls the grip of parts C and D on cup E. By releasing the wingnut (B), you can tilt the drawing board in any direction to level it. Another wingnut (F) acts only on the spindle and, when released, permits the leveled board to be rotated on azimuth for orientation. The tripod is shorter than the transit or level tripods and, when set up, brings the plane table about waist high for easy plotting. One precaution must be observed in attaching the plane table to the tripod head. A paper gasket should be placed between the fittings to prevent sticking or "freezing" of the threads.

The plane table is setup over a point on the ground whose position has been previously plotted, or will be plotted, on the plane table sheet during the operation. The board is oriented either by using a magnetic compass for north-south orientation or by sighting on another visible point whose position is plotted. The board is clamped and the alidade is pointed toward any new, desired point using the plotted position of the setup ground station as a pivot. A line drawn along the straightedge that is parallel to the line of sight will give the plotted direction from the setup point to the desired point. Once the distance between the points is determined, it is plotted along the line to the specified scale. The plotted position represents the new point at the correct distance and direction from the original point. By holding the plane table orientation and pivoting the alidade around the setup point, you can quickly draw the direction to any number of visible points. The distance to these points is determined by any conventional method that meets the requirements for the desired accuracy and can be plotted along their respective rays from the setup point. Thus, from one setup, the positions of a whole series of points can be established quickly. For mapping, the difference in elevation is also determined and plotted for each point. The map is completed by subdividing the distances between points with the correct number of contours spaced to represent the slope of the ground.

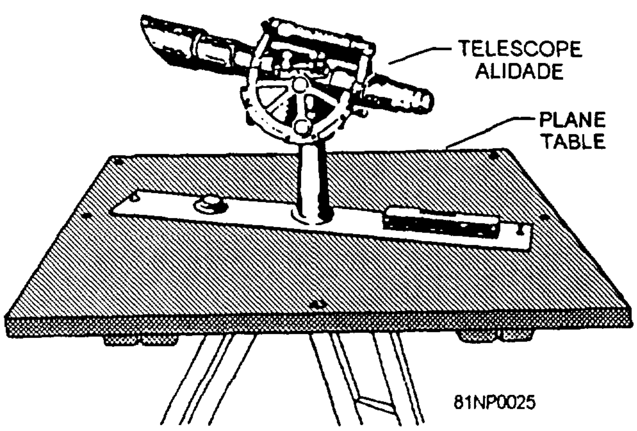

Figure 11-29.-Plane table.

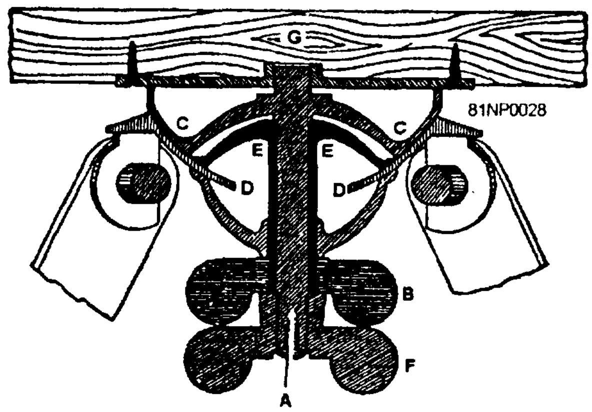

Figure 11-30.-Cross section of a plane table tripod bead.

The alidade (fig. 11-31) is a straightedge with a sighting device parallel to the edge. The more precise types have telescopes for sighting, special retitles for measuring distance, and graduated arcs for measuring vertical angles. A new version also includes a self-leveling, optical-reading system with enclosed graduated arcs.

1. The open-sight alidade (fig. 11-31, view A), which is very useful in sketching small areas, has a collapsible open sight attached to a straightedge. A level bubble is mounted on the straightedge for keeping the alidade level. A trough compass is also furnished for attaching to the sketch board. By sighting through the peep sight, the operator can determine a level line and the slope from the sighting point. No magnification is provided, so the sight lines are kept comparatively short. The distances can be estimated by pacing or can be measured with a tape if more accuracy is required. A 10-mil graduation that is numbered every fifth tick mark from 0 to 40 runs up on the right edge and down on the left edge of the front sight for determining slopes.

2. The telescopic alidades (fig. 11-31, views B and C) consist of straightedges with rigidly mounted telescopes that can be rotated through a vertical angle of $\pm 30^{\circ}$. One type has a telescope set on a high standard or post to raise it above the table. This permits direct viewing through the telescope, which is at a comfortable height. The other type has the telescope mounted close to the straightedge. A right-angle prism is attached to the eyepiece and permits viewing through the telescope by looking down into the eyepiece prism.

3. The telescope for the high standard is 16 power; for the low standard, 12 power. Both are the inverting type with internal focusing. The prismatic eyepiece inverts the image top to bottom, so that it appears erect but reversed side to side. The line of sight through the telescopes in a level position is parallel to the straightedge on the base. The telescope reticle has horizontal and vertical cross hairs and a set of stadia hairs. As you already knew, the stadia hairs are used to measure distances. The vertical distance between the upper and lower stadia hairs is carefully read and multiplied by the stadia interval factor. This value is the straight-line distance between the instrument and the rod.

4. A circular bubble and a magnetic compass needle are attached to the base. These are used to level the plane table and orient it to its proper position. Since the ball-and-socket head does not permit as fine a movement as the leveling screw, the bubble is centered as accurately as possible. Then, the wingnut (fig. 11-30, view B) is set firmly but not tightly. When the plane table is tapped lightly on the proper corner, the operator can refine the leveling and then properly tighten the wingnut. To orient the plane table, loosen wingnut F and rotate the table. It is a good practice to draw a magnetic north line on the cover sheet or on two pieces of tape attached near the edges of the board. The straightedge is set on this line during orientation. When the plane table is rotated to face north, the magnetic needle is released and will have room to swing in its case without hitting the sides.

5. The telescopic alidades have two other important features used for plane table surveying. These are the detachable striding level and the

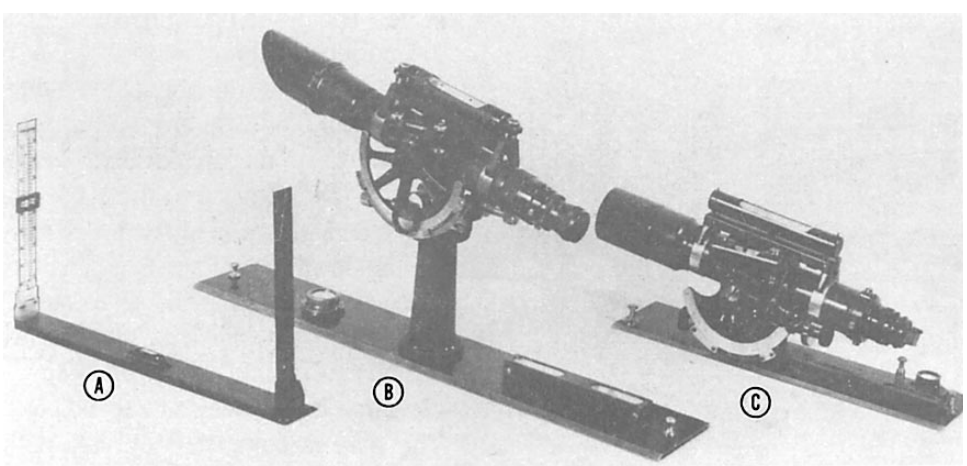

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Figure 11-31.-Types of alidades.

stadia arc. The striding level contains a long bubble, and when attached, permits accurate leveling of the line of sight. The bubble is mounted on a metal tube with V-fittings on each end. The fittings are placed astride the telescope and bear on built-in polished brass rings on each side of the center post. A spring clip on the level grips a center pin on top of the telescope and keeps the level from falling or being knocked off during operation. A button on the side of the level releases the clip for removing the level. For checking and adjusting, the level is reversible. The striding level normally is used to establish a horizontal line of sight and to use the alidade as a level. The stadia arc assembly consists of a vertical arc mounted on the end of the left trunnion and a vernier attached to the left bearing by an arm. A level vial is attached to the upper end of the arm; a tangent screw controls the movement of the vial. Once adjusted, this vial establishes a reference from which vertical angles can be measured even if the plane table is not exactly level. The stadia arc is a vertical scale attached to the alidade. With the stadia arc, it is possible to determine horizontal distances and differences in elevation by the stadia method.

6. A new model telescopic alidade is the self-leveling, optical-reading instrument. Instead of the exterior arc and level bubble, a prism system with a suspended element and enclosed arcs is used. As long as the alidade base is leveled to within one-half degree of horizontal, the suspending element (or pendulum) will swing into position. Then the vertical arc index that is attached to it will assume a leveled position. The scales are read directly through an optical train. This combination permits faster operation. In addition, there is no chance of forgetting to index the arc bubble and introducing errors into the readings.

Some of the auxiliary equipment used with a plane table consists of a coated plastic or a paper plane table sheet on which the map or sketch is drawn, drawing materials (scribing tools for coated plastic or pencils for the paper), scales for plotting distances, triangles, waterproof table covers, umbrella, and notebook. The plane table sheet is attached to the board by flatheaded, threaded studs that fit into recesses in the table and do not obstruct the alidade's movement.

FIELD EQUIPMENT

The term *field equipment,* as used in this training manual, includes all devices, tools, and instrument accessories used in connection with field measurements.

FIELD TOOLS

If you are running a survey across rough terrain, the essential equipment you will need are various types of tools used for clearing the line; that is, for cutting down brush and other natural growth as necessary.

Surveying procedures usually permit the bypassing of large trees. Occasionally, however, it may be necessary to fell one of these. If heavy equipment is working in the vicinity, an EO may fell the tree with a bulldozer. The next best method is by means of a power-driven chain saw. In the absence of a chain saw, a one-man or two-man crosscut saw may be available.

The machete and brush hook (fig. 11-32) are used for clearing small saplings, bushes, vines, and similar growth. Axes and hatchets (fig. 11-32) are used for felling trees and also for marking trees

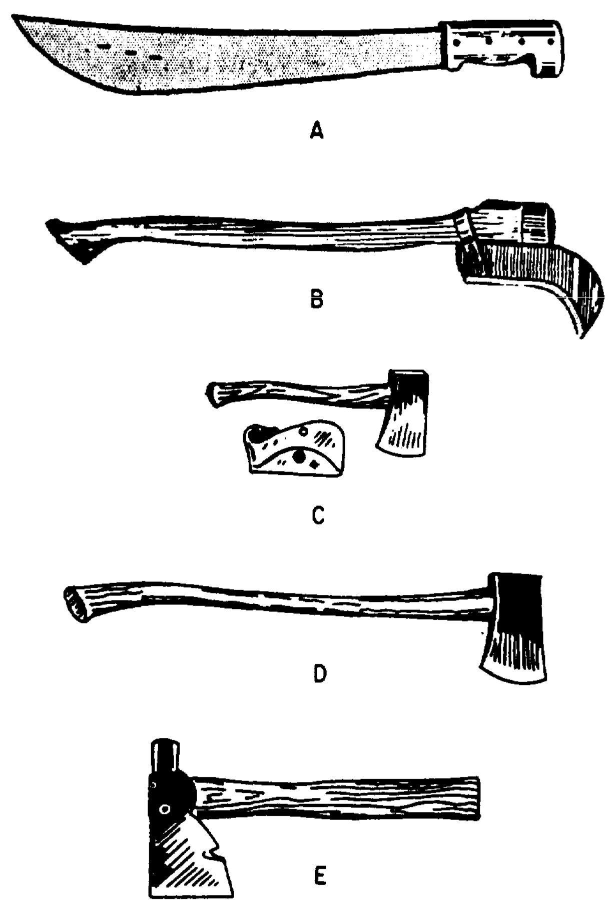

Figure 11-32.-(A) Machete; (B) Brush hook; (C) Single-bit belt ax; (D) Single-bit ax; (E) Half hatchet.

by blazing. Files and stones are usual items of equipment for sharpening the edges of tools.

Hubs, stakes, pipe, and other driven markers are often driven with the driving peen of a hatchet or a single-bit ax. A sledgehammer, however, is a more suitable tool for the purpose. A double-faced, long-handled sledgehammer is shown in figure 11-33. It is swung with both hands. There are also short-handled sledgehammers, swung with one hand. A sledgehammer is classified according to the weight of the head; common weights are 6, 8, 10, 12, 14, and 16 lb. The 8- and 10-lb weights are most commonly used.

When the ground is too compact or too frozen to permit wooden stakes and hubs to be driven directly, the way for a stake or hub is opened by first driving in a heavy, conical-pointed steel bar, 10 to 16 in. long, called a bull-point. One of the heavy steel form pins, used to pin down side forms for concrete paving, can be used as a bull-point; however, the pyramidal pavement-breaker bit on a jack hammer (pneumatic hammer used to drive paving breaker bits, stone drills, and the like) makes a better bull-point. Because a jack hammer bit is made of high-carbon steel, it is liable to chip and mushroom when subjected to heavy pounding. Do not use a bull-point with a badly damaged head; it should be refinished by grinding or cutting off before being used to avoid injury to personnel.

In searching for hidden markers, you may need a shovel like the one shown in figure 11-34 for clearing top cover by careful digging. In soft ground, such as loose, sandy soil, you may prefer to use a square-pointed shovel or a probing steel rod to locate buried markers.

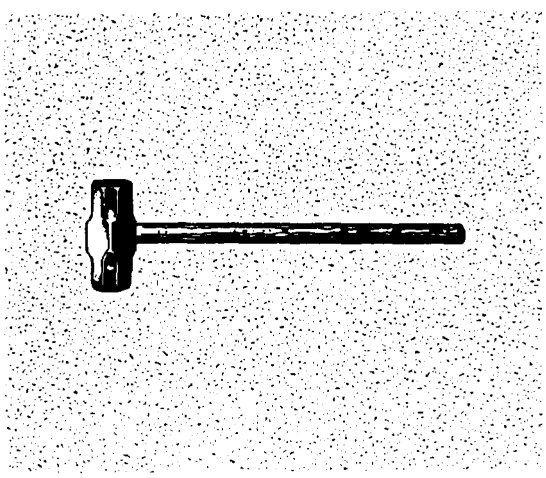

Figure 11-33.-A double-faced sledgehammer.

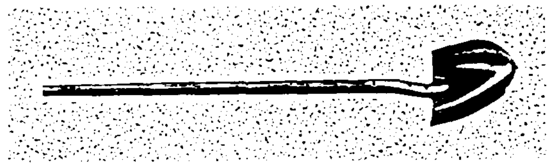

Figure 11-34.-Long-handled shovel.

A pick (fig. 11-35) may be required to chip bituminous pavement off of manhole covers and for levering up covers. Sometimes a crowbar is needed for levering manhole covers.

Buried metal markers may be located with the help of a magnetic device called a dip needle or a battery-powered instrument, similar in principle to a mine detector, commonly called a pipe finder. These instruments are used in engineering surveys to locate utility pipelines, buried manhole and valve box covers, and the like. These instruments can generally be borrowed from the utilities division of the public works department (PWD) of the larger shore stations.

SURVEYING TAPES

Tapes are used in surveying to measure horizontal, vertical, and slope distances. They may be made of a ribbon or a band of steel, an alloy of steel, cloth reinforced with metal, or synthetic materials. Tapes are issued in various lengths and widths and graduated in a variety of ways.

Metallic Tapes

A metallic tape is made of high-grade synthetic material with strong metallic. strands (bronze-brass-copper wire) woven in the warped face of the tape and coated with a tough plastic for

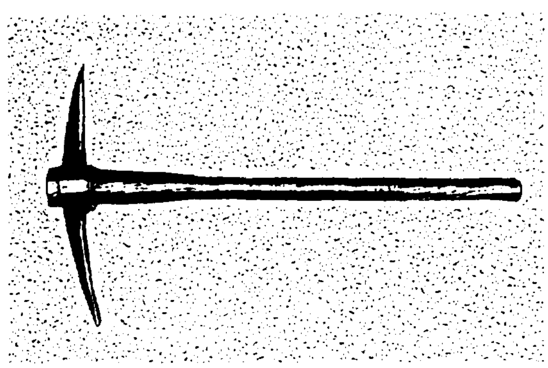

Figure 11-35.-Pick.

durability. Standard lengths are 50 and 100 ft. Some are graduated in feet and inches to the nearest one-fourth in. Others are graduated in feet and decimals of a foot to the nearest 0.05 ft.

Metallic tapes are generally used for rough measurements, such as cross-sectional work, road-work slope staking, side shots in topographic surveys, and many others in the same category.

Nonmetallic tapes woven from synthetic yarn, such as nylon, and coated with plastic are available; some surveyors prefer to use tapes of this type. Nonmetallic tapes are of special value to power and utility field personnel, especially when they are working in the vicinity of high-voltage circuits.

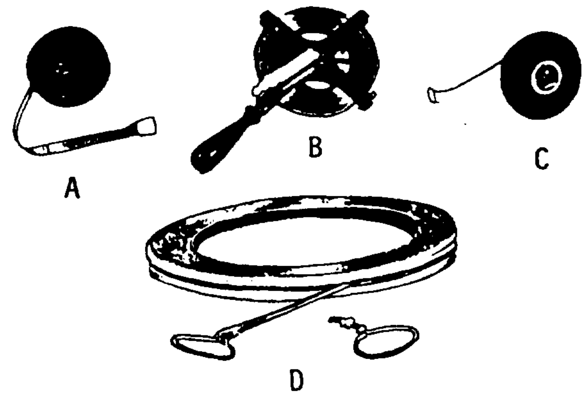

Figure 11-36.-Surveying tapes.

Steel Tapes

For direct linear measurements of ordinary or more accurate precision, a steel tape is required. The most commonly used length is 100 ft, but tapes are also available in 50-, 200-, 300-, and 500-ft lengths. All tapes except the 500-ft one are band-types, the common band widths being 1/4 and 5/16 in. The 500-ft tape is usually a flat-wire type.

Most steel tapes are graduated in feet and decimals of feet, but some are graduated in feet and inches, meters, Gunter's links, and chains or other linear units. From now on, when we discuss a tape, we will be talking about one that is graduated in feet and decimals of a foot unless we state otherwise.

Some tapes called engineer's or direct reading tapes are graduated throughout in subdivisions of each foot. The tape most commonly used, however, is the so-called chain tape, on which only the first foot at the zero end of the tape is graduated in subdivisions, the main body of the tape being graduated only at every 1-ft mark.

A steel tape is sometimes equipped with a reel on which the tape can be wound. A tape can be, and often is, detached from the reel, however, for more convenient use in taping.

Various types of surveying tapes are shown in figure 11-36. View A shows a metallic tape; view B, a steel tape on an open reel; view C, a steel tape or, a closed reel. View D shows a special type of low-expansion steel tape used in high-order work; it is generally called an Invar tape or Lovar tape.

Invar Tapes

Nickel-steel alloy tapes, known as Invar, Nilvar, or Lovar, have a coefficient of thermal expansion of about one-tenth to one-thirtieth (as low as 0.0000002 per 1°F) that of steel. These tapes are used primarily in high-precision taping. These tapes must be handled in exactly the same manner as other precise surveying instruments. The alloy metal is relatively soft and can be easily broken or kinked if mishandled. Ordinarily, Invar tapes should not be used when a steel tape can give the desired accuracy under the same operating conditions. Invar tapes are used for very precise measurements, such as those for base lines and in city work. When not in use, the tape should be stored in a reel, as shown in figure 11-36, view D. Except for special locations where the ground surface is hard and flat, such as roadways or railroads beds, the Invar tape is used over special supports or stools and is not permitted to touch the ground.

SURVEYING ACCESSORIES

Surveying accessories include the equipment, tools, and other devices used in surveying that are not considered to be an integral part of the surveying instrument itself. They come as separate items; thus, they are ordered separately through the Navy supply system.

When you run a traverse, for example, your primary instruments may be the transit and the steel tape. The accessories you need to do the actual measurement will be the following: a tripod to support the transit; a range pole to sight on in line; a plumb bob to center the instrument on the point; perhaps tape supports if the survey is of high precision; and so forth. It is important that you become familiar with the proper care of this equipment and use it properly.

Tripod

The tripod is the base or foundation that supports the survey instrument and keeps it stable during observations. A tripod consists of a head to which the instrument is attached, three wooden or metal legs that are hinged at the head, and pointed metal shoes on each leg to be pressed or anchored into the ground to achieve a firm setup. The leg hinge is adjusted so that the leg will just begin to fall slowly when it is raised to an angle of about 45°. The tripod head may have screw threads on which the instrument is mounted directly, a screw projecting upward through the plate, or a hole or slot through which a special bolt is inserted to attach to the instrument.

Two types of tripods are furnished to surveyors: the fixed-leg tripod and the extension-leg tripod. The fixed-leg type is also called a STILT-LEG or RIGID tripod, and the extension-leg tripod is also called a JACK-LEG tripod. Both types are shown in figure 11-37. Each fixed leg may consist of two lengths of wood as a unit or a single length of wood split at the top, attached to a hinged tripod head fitting and to a metal shoe. At points along the length, perpendicular brace pieces are sometimes added to give greater stability. The extension tripod leg is made of two sections that slide longitudinally. On rough ground, the legs are adjusted to different lengths to establish a horizontal tripod head or to set the instrument at the most comfortable working height for the observer. A leg may be shortened and set as shown in the extreme right view of figure 11-37.

The fixed legs must be swung in or out in varying amounts to level the head. Instrument height is not easily controlled, and the observer must learn the correct spread of the legs to get the desired height.

WIDE-FRAME tripods, like those shown in figure 11-38, have greater torsional stability and tend to vibrate less in the wind.

You should grip the surveying instrument firmly to avoid dropping it while you are mounting it on the tripod. Hold the transit by the right standard (opposite the vertical circle) while you are attaching it. The engineer's level should be held at the center of the telescope, while theodolites and precise levels should be gripped near the base of the instrument. The instruments should be screwed down to a firm bearing but not so tightly that they will bind or the screw threads will strip.

In setting up the tripod, you should be sure to place the legs so that you achieve a stable setup. On level terrain, you can achieve this by having each leg form an angle of about 60° with the ground surface.

Loosen the restraining strap from around the three legs, and secure it around one leg. An effective way to set the tripod down is to grip it with two of the legs close to the body while you stand over the point where the setup is required. By using one hand, you push the third leg out away from the body until it is about 50° to 60° with a horizontal. Lower the tripod until the third leg is on the ground. Place one hand on each of the first two legs, and spread them while taking a short backward step, using the third leg as a

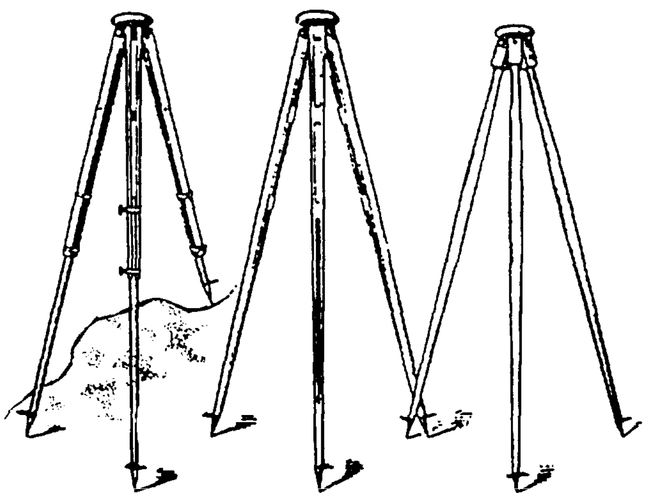

Figure 11-37.-Types of tripods.

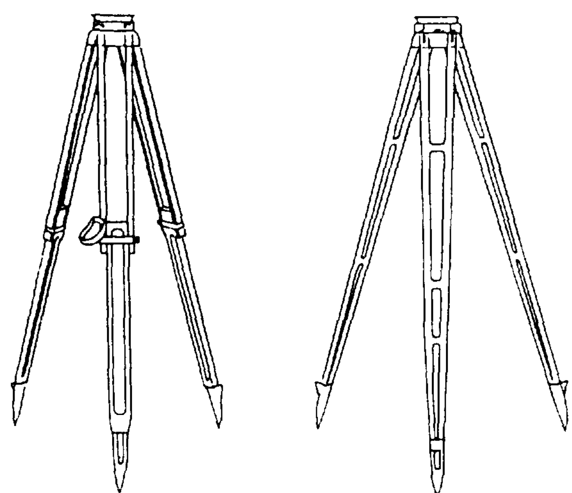

Figure 11-38.-Wide-frame tripods.

pivot point. When the two legs look about as far away from the mark as the third one and all three are about equally spaced, you lower the two legs and press them into the ground. Make any slight adjustment to level the head further by moving the third leg a few inches in or out before pressing it into the ground.

On smooth or slippery paved rock surfaces, you should tighten the tripod legs hinges while setting up to prevent the legs from spreading and causing the tripod to fall. You should make use of holes or cracks in the ground to brace the tripod. In some cases, as a safety factor, you should tie the three legs together or brace them with rock or bushes after they are set to keep them from spreading. If setups are to be made on a slippery finished floor, rubber shoes may be fitted to the metal shoes, or an equilateral triangle leg retainer may be used to prevent the legs from sliding.

When you are setting up on steeply sloping ground, place the third leg uphill and at a greater distance from the mark. Set the other two legs as before, but before releasing them, check the stability of the setup to see that the weight of the instrument and tripod head will not overbalance and cause the tripod to slip or fall.

Proper care must be observed in handling the tripod. When the legs are set in the ground, care must be taken to apply pressure longitudinally. Pressure across the leg can crack the wooden pieces. The hinge joint should be adjusted and not overtightened to the degree that it would cause strain on the joint or strip or lock the metal threads. The machined tripod head is to be kept covered with the head cover or protective cap when not in use, and the head should not be scratched or burred by mishandling. When the tripod is in use, the protective cap is to be placed in the instrument box to prevent it from being misplaced or damaged. Any damage to the protective cap can be transferred to the tripod head. Mud, clay, or sand adhering to the tripod has to be removed, and the tripod is to be wiped with a damp cloth and dried. The metal parts should be coated with a light film of oil or wiped with an oily cloth. Foreign matter can get into hinged joints or on the machined surfaces and cause wear. Stability is the tripod's greatest asset. Instability, wear, or damaged bearing surfaces on the tripod can evolve into unexplainable errors in the final survey results.

Range Pole

A range pole (also called a lining rod) is a wood or metal pole, usually about 8 ft long and about 1/2 to 1 in. in diameter; it is provided with a steel point or shoe and painted in alternate bands of red and white to increase its visibility. Figure 11-39 shows a variety of range poles. The range pole is held vertically on a point or plumbed over a point, so the point may be observed through an optical instrument. It is primarily used as a sighting rod for either linear or angular measurements. For work of ordinary precision, chainmen may keep on line by observing a range pole. A range pole may also be used for approximate stadia measurement.

Plumb Bob, Cord, and Target

A plumb bob is a pointed, tapered brass or bronze weight that is suspended from a cord for the general purpose of determining the plumb line from a point on the ground. Common weights for

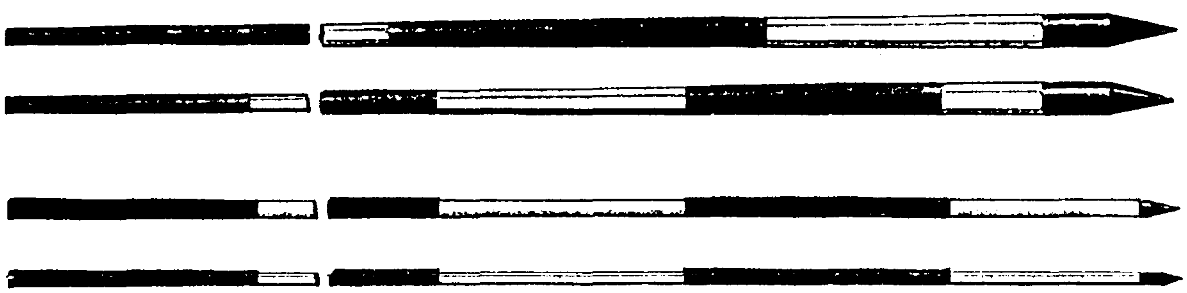

Figure 11-39.-Range poles.

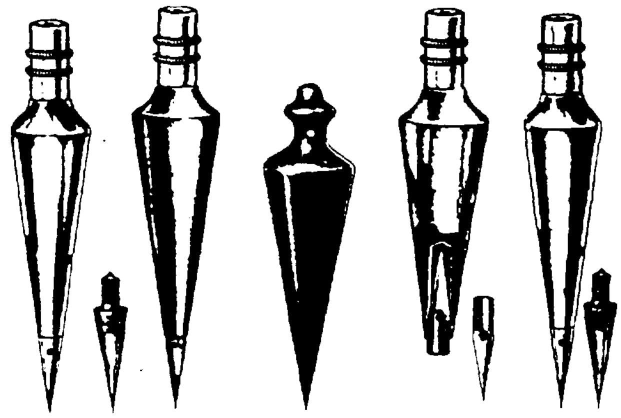

Figure 11-40.-Types of plumb bobs.

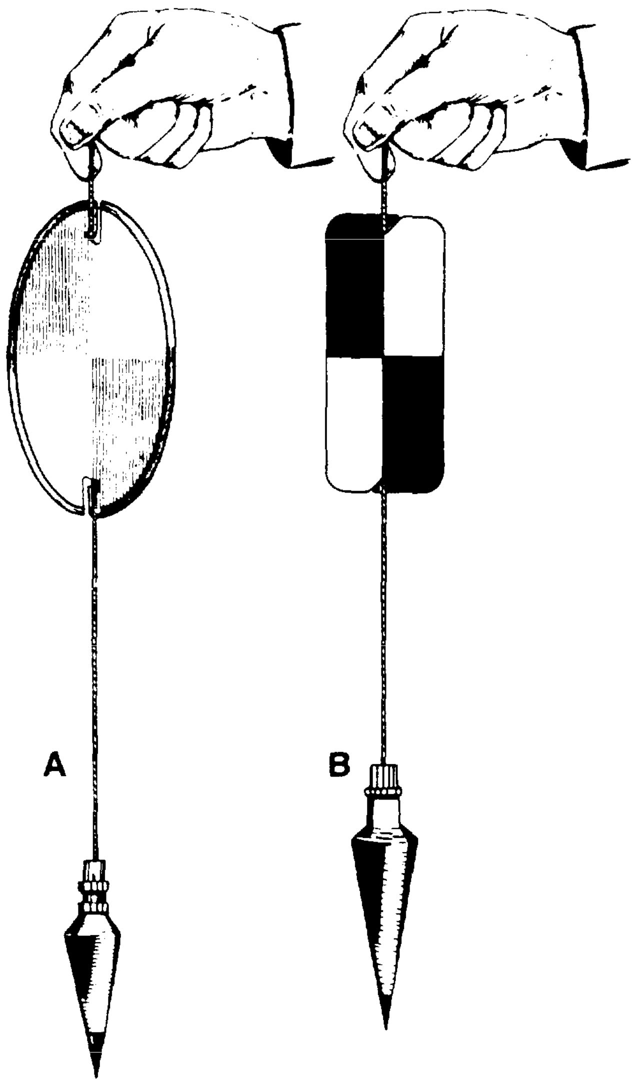

Figure 11-41.-Plumb bob, cord, and target.

plumb bobs are 6, 8, 10, 12, 14, 16, 18, and 24 oz; the 12- and the 16-oz are the most popular. Typical plumb bobs are shown in figure 11-40.

A plumb bob is a precision instrument and must be cared for as such. If the tip becomes bent, the cord from which the bob is suspended will not occupy the true plumb line over the point indicated by the tip. A plumb bob usually has a detachable tip, as shown in figure 11-40, so if the tip becomes damaged, it can be renewed without replacing the entire instrument.

Each survey party member should be equipped with a leather sheath, and the bob should be placed in the sheath whenever it is not in use.

The cord from a plumb bob can be made more conspicuous for observation purposes by the attachment of an oval form aluminum target (fig. 11-41, view A). The oval target has reinforced edges, and the face is enameled in quadrants alternately with red and white. Also, a flat rectangular plastic target may be used (fig. 11-41, view B). It has rounded corners with alternate red and white quadrants on its face. These plumb bob string targets are pocket size with approximate dimensions of 2 by 4 in.

Optical Plumbing Assembly

The optical plumbing assembly, or plummet, is a device built into the alidade or the tribrach of some of the instruments to center the instrument over a point. Its working principle is shown in figure 11-42. The plummet consists of a small prismatic telescope with a cross wire or

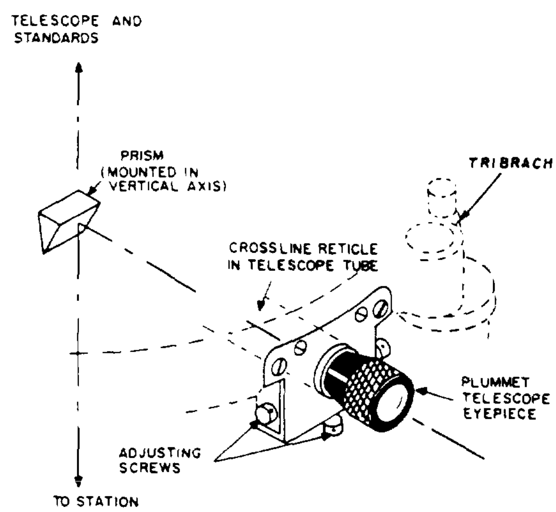

Figure 11-42.-Optical plumbing assembly.

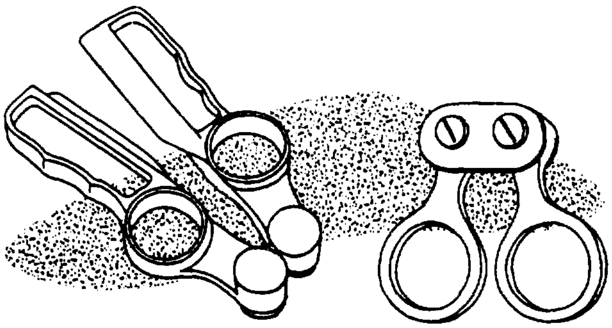

Figure 11-43.-Types of tape clamp handles.

marked circle reticle adjusted to be in line with the vertical axis of the instrument. After the instrument is leveled, a sighting through the plummet will check the centering over a point quickly. The advantages of the plummet over the plumb bob are that it permits the observer to center over a point from the height of the instrument stand, and it is not affected by the wind. The plummet is especially useful for work on high stands. A plumb bob requires someone at ground level to steady it and to inform the observer on the platform how to move the instrument and when it is exactly over the point. With the plummet, the centering and checking is done by the observer.

Tape Accessories

There is usually a leather thong at each end of a tape, by which the tape can be held when the full length is being used. When only part of the tape is used, the zero end can be held by the thong, and the tape can be held at an intermediate point by means of a tape clamp handle, like those shown in figure 11-43.

When a tape is not supported throughout—that is, when it is held aboveground between a couple of crew members—a correction must be applied for the amount of sag in the tape. To make this correction, you apply a certain amount of tension. Figure 11-44 shows two devices for applying a given amount of tension.

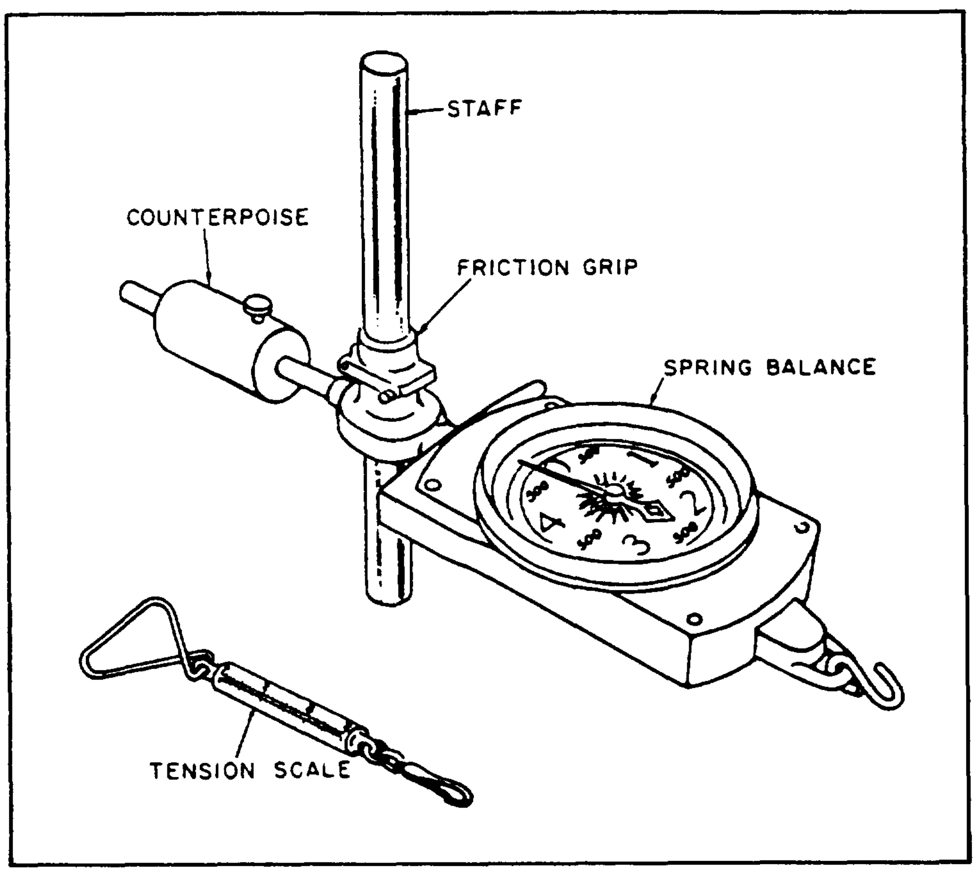

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Figure 11-44.-Tension scale and spring balance.

The tension scale is graduated in pounds from 0 to 30. It is clipped to the eye at the end of the tape, and the tension is applied until the desired reading appears on the scale. A pair of staffs can be used' to make the work easier. The rawhide thongs are wrapped around the staff at a convenient height and gripped firmly. The bottom end of the staff is braced against the foot (fig. 11-45) and the upper end tucked under the arm. Tension is applied by using the shoulder and leaning against the poles. The spring balance is used in a similar fashion for work of higher precision.

The stool device in figure 11-45 is called a tapping stool or chaining buck and is used in high-precision work. It is a metal three-legged stand with an adjustable sliding head and a handwheel-operated device for locking the plate (the top surface of the sliding head) in any desired position. A line is scribed on the plate. During taping operations, the head is moved until the scribed line is directly under a particular graduation on the tape; the handwheel is then used to lock the head. When the tape is shifted ahead to measure the next interval, the graduation is held exactly over the line until the next stool is adjusted and locked. The basic purpose of taping stools is to furnish stable, elevated surfaces on which taped distances can be marked accurately. When stools are not available, 2 by 4s or 4 by 4s are often driven into the ground for use as chaining bucks.

The length of a tape varies with the temperature, and the precision of a survey may require the application of corrections for this. For work of ordinary precision, you can assume that the

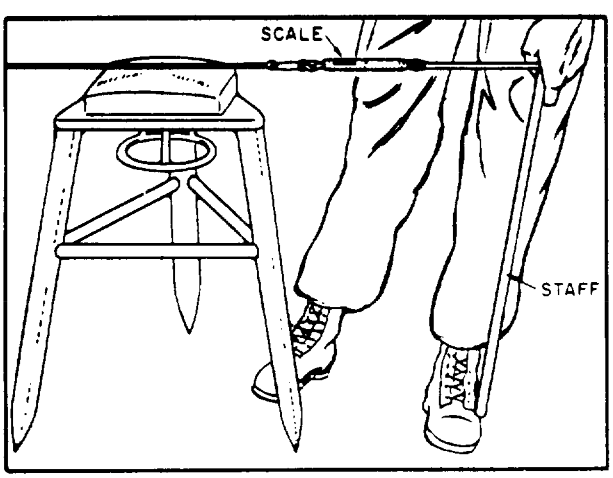

Figure 11-45.-Applying tension to tape.

Figure 11-46.-Tape thermometer.

temperature of the tape is about the same as that of the air. For work requiring higher precision, a tape thermometer, like the one shown in figure 11-46, is attached to the tape. For very precise work, two thermometers, one positioned at each end, may be used. If the two indicate different temperatures, the mean between them is calculated and used.

Chaining Pin

A chaining pin (also called a taping arrow) is a metal pin about 1 ft long. It has a circular eye at one end and a point for pushing it into the ground at the other (fig. 11-47). These pins come in sets of 11 pins, carried on a wire ring passed through the eyes in the pins or in a sheath called a quiver.

Chaining pins can be used for the temporary marking of points in a great variety of situations, but they are used most frequently to keep count of tape increments in the chaining of long distances.

Leveling Rod, Target, and Rod Level

A leveling rod, in essence, is a tape supported vertically and is used to measure the vertical distance (difference in elevation) between a line

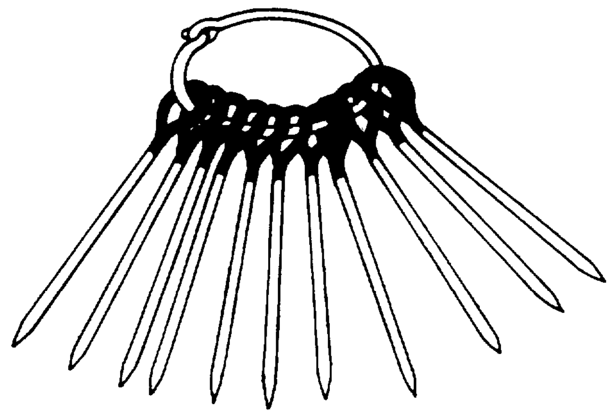

Figure 11-47.-Taping arrows or chaining pins.

of sight and a required point above or below it. This point may be a permanent elevation (bench mark), or it may be some natural or constructed surface.

There are several types of leveling rods. The most popular of all is the Philadelphia rod, as shown in figure 11-48. it is a graduated wooden rod made of two sections and can be extended from 7 to 13 ft. In view A, each foot is subdivided into hundredths of a foot. Instead of each hundredth being marked with a line or tick, the distance between alternate ones is painted black on a white background. Thus, the value for each hundredth is the distance between the colors; the TOP of the black, EVEN values, the BOTTOM of the black, ODD values. The tenths are numbered in black, the feet in red. This rod may be used with the level, transit, theodolite, and with the hand level on occasion to measure the difference in elevation.

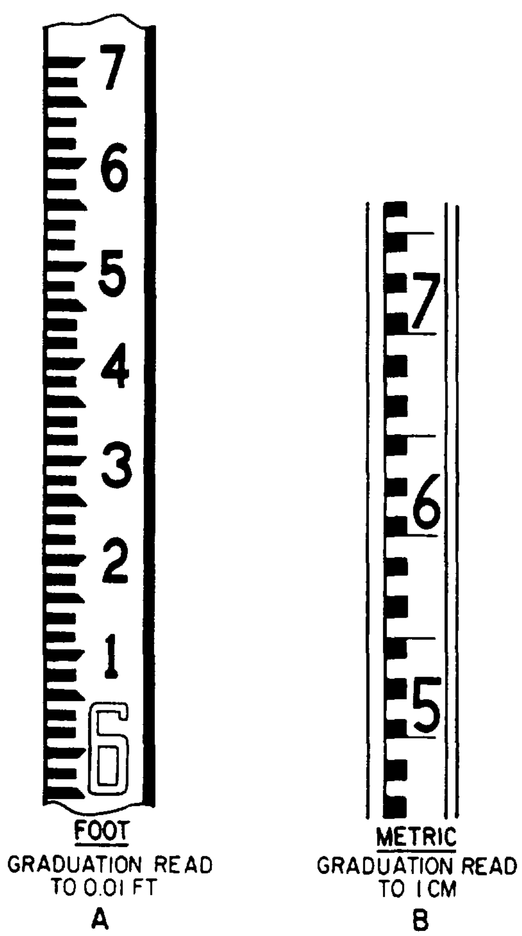

Figure 11-48.-Philadelphia rod.

The leveling rod may be read directly by the instrumentman sighting through the telescope, or it may be target-read. Conditions that hinder direct reading, such as poor visibility, long sights, and partially obstructed sights, as through brush or leaves, sometimes make it necessary to use targets. The target is also used to mark a rod reading when numerous points are set to the same elevation from one instrument setup.

Targets for the Philadelphia rod are usually oval, with the long axis at right angles to the rod, and the quadrants of the target painted alternately red and white. The target is held in place on the rod by a C-clamp and a thumbscrew. A lever on the face of the target is used for fine adjustment of the target to the line of sight of the level. The targets have rectangular openings approximately the width of the rod and 0.15 ft high through which the face of the rod may be seen. A linear vernier scale is mounted on the edge of the opening with the zero on the horizontal line of the target for reading to thousandths of a foot. When the target is used, the rodman takes the rod reading.

The other types of leveling rods differ from the Philadelphia rod only in details. The Frisco rod, for direct reading only, is available with two or three sliding sections. The Chicago rod is available with three or four sections that, instead of sliding, are joined at the end to each other like a fishing rod. The architect's or builder's rod is a two-section rod similar to the Philadelphia but is graduated in feet and inches to the nearest one-eighth in. rather than decimally. The upper section of the Lenker self-computing rod has the graduations on a continuous metal belt that can be rotated to set any desired graduation at the level of the height of the instrument (HI). To use the rod, you set the rod on the bench mark and bring the graduation that indicates the elevation of the bench mark level with the HI. As long as the level remains at that same setup, wherever you set the rod on a point, you read the elevation of the point directly. In short, the Lenker rod does away with the necessity for computing the elevations.

View B (fig. 11-48) shows the rod marked with metric measurements; the graduations of the rod are in meters, decimeters, and centimeters. The targets that are furnished with the metric rod have a vernier that permits reading the scale to the nearest millimeter. The metric rod can be extended from 2.0 to 3.7 meters.

For high-precision leveling, there are precise leveling rods as well as precise engineer's levels. A Lovar rod is usually T-shaped in cross section

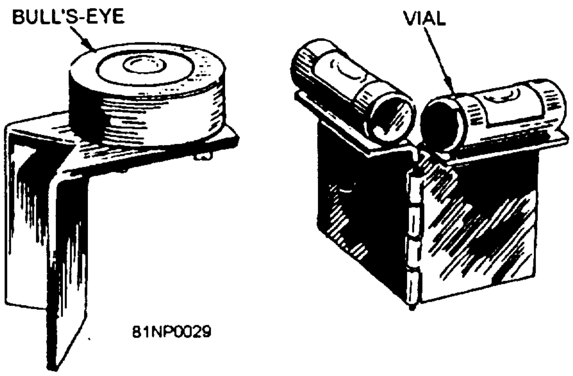

Figure 11-49.-Types of rod levels.

and has the scale inscribed on the strip of Lovar metal. A precise rod usually has a tapering, hardened steel base. Some are equipped with thermometers, so temperature correction can be applied. Precise rods generally contain built-in rod levels.

When a rod reading is made, it is accurate only if the rod is perfectly plumbed. If it is out of plumb, the reading will be greater that the actual vertical distance between the HI and the base of the rod. Therefore, to ensure a truly plumbed leveling rod, use a rod level.

Two types of rod levels that are generally used with standard leveling rods are shown in figure 11-49. The one at the left is called the bull's-eye level, and one on the right is the vial level. Figure 11-50 shows the proper way of using the bull's-eye level; the vial level is attached in the same manner.

Proper care should be taken of leveling rods. The care consists of keeping them clean, free of sand and dirt, unwarped, and readable. They must be carried over the shoulder or under the arm from point to point.

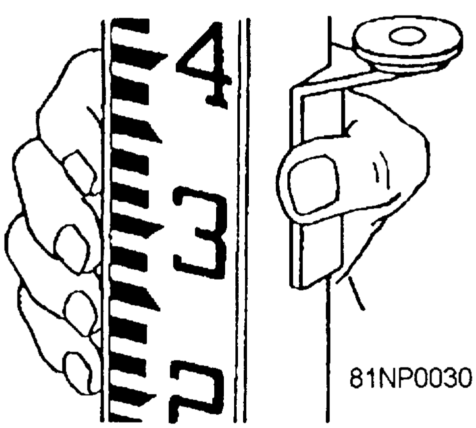

Figure 11-50.-Proper attachment of a bull's-eye rod level to the rod.

Dragging them through the brush or along the ground will wear away or chip the paint. When not in use, the leveling rods should be stored in their cases to prevent warping. The cases are generally designed to support the reds either flat or on their sides. The rods are not to be leaned against a wall or to remain on damp ground for any extended period, since this can produce a curvature in the rods and result in unpredictable random and systematic errors in leveling.

Stadia Boards

In determining linear distance by stadia, you observe a stadia rod or stadia board through a telescope containing stadia hairs, and note the size of the interval intercepted by the hairs. Atypical stadia board is shown

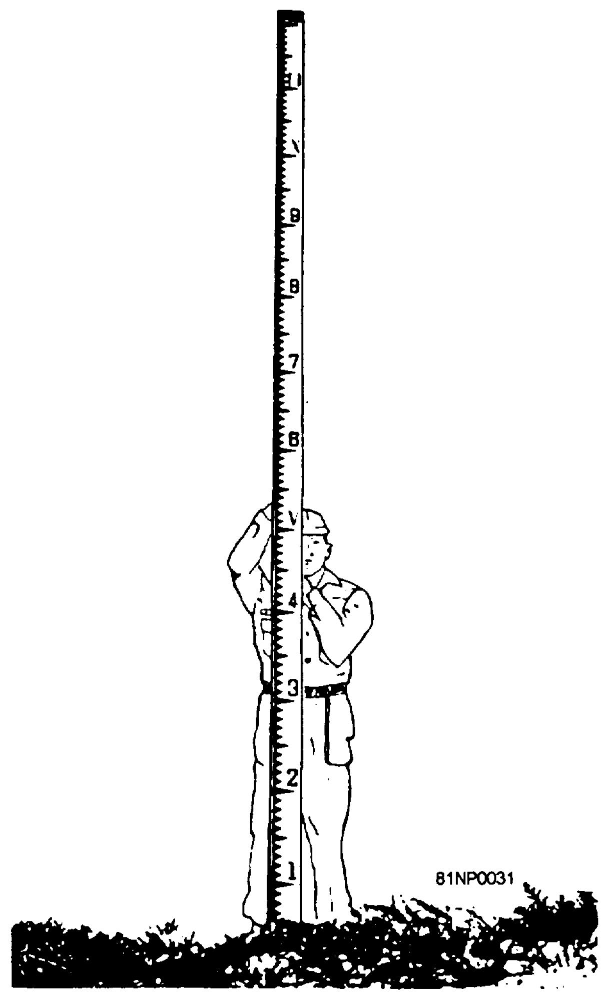

Figure 11-51.-Nadia board.

in figure 11-51. Note that it is graduated in a manner that facilitates counting the number of graduations intercepted between the hairs. Each tenth of a foot is marked by the point of one of the black, saw-toothed graduations. The interval between the point of a black tooth and the next adjacent white gullet between two black teeth represents 0.05 ft.

Other types of graduations on stadia rods or boards are shown in figure 11-52.

Turning-Point Pins and Plates

The point on which a leveling rod is held between a foresight and the next backsight while the instrument is being moved to the next setup is called a TURNING POINT. It must be sufficiently stable to maintain the accuracy of the level line. Where either proper natural features of man-made construction is not available, a turning-point pin, a turning-point plate, or a wooden stake is used. These not only furnish the solid footings but also identify the same position for both sightings. Normally, the pins or plates are used for short periods and are taken up for future use as soon as the instrument readings are completed. Wooden stakes are used for longer periods except when wood is scarce or local regulations require their removal.

A turning-point pin is shown in figure 11-53, view A. It is made of a tapered steel spike with a round top with a chain or a ring through the shaft for ease in pulling. The pin is driven into the ground with a sledgehammer. After a turning pin has served its purpose atone point, it is pulled and carried to the next turning point.

Turning-point plates (fig. 11-53, view B) are triangular metal plates with turned-down corners or added spikes that form prongs and have a projection or bump in the center to accept the rod. The plates are devised for use in loose, sandy, or unstable soils. The plate is set by placing it on the ground, points down, and stepping on it to press it to a firm bearing. After use, it is lifted, shaken free of dirt and mud, and carried forward to the next turning point.

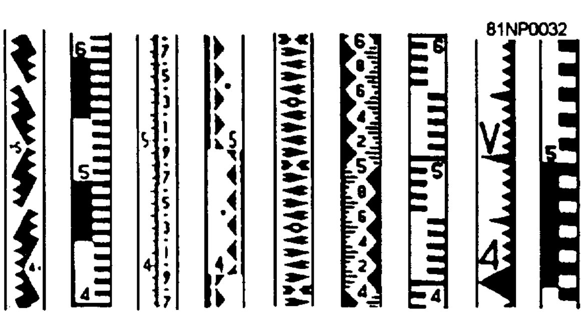

Figure 11-52.-Types of graduations on stadia boards.

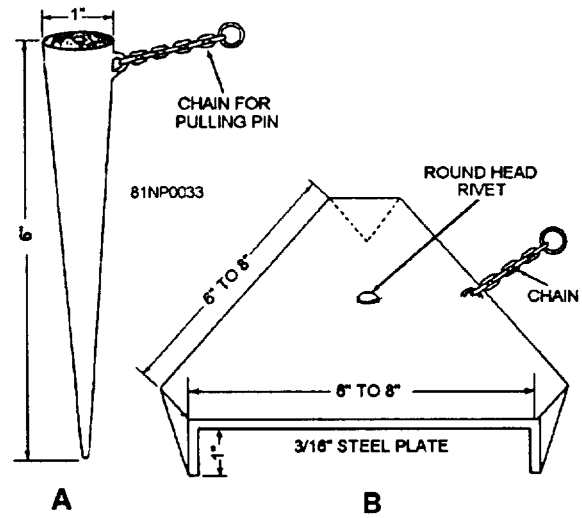

Figure 11-53.-Turning-point pin and plate.

Magnifying Glass

A magnifying glass is used mainly to aid the instrumentman in reading graduations that are provided with verniers, such as the horizontal and vertical circle of a transit. Although these graduations can be read with the naked eye, the use of a magnifying glass makes the reading easier and decreases the chance of reading the wrong coincidence.

Two types of magnifying glasses that you will generally find in the transit box are shown in figure 11-54. They are usually called pocket

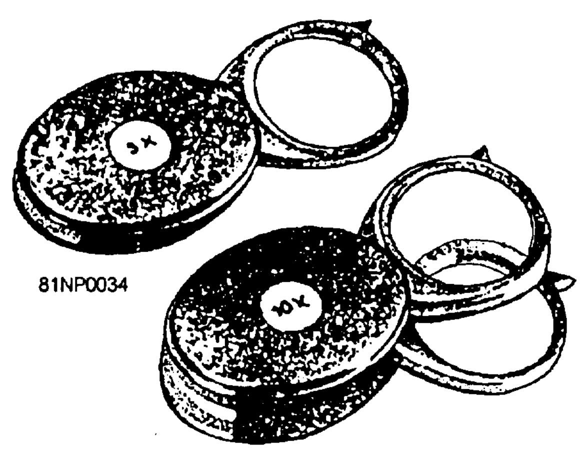

Figure 11-54.-Types of pocket magnifying glasses.

magnifying glasses. To avoid unknowingly dropping a magnifying glass in the field, you should attach it to a loop of string. The instrumentman puts his head through the loop, retaining the string around the neck, and carrying the magnifying glass in a pocket. At the end of each day's work, it is a good practice always to return the magnifying glass to its proper place in the instrument case.

Adjusting Pins

Surveying instruments are built in such a way that minor adjustments can be performed in the field without much loss of time while the work is in progress. The adjustments are made by loosening or tightening the capstan screws that are turned by the use of adjusting pins. These pins are also included in the instrument box. They come in various sizes that depend upon the type of instrument and the hole sizes of its capstan screws. Use the pin that fits the hole in the capstan head. If the pin is too small, the head of the screw will be ruined.

Replacements for these pins are generally given free of charge by surveying instrument dealers. Like the magnifying glass, adjusting pins should be carried in the pocket and not left in the instrument box while a survey is in progress. This will save a lot of valuable time when the pins are needed. Do not use wires, nails, screwdrivers, and the like, as substitutes for adjusting pins.

Tape Repair Kit

Even though you handle the tape properly and carefully during field measurements, some tapes still break under unforeseen circumstances. During chaining operations, when the area is quite far from the base of operations, the surveyor should always be sure to have a tape repair kit (fig. 11-55) with him so that he can rejoin any broken tape in the field, or if the surveyor has brought an extra tape, he can take the broken tape back to the office to be repaired.

The tape repair kit usually contains a pair of small snips, the tape sections of proper size and graduations, a hand punch or bench punch with block, an assortment of small rivets, a pair of tweezers, a small hammer, and a small file. Before reusing a repaired tape, always compare it with an Invar or Lovar tape to check it for accuracy.

FIELD SUPPLIES

Field supplies consist principally of a variety of materials used to mark the locations of points in the field. For example, pencils, field notebooks, and spare handles for sledgehammers

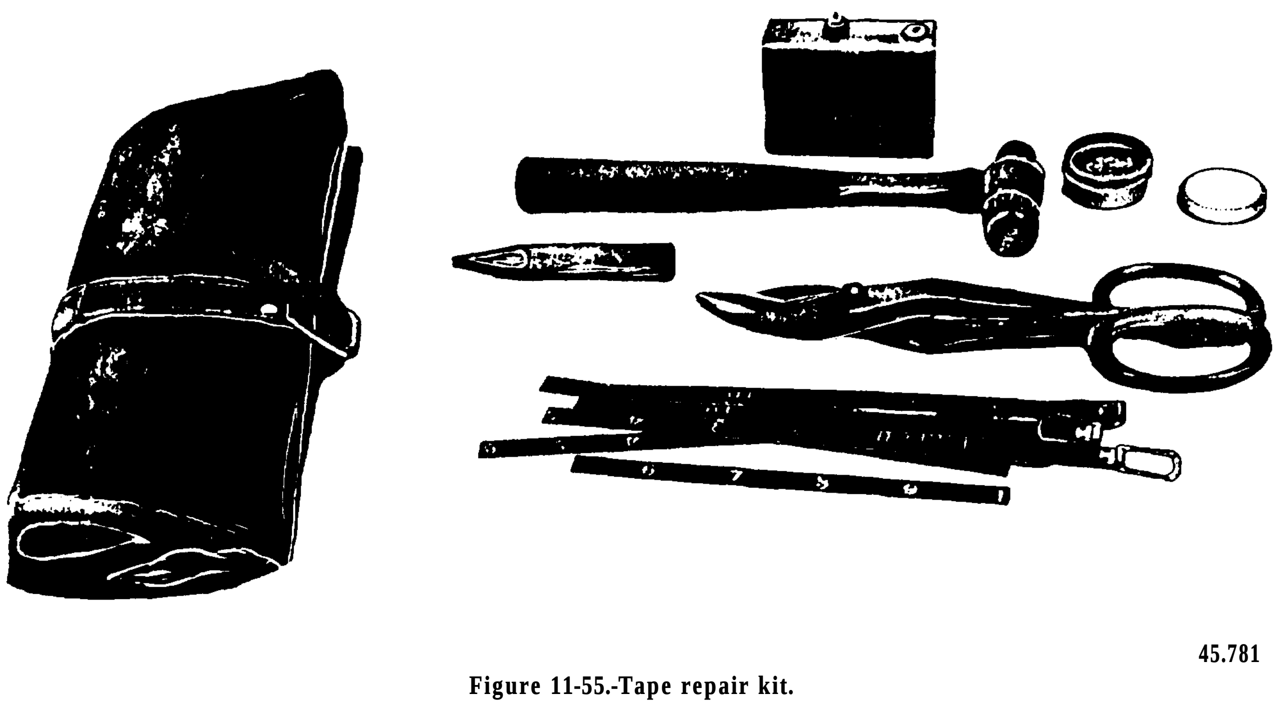

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Figure 11-55.-Tape repair kit.

are generally classified as field supplies. Because SEABEEs operate in so many different places and under such varied conditions, we have not tried to list in this training manual the supply requirements for every location. From your own experience and with the aid of your leading petty officer, you can easily make a list of supplies necessary for a projected survey mission. Those items generally required for a mission are described in this section.

SURVEY POINT MARKERS

The material used as a SURVEY POINT MARKER depends upon where the point is located and whether the marker is to be of a temporary, semipermanent, or permanent character. For example, a wooden stake can be easily driven to mark the location of a point in a grassy field, but it cannot be used to mark a point on the surface of a concrete highway. Similarly, though a wooden stake may be easily driven in a grassy field to mark a property line corner, a marker of this kind would not last as long as a piece of pipe or a concrete monument.

Most of the material commonly used as semipermanent or permanent markers of points in the field is described in the following sections. For purely temporary marking, it is often unnecessary to expend any marking materials. For example, a point in ordinary soil is often temporarily marked by a hole made with the point of a plumb bob, a chaining pin, or some other pointed device. In rough chaining of distances, even the mere imprint of a heel in the ground may suffice. A point on a concrete surface may be temporarily marked by an X drawn with keel (lumber crayon), a pencil, or some similar marking device. A large nail serves well as a temporary point in relatively stable ground or compacted materials.

Semipermanent Markers

Wooden hubs and stakes are extensively used as semipermanent markers of points in the field. The principal distinction between the two is the fact that a hub is usually driven to bring its top flush with, or almost flush with, the ground surface. A hub is used principally to mark the station point for an instrument setup. It is usually made of 2- by 2-in. stock and is from 5 to 12 in. long. The average length is about 8 in. Shorter lengths are used in hard ground, longer lengths in softer ground. A surveyor's tack, made of galvanized iron or stainless steel with a depression in the center of the head, is driven into the top of the hub to locate the exact point where the instrument is to be plumbed.

Stakes improvised in the field may be either cylindrical or any other shape available. However, manufactured stakes are rectangular in cross section because the faces of a stake are often inscribed with data relevant to the point that the stake is marking. A stake that marks a bench mark, for instance, is inscribed with the symbol that identifies the bench mark and with the elevation. A stake that marks a station on a traverse is inscribed with the symbol of the particular station, such as 2 + 45.06. A grade stake is inscribed with the number of vertical feet of cut (material to be excavated) or of fill (material to be filled in) required to bring the elevation of the surface to the specified grade elevation.

Figure 11-56 shows typical dimensions for an average-sized hub and stake. These dimensions, however, may be modified as situations arise, such as material limitations.

Permanent Markers

Permanent station markers are used to mark points that are to be used for a long period of time. Horizontal and vertical control stations are

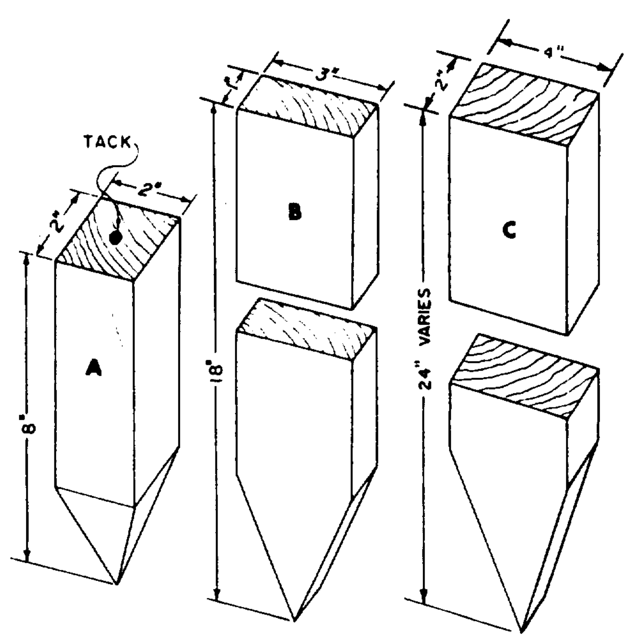


Figure 11-56.-Hub and stakes.

generally marked with permanent markers. These markers could be in the following forms:

- A bronze disk set in concrete

- An iron pipe filled with concrete

- A crosscut on an existing concrete structure or on a rock outcrop

- A hole drilled in concrete and filled with lead or a metal rod driven into the ground with a center-punched mark to designate the exact point

All permanent survey station markers should be referenced so they can be replaced if disturbed. Methods of referencing points are discussed later in this training manual.

Surveyor's tacks, spikes, and nails are often driven into growing trees, bituminous, or other semisolid surfaces as permanent markers. A nail will be more conspicuous if it is driven through a bottle cap, a washer, a plastic tape, or a "shiner." A shiner is a thin metal disk much like the top or bottom of a frozen fruit juice can.

A SPAD is a nail equipped with a hook for suspending a plumb bob. It is driven into an overhead surface, such as the top of a tunnel. The plumb bob will locate on the floor the point vertically below the point where the spad is driven.

Points on concrete or stone surfaces are often marked with an X cut with a hammer and chisel. Another way to do this is to cut holes with a star drill and then plug them with lead.

A much more durable form of marker is made of a length of metal pipe—usually called iron pipe regardless of the actual metal used. Lengths run from about 18 to 24 in. Sawed-off lengths of pipe have open ends; pipes cut with a shear have pinched ends and are called pinch pipe. There are also manufactured pipe markers, some of which are T-shaped rather than cylindrical in cross section. A commercial marker may consist of a copper-plated steel rod. All commercial markers have caps or heads that permit center punching for precise point location and stamping of the identifying information.

A still more durable form of marker is the concrete monument. A short length of brass rod is often set in the concrete to mark the exact location of the point. Concrete monuments that are used as permanent markers by various federal survey agencies have identifying disks set in concrete, like those shown in figure 11-57.

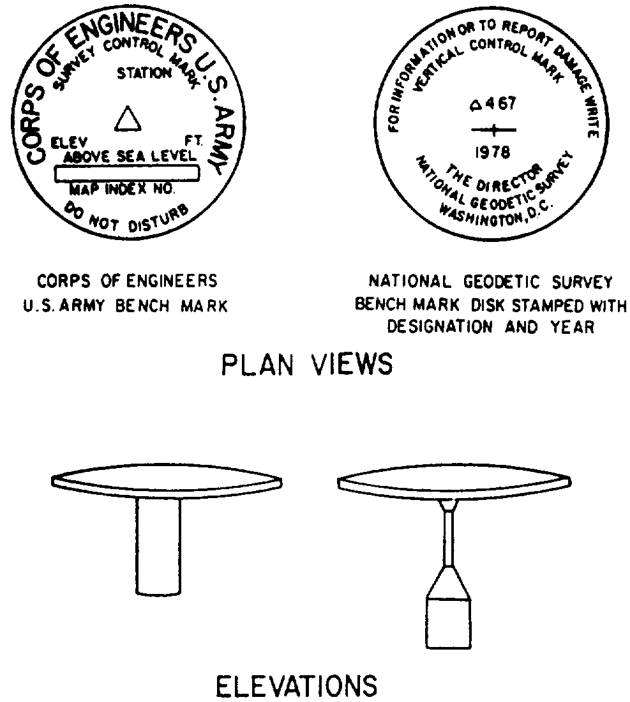


Figure 11-57.-Various types of federal marking disks.

Points on concrete or masonry surfaces may be permanently marked by setting lengths of cylindrical brass stock into holes plugged with lead or grout. Brass stock markers set in pavement are commonly called coppers. Manufactured brass disks, similar to the ones shown in figure 11-57, may be set in grouted holes in street pavements, sidewalks, steps, or the tops of retaining walls. Points on bituminous surfaces maybe marked by driving in pipe, railroad spikes, or case-hardened masonry nails, commonly called PK nails. A center punch for marking a precise location on metal stock or metal caps is a common item of equipment for a surveyor.

MARKING MATERIALS

KEEL, or LUMBER CRAYON, is a thick crayon used for marking stakes or other surfaces. Common marking devices that contain a quick-drying fluid and a felt tip are also popular for marking stakes. All of these types of graphic marking materials come in various colors.

In addition to keel, paint is used to mark pavement surfaces. Paint may be brushed on or sprayed from a spray can. To make the location of a point conspicuous, use a circle, a cross, or a triangle. Identification symbols, such as station or traverse numbers, may also be painted on. For a neater job, stencils are sometimes used.

FLAGGING

Colored cloth bunting or plastic tape is often used to make stakes conspicuous so they will be easier to find or to warn Equipment Operators away. Flagging may also be used for identification purposes. For example, traverse stakes may be marked with one color, grade stakes with another. Red, yellow, orange, and white are the most popular colors of flagging.

NOTE-KEEPING MATERIALS

Field notes are usually kept in a bound, standard field notebook. Sometimes loose-leaf notebooks are used but are not generally recommended because of the chance of losing some pages. Notebooks are classified as ENGINEER'S or TRANSIT FIELD BOOKS, LEVEL BOOKS, CROSS SECTION BOOKS, and so forth, depending on their use.

In a transit book, the left-hand side of the page is used for recording measurement data, and the right-hand side of the page, for remarks, sketches, and other supplementary information. The other field books generally follow the same pattern of usage. Different types of field books and inside pages are shown in figure 11-58. Note how each type is lined or gridded. Actually, a transit or a level book may be used for recording any type of survey. You may add or modify the column headings to suit the required data you desire to record.

PERSONAL PROTECTIVE AND SAFETY EQUIPMENT

In addition to the necessary field supplies and equipment, a field party must carry all necessary items of personal protective equipment, such as containers for drinking water, first-aid kits, gloves, and foul weather gear, as needed. A field survey party is usually working a considerable distance away from the main operational base. If, for example, you happen to be chaining through a marsh filled with icy water, you would not have a chance to return to the base to get your rubber boots.

You are required to wear a hard hat whenever you work in a construction area where the

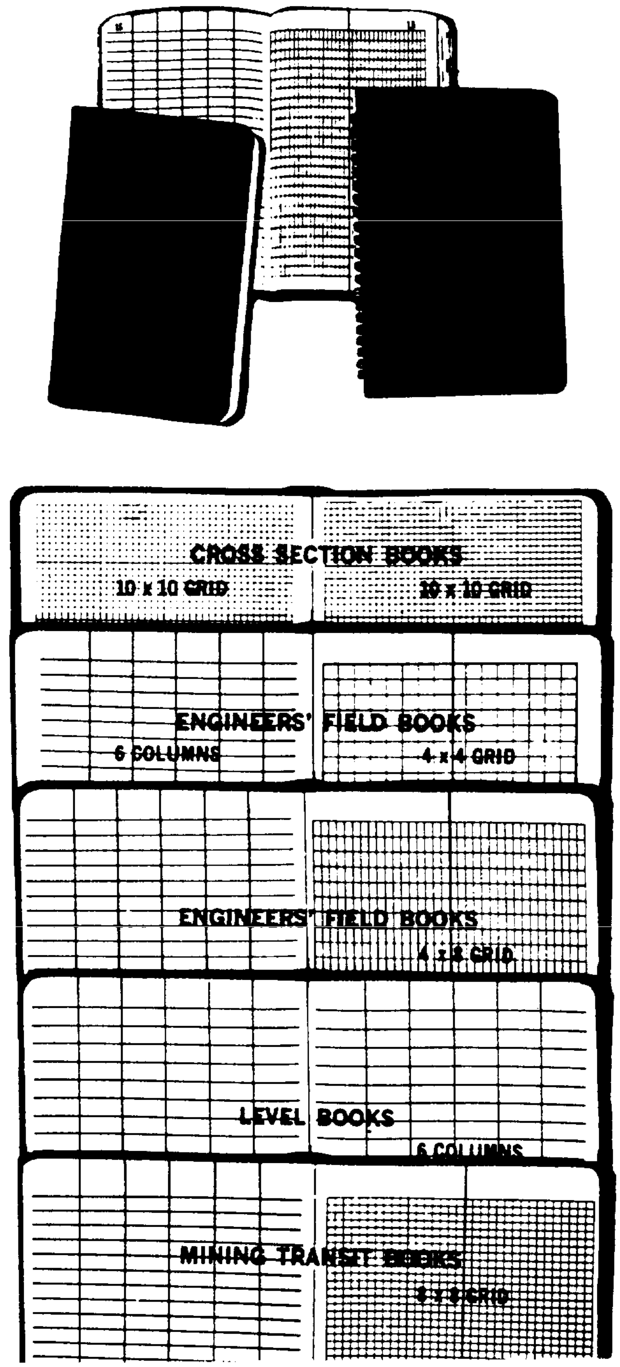


Figure 11-58.-Diffferent types of field books.

assigned personnel are regularly required to wear hard hats. Do NOT get caught-flat-footed in any situation. To avoid this, you should study the situation in advance—considering both the physical and environmental conditions.

CHAPTER 12

DIRECT LINEAR MEASUREMENTS AND FIELD SURVEY SAFETY

This chapter covers the various duties, the techniques, and the skills a chaining crew member must learn thoroughly concerning chaining operations and some of the devices used in chaining itself. DIRECT LINEAR MEASUREMENTS, as used in this chapter, are methods used for measuring horizontal distances with a tape (or chain) and/or with electronic distance-measuring instruments presently available in the military.

As a crew member, you should be concerned not only about the task at hand but also about the potential hazards to which you may be exposed in the field. It is important, therefore, that you recognize the precautions and safety measures applicable to the survey field crew. In this chapter we shall discuss these precautions and safety measures and also additional duties normally performed by the crew.

DUTIES OF A CHAINING CREW MEMBER

During a typical chaining operation, it is possible that many and varied duties other than the actual chaining itself are to be undertaken as part of the whole process. To prepare the field chaining party for the task ahead, we shall present some of these duties, as applicable. In some cases, these duties can be modified or tailored, contingent upon the mission, terrain features, and other conditions that may affect the speed and accuracy of the operation.

GIVING HAND AND VOICE SIGNALS

During fieldwork, it is essential that you communicate with the other members of the survey party over considerable distances. Sometimes you may be close enough to use voice communication; more often, you will use hand signals. Avoid shouting; it is the sign of a beginner. Standard voice signals between chainmen must be used at all times to avoid misunderstanding. There are also several recommended hand signals, most of which are shown in figure 12-1. Those shown are recommended, but any set of signals mutually agreed upon and understood by all members of the party can also be used. It is important to face the person being signaled. Sometimes, if it is difficult for you to see the other person, it helps to hold white flagging in your hand when giving signals. When signals are given over snow-covered areas, red or orange flagging is more appropriate.

Explanations of the hand signals shown in figure 12-1 are as follows:

1. ALL RIGHT. The “all right” is given by the instrumentman when the alignment is OK for a plumb line, a range pole, a stake, a hub, or any other device used as a target, or when the instrumentman has finished all activities at your location.

It is given by waving both arms up and down while extending them out horizontally from the shoulders. If the instrumentman, in aligning a target, extends both arms out horizontally from the shoulders without waving them, the signal means that the target should be held steady while a quick check of its position is being made.

2. MOVE RIGHT OR LEFT. This signal is given by the instrumentman when lining in a target on a predetermined line. It is given by moving the appropriate hand outward from the shoulder. A slow motion of the hand means that you must move a long distance; a quick, short motion means that you must move a short distance.

3. GIVE ME A BACKSIGHT. This signal is given when the instrumentman wants a target held at a previously located point. It is given by extending one arm upward with the palm of the hand forward.

4. GIVE ME A LINE OR THIS ISA HUB. This signal, given by the rodman or the chainman, is intended to indicate a hub or to ask for a line on the point indicating the exact location.

It is given by holding a range pole horizontally overhead, then moving it to a vertical

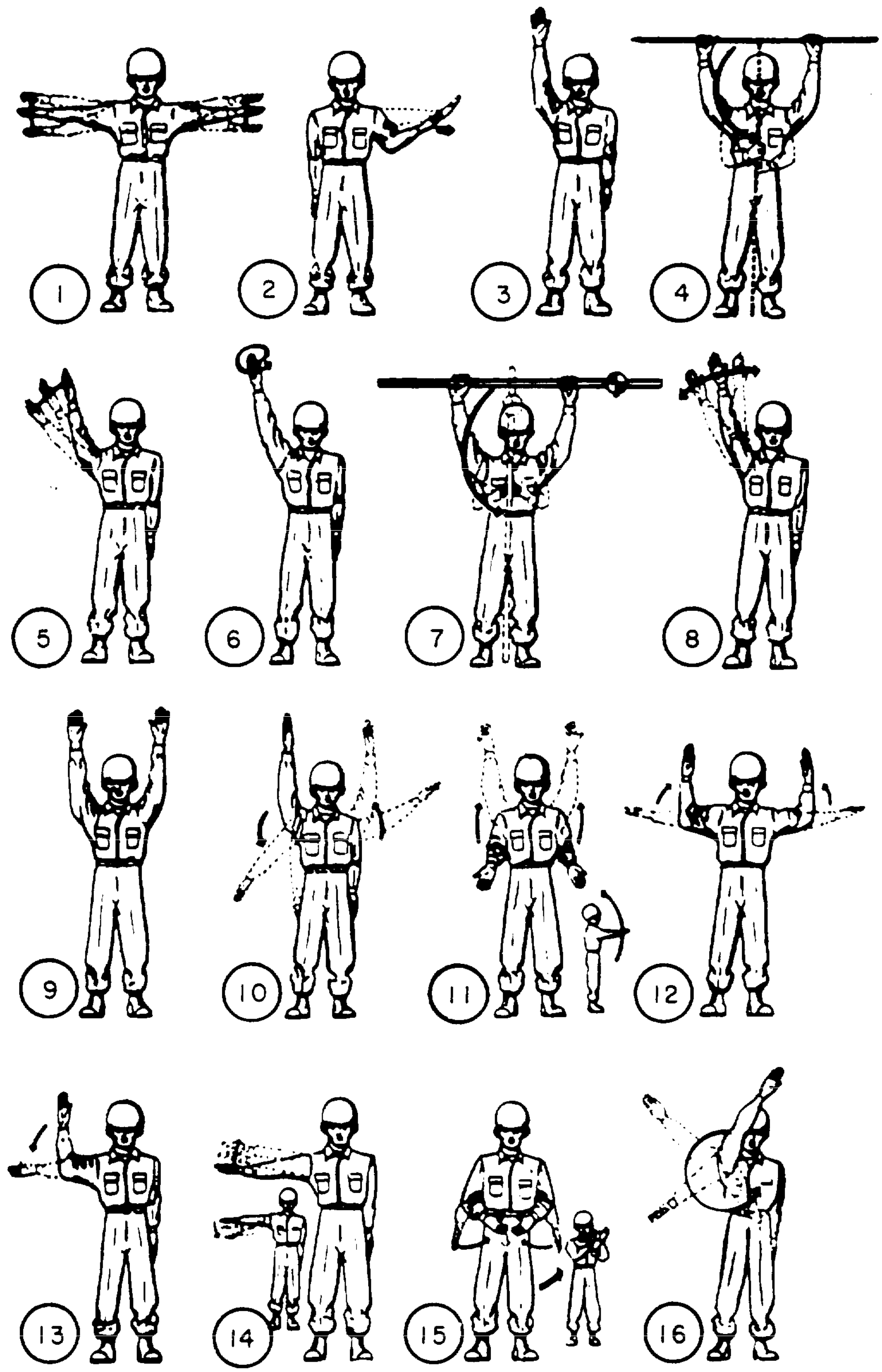


Figure 12-1.-Surveyor's hand signals.

position in front of the body. Sometimes the range pole tip is set on the ground to serve as a pivot. Then the pole may be swayed slowly to the left and/or right until the instrumentman picks up the signal.

5. PLUMB THE ROD. The signal to plumb the rod to the desired direction (right or left) is given by extending the appropriate arm upward and moving the hand in the direction the top of the rod must be moved to make it vertical.

6. ESTABLISH A TURNING POINT. This signal is given when the instrumentman wants a turning point established during traversing or leveling operations. It is given by extending either arm upward and making a circular motion.

7. THIS IS A TURNING POINT. The rodman gives this signal to indicate a turning point. This is done using a leveling rod and applying the method described in 4.

8. WAVE THE ROD. This signal, given by the instrumentman to the rodman, is important to get the lowest stadia reading. The instrumentman extends one arm upward, palm of the hand forward, and waves the arm slowly from side to side. The rodman then moves the top of the leveling rod forward and backward slowly about a foot each way from the vertical.

9. FACE THE ROD. To give this signal, the instrumentman extends both arms upward to indicate to the rodman that the leveling rod is facing in the wrong direction.

10. REVERSE THE ROD. The instrumentman gives this signal by holding one arm upward and the other downward, and then reversing their positions with full sidearm swings.

11. BOOST THE ROD. The instrumentman gives this signal by swinging both arms forward and upward, palms of the hands upward. This signal is used when the instrumentman wants the leveling rod raised and held with its bottom end at a specified distance, usually about 3 ft, above the ground.

12. MOVE FORWARD. The instrumentman gives this signal by extending both arms out horizontally from the shoulders, palms up, then swinging the forearms upward.

13. MOVE BACK. The instrumentman gives this signal by extending one arm out horizontally from the shoulder, hand and forearm extended vertically, and moving the hand and forearm outward until the whole arm is extended horizontally.

14. UP OR DOWN. The instrumentman gives this signal by extending one arm out horizontally from the shoulder and moving it upward or downward. This directs the rodman to slide the target up or down on the rod.

15. PICK UP THE INSTRUMENT. The party chief gives this signal by imitating the motions of picking up an instrument and putting in on the shoulder. The party chief or other responsible member of the party gives this signal, directing the instrumentman to move forward to the point that has just been established.

16. COME IN. The chief of party gives this signal at the end of the day's work and at other times, as necessary.

Two additional hand signals are shown in figure 12-2. Their meanings are given in the next two paragraphs.

RAISE FOR RED. The instrumentman gives this signal in a leveling operation to ascertain the immediate whole-foot mark after reading the tenths and hundredths of a foot. This usually happens when the rodman is near the instrument or if something is in the way and obscures the whole-foot mark.

EXTEND THE ROD. The instrumentman gives this signal when there is a need to extend an adjustable rod. This happens when the height of the instrument becomes greater than the standard length of the unextended adjustable level rod.

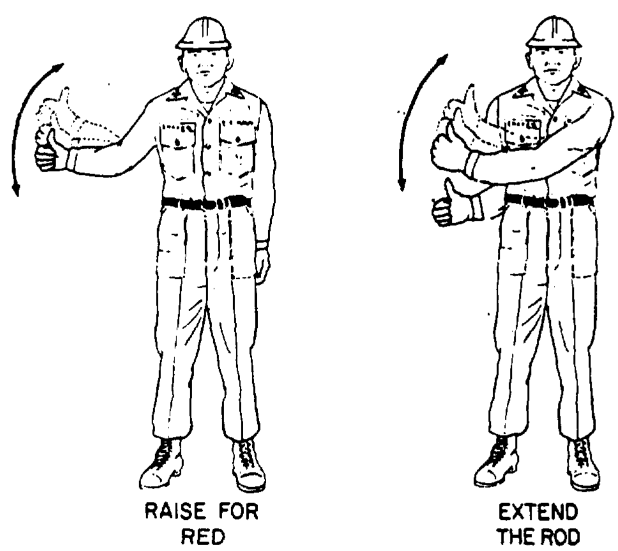


Figure 12-2.-Additional hand signals.

SIGNALS FOR NUMERALS. Figure 12-3 shows a simple system for numerals.

ONE—Right arm extended diagonally down to the right from the body

TWO—Right arm extended straight out from the body

THREE—Right arm extended diagonally up and out from the right shoulder

FOUR—Left arm extended diagonally up and out from the left shoulder

FIVE—Left arm extended straight out from the body

SIX—Left arm extended diagonally down to the left from the body

SEVEN—Both arms extended diagonally down and out from the body

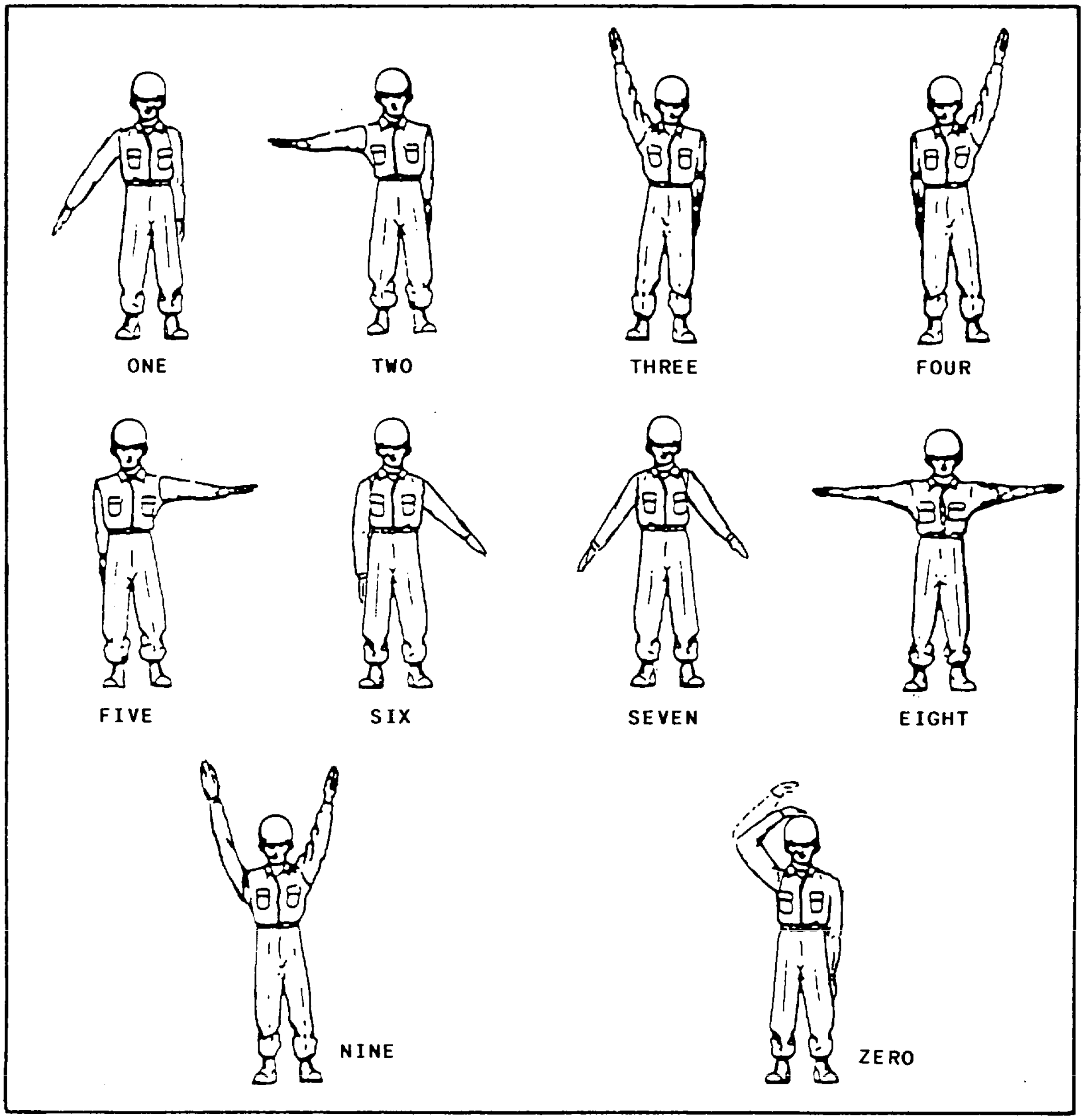


Figure 12-3.-Hand signals for numerals.

EIGHT—Both arms extended straight out from the body

NINE—Both arms extended diagonally up and out from the body

ZERO—Hitting the top of the head with an up-and-down motion of the palm

A decimal point should be indicated by using a signal that maybe easily distinguished from the other signals.

Make sure to orient yourself properly when receiving signals for Number 1 through Number 6; your left is the right of the signalman. The other numerals can be read without thinking of right or left. Use numeral signals only when necessary. Mistakes can easily result from misinterpreted signals.

It is important to remember that, if hand signals are used, they should be used consistently. It is important that every member of the survey party be completely familiar with them.

CLEARING THE LINE

A line must be cleared ahead when a crew is chaining (or taping) across brush-covered country. Specific tools, such as those presented in chapter 11, for the kind of job assigned must be used and handled with care. Before you start to swing, make sure that no one is within range.

You may cut ordinary scrub growth in unsettled areas more or less as needed. If, however, you encounter large trees or shrubs that may be of value, you should consult your party chief for advice. Even though a tree or shrub lies directly on the chaining line, it is never absolutely necessary that it be cut down. If it is desirable that it be preserved, you can always triangulate around it or bypass it by some other method, as described in a later chapter.

The principle technical problem in clearing the line is keeping on the line. When possible, this is accomplished by the use of natural foresights; that is, by the use of bearings taken on natural objects (or, perhaps, on artificial objects) lying ahead.

Suppose there is no distinctive object lying on the line of bearing ahead. In this case, you may be able to keep on the line by BLAZING ahead. To do this, you set up the compass and sight ahead on a tree lying as far ahead as possible. You then mark this tree by blazing. (A blaze is a scar notched on a tree with a hatchet or machete.) You could also use red or white flagging as markers. You then clear a line toward the tree.

Suppose the growth is too high and thick for you to sight ahead. In this case, you'll have to work ahead by looking back and aligning yourself on a couple of markers on the line already covered.

GIVING BACKSIGHTS AND FORESIGHTS

To run a line by instrument from a point of known location A to point B, for example, and given a distance and direction ahead, the instrumentman usually proceeds in the following manner:

1. Sets up the instrument (usually a transit) over point A.

2. Trains the telescope on the given direction of the line to B.

3. Sights through the telescope to keep the chainmen on line for as many consecutive foresights as can be observed from that particular instrument setup.

Suppose, for example, that the chainmen are using a 100-ft tape. After the instrument has been trained along the line of direction, the head chainman walks away with the zero-foot end of the tape, while the rear chainman holds the 100-ft end on the point plumbed by the instrument. After the head chainman has walked out the whole 100 ft, a plumb bob is dropped on a cord from the zero-foot mark to the ground.

The instrumentman sights along the line and thus determines the direction in which the head chainman must move to bring the plumb bob on to the line. The "move right" or "move left" signal is given, if needed. When the head chainman has been brought by signal to the vicinity of the line, the instrumentman signals for the final placement of the plumb bob by calling out, "To you!" (meaning "Move the plumb bob toward yourself!") or "Away!" (meaning "Move the plumb bob away from yourself!"). When the plumb bob is exactly on the line, the instrument man calls out, "Good!" or "All right!" The head chainman then marks the point indicated by the plumb bob in the correct manner. The first 100 ft have now been measured on the given line of direction.

If the distance to be measured is long, the chainmen will eventually proceed beyond the scope of the instrument as it is then set up. The instrument must then be shifted ahead to the last point marked by the head chainman. When the instrument has been set up over this point, the telescope must be reoriented to the line of direction. To do this, the instrumentman usually plunges the telescope (rotates it vertically) and backlights on a point on the line already laid off. In taking backlights, the instrumentman is guided by the rear chainman who holds on, or plumbs over, the point. When the telescope has been trained on the backsight point, it is again plunged. The telescope is now again trained in the desired direction.

Holding on a Point

If the point on the ground can be sighted through the telescope, the chainman may simply hold on the point; that is, hold a pencil point, chaining pin point, plumb bob point, or some other appropriate indicator on the point (fig. 12-4). Whatever the indicator may be, it is essential that it be held in an exactly vertical position. For short sights, it is also essential that the shaft of the indicator be relatively slender so that the vertical cross hair can be aligned with sufficient exactness.

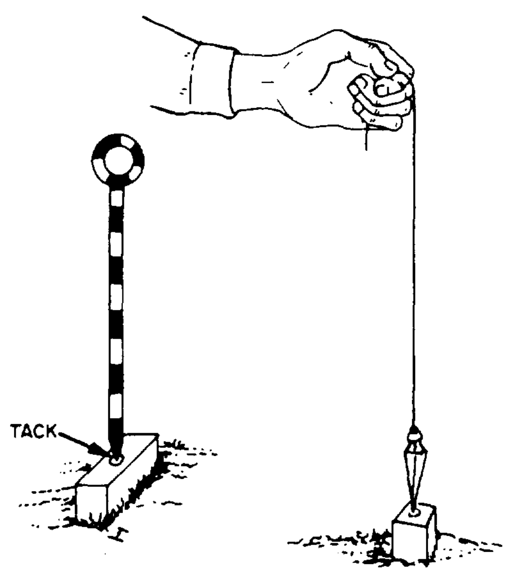


Figure 12-4.-Indicators used for short sights.

Plumbing over a Point

If intervening low growth or some other circumstance makes it impossible for the instrumentman to sight the point on the ground, the chainman must plumb over the point, using the plumb bob and cord. If the distance is too far for observation of the plumb bob cord, the cord should be equipped with a plumb bob target, or a range pole may be used. In the absence of a target when using the plumb bob, you may tie a piece of colored flagging to the cord, or you may use a handkerchief, as shown in figure 12-5.

Some chainmen prefer to hold the plumb bob and cord with the cord running over the forefinger. Others prefer to have the cord running over the thumb. If you are plumbing high (that is, required to hold the cord at chest level or

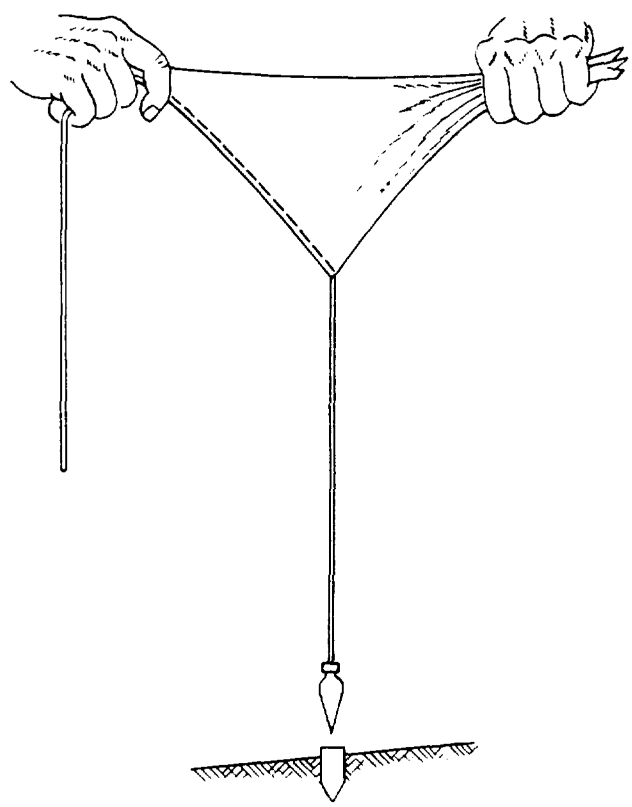


Figure 12-5.-Using a handkerchief as a substitute for a target on a plumb bob cord.

above), you need to learn to brace your holding arm with your other arm, and against your body or head or both, to avoid unsteadiness and fatigue. When there is a wind, you may find it difficult to hold the plumb bob suspended over a point. The plumb bob will tend to swing back and forth. You can overcome this problem by bouncing the point of the plumb bob slightly up and down on the point.

For a long sight, it is much better to plumb over a point with a range pole. For a short sight, however, the shaft of a range pole is too thick to permit exact alignment of the vertical cross hair.

For long sights, or for sights on a point that is to be sighted repeatedly, it is often desirable to construct a semipermanent target. There are no definite rules that can be stated for constructing targets because they usually must be built from materials at hand. Use your ingenuity; but make the target high enough to be seen, strong enough to withstand prevailing winds, and plumb over a point. Several types of semipermanent targets are shown in figure 12-6.

MARKING CONTROL POINTS, REFERENCE POINTS, AND MONUMENTS

In general, control surveys deal with established points. To define these points, surveyors have to mark them. Certain points are made permanent; on the other hand, others are temporary. A line that will be used for a long period of time, for example, may be marked at each end with a bronze disk set in concrete, or with a center-punched metal rod driven flush with the ground. For less permanent control points, wooden stakes or hubs with nails, shiners, and flaggings can be used.

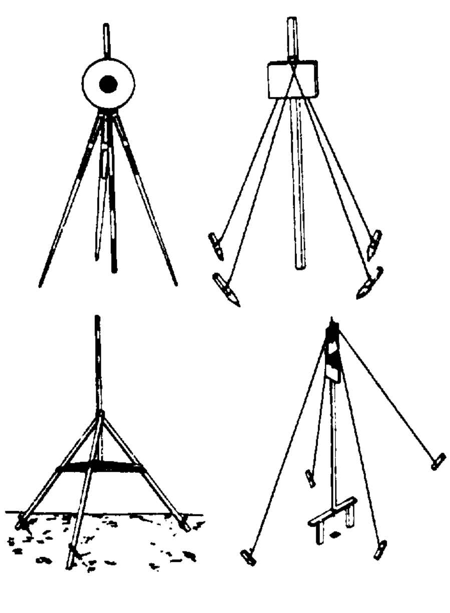


Figure 12-6.-Field-constructed semipermanent targets.

Placing Driven Markers

A DRIVEN MARKER must be set exactly vertically on the point it is supposed to mark. If it is driven on a slant, the top of the marker will not define the correct location of the point. To drive the marker vertically, first align it vertically; then, using a sledgehammer or other type of driving implement, strike each blow squarely on the flat end of the hub or stake.

A wooden hub is normally driven to mark the exact horizontal location of a point, usually for the purpose of plumbing an instrument over the point. Consequently, it is not normally necessary for the top of a hub (or other markers used for the same purpose) to extend much above the ground line. The precise location of the point is marked by a hub tack, punch mark, or other precise marker driven or set in the top of the hub. For work on asphalt roads or runways, you'll find it easier to use flagging or a soda pop top and a nail as a marker; in concrete and other hard surfaces, you can use orange paint or a star-drilled hole plugged with lead. The choice of markers to be used depends on the surveyor's judgment as well as the purpose of the survey.

In frozen or otherwise extra hard ground, use a bull-point to start a hole for a stake or hub. Remember that the stake or hub will follow the line of the opening made by the bull-point. Therefore, if the bull-point is not driven vertically, the stake or hub will not be vertical either.

Placing Monuments

In surveying, a MONUMENT is a permanent object or structure used where a point or station must be retained indefinitely for future reference. It may simply consist of a conspicuous point carved on an outcrop of a ledge rock or otherwise constructed in concrete. Figure 12-7 shows common types of concrete monuments. The top of the monument should have an area large enough to include the required point and any necessary reference data. The depth of the monument should be sufficient to extend below the frost line. If the depth of the frost line is unknown, a minimum depth of 3 ft is generally accepted. Other factors, such as soil condition and stability of foundation, may also affect the depth of the monuments. The area should be checked out for soil stability to provide an adequate foundation. A monument settles in the same manner as any other structure if an adequate foundation is not provided.

The exact location of the point on a monument may be marked by chiseling an X on the surface or by drilling a hole with a star drill and hammering in a lead filler or grouting in a length of brass stock (often called a COPPER). When grouting a copper, you should use neat cement grout because a fluid grout would flow into and fill the small space around the copper. If the point can be placed at the same time as the monument is being cast in place, the copper can be pushed down into the surface of the monument before the concrete begins to harden. If you are near an armory, you may be able to obtain large, expended brass shell casings. The primer end of a shell casing makes an excellent survey point marker when it is embedded in a concrete monument.

With a little imagination and ingenuity, you can easily design and construct adequate survey monuments when they are required.

Identifying Points

A point is marked with the information required to identify the point and with any other relevant data. Temporary identification marks can be made with keel. More permanent marks can be made with paint. An even more permanent mark consists of a metal plate set in concrete.

A. point that indicates a traverse station is marked with the symbol or number of the station, such as STA. B or STA. 21. A point on a stationed traverse is marked with the particular station, such as 2 + 87.08. Frequently, a point will serve as a traverse station and a bench mark. A bench mark is marked with an identifying symbol and usually with the elevation. In marking such an elevation, do not use a decimal point, as in 317.22 ft. Instead, raise the figures that indicate the fractional part and underline them; for example, $317^{\underline{22}}$ ft.

Referencing Points

All control points should be tied in or referenced. The ties or reference points are

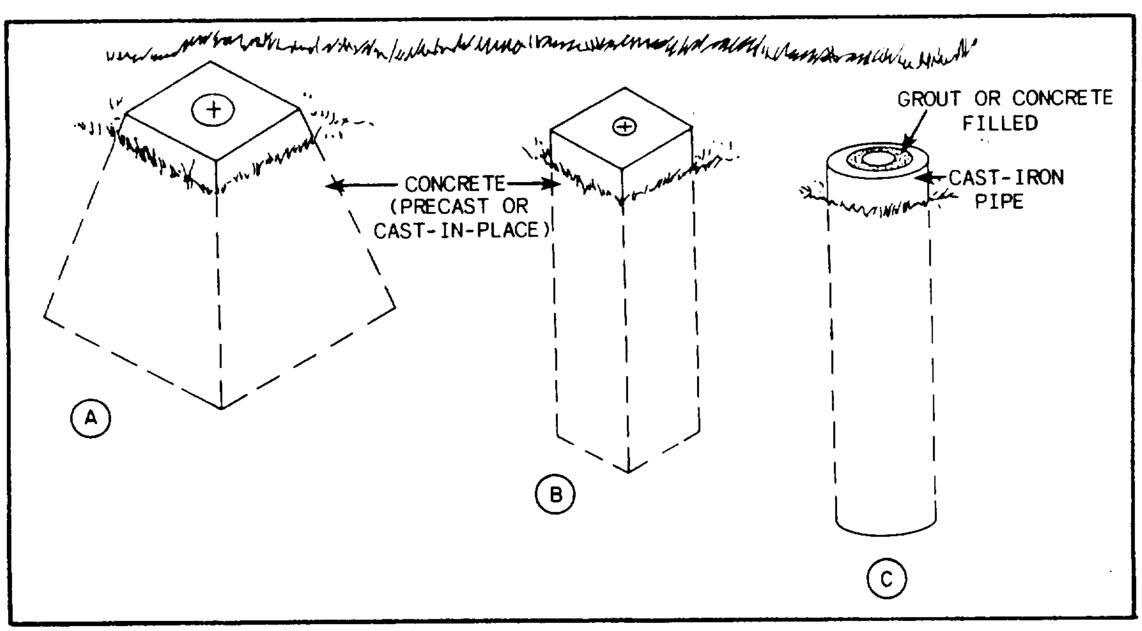


Figure 12-7.-Common types of survey monuments.

recorded in the field book as they are established in the field. The record may be done either by sketch, by work description, or by the combination of the sketch and notes. The control point must be referenced to some permanent type of object in its vicinity; if no such objects exist, REFERENCE HUBS are driven at points where they are unlikely to be disturbed. These ties are important in recovering control points that have been covered or otherwise hidden or in reestablishing them accurately if they have been removed.

The reference location of a particular point is recorded on the remarks page of the field book by sketches like those shown in figures 12-8 and 12-9. For a permanent control point, such as a triangulation point, monument, or bench mark, a complete "Station Description" is individually prepared for each station. The field offices of the National Oceanic and Atmospheric Administration or the National Geological Survey have these station descriptions on separate cards. This is done so they can easily run a copy for anyone requesting a description of a particular station. They also maintain a vicinity map on which these

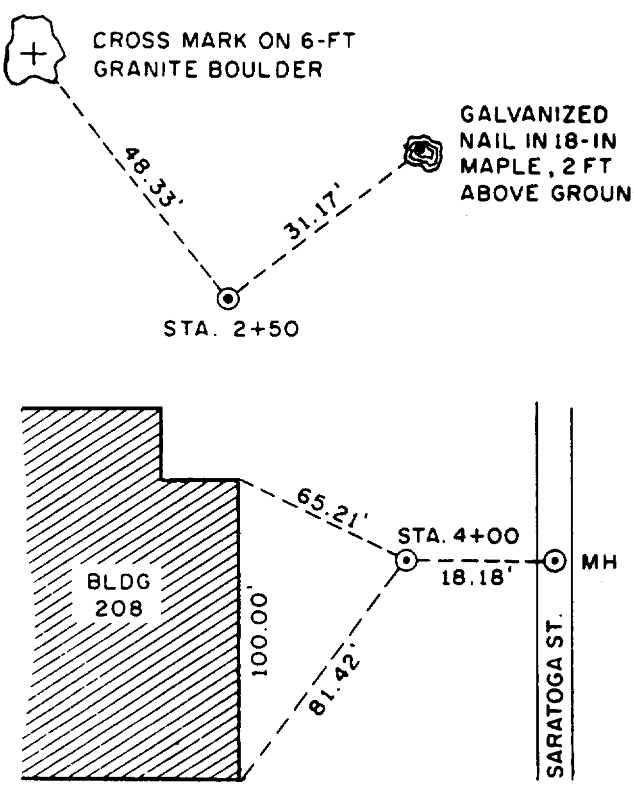


Figure 12-8.-Natural objects or man-made structures used as reference points.

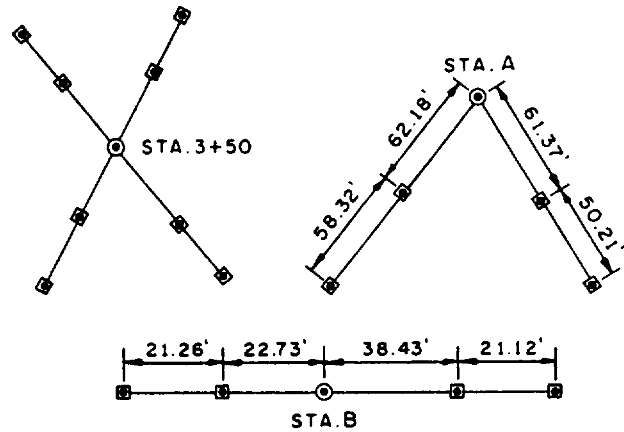


Figure 12-9.-Accurate methods for tying points.

points are plotted, and these station descriptions are used in conjunction with this map. The Navy's public works offices also maintain descriptions of stations within their naval reservation and its vicinity for immediate reference.

The methods of referencing points shown in figure 12-8 are ideal for recovering points that have been covered or otherwise hidden, and those shown in figure 12-9 are for reestablishment of these points accurately. The methods shown in figure 12-9 are generally used in construction surveys.

As you gain more experience, you may be assigned the task of writing a station description. In doing this, be sure to describe the location in detail, and make a sketch showing the location, ties, and magnetic or true meridian. Make your description concise and clear; and be sure to test its effectiveness by letting another EA (preferably not a member of the survey party that established the point) interpret your description. From the feedback of the interpretation, you can determine the accuracy of your written description. Your description, for example, should be written as follows (refer to figure 12-8): "Point A—plugged G.I. pipe 65.21 ft SE of NE corner of PWC Admin. Bldg. (Bldg. 208) and 81.42 ft from the SE corner of same building. It is 18.18 ft W of the center of a circular manhole cover located in Saratoga Street."

Protecting Markers

Markers are to be protected against physical disturbance by the erection of a temporary fence (or barricade) around them. Sometimes guard stakes embellished with colored flaggings are simply driven near the hub or similar marker to serve as deterrence against machinery or heavy equipment traffic. On the other hand, permanent markers are protected by fixed barricades, such as steel or concrete casing.

METHODS OF DIRECT LINEAR MEASUREMENTS

One of the most fundamental surveying operations is the measurement of horizontal distance between two points on the surface of the earth. Generally, there are two basic methods used: direct and indirect. Direct linear measurements, as explained earlier in this chapter, are methods used for determining horizontal distances with a tape (or chain) and/or with an electronic distance-measuring instrument. In indirect methods, the transit and stadia or theodolite and stadia are used. This section will discuss the common methods used in direct linear measurements.

CHAINING (OR TAPING)

The most common method used in determining or laying off linear measurements for construction surveys, triangulation base lines, and traverse distances is often referred to as CHAINING. The name is carried over from the early days when the Gunter's chain and the engineer's chain were in use. Today, it is more appropriate to call this operation TAPING because the steel tape has replaced the chain as the surveyor's measuring device. In this manual, however, chaining and taping are used interchangeably.

Identifying Duties of Chaining Party Members

Obviously, the smallest chaining party could consist of only two people—one at each end of the tape. To lay off a line to a desired distance, one person holds the zero end of the tape and advances in the direction of the distant point, while the other holds a whole number of the tape at the starting point. The person ahead, holding the zero end, is called the HEAD CHAINMAN; the other person is known as the REAR CHAINMAN.

In ordinary chaining operations, if the distance being measured is greater than a tape length, it is necessary to mark the terminal point with a range pole. In this way, the rear chainman can keep the head chainman aligned at all times whenever a full tape length or a portion of it is transferred to the ground.

The head chainman also acts as the recorder, and the rear chainman is responsible for keeping the tape in alignment. If more speed or precision in taping is required, additional personnel are assigned to the party. This relieves the chainmen of some of their duties and permits them to concentrate primarily on the measurement.

For more precise chaining, a three-man party is essential. In addition to the head and rear chainmen, a stretcherman is added. The duties of the stretcherman are to apply and to maintain the correct tension on the tape while the chainmen do the measuring. The head chainman still acts as the recorder and also reads and records the temperature of the tape.

Either of the two chaining parties described may have additional personnel assigned as follows:

- A recorder keeps a complete record of all measurements made by the taping party, makes any sketches necessary, writes descriptions of stations and reference points, and records any other data required. The head chainman or the chief of the chaining party may perform these duties.

- A rodman sets a range pole at the forward station to define the line to be taped, drives stakes to mark stations and reference points, carries the taping stool (discussed later) to the forward point, and performs other duties as directed.

- One or more axmen clear lines of sight between stations, cut and drive stakes, and perform other duties as directed.

- The chief of the chaining party directs the work of making the tape measurements, the establishment of stations, and other activities of the party in the field. The head chainman performs these duties when there is no separate party chief.

Coiling and Throwing a Steel Tape

Tapes generally come equipped with a reel; however, it is not always necessary to replace a steel tape on the reel at the end of each work period. A tape can be easily coiled and thrown into a circular roll.

Grasp the 100-ft graduation on the tape faceup with your left hand. Using your right hand, you take in 5 ft of tape at a time. Place the 95-ft mark over the 100-ft mark, next the 90-ft mark over the 95-ft mark—holding these 5-ft marks firmly with the left hand so that the tape will not turn over. Continue this operation for the entire length of the tape, placing each 5-ft division over the preceding one until the zero graduation is reached, (Actually, you can start at either end of the tape, whichever is convenient.) As you are taking in the tape, you will notice that the coils fall into the shape of the figure "8." (See fig. 12-10.)

When you have completed this coiling, square up the tape ribbons. The leather thong at the 100-ft end should be on the underneath side of the coil next to your hand. Wrap the thong around the complete coil. Continue wrapping until there is just enough of the thong left to conveniently insert it through the coil at about the 50-ft graduation. Draw the thong firmly back against the completed windings of the thong.

You can throw the tape into a more compact circular roll by giving the "8" a twist, as shown in figure 12-11. Now, tie the tape with the remaining thong.

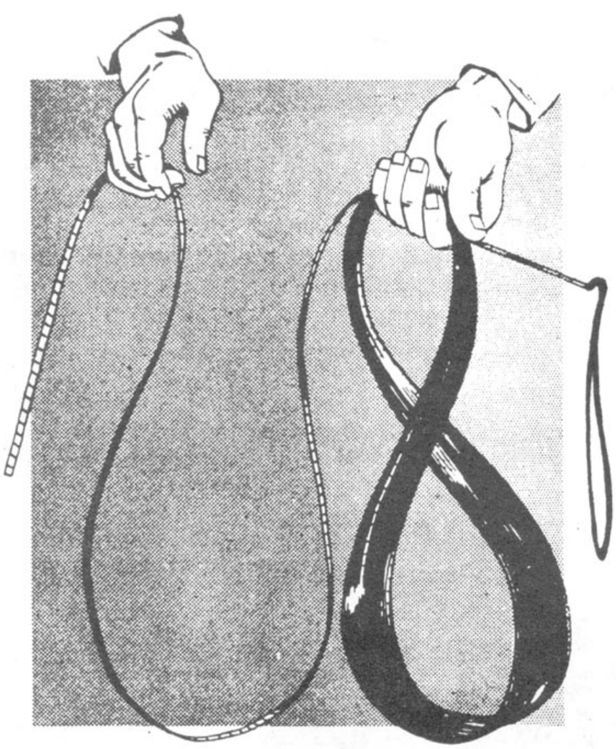


Figure 12-10.-Coiling a tape into a figure "8" form.

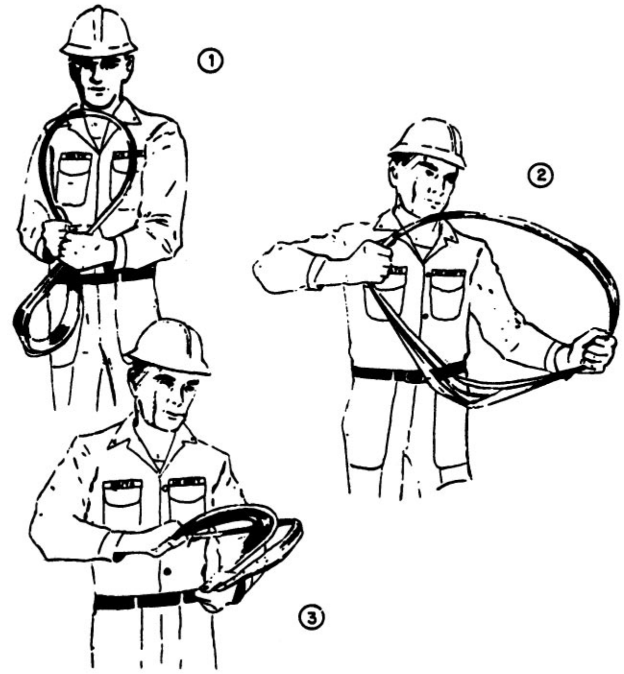


Figure 12-11.-Throwing the tape into a circular roll.

When you wish to use the tape again, reverse the process. Be sure you let the tape out from the zero end in the same way that it was wound. Walk away from the end of the tape as you unwind it to prevent kinks.

Chaining on Level Ground

When taping distances on a relatively level surface and of the third or lower order accuracy, you may lay the tape on smooth ground or on a paved road or support its ends by taping stools or stakes. In horizontal chaining, the tape is held horizontally, and the positions of the pertinent graduations are projected to the ground by a plumb bob and cord. For ordinary chaining on level ground, the following procedures are generally used:

1. A range pole is set on line slightly behind the point toward which the taping will proceed. The rear chainman, with one chaining pin, stations himself at the starting point of the line to be measured.

2. The head chainman, holding the zero end of the tape and with 10 pins in his hand, then moves forward toward the distant point while guiding himself with the range pole. Assuming that the tape was already off the reel when they

started, the rear chainman watches the tai1 end (100-ft mark) of the tape as the head chainman moves forward.

3. When the rear chainman sees that the tail end is about to reach his position, he calls "Chain!" At that time, the head chainman stops and looks back. The rear chainman holds the 100-ft mark at the starting point and checks the alignment; then signals the way the head chainman should move the chaining pin to be in line. While doing this, they are both in a kneeling position, the rear chainman facing the distant point, and the head chainman to one side facing the line so that the rear chainman has a clear view of the range pole. The head chainman, while stretching the tape with one hand, sets the pin vertically on line a short distance past the zero mark with the other hand. Then by pulling the tape taut and making sure that the tape is straight, the head chainman brings it in contact with the pin, The rear chainman, watching carefully for the 100-ft mark to be exactly on the point, calls "All right!" The head chainman relocates the pin to exactly the zero mark of the tape and places it sloping away from the line. He then pulls on the tape again to make sure that the zero mark really matches the point where the pin is stuck in the ground. Then, he calls "All right!" or "Stuck!" This is a signal to the rear chainman to release the tape so he can continue forward for the next measurement. The process is repeated until the entire distance is measured.

4. As the rear chainman moves forward, he pulls the pin from his point. Thus, there is always one pin stuck in the ground; therefore, the number of pins in his possession at any time indicates the number of 100-ft (stations) tape lengths they have measured from the starting point to the pin in the ground.

Every time the head chainman runs out of pins, he signals the rear chainman to come forward, and both of them count the pins in the rear chainman's possession. There should be 10 pins.

SUPPORTING THE TAPE.— When a full tape length is being measured, the two chainmen support the ends of the tape. The tape maybe laid on a level ground surface, such as a paved road or railroad rail, or suspended between stools or bucks set under the ends of the tape. For precise measurement, such as base line measurement, the tape is supported at midpoint or even at quarter points by bucks or stakes.

In horizontal taping over sloping or irregular terrain, one end of the tape is held on the point at ground level, while the other end is supported high enough to make the tape horizontal. As shown in figure 12-12, the rear chainman is holding a full graduation of the tape at the point near the ground, and the head chainman, holding the zero end, projects the desired distance to the point on the ground by using the plumb bob.

ALIGNING THE TAPE.— Any misalignment of the tape, either horizontally or vertically, will result in an error in the measurement. Misalignment always results in a recorded distance that is too great, or a laid offline that is too short. This is obvious, since the shortest distance between two points is a straight line. Keep the tape straight and level at all times.

APPLYING TENSION.— A tape supported or held only at the ends will hang in the shape of a curve, called a catenary, because of its own weight. Depending on the tension or pull applied at the ends, this catenary will become shallower or deeper; and the distance between the supported ends will vary considerably. To standardize this distance, you should apply a recommended "standard" tension when you are measuring. You should attach a spring balance or tension handle to one end of the tape and measure the correct standard tension. The amount of standard tension is discussed later under "Making Tape Corrections."

Maintaining a constant tension for any length of time by a hand pull is uncomfortable and can be erratic. For easier chaining, each chainman uses a pole or rod about 1/2 to 2 in. in diameter and about 6 ft long. The leather thong attached to the tension handle is wrapped around the pole at the proper height. The chainman braces the bottom end of the pole against the outside of his foot and applies tension by bracing his shoulder against the

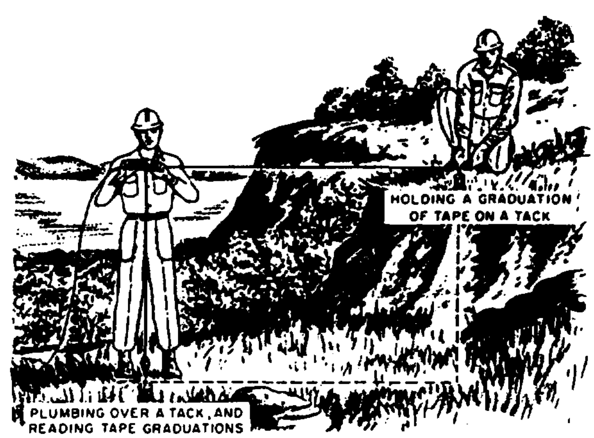


Figure 12-12.-Horizontal taping on a slope.

pole and shifting his body weight until the correct tension is read on the scale. This position can be held steadily and comfortably for a comparatively long time.

Measuring distances less than a full tape length requires the use of the clamp handle (or “scissors clamp”), which is attached to the tape at some convenient point along its length. The handle permits a firm hold on the tape and furnishes a convenient attachment for a spring balance. When properly used, the handle will prevent kinking of the tape.

READING THE TAPE.— A chain tape may be either a PLUS (or ADD) tape or a MINUS (or SUBTRACT) tape. On a plus tape, the end foot, graduated in subdivisions, is an extra foot, lying outside the 0-ft mark on the tape and graduated AWAY FROM the 0-ft mark. On a minus tape, the end foot, graduated in subdivisions, is the foot lying between the 0-ft mark and 1-ft mark and graduated AWAY FROM the 0-ft mark and TOWARD the 1-ft mark. As will be seen, this difference is significant when a distance of less than a full tape length is being measured.

Suppose that you are measuring the distance between point A and point B with a 100-ft tape, and the distance is less than 100 ft. Suppose that you are the head chainman. To start off, you and the rear chainman are both at point A. You walk away from point A with the zero-foot end of the tape. Because this is a plus tape, the tape has an extra foot beyond the zero-foot end, and this foot is subdivided in hundredths of a foot, reading from the zero.

You set the zero on point B, or plumb it over point B; then call out, “Take a foot!” When the rear chainman hears this, he pulls back the first even-foot graduation between A and B to point A, or plumbs it over point A. Let’s say this is the 34-ft graduation, The rear chainman calls out, “Thirty-four!”

You now read the subdivided end-foot graduation that is on or over point B. Let’s say it is the 0.82-ft graduation. You call out, “Point eight two!” The rear chainman rechecks the even-foot graduation on point A and calls out, “Thirty-four point eight two!” As you can see, your subdivided-foot reading is added to his even-foot reading; hence, the expression “plus” tape.

Suppose now that you are measuring the same distance between the same points, but using a “minus” tape; that is, a tape on which the subdivided end-foot lies between the zero-foot and 1-ft graduations. This time when you walk away with the zero-foot end, you set the 1-ft graduation on point B and call out, “Take a foot!” When he hears this, the rear chainman again hauls back the first even-foot graduation between A and B to point A—but this time this will be the 35-ft graduation. So the rear chainman sings out, “Thirty-five!” When you hear this, you read the subdivided-foot graduation on point B. This time this will be 0.18-ft graduation, so you call out, “Minus point one eight!” The rear chainman mentally subtracts 0.18-ft from 35.00 ft and calls out, “Thirty-four point eight two!” When you are also acting as the recorder, recheck the subtraction before you record the distance in the field notebook.

GIVING A LINE.— The range pole is set on line slightly behind the point toward which the taping will proceed. Line may be given (that is, the person with the range pole may be guided or signaled onto the line) by “eyeball” (that is, by eye-observation alignment by the rear chainman or someone else at the point from which chaining is proceeding) or by instrument.

Slope Chaining

The methods used in slope chaining are basically the same as in chaining on level ground. There are some differences, however, as follows: In slope chaining, the tape is held along the slope of the ground, the slope distance is measured, and the slope distance is converted, by computation, to horizontal distance. The slope angle is usually measured with an Abney hand level and clinometer; however, for precise measurement, it is measured with a transit.

In using the clinometer, you take the slope angle along a line parallel to the slope of the ground or along the tape that is held taut and parallel to the slope of the ground. To use the clinometer, you sight on an object that is usually a point on a pole approximately equal to your height of instrument (HI); that is, the vertical distance from the ground to the center (horizontal axis) of the sight tube. While sighting the object, you rotate the level tube about the axis of vertical arc until the cross hairs bisect the bubble as you look through the eyepiece. Then, you read either the slope angle or percentage on the vertical arc and record it along with the slope distance measurement. The horizontal distance is computed, or in other words, the tape correction is applied.

If the station points are being marked, the corrections to the slope distances are applied as the chaining progresses. These correct ions are computed either mentally, by calculator, or by using a table.

If the ground slope is fairly uniform, and if the tape corrections do not exceed 1 ft, a plus 100-ft tape is very useful to establish these station points. The head chainman determines the slope correction first, then lays off the true slope distance that gives a horizontal distance of 100 ft. If the slope is less than 2 percent, no slope correction is required. Slope corrections will be discussed later in this chapter.

Horizontal Chaining

In horizontal chaining, the tape is supported only at its ends and held in a horizontal position. Plumb bobs are used to project the end graduations of the tape (or, for a less-than-tape-length measurement, an end and an intermediate graduation) to the ground. Be very careful when you use the plumb bob both in exerting a steady pull on the tape and in determining when the tape is horizontal.

PLUMBING.— Plumbing is complete when the tape is in horizontal alignment and under the proper tension.

The rear chainman holds a plumb bob cord at the proper graduation of the tape, and the point of the plumb bob about one-eighth of an inch above the marker from which the measurement is being made. When the plumb bob is directly over the marker, he calls, “Mark!”

The head chainman holds a plumb bob cord at the correct graduation of the tape with the point of the plumb bob about 1 in. above the ground. He allows his plumb bob to come to rest; sees that the tape is horizontal; checks its alignment and tension; and when the rear chainman calls, “Mark!” allows the plumb bob to fall and stick in the ground. This spot is then marked with a chaining pin.

At times, in rough country, a small area around the point may require clearing for dropping the plumb bob. Because the clearing is usually done by kicking away small growth, this type of clearing is commonly called a KICKOUT. To determine the approximate location of the kickout, the head chainman may call, “Line for kickout!” and then “Distance for kickout!” At “Line for kickout!” the rear chainman or instrumentman gives the approximate line by eyeball. At “Distance for kickout!” the rear chainman holds approximately over the starting point without being too particular about plumbing.

LEVELING THE TAPE.— Figure 12-13 shows a pair of chainmen making a horizontal measurement on a slope. You can see that, to make the tape level, the person at the lower level is holding the end at chest level while the person at the higher level is holding it at knee level.

To maintain the tape in a horizontal position, the chainman at the lower level held the hand level. By studying the position of the other chainman, he decided that it would be possible to hold the tape at chest level. He then held the hand level at about the height of his own chest level and trained it on the other chainman. It indicated that a level line from his own chest level intersected the person of the other chainman at that person’s knee level. So he called out, “At

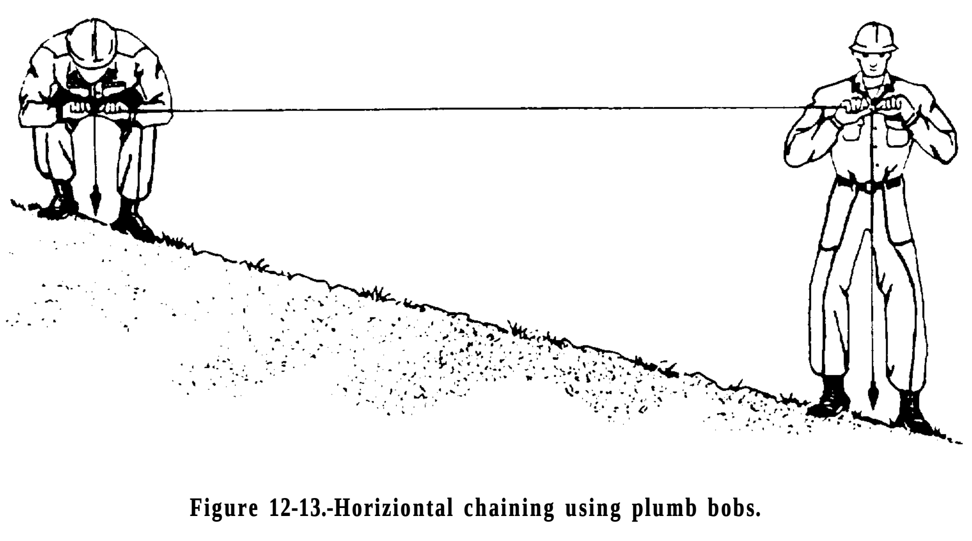


Figure 12-13.-Horiziontal chaining using plumb bobs.

your knee!" thus informing the other chainman where to hold the end of the tape.

BREAKING TAPE.— The term *breaking tape* is used to describe the procedure for measuring directly horizontal distance on sloping ground, or through obstacles that do not permit the use of a full tape length. The procedure used in breaking tape is the same as ordinary chaining on level ground, except that the distances are measured by using portions of a tape, as shown in figure 12-14.

Generally, you will start breaking tape when the slope of the existing ground exceeds 5 percent (this depends also on the height of the chainmen). The reason for breaking tape is that the chainman on the lower ground will have difficulty in holding the tape steady and horizontal when his point of support exceeds his height. You also break tape to avoid hazardous measurements, such as crossing power lines and making measurements across a heavily traveled highway.

Now, to measure the distance AB shown in figure 12-14, the chainmen may proceed as follows: The rear chainman stations himself at point A. The head chainman pulls the tape forward a full tape length uphill toward point B and drops it approximately on line with the two range poles. He then comes back along the tape until he reaches a point at which a partial tape length, held level, is below the armpits of the rear chainman at point A. At this point, the head chainman selects a convenient whole-foot graduation, and the chainmen measure off the partial tape length (distance Aa) from starting point. As shown in the figure, the head chainman must be holding at the 60-ft mark to measure Aa. Then, he calls out, "Holding sixty!" so that the rear chainman knows what graduation he is holding when the measurement is made. As in other chaining methods, the rear chainman always checks the alignment.

After the pin is placed, the rear chainman (leaving the tape lying in position) moves forward to point a and gives a pin to the head chainman who, in turn, moves to point b; to make sure that the rear chainman takes the right graduation, he calls out, "Hold Sixty!" This procedure is repeated until a full station is measured or until a full-tape length measurement can be resumed. You see that to measure distance bc, both chainmen will probably use plumb bobs to transfer the distance to the ground.

Remember that the rear chainman gives the head chainman a pin only at each INTERMEDIATE point of a tape length. He keeps the pin at full tape lengths to keep track of the number of stations laid out as in ordinary horizontal chaining.

LAYING OFF A GIVEN DISTANCE.— Frequently, a chaining party is required to lay off a given distance and establish a new point on the ground. This is measuring by using a known distance on the tape and transferring it to the ground. If the distance is greater than a tape length, then the procedure described for measuring a full tape length is followed for the

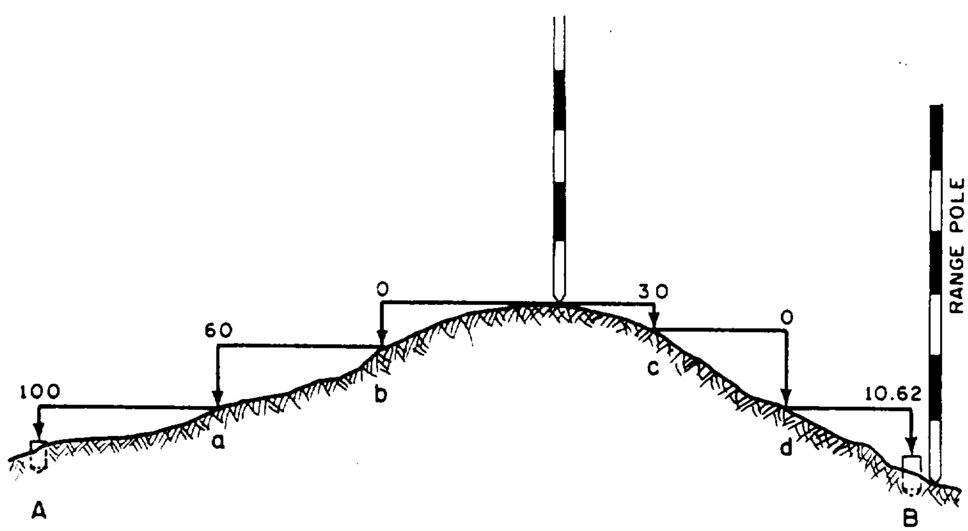


Figure 12-14.-Measuring horizontal distances by the "breaking tape" method.

required number of full tape lengths. The remaining partial tape length is then laid off by setting the rear chainman's plumb bob at the appropriate tape graduation.

Making Tape Corrections

A 100-ft tape should, in theory, indicate exactly 100.00 ft when it is in fact measuring 100.00 ft. However, a tape supported only at the ends has a sag in it, so when it indicates 100.00 ft, actually the distance measured is less. Even a tape supported throughout on a flat surface can be slightly longer under tension than it is without tension. Also, a tape will be longer when it is warm than when it is cold.

CALIBRATING A TAPE.— All tapes are graduated under controlled conditions of temperature and tension. When they are taken to the field, these conditions change. The tape, regardless of the material used to make it, will be either too short or too long. For low accuracy surveys, the amount of error is too small to be considered. As accuracy requirements increase, variations caused by the temperature and sag must be computed and used to correct the measured distance. In the higher orders of accuracy, the original graduation is checked for accuracy or calibrated at intervals against a standard distance. This standard is usually two points, a tape length apart, that have been set and marked using a more precise tape or a tape already checked. The standard may be just the precise or checked tape (known as the king or master tape). This tape is kept in a safe location and is not used for making field measurements, but only to check the accuracy of the field tapes. For the highest orders of accuracy, the tapes are sent to the National Bureau of Standards, U.S. Department of Commerce, Washington, DC, 20234, for standardization under exact conditions of tension, temperature, and points of support. A tape standardization certificate is issued for each tape, showing the amount of error under the different support conditions and the coefficient of expansion. The certificate (or a copy) is kept with each tape. For field operations, the tapes are combined in sets; one is selected as the king tape, while the others are used as field tapes.

The standard tension for a tape supported throughout is 10 lb, and the standard temperature is 68°F. Standard length is, simply, the nominal length of the tape. A 100-ft tape, for example, at a temperature of 68°F, supported throughout, and subject to a tension of 10 lb, should indicate 100 ft when it is measuring exactly 100 ft.

To CALIBRATE a 100-ft tape means to determine the exact distance it is actually measuring when it indicates 100 ft, while being supported throughout, at a temperature of 68°F and under a tension of 10 lb.

In addition to the National Bureau of Standards, many state and municipal authorities provide standardizing service.

RECOGNIZING TAPE OR STANDARD ERROR.— Suppose now that you send a 100-ft tape to the Bureau of Standards to be calibrated; the bureau will return a certificate with the tape. Assume that the certificate states that when the tape, supported throughout at a temperature of 68°F, and under a tension of 10 lb, indicates 100 ft, it actually measures 100.003 ft on the standard tape. The tape, then, has a STANDARD ERROR (also called TAPE ERROR) of 0.003 ft for every 100 ft it measures. This tape "reads short." Depending on the order of precision of the survey, you may have to apply this as a correction to measurements made with this particular tape.

CORRECTING FOR STANDARD ERROR.– Whether you add or subtract the standard error depends upon the direction of the error. The tape in the above example indicates a distance that is shorter than it actually measures; in other words, when you use this tape to lay off a distance of 100 ft, the line is actually 100.003 ft.

The decision to add or subtract the error depends upon whether you are measuring to determine the distance between two points or to set a point at a given distance from another.

Assume first that you're measuring the distance between two given points, and the distance as indicated by the tape is 362.73 ft. First, what is the total tape error? Obviously, it is 0.003 times the number of tape lengths. In this case, it is

$$0.003 \times 3.6273 = 0.0108819 \text{ ft},$$

which rounds off to 0.01 ft.

The next question is: Do you add this total correction to, or subtract it from, the recorded distance of 362.73 ft? Well, if you remember that the tape reads short, you will realize the reasonable thing to do is ADD the total standard error to the recorded distance. The correct distance between the two points, then, is 362.74 ft.

Suppose now that with the same tape, you are to set a point 362.73 ft away from another point.

Your correction here will be applied in the opposite direction. Since the tape reads short, the laid tape distance of 362.73 ft is LONGER than 362.73 ft by the amount of the total correction for standard error (0.01 ft). Therefore, you must SUBTRACT the total tape error. To lay off a distance of 362.73 ft with this tape, you would actually measure off a distance of 362.72 ft.

Suppose now that the Bureau of Standards calibration certificate states that when a tape indicates 100.00 ft under standard conditions, it is actually measuring only 99.997 ft. Again, the standard error is 0.003 ft per 100 ft, but this tape "reads long"; that is, the interval it indicates is LONGER than the interval it is actually measuring. Suppose you measure the distance between two given points with the tape and find that the tape indicates 362.73 ft. The total standard error is again 0.01 ft. Because the tape reads long, however, the distance it indicated was longer than the distance it actually measured. Therefore, the total standard error should be subtracted, and the distance between the given points should be finally recorded as 362.72 ft.

Suppose you are using this same tape to set a point 362.73 ft away from another point. Again, the total standard error is 0.01 ft. Because the tape reads long, however, a measurement of 362.73 ft by the tape will actually be LESS than 362.73 ft. Therefore, the total correction for standard error should be added, and you should measure off 362.74 ft by the tape.

CORRECTING FOR TEMPERATURE VARIATION.— Take again a 100-ft steel tape that has been calibrated at a standard temperature of 68°F. The coefficient of thermal expansion of steel is about 0.0000065 unit per 1°F. The steel tape becomes longer when its temperature is higher than the standard and shortens the same amount when it's colder. The general formula for variation in temperature correction is as follows:

$$C_t = 0.0000065L\,(T - To)$$

Where

C_t = Correction for expansion or contraction caused by variation in temperature

L = Tape calibrated length

To = Standard temperature (usually 68 °F)

T = Temperature during measurement.

From the above formula, you can deduce that the correction for a 100-ft tape is about 0.00065 ft per 1°F, which is about 0.01 ft for every 15°F change in temperature above or below the standard temperature of 68°F.

The temperature correction is applied in the same manner and direction as the standard tape error. If the tape measurement is taken at a higher temperature than standard, the tape will expand and will read short; naturally the correction should be added.

The error caused by variation in temperature is greatly reduced when an Invar tape is used.

CORRECTING FOR SAG.— Even under standard tension, a tape supported or held only at the ends will sag in the center, based on its weight per unit length. This sag will cause the recorded distance to be greater than the length being measured. When the tape is supported at its midpoint, the effect of sag in the two sections is considerably less than when the tape is supported only at its ends. As the number of equally spaced intermediate supports is increased, the distance between the end graduations will approach the length of the tape when supported throughout its length. The correction for the error caused by the sag between the two supports for any section can be determined by the following equation:

$$C_s = \frac{w^2 l^3}{24t^2}.$$

Where

C_s = correction for sag (in feet)

w = weight per unit length of the tape (in pounds per foot)

l = the length of the suspended section of tape (in feet)

t = tension applied to the tape (in pounds)

For full tape-length measurements, the correction for sag is usually taken care of by having the tape calibrated. The tape must be calibrated regardless of how it is supported and under standard temperatures and tension. To reduce the value of the horizontal correction for sag, the Bureau of Standards suggests standard tensions for tapes supported at only the ends as follows:

For 100-ft tapes, from 20 to 30 lb

For 150-ft tapes, from 25 to 30 lb

For 200-ft tapes, from 30 to 40 lb

Generally, for a heavy 100-ft tape weighing about 3 lb that was standardized, whether supported throughout or at the ends only, the systematic error per tape length caused by sag is as follows:

10-lb tension = 0.37 ft

20-lb tension = 0.09 ft

30-lb tension = 0.04 ft

For the Engineering Aid's survey work, measurements are normally in the lower order of precision. The correction for sag varies with the cube of the unsupported length; for short spans, it is often negligible.

CORRECTING FOR SLOPE.— When you take a measurement with a tape along an inclined plane (along the natural slope of the ground), obviously, the taped distance is greater than the horizontal distance. This taped distance is represented by s in figure 12-15.

The difference between the slope distance and the horizontal distance (s – d) is called the slope correction. This correction is always subtracted from the slope distance. To compute for the slope correction, you should know either the vertical angle, A, or the difference in elevation h between the taped stations.

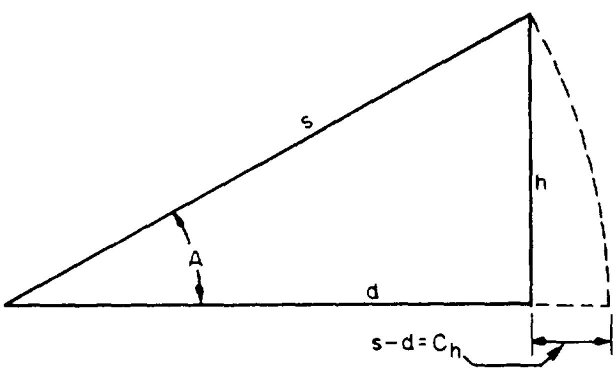


Figure 12-15.-Correction for slope distance.

When the vertical angle is used, the formula for slope correction is as follows:

$$C_h = s \text{ Vers } A.$$

Since

$$\text{Vers } A = (1 - \cos A),$$

then

$$C_h = s(1 - \cos A).$$

Where

C_h = the slope distance correction

s = the taped slope distance (usually a tape length)

A = the vertical angle

When the difference in elevation is used, the approximate formula derived by Pythagorean theorem of a right triangle (fig. 12-15) for the slope correction is as follows:

$$h^2 = s^2 - d^2$$

$$h^2 = (s + d)(s - d)$$

$$s - d = \frac{h^2}{s + d}.$$

But for a small slope, d is approximately equal to s; therefore,

$$s + d = 2s.$$

And since $C_h = s - d$ (from fig. 12-15), therefore,

$$C_h = \frac{h^2}{2s}.$$

For slopes greater than 5 percent, a closer approximation of C_h can be determined by expanding the above formula to this form.

$$C_h = \frac{h^2}{2s} + \frac{h^4}{8s^3}.$$

Preparing Chaining Notes

Before discussing the subject of chaining notes, we will mention a few general principles applicable to all types of field notes. It goes without saying that it is essential that measurements and other data be accurately recorded and that any additional information required to identify and clarify the data be included.

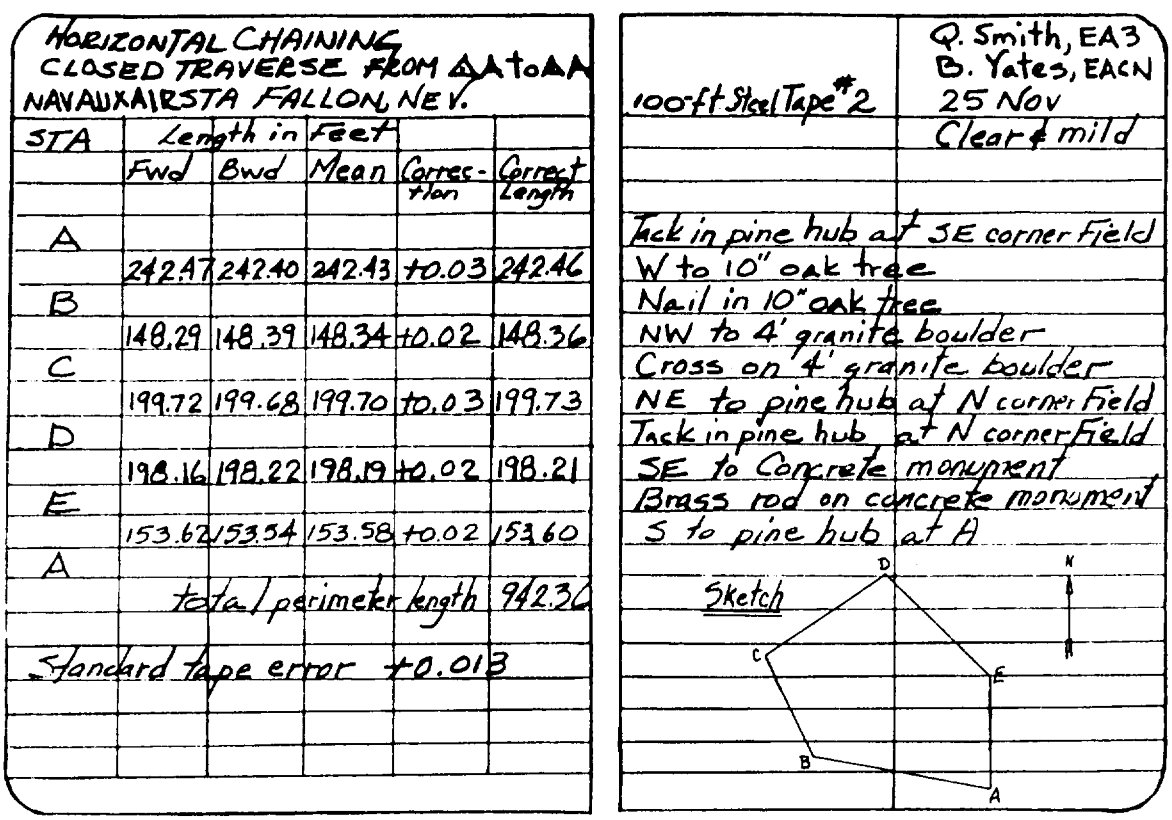
Field notes are required to be legible as well as accurate. If you don't write or print legibly, you will have to improve your script. All notes should be recorded in pencil; a 3H or 4H pencil is best for the job. A pencil that is too soft blunts too quickly; one that is too hard makes a faint mark and scores the paper. In the field, you need to carry a pocketknife or pocket pencil sharpener to keep your pencil sharpened or pointed.

There is a general rule to the effect that erasures are not permitted in field notes. Suppose that in the course of chaining several intervals you make a 10-ft "bust" in one of the intervals by misreading 10 ft as 20 ft. After you total up the distance, some circumstance leads you to suspect that the total is off. You recheck the work and discover where you made the bust. The notebook record for that interval must be changed. You make the change by crossing out the wrong entries and entering the correct ones above them—not by erasing the wrong entries.

RECORDING NOTES FOR HORIZONTAL CHAINING.— A typical example of a horizontal chaining conducted for a closed traverse is shown in figure 12-16. The chaining party started at station A and chained around by way of B, C, and so on. Arriving back at A, the party reversed its direction and chained back around by way of E, D, C, and so on, as a check. The distance finally recorded for each traverse line was the mean (average) between the forward measurement and the backward measurement.

Note on the bottom left-hand side the fact that the tape had a standard error of 0.013 ft per 100 ft of tape. The error is marked " + ," meaning that the amount of error should be added to the measurement as indicated by the tape. Obviously, the tape was reading short.

The corrections in the "Correction" column indicate that only correction for standard error



HORIZONTAL CHAINING
CLOSED TRAVERSE FROM △A to △A
NAVAUXAIRSTA FALLON, NEV.

STA	Length in Feet Fwd	Bwd	Mean	Correction	Correct Length
A					
	242.47	242.40	242.43	+0.03	242.46
B					
	148.29	148.39	148.34	+0.02	148.36
C					
	199.72	199.68	199.70	+0.03	199.73
D					
	198.16	198.22	198.19	+0.02	198.21
E					
	153.62	153.54	153.58	+0.02	153.60
A					
	total perimeter length				942.36

Standard tape error +0.013

Q. Smith, EA3
B. Yates, EACN
100-ft Steel Tape #2 | 25 Nov
Clear & mild

Tack in pine hub at SE corner Field
W to 10" oak tree
Nail in 10" oak tree
NW to 4' granite boulder
Cross on 4' granite boulder
NE to pine hub at N corner Field
Tack in pine hub at N corner Field
SE to Concrete monument
Brass rod on concrete monument
S to pine hub at A

Figure 12-16.-Notes for horizontal chaining.

was made. If corrections for temperature and sag had been made as well, the algebraic sum of all three would have been entered in the correction column, or additional columns for temperature and sag correction would appear.

The symbol for each station is listed in the first column on the data page. Opposite, on the remarks page, a description of the station is recorded.

In the second and third columns on the data page, the measured forward and backward distances between adjacent stations are recorded. The average distance is recorded in the fourth column. In the fifth column, the standard error of 0.013 ft per 100 ft of tape is computed for each mean measurement. In the sixth column, the result of this error, added to the mean measurement, appears as the "Corrected Length." The sum of the corrected lengths appears below as "total length perimeter."

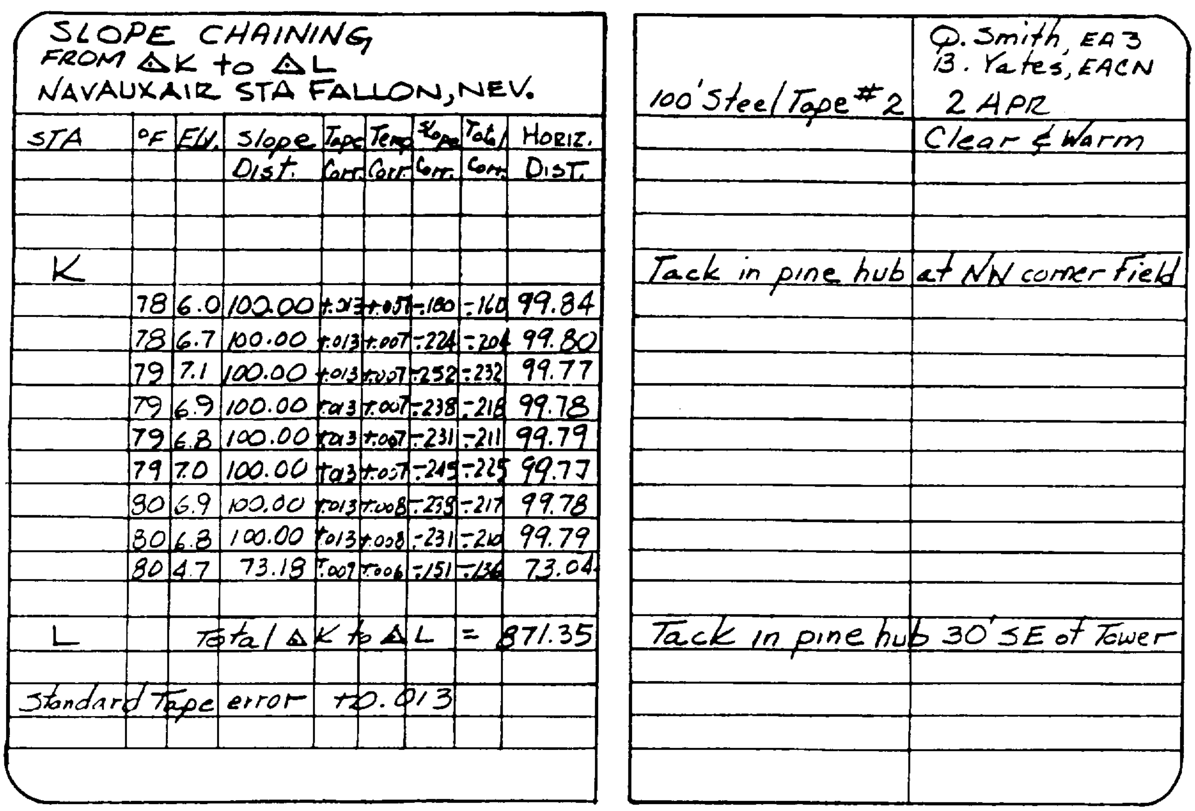
RECORDING NOTES FOR SLOPE CHAINING.— Figure 12-17 shows an example of slope chaining notes. Notice that on the data page, extra columns have been assigned for the temperature of the tape at each interval, the difference in elevation between supports, and the slope distance.

Under "Tape Corr." in the fifth column, the standard error for each interval is entered. Again, the tape had a standard error of 0.013 ft per 100 ft; therefore, the standard error for each interval except the last is 0.013 ft. For the last interval of 73.18 ft, the error works out as 0.009 ft.

If you will look to the right of the "Tape Corr." column, you will see the "Temp. Corr." column. For the first two intervals measured, the temperature of the tape was 78°F, or 10°F above standard. The correction amounts to 0.01 ft for each 15°F above standard; therefore, the total temperature correction for each of these intervals equals the value of x in the equation

$$\frac{0.01}{15} = \frac{x}{10}.$$

The total temperature correction is 0.007 ft. Because the temperature was above standard, the tape lengthened and was reading short. So the



SLOPE CHAINING
FROM △K to △L
NAVAUXAIR STA FALLON, NEV.

STA	°F	El.	Slope Dist.	Tape Corr.	Temp Corr.	Slope Corr.	Total Corr.	Horiz. Dist.
K								
	78	6.0	100.00	+.013	+.007	-.180	-.160	99.84
	78	6.7	100.00	+.013	+.007	-.224	-.204	99.80
	79	7.1	100.00	+.013	+.007	-.252	-.232	99.77
	79	6.9	100.00	+.013	+.007	-.238	-.218	99.78
	79	6.8	100.00	+.013	+.007	-.231	-.211	99.79
	79	7.0	100.00	+.013	+.007	-.245	-.225	99.77
	80	6.9	100.00	+.013	+.008	-.238	-.217	99.78
	80	6.8	100.00	+.013	+.008	-.231	-.210	99.79
	80	4.7	73.18	+.009	+.006	-.151	-.136	73.04
L		Total △K to △L					=	871.35
Standard Tape error				±0.013				

	Q. Smith, EA3 B. Yates, EACN
100' Steel Tape #2	2 APR
	Clear & Warm
Tack in pine hub	at NW corner Field
Tack in pine hub	30' SE of Tower

Figure 12-17.-Notes for slope chaining.

corrections should be added as indicated by the plus signs.

To the right of the “Temp. Corr.” column is the “Slope Corr.” column. Its entries are to be subtracted as indicated. Use the following equation to compute the slope correction.

$$C_h = \frac{h^2}{2s}.$$

For the first taped interval, we have an h of 6.0 ft and an s of 100 ft.

Therefore

$$h^2 = 6.0^2 = 36.0 \text{ ft and}$$

$$2s = 2 \times 100 = 200 \text{ ft.}$$

The slope correction is computed as follows:

$$\frac{36.00}{200.00} = 0.180 \text{ ft.}$$

Next to the column for slope correction comes the “Total Corr.” column, containing the algebraic sum of the three corrections for each taped interval. Finally, in the “Horiz. Dist.” column, each value is determined by subtracting the total correction for each interval from the measured slope distance for that interval. (This example used in figure 12-17 happens to be all negative.) At the bottom of this column, the sum of the horizontal distances appears. This is the horizontal distance from station K to station L.

Solving Surveying Problems by Tape

Before the modern instruments used to measure angles directly in the field were devised, the tape (or rather, its equivalent, the Gunter’s chain) was often used. This tape was used not only for measuring linear distances but also for measuring angles more accurately than was possible with a compass.

LAYING OUT A RIGHT ANGLE.— In laying out a right angle (or erecting a perpendicular) by tape, you apply the basic trigonometric theory that a triangle with sides in the ratio of 3:4:5 is always a right triangle.

Assume that on the line AB shown in figure 12-18, you want to use a 100-ft tape to run a line from C perpendicular to AB. If a triangle with sides in the ratio of 3:4:5 is a right triangle, then one with sides in the ratio of 30:40:50 is also a right triangle. From C, measure off DC, 30 ft long. Set the zero-foot end of the tape on D and the 100-ft end on C. Have a person hold the 50-ft and 60-ft marks on the tape together and run out the bight. When the tape becomes taut, the 40-ft length from C will be perpendicular to AB.

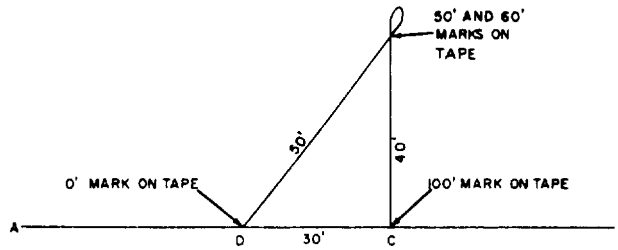


Figure 12-18.-Laying out a right angle using a 100-foot tape.

MEASURING AN ANGLE BY TAPE.— There are two methods commonly used to determine the size of an angle by tape: the CHORD method and the TANGENT method.

The chord method can be applied, using the example shown in figure 12-19. Suppose you want to determine the size of angle A. Measure off equal distances from A (80.0 ft), and establish points B and C. Measure BC; assume that it measures 39.5 ft, as shown. You can now determine the size of angle A by applying the following equation:

$$1 - \cos A = \frac{2(s - b)(s - c)}{bc}$$

in which

$$s = 1/2(a + b + c) = 99.7 \text{ ft.}$$

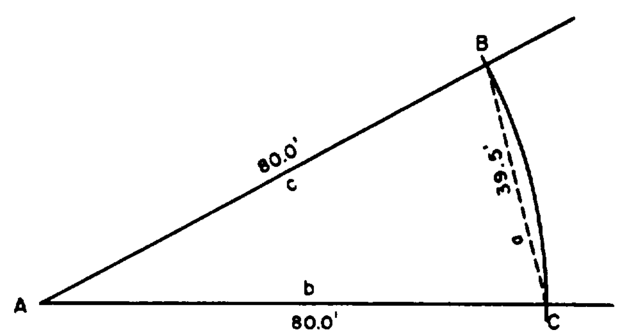


Figure 12-19.-Determining the size of an angle by the chord method.

First, solving for

$$1 - \cos A$$

we have

$$1 - \cos A = \frac{2(19.7)(19.7)}{6400} = \frac{776.2}{6400} = 0.12128.$$

Since

$$1 - \cos A = 0.12128$$

$$\cos A = 1.00000 - 0.12128 = 0.87872.$$

Reference to a table of natural functions shows that the angle with cos equal to 0.87872 measures, to the nearest 1 min., 28°29′.

The intervals measured off from A were made equal for mere convenience. The solution will work just as well for unequal intervals.

In determining the size of an angle by the tangent method, you simply lay off a right triangle and solve for angle A by the common tangent solution.

Suppose that in figure 12-20, you want to determine the size of angle A. Measure off AC a convenient length (say, 80.0 ft). Lay off CB perpendicular to AC and measure it; say it measures 54.5 ft, as shown. The angle is computed by using the following formula:

$$\tan A = \frac{54.5}{80.0} = 0.68125.$$

The angle with tangent 0.68125 measures 34°18′.

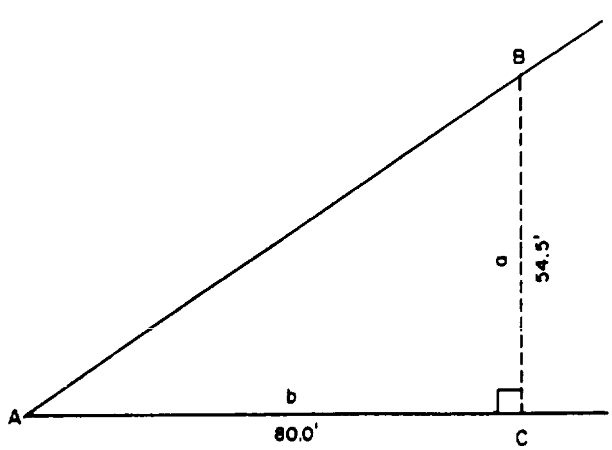


Figure 12-20.-Determining the size of an angle by the tangent method.

LAYING OFF AN ANGLE OF A GIVEN SIZE.— An angle of a given size can be laid off by tape by applying the tangent right triangle solution. Suppose that in figure 12-21, you want to lay off a line AC from A, 25° from line AB,

Again measure off a convenient 80.0 ft from A to establish point B. Erect a perpendicular from B as shown by the dotted line. You want to measure off along this perpendicular side a (opposite side), the distance that, when divided by the adjacent side, will give the value of the natural tangent of 25°. Use the following formula:

$$\tan 25° = \frac{a}{80.0}$$

$$a = 80.0 \tan 25°.$$

The tangent of 25° is 0.46631, so

$$a = 80.0 \times 0.46631 = 37.3 \text{ ft}.$$

Measure off 37.3 ft from B to establish point C. A line from A through C will form an angle of 25° from AB.

Identifying Chaining Mistakes and Errors

In surveying, distinctions are made between ERRORS and MISTAKES. Errors are caused by factors such as the effects of nature, the physical condition of the personnel performing the survey, and the condition of your instruments. Mistakes, however, are simply human blunders. While errors may be compensated for, mistakes can be detected, correct, and better yet, prevented only by the exercise of care.

COMMON MISTAKES.— Mistakes may result from poor work habits, lack of judgment, or confusion. They are often costly, time consuming, and difficult to detect. The easiest way to avoid them is to establish a definite procedure and follow it, being constantly alert during the

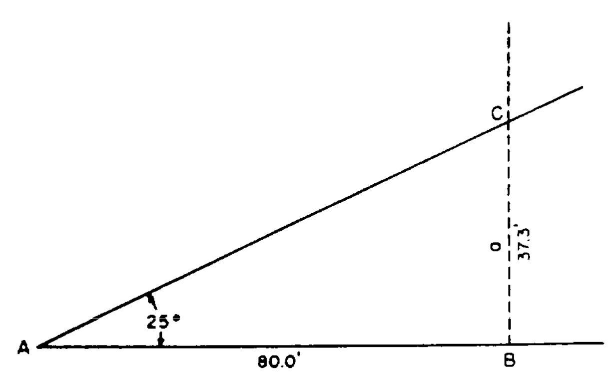


Figure 12-21.-Laying off an angle of a given size.

operations in which mistakes are possible. Some of the more common mistakes are as follows:

- Failing to hold graduations plumb over points

- Involuntarily transposing figures, such as recording 48.26 for 48.62

- Misreading figures that are viewed upside down, such as recording an upside-down 9 as a 6

- Reading a subdivided end-foot from the wrong end, as, for example, 0.28 ft instead of 0.22 ft

- Associating subdivided end-foot reading with wrong whole-foot mark, as 38.21 ft instead of 37.21 ft

- Subtracting incorrectly when using a minus tape

- Omitting an entire tape length

RECOGNIZING COMMON ERRORS.— There are two types of errors: accidental and systematic.

An accidental error is, generally speaking, one that may have a varying value. Examples are as follows: variation of the tension applied to the tape, inaccurate sticking of pins or other markings, and inaccurate determination of slope. Accidental errors can be minimized by carefulness, but not entirely eliminated.

A systematic error has a constant value. The standard error in a tape, for example, is a systematic error. Temperature and sag corrections are applied to correct systematic errors. Systematic errors can be compensated for or otherwise eliminated by the application of corrections.

Caring for and Maintaining a Survey Tape

If a steel or metallic tape gets a kink in it, it is then subjected to strain. The tape at best will be distorted at the point where the kink lies. At worst, if the strain is strong enough, the tape will break at the point where the kink lies. Kinks, therefore, are to be avoided at all costs; it is especially important to avoid putting a strain on a tape with a kink in it.

Under favorable circumstances, when a tape is shifted ahead, the head chainman may simply drag it over the ground. It is not a good idea for the rear chainman to assist by dragging that end because this develops a curve in the tape. This curve may snag on an obstruction and also may be the cause of a kink. When a tape is being dragged, the rear chainman should simply allow the end to trail along. The cardinal rule is "keep, the tape straight."

When taping in traffic, you plan your moves in advance and make the measurement as fast as possible. If possible, do not let vehicles run over the tape; however, if this is absolutely unavoidable, be sure the tape is laid flat and taut on the road. NEVER let a vehicle run over a tape laid on a soft or rugged ground surface.

Tapes are made as corrosion-resistant as possible, but no steel tape is entirely immune to corrosion, especially when used around salty water. Therefore, a tape should always be wiped dry before it is put away, and it should be oiled periodically with a light, rust-resistant oil. If a tape does rust, rubbing it with light steel wool dipped in a rust-removing compound is the best and safest way to remove the rust. Tapes, especially those in reels, though not used during the week, should be removed from the reel and inspected each week for signs of corrosion. A damp climate in your area of operations could easily start corrosion in tapes.

Splicing a Tape

In spite of being carefully handled, tapes sometimes break. A broken tape is rejoined by splicing. A relatively light tape can be repaired with a punch-and-rivet tape splicer and repair stock (fig. 12-22). A repair stock consists of a

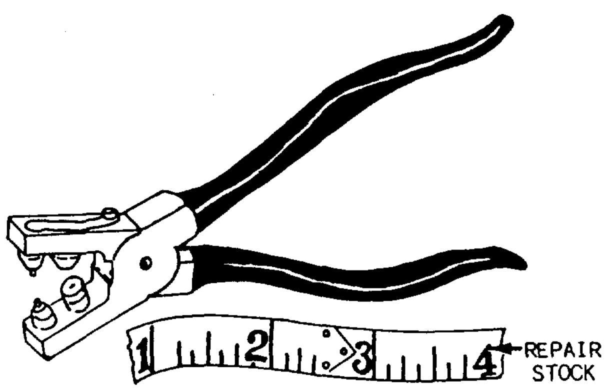


Figure 12-22.-A punch-and-rivet tape splicer with repair stock.

length of tape of the same thickness and width as that of the broken tape. When a tape is repaired, it is best to use a good section of the tape for calibration (matching a whole-foot mark). Place the section used for calibrating beside the broken section to make sure that you will maintain the original length of the tape after rejoining it.

In splicing a broken tape, first align and rivet the repair stock at one end of the break. Next, place the repair stock on the face of the other section of the tape by using the calibrating section as a measure for the break splice. Insert one rivet at a time and arrange rivets in a triangular pattern. Do not place rivets closer together than one-fourth in. from center to center. Now use a three-edge file. File partially through the surplus stock diagonally across the tape. The segment of the surplus will readily break off, leaving a clean splice.

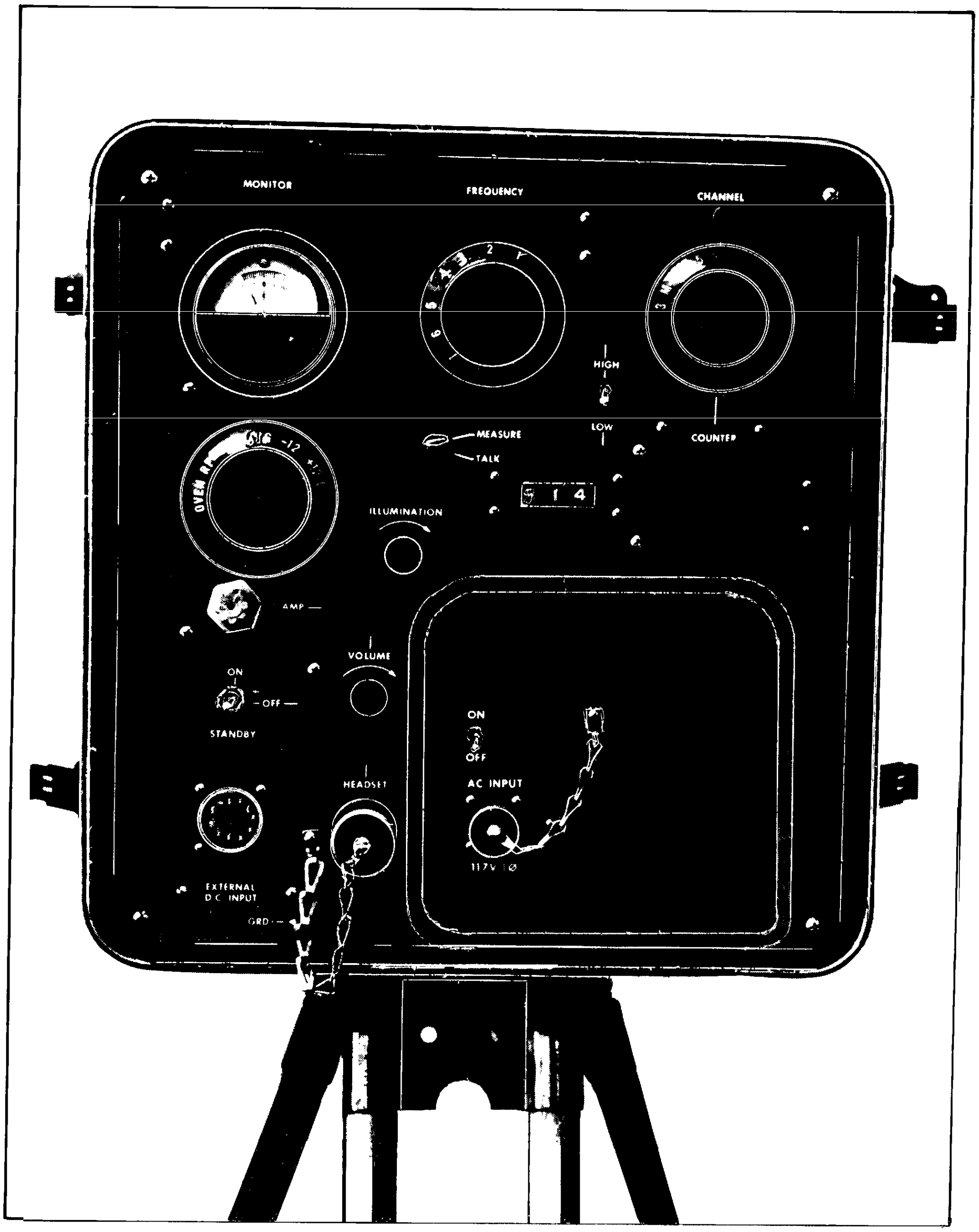


Figure 12-23.—A microwave distance-measuring device (Model 99).

Heavy steel tapes are repaired in a similar manner, using the tape repair kit shown in chapter 11, figure 11-55.

MEASURING BY THE ELECTRONIC DISTANCE-MEASURING SYSTEM

The electronic distance-measuring system is now incorporated in various present-day surveying practices, including traverse and triangulation network. In traverse measurements, accurate distances are directly measured in a straight line and with minimum instrument setups. In triangulation, the system is used to conduct base line measurements that are precise enough to maintain the accuracy of the survey.

In the electronic distance-measuring system, the length of a linear interval is determined by the use of equipment that (1) sends out an electronic impulse of some sort, such as a radar microwave or a modulated light wave, and (2) measures the time required for the impulse to travel the length of the interval. The velocity or rate of travel of the impulse is known. Therefore, once the time is also known, the length of the linear interval can be determined by applying the well-known equation "distance = rate x time."

Two types of electronic distance-measuring devices (also called EDMs) commonly used today are the MICROWAVE DEVICES and the LIGHT WAVE DEVICES.

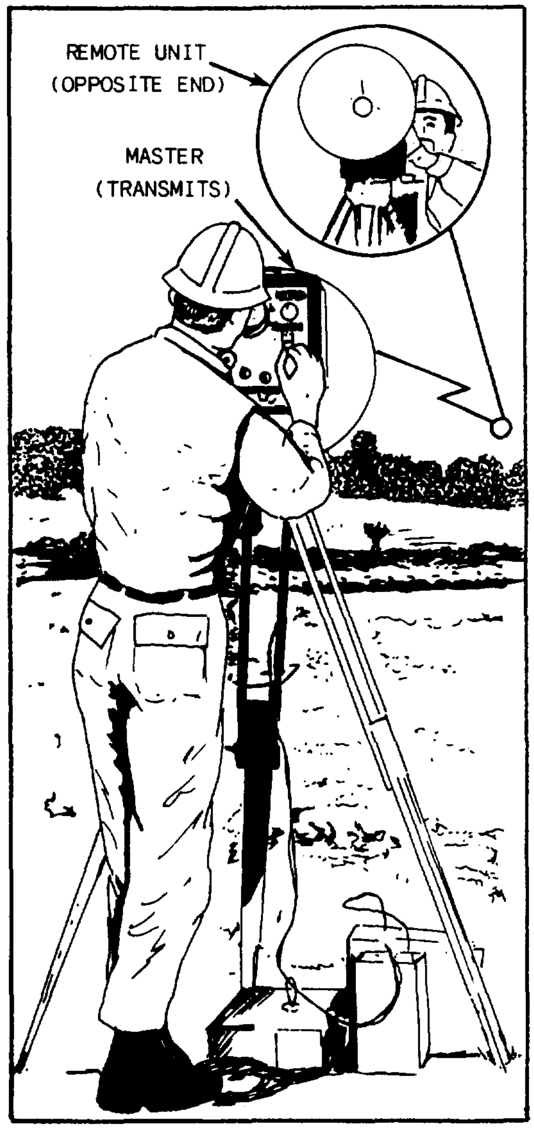


Figure 12-24.-Setting a microwave distance-measuring unit.

Measuring by Microwave Devices

The microwave distance-measuring device (fig. 12-23) is an electronic instrument that transmits precisely controlled RADIO WAVES between two units. The waves are compared and electronically changed into a visually readable form from which the distance between the units can be computed.

As shown in figure 12-24, the unit that originates and transmits the modulated radio waves is called the master. The unit at the opposite end of the line from the master is known as the remote. The two are identical instruments, each being adaptable to use as either master or remote. At the remote unit, the original transmission is received, interpreted, and put on a new carrier. This new modulation is amplified and retransmitted to the master. The master analyzes the new transmission and translates it into a trace on a cathode ray tube that can be read visually. The trace information is converted into a distance based on the velocity of the radio waves. Because this velocity is affected by atmospheric conditions, corrections for temperature and barometric pressure are applied according to instructions.

Each instrument is equipped with a shortwave telephone set. By this means, the person at each instrument can maintain communication with the other. Details of the method of operating the system must be learned from the manufacturer's instructions.

Measuring by Light Wave Devices

The light wave measuring device (fig. 12-25) uses electro-optical instruments to measure distances accurately. The device consists basically of two units: the measuring unit (transmitter/receiver) and the reflector unit (fig. 12-26). The distance is measured by precise electronic timing of a modulated LIGHT WAVE after it travels to, and when it returns from, a reflector at the other end of a course (fig. 12-27). When the instrument receives the reflected light flash, it registers readings that can be converted into the linear distance between the instrument and the reflector (with corrections made for atmospheric conditions).

Like their microwave counterparts, the light wave distance-measuring devices are capable of first order base lines in triangulation and all orders of traverse distance measurements. Most of these instruments have a rated range of 200 to 50,000 meters.

These instruments, as all delicate scientific equipment, are to be treated with proper care and operator maintenance so that they may continue to be available for use. Refer to the instrument manufacturer's manual for instructions on basic operation, care, adjustments, calibrations, and other details of the system.

FIELD PARTY SAFETY

A surveying field party is frequently working its way through rugged terrain a long distance away from any professional medical assistance. Working through brush, felling trees, scaling bluffs, and crossing streams are all hazardous. Also, the use of such sharp-edged tools as machetes, brush hooks, axes, and hatchets is equally hazardous. Besides those dangers that are inherent in the work itself, a party may be exposed to a variety of natural dangers, such as those created by weather conditions, by reptiles, by insects, and by poisonous plants. Occasionally, in some areas, there may be dangerous wild animals or even dangerous domestic animals, such as vicious dogs or angry bulls. When a party is working along a thoroughfare on which vehicular

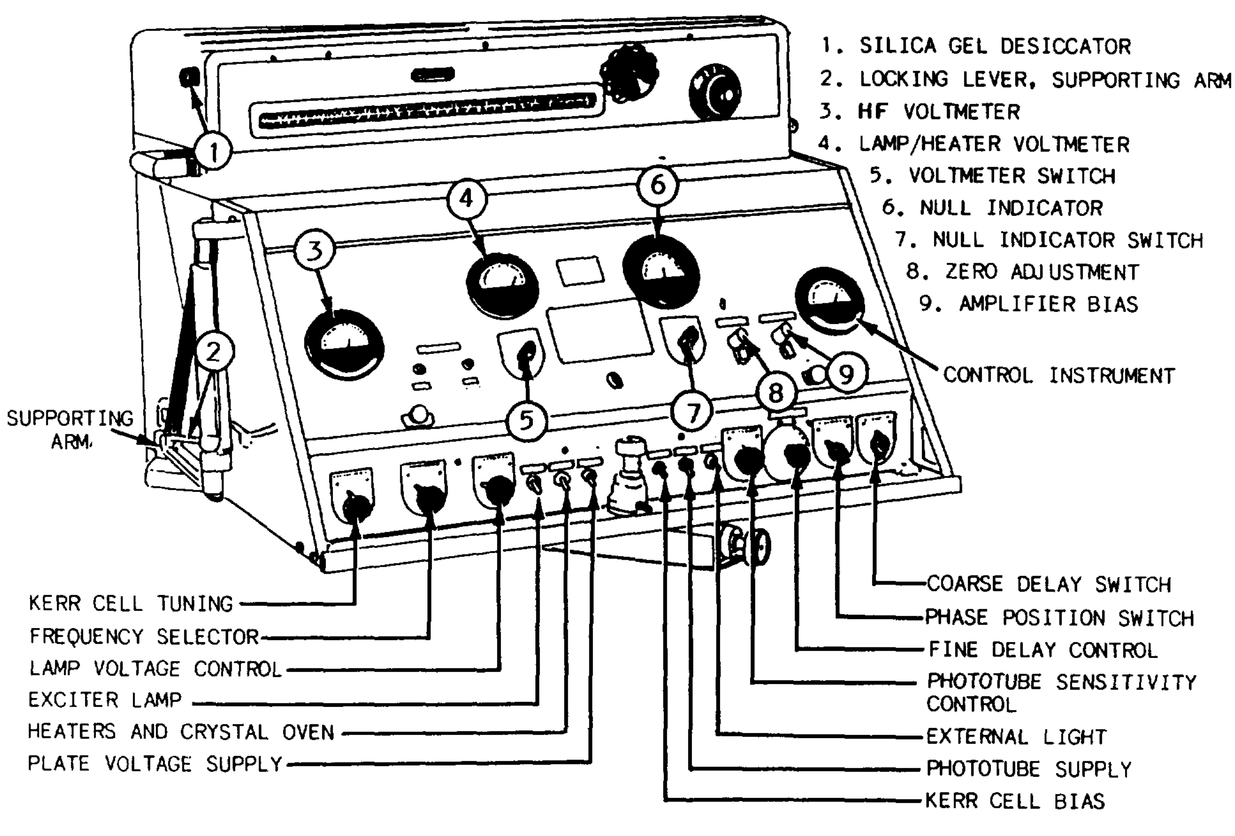


Figure 12-25.-A light wave distance-measuring device (Geodimeter, Model 2A).

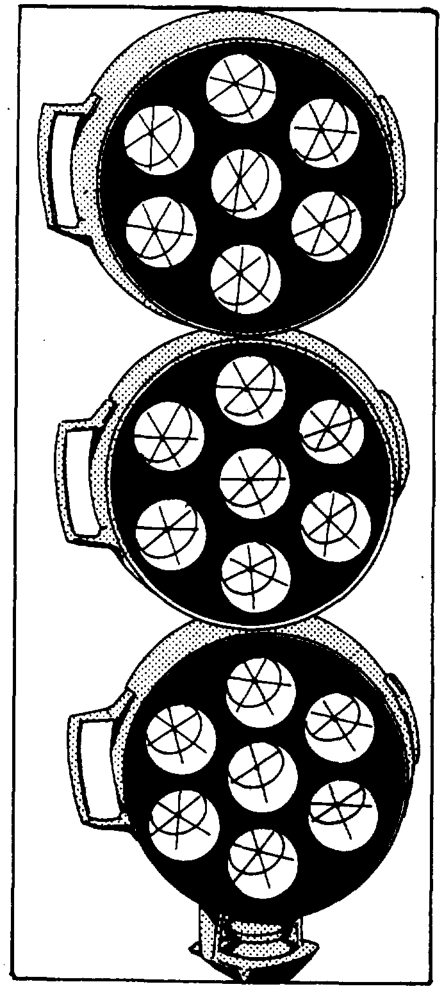


Figure 12-26.-Light wave reflector units, stacked.

traffic is proceeding as usual, there is the ever-present idanger of being hit by a vehicle.

In the midst of such a variety of constant dangers, the only way to prevent injury is by the exercise of continual care and vigilance. Every person in a party must be aware of all existing hazards, be able to recognize a hazardous situation, and be trained to take the correct preventive measures.

Indeed, it is common practice for surveying field crews to prepare a CHECKLIST of essential items, personal protective equipment, communication gear, and other miscellaneous items relative to their line of work.

ADMINISTERING FIRST AID

If personal injuries do occur, it is essential that the injuries be taken care of to the extent possible by the application of first aid. The *Standard First Aid Training Course,* NAVEDTRA 10081 (latest revision), defines first aid as "the emergency care given sick or injured persons until regular medical or surgical aid can be obtained." Your principal source of information on first aid is the *Standard First Aid Training Course.*

Every person in a field party should be able to administer first aid, regardless of how junior in rate and experience each person may be. A chaining party may consist of only two persons, one of whom may be very junior in rate and time in service. Since the party chief may be the one injured, the junior member of the party would be responsible for administering first aid.

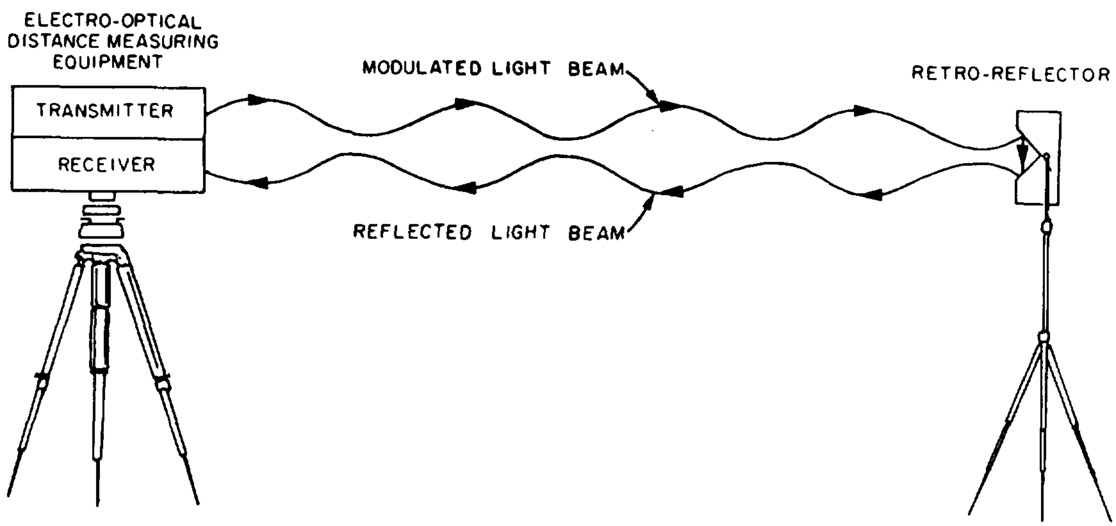


Figure 12-27.-Typical configuration of a light wave distance-measuring device.

As a rule, field crew members should be familiar with the telephone number and location of the nearest hospital or dispensary their party will be operating, should have a transport vehicle available and ready, and should have valid government vehicle operator's licenses. In addition, a first-aid kit should be kept handy at all times.

PROTECTING AGAINST WEATHER HAZARDS

For all weather hazards, the best preventive measure is the wearing of adequate protective clothing. When the weather is cold enough to cause frostbite, wear a hat that covers your ears, gloves or mittens for your hands, and cold-weather footgear for your feet. These are the primary areas most subject to frostbite. Wear a hat also when there is danger of heatstroke. Unless or until you are immune to sunburn (by tanning), keep your skin covered against the sun. Fair-haired or sandy-haired individuals, even when they tan, may be susceptible to a form of skin cancer caused by exposure to sunlight. If you are in this category, you should keep the skin covered whether you "tan" or not.

Two very common weather hazards, frostbite and heatstroke (commonly called sunstroke), are fully covered in the *Standard First Aid Training Course*. Lesser weather hazards, such as the exposure caused by wearing insufficient clothing in cold or wet weather and the possibility of a bad sunburn in hot weather, are not mentioned.

In general, when you set forth with a field party, wear or carry with you clothing that will provide adequate protection against the weather—not just as it is at the time you set forth, but as it may possibly develop before you get back.

RECOGNIZING AND AVOIDING POISONOUS REPTILES AND INSECTS

As a general rule, it is best to assume that all reptiles of the snake family found in the United States and overseas and that all insects you can't recognize as poisonous MAY BE poisonous.

The poisonous snakes of the North American continent belong to the viper family. The distinguishing characteristics of a viper area flat head and a thick body. The most common North American viper is the RATTLESNAKE. All rattlesnakes are distinguishable by a row of hard rings, called rattles, on the tail. The snake makes a hissing sound with them when it is angry or alarmed. The banded, or timber, rattler of the northeastern United States is smooth, silver gray in color. The diamondback rattler of the United States Deep South is silver gray with a diamond-shaped pattern on the skin. The western diamond-back rattler has the same diamond pattern, but is a copper color. The red rattler of southern California is a deeper copper color.

Besides the rattlesnake, the most common North American poisonous snake is the WATER MOCCASIN, sometimes called the cottonmouth because of a white mouth lining that the snake exposes when preparing to strike. The skin of the water moccasin is dark brown with black bars on the upper side and black blotched with yellowish white on the under side.

The reddish brown COPPERHEAD has no rattles. This viper is found especially in uplands of the eastern Unites States.

The most common poisonous insects encountered in North America are the BLACK WIDOW SPIDER, the TARANTULA, and the SCORPION. The black widow (which may be encountered anywhere in the United States) is recognizable by its small, shiny black body. The tarantula is a long-legged, hairy member of the spider family, found chiefly in and close to Texas. The scorpion, found mainly in the semitropical parts of the United States, resembles a lobster or crawfish in shape.

The symptoms that develop from the bite of each of the reptiles and insects mentioned, together with the appropriate first aid, are thoroughly described in the *Standard First Aid Training Course*, NAVEDTRA 10081 (latest edition).

AVOIDING OR TREATING POISONING FROM POISONOUS PLANTS

The *Standard First Aid Training Course* contains an extensive section on a variety of poisons. However, it does not mention a type of poisoning to which survey parties are particularly exposed—poisoning resulting from contact with poisonous plants. Poisoning of this kind is not likely to be fatal (although it can be, under certain circumstances), but it can cause you a lot of misery and considerable reduction in on-the-job efficiency.

The most common poisonous plants in the United States are POISON IVY (including a variety called poison oak) and POISON SUMAC, both of which occur everywhere in North America. These plants contain and exude a resinous juice that produces a severe reaction when it comes into contact with the skin of the average person. The first symptom of itching or a burning sensation may develop in a few hours or even after 5 days or more. The delay in the development of symptoms is often confusing when an attempt is made to determine the time or location where the contact with the plant occurred. The itching sensation and subsequent inflammation that usually develops into watery blisters under the skin may continue for several days from a single contamination. Persistence of symptoms over a long period is most likely caused by new contacts with plants or by contact with previously contaminated clothing or animals.

Severe infection may produce more serious symptoms that result in much pain through abscesses, enlarged glands, fever, or other complications. Secondary infections are always a possibility in any break in the skin that occurs when the watery blisters break.

With poison ivy, the next development is usually the appearance of a scabrous, deep red rash over large skin areas. With poison, sumac, it is usually the appearance of large blisters, filled with a thick yellowish white liquid strongly resembling pus. When the blisters break, this liquid runs over adjacent skin areas and, thus, enlarges the area of infection.

The resinous juice exuded by these poisonous plants is almost entirely nonvolatile; that is, nonevaporating or will not dry up. Consequently, the juice may be carried on clothing, shoes, tools, or soil for long periods. In this way, it may infect persons who have actually not come into contact with the plants themselves. Individuals have, in fact, been severely infected by juice carried through air by smoke from burning plants. Other persons have been infected by resinous juice being carried on the fur of animals.

Figure 12-29.-Poison oak (leaves and fruit).

To avoid contact with the plants themselves, you must have an idea of what they look like. Poison ivy has a trefoil (three leaflet) leaf, as shown in figure 12-28. The upper surface of the leaflet has a shiny, varnished appearance. The variety called poison oak has a leaflet with a serrated, or lobed, edge like that of an oak leaf, as shown in figure 12-29. Ordinary poison ivy is

Figure 12-28.-Different varieties of poison ivy leaves.

usually a vine; poison oak, usually a bush. In the flowering season, both types produce clusters of small white berries.

Different varieties of poisonous sumac leaves are shown in figure 12-30. There are poisonous sumacs and harmless sumacs, and it is difficult to distinguish the leaf of one from the leaf of the other. The only way to tell the poisonous plant from the harmless one is by the fruit. Both plants produce a drooping fruit cluster. The difference lies in the color of their fruits—that of the harmless sumac is RED; that of the poison sumac is WHITE. In other than the fruit season, it would be better to avoid contact with all sumacs.

There are no "do-it-yourself" remedies for plant poisoning; treatment must be by, or as directed by, professional medical personnel. However, if you have reason to believe that you have been infected, you should wash thoroughly with water and an alkaline laundry soap. Do not use an oily soap (most facial soaps are oily) because this will tend to spread the juice. Lather profusely, and do not rinse the lather off, but allow it to dry on the skin. Repeat this procedure every 3 to 4 hours, allowing the lather to dry each time.

If job conditions make contact with plants unavoidable, wear gloves and long sleeve shirts and keep all other skin areas covered. When you remove your clothing, take care not to allow any skin area to come into contact with exposed clothing. Launder all clothing at once.

USING FIELD EQUIPMENT SAFELY

The standard source of information on the safe use of dangerous field equipment and other safety precautions is *Safety Precautions for Shore Activities*, NAVMAT P-5100. A copy of this publication should be available in your technical library.

Since tools are a potential source of danger in all occupations, they should be inspected periodically to find out whether any repairs or replacements are needed. Only tools in good condition should be used. There should be no loose heads on any hand tools. Sharp-edged tools should be kept sharp. All tools should be stored safely when not being used.

If tools with sharp blades or points are laid down on the job temporarily, they should be placed in such a way that no injury can result to anyone. Sheaths or guards are desirable when sharp-edged or pointed tools are being carried from one place to another. If sheaths are not available, carry a tool with the sharp edge or point

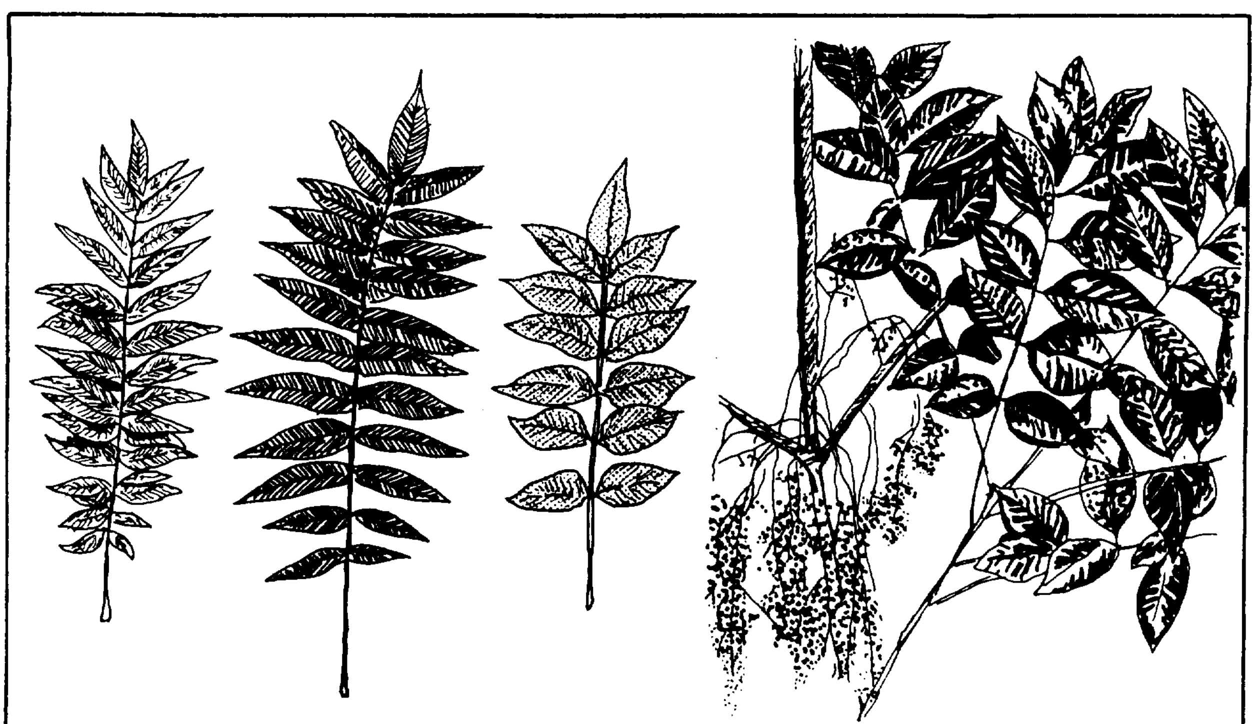


Figure 12-30.-Varieties of sumac leaves.

away from your body and take care that you do not injure others with it.

When working near other people, carry your range poles or level rods vertically against your body so that another person's head or eyes will not be injured if you turn suddenly. Do not hold a stake or bull-point with your hand around the shank while another person is driving it with a sledgehammer. Do not let a tape or plumb bob cord slide fast through your hands.

Always use tools correctly and for the purpose for which they are intended. For example, when cutting brush near the ground with a machete, swing it away from your legs and feet. Never cut at short range from your body. Be sure that the radius of your swing is clear of obstructions, such as vines or twigs, that might deflect the intended direction of the swing. Use your full arm's length to get a safe-swing radius. Always work at least 10 ft away from the nearest person. If it is necessary to use an ax to clear an area, you can prevent painful blisters by wearing a pair of thin gloves. Above all, use common sense and consider the possible results of your actions.

To climb poles and trees safely, it is best to use authorized climbing equipment. A lineman's pole climbers are made of steel and have a strap loop and short spur. Tree climbers have straps, pads for protection against friction, and a longer spur for penetrating bark. To avoid falling, use both belt and straps. Except in an emergency, never work in or on trees during a high wind. Watch out for power lines that may be in contact with the tree you are climbing.

Burning operations should always be conducted in the clear, where the fire will not ignite tree leaves or limbs, dry wooded areas, or nearby buildings. Remember that it is imperative that all burning or smoldering material be completely extinguished before it is left unattended.

When practicable, use only nonflammable solvents for cleaning instruments. Do not leave the caps off or the stoppers out of flammable liquid containers. Use solvents only in a well-ventilated location.

All of the above could be boiled down to this: **ALWAYS USE GOOD JUDGMENT AND COMMON SENSE.**

FOLLOWING SAFETY PROCEDURES IN TRAFFIC

A party working on a highway where vehicular traffic is proceeding is in great danger of being struck. Every motion made by a member of such a party must be made with a continuing, full awareness that vehicular traffic is, in fact, proceeding as usual. The dangers of the situation should be minimized as much as possible by the following measures as well as by others that some situations may require.

Work should be scheduled as much as possible to take place during those hours when traffic is slack. Work during "rush hour" on a metropolitan highway, for instance, could be so dangerous as not to be a practical endeavor.

Adequate traffic warning signs, such as "Men Working," "Drive Slowly," "Single Lane Ahead," and the like, should be placed where they will be most effective in warning drivers and, if possible, in detouring traffic away from the field party. If detouring requires two-way traffic on a single lane, a flagman has to be posted at each end of the lane.

Signs, barriers, and equipment in use, such as instruments, targets, and the like, should be made as conspicuous as possible by the attachment of bright-colored bunting. Personnel should also make themselves as conspicuous as possible by wearing orange-colored shirts, vests, or jackets.

One last word of advice may seem inconsistent with your standards about what constitutes proper performance of duty. Suppose you are functioning as an instrumentman with a party on a highway, and you suddenly observe that a car out of control is bearing down on the instrument at high speed. You will have a strong impulse to attempt to rescue the instrument. Do NOT do this if it could result in death or injury to yourself.

ADDITIONAL DUTIES OF A SURVEY CREW

Other tasks that you might perform as a survey crew member include the maintenance of various surveying equipment and accessories, preparation of the field party's essential needs, field sanitation, and the conducting of prestart checks and operator's maintenance of government survey vehicles.

MAINTAINING SURVEYING EQUIPMENT

Generally, the maintenance of surveying equipment and accessories involves proper cleaning and stowage. For example, steel tapes, brush hooks, axes, chain saws, and so forth, must be cleaned and dried and, if necessary, a thin coat of oil applied after each day's work before they are stored for the night. Never stow any surveying gear (especially if made of ferrous material) without checking it thoroughly to make sure it is clean and dry—particularly steel tapes. The reason for this is that, in the SEABEEs, we have a multitude of jobs done under variable conditions. Suppose that today you are sent to a job that does not require the same equipment you used yesterday and failed to clean. You are kept on this job for a few days. There is a good chance that the equipment you used the first day will be rusty when you return to use it again.

Remember that you are liable for payment for any loss of government property caused by your own negligence.

You will be required to sharpen surveying clearing tools, replace any broken handles, especially those on sledgehammers, and do many other things. For delicate equipment, consult the manufacturer's handbook or other applicable publications before you attempt any servicing or cleaning, and, if necessary, ask your senior EA to explain the correct procedure to follow.

PREPARING FOR FIELD PARTY'S ESSENTIAL NEEDS

You need to know how to prepare or gather your various needs for the day; for example, stakes, hubs, markers, safety gear, drinking water, and food. The preparation of the list of these things is the responsibility of your party chief; however, everyone in the survey party should review the list to make sure that everything needed for that particular job is there. Remember that you are concerned with the necessary equipment not only for the job, but also for your personal needs, especially if the job is quite a distance from your base camp.

In a triangulation survey, for example, your stations are generally situated in remote places. You may be ferried to your station point by helicopter or by some other means, depending on the location and the mode of transportation available. Be sure to take extra drinking water to jobs like this, and DO NOT discard your excess water until you are safely back to your base camp.

MAINTAINING FIELD SANITATION

In the field, devices necessary for maintaining personal hygiene and field sanitation must be improvised. If you are surveying at a remote location, it is unlikely that you will find a waterborne sewage system available for your use. The usual alternative is digging a "cat hole" about 1 ft deep and covering the feces completely with dirt.

Proper disposal of garbage should also be undertaken during field surveys. Whenever possible, avoid burning dry garbage on site. Disposal bags offer a good means of preventing litter and should be used whenever available.

In extremely hot climates, your supply of potable water is expected to run low at a faster rate. To avoid dehydration, you will be required to treat your own water or face infections or diseases, such as dysentery, cholera, diarrhea, and typhoid fever. It is imperative that water taken from any source (such as lakes, rivers, streams, and ponds) be properly treated before being used, as all these sources are presumed to be contaminated. To treat water for drinking, you can use either a plastic or aluminum canteen with the water purification compounds available in tablet form (iodine) or in ampule form (calcium hypochlorite). When disinfecting compounds are not available, boiling the water is another method for killing disease-producing organisms. The standard source of information for SEABEEs on field sanitation and personal hygiene is *Seabee Combat Handbook,* NAVEDTRA 10479-C2, chapter 8.

GIVING VEHICLE PRESTART CHECKS AND MAINTAINING VEHICLE OPERATIONS

It is likely that the field survey crew will be assigned a vehicle to transport people and equipment to and from the jobsite. Before operating the vehicle, the operator is to give it a prestart check to make sure that it is ready to run.

When a vehicle is assigned to you, an operator's daily preservice maintenance report is issued at the dispatch office. Use this form to record or log items in the vehicle requiring attention as observed during the prestart check and during the working day. Other information, such as mileage readings, operating hours, and fuel consumption may also be required.

A complete checklist of the vehicle prestart and operator's maintenance procedures are described in *Equipment Operator 3 & 2,* NAVEDTRA 10640-J1, chapters 2 and 4.

CHAPTER 13

HORIZONTAL CONTROL

A system of control stations, local or universal, must be established to locate the positions of various points, objects, or details on the surface of the earth. The relative positions of detail points can be easily determined if these points are TIED IN to a local control station; or, if the control station is tied in to a geodetic control, the positions of other detail points can also be located relative to a worldwide control system.

The main control system is formed by a triangulation network supplemented by traverse. A traverse that has been established and is used to locate detail points and objects is often spoken of as a CONTROL TRAVERSE. Any line from which points and objects are located is a CONTROL LINE. A survey is controlled horizontally by measuring horizontal distances and horizontal angles. This type of survey is often referred to as HORIZONTAL CONTROL.

Horizontal control surveys are also conducted to establish supplementary control stations for use in construction surveys. Supplementary control stations usually consist of one or more short traverses run close to or across a construction area to afford easy tie-ins for various projects. These stations are established to the degree of accuracy needed for the purpose of the survey.

In this chapter, we will identify common procedures used in converting angular measurements taken from a compass or transit survey, recognize the methods used in establishing horizontal control, and identify various field procedures used in running a traverse survey.

DIRECTIONS AND DISTANCES

There are various ways of describing the horizontal locations of a point, as mentioned in chapter 12. In the final analysis, these ways are all reducible to the basic method of description; that is, by stating the length (distance) and direction of a straight line between the point whose location is being described and a reference point.

Direction, like horizontal location itself, is also relative; that is, the direction of a line can only be stated relative to a REFERENCE LINE of known (or sometimes of assumed) direction. In true geographical direction, the reference line is the meridian passing through the point where the observer is located; and the direction of a line passing through that point is described in terms of the horizontal angle between that line and the meridian. In magnetic geographical direction, the reference line is the magnetic meridian instead of the true meridian.

CONVERTING DIRECTIONS

The direction of a traverse line is commonly given by bearing. In field traversing, however, turning deflection angles with a transit is more convenient than orienting each traverse line to a meridian. The method of converting bearings to deflection angles is explained in the following paragraphs.

Converting Bearings to Deflection Angles

Converting bearings to deflection angles is based on the well-known geometrical proposition shown in figure 13-1.

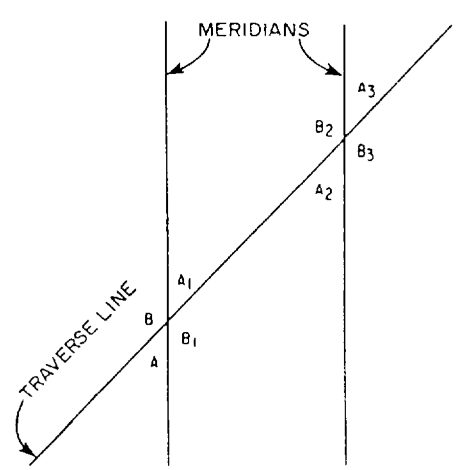


Figure 13-1.-Parallel lines (meridians) intersected by a traverse line, showing relationship of corresponding angles.

This figure shows two meridians or parallel lines that are intersected by another line called a traverse. It can be proved geometrically that the angles A and A_1, B and B_1, A_2 and A_3, and B_2 and B_3 are equal (vertically opposite angles). It can also be shown that angles $A = A_2$, and $B = B_2$ (corresponding angles). Therefore,

$$A = A_1 = A_2 = A_3 \text{ and}$$

$$B = B_1 = B_2 = B_3.$$

It can also be shown that the sum of the angles that form a straight line is 180°; the sum of all the angles around the point is 360°.

Figure 13-2 shows a traverse containing traverse lines AB, BC, and CD. The meridians through the traverse stations are indicated by the lines NS, N´S´, and N´´S´´. Although meridians are not, in fact, exactly parallel, they are assumed to be, for conversion purposes. Consequently, we have here three parallel lines intersected by traverses, and the angles created will therefore be equal, as shown in figure 13-1.

The bearing of AB is given as N20°E, which means that angle NAB measures 20°. To determine the deflection angle between AB and BC, you proceed as follows: If angle NAB measures 20°, then angle N'BB' must also measure 20° because the two corresponding angles are equal. The bearing of BC is given as S50°E, which means angle S´BC measures 50°E. The sum of angle N´BB´ plus S´BC plus the deflection angle between AB and BC (angle B´BC) is 180°. Therefore, the size of the deflection angle is

$$180° - (N'BB' + S'BC) \text{ or}$$

$$180° - (50° + 20°) = 110°.$$

The figure indicates that the angle should be turned to the right; therefore, the complete deflection angle description is 11°R.

The bearing of CD is given as N70°E; therefore, angle N´´CD measures70°. Angle S´´CC´ is equal to angle S´BC and therefore measures 50°. The deflection angle between BC and CD equals

$$180° - (S''CC + N''CD) \text{ or}$$

$$180° - (50° + 70°) = 60°.$$

The figure indicates that the angle should be turned to the left.

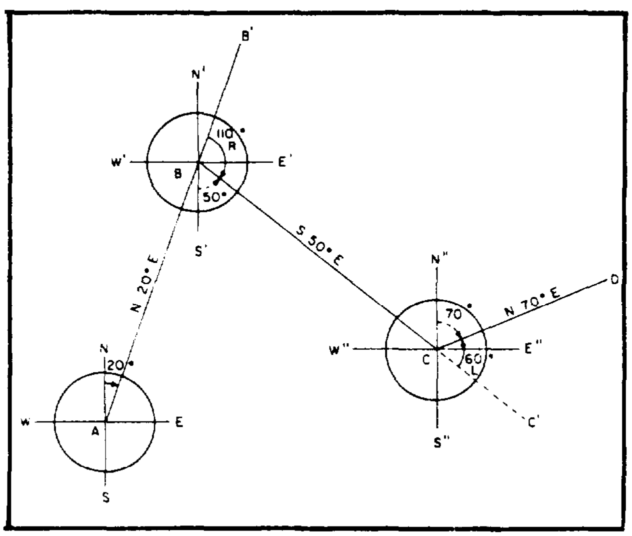


Figure 13-2.-Converting bearings to deflection angles from given traverse data.

Converting Deflection Angles to Bearings

Converting deflection angles to bearings is simply the same process used for a different end result. Suppose that in figure 13-2, you know the deflection angles and want to determine the corresponding bearings. To do this, you must know the bearing of at least one of the traverse lines. Let's assume that you know the bearing of AB and want to determine the bearing of BC. You know the size of the deflection angle B´BC is 110°. The size of angle N´BB´ is the same as the size of NAB, which is 20°. The size of the angle of bearing of BC is

$$180° - (B'BC + NAB) \text{ or}$$

$$180° - (110° + 20°) = 50°.$$

The figure shows you that BC lies in the second or SE quadrant; therefore, the full description of the bearing is S50°E.

Converting Bearings to Interior and Exterior Angles

Converting a bearing to an interior or exterior angle is, once again, the same procedure applied for a different end result. Suppose that in figure 13-2, angle ABC is an interior angle and you want to determine the size. You know that angle ABS´ equals angle NAB, and therefore measures 20°.

You know from the bearing of BC that, angle S′BC measures 50°. The interior angle ABC is

$$ABS' + S'BC \text{ or}$$

$$20° + 50° = 70°.$$

The sum of the interior and exterior angles at any traverse station or point equals the sum of all the angles around that point, or 360°. Therefore, the exterior angle at station B equals 360° minus the interior angle or

$$360° - 70° = 290°.$$

The process of measuring angles around a point to obtain a check on their sum, which should equal 360°00', is sometimes referred to as CLOSING THE HORIZON.

Converting Azimuths to Bearings or Vice Versa

Suppose you want to convert an azimuth of 135° to the corresponding bearing. This azimuth is greater than 90° but less than 180°; therefore, the line lies in the southeast quadrant. As shown in figure 13-3, the bearing angles are always measured from the north and south ends of thereference meridian. (When solving any bearing problem, draw a sketch to get a clear picture.) For the azimuth, the horizontal direction is reckoned clockwise from the meridian plane. It is measured between either the north or the south end of the reference meridian and the line in question. When we talk about azimuth in this training manual, however, you must understand that the azimuth is referenced clockwise from the NORTH point of the meridian. The numerical value of this 135° azimuth angle is measured from the north. Therefore, in this figure, the value of the bearing is

$$180° - 135 = 45°.$$

The complete description of the bearing then is S45°E.

For example, if you want to convert a bearing of N30°W into an azimuth angle, you know that the angle location must be in the northwest quadrant. Then, draw an angle of 30° from the north end of the reference meridian because you measure azimuth angles clockwise from the north end of the reference meridian. To compute this azimuth angle, subtract 30° from 360°; the result is 330°. Therefore, the bearing of N30°W is equal to 330° azimuth angle.

ESTABLISHING DIRECTION BY SURVEYOR'S COMPASS

The basic method of establishing direction of a survey line or a point is with a surveyor's compass. (Notice that on most surveyor's compasses, the east and west indicators are in the opposite positions from those of the east and west indicators on a map or chart.) In figure 13-4, an

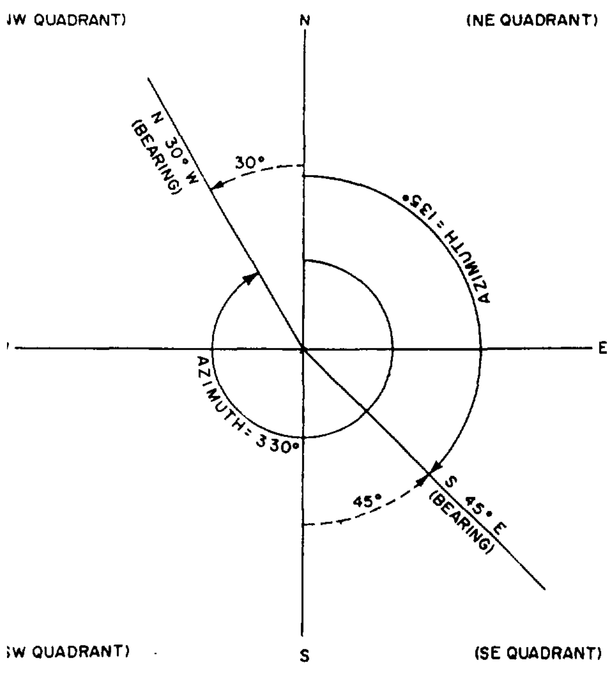


Figure 13-3.-Converting azimuths to corresponding bearings or vice versa.

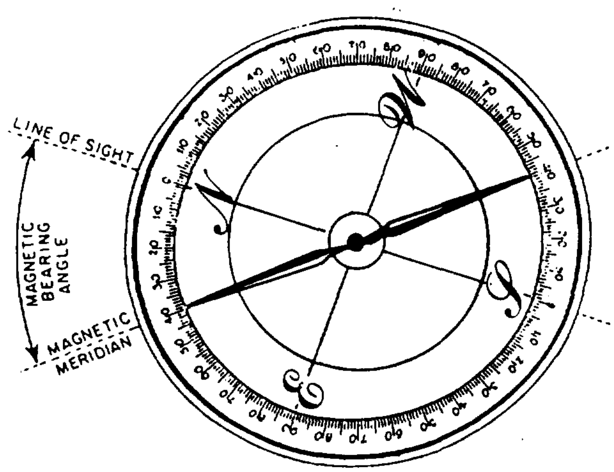


Figure 13-4.-A magnetic compass reading corrected for local attraction.

observer is determining the magnetic bearing of the dotted line labeled Line of Sight. First, the observer mounts the compass on a steady support, levels it, and waits for the needle to stop oscillating. Then, the observer carefully rotates the compass until the north-south line on the card lies exactly along the line whose bearing is being taken.

The bearing is now indicated by the needlepoint. The needlepoint indicates a numerical value of 40°. The card indicates the northeast quadrant. The magnetic bearing is, therefore, N40°E.

Correcting for Local Magnetic Attraction

Figure 13-4 shows the compass needle lying along the magnetic meridian. This means either that the compass is in an area free of "local magnetic attraction" or that the effect of local attraction has been eliminated by adjusting the compass card as described later. "Local magnetic attraction" means the deflection of the compass needle by a local magnetic force, such as that created by nearby electrical equipment or by a mass of metal, such as a bulldozer. When local attraction exists and is not compensated for, the bearing you get is a COMPASS bearing. A compass bearing does not become a magnetic bearing until it has been corrected for local attraction. Suppose, for example, you read a compass bearing of N37°E. Suppose the effect of the magnetic attraction of a nearby pole transformer is enough to deflect the compass needle 4° to the west of the magnetic meridian. In the absence of this local attraction, the compass would read N33°E, not N37°E. Therefore, the correct magnetic bearing is N33°E.

To correct a compass bearing for local attraction, you determine the amount and direction (east or west) of the local attraction. First, set up the compass where you propose to take the bearing. Then, select a distant object that you may presume to be outside the range of any local attraction. Take the bearing of this object. If you read a bearing of S60°W, shift the compass to the immediate vicinity of the object you sighted on; and take, from there, the bearing of the original setup point. In the absence of any local attraction at the original setup point, you would read the back bearing of the original bearing or N60°E. Suppose instead you read N48°E. The back bearing of this is S48°W. Therefore, the bearing as indicated by the compass under local attraction is S60°W; but as indicated by the compass not under local attraction, it is S48°W. The amount and direction of local attraction are, therefore, 12°W.

The question of whether you add the local attraction to, or subtract it from, the compass bearing to get the magnetic bearing depends on (1) the direction of the local attraction and (2) the quadrant the bearing is in.

As a rule, for a bearing in the northeast quadrant, you add an easterly attraction to the compass bearing to get the magnetic bearing and subtract a westerly attraction from the compass bearing to get the magnetic bearing.

Now, consider the compass shown in figure 13-5. This compass indicates a bearing of S40°W. Suppose the local attraction is 12°W. The needle, then, is 12°W of where it would be without local attraction. You can see that, in the southwest quadrant, you would subtract westerly attraction and add easterly attraction.

From a study of the paragraphs above, it becomes obvious that the procedure is the opposite for bearings in the northwest or southeast

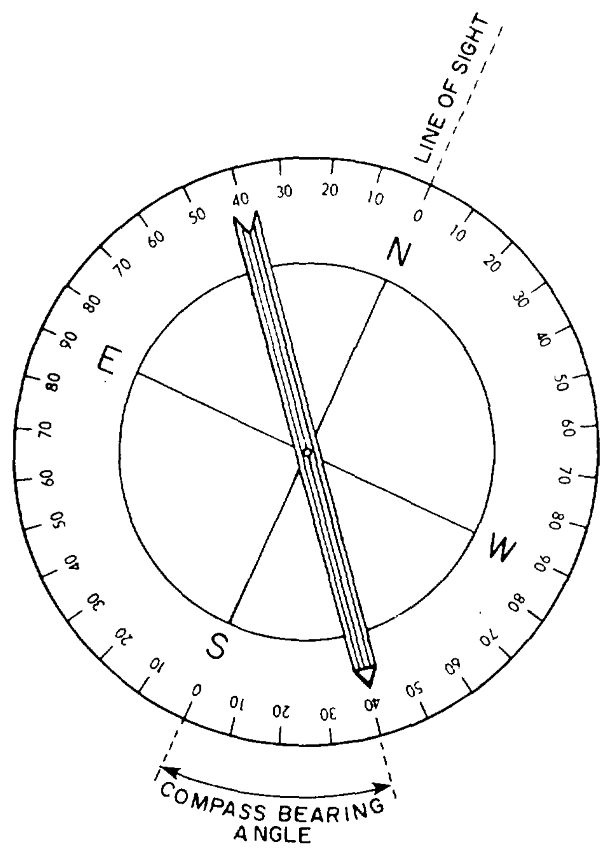


Figure 13-5.-Compass bearing affected by local magnetic attraction.

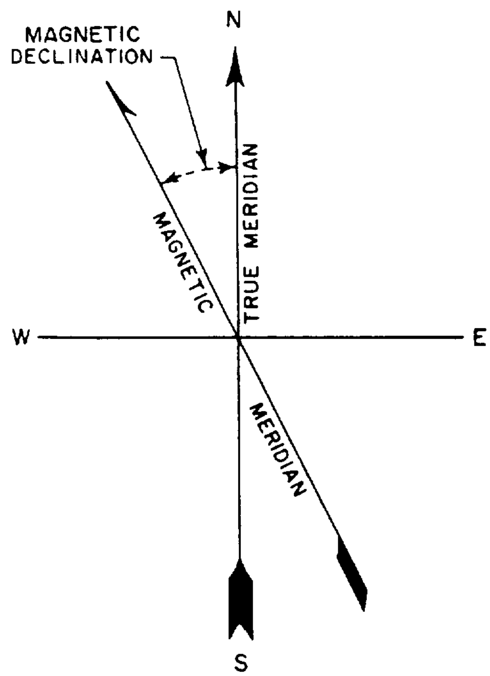


Figure 13-6.-Magnetic declination (west).

quadrants. In these quadrants, you add westerly attraction and subtract easterly attraction to the compass bearing to get the magnetic bearing.

Determining Magnetic Declination and Dip

The angle between the true meridian and the magnetic meridian is MAGNETIC DECLINATION. If the north end of the compass needle is pointing to the east of the true meridian, the declination is said to be east. If the north end of the compass needle is pointing to the west of the true meridian, the declination is said to be west. (See fig. 13-6.)

The magnetic needle aligns itself with the earth's magnetic field and points toward the earth's magnetic pole. In horizontal projections, these lines incline downward toward the north in the Northern Hemisphere and downward toward the south in the Southern Hemisphere. Since the bar takes the position parallel with the lines of force, it inclines with the horizontal. This phenomenon is the MAGNETIC DIP.

Converting Magnetic Bearings to True Bearings

When you have corrected a compass bearing for local attraction, you have a MAGNETIC BEARING. As explained previously, in most areas of the earth, a magnetic bearing differs from a true bearing by the amount of the local magnetic declination (called magnetic variation by navigators). The amount and direction of local declination are shown on maps or charts of the area in a format similar to the following: "Magnetic Declination 26°45°W (1968), Annual Increase 11′. " This means, if you are working in 1988 (20 years later), the local declination is

$$26°45' + (11' \times 20) \text{ or}$$

$$26°45' + 220' = 26°45' + 3°40' = 30°25'.$$

To convert a magnetic bearing to a TRUE BEARING, you apply the declination to the magnetic bearing in precisely the same way that you apply local attraction to a compass bearing. If the declination is east, it is added to northeast and southwest magnetic bearings, and it is subtracted from southeast and northwest magnetic bearings. If the declination is west, it is added to southeast and northwest magnetic bearings and subtracted from northeast and southwest magnetic bearings.

When you have a compass bearing and know both the local attraction and the local declination, you can go from compass bearing to true bearing in a single process by applying the ALGEBRAIC SUM of local attraction and local declination, Suppose that local attraction is 6°W and declination, 15°E. You could correct for local attraction and convert from magnetic to true in the same operation by applying a correction of 9°E to the compass bearing.

Uncorrecting and Unconverting

You correct a compass bearing to a magnetic bearing by applying the local attraction. You convert a magnetic bearing to a true bearing by applying the local declination.

At some time, you may be given a magnetic bearing and have to figure the corresponding compass bearing by using both local attraction and local declination.

The terms used to describe these calculations are, for the want of any better expressions, UNCORRECTING and UNCONVERTING. All YOU need to remember is that, when you are uncorrecting or unconverting, you apply local attraction and local declination in the REVERSE of the directions in which you apply them if you were correcting or converting.

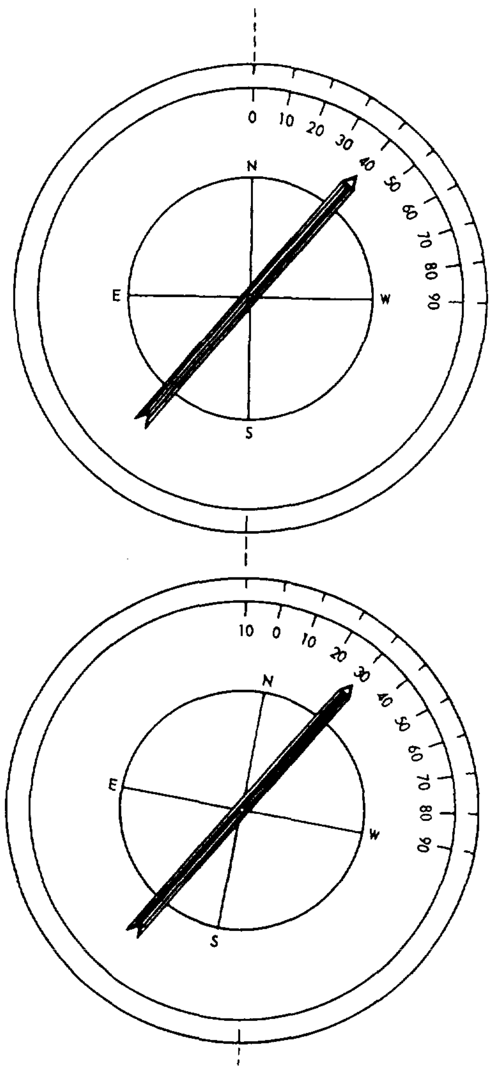


Figure 13-7.-Orienting a compass for a 10° easterly attraction.

For example, with a compass affected by a 10°W local attraction, you want to lay off a line bearing S28°W magnetic by compass. If you were correcting, you would subtract a westerly attraction in the southwest quadrant. However, for uncorrecting you ADD a westerly attraction in that quadrant. Therefore, to lay off a line bearing S28°W, you would lay off S38°W by the compass.

The same rule applies to azimuths. Suppose you have an azimuth-reading (measured from north) compass set up where local attraction is 10°W and declination is 25°E, and you want to lay off a line with true azimuth 256°. The algebraic sum of these is 15°E. For correcting or converting azimuths, you ADD easterly and SUBTRACT westerly corrections; therefore, if you were correcting or converting, you would add the 15° to 256°. Because you are uncorrecting or unconverting, however, you subtract; and, to lay off a line with true azimuth 256°, you read 241° by the compass.

Orienting a Compass

Some transit compasses and most surveyor's and forester's field compasses are equipped for offsetting local attraction, local declination, and/or the algebraic sum of the two. In figure 13-7, the upper view shows a compass bearing of N40°W on a compass presumed to be affected by a local attraction of 10°E. In this quadrant, you subtract easterly attraction; therefore, the magnetic bearing should read N30°W.

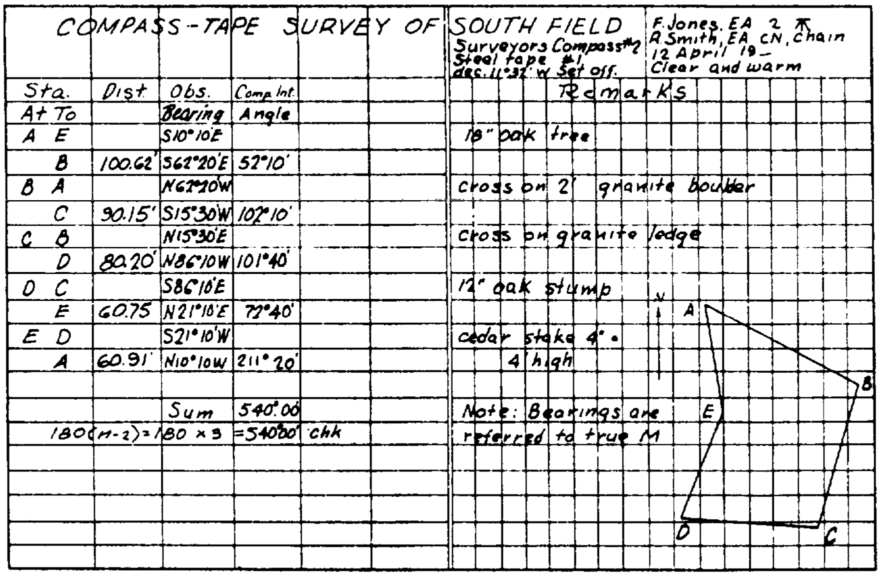
In the lower view, the same compass has been oriented for an error of 10°E by simply rotating the compass card 10°E clockwise. On most orienting compasses, the card can be released for rotating by backing off a small screw on the face of the card. Note that you now read the correct magnetic bearing of N30°W.

Conducting a Compass-Tape Survey

Figure 13-8 shows field notes from a compass-tape survey of a small field. The instrument used was a surveyor's compass. The compass was first set up at station A, shown in the sketch drawn on the remarks page. The first bearing taken was that of the line AE. This was actually the back bearing of EA, taken for the purpose of later checking against the forward bearing of EA.

Next, the bearing of AB was taken, and the distance from A to B was chained. The observed bearing (S62°20´E) was entered beside B in the column headed "Obs. Bearing." The chained distance was entered beside B in the column headed "Dist."

The compass was shifted to station B, and the back bearing of AB (that is, the bearing of BA) was taken as a check on the previously taken bearing of AB. The back bearing turned out to have, as it should have, the same numerical value (62°20´) as the forward bearing. A difference in the two would indicate either an inaccuracy in reading one bearing or the other or a difference in the strength of local attraction.



COMPASS-TAPE SURVEY OF SOUTH FIELD

Surveyors Compass #2
Steel tape #1
dec. 11°32' W Set off.

F. Jones, EA 2 ⊼
R. Smith, EA CN, Chain
12 April 19—
Clear and warm

Sta. At	Sta. To	Dist	Obs. Bearing	Comp. Int. Angle	Remarks
A	E		S10°10'E		18" oak tree
	B	100.62'	S62°20'E	52°10'	
B	A		N62°20'W		Cross on 2' granite boulder
	C	90.15'	S15°30'W	102°10'	
C	B		N15°30'E		Cross on granite ledge
	D	80.20'	N86°10'W	101°40'	
D	C		S86°10'E		12" oak stump
	E	60.75	N21°10'E	72°40'	
E	D		S21°10'W		cedar stake 4" □ 4' high
	A	60.91'	N10°10'W	211°20'	
			Sum	540°00'	Note: Bearings are referred to true M
180(n-2) = 180 × 3				= 540°00' chk	

Figure 13-8.-Sample field notes from a compass-tape survey.

Proceeding in this fashion, the party took bearings and back bearings, and chained distances all the way around to the starting point at station A. The last forward bearing taken, that of EA, has the same numerical value as the back bearing of EA (bearing of AE) taken at the start.

Checking Accuracy of Observed Bearings

As a check on the accuracy of the whole bearing-reading process, the size of the interior angle at each station was computed from the observed bearings by the method previously described for converting bearings to interior angles. The sizes of these angles were entered in the column headed "Comp. Int. Angle," and the sum was entered below.

The sum of the interior angles in a closed traverse should equal the product of 180° (n – 2), n being the number of traverse lines in the traverse. In this case, the traverse has five lines; therefore, the sum of the interior angles should be

$$180°(5 - 2) = 180° \times 3 = 540°.$$

The computed sum is, therefore, the same as the added sum of the angles converted from observed bearings.

Recognizing, Reducing, and Correcting Compass Errors

If a magnetic compass has a bent needle, there will be a constant instrumental error in all observed bearings and azimuths. To check for this condition, set up and level the compass, wait for the needle to cease oscillating, and read the graduation indicated at each end of the needle. If the compass is graduated for bearings, the numerical value at each end of the needle should be the same. If the compass is graduated for azimuths, the readings should be 180° apart.

Similarly, if the pivot supporting the needle on a magnetic compass is bent, there will be an instrumental error in the compass. However, this error, instead of being the same for all readings, will be variable.

You, can eliminate either of these instrumental errors by reading both ends of the needle and using the average between them. Suppose, for example, that with a compass graduated for bearings you read a bearing of N45°E and a back bearing of S44°W. You would use the average, or

$$1/2\ (45° + 44°) = N44°30'E.$$

The error in the compass should, of course, be corrected as soon as possible. Normally, this is a job for an expert. Remember the cause of a discrepancy in the reading at both ends when there is one. It is more probable that the needle, rather than the pivot, is bent. After a bent needle has been straightened, if a discrepancy still exists, then probably the pivot is bent too.

If a compass needle is sluggish—that is, if it moves unusually slowly in seeking magnetic north—it will probably come to rest a little off the magnetic meridian. The most common cause of sluggishness is weakening of the magnetism of the needle. A needle may be demagnetized by drawing it over a bar magnet. The needle should be drawn from the center of the bar magnet toward the end, with the south end of the needle drawn over the north end of the magnet and vice versa. On each return stroke, lift the needle well clear of the magnet.

Sometimes the cause of a sluggish needle is a blunt point on the pivot. This may be corrected by sharpening the pivot with a fine file.

If the compass is not level when a bearing or azimuth is being read, the reading will be incorrect. A similar error will exist if the compass is equipped with sighting vanes and one or more of them are bent. To check for bent compass vanes, you set up and level the compass, and then sight with the vanes on a plumb bob cord.

The most common personal error the observer can make in compass work is MISREADING. This is caused by the observer's eye not being vertically above the compass at the time of the reading. Other common mistakes are reading a needle at the wrong end and setting off local attraction or declination in the wrong direction when the compass is being oriented.

ESTABLISHING DIRECTIONS BY TRANSIT

Directions are similarly determined by the use of a transit. This can be done by measuring the size of the horizontal angle between the line whose direction is sought and a reference line. With a transit, however, you are expected to do this with considerably more accuracy and precision than with a surveyor's compass. Some of the basic procedures associated with the proper operation of the instrument will be discussed in the following paragraphs.

Setting Up the Transit

The point at which the line of sight, the horizontal axis, and the vertical axis of a transit meet is called the INSTRUMENT CENTER. The point on the ground over which the center of the instrument is placed is the INSTRUMENT POINT, TRANSIT POINT, or STATION. A wooden stake or hub is usually marked with a tack when used as a transit station or point. To prevent jarring or displacement of the transit, avoid those stations having loose planking, those having soft or marshy ground, and those having other conditions that would cause the legs of the tripod to move. The following steps are recommended when you are setting up a transit over a station point:

1. Center the instrument as closely as possible over the definite point by suspending a plumb line from a hook and chain beneath the instrument. The plumb string is tied with a slipknot, so that you can adjust the height of the plumb.

2. Move the tripod legs as necessary until the plumb bob is about 1/4 in. short of being over the tack, meanwhile maintaining a fairly level foot plate. Spread the tripod legs, and apply sufficient pressure to the legs to make sure of their firmness in the ground. Make sure to loosen the wing nuts to rid the static pressure in them before retightening.

3. Turn the plates so that each plate level is parallel to a pair of opposite leveling screws. (It is common practice to have a pair of opposite leveling screws in line with the approximate line of sight.) The leveling screws are then tightened to firmness, but not tight. Rotate opposing pairs of leveling screws either toward each other or away from each other until the plate bubbles are centered.

If the plumb bob is not directly over the center of the tack, you may loosen two adjacent leveling screws enough to free the shifting plate. Relevel the instrument if the bubbles become off-center. During breezy conditions, you may shield the plumb line with your body when setting up an instrument. Sometimes in windy locations, it may be necessary to construct a wind shield.

Setting and leveling the transit rapidly requires a skill on your part that you will learn and develop through consistent practice. You should take advantage of any opportunity that you can to train yourself and increase your skills in handling surveying instruments. Again, when setting up or operating a transit, you should remember the following points:

1. The plate bubble follows the direction of the left thumb when you are manipulating the leveling screws.

2. You should always check to see if the plumb bob is still over the point after leveling it. If the plumb bob has shifted, you should recenter the instrument.

3. While loosening the two adjacent leveling screws, you can shift the transit head laterally.

4. You should always maintain contact between the leveling screw shoes and the foot plate.

5. You should not disturb the setup of the instrument until you are certain that all observations at that point are completed and roughly checked. You should move the instrument from that setup only after checking with the party chief.

6. Before the transit is moved or taken up, you should center the instrument on the foot plate, roughly equalize the height of the leveling screws, clamp the upper motion (the lower motion may be tightened lightly), and point the telescope vertically upward and also lightly tighten the vertical motion clamp.

Measuring Horizontal Angles

The transit contains a graduated horizontal circle, referred to as the horizontal limb. The horizontal limb may be graduated clockwise from 0° through 360°, as shown in figure 13-9, view A, or clockwise from 0° through 360° and also in quadrants, as shown in figure 13-9, view B; or both clockwise and counterclockwise from 0° through 360°, as shown in figure 13-9, view C.

The horizontal limb can be clamped to stay fast when the telescope is rotated (called clamping the lower motion), or it can be released for rotating by hand (called releasing the lower motion).

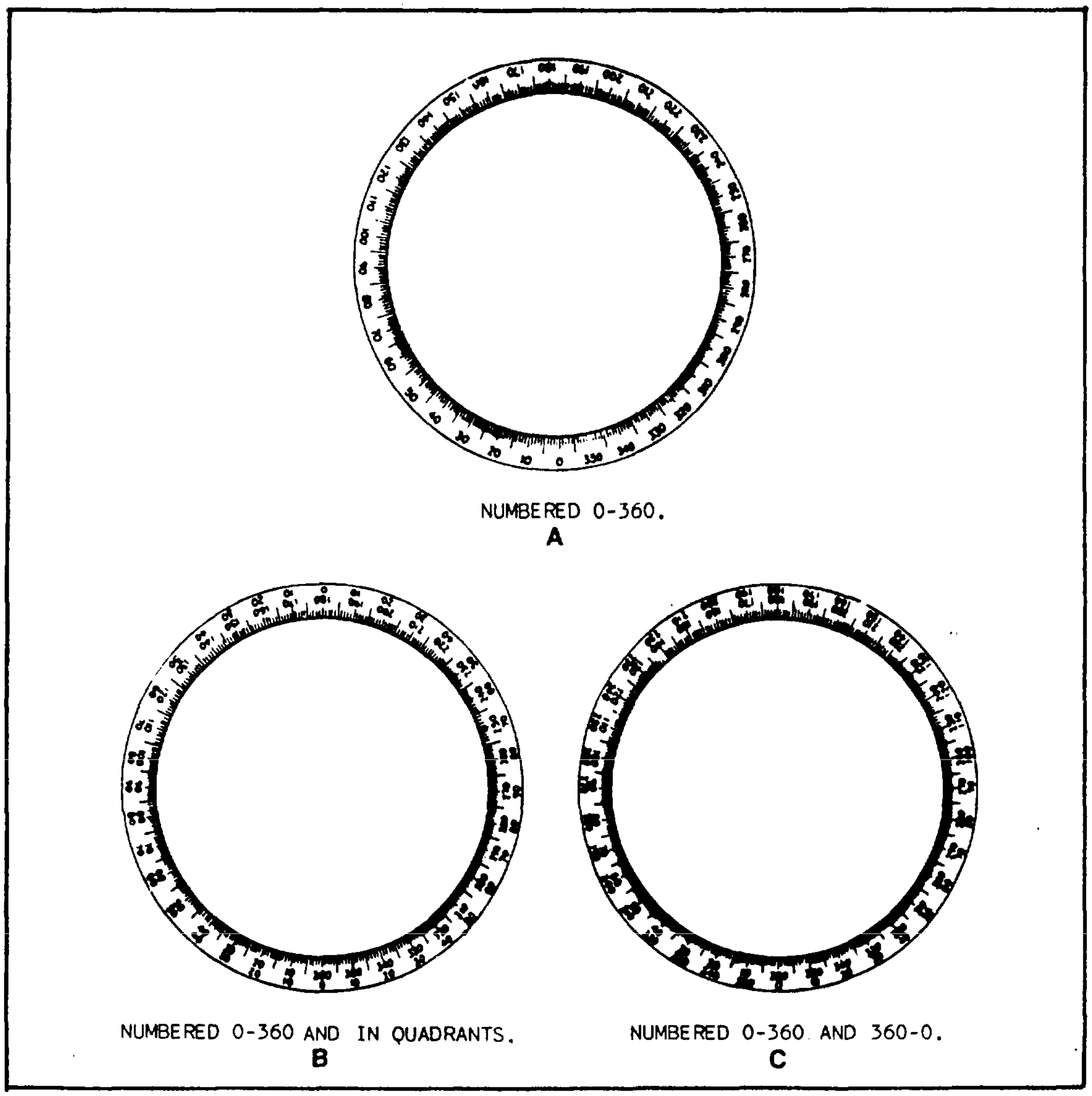


Figure 13-9.-Three types of horizontal limb graduations.

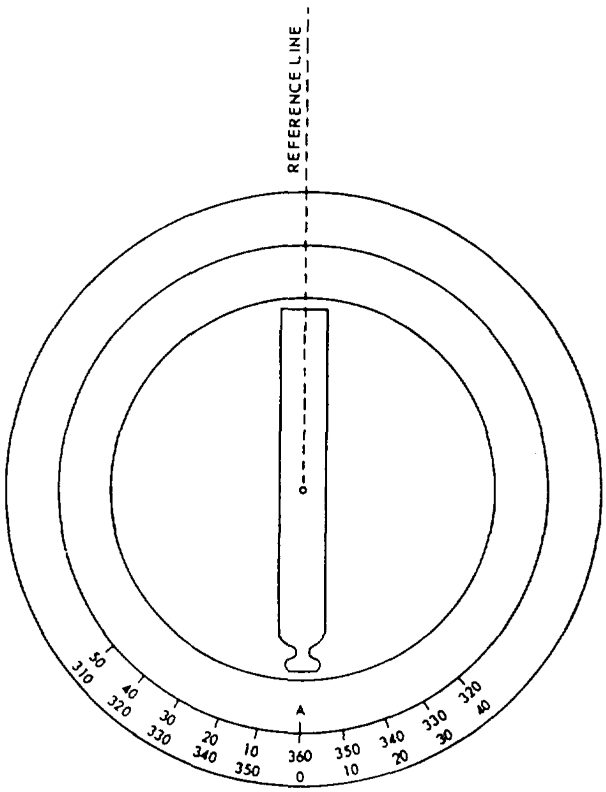


Figure 13-10.-Setting the vernier at zero-zero.

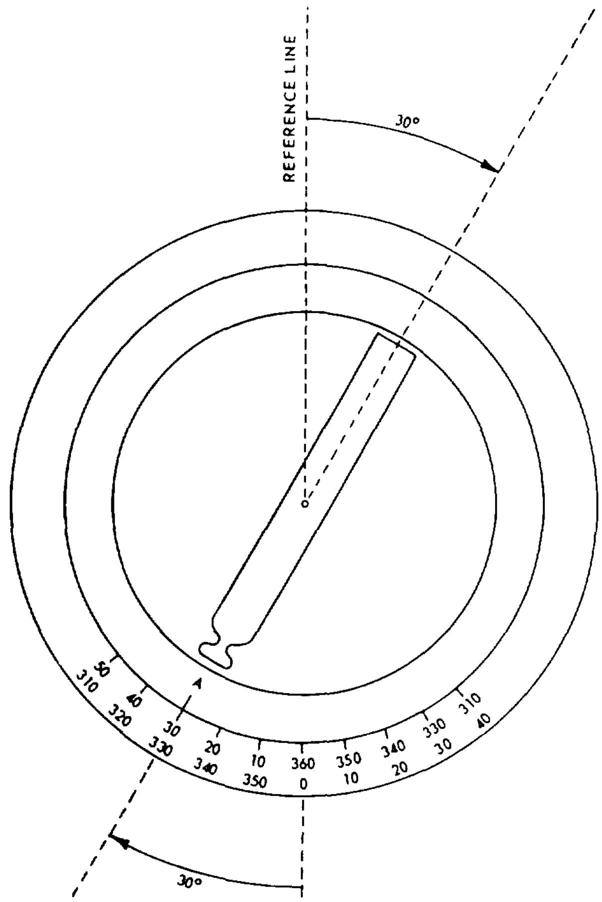


Figure 13-11.-Setting an angle exactly on the vernier zero.

The horizontal limb is paired with another circle (the vernier plate), which is partially graduated on either side of zero graduations located 180° apart on the plate. When the telescope is in the normal (upright) position, the A vernier is located vertically below the eyepiece, and the B vernier, below the objective end of the telescope. The zero on each vernier is the indicator for reading the sizes of horizontal angles turned on the horizontal limb.

Figures 13-10 and 13-11 illustrate the method of turning an angle of 30° from a reference line with a transit.

1. With the transit properly set over the point or station, bring one of the horizontal verniers near zero by hand; clamp the upper motion; and, by turning the upper tangent screw, set one vernier at 0°, usually starting with the A vernier (fig. 13-10). Train the telescope to sight the marker (range pole, chaining pin, or the like) held on the reference line; clamp the lower motion; and, by using the lower tangent screw, set the line of sight on the marker.

2. Release the upper motion and rotate the telescope to bring the zero on the A vernier in line with th3 30° graduation on the horizontal limb, as shown in figure 13-11. To set the vernier exactly at 30°, use the upper tangent screw. You may use a magnifying glass to set the vernier easily and accurately.

3. Mark the next point with a marker, and follow the procedures for establishing a point or station.

Similarly, you may use the procedures above to measure a horizontal angle by sighting on two existing points and reading their interior angle. In addition, the following hints may help you when you are taking horizontal measurements:

1. Make the centering of the line of sight as close as possible by hand so that you will not turn the tangent screw more than one or two turns. Make the last turn of the tangent screw clockwise to compress the opposing springs.

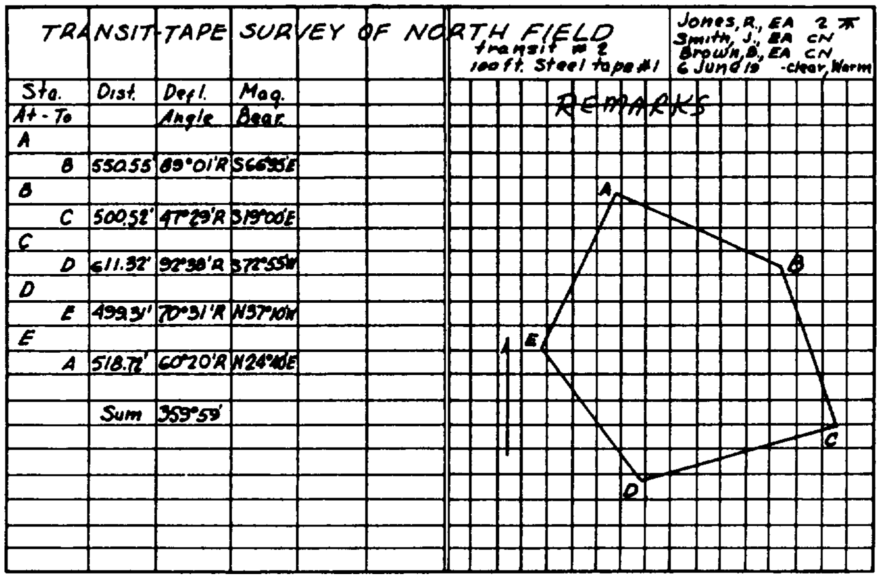


Figure 13-12.-Sample field notes from a deflection angle transit-tape survey.

2. Read the vernier with the eye directly over the top of the coinciding graduations to eliminate the effects of parallax.

3. Take the reading of the other vernier as a check. The readings should be 180° apart.

4. Check the plate bubbles before measuring an angle to see if they are centered, but do not disturb the leveling screws between the initial and final settings of the line of sight. If an angle is measured again, the plate may be releveled after each reading before sighting again on the starting point.

5. Make sure that the rodman is holding the range pole truly vertical when you sight at it. When the bottom of the range pole is not visible, let the rodman use a plumb bob.

6. Avoid accidental movement of the horizontal circle; for instance, moving the wrong clamp or tangent screw. If a number of angles will be observed from one setup without moving the horizontal circle, you should sight at some clearly defined distant object that will serve as a reference mark and take note of the angle. Occasionally, you should recheck the reading to this point during measurement to see if there is any accidental movement.

An example of a horizontal deflection angle measurement is shown in figure 13-12. The field notes contain data taken from a loop traverse shown in the sketch. The transit was first set up at station A, and the magnetic bearing of AB was read on the compass. Then the deflection angle between the extension of EA and AB was turned in the following manner:

1. The instrumentman released both clamps, matched the vernier to zero by hand, tightened the upper motion clamp, and set the zero exactly with the upper tangent screw.

2. With the telescope plunged (inverted position), the instrumentman sighted the range pole held on station E. Then he tightened the lower motion clamp and manipulated the lower motion tangent screw to bring the vertical cross hair to exact alignment with the range pole.

3. The instrumentman replunged the telescope and trained on the extension of EA. (Notice that the telescope is in its normal position now.) He then released the upper motion and rotated the telescope to the right until the vertical cross hair came into line with the range pole held on station B. He further set the upper motion clamp screw and brought the vertical cross hair into exact alignment with the range pole by manipulating the upper motion tangent screw.

4. The instrumentman then read the size of the deflection angle on the A vernier (89°01´). Since the angle was turned to the right, he recorded 89°01´R in the column headed "Defl. Angle." Likewise, he recorded the chained distance between stations A and B and the magnetic bearing of traverse line AB under their appropriate headings.

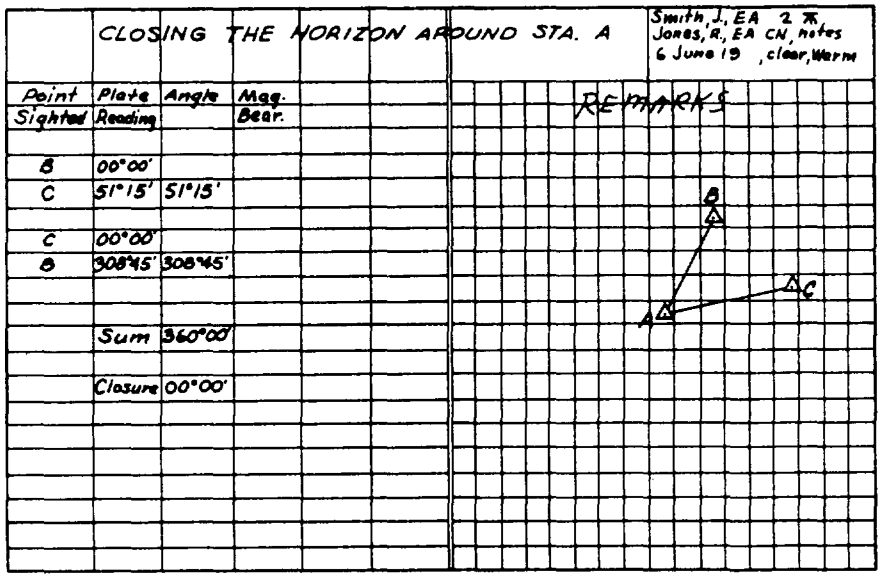


Figure 13-13.-Sample field notes for closing the horizon.

The instrumentman used the same method at each traverse station, working clockwise around the traverse to station E. Note that the algebraic sum of the measured deflection angle (angles to the right considered as plus, to the left as minus) is 350°59′. For a closed traverse, the algebraic sum of the deflection angles from the standpoint of pure geometry is 360°00′. Therefore, there is an ANGULAR ERROR OF CLOSURE here of 0°01′. This small error would probably be considered a normal error. A large variance would indicate a larger mistake made in the measurements.

In the example just presented, the general accuracy of all the angular measurements was checked by comparing the sum of the deflection angles with the theoretical sum. The accuracy of single angular measurement can be checked by the, procedure CLOSING THE HORIZON. The method is based on the fact that the theoretical sum of all the angles around a point is 360°00′.

The field notes in figure 13-13 show the procedure for closing the horizon. The transit was set up at station A, and angle BAC was turned, measuring 51°15′. Then the angle from AC clockwise around to AB was turned, measuring 308°45′. The sum of the two angles is 360°00′. The angular error of closure is therefore 0°00′, meaning that perfect closure is obtained.

Measuring Vertical Angles

The vertical circle and the vertical vernier of a transit were discussed in chapter 11 of this training manual. They are used for measuring vertical angles.

A vertical angle is the angle measured vertically from a horizontal plane of reference. (See fig. 13-14, view A.) When the telescope is pointed in the horizontal plane (level), the value of the vertical angle is zero. When the telescope is pointed up at a higher feature (elevated), the vertical angle increases from zero and is a PLUS VERTICAL ANGLE or ANGLE OF ELEVATION. These values increase from 0° to +90° when the telescope is pointed straight up.

As the telescope is depressed (pointed down), the angle also increases in numerical value, A depressed telescope reading, showing that it is below the horizontal plane, is a MINUS VERTICAL ANGLE or ANGLE OF DEPRESSION. These numerical values increase from 00 to –90° when the telescope is pointed straight down.

To measure vertical angles, you must set the transit upon a definite point and level it. The plate bubbles must be centered carefully, especially for transits that have a fixed vertical vernier. The line of sight is turned approximately at the point; the horizontal axis is clamped. Then, the horizontal cross hair is brought exactly to the point by means of the telescope tangent screw. The angle is read

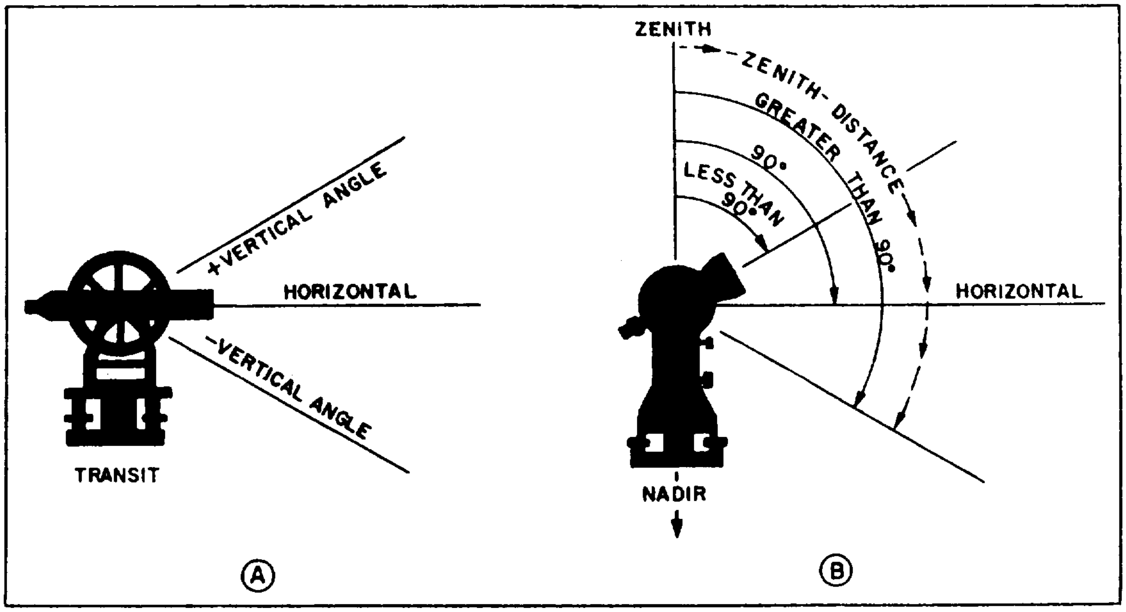


Figure 13-14.-Vertical angles and zenith distances.

on the vertical limb by means of the vertical vernier.

On a transit with a movable vertical vernier, the vernier is equipped with a control level. The telescope is centered on the point as described above, but the vernier bubble is centered before the angle is read.

The ZENITH is an imaginary point overhead where the extension of the plumb line will intersect an assumed sphere on which the stars appear projected. The equivalent point, directly below the zenith, is the NADIR. Use of the zenith permits reading angles in a vertical plane without using a plus or a minus. Theodolites have a vertical scale reading zero when the telescope is pointed at the zenith instead of in a horizontal plane. With the telescope in a direct position and pointed straight up, the reading is 0°; on a horizontal line, the reading is 90°; and straight down, 180°. When measuring vertical angles with the theodolites (fig. 13-14, view B), you should read the angle of elevation with values less than 90°and the angle of depression with values greater than 90°. These angle measurements with the zenith as the zero value are called the ZENITH DISTANCES. DOUBLE ZENITH DISTANCES are observations made with the telescope direct and reversed to eliminate errors caused by the inclination of the vertical axis and the collimation of the vertical circle.

Zenith distance is used in measuring vertical angles involving trigonometric leveling (discussed in the next chapter) and in astronomical observations. (See Engineering Aid 1 & C, NAVEDTRA 10635-C.)

Measuring Angles by Repetition

You may recall, from a previous discussion, the distinction between precision and accuracy. A transit on which angles can be measured to the nearest 20 sec is more precise than one that can measure only to the nearest 1 min. However, this transit is not necessarily more accurate.

The inherent angular precision of a transit can be increased by the process of REPETITION. To illustrate this principle, suppose that with a 1-min transit you turn the angle between two lines in the field and read 45°00´. The inherent error in the transit is 1´; therefore, the true size of this angle is somewhere between 44°59´30´´ and 45°00´30´´.

For example, when using repetition, you leave the upper motion locked but release the lower motion. The horizontal limb will now rotate with the telescope, holding the reading of 45°00´. You plunge the telescope, train again on the initial line of the angle, and again turn the angle. You have now doubled the angle. The A vernier should read approximately 90°00´.

For this second reading, the inherent error in the transit is still 1 min, but the angle indicated

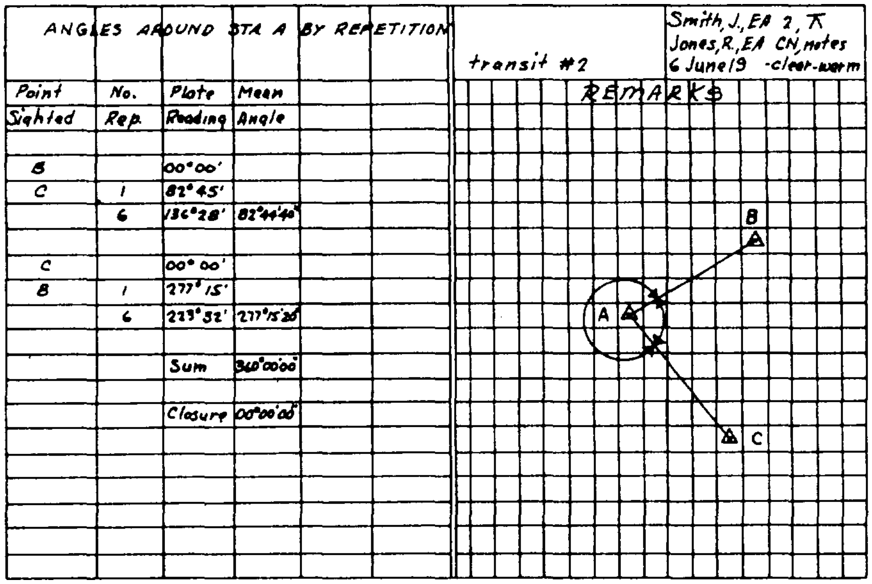


Figure 13-15.-Notes for the angle around a station, repeated six times.

on the A vernier is about twice the size of the actual angle measured. The effect of this is to halve the total possible error. This error was originally plus or minus 30 sec. Now, the error is plus or minus only 15 sec.

If you measure this angle a total of six times, the total possible error will be reduced to one-sixth of 30 see, or plus or minus 5 sec. In theory, you could go on repeating the angle and increasing the precision indefinitely. In actual practice, because of lost motion in the instrument and accidental errors, it is not necessary to repeat the angle more than six times.

The observation may be taken alternately with the telescope plunged before each subsequent observation. But a much simpler way is to take the first half of the observations with the telescope in the normal position, the other half, in an inverted position. In the example given above, the first three readings may be taken when the telescope is in its normal position; the last three when it is in its reversed position. To avoid the effect of tripod twist, after each repetition, rotate the instrument on its lower motion in the same direction that it was turned during the measurement; that is, the direction of movement should always be either clockwise or counterclockwise.

Measuring angles by repetition eliminates certain possible instrumental errors, such as those caused by eccentricity and by nonadjustment of the horizontal axis.

Figure 13-15 shows field notes for the angle around a station, repeated six times. The angle BAC was measured six times, and the angle closing the horizon around station A was also measured six times. The first measurement is not a true repeat, but it is counted as one in the column headed "No. Rep." (number of repetitions).

With the transit first trained on B and the zeros matched, the plate reading was 00°00´. This is recorded beside B in the column headed "Plate Reading." The upper motion clamp was then released, the telescope was trained on C, and a plate reading of 82°45´ was obtained. This reading is recorded next to the figure "1" (for "1st repetition") in the column headed "No. Rep." The measurement of angle BAC was then repeated five more times. After the final measurement, the plate reading was 136°28´. This plate reading is recorded as the sixth repetition.

Now to get the mean angle, it is obvious that you need to divide some number, or figure, by the total number of repetitions. The question is, what figure? To determine this, you first multiply the initial measurement by the total number of repetitions. In this case, this would be as follows:

$$82°45' \times 6 = 496°30'.$$

Next, you determine the largest multiple of 360° that can be subtracted from the above product. Obviously, the only multiple of 360° that can be subtracted from 496°30´ is 360°. This multiple is then added to the final measurement to obtain the figure that is to be divided by the total number of repetitions. In this example,

$$136°28' + 360° = 496°28'.$$

The mean angle then is

$$496°28' \div 6 = 82°44'40''.$$

Enter this in the column headed "Mean Angle."

The following computation shows that you should use the same method to obtain the mean closing angle.

$$277°15' \times 6 = 1663°30'$$

$$360° \times 4 = 1440° \text{ (largest multiple of } 360°)$$

$$223°32' + 1440° = 1663°32'$$

$$1663°32' \div 6 = 277°15'20''$$

In the example shown above, the sum of the mean angle (82°44´40´´) and the mean closing angle (277°15´20´´) equals 360°00´00´´. This reflects perfect closure. In actual practice, perfect angle closure would be unlikely.

RUNNING A DISTANCE (LINE)

It is often necessary to extend a straight line marked by two points on the ground. One of the methods discussed below may be used depending on whether or not there are obstacles in the line ahead, and, if so, whether the obstacles are small or large.

Double Centering or Double Reversing

This method is used to prolong or extend a line. Suppose you are extending line AB, shown in figure 13-16. You set up the transit at B, backsight on A, plunge the telescope to sight ahead, and set the marker at C´. With the telescope still inverted, you again sight back on A; but this time do it by rotating the telescope through 180°. You then replunge the telescope and mark the point C´´. Mark the point C halfway between C´ and C´´. This is the point on the line

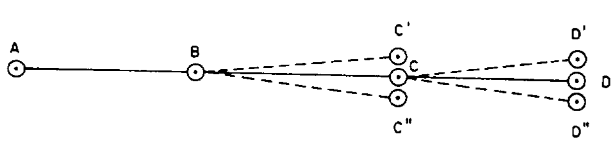


Figure 13-16.-Double centering.

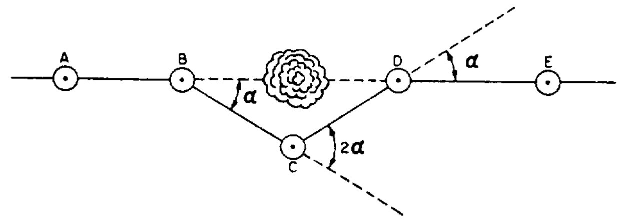


Figure 13-17.-Bypassing a small obstacle by the angle offset method.

AB you need to extend. If the instrument is in perfect adjustment (which seldom happens), points C´ and C´´ will coincide with point C. For further extension, the instrument is moved to C and the procedure repeated to obtain D.

Bypassing an Object by Angle Offset

This method is applied when a tree or other small obstacle is in the line of sight between two points. The transit or theodolite is set up at point B (fig. 13-17) as far from the obstacle as practical. Point C is set off the line near the obstacle and where the line BC will clear the obstacle. At B, measure the deflection angle a. Move the instrument to C, and lay off the deflection angle 2a. Measure the distance BC, and lay off the distance CD equal to BC. Move the instrument to D, and lay off the deflection angle α. Mark the point E. Then, line DE is the prolongation of the line AB.

Bypassing an Object by Perpendicular Offset

This method is used when a large obstruction, such as a building, is in the line of sight between two points. The solution establishes a line parallel to the original line at a distance clear from the obstacle, as shown in figure 13-18. The instrument

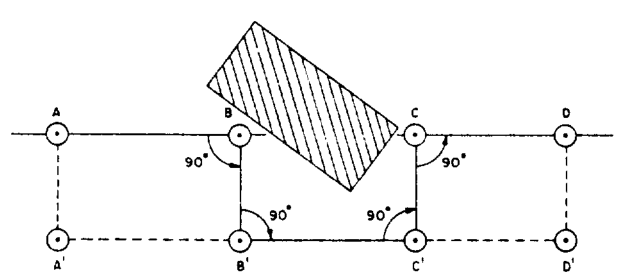


Figure 13-18.-Bypassing a large obstacle by the perpendicular offset method.

is set up at B, and a 90° angle is turned from line AB. The distance BB´ is carefully measured and recorded. The instrument is moved to B´, and another 90° angle is turned. B´C´ is laid off to clear the obstacle. The instrument is moved to C, and a third 90° angle is turned. Distance CC´, equal to BB´, is measured and marked. This establishes a point C on the original line. The instrument is moved to C, and a fourth 90° angle is turned to establish the alignment CD that is the extension of AB beyond the obstacle.

When the distance to clear the obstacle, BB´ or CC´, is less than a tape length, you can avoid turning four 90° angles as follows: Erect perpendicular offsets from points A and B in figure 13-18 so that AA´ equals BB´. Set up the instrument at B', and measure angle A´B´B to be sure that it's 90°. Extend line A´B´ to C´ and then to D´, making sure that point C clears the obstacle. Then, lay off perpendicular offset C´C equal to AA´ or BB´ and perpendicular offset D´D equal to C´C. Then, line CD is the extension of line AB. The total distance of the line AD is the sum of the distances AB, B´C´, and CD.

You also compute the diagonals formed by the end rectangles and compare the result to the actual measurement, if you can, as a further check.

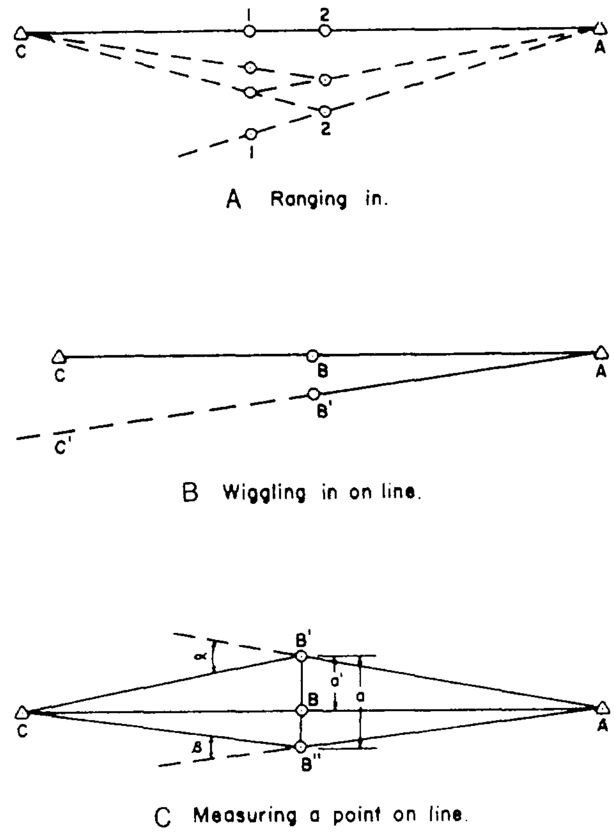


Figure 13-19.-Setting up on a line between two points.

Line Between Nonintervisible Points

Sometimes you need to run a straight line between nonintervisible points when events make the use of the above methods of bypassing an obstacle impractical. If there is an intermediate point on the straight line from which both of the end points can be observed, the method called BALANCING IN (also called BUCKING IN, JIGGLING IN, WIGGLING IN, or RANGING IN) may be used.

A problem often encountered in surveying is to find a point exactly on the line between two other points when neither can be occupied or when an obstruction, such as a hill lies between the two points. The point to be occupied must be located so that both of the other points are visible from it. The process of establishing the intermediate point is known as wiggling in or ranging in.

The approximate position of the line between the two points at the instrument station is first estimated by using two range poles. The range poles are lined in alternately in the following manner. In figure 13-19, view A, set range pole 1 and move range pole 2 until it is exactly on line between pole 1 and point A. You do this by sighting along the edge of pole 1 at the station *A* until pole 2 seems to be on line. Set range pole 2 and move pole 1 until it is on line between pole 2 and point C. Now, move pole 2 into line again, then pole 1, alternately, until both are on line AC. The line will appear to pass through both poles and both stations from either viewing position.

After finding the approximate position of the line between the two points, you set up the instrument on this line. The instrument probably will not be exactly on line, but will be over a point, such as *B´*, (see fig. 13-19, view B). With the instrument at *B´*, you backsight on A and plunge the telescope and notice where the line of sight *C* passes the point C. Estimate this distance CC´ and also the distance that *B´* would be away from C and A. Estimate the amount to move the instrument to place it on the line you need. Thus, if *B´* is midway between *A* and C, and C´ misses *C* by 3 feet to the left, *B´* must be moved about 1.5 feet to the right to reach *B*. Continue the sequence of backlighting, plunging the telescope, and moving the instrument until the line of sight

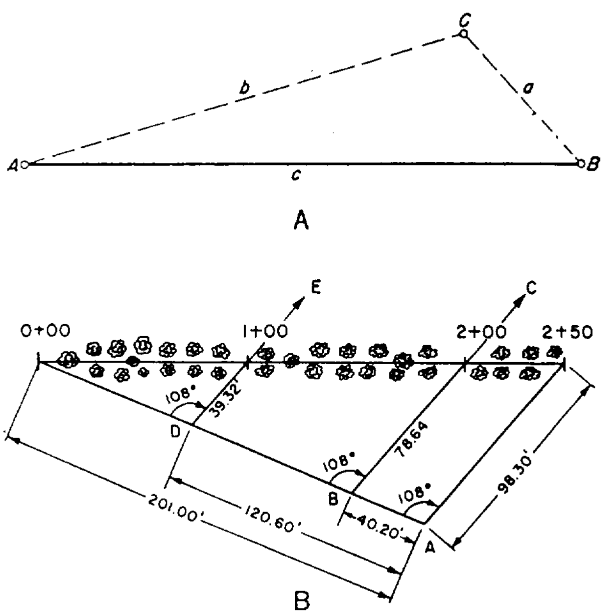


Figure 13-20.-Random line method of locating intermediate stations.

passes through both *A* and *C*. When you do this, the telescope is reversed, but the instrument is not rotated. This means that if the telescope is reversed for backlighting on *A,* all sightings on *A* are made with the telescope reversed. Mark a point on the ground directly under the instrument. Then, you continue to use this method with the telescope direct for each backsight on *A*. Mark a second point on the ground. The point you need on the line *AC* is then the midpoint between the two marked points.

The method outlined above is usually time consuming. Even though the shifting head of the instrument is used in the final instrument movements, you may have to pick up and move the instrument several times. The following method often saves time. After finding the approximate position of the line between the two points, you mark two points *B´* and *B´´*, (fig. 13-19, view C), 1 or 2 feet apart where you know they straddle the line *AC*. Set up over each of these two points in turn and measure the deflection angles α and β. Also measure the horizontal distance a, between points *B´* and B´´. Then you can find the position *B* on the line *AC* by using the following equation:

$$a' = a \frac{\alpha}{\alpha + \beta}$$

in which a' is the proportionate offset distance from *B´* toward B´´ for the required point *B*, and α and β are both expressed in minutes or in seconds.

RANDOM LINE

It is sometimes necessary to run a straight line from one point to another point that is not visible from the first point. If there is an intermediate point on the line from which both end-points are visible, this can be done by the balancing-in method described previously. If no such intermediate point exists, the RANDOM LINE method illustrated in figure 13-20, view A may be used.

The problem here is to run a line from A to B, B being a point not visible from A. It happens, however, that there is a clear area to the left of the line AB, through which a random line can be run to C; C being a point visible from A and B.

To train a transit set up at A on B, you must know the size of the angle at A, You can measure side b and side a, and you can measure the angle at C. Therefore, you have a triangle in which you know two sides and the included angle. You can solve this triangle for angle A by (1) determining the size of side c by the law of cosines, then determining the size of angle A by the law of sines, (2) solving for angle A by reducing to two right triangles.

Suppose you find that angle A measures 16°35´. To train a transit at A on B, you would simply train on C and then turn 16°35´ to the right.

You may also use the random line method to locate intermediate stations on a survey line, In figure 13-20, view B, stations 0 + 00 and 2 + 50, now separated by a grove of trees, were placed at some time in the past. You need to locate stations 1 + 00 and 2 + 00, which lie among the trees.

Run a line at random from station 0 + 00 until you can see station 2 + 50 from some point, A, on the line. The transitman measures the angle at A and finds it to be 108°00´. The distances from A to stations 0 + 00 and 2 + 50 are chained and found to be 201.00 ft and 98.30 ft. With this information, it is now possible to locate the intermediate stations between stations

0 + 00 and 2 + 50. The distances AB and AD can be computed by ratio and proportion, as follows:

$$AB = \frac{50}{250} \times 201.0 = 40.20 \text{ ft}$$

$$\text{and } AB = \frac{150}{250} \times 201.0 = 120.60 \text{ ft.}$$

These distances are laid off on the random line from point A toward station 0 + 00. The instrumentman then occupies points B and D; turns the same angle, 108°00′, that he measured at point A; and establishes points C and E on lines from points B and D through the stations being sought. The dist antes are computed by similar triangles as follows:

$$\text{B to station 2 + 00(BC)} = \frac{200}{250} \times 98.3 \text{ ft} = 78.64 \text{ ft}$$

$$\text{D to station 1 + 00(DE)} = \frac{100}{250} \times 98.3 \text{ ft} = 39.32 \text{ ft}$$

TYING IN A POINT

Determining the horizontal location of a point or points with reference to a station, or two stations, on a traverse line is commonly termed *TYING IN THE POINT*. Various methods used in the process are presented in the next several paragraphs.

Locating Points by Swing Offsets

The SWING OFFSET is used for locating points close to the control lines (fig. 13-21). Measurement of a swing offset distance provides an accurate determination of the perpendicular

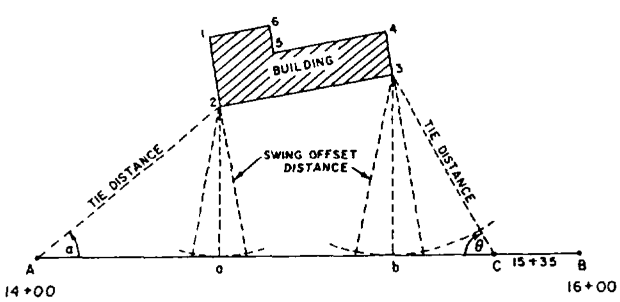


Figure 13-21.-Swing offset method of locating points.

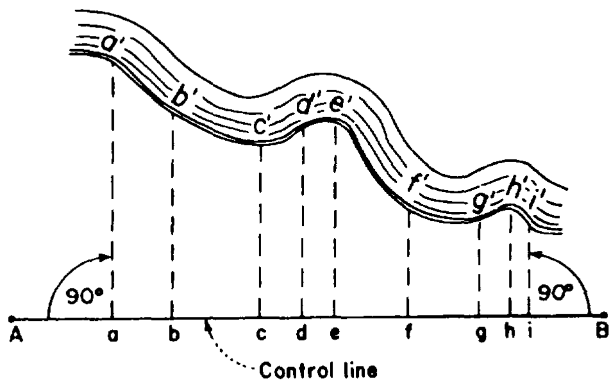


Figure 13-22.-Perpendicular offsets.

distance from the control line to the point being located. The swing offset is somewhat similar to the range tie (explained later), but as a rule, requires no angle measurement. To determine the swing offset distance, a chainman holds the zero mark of the tape at a corner of the structure while another chainman swings an arc with the graduated end of the tape at the transit line AB. When the shortest reading on the graduated end of the tape is observed, the swing offset or perpendicular distance to the control line is obtained at points a or b. In addition, the horizontal distances between the instrument stations (A and B) and the swing offset points (a and b) maybe measured and marked. A tie distance and angle α or Φ may be measured from either instrument station to the corner of the structure to serve as a check.

Locating Points by Perpendicular Offsets

The method of PERPENDICULAR OFFSETS from a control line (fig. 13-22) is similar to swing offsets. This method is more suitable than the swing offset method for locating details of irregular objects, such as stream banks and winding roads. The control line is established close to the irregular line to be located, and perpendicular offsets, aa′, bb′, cc′, and so on, are measured to define the irregular shape. When the offset distances are short, the 90° angles are usually estimated; but when the distances are several hundred feet long, the angles should be laid off with an instrument. The distances to the offset points from a to i are measured along the control line.

Locating Points by Range Ties

A point's location can also be determined by means of a RANGE TIE, using an angle and a

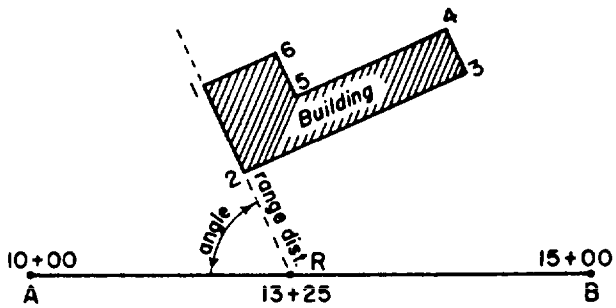


Figure 13-23.-Range ties.

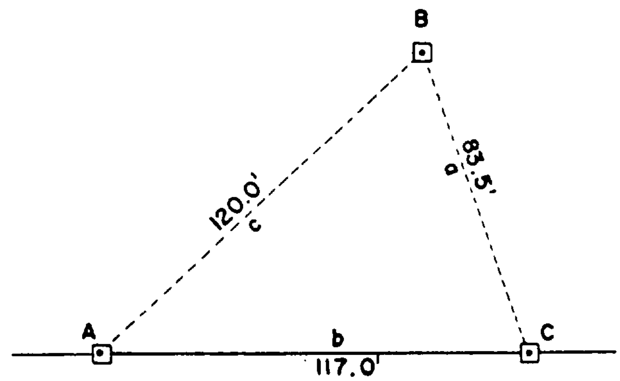


Figure 13-24.-Locating a point by distances from two stations.

distance. The method requires extra instrument manipulation and should be used only when none of the previous methods are satisfactory for use. Actually, range ties establish not only the corner of a structure but also the alignment of one of the sides. In figure 13-23, assume that the building is not visible from either A or B or that either or both of the distances from A to B to a corner of the building cannot be measured easily. With the instrument set up at either A or B and the line AB established, one member of the party moves along AB until he reaches point R, which is the intersection of line 1-2 extended. The instrument is moved and set up on R, and the distance along the line AB to R is measured. An angle measurement to the building is made by using either A or B as the backsight. The range distance, R-2, is measured as well as the building dimensions.

SETTING ADJACENT POINTS

"To set a point adjacent to a traverse line" means to establish the location of a point by following given tie data. This tie data may be (1) a perpendicular offset distance from a single specified station, (2) angles from two stations, or (3) an angle from one station and the distance from another station.

Setting Points When Given a Perpendicular Offset Distance

To set a point when given an angle and its distance from a single station, you simply setup the instrument at the station, turn the designated angle, and chain the distance along the line of sight. For perpendicular offset, the angle is 90°.

To set a point when given a distance from each of two stations, you can manage by using two tapes if each of the distances is less than a full tape length. To do so, you set the zero end of the tapes on both stations, run out the tapes, and match the distance mark on each tape to correspond with the required distance from the stations. When the tape is drawn taut, the point of contact between the tapes will be over the location of the desired point.

If one or both of the distances is greater than a full tape length, you can determine direction of one of the tie lines by correct triangle solution. For example, in figure 13-24, you want to set Point B 120.0 ft from station A and 83.5 ft from station C. A and C are 117.0 ft apart. You can determine the size of the angle at A by triangle solution as follows:

$$1 - \cos A = \frac{2(s - b)(s - c)}{bc}$$

$$s = 1/2(120.0 + 117.0 + 83.5) = 160.25$$

$$1 - \cos A = \frac{2(43.25)(40.25)}{(117.0)(120.0)} = 0.24797$$

$$\cos A = 1.00000 - 0.24797 - 0.75203$$

$$A = 41°14'$$

To set point B, you can set up a transit at A, sight on C, turn 41°14′ to the left, and measure off 120.0 ft on that line of sight. As a check, you can measure BC to be sure it measures 83.5 ft.

Setting Points When Given Angles from Two Stations

To set a point when given the angle from each of two traverse stations, you should ordinarily

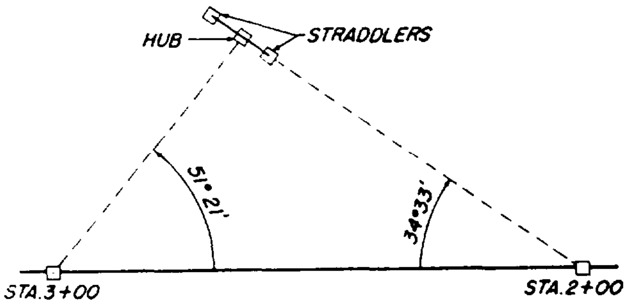


Figure 13-25.-Setting a point by the use of straddlers.

use a pair of straddle hubs (commonly called STRADDLERS), as shown in figure 13-25. Here the point was to be located at an angle of 34°33′ from station 2 + 00 and at an angle of 51°21′ from station 3 + 00. The transit was set up at station 2 + 00, sighted on station 3 + 00, and an angle of 34°33′ was turned to the right. On this line of sight, a pair of straddle hubs was driven, one on either side of the estimated point of intersection of the tie lines. A cord was stretched between the straddlers.

The transit was then shifted to station 3 + 00, sighted on station 2 + 00, and an angle of 51°21′ was turned to the left. A hub was driven at the point where this line of sight intercepted the cord between the straddlers.

Setting Points When Given an Angle from One Station and the Distance from Another

To set a point with a given angle from one station and the distance from another, you would find it best to determine the direction of the distance line by triangle solution. In figure 13-26,

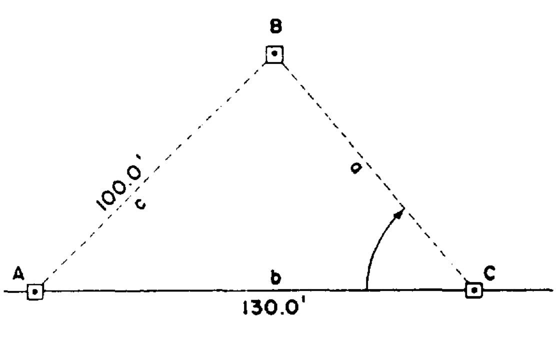


Figure 13-26.-Locating a point by angle and distance from two stations.

point B is to be located 100.0 ft from station A and at an angle of 50°00′ from station C.

In this example, you can determine the size of the angle at A by first determining the size of angle B, then subtracting the sum of angles B and C from 180°. The solution for angle B is as follows:

$$\sin B = \frac{130.0 \sin 50°00'}{100.0}$$

$$\sin B = \frac{130.0(0.76604)}{100.0} = 0.99585.$$

Angle B then measures, to the nearest minute, 84°47′. Therefore, angle A measures

$$180°00' - (84°47' + 50°00') = 45°13'.$$

Set up a transit at A, sight on C, and turn 45°13′ to the left. Then, you set B by measuring off 100.0 ft on this line of sight. As a check, you set up the transit at C, sight on A, turn 50°00′ to the right, and make sure this line of sight intercepts the marker at B.

TRANSIT-TAPE SURVEY

The exact method used in transit-tape survey may vary slightly, depending upon the nature of the survey, the intended purpose, the command or unit policy, and the preferences of the survey party chief. The procedures presented in this section are customary methods described in general terms.

SELECTING POINTS FOR MARKING

All points where a traverse changes direction are marked, usually with a hub that locates the station exactly, plus a guard stake on which the station of the change-of-direction point is inscribed, such as 12 + 35. In the expression "station 12 + 35," the 12 is called the full station and the 35 is called the plus.

The points that are to be tied to the traverse or set in the vicinity of the traverse are usually selected and marked or set as the traverse is run. The corresponding tie stations on the traverse are selected and marked at the same time. The first consideration in selecting tie stations is VISIBILITY, meaning that tie stations and the point to be tied or set must be intervisible. The next is PERMANENCY (not easily disturbed). Last is the STRENGTH OF INTERSECTION, which generally means that the angle between two tie lines should be as close to 90° as possible. The more acute or obtuse the angle is between tie lines, the less accurate the location of the point defined by their intersection.

IDENTIFYING PARTY PERSONNEL

A typical transit-tape survey party contains two chainmen, a transitman, a recorder (sometimes the transitman or party chief doubles as recorder), a party chief (who may serve as either instrumentman or recorder, or both), and axmen, if needed. The transitman carries, sets up, and operates the transit; the chainmen do the same with the tapes and the marking equipment.

When the transitman turns an angle, he calls out the identity and size of the angle to the recorder, as "Deflection angle AB to BC, 75°16′, right." The recorder repeats this, then makes the entry. Similarly, the head chainman calls out the identity and size of a linear distance, as "B to C, 265.72 ft," then the recorder repeats this back and makes the entry at that time. If the transitman closes the horizon around a point, he calls out, "Closing angle, such and such." The recorder repeats this and then adds the closing angle to the original angle. If the sum of the angles doesn't come close to 360°, the recorder notifies the party chief.

The party chief is in complete charge of the party and makes all the significant decisions, such as the stations to be marked on the traverse.

ATTAINING THE PRESCRIBED ORDER OF PRECISION

The important distinction between accuracy and precision in surveying is explained as follows:

- Accuracy denotes the degree of conformity with a standard. It relates to the quality of a result and is distinguished from precision, which relates to the quality of the operation by which the result is obtained.

The accuracy attained by field surveys is the product of the instructions or specifications to be followed in doing the work and the precision in following those instructions.

For example, the "accuracy of a surveyor's tape" means the degree to which an interval of 100 ft, as measured on the tape, actually agrees with the exact interval of a standard 100-ft tape. If a tape indicates 100 ft when the interval it measures is only 99.97 ft, the tape contains an inaccuracy of 0.03 ft for every 100 ft measured. The accuracy of this particular tape, expressed as a fraction, is 0.03/100, or approximately 1/3,300.

- Precision denotes degree of refinement in the performance of an operation or in the statement of a result. It relates to the quality of execution and is distinguished from accuracy that relates to the quality of the result. The term *precision* not only applies to the fidelity of performing the necessary operations but, by custom, has been applied to methods and instruments used in obtaining results of a high order of accuracy. Precision is exemplified by the number of decimal places to which a computation is carried and a result stated. In a general way, the accuracy of a result should determine the precision of its expression. Precision will not have significance unless accuracy is also obtained.

If you measure a linear distance with a tape graduated in feet that are subdivided into tenths, you can read (without estimation) only to the nearest tenth (0.1) of a foot. But with a tape graduated to hundredths of a foot, you can directly read distances measured to the nearest hundredth (0.01) of a foot. The apparent nearness of the second tape will be greater; that is, the second tape will have a higher precision.

Completely precise measurement is impossible in the nature of things. There is always a built-in or inherent error, amounting to the size of the smallest graduation. Precision for the first tape above, expressed as a fraction, is 0.1/100 or 1/1,000 and for the second tape, 1/10,000.

Precision in measurements is usually expressed in a fractional form with unity as the numerator, indicating the allowable error within a certain limit as indicated by the denominator, such as 1/500. In this case, you are allowed a maximum error of 1 unit per 500 units measured. If your unit of measure is in feet, you are allowed 1 ft for every 500 ft.

In general, any survey has to be carried out accurately, meaning that errors and mistakes have to be avoided. The precision of a survey, however, depends upon the order of precision that is either specified or is implied from the nature of the survey.

The various orders of precision are absolute, not relative, in meaning. Federal agencies control surveys. They are generally classified into four orders of precision; namely, FIRST ORDER, SECOND ORDER, THIRD ORDER, and

Table 13-1.-Control Traverse Order of Precision

ORDER OF PRECISION	MAXIMUM NUMBER OF AZIMUTH COURSES BETWEEN AZIMUTH CHECKS	DISTANCE MEASUREMENT ACCURATE WITHIN	MAXIMUM LINEAR ERROR OF CLOSURE	MAXIMUM ERRORS OF ANGLES
FIRST ORDER	15	$\frac{1}{35,000}$	$\frac{1}{25,000}$	* 2 sec $\sqrt{N}$ or 1.0 sec per station.
SECOND ORDER	25	$\frac{1}{15,000}$	$\frac{1}{10,000}$	* 10 sec $\sqrt{N}$ or 3.0 sec per station
THIRD ORDER	50	$\frac{1}{7,500}$	$\frac{1}{5,000}$	* 30 sec $\sqrt{N}$ or 8.0 sec per station
FOURTH ORDER	--	$\frac{1}{3,000}$	$\frac{1}{1,000}$	2 min or compass

N = the number of stations carrying azimuth.
* Use whichever is smaller in value.

FOURTH ORDER control surveys. The FIRST ORDER is the highest and the FOURTH ORDER, the lowest standard of accuracy.

Because of the type of instruments available in the SEABEEs, most of your surveys may not require a precision higher than a third order survey. When the order of precision is not specified, you may use table 13-1 in this training manual (TM) as a standard for a horizontal control survey when using the traverse control method. For surveys that call for a higher order of precision, you will have to use theodolites to obtain the required precision.

The triangulation control method is discussed fully in *Engineering Aid 1 & C,* NAVEDTRA 10635-C. At present, however, you may have survey problems that require the use of the triangulation method. In such a case, you may use table 13-2 in this TM as a guide for the order of precision if it is not specified in the survey.

The practical significance of a prescribed or implied order of precision lies in the fact that the instruments and methods used must be capable of attaining the required precision. The precision of an instrument is indicated by a fraction in which the numerator is the inherent error. (In a 1-min transit, the inherent error is 1 min.)

The denominator is the total number of units in which the error occurs. For a transit, this last is 90°, or 5,400′. The precision of a 1-min transit. then, is 1/5,400, adequate for a third order survey.

Precision of a tape is given in terms of the inherent error per 100 ft. A tape that can be read to the nearest 0.01 ft has a precision of 0.01/100, or 1/10,000—adequate for second order work.

Attaining Precision with a Linear Error of Closure

For a closed traverse, you should attain a RATIO OF LINEAR ERROR OF CLOSURE that corresponds to the order of precision prescribed or implied for the traverse. The ratio of linear error of closure is a fraction in which the numerator is the linear error of closure and the denominator is the total length of the traverse.

To understand the concept of linear error of closure, you should study the closed traverse shown in figure 13-27. Beginning at station C, this traverse runs N30°E300 ft, thence S30°E300 ft; thence S90°W 300 ft. The end of the closing traverse, BC, lies exactly on the point of beginning, C. This indicates that all angles were turned and all distances chained with perfect accuracy, resulting in perfect closure, or an error of closure of zero feet.

However, in reality, perfect accuracy in measurement seldom occurs. In actual practice,

Table 13-2.-Triangulation Order of Precision

PRECISION	APPLICATION	BASE LINE MEASUREMENT MAX. PROBABLE ERROR	TRIANGLE CLOSURE: MAX. AVERAGE ERROR	LENGTH CLOSURE: MAX. DISCREPANCY BET. MEASURED AND COMPUTED LENGTH BASE LINE
FIRST ORDER	CASE I For city and scientific study survey.	$\frac{1}{1,000,000}$	1.0 sec	$\frac{1}{100,000}$
	CASE II Basic network of U.S.	$\frac{1}{1,000,000}$	1.0 sec	$\frac{1}{50,000}$
	CASE III All other purposes.	$\frac{1}{1,000,000}$	1.0 sec	$\frac{1}{25,000}$
SECOND ORDER	CASE I Area networks and supplemental cross arcs in national net.	$\frac{1}{1,000,000}$	1.5 sec	$\frac{1}{20,000}$
	CASE II Coastal areas, inland waterways, and engineering surveys.	$\frac{1}{500,000}$	3.0 sec	$\frac{1}{10,000}$
THIRD ORDER	Topographic Mapping	$\frac{1}{250,000}$	5.0 sec	$\frac{1}{5,000}$

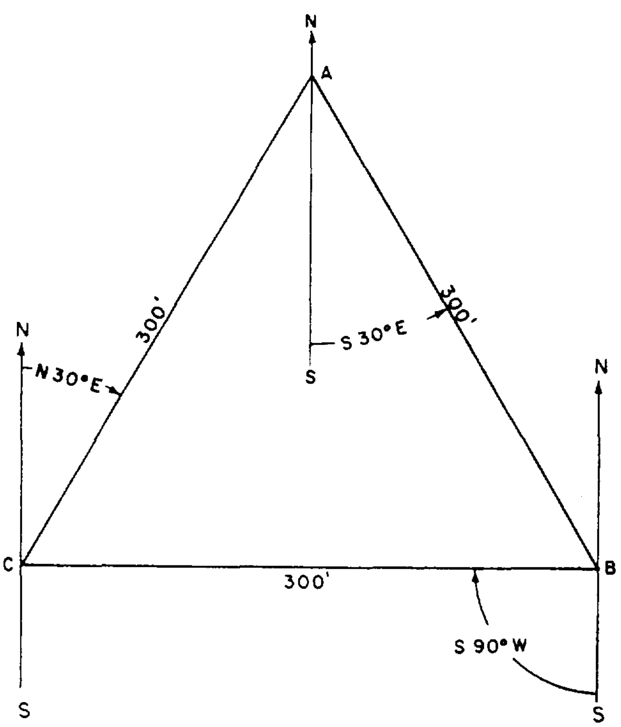


Figure 13-27.-An example of a closed traverse with a perfect (zero-error) closure.

the closing traverse line, BC, shown in figure 13-27, is likely to be some distance from the starting point, C. If this should happen, and, say, the total accumulated linear distance measured along the traverse lines is 900.09 ft, the ratio of error of closure then is .09/900 or 1/10,000. This resulting ratio is equivalent to the precision prescribed for second order work.

Attaining Precision with a Maximum Angular Error of Closure

You know that the sum of the interior angles of a closed traverse should theoretically equal the product of 180° (n – 2), n being the number of sides in the polygon described by the traverse. A prescribed MAXIMUM ANGULAR ERROR OF CLOSURE is stated in terms of the product of a given angular value times the square root of the number of interior angles in the traverse.

Again, if we use the traverse shown in figure 13-27 as an example, the prescribed maximum angular error of closure in minutes is 01 $\sqrt{3}$ because the figure has three interior angles. The sum of the interior angles should be 180°. If the sum of the angles as actually measured and recorded is 179°57′, the angular error of closure is 03′. The maximum permissible error of closure is the product of 01´ times the square root of 3, or about 1.73´. The prescribed maximum angular error of closure has therefore been exceeded.

Meeting Precision Specifications

The following specifications are intended to give you only a general idea of the typical precision requirements for various types of transit-tape surveys. When linear and angular errors of closure are specified, it is understood that a closed traverse is involved.

For many types of preliminary surveys and for land surveys, typical precision specifications may read as follows:

- Transit angles to nearest minute, measured once. Sights on range poles plumbed by eye. Tape leveled by eye, and standard tension estimated. No temperature or sag corrections. Slopes under 3 percent disregarded. Slopes over 3 percent measured by breaking chain or by chaining slope distance and applying calculated correction. Maximum angular error of closure in minutes is $1.5\sqrt{n}$. Maximum ratio linear error of closure, 1/1000. Pins or stakes set to nearest 0.1 ft.

For most land surveys and highway location surveys, typical precision specifications may read as follows:

- Transit angles to nearest minute, measured once. Sights on range poles, plumbed carefully. Tape leveled by hand level, with standard tension by tensionometer or sag correction applied. Temperature correction applied if air temperature more than 15° different from standard (68°F). Slopes under 2 percent disregarded. Slopes over 2 percent measured by breaking chain or by applying approximate slope correction to slope distance. Pins or stakes set to nearest 0.05 ft. Maximum angular error of closure in minutes is $1\sqrt{n}$. Maximum ratio linear error of closure, 1/3,000.

For important boundary surveys and extensive topographical surveys, typical precision specifications may read as follows:

- Transit angles by 1-rein transit, repeated four times. Sights taken on plumb lines or on range poles carefully plumbed. Temperature and slope corrections applied; tape leveled by level. Pins set to nearest 0.05 ft. Maximum angular error of closure in minutes is $0.5\sqrt{n}$. Maximum ratio linear error of closure is 1/5,000.

Note that in the first two specifications, one-time angular measurement is considered sufficiently precise. Many surveyors, however, use two-line angular measurement customarily to maintain a constant check on mistakes.

Measuring Angles vs. Measuring Distances

It is usually the case on a transit-tape survey that the equipment for measuring angles is considerably more precise than the equipment for measuring linear distances. This fact leads many surveyors into a tendency to measure angles with great precision, while overlooking important errors in linear distance measurements.

Making the precision of angular measurement greater than that of linear measurement is useless because your angles are only as good as your linear distances. Suppose that you are running traverse line BC at a right deflection angle of 63°45´ from AB, 180.00 ft to station C. You set up at B, orient the telescope to AB extended, and turn exactly 63°45´00´´ to the right. But instead of measuring off 180.00 ft, you measure off 179.96 ft. Regardless of how precisely you turn all of the other angles in the traverse, every station will be dislocated because of the error in the linear measurement of BC.

Remember that angles and linear distances must be measured with the same precision.

IDENTIFYING ERRORS AND MISTAKES IN TRANSIT WORK

In transit work, errors are grouped into three general categories; namely, INSTRUMENTAL, NATURAL, and PERSONAL errors. First, we will discuss these errors, and then, later, we will explain the common mistakes in transit work.

Identifying Instrumental Errors

A transit will not measure angles accurately unless the instrument is in the following condition:

1. The vertical cross hair must be perpendicular to the horizontal axis. If the vertical cross hair is not perpendicular, the measurement of horizontal angles will be inaccurate.
2. The axis of each of the plate levels must be perpendicular to the vertical axis. If they are not, the instrument cannot be accurately leveled.

If the instrument is not level, the measurement of both horizontal and vertical angles will be inaccurate.

3. The line of sight through the telescope must be perpendicular to the horizontal axis. If it is not, the line of sight through the telescope inverted will not be 1800 opposite the line of sight through the telescope erect.

4. The horizontal axis of the telescope must be perpendicular to the vertical axis. If it is not, the measurement of both horizontal and vertical angles will be inaccurate.

5. The axis of the telescope level must be parallel to the line of sight through the telescope. If it is not, the telescope cannot be accurately leveled. If the telescope cannot be accurately leveled, vertical angles cannot be accurately measured.

6. The point of intersection of the vertical and horizontal cross hairs must coincide with the true optical axis of the telescope. If it doesn't, measurement of both horizontal and vertical angles will be inaccurate.

NOTE: Any or all of the above conditions may be absent in an instrument that is defective or damaged, or one that needs adjustment or calibration.

Identifying Natural Errors

Common causes of natural errors in transit work are as follows:

1. Settlement of the tripod in yielding soil. If the tripod settled evenly—that is, if the tip of each leg settled precisely the same amount—there would be little error in the results of measuring horizontal angles. Settlement is usually uneven, however, which results in the instrument not being level.

2. Refraction—but the effect of this is usually negligible in ordinary precision surveying.

3. Unequal expansion or contraction of instrument parts caused by excessively high or low temperature. For ordinary precision surveying, the effect of this is also usually negligible.

4. High wind may cause plumbing errors when you are plumbing with a plumb bob and cord and may also cause reading errors because of vibration of the instrument.

Identifying Personal Errors

Personal errors are the combined results of carelessness and of the limitations of the human eye in setting up and leveling the instrument and in making observations.

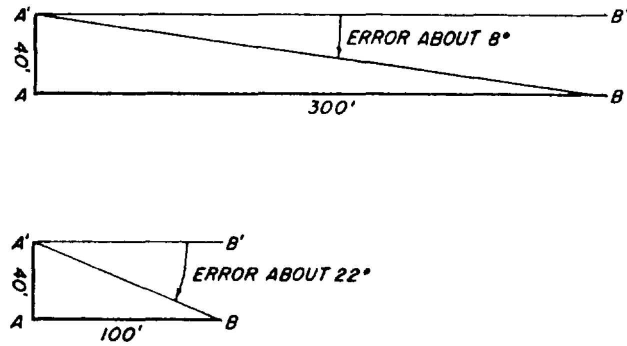


Figure 13-28.-Exaggerated illustration of error caused when the transit is not centered exactly over the occupied station.

Common causes of personal errors in transit work are as follows:

1. Failure to plumb the vertical axis exactly over the station. Figure 13-28 shows how the result of inaccuracy increases drastically as the sight distance decreases. In that figure, an instrument supposed to be set up at A was actually set up at A´, 40 ft away from A. (For demonstration purposes the figure was exaggerated to magnify the error; in actual practice the eccentricity amounts only to a fraction of an inch. Remember that mathematically, 1 in. is the arc of 1 min when the radius is 300 ft.)

In the upper view, you can see that with B located 300 ft from A, the angular error caused by the displacement is about 8°. In the lower view, however, with B located only 100 ft from A, the angular error caused by the displacement is about 22°.

The practical lesson to be learned from this is that you must plumb the instrument much more carefully for a short sight than for a long one.

2. Failure to center plate level bubbles exactly. The result of this is that the instrument is not leveled exactly. The consequent error is at a minimum for a horizontal sight and increases as a sight becomes inclined.

The practical lesson is that you should level the instrument much more carefully for an incline sight than for a horizontal one.

3. Inexact setting or reading of a vernier. The use of a small, powerful pocket magnifying glass is helpful here. Also, when you have determined the vernier graduation that most nearly coincides with a limb graduation, it is a good idea to check your selection by examining the graduations on either side of the one selected. These should fall in coincidence with the limb counterparts by about the same amount.

4. Failure to line up the vertical cross hair with the true vertical axis of the object sighted. The effect is similar to that of not plumbing exactly over the station, which means that the error increases drastically as the length of the sight decreases.

5. Failure to bring the image of the cross hair or that of the object sighted into clear focus (parallax). A fuzzy outline makes exact alignment difficult.

Common mistakes in transit work are the following:

1. Turning the wrong tangent screw. For example, by turning the lower tangent screw AFTER taking a backsight, you will introduce an error in the backsight reading.

2. Forgetting to tighten the clamp(s), or a clamp slipping when it is supposed to be tight.

3. Reading in the wrong direction from the index (zero mark) on a double vernier.

4. Reading the wrong vernier; for example, reading the vernier opposite the one that was set.

5. Reading angles in the wrong direction; that is, reading from the outer row rather than the inner row, or vice versa, on the horizontal scale.

6. Failure to take a full-scale reading before reading the vernier. For example, you may drop 20 to 30 min from the reading, erroneously recording only the number of minutes indicated on the vernier, such as 15°18´ instead of 15°48´. Do not be so intent on reading the vernier that you lose track of the full-scale reading of the circle.

CARING FOR AND MAINTAINING SURVEYING INSTRUMENTS

The accuracy and quality of a survey depend upon the condition of the surveying instrument and the experience of the surveyor. The life expectancy and usefulness of an instrument can be extended considerably by proper and careful handling, stowing, and maintenance. Undoubtedly, by simply working in your rating conscientiously, you will become experienced in the proper use of the instrument.

As stated earlier, every instrument is accompanied by an instruction manual that tells you not only the proper operation and components of the instrument but also procedures for its proper care and maintenance. Study this instruction manual thoroughly before you even attempt to use the instrument.

Carrying and Stowing

Every transit, theodolite, or level comes equipped with a carrying box or case. The instrument and its accessories can be stowed in the case in a manner that ensures a minimum of motion during transportation. The instrument should ALWAYS be stowed in the carrying case when it is not in use.

Cleaning and Lubricating

In general, all surveying instruments, equipment, or tools must be cleaned thoroughly immediately after you have used them. For example, you dust off the transit or theodolite and wipe it dry before placing it back in its case after each use. Remove all dust with a clean cloth. This applies particularly to the optical parts. Chamois leather is suitable for this purpose, but it is better to use a clean handkerchief than a soiled chamois leather. Use no liquid for cleaning — neither water, petrol, nor oil. If necessary, you can breathe on the lenses before polishing them. When the instrument becomes wet, you should remove its case and dry it thoroughly at room temperature as soon as you get home. If you leave the instrument in the closed case, the air inside the hood will take up humidity by increasing temperature and will in time diffuse inside the instrument. While cooling off, the water will condense and form a coating or tarnish that may make any sighting with the telescope and reading of the circles difficult.

Remove any mud or dirt that may adhere to the tripod, range pole, level rod, and so forth, after each use. Clean each instrument, equipment, or tool after each use to eliminate the chance of forgetting it. This is important, especially when the surveying gear is made of a material that is susceptible to rust action or decay.

When lubricating the instruments, you must use the recommended lubricant for each part in conjunction with the climatic condition in your area. For instance, it is recommended that graphite be used to lubricate transit moving parts when the transit is to be used in sub-zero temperatures instead of the light film of oil (preferably watch oil) when its use is confined to an area with normal weather conditions. The lubricant should be applied thinly to avoid making the lubricated parts an easy repository for dust or catcher of dust.

Consult the manufacturer's manual or your senior EA whenever you are in doubt before doing anything to an instrument.

NOTE: Information on tests, adjustments, and minor repairs of surveying instruments will be presented at the EA2 level.

TRAVERSE OPERATIONS (FIELD PROCEDURES)

A survey traverse is a sequence of lengths and directions of lines between points on the earth, obtained by or from field measurements and used in determining positions of the points. A survey traverse may determine the relative positions of the points that it connects in series; and, if tied to control stations based on some coordinate system, the positions may be referred to that system. From these computed relative positions, additional data can be measured for layout of new features, such as buildings and roads.

Traverse operations (actions commonly called TRAVERSING) are conducted for basic area control; mapping; large construction projects, such as military installation or air bases; road, railroad, and pipeline alignment; control of hydrographic surveys; and for many other projects. In general, a traverse is always classified as either a CLOSED TRAVERSE or an OPEN TRAVERSE.

A closed loop traverse (fig. 13-29, view A), as the name implies, forms a continuous loop, enclosing an area. This type of closed traverse starts and ends at the same point, whose relative horizontal position is known. A closed connecting traverse (fig. 13-29, view B) starts and ends at separate points, whose relative positions have been determined by a survey of an equal or higher order accuracy. An open traverse (fig. 13-29, view C) ends at a station whose relative position is not previously known, and unlike a closed traverse, provides no check against mistakes and large errors. Open traverses are often used for preliminary survey for a road or railroad.

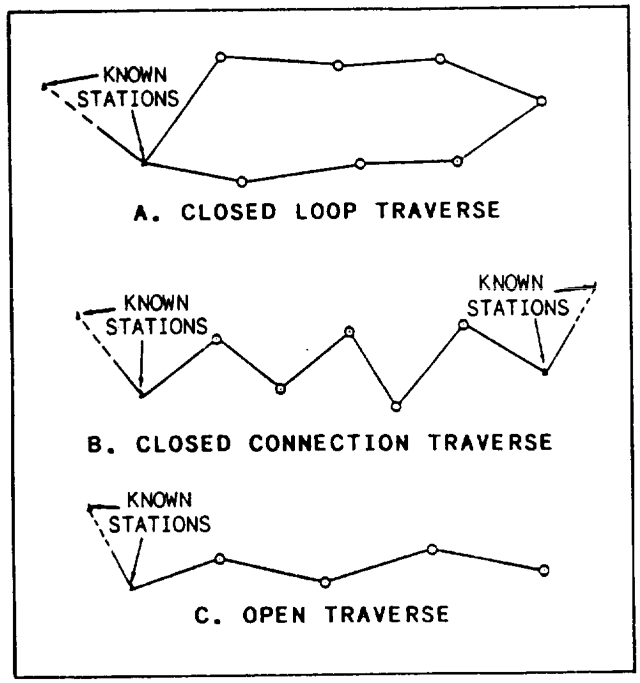


Figure 13-29.-Types of traverses.

The order of ACCURACY for any traverse is determined by the equipment and methods used in the traverse measurements, by the accuracy attained, and by the accuracy of the starting and terminating stations. Hence, the order of accuracy must be specified before the measurements are started. For engineering and mapping projects, the distance measurement accuracy for both electronic and taped traverses for first, second, and third order are 1/35,000, 1/15,000, and 1/7,500, respectively.

For military use such as field artillery, lower order accuracies of fourth, fifth, and sixth are 1/3,000, 1/1,000, and 1/500, respectively. The order referred to as lower order is applied to all traverses of less than third order.

To accomplish a successful operation, the traverse party chief must ensure that initial preparations and careful planning are done before the actual traversing begins. In the remainder of this chapter, we will discuss some of the basic procedures normally undertaken by a transit-tape traverse party.

ORGANIZING THE PARTY

A traverse party may vary from 2 to about 12 personnel, all under the supervision of a traverse party chief. It usually consists of a distance-measuring crew, an angle crew, sometimes a level crew, and other support personnel. This breakdown of personnel is ideal; but, on many occasions, the same personnel will have to perform a variety of tasks or functions. Therefore, each party member is trained to assume various duties and functions in several phases of the work survey.

CONDUCTING A RECONNAISSANCE

Whenever possible, a reconnaissance must be made to determine the starting point, the route to be followed, the points to be controlled, and the closing station. When selecting the starting and closing points, you must select an existing control station that was determined by a survey whose order of accuracy was equal to or greater than the traverse to be run. When running a traverse in which the direction of the traverse lines are not fixed before the start, select a route that offers minimum clearing of traverse lines. The best available maps and aerial photographs should be used during the office and field reconnaissance. By selecting a route properly, you can lay out the traverse to pass relatively close to points that have to be located or staked out.

On other surveys, such as road center line layout, the directions of the traverse lines are predetermined, and all obstructions, including large trees, have to be cleared from the line. Often the assistance of the equipment and construction crews is needed at this point. For the lower order surveys and where taping is used, the exact route and station locations normally are selected as the traverse progresses. These stations have to be selected so that at any one station, both the rear and forward stations are visible, and only a minimum number of instrument setups is kept, reducing the possibility of instrument error and the amount of computing required.

Furthermore, the electronic distance-measuring devices (EDMs) have made traverse reconnaissance even more important. The possibility y of using an EDM should be considered after the general alignment in direction and the planned positioning of stations. A tower or platform installed to clear surface obstruction will permit comparatively long optical sights and distance measurements, hence avoiding the necessity of taping it in short increments.

PLACING STATION MARKS

Some station marks are permanent markers, and some are temporary markers, depending upon the purpose of the traverse. A traverse station that will be reused over a period of several years is usually marked in a permanent manner. Permanent traverse station markers are of various forms, including such forms as an iron pipe filled with concrete; a crosscut in concrete or rock; or a hole drilled in concrete or rock and filled with lead, with a tack to mark the exact reference point. Temporary markers, on the other hand, are used on traverse stations that may never be reused, or perhaps will be reused only a few times within a period of 1 or 2 mo. Temporary traverse station markers are usually 2-in. by 2-in. wooden hubs, 12 in. or more in length. They are driven flush with the ground and have a tack or small nail on top to mark the exact point of reference for angular and linear measurements. To assist in recovering the hub, a 1-in. by 2-in. wooden guard stake, 16 in. or more in length is driven at an angle so that its top is about 1 ft over the hub. Keel (lumber crayon) or a large marking pen is used to mark letters and/or numbers on the guard stake to identify the hub. The marked face of the guard stake is toward the hub. Since many of the hubs marking the location of road center lines, landing strips, and other projects will require replacement during construction, reference marks are placed several hundred feet or meters away from the station they reference. Reference marks, usually similar in construction to that of the station hub, are used to reestablish a station if its marker has been disturbed or destroyed.

NOTE: Procedures for marking hub and guard stakes for traverse stations, road center line layout, and other surveys are presented in the next chapter.

TYING IN TO EXISTING CONTROL

As we discussed earlier in this chapter, the starting point of a closed traverse must be a known position or control point; and, for a closed loop traverse, this point is both the starting and closing point. Closed connecting traverses start at one control point and tie into another control point.

A traverse starting point should be an existing station with another station visible for orienting the new traverse. The adjacent station must be intervisible with the starting point to make the tie easy. If you do not find the adjacent station easily, you should observe an astronomic azimuth to orient the starting line, and then continue the traverse. Any existing control near the traverse line should be tied in to the new work.

PERFORMING LINEAR MEASUREMENTS

As traversing progresses, linear measurements are conducted to determine the distance between stations or points. Generally, the required traverse accuracy will determine the type of equipment and the method of measuring the distance. For the lower orders, a single taped distance is sufficient. However, as the order of accuracy gets higher, DOUBLE TAPING (once each way) is required. Ordinary steel tapes must be compared to an Invar or Lovar tape at specified intervals. For the highest accuracy, electronic distance-measuring devices (EDM) are used to measure linear distances. Linear measurements may also be made by indirect methods, using an angle measuring instrument, like the transit or theodolite with stadia. When the distances are determined by stadia readings, the vertical angles are read and used to convert slope distances to horizontal distances.

If double taping or chaining is required, follow these procedures:

1. Follow a direct line between stations, using a guide, such as a transit and a range pole, for alignment. Start measuring from the occupied station, keeping the front end of the tape aligned with the forward station.

2. Start back from the forward station, using the same alignment but not the same taping points. The second measurement must be independent of the first.

3. Compare the two distances, and if within accuracy requirements, the distance is accepted. If the two measurements disagree by more than the allowable amount, retape the distance.

4. Proceed to the next line measurement, and continue double taping until the tie-in control point is reached.

PERFORMING ANGULAR MEASUREMENT

Horizontal angles formed by the lines of each traverse station determine the relative directions of the traverse lines. These angles are measured using a transit or a theodolite, or determined graphically with a plane table and alidade. In a traverse, three traverse stations are significant: the REAR STATION, the OCCUPIED STATION, and the FORWARD STATION (fig. 13-30). The rear station is that station from which the crew performing the traverse has just moved, or it is a point, the azimuth to which is known. The occupied station is the station at which the crew is now located and over which the surveying instrument is set. The forward station is the next station in succession and constitutes the immediate destination of the crew. The stations are numbered consecutively starting at Number 1 and continuing throughout the traverse. In addition to the number of station, an abbreviation indicating the type of traverse is oftentimes

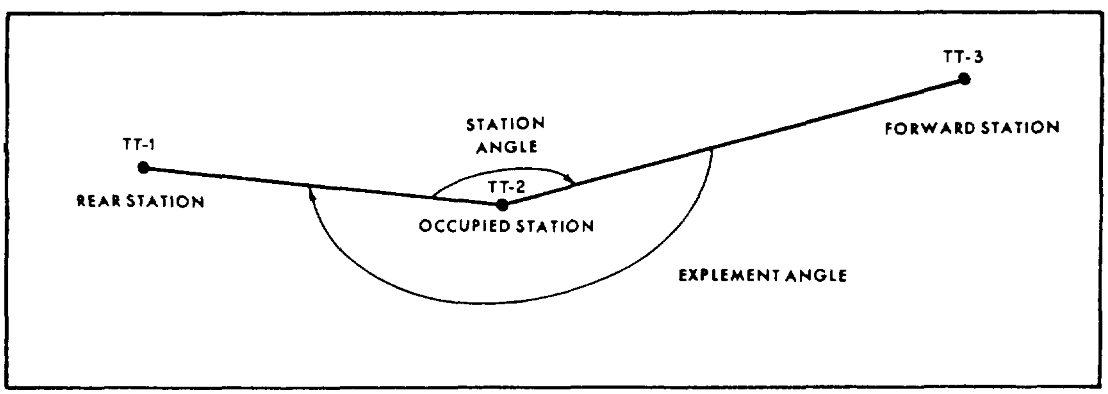


Figure 13-30.-Traverse stations and angles.

included; for example, ET for electronic traverse or TT for theodolite- or transit-tape traverse.

Horizontal angles are always measured at the occupied station by pointing the instrument toward the rear station and turning the angle clockwise to the forward station for the direct angle, and clockwise from the forward to the rear station for the explement (fig. 13-31). If a deflection angle is to be used, plunge the instrument telescope, after sighting the rear station, and read the angle left or right of the forward station.

NOTE: Office procedures for traverse computations and adjustments, methods of computing traverse area, and plotting horizontal control are discussed at the EA2 level.

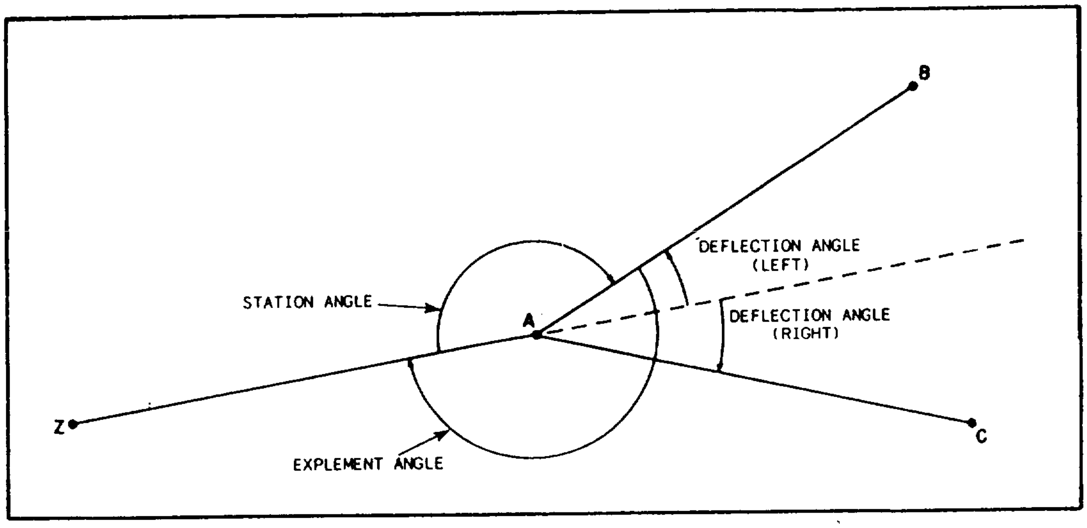


Figure 13-31.-Kinds of angles measured at the occupied station.

CHAPTER 14

DIRECT LEVELING AND BASIC ENGINEERING SURVEYS

Leveling is an operation that is used for determining the elevations of points or the differences in elevation between points on the earth's surface. This operation is extremely vital for deriving necessary data required for various engineering designs, mapping, and construction. Data from a finished level survey are used to (1) design roads, highways, and airfields; (2) develop maps, showing the general configuration of the ground; (3) calculate volume of earthwork; and (4) lay out construction projects.

In this chapter, we discuss the basic principles of DIRECT LEVELING and the types of methods used; the duties and responsibilities of the leveling crew; field procedures used in differential leveling; precision in leveling; and proper ways of handling leveling instruments and equipment. INDIRECT LEVELING, such as barometric and trigonometric leveling, adjustment of level network, and end areas and volume of earth's computations, is not covered in this book.

In this chapter, you will find a general description of basic engineering surveys and various construction-site safety hazards commonly associated with the EA survey party. Other types of engineering and construction surveys—particularly those for curves and earthwork—will be presented at the EA2 level.

BASIC TERMS USED IN LEVELING OPERATIONS

Generally, the basic vertical control for topographic survey and mapping is derived from first- and second-order leveling. For many construction projects and for filling gaps between second-order bench marks (BMs), less precise third-order leveling is acceptable.

In leveling, a level reference surface, or datum, is established, and an elevation is assigned to it. This datum may be assigned an assumed elevation, but true elevation is required for the establishment of a BM. A series of properly established BMs is therefore the framework of any vertical control.

Although further discussion will follow, fundamentally, direct leveling describes the method of measuring vertical distances (differences in elevation) between the plane of known or assumed elevation (datum) and the plane of a point whose elevation you are seeking. Once these distances are known, they may be added to, or subtracted from, the known or assumed elevation to get the elevation of the desired point. These vertical distances are obtained by use of a leveling rod and, usually, an engineer's level.

Some of the basic terms commonly used in leveling operations are defined in the following paragraphs.

BENCH MARK

ABM is a relatively permanent object, natural or artificial, bearing a marked point whose elevation is known. BMs are established over an area to serve as (1) starting points for leveling operations so the topographic parties can determine other unknown elevation points and (2) reference marks during later construction work. BMs are classified as PERMANENT or TEMPORARY. Generally, BM is used to indicate a permanent bench mark and TBM, to signify a temporary bench mark. TBMs are established to use for a particular job and are retained for the duration of that job. Throughout the United States, a series of BMs have been established by various government agencies. These identification markers are set in stone, iron pipe, or concrete

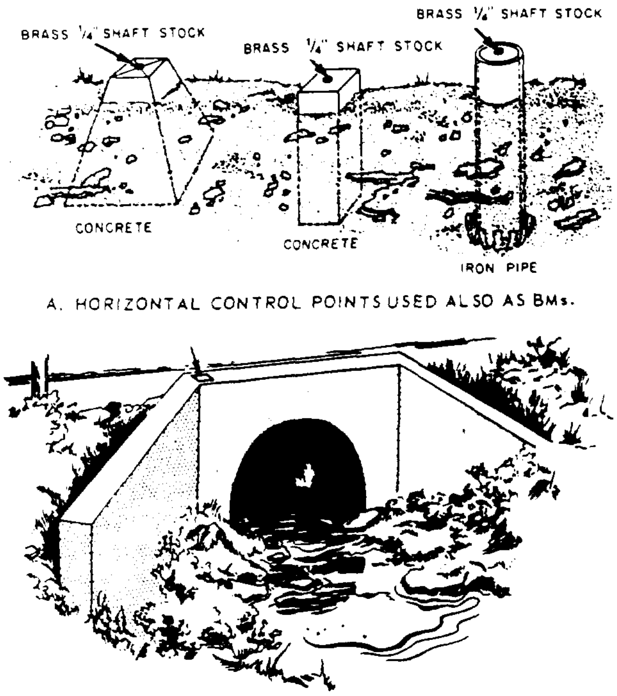


Figure 14-1.-Common types of bench mark construction and application.

and are generally marked to show the elevation above sea level. When the elevation is not marked, you can find out what it is by contacting the government agency that originally set the BM. Just be sure you give them the same identification number as the one on the marker. The type of standard bronze markers used was discussed in chapter 11 of this training manual.

BMs may be constructed in several ways. Figure 14-1, view A, shows brass shaft stocks in the tops of permanent horizontal control points (monuments). Sometimes, monuments of this type are also used for vertical control BMs. Original BMs may be constructed in the same manner. When regular BM disks are not available, brass, not steel, 50-caliber empty shell casings may be used. The shank of the empty shell casings should be drilled crosswise and a nail inserted to prevent its being pulled out or forced out by either expansion or contraction.

For short lines and a level circuit of a limited area, any substantial object may be used for vertical control BMs. The remark in the field notes should bear the proper identification of the BMs used.

Figure 14-1, view B, shows a mark like those commonly used on tops of concrete walls, foundations, and the like. Lines are chiseled out with a cold chisel or small star drill and then marked with paint or keel. The chiseled figures should be about the same size as the base area of the rod. Preferably, they should be placed on some high spot on the surface of the concrete structure.

A spike may be driven into the root of a tree or placed higher up on the trunk of the tree when the limb clearance allows higher rod readings. Figure 14-2, view A, shows the recommended way to do this. The rod should be held on the highest edge of the spike, and the elevation should be marked on the blazed portion of the tree. Figure 14-2, view B, shows a spike driven on a pole or post that also represents a BM. Drive the spike in horizontally on the face of the post in line with the direction of the level line. For the reading, hold the rod on the uppermost edge of the spike. After the elevation has been figured, mark it on the pole or post for future reference.

Stakes driven into the ground can also be used as TBMs, especially if no frost is expected before they are needed. A detailed description of these points is just as important as one for a monument station.

In most permanent military installations, monument BMs are established in a grid system approximately one-half mile apart throughout the base to have a ready reference for elevations of later construction in the station. Generally, these BMs are fenced to mark their locations. The fence also serves to protect them from being accidentally disturbed.

BM systems or level nets consist of a series of BMs that are established within a prescribed order of accuracy along closed circuits and are tied to a datum. These nets are adjusted by computations that minimize the effects of accidental errors and are identified as being of a specific order of accuracy.

In certain areas, TIDAL BENCH MARKS must be established to obtain the starting datum plane or to check previously established elevations. Tidal bench marks are permanent BMs set on high ground and are tied to the tide station near the water surface.

Tide stations are classified as primary and secondary. Primary stations require observations for periods of 19 yr or more to derive basic tidal data for a locality. Secondary stations are operated over a limited period (usually less than 1 yr) and for a specific purpose, such as checking elevations. The secondary station observations are always compared to, and computed from, data obtained by primary stations.

A tide station is set up, and observations are made for a period that is determined by a desired accuracy. These observations are compared with a primary tide station in the area and, then, are furnished with a mean value of sea level in the area.

A closed loop of spirit levels is run from the tide station over the tidal BMs and is tied back to the tide station. The accuracy of this level line must be the same as or higher than the accuracy required for the BMs.

For permanency, tidal BMs usually are set in sets of three and away from the shoreline where natural activity or future construction probably will not disturb or destroy them.

DATUM

Tidal datums are specific tide levels that are used as surfaces of reference for depth measurements in the sea and as a base for determining elevations on land. In leveling operations, the tidal datum most commonly used is the MEAN SEA LEVEL. Other datums, such as mean low water, mean lower low water, mean high water, and mean higher high water, are sometimes used, depending upon the purpose of the survey. Still other datums have been used in foreign countries. When conducting leveling operations overseas, you should check into this matter carefully to avoid mistakes.

Mean Sea Level

Mean sea level (MSL) is defined as the average height of the sea for all stages of the tide after long periods of observations. It is obtained by averaging the hourly heights as they are tabulated on a form similar to that

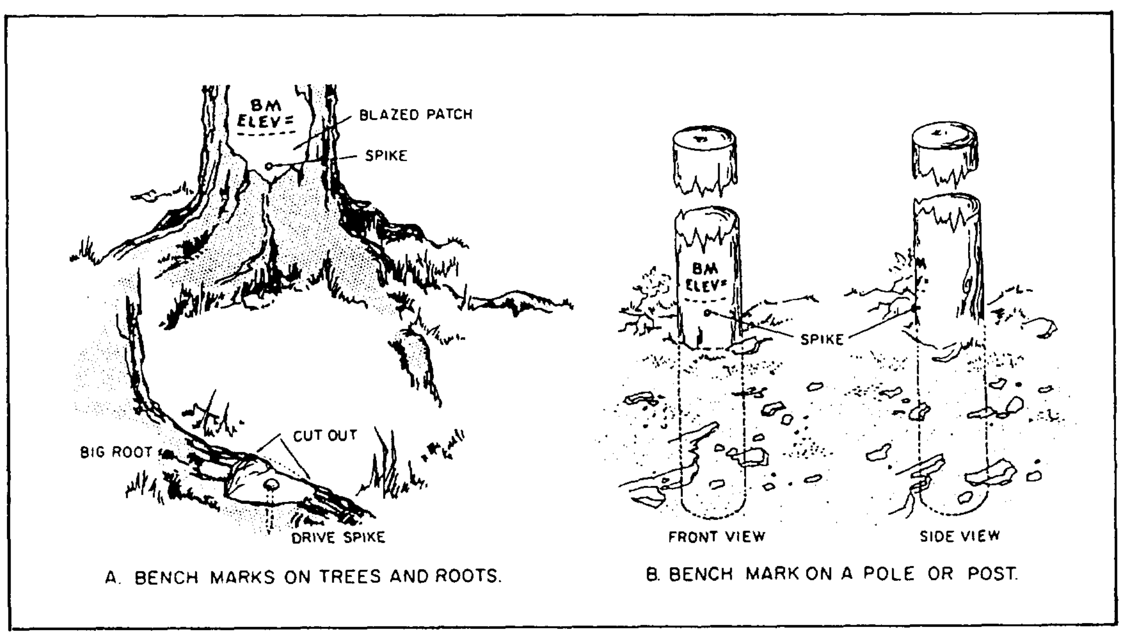


Figure 14-2.-Ways of using spikes as bench marks.

Day & Mo. / Hour	1 Mar.	2	3	4	5	6	7	Sum	Remarks:		
0	15.1 Ft.	15.5 Ft.	15.4 Ft.	13.9 Ft.	12.0 Ft.	9.0 Ft.	6.6 Ft.	87.5 Ft.	Tides: Hourly Heights		
1	14.4	15.7	16.6	15.9	14.8	12.1	9.5	99.0	Station: Portsmouth		
2	13.5	15.4	17.0	17.3	17.1	15.1	12.8	108.2	Lat. 44° 50′ N		
3	12.5	14.8	16.9	17.9	18.6	17.5	15.8	114.0	Long. 68° 10′ W		
4	11.7	14.0	16.5	17.8	19.2	19.0	18.0	116.2	Party Chief EA2 Long		
5	11.6	13.3	15.7	17.3	19.1	19.6	19.4	116.0	Tide Gage No. 85		
6	12.3	13.2	14.9	16.4	18.5	19.5	19.8	114.6	Scale 1:24		
7	13.7	13.7	14.6	15.5	17.4	18.7	19.5	113.1	Tabulated by EA3 Smith		
8	15.4	15.0	15.0	15.0	16.3	17.6	18.6	112.9			
9	17.6	16.5	15.9	15.2	15.6	16.3	17.1	114.2			
10	19.2	18.2	17.2	16.0	15.8	15.6	15.9	117.9			
11	20.1	19.4	18.5	17.2	16.6	15.6	15.1	122.5			
12	19.9	19.8	19.4	18.4	17.7	16.3	15.4	126.9			
13	19.0	19.3	19.7	19.2	18.7	17.5	16.2	129.6			
14	17.3	18.0	18.9	19.2	19.5	18.4	17.3	128.6			
15	15.0	15.9	17.3	18.2	19.4	19.0	18.3	123.3			
16	12.2	13.1	14.8	16.3	18.1	18.6	18.9	112.0			
17	10.3	10.5	11.8	13.6	15.9	17.1	18.4	97.7			
18	9.5	8.5	9.2	10.5	13.0	14.7	16.8	82.2			
19	9.7	7.8	7.4	7.8	9.8	11.5	14.1	68.1			
20	10.5	8.3	6.7	6.1	7.0	8.1	10.9	57.6			
21	11.8	9.5	7.5	5.8	5.3	5.6	7.8	53.3			
22	13.4	11.4	9.1	7.0	5.1	4.2	5.4	55.6			
23	14.8	13.6	11.4	9.1	6.6	4.6	4.2	64.3			
Sum	340.5	340.4	347.5	346.6	357.1	351.2	352.0	2435.3			

Figure 14-3.–Sample format showing hourly heights of tide required for computing average mean sea level (MSL).

shown in figure 14-3. The heights on this form are added both horizontally and vertically. The total sum covering 7 days of record is entered in the lower right-hand corner of the page. The mean for each calendar month is found by combining all daily sums for the month and dividing by the total number of hours in the month. The monthly mean, to two decimal places, is entered on the sheet that includes the record for the last day of the month. Yearly means are determined from the monthly means, and a mean is taken of all yearly means for the period of record. Three or more years of record should be used for a good determination of sea level. The actual value varies somewhat from place to place, but this variation is small. The station used for MSL determinations should be on the open coast or on the shore of bays or harbors having free access to the sea. Stations on tidal rivers at some distance from the open sea will have a MEAN RIVER LEVEL that is higher than mean sea level because of the river slope. It should be noted that mean sea level is NOT identical with mean tide level (MTL). The latter is derived from the mean of all high and low points on the tidal curve. But MSL is derived from the mean of a much larger number of points taken at hourly intervals along the tidal curve.

The datum universally used in leveling is mean sea level (MSL), and it is considered to be the zero unit. The vertical distance of a given point above or below this datum then becomes the elevation of that point.

Other Datums

Along the Atlantic coast of the United States, the mean low water (MLW) datum has been generally adopted as the datum used for hydrographic surveys. It is the mean of all low water tides observed over a long period (usually a 19-yr period). Mean lower low water (MLLW) has been generally adopted for hydrographic surveys along the Pacific coast of the United States, Hawaii, Alaska, and the Philippine Islands. It is the mean of the lower of the two low water tides for each day observed over a long period. Mean low water spring (MLWS) is used on the Pacific coast of the Panama Canal Zone. It is defined as the mean of the low waters of the spring tides occurring a day or two after a full moon and is obtained by subtracting one-half of the range of the spring tides from the mean sea tide level.

LEVEL PARTY ORGANIZATION, EQUIPMENT, AND FIELD PROCEDURES

Certain basic preparations relative to the magnitude and complexity of the job must be performed before any leveling survey is undertaken. Proper planning and thorough identification of the procedures to be followed in all phases of the work are essential to the success of the leveling operation. Participating in this preparatory work will also enhance the experience and increase the capabilities of the crew members. Some of the preparations you must be familiar wit h are discussed in the next several paragraphs.

LEVEL PARTY ORGANIZATION

The size of your leveling party will depend upon such variables as the order of accuracy required and the number of experienced personnel available. Ordinarily, the smallest crew may consist of two individuals: an instrumentman and a rodman. To improve the efficiency of the leveling operations, additional personnel are required. The addition of a second rodman to alternate on backlights (BSs) and foresights (FSs) will speed up leveling. If you add a recorder, the instrumentman will be able to take readings as soon as the rodmen are in position. In surveys requiring a shaded instrument, an umbrellaman is required.

Duties of the Instrumentman

An instrumentman, or levelman, runs the level and makes adjustments required for proper operation. He makes certain that no stations are omitted, that turning points (TPs) are properly selected, and that BMs are properly established and identified. The levelman is usually designated by the EA1 or EAC to act as the chief of the party. When a two-man leveling party uses a self-reading rod, the levelman is also the recorder. However, if a target rod is used, the rodman usually acts as the recorder. A good levelman keeps within the required limits of error.

As chief of the party, you must be alert to recognize common problems encountered in the field and be able and ready to solve them using the best solution. Your sound judgment and proper course of action in handling these field problems will influence the quality of your survey and the meeting of your survey schedules.

Handling Leveling Instruments and Equipments

Leveling instruments, as well as all surveying instruments and equipments, have to be accorded the care and proper handling that any delicate instrument merits. Give special attention to prevent sudden shocks, jolts, and bumps, which will cause retesting of the instrument to be required. A damaged or disturbed scientific instrument, however minor, will adversely affect correct and accurate results. As a rule, a visual inspection for signs of physical damage of the instrument is to be conducted before each use.

An engineer's level is a precision instrument containing many delicate and fragile parts. Movable parts should, when not locked in place, work easily and smoothly. When a part resists movement, there is something wrong; if you force the part to move, you are quite likely to damage the instrument. You will also cause damage by wear if you use excessive force in tightening clamps and the like.

To ensure easy movement, keep threads and bearing surfaces on movable parts lubricated. For the same reasons, these parts have to be kept clean. Always clean the parts before oiling them. When oiling the parts, use only fine instrument oil; and do not use too much of it. An excess of oil gathers dust and also thickens, which will interfere with free movement of the parts. This is especially true in cold weather because low temperatures cause oil to congeal. In cold weather, graphite powder is a more suitable lubricant than oil.

Keep the level in its case when it is not in use and when you are transporting it to and from the jobsite. The level screws and the clamp screws should be tightened just enough to prevent motion of the parts inside the case. The instrument case is designed to reduce the effect of jarring and is strongly made and well padded to protect the level from damage. When transporting the level by vehicle, you should place the carrying case about midway between the front and rear wheels. This is the point at which the bouncing of the wheels has the minimum effect.

Never lift the instrument out of the carrying case by grasping the telescope; wrenching the telescope in this manner could damage a number of delicate parts. Always lift the instrument out of the case by grasping the footplate or the level bar.

When the instrument and the tripod are to be carried from one setup point to another, loosen

Figure 14-4.-Recommended carrying position of instrument when obstacles may be encountered.

the level and clamp screws slightly. They should be tight enough to prevent the telescope from swinging and the instrument from sliding on the footplate, but loose enough to allow a "give" in case of an accidental bump against an obstacle.

When you are carrying the instrument over terrain that is free of possible contacts (for example, across an open field), you may carry it over your shoulder like a rifle. But when obstacles may be encountered, carry the instrument under your arm, as shown in figure 14-4.

To avoid the effects of sunlight, you should use a surveyor's umbrella or the like. If there is any great difference between the working and storage temperature, the instrument should be allowed to adjust itself to the actual working conditions for about 15 min before observations are started.

Duties of the Rodman

The rodman must hold the leveling rod properly in order to sight on it or read it accurately. This is the rodman's responsibility. The actions of a rodman in positioning and holding the rod will affect the speed and accuracy of the leveling operation, so if you are the rodman, use extreme care. It is also the rodman's responsibility to take care of the rod during and after the leveling operation. Your duties as a rodman are as follows:

1. Clean the base (or shoe) of the rod before setting the rod on any point. Also, clean the top of the point to ensure good contact between the rod and the point.

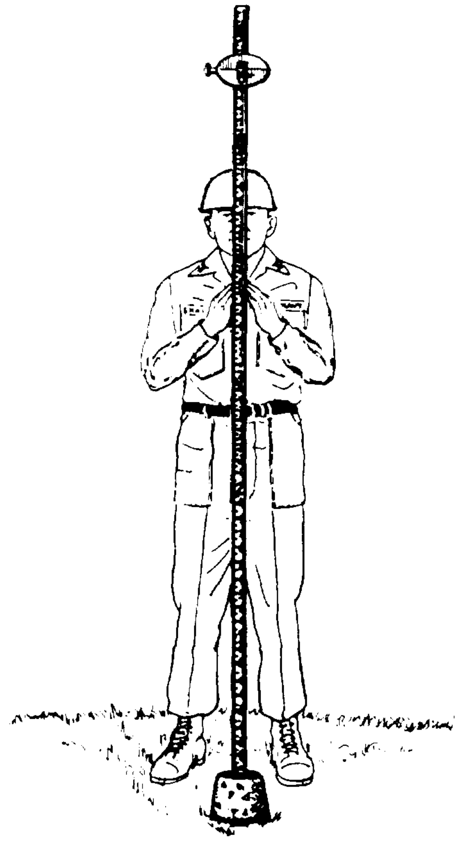


Figure 14-5.-Proper stance for holding a level rod on a bench mark while facing the instrument.

2. Place the rod firmly on the point; then stand facing the instrument and slightly behind the rod; hold the rod in front of you with both hands (fig. 14-5). Space your feet about 1 ft apart for a comfortable stance. Also, make sure that the graduations of the rod are right side up and are turned towards the instrumentman.

3. Hold the rod as nearly vertical as possible, then place a rod level against the rod, and move the top end of the rod until the bubbles are centered. If you do not use a rod level, balance the rod by using your fingertips to prevent it from falling. A properly balanced rod will stand for several seconds before starting to fall. This process of balancing the rod vertically is known as PLUMBING THE ROD.

4. Plumb the rod and hold it as steady as possible during strong winds. When this condition exists, the instrumentman may call for you, as the rodman, to WAVE THE ROD. Wave the rod by pivoting it on its base and swinging it in a slow arc toward the instrument and away. Keep the shoe firmly seated during this operation. The

motion of the rod permits the instrumentman to read the rod when it reaches a vertical position at the top of the arc and when the lowest reading appears on the rod. Before or after the rod is in this vertical position, the rod reading is greater.

5. Set the turning pin or pedestal firmly in contact with the ground when setting a TP. Any unfirm footing can sag under the weight of the rod and result in incorrect readings between the FS and BS. During freezing and thawing weather conditions, the ground surface can heave in a comparatively short time. Pins and pedestals can be affected by the heave between the FS and the following BS. For higher order of accuracy surveys, you should be aware of this possibility and select firm locations.

6. Extend the leveling rod to its maximum length when the instrumentman calls for extending the rod. The standard Philadelphia leveling rod can be read to 7.100 ft or 2.164 meters when collapsed and 13.000 ft or 3.962 meters when extended. An extended leveling rod is called a LONG ROD.

A leveling rod is a precision instrument and has to be treated with care. Most rods are made of carefully selected, kiln-dried, well-seasoned hardwood and have metal scale faces on which the scale graduations are painted. Unless a rod is always handled with great care, the painted face will become scratched, dented, or damaged in other ways. Accurate readings on a rod that is damaged are difficult.

Letting an extended rod close “on the run” by allowing the extended upper section to drop tends to damage both sections of the rod and to displace the vernier. Always close an extended rod by easing down the upper section.

A rod will read accurately only if it is perfectly straight, so you must avoid anything that might bend or warp the rod. Do not lay a rod down flat unless it is supported throughout on a flat surface. Do not use a rod as a support or as a lever. Store the rod in a dry place to avoid any possible warping and swelling from dampness, and always wipe a wet rod dry before stowing it away.

If there is mud on the rod, rinse it off, but do not scrub it. If you have to use a soap solution to remove grease, use a mild solution. Repeated washings with strong soap solutions will eventually cause the painted graduations to fade.

FIELD PROCEDURES FOR DIFFERENTIAL LEVELING

Leveling operations require the teamwork of both the instrumentman and the rodman to achieve consistent results. The accuracy of the survey depends upon the refinement with which the line of sight can be made horizontal by the instrumentman, the ability of the rodman to hold the rod vertically, and the precision with which the rod reading is made. Some of the basic procedures and preparations applicable to direct leveling are presented below.

Selecting Setup Points

Terrain and atmospheric conditions are the main considerations affecting the selection of setup points. It is essential that you select a point from which you can best observe a rod reading on the BS and FS points. In the interest of balanced shots, a setup point should be about equidistant from both BS and FS. In addition, shorter setup distances will result in smaller instrument errors caused by the atmospheric refraction and curvature of the earth.

The average instrument height at any setup is about 5 ft (1.5 m). On even downhill slopes, the ground where the instrument is set up may not be more than 3 to 5 ft below the TP for a level BS. On the FS, the extended rod can be held on the ground about 8 ft (2.5 m) below the instrument ground level and still permit a reading to be taken. This means that the tendency will be to make FS distances longer going downhill and to make BSs longer going uphill.

Therefore, it is necessary to conduct a reconnaissance of the terrain before you start leveling. You should note probable locations of instrument setup and TPs. During the reconnaissance, you should estimate the line of sight by sighting through a hand level.

Setting Up a Level

In setting up the tripod, you first hold two tripod legs with both hands and spread the tips of these legs a convenient distance apart. Then bring the third leg to a position that approximately levels the top of the protector cap when the tripod stands on all three legs. Then unscrew the protector cap.

Next, you lift the instrument out of the carrying case by the footplate or level bar, NOT by the telescope, and set it gently and squarely on the tripod head threads. Rotate the footplate counterclockwise one-fourth turn or until the instrument seats itself; then rotate it clockwise to engage the head nut threads to the tripod head threads. If the threads do not engage smoothly, they are cross-threaded. Do not force the head if you encounter resistance, but back it off, square up the instrument, and try again gently to engage the threads. When they engage, screw the head nut up firmly but not too tightly. Setting up the instrument too tightly causes eventual wearing of the threads, making unthreading difficult.

After you have attached the instrument, if you are set up on stable soil, thrust the tripod legs' tips into the ground far enough to be sure of a stable support, taking care to keep the footplate approximately level. Some tripods have legs equipped with short metal stirrups. These stirrups allow you to force the legs' tips into the ground by foot pressure.

If you are set upon a hardened surface, such as concrete, make sure the tripod legs do not accidentally spread, causing the tripod to collapse. In figure 14-6, view A, the legs' tips are inserted in cracks in a concrete pavement. In figure 14-6, view B, they are held by an equilateral wooden triangle called a floor triangle.

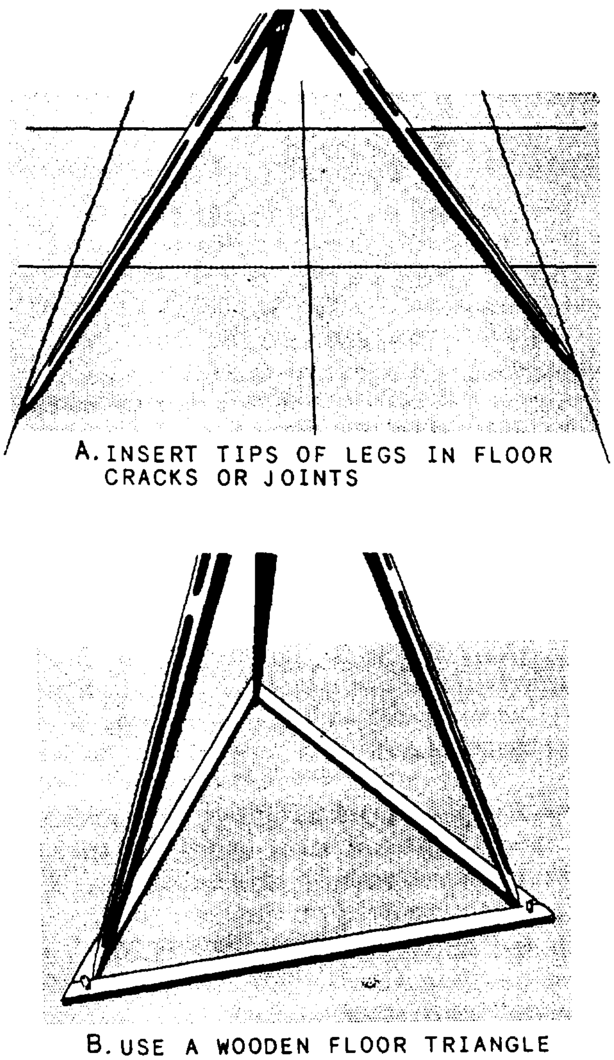


Figure 14-6.-Two ways of preventing tripod legs from spreading on hardened surface.

Leveling the Engineer's Level

As a rodman, you must concentrate on keeping your rod perfectly plumb. Readings on a rod that is out of plumb are inaccurate. Similarly, as a levelman, you must constantly bear in mind that the line of sight through the telescope must be perfectly level in every direction or every reading you make with the instrument will be inaccurate. After you initially place the instrument, level it carefully as follows:

Train the telescope in line with a pair of level screws and manipulate the level screws by turning them in opposite directions, as shown in figure 14-7, until the bubble in the level vial is in the exact center. It is helpful to know that the bubble in the level vial will move in the direction that your left thumb moves. To put this another way: When you turn the left-hand screw clockwise, the bubble moves to your left; when you turn the left-hand screw counterclockwise, it moves to your right.

When the bubble is centered with the telescope over one pair of screws, train the telescope over the other pair and repeat the process. As a check, swing the telescope over each pair of screws in all four possible positions to make sure the bubble is centered in each position.

Making Direct Readings

The instrumentman makes a direct rod reading as viewed directly on the graduation of the rod (self-reading) that is in line with the horizontal

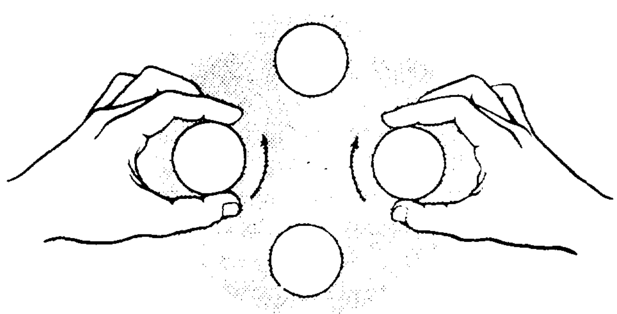


Figure 14-7.-Manipulating level screws.

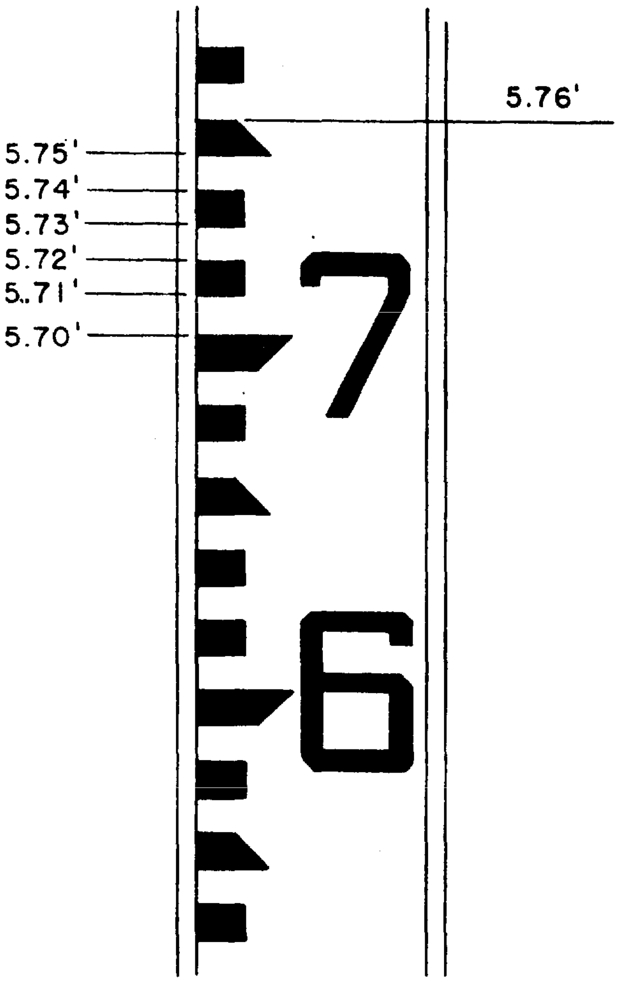


Figure 14-8.-Showing a direct reading of 5.76 ft on a Philadelphia rod.

cross hair. A rod other than an architect's rod is usually graduated in feet subdivided to the nearest 0.01 ft; therefore, direct readings are possible only to the nearest 0.01 ft.

Figure 14-8 shows a direct reading of 5.76 ft on a Philadelphia rod. You can see that each black graduation and each white, interval represents 0.01 ft.

You can see also that the black figure 7 is the only numeral of the reading 5.76 ft that appears in the view. The red numeral 5 would not be visible through the telescope unless the sight distance was quite far away. For this reason, you would signal the rodman to "raise for red," as described in the previous chapter.

To make sure you relate the reading for tenths and hundredths to the correct whole-foot red numeral, it is best to make a direct reading as follows: When the horizontal cross hair and the rod are brought into clear focus, first determine the number of hundredths. Then, read the next lower black figure for the tenths. Finally, signal for a "raise for red," and note the number of whole feet.

Making Target Readings

The three most common situations in which target readings rather than direct readings are made are as follows: (1) when the rod is too far from the instrument to be read directly; (2) when you desire a reading to the nearest 0.001 ft, which requires the use of the vernier by the rodman; and (3) when the instrumentman thinks a reading by the rodman instead of by himself more likely will be accurate.

For target readings up to 7.000 ft, the Philadelphia rod is used fully closed and read on the face by the rodman. The rodman sets the target on the face by the signals from the instrumentman, who determines when the horizontal axis of the target intercepts the horizontal cross hair.

When the instrumentman signals "all right," the rodman clamps the target in place with the target screw clamp, as shown in figure 14-9; then

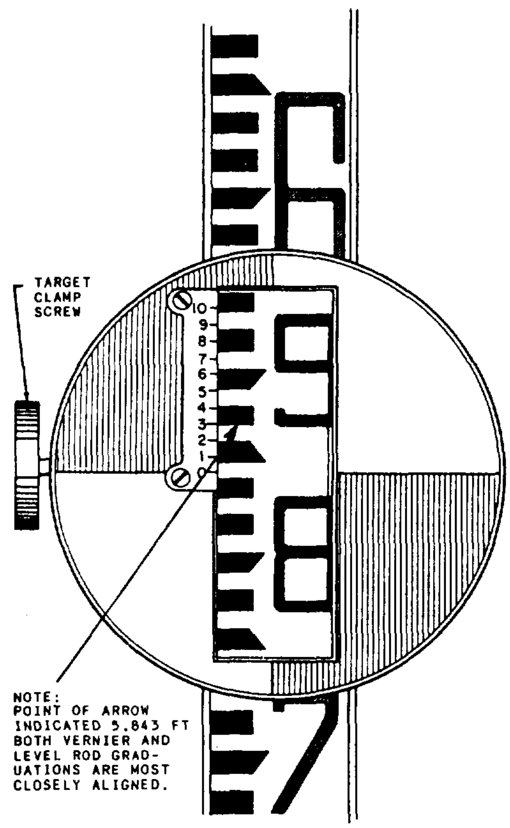


Figure 14-9.-Target reading of 5.843 ft on a Philadelphia rod.

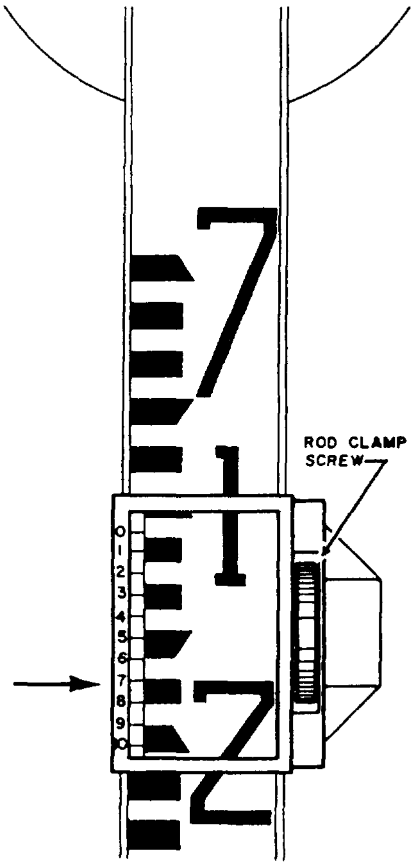


Figure 14-10.-Reading of 7.107 ft on back of Philadelphia rod as indicated by arrow.

the rodman reads the target vernier, shown in the same figure.

The reading to the nearest 0.01 ft is indicated by the zero on the vernier. In figure 14-9, the vernier zero indicates a reading of a few thousandths of a foot more than 5.84 ft. To determine how many thousandths over 5.84 ft, you examine the graduations on the vernier to determine the one most exactly in line with a graduation on the rod. In figure 14-9, this is the 0.003-ft graduation; therefore, the reading to the nearest 0.001 ft is 5.843 ft.

For target readings of more than 7.000 ft, the Philadelphia rod is used extended; the rodman makes the reading on the back of the rod. In figure 14-10, the back of the upper section of the rod is shown, graduated FROM THE TOP DOWN, from 7.000 ft through 13.000 ft. You can also see a rod vernier on the back, fixed to the top of the lower section of the rod, also reading from the top down.

For a target reading of more than 7.000 ft, the rodman, on receiving the signal to "extend the rod," fixes the target on the face of the upper section all the way to the top of the upper section. While doing this, the rodman makes sure the target vernier is set at exactly the same reading indicated by the rod vernier on the back of the rod, He then releases the rod screw clamp and slides the upper section of the rod slowly upwards until the instrumentman gives the signal "all right." When the horizontal axis of the target reaches the level where it is intersected by the horizontal cross hair, the instrumentman gives this signal.

FUNDAMENTAL LEVELING PROCEDURE

Now that you have learned how to setup and level the engineer's level and how to read the leveling rod, let us take a look at an example that will explain the basic procedure of determining elevations during a leveling operation.

In figure 14-11, there is a BM at Point A with a known elevation of 365.01 ft. You wish to determine the elevation of a point on the ground at Point B. To do so, you first set up and level your engineer's level approximately half-way between Points A and B. When the instrument is leveled properly, you will have a perfectly level line of sight that can be rotated all around the horizon.

The next thing to do is to determine the elevation of this line of sight. This elevation is called the HEIGHT OF INSTRUMENT, familiarly known as the HI. To obtain this elevation, the instrumentman takes a backsight (BS) on a leveling rod held on the BM and, in this example, obtains a rod reading of 11.65 ft. The HI, then, is the BM elevation PLUS the rod reading, or 365.01 + 11.56, which equals 376.57 ft. This means that no matter to which direction the telescope is trained, any point around the horizon that is intercepted by the horizontal cross hair has an elevation of 376.57 ft.

To determine the ground elevation at Point B, the instrumentman now takes a foresight (FS) on a rod held at Point B. This time, a rod reading of 1.42 ft is read. Since the elevation of the line of sight (HI) is 376.57 ft, obviously the ground elevation at Point B is the HI MINUS the rod reading, or 376.57 – 1.42, which equals 375.15 ft.

Balancing Shots

The balancing of the FS and BS distances is important in leveling. The effeet of curvature and refraction may be eliminated by a balanced BS and FS distance; however, instrumental error is a far more important reason for careful balancing.

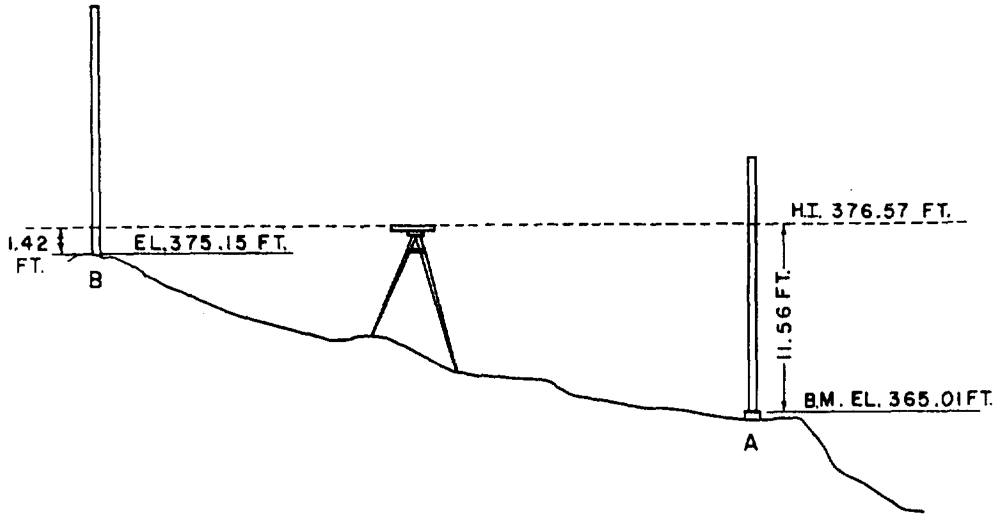


Figure 14-11.-Procedure for direct leveling.

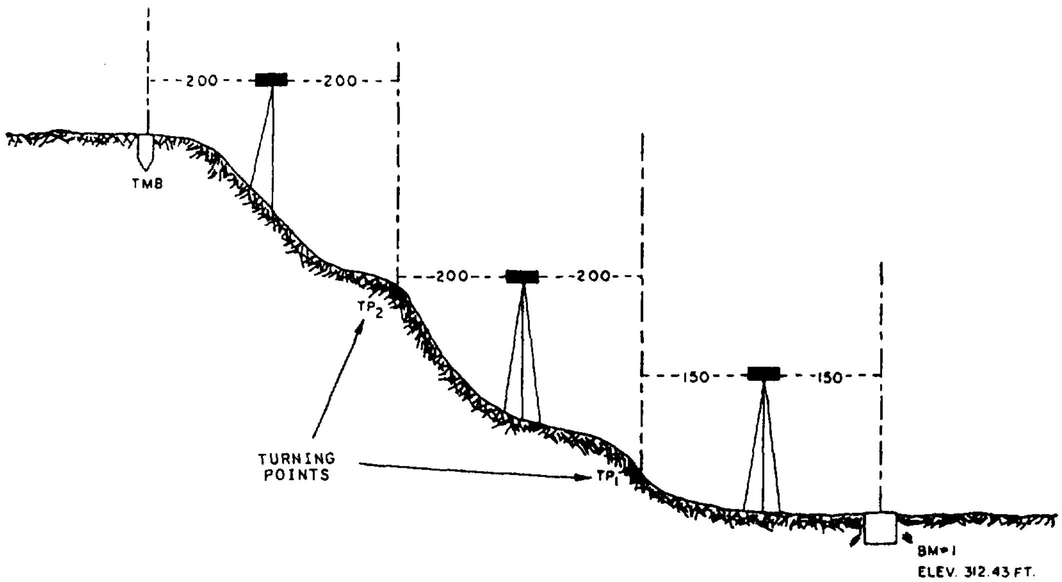


Figure 14-12.-Turning points.

"Balancing shots" means equalizing as much as possible BS and FS distances by selecting turning points that are approximately an equal distance from both the BS and FS points.

No matter how carefully you level a level telescope, it is likely to be still slightly out of the horizontal. The error this causes increases with the length of the sight taken. If the BS distance differs from the FS distance, the BS and FS errors will also differ. If the distances are the same, the errors will be the same. Balancing shots therefore eliminates the effect of instrumental error and also of curvature and refraction, other errors that increase with distance.

To balance distances for a setup, you will find that using the same number of paces for BS as for FS is helpful. In general, BS and FS distances should be kept under 300 ft except when necessary to pass or cross an obstacle.

Establishing Turning Points

Suppose you want to determine the elevation of a point at the summit of a long slope, and the nearest BM is at the foot of the slope some 30 ft or so below the summit. Obviously, you cannot sight a rod held on the BM and another held on the summit from the same instrument setup point. You must work up the slope in a series of steps, as shown in figure 14-12, by establishing as many intermediate TPs as you need to solve the problem. A "turning point" is defined as a point on which both a minus sight (FS) and a plus sight (BS) are taken on a line of direct levels.

As shown in figure 14-12, if we assume that the elevation of the BM is correct, the accuracy of the elevation you determine for the summit depends upon how accurately you determine the elevation of each intermediate TP. This accuracy depends upon a number of things, the most important of which are the following:

1. If you are doing leveling of ordinary precision, FS and BS distances should not exceed 300 ft. Therefore, the first setup point for the instrument should be not more than 300 ft from the BM, and the first TP should be not more than 300 ft from the instrument. To balance shots, you should place the instrument about the same distance from the BM as the distance to the TP.

2. Obviously, the first setup point must be one you can observe with a rod held on the BM and also a rod held on the first TP.

3. Generally, setup points should be used that make rod readings as small as possible. The reason small rod readings are desirable is that, for a rod held out of plumb, each reading on the rod will be in error. The larger the rod reading, the greater the error. Suppose, for example, a rod is so far out of plumb that it indicates 12.01 ft for a reading that should be 12.00 ft if the rod were plumb. For a 12.00-ft reading on the rod, the error is 0.01 ft. For a 2.00-ft reading on the same rod held in the same manner, however, the error would be only about 0.002 ft.

4. A TP must have not only visibility and accessibility, but also stability; that is, it must furnish a firm, nonsettling support for the base of the rod. Suppose you select a point in soft, yielding ground as your first TP. Assume the elevation of the BM is 312.42 ft. You take a BS on the BM and read 3.42 ft. Then, HI is

$$312.42 + 3.42 = 315.84 \text{ ft.}$$

The rodman shifts the rod to the TP. You take an FS and read 5.61 ft. The elevation of the TP is, therefore,

$$315.84 - 5.61 = 310.23 \text{ ft.}$$

Now, you shift the instrument ahead and take a BS to carry on the line of levels to a new TP.

But suppose that before you take the BS on the rod, the TP has settled 0.02 ft in the ground. Then you take a BS and read 4.74 ft. There is now an error of 0.02 ft in the new HI, and every subsequent HI and elevation of TP will be off by the same amount.

So BE SURE that each TP is stable. When the use of a point in yielding ground is unavoidable, you need to base the rod on a turning point pin or turning point plate. A pin is driven in the ground; if you don't have a regular pin, a marlinspike or a railroad spike makes a good substitute. You should use a plate on soil too soft to support a driven pin.

METHODS OF LEVELING

Leveling methods are subdivided into two major categories: DIRECT and INDIRECT. Direct leveling describes the method of measuring vertical distance (difference in elevation) directly with the use of precise or semi-precise leveling instruments. Indirect leveling methods, on the other hand, apply to measuring vertical distances indirectly or by computation. Unlike direct leveling operations, indirect leveling operations do not depend on lines of sight or intervisibility of points or stations. Some of the surveying instruments commonly used for indirect leveling methods are the transit and theodolite.

DIRECT LEVELING

This method of leveling uses the measured vertical distance to carry elevation from a known point to an unknown point. Direct leveling is the most precise method of determining elevation and yields accuracies of third or higher orders. When this method is specified for lower accuracy surveys, direct leveling is sometimes referred to as "spirit" or "fly" levels. Fly levels are leveling operations used to rerun original levels to make sure that no mistake has been made. Fly levels use a shorter route and smaller number of turning points than the original survey. Let's take a look at some of the processes involving direct leveling.

Differential Leveling

Differential leveling (also called direct leveling) is generally used in determining elevations of points to establish a chain or network of BMs for future use. It requires a series of instrument setups along the survey route; and for setup, a horizontal line of sight is established, using a sensitive level. The SEABEEs commonly use this type of leveling in determining elevation during construction surveys.

As shown in figure 14-13, the basic procedure used to determine elevations in a differential leveling operation is the same as previously discussed. First, you take a BS on a rod held on a point of known elevation (KE). Then add the BS reading to the known elevation to determine the HI. Next, take an FS on a rod held at the point of unknown elevation (UKE). Finally, subtract the FS reading from the HI to establish the elevation of the new point.

After you complete the FS, leave the rod on that point and move the instrument forward. Set up the instrument approximately MIDWAY between the old and new rod positions. The new sighting on the back rod becomes a BS, and you can now establish a new HI. The points other than the BMs or TBMs on which you hold the rods for the BSs and FSs are called TURNING POINTS (TPs). Other FSs made to points not along the main route are known as SIDESHOTS. You can use this procedure as many times as necessary to transfer a point of known elevation to another distant point of unknown elevation.

Figure 14-14 shows a sample differential leveling run. The rod is held on BM 35 (Elev. = 133.163). The level is set up midway between BM 35 and

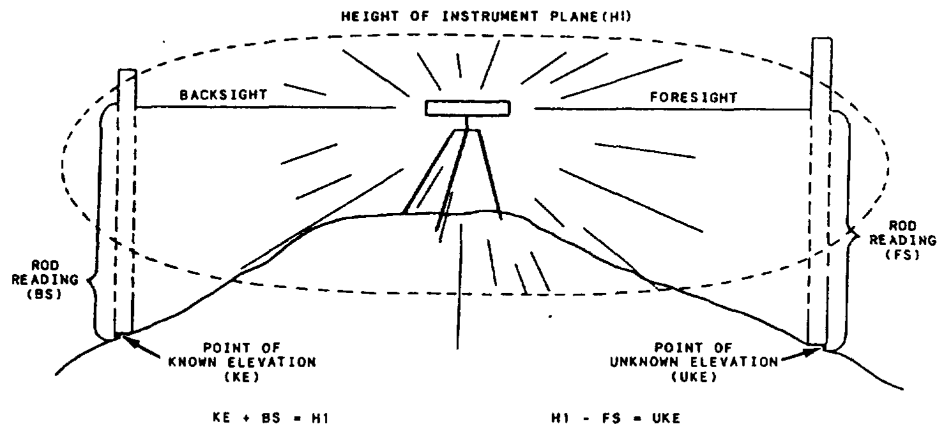


Figure 14-13.-Differersthd leveling.

LEVEL CIRCUIT FROM B.M. 35 TO B.M. 19

Leveler EA2 M T Todd — Rodman EA3 C L Miller — B & B Dumpy Level 31057

Sta	BS +	HI	FS −	Elev	Sights BS	Sights FS	Remarks
							April 3, 1984 (3 hours) Cloudy, moderate
BM 35	6 659	139 822		133 163	220		Concrete monument
⊙ 16	4.968	139 819	4.971	134 851	250	220	Peg
⊙ 17	4 508	136 875	7.452	132 367	310	250	"
⊙ 18	1.412	132 430	5.857	131.018	100	310	"
TP 1	7073	138 242	1.261	131 169	190	100	Turning Point
BM 19			1.785	136 457		190	Concrete monument
	24.620		21 326	133 163	1070	1070	Actual elevation of □ 19 = 136.442 ft
			24 620	3 294		1070	Permissible error = 0 05 √(2140/5280) = 0 032 ft
			3 294	Check		2140	Actual error of closure = 0 015 ft

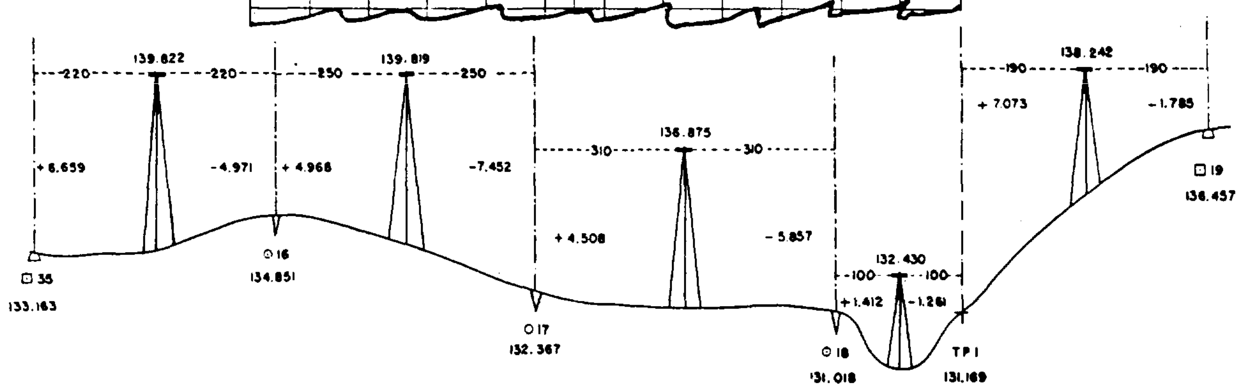


Figure 14-14—Sample field notes and profile of a differential-level circuit.

TBM 16. The BS reading of +6.659 is added to the elevation of BM 35 and gives the resulting HI (139.822). The rod is moved to Peg 16 (which later becomes TBM 16). The FS reading of –4.971 is subtracted from the HI to get the elevation of Peg 16. Note that the distance (220 ft each way) is also recorded for balancing. The process continues until BM 19 is reached.

LEVEL COMPUTATIONS.— In making level computations, you should be sure to check on the notes for a level run by verifying the beginning BM; that is, by determining that you used the correct BM and recorded its correct elevation, as required.

Then, you should check on the arithmetical accuracy with which you added BSs and subtracted FSs. The difference between the sum of the BSs taken on BMs or TPs and the sum of the FSs taken on BMs or TPs should equal the difference in elevation between the initial BM or TP and the final BM or TP.

Balanced BS and FS distances are shown in figure 14-14. The distance used for the first instrument setup was 220 ft. The first BS (rod reading on ⊡ 35) was 6,659 ft. The first FS (rod reading on ⊙ 16) was 4.971. Notice that the plus sign (+) appears at the top of the BS column and that the minus sign (–) appears at the top of the FS column in the field notebook. This helps you to remember that BSs are added and FSs are subtracted as you compute the new elevations.

The BS taken on a point added to the elevation of the point gives the HI. This establishes the elevation of the line of sight so that an FS can then be taken on any point (BM, TBM, or TP). The level line is extended as far as desired with as many instrument setups as may be necessary by a repetition of the process used in the first setup.

The elevation of ⊡ 35 is 133.163 ft. The first HI is

$$133.163 + 6,659 = 139.822 \text{ ft.}$$

The FS subtracted from the HI,

$$139.822 - 4.971 = 134.851 \text{ ft},$$

gives the elevation of ⊙ 16, the first established. Following through with a similar computation for each setup, notice that the elevation of ⊡ 19 was found to be 136.457 ft.

Look now at the notes in figure 14-14. The sum of all the BSs is 24.620 ft. The sum of all the FSs is 21.326 ft. The difference between the sum of the BSs and the sum of the FSs is

$$24.620 - 21.326 = 3.294 \text{ ft.}$$

This difference should agree with the difference between the actual elevation of BM 35 and the elevation already found for BM 19; that is,

$$136.457 - 133.163 = 3.294 \text{ ft.}$$

This provides a check on the step-by-step computation of elevations.

ADJUSTMENT OF INTERMEDIATE BENCH MARK ELEVATIONS.— Level lines that begin and end on points that have fixed elevations, such as BMs, are often called level circuits. When leveling is accomplished between two previously established BMs or over a loop that closes back on the starting point, the elevation determined for the final BM will seldom be equal to its previously established elevation. The difference between these two elevations for the same BM is known as the ERROR OF CLOSURE. The Remarks column of figure 14-14 indicates that the actual elevation of BM 19 is known to be 136.442 ft. The elevation found through differential leveling was 136.457 ft. The error of closure of the level circuit is

$$136.457 - 136.442 = 0.015 \text{ ft.}$$

It is assumed that errors have occurred progressively along the line over which the leveling was done so that adjustments for these errors are distributed proportionally along the line as shown by the following example: Referring to figure 14-14, you will notice that the total distance between BM 35 and BM 19, over which the line of levels was run, was 2,140 ft. The elevation on the closing BM 19 was found to be 0.015 ft greater than its known elevation. You must therefore adjust the elevations found for the intermediate TBMs 16, 17, and 18.

The amount of correction is calculated as follows:

$$\text{Correction} = \begin{matrix}\text{Error}\\ \text{of}\\ \text{closure}\end{matrix} \left[\frac{\text{distance between the starting BM and the intermediate BM}}{\text{distance between the starting and closing BM}}\right]$$

TBM 16 is 440 ft from the starting BM. The total length distance between the starting and closing BMs is 2,140 ft. The error of closure is 0.015 ft.

$$\text{Correction} = -0.015 \times \frac{440}{2140} = -0.003 \text{ ft}$$

The adjusted elevation of TBM 16 is

134.851-0.003 = 134.848 ft.

The adjustments for intermediate TBMs 17 and 18 are made in a similar manner.

Reciprocal Leveling

This procedure is used for either differential or trigonometric leveling when along sight across a wide river, ravine, or similar obstacle must be made. This long sight will be affected by curvature and refraction and by any small error in aligning the line of sight with the bubble axis. The alignment error can be minimized by balancing the long sight and computing the curvature. The atmospheric conditions will vary so much over an open expanse that the refraction correction will be quite erratic. Reciprocal leveling is desired to minimize the effect of the atmosphere as well as the line of sight and curvature corrections. To do this, take the following actions:

1. In reciprocal leveling, balance the BSs and FSs as carefully as possible before you reach the obstacle. In figure 14-15, a TP, N, is selected close to the edge of the obstruction so that it is visible from a proposed instrument location, B, on the other side. A second rod is held on the other side of the obstruction at F. Point F should be selected so that the equivalent distances, AN and FB, and AF and NB, are almost equal. The instrument is setup at point A and leveled carefully. A BS reading is taken on the N rod and an FS on the F rod. These readings are repeated several times. The instrument is moved to point B, set up, and carefully leveled. The rods remain at their stations. Again, a BS is taken on the N rod and an FS on the F rod, and repeated several times. Since instrument leveling is especially critical on reciprocal leveling, you need to check the bubble before each reading and center it carefully. If it is off-center a slight amount, the procedure must be repeated. The difference in elevation between N and F is computed from the readings at A setup and from the readings at B setup separately. Because of the errors in the long sight, the two results will have slightly different values. Note, however, that the long sight is an FS from A and a BS from B. The true difference in elevation is the average of both values, since the errors have opposite signs and will cancel each other.

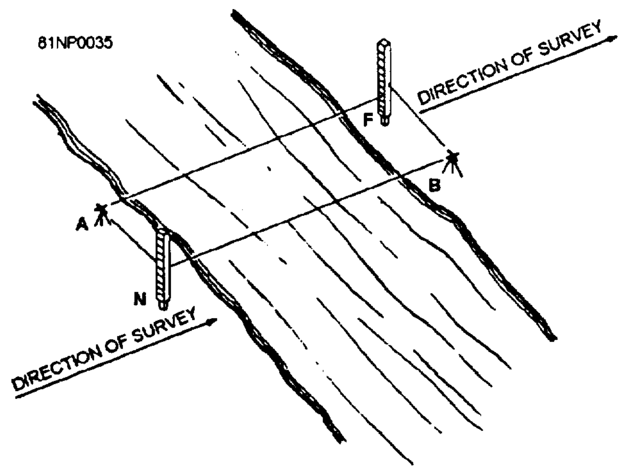


Figure 14-15.-Reciprocal leveling.

2. For more accuracy, make several long sight readings for each short sight and average them. You should use a target on the rod and reset it for each reading. Average each series of long sights and combine this average with corresponding short sights for the computations.

3. Changes in atmospheric density and temperature affect the refraction of a line of sight. The longer the time interval is between reciprocal long sights, the greater the chance of an atmospheric change and a variation in the refraction value. For this reason, you should keep the time lapse between the long sights as short as possible.

4. An excellent method of avoiding the time lapse problem is simultaneous-reciprocal observation. The object is to read both long sight values at the same time. This requires two instruments and two observers and two rods and two rodmen. Some method of communication or sequence of operations must be agreed upon.

5. The note keeping for reciprocal leveling is identical to differential leveling. Take a series of either BS or FS readings on the far rod from one setup and take only one sighting on the rear rod. Average the series of readings, and use a single value to make the elevation computations.

Profile Leveling

In surveying, a PROFILE is a vertical section of the earth measured along a predetermined or fixed line. In practice, profiles are a series of ground elevations determined by differential leveling or other methods that, when plotted along

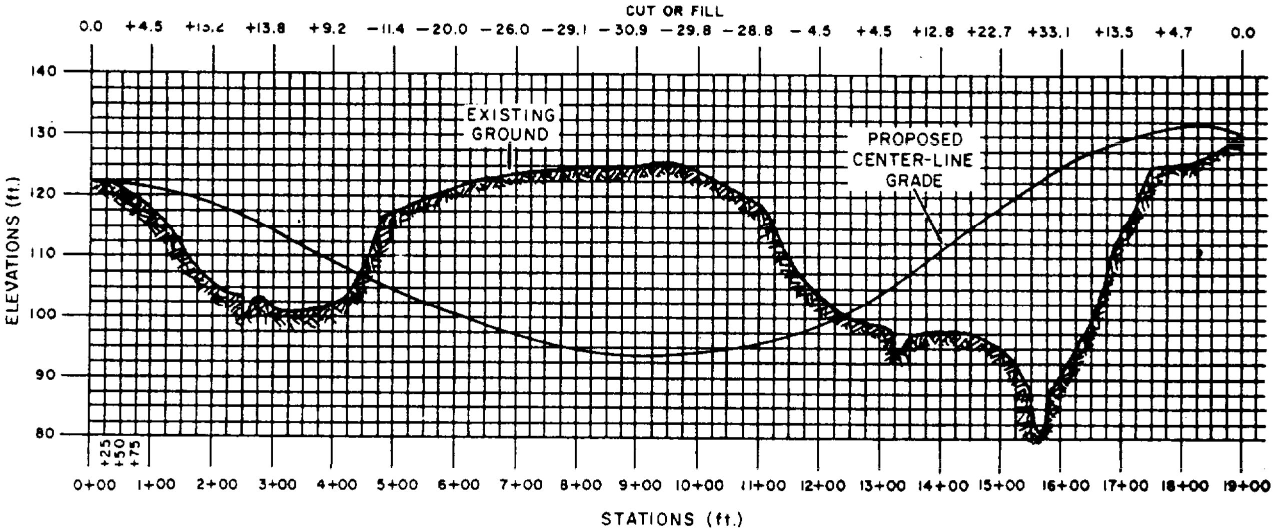


Figure 14-16.-Plotted profile and grade lines along a proposed road center line.

PROFILE LEVELS

Sta.	B+S	H.I.	FS	IFS	Elev.
BM1	7.42	124.93			117.51
0+00				2.4	122.53
1+00(TP1)	0.92	118.45	7.40		117.53
2+00(TP2)	1.42	107.34	12.53		105.92
3+00				4.8	102.54
4+00(TP3)	12.78	115.34	4.78		102.56
4+75(TP4)	12.02	127.21	0.15		115.19
5+00				9.6	117.61
6+00				5.8	121.41
7+00				3.9	123.31
8+00(TP5)	5.07	129.44	2.84		124.37
9+00				4.1	125.34
10+00				4.5	124.94
	39.63		27.70		
−	27.70				
	11.93	TP5 =	124.37		
−	5.07	BM1 =	117.51		
	6.86	CHK.	6.86		

0+00 to 10+00	4 JAN 19__
Cloudy & Cold	⊼ SMITH, J., EA 2
Dumpy Level #1	ϕ JONES, R. EA 2
Phila. Rod #1	
National Geodetic Survey Monument,	Bradley, Mo.
Hub driven flush with	existing grade
" " " "	" "
" "	
" " " "	" "
" " " "	" "

Figure 14-17.-Field notes for profile levels shown in figure 14-7.

some line, such as the center line of a road, can be used to determine the final grade or alignment of that road, railroad, or sewer line. Profiles are also used to compute volumes of earthwork.

Figure 14-16 shows a plotted profile of the existing ground surface along a proposed highway center line. Horizontally on the graph, you read a succession of 100-ft stations, from 0 + 00 to 19 + 00. Vertically, you read elevations. Note that, horizontally, the interval between adjacent vertical grid lines represents 25 ft; but vertically the interval between adjacent horizontal grid lines represents 2.5 ft.

The profile was plotted through a succession of points, each of which was obtained from a profile elevation taken on the ground. Figure 14-17 shows field notes for the levels taken from 0 + 00 through 10 + 00. The level was first set up at a point about equidistant from station 0 + 00 and from a BM identified as National Geodetic Survey Monument, Bradley, Missouri. The elevation of the BM was 117.51 ft. The first backsight reading on a rod held on the BM was 7.42 ft. The height of instrument (HI) was therefore

117.51 + 7.42 = 124.93 ft.

You can see this entered in the "HI" column.

From the first instrument setup, FSs were taken on station 0 + 00 and 1 + 00. The elevation of the station in each case was determined by subtracting the FS reading from the HI. Note that the FS taken on station 1 + 00 is entered in a column headed "FS, " while the one taken on station 0 + 00 is entered in a different column, headed "IFS." "IFS" means intermediate FS, or an FS taken on a point that is neither a BM nor a TP, You can see that station 1 + 00 was used as a TP in shifting the instrument ahead. Only FSS taken on BMs or TPs are entered in the column headed "FS."

After an FS was taken on station 1 + 00, it became necessary to shift the instrument ahead. Station 1 + 00 was used as the TP. From the new instrument setup, a BS was taken on a rod held on 1 + 00. The new HI was found by adding the BS reading to the previously determined elevation of 1 + 00.

From the new setup, an FS was taken on station 2 + 00; again, the elevation was found by subtracting the FS reading from the HI. After this sight was taken, the instrument was again shifted ahead, probably because of the steepness of the slope. This time, station 2 + 00 was used as the TP_2. From the new setup, a BS was taken on station 2 + 00 and a new HI established. From this setup, it was possible to take FSs on both station 3 + 00 and station 4 + 00. Because station 3 + 00 was not used as a TP, the FS on it was entered under IFS.

Apparently, the slope between station 4 + 00 and station 5 + 00 was so steep that sighting both stations from the same setup with the rod being used was impossible. Consequently, an intermediate TP (TP_4) was established at station 4 + 75 by determining the elevation of this station. The instrument was shifted to a setup from which a BS could be obtained on a rod held on this station and from which FSs on stations 5 + 00, 6 + 00, 7 + 00, and 8 + 00 could be taken, Station 8 + 00 was then used as a TP for the last shift ahead. From this last setup, it was possible to take FSs on stations 9 + 00 and 10 + 00.

As a check on the arithmetic, you customarily check each page of level notes to check the difference between the sum of the FSs and the sum of the BSs against the difference in elevation between the initial BM or TP and final BM or TP. Obviously, only the BSs and FSs taken on BMs and TPs are relevant to this check, This is the reason why intermediate FSS not taken on BMs or TPs are entered in a separate column.

If the arithmetic is correct, the two differences will be the same. As you can see, the sum of the relevant BSs in figure 14-17 is 39.63; the sum of the FSs is 27.70; and the difference between the two is 11.93. Note that from this difference, the BS taken on TP_5 is deducted. The reason is the fact that this BS is not offset by a corresponding FS on a BM or TP. With the BS taken on TP_5 deducted, the difference between the sum of the FSs and the sum of the BSs is 6.86. The difference between the elevation of TP_5 and the elevation of the initial BM is 6.86, so the arithmetic checks.

Remember that this procedure provides a check on the arithmetic only. If you have recorded any incorrect values, the arithmetic will check out just as well as when you have recorded the correct values. The procedure is valuable, however, for detecting two mistakes commonly made by beginners. These are subtracting a BS from, instead of adding it to, a BM elevation to get the HI; and adding an FS to, instead of subtracting it from, the HI to get an elevation.

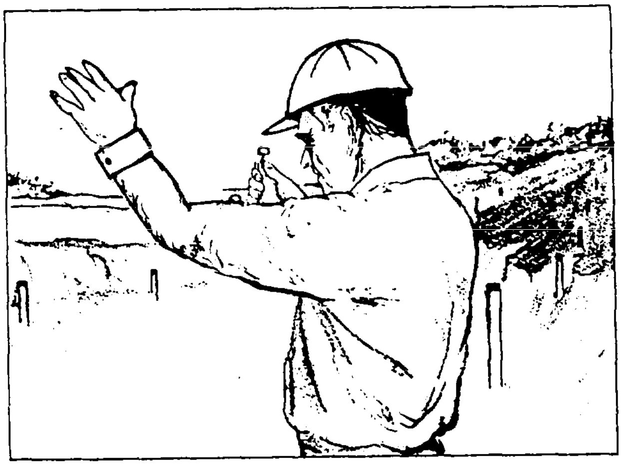


Figure 14-18.—Using angle prism for sighting 90° from the center-line stakes.

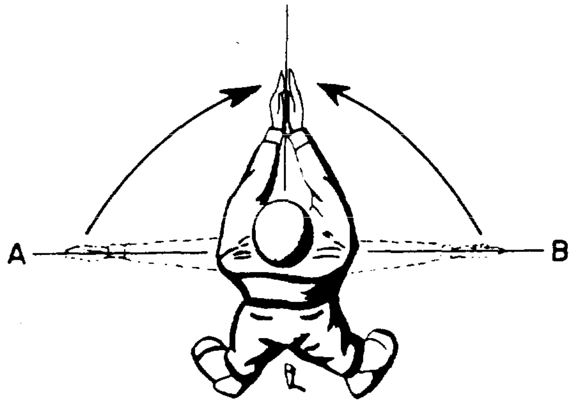


Figure 14-19.-Laying off a 90° angle from the center-line stakes.

Cross-Section Leveling

In profile leveling, you determine the elevations of a series of points lengthwise along a highway. In cross-section leveling, you determine the elevations of points on a succession of lines running at right angles to the lengthwise line of the highway. The principal purpose of profile leveling is to provide data from which the depth of fill or cut required to bring the existing surface up to, or down to, the grade elevation required for the highway can be determined.

Note that profile leveling provides this data relative to the center line. In figure 14-16, you can see along the top the depth of cut or fill required at each station to bring the existing surface to grade—the prescribed grade line for the highway is indicated by the smoothly curved grade line shown. At each station, you can determine the cut or fill by counting the squares between the profile and the grade line.

The cross-section lines are established at regular stations, at any plus stations, and at intermediate breaks in the ground. Short cross-lines are laid out by eye, but long crosslines are laid out at a 90° angle to the center line with the transit. For short crosslines, most surveyors prefer to use an angle prism for sighting 90° angles from the center line. Figure 14-18 shows a surveyor using an angle prism for sighting a 90° angle from the center line of the highway.

For cross-section leveling, strip topography, and some other purposes, it is necessary to lay off a 90° angle at numerous points along a line. This 90° angle can often be established by estimation with sufficient accuracy for the particular job. The surveyor straddles the point on the line, arms extended sideward along the marked line (fig. 14- 19). By looking alternately right then left, he adjusts the position of his feet until his body is in line with AB. He then brings his hands together in front of him, thus pointing along an approximate 90° line from the marked line. An experienced surveyor can lay off a 90° angle by this method so that a point 100 ft away will be within 1 ft of the true perpendicular.

You should measure all elevations at abrupt changes or breaks in the ground with a rod and level. Measure all distances from the center line with a metallic tape. In rough country, the hand level can be used to advantage for obtaining cross sections if the center-line elevations have been determined by use of the engineer's level.

Cross-section leveling is usually done with a hand level after the profile run has been made. The method is as follows:

From the profile run, you know the center-line elevation at each station. Suppose you want to take cross-section elevations at 10 ft intervals for 40 ft on either side of the center line. The first thing you do is to determine the vertical distance from the ground to your line of sight through the hand level when you stand erect with the level at your eye. The best way to do this is to sight on a level rod held plumb in front of you. Suppose you find that the vertical distance is 5.5 ft. Then your HI at any center-line station is the center-line elevation (obtained in the profile level run) plus 5.5 ft.

Suppose that you are standing at station 0 + 00, figure 14-16. The elevation of this station is 122.53 ft. Your HI is therefore

.122.53 + 5.5 = 128.03 ft.

You round off cross-section elevations to the nearest 0.1 ft. If a rodman holds a rod 40 ft to the left of the center line at station 0 + 00 and you read 1.9 ft on the rod, then the elevation of the point plumbed by the rod is

128.0 – 1.9 = 126.1 ft.

The rodman now moves on to a point 30 ft from the center line. If you read 3.3 ft on the rod, the elevation of this point is

128.0 – 3.3 = 124.7 ft.

Going on in this manner, you determine the elevations at all the required points on the cross section. You then move to the next station and repeat the process.

Cross section notes are recorded in the field book by using one of two basic methods. In the first, and often preferred, method, begin at the bottom of the page and read upward, as shown in figure 14-20. This method helps to keep you oriented in the direction in which the line runs and helps to prevent confusion as to which is the right or left side of the line. It therefore reduces the possibility of recording your readings on the wrong side of the center line.

In the second method, the notes are recorded in the conventional manner of reading from top to bottom of the page. Whichever method you use, you must remember that as you stand facing the direction in which the line runs, left

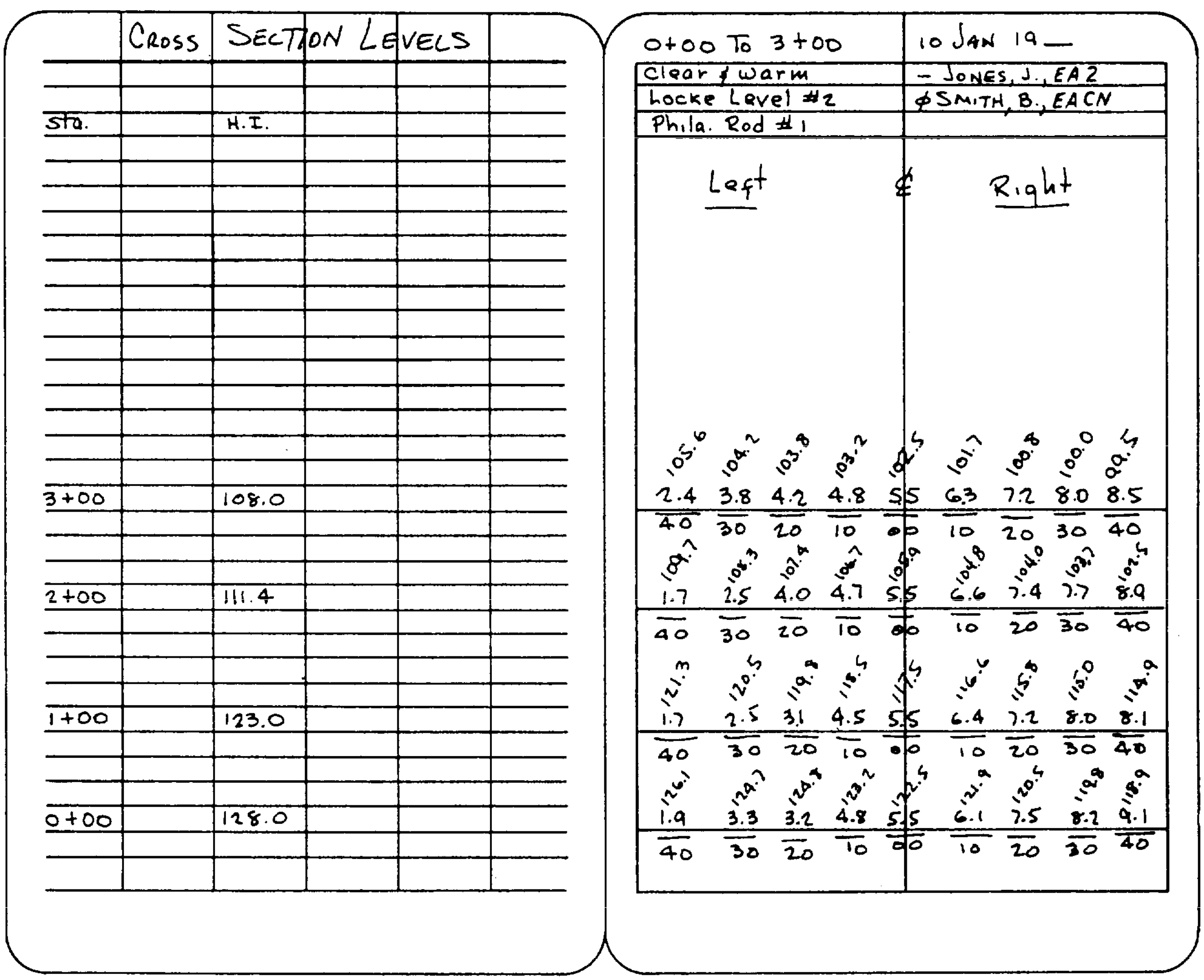


Figure 14-20.-Sample field notes from cross-section leveling at first three stations shown in figure 14-7.

and right in the notebook must correspond to left and right in the field.

Figure 14-20 shows field notes for cross-section levels taken on the first three stations shown in figures 14-16 and 14-17. On the data side, only the station and the HI need to be listed. On the remarks side, each entry consists of a point elevation, written over the distance of the point from the center line. The computed elevation, determined by subtracting the rod reading from the HI, is written in above as shown. Note that the rod reading at the center line is the 5.5-ft vertical distance from your line of sight to the ground. Also, notice that the center-line elevation written in at each station. is the one obtained in the profile level run. You obtain the HI for each station by simply adding together these two figures.

Double Rodding

Double rodding is a form of differential leveling in which a continuous check is maintained on the accuracy of the leveling procedure. It is called double rodding because it can be done most conveniently by two rodmen. However, it is possible to carry out the procedure using only one rodman.

In double rodding, you determine the HI at each setup point by backlights taken on two different TPs. If no mistake or large error has been made, the result will be two HIs that differ slightly from each other. Elevations computed this way will also differ slightly. In each case, the average is taken as the elevation.

Figure 14-21 shows double-rodded level notes for a run from one BM to another by way of three

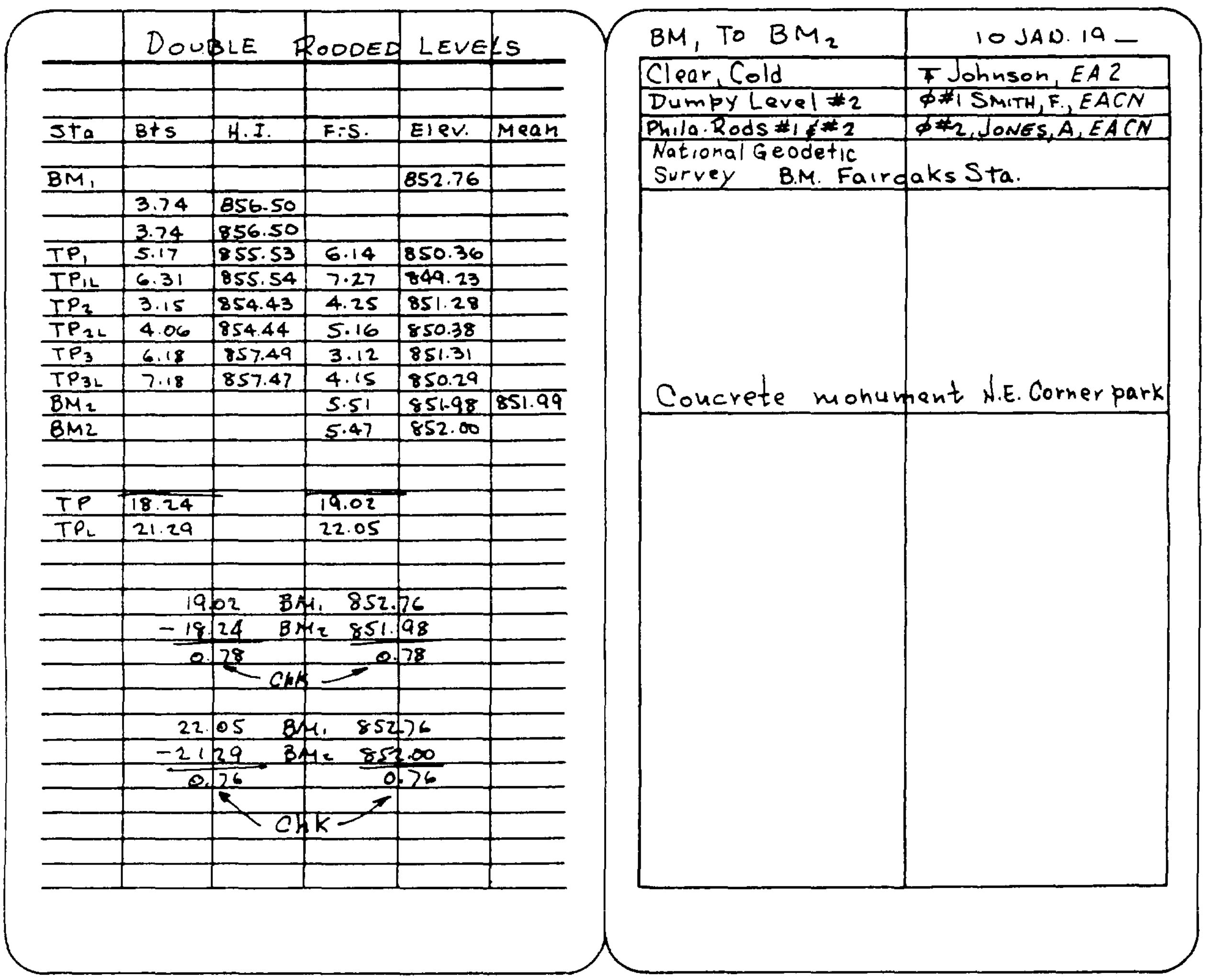


Figure 14-21.-Sample field notes from double-rodded levels.

intermediate TPs. In each case, a “higher” TP (as TP_1) and a “lower” TP (as **TP** was used, resulting in two different HIs for each. Computed by way of the higher HIs, the elevation of BM_2 came to 851.98 ft. Computed by way of the lower HIs, it came to 852.00 ft. The mean (average) of 851.99 ft was taken as the correct elevation.

INDIRECT LEVELING

Indirect methods of leveling encompass both trigonometric and barometric leveling. TRIGONOMETRIC LEVELING uses vertical angles and a horizontal distance to compute the difference in elevation, BAROMETRIC LEVELING uses the difference in atmospheric pressures that are observed by a barometer or an altimeter to determine the elevation differences. Indirect methods of leveling will be discussed at the EA2 level.

PRECISION IN LEVELING; MISTAKES AND ERRORS IN LEVELING

Leveling, like any other surveying operation, is carried out by following a prescribed ORDER OF PRECISION—meaning that the instruments you use and the methods you follow have to be those that can give you the specified standard of accuracy.

PRECISION IN LEVELING

FIRST-ORDER leveling is used to establish the main level network for an area and to provide basic vertical control for the extension of level networks of the same, or lower, accuracy in support of mapping projects, cadastral (recording property boundaries, subdivision lines, buildings, etc.), and local surveys. Level lines must start and end on proven, existing BMs of the same order. New levels must be run between the starting BM being used and at least one other existing BM and must show there is no change in their relative elevations.

SECOND-ORDER leveling is used to subdivide nets of first-order leveling and to provide basic control for the extension of levels of the same, or lower, accuracy in support of mapping projects and local surveys. Second-order levels are divided into two classes: Class I and Class II. CLASS I is used in remote areas where the line must be longer than 25 mi because routes are unavailable for the development of additional or higher order networks and for spur lines. CLASS II levels are used for the development of nets in the more accessible areas. In Class I leveling, it is required that all lines start and close on previously established BMs of first or second order. New levels have to be run between the existing BM being used and at least one other existing BM to prove that they have not changed their relative elevations. The criteria for Class II are the same as for Class 1, except that Class II lines are run in one direction only.

THIRD-ORDER leveling is used to subdivide an area surrounded by first- and second-order leveling and to provide elevations for the immediate control of cadastral, topographic, and construction surveys for permanent structures. The following criteria should be observed in third-order leveling:

1. All lines have to start from, and close on, two previously established BMs of third, or higher, order of accuracy if the new leveling indicates they have not changed in their relative elevations.
2. In the United States, third-order lines should not be extended more than 30 mi from BMs of first or second order. In foreign or remote areas, the distance may be extended according to the evaluation of the existing control and the situation. They may be single-run (one direction) lines but should always be loops or circuits that close upon BMs of an equal or a higher order.
3. When a line from previously established third-order marks is extended, the maximum length of the new line is greatly reduced. The distance and allowable error are to be carried back through the existing line to the nearest tie BM of the second or higher order.
4. Balanced sights should not be greater than 300 ft. BS and FS distances maybe measured by pacing and approximately balanced between BMs, Rod readings are read to thousandths and the rod waved for extended rod readings. The bubble is checked to make sure it is exactly centered before each sighting and reading. Turning point pins or plates or well-defined points on solid objects are used for TPs.

FOURTH-ORDER leveling is used to subdivide an area within a third-order network. This is the method of leveling used in connection “with the location and construction of highways, railroads, and most other engineering works that concern the SEABEEs in advanced base projects.

But, in practice, trying to shoot for a higher degree of accuracy is advantageous if it does not affect the proper progress of the work. The following criteria should be observed in fourth-order leveling:

1. All lines are to start from, and close on, previously established BMs of the third or fourth order of accuracy.

2. Maximum sight distance is about 500 ft. Rod readings are read to hundredths of a foot. BS and FS distances are roughly balanced only when lines of great lengths are run, either uphill or downhill. TPs are taken on solid or any well-defined, firm objects.

The instrument commonly used in third- and fourth-order leveling is the engineer's level and the Philadelphia rod. Always check the proper adjustments of the instrument before using it.

Order of Precision

The precision of a level run is usually prescribed in terms of a maximum error of closure. This is obtained by multiplying a constant factor by the square root of the length of the run in miles or in kilometers, depending upon the system of measurement being used. The Federal Bureau of Surveying and Mapping specifies certain requirements and the maximum closing errors, such as those shown in table 14-1. You may refer to this standard if the order of precision is not specified for a particular survey project.

Calculating Error of Closure

A level run that begins at a particular BM and is carried back again to the same BM is called a level loop. A run that does not close on the initial BM is called a level line. A level line closes on another BM; but when a level line is carried back to its origin, it becomes a level loop. Usually, a level line is carried back to the initial BM to determine the error of closure.

Error of closure is simply the difference between the known elevation of the initial BM and the elevation of the same (BM) as computed in the level run.

The error of closure that can be allowed depends on the precision required (first, second, or third order). The permissible (or allowable) error of closure in accuracy leveling is expressed in terms of a coefficient and the square root of the horizontal length of the actual route over which the leveling was done.

Most differential leveling (plane surveying) is third-order work. In third-order leveling, the closure is usually made on surveys of higher accuracy without doubling back to the old BM at the original starting point of the level circuit. The length of the level circuit, therefore, is the actual distance leveled. For third-order leveling, the allowable error is as follows:

$$0.050 \text{ ft}\sqrt{\text{length of the level circuit in miles}}$$

By adding the sight distances in the sixth and seventh columns of the differential level circuit shown in figure 14-14, you will find that the length of the level circuit is 2,140 ft. The length in miles is

$$2140 + 5280 = 0.405.$$

The allowable error of closure is

$$0.050\sqrt{0.405} = 0.050(0.64) = 0.032 \text{ ft}.$$

Since the actual error is only 0.015 ft, the results are sufficiently accurate.

First- and second-order levels usually close on themselves. The leveling party runs a line of levels from an old BM or station to the new BM or station, and then doubles back to the old BM for closure. The actual distance leveled is twice the length of the level circuit.

For second-order leveling, the allowable error is

$$0.035 \text{ ft}\sqrt{\text{length of the level circuit in miles}}$$

First-order leveling is still more precise. The allowable error cannot be greater than

$$0.017 \text{ ft}\sqrt{\text{length of the level circuit in miles}}$$

MISTAKES AND ERRORS IN LEVELING

As explained in an earlier chapter, the terms *mistakes* and *errors* are NOT synonymous in surveying.

Leveling operations, like other survey measurements, are susceptible to both. Mistakes can be avoided by a well-arranged system of operation and by constant alertness by the survey party members. Checking, as described in some of the operations, will eliminate many possible

Table 14-1.—Leveling Order of Precision

REQUIREMENTS	FIRST ORDER	SECOND ORDER		THIRD ORDER	FOURTH ORDER
		Class 1	Class II		
*Spacing of lines and crosslines ----------------	72 km or 40 miles	40-56 km or 25-35 miles	10 km or 6 miles	Not specified	None
Average spacing of permanently marked BMs along lines, not to exceed ----------------	2 km or 1 mile	2 km or 1 mile	2 km or 1 mile	5 km or 3 mile	None
Length of sections -----	1-2 km or 1/2-1 mile	1-2 km or 1/2-1 mile	1-2 km or 1/2-1 mile	Not specified	None
Check between forward and backward running between fixed elevations or loop closure not to exceed -------------------	$4mm\sqrt{k}$ or $0.017\ ft\sqrt{M}$	$8.4mm\sqrt{k}$ or $0.035\ ft\sqrt{M}$	$8.4mm\sqrt{k}$ or $0.035\ ft\sqrt{M}$	$12mm\sqrt{k}$ or $0.05\ ft\sqrt{M}$	0.6 m for lines up to 20 km or $0.1\ ft\sqrt{M}$

k = the distance in kilometers.
M = the distance in miles.
*In areas outside the U.S. this criteria may be changed to conform with the situation.

areas of mistakes. Errors cannot be completely eliminated, but they can be minimized so that their effect on the survey accuracy will be small and within the tolerances permitted.

Identifying Leveling Mistakes

The leveling mistakes discussed here are not intended to include all possibilities but will give an idea of the more common ones. The survey party personnel should be aware of these possibilities and should be careful to avoid these mistakes. Some of the common mistakes are as follows:

1. Not setting the rod on the same point for an FS and the following BS. Using a turning pin, pedestal, stake, or marking the location with chalk on hard surfaces will help you to recover the identical point.

2. Neglecting to clamp the target or the rod when extended. Any slippage can pass unnoticed and result in a wrong reading that may require an entire rerun of the line to discover the mistake. The rodman should watch the rod or target for any movement as the clamp is tightened. The rod extension or target should be read again after the clamp has been set.

3. Reading the wrong mark. This is a common mistake. The figures on a rod may be obscured by brush or may fall in a position in the field of view so that the instrumentman cannot see two consecutive numbers. Under these conditions, he may read the wrong mark or even read in the wrong direction. This is a great possibility when an inverting eyepiece is being used. For example, if the figure 2 is the only number visible, the instrumentman might read "up" the rod—2.1, 2.2, 2.3 when actually he should be reading 1.9, 1.8, 1.7. Another possibility is miscounting the number of divisions. There is no way to check or discover these mistakes except to be aware of their possibility and to read carefully.

4. Recording a reading in the wrong column. In leveling, readings are not entered into the notebook in a normal sequence, such as left to right across the page. There is always a chance that one or more values may be recorded in the wrong column. The recorder must be alert to avoid making this mistake.

5. Reading the wrong angle sign in trigonometric leveling. The instrumentman can accidentally call out a wrong sign in reading the angle. This type of mistake can be eliminated by the recorder watching the telescope as a pointing is made on the rod. If the wrong one is called out, both the recorder and the instrumentman can resolve it immediately.

6. Recording the wrong sign. The sign varies depending on whether the rod reading is a BS or an FS, and whether the angle is a depression or an elevation. Also, the difference in elevation computation requires a sign reversal if the angle is read for the BS, but not for the FS. These variations can be confusing; the recorder has to be careful to avoid mistakes. This can be done by recording the angle and rod reading signs as read. The sign conversion, if needed, shows up when you compute the DE. Examining the computations to see if all BS DEs have a sign opposite to the angle sign is simple.

7. Subtracting the BS or adding the FS in differential leveling. If the BS or FS is recorded properly (see Number 4 above), you can discover the mistake when you add the BS column and the FS column for a computation check.

8. Using the wrong horizontal cross hairs. This occurs on an instrument provided with stadia hairs.

Identifying Leveling Errors

Generally, errors cannot be totally eliminated, but they can be contained within acceptable tolerances. This requires you to use the prescribed methods and instruments and apply corrections established either mathematically or by experience. Some of the conditions that produce errors are listed below.

1. Instrument not properly adjusted. A small amount of residual error will always exist in any adjustment. For the more accurate surveys, the residual error can be minimized by using BS and FS balancing and, in trigonometric leveling, by taking direct and reverse (circle left and circle right) readings for the angles.

2. Instrument not leveled properly. Unlike the residual adjustment error that will affect the readings one way consistently, this is a random or accidental error. It may affect the line of sight differently at each setup. This error can be minimized only by careful leveling each time the instrument is set up and by recentering the bubble before each reading.

3. Telescope not focused properly. Misfocusing and parallax in the eyepiece create accidental errors that cannot be corrected. The only way to avoid or minimize this error is to take care to focus properly at each setup. The instrumentman

should check and clear parallax before the first sighting and should not readjust it until all sightings from the setup are complete.

4. Rod improperly plumbed. This error is caused by a rodman who does not pay attention to his work. The instrumentman can call attention to plumbing if it is at a right angle to his line of sight, but he cannot see it in the direction of line of sight. The use of a rod level or waving the rod will avoid this error.

5. Unstable object used for a TP. The rodman causes this error by selecting a poor point of support, such as loose rocks or soft ground. As the rod is turned between sights, the weight of the rod can shift a loose rock or sink into soft ground. The elevation of the TP as used for the next BS can change appreciably from the value that had been computed from the previous FS. This error can be avoided by using the turning pin or pedestal when the ground does not present solid points.

6. Rod length erroneous. This error results in either too long or too short rod readings at each point. In a survey predominately over slopes, this error will accumulate. The rod length should be checked with a steel tape at intervals to locate this error.

7. Unbalanced BS and FS distances. The unbalanced distances do not cause the error. It is caused by the effect on the line of sight from residual adjustment and leveling errors and the effect of curvature and refraction errors. Readings you take at a long distance will have a greater error than those at a short distance. This unbalance may not be critical on one setup but can be compounded into a considerable error if the unbalance continues over several setups. By balancing the sight distances at each instrument setup, if possible, and the sums of the BS and FS distances at every opportunity, you will keep these errors to a minimum.

8. Earth's curvature. This produces an error only on unbalanced sights in leveling. When the BS distances are constantly greater than FS distances, or vice versa, a greater systematic error results, especially when the sights are long. To eliminate this error, you must maintain a balanced sight distance in every BS and FS reading, not just their sum total between BMs (the error varies directly as the square of the distance from the instrument to the rod).

9. Atmospheric refraction. This error also varies as the square of the distance but opposite in sign (+ or –) to that caused by the earth's curvature. The effect of atmospheric refraction is only one-seventh of that caused by the earth's curvature. In first- and second-order leveling, the effect of refraction is minimized by taking the BS and FS readings in quick succession and avoiding readings near the ground. (They should be taken at least 2 ft from the ground.)

10. Variation in temperature. If a portion of the telescope is shaded and some parts are exposed to the sun's rays, it produces some warping effect on the instrument that may affect its line of sight. This effect is negligible in ordinary leveling; but in leveling of higher precision, this effect may produce appreciable error. This is one of the reasons why surveyors use an umbrella to shield the instrument when doing more refined work.

BASIC ENGINEERING SURVEYS AND CONSTRUCTION SITE SAFETY

An engineering survey forms the first of a chain of activities that will ultimately lead to a completed structure of some kind, such as a building, a bridge, or a highway. An engineering survey is usually subdivided into a DESIGN-DATA SURVEY and a CONSTRUCTION SURVEY.

This section discusses the basic engineering surveys commonly performed by an EA survey party in support of military construction activities. In addition, various types of occupational hazards relating to specific surveying operation are also presented in this section together with the precautions or applicable abatement procedures that must be carried out to deter injury to the survey crew and/or damage to surveying equipment or material.

HIGHWAY SURVEYS

Surveys for roads and streets involve both field work and office work. The extent of each type of work depends on the magnitude and complexity of the job. Some phases of the work may be done either in the field or in the office, and the decision as to the exact procedures to be followed will be influenced by the number of personnel available and by the experience and capabilities of the individuals involved.

Design-Data Survey

This type of survey is conducted for the purpose of obtaining information that is essential for planning an engineering project or development and estimating its cost. A typical design-data survey, for example, is a route survey required in the design and construction of a particular road or highway. The initial activities included in a route survey are as follows: reconnaissance survey, preliminary-location survey, and final-location survey.

On the other hand, a long established Navy base might already have well-marked horizontal and vertical control networks and up-to-date topographic maps available. Then perhaps neither a reconnaissance nor a preliminary survey would be required. The road could probably be designed by using the existing design data, and the fieldwork would begin with making the final location survey. In summary, the extent to which data is already available is an important factor in determining what field operations have to be performed.

RECONNAISSANCE SURVEY.— A reconnaissance survey provides data that enables design engineers to study the advantages and disadvantages of a variety of routes and then to determine which routes are feasible. You begin by finding all existing maps that show the area to be reconnoitered. In reconnaissance, studying existing maps is as important as the actual fieldwork. Studying these maps and aerial photographs, if any exist, will often eliminate an unfavorable route from further consideration, thus saving your reconnaissance field party much time and effort.

Contour maps give essential information about the relief of an area. Aerial photographs provide a quick means for preparing valuable sketches and overlays for your field party. Direct aerial observation gives you an overview of an area that speeds up later ground reconnaissance if the region has already been mapped.

Begin the study of a map by marking the limits of the area to be reconnoitered and the specified terminals to be connected by the highway. Note whether or not there are any existing routes. Note ridgelines, water courses, mountain gaps, and similar control features. Look for terrain that will permit moderate grades without too much excavating. Use simplicity in alignment and have a good balance of cuts and fills; or use a profile arrangement that makes it possible to fill depressions with the cut taken from nearby high places.

Mark the routes that seem to fit the needs and that should be reconnoitered in the field. From the map study, determine grades, estimate the amount of clearing required, and locate routes that will keep excavation to a minimum by taking advantage of terrain conditions. Mark stream crossings and marshy areas as possible locations for fords, bridges, or culverts.

Have the reconnaissance field party follow the route or routes marked earlier during the map study. Field reconnaissance provides you with an opportunity for checking the actual conditions on the ground and for noting any discrepancies in the maps or aerial photographs. Make notes of soil conditions, availability of construction materials, such as sand or gravel, unusual grade or alignment problems, and requirements for clearing and grubbing. Take photographs or make sketches of reference points, control points, structure sites, terrain obstacles, landslides, washouts, or any other unusual circumstances.

Your reconnaissance survey party will usually carry lightweight instruments that are not precise. Determine by compass the direction and angles. Determine the approximate elevations by an aneroid barometer or altimeter. Use an Abney hand level (clinometer) to estimate elevations and to project level lines. Other useful items to carry are pocket tapes, binoculars, pedometer and pace tallies, cameras, watches, maps, and field notebooks.

Keep design considerations in mind while running a reconnaissance survey. Remember that future operations may require further expansion of the route system presently being designed. Locate portions of the new route, whenever possible, along roads or trails that already exist. Locate them on stable, easily drained, high-bearing-strength soils. Avoid swamps, marshes, low-bearing-strength soils, sharp curves, and routes requiring large amounts of earthmoving.

Keep the need for bridges and drainage structures to a minimum. When the tactical situation permits, locate roads in forward combat zones where they can be concealed and protected from enemy fire.

The report you turn in for the reconnaissance field party must be as complete as possible; it provides the major data that makes the selection of the most feasible route or routes possible.

PRELIMINARY SURVEY.— A preliminary survey is a more detailed study of one or more routes tentatively selected on the basis of a reconnaissance survey report. It consists essentially of surveying and mapping a strip of land along the center line of a tentatively selected route.

Some of the activities associated with a preliminary survey are as follows: running a traverse (sometimes called a P-line or survey base line), establishing BMs, running profiles, and taking cross sections. For many projects, the preliminary survey may be conducted by a transit-tape party alone. Other projects may require a level party and a topographic party.

Normally, the data gathered from a preliminary survey are plotted while the party is in the field, This practice gives a more accurate representation of the terrain, reduces the possibility of error, and helps to resolve any doubtful situations while you are actually observing the terrain.

FINAL-LOCATION SURVEY.— The final-location survey, usually called the location, constitutes a continuous operation; or, in other words, the survey operation goes on from the start of the project through to the end of the actual construction. The location survey consists of establishing the approved layout in the field, such as providing the alignment, grades, and locations that will guide the construction crew.

The EAs tasked with final-location survey normally start (time and distance) ahead of the construction crew. This is often done to save construction time and to avoid delay of scheduled activities. Some of these activities are setting stakes to mark the limits of final earthmoving operations to locate structures and establishing final grades and alignment.

Before making the final-location survey, you should make office studies consisting of the preparation of a map from preliminary survey data, projection of a tentative alignment and profile, and preliminary estimates of quantities and costs. Use this information as a guide for the final location phase. The final location in the field is carefully established by your transit party, using the paper location prepared from the preliminary survey. The center line may vary from the paper location because of objects or conditions that were not previously considered; but these changes should not be made by you, the surveyor, without the authority of the engineering officer.

Office Work

After the type and general location of a highway are decided and the necessary design data is obtained in the field, a number of office tasks must be performed. These tasks include the following:

1. Plotting the plan view
2. Plotting the profile
3. Plotting the alignment
4. Designing the gradients
5. Plotting the cross sections
6. Determining end areas
7. Computing the volumes of cut and fill

Repeat these operations one or more times as trial designs are developed and then revised or discarded. For a highway plan and profile, plot on the same sheet. Figure 14-22 shows a plotted highway plan and profile view. Plotting cross sections is discussed later in this chapter.

PLOTTING THE PLAN VIEW.— Plotting the plan view of a highway is similar to a traverse except for the introduction of topographic details, curves, and curve data. As a study of highway curves and curve data is beyond the scope of this TRAMAN (but will be studied at the EA2 level), suffice it to say that the important elements of the curve are shown in the form of notes at each curve point. (See the plan view, figure 14-22.)

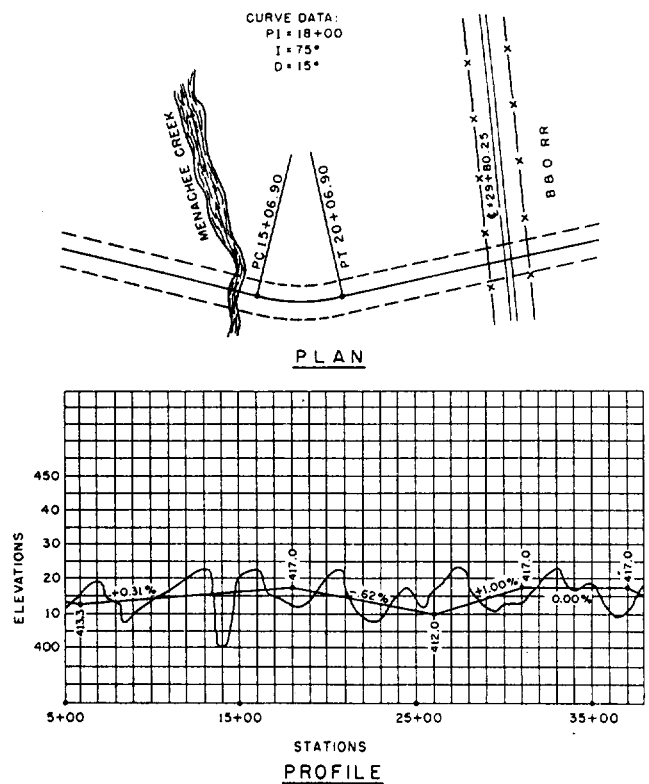


Figure 14-22.-Plan and profile for a highway.

PROFILE PLOTTING.— Make profile plotting on regular profile paper that has ruled horizontal and vertical parallel lines, as shown in figure 14-22. Vertical lines are spaced 1/4 or 1/2 in. apart; horizontal lines are spaced 1/20 or 1/10 in. apart. In figure 14-22, the vertical lines on the original paper (reduced in size for reproduction in this book) were 1/4 in. apart. On the original paper, there was a horizontal line at every 1/20-in. interval; for the sake of clarity, only those at every 1/4-in. interval have been reproduced.

For the first consideration in profile plotting, select suitable horizontal and vertical scales for the profile paper. The suitability of scales varies with the character of the ground and other factors. In figure 14-22, the horizontal scale used was 1 in. = 400 ft, and the vertical scale used was 1 in. = 20 ft (reduced in size for reproduction in this book). Normally, to facilitate the plan plotting, choose scales that are proportional numbers in multiples of ten, such as those given above (H, 1 in. = 400 ft, and V, 1 in. = 20 ft). Write the stations and elevations, as shown in figure 14-22.

Plot the profile, usually from profile level notes, though you may plot it from the elevations obtained from the contour lines. Assume that profile level notes indicate the following centerline elevations at the following stations from 5 + 00 through 15 + 00.

Station	Elevation (feet)
5 + 00	411.9
6 + 00	415.0
7 + 00	417.8
8 + 00	412.0
8 + 75	406.9
9 + 00	411.0
10 + 00	413.2
10 + 50	413.5
11 + 00	415.9
12 + 00	417.3
13 + 00	423.0
13 + 80	412.0
14 + 00	402.0
15 + 00	418.2

As you can see, an elevation was taken at every full station and also at every plus where there was a significant change in elevation. Can you see now how important it is to follow this last procedure? If an elevation had not been taken at 8 + 75, the drop that exists between 8 + 00 and 9 + 00 would not show on the profile.

Check through the listed elevations, and see how each of them was plotted as a point located where a vertical line indicating the station intersected a horizontal line indicating the elevation of that station. Note, too, that usually stations are labeled where the line crosses highways, streams, and railroads.

Besides the profile of the existing terrain, the vertical tangents of the proposed highway center line have been plotted. The end elevation for each of these (that is, the elevations of points of vertical intersection [PVI]) were determined by the design engineers. Various circumstances were considered. One of the important ones was facilitating, as much as possible, the filling of each depression with an approximately equal volume of cut taken from a nearby hump or from two nearby humps.

The gradient, in terms of percentage of slope (total rise or fall in feet per 100 horizontal feet), is marked on each of the vertical tangents. This percentage is computed for a tangent as follows. For the tangent running from station 6 + 00 to station 18 + 00, the total rise is the difference in elevation, or

$$417.0 - 413.3, \text{ or } + 3.7 \text{ ft.}$$

The horizontal distance between the stations is 1,200 ft. The percentage of slope, then, is the value of x in the equation

$$\frac{1200.00}{3.7} = \frac{100}{x} = \text{or } 0.31 \text{ or } 31\%$$

For a tangent running from station 18 + 00 to station 26 + 00, the total slope downward is the difference in elevation, or

$$412.0 - 417.0, \text{ or } -5.0 \text{ ft.}$$

The distance between the stations is 800 ft. The percentage of slope then is the value of x in the equation

$$\frac{800}{-5.0} = \frac{100}{x} = -0.62 \text{ or } -62\%.$$

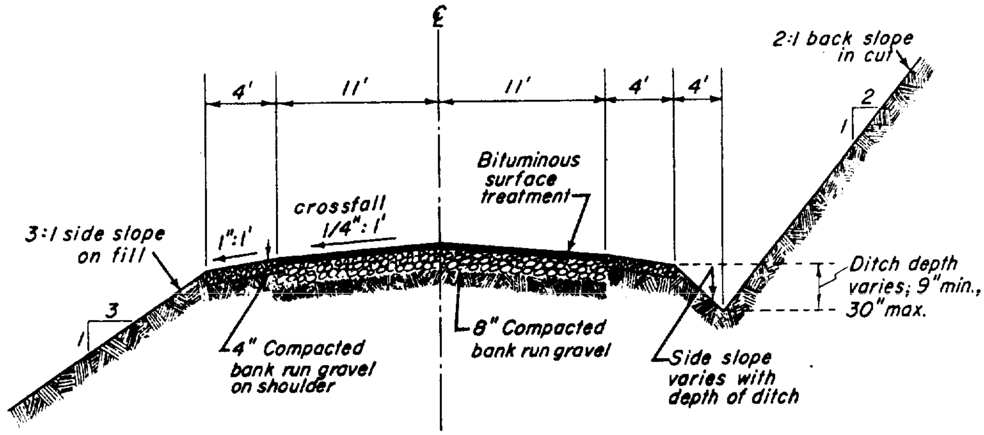


Figure 14-23.-Typical design cross section.

TYPES OF CROSS SECTIONS.— Figure 14-23 shows a typical design cross section, Just about everything you need to know to construct the highway, including the materials to be used and their thicknesses, is given here.

However, this design section is a section of the completed highway. For the purpose of staking out and for earthmoving calculations, the cross-section line of the existing ground at each successive station must be plotted; the design data cross section (typical section of the highway) is then superimposed.

The cross section of the road, with design data available from a previous design-data survey, is staked out by an EA survey party, preferably the leveling crew. Figure 14-24 shows a designed cross section of a 40-ft-wide road taken from a station or point along the road center line. The elevation of the existing surface is 237.4 ft all the way across; therefore, this is called a level section. Finished grade for the highway at this station—that is, the proposed center-line elevation for the finished highway surface—is 220.4 ft. The prescribed side-slope ratio is 1.5:1; that is; a horizontal unit of 1.5 for every unit of vertical rise.

Because the ground line across the cross section is level and the side-slope ratio is the same on both sides, the horizontal distance from the center line to the point where the side slope will meet the natural surface will be the same on both sides. A slope stake is driven at this point to guide the earthmovers. The horizontal distance from the center line to a slope stake can be computed by methods that will be explained later.

In the case of this designed cross section, the data available to you are

1. the width of the highway,

2. the side-slope ratio, and

3. the proposed finished grade.

Besides this, all you need to know to set slope stakes is the ground elevation of the slope-stake point on each side. Because the elevation of the level section in figure 14-24 is the same on both sides, only a single-level shot for elevation is needed. For this reason, a section of this kind is called either a one-level section, or just a level section. Because the entire sectional area consists of material to be excavated or CUT, it is called a section in cut.

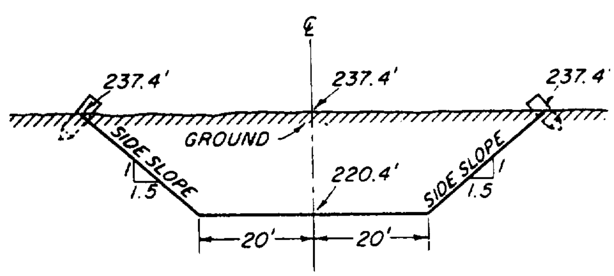


Figure 14-24.-Level section in cut.

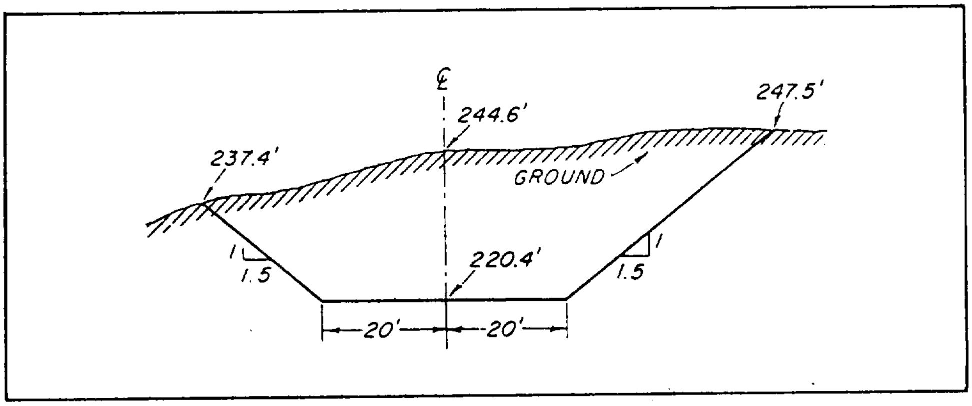


Figure 14-25.-Three-level section in cut.

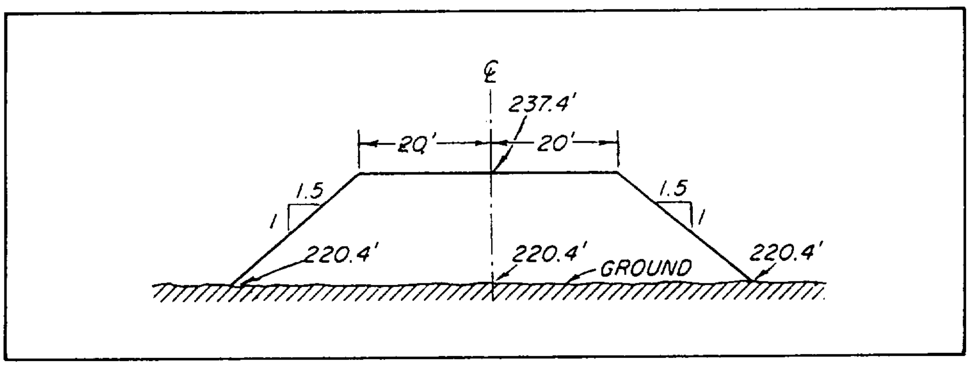


Figure 14-26.-Level section in fill.

In the section shown in figure 14-25, the ground line across the section is sloping rather than level. Therefore, to plot this section, you would need three different elevations: one for the left slope stake, one for the center-line grade stake, and one for the right slope stake. If these three levels are taken, the section is called a three-level section in cut. If additional levels are taken midway between the center line and the slope stake on either side, it is called a five-level section in cut. Therefore, it is a section in cut because the entire cross-sectional area consists of cut.

Level, three-level, and five-level sections are called regular sections.

Figure 14-26 shows a level section in fill; figure 14-27 shows a three-level section in fill. The section shown in figure 14-28 consists of both cut and fill and is called a sidehill section.

When a more accurate picture of cross sections than can be obtained from regular sections is desired, irregular sections are taken and plotted. For an irregular section you take, besides the regular levels, additional levels on either side of the center line. You take these at set intervals and at major breaks in the ground line.

Cross sections may be preliminary or final. Preliminary cross sections, from the P-line or survey base line, are irregular sections that are plotted before the finished grade has been determined. They may be obtained by levels run in the field or by elevations found on the contour lines of a topographic map.

Final cross sections are sections of the final road design. They may be prepared in the same manner as preliminary sections, or they may be regular sections plotted from field data obtained after the finished grade has been set. The term *final cross section* is also applied to as-built sections taken after construction is completed.

PLOTTING CROSS SECTIC)NS.— Cross sections are usually plotted on cross-section paper, which comes either in rolls or sheets. It is ruled into 1-in. squares with heavy, orange or green

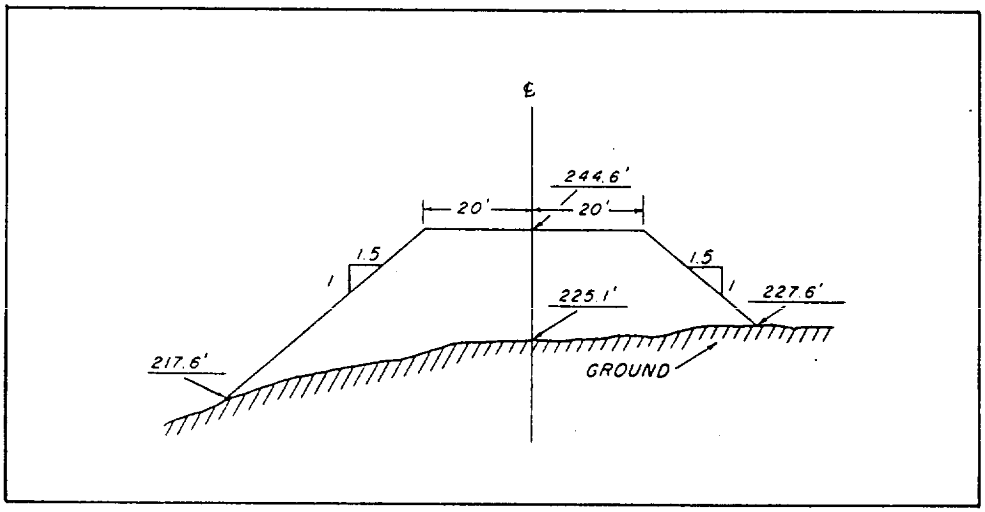


Figure 14-27.-Three-level section in fill.

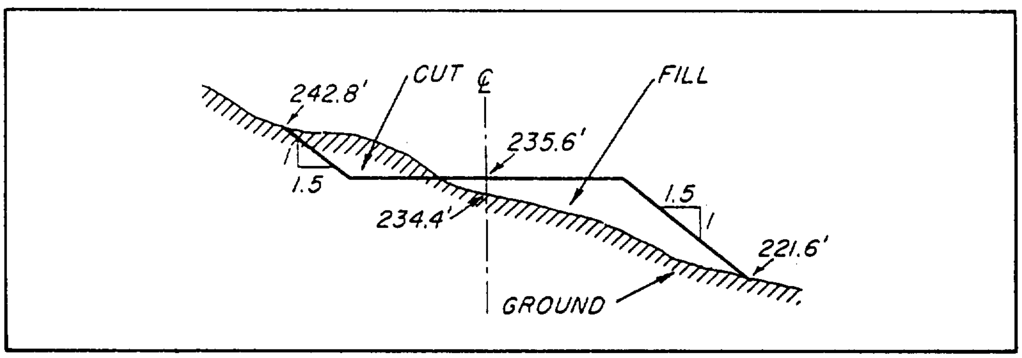


Figure 14-28.-Sidehlll section.

lines and with lighter lines into 1/10-in. squares, Cross-section paper is commonly called 10- x 10-in, paper.

Plot each cross section separately; and below each plot, show the station number. Place the first cross section at the top of a sheet and continue downward until you plot all the sections. Two or more sections may be plotted on the same sheet. In a major highway project, plot cross sections on a continuous roll of cross-section paper. Some surveyors prefer to plot the cross sections from the bottom to the top of the paper. They may also prefer to record cross-section notes in the same manner. If you follow these methods of plotting and recording, you are properly oriented with the actual direction of the highway; that is, your left is also towards the left of the highway; it is also to the left of the cross-section notes and the plotted cross section. Really, it doesn't matter which method you follow as long as you are properly oriented to the direction of the highway at all times.

Unlike profile plotting, in cross-section plotting, the same scale is often used for both the vertical and the horizontal distance. Common scales are 1 in. = 5 ft and 1 in. = 10 ft. When sections are shallow, it is best to exaggerate the vertical scale, making it from two to ten times the horizontal scale.

For the center line for a row of sections, use one of the heavier vertical lines on the paper far enough away from the margin so that no points plotted will run outside the limits of the paper. Note the depths indicated for the first section to be plotted, and select a horizontal line for the base

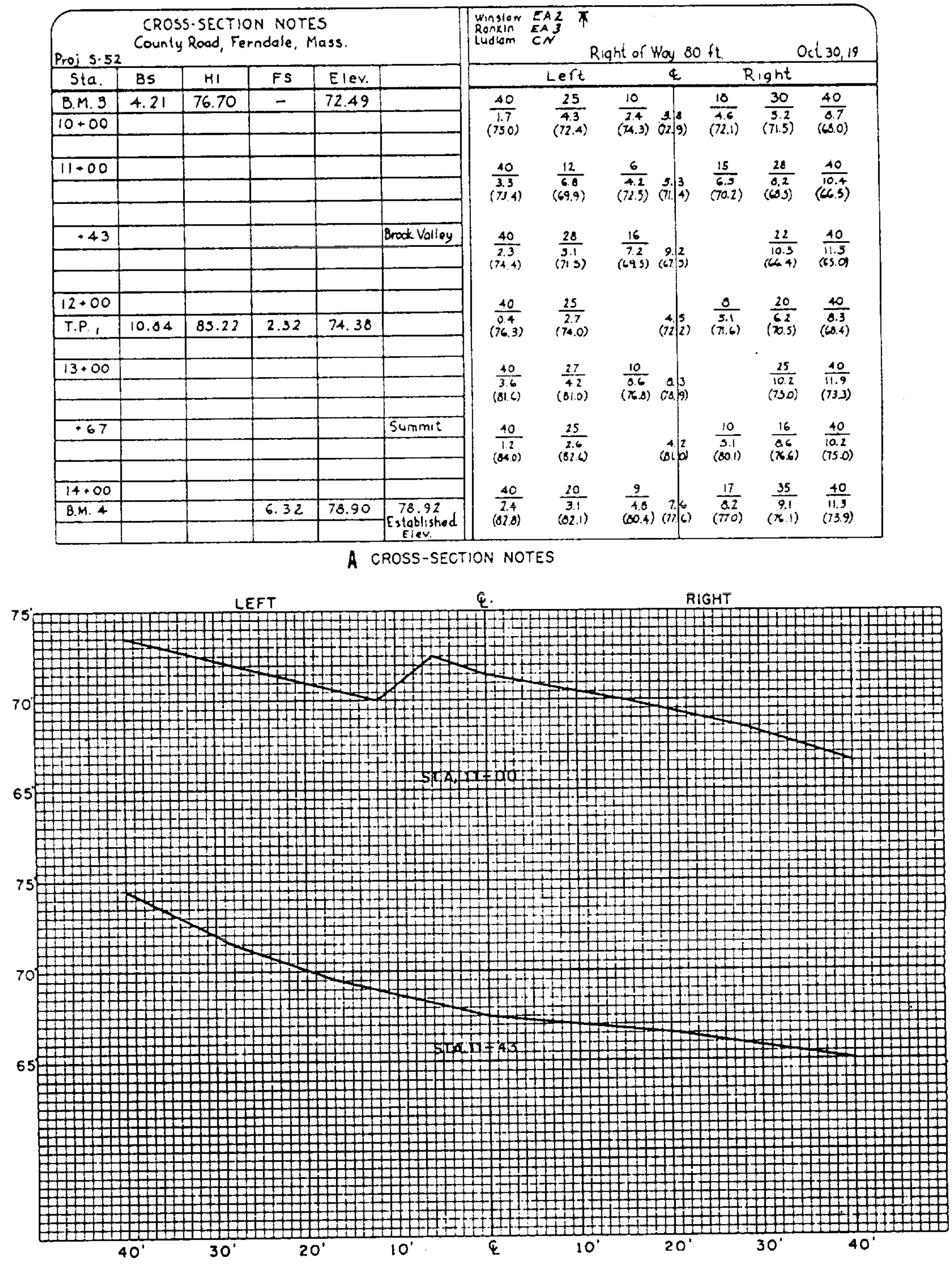


Figure 14-29.-A. Cross section notes. B. Cross sections plotted.

that is about centered between the top and bottom margins. Mark this with the base elevation. Then lay off the horizontal distances of the section surface elevations on either side of the center line, and plot the elevations by using the level data. Finally, connect these plotted points by using a straightedge or by drawing freehand lines.

In figure 14-29, view A, cross-section notes are shown for the existing ground along a proposed road. In figure 14-29, view B, the sections at stations 11 + 00 and 11 + 43 have been plotted. The field party took, for each station, the ground elevation 40 ft to both the right and to the left of the center line. For each station, however, the center-line distance of the intermediate elevations varies. Therefore, these are irregular sections.

For both of the stations plotted, the HI was 76.70 ft. For the point 6 ft left of the center line at station 11 + 00, note the 4.2 written below the 6. This reading was obtained from a rod held on this point. The number 72.5 shown in the parentheses right below the number 4.2 is the elevation of this point. You obtain the elevation by subtracting from the HI, the rod reading FS:

76.70 – 4.20, or 72.50

You can see this point is plotted 6 ft to the left of the center line and at an elevation of 72.5 ft in figure 14-29, view B. Now if the notes are reduced in the office, the general practice is to print the elevations in RED; then the elevation just computed (72.5) will appear in red in the cross-section notes (fig. 14-29, view A).

After the road gradients, either preliminary or final, have been designed, plot the design data cross section on the existing ground line section plot at each station to complete the picture of the end-area as it will be in the finished highway. Obtain the finished grade elevation for each station from the profile. Plot the finished grade point usually located on the center at each cross section. Then draw in the outline of the pavement surface, ditches, and cut or fill slopes as they show on the typical design section. Plotting may be done with triangles, but a faster method is to use templates made of plastic, thin wood, sturdy cardboard, or other suitable material. Prepare templates for a cut section, a fill section, and a sidehill section that may be flipped over to accommodate the direction of hillside slope.

The procedures just described are the most common and pertain to irregular sections. However, if regular sections have been taken in the field after the gradients have been designed, then both the existing and the finished surfaces will be plotted. Field notes for simplified three-level sections on a highway are shown in figure 14-30. On the data side, the profile elevation and the grade elevation at each station are listed. In the columns headed Left and Right on the

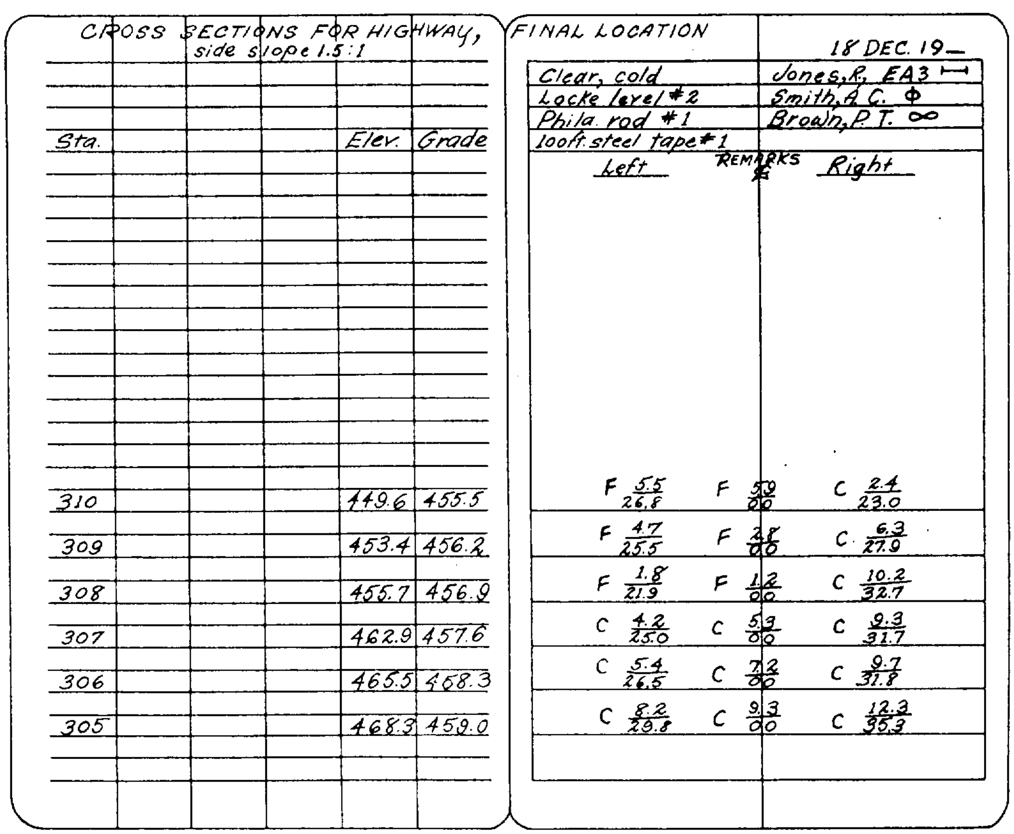


Figure 14-30.-Field notes for three-level cross sections.

remarks side, the upper numbers with the appropriate letter symbols (C for cut, F for fill) are the cuts or fills; the lower numbers are the distances out from the center. These values indicate points at which the slope stakes are driven. If a five-level or irregular section is being recorded, the other points must be written between those for the center and for the slope stakes.

These field notes given you the coordinates that you can use to plot sections, as shown in figure 14-30. In that figure for purposes of clarity, only the lines at every 1/4-in. interval are shown. The scale, both horizontal and vertical, is 1 in. = 10 ft; therefore, the interval between each pair of lines represents 2.5 ft.

The highway is to be 40 ft wide; therefore, the edge of the pavement for each plotted section will be 8 squares (8 x 2.5 = 20) on either side of the center line. Figure 14-30 shows that, for station 305, the left-hand slope stake is located 29.8 ft from the center line and 8.2 ft above grade. The right-hand slope stake is located 35.3 ft from the center line and 12.3 ft above grade. Note how the locations of these stakes can be plotted after you have selected an appropriate horizontal line for the grade line and how the side slopes can then be drawn.

The ground line at the center line is 9.3 feet above grade. Plot a point here, and then finish the plot of the section by drawing lines from the center-line point to the two slope stake points.

Plot a five-level section in exactly the same way, except that you plot in additional ground points between the center line and the slope stakes.

Layout/Stakeout Procedures

The design-data survey is followed by the construction survey that consists broadly of the LAYOUT or STAKEOUT survey and the AS-BUILT survey, which will be discussed later in this chapter. In a layout survey, both horizontal and vertical control points are located and marked (that is, staked out) to guide the construction crews. Figure 14-31 identifies various stakes and hubs used in highway or road construction and their typical arrangement. The functions of the various stakes and hubs are described briefly as follows:

1. CENTER-LINE STAKES indicate the exact center of the roadway construction.
2. SHOULDER STAKES are used to indicate the inside edge of the roadway shoulders. These stakes are set opposite each center-line stake.
3. REFERENCE HUBS, as the name implies, are used to reference other stakes or to aid in establishing or reestablishing other stakes.
4. SLOPE STAKES mark the intersection of side slopes with the natural ground surface. They indicate the earthwork limits on each side of the center line.
5. RIGHT-OF-WAY STAKES indicate the legal right of passage and outmost bounds of construction.
6. GRADE STAKES indicate required grade elevations to the construction crews. During the final grading stage of construction, hubs called "blue tops" are used in lieu of stakes. The blue

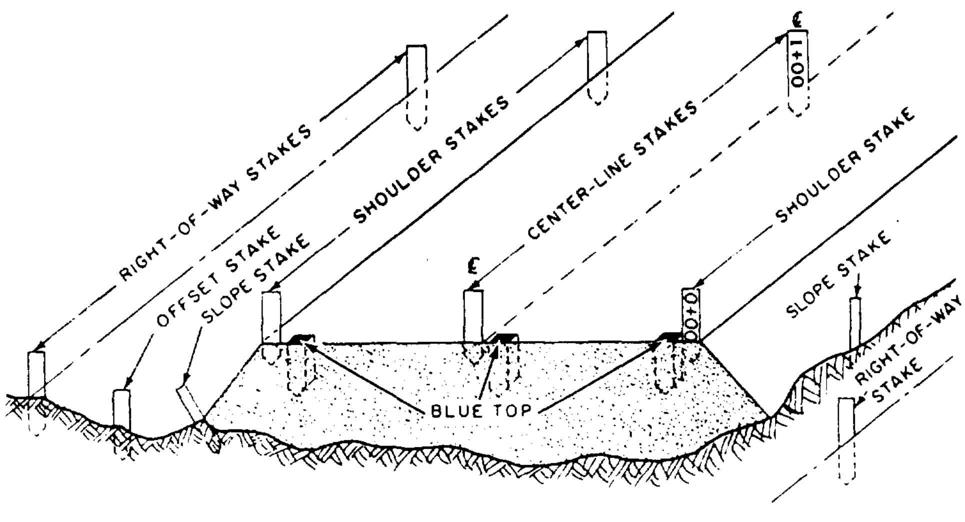


Figure 14-31.-Typical arrangement of various hubs and stakes on a road section (final grading).

tops are driven so that the top of the hub is set at the required grade elevation.

7. GUARD STAKES are used to identify and protect hubs. The face of the stake is marked with station identification and is placed so that the stake faces the hub it identifies. Sometimes more than one guard stake will be used to protect a hub.

8. OFFSET STAKES may be additional stakes that are offset a known distance from other stakes that will likely be disturbed during construction. The offset stake is marked with the same information as the stake it offsets, and it is also marked to show the offset distance. Often, stakes will themselves be offset a known distance from their true location. This eliminates the requirement for additional stakes.

CENTER-LINE LAYOUT.— The first major step in highway construction is usually the rough grading; that is, the earthmoving that is required to bring the surface up to, or down to, the approximate elevation prescribed for the subgrade. The SUBGRADE is the surface of natural soil, or the place where the pavement will be laid. The subgrade elevation, therefore, equals grade (finished surface) elevation minus the thickness of the pavement.

In rough grading, the equipment operators are usually guided by grade stakes that are set along the center line by the transit-tape survey party at center-line stations. The center-line stations (stakes) are usually set at intervals of 100 ft or more on straight-line stretches and intervals of 50 ft or less on roads with horizontal and vertical curvatures. On a small-radius, street-corner curve, a center-line hub or stake might be set at the center of the circle of which the curve is a part. This is done so the construction crew may outline the curve by swinging the radius with the tape. Reference stakes or hubs are also set on one or both sides of the center line to permit reestablishment of the center line at any time.

Each center-line stake is marked with the vertical depth of cut or fill required to bring the surface to grade elevation. The surveyor must indicate the station markings and the cut and fill directions on stakes. Let's look at the stakes on the center line of the road-building job. The starting point is the first station in the survey; this station is numbered 0 + 00. The next station is normally 100 ft farther and is marked 1 + 00; the third station is another 100 ft farther and is marked 2 + 00; and so on. On sharp curves on rough ground, the stakes may be closer together. (See fig. 14-32.) Generally, the station markings face the starting point. The mark ℄, which is also on the side facing the starting point, is used to indicate that the stake is a center-line stake.

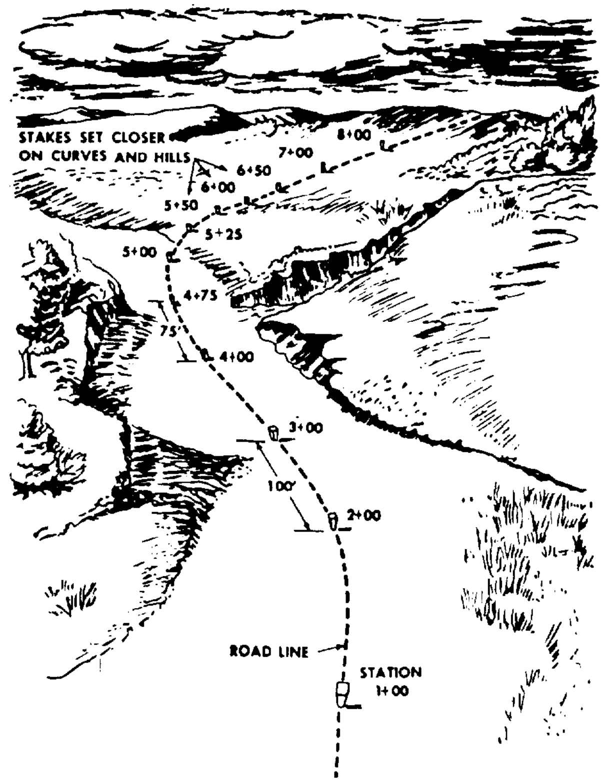


Figure 14-32.-Station markings.

A cut is designated by the letter C, and the fill is indicated by the letter *F*. Numerals follow the letters to indicate the amount that the ground should be cut or filled. The symbol C– $1^{\underline{5}}$ indicates that the existing ground should be cut 1.5 ft, as measured from the reference mark. During rough grading, the cut and fill are generally carried just up to the nearest half foot; exact grade elevations are later marked with hubs (blue tops). The mark $\underline{V}$ is called a crowfoot. The apex of the V indicates the direction of the required change in elevation; so a cut is indicated by $\underline{V}$, and a fill is indicated by $\overline{\Lambda}$. In some cases, surveyors mark the grade stake only with a negative or a positive number and the crowfoot, indicating the cut or fill.

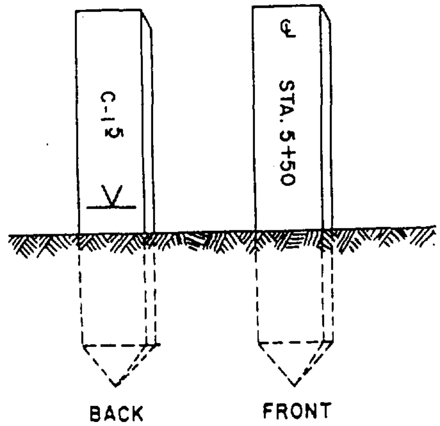


Figure 14-33.—Cut stake.

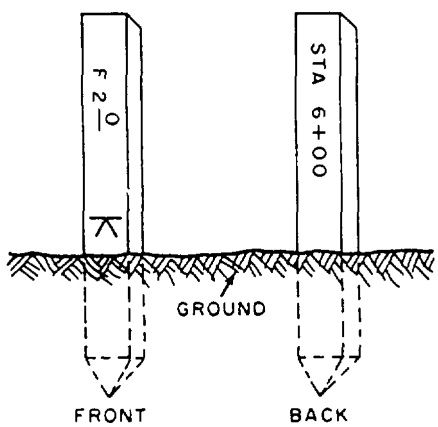


Figure 14-34.-Fillstake (not on centerline).

Figure 14-33 shows a cut stake that also happens to be a center-line marker. Note that station mark is written on the front of the stake and the construction information on the back. On grade stakes other than the center-line stakes, the construction information should be written on the front and the station marked on the back.

The stake shown in figure 14-34 indicates that fill operations are to be performed. The letter *F* at the top of the stake stands for fill. The numerals $2^{\underline{0}}$ indicate that 2 ft of fill are required to bring the construction up to grade.

Some stakes indicate that no cutting or filling is required. Figure 14-35, for example, shows a grade stake that is on the proper grade and also is a center-line stake. The word *GRADE* (or *GRD)* is on the back of the stake, and the crowfoot mark may not be indicated; some surveyors prefer to use a crowfoot mark on all grade stakes. If this grade stake is not a center-line stake, the GRD mark will be written on the front of the stake.

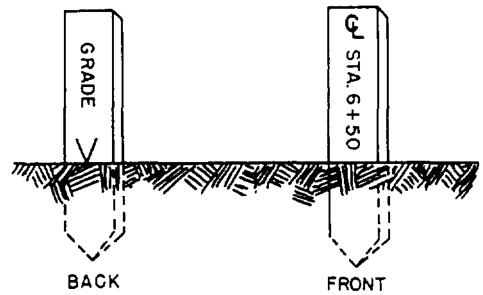


Figure 14-35.-Stake on proper grade.

SETTING GRADE STAKES.— GRADE STAKES are set at points having the same ground and grade elevation. They are usually set after the center line has been laid out and marked with hubs and guard stakes. They can be reestablished if the markers are disturbed. Elevations are usually determined by an engineer's level and level rod. One procedure you can use for setting grade stakes is as follows:

1. From BMs, turn levels on the center-line hubs or on the ground next to a grade stake at each station.
2. Reduce the notes to obtain hub-top or ground elevation.
3. Obtain the finished grade elevation for each station from the construction plans.
4. Compute the difference between finished grade and the hub or ground elevation to determine the cut or fill at each station.
5. Go back down the line and mark the cut or fill on each grade stake or guard stake.

The elevations and the cuts or fills may be recorded in the level notes, or they may be set down on a construction sheet, as explained later in this chapter.

Another procedure may be used that combines the method listed above so that the computations may be completed while at each station; then the cut or fill can be marked on the stake immediately.

As before, levels are run from BMs; the procedure at each station is as follows:

1. Determine the ground elevation of the station from the level notes to obtain HI.
2. Obtain the finished grade for the station from the plans.

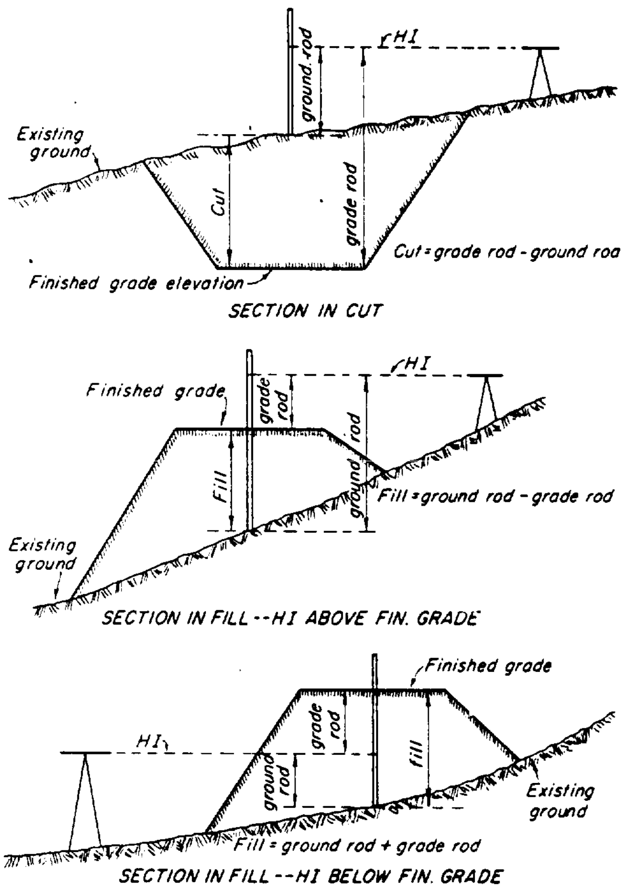


Figure 14-36.-Determining cut or fill from grade rod and ground rod.

3. Compute the difference between the HI and finished grade; this vertical distance is called grade rod.
4. Read a rod held on the hub top or ground point for which the cut or fill is desired. This rod reading is called ground rod.
5. Determine the cut or fill by adding or subtracting the grade rod and the ground rod, according to the circumstances, as shown in figure 14-36.
6. Mark the cut or fill on the stake.

During the final grading, you will most likely be working with hubs called BLUE TOPS (fig. 14-31). These hubs are driven into the ground until the top is at the exact elevation of the finished grade as determined by the surveying crew. When the top of the stake is at the desired finish grade elevation, it is colored with blue lumber crayon (keel) to identify it as a finished grade stake. Other colors may be used, but be consistent and use the same color keel throughout the project so as not to confuse the Equipment Operators. Blue tops are normally provided with a guard stake to avoid displacement during construction work. The guard stake usually shows the station and the elevation of the top of the hub. The elevation and station markings may be required only at station points; otherwise, all that is needed is the blue top and the guard stake with flagging.

The procedure for setting blue tops lends itself primarily to final grading operations. It is carried out as follows:

1. Study construction plans and center-line profiles for each station to determine (1) the exact profile elevation and (2) the horizontal distance from center line to the edge of the shoulder.
2. Measure the horizontal distance from the center line to the shoulder edge at each station, and drive a grade stake at this point on each side. Sometimes it is advisable to offset these stakes a few feet to avoid displacement during construction.
3. Set the top of the stake even with the grade elevation, using both the level and the rod. This is accomplished by measuring down from the HI a distance equal to the grade rod (determined by subtracting grade elevation from the HI). The target on the rod is set at the grade-rod reading; the rod is held on the top of the stake; and after a few trials, the stake is driven into the ground until the horizontal hair of the level intersects the rod level indicated by the target. Color the top of a stake with blue crayon (keel).
4. Where the tops of stakes cannot be set to grade because grade elevation is too far below or above the ground line, set in ordinary grade stakes marked with the cut or fill as in rough grading. However, for final grading, it is usually possible to set mostly blue tops.

Where grade stakes cannot be driven, for example, in hard coral or rock areas, use your ingenuity to set and preserve grade markings in a variety of conditions. Markings may often be made on the rock itself with a chisel or with a keel.

SETTING SLOPE STAKES.– SLOPE STAKES are driven at the intersection of the ground and each side slope or offset a short distance; they indicate the earthwork limits on each side of the center line. The minimum areas to be cleared and grubbed extend outward about 6 ft from the slope stakes.

Refer back to figure 14-31 and take a close look at the position of the slope stakes. The horizontal distance of a slope stake from the center line varies, and to determine what it is, you must know three things.

1. The width of the roadbed, including widths of shoulders and ditches, if any
2. The side-slope ratio (expressed in units of horizontal run in feet per foot of vertical rise or fall)
3. The difference in elevation between the grade for the road and the point on the natural ground line where the slope stake will be set

In figure 14-37, view A, d is the horizontal distance from the center line to the slope stake, W/2 is the horizontal distance from the center line to the top of the slope, h is the difference in elevation between the finished grade and the ground at the slope stake, ands is the slope ratio. The product of h x s gives the run of the slope; that is, the horizontal distance the slope covers. The horizontal distance (d) of the slope stake from the center line, then, equals the sum of W/2 plus hs. For example, suppose that W/2 is 20 ft, h is 10 ft, and the bank is a 4:1 slope. Then

$$hs = 10 \times 4, \text{ or } 40$$

and

$$d = 20 \text{ ft} + 40 \text{ ft, or } 60 \text{ ft.}$$

In practice, you may have to take other factors into account, such as transverse slope or the crossfall of the pavement (sometimes called the crown), ditches, and so on. In figure 14-37, view B, for example, there is a crossfall (h=) across W/2 so that the run (horizontal distance covered) of the bank ($h_b s$) is the product of s x h_b instead of hs, as in figure 14-31, view A. The crossfall is usually constant and may be obtained from the typical design sect ion shown on the plans.

Figure 14-37, view C, shows a cut section in which W/2 varies with crossfall, side slope, ditch depth, and back slope. For example, assume that the distance from the center line to the beginning of the side slope is 20 ft, that the cross fall totals 1 ft, that ditch depth is 1.5 ft, and that both the side slope and back slope ratios are 2:1. The distance W/2, then, comprises horizontal segments as follows:

1. From the center line to the top of the slope which is 20 ft

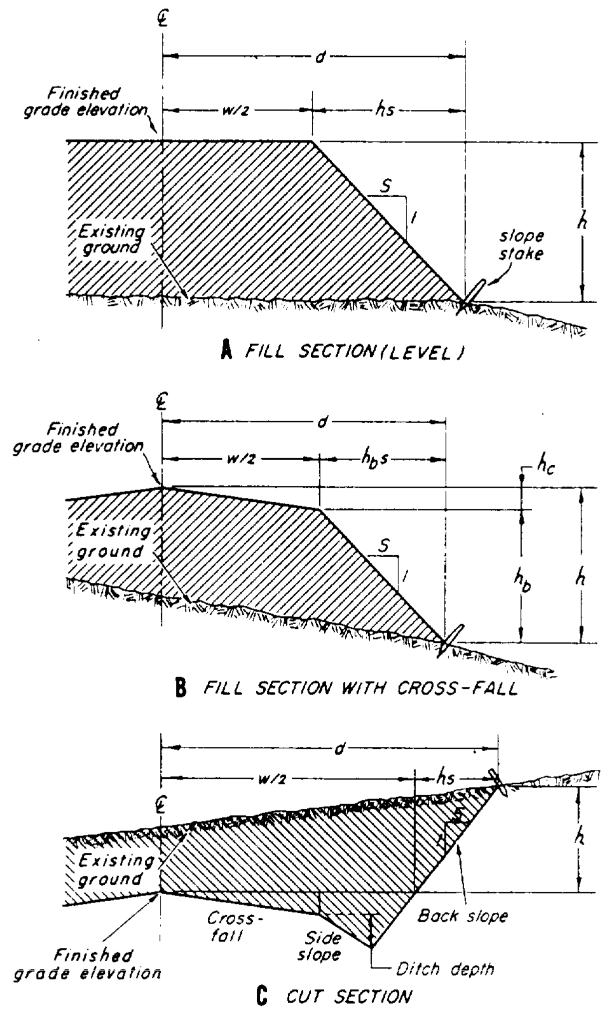


Figure 14-37.-Determining slope stake location (distance from center line) for a proposed roadway.

2. Then to the ditch flow line, which equals the product of slope ratio (2) times ditch depth (1.5), or 3 ft
3. Then to the point on the back slope that is level with the finished center line, which equals slope ratio (2) times difference in elevation; that is, crossfall plus ditch depth,

$$2(1 + 1.5), \text{ or } 5 \text{ ft.}$$

The total distance, W/2, then, is the sum of

$$20 + 3 + 5, \text{ or } 28 \text{ ft.}$$

SLOPE-STAKE PARTY PROCEDURE.— Slope stakes are usually set with an engineer's or automatic level, a level rod, and a metallic or nonmetallic tape. In rough terrain, a hand level is generally used instead of an engineer's level.

If the engineer's level is used, three crew members are generally employed for fieldwork; they are the instrumentman, the rodman, and one person to hold the zero end of the tape at the center line. When a hand level is used, two persons can take care of the job—the instrumentman also holds the zero end of the tape and is positioned at the center-line station as the rod reading is taken. The procedure followed is a trial and error process. Under field conditions, the rodman is at times as much as 200 or 300 ft away from the instrumentman. If power equipment is operating nearby or a wind is blowing, oral instructions cannot be given to the rodman about where to take trials shots; in fact, often there. is not a clear view of the ground slope at the station being worked.

Consequently, the rodman must know as much as the instrumentman does about the theory and practice of setting slope stakes. The speed and efficiency of the party depend on the rodman more than on any other member. The rodman must be constantly mentally alert.

The most practical field procedure requires that the rodman know the value of W/2 and of s (the slope ratio). This is not difficult, since these values are usually constant for several stations, and the rodman can be informed when they change. A typical procedure for setting slope stakes is as follows:

1. The instrumentman computes the center-line cut or fill, using the HI, finished grade, and the existing ground elevation. Refer back to figure 14-36.
2. The instrumentman calls or signals the center-line cut or fill to the rodman.
3. The rodman mentally computes the approximate value of d by multiplying h x s and adding W/2. He pulls the tape taut while holding the tape at the computed distances.
4. Noting the approximate rise or fall of the ground, the rodman adjusts the approximate value of d, moves to the d point, and sets up the rod for a trial shot.
5. The instrumentman quickly calculates the cut or fill at this point and calls the value to the rodman.
6. The rodman compares this with the estimated cut or fill. He should be fairly close and should know at once whether to move toward, or away from, the center line. Having a much shorter distance over which to estimate ground slope, he again estimates new cut or fill and hs + W/2, and moves the rod to the new d value.

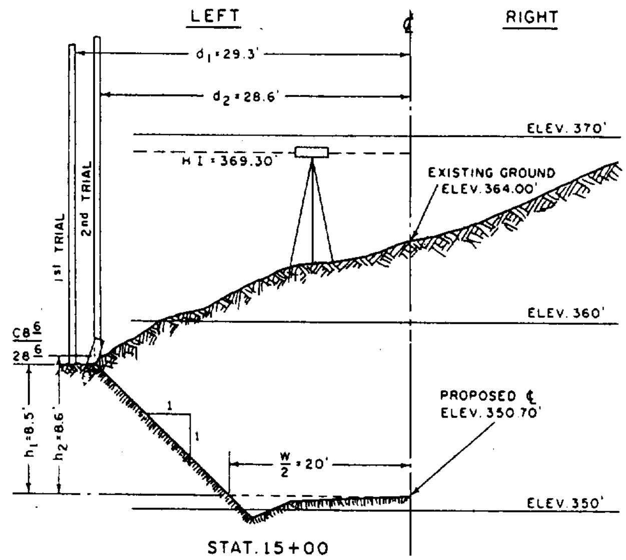


Figure 14-38.-Setting slope stakes.

7. The instrumentman again gives the cut or fill; if the value checks, the rodman calls or signals back the cut or fill and the distance.

8. The instrumentman quickly checks the two values mentally, and if the values are correct, records the values in the field book, signaling "Good" to the rodman.

9. The rodman marks and drives the stake.

With practice and on fairly smooth ground, a good rodman will seldom miss the first trial by more than 0.2 ft vertically and will, quite often, hit the correct value on the first trial.

Figure 14-38 shows the application of these procedures to an actual situation. The following data are known for this slope-stake stakeout:

1. The station is 15 + 00.

2. The W/2 (from the typical design section) is 20 ft.

3. The slope ratio is 1:1; therefore, s = 1.

4. The existing ground elevation at the center line (from the previously run profile) is 364.00 ft.

5. The HI is determined to be 369.30 ft at that setup.

The steps taken by the instrumentman and the rodman are as follows:

1. The instrumentman determines the centerline cut by subtracting 350.7 ft from 364.0 ft to get the cut, or 13.3 ft.

2. The rodman holds at the center line for a check. The rod should-read 369.3 (the HI) minus 364.0, or 5.3 ft.

3. The instrumentman calls to the rodman, "Cut 13.3 feet."

4. The rodman computes

$$d= 20+(1 \times 13.3) = 33.3$$

as he walks to the left.

5. As he approaches about 30.0 ft from the center line, he estimates that the ground has a fall of 4 ft. Therefore, he computes the new cut as

$$13.3 - 4.0, \text{ or } 9.3 \text{ ft.}$$

This means a new d of

$$20 + (1 \times 9.3) = 29.3 \text{ ft.}$$

6. The rodman sets up the rod 29.3 ft from the center line, as measured by metallic tape.

7. The instrumentman reads 10.1 on the rod and computes the new cut as

$$369.3 - (350.7 + 10.1), \text{ or } 8.5 \text{ ft.}$$

NOTE: Here you can also use the grade rod and ground rod values as explained earlier; the new cut then will be

$$18.6 - 10.1 = 8.5 \text{ ft.}$$

Refer back to figure 14-36.

8. The instrumentman calls, "Cut 8.5," to the rodman.

9. The rodman computes

$$d = 20 + (1 \times 8.5) = 28.5 \text{ ft.}$$

He knows, therefore, that 29.3 ft from the center line is too far out.

10. Figuring that the ground rises about 0.1 ft between 29.3 left and 28.5 left, the rodman calculates that the more nearly correct cut will be

$$8.5 + 0.1, \text{ or } 8.6 \text{ ft.}$$

11. By using this cut, the rodman calculates the new d as

$$20 + (1 \times 8.6),$$

and sets the rod at 28.6 ft left.

12. The instrumentman reads 10.0 on the rod and computes the new cut as

$$369.3 - (350.7 + 10.0) = 8.6 \text{ ft.}$$

13. The instrumentman calls, "Cut 8.6," to the rodman.

14. The rodman sees that the actual cut of 8.6 ft agrees with his estimated cut of the same, and calls, "Cut 8.6 at 28.6," to the instrumentman.

15. The instrumentman checks

$$d = 20 + (1 \times 8.6) = 28.6,$$

signals the rodman, "Good," and makes the following entry into the field book:

$$\frac{C8^6}{28}$$

16. The rodman marks a stake with 15 + 00 and $C8^6$ and drives it in the ground at 28.6 ft left.

More often, slope stakes may be set by using a hand level. Their distances out are generally measured to the nearest half or tenth of a foot. If a slope stake is placed in an offset position, the offset distance is also marked on the stake so the equipment operator is not confused about its actual location. Slope stakes are seldom used in areas requiring less than 2 ft of cut or fill.

Curb and Gutter Stakeout

For a thoroughfare that will have a curb and gutter, these items are usually constructed before the finish grading is done. The curb constructors obtain their line and grade from offset hubs like those described previously. Guided by these, the earthmovers make the excavation for the curb, the formsetters set the forms, and the concrete crew members pour, finish, and cure the curb.

Once the curb has been constructed, shaping the subgrade to correct subgrade elevation and laying the pavement to correct finished grade is simply a matter of measuring down the correct distance from a cord stretched from the top of one curb to the top of the curb opposite.

Pavement Stakeout

Pavement stakeout will depend on the type of paving equipment used. Steps in the method commonly used for paving concrete highways are as follows:

1. Set a double line of steel side forms, equipped with flanges that serve as tracts for traveling paving equipment.
2. Fill the space between the forms with concrete poured from a concrete paving machine (commonly called just a paver).
3. Spread the' concrete with a mechanical spreader that travels on the flanges of the side forms.
4. Finish the surface with a finisher, a machine that also travels on the side forms.

The line-and-grade problem—that is, the layout or stakeout problem—consists principally of setting the side forms to correct line with the upper edges of the flanges at the grade prescribed for the highway. If the finished grade shown on the plans is the center-line grade, then the forms are set with tops at the center-line grade less the crossfall. If the design elevations are shown for points other than those on the center line, the form elevation is related to the design points as indicated by the typical section.

Stakeout maybe done by setting a line or lines of offset hubs, as previously described. Sometimes, however, a line of hubs is driven along the line the forms will occupy and driven to grade elevation less the depth of a side form. The forms are then set to the line and the grade by simply placing them on the hubs.

Concrete paving is also done by the slip form method in which, instead of a complete double line of forms, a sliding or traveling section of formwork is an integral part of the spreading and finishing machinery. The machinery is kept on line and the pavement finished at grade by a control device or devices. The line control device usually follows a wire stretched between rods that are offset from the pavement edge.

Forms are not usually used in asphalt paving. Asphalt paving equipment, in general, is designed to lay the pavement at a given thickness, following the fine-graded subgrade surface. The manner in which a given piece of equipment is kept on line varies, and the stakeout for equipment varies accordingly.

STRUCTURAL SURVEYS

A STRUCTURAL survey is one that is part of the chain of human activities that will bring a structure, such as a building, a bridge, or a pier into existence.

Earthwork

As when a highway is built, the first major step in the construction of a structure is usually the rough grading—that is, the earthmoving needed to bring the surface of the site up to, or down to, the approximate specified rough grade.

The stakeout for rough grading is commonly done by the GRID method. The area to be graded, which is shown, along with the prescribed finish grade elevation on the site or plot plan is laid off in 25-, 50-, or 100-ft grid squares. The elevation at each corner point is determined; the difference between that and the prescribed grade elevation is computed; and a grade stake is marked with the depth of cut or fill; then the stake is driven into the ground at the point.

Building Stakeout

If the structure is a building, the next major step after the rough grading is the building stakeout; that is, the locating and staking of the main horizontal control points of the building. These are usually the principal corner points plus any other points of intersection between building lines.

The procedure followed varies with circumstances. Figure 14-39 shows a simple building

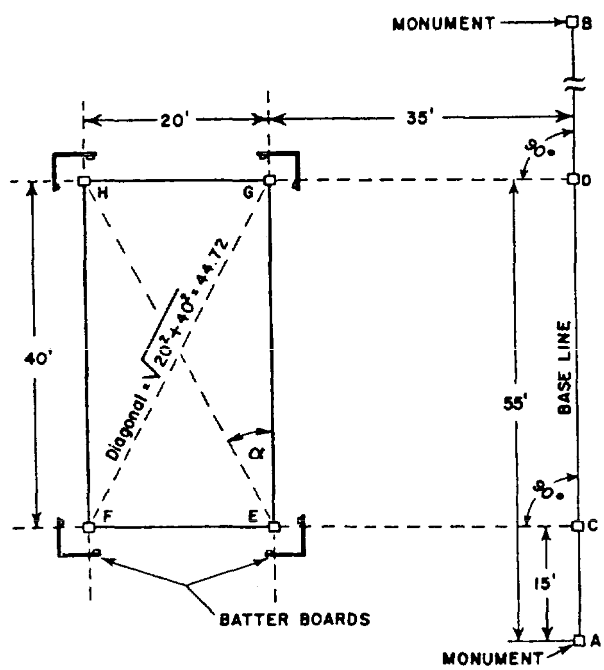


Figure 14-39.-Building stakeout.

stakeout. This site plan shows that the building is to be a 40- by 20-ft rectangular structure, located with one of the long sides parallel to, and 35 ft away from, a base line. The base line is indicated at the site and on the plans by Monuments A and B.

One of the short sides of the building will lie on a line running from C, a point on AB 15 ft from A, perpendicular to AB, The other short side will lie on a similar line running from D, a point on AB 40 ft from C and, therefore, 40 + 15, or 55 ft from A, perpendicular to AB.

The steps in the stakeout procedure would probably be as follows:

1. Set up the transit at Monument A; train the telescope on a marker held on a Monument B; then have the hubs driven on the line of sight, one at C 15 ft from A, the other at D 55 ft from A and 40 ft from C.

2. Shift the transit to C, train on B, match the zeros, and turn 900 left. Measure off 35 ft from C on the line of sight and drive a stake to locate E. Measure off 55 ft from C (or 20 ft from E) and drive another stake to locate F.

3. Shift the transit to D and repeat the procedure described in Step 2 to locate and stake points G and H.

THE ACCURACY OF A RECTANGULAR STAKEOUT CAN BE CHECKED BY MEASURING THE DIAGONALS OF THE RECTANGLE. The diagonals should, of course, be equal. You can determine what the correct length of each diagonal should be by applying the Pythagorean theorem, as shown in figure 14-39.

For a large rectangle, checking the accuracy of the stakeout by angular measurement with the transit may be more convenient. For example: You can determine the correct size of angle GEH, (let's call it a) in figure 14-39 by a convenient right-triangle solution, such as

$$\tan \alpha = 20/40 = 0.50000.$$

The angle with tangent 0.50000 measures (to the nearest minute) 26°34′. Therefore, angle FEH should measure

$$90°00' - 26°34', \text{ or } 63°26'.$$

The corresponding angles at the other three corners should have the same dimensions. If the sizes as actually measured vary at any corner, the stakeout is inaccurate.

Remembering the angles may be necessary to obtain the correct angular precision for the lengths of the lines being checked.

BATTER BOARDS are suitable marks placed for use as references or guides during the initial excavation and rough grading of a building construction and/or a sewer line stakeout. They are more or less temporary devices that support the stretched cords that mark the outline and grade of the structure.

Batter boards consist of 2- by 4-in. stakes driven into the ground. Each stake has a crosspiece of 1- by 6-in. lumber nailed to it. The

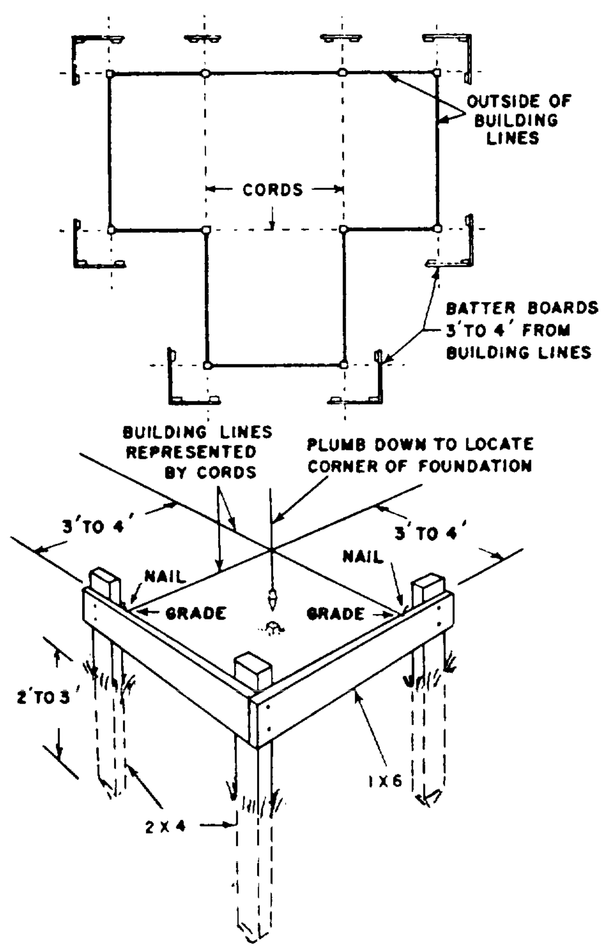


Figure 14-40.-Batter boards.

stakes are driven about 3 to 4 ft away from the building line where they will not be disturbed by the construction. They are driven far enough apart to straddle the line to be marked. Note in figure 14-40, only three stakes are driven on outside corners because one of them is a common post for two directions. The length of the stakes is determined by the required grade line. They must be long enough to accept the 1- by 6-in, crosspiece to mark the grade. The 1- by 6-in, crosspiece is cut long enough to join both stakes and is nailed firmly to them after the grade has been established. The top of the crosspiece becomes the mark from which the grade will be measured. All batter boards for one structure are set to the same grade or level line. A transit is used to locate the building lines and to mark them on the top edge of the crosspiece. A nail is driven at each of these marked points, or a V notch is carved at the top outer edge of the crosspiece towards the marked point and the nail is driven on the outer face of the board.

When a string is stretched over the top edge of the two batter boards and is held against the nails or against the bottom of the notch, the string will define the outside building line and grade elevation.

Sometimes a transit is not available for marking the building line on the batter boards, but the corner stakes have not been disturbed. A cord is stretched over two opposite batter boards, and plumb bobs are held over the corner stakes; then the building line can be transferred to the batter boards. The cord is moved on each batter board until it just touches both plumb bob strings. This position of the cords is marked, and nails are driven into the top of the batter boards.

Batter boards are set and marked as follows:

1. After the corner stakes are laid out, 2-by 4-in. stakes are driven 3 to 4 ft outside of each corner. These are selected to bring all crosspieces to the same elevation.

2. These stakes are marked at the grade of the top of the foundation or at some whole number of inches or feet above or below the top of the foundation. A level is used to mark the same grade or elevation on all stakes.

3. One- by six-in. boards are nailed to the stakes so the edge of the boards is flush with the grade marks.

4. The prolongation of the building lines on the batter boards is located by using a transit or by using a line and plumb bob.

5. Either nails are driven into the top edges of the batter boards or the boards are notched to mark the building line.

UTILITIES STAKEOUT

UTILITIES is a general term applied to pipelines, such as sewer, water, gas, and oil pipelines; communications lines, such as telephone or telegraph lines; and electric power lines.

Aboveground Utilities

For an aboveground utility, such as a pole-mounted telephone, telegraph, or power line, the survey problem consists simply of locating the line horizontally as required and marking the stations where poles or towers are to be erected. Often, the directions of guys and anchors maybe staked as well, and sometimes pole height for vertical clearance of obstructions is determined.

Underground Utilities

For an underground utility, you will often need to determine both line and grade. For pressure lines, such as water lines, it is usually necessary to stake out only the line, since the only grade requirement is that the prescribed depth of soil cover be maintained. However, staking elevations may be necessary for any pressure lines being installed in an area that (1) is to be graded downward or (2) is to have other, conflicting underground utilities.

Gravity flow lines, such as storm sewer lines, require staking for grade to be sure the pipe is installed at the design elevation and at the gradient (slope) the design requires for gravity flow through the pipe.

Grade for an underground sewer pipe is given in terms of the elevation of the invert. The INVERT of the pipe is the elevation of the lowest

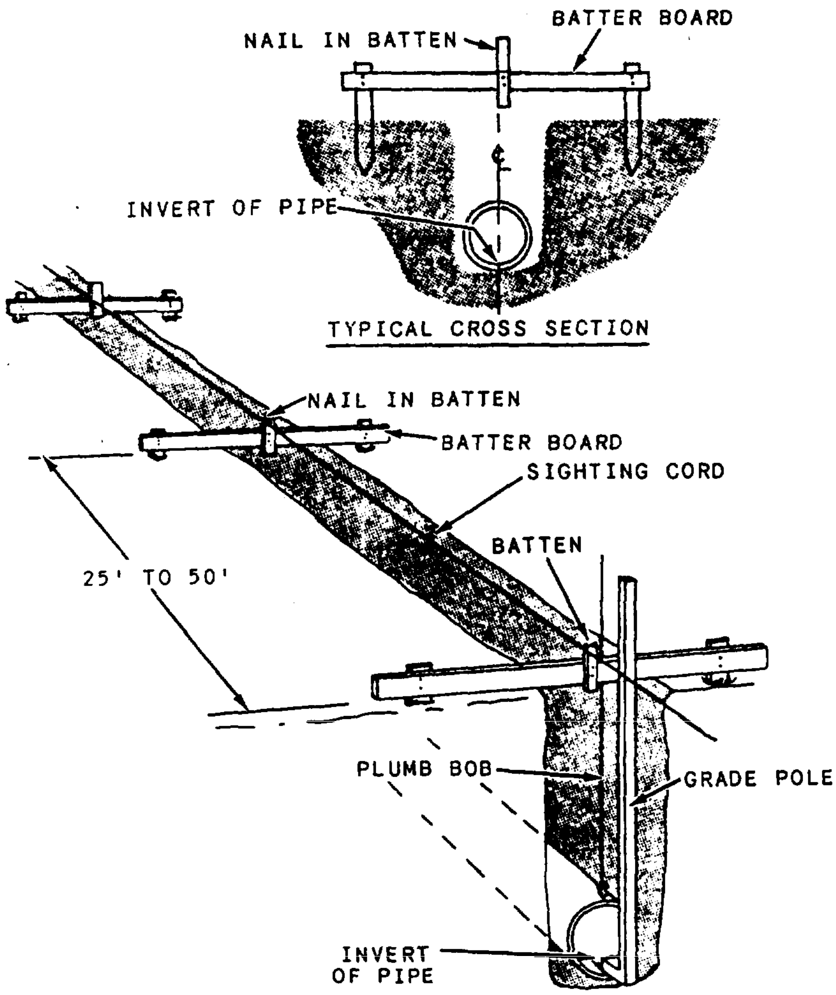


Figure 14-41.-Use of batter boards (with battens) for utility shakeout.

part of the inner surface of the pipe. Figure 14-41 shows a common method of staking out an underground pipe. Notice that both alignment and elevation are facilitated by a line of batter boards and battens (small pieces of wood) set at about 25- to 50-ft intervals. The battens, nailed to the batter boards, determine the horizontal alignment of the pipe when placed vertically on the same side of the batter boards and with the same edges directly over the center line of the pipe. As the work progresses, you should check the alignment of these battens frequently. A sighting cord, stretched parallel to the center line of the pipe at a uniform distance above the invert grade, is used to transfer line and grade into the trench. The center line of the pipe, therefore, will be directly below the cord, and the sewer invert grade will be at the selected distance below the cord. A MEASURING stick, also called a grade pole, is normally used to transfer the grade from the sighting cord to the pipe (fig. 14-41). The grade pole, with markings of feet and inches, is placed on the invert of the pipe and held plumbed. The pipe is then lowered into the trench until the mark on the grade pole is on a horizontal line with the cord.

Figure 14-42 shows another method of staking out an underground sewer pipe without the use of battens. Nails are driven directly into the tops of the batter boards so that a string stretched tightly between them will define the pipe center line. The string or cord can be kept taut by wrapping it around the nails and hanging a weight

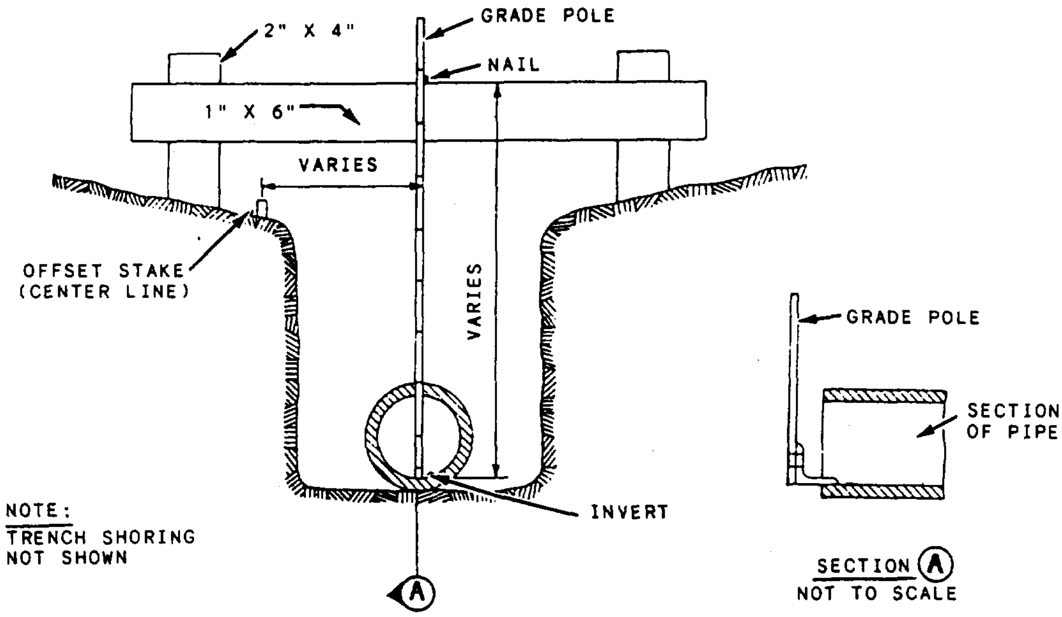


Figure 14-42.-Batter boards (without battens) for utility stakeout.

on each end. Similarly, the string (or cord) gives both line and grade.

AS-BUILT SURVEY

A finished structure seldom corresponds exactly to the original plans in every detail. Unexpected, usually unforeseeable difficulties often make variations from the plans necessary—or, occasionally, variations may occur accidentally that are economically unfeasible to correct.

The purpose of an AS-BUILT SURVEY is to record these variations. The as-built survey should begin as soon as it becomes feasible—meaning that the actual horizontal and vertical locations of features in the completed structure should be determined as soon as the features are erected.

At times, variations from the original plans are recorded on new tracings of the working drawings, on which as-built data are recorded in the place of the original design data when the two happen to differ. Sometimes, reproductions of the original drawings are used with variations recorded by crossing out the original design data and writing in the as-built data.

In either case, the term *as-built survey*, together with the date of revision, is written in, or near, the title block.

CONSTRUCTION-SITE SAFETY

WARNING

A survey party working at a construction site is always in a dangerous situation.

Where blasting or logging is going on, inform the powder crew or logging crew of the location of the area in which surveyors are working. Also, instruct the individual crew members of the survey party to be on the alert at all times—particularly to listen for the warning signal given by a crew using powder to set off a charge or a logger felling a tree.

When surveying near highways, railroads, or airstrips, use red flagging generously unless you are working in a combat area. Place flagging on the legs of your surveying equipment and at a few places along the tape. Put flags on rods and range poles. Attach some flagging to your hat and also to the back of your shirt or jacket.

Think constantly of personal safety when working near heavy construction equipment. Let the equipment operators know when surveyors are in the vicinity. Also, alert all members of the surveying crew because an equipment operator's vision is often obscured by dust or by the equipment itself.

When ascending steep, rocky slopes, do not climb directly behind another crew member. If the crew member were to accidentally fall, loosen a rock, or drop something, it could mean serious injury to anyone directly below the crew member.

EXCAVATIONS

WARNING

When your work involves excavation, you should observe definite precautions to prevent accidents.

To avoid slides or cave-ins, support the sides of the excavations 5 ft or more deep by substantial bracing, shoring, or sheet piling if the sides are steeper than the angle of repose. The ANGLE OF REPOSE is the maximum angle at which material will repose without sliding. Trenches in partly saturated or otherwise highly unstable soil should be stabilized with vertical sheet piling or suitable braces. Foundations of structures adjacent to excavations should be shored, braced, or underpinned as long as the excavation remains open. Excavated or other material should not be allowed to accumulate closer than 2 ft from the edge of an excavation. In a traffic area use barricades, safety signs, danger signals, red lights, or red flagging on at least two sides.

Do not enter a manhole until you are certain that it is free from dangerous gases. Do not guess. If there is any question at all as to whether a sewer is free of gas, wait for clearance from a competent authority. If necessary, provide first for thorough ventilation. Do not smoke in manholes; and if illumination is required, use only a safety flashlight or lantern.

Avoid contact with ALL ELECTRIC wiring. Never throw a metal tape across electric wires; if you must chain across wiring, do it by breaking chain. Avoid placing yourself so that you might fall across wiring in the event of an accident.

When walking, stay at least 2 feet away from the edge of a vertical excavation. Near thoroughfares or walkways, excavations should have temporary guardrails or barricades; and if permissible, depending on combat conditions, red lights or torches should be kept alongside from sunset to sunrise.

TREE CLIMBING

Before climbing a tree, be sure it is safe to climb, and carefully cheek the condition of the branches on which you are likely to stand. Different kinds of wood vary greatly in strength. Oak, hickory, and elm trees that have strong, flexible wood are safer for climbing than trees such as poplar, catalpa, chestnut, or willow, which have soft or brittle wood. Limbs of all trees become brittle at low temperature—meaning that they break more easily in cold weather than they do in warm. Dead branches or those containing many knots or fungus growths are usually weak.

When standing on a limb, have your feet as close to the parent trunk as possible. Climb with special care when limbs are wet or icy. Wear goggles when working in bushy trees; they may prevent an eye injury.

WARNING

Before climbing a tree, be sure there are no overhead wires passing through its foliage. If you MUST take a position in a tree within reach of live wire, place some sort of insulating safety equipment between yourself and the wire. DO NOT allow tree limbs to contact live wires because moisture in a limb may cause a short circuit.

If you require cutting tools to clear a working space in a tree, haul them up with a handline, and lower them by the same device. Tools should never be thrown up into a tree or down onto the ground.

UNDERGROUND AND OVERHEAD LINES

If a structure has an access opening and is below the street, such as a manhole or a transformer vault, it should be protected by a barrier or other suitable guard when the cover to the access opening is removed.

CROSSING ICE

Do not cross ice unless, and until, you are certain it will support your weight.

Both the thickness and the nature of ice are important in determining its carrying capacity.

Because part of the supporting power of ice is derived from the water below it, a layer of ice that is in contact with the water surface is safer than one that has no contact with the water surface.

An ice layer usually becomes thinner over current, near banks of streams or lakes, over warm springs, and over swampy ground. Rotten ice that can be identified by its dull color and honeycomb texture has little supporting power.

WORK SAFELY—STRESS SAFETY

CHAPTER 15

MATERIALS TESTING: SOIL AND CONCRETE

In previous chapters of this TRAMAN, you studied the importance of many and various construction materials. However, one material that was not discussed was SOIL which, as you will learn in this chapter, is perhaps the most important material of all. Just as a poorly constructed and weak concrete foundation will not support a building, neither will a poorly "constructed" and weak soil, since the ultimate foundation for any road, airfield, building, or other structure is the natural earth upon which it is built.

During this chapter you will learn what soil is. You will learn the different types of soil you might encounter. You will also learn the basic properties and characteristics of soil and the importance those characteristics play in determining the adequacy of a soil for use as a construction material. In addition, you will learn how to collect (sample) soil for testing purposes and how to perform certain tests that you, as an EA3, will be responsible for performing. Most importantly, you will learn why those tests are performed and their importance in properly and correctly identifying and classifying the many types of soil that exist in nature.

Finally, this chapter begins your studies of concrete testing. In this chapter you will learn what the various tests are and the purpose and importance of those tests. You will learn how to perform certain tests and how to prepare concrete samples for other tests that will be performed by more senior EAs.

SOIL ORIGIN

As defined by Webster's New World Dictionary, *soil* is the surface layer of the Earth that supports plant life. While that is certainly a correct definition and one that is perfectly satisfactory to many groups of people, it lacks the precision required by the civil engineer and soil technician. A more precise definition is that soil is a mixture of uncemented or loosely cemented mineral grains enclosing various sizes of voids that contain air (or other gases), water, organic matter, or different combinations of these materials in varying amounts. The importance of understanding this definition will become obvious as you progress through this chapter; but, first, let us consider where soil comes from.

SOIL FORMATION

The formation of soil is a continuous process that is still in action today. Basically, the Earth's crust consists of rock, which geologists classify into three groups: igneous, which is formed by cooling from a molten state; sedimentary, formed by the accumulation and cementing of existing particles and remains of plants and animals; and metamorphic, formed from existing rocks that have been subjected to heat and pressure. When exposed to the atmosphere, this rock undergoes a physical and chemical process called WEATHERING, which, over a sufficient length of time, disintegrates and decomposes the rock into a loose, incoherent mixture of gravel, sand, and finer material. It is this process that produces soils of various designations.

RESIDUAL SOIL

Any soil that results from weathering in place, and that is not moved during the weathering process, is called a RESIDUAL soil. A mantle of residual soil reflects the characteristics of the underlying parent rock from which it was derived.

TRANSPORTED SOIL

When the forces of nature cause the mantle of soil to be moved to a place other than that of its origin, the soil becomes a TRANSPORTED soil. One of these soils often bears properties induced by its mode of transportation. The chief agents of transportation are water, wind, ice, and the force of gravity.

Alluvial Soil

ALLUVIAL soil is formed when a soil-carrying stream gradually loses its carrying capacity with decreasing velocity. In slowing down, a river does not have sufficient power to keep the large particles of soil suspended; these particles settle to the riverbed. Further decrease in velocity causes smaller particles to settle. As the river becomes slow and sluggish (as in the lowlands where its gradient becomes small), it holds only the extremely fine particles in suspension. These particles are deposited, finally, at the mouth of the river, where they form DELTAS of fine-grained soil.

Marine Soil

MARINE soil is formed from materials carried into the seas by streams and by material eroded from the beaches by the tidal action of the waves. Part of the material is carried out and deposited in deep water; part is heaped upon the beaches along the coast.

Lacustrine Soil

Freshwater lake deposits are called LACUSTRINE soils. Generally speaking, they are fine-grained soils resulting from material brought into freshwater lakes by streams or rivers.

Aeolian Soil

Wind-transported grains make up AEOLIAN soils. Sand deposits from wind are called "dunes," and the finer particles (which are generally carried further) are deposited to form a material called LOESS. Dune deposits seldom contain material larger than sand size.

Glacial Soil

GLACIAL soil is often called DRIFT. It consists of material carried along with or upon an advancing ice sheet or of material pushed ahead of it. As glaciers melt, deposits of various forms occur, such as MORAINES, KAME TERRACES, ESKERS, and OUTWASH PLANES. Moraines consist of mixtures of unstratified boulders, gravels, sands, and clays. The other forms (kame terraces, eskers, and outwash planes) mentioned consist of somewhat stratified and partly sorted stream gravels, sand, and fines transported outward from the glacier by streams during the melting period.

Colluvial Soil

COLLUVIAL soil consists of mixed deposits of rock fragments and soil materials accumulated at the bases of steep slopes through the influence of gravity.

Table 15-1.-Size Groups as Used in the Unified Soil Classification System

Size Groups	Sieve Size	
	Passing	Retained on
Cobbles ------------	No maximum size* --------------------	3 in.
Gravels -------------	3 in. --------------------------------------	No. 4
Sands ---------------	No. 4--------------------------------------	No. 200
Fines ----------------	No. 200-----------------------------------	No minimum size

*In military engineering, maximum size of cobbles is accepted as 40 inches, based upon maximum jaw opening of the crushing unit.

PHYSICAL CHARACTERISTICS OF SOILS

The physical characteristics of soils aid in determining their engineering characteristics and are the basis of the system of soil classification used in the SEABEEs and by the military in general for the identification of soil types. A knowledge of these physical characteristics aids in determining the degree to which local soils can be used in engineering projects to support traffic loads or to serve as a subgrade or foundation material. Those characteristics of concern to the EA are discussed below.

PARTICLE SIZE

Soils are divided into groups based on the size of the particle grains in the soil mass. The EA identifies the sizes through the use of sieves. A sieve is a screen attached across the end of a shallow cylindrical frame. The screen permits particles smaller than the openings to fall through and larger ones to be retained on the sieve. When sieves of different sizes are stacked so that the largest screen openings are at the top and the smallest at the bottom, soil can be separated into particle groups based on size. The amount remaining on each sieve is measured and described as a percentage by weight of the entire sample. Table 15-1 shows size groups as used in the Unified Soil Classification System. Particles passing the No. 200 sieve but larger than 0.002 mm to 0.005 mm are called silt, and those finer are clays.

PARTICLE SHAPE

The shape of the particles influences the strength and stability of a soil. Two general shapes are normally recognized: BULKY (fig. 15- 1) and PLATY.

Bulky

Cobbles, gravel, sand, and silt particles cover a large range of sizes; however, they are all bulky in shape. The term bulky is confined to particles that are relatively large in all three dimensions, as contrasted to platy particles, in which one dimension is small as compared to the other two. The bulky shape has the following four subdivisions listed in descending order of desirability for construction:

ANGULAR particles are those that have been recently broken up and are characterized by jagged projections, sharp ridges, and flat surfaces. Angular gravels and sands are generally the best materials for construction because of their interlocking characteristics. Such particles are seldom found in nature, however, because the weathering process does not generally produce them. Angular material must usually be produced artificially, by crushing.

SUBANGULAR particles are those that have been weathered to the extent that the sharper points and ridges have been worn off.

SUBROUNDED particles are those that have been weathered to a further degree than subangular particles. They are still somewhat irregular in shape but have no sharp corners and few flat areas. Materials with this shape are frequently found in stream beds. If composed of hard, durable particles, subrounded material is adequate for most construction needs.

ROUNDED particles are those on which all projections have been removed, with few irregularities in shape remaining. The particles resemble spheres and are of varying sizes. Rounded particles are usually found in or near stream beds or beaches.

Platy

Platy (or flaky) particles are those that have flat, platelike grains. Clay is a common example. Because of their shape, these flaky particles have a greater contact area for moisture and are undesirable for construction purposes.

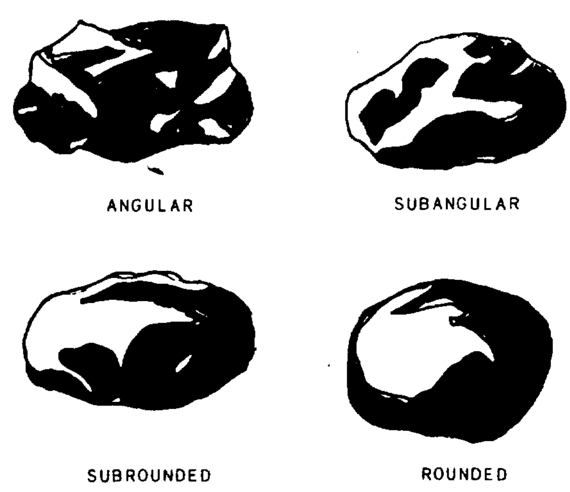


Figure 15-1.-Types of bulky-shaped soil particles (grains).

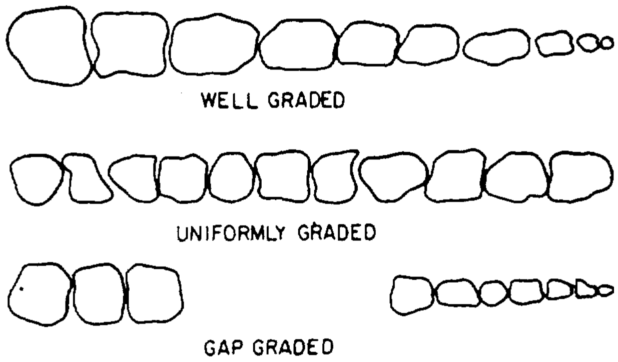


Figure 15-2.-Types of soil gradation.

GRADATION

The size and shape of the soil particles discussed above deal with properties of the individual grains in a soil mass. Gradation describes the distribution of the different size groups within a soil sample. The soil may be well or poorly graded.

To be classified as WELL GRADED, a soil must have a good range of all representative particle sizes between the largest and the smallest. All sizes must be represented, and no one size should be either overabundant or missing (fig. 15-2).

Poorly graded soils are either those containing a narrow range of particle sizes or those with some intermediate sizes lacking (fig. 15-2). Soils with a limited range of particle sizes are called UNIFORMLY GRADED. Soils that have some intermediate size or sizes not well represented or missing are called GAP GRADED, STEP GRADED, or SKIP GRADED.

COMPACTNESS

Compactness refers to how closely a mass of soil particles are packed together; the closer the packing, the greater the compactness and the larger the weight of soil per unit volume.

The structure of a total mass of soil particles may be dense. In this case, the particles are closely packed and have a high degree of compactness. A dense structure provides interlocking of particles with smaller grains filling the voids between the larger particles. When each particle is closely surrounded by other particles, the grain-to-grain contacts are increased. This lessens the tendency for displacement of the individual grains under load, and the soil is then capable of supporting heavier loads. Well-graded coarse materials usually are dense and have strength and stability under load.

On the other hand, the structure may be loose, in which case the particles are not packed as closely together as possible, thereby lacking compactness. Loose, open structures have large voids, which will lead to settlement or disintegration when foundation or traffic loads are applied.

SPECIFIC GRAVITY

Specific gravity is designated by the symbol G_s. It is defined as the ratio between the weight per unit volume of the material and the weight per unit volume of water at a stated temperature—usually 20°C. If you use the system international (SI) (metric) system, you can determine specific gravity by the following formula:

$$\text{Specific gravity} = \frac{\text{weight of sample in air (g)}}{\text{weight of sample in air (g)} - \text{weight of sample submerged (g)}}$$

Test procedures will be discussed in detail later in this chapter. The specific gravity of the solid substance of most inorganic soils varies between 2.60 and 2.80. Tropical iron-rich laterite, as well as some lateritic soils, generally has a specific gravity of 3.0 or more. Sand particles composed of quartz have a specific gravity of about 2.65. Clays can have values as high as 3.50. The solids of soil particles are composed of minerals. Generally, these minerals have a specific gravity greater than 2.60. Values of specific gravity smaller than that are an indication of the possible presence of organic matter.

SOIL MOISTURE

The moisture content of a soil mass is often the most important factor affecting the engineering characteristics of the soil. The water may enter from the surface or may move through the subsurface layers by either gravitational pull, capillary action, or absorption. This moisture is present in most cases. It influences various soils differently; it probably has the greatest effect upon the behavior of the soil when the soil is subjected to loading.

Sources of Water in Soils

Surface water results from precipitation or runoff and enters the soil through the openings between the particles. This moisture may adhere to the different particles, or it may penetrate the soil to some lower layer.

Subsurface water is collected or held in pools or layers beneath the surface by a restricting layer of soil or rock. This water is constantly acted upon by one or more external forces.

Water controlled by gravity (free or gravitational water) seeks a lower layer and moves through the voids or spaces until it reaches some restriction. This restriction may be a bedrock or an impervious layer of soil whose openings or voids are so small as to prevent water passage.

The voids or spaces in a soil may form continuous tunnels or tubes and cause the water to rise in the tubes by capillary action (capillary moisture). The smaller the tube, the stronger the capillary action; therefore, the water rises higher in the finer soils, which have smaller interconnected voids. This area of moisture above the free water layer or pool is called the capillary fringe.

Another force acting on soil water is absorption by the atmosphere. As the moisture evaporates from the soil surface, more moisture is drawn from the soil below and is, in turn, also evaporated. This process continues until the soil is in an airdry condition in which the moisture in the soil is in equilibrium with the moisture vapor in the air. In this airdry state, the moisture remaining in the soil is in the form of thin films of water surrounding the individual soil particles and is called the hydroscopic moisture. These moisture films are due to naturally occurring electrical forces, which bind the water molecules to the soil particles. Hydroscopic moisture films may be driven off from airdried soil by heating the material in an oven at a controlled temperature for 24 hr or until constant weight is attained.

To define the amount of water present in a soil sample, the term *moisture content* (symbol w) is used. It is the proportion of the weight of water to the weight of the solid mineral grains (weight of dry soil) expressed as a percentage or

$$w = \frac{\text{weight of water}}{\text{weight of dry soil}} \times 100$$

When wet soil is dried in air in the laboratory, the amount of hydroscopic moisture remaining in the airdried soil, expressed as a percentage of the weight of the dry soil, is called the hydroscopic moisture content.

Plasticity

Plasticity is a property of the fine-grained portion of a soil that allows it to be deformed beyond the point of recovery without cracking or changing volume appreciably. Some minerals, such as quartz powder, cannot be made plastic no matter how fine the particles or how much water is added. All clay minerals, on the other hand, are plastic and can be rolled into thin threads at a certain moisture content without crumbling. Since practically all fine-grained soils contain some clay, most of them are plastic. The degree of plasticity is a general index to the clay content of a soil.

The term *fat* and *lean* are sometimes used to distinguish between highly plastic and slightly plastic soils. For example, lean clay is only slightly plastic, whereas fat clay is highly plastic. In engineering practice, soil plasticity is determined by observing the different physical states that a plastic soil passes through as the moisture conditions change. The boundaries between the different states, as described by the moisture content at the time of change, are called consistency limits or Atterberg limits.

The liquid limit (LL) is the moisture content corresponding to the arbitrary limit between the liquid and plastic states of consistency of a soil. Above this value, the soil is presumed to be a liquid and behaves as such by flowing freely under its own weight. Below this value, it deforms under pressure without crumbling, provided the soil exhibits a plastic state.

The plastic limit (PL) is the moisture content at an arbitrary limit between the plastic and semisolid state. It is reached when the soil is no longer pliable and crumbles under pressure. Between the liquid and plastic limits is the plastic range. The numerical difference in moisture content between the two limits is called the plasticity index (PI). The equation is $PI = LL - PL$. It defines the range of moisture content within which the soil is in a plastic state.

The shrinkage limit is the boundary in moisture content between the solid and the semisolid states. The solid state is reached when the soil sample, upon being dried, finally reaches a limiting or minimum volume. Beyond this point, further drying does not reduce the volume but may cause cracking. The limit tests are described later in this chapter.

Effects of Soil Moisture

Moisture affects coarse-grained soils much less than fine-grained soils. One reason for this is that coarser soils have larger void openings, and, as a rule, drain more rapidly. Capillarity is practically nonexistent in gravels and in sands containing little fines. These soils, if they are above the groundwater table, will not usually retain large amounts of water. A second reason is that since the particles in gravelly and sandy soils are relatively large (in comparison to clay and silt particles), they are, by weight, heavy in comparison to the films of moisture that might surround them.

On the other hand, the small (sometimes microscopic) particles of fine-grained soil weigh so little that water in the voids has considerable effect. It is not unusual, for example, for clays to undergo large volume changes with variations in moisture content, as witness the shrinkage cracks in a dry lake bed. Consequently, unpaved clay roads, though hard enough when sun-baked, often lose stability and turn into mud in rainy weather.

Not only do clays swell and lose stability when they become wet, but they also, because of their flat, platelike grain shapes and small size, retard the drainage of water. Since drainage is of the greatest importance in (for example) the construction of airfield pavement, design engineers must know whether or not subsurface clay exists. Plasticity is, as you know, the characteristic by which clay is primarily identified.

ORGANIC SOILS

Soils of organic origin are formed either by the growth and subsequent decay of plant life or by the accumulation of inorganic particles of skeletons or shells of organisms. The term *organic soil,* though, refers to soils containing mineral grains and a more or less conspicuous admixture of vegetable matter. An organic soil may be an organic silt or clay, or it may be a HIGHLY ORGANIC soil, such as peat or meadow mat.

Organic soils are most often black in color, and usually have a characteristic musty odor. These soils are usually compressible and have poor load-maintaining properties.

EFFECTS OF SOIL CHARACTERISTICS

In summary, soil characteristics area measure of the suitability of the soil to serve some intended purpose. Generally, a dense, solid soil withstands greater applied loads (has greater bearing capacity) than a loose soil. Particle size has a definite relation to this capacity. From empirical tests, it has been found that well-graded, coarse-grained soils generally can be compacted to a greater density than fine-grained soils. This is because the smaller particles tend to fill the spaces between the larger ones. The shape of the grains also affects the bearing capacity. Angular particles tend to interlock, forma denser mass, and become more stable than the rounded particles, which can roll or slide past one another. Poorly graded soils, with their lack of one or more sizes, leave more or greater voids and comprise a less dense mass. Moisture content and the consistency limits aid in describing the suitability of the soil. A coarse-grained sandy or gravelly soil generally has good drainage characteristics and may be used in its natural state. A fine-grained clayey soil with a high plasticity index may require considerable treatment, especially if used in a moist location.

SOIL CLASSIFICATION

As can be inferred from the previous discussions in this chapter, soil types are important factors to consider when selecting the proper location on which to construct any structure or facility. With the soil accurately identified and described, its suitability for supporting traffic as a subgrade, base, or foundation material or as an aggregate, a filler, or a binder for a mixture can be evaluated.

CLASSIFYING SOILS

The UNIFIED SOIL CLASSIFICATION SYSTEM (USCS) is a common soil classification reference or system that has a universal interpretation. In this system, all soils are divided into three major divisions as follows:

COARSE-GRAINED SOILS are those in which at least half of the material, by weight, is larger than (retained on) a No. 200 sieve. This division is further divided in GRAVELS and SANDS. If more than half of the coarse fraction, by weight, is retained on a No. 4 sieve, it is classified as a gravel. If less than half is retained on a No. 4 sieve, then it is a sand. Gravels and sands are further subdivided into additional categories dependent upon the amount and characteristics of any plastic fines the soil sample contains.

FINE-GRAINED SOILS are those in which more than half of the material, by weight, is smaller than (passes) a No. 200 sieve. The fine-grained soils are not classified on the basis of grain size distribution but according to plasticity and compressibility.

HIGHLY ORGANIC SOILS are those organic soils, such as peat, that have too many undesirable characteristics from the standpoint of their behavior as foundations and their use as construction materials. A special classification is reserved for these soils, and no laboratory criteria are established for them. Highly organic soils can generally be readily identified in the field by their distinctive color and odor, spongy feel, and frequently fibrous textures. Particles of leaves, grass, branches, or other fibrous vegetable matter are common components of these soils.

CLASSIFICATION TESTS

The above is by no means a thorough description of the USCS and the methods used to classify soils; nor is it intended to be. However, the results of certain tests (sieve analysis and Atterberg limits) that you will be performing as an EA3 will be used for the purpose of soil classification. The preceding discussion is presented so that you have an understanding of why you perform the tests, what the results are used for, and the importance of ensuring that your test results are correct and reliable. A full discussion of the test procedures will be presented later in this chapter, Should you desire to learn more about the USCS and soils classification, you may refer to the EA1 TRAMAN, to NAVFAC MO-330, *Materials Testing,* or to one of numerous commercial publications on soil mechanics.

SOIL SAMPLING

In the planning and execution of construction operations, it is vital to know as much information of engineering significance as possible about the subsurface conditions in the construction area. That information includes not only the location, extent, and condition of the soil layers but also the elevation of the groundwater table and bedrock; the drainage characteristics of the surface and subsurface soils; and the location of possible borrow areas from which soil and other mineral-product materials may be “borrowed” for a construction operation. Soil surveys are conducted to gather (explore) this information. These are multifaceted surveys that consist of the following: gathering soil samples; soil testing by either laboratory or field procedures, or both; soil classification; and the development of soil profiles.

In the full scope of soil surveying, your primary concern, as an EA3, is gathering soil samples and conducting certain of the laboratory soils tests. Should you desire to learn more about soil surveying, an excellent source is NAVFAC MO-330, *Materials Testing.*

SAMPLING METHODS

The gathering, or collecting, of soil samples in the field for testing is called SOIL SAMPLING. The three principal methods of sampling are the taking of samples from the surface, from already existing excavations, and from test pits and test holes. The extent and methods used will be dependent upon the time available.

The method that provides the most satisfactory results for both studying the natural soil conditions and for collecting undisturbed soil samples is the taking of samples from test pits. A test pit is an open excavation that is large enough for a person to enter. Usually, these pits are dug by hand; however, when power equipment is available, power excavation by clamshell, dragline, bulldozer, backhoe, or a power-driven earth auger can expedite the digging. Excavations below the groundwater table require the use of pneumatic caissons or the lowering of the water table. Additionally, excavations that extend to 5 ft or more in depth may require adequate shoring and bracing to prevent cave-ins, as discussed in the previous chapter. Load-bearing tests can also be performed on the soil in the bottom of the pit.

Test hole exploration, with the use of the hand auger, is the most common method of digging test holes. It is best suited to cohesive soils but can be used on cohesionless soils above the water table, provided the diameter of the individual aggregate particles is smaller than the bit clearance of the auger. Auger borings are usually used for work at shallow depths, but if pipe extensions are added, the earth auger may be used to a depth of about 30 ft in relatively soft soils. Samples obtained by this method are completely disturbed but are satisfactory for determining the soil profile, classification, moisture content, compaction capabilities, and similar soil properties.

In a hasty soil survey, which is made under expedient conditions or when time is limited, the number of test pits and test holes is kept to a minimum by the use of existing excavations for soil sampling. In a deliberate survey, where time and conditions allow a more thorough sampling operation, test holes are used extensively and are augmented by test pits, governed by the judgment of the engineering officer.

Table 15-2.-Methods of Underground Exploration and Sampling

Common name of method	Materials in which used	Method of advancing the hole	Method of sampling	Value for foundation purposes
Auger boring	Cohesive soils and cohesionless soils above groundwater elevation	Augers rotated until filled with soil and then removed to surface	Samples recovered from material brought up on augers	Satisfactory for highway exploration at shallow depths
Well drilling	All soils, rock, and boulders	Churn drilling with power machine	Bailed sample of churned material or clay socket	Clay socket samples are dry samples Bailed samples are valueless
Rotary drilling	All soils, rock, and boulders	Rotating bits operating in a heavy circulating liquid	Samples recovered from circulating liquid	Samples are of no value
Test pits	All soils. Lowering of groundwater may be necessary	Hand digging or power excavation	Samples taken by hand from original position in ground	Materials can be inspected in natural condition and place

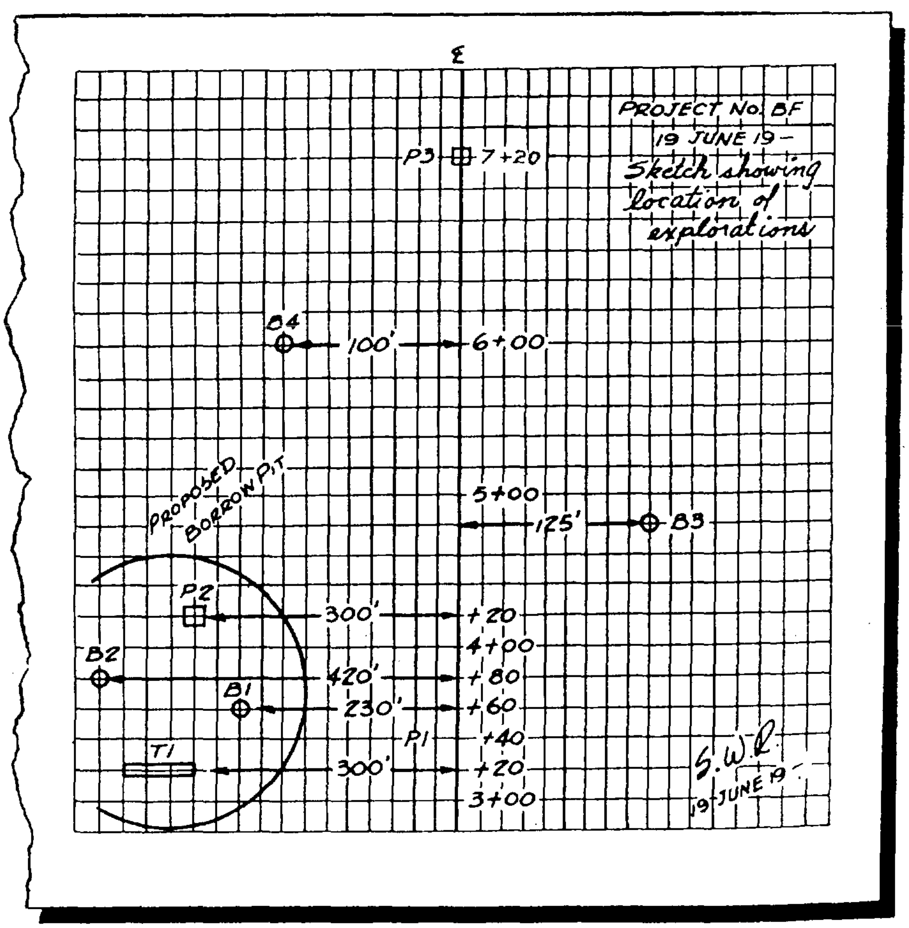


Figure 15-3.-Sketch showing locations of soil exploration points.

Table 15-2 shows methods of underground exploration and sampling in a condensed form.

TAGGING SAMPLES

Let us suppose that soil in a given area is to be tested (such as the area on which a structure is to be erected). The officer in charge of soil exploration decides how many points are needed and where they must be located to produce a representative test of the soil in the area. This information is recorded in a sketch like the one shown in figure 15-3.

This figure shows the locations of exploratory points along a highway, the point locations referenced by the center-line station and the distance from the center line. To the left of the center line, between stations 2 + 80 and 4 + 60, there is a borrow pit, from which soil for fill is taken. The soil here is tested by samples taken from a 60-ft trench (T1), located at station 3 + 20, 300 ft from the highway center line; from two borings (B1 and B2) at stations 3 + 60 and 3 + 80, 230 ft and 420 ft from the center line, respectively; and from a 20-ft- square pit (P2) at station 4 + 20, 300 ft from the center line.

Besides the borrow pit exploration, there is a boring (B3) at station 4 + 80, 125 ft to the right of the center line; another boring (B4) at station 6 + 00, 100 ft to the left of the center line; and a 20-ft-square pit (P3) on the center line at station 7 + 20.

Each sample taken is tagged according to the location from which it was taken. Locations are given in consecutive numbers; for those shown in figure 15-3, the numbers might run from the bottom up, with T1 being No. 1; B 1, No. 2; and so on. A sample is tagged with the project symbol (the symbol for the project shown in fig. 15-3 is BF) and the location symbol (such as T1 or B1). If more than one sample is taken from the same location, you need to use additional numbers. For example, a sample taken from B2 in figure 15-3 maybe tagged "BF-B2-4, bag 1 of 6." This means "boring No. 2, location No. 4, the first of 6 bags taken from that location."

The sample identification is printed with a marking pencil or pen on two tags, one of which is placed inside the bag, and the other of which is tied on the outside. Gummed labels may be similarly used to identify samples that are placed in moisture content boxes, cylinders, or jars.

DISTURBED SAMPLES

Samples taken by hand scoops, auger borings, shovels, or any other convenient hand tool with no attempt to obtain the material in its natural state of structure or density is known as a DISTURBED sample. These samples are used for mechanical analysis, plasticity, specific gravity, frost susceptibility, compaction, and laboratory compacted CBR tests. The size of the sample taken will depend upon the tests to be performed.

Individual Samples

When taking individual samples from a pit, trench, or exposed face (fig. 15-4), first shave off loose and dried soil to obtain a fresh surface and to expose any soil variations clearly. Then take a typical sample of each type of soil or of those requiring additional investigation. When sampling in auger holes, place typical portions of the soil obtained

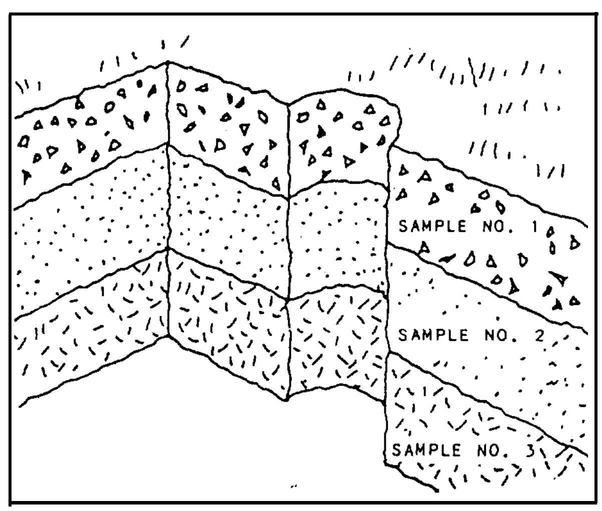


Figure 15-4.-Obtaining individual bag samples from an exposed face.

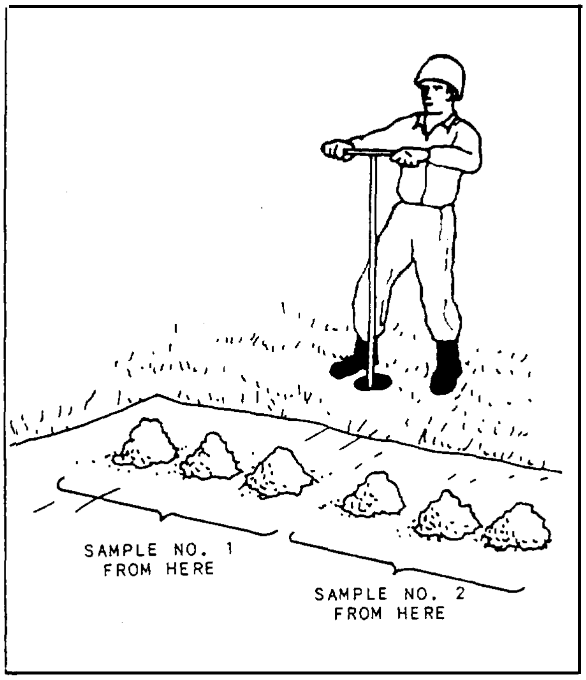


Figure 15-5.-Obtaining individual bag samples.

along a row in correct order, as shown in figure 15-5.

Composite Samples

A composite sample is a representative mixture of all soil within a soil mass to be investigated or of the material contained in a stockpile or windrow of soil excavated from a trench. A test sample is obtained from a composite sample by quartering (to be explained later) in the laboratory.

To take composite samples from test pits, trenches, or power shovel cuts, take the following steps:

1. Remove any overburden or surface soil that is to be wasted.

2. Shave off loose and dried soil to obtain a fresh surface for taking the sample.

3. Excavate a channel of uniform cross section from top to bottom, and deposit the soil onto a quartering cloth, canvas, or tarpaulin, as shown in figure 15-6.

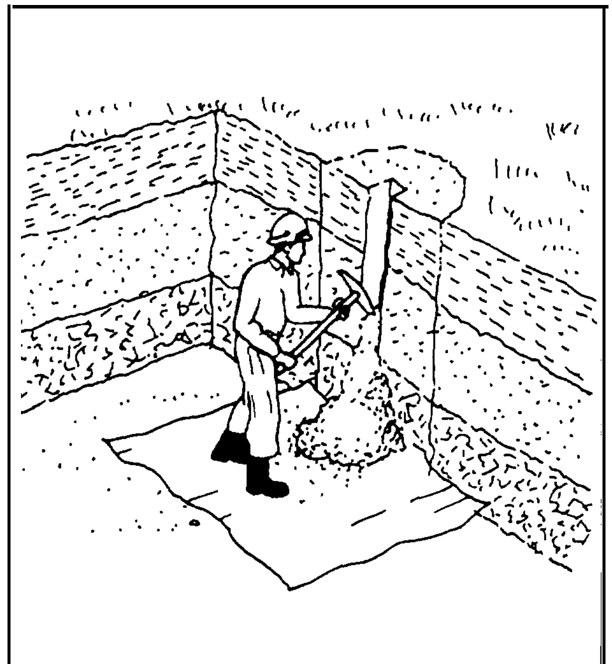


Figure 15-6.-Taking a composite sample with an exposed face.

Collect and bag all material removed to ensure that the sample contains the correct proportions. To take composite samples from auger holes, collect all material excavated from the hole after first removing the overburden. When taking representative composite samples from stockpiles or large windrows, take particular care. When material is dumped on large piles, the coarse material tends to roll to the bottom, leaving the finer material on the top. To compensate for this, take the sample from a full height strip after clearing the surface. To sample from a small windrow, excavate and bag material from a short section, as shown in figure 15-7.

Moisture Content Samples

The natural moisture content of soil is determined from samples taken in the field and placed in a container, which is then sealed to prevent loss of moisture by evaporation. Natural moisture content determinations are valuable in interpreting information obtained from test borings or pits,

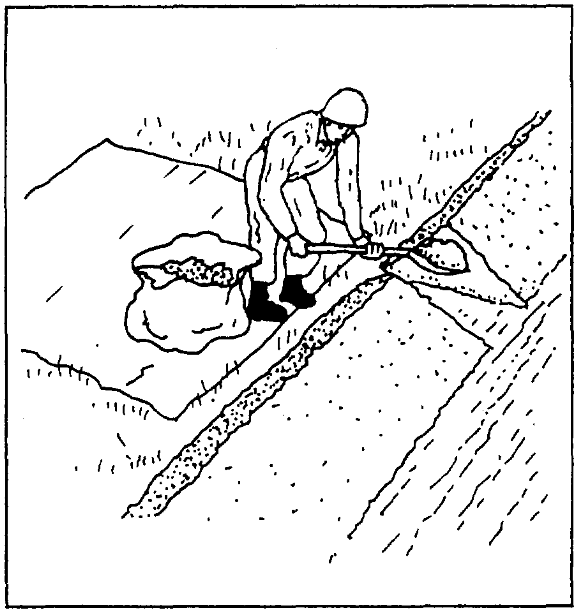


Figure 15-7.-Taking a composite sample from a small windrow.

in drawing the soil profile, and in estimating the physical properties of soils encountered in the field.

Generally, 100 g of soil is enough to determine the moisture content of fine-grained soils. Larger samples are required for soils that contain gravel. Normally, moisture content samples are placed in metal dishes (canisters) that have tight-fitting covers; however, any other clean container that can be adequately sealed may be used. When the moisture content test is to be performed within 1 day after the sample is obtained, sealing of the container is not required. If a longer time interval will elapse between sampling and testing, the containers may be sealed, as shown in figure 15-8.

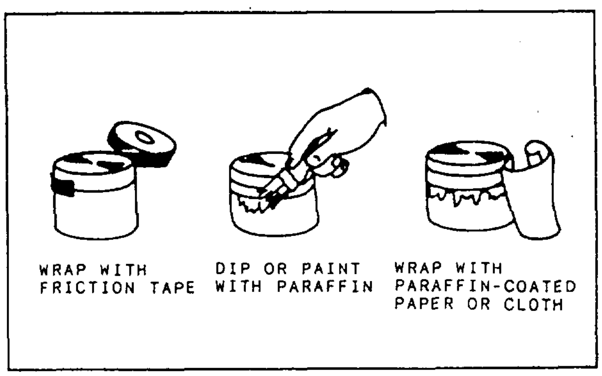


Figure 15-8.-Sealing a container to retain moisture content of a sample.

UNDISTURBED SAMPLES

UNDISTURBED soil samples are those that are cut, removed, and packed with the least possible disturbance. They are samples in which the natural structures, void ratio, and moisture content are preserved as carefully as possible. Samples of this type are used for determining the density (unit weight) of soil in the laboratory and investigating the strength of undisturbed soils in the laboratory by the CBR or unconfined compression tests. These samples may be shipped to more completely equipped laboratories for shear, consolidation, or other strength tests.

Types of undisturbed samples are chunk samples, cut by hand with a shovel and knife, and cylinder samples, obtained by use of a cylindrical sampler or the CBR mold equipped with a sampling cutter. Expedient methods of obtaining cylinder samples are also used.

The method of sampling chosen depends upon the equipment available, the tests required, and the type of soil. All undisturbed samples must be handled with care. Cohesionless soil samples must be kept in the container until ready for testing, and the container should be handled without jarring or vibration. Some soils are too hard or contain too many stones to permit sampling with the cylindrical samplers and can be sampled only by cutting out chunks by hand. Taking of undisturbed samples frequently requires a great deal of ingenuity in adapting the sampling devices to job conditions and in devising schemes for their use. Whatever method is used, the sample must be taken and packed in the container for shipment without allowing its structure to change. Protection against change in moisture content during sampling and shipment is also required.

Chunk Samples

The simplest type of undisturbed sample is the chunk sample. It should be noted, however, that these can be obtained only from soils that will not deform, break, or crumble while being removed.

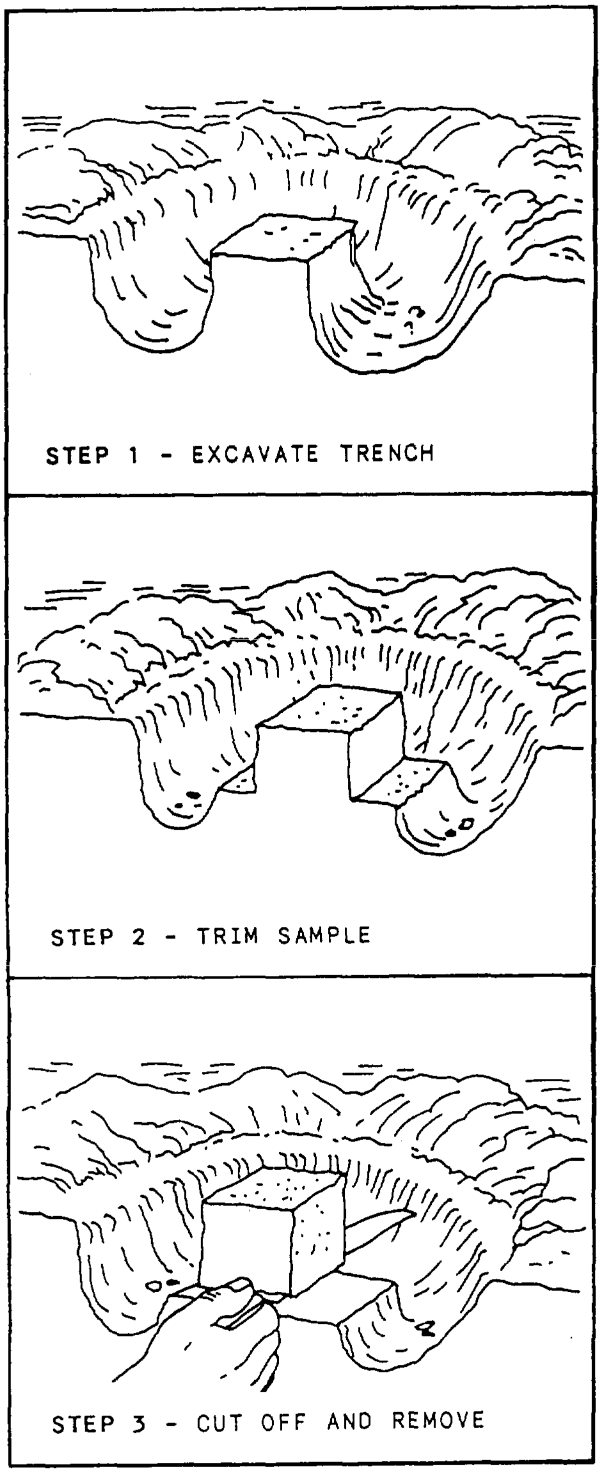


Figure 15-9.-Taking a chunk sample from a level surface.

Figure 15-9 shows the process of taking a chunk sample from a level surface, such as a subgrade or the bottom of a test pit. After smoothing the ground surface and marking the outline of the chunk, the first step is to excavate a trench around the chunk. Then deepen the excavation and trim the sides of the chunk with a knife. Finally, using a knife, trowel, or hacksaw blade, cut off the chunk at the bottom and carefully remove it from the hole.

To take a chunk. from the vertical face of a test pit or trench, as shown in figure 15-10, smooth the surface of the face and mark the chunk outline. Then excavate the soil from the top, sides, and back of the chunk. After shaping the chunk with a knife, cut it off and carefully remove it.

After removing the chunk sample from the hole, you need to seal it. One method is to apply three coats of melted paraffin, as shown in figure 15-11. Each coat is allowed to cool and become firm before the next coat is applied. This gives adequate protection for strong samples that will be used within a few days. When the samples are weak or may not be used within a few days, wrap them with cheesecloth or other soft cloth and seal them with paraffin (fig. 15-12). If cloth is not available, you can reinforce the sample with several loops of friction tape or twine. Then apply three coats of paraffin. Take extra precaution in these operations so that the sample is not damaged.

Another method is to dip the entire sample in melted paraffin after the first brush coat is applied and the sample is wrapped (fig. 15-13). This requires a larger container and more paraffin. However; this method provides a more uniform coating that, by repeated dippings, can be built up to 1/8 in. or more in thickness.

When samples are to shipped, as from a construction battalion's remote detail site to the battalion's main body site, additional protection is required. This can be accomplished by applying many coats of paraffin or by placing the chunk in a small

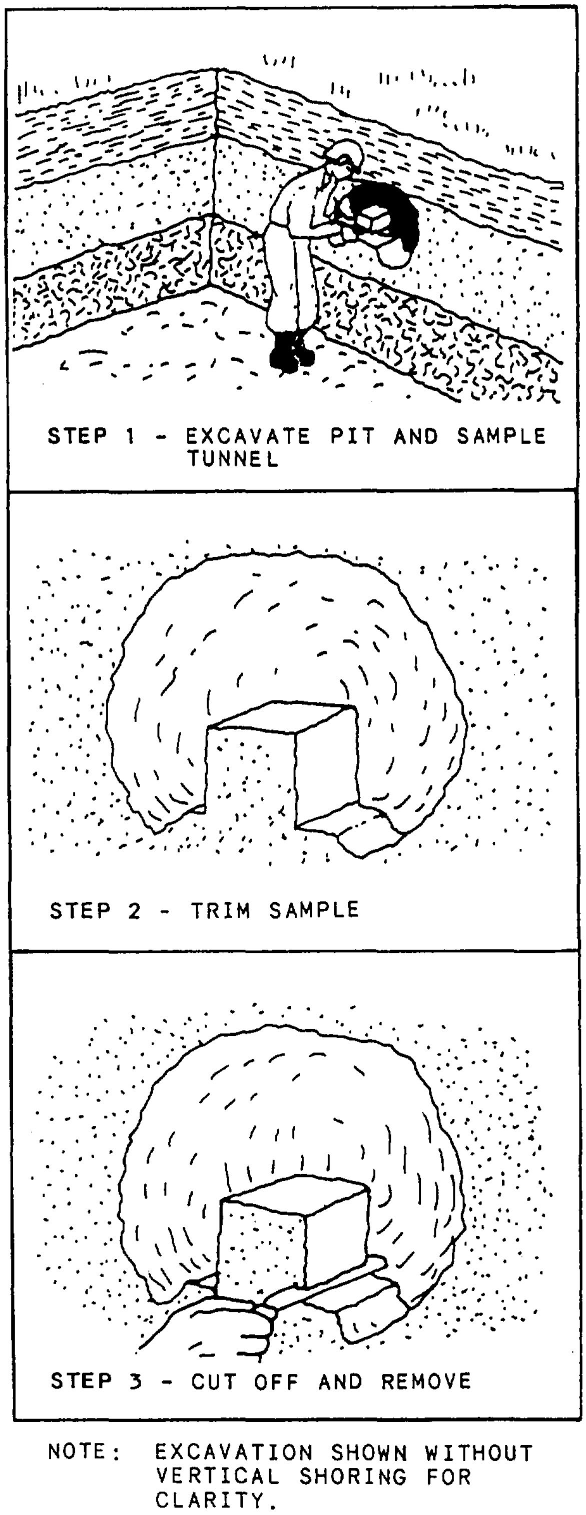


Figure 15-10.-Taking a chunk sample from a vertical face.

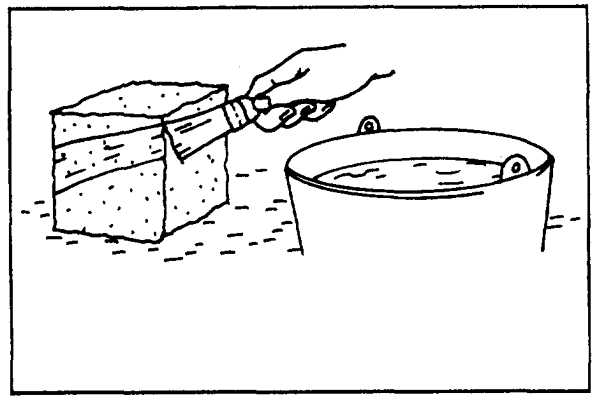


Figure 15-11.-Applying paraffin to seal a chunk sample.

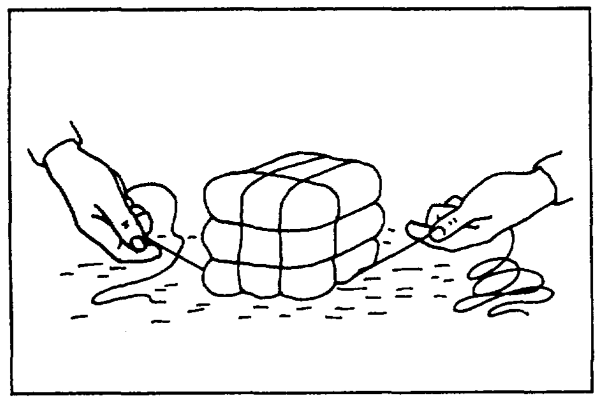


Figure 15-12.-Wrapping a weak chunk sample before final sealing.

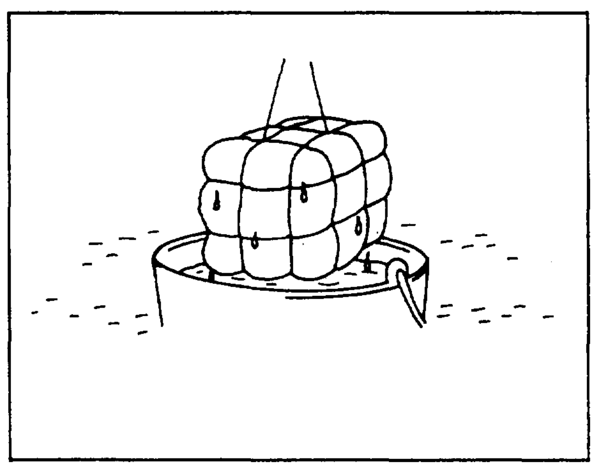


Figure 15-13.-Dipping a chunk sample into melted paraffin.

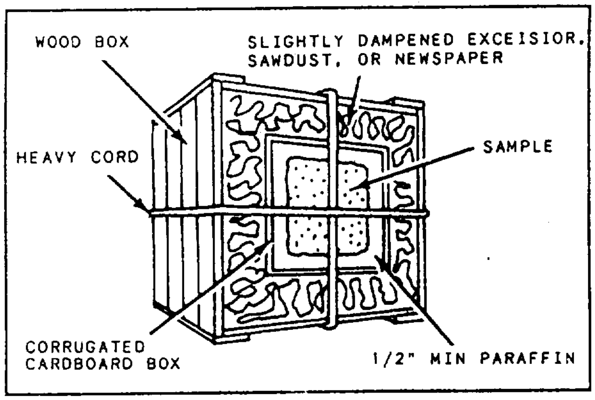


Figure 15-14.-Packing a chunk sample for transportation or shipment to laboratory.

box and packing it, as shown in figure 15-14.

Cylinder Samples by CBR Mold

Figures 15-15 through 15-19 show a CBR compaction mold, fitted with a sampling collar (or cutter), and how to obtain a cylinder sample by using the CBR mold. This method may be used in taking an undisturbed sample from soft, fine-grained soils for undisturbed CBR or density tests.

When using this method, first smooth the ground surface and then press the sampling collar and mold into the soil with moderate

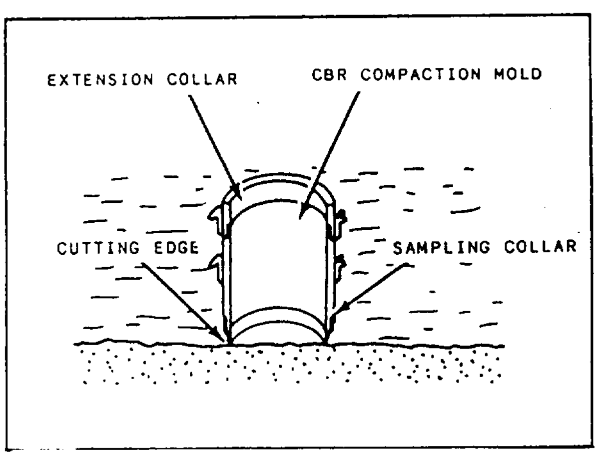


Figure 15-15.-Section through a CBR mold.

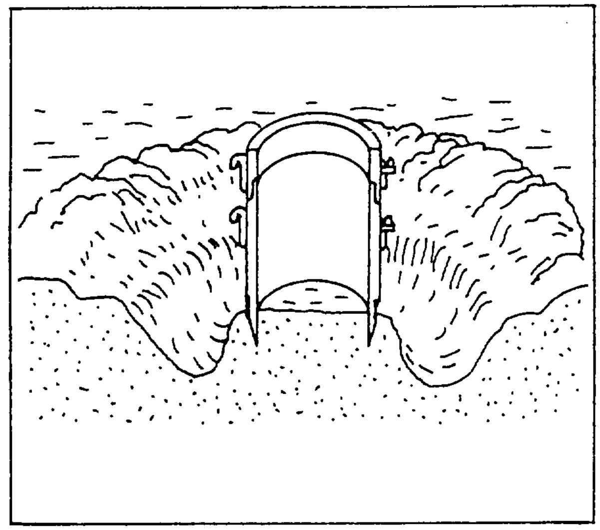


Figure 15-16.-Trench cut around a cylinder.

pressure. Then excavate a trench around the cylinder and again press the mold down over the soil, using the hand driver or loading bar if necessary. You can improvise a loading bar from any suitably sized piece of timber. Trim the soil away from the sampling collar carefully with a knife, cutting downward and outward to avoid cutting into the

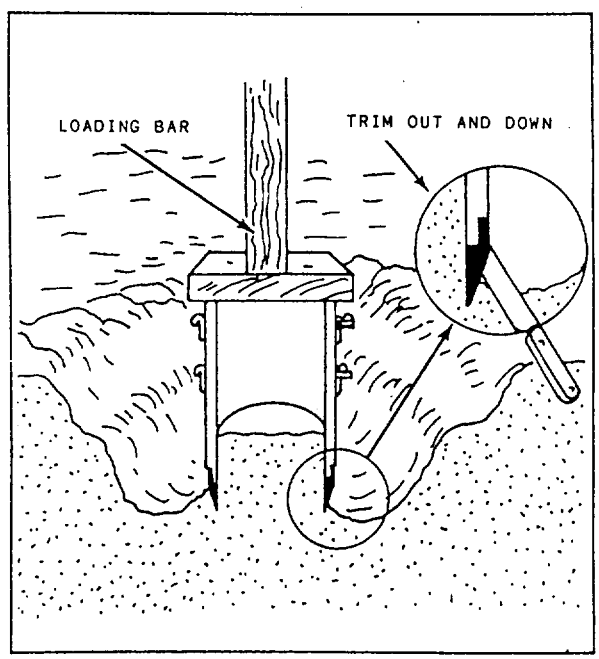


Figure 15-17.-Using a loading bar to drive a cylinder.

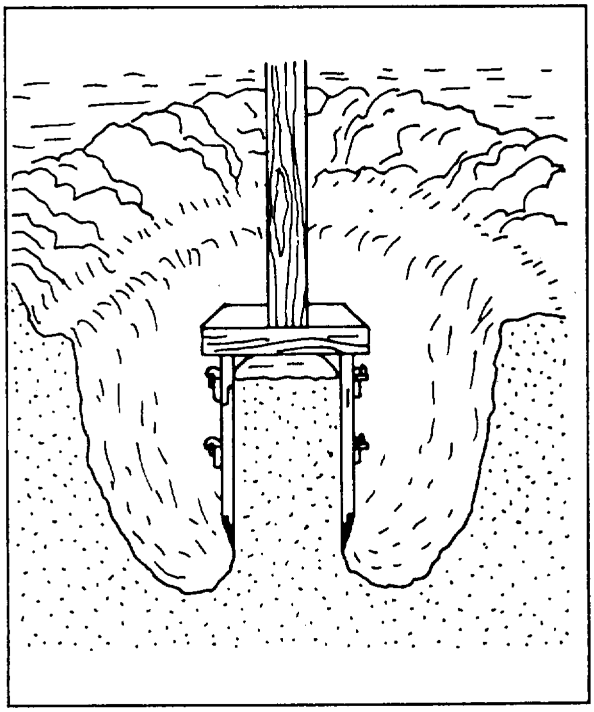


Figure 15-18.-Cylinder in position before cutting a sample.

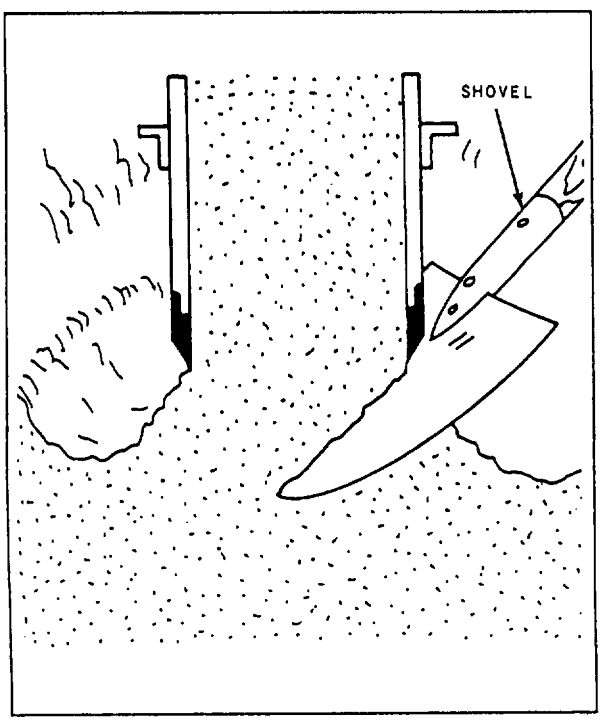


Figure 15-19.-Cutting off a cylindrical sample.

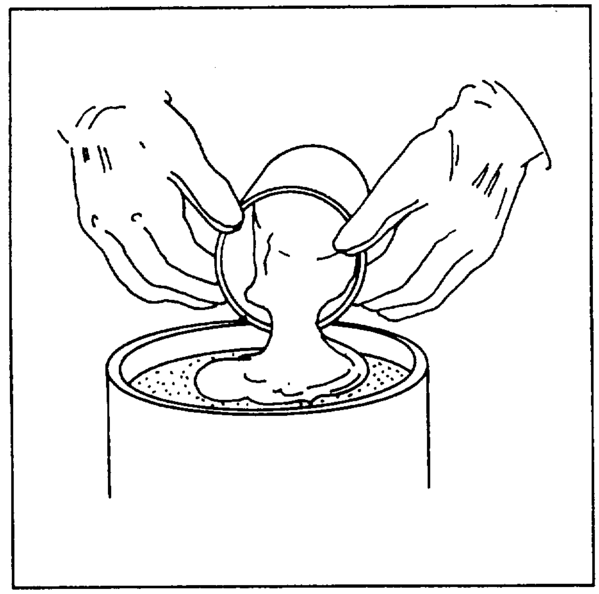


Figure 15-20.-Sealing a sample in a CBR mold.

sample. You actually do the cutting to size with the sampling collar. You can force the sampler down with the field CBR jack; however, since this jack has only about 2 in. of travel, you would do better to use a truck jack, if available. In either case, you should not force the sampler down ahead of the trimming on the outside of the cylinder. Then excavate the trench deeper and repeat the process until the soil penetrates well into the extension collar. Finally, as shown in figure 15-19, cut off the sample at the bottom of the mold with a shovel, knife, or wire, and remove the mold and sample from the hole.

After removing the mold and sample from the hole, remove the upper collar of the mold, and trim the top surface of the sample down to approximately 1/2 in. from the top of the mold. Then fill this recess with paraffin, as shown in figure 15-20, to seal the end of the sample. Then, after you turn the mold over and remove the cutting edge, a similar recess is formed in the bottom of the sample. Fill this recess with paraffin also. If the sample is to be handled a great deal, you should overfill the ends with paraffin and then trim them exactly flush, using a straightedge. Place boards over both ends and clamp them in place, using bolts, string, or wire, as

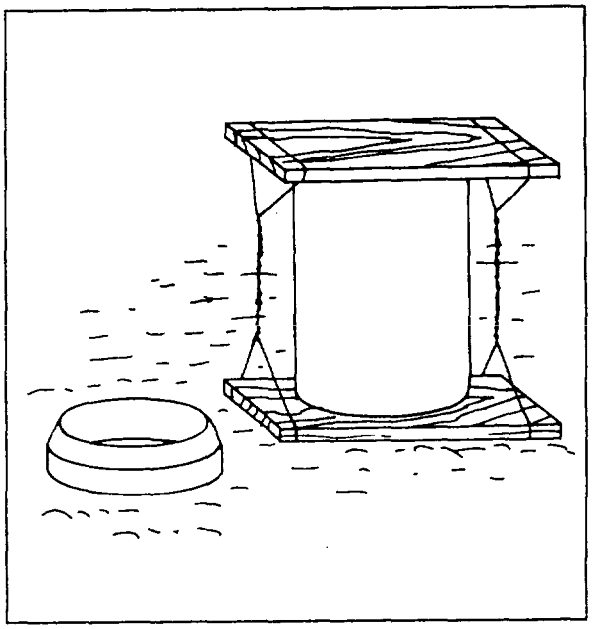


Figure 15-21.-Potecting a sample in a CBR mold.

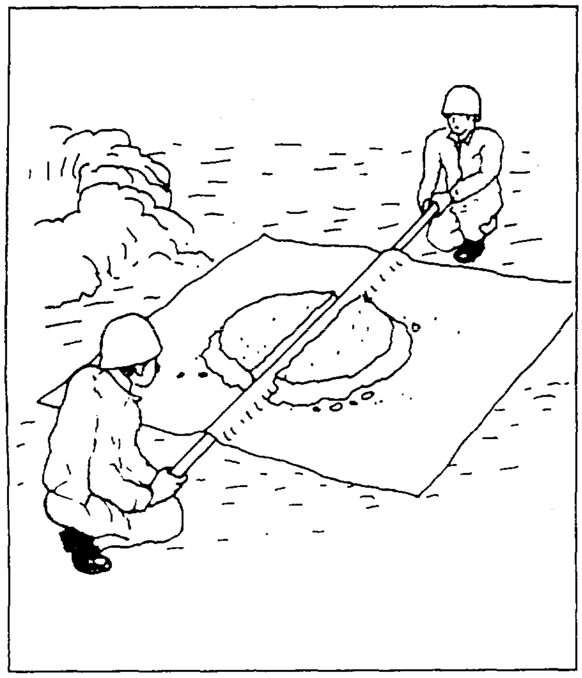


Figure 15-22.-Halving the sample.

shown in figure 15-21. If the samples are to be transported some distance or will be handled quite a bit before testing, you should wrap them in cloth and soak them in paraffin layers.

QUARTERING SAMPLES

The process of reducing a representative soil sample to a convenient size or of dividing a sample into two or more smaller samples for testing is called QUARTERING. The procedures vary somewhat, depending upon the size of the sample.

Samples Weighing Over 100 Pounds

To quarter a sample of this size, first mix and pile the sample on a canvas, using a shovel. Place each new shovelful on the top-center of the preceding one so that the soil will be distributed evenly in all directions. Then flatten the sample to a circular layer of approximately uniform thickness. Next, insert a stick or length of pipe under the canvas and then lift it at both ends to divide the sample into two equal parts, as shown in figure 15-22. Remove the stick, leaving a fold in the canvas, and then reinsert it under the sample, but this time, at right angles to the first division. Again, lift the stick. This divides the sample into four parts, as shown in figure 15-23. Discard two diagonally opposite quarters, taking care to clean the fines from the canvas. Then remix the remaining material, taking alternate shovelful from each quarter. Repeat the quartering process as necessary to reduce the sample to the desired size.

Samples Weighing Between 25 and 100 Pounds

In quartering a sample of this size, pile the soil on the canvas and mix it by alternately lifting the

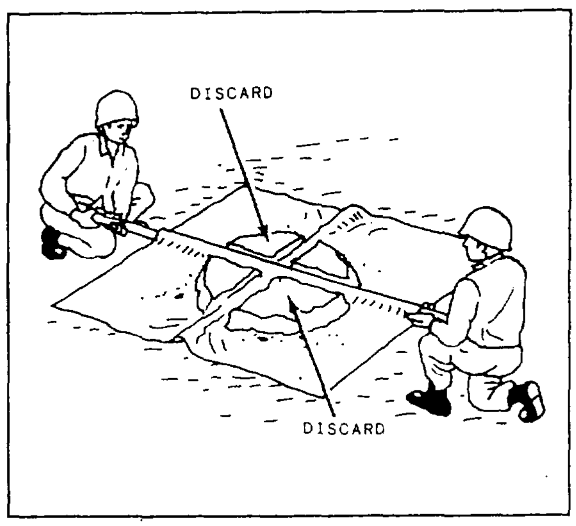


Figure 15-23.-Quartering the sample.

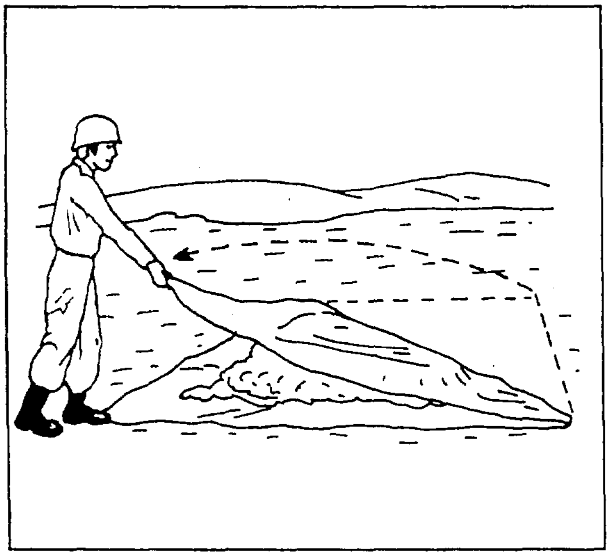


Figure 15-24.-Mixing a sample weighing 25 to 100 pounds.

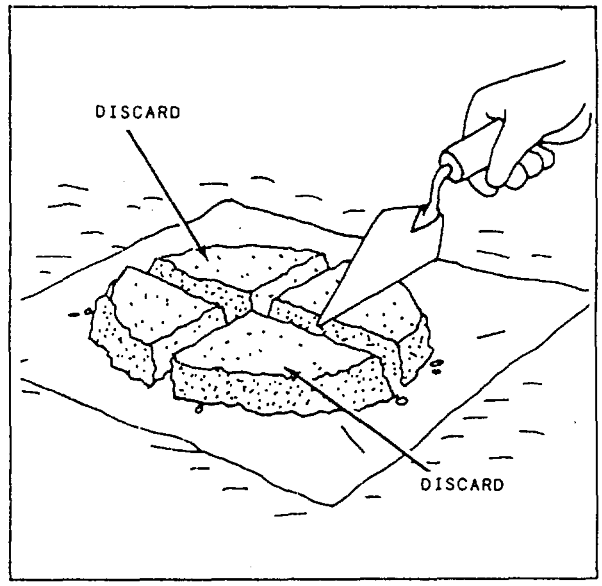


Figure 15-25.-Quartering a small sample.

corners of the canvas and pulling over the samples as if preparing to fold the canvas diagonally, as shown in figure 15-24. Then flatten and quarter the sample.

Samples Weighing Less Than 25 Pounds

For samples of this size, place the sample on the canvas or a clean sheet of paper. Mix it thoroughly with a trowel, form it into a conical shape, and then flatten it with the trowel. Using the trowel, divide the sample into quarters, and discard two diagonally opposite quarters, as shown in figure 15-25. Remix the remaining material, and repeat the process until the sample is the size needed for the test.

SOIL TESTING

In soil testing, the Navy follows procedures laid down by the American Society for Testing Materials (ASTM). Generally speaking, a complete soil test proceeds according to the following steps:

1. Determine the moisture content of representative samples. (This is preceded, of course, by the extraction of representative samples.)
2. Perform a mechanical analysis of the sample to determine the sizes of soil particles (or grains) and the distribution of sizes; this means the percentage of each size contained in the whole mass.
3. Determine the specific gravity of representative samples. The specific gravity of a substance is expressed in terms of the ratio of the weight of a given volume of the substance to the weight of an equal volume of water. A cubic foot of water weighs 62.43 lb.

For soil, determine the absolute specific gravity; by this we mean determine the ratio of the weight of a dense volume (volume exclusive of air spaces) to the weight of an equal volume of water. A cubic foot of dry sand, for example, weighs about 100 lb. With air exhausted, however, a cubic foot of sand weighs about 165.44 lb. Therefore, the specific gravity of sand equals 165.44 divided by 62.43, or about 2.65.

4. If the soil is clay or a similar fine-grained soil, determine the Atterberg limits. Over a certain range of moisture content, a fine-grained soil remains plastic. A reduction below the bottom of the range causes the soil to become semisolid; an increase above the range causes it to become fluid. The upper moisture content is called the liquid limit; the lower is called the plastic limit.
5. Compaction testing is used to determine the moisture-density relationships; or, in other words, to determine what moisture content results in maximum compaction for a given compactive

effort. Compaction testing is not included in this TRAMAN but will be discussed at the EA2 level.

6. Field control testing is used to determine (1) the field moisture content (with an eye to reducing or increasing it to the optimum, if feasible) and (2) the point at which the specified density has been obtained by compaction. Field control testing is not included in this TRAMAN but will be discussed at the EA2 level.

DETERMINING MOISTURE CONTENT

Several methods of determining moisture content of soil are in existence. The most accurate is the ovendrying method, in which an electric or portable gasoline oven is used to dry the samples. A more expedient method is the calcium carbide gas pressure method. This method, however, is less accurate and should always be approved by your supervisor. A third method uses the NUCLEAR MOISTURE-DENSITY METER. Since specialized training and operator certification are required, use of the nuclear moisture-density meter will not be discussed in this training manual.

Ovendrying Method

As noted above, this is the most accurate method used to determine moisture content. The apparatus and procedures used are discussed below.

APPARATUS.— Laboratory apparatus for moisture content determination includes the following items:

- A balance (fig. 15-26) for weighing material in grams. There are 453.6 g in a pound.

- Several small circular moisture boxes (called cans) (fig. 15-26) for placing samples in to weigh and dry.

- An electric oven or a portable gasoline oven to dry samples.

- Crucible tongs.

In the absence of an electric oven or gasoline oven, you may dry the materials in a frying pan held over an ordinary stove or hot plate. The

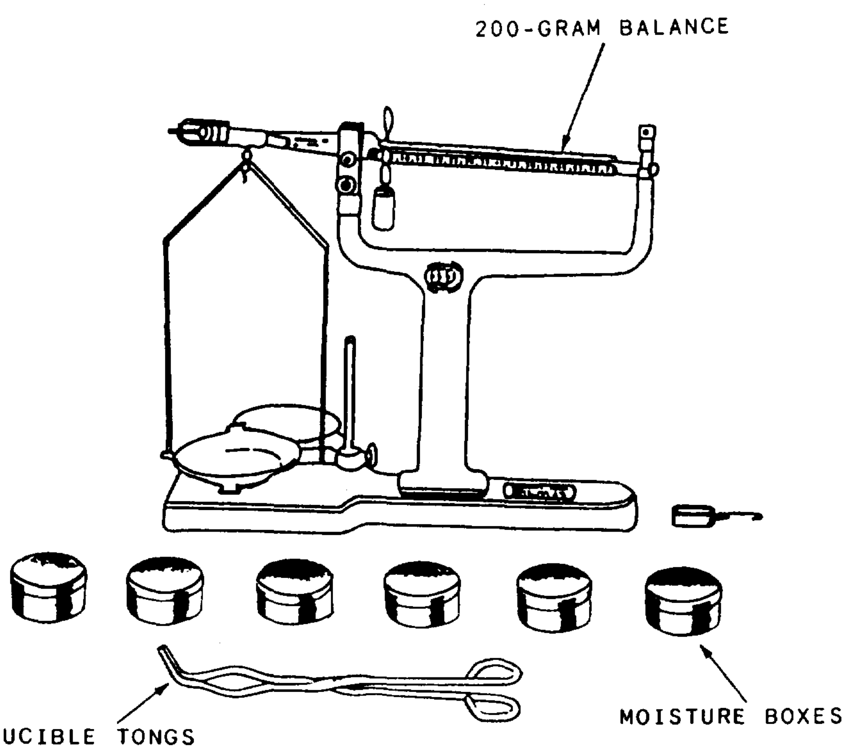


Figure 15-26.-Apparatus for determining moisture content.

disadvantage here is that the temperature is hard to control and the organic material in the sample may be burned; this would cause a slight to moderate inaccuracy in the result. The thermostat on an electric oven can be set to the desired temperature.

PROCEDURE.— Before beginning the tests, weigh each of the moisture boxes and record the weight by can number. Record this weight as tare weight (weight that allows for a deduction of the can). Then fill each can with a sample and weigh the can (with lid on) and contents.

Remove the lid and place the can, contents, and lid in the oven or pan to dry. In an electric oven, maintain the temperature between 212°F and 230°F (105°C ± 10°C); dry the sample for at least 8 hr—even longer for clay or silt. Then weigh the dry can, contents, and lid.

Record the results on a form like the one shown in figure 15-27. In the example shown in

SOIL MOISTURE CONTENT						DATE 16 June 19 –
PROJECT Faulkner Airbase						
EXCAVATION NUMBER 3	SAMPLE NUMBER FA-P2-1			FORMULA Water Content, $w = \frac{W_w}{W_s} \times 100$		
TEST Natural Soil Moisture Content						UNIT
RUN NUMBER	1	2	3			
TARE NUMBER	5	10	1			
A. WEIGHT OF TARE + WET SOIL	189.3	175.0	223.0			g
B. WEIGHT OF TARE + DRY SOIL	170.0	162.1	204.0			g
C. WEIGHT OF WATER, W_w (A.-B.)	19.3	12.9	19.0			g
D. WEIGHT OF TARE	44.0	42.9	45.2			g
E. WEIGHT OF DRY SOIL, W_s (B.-D.)	126.0	119.2	158.8			g
WATER CONTENT, w	15.3 %	10.8 %	12.0 %	%	%	
TEST						UNIT
RUN NUMBER						
TARE NUMBER						
A. WEIGHT OF TARE + WET SOIL						
B. WEIGHT OF TARE + DRY SOIL						
C. WEIGHT OF WATER, W_w (A.-B.)						
D. WEIGHT OF TARE						
E. WEIGHT OF DRY SOIL, W_s (B.-D.)						
WATER CONTENT, w	%	%	%	%	%	
TEST						UNIT
RUN NUMBER						
TARE NUMBER						
A. WEIGHT OF TARE + WET SOIL						
B. WEIGHT OF TARE + DRY SOIL						
C. WEIGHT OF WATER, W_w (A.-B.)						
D. WEIGHT OF TARE						
E. WEIGHT OF DRY SOIL, W_s (B.-D.)						
WATER CONTENT, w	%	%	%	%	%	
REMARKS						

TECHNICIAN (Signature)	COMPUTED BY (Signature)	CHECKED BY (Signature)
James Perry	James Perry	Thomas Connors

Figure 15-27.-Data sheet for moisture content tests.

figure 15-27, three tests (called runs) were made, using cans numbered 5, 10, and 1. Online D (weight of tare), record the weight of each can. Note that although the cans are identical in appearance, they vary slightly in weight. Online A (weight of tare and wet soil), record the weight of each can with wet contents. On line B (weight of tare and dry soil), record the weight of each can with contents after drying.

Online C, Ww (weight of water in the soil sample) was obtained by subtracting (B) from (A). On line E, Ws (weight of dry soil) was obtained by subtracting (D) from (B).

The line labeled "water content, w," shows the results obtained by substituting the known values in the following formula:

$$w = \frac{Ww}{Ws} \times 100$$

The average of these three values, or 12.7 percent, is the value of w (percentage of moisture content) for the sample.

Calcium Carbide Gas Pressure Method

This method uses a 26-g SPEEDY MOISTURE TESTER to determine the moisture content of soils, fine aggregates, sand, and clay. By using the SPEEDY tester, the moisture content can be determined in the laboratory or field in from 45 sec to 3 rein, depending upon the material being tested. The tester operates on the principle of a calcium carbide reagent (reactive agent) being introduced into the free moisture of the soil sample. The resulting chemical reaction creates a gas that is contained in a sealed chamber, the pressure of which can be measured with the built-in gas pressure gauge.

APPARATUS.— The SPEEDY moisture test set (fig. 15-28) includes the SPEEDY tester, a balance, half-weight reagent, measuring scoop, brushes, cleaning cloth, and two 1 1/4-in. steel balls.

PROCEDURE.— The procedure for determining moisture content using the SPEEDY MOISTURE TESTER is as follows:

1. Weigh a 26-g sample of soil.

2. Place the soil sample and two 1 1/4-in. steel balls in the large chamber.

FIGURE REMOVED
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for electronic media.

Figure 15-28.—SPEEDY moisture test set.

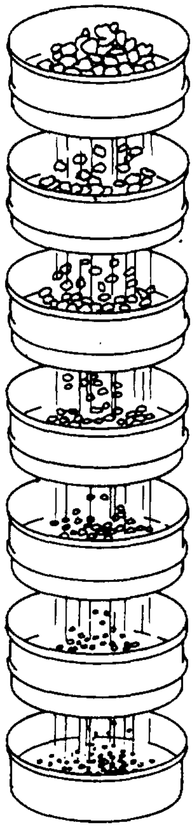


Figure 15-29.-Varying sieve sizes.

3. Place three scoops (24 g) of reagent in the cap. Then, with the pressure vessel in a horizontal position, insert the cap into the pressure vessel and tighten the clamp to seal the cap to the unit.

4. Raise the moisture tester to a vertical position so that the reagent falls into the vessel.

5. Hold the moisture tester horizontally; vigorously shake the device with a rotating motion for 10 sec to put the steel balls into orbit around the inside circumference; then rest for 20 sec. Repeat the shake-rest cycle for a total of 3 min. Do not allow the steel balls to fall against either the cap or orifice leading to the dial; this may cause damage.

6. Holding the tester horizontally at eye level, read and record the dial reading as the percent of moisture by wet mass.

7. When the sample is dumped, examine it for lumps. If the soil sample is not completely broken down, increase the time limit (shaking unit) by 1 min on the next test.

8. To determine the percentage of moisture by dry mass (ovendry moisture percentage), read the direct reading obtained in No. 6 above into a calibration curve that is also supplied with the test set.

MECHANICAL ANALYSIS

Mechanical analysis is the determination of grain sizes and the percentage distribution of each size. A complete mechanical analysis is accomplished in two parts: sieve analysis and hydrometer analysis.

Sieve Analysis

A sieve analysis is applicable to soils that are larger than the No. 200 sieve or that contain small amounts of material passing the No. 200 sieve. You can conduct the sieve analysis either on the entire sample or on the sample after the fines are removed by prewashing. The apparatus and procedures used to conduct a sieve analysis are described below.

APPARATUS.— Typical sieve analysis apparatus includes a gram weighing balance and a number of sieves with apertures of varying sizes used to determine grain sizes (fig. 15-29). Sieves may be of the ordinary circular SIFTER type (usually about 8 in. in diameter) or the ROCKER type, which consists of a rocker frame in which screens with apertures of various sizes can be placed.

The sieve used for analysis is the so-called standard sieve. A standard sieve has a square aperture. Screen sizes are designated as follows: A sieve with fewer than four apertures to the linear inch is designated by the size of an aperture; for example, a 1/4-in., 1/2-in., 3/4-in., or 1-in. sieve.

A sieve with four or more apertures to the linear inch is designated by a number that represents the number of apertures to the linear inch. A No, 4 sieve, for example, has four apertures to the linear inch, a No. 6 has six apertures, and so on. The finest sieve used is a No. 200, with 200 apertures to the linear inch and an aperture size slightly smaller than one two-hundredth of an inch square.

To conduct a sieve analysis, you need an electric or hand-operated sieve shaker.

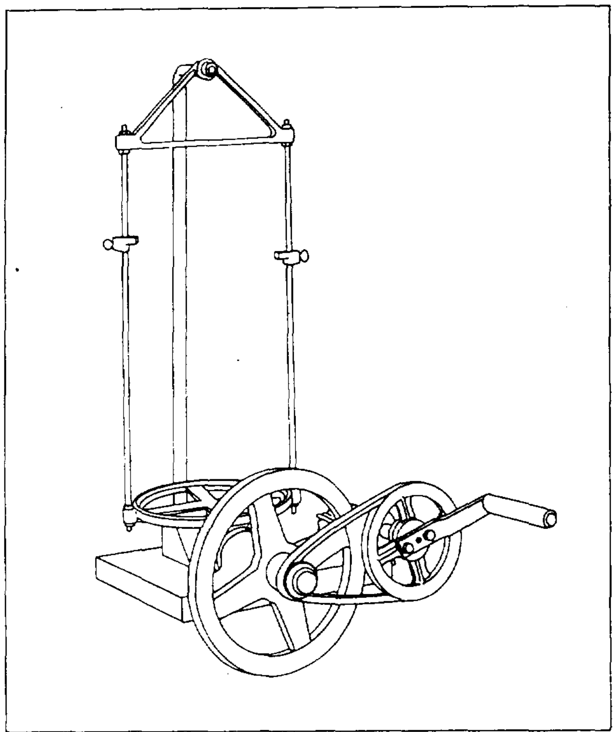


Figure 15-30.-Hand-operated sieve shaker.

The hand-operated shaker is shown in figure 15-30.

SIEVE ANALYSIS, DRY.— The minimum sample weight required for a sieve analysis is dependent upon the maximum particle size in the sample as follows:

Maximum particle size (sieve opening)	Minimum dry weight of test specimen
3 in.	6,000 g
1 1/2 in.	3,000 g
3/4 in.	1,500 g
3/8 in.	600 g
No. 4	200 g

Samples that contain cohesive soil, which forms hard lumps, must be prewashed. This procedure is described later. Other samples are analyzed DRY by the following procedure:

1. Oven-dry the sample.
2. Break up lumps. For coarse material, use a rolling pin on a clean, hard, smooth surface. For fine material, use a mortar and pestle (usually a part of the laboratory apparatus). Take care not to crush individual grains. The object is to separate aggregations of clustering grains.
3. Weigh the sample.
4. Select and weigh the sieves and pan to be used in the test. The sieve selection varies according to the type of soil being tested. The following is a selection commonly used:

3 in. (76.2 mm)	No. 10 (2.00 mm)
1 1/2 in. (38.1 mm)	No. 20 (1.21 mm)
1/2 in. (12.7 mm)	No. 40 (0.42) mm
3/8 in. (9.52 mm)	No. 100 (0.149 mm)
No. 4 (4.76 mm)	No. 200 (0.074 mm)

Stack (nest) the sieves one on top of the other such that the largest sieve is on top. The coarsest sieve actually recorded is the next above the first one that retains any material. The weight recorded as retained on this sieve is 0 g; the weight recorded as passing it is the total weight of the sample.

5. Place the sieve pan under the stack of sieves; place the total sample in the top sieve and shake. The shaking interval depends on the amount of fine material. Five minutes is usually enough for most coarse-grained soils, and 15 min is enough for most fine-grained soils.
6. Remove the sieves from the shaker. Starting with the first to retain any material, carefully weigh each sieve with the retained material. Subtract the weight of the sieve from the combined weight of the sieve and material to determine the weight of the material retained on each sieve. Finally, determine the weight of the material that reached the pan; that is, that passed the No. 200, or finest, sieve.

Enter the results on a data sheet like the one shown in figure 15-31. In this analysis, all the material (359. 1 g) passed the 3/8-in. sieve; none was retained on this one. The No. 4 retained 51.0 g. This means that 308.1 g (359.1 – 51.0) passed this sieve. You can see how the weight passing was determined from the weight retained in each subsequent case. In column d, the percent passing is computed for each sieve by multiplying the weight passing by 100 and dividing the result by the total weight of the sample.

SIEVE ANALYSIS DATA

DATE: 11 July 19—

PROJECT: Fraunce Theater | EXCAVATION NUMBER: 2 | SAMPLE NUMBER: FT-P1-1

DESCRIPTION OF SAMPLE: 25 lb. bag sample

PREWASHED: ☐ YES ☒ NO

WEIGHT ORIGINAL SAMPLE (g): 359.1 | WEIGHT AFTER PREWASHING[1] (g): | WASHING LOSS[1] (g):

SIEVE OR SCREEN a	WEIGHT RETAINED ON SIEVE (g) b	PASSING SIEVE WEIGHT (g) c	PASSING SIEVE PERCENT d
*	0		100
3/4			
1/2			
3/8		359.1	100.0
No. 4	51.0	308.1	85.8
10	40.9	267.2	74.4
20	83.3	183.9	51.2
40	75.4	108.5	30.2
100	49.9	58.6	16.3
NUMBER 200	47.4	11.2	3.1

A. WEIGHT SIEVED THROUGH NO. 200 (g): 11.1

B. WASHING LOSS[1] (g):

ERROR (Original weight - total weight of fractions)(g): 359.1 - 359.0 = 0.1

TOTAL PASSING NO. 200 (g) (A + B.) C.: 11.1

TOTAL WEIGHT OF FRACTIONS (Total of all entries in Col. b + c): 359.0

PERCENT ERROR: $\left(\frac{\text{Error (g)}}{\text{Original weight (g)}} \times 100\right) = .028\%$

REMARKS

TECHNICIAN (Signature): Paul Massin | COMPUTED BY (Signature): Paul Massin | CHECKED BY (Signature): John Stark

[1] For prewashed samples only. *Maximum particle size.

Figure 15-31.-Data sheet for dry sieve analysis.

The total weight of fractions plus the weight of the material that reached the pan comes to 359.0 g. The weight of the sample originally was 359.1 g; there is an error here of 0.1 g. At the lower right, you can see how the percentage of error is computed. The maximum permissible percentage of error is normally (±) 1 percent. If the percentage exceeds the maximum, the test must be rerun. For an error smaller than the maximum permissible, correction is made by adding the value of the error to the largest amount listed as retained. The value of the error in this case is 0.1 g. The largest amount retained is 83.3 g for the No. 20 sieve. This amount would be changed to 83.4 g.

SIEVE ANALYSIS WITH PREWASHING.— When inspection indicates that a sample contains an excessively high portion of superfine material (material that passes the No. 200 sieve), analysis with prewashing is done as follows:

1. Oven-dry the sample.
2. Weigh and record the total weight after cooling.
3. Place the sample in a clean pan and add clean water until it is completely covered. Allow it to soak until it is completely disintegrated—from 2 to 12 hr. Stir to break up lumps and hasten the action.
4. Wash the material thoroughly on a No. 200 sieve under running water and discard the material that passes.
5. Oven-dry and reweigh. Record the difference between this weight and the original weight as washing loss.
6. Continue as for sieve analysis, dry.

Figure 15-32 shows a data sheet for sieve analysis with prewashing. The ovendry weight of the original sample was 75.0 g; the ovendry weight after prewashing was 55.0 g; therefore, the washing loss was 75.0 -55.0 or 20.0 g. The sum of the weights retained (53.0 g, the total of column b) plus the 2.0 g that, in spite of prewashing, was still left in the sample to pass the No. 200 sieve, equals 55.0 g. This was the original weight after prewashing. Therefore, no error was made.

Hydrometer Analysis

As you learned in the preceding discussion, the determination of grain size distribution by sieve analysis is limited to those materials larger than the No. 200 (0.074-mm) sieve. For uses such as soil classification, this is sufficient since grain size distribution is not used to classify fine-grained soils. For determination of frost susceptibility, however, the distribution of particles smaller than the No. 200 sieve is necessary. A soil is considered frost susceptible if it contains 3 percent or more by weight of particles smaller than 0.020 mm in diameter. Frost susceptibility should always be considered in areas subject to substantially freezing temperatures, since repeated freezing, and subsequent thawing, of water in the soil can seriously affect the ability of the soil to support a structure. Hydrometer analysis is the test used to determine the grain size distribution of the soils passing the No. 200 sieve.

Hydrometer analysis is based on Stokes' law, which relates the terminal velocity of a free-falling sphere in a liquid to its diameter. The relation is expressed by the following equation.

$$V = \frac{G_s - G_w}{18n} D^2$$

Where:

V = terminal velocity
G_s = specific gravity of solids
G_w = specific gravity of the liquid in which the sphere is falling
n = viscosity of the liquid
D = diameter of the sphere

It is assumed that Stokes' law can be applied to a mass of dispersed soil particles of various shapes and sizes. Larger particles settle more rapidly than the smaller ones. The hydrometer analysis is an application of Stokes' law that permits the calculation of the grain size distribution in silts and clays, where the soil particles are given the sizes of equivalent spherical particles.

The density of a soil-water suspension depends upon the concentration and specific gravity of the soil particles. If the suspension is allowed to stand, the particles will gradually settle out of the suspension, and the density will be decreased. The hydrometer is the instrument used to measure the density of the suspension at a known depth below the surface. The density measurement, together with knowledge of specific gravity of the soil particles, determines the percentage of dispersed soil particles in suspension at the time and depth of measurement. Stokes' law is used to calculate the maximum equivalent particle diameter for the material in suspension at this depth and for the elapsed time of settlement. A series of density measurements at known depth of suspension and at known times of settlement gives the percentages of particles finer than the diameters given by Stokes' law. Thus the series of readings will reflect the amount of different sizes of particles in the fine-grained soils. The particle diameter (D) is

SIEVE ANALYSIS DATA		DATE: 11 July 19—
PROJECT: Fraunce Theater	EXCAVATION NUMBER: 2	SAMPLE NUMBER: FT-P2-1
DESCRIPTION OF SAMPLE: 25 lb bag sample		PREWASHED: [X] YES [ ] NO
WEIGHT ORIGINAL SAMPLE (g): 75.0	WEIGHT AFTER PREWASHING[1] (g): 55.0	WASHING LOSS[1] (g): 20.0

SIEVE OR SCREEN (a)	WEIGHT RETAINED ON SIEVE (g) (b)	PASSING SIEVE WEIGHT (g) (c)	PASSING SIEVE PERCENT (d)
	0		100
No. 10		75.0	100.0
20	8.7	66.3	88.4
40	29.0	37.3	49.8
100	13.3	24.0	31.1
NUMBER 200	2.0	22.0	29.4

A. WEIGHT SIEVED THROUGH NO. 200 (g): 2.0	ERROR (Original weight - total weight of fractions)(g): none
B. WASHING LOSS[1] (g): 20.0	
TOTAL PASSING NO. 200 (g.) (A. + B.) c: 22.0	PERCENT ERROR ($\frac{\text{Error (g)}}{\text{Original weight (g)}}$ x 100) none
TOTAL WEIGHT OF FRACTIONS (Total of all entries in Col. b + c: 75.0	

REMARKS

TECHNICIAN (Signature)	COMPUTED BY (Signature)	CHECKED BY (Signature)
Paul Massin	Paul Massin	John Stark

[1] For prewashed samples only. [2] Maximum particle size.

Figure 15-32.-Data sheet for sieve analysis with prewashing.

calculated from Stoke's equation using corrected hydrometer reading and a nomographic chart.

The procedures used to perform the hydrometer analysis are not discussed in this TRAMAN but are contained in ASTM D 422.

SPECIFIC GRAVITY TESTING

The specific gravity of a solid substance is the ratio of the weight of the solid to the weight of an equal volume of water. In dealing with soils, the specific gravity is necessary for certain tests, such as hydrometer analysis. It is also necessary for computations involving volume and weight relationships. The specific gravity of a soil mass can be expressed in one of three different forms as follows:

SPECIFIC GRAVITY OF SOLIDS (G_s) is the ratio of the weight in air of a given volume of soil particles to the weight of an equal volume of distilled water, both at a stated temperature. The specific gravity of solids is only applied to that fraction of a soil that passes a No. 4 sieve.

APPARENT SPECIFIC GRAVITY (G_a) is the ratio of the weight in air of a given volume of the impermeable portion of soil particles to the weight in air of an equal volume of distilled water, both at a stated temperature. The impermeable portion of a porous material, such as most large soil grains, includes the solid material plus impermeable pores or voids within the particles.

BULK SPECIFIC GRAVITY (G_m) is the ratio of the weight in air of a given volume of permeable material (including permeable and impermeable voids) to the weight of an equal volume of distilled water at a stated temperature.

Sample Selection

For specific gravity tests, the soil samples may be either disturbed or undisturbed. Care must be taken, however, to ensure that representative samples are obtained. When the sample contains both large and small particles, the sample should be separated on a No. 4 sieve. Then the specific gravity of the fine fraction is determined separately from the coarse fraction. A composite specific gravity for the entire soil sample is then calculated in the manner to be described later.

For samples smaller than the No. 4 sieve, it is easier to begin the test with an ovendried sample. However, some soils, particularly those with high organic content, should be tested at their natural water content; the ovendried weight determined at the end of the test.

Specific Gravity of Solids

As discussed earlier, the specific gravity of solids is applied to soil that passes a No. 4 sieve. However, when the specific gravity is to be used in conjunction with hydrometer analysis, it is determined only on the fraction that passes a No. 200 sieve. In either case, the specific gravity may be determined for soil at natural water content or ovendried.

APPARATUS.— A 500-milliliter (ml) volumetric flask is required for this test. For the discussion in this TRAMAN, it is assumed that the flask has been calibrated. This means that the weight of the flask and water has been calibrated over a range of temperatures that would likely be encountered in the laboratory. As a matter of interest, calibration procedures are located in ASTM D 854. Some other apparatus used to perform test are as follows:

Balance, 2,000-g capacity
Balance, 200-g capacity
Cans, moisture content
Dishes, evaporating
Funnel
Mortar and pestle
Pump, vacuum (optional)
Stirrer, soil dispersion (optional)
Thermometer, general laboratory

PROCEDURE.— AS mentioned previously, you can perform the specific gravity test on soils at natural water content. When possible, however, you should first oven-dry the sample, as this makes it easier to perform the test. The procedure for performing the specific gravity test is as follows:

1. Record all identifying information regarding the sample on a data sheet similar to figure 15-33. Also, record identifying information for the flask and dish (or moisture can) that will be used for the test.
2. Air-or oven-dry the sample and breakup all lumps with a mortar and pestle. About 50 g of clay and about 100 g of coarser samples are the usual quantities.
3. Weigh and record the tare weight of a moisture can. Then fill the can with the dry sample; oven-dry and determine the weight to the nearest 0.01 g. This weight minus the tare weight is the weight of the dry soil (W_s) entered in block 6g of figure 15-33. This weight is critical to the accuracy of the test. **YOU MUST TAKE GREAT CARE NOT TO LOSE ANY OF THE MATERIAL DURING THE REMAINDER OF THE TEST.**
4. Transfer the material to the volumetric flask, using a funnel. Use a battery filler, or syringe, to CAREFULLY wash ALL material from the can and funnel into the flask.
5. Fill the flask two-thirds full of clean water (for exact analysis use distilled or demineralized water). Allow the material to soak from 4 to 6 hr, except for clean, sandy soil, which does not require soaking.

SPECIFIC GRAVITY TESTS			1. DATE 10 JAN 1991	
2. PROJECT Parking Apron Expansion		3. BORING NUMBER Test Pit	4. JOB NUMBER	5. EXCAVATION NUMBER

6.	SPECIFIC GRAVITY OF SOLIDS (G_s)					
a.	SAMPLE OR SPECIMEN NUMBER			TP-1		
b.	FLASK NUMBER			1		
c.	TEMPERATURE OF WATER AND SOIL (T, °C)			28.5		
d.	DISH NUMBER			3		
WEIGHT IN GRAMS	e. DISH + DRY SOIL			123.0		
	f. DISH			41.0		
	g. DRY SOIL	W_s		82.0		
	h. FLASK + WATER AT T, °C)	W_{bw}		637.85		
	i. $W_s + W_{bw}$			719.85		
	j. FLASK + WATER + IMMERSED SOIL	W_{bws}		690.5		
	k. DISPLACED WATER, $W_s + W_{bw} - W_{bws}$			29.35		
l.	CORRECTION FACTOR	K		0.9979		
m.	$(W_sK) \div (W_s + W_{bw} - W_{bws})$	G_s		2.79		

7.	APPARENT (G_a) AND BULK (G_m) SPECIFIC GRAVITY				
a.	SAMPLE OR SPECIMEN NUMBER		TP-1		
b.	TEMPERATURE OF WATER AND SOIL (T, °C)		25.0		
c.	TARE + SATURATED SURFACE-DRY SOIL		1200.0		
WEIGHT IN GRAMS	d. TARE		225.0		
	e. SATURATED SURFACE-DRY SOIL	B	945.0		
	f. (WIRE BASKET + SOIL) IN WATER		1994.0		
	g. WIRE BASKET IN WATER		1420.0		
	h. SATURATED SOIL IN WATER	C	574.0		
	i. TARE AND DRY SOIL		1149.0		
	j. TARE		230.0		
	k. DRY SOIL	A	919.0		
	l. CORRECTION FACTOR	K	0.9988		
	m. (AK) ÷ (A − C) (APPARENT)	G_a	2.66		
n.	(AK) ÷ (B − C) (BULK)	G_m	2.47		

8. REMARKS

Retained No. 4 – 60%
Passed No. 4 – 40%

Composite G = 2.71

9. TECHNICIAN (Signature)	10. COMPUTED BY (Signature)	11. CHECKED BY (Signature)
[signature]	Fred Sherman	[signature]

DD Form 1208, DEC 86 *Previous editions are obsolete.*

Figure 15-33.-Data sheet for specific gravity test.

6. Attach a vacuum pump to the flask and exhaust all air. The exhausted air is indicated by rising bubbles. For most soils, 30 min of pumping is enough. A heavy clay, however, may require as much as 2 hr of pumping. As an alternative to the vacuum pump, the air may be exhausted by gently boiling the suspension for at least 10 min. To aid in the removal of entrapped air, occasionally roll the flask. A slow boil should be used, as fast

Table 15-3.-Relative Density of Water and Correction Factor (K) at Various Temperatures

TEMP °C	RELATIVE DENSITY	CORRECTION FACTOR, K	TEMP °C	RELATIVE DENSITY	CORRECTION FACTOR, K	TEMP °C	RELATIVE DENSITY	CORRECTION FACTOR, K
18.0	0.99862	1.0004	23.0	0.99756	0.9993	28.0	0.99626	0.9980
18.5	0.99852	1.0003	23.5	0.99744	0.9992	28.5	0.99611	0.9979
19.0	0.99843	1.0002	24.0	0.99732	0.9991	29.0	0.99597	0.9977
19.5	0.99833	1.0001	24.5	0.99720	0.9990	29.5	0.99582	0.9976
20.0	0.99823	1.0000	25.0	0.99707	0.9988	30.0	0.99567	0.9974
20.5	0.99813	0.9999	25.5	0.99694	0.9987	30.5	0.99552	0.9973
21.0	0.99802	0.9998	26.0	0.99681	0.9986	31.0	0.99537	0.9971
21.5	0.99791	0.9997	26.5	0.99668	0.9984	31.5	0.99521	0.9970
22.0	0.99780	0.9996	27.0	0.99654	0.9983	32.0	0.99505	0.9968
22.5	0.99768	0.9995	27.5	0.99640	0.9982	32.5	0.99490	0.9967

boiling may cause material to be boiled out of the flask.

7. After all air has been exhausted, and the flask and contents have cooled, add more de-aired, distilled water until the flask is filled to the ring marked on the neck. To ensure all air is exhausted, a second boiling may be necessary.

8. Next, dry the outside of the flask and any moisture above the water surface inside the flask.

9. Weigh the flask and contents to the nearest 0.01 g, and record the information in block 6j (fig. 15-33). This is W_{bws}.

10. Immediately after weighing, stir the suspension to assure even temperature distribution. Immerse a thermometer to mid-depth of the flask, and read the temperature of the soil-water suspension. Record this temperature in block 6c (fig. 15-33).

11. Finally, with the data entered on the data sheet, compute the specific gravity using the following formula:

$$G = \frac{W_s K}{W_s + W_{bw} - W_{bws}}$$

where:

W_s = Dry weight of the sample

K = Correction factor based on the density of water at 20°C. You can get this factor from table 15-3 by selecting the correction factor that corresponds to the temperature obtained in Step 10, above.

W_{bw} = Weight of the flask filled with water only, at test temperature. You can get this value from a calibration curve, or table, previously prepared for the flask used in the test.

W_{bws} = Weight of the flask, water, and sample at test temperature

Bulk and Apparent Specific Gravity

The following discussion applies to determination of bulk and apparent specific gravity. Bulk specific gravity is usually determined for the coarser materials that are retained on a No. 4 sieve. Large stones may be determined individually.

SAMPLE PREPARATION.— Separate the sample on a No. 4 sieve, and use the material retained on that sieve for the test. Approximately 2 kg is required. Ensure the sample is a representative sample.

In preparing the sample, first wash the material to remove dust and coatings. Then immerse and soak the sample in water for 24 hr. Just before making the test, dry the sample to-a saturated-surface-dry condition. Do this by rolling the sample in art absorbent cloth to remove excess surface water. You may wipe large particles individually. When saturated-surface-dry, the surface may still appear damp. Take care to avoid excessive evaporation during the surface drying.

APPARATUS.— Apparatus for the test is as follows:

Balance, 5 kg or larger, sensitive to 0.1 g

Wire mesh basket, approximately 8 in. in diameter and 8 in. high; 2-mm (No. 6) or finer mesh

Container, large enough to permit immersing the wire basket

Suitable equipment for suspending the wire basket from the center of balance scale pan

Thermometer, general laboratory

PROCEDURE.— Perform the test in the following steps. You must complete the first step as quickly as possible after surface-drying the sample.

1. Determine the weight of the saturated-surface-dry sample and container. This weight minus the tare weight of the container is the weight of the saturated-surface-dry soil that you should enter in block 7e (fig. 15-33).

2. Determine the weight of the wire basket suspended in water. Record this weight in block 7g (fig. 15-33).

3. Place the sample in the basket and immerse the basket and sample in water. (Hang the basket from the balance and support the container so that the basket hangs freely in the water.) Read the weight and record it in block 7f (fig. 15-33). Subtract the weight of the empty basket suspended in water, Step 2 above, to determine the weight of the saturated soil in water. Record this weight in block 7h (fig. 15-33).

4. Measure and record the temperature of the water and soil. Enter this temperature in block 7b (fig. 15-33).

5. Determine the ovendry weight of the sample and enter the results in block 7k (fig.15-33).

6. From the recorded information, you may now calculate both the bulk specific gravity (G_m) and the apparent specific gravity (G_a) using the following formulas:

$$G_m = \frac{\text{weight of dry soil in air x K}}{\text{weight of satured sample in air} - \text{weight of sample in water}} = \frac{AK}{B-C}$$

and

$$G_a = \frac{\text{weight of dry soil in air x K}}{\text{weight of dry soil in air} - \text{weight of sample in water}} = \frac{AK}{A-C}$$

Specific Gravity of Composite Sample

After determining the specific gravity of solids (G_s) and the apparent specific gravity (G_a), you can calculate the specific gravity of an entire soil sample (both larger and smaller than a No. 4 sieve). To do so, use the following formula:

$$G = \frac{100}{\frac{\text{\% Passing No. 4 Sieve}}{G_s} + \frac{\text{\% Retained No. 4 Sieve}}{G_a}}$$

Enter this composite specific gravity in the remarks block of the data sheet. Note, too, that you should also enter in the remarks block the percent of materials that is retained on, or passes, the No. 4 sieve.

Comment Regarding Correction Factor (K)

Refer again to figure 15-33. In this figure, you see the values of G_s, G_a, and G_m that were obtained using the correction factor (K). Now, if you were to disregard K and recalculate, you would obtain values of the following: G_s = 2.7939, G_a = 2.6638, and G_m = 2.4471. As you can see, these values, obtained without the correction factor, are hardly different than the values obtained with the correction factor. Therefore, unless unusually accurate precision is required, the correction factor may be disregarded.

ATTERBERG LIMITS

As you previously learned, fine-grained soils are not classified under the Unified Soils Classification System on the basis of grain size distribution. They are, instead, classified on the basis of plasticity and compressibility. The Atterberg limits are laboratory classification criteria used for classifying fine-grained soils. As an EA3, you will be responsible for the performance of the Atterberg limits test.

A clay or related fine-grained soil, when dry or nearly dry, has a semisolid consistency. As moisture content increases, a point is reached where the material has a plastic (putty like) consistency. This point is called the PLASTIC LIMIT (PL). As moisture content continues to increase, the material remains plastic over a certain range. However, at a point called the LIQUID LIMIT (LL), the consistency of the material finally changes to semiliquid.

The upper and lower limits of the plastic range (that is, the liquid and plastic limits) are called ATTERBERG LIMITS. These limits were named after a Swedish scientist who developed the concept of the limits. The liquid limit (LL) is simply the moisture content (W_L) at the upper limit of the plastic range, expressed as a percentage. The plastic limit (PL) is the moisture content at the lower limit of the plastic range.

Test Equipment

Figure 15-34 shows equipment for determining the Atterberg limits of a soil sample. The LIQUID LIMIT TESTING DEVICE consists of a brass bowl mounted on a box type of apparatus. When you turn the crank, the apparatus elevates the bowl containing the sample and then drops it downward a specific distance onto the hard-rubber anvil of the testing device. Each of these drops is called a BLOW. We will explain the purpose of the procedure as we describe the test.

TeBst **Procedure**

The liquid and plastic limit tests normally are conducted only on the portion of the soil that passes the No. 40 sieve. A few particles that are large enough to be retained on the No. 40 sieve do not cause serious difficulty. However, it is generally faster to remove these larger particles by hand by kneading the soil between the fingers. If the percentage of particles retained on the No. 40 sieve is higher, these particles must be removed by passing the soil through the No. 40 sieve. Do not oven-dry or subject the sample to any artificial drying before you process or test it.

Soak the sample in water for 24 hr before washing. Then wash it through the No. 40 sieve and collect it in a large evaporating dish or collecting can. Oven-dry the material retained on the sieve, then dry-sieve it through the No. 40 sieve. Combine the portion dry sieved through the No. 40 sieve with the material washed through the sieve; the combined material is used for the tests. Break up soil particles that are lumping together or adhering to aggregate particles and separate them by rubbing them with your hands.

Next, dry the sample to approximately the liquid limit by decanting or blotting the water off, by evaporating it off (taking care to stir the soil frequently during evaporation), or by a combination of both procedures.

After this, place the soil mass in the liquid limit testing device cup, and divide it into sections by a central groove made with the grooving tool (fig. 15-34). The water content at the liquid limit is the water content at which the soil mass makes contact for a distance of 1/2 in. when the cup is dropped 25 times (25 blows) for a distance of 1 cm (0.3937 in.) at a rate of two drops per second. First, adjust the machine for this drop distance as follows:

A metric gauge is located on the handle of the grooving tool. The machine has an ADJUSTMENT PLATE and a pair of ADJUSTMENT

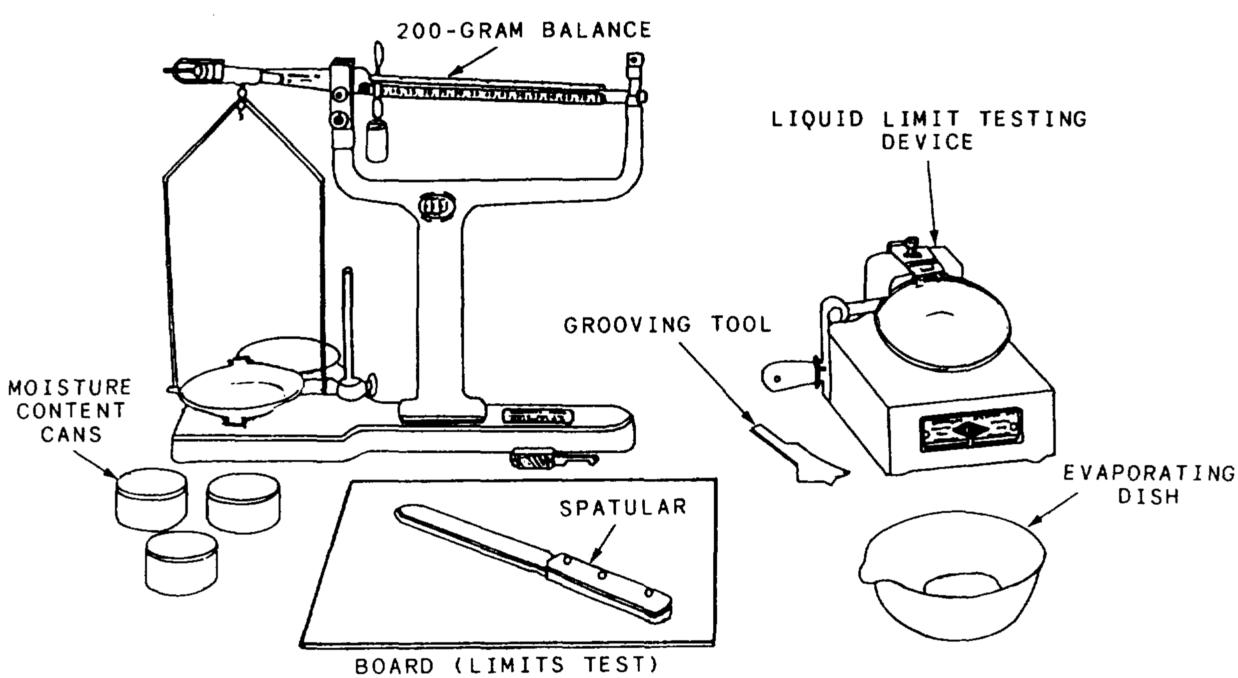


Figure 15-34.-Apparatus for determining Atterberg limits.

SCREWS. Manipulate the screws to adjust the height to which the cup is lifted. The point on the cup that comes into contact with the anvil of the machine should be exactly 1 cm above the anvil (the upper surface of the hard-rubber base of the machine). Check the adjustment by turning the crank at a rate of two drops per second. You should hear a slight click when the adjustment is correct.

Steps in the test procedure are as follows:

1. From the prepared test material, take a sample that weighs about 100 g and place a portion in the cup above the spot where the cup rests on the base. Squeeze the sample and spread it with as few strokes of the spatula as possible, taking care to prevent the air bubbles from getting trapped within the mass. With the spatula, level the soil as you trim it to a depth of 1 cm at the point of maximum depth. Divide the soil in the cup by making a groove with the grooving tool along the center line of the cam follower or hook that holds the cup. When you make the groove, hold the cup in your left hand with the hook upward, and draw the grooving tool, beveled edge forward, through the material downward away from the hook. With some soils (especially sandy soils and soils containing organic matter), it is not possible to draw the grooving tool through the specimen without tearing the sides of the groove. In such cases, make the groove with a spatula, using the tool only for final shaping. When made correctly, the groove is wedge-shaped in section; it is open at the bottom for a distance equal to the width of the tip of the grooving tool.

2. Attach the cup to the carriage and turn the crank at a rate of two revolutions per second. Count the blows as you continue to turn the crank until the two halves of the soil cake come into contact at the bottom of the groove along a distance of about 1/2 in. (fig. 15-35). Record the number of blows required to close the groove in this manner.

After you record the number of blows, remove the cup from the testing device. Remix and regroove the sample. Place the cup again in the testing device and repeat the test. If the number of blows on the second test differs from the number on the first by one or less, record both numbers on the data sheet and consider the test finished. If the number of blows on the second test differs by more than one, repeat the test until three successive tests give a reasonably consistent sequence. The average of the three is taken as the number required for the closure.

3. Remove a slice of soil approximately the width of the spatula (say about 10 g), extending from the edge of the soil cake at right angles to

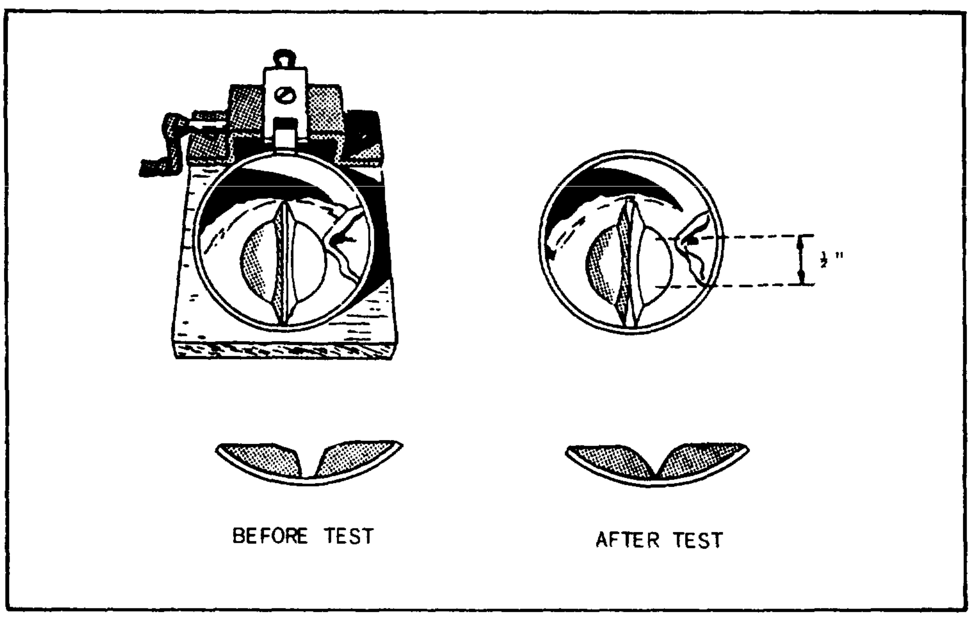


Figure 15-35.-Liquid limit test.

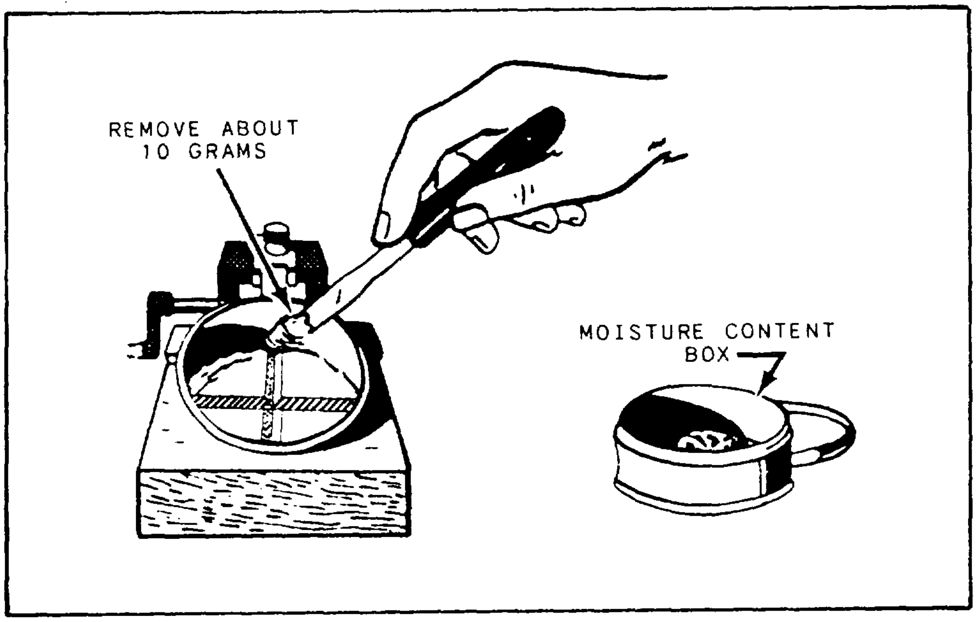


Figure 15-36.-Removing sample portion for moisture content.

the groove (fig. 15-36). Place this in a moisture content can, weigh it, and record the weight. Oven-dry and record the difference in weights. This is the weight of the water content.

4. Transfer the remaining soil in the cup to the evaporation dish. Wash and dry the cup and grooving tool. Reattach the cup in preparation for the next run.

5. Run at least five tests on each soil, with two closures above, two closures below, and one closure at or near the 25-blow line. An ideal spread is closures at 16, 23.5, 29, and 33 blows. If each testis perfect, the plotted line through all points is shown as a straight line. If some tests are imperfect, the operator can usually get good results by using the three plotted points lying most nearly in a straight line.

To determine the liquid limit, plot a FLOW CURVE on a graph like the one shown in figure 15-37. It is a semilogarithmic graph, in which the vertical coordinates are water content and the horizontal coordinates are number of blows. The flow curve is a straight line plotted as nearly as possible through three or more of the plotted points.

In figure 15-37, the first-run sample was tested three times for an average number of 16 hammer blows. The water content was 47.3 percent. On the graph, 16 and 47.3 are the coordinates of one of the three Xs shown plotted. The second-run sample indicated 24 hammer blows and 46.6 percent water content; these are the coordinates of another of the Xs plotted to the right. Coordinates for the third X are the hammer blows and water content for the third-run sample. The coordinates of the rest of the plotted points are as indicated by the hammer blows and water content for the succeeding runs. The plotted points in the graph may not form a straight line; however, the liquid limit line (or flow curve) is a straight line, passing nearly through the mean of the plotted points (fig. 15-37). The usual recommendation is that five or six trials be made so that the results are more representative.

The liquid limit (LL) is the water content for 25 blows; it is therefore indicated by the point of intersection between the flow curve and the vertical line representing 25 blows. The water content indicated is about 46.4 percent. This, when rounded off to 46, is the liquid limit.

The plastic limit of soil is the lowest water content at which the soil just begins to crumble when rolled into threads 1/8 in. in diameter, at slowly decreasing water content. First, prepare the sample as follows:

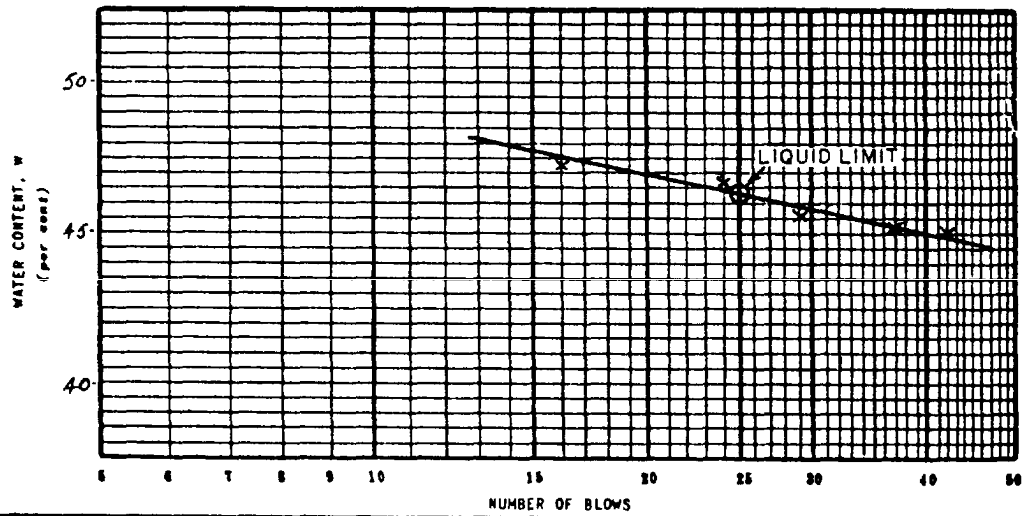
If you need only the plastic limit, take a quantity of soil weighing about 15 g from the prepared material in the evaporating dish. Place this air-dried soil in an evaporating

ATTERBERG LIMITS DETERMINATION			DATE: 1 June 19—
PROJECT: Britt Airfield		EXCAVATION NUMBER:	SAMPLE NUMBER: B-P3-1

LIQUID LIMIT, w_L

RUN NUMBER	1	2	3	4	5	6
TARE NUMBER	41	42	43	44	45	46
A. WEIGHT OF WET SOIL + TARE	44.41	44.89	41.07	41.27	41.17	40.91
B. WEIGHT OF DRY SOIL + TARE	41.08	41.52	38.16	38.39	38.32	38.08
C. WEIGHT OF WATER, W_w (A.-B.)	3.33	3.37	2.91	2.88	2.85	2.83
D. WEIGHT OF TARE	34.04	34.29	31.88	32.06	32.01	31.80
E. WEIGHT OF DRY SOIL, W_s (B.-D.)	7.04	7.23	6.28	6.33	6.31	6.28
WATER CONTENT, $w = (\frac{W_w}{W_s} \times 100)$ %	47.3	46.6	46.3	45.5	45.2	45.0
NUMBER OF BLOWS	15-17-16	23-24	29-28-30	33-33	37-38	41-42

LL	PL	PI=LL-PL
46	18	28



PLASTIC LIMIT, w_P

RUN NUMBER	1	2	3		NATURAL WATER CONTENT
TARE NUMBER	45	46	47		48
F. WEIGHT OF WET SOIL + TARE	56.21	55.15	60.60		58.72
G. WEIGHT OF DRY SOIL + TARE	55.90	54.89	60.10		57.82
H. WEIGHT OF WATER, W_w (F.-G.)	0.31	0.26	0.50		0.90
I. WEIGHT OF TARE	54.10	53.40	57.43		55.02
J. WEIGHT OF DRY SOIL, W_s (G.-I.)	1.80	1.49	2.67		2.80
WATER CONTENT, $w = (\frac{W_w}{W_s} \times 100)$	17.2	17.4	18.7		32.1
PLASTIC LIMIT, I_p (Average w)			18		

REMARKS		
TECHNICIAN (Signature): William Davis	COMPUTED BY (Signature): William Davis	CHECKED BY (Signature): Joseph Stephen

Figure 15-37.-Data sheet, Atterberg limits determination.

dish and thoroughly mix it with distilled water, adding water until the soil mass becomes plastic enough to be shaped into a ball easily. Take a portion of the ball weighing about 8 g for the sample.

Steps in the test procedure are as follows:

1. Squeeze and form the 8-g test sample into an oval-shaped mass. Roll this mass between the

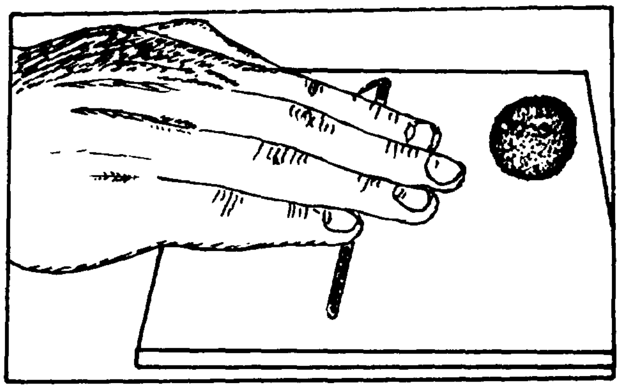


Figure 15-38.-Roll or thread test.

fingers and the test board (fig. 15-38) with just enough pressure to roll the mass into a thread of uniform diameter throughout its length. The rate of rolling should be between 80 and 90 strokes a minute, considering a stroke to be one complete motion of the hand forward from and back to the starting point.

2. When the diameter of the thread has been reduced to 1/8 in., break the thread into six or eight pieces (fig. 15-39). Squeeze the pieces together between the thumbs and fingers of both hands into a uniform mass roughly oval in shape, and again roll out into a thread. Continue this alternate rolling to a thread 1/8 in. in diameter, breaking, combining together, and rerolling. Do this until the thread crumbles under the pressure required for rolling and the soil can no longer be rolled into a thread. The crumbling may occur when the diameter of the thread is still greater than 1/8 in. This is considered a satisfactory end point, provided the soil has previously been rolled into a 1/8-in. thread at least once.

3. Gather the portions of the crumbled soil together, place it in the moisture content can, and determine the water content from the difference in weight before and after you oven-dry it.

4. Repeat the process on at least two additional specimens. All three tests should agree within 1 percent.

The plastic limit is simply the determined water content.

Plasticity Index

The PLASTICITY INDEX (PI) of a soil is the numerical difference between its liquid limit and its plastic limit; that is, PI = LL – PL. The PI that appears in figure 15-37 means plasticity index.

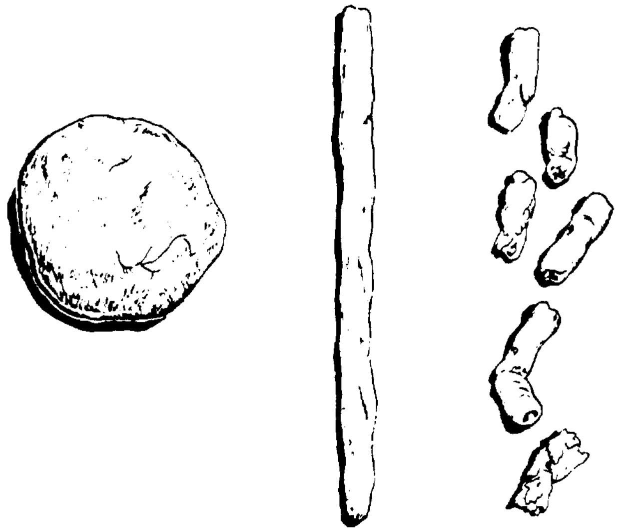


Figure 15-39.-Roll or thread test sample, before and after crumbling.

CONCRETE TESTING

Before delving into the remainder of this chapter, you may find it helpful to return to chapter 7 and review the topics concerning concrete. As you recall, in that chapter you studied concrete in terms of its use as a construction material, and you learned of the properties and requirements that comprise a good concrete. You also know that when concrete is placed in the field on a construction project, the concrete used must satisfy certain specified requirements. It is towards those properties and various requirements that concrete testing is directed.

CONCRETE TESTS

In concrete testing, as in soils testing, no single test will provide all of the information required. Rather, there is an array of tests that must be performed. The following describes those tests with which an EA is most commonly concerned.

Aggregate Tests

In order to provide the strongest and most durable concrete, the aggregate contained in the mixture must be the best possible in terms of gradation, shape, strength, and cleanliness. During the design of a concrete mixture, the aggregate selected for use must adequately meet those requirements. To determine this, various tests are performed. These include tests for

Table 15-4.-Recommended Slumps for Various Types of Construction

Types of construction	Slump, inches*	
	Maximum	Minimum
Reinforced foundation walls and footings	5	2
Plain footings, caissons, and substructure walls	4	1
Reinforced slabs, beams, and walls	6	3
Building columns	6	3
Pavements	3	2
Heavy mass construction	3	2
Bridge decks	4	3
Sidewalks, driveways, and slabs on ground	6	3

*When high-frequency vibrators are used, the values may be decreased approximately one-third; in no case should the slump exceed 6 inches.

gradation; specific gravity, absorption, and surface moisture; impurities, such as organic material, clay, or other water-absorbing particles; and soundness, which is the property of an aggregate to resist disintegration due to freezing and thawing. Although these tests are not included in this TRAMAN, you may refer to NAVFAC MO-330, *Materials Testing,* should you desire to learn more about them.

Slump Tests

As you are aware from your study of chapter 7, WORKABILITY is the relative ease or difficult y of placing and consolidating concrete. When placed, all concrete should be as stiff as possible, yet maintain a homogeneous, voidless mass. Too much stiffness, however, makes it too difficult or impossible to work the concrete into the forms and around reinforcing steel. On the other hand, too fluid a mixture is also detrimental. The measure of the workability or consistency of concrete is its slump, which is a design consideration that is inversely proportional to the stiffness of the mix. As shown in table 15-4, the recommended values for slump vary for different types of construction. To measure slump, either during the preparation of concrete trial batches or as a quality control check during construction, testers perform slump tests. The procedures for performing slump tests will be explained later in this chapter.

Strength Tests

In the design of concrete structures, the design engineer specifies given strengths that the final concrete products must be capable of attaining. When trial batches are prepared during mix design or as a quality control measure to ensure that concrete mixed or delivered in the field satisfies those specified strengths, the following tests are performed.

COMPRESSION TEST.— Compression tests are conducted to determine the compressive strength of concrete (or its ability to resist a crushing force). In this test, a standard test load is applied parallel to the longitudinal axis of a premolded and properly cured concrete cylinder of a standard size. When the testis properly conducted, a maximum load is obtained at the point at which the cylinder ruptures. With this maximum load, the compressive strength, measured in pounds per square inch (psi), can be easily calculated. Although the test procedures will be covered at the EA2 level, the procedures used to prepare the cylinders for testing will be discussed later in this chapter.

FLEXURAL STRENGTH TEST.— The flexural strength (modulus of rupture) test determines the flexural strength of concrete (or its ability to resist a breaking force). In this test, a standard

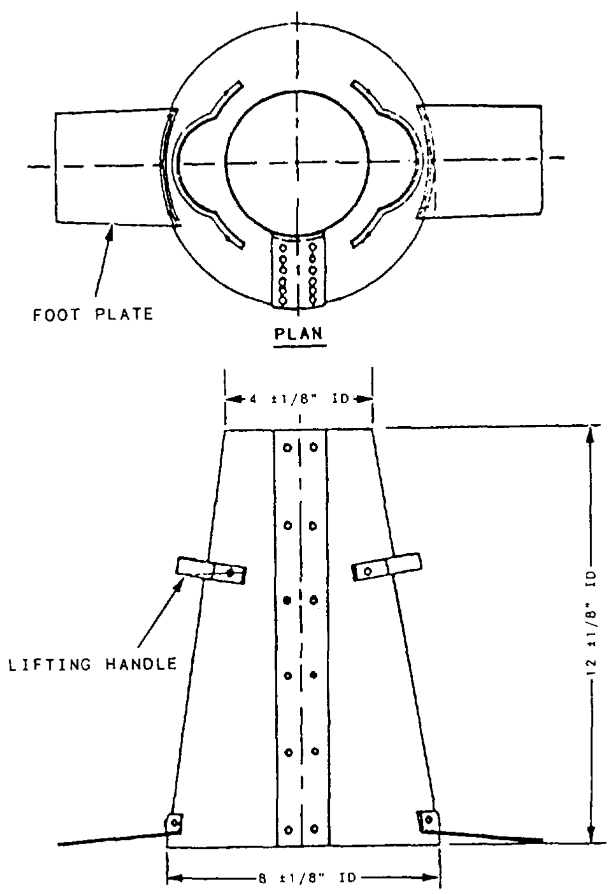


Figure 15-40.-Slump cone.

test load is applied perpendicular to the longitudinal axis of a standard size, premolded, and-properly cured concrete beam. From this test, the flexural strength, expressed in terms of modulus of rupture and given in psi, can be readily calculated. As with the compression test, only the procedures to prepare the test beams correctly will be discussed in this TRAMAN.

SLUMP TESTS

The slump test is performed on newly mixed concrete. To perform the test, you need a slump cone and a tamping rod. The slump cone (fig. 15-40) should be made of galvanized steel, 12 in. in height, with a base opening 8 in. in diameter and the top opening 4 in. in diameter. Both the top and bottom openings are perpendicular to the vertical axis of the cone. The tamping rod is a straight, steel rod that is 5/8 in. in diameter and approximately 24 in. in length. One end of the rod is rounded to a diameter of 5/8 in. (Do not substitute a piece of rebar.)

Sampling Procedures

Sampling (or obtaining) concrete for the slump test should be accomplished according to ASTM C 172. In this TRAMAN, only the procedure of sampling from a revolving drum truck mixer (TM) or agitator is discussed. If you should ever need to sample from a paving mixer, open-top truck mixer, or other type of equipment, be sure to refer to the most recent ASTM C 172.

Samples taken for the test specimens must be representative of the entire batch. This is accomplished by taking the samples at two or more regularly spaced intervals during discharge of the middle portion of the batch. Sample by repeatedly passing a scoop or pail through the entire discharge stream. Composite these samples into one sample for testing purposes. Be sure that the first and last portions of the composite sample are taken as quickly as possible, but never exceeding 15 min. If it is necessary to transport the samples away from the mixer to the place where the slump test is to be performed, combine the samples and remix them with a shovel to ensure uniformity.

Testing Procedures

Perform the slump test according to ASTM C 143. Be sure to start the test within 5 min after obtaining the final portion of the composite sample. In performing the test, first dampen the slump cone and place it on a flat, moist, nonabsorbent, rigid surface. From the composite sample obtained and while standing on the two foot pieces of the cone, fill the cone in three layers, each approximately one third of the volume of the cone. In placing each scoopful of concrete, rotate the scoop around the top edge of the cone as the concrete slides from it to ensure even distribution of concrete within the mold.

Rod each layer with 25 strokes of the tamping rod (using the rounded end), and uniformly distribute the strokes over the entire cross section of each layer. Rod the bottom layer throughout its depth. Rod the second layer and the top layer each throughout its depth so that the strokes just penetrate into the underlying layer. In filling and rodding the top layer, heap the concrete above the mold before the rodding is started. If the rodding results

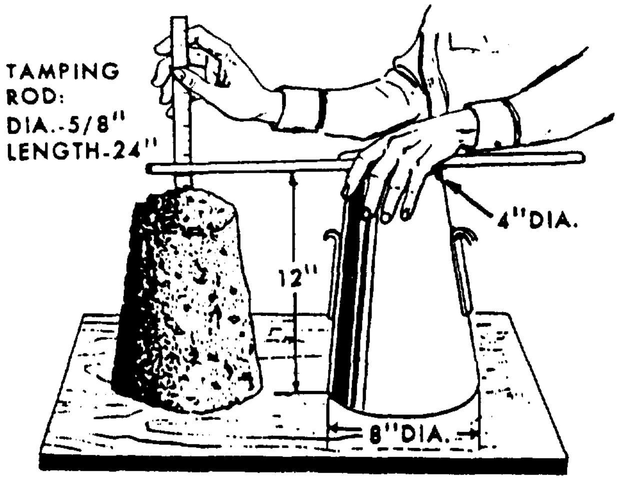


Figure 15-41.-Measurement of slump.

in subsidence of the concrete below the top edge of the cone, add additional concrete to keep an excess of concrete above the top of the cone at all times. After the top layer has been rodded, strike the surface of the concrete off flush by means of a screeding and rolling motion of the tamping rod. Immediately remove the slump cone from the sample by carefully and steadily lifting it straight up at the rate of 5 ± 2 sec for the height of the cone. Place the cone next to the test specimen. At this point, the entire test from the start of filling the cone to completing the removal of the cone should not exceed 2 1/2 min.

In measuring the slump, first place the tamping rod across the top of the cone so that it extends over the test specimen as shown in figure 15-41. Next, measure the vertical distance from the bottom of the rod to the average height of the subsided concrete specimen. This measurement is known as the SLUMP. If a decided falling away or shearing off of concrete from one side or portion of the specimen mass has occurred, disregard the slump measurement and make a new test on another portion of the sample. If two consecutive tests show a falling away or shearing off, the concrete probably lacks the necessary plasticity and cohesiveness for the slump test to be applicable.

After measuring and recording the slump, you have completed the slump test. As a supplementary procedure, however, tap the sides of the specimen gently with the tamping rod. The reaction of the concrete indicates its cohesiveness and workability. A well proportioned, workable mix gradually slumps to lower elevations and retains its original identity. A poor mix crumbles, segregates, and falls apart.

If the slump testis performed for a trial batch during concrete mix design, then too little, or too much, slump indicates the need for a new trial batch with revised ingredient proportions. When the test is performed as a quality control measure for a construction project, the slump obtained by testing will be compared to the specified slump for the concrete used for that particular project. If too little, or too much, slump has been determined by the test, then the quality control inspector, or other appropriate authority, will determine whether to accept or reject the concrete.

PREPARATION OF CONCRETE SPECIMENS

Concrete specimens that are representative of a distinct batch of concrete must be sampled and analyzed for the purpose of quality control.

Cylinder Specimens

Tests are performed on concrete cylinder specimens to evaluate the compressive strength of the concrete. The standard cylindrical specimen is 6 in. in diameter by 12 in. long.

STANDARDS FOR CYLINDER MOLDS.— Cylinder molds should be made of steel, cast iron, or other nonabsorbent material that does not react with concrete containing portland cement or other hydraulic cements. Molds should hold their dimensions and shapes under conditions of severe use. They should be able to hold, without leakage, the water poured into them. Before using the molds, coat them lightly with mineral oil or a suitable nonreactive form of release material.

FILLING CYLINDER MOLDS.— Place the molds on a level, rigid surface, free of vibration or other disturbances, at a place as near as possible to the location where they are to be stored for the first 24 hr.

Fill the molds with concrete specimens (taken as previously described for the slump test). The number of layers is determined by the mold size

Table 15-5.-Numbers of Layers Required for Specimens

Specimen Type and Size, as Depth, in. (mm)	Mode of Compaction	Number of Layers	Approximate Depth of Layer, in (mm)
Cylinders:			
12 (305)	rodding	3 equal	4 (100)
Over 12 (305)	rodding	as required	4 (100)
Beams:			
6 (125) to 8 (200)	rodding	2 equal	half depth of specimen
Over 8 (200)	rodding	3 or more	4 (100)

(table 15-5). As you fill a mold, rotate each scoopful of the concrete around the top edge of the mold as the concrete slides from it. This ensures a symmetrical concrete distribution within the mold.

Tamp each layer with the tamping rod, distributing the strokes uniformly over the cross section of the mold and penetrating the underlying layer. Tamp the bottom layer throughout its depth. The number of roddings is determined by the diameter of the cylinder. (See table 15-6.)

After tamping the top layer, strike off the surface with a trowel or rod so that the concrete fills the mold exactly. Do not add unrepresentative concrete to an underfilled mold. If voids are left by the tamping rod, tap the sides of the mold lightly with your open hand to close the voids. If desired, cap the top surface of freshly made cylinders with a thin layer of stiff portland cement paste, which you should then permit to harden and cure with the specimens. When finished, move the specimens to the storage place and leave them undisturbed for the initial curing period.

CURING AND STORING CYLINDERS.– During the initial curing period of test specimens, be sure to take precautions to prevent the evaporation and loss of water in the specimens. Cover the specimens with a sheet of plastic. You may place wet burlap on top of the plastic to help retard evaporation, but be sure that it does not come in contact with the concrete surface. The exterior of cardboard molds must be protected against the absorption of water or molds may expand, allowing the specimens to be damaged. The test specimens now begin the initial curing period of 24 hr ± 8 hr. Test specimens maybe transported after the initial curing period, providing they remain in the mold. Upon completion of the initial curing period, remove the specimens from the molds and place them immediately in a moist environment with water maintained on their surface at a temperature of 73.4°F ± 3° (23°C ± 1.7°). You can also obtain the required condition by immersing the specimens in saturated limewater or by storing them in a moist room or cabinet. Do not expose test specimens to a flow of running or dripping water.

CAPPING CYLINDERS.— The ends of compression-test specimens must be planed within 0.002 in. and within 0.5 degrees of being perpendicular to the axis of the cylinder.

Specimens formed in strong metal molds having accurately flat baseplates can be capped with neat cement at 2 to 4 hr after molding. A stiff paste of portland cement and water is made at the time the cylinder is molded so that the capping mixture will have shrunk before application. Any free water or laitance (layer of fine particles on the surface) is removed from the end of the specimen. The paste is applied to the top of the concrete and worked with a flat plate until it is smooth and level with the top of the mold.

Hardened concrete specimens may be ground to place ends or capped with a material having greater compressive strength than the concrete. Prepared mixtures of sulfur and granular materials, special high-strength gypsum plasters, and neat high-early strength cement are satisfactory capping materials (ordinary low-strength plaster of paris, compressible rubber, or fibrous materials are not suitable for caps). You should apply these materials in a plastic state and finish them to the desired plane surface by applying glass or metal

Table 15-6.-Number of Roddings to be Used in Molding Cylinder Specimens

Diameter of Cylinder, in. (mm)	Number of Strokes/Layer
6 (152)	25
8 (200)	50
10 (250)	75

plates and squeezing out excess material to provide a cap that is as thin as possible. Sulfur caps may be applied in time to harden for at least 2 hr before testing. Plaster caps cannot be stored over 4 hr in a moist room. Neat cement caps must be aged 6 days or more in a moist room (2 days when Type II cement is used). During capping, protect moist, cured specimens against drying by covering them with wet burlap.

Beam Specimens

Tests are performed on concrete beam specimens to evaluate the flexural strength of the concrete. The standard beam specimen is 6 in. by 6 in. by 21 in. (152 mm by 152 mm by 532 mm) for concrete in which the maximum size of the coarse aggregate is 2 in. (50 mm). When the maximum size of the coarse aggregate exceeds 2 in. (50 mm), the smaller cross-sectional dimension is to be increased to at least three times the nominal maximum size of the coarse aggregate. All beam specimens prepared in the field are to be at least 6 in. wide and 6 in. deep unless required otherwise by project specifications.

STANDARDS FOR BEAM MOLDS.— The beam molds are to be smooth on all interior surfaces and free from warpage. The molds are to produce specimens that do not exceed the required cross-sectional dimensions by 1/8 in. The length of the specimens is not to be more than 1/16 in. shorter than the specified length, but it may exceed that length.

RODDING.— Place the concrete in the mold in the required number of layers. (See table 15-5.) Rod the bottom layer throughout, distributing the strokes uniformly over the cross section of the mold. When rodding the upper layers, allow the rod to penetrate the previous layer 1/2 in., providing the previous layer is 4 in. or less and 1 in. if the previous layer is greater than 4 in. The number of strokes' per layer is one for each 2 $in.^2$ (13 cm^2) of the top surface area of the specimen. After each layer is rodded, spade the concrete with a trowel along the sides of the mold to help in the removal of surface voids. Strike off the top surface with a straightedge, and finish it with a wooden float.

CURING.— YOU should cure the beam specimens in the same manner as the cylinder specimens with the following exceptions: (1) extend the initial curing period to 48 hr ± 4 hr and (2) do not allow the surface of the beam specimen to become dry between the time of removal from curing and the completion of testing.

When transporting specimens from the field to the laboratory, be sure they are sufficiently cushioned to protect them from damage by jarring. Additional measures are required to prevent damage by freezing temperatures and moisture loss. You can prevent moisture loss by covering the specimens with plastic or surrounding them by wet sand or wet sawdust.

CHAPTER 16

ADMINISTRATION

This chapter is provided to help you prepare for the "job ahead" and to acquaint you with your duties and responsibilities as an EA3 in a typical SEABEE billet. This chapter also discusses the training requirements and methods of preparing for in-rate advancement and discusses your role, in general, in the overall organization of the Naval Construction Force (NCF).

THE ENGINEERING AID RATING

The Engineering Aid rating is a general rating, as are all others in the Occupational Field 13 ratings. The scope of duties and responsibilities follows.

SCOPE OF DUTIES AND RESPONSIBILITIES

Engineering Aids plan, supervise, and perform tasks required in construction surveying, construction drafting, planning and estimating, and quality control; prepare progress reports, time records, construction schedules, and material and labor estimates; establish and operate a basic quality control system for testing soils, concrete, and other construction materials; prepare, edit, and reproduce construction drawings; and make and control surveys, performing such tasks as running and closing traverses, running level circuits, staking out construction projects, and obtaining other field data necessary for engineering studies or for actual construction of any type of structure that may come under the cognizance of the NCF.

IMPORTANCE OF THE EA RATING

The necessity for naval construction need not be emphasized, and each of the Occupational Field 13 ratings performs a vital and indispensable function in naval construction. In one sense, however, the function of the EA is of special significance. By merely studying the scope of the EA's duties and responsibilities, one can deduce that the EA's functions relate to the WHOLE construction project, rather than to one particular phase of it. From the project's conception until its final completion report, the EA contributes directly or indirectly towards its completion.

Some of your efforts might not be measurable in terms of work-in-place; however, they may be the deciding factor as to the accuracy and quality of the finished project. Your alertness in compiling man-hour expenditures and progress reports may have alerted the operations officer to see lagging work schedules. This enables the operations officer to readjust timetables and priorities to meet standing completion requirements.

The foregoing are just a few examples of your support to the mission of the NCF. You will encounter and learn a majority of your tasks through on-the-job training (or informal schools). The specific tasks you perform will depend upon your particular duty assignments and the prevailing contingency—operational, logistical, or both. Some of the various support assignments that you, as an EA, might encounter are discussed in later sections.

TYPICAL EA BILLETS

Generally, most of the billets for an EA3 on sea duty are in the Naval Mobile Construction Battalion, commonly called the "green machine. " This is where most of your skills as an EA will be put to use, honed, and tested. The experience you will gather from this type of duty is vast, provided you take on the challenges of your rate. For shore duty, assignment to public works activities is common to an EA3. However, other types of independent sea, shore, or oversea billets are available to you. Ask your leading petty officer (LPO) or your unit career counselor for additional information.

Assignment to an NMCB Operations Department

Normally, EAs reporting to a SEABEE unit for duty will be assigned to the operations department (S-3). The organization of a SEABEE operations department—be it in a staff, in a battalion, or in any detached unit—is similar in basic composition, with minor variations to suit the type of unit, its mission, and the prevailing conditions. In support of the construction organization, the specific functions of the operations department include planning and estimating, engineering, monitoring/reporting, quality control, disaster preparedness, minicomputer operations, and resources control. Figure 16-1 shows a standard organizational chart of a Naval Mobile Construction Battalion operations department. Using this chart as a guide, the operations officer may expand or modify the organization to suit the mission of the battalion and the availability of personnel to fill the billets.

In the following sections you will learn where you fit into the organization and how your duties and responsibilities relate to the functions of the operations department. The information is taken mainly from the *Naval Construction Force Manual*, NAVFAC P-315, and some actual observations currently prevailing in the NMCBs.

ENGINEERING DIVISION.— Most EAs are assigned to the engineering division of the operations department. Therefore, it is important that you become familiar with the overall organization breakdown of the division and the duties and responsibilities of personnel within the division. As you study the following sections, try to visualize how your contributions to the division will assist in accomplishing the overall mission of the division and the mission of the operations department. In other words, see where you fit into the "big picture."

The engineering division is under the direction of the engineering officer (fig. 16-1), who is normally a Civil Engineer Corps (CEC) officer. The engineering officer and his staff are

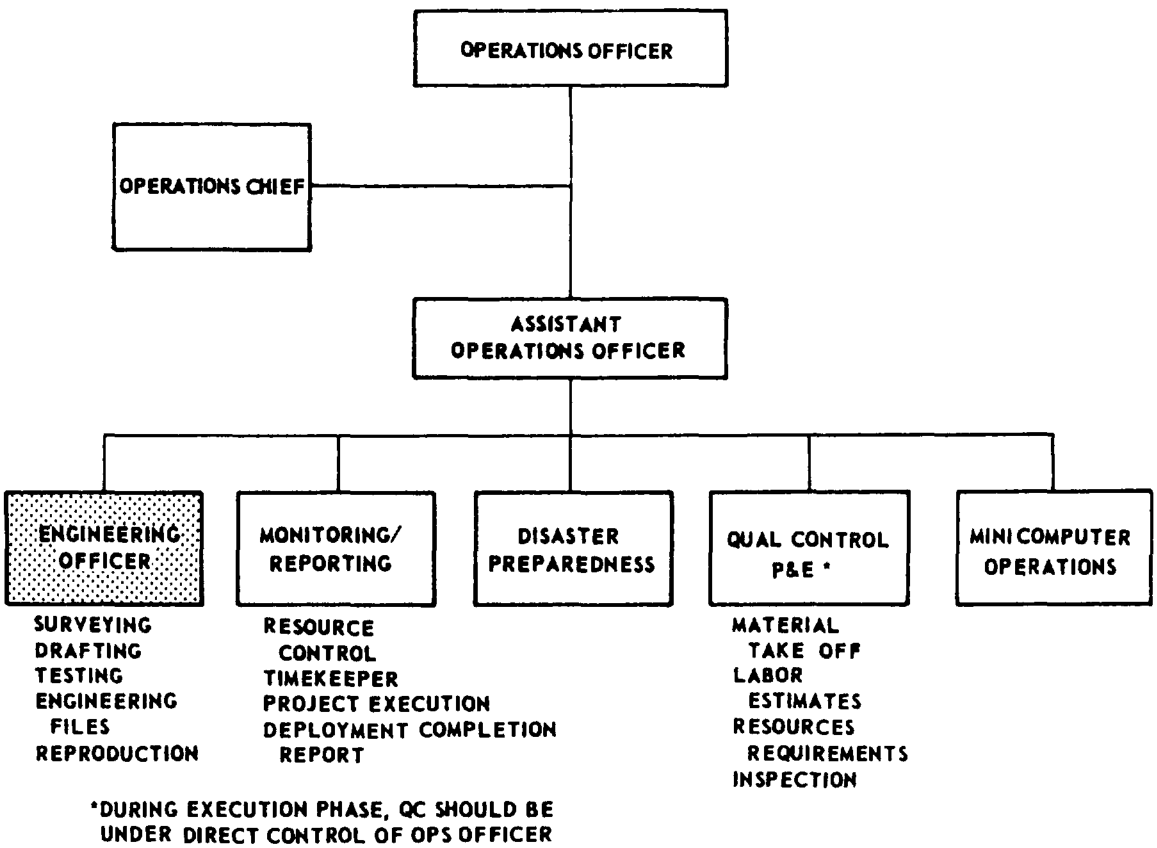


Figure 16-1.-Standard operations department organization.

responsible for providing all engineering services and design necessary for the successful conduct of the construction program. Their specific responsibilities are as follows:

1. Providing guidance and support to the company deployment planning team
2. Reviewing all plans for sound engineering practices and practicability of planning and construction
3. Resolving field problems relative to errors or revisions in design
4. Briefing company commanders on engineering aspects of new projects
5. Providing liaison with customers concerning engineering and design
6. Providing liaison with other divisions in the operations department in the interest of the successful conduct of the construction program

The engineering division is also responsible for, and renders technical support in, the following areas:

1. Providing technical engineering construction inspection by the engineering officer on behalf of the operations officer to ensure that projects are built according to the plans and specification and that quality workmanship prevails at all times
2. Providing survey services for the construction companies, as required
3. Providing up-to-date drawings and specifications for projects in progress
4. Providing soils and materials testing and evaluation services
5. Maintaining as-built drawings and providing copies, as appropriate, to customer commands

MONITORING/REPORTING DIVISION.— The monitoring/reporting division of the operations department is headed by the assistant operations officer. This division is sometimes referred to as the management division of the operations department. The division is normally staffed by the operations Yeomen and the battalion timekeeper. Sometimes the position of timekeeper/computer is assigned to capable EAs.

The monitoring/reporting division collects, compiles, and analyzes all information related to the construction operations. This information is used in the preparation of construction operations reports, including the Deployment Completion Report, the Project Execution Report, the Monthly Situation Reports, and any other special reports that may be required by higher authority. The engineering division will be required to assist in the preparation of these reports by supplying technical information concerning construction projects. Some reports may be compiled from existing records, and others may require special investigation and research.

For example, let us take the preparation of a Monthly Situation Report. Each battalion submits a monthly report of operations to either COMCBLANT or COMCBPAC (depending on what theater of operation it is in). Copies are sent to the commander, NAVFAC, and to administrative, military, and operational commanders concerned. This report is a concise review of the activities of the battalion during the month, regarding accomplishments, problems, and capabilities. It includes such information as planning, construction, welfare, morale, discipline, safety, training, and equipment. The numbers of officers and enlisted men are shown for the battalion and for all detachments, specifying the method of movement.

Enclosures to the Monthly Situation Report are specified by the commander, NCF. The following are generally included:

1. Progress and performance reports
2. Progress photographs
3. Labor distribution reports
4. Financial reports
5. Equipment status reports
6. Training reports
7. Summary of important events that occurred in the battalion during the reporting period

There are detailed instructions covering the preparation of the Monthly Situation Report and other reports, so your only problem is the compilation of the data that will go with them.

Besides the aforementioned reports, the monitoring/reporting division is responsible for the following:

1. Maintaining a complete status folder on each project
2. Maintaining complete and accurate timekeeping records and labor analysis reports
3. Maintaining and updating visual status boards required for effective construction management including the following: (1) company personnel strength, (2) project status, 3) labor analysis, and (4) project schedules

4. Preparing project completion letters according to applicable instructions from higher authority

5. Maintaining constant liaison with the material liaison officer

The monitoring/reporting division maintains constant coordination and works closely with the quality control or planning and estimating division and the company deployment planning team on the technical aspects of the project, progress reports, and master scheduling.

Assignment to a Typical Public Works Department

SEABEEs receiving orders to a shore or overseas shore activity other than a SEABEE staff or school command are normally assigned to the public works department (PWD) of the activity. EAs assigned to PWDs may fill several different types of billets, depending on the organization of the department and the capabilities of the EAs assigned. Although most PWD jobs are filled by civilians, military billets do exist to implement rotation of Occupational Field 13 personnel from sea to shore duty. Most of the EA public works billets are in the engineering division, where the EA works hand in hand with civil service personnel in performing drafting and/or surveying tasks. Senior EAs with planning and estimating or inspecting experience may be assigned to the facilities management engineering division to work as planners and estimators or maintenance inspectors. Sometimes when there is a shortage of senior military personnel in the facilities management engineering division, EAs and other Occupational Field 13 petty officers are trained for planning and estimating or maintenance inspecting.

A unique situation exists at most public works departments. Your military duties and responsibilities will fall under military supervision, whereas your professional work will be directly supervised by a civilian engineer. Adjusting to this situation may be difficult at first, but as an alert EA, you will benefit from the vast experience of the professional civilian engineer. A good working relationship between you and your civilian co-worker is of the utmost importance. Once this relationship is established, duty at a public works department becomes interesting and rewarding.

The basic organization for a public works department is shown in figure 16-2.

ENGINEERING DIVISION.— The public works engineering division (fig. 16-2) is responsible for all matters pertaining to engineering studies and reports, including preliminary designs and estimates for special repair and improvement projects; for engineering design, including development of plans and specifications; and for the maintenance of technical plan files and records. This division is responsible for preparation of shore facilities development reports and for the submission of basic data required by the NAVFAC engineering field division director for preliminary engineering studies.

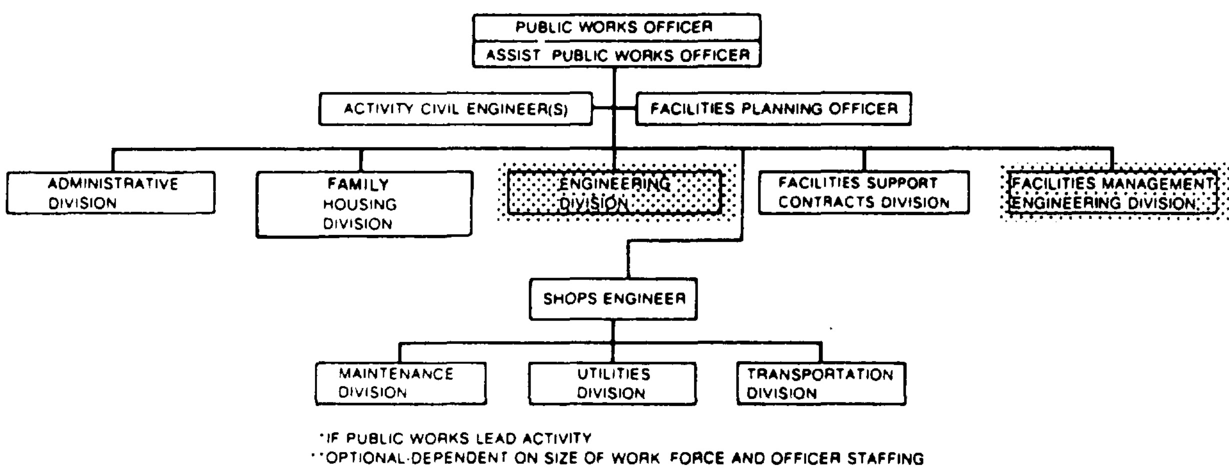


Figure 16-2.-Standard organization for a public works department.

Whenever the work load justifies or requires such action, the engineering division may be subdivided into the following branches:

1. Electrical branch
2. Mechanical branch
3. Architectural and structural branch
4. Civil branch
5. Plans and specifications branch

In some PW departments, it will be desirable to combine the mechanical and electrical branches or to merge the civil branch into the architectural and structural branch. In all cases, surveying work is performed as part of the civil component.

The PW officer establishes an engineering division to handle only routine work. He relies upon the engineering field division of NAVFAC for the design of major public works and public utilities, for the preparation of specifications in connection with them, and for the engineering investigations in specialized fields.

PW departments with limited work load and staffing may combine the engineering and maintenance control components into a single engineering division.

As mentioned previously, the majority of the EAs assigned to public works activities will work in the engineering division. With the exception of supervision, your tasks, such as design, reproduction, surveying, and so forth, will be similar to those performed in the engineering division of the NMCB. Often you will be the only EA assigned to a particular public works activity; therefore, your supervisory duties, if any, will be limited.

MANAGEMENT ENGINEERING FACILITIES DIVISION.— This is the division in the public works department whose entire effort is directed toward maintenance management. It is responsible for the integration of a maintenance work load program; the screening and classifying of all work requests, including emergency-service-type work, before submission to shops for accomplishment; the continuous inspection of public works and public utilities to reveal the need for maintenance work; the preparation of manpower and material estimates for job orders; the determination of the need for engineering advice and assistance; and the initiation of requests to the public works officer for approval to perform work by contract. The facilities management engineering division may be composed of the following branches:

1. Inspection branch
2. Planning and estimating branch
3. Work reception and control branch

At some PWDs, the inspection branch is supplemented with experienced BUs, CEs, UTs, SWs, and a few EAs with broad construction experience. Public works departments that are primarily staffed with SEABEEs may have senior or master chief petty officers for the inspection branch and planning and estimating branch supervisors.

Other EA Billets

As mentioned earlier, you, as an EA, maybe offered a variety of available billets or be given orders to a particular unit as the needs arise. Other types of billets for EAs include assignment to Construction Battalion Units (CBUs), Naval Oceanographic Units, Naval Support Force Antarctica (NSFA), Underwater Construction Teams (UCTs), SEABEE teams, and various other commands. Senior EAs are commonly assigned to SEABEE headquarters or regimental staff; as instructors at one of the Naval Construction Training Centers (NCTCs); as personnel detailers at Naval Manpower Procurement Center (NMPC); and as writers of advancement examinations and training manuals at the Naval Education and Training Program Management Support Activity (NETPMSA).

ADMINISTRATIVE DUTIES

As an EA3, you have a great deal to learn about your profession, including the development of skills related to drafting, surveying, materials testing, quality control, and eventually planning and estimating. However, from time to time, you will be called upon to demonstrate your supervisory abilities. Your duties and responsibilities as a supervisor will probably be limited, but they will gradually increase as you advance in your career development.

Becoming an EA3 is a big step in your naval career. The Navy imposes special trust and confidence in you. In return, the Navy expects you to be professionally competent and capable of instructing and supervising your subordinates. Your example of leadership and responsibility will influence others, so you must always exhibit a strong sense of personal integrity and dedication to your work and to the Navy.

The most challenging task you will have is adjusting to your role as a supervisor. Now is the time to start preparing yourself for the job ahead. Prior knowledge of both professional and administrative duties will put you ahead. Proper training and diligent study will prove itself beneficial when you are called upon to lead others.

To help you prepare for the job ahead, we will acquaint you with some of the common administrative and professional duties and responsibilities of an EA3. We will not attempt, however, to discuss the basic techniques of leadership; they are adequately covered in *Military Requirements for Petty Officer Third Class,* NAVEDTRA 10044, and *Military Requirements for Petty Officer Second Class,* NAVEDTRA 10045 (latest revisions). You need to carefully review those basic leadership techniques and apply them, where applicable, in all phases of your job. Also, in this section, you will learn to recognize the scope of other general duties and responsibilities associated with an EA3 in a typical SEABEE billet or assignment.

Several other administrative duties and responsibilities that you, as an EA3, may be exposed to or tasked with in your current assignment may be that of an EA2 or higher. You will notice that this section, for the most part, will discuss only your duties as outlined in the current EA3 occupational standards.

ASSIGNMENT AS TEAM LEADER

Normally, assignment as team, party, or crew leader is awarded to you at the EA2 level. However, in some cases in which you hold seniority in years over the rest of the junior personnel assigned to your team or section, you will be called upon to perform EA2 duties and occupy a position of higher responsibility. EA3 supervisory roles have been, at most times, assignments as party chief of a survey crew or a drafting room supervisor.

In general, your duties as a crew leader or party chief will involve planning work assignments, supervising, coordinating your work with the work of other teams, initiating requisitions, and keeping time cards. Information that will aid you in carrying out these duties is given below.

Planning Work Assignments

Proper planning saves time, effort, and money for the Navy and makes the job easier for all concerned parties. The following pointers will help you in planning day-to-day work assignments.

UNDERSTAND THE TASK CLEARLY.— When you are assigned a task, whether in writing or orally, the first thing you should do is make sure you fully understand just what is to be accomplished. Don't be afraid to ask questions. Find out the answers from those in a position to supply the information you need. Make sure you know the priority of the project, required time of completion, and any special instructions that must be followed. When the task is assigned orally, take detailed notes. Don't leave anything to memory; you might forget important information or instructions. A good supervisor carries a notebook at all times.

KNOW THE CAPABILITY OF YOUR CREW.— You should always consider the capability of your crew when planning for the accomplishment of each assigned task. With this in mind, you can determine who is to do what and how long it should take to finish the job. Realizing that idleness tends to breed boredom and discontent, plan to have another job ready to start as soon as the first one is finished.

ESTABLISH DAILY GOALS.— Each workday, encourage your crew to work together as a team to accomplish these goals. You want your goals to be such that your crew will be kept busy, but make sure they are "realistic" goals. During a contingency, people will make a tremendous effort to meet the deadline. But these people are not machines. When there is no anticipated urgency, they cannot be expected to continuously achieve an excessively high rate of production. In your planning, you should allow for those things that do not contribute directly to the accomplishment of the assigned task, such as in-house technical training, safety stand-down and other administrative matters.

SELECT PROPER METHODS, EQUIPMENT, AND SUPPLIES.— When you are planning an assigned task, you should consider every possible method that could be used to accomplish the task. If there is more than one way of doing a particular job, make sure the method you select is the best way. After selecting a method, analyze it to see if it can be simplified with a resultant saving in time and effort.

When you are planning for surveying operations, a vital step is the selection of proper required equipment and supplies. Proper selection of surveying equipment may greatly affect the end result of a survey. Forgetting to bring certain equipment or supplies to the jobsite is one of the most common mistakes made by supervisors. Nothing is more frustrating than to arrive at the jobsite only to discover that "someone" forgot to bring a tripod for the transit. The best way to minimize this embarrassing situation is to prepare an equipment and supply checklist for each job assignment and double-check the list after gathering all the items to make sure nothing was omitted. If more than one job is planned, include sufficient equipment and supplies to accomplish all jobs.

The same planning steps apply to drafting assignments. Certain drafting assignments are difficult to accomplish without proper equipment and supplies. As you gain experience, you will devise methods that will enable you to improvise with the equipment and supplies you have on hand.

Supervision

After a task has been properly planned, it is necessary to supervise the job carefully to ensure that it is completed properly, safely, and on time. Some pointers that will aid you in supervising work teams are outlined below.

KEEP THE CREW WELL INFORMED.— Before starting a job, make sure your crew knows what is to be done. Give instructions clearly and urge your people to ask questions about any points that are not clear to them. Explain how the job is related to other jobs and to the overall mission. Make sure that each crew member knows exactly what is expected of him and what his responsibilities are.

A crew performs much more efficiently when it is well informed. Be sure each crew member knows all pertinent safety precautions and wears safety apparel where required. Check all equipment and tools before use to ensure they are in safe condition. Do not permit the use of dangerously defective tools and equipment; see that they are turned in for repair immediately.

While the job is under way, check from time to time to ensure that the work is progressing satisfactorily. Determine if the proper methods and equipment are being used. If a member is doing a job incorrectly, stop him and point out his mistakes. Then explain the correct procedure and check to see that he follows it. In checking the work of your crew, try to do it in such a way that your men will feel that the purpose of your checking is to teach, guide, and direct, rather than to criticize and find fault.

When time permits, rotate your crew members to various jobs. Rotation gives them varied experience and will help ensure your having somebody who can do the work if a member is hospitalized, transferred, or on leave.

SEEK TEAMWORK.— A good supervisor should be able to get others to work together in getting the job accomplished. You should maintain an approachable attitude towards your men, making them feel free to come to you and seek your advice when in doubt at any time during the project. Emotional balance is especially important; a supervisor cannot become panicky before his men, unsure of himself in the face of conflicting forces, or pliable with influence. You should use tact and courtesy in dealing with your men and not show partiality to certain members of the work team. You should keep your men informed on matters that affect them personally or concern their work. You should also seek to maintain a high level of morale, keeping in mind that low morale can have a definite effect upon the quantity and quality of work turned out by your men.

The above is only a brief treatment on the subject of supervision. As you advance in rate, you will be spending more and more of your time in supervising others, so let us urge that you make a continuing effort to learn more about the subject. Study books on supervision as well as leadership. Also, read articles on topics of concern to supervisors, such as safety, training, job planning, and so forth, that appear from time to time in trade journals and other publications. There is a big need in the Navy for petty officers who are skilled supervisors. So, consider the role of supervisor a challenge and endeavor to become proficient in all areas of the supervisor's job.

Cooperation

If a project is to run smoothly and be completed on time, all crew leaders or supervisors must coordinate their work efforts and cooperate with one another as one big team. Most surveying operations are performed to guide the work done by other construction crews. You must therefore work closely with other crew leaders to ensure that your surveys are timely and do not delay the overall project. Cooperation with other supervisors will eliminate many problems that would otherwise arise when you are coordinating work efforts. In effect, you are merging your ideas and efforts to make the project run smoothly.

Cooperation is also essential to your success as a drafting supervisor. Consult the Builder crew supervisor on design problems and construction methods. Spending too much time on unnecessary details could delay the job if the Builders are awaiting the drawings to start the job. So right from the start, get into the habit of cooperating with other supervisors, and you will soon gain their respect as well as the respect of your superiors and your crew members.

MAINTAINING FILES

Maintaining file records, or simply "filing," is one job an EA needs to learn fast and well. When you are transferred to a new unit or command, chances are good that you will be involved in organizing and keeping track of a variety of engineering drawings normally found in the drafting and reproduction section. Your biggest challenge in filing is to make it possible for any single drawing (sheet), as well as the record pertaining to that particular drawing, to be readily located. Since most filing cabinets or protected stowage receptacles are limited in space, you may develop an ingenious approach to a highly organized filing system.

You must keep in mind that each engineering drawing is commonly identifiable by a drawing number assigned by the agency (such as NAVFACENGCOM) that made the drawing. The first major file breakdown for drawings, then, is a breakdown into separate files for the different agencies that have supplied the drawings. Within each agency file, the most convenient way to file drawings and prints is by the numerical sequence of drawing numbers.

Filing Original Copies

Original drawings and sepia copies are filed flat-NEVER folded. For large size originals, use shallow-drawer file cabinets of the type shown in figure 16-3. Smaller size drawings are generally stowed on edge in the standard deep-drawer-type cabinet, as shown in figure 16-4. Each drawer is divided into compartments by stationary partitions, and in each compartment there is a "compressor spring" to keep the drawings on edge and in a compressed stack.

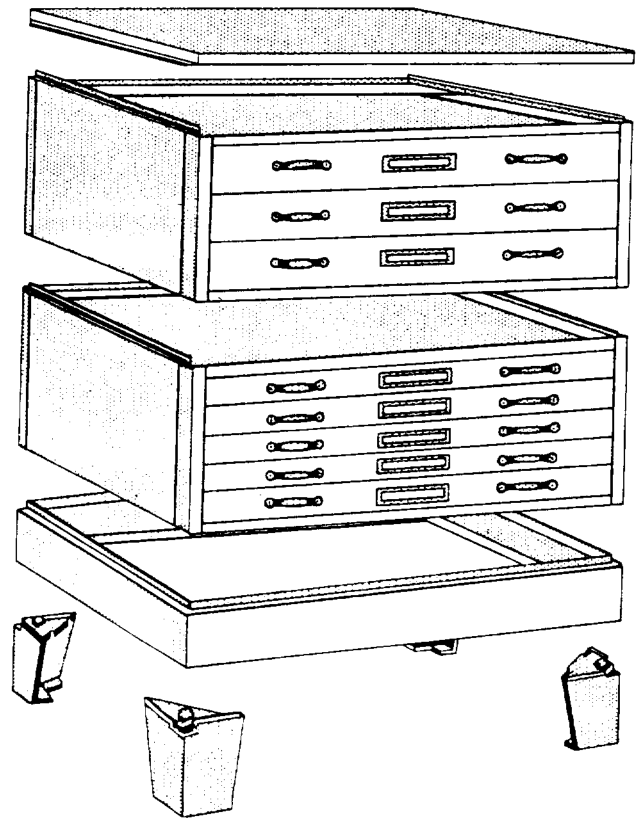


Figure 16-3.-Shallow-drawer cabinet for filing large original drawings, tracings, and negatives.

Filing Prints and Data

Prints are handled in a manner appropriate for their current status. Prints of drawings for active projects are generally placed on STICK FILES for easy reference. Stick files are either manufactured metal components or locally prepared strips of wood. Inactive prints, such as those from completed projects and some as-built drawings, are either stowed flat in shallow-drawer file cabinets (fig. 16-3) or folded and stowed in the standard deep-drawer-type cabinet (fig. 16-4). Extra sets of project drawings are sometimes rolled and stowed in some type of cylindrical plastic or cardboard tube.

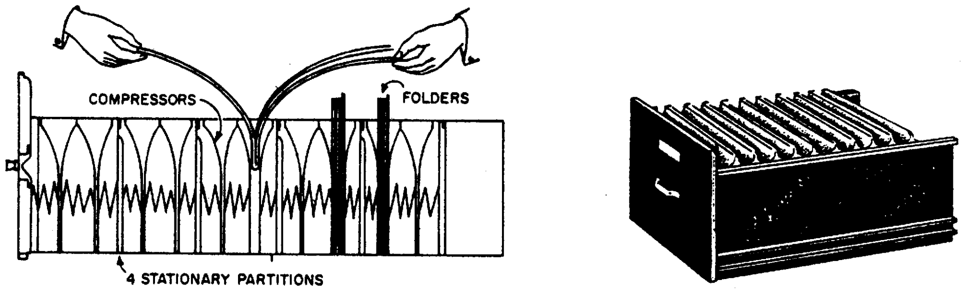


Figure 16-4.—Drawer of cabinet used for filing small original drawings, tracings, and negatives.

A print larger than size B is folded in accordion-pleat type folds in such a manner as to ensure that the drawing number is outside after the print has been folded. Final folded size should be 8 1/2 by 11 in. You should make yourself a plastic or plywood 8 3/8- by 10 7/8-in. "folding guide" or procure a ready-made one. The steps in folding a large print are as follows:

1. First, fold the print into 10 7/8-in. lengthwise accordion-pleat folds. Lay the print face-down, and start by turning the edge containing the drawing number, using the folding guide, as shown in figure 16-5. Use a small block of wood, like the one shown in the figure, to compress the crease.
2. Turn the print over and make the next lengthwise fold, as shown in figure 16-6. Continue turning over and folding until the width of the drawing is used up.
3. Place the lengthwise-folded drawing so that the side on which the drawing number appears is down. Begin at the end that contains the drawing number, and make the first 8 1/2-in. crosswise accordion-pleat fold, using the folding guide, as shown in figure 16-7.
4. Turn the print over and make the next fold. Continue until the length of the drawing is used up.

Data related to drawings discussed above, such as correspondence, should be filed according to SECNAVINST 5210.11 (series), or if a limited number of drawings are affected, they can be filed by drawing numbers in a separate drawer or cabinet. If a separate folder for each project is

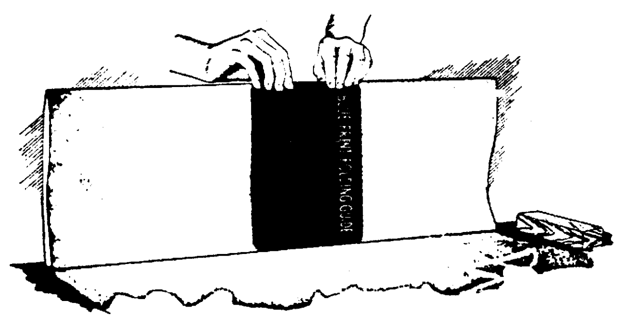


Figure 16-6.-Making second lengthwise fold in a large print.

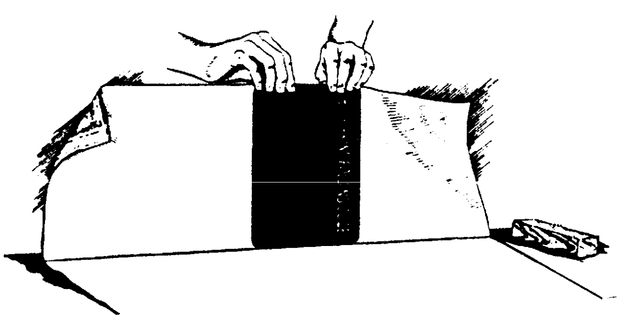


Figure 16-5.—Making first lengthwise fold in a large print.

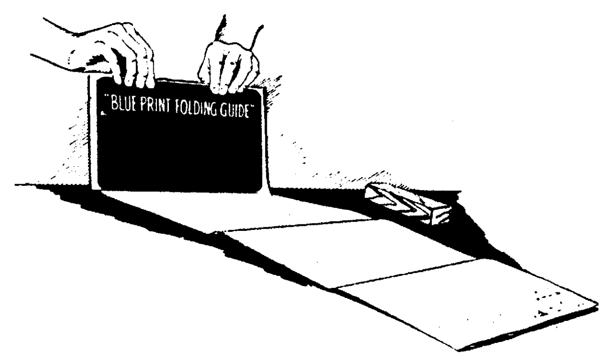


Figure 16-7.—Making first crosswise fold in a large print.

maintained, such data must be filed in the related projects folder.

Recording Files

A record of each drawing should be kept on an INDEX CARD in a suitable file drawer. A card similar to that shown in figure 16-8 may be used. A brief description of the information to be entered in each of the numbered spaces shown on this card is as follows:

① The standard subject identification code (numerical and/or name title). These classification codes are prescribed in the Department of the Navy *Standard Subject Identification Codes Manual*, SECNAVINST 5210.11 series. A copy of this instruction is available in your personnel office and in your technical library. The classification systems in this manual are designed to meet the needs of the entire Department of the Navy for a single, standard subject scheme to be used in numbering, arranging, filing, and referencing various types of Navy and Marine Corps documents by subject.

The Subject Identification Codes System is generally used by large shore activities, such as public works departments, Naval Construction Battalion Centers, or regimental headquarters. For smaller mobile units, such as an NMCB, the drafting room supervisor, the quality control (QC) staff, and EAs assigned to various detachments may devise their own indexing systems for field drawings according to the volume of records handled by the unit.

② The agency drawing number (NAVFACENGCOM DWG No.).

③ The title of the drawing, taken from the title block.

④ Cross-index references to any correspondence or data that may be on file relating to the drawing.

⑤ Number of the agency letter, if any, that was forwarded with the drawing.

⑥ and ⑦ The number and name of the A & E firm, contractor, naval shipyard, or other agency that actually made the drawings.

⑧ Applicable unit or vessel.

Again, if a separate folder or drawer file is maintained for each project, a notation must be

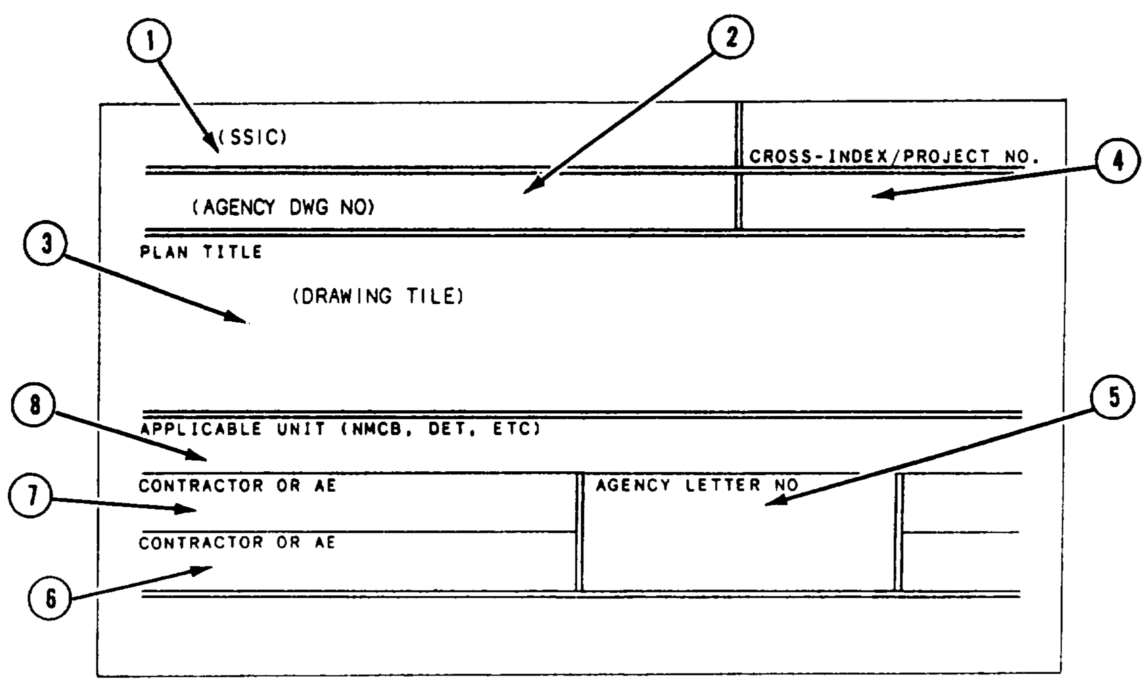


Figure 16-8.-Sample of a drawing file index card.

placed in the folder as to where to find the drawings related to that project. The project number will appear in the cross-index block ④ of the index card. You may, however, modify your index card to accommodate additional information or to suit the requirements in your unit.

PROFESSIONAL DUTIES

On the technical side, you, as an EA3, assigned to a typical SEABEE battalion, have a variety of jobs to choose from or to be assigned to. The sections within the engineering division to which you may be assigned are the drafting/print-reproduction section, the surveying section, and the materials testing section. Some of your duties and responsibilities while assigned to these sections are presented in the following paragraphs.

ASSIGNMENT TO DRAFTING/ REPRODUCTION SECTION

When you are first assigned to the drafting section, you are usually tasked with the simplest drafting or reproduction tasks so that the experienced drafting crew may be freed for more complicated work. These tasks also serve as training for the inexperienced draftsman. Your drafting assignments should include, in general, a variety of engineering services requests, such as reproduction of prints, preparation of charts, revising working drawings, preparing simple construction and fabrication drawings from sketches, and performing other EA3-related office jobs. Other EA-related tasks may include preparing overlay maps for operational, logistics, and/or contingency needs; performing operator's maintenance of reproduction machines; lettering, using the Kroy machine; plastic and metal engraving; maintaining a complete up-to-date technical library; and assisting other divisions and sections within the operations department as directed by the drafting supervisor.

Reproducing Blueprints

Quite often, the bulk of your job in the drafting section during home port is to reproduce several project drawings needed for planning and material estimates by the different construction crews and details. Failure to produce required quantities on time could have an adverse effect on the whole construction project planning and execution. To achieve maximum production, it is essential that every draftsman be properly trained to perform this assigned task. An experienced EA3 must be able to plan ahead to make sure that sufficient quantities of basic reproduction material requirements, such as print paper, are on hand and that the reproduction machine is in good working condition. Along with other preparations, you, as an EA3, need to learn to properly store blueprint paper and ammonia. Procedures related to the care and use of reproduction machines and supplies were discussed earlier in chapter 3.

Maintaining a Technical Library

Another important responsibility of the drafting section is that of establishing and maintaining an engineering technical library of current reference publications. The library is used by all personnel of the operations department as well as by anyone else in the battalion who requires technical information. To render service to others, the library must be maintained in an orderly manner.

Normally, the collateral duty of a librarian will be assigned to an EA3 working in the drafting room. He is responsible for arranging the publications, indexing, checking in and checking out publications. He is also tasked with packing the entire library for embarkation during overseas deployment.

Minimum requirements for a technical library are contained in a current COMCBPAC 5070 series instruction. The instruction includes all administrative, military, and technical library requirements that have to be met by each construction battalion. Publications not listed in the COMCBPAC instruction are included in appendix 11 of this training manual. Additional publications may be required depending on the particular mission of the battalion at each deployment.

It is essential that the librarian constantly monitor the technical library and know where each publication is at all times. Loss of important reference publications could cause delays in solving engineering problems. Security of frequently borrowed publications and a good checkout system will help prevent the loss of important publications.

ASSIGNMENT TO SURVEYING SECTION

One of the main units of the engineering division is the surveying or field engineering section. This section, like the drafting reproduction section, falls under the direct supervision of an EA1, depending on the number of senior EAs on board and their surveying experience. The size and organization of the entire surveying section will vary with the anticipated work load.

Your job, as an EA3, along with the other crew members in this section, is to carry out the scope of the tasks and responsibilities required of the surveying section. Depending on the overall mission of the battalion, typical surveying tasks may include the following: collecting field data and sketches for design purposes; conducting surveys for horizontal construction (roads, airfields, aboveground and belowground utilities); conducting layout surveys for vertical construction (buildings, retaining walls, waterfront structures, and so forth); developing level nets and level loops to establish vertical control; developing triangulation networks to establish horizontal control; and measuring structures in place for the purpose of preparing as-built drawings.

Versatility of the surveying section is essential to the accomplishment of all the assigned tasks. Sometimes all crews are used on one phase of the surveying task; at other times, crews are shuttled from one phase to another. Basically, for most surveying tasks, personnel are organized into two types of surveying parties: the TRANSIT PARTY and the LEVEL PARTY. They are named after the type of surveying instrument used.

ASSIGNMENT TO MATERIALS TESTING SECTION

EAs assigned to the soils laboratory are tasked with performing tests on such items as subbase materials, aggregates, and concrete and bituminous mixes to determine if these materials meet specified quality requirements. You, as an EA3, may be tasked to perform some of these tests together with a more experienced EA. Chapter 15 of this book can serve as a guide for a review of some of the tests commonly performed by an EA3.

As you gain experience in testing different types of materials used in construction, you may be tasked to work with the quality control section of the operations department. EAs assigned to the material testing section work closely with the QC staff in several areas, such as in testing materials to ensure that their inherent character meets minimum requirements; interpreting results of tests conducted on soil, concrete, and asphalt; and preparing reports of the tests performed by the testing section.

CAREER DEVELOPMENT

To get ahead, you, as an EA3, must meet certain requirements that have been prescribed for your paygrade and rating. These requirements are referred to as standards. Since these standards deal with the technical or occupational subject matter of each rating, they are called occupational standards. Occupational standards may be found in the *Advancement Handbook for Petty Officers*, NAVEDTRA 71365 (fig. 16-9).

In addition to the occupational standards prescribed for each rating, there are certain military requirements to be met. The military requirements for advancement are discussed briefly later in this chapter and are discussed in detail in special training manuals prepared to cover the military requirements for advancement.

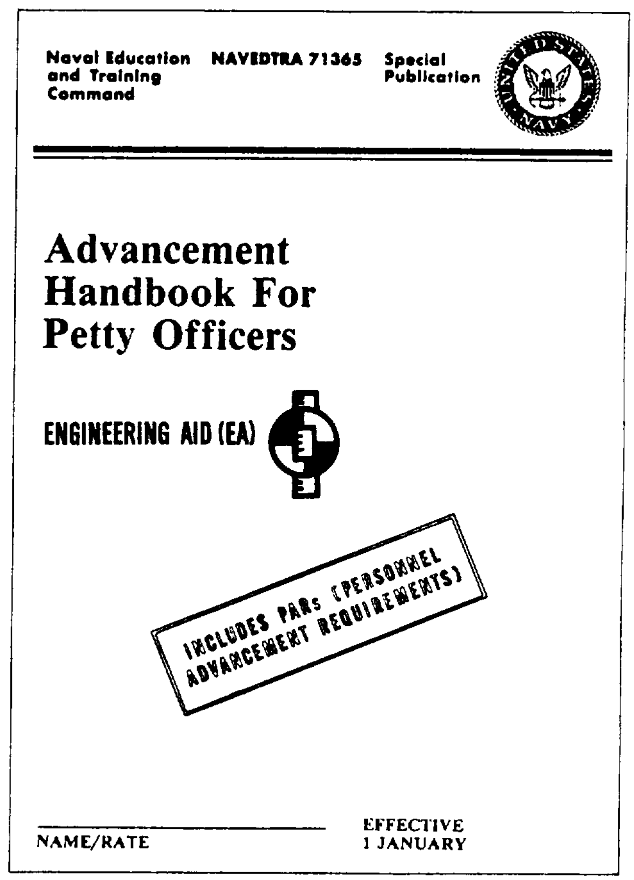


Figure 16-9.-Cover page of Advancement Handbook for Petty Officers (EA), NAVEDTRA 71365.

These military requirements are called naval standards.

The advantages of developing your career and getting ahead are not yours alone. The Navy also profits. Highly trained personnel are essential to the functioning of the Navy. By each advancement, you increase your value to the Navy in two ways. First, you become more valuable as a specialist in your own rating. And second, you become more valuable as a person who can train others and thus make far-reaching contributions to the entire Navy.

Many of the rewards of the Navy life are earned through the advancement system. The basic ideas behind the system have remained stable for years, but specific portions may change rather rapidly. It is important that you know the system and follow the changes carefully. One handbook that will normally keep you up to date regarding the basic advancement requirements is the *Advancement Handbook for Petty Officers,* NAVEDTRA 71365. The handbook outlines the Navy Advancement System in general and provides you with information about advancement paths, eligibility requirements for advancement, professional development, exams, and exam scoring. It contains naval and occupational standards with their supporting bibliographies and also personnel advancement requirements (PARS) certification.

One of the most useful things you can learn about a subject is how to find out more about it. No single publication can give you all the information you need to perform the duties and responsibilities of the EA rating. You should learn where to look for accurate, authoritative, up-to-date information on all subjects related to the naval and occupational standards of your rating.

Some publications are subject to change or revision from time to time—some at regular intervals, others as the need arises. When using any publication that is subject to change or revision, be sure that you have the latest edition. When using any publication that is kept current by means of changes, be sure you have a copy in which all official changes have been made. Studying canceled or obsolete information will not help you to do your work or to advance; it is likely to be a waste of time and may even be seriously misleading.

PERSONNEL READINESS CAPABILITY PROGRAM

The Personnel Readiness Capability Program (PRCP) provides a standard means of identifying, collecting, processing, and utilizing information on all members of the Naval Construction Force, both active and reserve. This information can be used by all levels of management and supervision to determine a unit's readiness capability by comparing it to actual or planned requirements.

The majority of PRCP information consists of an inventory of individual skills acquired through formal or on-the-job training. A record of these skills, combined with other data from the service record, such as expiration of enlistment, rotation data, and so forth, provides a ready means of predicting future capabilities and requirements. Some of these may be the following:

a. Construction and military capabilities

b. Personnel, logistics, and training requirements

c. Berthing, messing, and housing requirements

d. Contingency requirements

Your initial PRCP skill inventory will be based upon an interview with your crew/squad leader or another senior petty officer of your rating. Special PRCP Interviewer's Standards and Guides have been prepared to assist persons conducting interviews. Each "Guide" contains a detailed explanation of every skill identified in the PRCP. These definitions are standard throughout the entire Naval Construction Force, and any person, regardless of duty assignment, can turn to these standards and know what is expected in a given skill area.

During an interview, it is imperative that you discuss your capabilities openly and honestly. Remember, if you exaggerate, you may be depriving yourself of valuable and needed training. Then too, you may be the one selected to do that special job all on your own. Will you be ready?

A more detailed discussion of the Personnel Readiness Capability Program may be found in chapter 2 of *Engineering Aid 1 & C,* NAVEDTRA 10635-C.

SOURCES OF INFORMATION—GOVERNMENT

There are various government publications that you may find useful as sources of reference. A number of publications issued by the Naval Facilities Engineering Command (NAVFACENGCOM) that will be of interest to you are listed in the *Documentation Index*, NAVFAC P-349 (updated semiannually). The publications are generally classified as follows: Design Manuals (DMs); Technical Publications (TPs); Maintenance and Operations (MOs); and Administrative Information (P).

NAVFAC publications should be available in your battalion technical library or in the engineering division of the public works activity. Their titles are self-explanatory and you can consult the publications that contain the subject matter in which you are interested. Suggested publications that should be in the engineering section of the battalion technical library are listed in appendix II.

Some Air Force Manuals (AFMs) and Army Technical Manuals (TMs) have subjects that are related to the Engineering Aid rating. They may be available in the technical library of the battalion; if not, they are easily ordered through the normal naval supply procurement system. TMs and AFMs of particular importance to you are included in the engineering section of the battalion technical library listing in appendix II of this manual.

To improve your ability in preparing any type of construction drawing, you should also refer to training manuals of other Occupational Field 13 ratings, especially those for the E-4 level.

Detailed standards for armed forces drawings are set forth in *Military Standards,* published by the Assistant Secretary of Defense (Supply and Logistics), Office of Standardization. Any Navy activity can obtain copies of these standards by writing to the Commanding Officer, Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, Pennsylvania 19120. A complete and up-to-date copy of each of these standards is a must to have in any drafting room library of the SEABEES.

SOURCES OF INFORMATION—COMMERCIAL

To keep up to date on the current progress of new equipment and on the new materials related to your rating, you will find that the best source of information is commercial publications. These publications may be in the form of a textbook or an operation manual for a particular instrument. The instrument operation manual can be obtained from instrument manufacturers or dealers. On the other hand, textbooks are to be purchased. Your technical library may, however, have some of them on hand.

Every EA should strive to acquire at least a few textbooks for his personal use by purchasing them himself, if feasible. The knowledge and skill you learned through formal studies and on-the-job training in the SEABEEs must be supplemented continuously with off-hours studies on your own initiative. This will not only broaden your knowledge but will also enhance your chances of getting a high score in Navy-wide professional examinations.

APPENDIX I

GLOSSARY

Many terms have different meanings when used in relation to different subjects. The definitions in this glossary of terms are meant to be used in conjunction with the subject matter within this text.

ACCIDENTAL ERROR—Any small error accidentally incurred in a measurement. Unlike systematic errors, accidental errors are not governed by fixed laws. They are as likely to be positive as negative, and the theory of probability is based on the occurrence of these errors.

ACCURACY—The degree of conformity with a standard or the degree of perfection attained in a measurement. Accuracy relates to the quality of a result and is distinguished from precision, which relates to the quality of the operation by which the result is obtained.

ACTUAL ERROR—The difference between the accepted value and the measured value of a physical quantity.

ACUTE ANGLE—An angle of less than 90°.

ADJUSTED POSITION—An adjusted value for the horizontal or vertical position of a survey station, in which discrepancies due to errors in the observed data are removed. This adjustment forms a coordinated and correlated system of stations.

ADMIXTURE—A material other than water, aggregates, and portland cement (including air-entraining portland cement and portland blast-furnace slag cement) that is used as an ingredient of concrete and is added to the batch immediately before or during its mixing.

ADSORBED MOISTURE—In soil mechanics, the thin films of moisture that may surround and cling to the individual particles in a soil mass because of naturally occurring electrical attraction of water molecules to the soil particles.

AGGREGATE—Any hard, inert, mineral material used for mixing in graduated fragments. It includes sand, gravel, crushed stone, and slag.

AGGREGATE, COARSE—Aggregate that is retained on the No. 8 sieve.

AGGREGATE, FINE-Aggregate that passes the No. 8 sieve.

AGONIC LINE—The line along which the magnetic declination is zero.

ALGEBRA—That branch of mathematics that pertains to the relations and properties of numbers by means of letters, signs of operation, and other symbols. Algebra includes solution of equations, polynomials, verbal problems, graphs, and so on.

ALIDADE—The part of a surveying instrument that consists of a sighting device with index and reading or recording accessories. 1. The alidade of a theodolite or engineer transit is the part of the instrument that includes the telescope, micrometer microscopes or verniers, and accessories. These are mounted on what is called the “upper motion” of the instrument, and they are used in observing direction or angle on the graduated circle, which is mounted on the “lower motion.” 2. The alidade used in topographic surveying consists of a straightedge ruler carrying a telescope or other sighting device, and it is used in plotting a direction on the plane-table sheet. If a telescope is used, the instrument is often called a “telescopic alidade. ”

ALTITUDE—1. The vertical angle between a horizontal plane and the line to the observed or defined object. In surveying, a positive altitude (measured upward from the horizon) is termed an angle of elevation, and a negative altitude (measured downward from the horizontal) is termed an angle of depression. 2. Altitude is sometimes used to apply to elevation above a datum; for example, the altitude of an airplane.

ANGLE—A figure formed by two lines or planes extending from or diverging at the same point.

ANGLE OF DEPRESSION—A negative altitude.

ANGLE OF ELEVATION—A positive altitude.

ANGLE OF INCLINATION—A vertical angle of elevation or depression.

ANNUAL VARIATION—The annual change in the magnetic declination.

ANTILOG—The result when a logarithm is converted to a number.

ARC—A portion of the circumference of a circle.

ARCHITECT'S SCALE—Scale used when dimensions or measurements are to be expressed in feet and inches.

ARITHMETIC—The art of computation by the use of positive real numbers.

ASPHALT—A dark brown to black cementitious material in which the predominating constituents are bitumens that occur in nature or are obtained in petroleum processing. Asphalt is a constituent in varying proportions of most crude petroleums.

AUXILIARY PLANE—A plane (NOT one of the normal planes) from which the auxiliary view is projected.

AUXILIARY VIEW—A view that is not on one of the normal planes of projection. It is used to show features of objects that do not appear in their true size and shape in the normal views.

AXONOMETRIC—A single view of an object depicting all three dimensions. The projection lines are parallel to each other and perpendicular to the plane of projection. The object is inclined to the plane of projection, thereby allowing the viewer to see three dimensions.

AZIMUTH (Surveying)—The horizontal direction of a line measured clockwise from a reference plane, usually the meridian; often called FORWARD AZIMUTH to differentiate from BACK AZIMUTH. In the basic control surveys of the United States, azimuths are measured clockwise from south following the continental European geodetic practice. However, this practice is not followed in all countries.

AZIMUTH MARK—A marked point visible from a survey station, the azimuth to which is determined for use in dependent surveys.

BACK AZIMUTH—As the azimuth of the line from A to B is known as the forward azimuth, the azimuth of the same line from B to A is known as the back azimuth.

BACKSIGHT—1. In traversing, a backsight (BS) is a sight on a previously established traverse or triangulation station, that is not the closing sight of the traverse. 2. In leveling, a backsight is a reading on a rod held on a point whose elevation has been previously determined and not the closing sight of a level line.

BALANCING A SURVEY—Distributing corrections through a closed traverse to eliminate the error of closure and to obtain an adjusted position for each traverse station.

BASE COURSE—The layer of material immediately beneath the surface or intermediate course. It may be composed of crushed stone, crushed slag, crushed or uncrushed gravel and sand, or combinations of these materials. It also may be bound with asphalt.

BASE LINE—A surveyed line established with more than usual care as the known length of a triangle side for computing other triangle sides.

BASE CONTROL—Horizontal or vertical control, the positions of whose stations have been accurately coordinated and correlated, forming a framework to which other surveys are adjusted.

BEARING—The direction of a line within a quadrant, with respect to the meridian. Bearings are measured clockwise or counterclockwise from north or south, depending on the quadrant.

BENCH MARK-A relatively permanent object, natural or artificial, bearing a marked point whose elevation above or below an adopted datum is known. Usually designated as a BM, such a mark is sometimes further qualified as a PBM (permanent bench mark) or as a TBM (temporary bench mark).

BILL OF MATERIALS—List of materials needed for a given project placed directly above the title block; not normally found on construction drawings.

BISECT—To divide into two equal parts.

BITUMEN—A mixture of hydrocarbons of natural or pyrogenous origin, or a combination of both; frequently accompanied by nonmetallic derivatives, which may be gaseous, liquid, semisolid, or solid, and which are completely soluble in carbon disulfide.

BLAST-FURNACE SLAG—The nonmetallic product, consisting essentially of silicates and aluminosilicates of lime and of other bases, which is developed simultaneously with iron in a blast furnace.

BLAZE—A mark made on the trunk of a standing tree by chipping off a spot of bark with an axe. It is used to indicate a trail, a boundary, location for a road, a tree to be cut, and so on.

BORDER LINES—Dark lines defining the inside edge of the margin on a drawing.

BREAK LINES—Lines used to reduce the graphic size of an object generally to conserve paper space. There are two types.

Long—Thin ruled line with freehand zigzag.

Short—Thick, wavy freehand line.

BROKEN SECTION—See partial section.

BUBBLE AXIS (LEVEL VIAL)—The horizontal line tangent to the upper surface of the centered bubble, which lies in the vertical plane through the longitudinal axis of the bubble tube.

CABINET PROJECTION—A single view of an object having one face in orthographic projection and depicting all three dimensions (length, width, and height). The projection lines are parallel and at an oblique angle with the plane of projection (generally 45°). The lengths of the receding lines are foreshortened to make the object appear optically correct.

CALIBRATION—The determination in terms of an adopted unit and by mechanical interpolation based on the values obtained by standardization of the supplementary marks on a measuring instrument or device. Also, the determination of the values of the divisions of a circle as proportional parts of a circumference.

CAVALIER PROJECTION—A single view of an object having one face in orthographic projection and showing all three dimensions. The projection lines are parallel and at an oblique angle with the plane of projection (generally 45°). The lengths of all object lines are drawn to scale and do not appear optically correct.

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

CHAIN (Gunter's)—A unit of distance formerly much used in land measurement and a term frequently found in deed descriptions. A chain equals 66 ft, 4 rods, 1/80 mi.

CIRCLE—A plane closed figure having every point on its circumference (perimeter) equidistant from its center.

CIRCUIT CLOSURE—In leveling, the amount by which the algebraic sum of the measured differences of elevation around a circuit fails to equal the theoretical closure, zero.

CIRCUMFERENCE—The length of a line that forms a circle.

CIRCUMSCRIBED FIGURE—A figure that completely encloses another figure.

CLOCKWISE ANGLE—A horizontal angle measured from left to right. A clockwise angle may have between 0° and 360°. Azimuths are clockwise angles measured from either north or south.

CLOSED TRAVERSE—A traverse that starts and ends at the same point or at stations whose positions have been determined by other surveys. (See CONNECTING TRAVERSE and LOOP TRAVERSE.)

CLOSING THE HORIZON—Measuring the last of a series of horizontal angles at a station required to make the series complete around the horizon. At any station, the sum of the horizontal angles between adjacent lines should equal 360°. The amount by which the sum of the measured angles fails to equal 360° is the angular error of closure. This error is distributed as a correction among the measured angles to make their sum exactly 360°. The error and the correction have opposite algebraic signs.

COLLIMATE—Adjust the line of sight of a telescopic surveying instrument to its proper position relative to the other parts of the instrument.

COLLIMATION LINE—The line through the second nodal point of the objective (object glass) of a telescope and the center of the reticle. It is variously termed the line of sight, sight line, pointing line, and the aiming line of the instrument. The center of the reticle of the telescope of a transit can be defined by the intersection of cross hairs or by the middle point of a fixed vertical wire or of a micrometer wire in its mean position. In a leveling instrument, the center of the reticle may be the middle point of a fixed horizontal wire.

COMMON LOGARITHMS—Logarithms with 10 as a base.

COMPASS-PIVOT JOINT, BOW, DROP BOW, BEAM—Instrument used to draw circles or arcs of circles.

COMPOUND CURVE—A curve composed of a series of successive tangent circular arcs.

CONE—A solid figure that tapers uniformly from a circular base to a point.

CONNECTING TRAVERSE-A closed traverse that starts and ends at different stations whose relative positions have been determined by other surveys.

CONSTRUCTION LINES—Lightly drawn lines used in the preliminary layout of a drawing.

CONTOUR—An imaginary level line (constant elevation) on the ground surface; it is called a CONTOUR LINE on a corresponding map.

CONTOUR INTERVAL—A predetermined difference in elevation (vertical distance) at which contour lines are drawn. The contour interval is usually the same for maps of the same scale.

CONTOUR LINE—An imaginary line on the ground, all points of which are at the same elevation above or below a specified datum.

CONTOUR MAP—A map that portrays relief by means of contour lines.

CONTROL—A system of points whose relative positions have been determined from survey data. (See BASIC CONTROL, HORIZONTAL CONTROL, and VERTICAL CONTROL.)

CONTROL STATION—A station whose position (horizontal or vertical) has been determined from survey data and is used as a base for a dependent survey.

CONTROL SURVEY—A survey that provides positions (horizontal or vertical) of points to which supplementary surveys are adjusted.

COORDINATES—Linear or angular quantities, or both, that designate the position of a point in relation to a given reference frame. There are two general divisions of coordinates used in surveying: polar coordinates and rectangular coordinates. These may be subdivided into three classes: plane coordinates, spherical coordinates, and space coordinates.

COUNTERCLOCKWISE ANGLE—A horizontal angle measured in a counterclockwise direction. The counterclockwise angle is used primarily for the measurement of deflection angles.

COURSE—The direction of a line with reference to a meridian, usually given as a true or as a magnetic bearing.

CRUSHED GRAVEL-The product resulting from the artificial crushing of gravel with substantially all fragments having at least one face resulting from fracture.

CRUSHED STONE—The product resulting from the artificial crushing of rocks, boulders, or large cobblestones, substantially all faces of which have resulted from the crushing operation.

CUBE—Rectangular solid figure in which all six faces are square.

CUTTING PLANE LINES—Thick, heavy lines used to indicate a plane or planes in which a sectional view is taken.

CYLINDER—A solid figure with two equal circular bases.

DATUM—Any numerical or geometrical quantity that serves as a reference or base for other quantities. It is described by such names as geodetic, leveling, North American, or tidal datum, depending upon its purpose when established.

DATUM LINES—Dark medium lines consisting of one long and two short dashes evenly spaced; used to define a line or plane of reference.

DECIMAL—The result of dividing the numerator (top number) of a fraction by the denominator (bottom number); for example, 1/2 = .5, 3/8 = .375, 17/100 = .17.

DECLINATION—The angle between true north and either grid or magnetic north.

DEFLECTION ANGLE—A horizontal angle measured from the prolongation of the preceding line, clockwise or counterclockwise as necessary, to the following line.

DEGREE—A 360th part of the circumference of a circle; also, a 360th part of a revolution about a point; used to define the size of an angle.

DEPARTURE—In a plane survey, the amount that one end of a line is east or west of the other end. The plane coordinates of a point are known as the casting and northing of the point, and the departure is the difference between the castings of the two ends of the line, which may be either plus or minus.

DESIGN MANUALS (DMs)—Publications containing guidelines set forth by the Naval Facilities Engineering Command.

DETAIL PAPER—Heavy opaque, buff, or neutral green drawing paper that takes pencil well.

DIAGONAL—A line that connects any two nonadjacent corners of a plane figure.

DIAMETER—A straight line passing through the center of a circle or sphere whose ends terminate at the circumference or surface.

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

DIRECT LEVELING—The determination of differences of elevation by means of a continuous series of short horizontal lines. Vertical distances from these lines to adjacent ground marks are determined by direct observations on graduated rods with a leveling instrument equipped with a spirit level.

DIRECT READING—The reading of the horizontal or vertical circle of a theodolite or engineer transit with the telescope direct.

DISCREPANCY—1. The difference between duplicate or comparable measures of a quantity. 2. The difference between computed values of a quantity obtained by different processes in the same survey.

DISPLAY CHART—Chart used to convey data to nontechnical audiences.

DIVIDERS—Instrument used to transfer distances.

DRAFTING MEDIA—Materials used to draw on. Basically, three types are used: paper, cloth, and film.

EASTING—One of the two values indicating the position of a point on a grid system. The casting coordinate is abbreviated E.

ELEVATION—The vertical distance of a point above or below a reference surface, or level datum; often abbreviated ELEV.

ELLIPSE—A plane closed curve having the sum of the distances from any point on the curve to two fixed points a constant.

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

EQUILATERAL—A polygon with sides of equal length.

ERROR—The difference between an observed or computed value of a quantity and the true value of the quantity. Errors are of two classifications: accidental errors and systematic errors.

ERROR OF CLOSURE—The amount by which the value of a quantity obtained by surveying operations fails to agree with another value of the same quantity held fixed from earlier determinations or with a theoretical value of the quantity.

EXPONENT—A small number or symbol placed above and to the right of a mathematical quantity to indicate the number of times the quantity is to be multiplied by itself; for example, $3^3 = 3 \cdot 3 \cdot 3 = 27$.

EXTENSION LINES—Thin, unbroken lines used to extend dimensions beyond the outline of a view so they can be more easily read.

FINITE DISTANCE—A defining measurable distance.

FIRST ANGLE PROJECTION—Multiview projection commonly used in Europe in which the top view is below the front view and the right side of the object, as shown in the front view, is toward the left side view of the object.

FORESHORTENING—The reduction in length of receding lines in an oblique projection that allows the object to appear to be optically correct.

FORESIGHT— 1. A sight on a new survey point, made in connection with its position determination; or a sight on a previously established point to close a circuit. 2. In leveling, a foresight (FS) is the rod reading on a rod held on a point whose elevation is being determined. (See BACKSIGHT.)

FORMAT—The systematic arrangement of drawing sheet space to standardize the location of required information.

FRACTION—A division indicated by placing the dividend (numerator) over the divisor (denominator) wit h a line between them.

Proper Fraction: 3/4

Improper Fraction: 3/2 = 1 1/2

Mixed Fraction: 1 7/8

FRENCH CURVE—Instrument used to draw smooth irregular curves.

FREEHAND DRAFTING—Any drawing in which the pen or pencil is guided solely by hand.

FRUSTUM OF A CONE—The portion of a cone-shaped solid next to the base that is formed by cutting off the upper part by a plane parallel to the base.

FRUSTUM OF A PYRAMID—The portion of a pyramid-shaped solid next to the base that is formed by cutting off the top by a plane parallel to the base.

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

GEODETIC DATUM—Datum that forms the basis for the computation of horizontal-control surveys in geodetic surveying. It consists of five quantities: the latitude and the longitude of an initial point, the azimuth of a line from this point, and two constants necessary to define the terrestrial spheroid.

GEOMETRY—That branch of mathematics that investigates the relations, properties, and measurement of solids, surfaces, lines, and angles; it also deals with the theory of space and of figures in space.

GRADE (GRADIENT)—The rate of rise and fall or slope of a line; generally expressed in percent or as a ratio.

GRAPH PAPER—Gridded paper in a variety of scales and patterns used for plotting, sketching, and drawing.

GRID—A network composed of two sets of equidistant parallel lines intersecting at right angles.

GRID COORDINATES—The numbers and letters of a coordinate system that designate a point on a grid.

GUARD STAKE—A stake driven near a hub, usually sloped with the top of the guard stake over the hub. The guard stake protects, and its markings identify, the hub.

HACHURES—A method of portraying relief by short, wedge-shaped marks radiating from high elevations and following the direction of slope to the lowland.

HALF SECTION—A sectional view that passes halfway through the object; used when the shape of one half is identical to the other half.

HATCHING—Sections lines that are drawn on the internal surface of sectional views; may be used to define the kind or type of material of which the sectioned surface consists.

HEIGHT OF INSTRUMENT—1. (Spirit leveling) The height of the line of sight of a leveling instrument above the adopted datum. 2. (Stadia surveying) The height of the center of the telescope (horizontal axis) of transit or telescopic alidade above the ground or station mark. 3. (Trigonometrical leveling) The height of the center of the theodolite (horizontal axis) above the ground or station mark.

HELIOTROPE—An instrument composed of one or more plane mirrors so mounted at the station being sighted upon that the sun's rays can be reflected to any one observing the station.

HEPTAGON—A polygon of seven sides.

HEXAGON—A polygon of six sides.

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

HORIZONTAL ANGLE—The angle formed by two intersecting lines on a horizontal plane.

HORIZONTAL CONTROL—Control that determines horizontal positions only, with respect to parallels and meridians or to other lines of reference.

HORIZONTAL DATUM—In plane surveying, the grid system of reference used for the horizontal control of an area; defined by the casting and northing of one station in the area, and the azimuth from this selected station to an adjacent station.

HORIZONTAL DIRECTION—A direction in a horizontal plane.

HORIZONTAL DISTANCE—A distance measured along a level line. It is commonly thought of as the distance between two plumb lines. The distance may be measured either horizontally or inclined, but the inclined distance is always reduced to its horizontal length.

HORIZONTAL LINE—A line tangent to a level surface, or a line lying on a horizontal plane.

HORIZONTAL PLANE—A plane perpendicular to the direction of gravity.

HORIZONTAL POSITION—The grid position of a horizontal control point.

HORIZONTAL REFRACTION—A natural error in surveying that is the result of the horizontal bending of light rays between a target and an observing instrument. This refraction is usually caused by the differences in density of the air along the path of the light rays, resulting from temperature variations.

HORN CENTER—Device used to prevent the compass needle from making holes in a drawing.

HUB—A wooden stake or pipe set in the ground with a tack or other marker to indicate the exact position. A guard stake protects and identifies the hub.

HYDROSCOPIC MOISTURE—The films of adsorbed moisture that may be present in airdried soil. Hydroscopic moisture may be driven off by oven-drying. (See also adsorbed moisture.)

ILLUSTRATION BOARD—Smooth white paper with a cardboard backing, used for signs or charts or mounting of maps, photos, or drawings that require a strong backing.

IMAGE PLANE—See PLANE OF PROJECTION.

INDIA INK—Drawing ink consisting of a pigment (usually powdered carbon) suspended in an ammonia-water solution.

INFINITE DISTANCE—An indefinite unmeasurable distance; for example, parallel lines are said to converge at infinity.

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

INTERSECTION—A method of locating the horizontal position of a point by observations from two or more points of known position, thus measuring directions that intersect at the station being located. A station whose horizontal position is located by an intersection is known as an intersection station.

IRRATIONAL NUMBER—Real number that cannot be expressed in the ratio of two integers; for example, 3, π.

IRREGULAR POLYGON—A nonequilateral polygon.

ISOMETRIC AXIS—Axis used in isometric projections and drawings. Each line in the axis forms an angle of 120° with the adjacent line, easily constructed with a straightedge and a 30°/60° triangle.

ISOMETRIC DRAWING—Same as an isometric projection except that the dimensions of the object drawn are scaled and not projected.

ISOMETRIC PROJECTION—A single view projection of an object showing three dimensions. The object is inclined so all faces make the same angle with the plane of projection, making all lines and surfaces foreshortened in the same ratio. This allows one scale to be used throughout.

ISOSCELES TRIANGLE—A triangle having two equal sides.

LATERAL FACES—Faces or surfaces forming the sides of a solid figure; also known as lateral surfaces.

LATERAL SURFACES—See LATERAL FACES.

LATITUDE—In plane surveying, the amount that one end of a line is north or south of the other end. As the plane coordinates of a point are known as the casting and northing of the point, the latitude is the difference between the northings of the two ends of the line, which may be either plus or minus. (See DEPARTURE.)

LAW OF COSINES—A law of mathematics that states that, in any triangle, the square of one side is equal to the sum of the squares of the other two sides minus twice the product of these two sides multiplied by the cosine of the angle between them. This statement may be expressed in formula form as follows:

$$a^2 = b^2 + c^2 - 2bc \cos A$$

$$b^2 = a^2 + c^2 - 2ac \cos B$$

$$c^2 = a^2 + b^2 - 2ab \cos C$$

LAW OF SINES—A law of mathematics that states that the lengths of the sides of any triangle are proportional to the sines of their opposite angles. It is expressed in formula form as follows:

$$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$$

LAW OF TANGENTS—A law of mathematics that states that, in any triangle, the difference between two sides is to their sum as the tangent of half the difference of the opposite angles is to the tangent of half their sum. For any pair of sides—as, side a and side b—the law may be expressed as follows:

$$\frac{a - b}{a + b} = \frac{\tan 1/2(A-B)}{\tan 1/2(A+B)}$$

LEADER LINES—Thin unbroken lines used to connect numbers, references, or notes to appropriate surfaces or lines.

LEGEND—A description, explanation, table of symbols, and so on, printed on a map or chart for a better understanding and interpretation of it.

LEVEL—1. Pertaining to a level surface; 2. To make horizontal at the point of observation; 3. An instrument for leveling.

LEVEL DATUM—A level surface to which elevations are referred. The generally adopted level datum for leveling in the United States is mean sea level. For local surveys, an arbitrary level datum is often adopted and defined in terms of an assumed elevation for some physical mark (bench mark).

LEVEL LINE—1. A line in a horizontal plane; 2. A line over which leveling operations are accomplished.

LEVEL NET—Lines of spirit leveling connected together to form a system of loops or circuits extending over an area. This is also called a vertical control net.

LEVEL SURFACE—A surface that is parallel with the spheroidal surface of the earth, such as a body of still water.

LEVELING—The operations of measuring vertical distances, directly or indirectly, to determine elevations.

LINE OF SIGHT—1. The straight line between two points. This line is in the direction of a great circle, but it does not follow the curvature of the earth. 2. The line extending from an instrument along which distant objects are seen when viewed with a telescope or other sighting device.

LINE OF SYMMETRY—A line that divides an object into two equal identical parts; used only when the two halves of an object are identical.

LIQUID LIMIT—The upper limit of the plastic state, expressed as the moisture content at which the flow curve intersects the "25 blows" ordinate.

LOGARITHM—The exponent or the power to which a fixed number, called the base, must be raised to produce a given number; for example, common log $.3979 = 10^{.3979} = 2.5$

LOOP TRAVERSE—A closed traverse that starts and ends at the same station.

MAGNETIC AZIMUTH—An azimuth measured with reference to the direction indicated by a magnetic compass needle. Magnetic azimuth is measured from magnetic north, which is east or west of true north, as shown by the magnetic declination.

MAGNETIC DECLINATION—The angular amount that a magnetic compass needle points eastward or westward from true north.

MAP MEASURE—Instrument used when lengths of irregular outlines are measured.

MATCH LINES—Lines used when an object is too large to fit on a single drawing sheet and must be continued on another sheet. The points where the object stops on one sheet and continues on the next sheet must be identified with corresponding match lines. They are medium weight lines indicated with the words *match line* and referenced to the sheet that has the corresponding match line.

MATHEMATICS—The science that deals with the relationships that exist between quantities and operations, and with methods by which these relationships can be applied to determine unknown quantities from given or measured data.

MEAN SEA LEVEL—The average height of the sea for all stages of the tide. Mean sea level at numerous tide-gaging stations usually forms the basis of a level datum for large areas.

MEASURED ANGLES—Angles that are either vertical or horizontal.

MECHANICAL DRAFTING—Any drawing in which the pen or pencil is guided by a mechanical device.

MERIDIAN—A north-south line from which longitudes (or departures) and azimuths are reckoned.

MIDPOINT—That point on the arc of a circular curve that is the same distance from both ends of the arc.

MILITARY STANDARDS (MIL-STDs)—Instructions set forth by the Department of Defense that members of all armed services are required to follow. Only a few of these standards refer directly to drafting.

MINUTE—A 60th part of a degree used to define the size of an angle.

MOISTURE CONTENT (w.)—The ratio, expressed as a percentage, of the weight of water in a given soil mass to the weight of solid particles.

MONUMENT—Any object or collection of objects that indicates the position on the ground of a survey station. In military surveys, the term *monument* usually refers to a stone or concrete station marker containing a special bronze plate on which the exact station point is marked.

NONCIRCULAR CURVE—A curve composed of a series of extremely small circular arcs of varying radii.

NON-NORMAL LINE—A line that is oblique to one or more of the planes of projection.

NORMAL LINE—A line that is parallel to two planes of projection and perpendicular to the third. A line or plane that forms a 90° angle with another line or plane is normal to that line or plane.

NORTHING—One of the two values indicating the position of a point on a grid system. The northing coordinate is abbreviated N. (See GRID COORDINATES.)

OBLIQUE PROJECTION—A single view of an object showing three dimensions (length, width, and height).

OBLONG—A nonequilateral rectangle.

OBTUSE ANGLE—An angle greater than 90°.

OCCUPIED STATION—A traverse or triangulation station over which a theodolite or an engineer transit is set up for the measurement of angles at this station. Also, a station at which angles have been so measured.

OCTAGON—A polygon of eight sides.

OFFSET LINE—A supplementary line close to, and usually parallel to, a main survey line to which it is referenced by measured offsets. When the line for which data are desired is in such a position that it is difficult to measure over it, the required data are obtained by running an offset line in a convenient location and measuring offsets from it to salient points on the other line.

OGEE CURVE—Any curve composed of two consecutive tangent circular arcs that curve in opposite directions; also known as reverse curve.

OPEN TRAVERSE—A traverse that starts at a point of known or assumed position and ends at a point whose relative position is unknown with respect to the starting point.

ORDER OF ACCURACY—A mathematical ratio defining the general accuracy of the measurements made in a survey. The orders of accuracy for surveys are divided into four classes named first-order, second-order, third-order, and fourth-order.

ORGANIC SOIL—Soil that contains mineral grains and a more or less conspicuous admixture of vegetable matter.

ORIENT—To establish the correct relationship in direction with reference to the points of the compass; to bring into correct relationship in direction with reference to the points of the compass.

ORTHOGRAPHIC PROJECTION—The projection of height, width, and depth of an object into various single planes so as to depict the true size and shape of the object as seen from each individual plane, each plane showing only two dimensions, thereby necessitating a minimum of two planes to show all three dimensions.

PARALLAX—The apparent displacement or the difference in apparent direction of an object as seen from two different points not on a straight line with the object. In testing the focus of a telescope, the head of the observer must move from side to side or up and down while sighting through the eyepiece. Any apparent movement of the cross hairs in relation to the object image means that parallax is present. Parallax can be practically eliminated by careful focusing.

PARALLEL OF LATITUDE—A line on the surface of the earth having the same latitude at every point.

PARALLELEPIPED—A solid figure whose base is a parallelogram.

PARALLELOGRAM—A quadrilateral with each pair of opposite sides parallel.

PARTIAL AUXILIARY VIEW—An auxiliary view in which only the features of an object that are specifically desired are shown.

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

PAVEMENT STRUCTURE—All courses of selected material placed on the foundation or subgrade soil, other than any layers or courses constructed in grading operations.

PENTAGON—A polygon of five sides.

PERCENT—Portion in one hundred parts.

PERIMETER—The sum of the sides of a polygon.

PERMANENT BENCH MARK—A bench mark of as nearly permanent character as it is practicable to establish; usually designated bench mark.

PERSPECTIVE—A single-view drawing of an object showing three dimensions. Lines and surfaces are foreshortened to make it appear optically correct. Perspective drawing is used when the end product is to be of an illustrative nature.

PHANTOM LINE—Thin broken line consisting of one long and two short evenly spaced dashes; used to indicate the alternate position of **a** moving part.

PICTORIAL PROJECTION—Any projection that shows three dimensions in a single view as it would be seen by the eye.

PLAN/PROFILE PAPER—Upper half (plan) is plain white paper used to draw the plan view; lower half is gridded and used to draw profiles.

PLANE COORDINATES—See GRID COORDINATES.

PLANE OF PROJECTION—The theoretical, transparent plane placed between the point of sight and the object in any type of projection. The observer sees the features of an object as they lie on the plane of projection; also known as image plane.

PLANE SURVEY—A survey in which the effect of the curvature of the earth is almost entirely neglected, and computations of the relative positions of the stations are made using the principles of plane geometry and plane trigonometry.

PLASTIC LIMIT (PL)—The lower limit of the plastic state, expressed as the minimum moisture content, at which a soil can be rolled into a thread one-eighth in, in diameter without crumbling.

PLASTICITY—The property of a fine-grained soil that allows it to be deformed beyond the point of recovery without cracking or changing volume appreciably.

PLASTICITY INDEX (PI)—The numerical difference between the moisture content at the liquid limit and the moisture content at the plastic limit.

PLUMB LINE—The line indicated by a plumb bob cord. The direction in which gravity acts.

PLUNGE THE INSTRUMENT—Turn the instrument telescope end-for-end about its horizontal axis.

POINT OF SIGHT—The position of the observer in relation to the object and the plane of projection in any type of projection; also known as station point.

POLYGON—A plane figure that is bounded by straight-line sides.

POROSITY—The ratio, expressed as a percentage, of the intergranular space in a given soil mass to the total volume of the soil mass.

POSITION— 1. Data that define the location of a point with respect to a reference system. The coordinates that define the location of a point on a grid. 2. A circle position.

POWER—The number of times, as indicated by an exponent, a number occurs as a factor; for example, $2^4 = 2 \cdot 2 \cdot 2 \cdot 2 =$ to the 4th power=16.

POZZOLAN—A siliceous or aluminous material that in itself possesses little or no cementitious value but will, in finely divided form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties.

PRECISION—The degree of refinement in the performance of an operation or the degree of perfection in the instruments and methods used when making measurements. Precision relates to the quality of the operation by which a result is obtained and is distinguished from accuracy that relates to the quality of the result.

PROJECTION CHART—Chart showing the comparison of scheduled progress and actual progress.

PROJECTION LINES—The imaginary lines from the eye of the viewer to the points on the object in any type of projection; also known as lines of sight.

PROPORTION—An equation in which two ratios are set equal to each other; for example, 3/4 = 9/12, 3:4::9:12.

PROTRACTOR—Instrument used for measuring and laying off angles.

PYRAMID—A figure having a plane polygon for its base and triangles meeting at a common vertex for its sides.

PYTHAGOREAN THEOREM—A law of mathematics that states that the square of the hypotenuse of a right triangle equals the sum of the squares of the other two sides.

QUADRILATERAL—A polygon bounded by four sides.

QUALITATIVE CHART OR GRAPH—Any chart that emphasizes the relationships of facts.

QUANTITATIVE CHART OR GRAPH—A chart or graph that emphasizes numerical values.

RADIAN—A system for measuring angles where 2π radians equals 360°; 1 radian = 57.3°.

RADICAL—A symbol placed on a mathematical quantity to indicate the root of the quantity; for example.

$\sqrt{4}$ = square root = 2 (that is, $2 \cdot 2 = 4$)

$\sqrt[3]{8}$ = cube root = 2 (that is, $2 \cdot 2 \cdot 2 = 8$)

$\sqrt[4]{16}$ = 4th root = 2 (that is, $2 \cdot 2 \cdot 2 \cdot 2 = 16$)

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

RATIO-A comparison of two like quantities; for example, 2/3, 2:3.

RATIONAL NUMBER—A number that can be expressed as the quotient or ratio of two whole numbers: Fractions 2/7, Integers 3/1 = 3. A radical is a rational number if the radical is removable; for example, $\sqrt{4} = 2$, $\sqrt[3]{27} = 3$.

REAL NUMBERS—All positive and negative numbers.

RECIPROCAL—The reciprocal of a number equals 1 divided by the number.

RECTANGLE—A parallelogram in which adjacent sides join at right angles.

RECTANGULAR PRISM—A solid figure whose base is a rectangle.

REFERENCE PLANE—The normal plane from which all information is referenced.

REGULAR POLYGON—An equilateral polygon.

RESIDUAL SOIL—Any soil that results from weathering in place and that is not moved from its place of origin.

RETICLE—A system of wires, hairs, threads, etched lines, or the like, placed normal to the axis of a telescope at its principal focus by means of which the telescope is sighted on a star, or target, or by means of which appropriate readings are made on some scale, such as a leveling or stadia rod.

REVERSE CURVE—See OGEE CURVE.

REVISION BLOCK—Block drawn in the upper right corner of construction drawings; contains chronological list of all changes or revisions to the drawing.

REVOLUTION—Object is projected on one or more of the planes of projection but rather than being in the normal position, it is revolved on an axis perpendicular to one of the regular planes; used when it can show the features of an object more clearly than a normal orthographic projection.

REVOLVED SECTION—A sectional view used to show the internal structure of an item within the normal orthographic view.

RHOMBOID—A nonequilateral parallelogram in which adjacent sides join at oblique angles.

RHOMBUS—An equilateral parallelogram in which adjacent sides join at oblique (other than right) angles.

RIGHT ANGLE—An angle of 90°.

ROOT—The number of times a quantity is found as an equal factor within another quantity; for example.

$\sqrt[4]{16}$ = 4th root of 16 = 2

$2 \cdot 2 \cdot 2 \cdot 2 = 16$

2 is the 4th root of 16

SATURATION, DEGREE OF (S.)—The ratio, expressed as a percentage, of the volume of water in a given soil mass to the total volume of intergranular space (voids).

SCALE—The ratio between the dimensions of the graphic representation of an object and the corresponding dimensions of the object itself.

SCALENE TRIANGLE—A triangle in which no sides or angles are equal.

SECANT—The ratio between the hypotenuse and the side adjacent an angle in a right triangle: sec = hyp/ad.

SECONDARY AUXILIARY VIEW—An auxiliary view that is used when neither the normal views nor the primary auxiliary view shows the features of an object in its true size and shape.

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

SECTION VIEW—A view used to show the internal structure of an object; used when hidden lines in the normal orthographic views do not amply describe the object.

SECTOR OF A CIRCLE—The part of a circle bounded by two radii and their intercepted arc.

SEGMENT OF A CIRCLE—The part of a circle bounded by a chord and its arc.

SHRINKAGE LIMIT—The maximum water content at which a reduction in water content will not cause a decrease in volume of the soil mass.

SHRINKAGE RATIO-The ratio between a given volume change, expressed as a percentage of the dry volume, and the corresponding change in water content above the shrinkage limit, expressed as a percent of the weight of the oven-dried soil.

SINE—The ratio between the side opposite an angle and the hypotenuse of a triangle: sin = opp/hy.

SKETCH—A quick freehand drawing, usually pictorial, used to convey information or an idea.

SOIL—A mixture of uncemented or loosely cemented mineral grains enclosing various sizes of voids containing air (or other gases), water, and organic matter, or varying combinations of these materials.

SOIL, COARSE-GRAINED-Soil in which more than half of the material, by weight, is retained on a No. 200 sieve.

SOIL, FINE-GRAINED—Soil in which more than half of the material, by weight, passes a No. 200 sieve.

SPACE BLOCKS—Strips placed under the edges of triangles, french curves, and like instruments to prevent ink from running under the edge.

SPECIFIC GRAVITY, APPARENT **(G_A)—The** The ratio of the weight in air of a given volume of the impermeable portion of soil particles to the weight in air of an equal volume of distilled water, both at a stated temperature.

SPECIFIC GRAVITY, BULK **(G_M)—The** The ratio of the weight in air of a given volume of permeable material (including permeable and impermeable voids) to the weight of an equal volume of distilled water at a stated temperature.

SPECIFIC GRAVITY OF SOLIDS **(G_S)—The** The ratio of the weight in air of a given volume of soil particles to the weight of an equal volume of distilled water, both at a stated temperature.

SPHERE—A solid figure having every point on its surface equidistant from its center.

SQUARE—An equilateral rectangle.

STATION—A definite point on the earth's surface whose location has been determined by surveying methods. It maybe a point on a traverse over which an instrument is set up or a length of 100 ft measured on a given line-broken, straight, or curved.

STATION POINT—See POINT OF SIGHT.

STITCH LINE—Dark medium line consisting of very short dashes closely spaced; used to indicate stitching or sewing lines on an article.

SUBBASE—The course in the asphalt pavement structure immediately below the base course is called the subbase course. If the subgrade soil is of adequate quality, it may serve as the subbase.

SUBGRADE—The soil prepared to support a structure or a pavement system. It is the foundation for the pavement structure. The subgrade soil is sometimes called “basement soil” or “foundation soil.”

SYSTEMATIC ERRORS—Errors that, as long as conditions are unchanged, will always have the same magnitude and the same algebraic sign.

TANGENT—The ratio between the side opposite and the side adjacent an angle in a right triangle: tan = opp/ad.

TANGENT LINE—A line that touches the circumference of a circle at one point and is perpendicular to the radius at the point of tangency.

TARGET—Any object to which the instrument is pointed. A target may be a plumb bob or plumb bob cord, a nail in the top of a stake, a taping arrow, a ranging pole, a pencil, or any other object that will provide a sharply defined, stationary point or line. A target is usually placed vertically over an unoccupied transit station.

TECHNICAL ENGINEERING CHARTS—Charts based on a series of measurements of laboratory experiments or work activities.

TEMPLATES—Timesaving devices used to draw various shapes and symbols. Templates are available for all types of drawings.

THIRD-ANGLE PROJECTION—Multiview projection commonly used in the United States. The top view projects above the front view, and the sides and bottom automatically project into their proper positions.

TITLE BLOCK—Block drawn in the lower right corner of a drawing; it should contain all the information necessary to identify the drawing.

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

TRACING VELLUM—See TRACING PAPER.

TRANSIT STATION—A marked point over which the instrument is, has been, or will be, accurately positioned for use.

TRANSPORTED SOIL—A soil that has been moved by natural forces to a location other than its origin.

TRAVERSE THE INSTRUMENT—Rotate the instrument about its vertical axis; that is, turn the instrument in azimuth.

TRIANGLE—A polygon of three sides.

TRIANGULAR PRISM—A solid figure whose base is a triangle.

TRIGONOMETRY—That branch of mathematics that deals with certain constant relationships that exist in triangles and with methods of applying these relationships to compute unknown values from known values.

TRAPEZOID—A quadrilateral with only one pair of opposite sides parallel, the other pair being not parallel.

TRAPEZIUM—A quadrilateral with no sides parallel.

TRIM LINES—Lightly drawn lines used as guides to trim a drawing to standard size.

VERTICAL ANGLE—An angle between two intersecting lines in a vertical plane. It should be understood that one line lies on the horizontal plane, and the angle originates from the intersection of the two planes.

VERTICAL CONTROL—Established bench marks.

VERTICAL LINE—A line that lies in the vertical plane and is perpendicular to the plane of the horizon, such as the direction of a plumb line.

VERTICAL PLANE—A plane that is perpendicular to the horizontal plane.

VIEWING PLANE LINES—Thick, heavy lines used to indicate the plane or planes from which a surface or several surfaces are viewed.

VISIBLE LINES—Solid, thick lines indicating the edges of the object being drawn.

WATER-CEMENT RATIO—The ratio of the amount of water, exclusive only of that absorbed by the aggregates, to the amount of cement in a concrete mixture. This ratio is variously stated as follows: (1) by bulk volume of cement (assuming cement to weigh 94 lb per cu ft); (2) by absolute volume of cement; (3) by weight; and (4) in terms of gallons of water per 94-lb sack of cement.

APPENDIX II

ENGINEERING TECHNICAL LIBRARY

The technical library is setup and maintained according to guidelines set forth in the COMCBPAC/LANT 5070 series instructions. These instructions contain a list of both civilian and military publications that are pertinent to most normal construction. It is the responsibility of the Engineering Aid to ensure that the library contains up-to-date publications. This is done by checking the contents of the library against the latest instructions. As the instructions give only the title and not the year of the publication, they must be compared with (1) the NAVFAC *Documentation Index,* P-349, a list of current publications available through the Navy, and (2) the Department of the Army Pamphlet 310-4, *Military Publications,* a list of current Army Technical Manuals (TMs). If special construction is anticipated, it may be necessary to add publications not included in the COMCBPAC/LANT 5070 instructions.

The following is a suggested list of civilian publications that could be added to the technical library:

AASHTO *Standard Method of Tests,* American Association of State Highway and Transportation Officials

Annual Book of ASTM Standards, American Society of Testing Materials

Architectural and Building Trades Dictionary, American Technical Society

Architectural Drawing and Light Construction, Muller

Architectural Graphic Standards, Ramsey and Sleeper

Concrete Topics, Kaiser Cement and Gypsum Corporation

Construction Form work, Design and Erection, Boley

Design and Construction of Aspha[t Pavements, Rogers and Wallace

Design and Control of Concrete Mixtures, Koswatka and Panarese

Handbook of Standard Structural Details for Buildings, Ketchum

Mechanical and Electrical Systems in Construction and Architecture, Dagostino

Placing Reinforcing Steel, Concrete Reinforcing Steel Institute

Principles and Practices of Heavy Construction, Smith

Reinforcing Bar Detailing, Concrete Reinforcing Steel Institute

Route Surveys and Design, Hickerson

Surveying, Legault, McMaster, and Marlette

Surveying: Theory and Practice, Davis, Foote, and Kelley

Elementary Surveying, Brinker and Wolf

APPENDIX III

USEFUL MATHEMATICAL SYMBOLS, FORMULAS, AND CONSTANTS

A. MATHEMATICAL SYMBOLS

SYMBOL	NAME OR MEANING
+	Addition or positive value
-	Subtraction or negative value
±	Positive or negative value
·	Multiplication dot (Centered; not to be mistaken for decimal point.)
x	Multiplication symbol
( )	Parentheses (Grouping symbols)
[ ]	Brackets (Grouping symbols)
{ }	Braces (Grouping symbols)
——	Vinculum (overscore) (Grouping symbols)
%	Percent
÷	Division symbol
:	Ratio symbol
: :	Proportion symbol
=	Equality symbol
≠	"Not equal" symbol
<	Less than
≤	Less than or equal to
>	Greater than
≥	Greater than or equal to
∝	"Varies directly as" or "is proportional to" (Not to be mistaken for Greek alpha (α).)
√	Square root symbol
$\sqrt{}$	Square root symbol with vinculum. Vinculum is made long enough to cover all factors of the number whose square root is to be taken.
$\sqrt[n]{}$	Radical symbol. Letter n represents a number indicating which root is to be taken.
i or j	Imaginary unit; operator j for electronics; represents $\sqrt{-1}$.
∞	Infinity symbol
. . .	Ellipsis. Used in series of numbers in which successive numbers are predictable by their conformance to a pattern; meaning is approximated by "etc."
$\log_a N$	Logarithm of N to the base a.
log N	Logarithm of N to the base 10. (understood)
ln N	Natural or Napierian logarithm of N.
e	Base of the natural or Napierian logarithm system=2.71 828 (Approx.)
|X|	Absolute value of X.
π	Pi. The ratio of the circumference of any circle to its diameter. Approximate numerical value is 22/7.
∴	Therefore
∠ or ∢	Angle

B. WEIGHTS AND MEASURES

Dry Measure

2 cups = 1 pint (pt)

2 pints = 1 quart (qt)

4 quarts = 1 gallon (gal)

8 quarts = 1 peck (pk)

4 pecks = 1 bushel (bu)

Liquid Measure

3 teapoons (tsp) = 1 tablespoon (tbsp)

16 tablespoons = 1 cup

2 cups = 1 pint

16 fluid ounces (OZ) = 1 pint

2 pints = 1 quart

4 quarts = 1 gallon

31.5 gallons = 1 barrel (bbl)

231 cubic inches = 1 gallon

7.48 gallons = 1 cubic foot (CU ft)

Weight

16 ounces = 1 pound (lb)

2,000 pounds = 1 short ton (T)

2,240 pounds = 1 long ton

Distance

12 inches = 1 foot (ft)

3 feet = 1 yard (yd)

5-1/2 yards = 1 rod (rd)

16-1/2 feet = 1 rod

1,760 yards = 1 statute mile (mi)

5,280 feet = 1 statute mile

Area

144 square inches = 1 square foot (sq ft)

9 square feet = 1 square yd (sq yd)

30- 1/4 square yards = 1 square rod

160 square rods = 1 acre (A)

640 acres = 1 square mile (sq mi)

Volume

1,728 cubic inches = 1 cubic foot

27 cubic feet = 1 cubic yard (CU yd)

Counting Units

12 units = 1 dozen (doz)

12 dozens = 1 gross

144 units = 1 gross

24 sheets = 1 quire

480 sheets = 1 ream

Equivalents

1 cubic foot of water weighs 62.5 pounds (approx) = 1,000 ounces

1 gallon of water weighs 8-1/3 pounds (approx)

1 cubic foot = 7.48 gallons

1 inch = 2.54 centimeters

1 foot = 30.4801 centimeters

1 meter = 39.37 inches

1 liter = 1.05668 quarts (liquid) = 0.90808 quart (dry)

1 nautical mile = 6,080 feet (approx)

1 fathom = 6 feet

1 shot of chain = 15 fathoms

Feet	× .00019	= miles
Feet	× 1.5	= links
Yards	× .9144	= meters
Yards	× .0006	= miles
Links	× .22	= yards
Links	× .66	= feet
Rods	× 25	= links
Rods	× 16.5	= feet
Square inches	× .007	= square feet
Square inches	× 6.451	= square centimeters
Square centimeters	× 0.1550	= square inches
Square feet	× .111	= square yards
Square feet	× .0929	= centares (square meters)
Square feet	× 929	= square centimeters
Square feet	× 144	= square inches
Square yards	× .0002067	= acres
Acres	× 4840.0	= square yards
Square yards	× 1,296	= square inches
Square yards	× 9	= square feet
Square yards	× 0.8362	= centares
Square miles, statute	× 640	= acres
Square miles, statute	× 25,900	= ares
Square miles, statute	× 259	= hectares
Square miles, statute	× 2.590	= square kilometers
Cubic inches	× .00058	= cubic feet

Cubic feet	× .03704	= cubic yards
Tons (metric)	× 2,204.6	= pounds (avoirdupois)
Tons (metric)	× 1,000	= kilograms
Tons (short)	× 2,000	= pounds (avoirdupois)
Tons (short)	× 0.9072	= metric tons
Tons (long)	× 2,240	= pounds (avoirdupois)
Tons (long)	× 1.016	= metric tons
π	= 3.141592654	
1 radian	= $180°/\pi$ = 57.2957790° = approx. 57°17′44.8″	
1 radian	= 1018.6 miles	
1 degree	= 0.0174533 radian	
1 minute	= 0.0002909 radian	
1 mil	= 0.0009817 radian	
π radians	= 180°	
$\pi/2$ radians	= 90°	
Radius	= arc of 57.2957790°	

Arc of 1° (radius = 1) = .017453292

Arc of 1′ (radius = 1) = .000290888

Arc of 1″ (radius = 1) = .000004848

Area of sector of circle = 1/2 Lr (L = length of arc; r = radius)

Area of segment of parabola = 2/3 cm (c = chord; m = mid. ord.)

Area of segment of circle = approx. 2/3 cm

Arc − chord length = 0.02 foot per 11 1/2 miles

Curvature of earth's surface = approx. 0.667 foot per mile

C. GEOMETRIC FORMULAS

(Area, Perimeter, Volume, Surface Area)

In the geometric formulas listed in this appendix the following letter designations are used except as noted otherwise:

a, b, c, d and e denote lengths of sides

h denotes perpendicular height

s denotes slant height

A denotes area (plane figures)

C denotes circumference

D denotes diameter

I denotes interior angles

L denotes lateral area (lateral area)

P denotes perimeter

R denotes radius

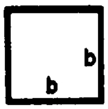
S denotes surface area (solid figures)

V denotes volume

C. GEOMETRIC FORMULAS—CONTINUED

TRIANGLES

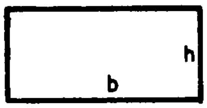
$$A = \frac{bh}{2}$$



SQUARE

$$A = b^2$$

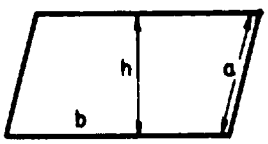
$$P = 4b$$



RECTANGLE

$$A = bh$$

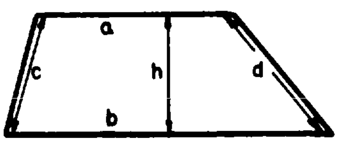
$$P = 2b + 2h$$



PARALLELOGRAM

$$A = bh$$

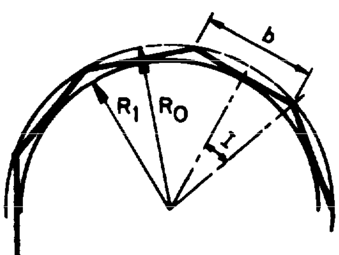
$$P = 2a + 2b$$



TRAPEZOID

$$A = \frac{h\,(a+b)}{2}$$

$$P = a + b + c + d$$

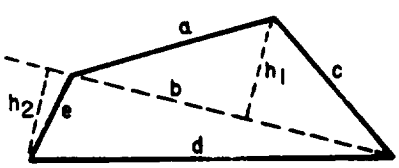


REGULAR POLYGON

$$A = \frac{nb\ R_1}{2}$$ WHERE n DENOTES THE NUMBER OF SIDES

$$b = 2\sqrt{R_O^2 - R_1^2}$$

$$R_O = \frac{b}{2 \tan I}, \quad R_1 = \frac{b}{2 \sin I}$$

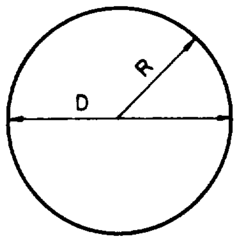


TRAPEZIUM

$$A = \frac{b\,(h_1 + h_2)}{2}$$ WHERE b IS A COMMON BASE

$$P = a + c + d + e$$

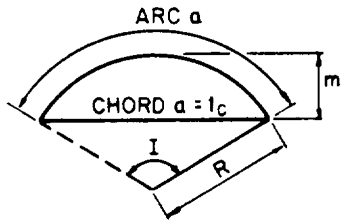
C. GEOMETRIC FORMULAS—CONTINUED



CIRCLE

$A = \pi R^2$, $A = \frac{1}{4}\pi D^2$

$C = 2\pi R$, $C = \pi D$



CIRCULAR SEGMENT

$A = \dfrac{a(R - 1_c)(R - m)}{2}$ WHERE a DENOTES LENGTH OF ARC

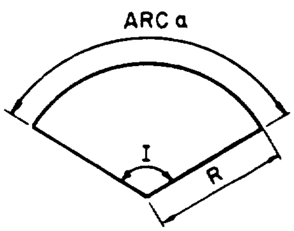
1_c DENOTES CHORD LENGTH

m DENOTES MIDDLE ORDINATE

$1_c = 2\sqrt{2mR - m^2}$

$1_c = 2R \sin \frac{I}{2}$

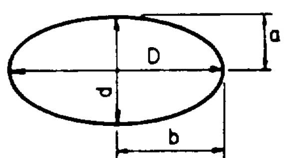
$a = \dfrac{\pi R I}{180°}$, $a = 0.0175RI$ (APPROX.)



CIRCULAR SECTOR

$A = \dfrac{aR}{2}$, $A = \dfrac{\pi R^2 I}{360}$, $A = 0.0087R^2 I$ (APPROX.)

a = (SEE FORMULAS FOR CIRCULAR SEGMENT)



ELLIPSE

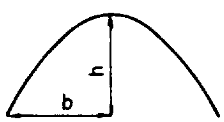
$A = \dfrac{\pi D d}{4}$ WHERE D = THE MAJOR AXIS

d = THE MINOR AXIS

$P = \pi\sqrt{2(a^2 + b^2)}$ (APPROX.) WHERE

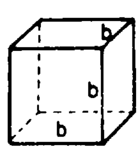
$a = \frac{1}{2}$ THE MINOR AXIS

$b = \frac{1}{2}$ THE MAJOR AXIS



PARABOLA

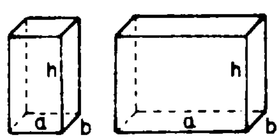
$A = \dfrac{4hb}{3}$



CUBE

$V = b^3$

$S = 6b^2$

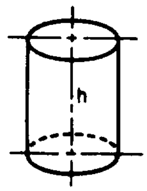


RIGHT RECTANGULAR PRISMS

$V = abh$

$S = 2ab + 2ah + 2bh$

C. GEOMETRIC FORMULAS—CONTINUED



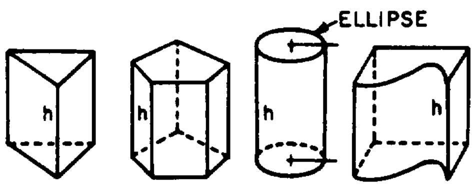
RIGHT CIRCULAR

$V = \pi R^2 h$

$L = 2\pi R h$

$S = 2\pi R^2 + 2\pi R h$

S = 2 (AREA OF BASE) + (CIRCUMFERENCE X HEIGHT)

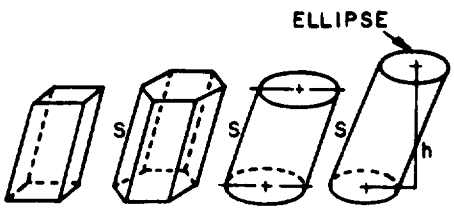


ANY RIGHT PRISM OR CYLINDER
REGULAR OR IRREGULAR

V = AREA OF THE BASE X THE HEIGHT

L = PERIMETER OF BASE X HEIGHT

S = 2 (AREA OF BASE) + (PERIMETER OF BASE X HEIGHT)



ANY OBLIQUE PRISM OR CYLINDER
REGULAR OR IRREGULAR

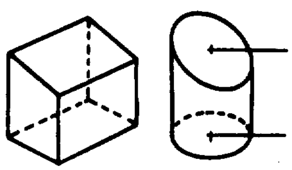
V = AREA OF BASE X HEIGHT

L = PERIMETER X SLANT HEIGHT

S = 2 (AREA OF BASE) + (PERIMETER OF BASE X SLANT HEIGHT)

WHERE HEIGHT = PERPENDICULAR DISTANCE BETWEEN BASES

SLANT HEIGHT = DISTANCE ALONG SLANTED SURFACE BETWEEN BASES



ANY REGULAR RIGHT PRISM OR
CYLINDER WITH NONPARALLEL
BASES

V = COMPUTE VOLUME THE SAME AS IF BASES ARE PARALLEL BUT LET THE HEIGHT EQUAL THE AVERAGE PERPENDICULAR DISTANCES BETWEEN BASES

NOTE: PRISMS MUST HAVE AN EVEN NUMBER OF SIDES (2,4,6,...) THERE IS NO SIMPLE METHOD OF COMPUTING THE VOLUME OF PRISMS WITH AN ODD NUMBER OF SIDES OR FACES.

AREAS – (CYLINDERS AND EVEN-SIDED PRISMS)

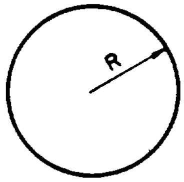
L = PERIMETER OF BASE X AVERAGE HEIGHT

(ODD-SIDED PRISMS)

L = DIVIDE EACH SIDE INTO SIMPLE GEOMETRIC FIGURES COMPUTE AREA AND TOTAL

S = LATERAL AREA + AREA OF BASES

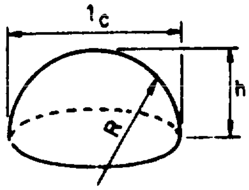
NOTE: THE AREA OF THE OBLIQUE BASE MAY NOT BE COMPUTABLE BY A SIMPLE METHOD.



SPHERE

$$V = \frac{4\pi R^3}{3}, \quad V = 0.5236D^3 \text{ (APPROX.)}$$

$$S = 4\pi R^2, \quad S = \pi D^2$$

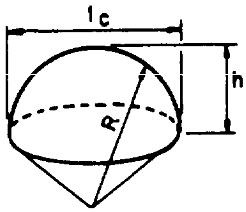


SEGMENT OF SPHERE

$$V = \frac{\pi h^2 (3R - h)}{3}$$

$$S = 2\pi Rh \text{ (NOT INCLUDING CIRCULAR BASE)}$$

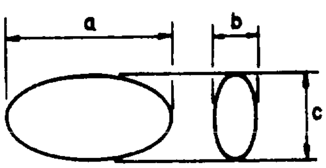
$$S = 2\pi Rh + \frac{l_c^2}{4} \text{ (TOTAL)}$$ WHERE l_c = CHORD LENGTH



SECTOR OF SPHERE

$$V = 2\pi R^2 h$$

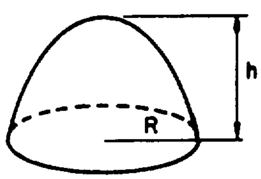
$$S = \frac{\pi R (4h + l_c)}{2}$$ WHERE l_c = CHORD LENGTH



ELLIPSOID

$$V = \frac{\pi abc}{6}$$

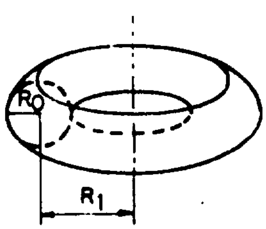
SURFACE AREA - NO SIMPLE METHOD OF COMPUTATION



PARABOLOID OF REVOLUTION

$$V = \frac{\pi R^2 h}{2}$$

SURFACE AREA - NO SIMPLE METHOD OF COMPUTATION

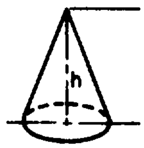


CIRCULAR RING (TORUS)

$$V = 2\pi^2 R_0^2 R_1$$

$$S = 4\pi^2 R_0 R_1$$

C. GEOMETRIC FORMULAS–CONTINUED

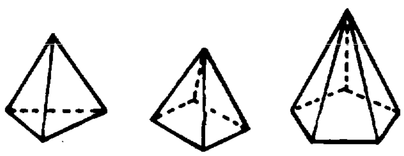


RIGHT CIRCULAR CONE

$V = \frac{\pi R^2 h}{3}$

$L = s\pi R$

$S = s\pi R + \pi R^2$ (TOTAL)

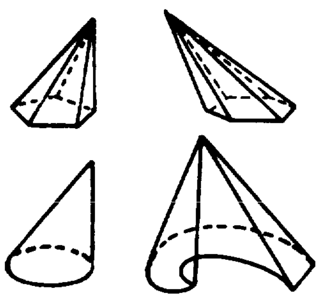


ANY REGULAR RIGHT PYRAMID

$V = \frac{1}{3}$ HEIGHT X AREA OF THE BASE

$L = \frac{1}{2}$ SLANT HEIGHT X PERIMETER OF THE BASE

NOTE: TO OBTAIN TOTAL SURFACE, ADD AREA OF BASE TO GIVEN SURFACE FORMULA.

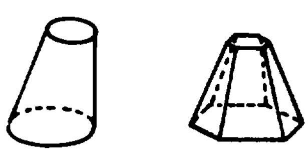


ANY OBLIQUE PYRAMID OR CONE
(REGULAR OR IRREGULAR)

$V = \frac{1}{3}$ HEIGHT X AREA OF THE BASE

WHERE THE HEIGHT IS THE PERPENDICULAR DISTANCE FROM THE BASE TO THE VERTEX

L, S, – NO SIMPLE METHOD OF COMPUTATION

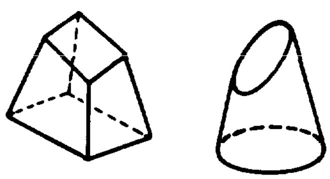


FRUSTUM OF ANY PYRAMID OR CONE

IN ANY FRUSTUM THE BASES ARE PARALLEL:

1. TOTAL HEIGHT OF FIGURE MUST BE KNOWN OR COMPUTED (PERPENDICULAR AND SLANT HEIGHT)
2. HEIGHT OF FRUSTUM MUST BE KNOWN OR COMPUTED (PERPENDICULAR AND SLANT HEIGHT)
3. COMPUTE VOLUME OR SURFACE AREA OF TOTAL FIGURE
4. COMPUTE VOLUME OR SURFACE AREA OF PORTION REMOVED
5. SUBTRACT REMOVED PORTION FROM TOTAL
6. ADD AREA OF BOTH BASES TO OBTAIN TOTAL SURFACE AREA

C. GEOMETRIC FORMULAS—CONTINUED



TRUNCATED PORTION OF ANY PYRAMID OR CONE

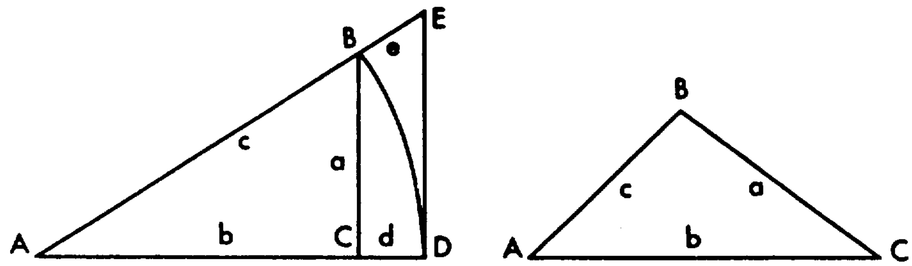
IN ANY TRUNCATED FIGURE THE BASES ARE NOT PARALLEL:

1. TOTAL HEIGHT OF FIGURE MUST BE KNOWN OR COMPUTED (PERPENDICULAR AND SLANT HEIGHT)
2. AVERAGE HEIGHT OF TRUNCATED FIGURE MUST BE KNOWN OR COMPUTED (PERPENDICULAR AND SLANT HEIGHT)
3. COMPUTE VOLUME OR SURFACE AREA OF TOTAL FIGURE
4. COMPUTE VOLUME OR SURFACE AREA OF PORTION REMOVED (HEIGHT = HEIGHT OF TOTAL FIGURE MINUS THE AVERAGE HEIGHT OF THE TRUNCATED FIGURE)
5. SUBTRACT REMOVED PORTION FROM TOTAL
6. ADD AREA OF BOTH BASES (IF THEY ARE OBTAINABLE) TO OBTAIN TOTAL AREA

NOTE: TRUNCATED PYRAMIDS MUST HAVE AN EVEN NUMBER OF SIDES (2, 4, 6, ... etc.) TO BE COMPUTED.
OBLIQUE TRUNCATED PYRAMIDS AND CONES ARE TREATED IN THE SAME MANNER AS FULL OBLIQUE PYRAMIDS AND CONES

D. RIGHT AND OBLIQUE TRIANGLE FORMULAS

1. Solution of triangles



SOLUTION OF RIGHT TRIANGLES

1. $\sin A = \frac{a}{c} = \cos B$

2. $\cos A = \frac{b}{c} = \sin B$

3. $\tan A = \frac{a}{b} = \cot B$

4. $\cot A = \frac{b}{a} = \tan B$

5. $\sec A = \frac{c}{b} = \operatorname{cosec} B$

6. $\operatorname{cosec} A = \frac{c}{a} = \sec B$

7. $\operatorname{vers} A = \frac{c-b}{c} = \frac{d}{c}$

8. $\operatorname{exsec} A = \frac{e}{c}$

9. $a = c \sin A = b \tan A = c \cos B = b \cot B = \sqrt{(c+b)(c-b)}$

10. $b = c \cos A = a \cot A = c \sin B = a \tan B = \sqrt{(c+a)(c-a)}$

11. $d = c \operatorname{vers} A$

12. $e = c \operatorname{exsec} A$

13. $c = \frac{a}{\cos B} = \frac{b}{\sin B} = \frac{a}{\sin A} = \frac{b}{\cos A} = \frac{d}{\operatorname{vers} A} = \frac{e}{\operatorname{exsec} A}$

SOLUTION OF OBLIQUE TRIANGLES

Given	Sought	Formulas
14. A, B, a	b, c	$b = \frac{a}{\sin A} \cdot \sin B.$ $\quad c = \frac{a}{\sin A} \sin (A + B)$
15. A, a, b	B, c	$\sin B = \frac{\sin A}{a}\ b.$ $\quad c = \frac{a}{\sin a} \cdot \sin C.$
16. C, a, b	A − B	$\tan \frac{1}{2}(A - B) = \frac{a - b}{a + b} \tan \frac{1}{2}(A + B)$
17. a, b, c	A	Let $s = \frac{1}{2}(a + b + c)$; $\sin \frac{1}{2} A = \sqrt{\frac{(s - b)(s - c)}{bc}}$
18.		$\cos \frac{1}{2} A = \sqrt{\frac{s(s - a)}{bc}}$; $\tan \frac{1}{2} A = \sqrt{\frac{(s - b)(s - c)}{s(s - a)}}$
19.		$\sin A = \frac{2\sqrt{s(s - a)(s - b)(s - c)}}{bc}$;
20.		$\operatorname{vers} A = \frac{2(s - b)(s - c)}{bc}$
21.	area	$\text{area} = \sqrt{s(s - a)(s - b)(s - c)}$
22. A, B, C, a	area	$\text{area} = \frac{a^2 \sin B \cdot \sin C}{2 \sin A}$
23. C, a, b	area	$\text{area} = \frac{1}{2} a b \sin C.$

	0°	30°	45°	60°	90°	120°	135°	150°	180°	270°
Sine	0	$\frac{1}{2}$	$\frac{1}{2}\sqrt{2}$	$\frac{1}{2}\sqrt{3}$	1	$\frac{1}{2}\sqrt{3}$	$\frac{1}{2}\sqrt{2}$	$\frac{1}{2}$	0	-1
Cosine	1	$\frac{1}{2}\sqrt{3}$	$\frac{1}{2}\sqrt{2}$	$\frac{1}{2}$	0	$-\frac{1}{2}$	$-\frac{1}{2}\sqrt{2}$	$-\frac{1}{2}\sqrt{3}$	-1	0
Tangent	0	$\frac{1}{3}\sqrt{3}$	1	$\sqrt{3}$	$\pm\infty$	$-\sqrt{3}$	-1	$-\frac{1}{3}\sqrt{3}$	0	$\pm\infty$
Cotangent	$\pm\infty$	$\sqrt{3}$	1	$\frac{1}{3}\sqrt{3}$	0	$-\frac{1}{3}\sqrt{3}$	-1	$-\sqrt{3}$	$\pm\infty$	0
Secant	1	$\frac{2}{3}\sqrt{3}$	$\sqrt{2}$	2	$\pm\infty$	-2	$-\sqrt{2}$	$-\frac{2}{3}\sqrt{3}$	-1	$\pm\infty$
Cosecant	$\pm\infty$	2	$\sqrt{2}$	$\frac{2}{3}\sqrt{3}$	1	$\frac{2}{3}\sqrt{3}$	$\sqrt{2}$	2	$\pm\infty$	-1

a. Trigonometrical formulas.—The six most usual trigonometrical functions are the ratios defined for a right-angled triangle, as follows:

$$\text{sine} = \frac{\text{opposite side}}{\text{hypotenuse}}$$

$$\text{cosine} = \frac{\text{adjacent side}}{\text{hypotenuse}}$$

$$\text{tangent} = \frac{\text{opposite side}}{\text{adjacent side}}$$

$$\text{cotangent} = \frac{\text{adjacent side}}{\text{opposite side}}$$

$$\text{secant} = \frac{\text{hypotenuse}}{\text{adjacent side}}$$

$$\text{cosecant} = \frac{\text{hypotenuse}}{\text{opposite side}}$$

Right-angled triangles can be solved by the above and oblique triangles may be solved by the use of the additional relations for any triangle

$$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$$

$$\frac{a-b}{a+b} = \frac{\tan \frac{1}{2}(A-B)}{\tan \frac{1}{2}(A+B)}$$

and the group

$$a^2 = b^2 + c^2 - 2bc \cos A$$
$$b^2 = a^2 + c^2 - 2ac \cos B$$
$$c^2 = a^2 + b^2 - 2ab \cos C$$

Where A, B, and C are the angles and a, b, and c are the sides opposite to these angles, respectively.

b. Fundamental relations.

$$\sin A = \frac{1}{\csc A};\ \cos A = \frac{1}{\sec A};\ \tan A = \frac{1}{\cot A} = \frac{\sin A}{\cos A}$$

$$\csc A = \frac{1}{\sin A};\ \sec A = \frac{1}{\cos A};\ \cot A = \frac{1}{\tan A} = \frac{\cos A}{\sin A}$$

$$\sin^2 A + \cos^2 A = 1;\ \sec^2 A - \tan^2 A = 1;\ \csc^2 A - \cot^2 A = 1$$

c. Functions of multiple angles.

$$\sin 2A = 2 \sin A \cos A$$
$$\cos 2A = 2\cos^2 A - 1 = 1 - 2\sin^2 A = \cos^2 A - \sin^2 A$$
$$\sin 3A = 3 \sin A - 4 \sin^3 A;$$
$$\cos 3A = 4 \cos^3 A - 3 \cos A$$

d. Functions of half angles.

$$\sin\frac{A}{2} = \pm\sqrt{\frac{1-\cos A}{2}} \qquad \cos\frac{A}{2} = \pm\sqrt{\frac{1+\cos A}{2}}$$

$$\tan\frac{A}{2} = \pm\frac{1-\cos A}{\sin A} = \frac{\sin A}{1+\cos A} = \pm\sqrt{\frac{1-\cos A}{1+\cos A}}$$

Powers of functions.

$\sin^2 A = \frac{1}{2}(1-\cos 2A)$; $\quad \cos^2 A = \frac{1}{2}(1+\cos 2A)$

$\sin^3 A = \frac{1}{4}(3\sin A - \sin 3A)$; $A = \frac{1}{4}(\cos 3A + 3\cos A)$

e. Sum and difference of angles.

$$\sin(A \pm B) = \sin A \cos B \pm \cos A \sin B$$

$$\cos(A \pm B) = \cos A \cos B \mp \sin A \sin B$$

$$\tan(A \pm B) = \frac{\tan A \pm \tan B}{1 \mp \tan A \tan B}$$

f. Sums, differences, and products of functions.

$$\sin A \pm \sin B = 2\sin\tfrac{1}{2}(A \pm B)\cos\tfrac{1}{2}(A \mp B)$$

$$\cos A + \cos B = 2\cos\tfrac{1}{2}(A+B)\cos\tfrac{1}{2}(A-B)$$

$$\cos A - \cos B = -2\sin\tfrac{1}{2}(A+B)\sin\tfrac{1}{2}(A-B)$$

$$\tan A \pm \tan B = \frac{\sin(A \pm B)}{\cos A \cos B}$$

$$\sin^2 A - \sin^2 B = \sin(A+B)\sin(A-B)$$

$$\cos^2 A - \cos^2 B = -\sin(A+B)\sin(A-B)$$

$$\cos^2 A - \sin^2 B = \cos(A+B)\cos(A-B)$$

$$\sin A \sin B = \tfrac{1}{2}\cos(A-B) - \tfrac{1}{2}\cos(A+B)$$

$$\cos A \cos B = \tfrac{1}{2}\cos(A-B) + \tfrac{1}{2}\cos(A+B)$$

$$\sin A \cos B = \tfrac{1}{2}\sin(A+B) + \tfrac{1}{2}\sin(A-B)$$

The relations for angles greater than 90° are shown in the following tabulation where x represents an angle in the first quadrant where all the functions are positive.

angle	sine	cosine	tangent	cotangent
x	+ sin x	+ cos x	+ tan x	+ cot x
90° + x	+ cos x	− sin x	− cot x	− tan x
180° + x	− sin x	− cos x	+ tan x	+ cot x
270° + x	− cos x	+ sin x	− cot x	− tan x

D. RIGHT AND OBLIQUE TRIANGLE FiORMULAS—CONTINUED

2. General formulas

24. $\sin A = 2 \sin \tfrac{1}{2} A \cos \tfrac{1}{2} A = \sqrt{1 - \cos^2 A} = \tan A \cos A$

25. $\cos A = 2 \cos^2 \tfrac{1}{2} A - 1 = 1 - 2 \sin^2 \tfrac{1}{2} A = \cos^2 \tfrac{1}{2} A - \sin^2 \tfrac{1}{2} A$

26. $\tan A = \dfrac{\sin A}{\cos A} = \dfrac{\sin 2A}{1 + \cos 2A}$

27. $\cot A = \dfrac{\cos A}{\sin A} = \dfrac{\sin 2A}{1 - \cos 2A} = \dfrac{\sin 2A}{\text{vers } 2A}$

28. $\text{vers } A = 1 - \cos A = \sin A \tan \tfrac{1}{2} A = 2 \sin^2 \tfrac{1}{2} A$

29. $\text{exsec } A = \sec A - 1 = \tan A \tan \tfrac{1}{2} A = \dfrac{\text{vers } A}{\cos A}$

30. $\sin 2A = 2 \sin A \cos A$

31. $\cos 2A = 2 \cos^2 A - 1 = \cos^2 A - \sin^2 A = 1 - 2 \sin^2 A$

32. $\tan 2A = \dfrac{2 \tan A}{1 - \tan^2 A}$

33. $\cot 2A = \dfrac{\cot^2 A - 1}{2 \cot A}$

34. $\text{vers } 2A = 2 \sin^2 A = 2 \sin A \cos A \tan A$

35. $\text{exsec } 2A = \dfrac{2 \tan^2 A}{1 - \tan^2 A}$

36. $\sin^2 A + \cos^2 A = 1$

37. $\sin (A \pm B) = \sin A \,.\, \cos B \pm \sin B \,.\, \cos A$

38. $\cos (A \pm B) = \cos A \,.\, \cos B \pm \sin A \,.\, \sin B$

39. $\sin A + \sin B = 2 \sin \tfrac{1}{2} (A + B) \cos \tfrac{1}{2} (A - B)$

40. $\sin A - \sin B = 2 \cos \tfrac{1}{2} (A + B) \sin \tfrac{1}{2} (A - B)$

41. $\cos A + \cos B = 2 \cos \tfrac{1}{2} (A + B) \cos \tfrac{1}{2} (A - B)$

42. $\cos B - \cos A = 2 \sin \tfrac{1}{2} (A + B) \sin \tfrac{1}{2} (A - B)$

43. $\sin^2 A - \sin^2 B = \cos^2 B - \cos^2 A = \sin (A + B) \sin (A - B)$

44. $\cos^2 A - \sin^2 B = \cos (A + B) \cos (A - B)$

45. $\tan A + \tan B = \dfrac{\sin (A + B)}{\cos A \,.\, \cos B}$

46. $\tan A - \tan B = \dfrac{\sin (A - B)}{\cos A \,.\, \cos B}$

47. $\sin 3A = 3 \sin A - 4 \sin^3 A$

48. $\cos 3A = 4 \cos^3 A - 3 \cos A$

49. $\sin \dfrac{A}{2} = \pm \sqrt{\dfrac{1 - \cos A}{2}}$

50. $\cos \dfrac{A}{2} = \pm \sqrt{\dfrac{1 + \cos A}{2}}$

51. $\tan \dfrac{A}{2} = \pm \dfrac{1 - \cos A}{\sin A} = \dfrac{\sin A}{1 + \cos A} = \pm \sqrt{\dfrac{1 - \cos A}{1 + \cos A}}$

52. $\sin^2 A = \tfrac{1}{2} (1 - \cos 2A)$

53. $\cos^2 A = \tfrac{1}{2} (1 + \cos 2A)$

54. $\sin^3 A = \tfrac{1}{4} (3 \sin A - \sin 3A)$

55. $\cos^3 A = \tfrac{1}{4} (\cos 3A + 3 \cos A)$

56. $\sin A \sin B = \tfrac{1}{2} \cos (A - B) - \tfrac{1}{2} \cos (A + B)$

57. $\cos A \cos B = \tfrac{1}{2} \cos (A - B) + \tfrac{1}{2} \cos (A + B)$

58. $\sin A \cos B = \tfrac{1}{2} \sin (A + B) + \tfrac{1}{2} \sin A - B$

E. NATURAL SINES AND COSINES

MIN	0°		1°		2°		3°		4°		
	SIN	COS	SIN	COS	SIN	COS	SIN	COS	SIN	COS	
0	0000000	1.00000	0.01745	0.99985	0.03490	0.99939	0.05234	0.99863	0.06976	0.99756	60
1	0.00029	1.00000	0.01774	0.99984	0.03519	0.99938	0.05263	0.99861	0.07005	0.99754	59
2	0.00058	1.00000	0.01803	0.99984	0.03548	0.99937	0.05292	0.99860	0.07034	0.99752	58
3	0.00087	1.00000	0.01832	0.99983	0.03577	0.99936	0.05321	0.99858	0.07063	0.99750	57
4	0.00116	1.00000	0.01862	0.99983	0.03606	0.99935	0.05350	0.99857	0.07092	0.99748	56
5	0.00145	1.00000	0.01891	0.99982	0.03635	0.99934	0.05379	0.99855	0.07121	0.99746	55
6	0.00175	1.00000	0.01920	0.99982	0.03664	0.99933	0.05408	0.99854	0.07150	0.99744	54
7	0.00204	1.00000	0.01949	0.99981	0.03693	0.99932	0.05437	0.99852	0.07179	0.99742	53
8	0.00233	1.00000	0.01978	0.99980	0.03723	0.99931	0.05466	0.99851	0.07208	0.99740	52
9	0.00262	1.00000	0.02007	0.99980	0.03752	0.99930	0.05495	0.99849	0.07237	0.99738	51
10	0.00291	1.00000	0.02036	0.99979	0.03781	0.99929	0.05524	0.99847	0.07266	0.99736	50
11	0.00320	0.99999	0.02065	0.99979	0.03810	0.99927	0.05553	0.99846	0.07295	0.99734	49
12	0.00349	0.99999	0.02094	0.99978	0.03839	0.99926	0.05582	0.99844	0.07324	0.99731	48
13	0.00378	0.99999	0.02123	0.99977	0.03868	0.99925	0.05611	0.99842	0.07353	0.99729	47
14	0.00407	0.99999	0.02152	0.99977	0.03897	0.99924	0.05640	0.99841	0.07382	0.99727	46
15	0.00436	0.99999	0.02181	0.99976	0.03926	0.99923	0.05669	0.99839	0.07411	0.99725	45
16	0.00465	0.99999	0.02211	0.99976	0.03955	0.99922	0.05698	0.99838	0.07440	0.99723	44
17	0.00495	0.99999	0.02240	0.99975	0.03984	0.99921	0.05727	0.99836	0.07469	0.99721	43
18	0.00524	0.99999	0.02269	0.99974	0.04013	0.99919	0.05756	0.99834	0.07498	0.99719	42
19	0.00553	0.99998	0.02298	0.99974	0.04042	0.99918	0.05785	0.99833	0.07527	0.99716	41
20	0.00582	0.99998	0.02327	0.99973	0.04071	0.99917	0.05814	0.99831	0.07556	0.99714	40
21	0.00611	0.99998	0.02356	0.99972	0.04100	0.99916	0.05844	0.99829	0.07585	0.99712	39
22	0.00640	0.99998	0.02385	0.99972	0.04129	0.99915	0.05873	0.99827	0.07614	0.99710	38
23	0.00669	0.99998	0.02414	0.99971	0.04159	0.99913	0.05902	0.99826	0.07643	0.99708	37
24	0.00698	0.99998	0.02443	0.99970	0.04188	0.99912	0.05931	0.99824	0.07672	0.99705	36
25	0.00727	0.99997	0.02472	0.99969	0.04217	0.99911	0.05960	0.99822	0.07701	0.99703	35
26	0.00756	0.99997	0.02501	0.99969	0.04246	0.99910	0.05989	0.99821	0.07730	0.99701	34
27	0.00785	0.99997	0.02530	0.99968	0.04275	0.99909	0.06018	0.99819	0.07759	0.99699	33
28	0.00814	0.99997	0.02560	0.99967	0.04304	0.99907	0.06047	0.99817	0.07788	0.99696	32
29	0.00844	0.99996	0.02589	0.99966	0.04333	0.99906	0.06076	0.99815	0.07817	0.99694	31
30	0.00873	0.99996	0.02618	0.99966	0.04362	0.99905	0.06105	0.99813	0.07846	0.99692	30
31	0.00902	0.99996	0.02647	0.99965	0.04391	0.99904	0.06134	0.99812	0.07875	0.99689	29
32	0.00931	0.99996	0.02676	0.99964	0.04420	0.99902	0.06163	0.99810	0.07904	0.99687	28
33	0.00960	0.99995	0.02705	0.99963	0.04449	0.99901	0.06192	0.99808	0.07933	0.99685	27
34	0.00989	0.99995	0.02734	0.99963	0.04478	0.99900	0.06221	0.99806	0.07962	0.99683	26
35	0.01018	0.99995	0.02763	0.99962	0.04507	0.99898	0.06250	0.99804	0.07991	0.99680	25
36	0.01047	0.99995	0.02792	0.99961	0.04536	0.99897	0.06279	0.99803	0.08020	0.99678	24
37	0.01076	0.99994	0.02821	0.99960	0.04565	0.99896	0.06308	0.99801	0.08049	0.99676	23
38	0.01105	0.99994	0.02850	0.99959	0.04594	0.99894	0.06337	0.99799	0.08078	0.99673	22
39	0.01134	0.99994	0.02879	0.99959	0.04623	0.99893	0.06366	0.99797	0.08107	0.99671	21
40	0.01164	0.99993	0.02908	0.99958	0.04653	0.99892	0.06395	0.99795	0.08136	0.99668	20
41	0.01193	0.99993	0.02938	0.99957	0.04682	0.99890	0.06424	0.99793	0.08165	0.99666	19
42	0.01222	0.99993	0.02967	0.99956	0.04711	0.99889	0.06453	0.99792	0.08194	0.99664	18
43	0.01251	0.99992	0.02996	0.99955	0.04740	0.99888	0.06482	0.99790	0.08223	0.99661	17
44	0.01280	0.99992	0.03025	0.99954	0.04769	0.99886	0.06511	0.99788	0.08252	0.99659	16
45	0.01309	0.99991	0.03054	0.99953	0.04798	0.99885	0.06540	0.99786	0.08281	0.99657	15
46	0.01338	0.99991	0.03083	0.99952	0.04827	0.99883	0.06569	0.99784	0.08310	0.99654	14
47	0.01367	0.99991	0.03112	0.99952	0.04856	0.99882	0.06598	0.99782	0.08339	0.99652	13
48	0.01396	0.99990	0.03141	0.99951	0.04885	0.99881	0.06627	0.99780	0.08368	0.99649	12
49	0.01425	0.99990	0.03170	0.99950	0.04914	0.99879	0.06656	0.99778	0.08397	0.99647	11
50	0.01454	0.99989	0.03199	0.99949	0.04943	0.99878	0.06685	0.99776	0.08426	0.99644	10
51	0.01483	0.99989	0.03228	0.99948	0.04972	0.99876	0.06714	0.99774	0.08455	0.99642	9
52	0.01513	0.99989	0.03257	0.99947	0.05001	0.99875	0.06743	0.99772	0.08484	0.99639	8
53	0.01542	0.99988	0.03286	0.99946	0.05030	0.99873	0.06773	0.99770	0.08513	0.99637	7
54	0.01571	0.99988	0.03316	0.99945	0.05059	0.99872	0.06802	0.99768	0.08542	0.99635	6
55	0.01600	0.99987	0.03345	0.99944	0.05088	0.99870	0.06831	0.99766	0.08571	0.99632	5
56	0.01629	0.99987	0.03374	0.99943	0.05117	0.99869	0.06860	0.99764	0.08600	0.99630	4
57	0.01658	0.99986	0.03403	0.99942	0.05146	0.99867	0.06889	0.99762	0.08629	0.99627	3
58	0.01687	0.99986	0.03432	0.99941	0.05175	0.99866	0.06918	0.99760	0.08658	0.99625	2
59	0.01716	0.99985	0.03461	0.99940	0.05205	0.99864	0.06947	0.99758	0.08687	0.99622	1
60	0.01745	0.99985	0.03490	0.99939	0.05234	0.99863	0.06976	0.99756	0.08716	0.99619	0
	COS	SIN	COS	SIN	COS	SIN	COS	SIN	COS	SIN	MIN
	89°		88°		87°		86°		85°		

E. NATURAL SINES AND COSINES—CONTINUED

MIN	5°		6°		7°		8°		9°		
	SIN	COS	SIN	COS	SIN	COS	SIN	COS	SIN	COS	
0	0.08716	0.99619	0.10453	0.99452	0.12187	0.99255	0.13917	0.99027	0.15643	0.98769	60
1	0.08745	0.99617	0.10482	0.99449	0.12216	0.99251	0.13946	0.99023	0.15672	0.98764	59
2	0.08774	0.99614	0.10511	0.99446	0.12245	0.99248	0.13975	0.99019	0.15701	0.98760	58
3	0.08803	0.99612	0.10540	0.99443	0.12274	0.99244	0.14004	0.99015	0.15730	0.98755	57
4	0.08831	0.99609	0.10569	0.99440	0.12302	0.99240	0.14033	0.99011	0.15758	0.98751	56
5	0.08860	0.99607	0.10597	0.99437	0.12331	0.99237	0.14061	0.99006	0.15787	0.98746	55
6	0.08889	0.99604	0.10626	0.99434	0.12360	0.99233	0.14090	0.99002	0.15816	0.98741	54
7	0.08918	0.99602	0.10655	0.99431	0.12389	0.99230	0.14119	0.98998	0.15845	0.98737	53
8	0.08947	0.99599	0.10684	0.99428	0.12418	0.99226	0.14148	0.98994	0.15873	0.98732	52
9	0.08976	0.99596	0.10713	0.99424	0.12447	0.99222	0.14177	0.98990	0.15902	0.98728	51
10	0.09005	0.99594	0.10742	0.99421	0.12476	0.99219	0.14205	0.98986	0.15931	0.98723	50
11	0.09034	0.99591	0.10771	0.99418	0.12504	0.99215	0.14234	0.98982	0.15959	0.98718	49
12	0.09063	0.99588	0.10800	0.99415	0.12533	0.99211	0.14263	0.98978	0.15988	0.98714	48
13	0.09092	0.99586	0.10829	0.99412	0.12562	0.99208	0.14292	0.98973	0.16017	0.98709	47
14	0.09121	0.99583	0.10858	0.99409	0.12591	0.99204	0.14320	0.98969	0.16046	0.98704	46
15	0.09150	0.99580	0.10887	0.99406	0.12620	0.99200	0.14349	0.98965	0.16074	0.98700	45
16	0.09179	0.99578	0.10916	0.99402	0.12649	0.99197	0.14378	0.98961	0.16103	0.98695	44
17	0.09208	0.99575	0.10945	0.99399	0.12678	0.99193	0.14407	0.98957	0.16132	0.98690	43
18	0.09237	0.99572	0.10973	0.99396	0.12706	0.99189	0.14436	0.98953	0.16160	0.98686	42
19	0.09266	0.99570	0.11002	0.99393	0.12735	0.99186	0.14464	0.98948	0.16189	0.98681	41
20	0.09295	0.99567	0.11031	0.99390	0.12764	0.99182	0.14493	0.98944	0.16218	0.98676	40
21	0.09324	0.99564	0.11060	0.99386	0.12793	0.99178	0.14522	0.98940	0.16246	0.98671	39
22	0.09353	0.99562	0.11089	0.99383	0.12822	0.99175	0.14551	0.98936	0.16275	0.98667	38
23	0.09382	0.99559	0.11118	0.99380	0.12851	0.99171	0.14580	0.98931	0.16304	0.98662	37
24	0.09411	0.99556	0.11147	0.99377	0.12880	0.99167	0.14608	0.98927	0.16333	0.98657	36
25	0.09440	0.99553	0.11176	0.99374	0.12908	0.99163	0.14637	0.98923	0.16361	0.98652	35
26	0.09469	0.99551	0.11205	0.99370	0.12937	0.99160	0.14666	0.98919	0.16390	0.98648	34
27	0.09498	0.99548	0.11234	0.99367	0.12966	0.99156	0.14695	0.98914	0.16419	0.98643	33
28	0.09527	0.99545	0.11263	0.99364	0.12995	0.99152	0.14723	0.98910	0.16447	0.98638	32
29	0.09556	0.99542	0.11291	0.99360	0.13024	0.99148	0.14752	0.98906	0.16476	0.98633	31
30	0.09585	0.99540	0.11320	0.99357	0.13053	0.99144	0.14781	0.98902	0.16505	0.98629	30
31	0.09614	0.99537	0.11349	0.99354	0.13081	0.99141	0.14810	0.98897	0.16533	0.98624	29
32	0.09642	0.99534	0.11378	0.99351	0.13110	0.99137	0.14838	0.98893	0.16562	0.98619	28
33	0.09671	0.99531	0.11407	0.99347	0.13139	0.99133	0.14867	0.98889	0.16591	0.98614	27
34	0.09700	0.99528	0.11436	0.99344	0.13168	0.99129	0.14896	0.98884	0.16620	0.98609	26
35	0.09729	0.99526	0.11465	0.99341	0.13197	0.99125	0.14925	0.98880	0.16648	0.98604	25
36	0.09758	0.99523	0.11494	0.99337	0.13226	0.99122	0.14954	0.98876	0.16677	0.98600	24
37	0.09787	0.99520	0.11523	0.99334	0.13254	0.99118	0.14982	0.98871	0.16706	0.98595	23
38	0.09816	0.99517	0.11552	0.99331	0.13283	0.99114	0.15011	0.98867	0.16734	0.98590	22
39	0.09845	0.99514	0.11580	0.99327	0.13312	0.99110	0.15040	0.98863	0.16763	0.98585	21
40	0.09874	0.99511	0.11609	0.99324	0.13341	0.99106	0.15069	0.98858	0.16792	0.98580	20
41	0.09903	0.99508	0.11638	0.99320	0.13370	0.99102	0.15097	0.98854	0.16820	0.98575	19
42	0.09932	0.99506	0.11667	0.99317	0.13399	0.99098	0.15126	0.98849	0.16849	0.98570	18
43	0.09961	0.99503	0.11696	0.99314	0.13427	0.99094	0.15155	0.98845	0.16878	0.98565	17
44	0.09990	0.99500	0.11725	0.99310	0.13456	0.99091	0.15184	0.98841	0.16906	0.98561	16
45	0.10019	0.99497	0.11754	0.99307	0.13485	0.99087	0.15212	0.98836	0.16935	0.98556	15
46	0.10048	0.99494	0.11783	0.99303	0.13514	0.99083	0.15241	0.98832	0.16964	0.98551	14
47	0.10077	0.99491	0.11812	0.99300	0.13543	0.99079	0.15270	0.98827	0.16992	0.98546	13
48	0.10106	0.99488	0.11840	0.99297	0.13572	0.99075	0.15299	0.98823	0.17021	0.98541	12
49	0.10135	0.99485	0.11869	0.99293	0.13600	0.99071	0.15327	0.98818	0.17050	0.98536	11
50	0.10164	0.99482	0.11898	0.99290	0.13629	0.99067	0.15356	0.98814	0.17078	0.98531	10
51	0.10192	0.99479	0.11927	0.99286	0.13658	0.99063	0.15385	0.98809	0.17107	0.98526	9
52	0.10221	0.99476	0.11956	0.99283	0.13687	0.99059	0.15414	0.98805	0.17136	0.98521	8
53	0.10250	0.99473	0.11985	0.99279	0.13716	0.99055	0.15442	0.98800	0.17164	0.98516	7
54	0.10279	0.99470	0.12014	0.99276	0.13744	0.99051	0.15471	0.98796	0.17193	0.98511	6
55	0.10308	0.99467	0.12043	0.99272	0.13773	0.99047	0.15500	0.98791	0.17222	0.98506	5
56	0.10337	0.99464	0.12071	0.99269	0.13802	0.99043	0.15529	0.98787	0.17250	0.98501	4
57	0.10366	0.99461	0.12100	0.99265	0.13831	0.99039	0.15557	0.98782	0.17279	0.98496	3
58	0.10395	0.99458	0.12129	0.99262	0.13860	0.99035	0.15586	0.98778	0.17308	0.98491	2
59	0.10424	0.99455	0.12158	0.99258	0.13889	0.99031	0.15615	0.98773	0.17336	0.98486	1
60	0.10453	0.99452	0.12187	0.99255	0.13917	0.99027	0.15643	0.98769	0.17365	0.98481	0
	COS	SIN	COS	SIN	COS	SIN	COS	SIN	COS	SIN	MIN
	84°		83°		82°		81°		80°		

E. NATURAL SINES AND COSINES—CONTINUED

MIN	10°		11°		12°		13°		14°		
	SIN	COS	SIN	COS	SIN	COS	SIN	COS	SIN	COS	
0	0.17365	0.98481	0.19081	0.98163	0.20791	0.97815	0.22495	0.97437	0.24192	0.97030	60
1	0.17393	0.98476	0.19109	0.98157	0.20820	0.97809	0.22523	0.97430	0.24220	0.97023	59
2	0.17422	0.98471	0.19138	0.98152	0.20848	0.97803	0.22552	0.97424	0.24249	0.97015	58
3	0.17451	0.98466	0.19167	0.98146	0.20877	0.97797	0.22580	0.97417	0.24277	0.97008	57
4	0.17479	0.98461	0.19195	0.98140	0.20905	0.97791	0.22608	0.97411	0.24305	0.97001	56
5	0.17508	0.98455	0.19224	0.98135	0.20933	0.97784	0.22637	0.97404	0.24333	0.96994	55
6	0.17537	0.98450	0.19252	0.98129	0.20962	0.97778	0.22665	0.97398	0.24362	0.96987	54
7	0.17565	0.98445	0.19281	0.98124	0.20990	0.97772	0.22693	0.97391	0.24390	0.96980	53
8	0.17594	0.98440	0.19309	0.98118	0.21019	0.97766	0.22722	0.97384	0.24418	0.96973	52
9	0.17623	0.98435	0.19338	0.98112	0.21047	0.97760	0.22750	0.97378	0.24446	0.96966	51
10	0.17651	0.98430	0.19366	0.98107	0.21076	0.97754	0.22778	0.97371	0.24474	0.96959	50
11	0.17680	0.98425	0.19395	0.98101	0.21104	0.97748	0.22807	0.97365	0.24503	0.96952	49
12	0.17708	0.98420	0.19423	0.98096	0.21132	0.97742	0.22835	0.97358	0.24531	0.96945	48
13	0.17737	0.98414	0.19452	0.98090	0.21161	0.97735	0.22863	0.97351	0.24559	0.96937	47
14	0.17766	0.98409	0.19481	0.98084	0.21189	0.97729	0.22892	0.97345	0.24587	0.96930	46
15	0.17794	0.98404	0.19509	0.98079	0.21218	0.97723	0.22920	0.97338	0.24615	0.96923	45
16	0.17823	0.98399	0.19538	0.98073	0.21246	0.97717	0.22948	0.97331	0.24644	0.96916	44
17	0.17852	0.98394	0.19566	0.98067	0.21275	0.97711	0.22977	0.97325	0.24672	0.96909	43
18	0.17880	0.98389	0.19595	0.98061	0.21303	0.97705	0.23005	0.97318	0.24700	0.96902	42
19	0.17909	0.98383	0.19623	0.98056	0.21331	0.97698	0.23033	0.97311	0.24728	0.96894	41
20	0.17937	0.98378	0.19652	0.98050	0.21360	0.97692	0.23062	0.97304	0.24756	0.96887	40
21	0.17966	0.98373	0.19680	0.98044	0.21388	0.97686	0.23090	0.97298	0.24784	0.96880	39
22	0.17995	0.98368	0.19709	0.98039	0.21417	0.97680	0.23118	0.97291	0.24813	0.96873	38
23	0.18023	0.98362	0.19737	0.98033	0.21445	0.97673	0.23146	0.97284	0.24841	0.96866	37
24	0.18052	0.98357	0.19766	0.98027	0.21474	0.97667	0.23175	0.97278	0.24869	0.96858	36
25	0.18081	0.98352	0.19794	0.98021	0.21502	0.97661	0.23203	0.97271	0.24897	0.96851	35
26	0.18109	0.98347	0.19823	0.98016	0.21530	0.97655	0.23231	0.97264	0.24925	0.96844	34
27	0.18138	0.98341	0.19851	0.98010	0.21559	0.97648	0.23260	0.97257	0.24954	0.96837	33
28	0.18166	0.98336	0.19880	0.98004	0.21587	0.97642	0.23288	0.97251	0.24982	0.96829	32
29	0.18195	0.98331	0.19908	0.97998	0.21616	0.97636	0.23316	0.97244	0.25010	0.96822	31
30	0.18224	0.98325	0.19937	0.97992	0.21644	0.97630	0.23345	0.97237	0.25038	0.96815	30
31	0.18252	0.98320	0.19965	0.97987	0.21672	0.97623	0.23373	0.97230	0.25066	0.96807	29
32	0.18281	0.98315	0.19994	0.97981	0.21701	0.97617	0.23401	0.97223	0.25094	0.96800	28
33	0.18309	0.98310	0.20022	0.97975	0.21729	0.97611	0.23429	0.97217	0.25122	0.96793	27
34	0.18338	0.98304	0.20051	0.97969	0.21758	0.97604	0.23458	0.97210	0.25151	0.96786	26
35	0.18367	0.98299	0.20079	0.97963	0.21786	0.97598	0.23486	0.97203	0.25179	0.96778	25
36	0.18395	0.98294	0.20108	0.97958	0.21814	0.97592	0.23514	0.97196	0.25207	0.96771	24
37	0.18424	0.98288	0.20136	0.97952	0.21843	0.97585	0.23542	0.97189	0.25235	0.96764	23
38	0.18452	0.98283	0.20165	0.97946	0.21871	0.97579	0.23571	0.97182	0.25263	0.96756	22
39	0.18481	0.98277	0.20193	0.97940	0.21899	0.97573	0.23599	0.97176	0.25291	0.96749	21
40	0.18509	0.98272	0.20222	0.97934	0.21928	0.97566	0.23627	0.97169	0.25320	0.96742	20
41	0.18538	0.98267	0.20250	0.97928	0.21956	0.97560	0.23656	0.97162	0.25348	0.96734	19
42	0.18567	0.98261	0.20279	0.97922	0.21985	0.97553	0.23684	0.97155	0.25376	0.96727	18
43	0.18595	0.98256	0.20307	0.97916	0.22013	0.97547	0.23712	0.97148	0.25404	0.96719	17
44	0.18624	0.98250	0.20336	0.97910	0.22041	0.97541	0.23740	0.97141	0.25432	0.96712	16
45	0.18652	0.98245	0.20364	0.97905	0.22070	0.97534	0.23769	0.97134	0.25460	0.96705	15
46	0.18681	0.98240	0.20393	0.97899	0.22098	0.97528	0.23797	0.97127	0.25488	0.96697	14
47	0.18710	0.98234	0.20421	0.97893	0.22126	0.97521	0.23825	0.97120	0.25516	0.96690	13
48	0.18738	0.98229	0.20450	0.97887	0.22155	0.97515	0.23853	0.97113	0.25545	0.96682	12
49	0.18767	0.98223	0.20478	0.97881	0.22183	0.97508	0.23882	0.97106	0.25573	0.96675	11
50	0.18795	0.98218	0.20507	0.97875	0.22212	0.97502	0.23910	0.97100	0.25601	0.96667	10
51	0.18824	0.98212	0.20535	0.97869	0.22240	0.97496	0.23938	0.97093	0.25629	0.96660	9
52	0.18852	0.98207	0.20563	0.97863	0.22268	0.97489	0.23966	0.97086	0.25657	0.96653	8
53	0.18881	0.98201	0.20592	0.97857	0.22297	0.97483	0.23995	0.97079	0.25685	0.96645	7
54	0.18910	0.98196	0.20620	0.97851	0.22325	0.97476	0.24023	0.97072	0.25713	0.96638	6
55	0.18938	0.98190	0.20649	0.97845	0.22353	0.97470	0.24051	0.97065	0.25741	0.96630	5
56	0.18967	0.98185	0.20677	0.97839	0.22382	0.97463	0.24079	0.97058	0.25769	0.96623	4
57	0.18995	0.98179	0.20706	0.97833	0.22410	0.97457	0.24108	0.97051	0.25798	0.96615	3
58	0.19024	0.98174	0.20734	0.97827	0.22438	0.97450	0.24136	0.97044	0.25826	0.96608	2
59	0.19052	0.98168	0.20763	0.97821	0.22467	0.97444	0.24164	0.97037	0.25854	0.96600	1
60	0.19081	0.98163	0.20791	0.97815	0.22495	0.97437	0.24192	0.97030	0.25882	0.96593	0
	COS	SIN	COS	SIN	COS	SIN	COS	SIN	COS	SIN	MIN
	79°		78°		77°		76°		75°		

E. NATURAL SINES AND COSINES—CONTINUED

MIN	15° SIN	15° COS	16° SIN	16° COS	17° SIN	17° COS	18° SIN	18° COS	19° SIN	19° COS	
0	0.25882	0.96593	0.27564	0.96126	0.29237	0.95630	0.30902	0.95106	0.32557	0.94552	60
1	0.25910	0.96585	0.27592	0.96118	0.29265	0.95622	0.30929	0.95097	0.32584	0.94542	59
2	0.25938	0.96578	0.27620	0.96110	0.29293	0.95613	0.30957	0.95088	0.32612	0.94533	58
3	0.25966	0.96570	0.27648	0.96102	0.29321	0.95605	0.30985	0.95079	0.32639	0.94523	57
4	0.25994	0.96562	0.27676	0.96094	0.29348	0.95596	0.31012	0.95070	0.32667	0.94514	56
5	0.26022	0.96555	0.27704	0.96086	0.29376	0.95588	0.31040	0.95061	0.32694	0.94504	55
6	0.26050	0.96547	0.27731	0.96078	0.29404	0.95579	0.31068	0.95052	0.32722	0.94495	54
7	0.26079	0.96540	0.27759	0.96070	0.29432	0.95571	0.31095	0.95043	0.32749	0.94485	53
8	0.26107	0.96532	0.27787	0.96062	0.29460	0.95562	0.31123	0.95033	0.32777	0.94476	52
9	0.26135	0.96524	0.27815	0.96054	0.29487	0.95554	0.31151	0.95024	0.32804	0.94466	51
10	0.26163	0.96517	0.27843	0.96046	0.29515	0.95545	0.31178	0.95015	0.32832	0.94457	50
11	0.26191	0.96509	0.27871	0.96037	0.29543	0.95536	0.31206	0.95006	0.32859	0.94447	49
12	0.26219	0.96502	0.27899	0.96029	0.29571	0.95528	0.31233	0.94997	0.32887	0.94438	48
13	0.26247	0.96494	0.27927	0.96021	0.29599	0.95519	0.31261	0.94988	0.32914	0.94428	47
14	0.26275	0.96486	0.27955	0.96013	0.29626	0.95511	0.31289	0.94979	0.32942	0.94418	46
15	0.26303	0.96479	0.27983	0.96005	0.29654	0.95502	0.31316	0.94970	0.32969	0.94409	45
16	0.26331	0.96471	0.28011	0.95997	0.29682	0.95493	0.31344	0.94961	0.32997	0.94399	44
17	0.26359	0.96463	0.28039	0.95989	0.29710	0.95485	0.31372	0.94952	0.33024	0.94390	43
18	0.26387	0.96456	0.28067	0.95981	0.29737	0.95476	0.31399	0.94943	0.33051	0.94380	42
19	0.26415	0.96448	0.28095	0.95972	0.29765	0.95467	0.31427	0.94933	0.33079	0.94370	41
20	0.26443	0.96440	0.28123	0.95964	0.29793	0.95459	0.31454	0.94924	0.33106	0.94361	40
21	0.26471	0.96433	0.28150	0.95956	0.29821	0.95450	0.31482	0.94915	0.33134	0.94351	39
22	0.26500	0.96425	0.28178	0.95948	0.29849	0.95441	0.31510	0.94906	0.33161	0.94342	38
23	0.26528	0.96417	0.28206	0.95940	0.29876	0.95433	0.31537	0.94897	0.33189	0.94332	37
24	0.26556	0.96410	0.28234	0.95931	0.29904	0.95424	0.31565	0.94888	0.33216	0.94322	36
25	0.26584	0.96402	0.28262	0.95923	0.29932	0.95415	0.31593	0.94878	0.33244	0.94313	35
26	0.26612	0.96394	0.28290	0.95915	0.29960	0.95407	0.31620	0.94869	0.33271	0.94303	34
27	0.26640	0.96386	0.28318	0.95907	0.29987	0.95398	0.31648	0.94860	0.33298	0.94293	33
28	0.26668	0.96379	0.28346	0.95898	0.30015	0.95389	0.31675	0.94851	0.33326	0.94284	32
29	0.26696	0.96371	0.28374	0.95890	0.30043	0.95380	0.31703	0.94842	0.33353	0.94274	31
30	0.26724	0.96363	0.28402	0.95882	0.30071	0.95372	0.31730	0.94832	0.33381	0.94264	30
31	0.26752	0.96355	0.28429	0.95874	0.30098	0.95363	0.31758	0.94823	0.33408	0.94254	29
32	0.26780	0.96347	0.28457	0.95865	0.30126	0.95354	0.31786	0.94814	0.33436	0.94245	28
33	0.26808	0.96340	0.28485	0.95857	0.30154	0.95345	0.31813	0.94805	0.33463	0.94235	27
34	0.26836	0.96332	0.28513	0.95849	0.30182	0.95337	0.31841	0.94795	0.33490	0.94225	26
35	0.26864	0.96324	0.28541	0.95841	0.30209	0.95328	0.31868	0.94786	0.33518	0.94215	25
36	0.26892	0.96316	0.28569	0.95832	0.30237	0.95319	0.31896	0.94777	0.33545	0.94206	24
37	0.26920	0.96308	0.28597	0.95824	0.30265	0.95310	0.31923	0.94768	0.33573	0.94196	23
38	0.26948	0.96301	0.28625	0.95816	0.30292	0.95301	0.31951	0.94758	0.33600	0.94186	22
39	0.26976	0.96293	0.28652	0.95807	0.30320	0.95293	0.31979	0.94749	0.33627	0.94176	21
40	0.27004	0.96285	0.28680	0.95799	0.30348	0.95284	0.32006	0.94740	0.33655	0.94167	20
41	0.27032	0.96277	0.28708	0.95791	0.30376	0.95275	0.32034	0.94730	0.33682	0.94157	19
42	0.27060	0.96269	0.28736	0.95782	0.30403	0.95266	0.32061	0.94721	0.33710	0.94147	18
43	0.27088	0.96261	0.28764	0.95774	0.30431	0.95257	0.32089	0.94712	0.33737	0.94137	17
44	0.27116	0.96253	0.28792	0.95766	0.30459	0.95248	0.32116	0.94702	0.33764	0.94127	16
45	0.27144	0.96246	0.28820	0.95757	0.30486	0.95240	0.32144	0.94693	0.33792	0.94118	15
46	0.27172	0.96238	0.28847	0.95749	0.30514	0.95231	0.32171	0.94684	0.33819	0.94108	14
47	0.27200	0.96230	0.28875	0.95740	0.30542	0.95222	0.32199	0.94674	0.33846	0.94098	13
48	0.27228	0.96222	0.28903	0.95732	0.30570	0.95213	0.32227	0.94665	0.33874	0.94088	12
49	0.27256	0.96214	0.28931	0.95724	0.30597	0.95204	0.32254	0.94656	0.33901	0.94078	11
50	0.27284	0.96206	0.28959	0.95715	0.30625	0.95195	0.32282	0.94646	0.33929	0.94068	10
51	0.27312	0.96198	0.28987	0.95707	0.30653	0.95186	0.32309	0.94637	0.33956	0.94058	9
52	0.27340	0.96190	0.29015	0.95698	0.30680	0.95177	0.32337	0.94627	0.33983	0.94049	8
53	0.27368	0.96182	0.29042	0.95690	0.30708	0.95168	0.32364	0.94618	0.34011	0.94039	7
54	0.27396	0.96174	0.29070	0.95681	0.30736	0.95159	0.32392	0.94609	0.34038	0.94029	6
55	0.27424	0.96166	0.29098	0.95673	0.30763	0.95150	0.32419	0.94599	0.34065	0.94019	5
56	0.27452	0.96158	0.29126	0.95664	0.30791	0.95142	0.32447	0.94590	0.34093	0.94009	4
57	0.27480	0.96150	0.29154	0.95656	0.30819	0.95133	0.32474	0.94580	0.34120	0.93999	3
58	0.27508	0.96142	0.29182	0.95647	0.30846	0.95124	0.32502	0.94571	0.34147	0.93989	2
59	0.27536	0.96134	0.29209	0.95639	0.30874	0.95115	0.32529	0.94561	0.34175	0.93979	1
60	0.27564	0.96126	0.29237	0.95630	0.30902	0.95106	0.32557	0.94552	0.34202	0.93969	0
	COS	SIN	COS	SIN	COS	SIN	COS	SIN	COS	SIN	MIN
	74°		73°		72°		71°		70°		

E. NATURAL SINES AND COSINES—CONTINUED

MIN	20° SIN	20° COS	21° SIN	21° COS	22° SIN	22° COS	23° SIN	23° COS	24° SIN	24° COS	
0	0.34202	0.93969	0.35837	0.93358	0.37461	0.92718	0.39073	0.92050	0.40674	0.91355	60
1	0.34229	0.93959	0.35864	0.93348	0.37488	0.92707	0.39100	0.92039	0.40700	0.91343	59
2	0.34257	0.93949	0.35891	0.93337	0.37515	0.92697	0.39127	0.92028	0.40727	0.91331	58
3	0.34284	0.93939	0.35918	0.93327	0.37542	0.92686	0.39153	0.92016	0.40753	0.91319	57
4	0.34311	0.93929	0.35945	0.93316	0.37569	0.92675	0.39180	0.92005	0.40780	0.91307	56
5	0.34339	0.93919	0.35973	0.93306	0.37595	0.92664	0.39207	0.91994	0.40806	0.91295	55
6	0.34366	0.93909	0.36000	0.93295	0.37622	0.92653	0.39234	0.91982	0.40833	0.91283	54
7	0.34393	0.93899	0.36027	0.93285	0.37649	0.92642	0.39260	0.91971	0.40860	0.91272	53
8	0.34421	0.93889	0.36054	0.93274	0.37676	0.92631	0.39287	0.91959	0.40886	0.91260	52
9	0.34448	0.93879	0.36081	0.93264	0.37703	0.92620	0.39314	0.91948	0.40913	0.91248	51
10	0.34475	0.93869	0.36108	0.93253	0.37730	0.92609	0.39341	0.91936	0.40939	0.91236	50
11	0.34503	0.93859	0.36135	0.93243	0.37757	0.92598	0.39367	0.91925	0.40966	0.91224	49
12	0.34530	0.93849	0.36162	0.93232	0.37784	0.92587	0.39394	0.91914	0.40992	0.91212	48
13	0.34557	0.93839	0.36190	0.93222	0.37811	0.92576	0.39421	0.91902	0.41019	0.91200	47
14	0.34584	0.93829	0.36217	0.93211	0.37838	0.92565	0.39448	0.91891	0.41045	0.91188	46
15	0.34612	0.93819	0.36244	0.93201	0.37865	0.92554	0.39474	0.91879	0.41072	0.91176	45
16	0.34639	0.93809	0.36271	0.93190	0.37892	0.92543	0.39501	0.91868	0.41098	0.91164	44
17	0.34666	0.93799	0.36298	0.93180	0.37919	0.92532	0.39528	0.91856	0.41125	0.91152	43
18	0.34694	0.93789	0.36325	0.93169	0.37946	0.92521	0.39555	0.91845	0.41151	0.91140	42
19	0.34721	0.93779	0.36352	0.93159	0.37973	0.92510	0.39581	0.91833	0.41178	0.91128	41
20	0.34748	0.93769	0.36379	0.93148	0.37999	0.92499	0.39608	0.91822	0.41204	0.91116	40
21	0.34775	0.93759	0.36406	0.93137	0.38026	0.92488	0.39635	0.91810	0.41231	0.91104	39
22	0.34803	0.93748	0.36434	0.93127	0.38053	0.92477	0.39661	0.91799	0.41257	0.91092	38
23	0.34830	0.93738	0.36461	0.93116	0.38080	0.92466	0.39688	0.91787	0.41284	0.91080	37
24	0.34857	0.93728	0.36488	0.93106	0.38107	0.92455	0.39715	0.91775	0.41310	0.91068	36
25	0.34884	0.93718	0.36515	0.93095	0.38134	0.92444	0.39741	0.91764	0.41337	0.91056	35
26	0.34912	0.93708	0.36542	0.93084	0.38161	0.92432	0.39768	0.91752	0.41363	0.91044	34
27	0.34939	0.93698	0.36569	0.93074	0.38188	0.92421	0.39795	0.91741	0.41390	0.91032	33
28	0.34966	0.93688	0.36596	0.93063	0.38215	0.92410	0.39822	0.91729	0.41416	0.91020	32
29	0.34993	0.93677	0.36623	0.93052	0.38241	0.92399	0.39848	0.91718	0.41443	0.91008	31
30	0.35021	0.93667	0.36650	0.93042	0.38268	0.92388	0.39875	0.91706	0.41469	0.90996	30
31	0.35048	0.93657	0.36677	0.93031	0.38295	0.92377	0.39902	0.91694	0.41496	0.90984	29
32	0.35075	0.93647	0.36704	0.93020	0.38322	0.92366	0.39928	0.91683	0.41522	0.90972	28
33	0.35102	0.93637	0.36731	0.93010	0.38349	0.92355	0.39955	0.91671	0.41549	0.90960	27
34	0.35130	0.93626	0.36758	0.92999	0.38376	0.92343	0.39982	0.91660	0.41575	0.90948	26
35	0.35157	0.93616	0.36785	0.92988	0.38403	0.92332	0.40008	0.91648	0.41602	0.90936	25
36	0.35184	0.93606	0.36812	0.92978	0.38430	0.92321	0.40035	0.91636	0.41628	0.90924	24
37	0.35211	0.93596	0.36839	0.92967	0.38456	0.92310	0.40062	0.91625	0.41655	0.90911	23
38	0.35239	0.93585	0.36867	0.92956	0.38483	0.92299	0.40088	0.91613	0.41681	0.90899	22
39	0.35266	0.93575	0.36894	0.92945	0.38510	0.92287	0.40115	0.91601	0.41707	0.90887	21
40	0.35293	0.93565	0.36921	0.92935	0.38537	0.92276	0.40141	0.91590	0.41734	0.90875	20
41	0.35320	0.93555	0.36948	0.92924	0.38564	0.92265	0.40168	0.91578	0.41760	0.90863	19
42	0.35347	0.93544	0.36975	0.92913	0.38591	0.92254	0.40195	0.91566	0.41787	0.90851	18
43	0.35375	0.93534	0.37002	0.92902	0.38617	0.92243	0.40221	0.91555	0.41813	0.90839	17
44	0.35402	0.93524	0.37029	0.92892	0.38644	0.92231	0.40248	0.91543	0.41840	0.90826	16
45	0.35429	0.93514	0.37056	0.92881	0.38671	0.92220	0.40275	0.91531	0.41866	0.90814	15
46	0.35456	0.93503	0.37083	0.92870	0.38698	0.92209	0.40301	0.91519	0.41892	0.90802	14
47	0.35484	0.93493	0.37110	0.92859	0.38725	0.92198	0.40328	0.91508	0.41919	0.90790	13
48	0.35511	0.93483	0.37137	0.92849	0.38752	0.92186	0.40355	0.91496	0.41945	0.90778	12
49	0.35538	0.93472	0.37164	0.92838	0.38778	0.92175	0.40381	0.91484	0.41972	0.90766	11
50	0.35565	0.93462	0.37191	0.92827	0.38805	0.92164	0.40408	0.91472	0.41998	0.90753	10
51	0.35592	0.93452	0.37218	0.92816	0.38832	0.92152	0.40434	0.91461	0.42024	0.90741	9
52	0.35619	0.93441	0.37245	0.92805	0.38859	0.92141	0.40461	0.91449	0.42051	0.90729	8
53	0.35647	0.93431	0.37272	0.92794	0.38886	0.92130	0.40488	0.91437	0.42077	0.90717	7
54	0.35674	0.93420	0.37299	0.92784	0.38912	0.92119	0.40514	0.91425	0.42104	0.90704	6
55	0.35701	0.93410	0.37326	0.92773	0.38939	0.92107	0.40541	0.91414	0.42130	0.90692	5
56	0.35728	0.93400	0.37353	0.92762	0.38966	0.92096	0.40567	0.91402	0.42156	0.90680	4
57	0.35755	0.93389	0.37380	0.92751	0.38993	0.92085	0.40594	0.91390	0.42183	0.90668	3
58	0.35782	0.93379	0.37407	0.92740	0.39020	0.92073	0.40621	0.91378	0.42209	0.90655	2
59	0.35810	0.93368	0.37434	0.92729	0.39046	0.92062	0.40647	0.91366	0.42235	0.90643	1
60	0.35837	0.93358	0.37461	0.92718	0.39073	0.92050	0.40674	0.91355	0.42262	0.90631	0
	COS	SIN	COS	SIN	COS	SIN	COS	SIN	COS	SIN	MIN
	69°		68°		67°		66°		65°		

E. NATURAL SINES AND COSINES—CONTINUED

M I N	25° SIN	25° COS	26° SIN	26° COS	27° SIN	27° COS	28° SIN	28° COS	29° SIN	29° COS	
0	0.42262	0.90631	0.43837	0.89879	0.45399	0.89101	0.46947	0.88295	0.48481	0.87462	60
1	0.42288	0.90618	0.43863	0.89867	0.45425	0.89087	0.46973	0.88281	0.48506	0.87448	59
2	0.42315	0.90606	0.43889	0.89854	0.45451	0.89074	0.46999	0.88267	0.48532	0.87434	58
3	0.42341	0.90594	0.43916	0.89841	0.45477	0.89061	0.47024	0.88254	0.48557	0.87420	57
4	0.42367	0.90582	0.43942	0.89828	0.45503	0.89048	0.47050	0.88240	0.48583	0.87406	56
5	0.42394	0.90569	0.43968	0.89816	0.45529	0.89035	0.47076	0.88226	0.48608	0.87391	55
6	0.42420	0.90557	0.43994	0.89803	0.45554	0.89021	0.47101	0.88213	0.48634	0.87377	54
7	0.42446	0.90545	0.44020	0.89790	0.45580	0.89008	0.47127	0.88199	0.48659	0.87363	53
8	0.42473	0.90532	0.44046	0.89777	0.45606	0.88995	0.47153	0.88185	0.48684	0.87349	52
9	0.42499	0.90520	0.44072	0.89764	0.45632	0.88981	0.47178	0.88172	0.48710	0.87335	51
10	0.42525	0.90507	0.44098	0.89752	0.45658	0.88968	0.47204	0.88158	0.48735	0.87321	50
11	0.42552	0.90495	0.44124	0.89739	0.45684	0.88955	0.47229	0.88144	0.48761	0.87306	49
12	0.42578	0.90483	0.44151	0.89726	0.45710	0.88942	0.47255	0.88130	0.48786	0.87292	48
13	0.42604	0.90470	0.44177	0.89713	0.45736	0.88928	0.47281	0.88117	0.48811	0.87278	47
14	0.42631	0.90458	0.44203	0.89700	0.45762	0.88915	0.47306	0.88103	0.48837	0.87264	46
15	0.42657	0.90446	0.44229	0.89687	0.45787	0.88902	0.47332	0.88089	0.48862	0.87250	45
16	0.42683	0.90433	0.44255	0.89674	0.45813	0.88888	0.47358	0.88075	0.48888	0.87235	44
17	0.42709	0.90421	0.44281	0.89662	0.45839	0.88875	0.47383	0.88062	0.48913	0.87221	43
18	0.42736	0.90408	0.44307	0.89649	0.45865	0.88862	0.47409	0.88048	0.48938	0.87207	42
19	0.42762	0.90396	0.44333	0.89636	0.45891	0.88848	0.47434	0.88034	0.48964	0.87193	41
20	0.42788	0.90383	0.44359	0.89623	0.45917	0.88835	0.47460	0.88020	0.48989	0.87178	40
21	0.42815	0.90371	0.44385	0.89610	0.45942	0.88822	0.47486	0.88006	0.49014	0.87164	39
22	0.42841	0.90358	0.44411	0.89597	0.45968	0.88808	0.47511	0.87993	0.49040	0.87150	38
23	0.42867	0.90346	0.44437	0.89584	0.45994	0.88795	0.47537	0.87979	0.49065	0.87136	37
24	0.42894	0.90334	0.44464	0.89571	0.46020	0.88782	0.47562	0.87965	0.49090	0.87121	36
25	0.42920	0.90321	0.44490	0.89558	0.46046	0.88768	0.47588	0.87951	0.49116	0.87107	35
26	0.42946	0.90309	0.44516	0.89545	0.46072	0.88755	0.47614	0.87937	0.49141	0.87093	34
27	0.42972	0.90296	0.44542	0.89532	0.46097	0.88741	0.47639	0.87923	0.49166	0.87079	33
28	0.42999	0.90284	0.44568	0.89519	0.46123	0.88728	0.47665	0.87909	0.49192	0.87064	32
29	0.43025	0.90271	0.44594	0.89506	0.46149	0.88715	0.47690	0.87896	0.49217	0.87050	31
30	0.43051	0.90259	0.44620	0.89493	0.46175	0.88701	0.47716	0.87882	0.49242	0.87036	30
31	0.43077	0.90246	0.44646	0.89480	0.46201	0.88688	0.47741	0.87868	0.49268	0.87021	29
32	0.43104	0.90233	0.44672	0.89467	0.46226	0.88674	0.47767	0.87854	0.49293	0.87007	28
33	0.43130	0.90221	0.44698	0.89454	0.46252	0.88661	0.47793	0.87840	0.49318	0.86993	27
34	0.43156	0.90208	0.44724	0.89441	0.46278	0.88647	0.47818	0.87826	0.49344	0.86978	26
35	0.43182	0.90196	0.44750	0.89428	0.46304	0.88634	0.47844	0.87812	0.49369	0.86964	25
36	0.43209	0.90183	0.44776	0.89415	0.46330	0.88620	0.47869	0.87798	0.49394	0.86949	24
37	0.43235	0.90171	0.44802	0.89402	0.46355	0.88607	0.47895	0.87784	0.49419	0.86935	23
38	0.43261	0.90158	0.44828	0.89389	0.46381	0.88593	0.47920	0.87770	0.49445	0.86921	22
39	0.43287	0.90146	0.44854	0.89376	0.46407	0.88580	0.47946	0.87756	0.49470	0.86906	21
40	0.43313	0.90133	0.44880	0.89363	0.46433	0.88566	0.47971	0.87743	0.49495	0.86892	20
41	0.43340	0.90120	0.44906	0.89350	0.46458	0.88553	0.47997	0.87729	0.49521	0.86878	19
42	0.43366	0.90108	0.44932	0.89337	0.46484	0.88539	0.48022	0.87715	0.49546	0.86863	18
43	0.43392	0.90095	0.44958	0.89324	0.46510	0.88526	0.48048	0.87701	0.49571	0.86849	17
44	0.43418	0.90082	0.44984	0.89311	0.46536	0.88512	0.48073	0.87687	0.49596	0.86834	16
45	0.43445	0.90070	0.45010	0.89298	0.46561	0.88499	0.48099	0.87673	0.49622	0.86820	15
46	0.43471	0.90057	0.45036	0.89285	0.46587	0.88485	0.48124	0.87659	0.49647	0.86805	14
47	0.43497	0.90045	0.45062	0.89272	0.46613	0.88472	0.48150	0.87645	0.49672	0.86791	13
48	0.43523	0.90032	0.45088	0.89259	0.46639	0.88458	0.48175	0.87631	0.49697	0.86777	12
49	0.43549	0.90019	0.45114	0.89245	0.46664	0.88445	0.48201	0.87617	0.49723	0.86762	11
50	0.43575	0.90007	0.45140	0.89232	0.46690	0.88431	0.48226	0.87603	0.49748	0.86748	10
51	0.43602	0.89994	0.45166	0.89219	0.46716	0.88417	0.48252	0.87589	0.49773	0.86733	9
52	0.43628	0.89981	0.45192	0.89206	0.46742	0.88404	0.48277	0.87575	0.49798	0.86719	8
53	0.43654	0.89968	0.45218	0.89193	0.46767	0.88390	0.48303	0.87561	0.49824	0.86704	7
54	0.43680	0.89956	0.45243	0.89180	0.46793	0.88377	0.48328	0.87546	0.49849	0.86690	6
55	0.43706	0.89943	0.45269	0.89167	0.46819	0.88363	0.48354	0.87532	0.49874	0.86675	5
56	0.43733	0.89930	0.45295	0.89153	0.46844	0.88349	0.48379	0.87518	0.49899	0.86661	4
57	0.43759	0.89918	0.45321	0.89140	0.46870	0.88336	0.48405	0.87504	0.49924	0.86646	3
58	0.43785	0.89905	0.45347	0.89127	0.46896	0.88322	0.48430	0.87490	0.49950	0.86632	2
59	0.43811	0.89892	0.45373	0.89114	0.46921	0.88308	0.48456	0.87476	0.49975	0.86617	1
60	0.43837	0.89879	0.45399	0.89101	0.46947	0.88295	0.48481	0.87462	0.50000	0.86603	0
	COS	SIN	COS	SIN	COS	SIN	COS	SIN	COS	SIN	M I N
	64°		63°		62°		61°		60°		

E. NATURAL SINES AND COSINES—CONTINUED

MIN	30°		31°		32°		33°		34°		
	SIN	COS	SIN	COS	SIN	COS	SIN	COS	SIN	COS	
0	0.50000	0.86603	0.51504	0.85717	0.52992	0.84805	0.54464	0.83867	0.55919	0.82904	60
1	0.50025	0.86588	0.51529	0.85702	0.53017	0.84789	0.54488	0.83851	0.55943	0.82887	59
2	0.50050	0.86573	0.51554	0.85687	0.53041	0.84774	0.54513	0.83835	0.55968	0.82871	58
3	0.50076	0.86559	0.51579	0.85672	0.53066	0.84759	0.54537	0.83819	0.55992	0.82855	57
4	0.50101	0.86544	0.51604	0.85657	0.53091	0.84743	0.54561	0.83804	0.56016	0.82839	56
5	0.50126	0.86530	0.51628	0.85642	0.53115	0.84728	0.54586	0.83788	0.56040	0.82822	55
6	0.50151	0.86515	0.51653	0.85627	0.53140	0.84712	0.54610	0.83772	0.56064	0.82806	54
7	0.50176	0.86501	0.51678	0.85612	0.53164	0.84697	0.54635	0.83756	0.56088	0.82790	53
8	0.50201	0.86486	0.51703	0.85597	0.53189	0.84681	0.54659	0.83740	0.56112	0.82773	52
9	0.50227	0.86471	0.51728	0.85582	0.53214	0.84666	0.54683	0.83724	0.56136	0.82757	51
10	0.50252	0.86457	0.51753	0.85567	0.53238	0.84650	0.54708	0.83708	0.56160	0.82741	50
11	0.50277	0.86442	0.51778	0.85551	0.53263	0.84635	0.54732	0.83692	0.56184	0.82724	49
12	0.50302	0.86427	0.51803	0.85536	0.53288	0.84619	0.54756	0.83676	0.56208	0.82708	48
13	0.50327	0.86413	0.51828	0.85521	0.53312	0.84604	0.54781	0.83660	0.56232	0.82692	47
14	0.50352	0.86398	0.51852	0.85506	0.53337	0.84588	0.54805	0.83645	0.56256	0.82675	46
15	0.50377	0.86384	0.51877	0.85491	0.53361	0.84573	0.54829	0.83629	0.56280	0.82659	45
16	0.50403	0.86369	0.51902	0.85476	0.53386	0.84557	0.54854	0.83613	0.56305	0.82643	44
17	0.50428	0.86354	0.51927	0.85461	0.53411	0.84542	0.54878	0.83597	0.56329	0.82626	43
18	0.50453	0.86340	0.51952	0.85446	0.53435	0.84526	0.54902	0.83581	0.56353	0.82610	42
19	0.50478	0.86325	0.51977	0.85431	0.53460	0.84511	0.54927	0.83565	0.56377	0.82593	41
20	0.50503	0.86310	0.52002	0.85416	0.53484	0.84495	0.54951	0.83549	0.56401	0.82577	40
21	0.50528	0.86295	0.52026	0.85401	0.53509	0.84480	0.54975	0.83533	0.56425	0.82561	39
22	0.50553	0.86281	0.52051	0.85385	0.53534	0.84464	0.54999	0.83517	0.56449	0.82544	38
23	0.50578	0.86266	0.52076	0.85370	0.53558	0.84448	0.55024	0.83501	0.56473	0.82528	37
24	0.50603	0.86251	0.52101	0.85355	0.53583	0.84433	0.55048	0.83485	0.56497	0.82511	36
25	0.50628	0.86237	0.52126	0.85340	0.53607	0.84417	0.55072	0.83469	0.56521	0.82495	35
26	0.50654	0.86222	0.52151	0.85325	0.53632	0.84402	0.55097	0.83453	0.56545	0.82478	34
27	0.50679	0.86207	0.52175	0.85310	0.53656	0.84386	0.55121	0.83437	0.56569	0.82462	33
28	0.50704	0.86192	0.52200	0.85294	0.53681	0.84370	0.55145	0.83421	0.56593	0.82446	32
29	0.50729	0.86178	0.52225	0.85279	0.53705	0.84355	0.55169	0.83405	0.56617	0.82429	31
30	0.50754	0.86163	0.52250	0.85264	0.53730	0.84339	0.55194	0.83389	0.56641	0.82413	30
31	0.50779	0.86148	0.52275	0.85249	0.53754	0.84324	0.55218	0.83373	0.56665	0.82396	29
32	0.50804	0.86133	0.52299	0.85234	0.53779	0.84308	0.55242	0.83356	0.56689	0.82380	28
33	0.50829	0.86119	0.52324	0.85218	0.53804	0.84292	0.55266	0.83340	0.56713	0.82363	27
34	0.50854	0.86104	0.52349	0.85203	0.53828	0.84277	0.55291	0.83324	0.56736	0.82347	26
35	0.50879	0.86089	0.52374	0.85188	0.53853	0.84261	0.55315	0.83308	0.56760	0.82330	25
36	0.50904	0.86074	0.52399	0.85173	0.53877	0.84245	0.55339	0.83292	0.56784	0.82314	24
37	0.50929	0.86059	0.52423	0.85157	0.53902	0.84230	0.55363	0.83276	0.56808	0.82297	23
38	0.50954	0.86045	0.52448	0.85142	0.53926	0.84214	0.55388	0.83260	0.56832	0.82281	22
39	0.50979	0.86030	0.52473	0.85127	0.53951	0.84198	0.55412	0.83244	0.56856	0.82264	21
40	0.51004	0.86015	0.52498	0.85112	0.53975	0.84182	0.55436	0.83228	0.56880	0.82248	20
41	0.51029	0.86000	0.52522	0.85096	0.54000	0.84167	0.55460	0.83212	0.56904	0.82231	19
42	0.51054	0.85985	0.52547	0.85081	0.54024	0.84151	0.55484	0.83195	0.56928	0.82214	18
43	0.51079	0.85970	0.52572	0.85066	0.54049	0.84135	0.55509	0.83179	0.56952	0.82198	17
44	0.51104	0.85956	0.52597	0.85051	0.54073	0.84120	0.55533	0.83163	0.56976	0.82181	16
45	0.51129	0.85941	0.52621	0.85035	0.54097	0.84104	0.55557	0.83147	0.57000	0.82165	15
46	0.51154	0.85926	0.52646	0.85020	0.54122	0.84088	0.55581	0.83131	0.57024	0.82148	14
47	0.51179	0.85911	0.52671	0.85005	0.54146	0.84072	0.55605	0.83115	0.57047	0.82132	13
48	0.51204	0.85896	0.52696	0.84989	0.54171	0.84057	0.55630	0.83098	0.57071	0.82115	12
49	0.51229	0.85881	0.52720	0.84974	0.54195	0.84041	0.55654	0.83082	0.57095	0.82098	11
50	0.51254	0.85866	0.52745	0.84959	0.54220	0.84025	0.55678	0.83066	0.57119	0.82082	10
51	0.51279	0.85851	0.52770	0.84943	0.54244	0.84009	0.55702	0.83050	0.57143	0.82065	9
52	0.51304	0.85836	0.52794	0.84928	0.54269	0.83994	0.55726	0.83034	0.57167	0.82048	8
53	0.51329	0.85821	0.52819	0.84913	0.54293	0.83978	0.55750	0.83017	0.57191	0.82032	7
54	0.51354	0.85806	0.52844	0.84897	0.54317	0.83962	0.55775	0.83001	0.57215	0.82015	6
55	0.51379	0.85792	0.52869	0.84882	0.54342	0.83946	0.55799	0.82985	0.57238	0.81999	5
56	0.51404	0.85777	0.52893	0.84866	0.54366	0.83930	0.55823	0.82969	0.57262	0.81982	4
57	0.51429	0.85762	0.52918	0.84851	0.54391	0.83915	0.55847	0.82953	0.57286	0.81965	3
58	0.51454	0.85747	0.52943	0.84836	0.54415	0.83899	0.55871	0.82936	0.57310	0.81949	2
59	0.51479	0.85732	0.52967	0.84820	0.54440	0.83883	0.55895	0.82920	0.57334	0.81932	1
60	0.51504	0.85717	0.52992	0.84805	0.54464	0.83867	0.55919	0.82904	0.57358	0.81915	0
	COS	SIN	COS	SIN	COS	SIN	COS	SIN	COS	SIN	MIN
	59°		58°		57°		56°		55°		

E. NATURAL SINES AND COSINES—CONTINUED

MIN	35°		36°		37°		38°		39°		
	SIN	COS	SIN	COS	SIN	COS	SIN	COS	SIN	COS	
0	0.57358	0.81915	0.58779	0.80902	0.60182	0.79864	0.61566	0.78801	0.62932	0.77715	60
1	0.57381	0.81899	0.58802	0.80885	0.60205	0.79846	0.61589	0.78783	0.62955	0.77696	59
2	0.57405	0.81882	0.58826	0.80867	0.60228	0.79829	0.61612	0.78765	0.62977	0.77678	58
3	0.57429	0.81865	0.58849	0.80850	0.60251	0.79811	0.61635	0.78747	0.63000	0.77660	57
4	0.57453	0.81848	0.58873	0.80833	0.60274	0.79793	0.61658	0.78729	0.63022	0.77641	56
5	0.57477	0.81832	0.58896	0.80816	0.60298	0.79776	0.61681	0.78711	0.63045	0.77623	55
6	0.57501	0.81815	0.58920	0.80799	0.60321	0.79758	0.61704	0.78694	0.63068	0.77605	54
7	0.57524	0.81798	0.58943	0.80782	0.60344	0.79741	0.61726	0.78676	0.63090	0.77586	53
8	0.57548	0.81782	0.58967	0.80765	0.60367	0.79723	0.61749	0.78658	0.63113	0.77568	52
9	0.57572	0.81765	0.58990	0.80748	0.60390	0.79706	0.61772	0.78640	0.63135	0.77550	51
10	0.57596	0.81748	0.59014	0.80730	0.60414	0.79688	0.61795	0.78622	0.63158	0.77531	50
11	0.57619	0.81731	0.59037	0.80713	0.60437	0.79671	0.61818	0.78604	0.63180	0.77513	49
12	0.57643	0.81714	0.59061	0.80696	0.60460	0.79653	0.61841	0.78586	0.63203	0.77494	48
13	0.57667	0.81698	0.59084	0.80679	0.60483	0.79635	0.61864	0.78568	0.63225	0.77476	47
14	0.57691	0.81681	0.59108	0.80662	0.60506	0.79618	0.61887	0.78550	0.63248	0.77458	46
15	0.57715	0.81664	0.59131	0.80644	0.60529	0.79600	0.61909	0.78532	0.63271	0.77439	45
16	0.57738	0.81647	0.59154	0.80627	0.60553	0.79583	0.61932	0.78514	0.63293	0.77421	44
17	0.57762	0.81631	0.59178	0.80610	0.60576	0.79565	0.61955	0.78496	0.63316	0.77402	43
18	0.57786	0.81614	0.59201	0.80593	0.60599	0.79547	0.61978	0.78478	0.63338	0.77384	42
19	0.57810	0.81597	0.59225	0.80576	0.60622	0.79530	0.62001	0.78460	0.63361	0.77366	41
20	0.57833	0.81580	0.59248	0.80558	0.60645	0.79512	0.62024	0.78442	0.63383	0.77347	40
21	0.57857	0.81563	0.59272	0.80541	0.60668	0.79494	0.62046	0.78424	0.63406	0.77329	39
22	0.57881	0.81546	0.59295	0.80524	0.60691	0.79477	0.62069	0.78405	0.63428	0.77310	38
23	0.57904	0.81530	0.59318	0.80507	0.60714	0.79459	0.62092	0.78387	0.63451	0.77292	37
24	0.57928	0.81513	0.59342	0.80489	0.60738	0.79441	0.62115	0.78369	0.63473	0.77273	36
25	0.57952	0.81496	0.59365	0.80472	0.60761	0.79424	0.62138	0.78351	0.63496	0.77255	35
26	0.57976	0.81479	0.59389	0.80455	0.60784	0.79406	0.62160	0.78333	0.63518	0.77236	34
27	0.57999	0.81462	0.59412	0.80438	0.60807	0.79388	0.62183	0.78315	0.63540	0.77218	33
28	0.58023	0.81445	0.59436	0.80420	0.60830	0.79371	0.62206	0.78297	0.63563	0.77199	32
29	0.58047	0.81428	0.59459	0.80403	0.60853	0.79353	0.62229	0.78279	0.63585	0.77181	31
30	0.58070	0.81412	0.59482	0.80386	0.60876	0.79335	0.62251	0.78261	0.63608	0.77162	30
31	0.58094	0.81395	0.59506	0.80368	0.60899	0.79318	0.62274	0.78243	0.63630	0.77144	29
32	0.58118	0.81378	0.59529	0.80351	0.60922	0.79300	0.62297	0.78225	0.63653	0.77125	28
33	0.58141	0.81361	0.59552	0.80334	0.60945	0.79282	0.62320	0.78206	0.63675	0.77107	27
34	0.58165	0.81344	0.59576	0.80316	0.60968	0.79264	0.62342	0.78188	0.63698	0.77088	26
35	0.58189	0.81327	0.59599	0.80299	0.60991	0.79247	0.62365	0.78170	0.63720	0.77070	25
36	0.58212	0.81310	0.59622	0.80282	0.61015	0.79229	0.62388	0.78152	0.63742	0.77051	24
37	0.58236	0.81293	0.59646	0.80264	0.61038	0.79211	0.62411	0.78134	0.63765	0.77033	23
38	0.58260	0.81276	0.59669	0.80247	0.61061	0.79193	0.62433	0.78116	0.63787	0.77014	22
39	0.58283	0.81259	0.59693	0.80230	0.61084	0.79176	0.62456	0.78098	0.63810	0.76996	21
40	0.58307	0.81242	0.59716	0.80212	0.61107	0.79158	0.62479	0.78079	0.63832	0.76977	20
41	0.58330	0.81225	0.59739	0.80195	0.61130	0.79140	0.62502	0.78061	0.63854	0.76959	19
42	0.58354	0.81208	0.59763	0.80178	0.61153	0.79122	0.62524	0.78043	0.63877	0.76940	18
43	0.58378	0.81191	0.59786	0.80160	0.61176	0.79105	0.62547	0.78025	0.63899	0.76921	17
44	0.58401	0.81174	0.59809	0.80143	0.61199	0.79087	0.62570	0.78007	0.63922	0.76903	16
45	0.58425	0.81157	0.59832	0.80125	0.61222	0.79069	0.62592	0.77988	0.63944	0.76884	15
46	0.58449	0.81140	0.59856	0.80108	0.61245	0.79051	0.62615	0.77970	0.63966	0.76866	14
47	0.58472	0.81123	0.59879	0.80091	0.61268	0.79033	0.62638	0.77952	0.63989	0.76847	13
48	0.58496	0.81106	0.59902	0.80073	0.61291	0.79016	0.62660	0.77934	0.64011	0.76828	12
49	0.58519	0.81089	0.59926	0.80056	0.61314	0.78998	0.62683	0.77916	0.64033	0.76810	11
50	0.58543	0.81072	0.59949	0.80038	0.61337	0.78980	0.62706	0.77897	0.64056	0.76791	10
51	0.58567	0.81055	0.59972	0.80021	0.61360	0.78962	0.62728	0.77879	0.64078	0.76772	9
52	0.58590	0.81038	0.59995	0.80003	0.61383	0.78944	0.62751	0.77861	0.64100	0.76754	8
53	0.58614	0.81021	0.60019	0.79986	0.61406	0.78926	0.62774	0.77843	0.64123	0.76735	7
54	0.58637	0.81004	0.60042	0.79968	0.61429	0.78908	0.62796	0.77824	0.64145	0.76717	6
55	0.58661	0.80987	0.60065	0.79951	0.61451	0.78891	0.62819	0.77806	0.64167	0.76698	5
56	0.58684	0.80970	0.60089	0.79934	0.61474	0.78873	0.62842	0.77788	0.64190	0.76679	4
57	0.58708	0.80953	0.60112	0.79916	0.61497	0.78855	0.62864	0.77769	0.64212	0.76661	3
58	0.58731	0.80936	0.60135	0.79899	0.61520	0.78837	0.62887	0.77751	0.64234	0.76642	2
59	0.58755	0.80919	0.60158	0.79881	0.61543	0.78819	0.62909	0.77733	0.64256	0.76623	1
60	0.58779	0.80902	0.60182	0.79864	0.61566	0.78801	0.62932	0.77715	0.64279	0.76604	0
	COS	SIN	COS	SIN	COS	SIN	COS	SIN	COS	SIN	MIN
	54°		53°		52°		51°		50°		

E. NATURAL SINES AND COSINES—CONTINUED

MIN	40° SIN	40° COS	41° SIN	41° COS	42° SIN	42° COS	43° SIN	43° COS	44° SIN	44° COS	
0	0.64279	0.76604	0.65606	0.75471	0.66913	0.74314	0.68200	0.73135	0.69466	0.71934	60
1	0.64301	0.76586	0.65628	0.75452	0.66935	0.74295	0.68221	0.73116	0.69487	0.71914	59
2	0.64323	0.76567	0.65650	0.75433	0.66956	0.74276	0.68242	0.73096	0.69508	0.71894	58
3	0.64346	0.76548	0.65672	0.75414	0.66978	0.74256	0.68264	0.73076	0.69529	0.71873	57
4	0.64368	0.76530	0.65694	0.75395	0.66999	0.74237	0.68285	0.73056	0.69549	0.71853	56
5	0.64390	0.76511	0.65716	0.75375	0.67021	0.74217	0.68306	0.73036	0.69570	0.71833	55
6	0.64412	0.76492	0.65738	0.75356	0.67043	0.74198	0.68327	0.73016	0.69591	0.71813	54
7	0.64435	0.76473	0.65759	0.75337	0.67064	0.74178	0.68349	0.72996	0.69612	0.71792	53
8	0.64457	0.76455	0.65781	0.75318	0.67086	0.74159	0.68370	0.72976	0.69633	0.71772	52
9	0.64479	0.76436	0.65803	0.75299	0.67107	0.74139	0.68391	0.72957	0.69654	0.71752	51
10	0.64501	0.76417	0.65825	0.75280	0.67129	0.74120	0.68412	0.72937	0.69675	0.71732	50
11	0.64524	0.76398	0.65847	0.75261	0.67151	0.74100	0.68434	0.72917	0.69696	0.71711	49
12	0.64546	0.76380	0.65869	0.75241	0.67172	0.74080	0.68455	0.72897	0.69717	0.71691	48
13	0.64568	0.76361	0.65891	0.75222	0.67194	0.74061	0.68476	0.72877	0.69737	0.71671	47
14	0.64590	0.76342	0.65913	0.75203	0.67215	0.74041	0.68497	0.72857	0.69758	0.71650	46
15	0.64612	0.76323	0.65935	0.75184	0.67237	0.74022	0.68518	0.72837	0.69779	0.71630	45
16	0.64635	0.76304	0.65956	0.75165	0.67258	0.74002	0.68539	0.72817	0.69800	0.71610	44
17	0.64657	0.76286	0.65978	0.75146	0.67280	0.73983	0.68561	0.72797	0.69821	0.71590	43
18	0.64679	0.76267	0.66000	0.75126	0.67301	0.73963	0.68582	0.72777	0.69842	0.71569	42
19	0.64701	0.76248	0.66022	0.75107	0.67323	0.73944	0.68603	0.72757	0.69862	0.71549	41
20	0.64723	0.76229	0.66044	0.75088	0.67344	0.73924	0.68624	0.72737	0.69883	0.71529	40
21	0.64746	0.76210	0.66066	0.75069	0.67366	0.73904	0.68645	0.72717	0.69904	0.71508	39
22	0.64768	0.76192	0.66088	0.75050	0.67387	0.73885	0.68666	0.72697	0.69925	0.71488	38
23	0.64790	0.76173	0.66109	0.75030	0.67409	0.73865	0.68688	0.72677	0.69946	0.71468	37
24	0.64812	0.76154	0.66131	0.75011	0.67430	0.73846	0.68709	0.72657	0.69966	0.71447	36
25	0.64834	0.76135	0.66153	0.74992	0.67452	0.73826	0.68730	0.72637	0.69987	0.71427	35
26	0.64856	0.76116	0.66175	0.74973	0.67473	0.73806	0.68751	0.72617	0.70008	0.71407	34
27	0.64878	0.76097	0.66197	0.74953	0.67495	0.73787	0.68772	0.72597	0.70029	0.71386	33
28	0.64901	0.76078	0.66218	0.74934	0.67516	0.73767	0.68793	0.72577	0.70049	0.71366	32
29	0.64923	0.76059	0.66240	0.74915	0.67538	0.73747	0.68814	0.72557	0.70070	0.71345	31
30	0.64945	0.76041	0.66262	0.74896	0.67559	0.73728	0.68835	0.72537	0.70091	0.71325	30
31	0.64967	0.76022	0.66284	0.74876	0.67580	0.73708	0.68857	0.72517	0.70112	0.71305	29
32	0.64989	0.76003	0.66306	0.74857	0.67602	0.73688	0.68878	0.72497	0.70132	0.71284	28
33	0.65011	0.75984	0.66327	0.74838	0.67623	0.73669	0.68899	0.72477	0.70153	0.71264	27
34	0.65033	0.75965	0.66349	0.74818	0.67645	0.73649	0.68920	0.72457	0.70174	0.71243	26
35	0.65055	0.75946	0.66371	0.74799	0.67666	0.73629	0.68941	0.72437	0.70195	0.71223	25
36	0.65077	0.75927	0.66393	0.74780	0.67688	0.73610	0.68962	0.72417	0.70215	0.71203	24
37	0.65100	0.75908	0.66414	0.74760	0.67709	0.73590	0.68983	0.72397	0.70236	0.71182	23
38	0.65122	0.75889	0.66436	0.74741	0.67730	0.73570	0.69004	0.72377	0.70257	0.71162	22
39	0.65144	0.75870	0.66458	0.74722	0.67752	0.73551	0.69025	0.72357	0.70277	0.71141	21
40	0.65166	0.75851	0.66480	0.74703	0.67773	0.73531	0.69046	0.72337	0.70298	0.71121	20
41	0.65188	0.75832	0.66501	0.74683	0.67795	0.73511	0.69067	0.72317	0.70319	0.71100	19
42	0.65210	0.75813	0.66523	0.74664	0.67816	0.73491	0.69088	0.72297	0.70339	0.71080	18
43	0.65232	0.75794	0.66545	0.74644	0.67837	0.73472	0.69109	0.72277	0.70360	0.71059	17
44	0.65254	0.75775	0.66566	0.74625	0.67859	0.73452	0.69130	0.72257	0.70381	0.71039	16
45	0.65276	0.75756	0.66588	0.74606	0.67880	0.73432	0.69151	0.72236	0.70401	0.71019	15
46	0.65298	0.75738	0.66610	0.74586	0.67901	0.73413	0.69172	0.72216	0.70422	0.70998	14
47	0.65320	0.75719	0.66632	0.74567	0.67923	0.73393	0.69193	0.72196	0.70443	0.70978	13
48	0.65342	0.75700	0.66653	0.74548	0.67944	0.73373	0.69214	0.72176	0.70463	0.70957	12
49	0.65364	0.75680	0.66675	0.74528	0.67965	0.73353	0.69235	0.72156	0.70484	0.70937	11
50	0.65386	0.75661	0.66697	0.74509	0.67987	0.73333	0.69256	0.72136	0.70505	0.70916	10
51	0.65408	0.75642	0.66718	0.74489	0.68008	0.73314	0.69277	0.72116	0.70525	0.70896	9
52	0.65430	0.75623	0.66740	0.74470	0.68029	0.73294	0.69298	0.72095	0.70546	0.70875	8
53	0.65452	0.75604	0.66762	0.74451	0.68051	0.73274	0.69319	0.72075	0.70567	0.70855	7
54	0.65474	0.75585	0.66783	0.74431	0.68072	0.73254	0.69340	0.72055	0.70587	0.70834	6
55	0.65496	0.75566	0.66805	0.74412	0.68093	0.73234	0.69361	0.72035	0.70608	0.70813	5
56	0.65518	0.75547	0.66827	0.74392	0.68115	0.73215	0.69382	0.72015	0.70628	0.70793	4
57	0.65540	0.75528	0.66848	0.74373	0.68136	0.73195	0.69403	0.71995	0.70649	0.70772	3
58	0.65562	0.75509	0.66870	0.74353	0.68157	0.73175	0.69424	0.71974	0.70670	0.70752	2
59	0.65584	0.75490	0.66891	0.74334	0.68179	0.73155	0.69445	0.71954	0.70690	0.70731	1
60	0.65606	0.75471	0.66913	0.74314	0.68200	0.73135	0.69466	0.71934	0.70711	0.70711	0
	COS	SIN	COS	SIN	COS	SIN	COS	SIN	COS	SIN	MIN
	49°		48°		47°		46°		45°		

F. NATURAL TANGENTS AND COTANGENTS

MIN	0°		1°		2°		3°		4°		
	TAN	COT	TAN	COT	TAN	COT	TAN	COT	TAN	COT	
0	0000000	0000000	0.01746	57.2900	0.03492	28.6363	0.05241	19.0811	0.06993	14.3007	60
1	0.00029	3437.75	0.01775	56.3506	0.03521	28.3994	0.05270	18.9755	0.07022	14.2411	59
2	0.00058	1718.87	0.01804	55.4415	0.03550	28.1664	0.05299	18.8711	0.07051	14.1821	58
3	0.00087	1145.92	0.01833	54.5613	0.03579	27.9372	0.05328	18.7678	0.07080	14.1235	57
4	0.00116	859.436	0.01862	53.7086	0.03609	27.7117	0.05357	18.6656	0.07110	14.0655	56
5	0.00145	687.549	0.01891	52.8821	0.03638	27.4899	0.05387	18.5645	0.07139	14.0079	55
6	0.00175	572.957	0.01920	52.0807	0.03667	27.2715	0.05416	18.4645	0.07168	13.9507	54
7	0.00204	491.106	0.01949	51.3032	0.03696	27.0566	0.05445	18.3655	0.07197	13.8940	53
8	0.00233	429.718	0.01978	50.5485	0.03725	26.8450	0.05474	18.2677	0.07227	13.8378	52
9	0.00262	381.971	0.02007	49.8157	0.03754	26.6367	0.05503	18.1708	0.07256	13.7821	51
10	0.00291	343.774	0.02036	49.1039	0.03783	26.4316	0.05533	18.0750	0.07285	13.7267	50
11	0.00320	312.521	0.02066	48.4121	0.03812	26.2296	0.05562	17.9802	0.07314	13.6719	49
12	0.00349	286.478	0.02095	47.7395	0.03842	26.0307	0.05591	17.8863	0.07344	13.6174	48
13	0.00378	264.441	0.02124	47.0853	0.03871	25.8348	0.05620	17.7934	0.07373	13.5634	47
14	0.00407	245.552	0.02153	46.4489	0.03900	25.6418	0.05649	17.7015	0.07402	13.5098	46
15	0.00436	229.182	0.02182	45.8294	0.03929	25.4517	0.05678	17.6106	0.07431	13.4566	45
16	0.00465	214.858	0.02211	45.2261	0.03958	25.2644	0.05708	17.5205	0.07461	13.4039	44
17	0.00495	202.219	0.02240	44.6386	0.03987	25.0798	0.05737	17.4314	0.07490	13.3515	43
18	0.00524	190.984	0.02269	44.0661	0.04016	24.8978	0.05766	17.3432	0.07519	13.2996	42
19	0.00553	180.932	0.02298	43.5081	0.04046	24.7185	0.05795	17.2558	0.07548	13.2480	41
20	0.00582	171.885	0.02328	42.9641	0.04075	24.5418	0.05824	17.1693	0.07578	13.1969	40
21	0.00611	163.700	0.02357	42.4335	0.04104	24.3675	0.05854	17.0837	0.07607	13.1461	39
22	0.00640	156.259	0.02386	41.9158	0.04133	24.1957	0.05883	16.9990	0.07636	13.0958	38
23	0.00669	149.465	0.02415	41.4106	0.04162	24.0263	0.05912	16.9150	0.07665	13.0458	37
24	0.00698	143.237	0.02444	40.9174	0.04191	23.8593	0.05941	16.8319	0.07695	12.9962	36
25	0.00727	137.507	0.02473	40.4358	0.04220	23.6945	0.05970	16.7496	0.07724	12.9469	35
26	0.00756	132.219	0.02502	39.9655	0.04250	23.5321	0.05999	16.6681	0.07753	12.8981	34
27	0.00785	127.321	0.02531	39.5059	0.04279	23.3718	0.06029	16.5874	0.07782	12.8496	33
28	0.00815	122.774	0.02560	39.0568	0.04308	23.2137	0.06058	16.5075	0.07812	12.8014	32
29	0.00844	118.540	0.02589	38.6177	0.04337	23.0577	0.06087	16.4283	0.07841	12.7536	31
30	0.00873	114.589	0.02619	38.1885	0.04366	22.9038	0.06116	16.3499	0.07870	12.7062	30
31	0.00902	110.892	0.02648	37.7686	0.04395	22.7519	0.06145	16.2722	0.07899	12.6591	29
32	0.00931	107.426	0.02677	37.3579	0.04424	22.6020	0.06175	16.1952	0.07929	12.6124	28
33	0.00960	104.171	0.02706	36.9560	0.04454	22.4541	0.06204	16.1190	0.07958	12.5660	27
34	0.00989	101.107	0.02735	36.5627	0.04483	22.3081	0.06233	16.0435	0.07987	12.5199	26
35	0.01018	98.2179	0.02764	36.1776	0.04512	22.1640	0.06262	15.9687	0.08017	12.4742	25
36	0.01047	95.4895	0.02793	35.8006	0.04541	22.0217	0.06291	15.8945	0.08046	12.4288	24
37	0.01076	92.9085	0.02822	35.4313	0.04570	21.8813	0.06321	15.8211	0.08075	12.3838	23
38	0.01105	90.4633	0.02851	35.0695	0.04599	21.7426	0.06350	15.7483	0.08104	12.3390	22
39	0.01135	88.1436	0.02881	34.7151	0.04628	21.6056	0.06379	15.6762	0.08134	12.2946	21
40	0.01164	85.9398	0.02910	34.3678	0.04658	21.4704	0.06408	15.6048	0.08163	12.2505	20
41	0.01193	83.8435	0.02939	34.0273	0.04687	21.3369	0.06438	15.5340	0.08192	12.2067	19
42	0.01222	81.8470	0.02968	33.6935	0.04716	21.2049	0.06467	15.4638	0.08221	12.1632	18
43	0.01251	79.9434	0.02997	33.3662	0.04745	21.0747	0.06496	15.3943	0.08251	12.1201	17
44	0.01280	78.1263	0.03026	33.0452	0.04774	20.9460	0.06525	15.3254	0.08280	12.0772	16
45	0.01309	76.3900	0.03055	32.7303	0.04803	20.8188	0.06554	15.2571	0.08309	12.0346	15
46	0.01338	74.7292	0.03084	32.4213	0.04833	20.6932	0.06584	15.1893	0.08339	11.9923	14
47	0.01367	73.1390	0.03114	32.1181	0.04862	20.5691	0.06613	15.1222	0.08368	11.9504	13
48	0.01396	71.6151	0.03143	31.8205	0.04891	20.4465	0.06642	15.0557	0.08397	11.9087	12
49	0.01425	70.1533	0.03172	31.5284	0.04920	20.3253	0.06671	14.9898	0.08427	11.8673	11
50	0.01455	68.7501	0.03201	31.2416	0.04949	20.2056	0.06700	14.9244	0.08456	11.8262	10
51	0.01484	67.4019	0.03230	30.9599	0.04978	20.0872	0.06730	14.8596	0.08485	11.7853	9
52	0.01513	66.1055	0.03259	30.6833	0.05007	19.9702	0.06759	14.7954	0.08514	11.7448	8
53	0.01542	64.8580	0.03288	30.4116	0.05037	19.8546	0.06788	14.7317	0.08544	11.7045	7
54	0.01571	63.6567	0.03317	30.1446	0.05066	19.7403	0.06817	14.6685	0.08573	11.6645	6
55	0.01600	62.4992	0.03346	29.8823	0.05095	19.6273	0.06847	14.6059	0.08602	11.6248	5
56	0.01629	61.3829	0.03376	29.6245	0.05124	19.5156	0.06876	14.5438	0.08632	11.5853	4
57	0.01658	60.3058	0.03405	29.3711	0.05153	19.4051	0.06905	14.4823	0.08661	11.5461	3
58	0.01687	59.2659	0.03434	29.1220	0.05182	19.2959	0.06934	14.4212	0.08690	11.5072	2
59	0.01716	58.2612	0.03463	28.8771	0.05212	19.1879	0.06963	14.3607	0.08720	11.4685	1
60	0.01746	57.2900	0.03492	28.6363	0.05241	19.0811	0.06993	14.3007	0.08749	11.4301	0
	COT	TAN	COT	TAN	COT	TAN	COT	TAN	COT	TAN	MIN
	89°		88°		87°		86°		85°		

F. NATURAL TANGENTS AND COTANGENTS–CONTINUED

MIN	5°		6°		7°		8°		9°		
	TAN	COT	TAN	COT	TAN	COT	TAN	COT	TAN	COT	
0	0.08749	11.4301	0.10510	9.51436	0.12278	8.14435	0.14054	7.11537	0.15838	6.31375	60
1	0.08778	11.3919	0.10540	9.48781	0.12308	8.12481	0.14084	7.10038	0.15868	6.30189	59
2	0.08807	11.3540	0.10569	9.46141	0.12338	8.10536	0.14113	7.08546	0.15898	6.29007	58
3	0.08837	11.3163	0.10599	9.43515	0.12367	8.08600	0.14143	7.07059	0.15928	6.27829	57
4	0.08866	11.2789	0.10628	9.40904	0.12397	8.06674	0.14173	7.05579	0.15958	6.26655	56
5	0.08895	11.2417	0.10657	9.38307	0.12426	8.04756	0.14202	7.04105	0.15988	6.25486	55
6	0.08925	11.2048	0.10687	9.35724	0.12456	8.02848	0.14232	7.02637	0.16017	6.24321	54
7	0.08954	11.1681	0.10716	9.33155	0.12485	8.00948	0.14262	7.01174	0.16047	6.23160	53
8	0.08983	11.1316	0.10746	9.30599	0.12515	7.99058	0.14291	6.99718	0.16077	6.22003	52
9	0.09013	11.0954	0.10775	9.28058	0.12544	7.97176	0.14321	6.98268	0.16107	6.20851	51
10	0.09042	11.0594	0.10805	9.25530	0.12574	7.95302	0.14351	6.96823	0.16137	6.19703	50
11	0.09071	11.0237	0.10834	9.23016	0.12603	7.93438	0.14381	6.95385	0.16167	6.18559	49
12	0.09101	10.9882	0.10863	9.20516	0.12633	7.91582	0.14410	6.93952	0.16196	6.17419	48
13	0.09130	10.9529	0.10893	9.18028	0.12662	7.89734	0.14440	6.92525	0.16226	6.16283	47
14	0.09159	10.9178	0.10922	9.15554	0.12692	7.87895	0.14470	6.91104	0.16256	6.15151	46
15	0.09189	10.8829	0.10952	9.13093	0.12722	7.86064	0.14499	6.89688	0.16286	6.14023	45
16	0.09218	10.8483	0.10981	9.10646	0.12751	7.84242	0.14529	6.88278	0.16316	6.12899	44
17	0.09247	10.8139	0.11011	9.08211	0.12781	7.82428	0.14559	6.86874	0.16346	6.11779	43
18	0.09277	10.7797	0.11040	9.05789	0.12810	7.80622	0.14588	6.85475	0.16376	6.10664	42
19	0.09306	10.7457	0.11070	9.03379	0.12840	7.78825	0.14618	6.84082	0.16405	6.09552	41
20	0.09335	10.7119	0.11099	9.00983	0.12869	7.77035	0.14648	6.82694	0.16435	6.08444	40
21	0.09365	10.6783	0.11128	8.98598	0.12899	7.75254	0.14678	6.81312	0.16465	6.07340	39
22	0.09394	10.6450	0.11158	8.96227	0.12929	7.73480	0.14707	6.79936	0.16495	6.06240	38
23	0.09423	10.6118	0.11187	8.93867	0.12958	7.71715	0.14737	6.78564	0.16525	6.05143	37
24	0.09453	10.5789	0.11217	8.91520	0.12988	7.69957	0.14767	6.77199	0.16555	6.04051	36
25	0.09482	10.5462	0.11246	8.89185	0.13017	7.68208	0.14796	6.75838	0.16585	6.02962	35
26	0.09511	10.5136	0.11276	8.86862	0.13047	7.66466	0.14826	6.74483	0.16615	6.01878	34
27	0.09541	10.4813	0.11305	8.84551	0.13076	7.64732	0.14856	6.73133	0.16645	6.00797	33
28	0.09570	10.4491	0.11335	8.82252	0.13106	7.63005	0.14886	6.71789	0.16674	5.99720	32
29	0.09600	10.4172	0.11364	8.79964	0.13136	7.61287	0.14915	6.70450	0.16704	5.98646	31
30	0.09629	10.3854	0.11394	8.77689	0.13165	7.59575	0.14945	6.69116	0.16734	5.97576	30
31	0.09658	10.3538	0.11423	8.75425	0.13195	7.57872	0.14975	6.67787	0.16764	5.96510	29
32	0.09688	10.3224	0.11452	8.73172	0.13224	7.56176	0.15005	6.66463	0.16794	5.95448	28
33	0.09717	10.2913	0.11482	8.70931	0.13254	7.54487	0.15034	6.65144	0.16824	5.94390	27
34	0.09746	10.2602	0.11511	8.68701	0.13284	7.52806	0.15064	6.63831	0.16854	5.93335	26
35	0.09776	10.2294	0.11541	8.66482	0.13313	7.51132	0.15094	6.62523	0.16884	5.92283	25
36	0.09805	10.1988	0.11570	8.64275	0.13343	7.49465	0.15124	6.61219	0.16914	5.91236	24
37	0.09834	10.1683	0.11600	8.62078	0.13372	7.47806	0.15153	6.59921	0.16944	5.90191	23
38	0.09864	10.1381	0.11629	8.59893	0.13402	7.46154	0.15183	6.58627	0.16974	5.89151	22
39	0.09893	10.1080	0.11659	8.57718	0.13432	7.44509	0.15213	6.57339	0.17004	5.88114	21
40	0.09923	10.0780	0.11688	8.55555	0.13461	7.42871	0.15243	6.56055	0.17033	5.87080	20
41	0.09952	10.0483	0.11718	8.53402	0.13491	7.41240	0.15272	6.54777	0.17063	5.86051	19
42	0.09981	10.0187	0.11747	8.51259	0.13521	7.39616	0.15302	6.53503	0.17093	5.85024	18
43	0.10011	9.98931	0.11777	8.49128	0.13550	7.37999	0.15332	6.52234	0.17123	5.84001	17
44	0.10040	9.96007	0.11806	8.47007	0.13580	7.36389	0.15362	6.50970	0.17153	5.82982	16
45	0.10069	9.93101	0.11836	8.44896	0.13609	7.34786	0.15391	6.49710	0.17183	5.81966	15
46	0.10099	9.90211	0.11865	8.42795	0.13639	7.33190	0.15421	6.48456	0.17213	5.80953	14
47	0.10128	9.87338	0.11895	8.40705	0.13669	7.31600	0.15451	6.47206	0.17243	5.79944	13
48	0.10158	9.84482	0.11924	8.38625	0.13698	7.30018	0.15481	6.45961	0.17273	5.78938	12
49	0.10187	9.81641	0.11954	8.36555	0.13728	7.28442	0.15511	6.44720	0.17303	5.77936	11
50	0.10216	9.78817	0.11983	8.34496	0.13758	7.26873	0.15540	6.43484	0.17333	5.76937	10
51	0.10246	9.76009	0.12013	8.32446	0.13787	7.25310	0.15570	6.42253	0.17363	5.75941	9
52	0.10275	9.73217	0.12042	8.30406	0.13817	7.23754	0.15600	6.41026	0.17393	5.74949	8
53	0.10305	9.70441	0.12072	8.28376	0.13846	7.22204	0.15630	6.39804	0.17423	5.73960	7
54	0.10334	9.67680	0.12101	8.26355	0.13876	7.20661	0.15660	6.38587	0.17453	5.72974	6
55	0.10363	9.64935	0.12131	8.24345	0.13906	7.19125	0.15689	6.37374	0.17483	5.71992	5
56	0.10393	9.62205	0.12160	8.22344	0.13935	7.17594	0.15719	6.36165	0.17513	5.71013	4
57	0.10422	9.59490	0.12190	8.20352	0.13965	7.16071	0.15749	6.34961	0.17543	5.70037	3
58	0.10452	9.56791	0.12219	8.18370	0.13995	7.14553	0.15779	6.33761	0.17573	5.69064	2
59	0.10481	9.54106	0.12249	8.16398	0.14024	7.13042	0.15809	6.32566	0.17603	5.68094	1
60	0.10510	9.51436	0.12278	8.14435	0.14054	7.11537	0.15838	6.31375	0.17633	5.67128	0
	COT	TAN	COT	TAN	COT	TAN	COT	TAN	COT	TAN	MIN
	84°		83°		82°		81°		80°		

MIN	10°		11°		12°		13°		14°		
	TAN	COT	TAN	COT	TAN	COT	TAN	COT	TAN	COT	
0	0.17633	5.67128	0.19438	5.14455	0.21256	4.70463	0.23087	4.33148	0.24933	4.01078	60
1	0.17663	5.66165	0.19468	5.13658	0.21286	4.69791	0.23117	4.32573	0.24964	4.00582	59
2	0.17693	5.65205	0.19498	5.12862	0.21316	4.69121	0.23148	4.32001	0.24995	4.00086	58
3	0.17723	5.64248	0.19529	5.12069	0.21347	4.68452	0.23179	4.31430	0.25026	3.99592	57
4	0.17753	5.63295	0.19559	5.11279	0.21377	4.67786	0.23209	4.30860	0.25056	3.99099	56
5	0.17783	5.62344	0.19589	5.10490	0.21408	4.67121	0.23240	4.30291	0.25087	3.98607	55
6	0.17813	5.61397	0.19619	5.09704	0.21438	4.66458	0.23271	4.29724	0.25118	3.98117	54
7	0.17843	5.60452	0.19649	5.08921	0.21469	4.65797	0.23301	4.29159	0.25149	3.97627	53
8	0.17873	5.59511	0.19680	5.08139	0.21499	4.65138	0.23332	4.28595	0.25180	3.97139	52
9	0.17903	5.58573	0.19710	5.07360	0.21529	4.64480	0.23363	4.28032	0.25211	3.96651	51
10	0.17933	5.57638	0.19740	5.06584	0.21560	4.63825	0.23393	4.27471	0.25242	3.96165	50
11	0.17963	5.56706	0.19770	5.05809	0.21590	4.63171	0.23424	4.26911	0.25273	3.95680	49
12	0.17993	5.55777	0.19801	5.05037	0.21621	4.62518	0.23455	4.26352	0.25304	3.95196	48
13	0.18023	5.54851	0.19831	5.04267	0.21651	4.61868	0.23485	4.25795	0.25335	3.94713	47
14	0.18053	5.53927	0.19861	5.03499	0.21682	4.61219	0.23516	4.25239	0.25366	3.94232	46
15	0.18083	5.53007	0.19891	5.02734	0.21712	4.60572	0.23547	4.24685	0.25397	3.93751	45
16	0.18113	5.52090	0.19921	5.01971	0.21743	4.59927	0.23578	4.24132	0.25428	3.93271	44
17	0.18143	5.51176	0.19952	5.01210	0.21773	4.59283	0.23608	4.23580	0.25459	3.92793	43
18	0.18173	5.50264	0.19982	5.00451	0.21804	4.58641	0.23639	4.23030	0.25490	3.92316	42
19	0.18203	5.49356	0.20012	4.99695	0.21834	4.58001	0.23670	4.22481	0.25521	3.91839	41
20	0.18233	5.48451	0.20042	4.98940	0.21864	4.57363	0.23700	4.21933	0.25552	3.91364	40
21	0.18263	5.47548	0.20073	4.98188	0.21895	4.56726	0.23731	4.21387	0.25583	3.90890	39
22	0.18293	5.46648	0.20103	4.97438	0.21925	4.56091	0.23762	4.20842	0.25614	3.90417	38
23	0.18323	5.45751	0.20133	4.96690	0.21956	4.55458	0.23793	4.20298	0.25645	3.89945	37
24	0.18353	5.44857	0.20164	4.95945	0.21986	4.54826	0.23823	4.19756	0.25676	3.89474	36
25	0.18384	5.43966	0.20194	4.95201	0.22017	4.54196	0.23854	4.19215	0.25707	3.89004	35
26	0.18414	5.43077	0.20224	4.94460	0.22047	4.53568	0.23885	4.18675	0.25738	3.88536	34
27	0.18444	5.42192	0.20254	4.93721	0.22078	4.52941	0.23916	4.18137	0.25769	3.88068	33
28	0.18474	5.41309	0.20285	4.92984	0.22108	4.52316	0.23946	4.17600	0.25800	3.87601	32
29	0.18504	5.40429	0.20315	4.92249	0.22139	4.51693	0.23977	4.17064	0.25831	3.87136	31
30	0.18534	5.39552	0.20345	4.91516	0.22169	4.51071	0.24008	4.16530	0.25862	3.86671	30
31	0.18564	5.38677	0.20376	4.90785	0.22200	4.50451	0.24039	4.15997	0.25893	3.86208	29
32	0.18594	5.37805	0.20406	4.90056	0.22231	4.49832	0.24069	4.15465	0.25924	3.85745	28
33	0.18624	5.36936	0.20436	4.89330	0.22261	4.49215	0.24100	4.14934	0.25955	3.85284	27
34	0.18654	5.36070	0.20466	4.88605	0.22292	4.48600	0.24131	4.14405	0.25986	3.84824	26
35	0.18684	5.35206	0.20497	4.87882	0.22322	4.47986	0.24162	4.13877	0.26017	3.84364	25
36	0.18714	5.34345	0.20527	4.87162	0.22353	4.47374	0.24193	4.13350	0.26048	3.83906	24
37	0.18745	5.33487	0.20557	4.86444	0.22383	4.46764	0.24223	4.12825	0.26079	3.83449	23
38	0.18775	5.32631	0.20588	4.85727	0.22414	4.46155	0.24254	4.12301	0.26110	3.82992	22
39	0.18805	5.31778	0.20618	4.85013	0.22444	4.45548	0.24285	4.11778	0.26141	3.82537	21
40	0.18835	5.30928	0.20648	4.84300	0.22475	4.44942	0.24316	4.11256	0.26172	3.82083	20
41	0.18865	5.30080	0.20679	4.83590	0.22505	4.44338	0.24347	4.10736	0.26203	3.81630	19
42	0.18895	5.29235	0.20709	4.82882	0.22536	4.43735	0.24377	4.10216	0.26235	3.81177	18
43	0.18925	5.28393	0.20739	4.82175	0.22567	4.43134	0.24408	4.09699	0.26266	3.80726	17
44	0.18955	5.27553	0.20770	4.81471	0.22597	4.42534	0.24439	4.09182	0.26297	3.80276	16
45	0.18986	5.26715	0.20800	4.80769	0.22628	4.41936	0.24470	4.08666	0.26328	3.79827	15
46	0.19016	5.25880	0.20830	4.80068	0.22658	4.41340	0.24501	4.08152	0.26359	3.79378	14
47	0.19046	5.25048	0.20861	4.79370	0.22689	4.40745	0.24532	4.07639	0.26390	3.78931	13
48	0.19076	5.24218	0.20891	4.78673	0.22719	4.40152	0.24562	4.07127	0.26421	3.78485	12
49	0.19106	5.23391	0.20921	4.77978	0.22750	4.39560	0.24593	4.06616	0.26452	3.78040	11
50	0.19136	5.22566	0.20952	4.77286	0.22781	4.38969	0.24624	4.06107	0.26483	3.77595	10
51	0.19166	5.21744	0.20982	4.76595	0.22811	4.38381	0.24655	4.05599	0.26515	3.77152	9
52	0.19197	5.20925	0.21013	4.75906	0.22842	4.37793	0.24686	4.05092	0.26546	3.76709	8
53	0.19227	5.20107	0.21043	4.75219	0.22872	4.37207	0.24717	4.04586	0.26577	3.76268	7
54	0.19257	5.19293	0.21073	4.74534	0.22903	4.36623	0.24747	4.04081	0.26608	3.75828	6
55	0.19287	5.18480	0.21104	4.73851	0.22934	4.36040	0.24778	4.03578	0.26639	3.75388	5
56	0.19317	5.17671	0.21134	4.73170	0.22964	4.35459	0.24809	4.03076	0.26670	3.74950	4
57	0.19347	5.16863	0.21164	4.72490	0.22995	4.34879	0.24840	4.02574	0.26701	3.74512	3
58	0.19378	5.16058	0.21195	4.71813	0.23026	4.34300	0.24871	4.02074	0.26733	3.74075	2
59	0.19408	5.15256	0.21225	4.71137	0.23056	4.33723	0.24902	4.01576	0.26764	3.73640	1
60	0.19438	5.14455	0.21256	4.70463	0.23087	4.33148	0.24933	4.01078	0.26795	3.73205	0
	COT	TAN	COT	TAN	COT	TAN	COT	TAN	COT	TAN	MIN
	79°		78°		77°		76°		75°		

F. NATURAL TANGENTS AND COTANGENTS–CONTINUED

MIN	15°		16°		17°		18°		19°		
	TAN	COT	TAN	COT	TAN	COT	TAN	COT	TAN	COT	
0	0.26795	3.73205	0.28675	3.48741	0.30573	3.27085	0.32492	3.07768	0.34433	2.90421	60
1	0.26826	3.72771	0.28706	3.48359	0.30605	3.26745	0.32524	3.07464	0.34465	2.90147	59
2	0.26857	3.72338	0.28738	3.47977	0.30637	3.26406	0.32556	3.07160	0.34498	2.89873	58
3	0.26888	3.71907	0.28769	3.47596	0.30669	3.26067	0.32588	3.06857	0.34530	2.89600	57
4	0.26920	3.71476	0.28801	3.47216	0.30700	3.25729	0.32621	3.06554	0.34563	2.89327	56
5	0.26951	3.71046	0.28832	3.46837	0.30732	3.25392	0.32653	3.06252	0.34596	2.89055	55
6	0.26982	3.70616	0.28864	3.46458	0.30764	3.25055	0.32685	3.05950	0.34628	2.88783	54
7	0.27013	3.70188	0.28895	3.46080	0.30796	3.24719	0.32717	3.05649	0.34661	2.88511	53
8	0.27044	3.69761	0.28927	3.45703	0.30828	3.24383	0.32749	3.05349	0.34693	2.88240	52
9	0.27076	3.69335	0.28958	3.45327	0.30860	3.24049	0.32782	3.05049	0.34726	2.87970	51
10	0.27107	3.68909	0.28990	3.44951	0.30891	3.23714	0.32814	3.04749	0.34758	2.87700	50
11	0.27138	3.68485	0.29021	3.44576	0.30923	3.23381	0.32846	3.04450	0.34791	2.87430	49
12	0.27169	3.68061	0.29053	3.44202	0.30955	3.23048	0.32878	3.04152	0.34824	2.87161	48
13	0.27201	3.67638	0.29084	3.43829	0.30987	3.22715	0.32911	3.03854	0.34856	2.86892	47
14	0.27232	3.67217	0.29116	3.43456	0.31019	3.22384	0.32943	3.03556	0.34889	2.86624	46
15	0.27263	3.66796	0.29147	3.43084	0.31051	3.22053	0.32975	3.03260	0.34922	2.86356	45
16	0.27294	3.66376	0.29179	3.42713	0.31083	3.21722	0.33007	3.02963	0.34954	2.86089	44
17	0.27326	3.65957	0.29210	3.42343	0.31115	3.21392	0.33040	3.02667	0.34987	2.85822	43
18	0.27357	3.65538	0.29242	3.41973	0.31147	3.21063	0.33072	3.02372	0.35020	2.85555	42
19	0.27388	3.65121	0.29274	3.41604	0.31178	3.20734	0.33104	3.02077	0.35052	2.85289	41
20	0.27419	3.64705	0.29305	3.41236	0.31210	3.20406	0.33136	3.01783	0.35085	2.85023	40
21	0.27451	3.64289	0.29337	3.40869	0.31242	3.20079	0.33169	3.01489	0.35118	2.84758	39
22	0.27482	3.63874	0.29368	3.40502	0.31274	3.19752	0.33201	3.01196	0.35150	2.84494	38
23	0.27513	3.63461	0.29400	3.40136	0.31306	3.19426	0.33233	3.00903	0.35183	2.84229	37
24	0.27545	3.63048	0.29432	3.39771	0.31338	3.19100	0.33266	3.00611	0.35216	2.83965	36
25	0.27576	3.62636	0.29463	3.39406	0.31370	3.18775	0.33298	3.00319	0.35248	2.83702	35
26	0.27607	3.62224	0.29495	3.39042	0.31402	3.18451	0.33330	3.00028	0.35281	2.83439	34
27	0.27638	3.61814	0.29526	3.38679	0.31434	3.18127	0.33363	2.99738	0.35314	2.83176	33
28	0.27670	3.61405	0.29558	3.38317	0.31466	3.17804	0.33395	2.99447	0.35346	2.82914	32
29	0.27701	3.60996	0.29590	3.37955	0.31498	3.17481	0.33427	2.99158	0.35379	2.82653	31
30	0.27732	3.60588	0.29621	3.37594	0.31530	3.17159	0.33460	2.98868	0.35412	2.82391	30
31	0.27764	3.60181	0.29653	3.37234	0.31562	3.16838	0.33492	2.98580	0.35445	2.82130	29
32	0.27795	3.59775	0.29685	3.36875	0.31594	3.16517	0.33524	2.98292	0.35477	2.81870	28
33	0.27826	3.59370	0.29716	3.36516	0.31626	3.16197	0.33557	2.98004	0.35510	2.81610	27
34	0.27858	3.58966	0.29748	3.36158	0.31658	3.15877	0.33589	2.97717	0.35543	2.81350	26
35	0.27889	3.58562	0.29780	3.35800	0.31690	3.15558	0.33621	2.97430	0.35576	2.81091	25
36	0.27921	3.58160	0.29811	3.35443	0.31722	3.15240	0.33654	2.97144	0.35608	2.80833	24
37	0.27952	3.57758	0.29843	3.35087	0.31754	3.14922	0.33686	2.96858	0.35641	2.80574	23
38	0.27983	3.57357	0.29875	3.34732	0.31786	3.14605	0.33718	2.96573	0.35674	2.80316	22
39	0.28015	3.56957	0.29906	3.34377	0.31818	3.14288	0.33751	2.96288	0.35707	2.80059	21
40	0.28046	3.56557	0.29938	3.34023	0.31850	3.13972	0.33783	2.96004	0.35740	2.79802	20
41	0.28077	3.56159	0.29970	3.33670	0.31882	3.13656	0.33816	2.95721	0.35772	2.79545	19
42	0.28109	3.55761	0.30001	3.33317	0.31914	3.13341	0.33848	2.95437	0.35805	2.79289	18
43	0.28140	3.55364	0.30033	3.32965	0.31946	3.13027	0.33881	2.95155	0.35838	2.79033	17
44	0.28172	3.54968	0.30065	3.32614	0.31978	3.12713	0.33913	2.94872	0.35871	2.78778	16
45	0.28203	3.54573	0.30097	3.32264	0.32010	3.12400	0.33945	2.94591	0.35904	2.78523	15
46	0.28234	3.54179	0.30128	3.31914	0.32042	3.12087	0.33978	2.94309	0.35937	2.78269	14
47	0.28266	3.53785	0.30160	3.31565	0.32074	3.11775	0.34010	2.94028	0.35969	2.78014	13
48	0.28297	3.53393	0.30192	3.31216	0.32106	3.11464	0.34043	2.93748	0.36002	2.77761	12
49	0.28329	3.53001	0.30224	3.30868	0.32139	3.11153	0.34075	2.93468	0.36035	2.77507	11
50	0.28360	3.52609	0.30255	3.30521	0.32171	3.10842	0.34108	2.93189	0.36068	2.77254	10
51	0.28391	3.52219	0.30287	3.30174	0.32203	3.10532	0.34140	2.92910	0.36101	2.77002	9
52	0.28423	3.51829	0.30319	3.29829	0.32235	3.10223	0.34173	2.92632	0.36134	2.76750	8
53	0.28454	3.51441	0.30351	3.29483	0.32267	3.09914	0.34205	2.92354	0.36167	2.76498	7
54	0.28486	3.51053	0.30382	3.29139	0.32299	3.09606	0.34238	2.92076	0.36199	2.76247	6
55	0.28517	3.50666	0.30414	3.28795	0.32331	3.09298	0.34270	2.91799	0.36232	2.75996	5
56	0.28549	3.50279	0.30446	3.28452	0.32363	3.08991	0.34303	2.91523	0.36265	2.75746	4
57	0.28580	3.49894	0.30478	3.28109	0.32396	3.08685	0.34335	2.91246	0.36298	2.75496	3
58	0.28612	3.49509	0.30509	3.27767	0.32428	3.08379	0.34368	2.90971	0.36331	2.75246	2
59	0.28643	3.49125	0.30541	3.27426	0.32460	3.08073	0.34400	2.90696	0.36364	2.74997	1
60	0.28675	3.48741	0.30573	3.27085	0.32492	3.07768	0.34433	2.90421	0.36397	2.74748	0
	COT	TAN	COT	TAN	COT	TAN	COT	TAN	COT	TAN	MIN
	74°		73°		72°		71°		70°		

F. NATURAL TANGENTS AND COTANGENTS–CONTINUED

MIN	20° TAN	20° COT	21° TAN	21° COT	22° TAN	22° COT	23° TAN	23° COT	24° TAN	24° COT	
0	0.36397	2.74748	0.38386	2.60509	0.40403	2.47509	0.42447	2.35585	0.44523	2.24604	60
1	0.36430	2.74499	0.38420	2.60283	0.40436	2.47302	0.42482	2.35395	0.44558	2.24428	59
2	0.36463	2.74251	0.38453	2.60057	0.40470	2.47095	0.42516	2.35205	0.44593	2.24252	58
3	0.36496	2.74004	0.38487	2.59831	0.40504	2.46888	0.42551	2.35015	0.44627	2.24077	57
4	0.36529	2.73756	0.38520	2.59606	0.40538	2.46682	0.42585	2.34825	0.44662	2.23902	56
5	0.36562	2.73509	0.38553	2.59381	0.40572	2.46476	0.42619	2.34636	0.44697	2.23727	55
6	0.36595	2.73263	0.38587	2.59156	0.40606	2.46270	0.42654	2.34447	0.44732	2.23553	54
7	0.36628	2.73017	0.38620	2.58932	0.40640	2.46065	0.42688	2.34258	0.44767	2.23378	53
8	0.36661	2.72771	0.38654	2.58708	0.40674	2.45860	0.42722	2.34069	0.44802	2.23204	52
9	0.36694	2.72526	0.38687	2.58484	0.40707	2.45655	0.42757	2.33881	0.44837	2.23030	51
10	0.36727	2.72281	0.38721	2.58261	0.40741	2.45451	0.42791	2.33693	0.44872	2.22857	50
11	0.36760	2.72036	0.38754	2.58038	0.40775	2.45246	0.42826	2.33505	0.44907	2.22683	49
12	0.36793	2.71792	0.38787	2.57815	0.40809	2.45043	0.42860	2.33317	0.44942	2.22510	48
13	0.36826	2.71548	0.38821	2.57593	0.40843	2.44839	0.42894	2.33130	0.44977	2.22337	47
14	0.36859	2.71305	0.38854	2.57371	0.40877	2.44636	0.42929	2.32943	0.45012	2.22164	46
15	0.36892	2.71062	0.38888	2.57150	0.40911	2.44433	0.42963	2.32756	0.45047	2.21992	45
16	0.36925	2.70819	0.38921	2.56928	0.40945	2.44230	0.42998	2.32570	0.45082	2.21819	44
17	0.36958	2.70577	0.38955	2.56707	0.40979	2.44027	0.43032	2.32383	0.45117	2.21647	43
18	0.36991	2.70335	0.38988	2.56487	0.41013	2.43825	0.43067	2.32197	0.45152	2.21475	42
19	0.37024	2.70094	0.39022	2.56266	0.41047	2.43623	0.43101	2.32012	0.45187	2.21304	41
20	0.37057	2.69853	0.39055	2.56046	0.41081	2.43422	0.43136	2.31826	0.45222	2.21132	40
21	0.37090	2.69612	0.39089	2.55827	0.41115	2.43220	0.43170	2.31641	0.45257	2.20961	39
22	0.37123	2.69371	0.39122	2.55608	0.41149	2.43019	0.43205	2.31456	0.45292	2.20790	38
23	0.37157	2.69131	0.39156	2.55389	0.41183	2.42819	0.43239	2.31271	0.45327	2.20619	37
24	0.37190	2.68892	0.39190	2.55170	0.41217	2.42618	0.43274	2.31086	0.45362	2.20449	36
25	0.37223	2.68653	0.39223	2.54952	0.41251	2.42418	0.43308	2.30902	0.45397	2.20278	35
26	0.37256	2.68414	0.39257	2.54734	0.41285	2.42218	0.43343	2.30718	0.45432	2.20108	34
27	0.37289	2.68175	0.39290	2.54516	0.41319	2.42019	0.43378	2.30534	0.45467	2.19938	33
28	0.37322	2.67937	0.39324	2.54299	0.41353	2.41819	0.43412	2.30351	0.45502	2.19769	32
29	0.37355	2.67700	0.39357	2.54082	0.41387	2.41620	0.43447	2.30167	0.45538	2.19599	31
30	0.37388	2.67462	0.39391	2.53865	0.41421	2.41421	0.43481	2.29984	0.45573	2.19430	30
31	0.37422	2.67225	0.39425	2.53648	0.41455	2.41223	0.43516	2.29801	0.45608	2.19261	29
32	0.37455	2.66989	0.39458	2.53432	0.41490	2.41025	0.43550	2.29619	0.45643	2.19092	28
33	0.37488	2.66752	0.39492	2.53217	0.41524	2.40827	0.43585	2.29437	0.45678	2.18923	27
34	0.37521	2.66516	0.39526	2.53001	0.41558	2.40629	0.43620	2.29254	0.45713	2.18755	26
35	0.37554	2.66281	0.39559	2.52786	0.41592	2.40432	0.43654	2.29073	0.45748	2.18587	25
36	0.37588	2.66046	0.39593	2.52571	0.41626	2.40235	0.43689	2.28891	0.45784	2.18419	24
37	0.37621	2.65811	0.39626	2.52357	0.41660	2.40038	0.43724	2.28710	0.45819	2.18251	23
38	0.37654	2.65576	0.39660	2.52142	0.41694	2.39841	0.43758	2.28528	0.45854	2.18084	22
39	0.37687	2.65342	0.39694	2.51929	0.41728	2.39645	0.43793	2.28348	0.45889	2.17916	21
40	0.37720	2.65109	0.39727	2.51715	0.41763	2.39449	0.43828	2.28167	0.45924	2.17749	20
41	0.37754	2.64875	0.39761	2.51502	0.41797	2.39253	0.43862	2.27987	0.45960	2.17582	19
42	0.37787	2.64642	0.39795	2.51289	0.41831	2.39058	0.43897	2.27806	0.45995	2.17416	18
43	0.37820	2.64410	0.39829	2.51076	0.41865	2.38863	0.43932	2.27626	0.46030	2.17249	17
44	0.37853	2.64177	0.39862	2.50864	0.41899	2.38668	0.43966	2.27447	0.46065	2.17083	16
45	0.37887	2.63945	0.39896	2.50652	0.41933	2.38473	0.44001	2.27267	0.46101	2.16917	15
46	0.37920	2.63714	0.39930	2.50440	0.41968	2.38279	0.44036	2.27088	0.46136	2.16751	14
47	0.37953	2.63483	0.39963	2.50229	0.42002	2.38084	0.44071	2.26909	0.46171	2.16585	13
48	0.37986	2.63252	0.39997	2.50018	0.42036	2.37891	0.44105	2.26730	0.46206	2.16420	12
49	0.38020	2.63021	0.40031	2.49807	0.42070	2.37697	0.44140	2.26552	0.46242	2.16255	11
50	0.38053	2.62791	0.40065	2.49597	0.42105	2.37504	0.44175	2.26374	0.46277	2.16090	10
51	0.38086	2.62561	0.40098	2.49386	0.42139	2.37311	0.44210	2.26196	0.46312	2.15925	9
52	0.38120	2.62332	0.40132	2.49177	0.42173	2.37118	0.44244	2.26018	0.46348	2.15760	8
53	0.38153	2.62103	0.40166	2.48967	0.42207	2.36925	0.44279	2.25840	0.46383	2.15596	7
54	0.38186	2.61874	0.40200	2.48758	0.42242	2.36733	0.44314	2.25663	0.46418	2.15432	6
55	0.38220	2.61646	0.40234	2.48549	0.42276	2.36541	0.44349	2.25486	0.46454	2.15268	5
56	0.38253	2.61418	0.40267	2.48340	0.42310	2.36349	0.44384	2.25309	0.46489	2.15104	4
57	0.38286	2.61190	0.40301	2.48132	0.42345	2.36158	0.44418	2.25132	0.46525	2.14940	3
58	0.38320	2.60963	0.40335	2.47924	0.42379	2.35967	0.44453	2.24956	0.46560	2.14777	2
59	0.38353	2.60736	0.40369	2.47716	0.42413	2.35776	0.44488	2.24780	0.46595	2.14614	1
60	0.38386	2.60509	0.40403	2.47509	0.42447	2.35585	0.44523	2.24604	0.46631	2.14451	0
	COT	TAN	COT	TAN	COT	TAN	COT	TAN	COT	TAN	MIN
	69°		68°		67°		66°		65°		

F. NATURAL TANGENTS AND COTANGENTS—CONTINUED

MIN	25°		26°		27°		28°		29°		
	TAN	COT	TAN	COT	TAN	COT	TAN	COT	TAN	COT	
0	0.46631	2.14451	0.48773	2.05030	0.50953	1.96261	0.53171	1.88073	0.55431	1.80405	60
1	0.46666	2.14288	0.48809	2.04879	0.50989	1.96120	0.53208	1.87941	0.55469	1.80281	59
2	0.46702	2.14125	0.48845	2.04728	0.51026	1.95979	0.53246	1.87809	0.55507	1.80158	58
3	0.46737	2.13963	0.48881	2.04577	0.51063	1.95838	0.53283	1.87677	0.55545	1.80034	57
4	0.46772	2.13801	0.48917	2.04426	0.51099	1.95698	0.53320	1.87546	0.55583	1.79911	56
5	0.46808	2.13639	0.48953	2.04276	0.51136	1.95557	0.53358	1.87415	0.55621	1.79788	55
6	0.46843	2.13477	0.48989	2.04125	0.51173	1.95417	0.53395	1.87283	0.55659	1.79665	54
7	0.46879	2.13316	0.49026	2.03975	0.51209	1.95277	0.53432	1.87152	0.55697	1.79542	53
8	0.46914	2.13154	0.49062	2.03825	0.51246	1.95137	0.53470	1.87021	0.55736	1.79419	52
9	0.46950	2.12993	0.49098	2.03675	0.51283	1.94997	0.53507	1.86891	0.55774	1.79296	51
10	0.46985	2.12832	0.49134	2.03526	0.51319	1.94858	0.53545	1.86760	0.55812	1.79174	50
11	0.47021	2.12671	0.49170	2.03376	0.51356	1.94718	0.53582	1.86630	0.55850	1.79051	49
12	0.47056	2.12511	0.49206	2.03227	0.51393	1.94579	0.53620	1.86499	0.55888	1.78929	48
13	0.47092	2.12350	0.49242	2.03078	0.51430	1.94440	0.53657	1.86369	0.55926	1.78807	47
14	0.47128	2.12190	0.49278	2.02929	0.51467	1.94301	0.53694	1.86239	0.55964	1.78685	46
15	0.47163	2.12030	0.49315	2.02780	0.51503	1.94162	0.53732	1.86109	0.56003	1.78563	45
16	0.47199	2.11871	0.49351	2.02631	0.51540	1.94023	0.53769	1.85979	0.56041	1.78441	44
17	0.47234	2.11711	0.49387	2.02483	0.51577	1.93885	0.53807	1.85850	0.56079	1.78319	43
18	0.47270	2.11552	0.49423	2.02335	0.51614	1.93746	0.53844	1.85720	0.56117	1.78198	42
19	0.47305	2.11392	0.49459	2.02187	0.51651	1.93608	0.53882	1.85591	0.56156	1.78077	41
20	0.47341	2.11233	0.49495	2.02039	0.51688	1.93470	0.53920	1.85462	0.56194	1.77955	40
21	0.47377	2.11075	0.49532	2.01891	0.51724	1.93332	0.53957	1.85333	0.56232	1.77834	39
22	0.47412	2.10916	0.49568	2.01743	0.51761	1.93195	0.53995	1.85204	0.56270	1.77713	38
23	0.47448	2.10758	0.49604	2.01596	0.51798	1.93057	0.54032	1.85075	0.56309	1.77592	37
24	0.47483	2.10600	0.49640	2.01449	0.51835	1.92920	0.54070	1.84946	0.56347	1.77471	36
25	0.47519	2.10442	0.49677	2.01302	0.51872	1.92782	0.54107	1.84818	0.56385	1.77351	35
26	0.47555	2.10284	0.49713	2.01155	0.51909	1.92645	0.54145	1.84689	0.56424	1.77230	34
27	0.47590	2.10126	0.49749	2.01008	0.51946	1.92508	0.54183	1.84561	0.56462	1.77110	33
28	0.47626	2.09969	0.49786	2.00862	0.51983	1.92371	0.54220	1.84433	0.56501	1.76990	32
29	0.47662	2.09811	0.49822	2.00715	0.52020	1.92235	0.54258	1.84305	0.56539	1.76869	31
30	0.47698	2.09654	0.49858	2.00569	0.52057	1.92098	0.54296	1.84177	0.56577	1.76749	30
31	0.47733	2.09498	0.49894	2.00423	0.52094	1.91962	0.54333	1.84049	0.56616	1.76629	29
32	0.47769	2.09341	0.49931	2.00277	0.52131	1.91826	0.54371	1.83922	0.56654	1.76510	28
33	0.47805	2.09184	0.49967	2.00131	0.52168	1.91690	0.54409	1.83794	0.56693	1.76390	27
34	0.47840	2.09028	0.50004	1.99986	0.52205	1.91554	0.54446	1.83667	0.56731	1.76271	26
35	0.47876	2.08872	0.50040	1.99841	0.52242	1.91418	0.54484	1.83540	0.56769	1.76151	25
36	0.47912	2.08716	0.50076	1.99695	0.52279	1.91282	0.54522	1.83413	0.56808	1.76032	24
37	0.47948	2.08560	0.50113	1.99550	0.52316	1.91147	0.54560	1.83286	0.56846	1.75913	23
38	0.47984	2.08405	0.50149	1.99406	0.52353	1.91012	0.54597	1.83159	0.56885	1.75794	22
39	0.48019	2.08250	0.50185	1.99261	0.52390	1.90876	0.54635	1.83033	0.56923	1.75675	21
40	0.48055	2.08094	0.50222	1.99116	0.52427	1.90741	0.54673	1.82906	0.56962	1.75556	20
41	0.48091	2.07939	0.50258	1.98972	0.52464	1.90607	0.54711	1.82780	0.57000	1.75437	19
42	0.48127	2.07785	0.50295	1.98828	0.52501	1.90472	0.54748	1.82654	0.57039	1.75319	18
43	0.48163	2.07630	0.50331	1.98684	0.52538	1.90337	0.54786	1.82528	0.57078	1.75200	17
44	0.48198	2.07476	0.50368	1.98540	0.52575	1.90203	0.54824	1.82402	0.57116	1.75082	16
45	0.48234	2.07321	0.50404	1.98396	0.52613	1.90069	0.54862	1.82276	0.57155	1.74964	15
46	0.48270	2.07167	0.50441	1.98253	0.52650	1.89935	0.54900	1.82150	0.57193	1.74846	14
47	0.48306	2.07014	0.50477	1.98110	0.52687	1.89801	0.54938	1.82025	0.57232	1.74728	13
48	0.48342	2.06860	0.50514	1.97966	0.52724	1.89667	0.54975	1.81899	0.57271	1.74610	12
49	0.48378	2.06706	0.50550	1.97823	0.52761	1.89533	0.55013	1.81774	0.57309	1.74492	11
50	0.48414	2.06553	0.50587	1.97681	0.52798	1.89400	0.55051	1.81649	0.57348	1.74375	10
51	0.48450	2.06400	0.50623	1.97538	0.52836	1.89266	0.55089	1.81524	0.57386	1.74257	9
52	0.48486	2.06247	0.50660	1.97395	0.52873	1.89133	0.55127	1.81399	0.57425	1.74140	8
53	0.48521	2.06094	0.50696	1.97253	0.52910	1.89000	0.55165	1.81274	0.57464	1.74022	7
54	0.48557	2.05942	0.50733	1.97111	0.52947	1.88867	0.55203	1.81150	0.57503	1.73905	6
55	0.48593	2.05790	0.50769	1.96969	0.52985	1.88734	0.55241	1.81025	0.57541	1.73788	5
56	0.48629	2.05637	0.50806	1.96827	0.53022	1.88602	0.55279	1.80901	0.57580	1.73671	4
57	0.48665	2.05485	0.50843	1.96685	0.53059	1.88469	0.55317	1.80777	0.57619	1.73555	3
58	0.48701	2.05333	0.50879	1.96544	0.53096	1.88337	0.55355	1.80653	0.57657	1.73438	2
59	0.48737	2.05182	0.50916	1.96402	0.53134	1.88205	0.55393	1.80529	0.57696	1.73321	1
60	0.48773	2.05030	0.50953	1.96261	0.53171	1.88073	0.55431	1.80405	0.57735	1.73205	0
	COT	TAN	COT	TAN	COT	TAN	COT	TAN	COT	TAN	
	64°		63°		62°		61°		60°		MIN

F. NATURAL TANGENTS AND COTANGENTS—CONTINUED

MIN	30° TAN	30° COT	31° TAN	31° COT	32° TAN	32° COT	33° TAN	33° COT	34° TAN	34° COT	
0	0.57735	1.73205	0.60086	1.66428	0.62487	1.60033	0.64941	1.53986	0.67451	1.48256	60
1	0.57774	1.73089	0.60126	1.66318	0.62527	1.59930	0.64982	1.53888	0.67493	1.48163	59
2	0.57813	1.72973	0.60165	1.66209	0.62568	1.59826	0.65024	1.53791	0.67536	1.48070	58
3	0.57851	1.72857	0.60205	1.66099	0.62608	1.59723	0.65065	1.53693	0.67578	1.47977	57
4	0.57890	1.72741	0.60245	1.65990	0.62649	1.59620	0.65106	1.53595	0.67620	1.47885	56
5	0.57929	1.72625	0.60284	1.65881	0.62689	1.59517	0.65148	1.53497	0.67663	1.47792	55
6	0.57968	1.72509	0.60324	1.65772	0.62730	1.59414	0.65189	1.53400	0.67705	1.47699	54
7	0.58007	1.72393	0.60364	1.65663	0.62770	1.59311	0.65231	1.53302	0.67748	1.47607	53
8	0.58046	1.72278	0.60403	1.65554	0.62811	1.59208	0.65272	1.53205	0.67790	1.47514	52
9	0.58085	1.72163	0.60443	1.65445	0.62852	1.59105	0.65314	1.53107	0.67832	1.47422	51
10	0.58124	1.72047	0.60483	1.65337	0.62892	1.59002	0.65355	1.53010	0.67875	1.47330	50
11	0.58162	1.71932	0.60522	1.65228	0.62933	1.58900	0.65397	1.52913	0.67917	1.47238	49
12	0.58201	1.71817	0.60562	1.65120	0.62973	1.58797	0.65438	1.52816	0.67960	1.47146	48
13	0.58240	1.71702	0.60602	1.65011	0.63014	1.58695	0.65480	1.52719	0.68002	1.47053	47
14	0.58279	1.71588	0.60642	1.64903	0.63055	1.58593	0.65521	1.52622	0.68045	1.46962	46
15	0.58318	1.71473	0.60681	1.64795	0.63095	1.58490	0.65563	1.52525	0.68088	1.46870	45
16	0.58357	1.71358	0.60721	1.64687	0.63136	1.58388	0.65604	1.52429	0.68130	1.46778	44
17	0.58396	1.71244	0.60761	1.64579	0.63177	1.58286	0.65646	1.52332	0.68173	1.46686	43
18	0.58435	1.71129	0.60801	1.64471	0.63217	1.58184	0.65688	1.52235	0.68215	1.46595	42
19	0.58474	1.71015	0.60841	1.64363	0.63258	1.58083	0.65729	1.52139	0.68258	1.46503	41
20	0.58513	1.70901	0.60881	1.64256	0.63299	1.57981	0.65771	1.52043	0.68301	1.46411	40
21	0.58552	1.70787	0.60921	1.64148	0.63340	1.57879	0.65813	1.51946	0.68343	1.46320	39
22	0.58591	1.70673	0.60960	1.64041	0.63380	1.57778	0.65854	1.51850	0.68386	1.46229	38
23	0.58631	1.70560	0.61000	1.63934	0.63421	1.57676	0.65896	1.51754	0.68429	1.46137	37
24	0.58670	1.70446	0.61040	1.63826	0.63462	1.57575	0.65938	1.51658	0.68471	1.46046	36
25	0.58709	1.70332	0.61080	1.63719	0.63503	1.57474	0.65980	1.51562	0.68514	1.45955	35
26	0.58748	1.70219	0.61120	1.63612	0.63544	1.57372	0.66021	1.51466	0.68557	1.45864	34
27	0.58787	1.70106	0.61160	1.63505	0.63584	1.57271	0.66063	1.51370	0.68600	1.45773	33
28	0.58826	1.69992	0.61200	1.63398	0.63625	1.57170	0.66105	1.51275	0.68642	1.45682	32
29	0.58865	1.69879	0.61240	1.63292	0.63666	1.57069	0.66147	1.51179	0.68685	1.45592	31
30	0.58905	1.69766	0.61280	1.63185	0.63707	1.56969	0.66189	1.51084	0.68728	1.45501	30
31	0.58944	1.69653	0.61320	1.63079	0.63748	1.56868	0.66230	1.50988	0.68771	1.45410	29
32	0.58983	1.69541	0.61360	1.62972	0.63789	1.56767	0.66272	1.50893	0.68814	1.45320	28
33	0.59022	1.69428	0.61400	1.62866	0.63830	1.56667	0.66314	1.50797	0.68857	1.45229	27
34	0.59061	1.69316	0.61440	1.62760	0.63871	1.56566	0.66356	1.50702	0.68900	1.45139	26
35	0.59101	1.69203	0.61480	1.62654	0.63912	1.56466	0.66398	1.50607	0.68942	1.45049	25
36	0.59140	1.69091	0.61520	1.62548	0.63953	1.56366	0.66440	1.50512	0.68985	1.44958	24
37	0.59179	1.68979	0.61561	1.62442	0.63994	1.56265	0.66482	1.50417	0.69028	1.44868	23
38	0.59218	1.68866	0.61601	1.62336	0.64035	1.56165	0.66524	1.50322	0.69071	1.44778	22
39	0.59258	1.68754	0.61641	1.62230	0.64076	1.56065	0.66566	1.50228	0.69114	1.44688	21
40	0.59297	1.68643	0.61681	1.62125	0.64117	1.55966	0.66608	1.50133	0.69157	1.44598	20
41	0.59336	1.68531	0.61721	1.62019	0.64158	1.55866	0.66650	1.50038	0.69200	1.44508	19
42	0.59376	1.68419	0.61761	1.61914	0.64199	1.55766	0.66692	1.49944	0.69243	1.44418	18
43	0.59415	1.68308	0.61801	1.61808	0.64240	1.55666	0.66734	1.49849	0.69286	1.44329	17
44	0.59454	1.68196	0.61842	1.61703	0.64281	1.55567	0.66776	1.49755	0.69329	1.44239	16
45	0.59494	1.68085	0.61882	1.61598	0.64322	1.55467	0.66818	1.49661	0.69372	1.44149	15
46	0.59533	1.67974	0.61922	1.61493	0.64363	1.55368	0.66860	1.49566	0.69416	1.44060	14
47	0.59573	1.67863	0.61962	1.61388	0.64404	1.55269	0.66902	1.49472	0.69459	1.43970	13
48	0.59612	1.67752	0.62003	1.61283	0.64446	1.55170	0.66944	1.49378	0.69502	1.43881	12
49	0.59651	1.67641	0.62043	1.61179	0.64487	1.55071	0.66986	1.49284	0.69545	1.43792	11
50	0.59691	1.67530	0.62083	1.61074	0.64528	1.54972	0.67028	1.49190	0.69588	1.43703	10
51	0.59730	1.67419	0.62124	1.60970	0.64569	1.54873	0.67071	1.49097	0.69631	1.43614	9
52	0.59770	1.67309	0.62164	1.60865	0.64610	1.54774	0.67113	1.49003	0.69675	1.43525	8
53	0.59809	1.67198	0.62204	1.60761	0.64652	1.54675	0.67155	1.48909	0.69718	1.43436	7
54	0.59849	1.67088	0.62245	1.60657	0.64693	1.54576	0.67197	1.48816	0.69761	1.43347	6
55	0.59888	1.66978	0.62285	1.60553	0.64734	1.54478	0.67239	1.48722	0.69804	1.43258	5
56	0.59928	1.66867	0.62325	1.60449	0.64775	1.54379	0.67282	1.48629	0.69847	1.43169	4
57	0.59967	1.66757	0.62366	1.60345	0.64817	1.54281	0.67324	1.48536	0.69891	1.43080	3
58	0.60007	1.66647	0.62406	1.60241	0.64858	1.54183	0.67366	1.48442	0.69934	1.42992	2
59	0.60046	1.66538	0.62446	1.60137	0.64899	1.54085	0.67409	1.48349	0.69977	1.42903	1
60	0.60086	1.66428	0.62487	1.60033	0.64941	1.53986	0.67451	1.48256	0.70021	1.42815	0
	COT	TAN	COT	TAN	COT	TAN	COT	TAN	COT	TAN	MIN
	59°		58°		57°		56°		55°		

F. NATURAL TANGENTS AND COTANGENTS—CONTINUED

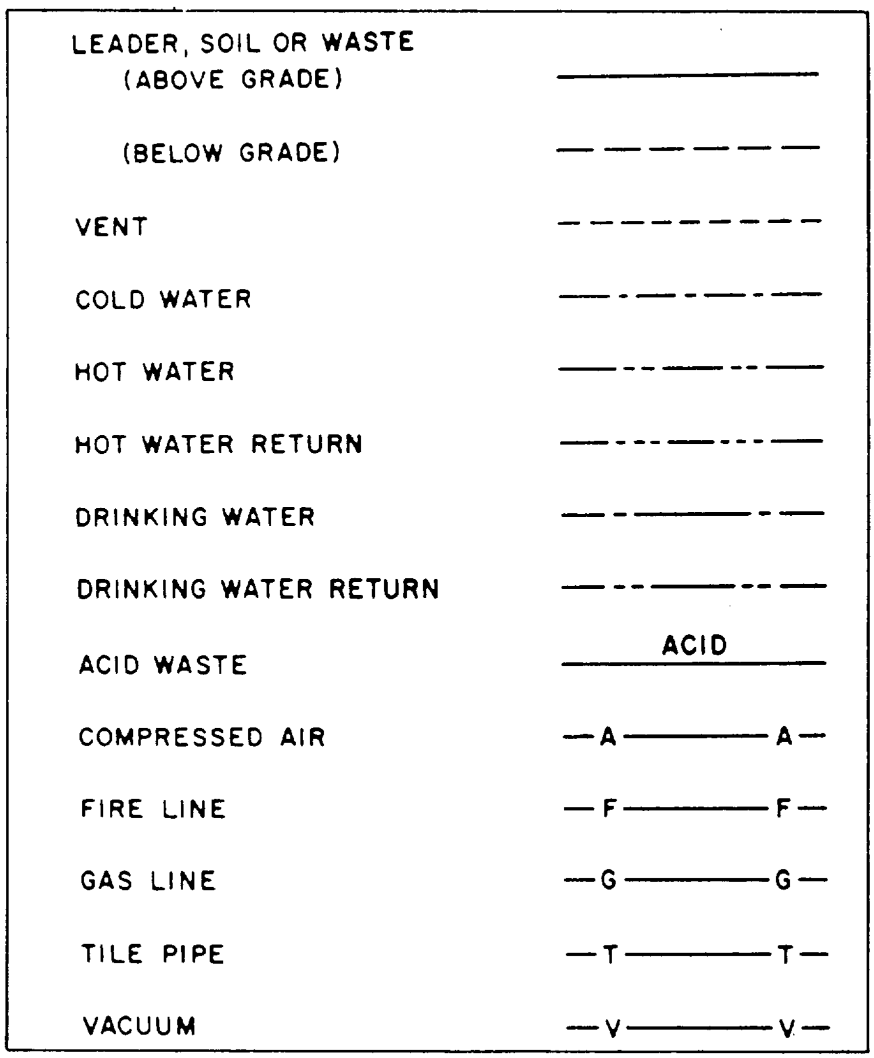
MIN	35° TAN	35° COT	36° TAN	36° COT	37° TAN	37° COT	38° TAN	38° COT	39° TAN	39° COT	
0	0.70021	1.42815	0.72654	1.37638	0.75355	1.32704	0.78129	1.27994	0.80978	1.23490	60
1	0.70064	1.42726	0.72699	1.37554	0.75401	1.32624	0.78175	1.27917	0.81027	1.23416	59
2	0.70107	1.42638	0.72743	1.37470	0.75447	1.32544	0.78222	1.27841	0.81075	1.23343	58
3	0.70151	1.42550	0.72788	1.37386	0.75492	1.32464	0.78269	1.27764	0.81123	1.23270	57
4	0.70194	1.42462	0.72832	1.37302	0.75538	1.32384	0.78316	1.27688	0.81171	1.23196	56
5	0.70238	1.42374	0.72877	1.37218	0.75584	1.32304	0.78363	1.27611	0.81220	1.23123	55
6	0.70281	1.42286	0.72921	1.37134	0.75629	1.32224	0.78410	1.27535	0.81268	1.23050	54
7	0.70325	1.42198	0.72966	1.37050	0.75675	1.32144	0.78457	1.27458	0.81316	1.22977	53
8	0.70368	1.42110	0.73010	1.36967	0.75721	1.32064	0.78504	1.27382	0.81364	1.22904	52
9	0.70412	1.42022	0.73055	1.36883	0.75767	1.31984	0.78551	1.27306	0.81413	1.22831	51
10	0.70455	1.41934	0.73100	1.36800	0.75812	1.31904	0.78598	1.27230	0.81461	1.22758	50
11	0.70499	1.41847	0.73144	1.36716	0.75858	1.31825	0.78645	1.27153	0.81510	1.22685	49
12	0.70542	1.41759	0.73189	1.36633	0.75904	1.31745	0.78692	1.27077	0.81558	1.22612	48
13	0.70586	1.41672	0.73234	1.36549	0.75950	1.31666	0.78739	1.27001	0.81606	1.22539	47
14	0.70629	1.41584	0.73278	1.36466	0.75996	1.31586	0.78786	1.26925	0.81655	1.22467	46
15	0.70673	1.41497	0.73323	1.36383	0.76042	1.31507	0.78834	1.26849	0.81703	1.22394	45
16	0.70717	1.41409	0.73368	1.36300	0.76088	1.31427	0.78881	1.26774	0.81752	1.22321	44
17	0.70760	1.41322	0.73413	1.36217	0.76134	1.31348	0.78928	1.26698	0.81800	1.22249	43
18	0.70804	1.41235	0.73457	1.36134	0.76180	1.31269	0.78975	1.26622	0.81849	1.22176	42
19	0.70848	1.41148	0.73502	1.36051	0.76226	1.31190	0.79022	1.26546	0.81898	1.22104	41
20	0.70891	1.41061	0.73547	1.35968	0.76272	1.31110	0.79070	1.26471	0.81946	1.22031	40
21	0.70935	1.40974	0.73592	1.35885	0.76318	1.31031	0.79117	1.26395	0.81995	1.21959	39
22	0.70979	1.40887	0.73637	1.35802	0.76364	1.30952	0.79164	1.26319	0.82044	1.21886	38
23	0.71023	1.40800	0.73681	1.35719	0.76410	1.30873	0.79212	1.26244	0.82092	1.21814	37
24	0.71066	1.40714	0.73726	1.35637	0.76456	1.30795	0.79259	1.26169	0.82141	1.21742	36
25	0.71110	1.40627	0.73771	1.35554	0.76502	1.30716	0.79306	1.26093	0.82190	1.21670	35
26	0.71154	1.40540	0.73816	1.35472	0.76548	1.30637	0.79354	1.26018	0.82238	1.21598	34
27	0.71198	1.40454	0.73861	1.35389	0.76594	1.30558	0.79401	1.25943	0.82287	1.21526	33
28	0.71242	1.40367	0.73906	1.35307	0.76640	1.30480	0.79449	1.25867	0.82336	1.21454	32
29	0.71285	1.40281	0.73951	1.35224	0.76686	1.30401	0.79496	1.25792	0.82385	1.21382	31
30	0.71329	1.40195	0.73996	1.35142	0.76733	1.30323	0.79544	1.25717	0.82434	1.21310	30
31	0.71373	1.40109	0.74041	1.35060	0.76779	1.30244	0.79591	1.25642	0.82483	1.21238	29
32	0.71417	1.40022	0.74086	1.34978	0.76825	1.30166	0.79639	1.25567	0.82531	1.21166	28
33	0.71461	1.39936	0.74131	1.34896	0.76871	1.30087	0.79686	1.25492	0.82580	1.21094	27
34	0.71505	1.39850	0.74176	1.34814	0.76918	1.30009	0.79734	1.25417	0.82629	1.21023	26
35	0.71549	1.39764	0.74221	1.34732	0.76964	1.29931	0.79781	1.25343	0.82678	1.20951	25
36	0.71593	1.39679	0.74267	1.34650	0.77010	1.29853	0.79829	1.25268	0.82727	1.20879	24
37	0.71637	1.39593	0.74312	1.34568	0.77057	1.29775	0.79877	1.25193	0.82776	1.20808	23
38	0.71681	1.39507	0.74357	1.34487	0.77103	1.29696	0.79924	1.25118	0.82825	1.20736	22
39	0.71725	1.39421	0.74402	1.34405	0.77149	1.29618	0.79972	1.25044	0.82874	1.20665	21
40	0.71769	1.39336	0.74447	1.34323	0.77196	1.29541	0.80020	1.24969	0.82923	1.20593	20
41	0.71813	1.39250	0.74492	1.34242	0.77242	1.29463	0.80067	1.24895	0.82972	1.20522	19
42	0.71857	1.39165	0.74538	1.34160	0.77289	1.29385	0.80115	1.24820	0.83022	1.20451	18
43	0.71901	1.39079	0.74583	1.34079	0.77335	1.29307	0.80163	1.24746	0.83071	1.20379	17
44	0.71946	1.38994	0.74628	1.33998	0.77382	1.29229	0.80211	1.24672	0.83120	1.20308	16
45	0.71990	1.38909	0.74674	1.33916	0.77428	1.29152	0.80258	1.24597	0.83169	1.20237	15
46	0.72034	1.38824	0.74719	1.33835	0.77475	1.29074	0.80306	1.24523	0.83218	1.20166	14
47	0.72078	1.38738	0.74764	1.33754	0.77521	1.28997	0.80354	1.24449	0.83268	1.20095	13
48	0.72122	1.38653	0.74810	1.33673	0.77568	1.28919	0.80402	1.24375	0.83317	1.20024	12
49	0.72167	1.38568	0.74855	1.33592	0.77615	1.28842	0.80450	1.24301	0.83366	1.19953	11
50	0.72211	1.38484	0.74900	1.33511	0.77661	1.28764	0.80498	1.24227	0.83415	1.19882	10
51	0.72255	1.38399	0.74946	1.33430	0.77708	1.28687	0.80546	1.24153	0.83465	1.19811	9
52	0.72299	1.38314	0.74991	1.33349	0.77754	1.28610	0.80594	1.24079	0.83514	1.19740	8
53	0.72344	1.38229	0.75037	1.33268	0.77801	1.28533	0.80642	1.24005	0.83564	1.19669	7
54	0.72388	1.38145	0.75082	1.33187	0.77848	1.28456	0.80690	1.23931	0.83613	1.19599	6
55	0.72432	1.38060	0.75128	1.33107	0.77895	1.28379	0.80738	1.23858	0.83662	1.19528	5
56	0.72477	1.37976	0.75173	1.33026	0.77941	1.28302	0.80786	1.23784	0.83712	1.19457	4
57	0.72521	1.37891	0.75219	1.32946	0.77988	1.28225	0.80834	1.23710	0.83761	1.19387	3
58	0.72565	1.37807	0.75264	1.32865	0.78035	1.28148	0.80882	1.23637	0.83811	1.19316	2
59	0.72610	1.37722	0.75310	1.32785	0.78082	1.28071	0.80930	1.23563	0.83860	1.19246	1
60	0.72654	1.37638	0.75355	1.32704	0.78129	1.27994	0.80978	1.23490	0.83910	1.19175	0
	COT	TAN	COT	TAN	COT	TAN	COT	TAN	COT	TAN	MIN
	54°		53°		52°		51°		50°		

MIN	40° TAN	40° COT	41° TAN	41° COT	42° TAN	42° COT	43° TAN	43° COT	44° TAN	44° COT	
0	0.83910	1.19175	0.86929	1.15037	0.90040	1.11061	0.93252	1.07237	0.96569	1.03553	60
1	0.83960	1.19105	0.86980	1.14969	0.90093	1.10996	0.93306	1.07174	0.96625	1.03493	59
2	0.84009	1.19035	0.87031	1.14902	0.90146	1.10931	0.93360	1.07112	0.96681	1.03433	58
3	0.84059	1.18964	0.87082	1.14834	0.90199	1.10867	0.93415	1.07049	0.96738	1.03372	57
4	0.84108	1.18894	0.87133	1.14767	0.90251	1.10802	0.93469	1.06987	0.96794	1.03312	56
5	0.84158	1.18824	0.87184	1.14699	0.90304	1.10737	0.93524	1.06925	0.96850	1.03252	55
6	0.84208	1.18754	0.87236	1.14632	0.90357	1.10672	0.93578	1.06862	0.96907	1.03192	54
7	0.84258	1.18684	0.87287	1.14565	0.90410	1.10607	0.93633	1.06800	0.96963	1.03132	53
8	0.84307	1.18614	0.87338	1.14498	0.90463	1.10543	0.93688	1.06738	0.97020	1.03072	52
9	0.84357	1.18544	0.87389	1.14430	0.90516	1.10478	0.93742	1.06676	0.97076	1.03012	51
10	0.84407	1.18474	0.87441	1.14363	0.90569	1.10414	0.93797	1.06613	0.97133	1.02952	50
11	0.84457	1.18404	0.87492	1.14296	0.90621	1.10349	0.93852	1.06551	0.97189	1.02892	49
12	0.84507	1.18334	0.87543	1.14229	0.90674	1.10285	0.93906	1.06489	0.97246	1.02832	48
13	0.84556	1.18264	0.87595	1.14162	0.90727	1.10220	0.93961	1.06427	0.97302	1.02772	47
14	0.84606	1.18194	0.87646	1.14095	0.90781	1.10156	0.94016	1.06365	0.97359	1.02713	46
15	0.84656	1.18125	0.87698	1.14028	0.90834	1.10091	0.94071	1.06303	0.97416	1.02653	45
16	0.84706	1.18055	0.87749	1.13961	0.90887	1.10027	0.94125	1.06241	0.97472	1.02593	44
17	0.84756	1.17986	0.87801	1.13894	0.90940	1.09963	0.94180	1.06179	0.97529	1.02533	43
18	0.84806	1.17916	0.87852	1.13828	0.90993	1.09899	0.94235	1.06117	0.97586	1.02474	42
19	0.84856	1.17846	0.87904	1.13761	0.91046	1.09834	0.94290	1.06056	0.97643	1.02414	41
20	0.84906	1.17777	0.87955	1.13694	0.91099	1.09770	0.94345	1.05994	0.97700	1.02355	40
21	0.84956	1.17708	0.88007	1.13627	0.91153	1.09706	0.94400	1.05932	0.97756	1.02295	39
22	0.85006	1.17638	0.88059	1.13561	0.91206	1.09642	0.94455	1.05870	0.97813	1.02236	38
23	0.85057	1.17569	0.88110	1.13494	0.91259	1.09578	0.94510	1.05809	0.97870	1.02176	37
24	0.85107	1.17500	0.88162	1.13428	0.91313	1.09514	0.94565	1.05747	0.97927	1.02117	36
25	0.85157	1.17430	0.88214	1.13361	0.91366	1.09450	0.94620	1.05685	0.97984	1.02057	35
26	0.85207	1.17361	0.88265	1.13295	0.91419	1.09386	0.94676	1.05624	0.98041	1.01998	34
27	0.85257	1.17292	0.88317	1.13228	0.91473	1.09322	0.94731	1.05562	0.98098	1.01939	33
28	0.85308	1.17223	0.88369	1.13162	0.91526	1.09258	0.94786	1.05501	0.98155	1.01879	32
29	0.85358	1.17154	0.88421	1.13096	0.91580	1.09195	0.94841	1.05439	0.98213	1.01820	31
30	0.85408	1.17085	0.88473	1.13029	0.91633	1.09131	0.94896	1.05378	0.98270	1.01761	30
31	0.85458	1.17016	0.88524	1.12963	0.91687	1.09067	0.94952	1.05317	0.98327	1.01702	29
32	0.85509	1.16947	0.88576	1.12897	0.91740	1.09003	0.95007	1.05255	0.98384	1.01642	28
33	0.85559	1.16878	0.88628	1.12831	0.91794	1.08940	0.95062	1.05194	0.98441	1.01583	27
34	0.85609	1.16809	0.88680	1.12765	0.91847	1.08876	0.95118	1.05133	0.98499	1.01524	26
35	0.85660	1.16741	0.88732	1.12699	0.91901	1.08813	0.95173	1.05072	0.98556	1.01465	25
36	0.85710	1.16672	0.88784	1.12633	0.91955	1.08749	0.95229	1.05010	0.98613	1.01406	24
37	0.85761	1.16603	0.88836	1.12567	0.92008	1.08686	0.95284	1.04949	0.98671	1.01347	23
38	0.85811	1.16535	0.88888	1.12501	0.92062	1.08622	0.95340	1.04888	0.98728	1.01288	22
39	0.85862	1.16466	0.88940	1.12435	0.92116	1.08559	0.95395	1.04827	0.98786	1.01229	21
40	0.85912	1.16398	0.88992	1.12369	0.92170	1.08496	0.95451	1.04766	0.98843	1.01170	20
41	0.85963	1.16329	0.89045	1.12303	0.92224	1.08432	0.95506	1.04705	0.98901	1.01112	19
42	0.86014	1.16261	0.89097	1.12238	0.92277	1.08369	0.95562	1.04644	0.98958	1.01053	18
43	0.86064	1.16192	0.89149	1.12172	0.92331	1.08306	0.95618	1.04583	0.99016	1.00994	17
44	0.86115	1.16124	0.89201	1.12106	0.92385	1.08243	0.95673	1.04522	0.99073	1.00935	16
45	0.86166	1.16056	0.89253	1.12041	0.92439	1.08179	0.95729	1.04461	0.99131	1.00876	15
46	0.86216	1.15987	0.89306	1.11975	0.92493	1.08116	0.95785	1.04401	0.99189	1.00818	14
47	0.86267	1.15919	0.89358	1.11909	0.92547	1.08053	0.95841	1.04340	0.99247	1.00759	13
48	0.86318	1.15851	0.89410	1.11844	0.92601	1.07990	0.95897	1.04279	0.99304	1.00701	12
49	0.86368	1.15783	0.89463	1.11778	0.92655	1.07927	0.95952	1.04218	0.99362	1.00642	11
50	0.86419	1.15715	0.89515	1.11713	0.92709	1.07864	0.96008	1.04158	0.99420	1.00583	10
51	0.86470	1.15647	0.89567	1.11648	0.92763	1.07801	0.96064	1.04097	0.99478	1.00525	9
52	0.86521	1.15579	0.89620	1.11582	0.92817	1.07738	0.96120	1.04036	0.99536	1.00467	8
53	0.86572	1.15511	0.89672	1.11517	0.92872	1.07676	0.96176	1.03976	0.99594	1.00408	7
54	0.86623	1.15443	0.89725	1.11452	0.92926	1.07613	0.96232	1.03915	0.99652	1.00350	6
55	0.86674	1.15375	0.89777	1.11387	0.92980	1.07550	0.96288	1.03855	0.99710	1.00291	5
56	0.86725	1.15308	0.89830	1.11321	0.93034	1.07487	0.96344	1.03794	0.99768	1.00233	4
57	0.86776	1.15240	0.89883	1.11256	0.93088	1.07425	0.96400	1.03734	0.99826	1.00175	3
58	0.86827	1.15172	0.89935	1.11191	0.93143	1.07362	0.96457	1.03674	0.99884	1.00116	2
59	0.86878	1.15104	0.89988	1.11126	0.93197	1.07299	0.96513	1.03613	0.99942	1.00058	1
60	0.86929	1.15037	0.90040	1.11061	0.93252	1.07237	0.96569	1.03553	1.00000	1.00000	0
	COT	TAN	COT	TAN	COT	TAN	COT	TAN	COT	TAN	MIN
	49°		48°		47°		46°		45°		

APPENDIX IV

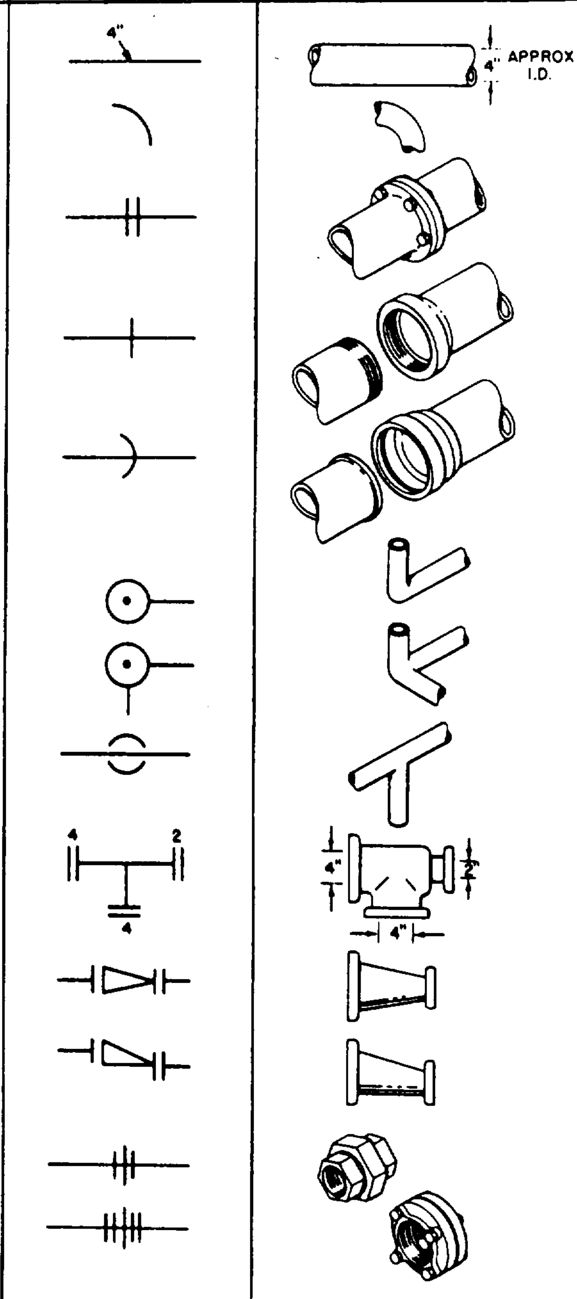
USEFUL DRAFTING SYMBOLS

A. MECHANICAL (PLUMBING) SYMBOLS



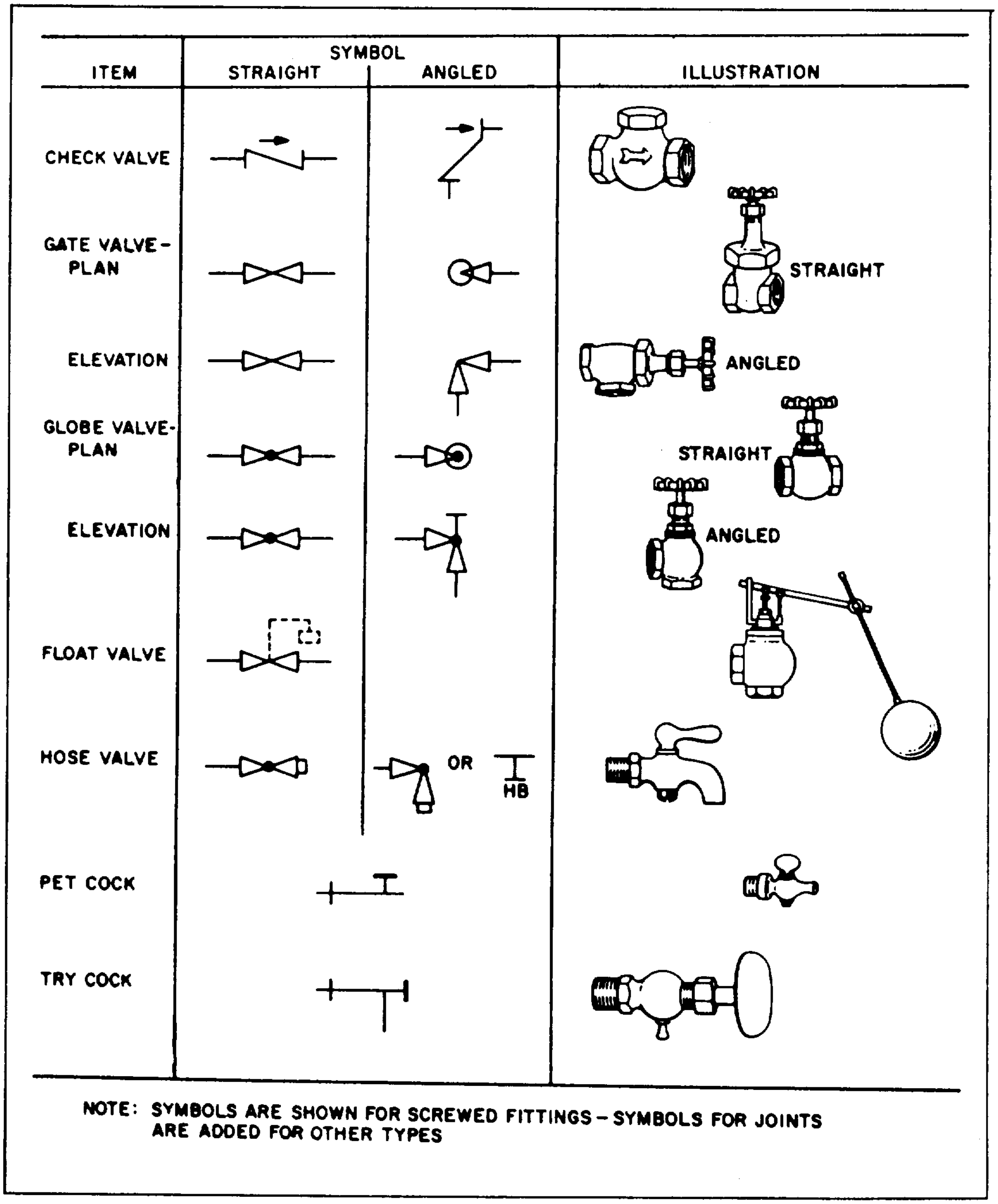
Line symbols for piping.

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



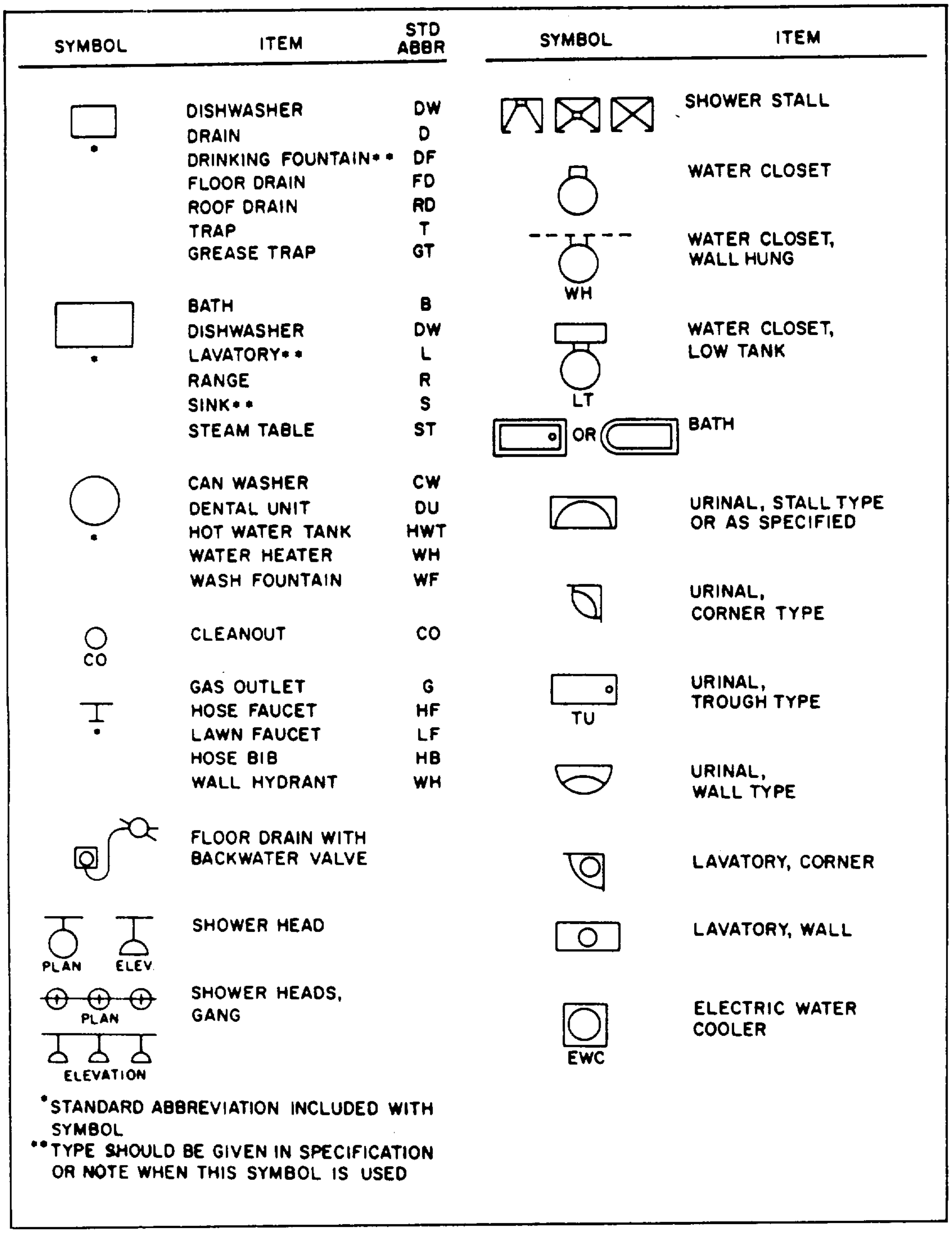
Pipe-fitting symbols.

A. MECHANICAL (PLUMBING) SYMBOLS—CONTINUED



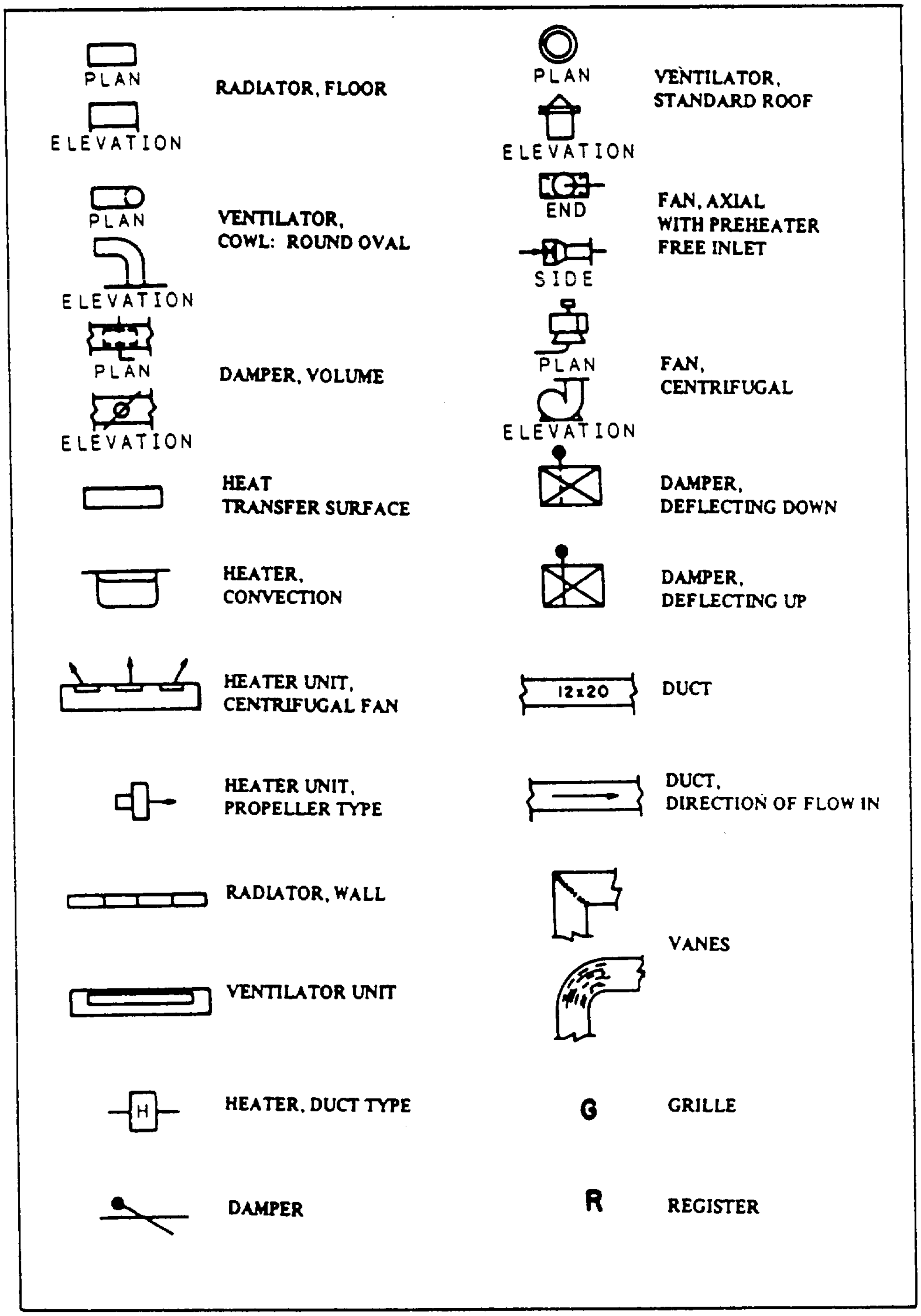
Valve symbols.

A. MECHANICAL (PLUMBING) SYMBOLS—CONTINUED

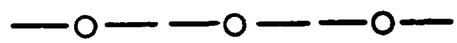
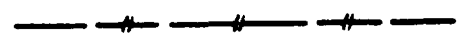
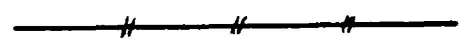


Symbols for plumbing fixtures.

B. HEATING SYMBOLS



B. HEATING SYMBOLS—CONTINUED

AIR–RELIEF LINE	
BOILER BLOW OFF	
COMPRESSED AIR	
CONDENSATE OR VACUUM PUMP DISCHARGE	
FEEDWATER PUMP DISCHARGE	
FUEL–OIL FLOW	
FUEL–OIL RETURN	
FUEL–OIL TANK VENT	
HIGH–PRESSURE RETURN	
HIGH–PRESSURE STEAM	
HOT–WATER HEATING RETURN	
HOT–WATER HEATING SUPPLY	
LOW–PRESSURE RETURN	
LOW–PRESSURE STEAM	
MAKE–UP WATER	
MEDIUM PRESSURE RETURN	
MEDIUM PRESSURE STEAD	

B. HEATING SYMBOLS—CONTINUED

RELIEF VALVE
(EITHER PRESSURE OR VACUUM)

BOILER RETURN TRAP

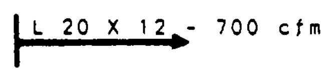
BLAST THERMOSTATIC TRAP

FLOAT TRAP

FLOAT AND THERMOSTATIC TRAP

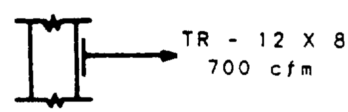
THERMOSTATIC TRAP

LOUVER OPENING

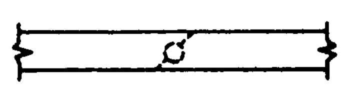


SUPPLY OUTLET CEILING
(INDICATE TYPE)

SUPPLY OUTLET WALL
(INDICATE TYPE)



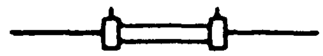
VOLUME DAMPER



CAPILLARY TUBE

B. HEATING SYMBOLS—CONTINUED

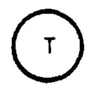
HEAT EXCHANGER



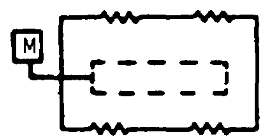
PUMP

THERMOMETER

THERMOSTAT

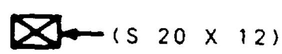


AUTOMATIC DAMPERS

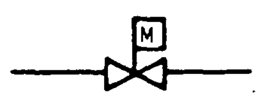


DUCT SECTION (EXHAUST OR RETURN)

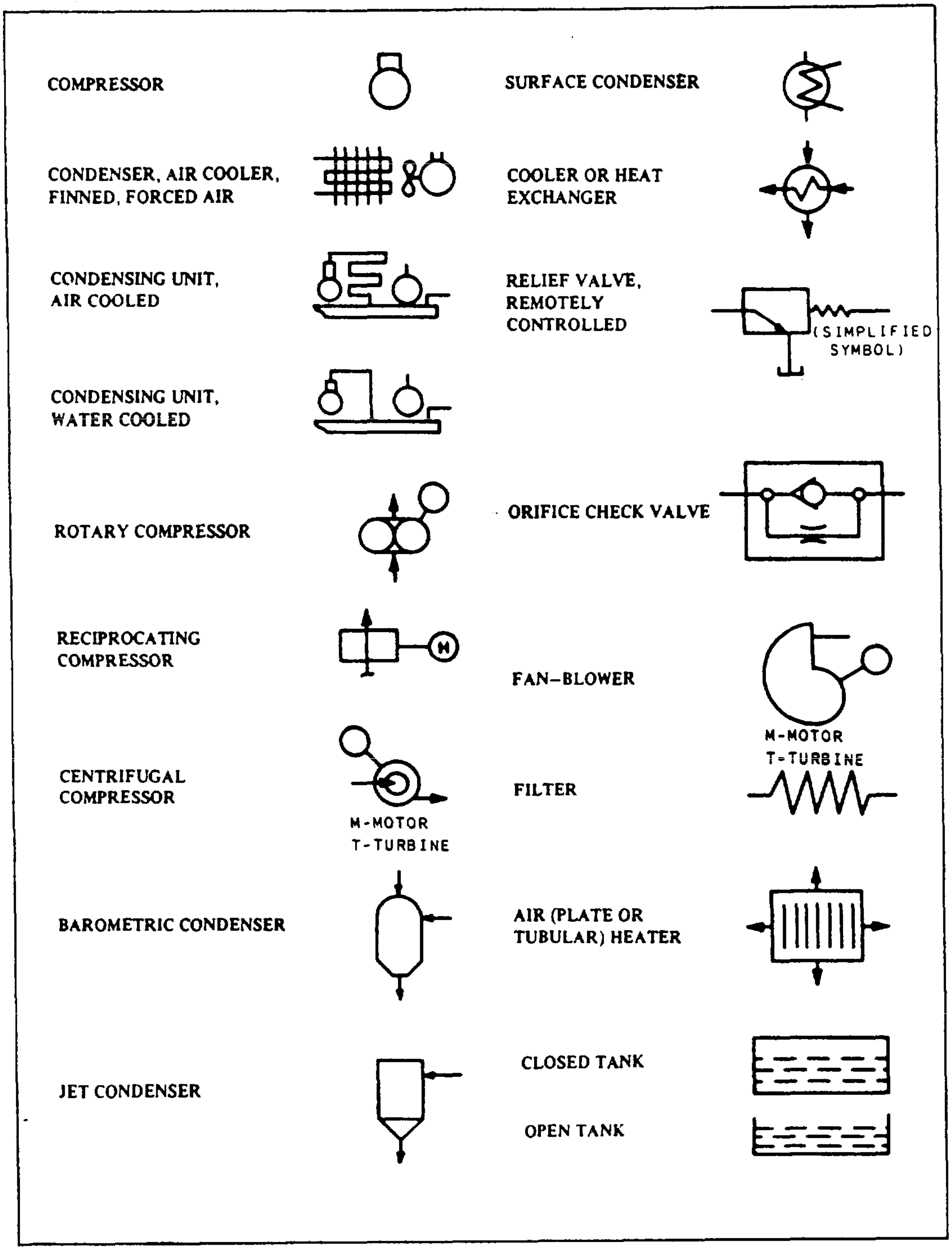
DUCT SECTION (SUPPLY)



MOTOR OPERATED VALVE



B. HEATING SYMBOLS—CONTINUED



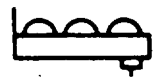
B. HEATING SYMBOLS—CONTINUED

QUICK DISCONNECT	
WITHOUT CHECKS	
WITH ONE CHECK	
WITH TWO CHECKS	
WITH CHECK DISCONNECTED	
SINGLE HYDRAULIC PUMP, FIXED DISPLACEMENT	
SINGLE HYDRAULIC PUMP, VARIABLE DISPLACEMENT	
AIR COMPRESSOR, FIXED DISPLACEMENT	
ROTARY FLUID MOTOR –	
FIXED DISPLACEMENT	
VARIABLE DISPLACEMENT	
OSCILLATING	

C. AIR-CONDITIONING AND REFRIGERATION SYMBOLS

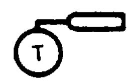
SCALE TRAP

SPRAY POND



THERMAL BULB

THERMOSTAT (REMOTE BULB)

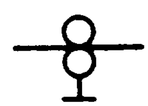


VALVES –

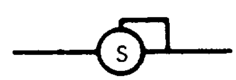
AUTOMATIC EXPANSION

COMPRESSOR SUCTION PRESSURE LIMITING, THROTTLING TYPE (COMPRESSOR SIDE)

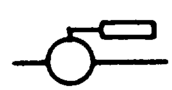
CONSTANT PRESSURE, SUCTION



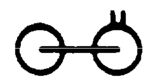
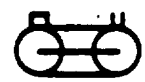
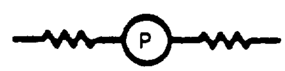
EVAPORATOR PRESSURE REGULATING, SNAP ACTION



EVAPORATOR PRESSURE REGULATING, THERMOSTATIC THROTTLING TYPE



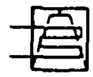
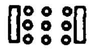
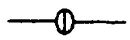
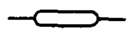
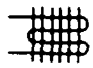
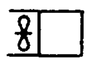
EVAPORATOR PRESSURE REGULATING, THROTTLING TYPE (EVAPORATOR SIDE)

IMMERSION COOLING UNIT	
LOW SIDE FLOAT	
MOTOR–COMPRESSOR, ENCLOSED CRANKCASE, RECIPROCATING, DIRECT CONNECTED	
MOTOR–COMPRESSOR, ENCLOSED CRANKCASE, ROTARY, DIRECT CONNECTED	
MOTOR–COMPRESSOR, SEALED CRANKCASE, RECIPROCATING	
MOTOR–COMPRESSOR, SEALED CRANKCASE, ROTARY	
PRESSURESTAT	
PRESSURE SWITCH	
PRESSURE SWITCH WITH HIGH PRESSURE CUT–OUT	
RECEIVER, HORIZONTAL	
RECEIVER, VERTICAL	

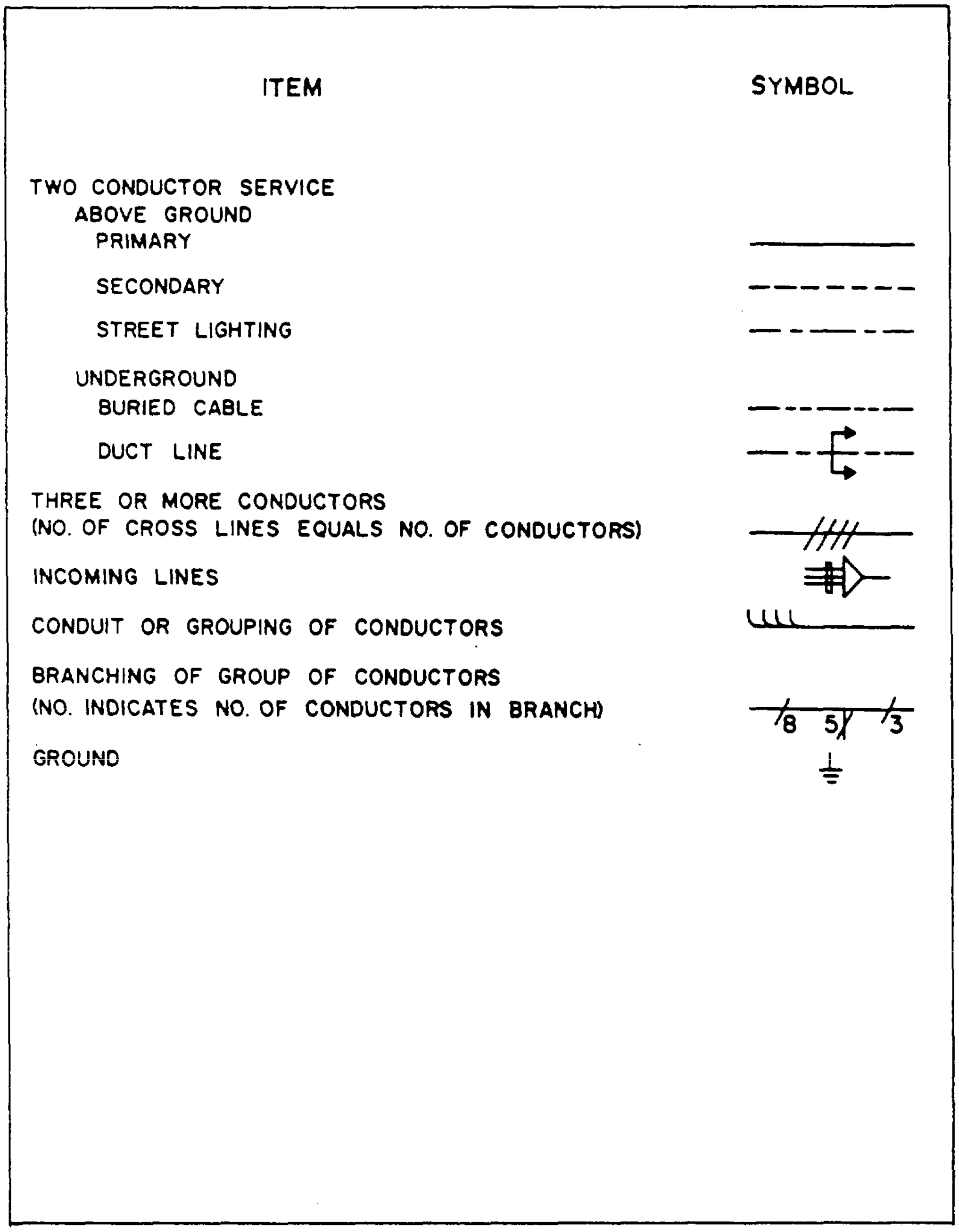
C. AIR-CONDITIONING AND REFRIGERATION SYMBOLS-CONTINUED

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

C. AIR-CONDITIONING AND REFRIGERATION SYMBOLS—CONTINUED

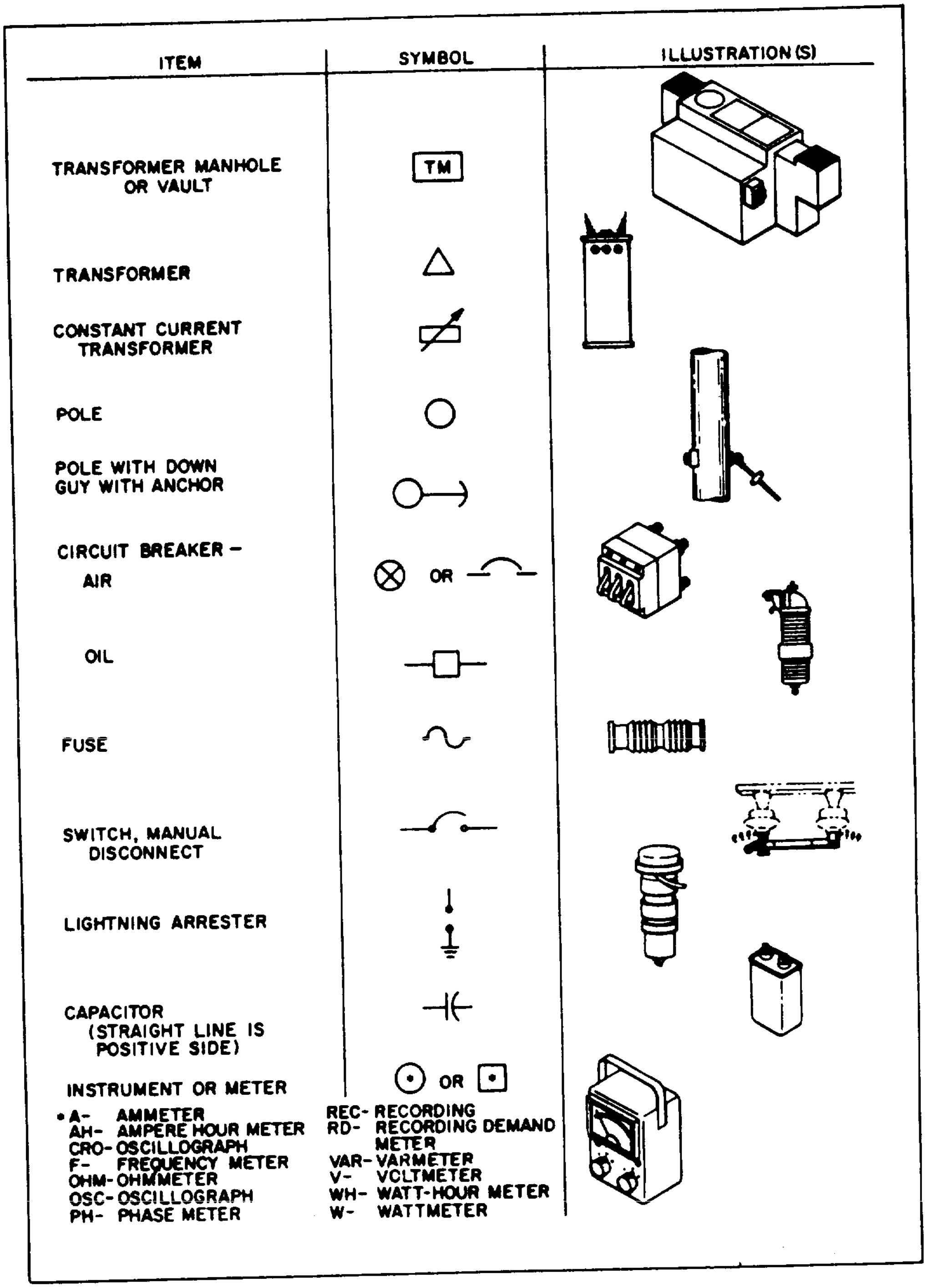
EVAPORATIVE CONDENSER	
EVAPORATOR, CIRCULAR, CEILING TYPE, FINNED	
EVAPORATOR, MANIFOLDED, BARE TUBE, GRAVITY AIR	
EVAPORATOR, MANIFOLDED, FINNED, FORCED AIR	
EVAPORATOR, MANIFOLDED, FINNED, GRAVITY AIR	
EVAPORATOR, PLATE COILS, HEADERED OR MANIFOLD	
FILTER, LINE	
FILTER & STRAINER, LINE	
FINNED TYPE COOLING UNIT, NATURAL CONVECTION	
FORCED CONVECTION COOLING UNIT	
GAUGE	
HIGH SIDE FLOAT	
HAND EXPANSION	
MAGNETIC STOP	
SNAP ACTION	
SUCTION VAPOR REGULATING	
THERMO SUCTION	
THERMOSTATIC EXPANSION	

D. ELECTRICAL SYMBOLS

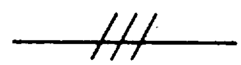
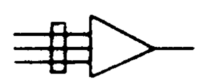
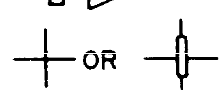
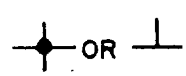
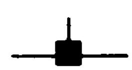


Line symbols for electric power distribution.

D. ELECTRICAL SYMBOLS—CONTINUED



Conventional symbols for electric distribution equipment.

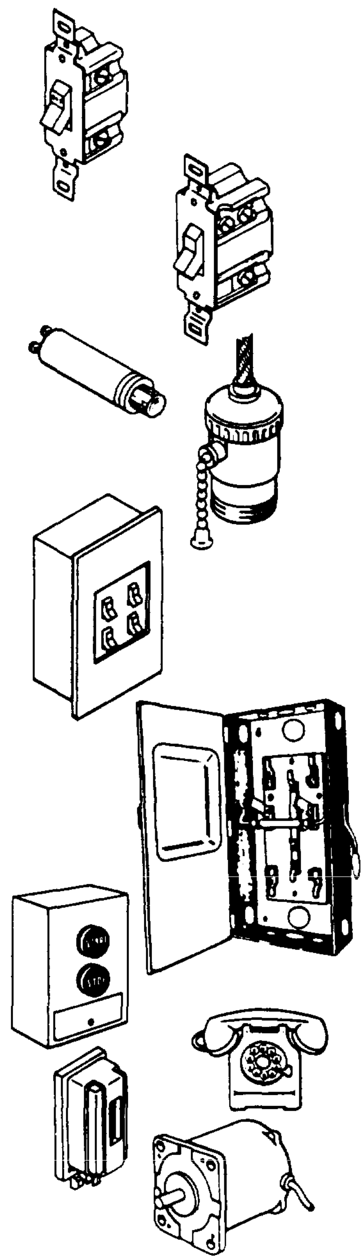
ITEM	SYMBOL
WIRING CONCEALED IN CEILING OR WALL	
WIRING CONCEALED IN FLOOR	
EXPOSED BRANCH CIRCUIT	
BRANCH CIRCUIT HOME RUN TO PANEL BOARD (NO. OF ARROWS EQUALS NO. OF CIRCUITS, DESIGNATION IDENTIFIES DESIGNATION AT PANEL)	
THREE OR MORE WIRES (NO. OF CROSS LINES EQUALS NO. OF CONDUCTORS. TWO CONDUCTORS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

Line symbols for electrical wiring.

D. ELECTRICAL SYMBOLS—CONTINUED

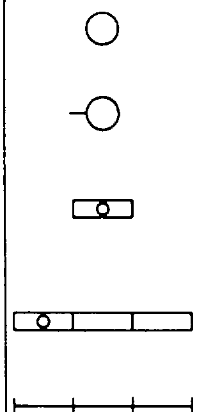
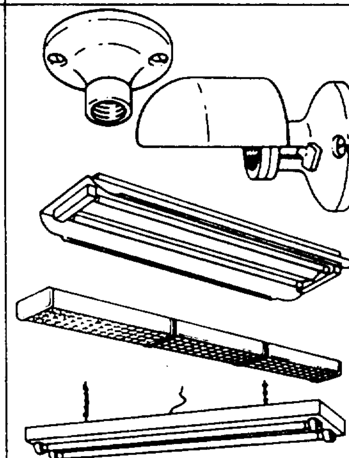
ITEM	SYMBOL
SWITCHES -	
SINGLE POLE SWITCH	S
DOUBLE POLE SWITCH	S_2
THREE WAY SWITCH	S_3
SWITCH AND PILOT LAMP	S_P
CEILING PULL SWITCH	Ⓢ
PANEL BOARDS AND RELATED EQUIPMENT	
PANEL BOARD AND CABINET	
SWITCHBOARD, CONTROL STATION OR SUBSTATION	
SERVICE SWITCH OR CIRCUIT BREAKER	■ OR ■ OR ⊗
EXTERNALLY OPERATED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

ILLUSTRATION



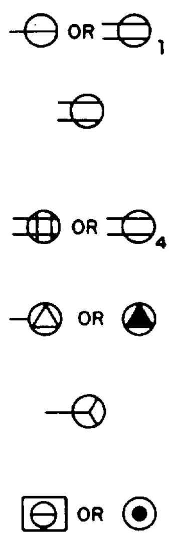
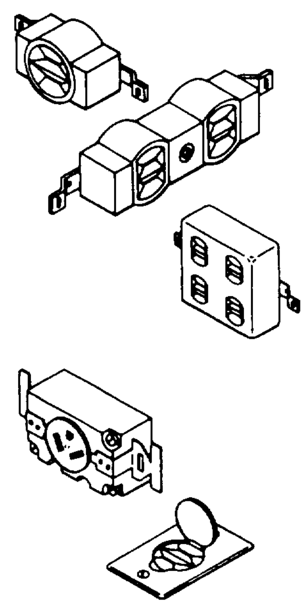
Symbols for electrical fixtures and controls.

D. ELECTRICAL SYMBOLS—CONTINUED

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

* LETTERS ADDED TO SYMBOLS INDICATE SPECIAL TYPE OR USAGE

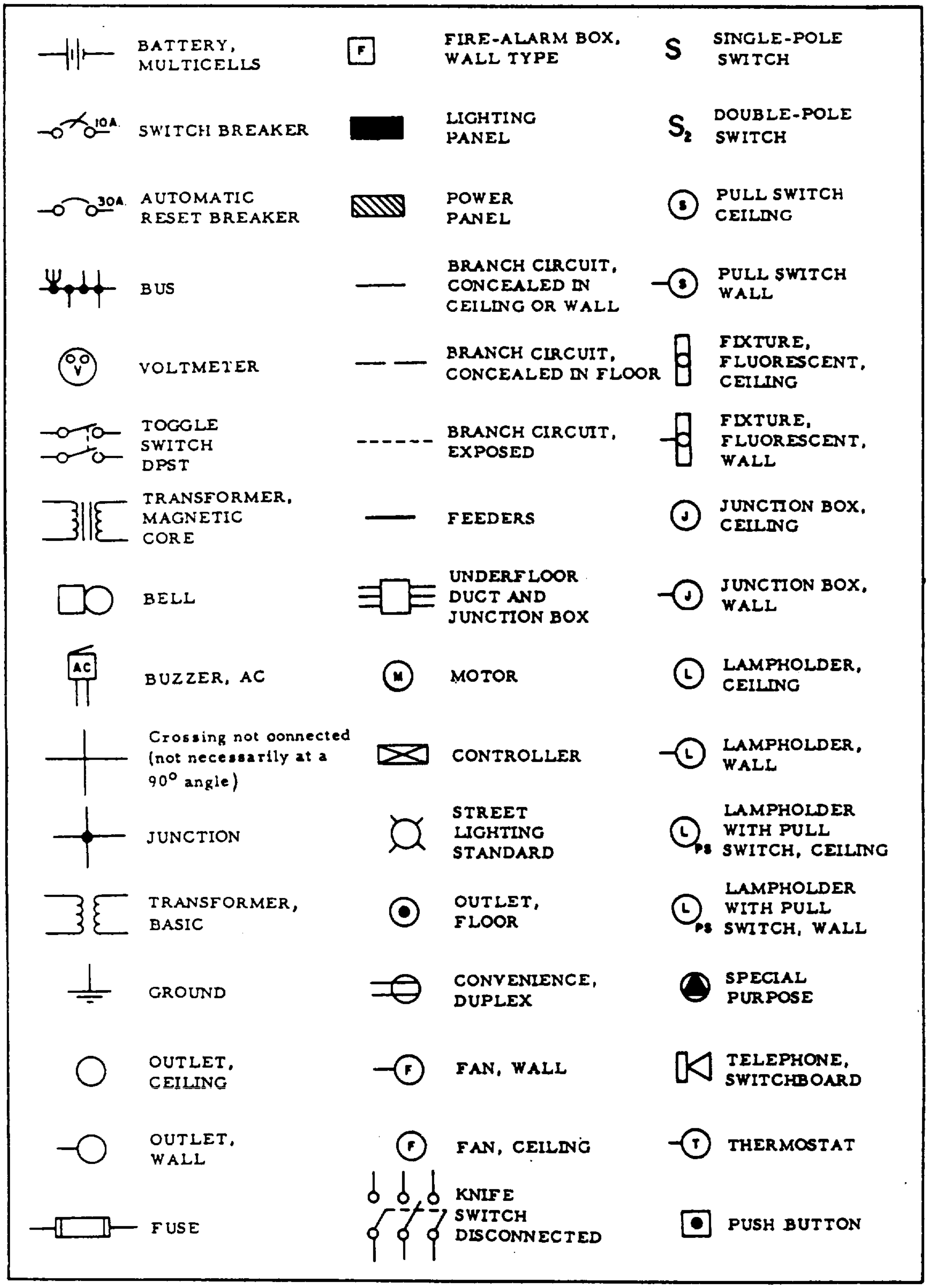
J- JUNCTION BOX R- RECESSED
L- LOW VOLTAGE X- EXIT LIGHT

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

** LETTER G NEXT TO SYMBOL INDICATES GROUNDING TYPE

Symbols for electrical fixtures and controls—Continued.

D. ELECTRICAL SYMBOLS—CONTINUED



Common types of electrical symbols.

APPENDIX V

SAMPLE SURVEY FIELD NOTES

Although some field notes are already explained in this training manual, these sample notes are presented so that you can see how the series of different field notes are indexed and arranged in a field notebook.

Keeping good notes is not only an art, it is a science as well. Art will make your notes pretty to look at, but it will not make them correct or meaningful. You must decide, BEFORE YOU GO INTO THE FIELD, how you want to run your survey and how to record your observations. You must also have decided what information you must record in order to make your notes meaningful. Keep in mind that extraneous entries in your notes can do just as much harm as omission of pertinent data. Before making any entry in your notebook, make certain that the entry, whether a sketch, remark, or other information, is necessary and will contribute to the completeness of the notes. On the following pages are samples of the types of notes kept, not of how they must be kept. It is really the surveyor who determines what to record and how to do it. Usually the chief of the party prescribes how notes on his project are to be kept. Above all, decide on your notekeeping procedures and format before you go out on your survey. The headings, members of party, instrument identification, weather, and so forth, may all be entered before you leave the office.

Figure AV-1 is a sample of the front page of a notebook. The front page is to be filled out as required by your unit. If possible, keep a separate book for each major project.

Figure AV-2 is a sample index. The index pages of the notebook must reflect all projects, by page number, recorded in the book. REMEMBER: Always keep your index up to date.

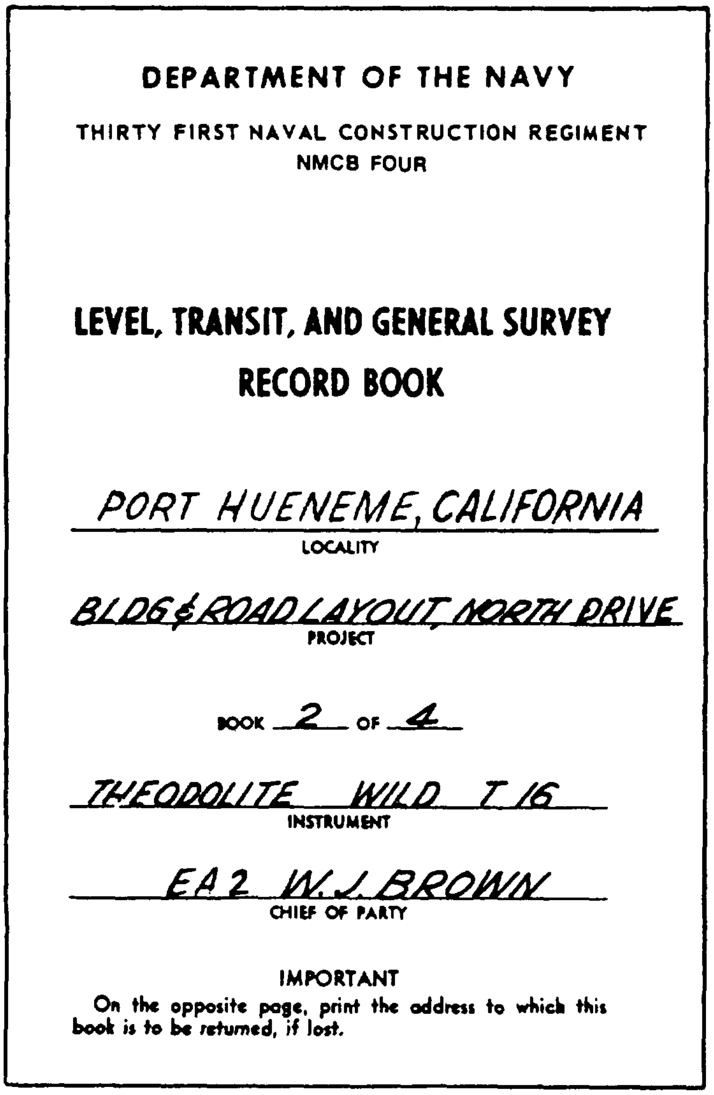
An example of recording horizontal measurement is shown in figure AV-3. To record taping problems, record distance measured (by parts of tapes, if measured) going from one station to the next. Record in the direction in which measured; that is, down for forward measurements, up for backward measurements.

Do not forget the page check (fig. AV-4), which is to be made at the bottom of each page. If notes exceed one page, this check also must be made on the page where notes end, When you make a page check on direct level circuit, you check only the accuracy of the arithmetic, not the accuracy of the level shots.

Profile and cross-section level notes (figs. AV-5 and AV-6) are best recorded from the bottom of the page UP. The left-hand side of the page should contain columns for STA, BS(+), HI, FS(–), and elevation. The right side, as shown, has left, ℄, and right columns. The top number is ground elevation at that point, the center number is rod reading, and the bottom number is the perpendicular distance to the center line. Slope stakes (fig. AV-7), as profile notes, are best recorded from the bottom of the page UP, as shown on this set of sample notes. Entries for STA 7 + 50 indicate the following:

	L	℄	R
Amount of cut or fill . . .	C 0.3	F 0.0	F 0.8
Ground rod	3.8	4.1	4.9
Dist of slope stake from ℄	22.6	0	16.6

See figure AV-8. Building corner numbers on the sketch must agree with the designation on the left side of the page. Grade rod setting is computed in the field. Batter elevations are entered in the first column on the right-hand page—after having been computed at the jobsite. Sketch must show all pertinent data for locating the building.


DEPARTMENT OF THE NAVY

THIRTY FIRST NAVAL CONSTRUCTION REGIMENT
NMCB FOUR

LEVEL, TRANSIT, AND GENERAL SURVEY
RECORD BOOK

PORT HUENEME, CALIFORNIA
LOCALITY

BLDG & ROAD LAYOUT, NORTH DRIVE
PROJECT

BOOK 2 OF 4

THEODOLITE WILD T 16
INSTRUMENT

EA2 W.J. BROWN
CHIEF OF PARTY

IMPORTANT
On the opposite page, print the address to which this book is to be returned, if lost.

Figure AV-1.-Front page of a notebook.

INDEX

DESIGNATION ____________ DATE ________ 19____

PAGE	PROJECT	DATE
6	HORIZONTAL TAPING - TRAV 27-A	16 JAN 64
10	DIRECT LEVEL CIRCUIT - BM 61 TO BM 63	12 JAN 64
11	HORIZON CLOSURE - TRAV #2	25 JAN 64
17	STATION ANGLE TRAV - TRAV #12	15 FEB 64
18	DEFL ANGLE TRAV - TRAV #12-A	17 FEB 64
19	TRIANGULATION - ELEV OF WATER TOW	13 FEB 64
20	TRIG ELEVATION - HT OF FLAG POLE	15 FEB 64
21	MCCOY AVE EXT'D - HOR & CONTROL	20 FEB 64
22	—"— HORIZ TAPING	22 FEB 64
23	—"— DIFF LEVELING	24 FEB 64
24	—"— HOR CURVE LAYOUT	20 MAR 64
25	—"— PROF & CR SECT LEVELS	21 MAR 64
26	—"— PROF LEV (SEWERLINE)	23 MAR 64
27	—"— SLOPE STAKES	30 MAR 64
28	BLDG T2855 - BLDG LAYOUT	1 APR 64
29	PLANETABLE MAPPING PROBLEM	10 APR 64

	LOCATION
S. DRIVE	PORT HUENEME, CALIFORNIA
PI AREA	—"—
AREA K	—"—
N. DRIVE	—"—
N. DRIVE	—"—
PI AREA	—"—
PI AREA	—"—
N. DRIVE	—"—
—"—	—"—
—"—	—"—
—"—	—"—
—"—	—"—
—"—	—"—
—"—	—"—
S. DRIVE	—"—
N. DRIVE	—"—

Figure AV-2.-Index.

HORIZONTAL TAPING

DESIGNATION TRAV # 27A DATE 16 JAN 19 84

STA	FWD	BKWD	MEAN	TC	DIST
⊙ A	60.00	~~61.89~~ 62.89			
	48.00	44.00			
	43.00	47.00			
	51.79	48.90			
⊙ B	202.79	202.79	202.79	-0.015	202.78
⊙ B	75.00	54.00			
	47.15	68.17			
⊙ C	122.15	122.17	122.16	-0.01	122.15

HAMWEY EA2
HT TILKIN EA3
RT SMITH EA3

INST 100 FT STL TAPE
TENSION 16 LBS

REMARKS

WEATHER CLOUDY
WIND SW 10
TEMP 44°

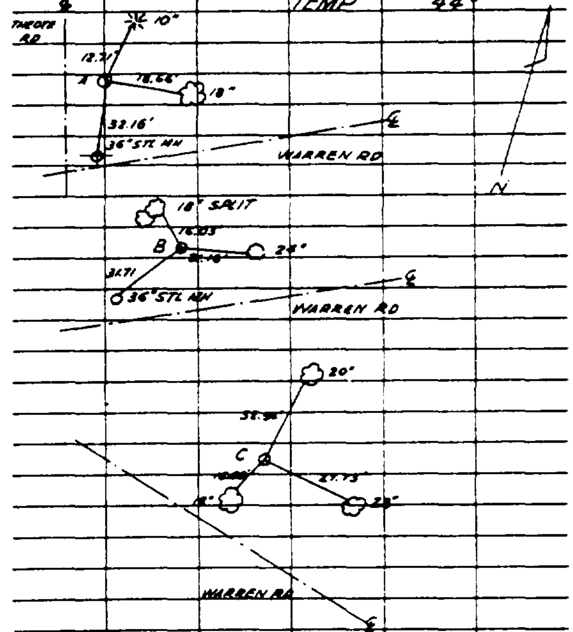


Figure AV-3.-Horizontal measurement.

DIRECT LEVEL CIRCUIT

DESIGNATION BM G1 TO BM G2 DATE 12 JAN 19 84

STA	BS	HI	FS	ELEV	DISTANCE BS	DISTANCE FS
BM G1	4.71			100.00	75	
		104.71				
TP 1	6.03		0.79	103.92	110	70
		109.95				
TP 2	12.06		3.68	106.27	94	110
		118.33				
BM G2	2.20		4.49	113.84	240	96
		116.04				
TP 3	1.43		7.12	108.92 ~~108.82~~	163	242
		110.35 ~~110.25~~				
TP 4	5.01		10.33	100.02 ~~99.92~~	93	166
		105.03 ~~104.93~~				
TP 5	3.64		2.99	102.04 ~~101.94~~	110	95
		105.68 ~~105.58~~		~~101.94~~		
BM G3			3.16	102.52 ~~102.42~~		112
	35.08 32.56 ~~32.66~~		32.66	2.32 ~~2.42~~	885	891
					1776	
	2.52 ~~2.42~~ ← PC					

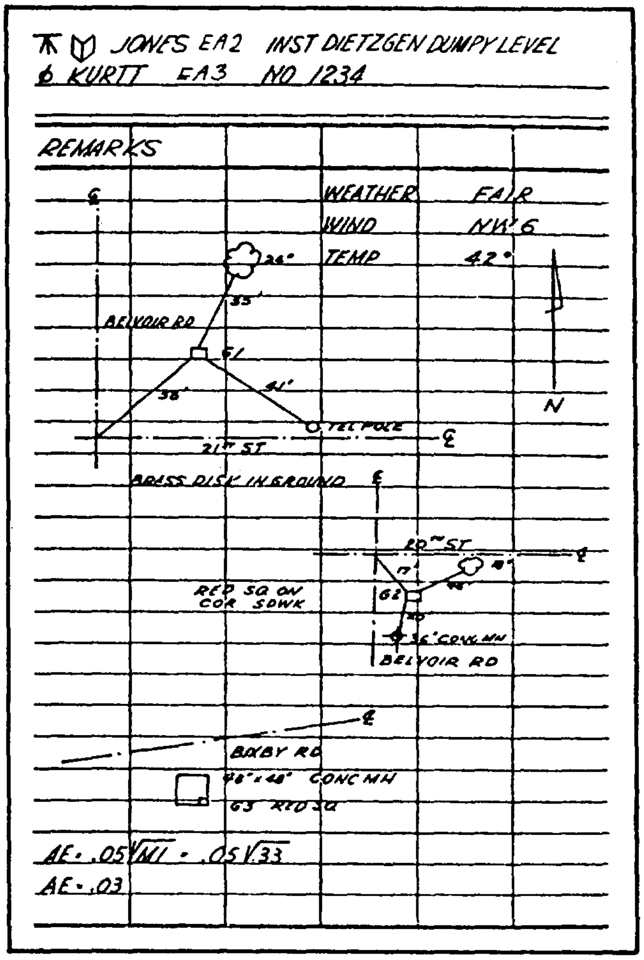
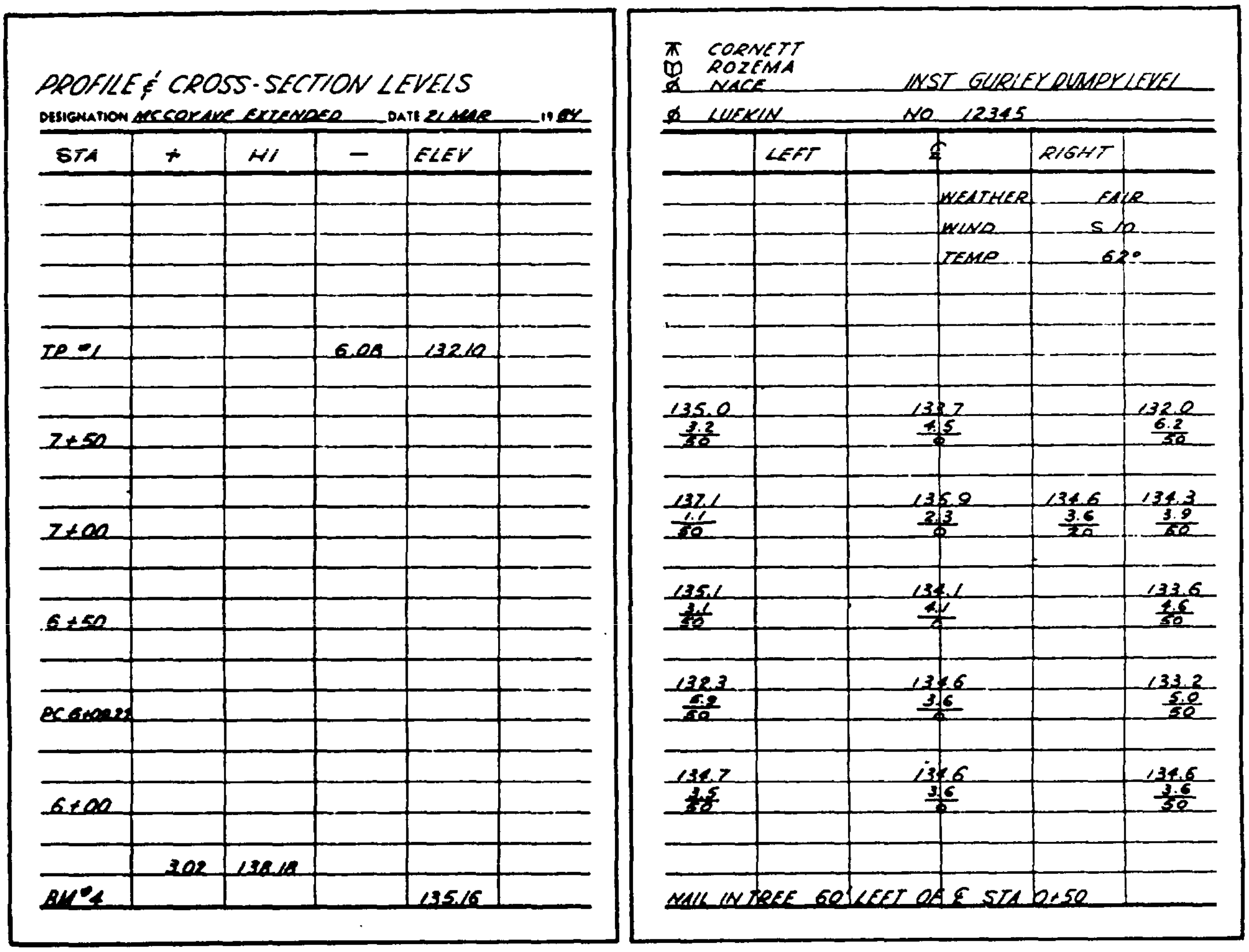


Figure AV-4.-Page check.



PROFILE & CROSS-SECTION LEVELS

DESIGNATION MC COY AVE EXTENDED DATE 21 MAR 19 84

STA	+	HI	−	ELEV	
TP #1			6.08	132.10	
7+50					
7+00					
6+50					
PC 6+08.21					
6+00					
	3.02	138.18			
BM #4				135.16	

CORNETT
ROZEMA
NACE INST GURLEY DUMPY LEVEL
LUFKIN NO 12345

	LEFT	℄	RIGHT	
		WEATHER	FAIR	
		WIND	S 10	
		TEMP	62°	
135.0 / 3.2 / 30		133.7 / 4.5 / 0		132.0 / 6.2 / 50
137.1 / 1.1 / 60		135.9 / 2.3 / 0	134.6 / 3.6 / 20	134.3 / 3.9 / 60
135.1 / 3.1 / 50		134.1 / 4.1 / 0		133.6 / 4.6 / 50
132.3 / 5.9 / 50		134.6 / 3.6 / 0		133.2 / 5.0 / 50
134.7 / 3.5 / 50		134.6 / 3.6 / 0		134.6 / 3.6 / 50
NAIL IN TREE 60' LEFT OF ℄ STA 0+50				

Figure AV-5.-Profile and cross-section levels.

PROFILE LEVELS (SEWER LINE)

DESIGNATION MC COY AVE EXTENDED DATE 23 MAR 19 84

⊼ BACK
SNIPES
ϕ KURTT
ϕ MATHEWS

INST GURLEY DUMPY LEVEL NO 123

STA	+	HI	−	ELEV	TP ELEV	REMARKS
BM #4	3.02	138.18			135.16	NAIL IN TREE 60' LEFT OF ℄ NEAR 0+50
0+00			3.6	134.6		℄ OF ROUTE 611
+21			5.1	133.1		BOTTOM OF DITCH
+50			3.6	134.6		
1+00			4.1	134.1		
+50			2.3	135.9		
+78			4.6	133.6		
2+00			4.5	133.7		WEATHER FAIR
+50			6.1	132.1		WIND S5
3+00			5.8	132.4		TEMP 60
4+00			5.7	132.5		
+10			5.0	133.2		
+60			6.0	132.2		
+76			5.9	132.3		
5+00			6.0	132.18		
TP #1	1.79	133.29	6.68		131.50	TOP OF HUB @ STA 6+00
6+00			2.3	131.0		
TP #2			4.76		128.53	ON STONE

Figure AV-6.-Additional example, profile levels.

SLOPE STAKES

DESIGNATION MC COY AVE EXTENDED DATE 30 MAR 19 84

STA	+	H I	−	ELEV	GRADE ELEV
TP #1			3.10	133.10	
7+50					132.10
7+00					132.60
6+50					133.10
PC 6+09.77					133.60
6+00					134.10
	1.04	136.20			
BM #4				135.16	

MANGAS
SNIPES
LUFKIN
STADELMAN

INST. GURLEY DUMPY LEVEL NO. 1453

GRADE ROD	LEFT	℄	RIGHT	
		WEATHER	CLOUDY	
		WIND	S 10	
		TEMP	70°	
TOP OF HUB STA 3+00				
	C 0.3	F 0.0	F 0.8	
4.1	3.8 / [illegible]	4.1 / 0	4.9 / 16.6	
	C 2.0	F 1.1	F 3.0	
3.6	1.6 / [illegible]	4.7 / 0	6.6 / 21.0	
	C 2.6	F 2.9	F 4.1	
3.1	0.5 / [illegible]	6.0 / 0	7.2 / 23.2	
	C 1.0	F 0.5	F 1.5	
2.6	1.6 / 26.0	3.1 / 0	4.1 / 18.0	
	F 1.0	F 1.6	F 2.1	
2.1	3.1 / 17.0	3.7 / 0	4.2 / [illegible]	

NAIL IN TREE 60' LEFT OF ℄ AT STA 0+50

Figure AV-7.-Slope stakes.

BUILDING LAYOUT

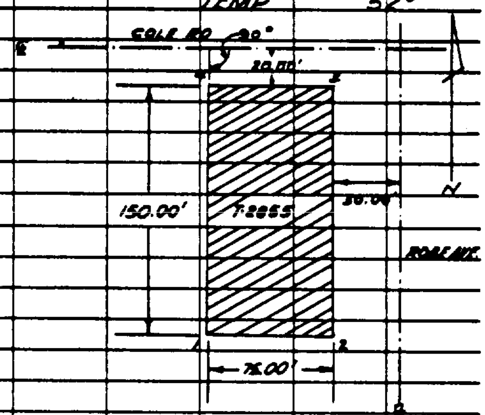
DESIGNATION BLDG T-2855 DATE 1 APR 19 84

STA	BS	HI	FS	ELEV	GRADE ROD
BM 18	5.22	35.22		30.00	
1			4.26	30.96	
2			4.14	31.08	
3			4.68	30.54	
4			4.52	30.70	
1					2.64
2					2.64
3					2.64
4					2.64

⊼ SNIPES
TILKIN
LUFKIN
⌀ COWART

INST K&E LEVEL / K&E 1' TRANSIT
NO 451206/4219

BATTER ELEV	REMARKS		
		WEATHER	FAIR
		WIND	S 8
		TEMP	52°
32.58			
32.58			
32.58			
32.58			



NOTE : BATTERBOARD ELEVATION 1.5' ABOVE HIGHEST CORNER.
BATTERBOARD ELEVATION IS TOP OF FOUNDATION.

Figure AV-8.-Building layout.

APPENDIX VI

REFERENCES

Chapter 1

Mathematics, Vol. 1, NAVEDTRA 10069-D1, Naval Education and Training Program Development Center, Pensacola, Fla, 1980.

Mathematics, Vol. 2, NAVEDTRA 10071-B, Naval Training Publications Center, Memphis, Term., 1971.

Oliva, Ralph A., M. Dean LaMont, Linda R. Fowler, Dr. Ruth 1. Hoffman, Michael R. Zastrocky, Richard Reeser, and Lucille P. Grogan, *Student Calculator Math,* Texas Instruments, Inc., Dallas, Tex., 1984.

The Metric System, NAVEDTRA 475-01-00-79, Naval Education and Training Program Development Center, Pensacola, Fla., 1979.

Chapter 2

Spencer, Henry C. and John T. Dygdon, *Basic Technical Drawing,* 2d rev, ed., Macmillan Publishing Co, Inc., New York, 1968.

U.S. Department of Defense, *General Drawing,* FM 5-553, Headquarters, Department of the Army, Washington, D.C., 1984.

Chapter 3

Spencer, Henry C. and John T. Dygdon, *Basic Technical Drawing,* 2d rev. ed, Macmillan Publishing Co, Inc., New York, 1968.

U.S. Department of Defense, *Engineering Drawing Practices,* DoD-STD-100C, U.S. Army Armament Research and Development Command, Dover, N. J., 1978.

U.S. Department of Defense, *General Drawing,* FM 5-553, Headquarters, Department of the Army, Washington, D.C., 1984.

U.S. Department of Defense, *Policy and Procedures for Project Drawing and Specification Preparation,* MIL-HDBK-1006/1, Chesapeake Division, Chesapeake, Va., 1987.

Chapter 4

Spencer, Henry C. and John T. Dygdon, *Basic Technical Drawing,* 2d rev. ed., Macmillan Publishing Co., Inc., New York, 1968.

U.S. Department of Defense, *General Drafting,* FM 5-553, Headquarters, Department of the Army, Washington, D.C., 1984.

Chapter 5

Giesecke, Frederick E., Alva Mitchell, Henry C. Spencer, and Ivan L. Hill, *Technical Drawing,* 5th ed., The Macmillan Co., New York, 1967.

Hoelscher, Randolph P., Clifford H. Springer, and Jerry Dobrovolny, *Basic Drawing for Engineering Technology,* John Wiley & Sons, Inc., New York, 1964.

Illustrator Draftsman, NAVEDTRA 10472, Naval Education and Training Program Development Center, Pensacola, Fla., 1985.

Spencer, Henry C. and John T. Dygdon, *Basic Technical Drawing,* 2d rev. ed., Macmillan Publishing Co., Inc., New York, 1968.

U.S. Department of Defense, *General Drafting,* FM 5-553, Headquarters, Department of the Army, Washington, D.C., 1984.

Zozzora, Frank, *Engineering Drawing,* 2d ed., McGraw-Hill Book Co., Inc., New York, 1958.

Chapter 6

Builder 3 & 2, NAVEDTRA 10648-G, Naval Education and Training Program Management Support Activity, Pensacola, Fla., 1981.

U.S. Department of Defense, *General Drafting,* FM 5-553, Headquarters, Department of the Army, Washington, D.C., 1984.

U.S. Department of Defense, *Engineering Drawing Practices*, DoD-STD-100C, U.S. Army Armament Research and Development Command, Dover, N. J., 1978.

Ramsey and Sleeper, *Architectural Graphic Standards,* 7th ed., J. Wiley & Sons, Inc., New York, 1981.

Chapter 7

Builder 3 & 2, NAVEDTRA 10648-G, Naval Education and Training Program Management Support Activity, Pensacola, Fla., 1981.

U.S. Department of Defense, *Engineering Drawing Practices*, DoD-STD-100C, U.S. Army Armament Research and Development Command, Dover, N.J., 1978.

Ramsey and Sleeper, *Architectural Graphic Standards,* 7th ed., J. Wiley & Sons, Inc., New York, 1981.

Chapter 8

Graphic Symbols for Plumbing Fixtures for Diagrams Used in Architecture and Building Construction, ANSI Y32.4-1977, American Society of Mechanical Engineers, New York, 1977.

U.S. Department of Defense, *Mechanica/Symbols,* MIL-STD-17B-1, Defense Supply Agency, Alexandria, Va., 1963.

Utilitiesman 3, NAVEDTRA 10663, Naval Education and Training Program Management Support Activity, Pensacola, Fla., 1988.

Chapter 9

Construction Electrician 3 & 2, NAVEDTRA 10636-H1, Naval Education and Training Program Development Center, Pensacola, Fla., 1976.

Dagostino, F. R., *Mechanical and Electrical Systems in Construction and Architecture,* Reston Publishing Company, Inc., Reston, Va., 1978.

Graphic Symbols for Electric Wiring and Layout Diagrams Used in Architecture and Building Construction, ANSI Y32.9, Institute of Electrical and Electronics Engineers, New York, 1972.

Planning Guide, Vol. 1, NAVFAC P-437, Naval Facilities Engineering Command, Alexandria, Va., 1988.

U.S. Department of Defense, *Construction Drafting,* TM 5-581-B, Headquarters, Department of the Army, Washington, D.C., 1972.

Chapter 10

Dimensioning and Tolerancing, ANSI Y14. 5M-1982, The American Society of Mechanical Engineers, New York, 1982.

Drawing Sheet Size and Format, ANSI Y14.1-1980, The American Society of Mechanical Engineers, New York, 1980.

U.S. Department of Defense, Construction *Drafting,* TM 5-581-B, Headquarters, Department of the Army, Washington, D.C., 1972.

U.S. Department of Defense, *Engineering Drawing Practices,* DoD-STD-100C, U.S. Army Armament Research and Development Command, Dover, N. J., 1978.

U.S. Department of Defense, *Policy and Procedures for Definitive and Standard Design and Standard Specification Preparation,* MIL-HDBK-1006/4, Washington, D.C., 1987.

U.S. Department of Defense, *Policy and Procedures for Project Drawing and Specification Preparation,* MIL-HDBK-1006/1, Chesapeake Division, Chesapeake, Va., 1987.

Chapter 11

Brinker, R. C. and P. R. Wolf, *Elementary Surveying,* 6th ed., Harper & Row, Publishers, New York, 1977.

Legault, A. R. H. M. McMaster, and R. R. Marlette, *Surveying, an Introduction to Engineering Measurement,* Prentice-Hall, Inc., Englewood Cliffs, N.J., 1956.

U.S. Department of Defense, *Elements of Surveying*, TM 5-232, Headquarters, Department of the Army, Washington, D.C., 1971.

Chapter 12

Equipment Operator 3 & 2, NAVEDTRA 10640-J1, Naval Education and Training Program Management Support Activity, Pensacola, Fla., 1989.

Seabee Combat Handbook, NAVEDTRA 10479-C3, Naval Education and Training Program Management Support Activity, Pensacola, Fla., 1989.

Standard First Aid Training Course, NAVEDTRA 10081-D, Naval Education and Training Program Development Center, Pensacola, Fla., 1982.

U.S. Department of Defense, *Elements of Surveying*, TM 5-232, Headquarters, Department of the Army, Washington, D.C., 1971.

Chapter 13

Brinker, R. C. and P. R. Wolf, *Elementary Surveying,* 6th ed., Harper & Row, Publishers, New York, 1977.

Davis, R. E., F. S. Foote, J. M. Anderson, and E. M. Mikhail, *Surveying, Theory and Practice,* 6th ed, McGraw-Hill Book Co., New York, 1981.

Legault, A. R. H. M. McMaster, and R. R. Marlette, *Surveying, an Introduction to Engineering Measurerment,* Prentice-Hall, Inc., Englewood Cliffs, N.J., 1956.

U.S. Department of Defense, *Elements of Surveying*, TM 5-232, Headquarters, Department of the Army, Washington, D.C., 1971.

Chapter 14

Brinker, R. C. and P. R. Wolf, *Elementary Surveying,* 6th ed., Harper & Row, Publishers, New York, 1977.

U.S. Department of Defense, *Construction Surveying,* FM 5-233, Headquarters, Department of the Army, Washington, D.C., 1985.

U.S. Department of Defense, *Elements of Surveying*, TM 5-232, Headquarters, Department of the Army, Washington, D.C., 1971.

Chapter 15

Standard Method of Making and Curing Concrete Test Specimens in the Field, ASTM C31-35, American Society for Testing and Materials, Philadelphia, Pa., 1986.

Standard Method for Particle-Size Analysis of Soils, ASTM D422-63, American Society for Testing and Materials, Philadelphia, Pa., 1985.

Standard Practice for Making and Curing Concrete Test Specimens in the Field, ASTM C31-88, American Society for Testing and Materials, Philadelphia, Pa, 1988.

Standard Practice for Sampling Freshly Mixed Concrete, ASTM C172-90, American Society for Testing and Materials, Philadelphia, Pa., 1990.

Standard Test Method for Slump of Hydraulic Cement Concrete, ASTM C143-90, American Society for Testing and Materials, Philadelphia, Pa., 1990.

U.S. Department of Defense, *Concrete and Masonry*, FM 5-742, Headquarters, Department of the Army, Washington, D.C., 1985.

U.S. Department of Defense, *Materials Testing,* TM 5-330/NAVFAC MO-330/AFM 89-3, Department of the Army, Navy, and Air Force, 1987.

Chapter 16

Advancement Handbook for Petty Officers, Engineering Aid (EA), NAVEDTRA 71365, Naval Education and Training Program Management Support Activity, Pensacola, Fla., 1989.

Construction Force Manual, NAVFAC P-315, Naval Facilities Engineering Command, Alexandria, Va., 1985.

Military Requirements for Petty Officer Third Class, NAVEDTRA 10044-A, Naval Education and Training Program Management Support Activity, Pensacola, Fla., 1987.

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Assignment Questions

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

ASSIGNMENT 1

Textbook Assignment: "Mathematics and Units of Measurement." Pages 1-1 through 1-35.

1-1. Which of the following mathematical branches deals, in part, with the theory of space and figures in space?

1. Arithmetic
2. Trigonometry
3. Geometry
4. Algebra

1-2. Which, if any, of the following expressions is an irrational number?

1. $\sqrt{2}$
2. $\sqrt{25/9}$
3. 5 2/7
4. None of the above

1-3. In fractions, the rule of ensuring that the denominators are alike applies to which of the following actions?

1. Multiplying fractions
2. Subtracting fractions only
3. Dividing fractions
4. Both adding and subtracting fractions

1-4. Which of the following fractions is the equivalent of 7/9?

1. 9/7
2. 21/27
3. 35/42
4. 126/288

1-5. What is the relationship between $\sqrt{20}$ and $2\sqrt{5}$?

1. They are rational numbers
2. They are imaginary numbers
3. They are equivalent
4. They are reciprocals of each other

1-6. When is the exponent of a number NOT required to be written?

1. When the exponent has been reduced to its lowest term
2. When the value of the exponent is 0
3. When the number has been raised to its highest power and its value is 0
4. When the value of the exponent is 1

1-7. When using the arithmetic extraction method, what is the first step you should take to determine the square root of a number?

1. Divide the number into two-digit groups working away from the decimal point in both directions
2. Divide the number into single-digit groups to the left of the decimal point
3. Divide the number into two-digit groups working only to the left of the decimal point
4. Determine the square root of the first digit of the number

1-8. When using the arithmetic extraction method to determine the square root of 368.42, what is the divisor you should use to determine the third digit of the result?

1. 29
2. 381
3. 389
4. 3829

1-9. Which of the following terms is the equivalent of $\sqrt{16^3}$?

1. 16^{-3}
2. $16^{-1/3}$
3. $16^{2/3}$
4. $16^{3/2}$

1-10. Solve $\sqrt{8\ 1/2}$.

1. 2.0000
2. 2.0615
3. 2.8284
4. 2.9155

1-11. To find the reciprocal of a fraction, you should take which of the following actions?

1. Divide the fraction by 1
2. Multiply the fraction by 1
3. Invert the fraction only
4. Invert the fraction and divide by 1

1-12. The use of a ratio would NOT be appropriate for which of the following comparisons?

1. Weight to volume of construction material
2. The rate a person reads to the rate that the average person reads
3. The acreage contained in one parcel of land to acreage contained in another
4. The weight of a construction material to the standard weight of a like material

1-13 Which of the following ratio? is expressed correctly in its final form?

1. 9.03 m/ 2.61 m
2. 2.5 ft : 17.5 ft
3. 9.03 : 2.61
4. 60 mi / 1 hr

1-14 Which of the following expressions represent(s) a correctly written proportion?

1. 3:9 / 11:33
2. 3:9 = 11:33
3. 3:9::33:11
4. Both 2 and 3 above

1-15. Which of the following equations is a linear equation?

1. $4x^2 = 16$
2. $y^2 + 16y = 0$
3. $1/4x^2 + 16 = 1$
4. $x/2 + 6x = 13$

A. ALL SIDES ARE EQUAL
B. OPPOSITE SIDES ARE PARALLEL
C. ALL INTERIOR ANGLES ARE EQUAL
D. ONLY TWO SIDES ARE PARALLEL

Figure 1A

IN ANSWERING QUESTIONS 1-16 THROUGH 1-18, SELECT THE CHARACTERISTIC FROM FIGURE 1A THAT APPLIES TO THE GEOMETRIC FIGURE LISTED.

1-16. Trapezoid.

1. A and B
2. B and C
3. c and D
4. D only

1-17. oblong.

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

1-18. Rhombus.

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

1-19. What is the total area of a rectangular parking lot that measures 310 ft by 784 ft?

1. 299,209 sq ft
2. 243,040 sq ft
3. 121,304 sq ft
4. 24,304 sq ft

1-20 What is the area of a right triangle if the sides adjacent to the right angle measure 5 and 8 feet long?

1. 13 sq ft
2. 20 sq ft
3. 26 sq ft
4. 40 sq ft

IN ANSWERING QUESTIONS 1-21 THROUGH 1-23, REFER TO FIGURES 1-8, 1-9, and 1-10 IN YOUR TEXT.

1-21. Assume that triangle ABC in Figure 1-8 has the following dimensions:

AC = 5 1/2 in
AD = 4 1/2 in
BD = 2 1/2 in
CD = 3 in

What is the area of this triangle?

1. 5 1/2 sq in
2. 7 sq in
3. 10 sq in
4. 10 1/2 sq in

1-22. Assume that rhomboid ABCD in figure 1-9 has the following dimensions:

AD = 7 1/2 in
CD = 4 3/4 in
EC = 6 in
AE = 4 1/2 in

What is the area of this rhomboid?

1. 27 sq in
2. 30 1/2 sq in
3. 33 3/4 sq in
4. 37 1/2 sq in

1-23. Assume that the trapezoid in figure 1-10 has the following dimensions:

AD = 5 in
BC = 3 in
CF = 3 in

What is the area of the trapezoid?

1. 8 sq in
2. 12 sq in
3. 16 sq in
4. 24 sq in

1-24. A circle with a diameter of 5 inches will have what area in square inches?

1. 12.6
2. 15.7
3. 19.6
4. 31.4

1-25. A circle with a circumference of 12 inches will have what area in square inches?

1. 11.46
2. 11.56
3. 12.45
4. 12.46

1-26. If the diameter of the circle in textbook figure 1-13 is 4 inches and the central angle of the sector portion is 60 degrees, what is the area of the sector?

1. 1.0944 sq in
2. 2.0944 sq in
3. 2.1416 sq in
4. 3.1416 sq in

1-27. What is the area of an equilateral octagon whose 1 l/2-inch sides are tangent to an inscribed circle with a diameter of 3 1/2 inches?

1. 10 sq in
2. 10 1/4 sq in
3. 10 1/2 sq in
4. 10 3/4 sq in

1-28. What is the approximate area of an ellipse in which the major axis is 8 feet long and the minor axis is 4 feet long?

1. 12 Sq ft
2. 16 sq ft
3. 25 sq ft
4. 32 sq ft

A. $V = Bh$
B. $V = 1/3\pi r^2 h$
C. $V = 1/3\pi h\ (r_1^2 + r_1 r_2 + r_2^2)$
D. $V = 4/3\pi r^3$

Figure 1B

IN ANSWERING QUESTIONS 1-29 THROUGH 1-34, SELECT THE FORMULA FROM FIGURE 1B THAT YOU SHOULD USE TO DETERMINE THE VOLUME OF THE GIVEN GEOMETRIC FIGURE.

1-29. Cylinder.

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

1-30. Frustum of a cone.

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

1-31. Cone.

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

1-32. Parallelepipeds.

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

1-33. Sphere.

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

1-34. Triangular prism.

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

1-35. What is the reciprocal function of cos 25°?

1. Ccs 25°
2. Cot 25°
3. Sec 25°
4. Sin 25°

1-36. What function of the 45° angle in textbook figure 1-21 is represented by the line DB?

1. conversed sine
2. Cosine
3. cotangent
4. cosecant

1-37. What angle is the complement of 75°?

1. 15°
2. 75°
3. 90°
4. 105°

1-38. When expressed as a function of another angle, cos 40° equals what value?

1. Sec 140°
2. Sin 140°
3. Sec 50°
4. Sin 50°

1-39. What angle is the supplement of 145°?

1. 10°
2. 35°
3. 45°
4. 55°

1-40. The value of -cos 118° is equal to which of the following values?

1. Cos 62°
2. Sin 62°
3. Sin 118°
4. Cos 180°

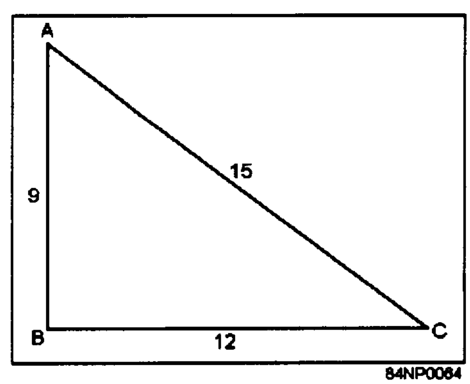


Figure 1C

IN ANSWERING QUESTIONS 1-41 AND 1-42, REFER TO FIGURE 1C.

1-41. What is the cosine of angle A?

1. 0.60000
2. 0.75000
3. 0.80000
4. 1.33333

1-42. What is the tangent of angle C?

1. 0.60000
2. 0.75000
3. 0.80000
4. 1.44444

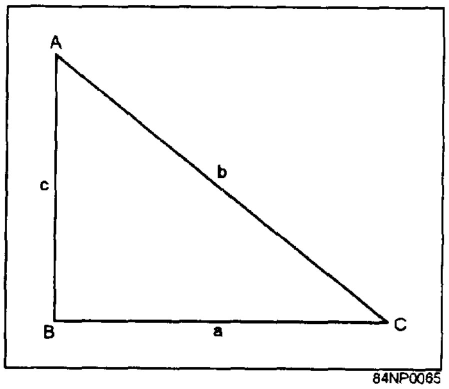


Figure 1D

IN ANSWERING QUESTIONS 1-43 THROUGH 1-45, REFER TO FIGURE ID. SELECT THE TRIGONOMETRIC FUNCTION FROM THE FOLLOWING LIST THAT SHOULD BE USED FOR THE SITUATION DESCRIBED.

A. SINE
B. COSINE
C. TANGENT
D. COTANGENT

1-43. Determining the size of angle A if the lengths of sides a and b are known.

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

1-44. Determining the size of angle C if the lengths of sides a and b are known.

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

1-45. Determining the size of angle C if the lengths of sides b and c are known.

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

1-46. Which function of the ground-slope angle is the ratio of the horizontal distance to the slope distance?

1. Sine
2. Cosine
3. Tangent
4. Versed sine

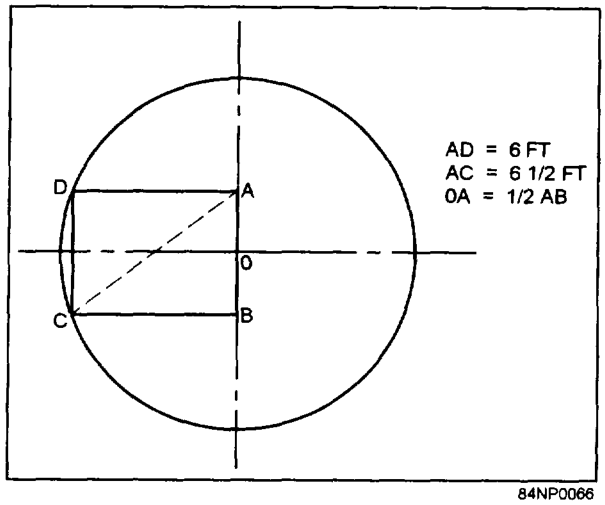


Figure 1E

IN ANSWERING QUESTIONS 1-47 AND 1-48, REFER TO FIGURE lE.

1-47. How many square feet are contained in rectangle ABCD?

1. 12.00
2. 15.00
3. 37.50
4. 53.08

1-48. How many square feet are contained within the circle?

1. 9.62
2. 10.20
3. 19.25
4. 118.00

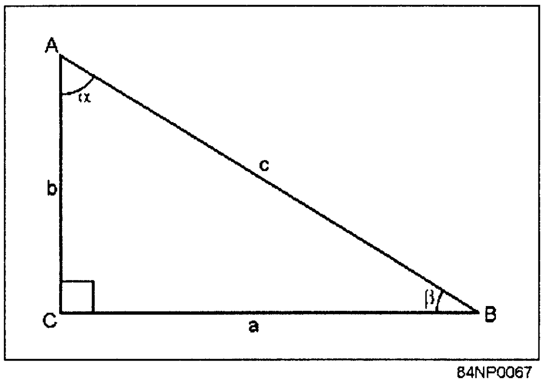


Figure 1F

IN ANSWERING QUESTIONS 1-49 THROUGH 1-51, REFER TO FIGURE 1F AND TO THE TABLE OF TRIGONOMETRIC FUNCTIONS LOCATED IN APPENDIX III OF YOUR TEXT.

1-49. How many degrees are contained in angle β if angle α = 55°?

1. 30°
2. 35°
3. 40°
4. 45°

1-50. What is the length of side b if side a = 6 feet and angle β = 30°?

1. 3.32 ft
2. 3.46 ft
3. 10.39 ft
4. 10.82 ft

1-51. What is the size of angle B if side b = 6 feet and side c = 20 feet?

1. 16°42′
2. 17°00′
3. 17°28′
4. 17°30′

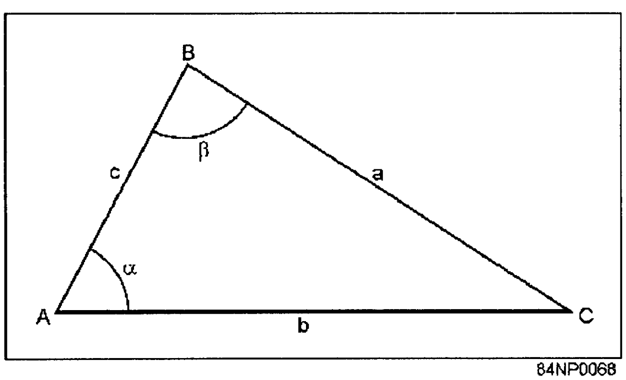


Figure 1G

IN ANSWERING QUESTIONS 1-52 THROUGH 1-56, REFER TO FIGURE 1G.

1-52. When given angle β and sides b and c, what law should you use to solve for all unknowns?

1. Law of sines
2. Law of cosines
3. Law of tangents

1-53. When angle α and sides b and c are known, what law should you use to determine side a?

1. Law of sines
2. Law of cosines
3. Law of tangents

1-54. When angle α and sides b and c are known, what law should you use to solve for all unknown angles?

1. Law of sines
2. Law of cosines
3. Law of tangents

1-55. When side a and angles α and β are known, what law should you use to solve for all unknowns?

1. Law of sines
2. Law of cosines
3. Law of tangents

1-56. When given sides a, b, and c, what law should you use to solve for all unknown angles?

1. Law of sines
2. Law of cosines
3. Law of tangents

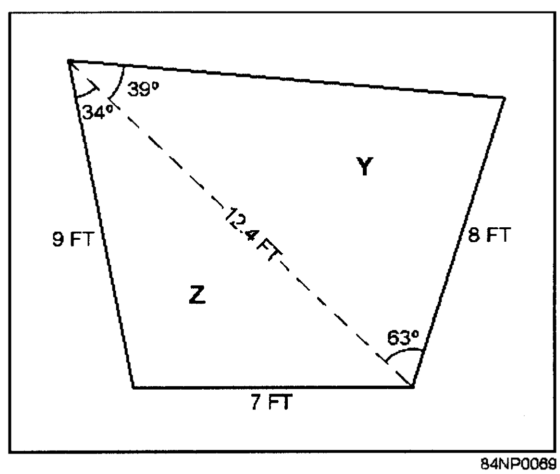


Figure 1H

IN ANSWERING QUESTIONS 1-57 AND 1-58, REFER TO FIGURE 1H.

1-57. The area of triangle Z is approximately equal to the square root of

1. 14
2. 67
3. 781
4. 957

1-58. The area of triangle Y is equal to

1. 49.6 sin 63°
2. 49.6 cos 63°
3. 99.2 sin 39°
4. 99.2 cos 39°

1-59. A distance of 1.25 statute miles is equivalent to how many (a) engineer's chains and (b) rods?

1. (a) 53 (b) 320
2. (a) 66 (b) 400
3. (a) 76 (b) 460
4. (a) 100 (b) 400

1-60. A linear distance of 0.68 kilometers is approximately equivalent to how many (a) meters and (b) nautical miles?

1. (a) 68 (b) 23.7
2. (a) 68 (b) 27.2
3. (a) 680 (b) 2.4
4. (a) 680 (b) 0.4

1-61. What is the area of a road 1,200 yards long and 22 feet wide?

1. 8,000 sq yd
2. 8,600 sq yd
3. 8,640 sq yd
4. 8,800 sq yd

1-62. A total of how many cubic yards of concrete are required for a retaining wall footing that measures 50 feet long, 15 feet wide, and 5 feet high?

1. 128
2. 130
3. 136
4. 139

1-63. What tension, in pounds, must be applied to a tape tension scale it you are required to apply 8 to 10 kilogram tension to an unsupported tape?

1. 8.6 to 10.0
2. 11.6 to 15.0
3. 17.6 to 22.0
4. 20.6 to 25.0

1-64. How many seconds are there in 0.44 minute of an arc?

1. 16.4
2. 26.4
3. 36.4
4. 46.4

1-65. How many degrees are there in 1.38 minutes?

1. 0.023
2. 0.033
3. 0.038
4. 0.41

1-66. 72.73 grads, converted into degrees, minutes, and seconds, equals

1. 57°17'25"
2. 59°27'17"
3. 65°27'25"
4. 68°39'17"

1-67. Approximately how many degrees are there in 4,300 roils?

1. 242
2. 245
3. 250
4. 255

1-68. Convert 95°F to degrees C.

1. 35°C
2. 34°C
3. 32°C
4. 30°C

1-69. It was determined that 435 linear feet of 2-inch by 4-inch lumber are required for formwork. How many board feet of lumber should be ordered for this job?

1. 278
2. 280
3. 286
4. 290

1-70. How many pints are there in 2,564 gallons?

1. 20,012
2. 20,112
3. 20,212
4. 20,512

1-71. How many liters are there in 100,000 U.S. gallons?

1. 368,500
2. 378,500
3. 388,500
4. 398,500

1-72. How many liters are there in 301 kiloliters?

1. 3,010
2. 30,100
3. 301,000
4. 3,010,000

1-73. Convert 135 horsepower to watts.

1. 100,710
2. 110,710
3. 120,610
4. 120,710

1-74. Convert 15.85 feet to the nearest 1/8 inch in carpenter's measure.

1. 15 ft 8 1/2 in
2. 15 ft 10 1/4 in
3. 15 ft 10 1/2 in
4. 15 ft 11 in

1-75. Approximately how many cubic yards of concrete are required for a 6-inch layer on a 3.5-acre parking lot?

1. 1,415
2. 2,830
3. 5,650
4. 16,950

ASSIGNMENT 2

Textbook Assignment: "Drafting Equipment." Pages 2-1 through 2-27.

2-1. A drawing is identified as technical or illustrative, depending on its

1. purpose
2. character
3. type
4. quality

2-2. The graphic representation of a utility system prepared by an EA is called a/an

1. industrial drawing
2. mechanical drawing
3. engineering survey
4. qualitative graph

2-3. The drawing of quantitative or qualitative display charts and graphs is characteristic of which of the following types of engineering drafting?

1. Construction
2. Topographic
3. Administrative
4. Each of the above

2-4. An engineering chart that shows relationships, rather than numerical values is called

1. quantitative
2. qualitative
3. visual
4. statistical

2-5. What type of engineering display chart is prepared to show the relationship between planned and actual work accomplishment?

1. Management information
2. Network analysis
3. Time-and-work
4. Progress

2-6. To provide uniform interpretation, all Navy drawings must be prepared according to which of the following manuals or standards?

1. NAVFAC design manuals
2. Military standards
3. DoD standards
4. All of the above

2-7. References to obsolete drawing symbols and unusual drawing features are normally found in what source(s)?

1. Architectural Graphic Standards
2. NAVFAC design manuals
3. Military standards
4. Explanatory notes and legends on the drawing

IN ANSWERING QUESTIONS 2-8 THROUGH 2-12, SELECT THE PUBLICATION FROM THE LIST THAT YOU SHOULD USE AS A REFERENCE TO LOCATE THE SUBJECT MATTER IDENTIFIED.

A. MIL-HDBK-1006/1
B. MIL-STD-12
C. MIL-STD-17
D. ANSI Y14.2

2-8. Mechanical symbols.

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

2-9. Policy and procedures for specifications preparation.

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

2-10. Abbreviations.

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

2-11. Line conventions and lettering.

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

2-12. Policy and procedures for project drawings.

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

2-13. A standard NMCB drafting kit contains sufficient supplies and equipment to outfit a total of how many drafters?

1. Ten
2. Two
3. Three
4. Five

2-14. Which of the following types of drafting media are used by SEABEE drafters?

1. Tracing paper, tracing cloth, and detail paper
2. Tracing paper, profile paper, and cross-section paper
3. Tracing cloth, film, and tracing paper
4. Tracing cloth, tracing paper, and graph paper

2-15. Compared with bristol board, illustration board differs in what respect?

1. It has only one white drawing surface
2. It is thinner and less rigid
3. It comes in a smaller size
4. It cannot be used for making small signs and charts

2-16. Which of the following grades of pencil lead is the hardest?

1. F
2. HB
3. 2H
4. 4B

2-17. Compared to an HB-grade pencil lead, an F-grade lead is

1. thinner and softer
2. thinner and harder
3. thicker and softer
4. thicker and harder

2-18. Which of the following types of erasers is best suited for removing unwanted smudges from ink drawings prepared on tracing vellum?

1. Vinyl
2. Pink pearl
3. Ruby red
4. Art gum

2-19. When erasing with an electric eraser, which of the following actions should you avoid taking because of the damage that may occur?

1. Erasing lightly penciled lines
2. Erasing heavily inked lines
3. Erasing closely spaced lines
4. Holding the eraser steady in one spot

2-20. To prevent fresh ink lines from spreading, what method should you use to prepare the surface of the drafting medium?

1. Cover it with a film of specially prepared chemical
2. Rub it with fine bone dust
3. Rub it with pulverized art gum particles
4. Scrape it lightly with a steel eraser

2-21. Concerning the use of drawing boards, which of the following statements accurately describes a correct procedure, method, or theory?

1. For a right-handed drafter, the working edge is the left vertical edge of the board
2. For any drafter the preferred working edge is the lower horizontal edge of the board
3. It is assumed that all edges of the board are perfectly square
4. The drawing surface of the board is leveled by adjusting the hinged attachment

2-22. Which of the following statements concerning the use, testing, or care of the T-square is an accurate guideline, procedure, or method?

1. To draw a long continuous vertical line, set the head of the T-square against the upper edge of the drawing board
2. To prevent warpage of the T-square when it is not in use, hang it vertically by the hole in its blade
3. To test a T-square, draw coinciding lines with both the top and bottom blade edges
4. To test a T-square, draw a continuous line using both vertical edges of the drawing board

2-23. Instead of using a T-square, some drafters prefer a parallel straightedge because it offers which of the following advantages?

1. It allows the drafter to produce cleaner drawings
2. It helps prevent ink blots on small drawings
3. It allows the drafter to work more accurately on large drawings
4. It helps keep drawings from sliding off an inclined drawing board

2-24. What is the most desirable source of illumination for drafting work?

1. Direct sunlight
2. Adjustable fluorescent table lamps
3. Overhead ceiling lights
4. Natural light

2-25. Assuming that a drafter is right-handed, the lighting should be from what direction?

1. Left-front
2. Right-front
3. Over the right shoulder
4. Over the left shoulder

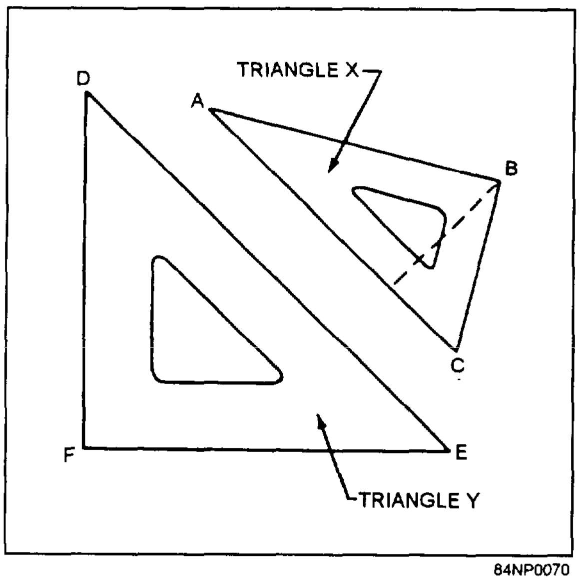


Figure 2A

IN ANSWERING QUESTIONS 2-26 AND 2-27, REFER TO TRIANGLES X AND Y IN FIGURE 2A.

2-26. The size of a 30°-60° triangle (X) is designated by the

1. length of AB
2. length of BC
3. size of angle A or C
4. perimeter of the triangle

2-27. The size of a 45° triangle (Y) is designated by the

1. length of DE
2. length of DF or EF, whichever you prefer
3. perimeter of the triangle
4. size of angle D or E

2-28. Assume that you are testing the straightness of a 45° triangle. The first step you should take is to place the triangle against a T-square and draw a vertical line. The next step is to take what actions?

1. Rotate the triangle and draw another vertical line, which should coincide with the first line
2. Slide the triangle to the left (or right) and draw an intersecting 45° line, which can be tested for accuracy with a protractor
3. Reverse the triangle and draw another vertical line along the same edge. This line should coincide with the first
4. Reverse the T-sauare and draw another vertical line along the same edge. This line should coincide with the first

2-29. In which of the following ways are circular protractors graduated?

1. Clockwise from 0° to 90° and 180° to 270°, and counterclockwise from 360° to 270° and 180° to 90°
2. Clockwise and counterclockwise from 0° to 180°
3. Clockwise and counterclockwise from 0° to 360°
4. Clockwise in quadrants from 0° to 90°

2-30. Without estimating, what is the minimum angle that can be set on the adjustable triangle shown in textbook figure 2-13?

1. 30 seconds
2. 15 seconds
3. 30 minutes
4. 1 degree

2-31. For which of the following shapes should you NOT use french curves?

1. Spirals
2. Ellipses
3. Parabolas
4. Circular arcs

IN ANSWERING QUESTIONS 2-32 THROUGH 2-35, REFER TO TEXTBOOK FIGURE 2-15.

2-32. Of the following instruments, which one is held in a set position by friction?

1. C
2. F
3. J
4. L

2-33. A series of eight circles with a diameter of 1/2 inch to 10 inches is drawn from a single center. What instruments should you use to ink the circles?

1. B and C
2. B, C, and D
3. B, C, and I
4. B, C, I, and K

2-34. Which of the following instruments require setscrew adjustment of the nibs ?

1. B, C, F, and G
2. B, F, G, and K
3. B, C, K, and L
4. F, G, K, and L

2-35. Of the following instruments, which one should you use to divide a 7 l/2-inch line into 20 equal segments?

1. A
2. C
3. J
4. K

2-36. Bringing together the points of dividers by bending the leg joints is a means of testing for

1. sharpness of the points
2. correct length of the points
3. alignment of the dividers
4. correct adjustment of the friction joints

2-37. When divider points become slightly uneven in length, what should you do to repair them?

1. Grind the points separately, in a horizontal position, by rubbing them on a whetstone
2. Hold the points vertically together and grind them lightly by drawing them back and forth against a whetstone
3. Grind the points separately, in a horizontal position, by twirling them against a whetstone
4. Replace the needlepoints

2-38. In what way, if any, should the needles of compasses and dividers compare in point size?

1. Those of the compass should be slightly larger
2. Those of the compass should be slightly smaller
3. They should be the same size
4. None; the size does not matter

2-39. Which of the following methods should you use to protect drawing instruments against corrosion?

1. Clean them with a soft cloth and coat them with a light film of oil
2. Polish them occasionally with metal polish
3. Clean them often with a chemical provided by the manufacturer of the instrument
4. Rub them lightly with emery paper and apply a light film of oil

IN ANSWERING QUESTIONS 2-40 THROUGH 2-44, SELECT THE DRAFTING INSTRUMENT FROM THE FOLLOWING LIST THAT SHOULD BE USED TO PERFORM THE DRAWING TASK LISTED.

A. HAIRSPRING DIVIDERS
B. DROP BOW PEN
C. PROPORTIONAL DIVIDERS
D. BEAM COMPASS

2-40. Ink a 3/32-inch radius circle.

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

2-41. Draw a circular arc that has a 30-inch radius.

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

2-42. Reduce or enlarge a drawing.

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

2-43. Transfer a measurement from one scale to another.

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

2-44. Draw a 60-inch radius circle.

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

2-45. The scale of 1/6,000 is equivalent to which of the following equations?

1. 1 in = 300 ft
2. 1 in = 500 ft
3. 1 in = 600 ft
4. 1 in = 1,000 ft

2-46. To show details of an object drawn to full scale on a drawing, you should present the details in what way?

1. Scaled up
2. Scaled down
3. Drawn to half scale
4. Drawn to full scale

2-47. Scales made of which of the following materials are the most accurate?

1. Plastic
2. Yellow hardwood
3. Boxwood
4. White pine

2-48. Which of the following scale shapes provides the most scale faces?

1. Two bevel
2. Opposite bevel
3. Four bevel
4. Triangular

IN ANSWERING QUESTIONS 2-49 THROUGH 2-52, SELECT THE TYPE OF SCALE FROM THE FOLLOWING LIST THAT YOU SHOULD USE TO ACCOMPLISH THE TASK LISTED.

A. METRIC SCALE
B. ENGINEER'S SCALE
C. ARCHITECT'S SCALE

2-49. Lay out drawing dimensions given in feet and inches.

1. A
2. B
3. C

2-50. Lay out drawing dimensions given in tenths of a foot.

1. A
2. B
3. C

2-51. Measure given dimensions to a scale of 1 cm = 50 m.

1. A
2. B
3. C

2-52. Measure given dimensions to a scale of 1 in = 200 ft.

1. A
2. B
3. C

2-53. What step must you take before using an engineer's scale for scaling when the scale is expressed as a fraction?

1. Determine the fractional equivalent of the scale on the engineer's scale
2. Multiply the scale numbers by 10
3. Multiply the scale numbers by 100
4. Multiply all measurements by 10

2-54. What scale on the engineer's scale should you use to determine that a line drawn 5 inches long is equivalent to 200 feet?

1. 10 scale
2. 20 scale
3. 40 scale
4. 50 scale

2-55. You want to draw the outline of a 200-foot by 200-foot rectangular area on an 8-inch by 10 l/2-inch sheet of paper. Which scale should you use to get the largest drawing that will fit on the paper?

1. 10 scale
2. 30 scale
3. 50 scale
4. 60 scale

2-56. Before using a map measure to determine the length of a pipeline on a SEABEE drawing, you should first take what step?

1. Adjust the tracing wheel with an odometer
2. Trace over the line to be measured
3. Set the scale indicator to the numerical scale indicated on the drawing
4. Trace over the graphical scale to ensure the accuracy of the reading

2-57. In what position should you hold the technical fountain pen when drawing a straight line?

1. Perpendicular to the drawing surface
2. Tilted slightly toward you
3. Tilted in the direction the line is drawn
4. Tilted opposite to the direction the line is drawn

ASSIGNMENT 3

Textbook Assignment: "Drafting: Fundamentals and Techniques; Reproduction Process." Pages 3-1 through 3-51.

3-1. For you to be positioned comfortably at your drawing board, your line of sight, in relation to the drawing surface, should be at approximately what angle?

1. 30°
2. 45°
3. 60°
4. 90°

3-2. If a drawing board has a severely marred drawing surface, you should cover the surface with which of the following materials?

1. A large sheet of butcher's paper
2. Two thicknesses of drawing paper
3. Laminated vinyl material
4. Self-adhesive linoleum

3-3. What step should you take to improve the surface of drawing paper that has become scratched from excessive erasing?

1. Rub the area smooth with your thumbnail
2. Rub the area lightly with pounce
3. Cover the damaged area with transparent tape
4. Apply a thin coating of clear acrylic spray

3-4. Which of the following drawing pencils should you select for the initial layout of a drawing?

1. 2B
2. F
3. H
4. 4H

3-5. When you view the back of a pencil drawing (on tracing paper) that is held against a light and see only indistinct lines, what, if anything, should you do?

1. Select a harder pencil to darken the lines
2. Select a softer pencil to darken the lines
3. Exert more pressure on the pencil used to prepare the drawing
4. Nothing; viewing the drawing from the back serves no purpose

3-6. You should always sharpen a pencil on its unlettered end for which of the following reasons?

1. To avoid breaking the lead
2. To retain the grade symbol
3. To retain the manufacturer's name
4. To permit easier dressing of the point

3-7. The mechanical pencil pointer produces what type of point?

1. Chisel
2. Elliptical
3. Conical
4. Wedge

3-8. A mechanical pencil has which of the following-advantages over a wooden pencil?

1. It is more comfortable to use
2. It does not need to be sharpened as frequently
3. It stays at a constant length
4. It uses leads that do not break as readily

3-9. When drawing a horizontal line, you should hold the pencil at what incline?

1. 30°
2. 45°
3. 60°
4. 75°

3-10. To draw vertical lines, you should (a) incline the pencil toward what part of the board and (b) draw the lines in what direction?

1. (a) Top (b) from bottom to top
2. (a) Top (b) from top to bottom
3. (a) Bottom (b) from bottom to top
4. (a) Bottom (b) from top to bottom

3-11. With a T-square as a base and using 30°-60° and 45° triangles in combination, inclined lines will be produced at which of the following angles?

1. 15° and 75°
2. 30° and 45°
3. 60° only
4. 30° and 60°

3-12. To lay off an angle from a given line, what marks on the protractor should you align for best accuracy?

1. Center mark and 0° mark only
2. 0° and 180° marks only
3. 0°, 180°, and center marks
4. 0°, 90° and 180° marks

3-13. In using a bow pencil to draw a circle, the drafter should take which of the following actions?

1. Rotate the bow pencil clockwise
2. Lean the bow pencil slightly forward
3. Apply even pressure
4. All of the above

3-14. When using a compass and pen attachment to draw a circle, what actions should you take to ensure proper ink flow?

1. Increase the forward incline of the compass
2. Adjust the needle leg of the compass to ensure it is perpendicular to the drawing surface
3. Adjust the pen leg of the compass to ensure that it is perpendicular to the drawing surface
4. Rub additional pounce into the drawing

3-15. A french curve is used to draw what types of lines?

1. Smooth, circular lines
2. Smooth, noncircular lines
3. Circular, parallel lines
4. Arcs of nonconcentric circles

3-16. In using a french curve to draw a line, what is the first step you should take?

1. Lightly sketch in the line between the plotted points
2. Avoid abrupt changes in curvature
3. Place the french curve so that it intersects at least two plotted points
4. Stop short of the last plotted point

3-17. When possible, you should use drafting templates for which of the following reasons?

1. They are as accurate as any other drawing method and usually much faster
2. They are not as accurate as other drawing methods but usually faster
3. They are more accurate than other drawing methods and usually faster
4. They are more accurate than other drawing methods although slower

3-18. Hairspring dividers are used for which of the following purposes?

1. Transferring measurements of different scales and stepping off a series of equal distances
2. Dividing lines into equal parts
3. Transferring measurements of the same scale and stepping off a series of equal distances
4. Both 2 and 3 above

3-19. Which of the following actions is NOT a proper use of the drafting scale?

1. To set a compass, mark the desired distance and adjust the instrument directly on the face of the scale
2. For measuring horizontal distances, point the desired scale face away from you
3. To measure distances, mark off short dashes at right angles to the scale face
4. To make successive measurements on a line, do not move the scale until necessary

3-20. Standard drawing sheet sizes are used for what primary reason?

1. To standardize the size of all drawings
2. To eliminate the waste of expensive tracing paper
3. To ensure that the supply department orders the correct sizes of trading paper
4. To facilitate filing

3-21. What are the dimensions of a size “C” sheet of drawing paper?

1. 11 in by 17 in
2. 17 in by 22 in
3. 22 in by 44 in
4. 34 in by 44 in

3-22. What are the actual dimensions inside the border lines on a size “D” sheet of drawing paper?

1. 20 in by 33 in
2. 21 in by 32 in
3. 21 in by 33 in
4. 21 in by 32½ in

3-23. On a sheet of “F” size drawing paper, what should be the dimensions between the trim lines?

1. 27½ in by 39½ in
2. 28 in by 40 in
3. 34 in by 44 in
4. 33½ in by 43½ in

3-24. What is the primary purpose of the title block on a drawing?

1. To describe the drawing
2. To tell who drew the drawing
3. To specify who is ultimately responsible for the drawing
4. To identify the drawing

3-25. The title block is generally located in what part of the drawing?

1. Lower right corner
2. Lower left corner
3. Lower center
4. Upper right corner

3-26. On a construction drawing, the revision block is placed at what corner of the drawing?

1. Lower right
2. Lower left
3. Upper right
4. Upper left

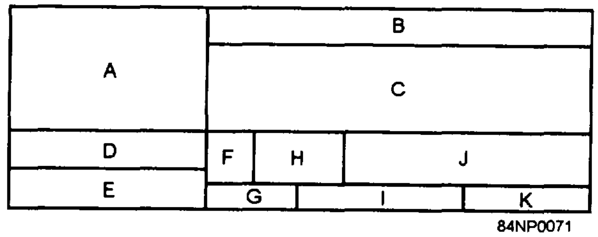


Figure 3A

IN ANSWERING QUESTIONS 3-27 THROUGH 3-29, REFER TO FIGURE 3A.

3-27. In what space should the terms “as shown, “as noted,” or “none” be correctly entered?

1. E
2. G
3. I
4. J

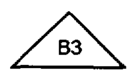
3-28. The five-digit number that identifies the government activity responsible for the design of the item is entered in what space?

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

3-29. What space holds the name of the drafter preparing the drawing?

1. A
2. D
3. E
4. J

3-30. What information about the drawing is indicated when the revision block contains the following symbol?



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1. It is the third change incorporated in the second revision
2. It is the third change incorporated in the third revision
3. It is the second change incorporated in the second revision
4. It is the second change incorporated in the third revision

3-31. What feature do all the lines in the system of line conventions have in common?

1. They convey information
2. They are drawn with a pen guided by a straightedge
3. They are drawn with a compass
4. They are drawn freehand

3-32. How should construction lines be drawn?

1. Thick and dark
2. Dark enough to see, but light enough to erase easily
3. Thin and dark
4. With a soft pencil

3-33. To indicate the travel of a moving center, which of the following lines should you use?

1. Center lines
2. Phantom lines
3. Reference lines
4. Visible lines

3-34. What line is an example of a center line?

1. ————————————————————
2. ——— - ——— - ——— - ———
3. - - - - - - - - - - - - - - -
4. ———— - - ———— - - ————

3-35. What line is a solid, thick line and defines the outlines of an object in a drawing?

1. Datum
2. Dimension
3. Extension
4. Visible

3-36. In a drawing of a certain view of an object, the features of the object that CANNOT be seen are indicated by what line?

1. ————————————————————
2. ——— - ——— - ——— - ———
3. - - - - - - - - - - - - - - -
4. ———— - - ———— - - ————

3-37. How should arrowheads be drawn?

1. Between 1/4 and 1/2 in long, the length twice the spread, and filled in
2. Between 1/4 and 1/2 in long, the length twice the spread, and not filled in
3. Between 1/8 and 1/4 in long, the length three times the spread, and filled in
4. Between 1/8 and 1/4 in long, the length three times the spread, and not filled in

3-38. Drawing space is saved in certain large-scale detailed drawings by omitting unimportant parts that are continuous and have the same size and shape. What lines are used to indicate these omitted parts?

1. Section
2. Leader
3. Break
4. Cutting plane

3-39. The alternate positions of a switch handle can be indicated on a drawing by the use of what lines?

1. ————————————————————
2. ——— - ——— - ——— - ———
3. - - - - - - - - - - - - - - -
4. ———— - - ———— - - ————

3-40. If an internal section of an object is needed, which of the following lines would indicate the plane from which the sectional view was taken?

1. Cutting plane
2. Sectional plane
3. Datum plane
4. Reference plane

IN ANSWERING QUESTIONS 3-41 THROUGH 3-44, SELECT THE TYPE OF LINE FROM THE FOLLOWING LIST THAT BEST MATCHES THE DESCRIPTION.

A. STITCH LINE
B. DATUM LINE
C. MATCH LINE

3-41. A line which indicates the plane from which an elevation is measured.

1. A
2. B
3. C

3-42. A line that connects corresponding points on different sheets of the same drawing.

1. A
2. B
3. C

3-43. The type of line that indicates sewing lines on an article.

1. A
2. B
3. C

3-44. A line that looks like a phantom line but is used differently.

1. A
2. B
3. C

3-45. In a pencil drawing, when should you draw the nonhorizontal and nonvertical lines?

1. After drawing the extension and dimension lines
2. After drawing the horizontal and vertical lines
3. Before drawing the horizontal and vertical lines
4. Before drawing any circles or arcs

3-46. On a drawing, which of the following lines are the last to be inked?

1. Horizontal lines
2. Vertical lines
3. Irregular curves
4. Border lines

3-47. As you practice freehand lettering, you develop "writer's cramp." What is the probable cause?

1. Applying excessive downward pressure on the pencil
2. Applying too little downward pressure on the pencil
3. Resting only the ball of the hand on the drawing board
4. Gripping the pencil too tightly

3-48. Which of the following pencil grades is most commonly used for freehand lettering on construction drawings?

1. 2B or 3B
2. B or H
3. F or H
4. H or 2H

3-49. What guidelines are used for lettering that requires only capitals?

1. Capline and baseline only
2. Capline and dropline only
3. Capline, waistline, and baseline
4. Capline, baseline, and dropline

3-50. If vertical guidelines are used to keep letters vertical, how should they be spaced along the horizontal guidelines?

1. Approximately every fifth letter
2. Approximately every two words
3. At the beginning, at the middle, and at the end of each line of lettering
4. At random

3-51. The number 6 on the inner circle of the Ames lettering instrument is aligned with the index on the outer circle. What is the distance between the capline and baseline produced by this setting?

1. 3/32 in
2. 3/16 in
3. 1/4 in
4. 3/8 in

3-52. For lowercase lettering, what is the normal spacing between continuous lines of lettering?

1. One half of the distance between the capline and dropline
2. Two thirds of the distance between the capline and baseline
3. Three times the distance between the capline and waistline
4. Equal to the distance between the capline and the baseline

3-53. Which of the following statements concerning the formation of single-stroke Gothic letters is NOT true?

1. Each letter is drawn by one single continuous stroke
2. All inclined strokes are drawn from the top down
3. All horizontal strokes are drawn from left to right
4. All curved strokes are drawn from above downward

3-54. To balance letters in words, which of the following actions should you take?

1. Extend the horizontal stroke of T when it precedes A
2. Compress the O to a narrower elliptical shape when it is between letters that have vertical strokes
3. Slightly compress the letter H
4. Place the central horizontal bar of H, F, and E slightly below center to create an optical illusion of widening

3-55. If the Ames lettering instrument is set on 8 to make capital letter guidelines for drawing notes, what number should be set on the instrument to produce guidelines for numerals that will be used in the same drawing notes?

1. 5
2. 6
3. 7
4. 8

3-56. Lowercase letters should NOT be used in which of the following situations?

1. For notes on maps
2. In combination with capitals on Navy drawings
3. On Navy drawings where the required size of lettering is more than one-fourth in high
4. On construction drawings and title blocks

3-57. A block of general notes on a drawing consists of several lines of lettering. Which of the following factors contributes the most to the appearance of the notes?

1. Spacing between letters and words
2. Formation of each letter
3. Size of the lettering
4. Spacing between the lines

3-58. In freehand Gothic lettering, the letters A and V in “HAVE” and the letters H and O in “HOLE” are properly spaced by moving the letters closer together.

1. True
2. False

3-59. For proper spacing of the letters in the word “NICKEL,” you should provide less space between the letters N and I than the letters I and C.

1. True
2. False

3-60. When freehand lettering the word “WORK,” you should provide the same amount of space between the letters W, O, and R.

1. True
2. False

3-61. For good appearance, the spacing between words should be equal to what size interval?

1. 1½ times the space occupied by the letter N
2. 1½ times the height of the capitals
3. The distance between the capline and the dropline
4. The space occupied by the letter O

3-62. As applied to lettering, what does the term “justifying” mean?

1. Adjusting words or letter spacing to make a line of lettering fit a given length
2. Spacing of letters for good appearance of words
3. Centering a line or lines of lettering about the center of a given area
4. Using sample lettering as a guide for centering

3-63. Using the templates in a standard Leroy lettering set, you can make letters of what maximum height?

1. 1½ in
2. 1¼ in
3. 1 in
4. ½ in

3-64. What part of the Leroy lettering set establishes line thickness of letters?

1. Ink reservoir
2. Tracing pin
3. Cleaning pin
4. Templates

3-65. What advantage does the adjustable scriber have over the standard fixed scriber?

1. Templates with larger lettering may be used
2. Larger pens may be inserted in the scriber to produce thicker lines
3. Templates with special types of lettering may be used
4. Inclined lettering may be produced with standard templates

3-66. Concerning the adjustment of the scriber, which of the following statements is a correct procedure?

1. Rough adjustment of the scriber adjustment screw should be made after the pen has been filled
2. The cleaning pen must be removed for proper rough adjustment
3. Rough adjustment should be made when the cleaning pen barely touches the paper, before the pen is filled
4. Final adjustment should be made after the locknut has been tightened

3-67. Which, if any, of the following requirements is necessary for reproduction rooms?

1. Lighting level equal to that of the drafting room
2. Sufficient room ventilation
3. Additional heat for protection of the reproduction paper
4. None of the above

3-68. In the reproduction of construction drawings, what process is most commonly used by the Navy?

1. Vacuum frames
2. Diazo or ammonia vapor
3. Sun frames
4. Photographic contact

3-69. Before using the Blu-Ray reproduction machine, all EAs should take which of the following actions?

1. Attend the formal school for operators
2. Obtain on-the-job training at one of the construction regiments
3. Acquire the necessary operator license
4. Become thoroughly familiar with the manufacturer’s operating and maintenance instructions

3-70. When making prints using the Model 842 printer, which of the following actions should you take?

1. Place the chemical side of the reproducing paper down
2. Run the original tracing through the machine before the reproducing paper
3. Feed the sensitized paper into the printer against the grain
4. Ensure that the leading edge of both the tracing and the sensitized paper are even, uncurled, and uncreased

3-71. What substance, solution, or cleaning method should you use to clean the glass-printing cylinder and lamps of the White printer?

1. Plain soap and water
2. Scouring powder and glass cleaner
3. Manufacturer’s recommended glass cleaner or an ammonia-water solution
4. Soap, water, and scouring pad

3-72. When the prints received from the Blu-Ray machine are too light, what action should you take?

1. Increase the speed
2. Decrease the speed
3. Increase the vapor
4. Decrease the vapor

3-73. What unit(s) of the printing section of the Ozalid machine carry(ies) the material around the revolving printing cylinder?

1. Pick-off assembly
2. Feed belts
3. Separator belts
4. Roller guide

3-74. Some Ozalid machines are equipped with a second ammonia supply system. What is the name of that system?

1. Second ammonia system
2. Second supply system
3. Anhydrous ammonia system
4. Hydrous ammonia system

3-75. What is the only positive method, if any, that you should use to obtain the correct speed for the Ozalid machine?

1. Consult the manufacturer’s manual
2. Check the label on the wrapper of the sensitized paper
3. Run one or more test strips
4. There is no positive method

ASSIGNMENT 4

Textbook Assignment: "Geometrical Construction." Pages 4-1 through 4-16. "Drafting:" Projections and Sketching." Pages 5-1 through 5-37.

4-1. What is the first step in drawing a line through a given point, P, parallel to line XY?

1. Place compass needlepoint on P; strike an arc intersecting XY at any point
2. Place compass needlepoint on P; strike an arc intersecting the approximate midpoint of line XY
3. Place compass needlepoint on any point along line XY; strike an arc through point P and line XY
4. Place compass needlepoint on X; strike an arc through Y and near point P

4-2. To construct a perpendicular from a given point, P, on line XY, you should first place the compass needle at what point(s) ?

1. P
2. X or Y
3. A point near the midpoint of PX and PY
4. Any convenient point along XY

4-3. What points on a line should be used as centers for the intersecting arcs drawn to bisect the line?

1. The center and one end
2. A random point and one end
3. A random point and the center
4. The two ends

4-4. Line XY is to be divided into 12 equal parts by geometric construction. Which of the following statements concerning this procedure is correct?

1. Ray line PY, drawn from Y, is the same length as XY
2. A compass should be set to spread equal to one twelfth of the length of XY
3. A line should be drawn from X to the 12th interval on ray line PY
4. The acute angle formed by XY and ray line PY should be 30° or less

4-5. From what point should you carry out the first step of the procedure to bisect or transfer angle XYZ? (Always use the middle letter as the apex.)

1. A random point on XY
2. A random point on YZ
3. The apex Y
4. The midpoint of arc XZ

4-6. In which, if any, of the following constructions is it necessary to draw an angle by using a protractor?

1. Constructing an equilateral triangle on a given inscribed circle .
2. Constructing a right triangle for which the hypotenuse and one side are given
3. Constructing an equilateral triangle for which the length of one side is given
4. None of the above

4-7. Which of the following actions should be your first step in constructing a square geometrically when you are given only the length of its diagonal?

1. Lay out a horizontal line equal to one half of the given length
2. Lay out a vertical line equal to one half of the given length
3. Lay out a horizontal line equal to twice the given length
4. Lay out a horizontal line equal to the given length

4-8. In completing the drawing of a certain geometric figure, you have drawn the sides of the figure tangent to the points where two diameters (at right angles to each other) intersect a given circle. What geometric figure have you drawn?

1. A square in a given circumscribed circle
2. A square on a given inscribed circle
3. An equilateral triangle in a given circumscribed circle
4. An equilateral triangle on a given inscribed circle

4-9. When the length of the sides are not known, for which of the following geometric figures is it necessary to equally divide the circumference of the circle by trial and error with a compass?

1. A 5-sided irregular polygon inscribed in a given circle
2. A 5-sided regular polygon inscribed in a given circle
3. A 5-sided polygon inscribed on a given circle
4. Both 2 and 3 above

4-10. When two diameters of a circle are at right angles to each other, in which of the following geometric figures are all of the sides then drawn at 45° angles to the diameters?

1. A hexagon inscribed in a given circle
2. An octagon inscribed in a given circle
3. A pentagon inscribed in a given circle
4. A square inscribed in a given circle

4-11. In which of the following geometric figures are two of the sides drawn at 60° to the horizontal diameter of a given circle?

1. An equilateral triangle in a given circle
2. An equilateral triangle on a given circle
3. Both 1 and 2 above

4-12. Which of the following regular polygons may be constructed with only the length of one side given?

1. 5-sided polygon
2. 7-sided polygon
3. 9-sided polygon
4. All of the above

4-13. Assume that you have drawn a hexagonal bolt head from the given distance between its opposite corners. On the drawing, this distance is equal to the

1. diameter of the circle inscribed in the hexagon
2. diameter of the circle circumscribing the hexagon
3. diagonal of the square circumscribing the hexagon
4. side of the square circumscribing the hexagon

4-14. In the construction of a circle that is to pass through three given points, the center of the circle is determined by the intersection of what lines?

1. The perpendicular bisector of the longest line and the perpendicular line drawn from the end of the shortest line
2. The perpendicular bisector of the shortest line and the perpendicular line drawn from the end of the longest line
3. The perpendicular bisectors of the lines that connect the points
4. The tangents drawn through each point

4-15. To construct a line tangent to a circle at a given point on the circle, first set the compass

1. equal to the diameter of the circle
2. equal to the radius of the circle
3. to a distance less than the radius of the circle
4. to a distance greater than the radius and less than the diameter of the circle

4-16. To draw an arc of a given radius tangent to the sides of any angle, one of the essential steps of the procedure is to construct what two lines?

1. Two nonparallel lines at right angles to the sides of the angle
2. Two lines that are parallel to the sides of the angle at a distance equal to one half of the given radius
3. Two lines that are parallel to the sides of the angle at a distance equal to the given radius
4. Two parallel lines at right angles to the sides of the angle

4-17. In textbook figure 4-39, the radius O’P is equal to what distance?

1. Double the radius OP
2. The radius OP plus the radii of arcs CD and EF
3. The radius of arc CD plus AB
4. The radius of arc EF plus AB

4-18. In textbook fiqure 4-37, the compass spread O'P is equal to what distance?

1. AB
2. The radius OP minus AB
3. The radius of arc EF minus AB
4. The radius OP minus the radius of arc CD

4-19. In textbook figure 4-38, the radius OP is equal to what distance?

1. O'P
2. The line AB less the radius of arc CD
3. The line AB less the radius of arc EF
4. The sum of the radii of arcs CD and EF

4-20. What is the first step for constructing a compound curve, as shown in figure 4-40 of the textbook?

1. Draw the chords connecting AB, BC , CD, and DE
2. Erect a perpendicular bisector from A to B
3. Establish the random distance O_1A
4. Draw arc AB

4-21. Assume that you just constructed the ogee curve skown in figure 4-42 of the textbook. Which of the following points was NOT established by geometric construction?

1. C
2. D
3. E
4. O_1

4-22. When using the pin-and-string method to construct an ellipse, which of the following points should you use to determine the length of the string before drawing the perimeter of the ellipse?

1. Both end points of the minor axis and one focus point
2. Both end points of the major axis and one focus point
3. Both foci points and one end point of the minor axis
4. Both foci points and one end point of the major axis

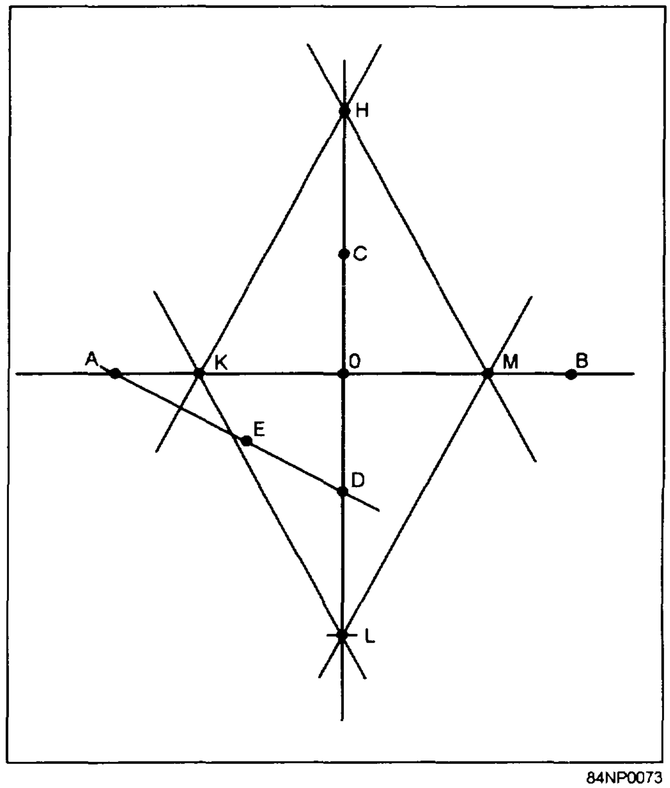


Figure 4A

IN ANSWERING QUESTIONS 4-23 AND 4-24, REFER TO FIGURE 4A WHICH SHOWS THE CONSTRUCTION LINES USED FOR DRAWING AN ELLIPSE BY THE FOUR-CENTER METHOD.

4-23. Line DE is equivalent to which of the following lines or distances?

1. Line DO
2. Line KO
3. Line AO minus line AK
4. Line AO minus line DO

4-24. Which of the following descriptions describes point K correctly?

1. The end point of line KO, which is on the minor axis
2. The intersection of line AO with the perpendicular bisector of line AE
3. The intersection of line KO with the perpendicular bisector of line AD
4. The end point of line KO, which is equal to the difference in lengths of lines AO and DO

4-25. In which of the following types of projection do the lines of sight converge?

1. Orthographic only
2. Perspective pictorial only
3. Both orthographic and perspective pictorial

4-26. In which of the following types of projection is the plane of projection between the point of sight and the object?

1. Orthographic only
2. Perspective pictorial only
3. Both orthographic and perspective pictorial

4-27. Which of the following types of projection involve only two-dimensional views of an object?

1. Orthographic only
2. Perspective pictorial only
3. Both orthographic and perspective pictorial

4-28. In which of the following types of projection is the point of sight located at infinity?

1. Orthographic only
2. Perspective pictorial only
3. Both orthographic and perspective pictorial

4-29. In an orthographic projection, which of the following views are the principal planes of projection?

1. Top, bottom, and side
2. Front, rear, and top
3. Front, bottom, and side
4. Front, top, and side

4-30. What is the most common orthographic projection used in the United States?

1. First-angle
2. Second-angle
3. Third-angle
4. Fourth-angle

4-31. Which of the following planes in the third-angle projection is considered to be in the plane of the drawing paper?

1. Horizontal
2. Vertical
3. Profile
4. Third-angle

4-32. How should views be spaced on tracing paper?

1. So they give the appearance of a balanced drawing
2. So they conserve as much paper as possible
3. In a manner that depicts a clear and concise picture of the object being drawn
4. In a manner that facilitates the projection of the views

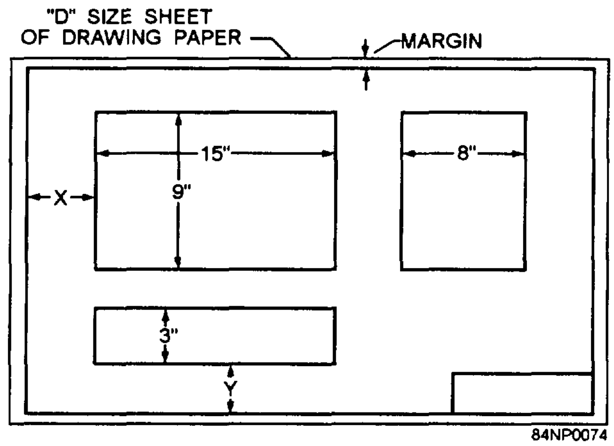


Figure 4B

IN ANSWERING QUESTIONS 4-33 AND 4-34, REFER TO FIGURE 4B.

4-33. The distance X is equal to

1. 3 in
2. 3 1/3 in
3. 4 in
4. 4 1/3 in

4-34. The distance Y is equal to

1. 2 in
2. 2 1/3 in
3. 3 in
4. 3 1/3 in

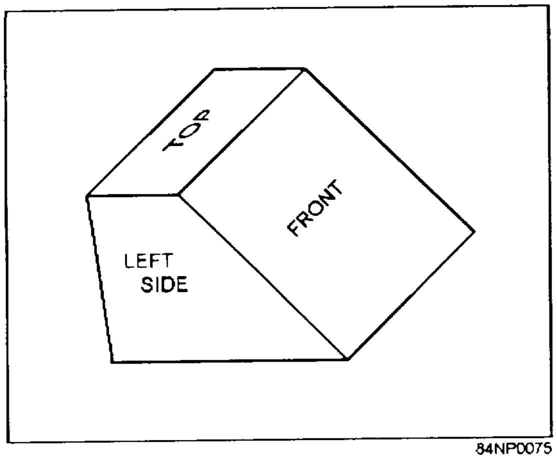
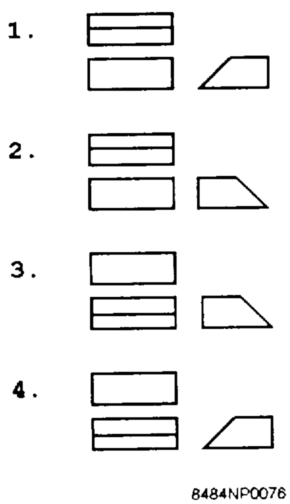


Figure 4C

IN ANSWERING QUESTION 4-35, REFER TO FIGURE 4C.

4-35. Which of the following arrangements is proper for the front-, top-, and right-side views?



4-36. Which of the following descriptions applies to a non-normal line?

1. It is curved
2. It is perpendicular to a plane of projection
3. It is oblique to one or more of the planes of projection
4. It is always shown at its true length

4-37. In multi-view orthographic projection, how should circles appear?

1. As ellipses Only
2. As either circles or ellipses, depending on the view
3. In their true shape, but their size may be distorted
4. Always in their true size and shape

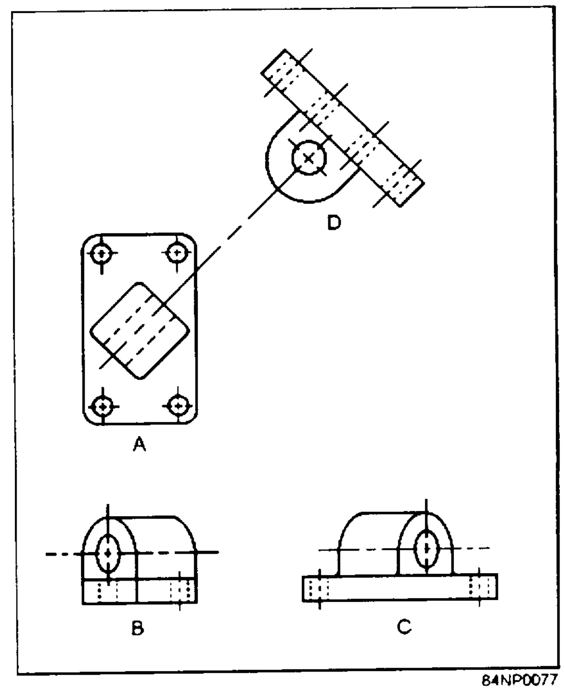


Figure 4D

IN ANSWERING QUESTION 4-38, REFER TO FIGURE 4D.

4-38. What drawing shows an auxiliary view of the object?

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

4-39. An auxiliary view to a three-view drawing is required if the object has what characteristics?

1. More than four sides
2. No symmetrical sides
3. A detail that is on a plane parallel to a regular plane of projection
4. A surface where the true shape cannot be shown by a regular plane of projection

IN ANSWERING QUESTIONS 4-40 THROUGH 4-43, SELECT THE CHARACTERISTIC FROM THE FOLLOWING LIST THAT IDENTIFIES OR APPLIES TO THE AUXILIARY VIEW GIVEN AS THE QUESTION.

A.	PROJECTED FROM THE FRONT VIEW
B.	PROJECTED FROM A SIDE VIEW
C.	PROJECTED FROM THE TOP VIEW

4-40. Front.

1. A
2. B
3. C

4-41. Right side.

1. A
2. B
3. C

4-42. Elevation.

1. A
2. B
3. c

4-43. Left side.

1. A
2. B
3. C

IN ANSWERING QUESTIONS 4-44 AND 4-45, REFER TO FIGURE 5-25 IN THE TEXTBOOK.

4-44. The rear auxiliary view could also have been projected from which of the following views?

1. Top
2. Front
3. Rear
4. Left side

4-45. The line BD appears in its true length in the rear auxiliary view and in what other view, if any?

1. The right side
2. The top
3. The front
4. None

4-46. What type of section view gives a complete cross-sectional view of an object?

1. Complete section
2. Full section
3. Full plane section
4. Plane section

4-47. In half-sectioning a cylinder, how far should you extend the cutting plane?

1. Half the diameter of the cylinder
2. Half the radius of the cylinder
3. Half the circumference of the cylinder
4. A quarter of the circumference of the cylinder

4-48. A section consisting of less than a half-section is referred to as what type of section?

1. Partial
2. Detail
3. Offset
4. Quarter

4-49. At what angle from the horizontal should diagonal hatching be drawn in an orthographic projection?

1. 15°
2. 30°
3. 45°
4. 60°

4-50. In an isometric drawing, what is the angle that each line of the axis forms with the adjacent line?

1. 45°
2. 60°
3. 90°
4. 120°

4-51. In an isometric projection, the object is inclined to conform with which of the following characteristics?

1. All surfaces make the same angle with the plane of projection
2. The face makes an angle of 30° with the plane of projection
3. The face makes an angle of 60° with the plane of projection
4. Each edge forms an angle of 45° with the plane of projection

4-52. Which of the following descriptions most accurately applies to the lines of projection in an isometric drawing?

1. Converging
2. Diverging
3. Parallel to the plane of projection
4. Perpendicular to the plane of projection

4-53. What method is used for drawing non-isometric lines whose ends do not fall on isometric lines or planes?

1. Corresponding end points
2. Conjugate axis
3. Orthographic
4. Section lining

4-54. When transferring an angle to an isometric view, which of the following guidelines should you use?

1. Represent the angle in its true size in the isometric view
2. Use the same method as when transferring a non-isometric line
3. Label the angle with its actual size as appearing on the isometric drawing
4. Reduce the size of the angle by one fifth

4-55. A figure appearing as a circle in regular multi-view view will take what shape in an isometric view?

1. Line
2. Circle
3. Oval
4. Ellipse

4-56. When an object is to be drawn in oblique projection, how should the front surface be positioned?

1. Perpendicular to the plane of projection
2. Parallel to the plane of projection
3. At an angle of 45° to the plane of projection
4. At an angle of either 30° or 60° to the plane of projection

IN ANSWERING QUESTIONS 4-57 THROUGH 4-60, SELECT THE OBLIQUE PROJECTION FROM THE FOLLOWING LIST THAT HAS THE CHARACTERISTICS LISTED.

A.	CABINET ONLY
B.	CAVALIER ONLY
C.	CABINET AND CAVALIER

4-57. Front surface drawn in orthographic projection.

1. A
2. B
3. C

4-58. Oblique projection drawn to actual or dimensional length.

1. A
2. B
3. C

4-59. Oblique projection foreshortened by one half.

1. A
2. B
3. C

4-60. Single view showing length, width, and thickness of an object.

1. A
2. B
3. C

4-61. To save time, sketching to scale is commonly done with the aid of which of the following materials or implements?

1. Engineer’s scale
2. Cross-section paper
3. Dividers
4. Draftsman’s triangles

4-62. When freehand sketching, you should hold the pencil in what manner?

1. Between your middle and index fingers
2. With your index finger as close to the point as possible
3. Below your hand and between your thumb and fingers
4. With a relaxed grip about an inch from the point

4-63. When freehand sketching of an object, each line should be drawn in what manner?

1. With one complete stroke of the pencil
2. With the arm held in one position
3. With a series of short strokes of the pencil
4. With a wrist movement, rather than an arm movement

4-64. When sketching a long, straight vertical line, you should first place a dot at each end of the line. What is your next step?

1. Connect the dots with a series of short pencil strokes
2. Connect the dots with one long pencil stroke
3. Place additional dots at intermediate points along the line, then connect the dots with a series of short pencil strokes
4. Place additional dots at intermediate points along the line, then connect the dots with one long pencil stroke

4-65. To divide lines and areas into equal parts, you should use what process?

1. Visual approximation
2. Arbitrary estimation
3. Geometric construction
4. Dividing and redividing

4-66 What is the basic angle you should use when sketching?

1. 30°
2. 60°
3. 45°
4. 90°

4-67. Which of the following items will serve as a substitute for a pencil compass?

1. Pencil, piece of string, and a thumbtack
2. Pencil, rubberband, and a thumbtack
3. Two pencils and a rubberband
4. Two pencils and a piece of paper

4-68. One method of freehand sketching of a circle calls for you rotate the-paper with one hand. What part of your hand serves as the pivot point?

1. The side
2. Index finger only
3. Second finger only
4. Either the index or second finger, whichever is easier

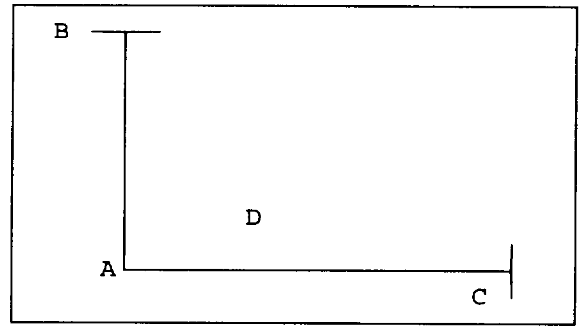


Figure 4E

IN ANSWERING QUESTIONS 4-69 AND 4-70, YOU ARE DFUIWING A CURVE TANGENT TO STRAIGHT LINES AND HAVE PROCEEDED AS FAR AS SHOWN IN FIGURE 4E.

4-69. What should your next step be?

1. Placing a dot at D
2. Sketching a light curve through D between B and C
3. Drawing a straight line between B and C
4. Drawing a straight line from A through D midway between B and C

4-70. What is the preferred way to sketch the curve after you place the dot or X through which the curve is to pass?

1. Start at B, and proceed through the dot or X, and end at C
2. Start at C, proceed through the dot or X, and end at D
3. Start at the dot or X and sketch to C, return to the dot or X, and then sketch to B
4. Start at D, proceed to C, back to D, and then to B

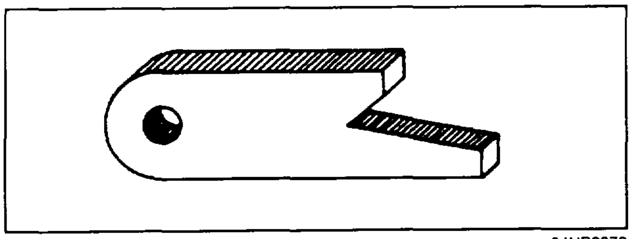


Figure 4F

IN ANSWERING QUESTION 4-71, REFER TO FIGURE 4F.

4-71. If you are sketching the object shown, what step should you take first?

1. Draw a circle
2. Draw a rectangular block
3. Draw light guidelines to represent the outlines of the object
4. Draw the details

4-72. Pictorial sketches differ from orthographic sketches in which of the following ways?

1. Pictorial sketches are normally drawn to scale while orthographic sketches are not
2. Pictorial sketches deal with volumes, rather than planes
3. Pictorial sketches are usually less detailed than orthographic sketches
4. Pictorial sketches require the use of mechanical aids in their preparation

4-73. What is the primary use of overlay sketches?

1. Preliminary design
2. Changes in design
3. Planning purposes
4. Supplementing previously drawn sketches

ASSIGNMENT 5

Textbook Assignment: "Wood and Light Frame Structures." Pages 6-1 through 6-51.

5-1. Of all the construction material, what material is considered the most often used and the most important?

1. Wood
2. Steel
3. Concrete
4. Plastic

5-2. In small construction projects that do NOT have written specifications included, where should you be able to find the type and classification of wood?

1. In the drawings themselves
2. In the bill of materials
3. In the special standards
4. In the special information sheets attached to the drawings

5-3. In construction, the terms "wood," "lumber" and "timber" have distinct and separate meanings. Which of the following definitions is an accurate description?

1. Wood is a soft, nonfibrous substance
2. Timber is lumber with a dimension of not less than 5 inches
3. Lumber is trees that have not been cut
4. Wood is lumber that has been made into manufactured products

5-4. "Millwork" is best defined by which of the following descriptions?

1. Wood selected for sawmill work
2. Timber made into lumber
3. Lumber made into manufactured products
4. Wood after it has been through the sawmill

5-5. In what way, if any, can the nominal size of lumber be compared to its dressed size?

1. It is larger
2. It is the same
3. It is smaller
4. It cannot be compared

5-6. What designation applies to wood surfaced on two sides only?

1. S2S
2. S2E
3. SS2
4. 2SS

5-7. In which of the following ways is lumber designated on drawings and purchase orders?

1. Dressed only
2. Nominal only
3. Dressed or nominal, whichever you chose

IN ANSWERING QUESTIONS 5-8 AND 5-9, REFER TO TABLE 6-2 IN YOUR TEXTBOOK.

5-8. What are the dressed dimensions of a 1- by 8-inch board?

1. 1 by 8 in
2. 1 by 7 1/2 in
3. 3/4 by 7 1/2 in
4. 3/4 by 7 1/4 in

5-9. What are the dressed dimensions of a 2- by 4-inch, S4S board?

1. 2 by 4 in
2. 2 by 3 1/2 in
3. 1 1/2 by 3 1/2 in
4. 1 1/2 by 3 1/4 in

5-10. Manufactured lumber, when classified according to its use, falls into what three categories?

1. Boards, dimension, and timbers
2. Rough, dressed, and worked
3. Yard, structural, and factory
4. Boards, shop, and yard

5-11. When you want lumber to show its natural finish, what grade(s) should you use?

1. A only
2. B only
3. A or B, whichever you prefer
4. C

5-12. When grain-tight lumber is required, what type of lumber is normally used?

1. No. 1 common
2. No. 2 common
3. Grade A select
4. Grade B select

5-13. Which type of lumber is primarily graded by its allowable stresses?

1. Factory
2. Structural
3. Shop
4. Yard

5-14. To find the board foot measurement of lumber, what formula should you use?

1. $\frac{\text{Thickness(in.) X width(in.) X length(in.)}}{144}$

2. $\frac{\text{Thickness(in.) X width(in.) X length(in.)}}{12}$

3. $\frac{\text{Thickness(in.) X width(in.) X length(ft)}}{144}$

4. $\frac{\text{Thickness(in.) X width(in.) X length(ft)}}{12}$

5-15. When computing the amount of board feet in a dressed 2- by 4-inch board, which of the following dimensions should you use?

1. 1 3/4 by 3/4 in
2. 2 by 4 in
3. 1 5/8 by 3 5/8 in
4. 1 7/8 by 3 5/8 in

5-16. When you are laminating lumber, how are the laminations (pieces) fastened together?

1. Nailed and glued together, with the grain of all pieces running perpendicular
2. Nailed or glued together, with the grain of all pieces running parallel
3. Nailed, bolted, or glued together, with the grain of all pieces running perpendicular
4. Nailed, bolted, or glued together, with the grain of all pieces running parallel

5-17. Which of the following characteristics applies to plywood?

1. Punctureproof
2. Resists splitting
3. Pound for pound one of the strongest materials available
4. Both 2 and 3 above

5-18. Plywood is used for which of the following purposes?

1. Formwork
2. Sheathing
3. Furniture
4. Each of the above

5-19. What are the two most common sizes of plywood sheets available for use in construction?

1. 3 by 6 ft and 4 by 8 ft
2. 4 by 8 ft and 4 by 10 ft
3. 4 by 8 ft and 4 by 12 ft
4. 4 by 10 ft and 4 by 12 ft

5-20. How are plywood panel grades generally designated?

1. By the grade of veneer on the face only
2. By the kind of glue only
3. By the grade of veneer on the face and back only
4. By the kind of glue and the grade of veneer on the face and back

IN ANSWERING QUESTION 5-21, REFER TO FIGURE 6-6 IN YOUR TEXTBOOK.

5-21. What plywood veneer grade allows knotholes up to 2 1/2 inches in width and under certain conditions up to 3 inches?

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

5-22. When index numbers 48/24 appear on a grading identification stamp, what does the number 24 represent?

1. Minimum on-center spacing of supports for subfloors
2. Maximum on-center spacing of supports for roof decking
3. Maximum on-center spacing of supports for subfloors
4. Maximum on-center spacing of supports for wall studs

5-23. Which of the following types of plywood panels is/are recommended for use in cabinets?

1. Standard plywood sheathing
2. Decorative panels only
3. Overlaid panels only
4. Decorative panels and overlaid panels

5-24. Which of the following types of wood substitutes provides good fire resistance?

1. Fiberboard
2. Gypsum wallboard
3. Particleboard
4. Hardboard

5-25. The type and amount of wood treatment is normally given in the project specifications. When no written specifications exist, where should you be able to find the wood treatment required?

1. Bill of materials
2. Commercial standards
3. Drawings
4. American Plywood Association

5-26. In platform construction, what is the first wood structural member to be set in place?

1. Header
2. Joist
3. Soleplate
4. Sill

5-27. What is the difference between a common joist and a cripple joist?

1. A cripple joist extends the full span, but a common joist does not
2. A common joist extends the full span, but a cripple joist does not
3. A cripple joist may be supported by a girder, but a common joist is never supported by a girder
4. Common joists are supported by pilasters, while cripple joists are not

5-28. At a door opening in an exterior wood-framed wall, the names of the horizontal members that connect at the (a) top and (b) bottom of the cripple studs are

1. (a) header (b) soleplate
2. (a) top plates (b) soleplate
3. (a) top plates (b) header
4. (a) header (b) sill

5-29. Frame structures are commonly brat.ad by use of which of the following methods?

1. Diagonal bracing
2. Let-in bracing
3. Cut-in bracing
4. All of the above

5-30. What is the rise per unit of run for a 1/4 pitch roof?

1. 12 in
2. 6 in
3. 8 in
4. 4 in

5-31. What is the rafter whose lower end rests on the top plate and whose upper end rests against a hip rafter?

1. Common
2. Valley jack
3. Hip jack
4. Cripple jack

5-32. What rafter does NOT meet either the top plate or the ridgeboard?

1. Common jack
2. Cripple jack
3. Valley jack
4. Hip jack

5-33. For what purpose are purlins used in wood frame construction?

1. To serve as a nailer for roofing
2. To act as a structural connector
3. To support rafters
4. To serve as bracing for rafters

5-34. On flat or nearly flat roofs, what type of roof covering is generally used?

1. Galvanized iron sheets
2. Asphalt shingles
3. Tile
4. Built-up

5-35. On a built-up roof, what material provides the weathering surface?

1. Asphalt shingles
2. Aggregate
3. Roofing felt
4. Asphalt binder

5-36. On a boxed cornice, what is the trim that is nailed to the rafter ends?

1. Frieze
2. Crown molding
3. Fascia
4. Plancier

5-37. A gable roof has a total of how many eaves?

1. Five
2. Two
3. Three
4. Four

5-38. What type of common siding comes in lengths of more than 4 feet and widths of 8 inches or less?

1. Bevel
2. Drop
3. Clapboard

5-39. In an attic, which of the following conditions is NOT prevented by the installation of vapor barriers and insulation?

1. Heat loss
2. Heat gain
3. Moisture seepage
4. Condensation

5-40. What elements are the two principal parts of a stairway?

1. Stringers and risers
2. Treads and risers
3. Treads and stringers
4. Stringers and nosing

5-41. What type of stairway continues in a straight line from one floor to the next?

1. Change
2. Cleat (open-riser)
3. Platform
4. Straight-flight

5-42. A platform is needed between floors in what type of stairway?

1. Straight-flight
2. Platform
3. Reverse
4. Directional

5-43. In a structure, what are the two categories of stairs?

1. Principal and service
2. Main and porch
3. Basement and attic
4. Front and rear

5-44. What stairs extend between floors above the basement and below the attic?

1. Basement
2. Porch
3. Attic
4. Principal

5-45. Which of the following types of stairs is a service stair?

1. Porch
2. Principal
3. Personnel
4. Equipment

5-46. Into what two types, if any, is finish flooring broadly divided?

1. Resilient and carpet
2. Wood and concrete
3. Resilient and wood
4. None; it is not divided

5-47. What is the primary difference between exterior and interior flush doors?

1. An exterior flush door always swings to the outside of a building
2. Exterior flush doors have a solid core
3. Plywood is never used as the outside face of an exterior flush door
4. Interior flush doors may be fabricated on the construction site, but exterior flush doors are always factory-assembled

5-48. What are the principal parts of the frame of an inside door?

1. Head jamb and side jambs only
2. Head and side jams and head and side casings
3. Sill, head jamb, and side casings
4. Sill, side jambs, and head casing

5-49. What part of a window forms a frame for the glass?

1. Casement
2. Sash
3. Frame
4. Finish

5-50. What type of window contains several horizontal hinged sashes that open and close together?

1. Casement
2. Louver
3. Jalousie
4. Double-hung

5-51. In construction drawings, the window schedule provides what type of information?

1. Type of windows
2. Size of windows
3. Number of panes of glass for each window
4. Each of the above

5-52. When the figure 6/12 appears on one of the lights in the window schedule, the dimensions of the glass are what type?

1. Nominal
2. Rough
3. Actual
4. Finish

5-53. In interior trim, which of the following items is/are considered to be the most prominent?

1. Inside door casing only
2. Window casing only
3. Inside door and window casings
4. Doorframes

5-54. In the building construction trade, which of the following items are considered to be hardware?

1. Sliding door supports
2. Fastenings for screens
3. Strike plates
4. All of the above

5-55. Of the following materials, which are considered to be finishing hardware?

1. Fastenings for screens
2. Sliding door supports
3. Folding door supports
4. Automatic exit devices

5-56. Which of the following materials is/are considered to be rough hardware?

1. Special window hardware
2. Strike plates
3. Push plates
4. Escutcheon plates

5-57. Nails are classified according to what factor(s)?

1. Use and form
2. Length and thickness
3. Composition
4. Holding power

5-58. What type of nail is made from finer wire and has a smaller head than the common nail?

1. Box
2. Finishing
3. Plasterboard
4. Roofing

5-59. What type of nail has two functions: maximum holding power and easy withdrawal?

1. Roofing
2. Finishing
3. Box
4. Duplex

5-60. Which of the following characteristics should be included in a description of a roofing nail?

1. Round shafted, galvanized, short body, large head
2. Square shafted, galvanized steel, long body, medium-sized head
3. Specially hardened steel, noncorrosive
4. Triangular shafted, nongalvanized

5-61. The body of what type of nail is usually grooved or spiraled?

1. Plasterboard
2. Concrete
3. Masonry
4. Roofing

5-62. When used to describe the length of wire nails, a penny is indicated by what symbol?

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

5-63. The thickness of a wire nail is expressed by what designation(s)?

1. Number only
2. Letter only
3. Both number and letter
4. Size

5-64. What type of a nail is longer than 6 inches?

1. Roofing
2. Spike
3. Concrete
4. Plasterboard

5-65. Wood screws are designated according to what factors?

1. Type of head and material
2. Length and thickness
3. Type of thread
4. Body diameter

5-66. When ordinary wood screws are too short or too light or where spikes do NOT hold securely, what type of screw should be used?

1. Lag bolt
2. Special purpose
3. General purpose
4. Thread-cutting

5-67. What type of screw is self-tapping?

1. wood
2. Sheet metal
3. Lag
4. Brass

5-68. Sheet metal screws can fasten metal up to what maximum thickness?

1. 28 gauge
2. 30 gauge
3. 32 gauge
4. 34 gauge

5-69. What type of screws are used to fasten metals up to one-fourth inch thick?

1. Sheet metal
2. Thread-cutting
3. Lag
4. Flathead brass

5-70. What type of bolts, because of their lack of strength, are used only for fastening light pieces?

1. Carriage
2. Machine
3. Stove
4. Expansion

5-71. Of the following types of bolts, which should be used to fasten load-bearing members?

1. Lag
2. Expansion
3. Stove
4. Carriage

5-72. What type of bolt has a square section below the head that embeds into the wood to keep the bolt from turning?

1. Carriage
2. Expansion
3. Machine
4. Stove

ASSIGNMENT 6

Textbook Assignment: "Concrete and Masonry." Pages 7-1 through 7-34.

6-1. Concrete is a synthetic construction material made by properly mixing together which of the following ingredients?

1. Water and cement only
2. Water, cement, and sand only
3. Water, cement, and gravel only
4. Water, cement, sand, and gravel or crushed stone

6-2. What is the name of the chemical reaction responsible for the hardening of concrete?

1. Dehydration
2. Hydration
3. Oxidation
4. Deoxidation

6-3. The chemical reaction that causes concrete to harden occurs between which of the following ingredients?

1. Cement and sand
2. Cement and gravel
3. Cement and water
4. Gravel and sand

6-4. What factor controls the strength, durability, and watertightness of concrete?

1. The amount of sand
2. The size and shape of the coarse aggregate
3. The proportion of sand to gravel
4. The proportion of water to cement

6-5. The tensile strength of concrete, in comparison to compressive strength, is

1. higher
2. lower
3. approximately the same

6-6. To ensure that concrete is watertight as possible, you should take which of the following actions?

1. Add more water
2. Add less water
3. Use only the amount of water required to attain the necessary workability
4. Add more sand to fill any voids

6-7. The extent to which concrete resists deterioration caused by exposure to service conditions is called

1. strength
2. compressibility
3. flexibility
4. durability

6-8. Which of the following materials are placed in concrete to produce reinforced concrete?

1. Steel bars
2. Steels rods
3. Steel strands, wire, and welded wire mesh
4. All of the above

6-9. What reinforced concrete structural member supports and distributes building loads to the ground?

1. Plain slab
2. Footing
3. Beam
4. column

6-10. In addition to the principal reinforcement, what other steel reinforcing is used in tied columns?

1. Vertical reinforcing
2. Lateral ties
3. Spiral reinforcing
4. Mats

6-11. The diameter of reinforcing bars increase from one size to the next by what increment?

1. 1/16 in
2. 1/8 in
3. 1/4 in
4. 3/8 in

6-12. Where, if anywhere, in a simple beam (a beam resting freely on two supports near its ends) is there NO stress?

1. Top
2. Bottom
3. Exact center
4. Nowhere; all areas have some stress

6-13. When a reinforcing bar is bent too sharply, what might occur?

1. The bar would crack or be weakened
2. The bar will not adhere to the concrete
3. Concrete strength would be reduced
4. Hydration would not occur

6-14. When not dimensioned on the drawings, what is the minimum length of a lap splice for (a) No. 3 bars and (b) No. 6 bars?

1. (a) 11.25 in (b) 22.50 in
2. (a) 12.00 in (b) 22.50 in
3. (a) 22.50 in (b) 12.00 in
4. (a) 22.50 in (b) 11.25 in

6-15. What pattern sizes are available in square pattern welded-wire fabric?

1. 1 by 1 in, 2 by 2 in, and 3 by 3 in
2. 2 by 2 in, 3 by 3 in, 4 by 4 in, and 5 by 5 in
3. 2 by 2 in, 3 by 3 in, 4 by 4 in, and 6 by 6 in
4. 3 by 3 in, 5 by 5 in, and 6 by 6 in

6-16. When concrete structural members are fabricated at locations other than the final position of use, they are known by what term?

1. preconstructed
2. Cast-in-place
3. Prefabricated
4. Precast

6-17. What term is concrete cast in its final position of use known by?

1. Preconstructed
2. Cast-in-place
3. Prefabricated
4. Precast

IN ANSWERING QUESTIONS 6-18 THROUGH 6-21, SELECT THE PRECAST STRUCTURAL MEMBER FROM THE FOLLOWING LIST WHICH BEST FITS THE USE DESCRIBED.

A. FLOOR OR ROOF DECK
B. DECK PANEL FOR A LARGE PIER
C. INSULATED EXTERIOR WALL

6-18. Tongue-and-groove panel.

1. A
2. B
3. C

6-19. Sandwich panel.

1. A
2. B
3. C

6-20. Double-T slab.

1. A
2. B
3. C

6-21. Channel slab.

1. A
2. B
3. C

6-22. What terms correctly refer to the small, closely spaced beams used in (a) floor and (b) roof construction?

1. (a) Joists (b) purlins
2. (a) Joists (b) joists
3. (a) Purlins (b) purlins
4. (a) Purlins (b) joists

6-23. What primary difference, if any, exists between the beams and girders?

1. Beams are shorter than girders
2. Beams are used for different purposes than girders
3. Beams are made of different material than girders
4. Nothing; they are the same

6-24. Unless the ends of beams are rectangular, most of them will be of what cross-sectional shape?

1. Single T
2. Double T
3. I
4. C

6-25. In hollow precast columns, what material is put in the core to help hold the column upright?

1. Concrete
2. Looped rod
3. Grout
4. Heavy cardboard

6-26. Of the following advantages of precasting identical concrete members, which is considered to be the most important?

1. Less required storage space
2. Faster erection time
3. Reusable forms
4. Quality-controlled concrete

6-27. Of the following descriptions, which most accurately describes pretensioning of concrete members?

1. After the concrete has been placed and has reached a specified strength, reinforcement strands are pulled through formed channels, and a predetermined amount of stress is applied
2. Reinforcement strands are pulled through inflated tubes and are stressed before placement of the concrete
3. Reinforcement strands are stressed to a predetermined point before placement of the concrete and are released just before the concrete has set
4. Reinforcement strands are placed in the forms and are stressed to a predetermined point before the concrete is placed; the strands are then released after the concrete has reached a specified strength

6-28. In what part of a prestressed beam does the tensioned steel produce high compression?

1. Upper
2. Lower
3. Exact center
4. Approximate center

6-29. What condition occurs when a load (force) is placed on a prestressed beam?

1. The camber is forced out, leaving a beam with positive deflection
2. The upward bow is increased
3. The camber is forced out, leaving a level beam with no deflection
4. The upward bow is forced out, creating deflection in the beam

6-30. What is the approximate weight of conventional concrete?

1. 175 lb/cu ft
2. 150 lb/cu ft
3. 130 lb/cu ft
4. 115 lb/cu ft

IN ANSWERING QUESTIONS 6-31 THROUGH 6-35, SELECT THE TYPE OF CONCRETE FROM THE FOLLOWING LIST THAT BEST MATCHES THE CHARACTERISTIC GIVEN.

A. HEAVYWEIGHT CONCRETE
B. SEMI-LIGHTWEIGHT CONCRETE
C. INSULATING LIGHTWEIGHT CONCRETE
D. STRUCTUTWL LIGHTWEIGHT CONCRETE

6-31. Weighs 115 to 140 lb/cu ft and has a compressive strength comparable to normal concrete.

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

6-32. Weighs 20 to 70 lb/cu ft and is used for fireproofing.

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

6-33. Weighs up to 400 lb/cu ft.

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

6-34. Weighs up to 115 lb/cu ft and is used to decrease the dead-load weight of structural members.

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

6-35. Normally has a compressive strength of 1,000 psi or less.

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

6-36. In what type of construction are concrete walls poured horizontally, lifted upright, and then secured in place?

1. Tilt-up
2. Lift-up
3. Cast-in-place
4. Prefab

6-37. In tilt-up panel construction, where is additional reinforcement generally needed?

1. At the top
2. At the bottom
3. Around the edges
4. Around any openings

6-38. For what purpose are inserts placed in the tilt-up panels?

1. For vertical support
2. For picking up or tilting
3. For extra reinforcement
4. For horizontal support

6-39. In a tilt-up panel, the inserts are installed in what manner?

1. Independent of the reinforcement
2. Tied to reinforcement
3. Welded to reinforcement
4. Tied to the panel forms

6-40. What is the strongest method of connecting panels together?

1. A butted connection using grout or gasket
2. A cast-in-place column with the panel-reinforcing steel tied into the column
3. Steel columns welded to steel angles or plates secured in the panel
4. Precast columns tied with the panel

6-41. To provide waterproofing in all panel joints, you should use what material?

1. Heavy plastic film
2. Heavy asphalt-laminated barriers
3. Polyethylene (6-mil)
4. Expansion joint

6-42. What is the purpose of contraction joints?

1. To prevent buckling due to expansion of the reinforcing steel caused by temperature changes
2. To prevent cracking due to shrinkage of the reinforcing steel
3. To prevent cracking due to shrinkage caused by temperature changes
4. To prevent buckling due to expansion of the concrete caused by temperature changes

6-43. Expansion joints are also known as what kind of joints?

1. Construction
2. Shrinkage
3. Contraction
4. Isolation

6-44. Placing plastic concrete into spaces enclosed by forms is referred to by what term?

1. Casting
2. Precasting
3. Molding
4. Premolding

6-45. The part of a wall form that shapes and retains the concrete until it sets is known by what term?

1. Brace
2. Wale
3. stud
4. Sheathing

6-46. In formwork, what devices are usually used to reinforce wall forms against concrete displacement?

1. Sheathing
2. Wales
3. Ties
4. Spreaders

6-47. Which of the followinq devices combines the functions of wire ties and wooden spreaders?

1. Tie holder
2. Snap tie
3. Tie spreader
4. Bar tie

6-48. What type of wall-form tie consists of an inner section and two threaded outer sections?

1. Snap tie
2. Bar tie
3. Tie rod
4. Tie spreader

6-49. For concrete column forms, (a) what is the name of the members that brace against bursting pressure, and (b) where is the bursting pressure greatest?

1. (a) Ties (b) middle
2. (a) Yokes (b) top
3. (a) Yokes (b) bottom
4. (a) Ties (b) top

6-50. In masonry construction, what is the most common concrete masonry unit used?

1. Concrete block
2. Clay tile
3. Stone
4. Brick

6-51. Which of the following requirements for concrete blocks measures the ability to carry loads and withstand structural stresses?

1. Absorption
2. Moisture content
3. Density
4. Compressive strength

6-52. What is the actual size, in inches, of an 8- by 8- by 16-inch CMU?

1. 7 l/2 by 7 1/2 by 15 1/2
2. 7 5/8 by 7 5/8 by 15 5/8
3. 8 by 8 by 16
4. 8 1/4 by 8 1/4 by 16 1/4

6-53. In concrete masonry construction, what part of the block is the face shell?

1. Material that forms the partitions between the cores
2. Holes between the webs
3. Long sides of the block unit
4. Recessed end of the block units

6-54. To minimize cutting and fitting, you should maximize modular planning by the use of which of the following size of block units?

1. Full-size units only
2. Half-size units only
3. Full-size and quarter-size units
4. Full-size and half-size units

6-55. Which of the following parts is best described as the solid side of a building tile?

1. Shell
2. Web
3. Cell
4. Core

6-56. In addition to the thickness of the shell and webs of tile, the compressive strength of tile depends upon which of the following factors?

1. Materials used and method of manufacture
2. The opening and cell size
3. Its resistance to abrasion
4. Its resistance to deterioration

6-57. When building tiles are used in construction that is exposed to the weather, mortar should be prepared only from which of the following materials?

1. Waterproofed cement
2. Portland cement-lime
3. Masonry cement
4. Both 2 and 3 above

6-58. The use of structural load-bearing tile is restricted by which of the following factors?

1. Fire rating of the tiles
2. Weight and sizes of the tiles
3. Availability of the material
4. Building codes and specifications

6-59. Which of the following stone masonry descriptions best describes the term “rubble”?

1. The faces of stone are square and placed in position so the finished surfaces will present a continuous plane surface appearance
2. The stones used are left in their natural state without any kind of shaping
3. The stones are unprocessed and laid in courses without consideration of size or weight
4. The stones are roughly squared and laid in such a manner to produce approximately continuous horizontal bed joints

6-60. Of the following types of stonework, which one is considered to be the crudest?

1. Coursed ashlar
2. Coursed rubble
3. Random ashlar
4. Random rubble

6-61. Which, if any, of the following materials is used in mortar mix to prevent staining of the stones?

1. Ordinary portland cement
2. White portland cement
3. Lime added to the mixed cement
4. None of the above

6-62. What standard dimensions, in inches, are of building brick?

1. 1 1/4 by 3 3/4 by 8
2. 1 1/2 by 3 3/4 by 8
3. 1 3/4 by 3 3/4 by 8
4. 2 1/4 by 3 3/4 by 8

6-63. Common brick is best described as

1. unglazed, uniform in color, and made from select clay
2. unglazed, variable in color, and made from inferior clay
3. unglazed, variable in color, and made from pit-run clay
4. glazed, uniform in color, and made from select clay

6-64. Brick that is designed to withstand exposure to below-freezing temperatures in a moist climate is what classification?

1. SW
2. MW
3. NW
4. MC

6-65. Which of the following types of brick should be used as the backing course for a cavity wall?

1. Face
2. Kiln-run
3. Glazed
4. Fire

6-66. What type of brick is made of special clay and is designed to withstand high temperatures?

1. Press
2. Clinker
3. Glazed
4. Fire

6-67. Structural bonding of brick walls causes the entire assembly to act as a single unit. This method of bonding is accomplished by which of the following means?

1. Adhesion of grout to adjacent wythes of masonry
2. Embedding metal ties in connecting joints
3. Interlocking of the masonry units
4. All of the above

6-68. The simplest pattern bond made up entirely of stretchers is referred to by what name?

1. Stack
2. Common
3. Running
4. English

6-69. In which of the following pattern bonds must you place a three-quarter brick at the corner of each header course?

1. Common
2. English
3. Block
4. Stack

6-70. An English bond pattern wall is composed of alternate courses of what types of brick?

1. Three-quarter and blind headers
2. Stretchers and bull-headers
3. Headers and stretchers
4. Headers and rigid steel ties

6-71. In masonry construction, which of the following statements best describes the term “soldier”?

1. A unit laid flat with its longest dimension perpendicular to the wall
2. A brick laid on its end so that its longest dimension is parallel to the vertical axis of the face of the wall
3. A unit laid with its longest dimension parallel to the face of the wall
4. One of the continuous horizontal layers of masonry which, bonded together, form the masonry structure

ASSIGNMENT 7

Textbook Assignment: "Mechanical Systems and Plan." Pages 8-1 through 8-24. "Electrical Systems and Plan." Pages 9-1 through 9-19. "Construction Drawings." Pages 10-1 through 10-33.

7-1. The system of pipes, fixtures, and appurtenances used inside a building for supplying water and removing wastes is known by what general term?

1. Mechanical systems
2. Plumbing
3. Water distribution
4. Piping

7-2. When working with mechanical plans, you must become familiar with which of the following codes?

1. National Plumbing Code and National Electrical Code®
2. National Plumbing Code and local NAVFAC codes
3. Local codes and National Plumbing Code
4. Local codes and ANSI codes

7-3. Copper is widely used for tubing in piping systems for which of the following reasons?

1. It is less costly than other types of pipe
2. It is available in two wall thicknesses and is faster to install
3. It does not rust and is resistant to scale particles in the pipe
4. Fittings are screwed to the pipe which allows for faster completion of the piping system

7-4. Which of the following types of copper tubing is frequently used as replacement piping because of its flexibility?

1. Type K
2. Type L, hard tempered
3. Type M
4. Type L, soft tempered

7-5. Which of the following advantages does plastic pipe have over metal?

1. Flexibility
2. High resistance to rupture and total resistance to rust
3. It can be installed either above or below ground
4. All of the above

7-6. What type of polyvinyl chloride pipe can be used in both cold-water and hot-water systems?

1. PVC
2. APVC
3. CPVC
4. PVC-C

7-7. Galvanized steel pipe sizes are based on what nominal size?

1. Inside diameter
2. Outside diameter
3. Wall thickness
4. Inside radius

7-8. What type of fitting should be used for joining straight runs of dissimilar metal pipe that require easy disconnection?

1. Union
2. Coupling
3. Dielectric union
4. Dielectric coupling

7-9. For what type of pipes should (a) solvent welded and (b) sweated joints be used?

1. (a) Galvanized (b) plastic
2. (a) Plastic (b) copper
3. (a) Plastic (b) galvanized
4. (a) Copper (b) plastic

IN ANSWERING QUESTIONS 7-10 THROUGH 7-13, SELECT THE TYPE OF VALVE FROM THE FOLLOWING LIST THAT BEST MATCHES THE DESCRIPTION GIVEN IN THE QUESTION.

A. GLOVE VALVE B. GATE VALVE C. CHECK VALVE

7-10. This valve has a wedge-shaped, movable plug that fits tightly against the seat when closed.

1. A
2. B
3. C

7-11. This valve is well suited for use when a regulated flow is required.

1. A
2. B
3. C

7-12. This valve must be operated in the fully open position.

1. A
2. B
3. C

7-13. This valve is used to prevent backflow in a pipeline.

1. A
2. B
3. C

7-14. On water mains, thrust blocks should be installed for what purpose?

1. To prevent pipe displacement caused by high water pressure
2. To prevent pipe ruptures caused by high water pressure
3. To prevent sagging due to the weight of the piping material
4. To prevent sagging due to the weight of the pipe and the water contained in the pipe

7-15. Which of the following types of piping is becoming increasingly popular for use in underground sanitary sewage systems?

1. Cast iron
2. polyvinyl chloride
3. Concrete
4. Wrought iron

7-16. To make a 22 l/2-degree change in pipe direction, what cast-iron fitting should you use?

1. Combination Y and 1/8 bend
2. 1/4 bend
3. Short sweep 1/4 bend
4. 1/16 bend

7-17. What fittings are used in waste pipe systems to catch and hold water, thereby forming a seal to prevent sewer gases from backing up into a building?

1. Traps
2. Street ells
3. Valves
4. All of the above

7-18. In what way, if any, do waste stacks differ from soil stacks?

1. Waste stacks carry human waste, soil stacks do not
2. Soil stacks carry human waste, waste stacks do not
3. Waste stacks empty into building drains, soil stacks empty into building sewers
4. None

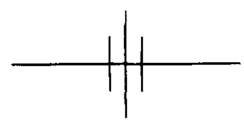
7-19. Under most local codes, what is the minimum distance that a building drain must extend beyond the building wall?

1. 2 ft
2. 3 ft
3. 6 ft
4. 10 ft

7-20. In a plumbing plan, which of the following symols should be used for a hot-water line?

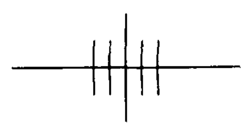
1.
2.
3. -------------------------
4.

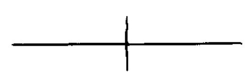
7-21. What symbol should you use to show a screwed joint in a piping plan?

1. 

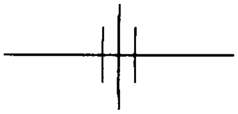
2. 

84NP0079

3. 

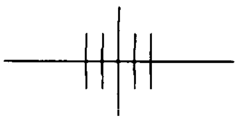
4. 

7-22. What symbol should you use to show a screwed union in a piping plan?

1. 

2. 

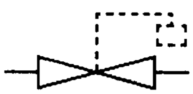
84NP0079

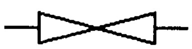
3. 

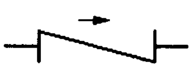
4. 

7-23. What valve symbol should you use for a gate valve?

1. 

2. 

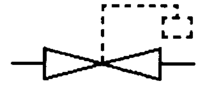
3. 

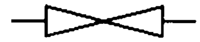
4. 

84NP0060

7-24. What valve symbol should you use for a hose valve?

1. 

2. 

3. 

4. 

84NP0060

7-25. Which of the following descriptions best defines electrical distribution?

1. The transmission of power from the power plant to the substations
2. The delivery of power from the power plants or substations through feeders and mains to the building premises
3. The interior wiring of a building
4. The overhead power lines that extend from the substations to the buildings

7-26. Most land-based power systems use what type of electrical current?

1. Indirect
2. Direct
3. Alternating
4. Variable

IN ANSWERING QUESTIONS 7-27 and 7-28, REFER TO FIGURE 9-2 IN YOUR TEXTBOOK.

7-27. The installation of a transformer between the primary and secondary main to the motor pool serves what purpose?

1. To reduce voltage
2. To increase voltage
3. To increase current flow
4. To act as a safety device

7-28. What voltage is needed to operate the single-phase motor at the motor pool?

1. 110 V
2. 220 V
3. 330 V
4. 440 V

7-29. When the voltage remains constant, what happens to amperage when (a) resistance is decreased or (b) power consumption is decreased?

1. (a) It increases (b) it decreases
2. (a) It decreases (b) it decreases
3. (a) It increases (b) it increases
4. (a) It decreases (b) it increases

7-30. Which of the following reasons is NOT an advantage of installing electrical distribution systems underground, rather than overhead?

1. Underground installation costs are less
2. Underground lines are secure against high winds
3. Underground lines are less susceptible to enemy attack
4. Underground installation provides open land areas free from distribution systems

7-31. Electrical power is brought into a building through what device or conductor?

1. Panel board
2. Switchboard
3. Service drop
4. Service entrance

7-32. What electrical device automatically opens a circuit when the amperage exceeds the rated value for that device?

1. Panel box
2. Circuit breaker
3. Switch
4. Disconnect

7-33. Compared to a No. 4 AWG conductor, the size of a No. 16 AWG conductor is

1. smaller
2. equal
3. larger

7-34. What size wire is most frequently used for interior wiring?

1. No. 16 AWG
2. No. 12 AWG
3. No. 8 AWG
4. No. 6 AWG

7-35. In which of the following locations is ROMEX NOT authorized for use?

1. Embedded in concrete
2. In garages
3. In an explosives storage building
4. All of the above

7-36. Which of the following types of insulation should be used for installation in wet locations?

1. RH
2. RHW
3. RUH
4. Each of the above

7-37. Which, if any, of the following types of insulation is considered to be suitable for use in dry locations?

1. RHW
2. T
3. TW
4. None of the above

7-38. Instead of manually making a sharp bend in rigid aluminum conduit, which of the following fittings should you use?

1. Coupling
2. Conduit union
3. Condulet
4. Galvanized steel elbow

7-39. Which of the following types of conduit can be threaded?

1. Rigid
2. PVC
3. EMT
4. Greenfield

7-40. For installing a switch, which of the following outlet boxes should you use?

1. 4-inch octagon box
2. Gem box
3. Handy box
4. 4-inch square box

7-41. The National Electrical Code® allows an outlet box to be recessed what maximum distance below the surface of a finished wall?

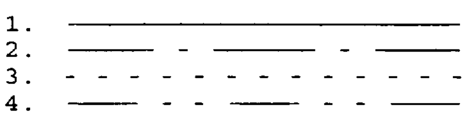
1. 1/16 inch
2. 1/8 inch
3. 1/4 inch
4. 1/2 inch

7-42. A ceiling light is controlled from two locations. To add a third location, which of the following types of switches must you use?

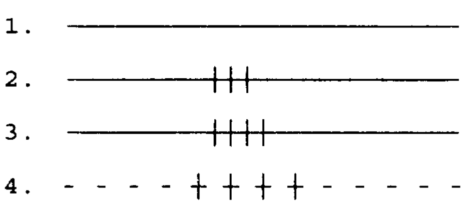
1. Single-pole
2. Two-pole
3. Three-way
4. Four-way

IN ANSWERING QUESTIONS 7-43 THROUGH 7-45, REFER TO APPENDIX IV OF YOUR TEXTBOOK.

7-43. When preparing an electrical power distribution plan, which of the following symbols should you use to show aboveground two-conductor primary service lines?



7-44. For interior wiring, which of the following symbols should you use to show a four-conductor circuit installed in a ceiling?



7-45. Which of the following definitions best describes the symbol for a special-purpose receptacle outlet?

1. A circle inscribed in a triangle
2. A circle containing a smaller inscribed circle
3. A triangle
4. A solid triangle inscribed in a circle

7-46. In general, construction drawings are categorized according to which of the following factors?

1. The methods used to prepare them
2. Their intended purpose
3. The persons who will use them
4. The persons who prepared them

IN ANSWERING QUESTIONS 7-47 THROUGH 7-50, SELECT THE TYPE OF DRAWING THAT BEST MATCHES THE DESCRIPTION OR PURPOSE GIVEN.

A.	**PRESENTATION DRAWING**
B.	**SHOP DRAWING**
C.	**WORKING DRAWING**
D.	**MASTER PLAN DRAWING**

7-47. This drawing is also known as a project drawing. A set includes general, detail, and assembly drawings.

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

7-48. This drawing is prepared for minor field work such as a small portable building.

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

7-49. A perspective drawing showing how a proposed building will appear after it is constructed.

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

7-50. This drawing is a map used in long-range planning.

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

7-51. Where in a set of working drawings should you look to find an item that was too small to appear on a foundation plan?

1. General drawings
2. Detail drawings
3. Assembly drawings

7-52. Sets of initial working drawings that are provided to a customer for review and approval before completion of the final drawings are known by what name?

1. Presentation
2. Shop
3. Preliminary
4. Concept

7-53. Both red-lined drawings and as-built drawings reflect as-built conditions. What, if anything, is the difference between them?

1. Red-lined drawings are prepared by marking-up a copy of the original drawings during construction, whereas as-built drawings are prepared by making changes to the original (or sepia) drawings during or after project completion
2. Red-lined drawings are prepared by making changes to the original drawings during construction, whereas as-built drawings are made by marking-up a copy of the original drawings after project completion
3. Red-lined drawings are prepared from the as-built drawings
4. There is no difference between red-lined and as-built drawings

IN ANSWERING QUESTIONS 7-54 THROUGH 7-56, SELECT THE PUBLICATION THAT YOU SHOULD USE TO LOCATE THE REQUESTED INFORMATION.

A.	NAVFAC P-34
B.	NAVFAC P-272, PART 1
C.	NAVFAC P-272, PART 2
D.	NAVFAC P-437

7-54. Facility and assembly drawings for pre-engineered structures used by SEABEES at advanced bases.

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

7-55. Typical floor plan arrangements provided to an A/E firm preparing project drawings.

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

7-56. The crew size required to erect a pre-engineered building assembly.

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

7-57. Project drawings are required to have which of the following attributes?

1. They must be complete
2. They must be accurate
3. They must be explicit
4. All of the above

7-58. For NAVFACENGCOM drawings, which of the following title block formats is prescribed for use on F-size sheets?

1. Vertical only
2. Horizontal only
3. Vertical or horizontal

7-59. Because of the likelihood of future size reduction, what information must be prominently placed on all drawings at the time they are prepared?

1. A numeric scale
2. A graphic scale
3. A warning stating the drawing may be reduced in size
4. Both 2 and 3 above

7-60. When performing freehand lettering on an architectural floor plan drawing, you should use (a) what type of lettering and (b) what minimum size lettering?

1. (a) uppercase (b) 0.150 in
2. (a) Lowercase (b) 0.150 in
3. (a) uppercase (b) 0.156 in
4. (a) Lowercase (b) 0.156 in

7-61. As applied to dimensioning and tolerancing of drawings, which of the following statements is NOT correct?

1. Dimensions should not be subject to more than one interpretation
2. When a dimension has a tolerance, the tolerance is always applied directly to the dimension
3. Only those dimensions necessary for complete definition should be shown
4. The use of the reference dimensions should be avoided when possible

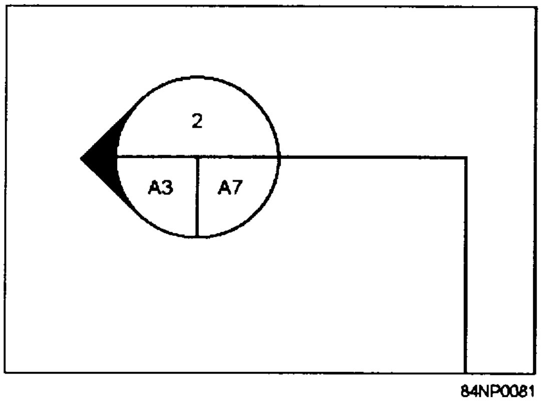


Figure 7A

IN ANSWERING QUESTIONS 7-62 AND 7-63, REFER TO THE WALL SECTION SYMBOL SHOWN IN FIGURE 7A.

7-62. What does the numeral "2" indicate?

1. The section number
2. The sheet number where the section is taken
3. The sheet number where the section is drawn

7-63. What does "A7" indicate?

1. The section number
2. The sheet number where the section is taken
3. The sheet number where the section is drawn

7-64. When using flat D-size sheets for a set of working drawings, where, on the first sheet of the set, should you place general notes?

1. Three inches below the space provided for the revision block
2. On the right side of the drawing
3. On the left side of the drawing
4. Anywhere that space permits

7-65. Of the following functions, which is NOT a function of working drawings in general?

1. To provide a basis for estimating material requirements
2. To complement the project specifications
3. To guide and instruct the construction personnel
4. To specify the type of equipment required during construction

7-66. What types of contours should be shown on a site plan drawing?

1. Existing only
2. Finished only
3. Existing and finished

7-67. On a site plan for a new building, which of the following elevations should be shown for the building?

1. Existing ground
2. Top of footing
3. Bottom of footing
4. Finished floor

7-68. At a minimum, when a new building is to be constructed parallel to the property lines, what total number of location dimensions should be shown on the site plan?

1. One
2. Two
3. Three
4. Four or more

7-69. In what main division of a set of project drawings for a new building should you look to find the types and sizes of the windows?

1. Civil
2. Architectural
3. Structural
4. Mechanical

7-70. To find the size and placement of reinforcing steel in the grade beams for a building, you should look in what main division of the drawings?

1. Civil
2. Architectural
3. Structural
4. Mechanical

7-71. In what main division should you look to find the ceiling height of each room in a building?

1. Civil
2. Architectural
3. Structural
4. Mechanical

7-72. For construction drawings, the dimension lines are always drawn broken for the insertion of the numerals.

1. True
2. False

7-73. When dimensioning a floor plan for a CMU building, you should dimension the interior block partitions in which of the following ways?

1. Face to face only
2. Center to center only
3. Face to center
4. Either face to face or center to center, depending upon your preference

7-74. In a set of drawings, a jamb detail provides the best graphical presentation of the framing and trim located above a door.

1. True
2. False

7-75. Which of the following divisions should contain a schedule of air-conditioning equipment used in a building?

1. Architectural
2. Structural
3. Mechanical
4. Plumbing

ASSIGNMENT 8

Textbook Assignment: "Elements of Surveying and Surveying Equipment." Pages 11-1 through 11-49.

8-1. In surveying, the relative horizontal positions of points are determined in relationship to which of the following elements-measured in the field?

1. Only from distances
2. Only from directions
3. From either distances or directions
4. From both distances and directions

8-2. In surveying, the vertical position of a point is determined in which of the following ways?

1. By measuring directly from a datum
2. By measuring indirectly from a da turn
3. By computation from differences in elevation that are measured directly or indirectly from a datum

8-3. In regard to results obtained with plane surveying methods, increasing the areas surveyed will have what effect on (a) accuracy and (b) precision?

1. (a) Increase (b) decrease
2. (a) Decrease (b) decrease
3. (a) Decrease (b) increase
4. (a) Increase (b) increase

8-4. When is a survey considered to be a geodetic survey?

1. When the earth's curvature must be considered
2. When the surface surveyed is water
3. When the data from the survey will be used for mapping
4. When the survey is either a ground or an aerial survey

IN ANSWERING QUESTIONS 8-5 THROUGH 8-9, SELECT THE TYPE OF SURVEY THAT SHOULD BE USED TO ACCOMPLISH THE TASKING DESCRIBED.

A. TOPOGOPHIC SURVEY
B. CONSTRUCTION SURVEY
C. ROUTE SURVEY
D. LAND SURVEY

8-5. Reestablishing an old property boundary from missing monuments.

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

8-6. Determining the directions and elevations of a new highway.

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

8-7. Laying out the corners of a new building.

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

8-8 Gathering data about the natural and man-made features of the land.

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

8-9 Gathering information needed to prepare as-built drawings for a completed project.

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

8-10. Which of the following types of surveys is also known as an engineering survey?

1. Route
2. Construction
3. Topographic
4. Cadastral

8-11. In surveying practice, which, if any, of the following tasks is considered to be an element of office work?

1. Computing and plotting necessary information
2. Taking measurements
3. Collecting engineering data
4. None of the above

8-12. When engineering data for a SEABEE construction project is being collected, which of the following items or information should be considered?

1. Climatology in the local area of the project site
2. Availability of labor and materials
3. Accessibility of construction equipment to the project site
4. All of the above

8-13. In general, which, if any, of the following actions will best predetermine field conditions and allow the selection of methods to be used for a survey?

1. Reviewing topographic maps
2. Site reconnaissance
3. Checking local weather conditions
4. None of the above

8-14. Which of the following factors makes the difference between a good surveyor and an exceptional surveyor?

1. The ability to collect data quickly
2. Consistent accuracy in fieldwork
3. The ability to exercise sound and mature common sense
4. The habit of ensuring that all survey results are verified before acceptance

8-15. Which of the following conditions must be considered when you determine the size of a field survey party?

1. The availability of equipment
2. The methods that will be used
3. The requirements of the survey
4. All of the above

8-16. A transit party should consist of at least what three persons?

1. Instrumentman, rodman, and note keeper
2. Rodman, head chainman, and party chief
3. Instrumentman, head chainman, and note keeper
4. Party chief, head chainman, and instrumentman

8-17. In a plane table party, the party chief functions as what team member?

1. Topographer
2. Rodman
3. Computer
4. Head chainman

8-18. In field notebooks, all lettering should be performed in a freehand Gothic style with which of the following grades of pencil lead?

1. 2H or 3H
2. 3H or 4H
3. 4H or 5H
4. F

IN ANSWERING QUESTIONS 8-19 THROUGH 8-21, SELECT THE PART OF THE FIELD NOTEBOOK FROM THE FOLLOWING LIST THAT SHOULD CONTAIN THE INFORMATION DESCRIBED.

A. FRONT COVER
B. INSIDE FRONT COVER
C. RIGHT-HAND PAGES

8-19. Name and location of the project, the types of measurements, and the designation of the survey unit.

1. A
2. B
3. C

8-20. List of party personnel and their duties.

1. A
2. B
3. C

8-21. Instructions for returning the notebook if it is lost.

1. A
2. B
3. C

8-22. In keeping field notes, which of the following procedures is/are mandatory?

1. Notes are never kept on individual scraps of paper for later transcription to notebooks
2. Erasures are never permitted; incorrect entries are lined-out and correct entries inserted
3. Rejected pages are neatly crossed-out and referenced to the substituted pages
4. All of the above

8-23. In a measured distance that required 200 measurements, the total error was -9 units. For this error to be adjusted, each measurement must be

1. increased by 0.450
2. increased by 0.045
3. decreased by 0.450
4. decreased by 0.045

8-24. A measured distance is 302.12 feet. This measurement contains what total number of significant figures?

1. Five
2. Two
3. Three
4. Four

8-25. If you round off 92.454 to three significant figures, what is the resulting number?

1. 92.4
2. 92.5
3. 92.40
4. 92.50

8-26. When drawing a property map, you should include which of the following items?

1. The length and direction of each boundary line
2. Reference points referred from an established coordinate system
3. Names of important details, such as roads, streams, and landmarks
4. All of the above

8-27. In an orientation symbol, a full-head arrow represents what direction or orientation information, if any?

1. Magnetic meridian
2. True meridian
3. Magnetic declination
4. None

8-28. Which of the following factors will influence the orientation of a map drawn on standard size drawing paper?

1. The shape of the mapped area
2. The size of the mapped area
3. The scale of the map
4. The purpose of the map

8-29. A map that should be used for making a model of an 18-hole golf course is known as what type?

1. Geographic
2. Planimetric
3. Topographic

8-30. An ordinary road map of the state of Florida is an example of what type of map?

1. Geographic
2. Planimetric
3. Topographic

8-31. A naval station base map that shows only the layout of buildings and roads is what type of map?

1. Geographic
2. Planimetric
3. Topographic

8-32. The various parts of a transit are divided into three major groups. Which of the following is NOT a major group?

1. Telescopic assembly
2. Upper plate assembly
3. Lower plate assembly
4. Leveling assembly

8-33. What part of a transit contains the graduated scale for determining the value of horizontal angles?

1. Upper plate
2. Lower plate
3. Alidade
4. Leveling head

8-34. What part of a transit is used for slow motion movement when the telescope is being centered on an object?

1. Clamp
2. Lower motion screw
3. Upper motion screw
4. Tangent screw

8-35. In addition to the two plate-level vials, the transit has a third level vial. What is the third vial used to level?

1. Tripod head
2. Standard
3. Footplate
4. Telescope

8-36. What part of a transit is graduated from 0° to 90° in four quadrants?

1. Horizontal circle
2. Vertical circle
3. A-vernier
4. Double vernier

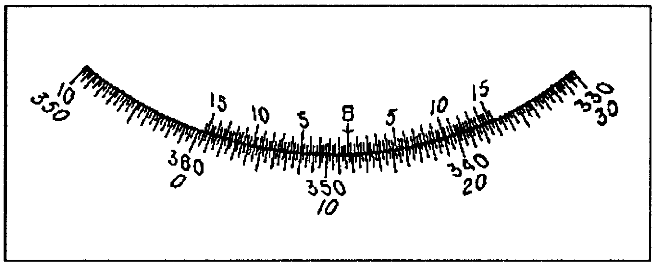


Figure 8A

IN ANSWERING QUESTIONS 8-37 AND 8-38, REFER TO FIGURE 8A.

8-37. The least reading of the horizontal scale shown is

1. 20 seconds
2. 30 seconds
3. 45 seconds
4. 1 minute

8-38. Reading clockwise, the vernier reads

1. 11°36′00″
2. 28°30′00″
3. 348°20′00″
4. 351°45′00″

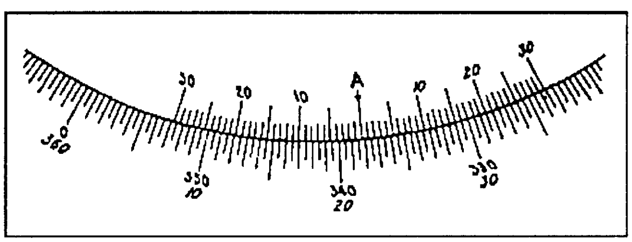


Figure 8B

IN ANSWERING QUESTIONS 8-39 AND 8-40, REFER TO FIGURE 8B.

8-39. The least reading of the horizontal scale shown is

1. 20 seconds
2. 30 seconds
3. 45 seconds
4. 1 minute

8-40. In a counterclockwise direction, the vernier reads

1. 341°45′
2. 338°15′
3. 39°10′
4. 21°47′

8-41. For a 1-minute theodolite, which of the following actions occur when the circle clamp is in the lever-down position?

1. The circle is clamped and turns with the telescope
2. The circle is clamped and the telescope turns independently
3. The circle is unclamped and the telescope turns independently
4. The circle is unclamped and turns with the telescope

8-42. The lower half of the vertical line on the reticle of a theodolite is split for what purpose?

1. To center triangular-shaped distant objects
2. To determine the width of distant objects
3. To center small distant objects
4. To determine the height of distant objects

8-43. What part of an engineer's transit serves the same function as the tribrach of the theodolite?

1. Leveling assembly
2. Lower plate
3. Upper plate
4. Standard

8-44. What are the values read from the vertical circle of a theodolite called?

1. Vertical angles
2. Direct angles
3. Zenith distances
4. Direct distances

8-45. What part of a one-second theodolite is used to select whether the angle being read is a vertical or horizontal angle?

1. Circle tangent screw
2. Inverter knob (circle-selector)
3. Circle setting knob
4. Circular level

8-46. The difference between two diametrically opposite members on the circle of a one-second theodolite as viewed through the circle reading microscope is equal to plus or minus how many degrees?

1. 90°
2. 180°
3. 270°
4. 360°

8-47. What is the main difference between a wye level and a dumpy level?

1. Their magnifying power
2. The way they are used in the field
3. The way their telescopes are attached to the horizontal (level) bar
4. The way their horizontal bars are attached to the leveling head

8-48. What part(s) of a telescope should you adjust to bring the cross hairs and the object into clear focus?

1. Eyepiece
2. Focusing knob
3. Both 1 and 2 above
4. Reticle adjusting screw

8-49. The bubble of a level vial on a surveying instrument may become increasingly difficult to center because of what factor?

1. Temperature
2. Vial age
3. Humidity
4. Vial sensitivity

8-50. On a tilting level, which of the following screws is used to bring the bubble to the exact center?

1. Tangent
2. Micrometer
3. Leveling
4. Centering

8-51. You are setting up a military level. You can accomplish preliminary leveling by using which of the following parts?

1. The level vial and circular bubble
2. The leveling screws and the micrometer drum
3. The leveling screws and the circular bubble
4. The leveling screws and the level vial

8-52. The purpose of the compensator in a self-leveling level is to compensate for which of the following factors?

1. Misalignment of the vertical hair only
2. Misalignment of the horizontal hair only
3. Misalignment of both the vertical and horizontal hairs
4. A slight out-of-level of the telescope

8-53. In surveying, what instrument is often called the universal survey instrument?

1. Theodolite
2. Engineer's transit
3. Wye level
4. Automatic level

8-54. The Abney hand level differs from the plain hand level in that it has what additional part?

1. A spirit level
2. An eyepiece
3. An optical telescope
4. A graduated arc

8-55. Which of the followinq advantages does use of the plane-table and alidade provide over use of other surveying instruments?

1. The need to measure horizontal distances is eliminated
2. The need to measure vertical and horizontal angles is eliminated
3. Both 1 and 2 above
4. A completed sketch or map manuscript is produced in the field

8-56. Which of the following methods can be used to orient a plane table during fieldwork?

1. A transit
2. A magnetic compass
3. Sight on a point whose position is plotted on the plane table
4. Either 2 or 3 above, depending on preference

8-57. What is the maximum angle above the horizontal that a telescopic alidade is capable of measuring?

1. 15°
2. 30°
3. 45°
4. 60°

8-58. Which of the following alidade attachments is used for accurate leveling of the line of sight?

1. Circular level
2. Striding level
3. Right-angle prism
4. Vertical circle scale

8-59. What type of assembly, when attached to the alidade, makes it possible to determine horizontal distances and differences in elevation by the stadia method?

1. Ball and socket
2. Optical reading
3. Stadia arc
4. Exterior arc

8-60. Which of the following tools should you use when clearing away small saplings and vines?

1. Chain saw
2. Brush hook
3. Coping saw
4. Bull point

8-61. Which of the following tools is best suited for driving pipe markers into asphalt surfaces?

1. A hatchet
2. A single bit ax
3. A sledgehammer
4. A bull point

8-62. Which of the following tools should you use to lift a manhole cover?

1. A long-handled shovel
2. A crowbar
3. A long-bladed screwdriver
4. A machete

8-63. Which, if any, of the following devices is used to locate buried metal markers?

1. Dip needle
2. Mine detector
3. Probing steel
4. None of the above

8-64. Which of the following tapes should be used for the high-precision measurement of a base line that is in the vicinity of a high-voltage circuit?

1. Metallic
2. Nonmetallic
3. Steel
4. Invar

8-65. To run a traverse in steep terrain on a windy day, which of the following tripods should you use to support the transit?

1. Stilt-leg
2. Wide-frame rigid
3. Wide-frame jack-leg
4. Jack-leg

8-66. After you secure the restraining strap, what is the next step in setting up a tripod?

1. Hold one leg only close to your body
2. Hold two legs close to your body
3. Spread the legs 60° apart
4. Spread the legs until they form about a 50° to 60° angle with the horizontal

8-67. Which of the following actions is NOT a proper way to care for a tripod?

1. Applying pressure across the tripod legs when pressing the tripod into the ground
2. Adjusting the hinge joint without overtightening
3. Applying a light coat of oil on the metal parts of the tripod
4. Applying pressure along the tripod legs when pressing the tripod into the ground

8-68. The effectiveness of the plumb bob, cord, and target set as a precision instrument will be most impaired by what condition?

1. Faded paint on the target
2. Dust on any part of the set
3. A damaged or bent tip on the plumb bob
4. A worn leather sheath

8-69. Which of the following tape accessories should be used to hold the tape securely at an intermediate point?

1. Tape clamp handle
2. Tension scale
3. Taping stool
4. Staff

8-70. In high-precision measurement, which of the following tape accessories should be used to mark accurately the distance indicated by the tape graduation?

1. Tension scale
2. Taping stool
3. Staff
4. Tape thermometer

8-71. When target reading is being performed, what survey party member reads the rod?

1. Chainman
2. Instrumentman
3. Flagman
4. Rodman

8-72. During leveling operations, in which of the following soil conditions should you use a turning point plate?

1. Sandy or muddy soil
2. Compacted gravel
3. Ordinary stable soils
4. Rocky pasture land

8-73. The type of material to be used for survey point markers depends upon which of the following conditions?

1. The location of the point
2. Whether the point is temporary or permanent
3. Both 1 and 2 above
4. The discretion of the engineer officer

8-74. Which of the following types of markers is/are generally used for horizontal and vertical control stations?

1. Iron pipe filled with concrete
2. Bronze disks set in concrete
3. A hole drilled in concrete and filled with lead
4. Each of the above

8-75. What method should you use to permanently mark a station located on an asphaltic concrete surface?

1. Nail a spad into the surface
2. Drive a railroad spike into the surface
3. Spot paint the surface
4. Drive a wooden hub into the surface

ASSIGNMENT 9

Textbook Assignment: "Direct Linear Measurements and Field Survey Safety." Pages 12-1 through 12-32.

9-1. The instrumentman is moving his right arm, which is extended upward, to the right. What message is he signaling to the rodman?

1. The rodman must move the rod to the right
2. The rodman must move the top of the rod to the right until it is vertical
3. The rodman must move the rod to the left
4. The rodman must move the top of the rod to the left until it is vertical

9-2. An instrumentman extends both arms upward, what does this indicate to the rodman?

1. Move forward
2. Reverse the rod
3. Pick up the instrument
4. Face the rod

9-3. What actions should the rodman take in response to a boost-the-rod signal?

1. Raise the rod and hold it at a specified distance above the ground
2. Turn the rod upside down
3. Raise the rod slowly until the instrumentman has read the whole-foot mark
4. Move the top of the rod, in a short arc, towards the instrument

9-4. The instrumentman extends both arms out horizontally from his shoulders and waves them up and down. What message is he giving to the rodman?

1. Come in
2. Pick up the instrument
3. All right
4. Move forward

9-5. In clearing a chaining line, what should you do when a valuable tree lies directly in your path?

1. Triangulate around it
2. Find the owner and request the tree to cut down
3. Cut it down
4. Choose a different chaining line

9-6. What term is used to describe consecutive sights taken through a telescope for the purpose of keeping chainmen on line?

1. Running line
2. Bench mark
3. Foresight
4. Backsight

9-7. When an instrumentman takes a sight along a portion of a line that has already been run, he is taking a

1. horizontal control step
2. vertical control step
3. foresight
4. backsight

9-8. For what reason should a chainman use an indicator that is narrower than a range pole when holding on or plumbing over a point for short sights?

1. To enable the instrumentman to align the indicator exactly with the vertical cross hair of his instrument
2. To enable the instrument to sight beyond the point
3. To enable the chainman to carry out his duties without becoming fatigued
4. To enable the chainman to hold the indicator steady

9-9. When running a line from point A to point B, what action does the instrumentman take when he "plunges" the telescope?

1. Turns the telescope 180° to the right from a sight on point A to a sight on point B
2. Rotates the telescope vertically from a sight on point A to a sight on point B
3. Turns the telescope 180° to the left from a sight on point A to a sight on point B
4. Moves the telescope from point A to point B

9-10. When plumbing over a point, which of the following actions should you take to overcome the problem of wind blowing the plumb bob back and forth?

1. Rest the point of the plumb bob on the point being plumbed
2. Bounce the point of the plumb bob slightly up and down on the point being plumbed
3. Shorten the plumb bob cord
4. Have a second person hold the point of the plumb bob steady on the point being plumbed

9-11. You should mark the horizontal location of a point over which to plumb a transit by which of the following means?

1. A flag or chaining pin
2. A leveling rod or range pole
3. A precise marker driven or set in the top of a hub
4. A bull-point or spad

9-12. Survey control points are marked in the field by which of the following means?

1. Bronze disks set in concrete
2. Center-punched metal rods driven flush with the ground
3. Wooden stakes or soda pop tops and nails driven flush with the ground
4. Each of the above

9-13. In addition to an identifying symbol, what marking is usually placed on a bench mark constructed by surveyors to identify a point for a construction project?

1. The abbreviation for bench mark, BM
2. The elevation of the bench mark
3. A number showing the order in which the bench mark is to be considered
4. A number denoting the distance of the bench mark from the point of beginning

9-14. As survey control points are established in the field, in what manner are they recorded in the field notebook?

1. By sketch
2. By word description
3. By either 1 or 2, or a combination of both
4. By detailed drawing

9-15. When an important station is marked with a hub, measurements are made to one or more other points and recorded in a field notebook to assure what information?

1. The hub can be relocated if plowed up and displaced
2. The hub location is precisely determined
3. The reference points are located accurately
4. The elevation of the hub can be determined

9-16. A hub can be made conspicuous to operators of earthmoving equipment by which of the following methods?

1. Casting a monument over the hub
2. Flagging or barricading
3. Marking the hub with a tack
4. Elevating the hub

9-17. What tool is used to mark a terminal point in a chaining operation when the distance being measured is greater than the tape length?

1. Surveyor's arrow
2. Chaining pin
3. Philadelphia rod
4. Range pole

9-18. In a three-man chaining party operation, who keeps a complete record of all measurements made by the party?

1. Head chainman
2. Rear chainman
3. Stretcherman
4. Instrumentman

9-19. In beginning a horizontal chaining operation, the rear chainman, with one chaining pin, stations himself at the starting point. The head chainman then moves toward the distant point to be measured holding (a) what part of the tape, and (b) a total of how many chaining pins?

1. (a) The 100-ft end (b) 1
2. (a) The 100-ft end (b) 10
3. (a) The zero end (b) 1
4. (a) The zero end (b) 10

9-20. When the tape is pulled forward for measuring the next 100-foot increment , what becomes of the chaining pins that were stuck in the ground by the head chainman and rear chainman?

1. Both pins are pulled and carried to the next stations
2. The head chainman leaves his pin in the ground; the rear chainman pulls and carries his pin
3. The head chainman pulls and carries his pin; the rear chainman leaves his pin in the ground
4. Both pins are left in the ground

9-21. When the head chainman runs out of chaining pins, what total number of pins should the rear chainman have?

1. 0
2. 1
3. 9
4. 10

9-22. Which of the following devices helps you apply the correct tension to a tape that is supported at its ends only?

1. Taping stool
2. Spring balance
3. Scissors clamp
4. Chaining buck

9-23. Including the O-foot mark, a total of how many whole-foot marks are contained on a 100-foot plus tape?

1. 99
2. 100
3. 101
4. 102

9-24. You are measuring the exact length of a building using a minus tape. What is the length of the building if you are holding a 65-foot mark at the outer face of the end wall when the head chainman calls out “Minus point three six”?

1. 63.64 ft
2. 64.36 ft
3. 64.64 ft
4. 65.36 ft

9-25. When slope chaining, which of the following information can you obtain by direct reading?

1. Slope angle only
2. Slope angle and slope distance
3. Horizontal distance only
4. Slope angle and horizontal distance

9-26. In horizontal chaining operations, a call of “Mark” from the rear chainman signals the head chainman to take which of the following actions?

1. Pull the end of the tape
2. Stick a chaining pin into the ground
3. Measure the tension on the tape
4. Release his plumb bob

9-27. Two men are making a horizontal measurement on a slope. The chainman on the lower level determines at what height the chainman on the higher level will hold his tape by using what instrument?

1. A transit
2. A theodolite
3. A hand level
4. A plumb bob

9-28. In which of the following situations should the breaking tape method of measuring be used?

1. Determining the horizontal distance between points on terrain havinq a 6-to-1 slope ratio
2. Measuring the width of major access roads
3. Measuring horizontal distances in heavily wooded and obstructed areas
4. All of the above

9-29. A two-man party is using the breaking chain-procedure and a 100-foot tape to chain a line on a steep slope. When, if ever, does the rear chainman give the front chainman a chaining pin?

1. Each time a 25-ft distance only is measured
2. Each time a 50-ft distance only is measured
3. Each time an even-foot distance of less than 100 ft is measured
4. Never

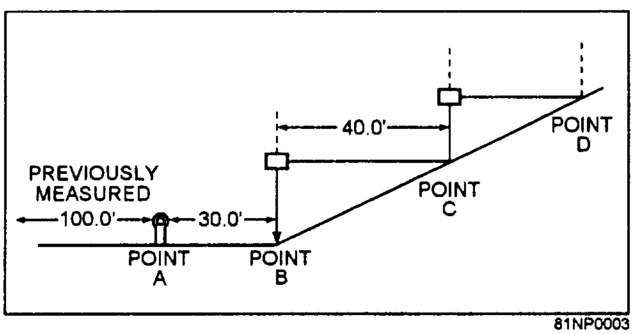


Figure 9A

IN ANSWERING QUESTION 9-30, REFER TO FIGURE 9A.

9-30. Assume that you continue measuring up the slope with a 100-foot tape. The head chainman is holding zero at point D. What is the horizontal distance between points C and D?

1. 10 ft
2. 15 ft
3. 25 ft
4. 30 ft

9-31. The standard error of a 100-foot tape can be determined in which of the following ways?

1. By calibration by the Bureau of Standards
2. By comparison with a length of a calibrated 100-foot tape
3. By comparison with a known 100-foot distance
4. By each of the above means

9-32. By calibrating a tape, you should remember that the standard tension and corresponding temperature for a 100-foot tape supported throughout is

1. 5 lb, 65°F
2. 10 lb, 68°F
3. 15 lb, 68°F
4. 20 lb, 65°F

9-33. A 100-foot tape has a standard error of 0.003 feet. What is the total error for a taped distance of 471.56 feet? (Round off to the nearest 0.01 foot.)

1. 0.00 ft
2. 0.01 ft
3. 0.02 ft
4. 0.05 ft

9-34. Under standard conditions, a tape indicates 100.00 feet when it actually should measure 99.996 feet . Using this tape, how far should you measure to set a point 450 feet away from another point?

1. 449.96 ft
2. 449.98 ft
3. 450.02 ft
4. 450.04 ft

9-35. A tape has a standard error which causes it to indicate 99.996 feet when it is actually measuring 100.00 feet. What is the actual distance between two points if the taped distance is 259.05 feet?

1. 259.04 ft
2. 259.05 ft
3. 259.06 ft
4. 260.00 ft

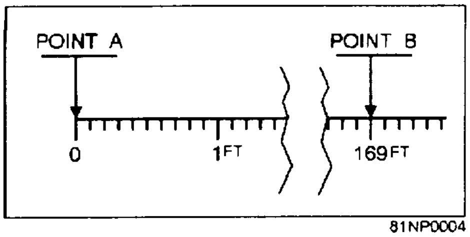


Figure 9B

IN ANSWERING QUESTIONS 9-36 and 9-37, REFER TO FIGURE 9B.

9-36. The steel tape shown is used to lay out the distance from point A to point B. If the thermometer attached to the tape reads 79°F, what is the actual distance laid to offset the effect of change in temperature?

1. 168.09 ft
2. 168.99 ft
3. 169.01 ft
4. 169.07 ft

9-37. At another time, the steel tape shown is used to measure the distance from point A to point B, but this time, the thermometer reads 35°F. How much should you add or subtract to the measurement in order to compensate for the change in temperature?

1. Add 0.02 ft
2. Subtract 0.02 ft
3. Add 0.04 ft
4. Subtract 0.04 ft

9-38. A 3-pound, 100-foot tape is used to measure a distance of 60 feet. If the chainman maintained a pull of 20 pounds, what is the correction of sag?

1. 0.02 ft
2. 0.03 ft
3. 0.04 ft
4. 0.05 ft

9-39. When is slope correction subtracted from the taped slope distance?

1. When taping uphill only
2. When taping downhill only
3. When applying the slope correction formula for 10% slopes Only
4. Always

9-40. When determining accurate slope correction, what is the maximum slope for which you should use this formula?

$$C_h = \frac{h^2}{2s}$$

1. 5%
2. 10%
3. 20%
4. 30%

9-41. The difference in elevation between two points is 4.0 feet. If the slope distance between the points is 125.00 feet, what is the horizontal distance?

1. 124.936 ft
2. 124.978 ft
3. 125.032 ft
4. 125.064 ft

9-42. Rules pertaining to the taking of chaining notes require that the notes reflect which of the following qualities?

1. Completeness
2. Accuracy
3. Legibility
4. All of the above

9-43. What is the proper way to correct an error in field notes?

1. Erase the error
2. Blot out the error
3. Draw a line through the error and enter the correct information above
4. Circle and initial the error

IN ANSWERING QUESTION 9-44, REFER TO FIGURE 12-17 IN YOUR TEXTBOOK.

9-44. What three types of corrections are made in the slope chaining measurements?

1. Tension, temperature, and humidity
2. Altitude, temperature, and wind
3. Hub, bench mark, and station
4. Tape, temperature, and slope

9-45. In which of the following ratios do the lengths of the sides indicate that the triangle is a right triangle?

1. 10:15:20
2. 18:24:30
3. 20:30:40
4. 25:30:40

IN ANSWERING QUESTION 9-46, REFER TO FIGURE 12-18 IN YOUR TEXTBOOK.

9-46. Assume that you are laying out a right angle, but you are using a 50-foot tape instead of a 100-foot tape, and the distance from D to C is 15 feet. You then set the tape with its 0-foot end on D and its 50-foot end on C. Your 50-foot tape will form two legs of a right triangle if the man running out the bight draws the tape taut while holding the 25-foot mark in contact with what other mark?

1. 20-ft mark
2. 30-ft mark
3. 35-ft mark
4. 40-ft mark

9-47. Computing the size of an angle by the chord method involves the partial solution of a triangle in which the only known values are which of the following measurements?

1. The sizes of two angles
2. The lengths of the sides
3. The sizes of two angles and length of one side
4. The lengths of two sides and the size of one angle

9-48. What method of computing the size of an angle X involves the partial solution of a right triangle in which X is an acute angle and two sides of the triangle (the side opposite X and the side adjacent to X) are measured?

1. Chord method
2. Sine method
3. Tangent method
4. Sum of squares method

9-49. Reading a tape upside down and obtaining, for example, 69 instead of 96 and leaving out an entire tape length are samples of

1. natural errors
2. instrumental errors
3. personal errors
4. mistakes

9-50. Concerning the care of steel tapes, three of the following statements represent correct guidelines. Which one does NOT?

1. Whenever a tape is laid across a gravel road, all drivers should be warned to slow their vehicles down before crossing over the tape
2. While dragging the tape, the head chainman should not ask someone else to help by picking up the free end
3. When given a choice between a tape which has a kink and one which does not, you should use the undamaged one when possible
4. When dragging a tape, keep it straight

9-51. In caring for and maintaining his steel tapes, a chainman should make it a practice to take which of the following steps?

1. Inspect all tapes weekly
2. Wipe them dry before storing them
3. Coat them from time to time with light rust-resistant oil
4. All of the above

9-52. Listed are the steps for splicinq a broken steel tape. Identify the proper sequence.

A. Align and rivet the repair stock at one end of the break.
B. Insert one rivet at a time and arrange rivets in a triangular pattern.
C. Place the repair stock on the face of the other section of the tape, using the calibration section as a measure for the break splice.
D. Use a three-edge file to partially cut through the surplus stock.

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

9-53. In which of the following ways are microwave and light wave EDM devices the same?

1. Both have interchangeable transmitters and receivers
2. Both require the application of corrections for atmospheric conditions
3. Both are used for the direct measurement of distances
4. Both should be used for only short distances of less than 600 feet

9-54. Which of the following descriptions is characteristic of most poisonous snakes found on the North American continent?

1. Brightly colored
2. Smaller than nonpoisonous snakes
3. Flat headed and thick bodied
4. Equipped with tail rattles

9-55. What North American poisonous snake shows its white inside mouth lining just before striking?

1. Copperhead
2. Rattler
3. Coral
4. Water moccasin

9-56. What symptom is usually the first to be noticed by someone who has come in contact with poison ivy or poison oak?

1. A cluster of large blisters
2. A deep red rash
3. An extreme itching
4. A cluster of small blisters

9-57. A poisonous plant has a juice that is nonvolatile. This means this plant is poisonous and the juice of this plant will

1. evaporate quickly
2. not stain clothing
3. not evaporate quickly
4. not nifect a person unless he atually touches the plant

9-58. Poisonous sumac can be distinguished from nonpoisonous sumac in what way?

1. It bears red berries
2. It has more leaves
3. It bears white fruit
4. It grows closer to the ground

9-59. The first-aid procedure for plant poisoning of the skin consists of which of the following steps?

1. Soaping and rinsing frequently
2. Applying a light coat of oil
3. Obtaining immediate medical care
4. Soaping with an alkaline laundry soap and not rinsing off

9-60. Of the following accident prevention guidelines or measures, which one is the most important to remember?

1. Never swing a machete within 10 ft of another person
2. Most accidents can be prevented by the application of common sense and good judgment
3. Never work in or on trees during high wind or thunderstorms
4. Properly sharpened axe blades are safer than blunt or nicked ones

9-61. While surveying, the members of a field party must work on and near a heavily traveled highway that they are forced to cross several times a day. They can reduce the danger of being struck by a moving vehicle by taking which of the following precautions?

1. Wearing brightly colored outer clothing
2. Detouring traffic away from the field party
3. Erecting conspicuous signs and barriers
4. All of the above

ASSIGNMENT 10

Textbook Assignment: "Horizontal Control." Pages 13-1 through 13-30.

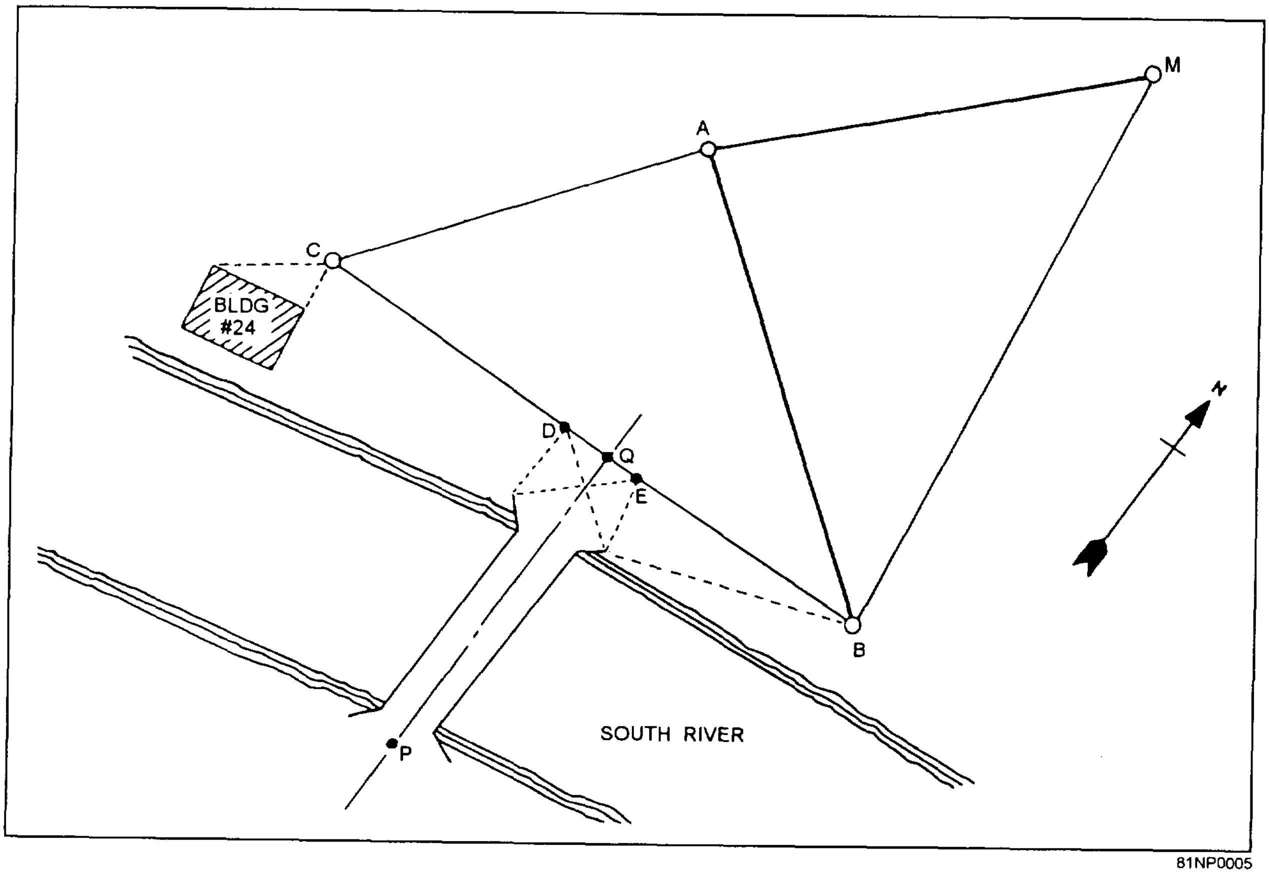


Figure 10A

IN ANSWERING QUESTIONS 10-1 THROUGH 10-3, REFER TO FIGURE 10A. POINT M IS A TRIANGULATION STATION MONUMENT.

10-1. What part of the triangulation network is the main control traverse?

1. △ ABM
2. △ ABC
3. △ CBM

10-2. What part of the network is the supplementary control traverse?

1. △ ABM only
2. △ ABC
3. △ CBM
4. △ ABM and line AC

10-3. What part of the network is the control line?

1. AM
2. AC
3. AB
4. BC

10-4. Direction measured between a traverse line and the preceding traverse line extended is direction by which of the following methods?

1. Azimuth
2. Exterior agle
3. Interior angle
4. Deflection angle

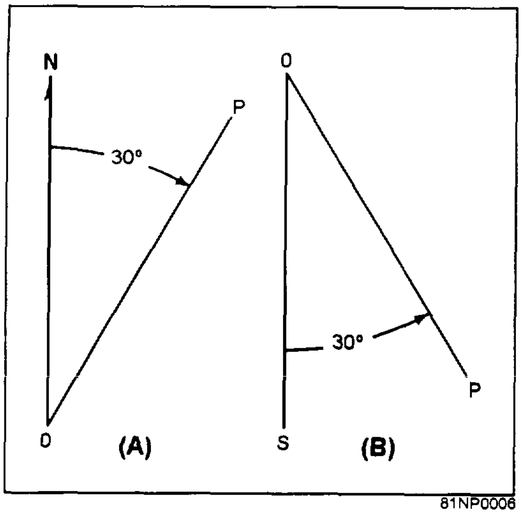


Figure 10B

IN ANSWERING QUESTION 10-5, REFER TO FIGURE 10B.

10-5. What are the respective bearings of traverse lines OP in A and B?

1. N30°E and S30°W
2. S30°W and N30°W
3. S30°E and N30°E
4. N30°E and S30°E

10-6. The bearing of line AB in a traverse is S27°26′W and the bearing of line BC is N10°17′W. What is the deflection angle between AB and BC?

1. 37°43′
2. 79°42′
3. 141°60′
4. 142°17′

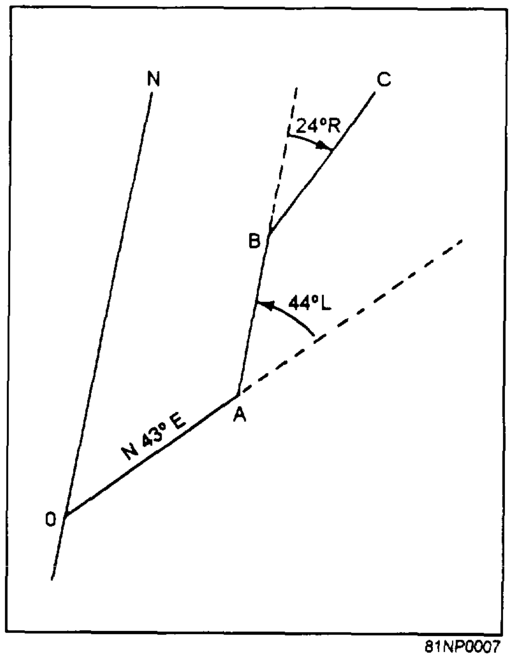


Figure 10C

IN ANSWERING QUESTION 10-7, REFER TO FIGURE 10C.

10-7. The directions of traverse lines AB and BC are indicated by deflection angles. Determine the bearing of BC.

1. N1°E
2. N20°E
3. N23°E
4. N43°E

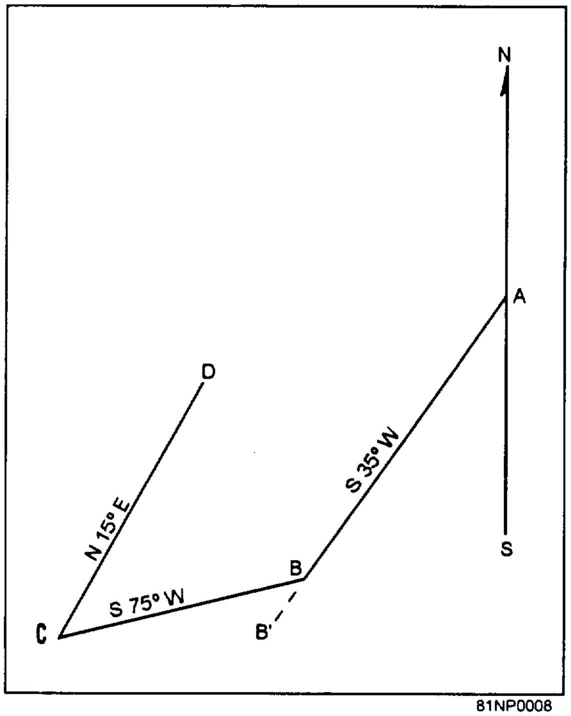


Figure 10D

IN ANSWERING QUESTIONS 10-8 THROUGH 10-10, REFER TO FIGURE 10D.

10-8. What is the size of the deflection angle between traverse lines BC and CD?

1. 60°
2. 90°
3. 105°
4. 120°

10-9. How many degrees are there in the exterior angle ABC?

1. 205°
2. 215°
3. 220°
4. 235°

10-10. How many degrees are there in the interior angle ABC?

1. 120°
2. 130°
3. 140°
4. 150°

10-11. To convert a bearing in the SE quadrant to the equivalent azimuth, you must use which of the following calculations?

1. Add 90° to the bearinq
2. Add 180° to the bearing
3. Subtract the bearing from 180°
4. Subtract the bearing from 360°

10-12. Assume that a measured forward bearing on a compass-tape survey was N15°35’W and the back bearing on the same line was S15°15’E. The difference was probably caused by which of the following conditions ?

1. Declination
2. Local attraction
3. An error in reading the compass
4. A defect in the compass mechanism

10-13. The magnetic declination at a given point on the surface of the earth is the horizontal angle that the magnetic meridian makes with what line?

1. The agonic line
2. The true meridian
3. The isogonic line
4. The assumed meridian

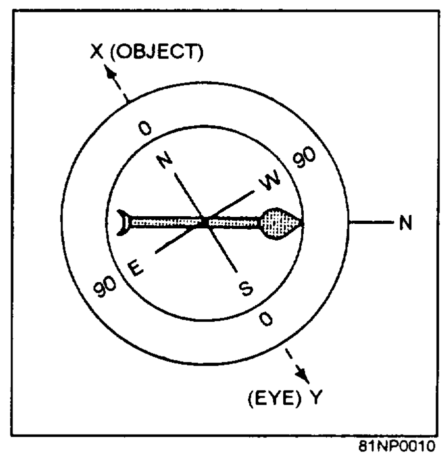


Figure 10E

IN ANSWERING QUESTIONS 10-14 THROUGH 10-16, REFER TO FIGURE 10E.

10-14. What is the approximate compass bearing of the object?

1. Due north
2. S70°W
3. S30°W
4. S30°E

10-15. What is the approximate magnetic bearing of the object if the local attraction is 20°E?

1. Due west
2. S50°W
3. Due south
4. N20°W

10-16. What is the approximate true bearing of the object if the local declination is 10°w and the local attraction is 20°E?

1. S80°W
2. S100°W
3. N80°W
4. N100°E

10-17. What method should you use to correct or convert a compass azimuth reading to a true azimuth reading when both local attraction and local declination are easterly?

1. Subtract the attraction and declination from the compass reading
2. Add the attraction and declination to the compass reading
3. Add the attraction to the compass reading, then subtract the declination from the sum
4. Add the declination to the compass reading, then subtract the attraction from the sum

10-18. When making a closed traverse compass-tape survey, for what reason should you first read and record the back bearing of a traverse line from the first setup point?

1. To offset local attraction
2. To get rid of declination
3. To check the accuracy of your compass
4. To verify the last bearing you will take

IN ANSWERING QUESTION 10-19, REFER TO FIGURE 13-8 IN YOUR TEXTBOOK.

10-19. Suppose that in the compass-tape survey field notes shown, the bearing AE is different from the bearing EA. This difference could have resulted from which of the following conditions?

1. Inaccuracy in reading the back bearing
2. Inaccuracy in reading the forward bearing
3. The difference in the strength of the local attractions at A and E
4. Each of the above

10-20. Station A bears N70°E (true) from station B and station C bears S10°W (true) from station B. What size of angle should be entered in the “computed interior angle” column of a compass-tape survey notebook page alongside the forward bearing of station C?

1. 60°
2. 80°
3. 120°
4. 240°

10-21. What is the sum of the interior angles in a closed traverse consisting of six traverse lines?

1. 360°
2. 540°
3. 720°
4. 1,080°

10-22. If a compass is in error when you are taking bearings at several different places and each error varies from the preceding one, the errors are probably due to which of the following factors?

1. A shifted movable circle
2. A bent frame
3. A bent pivot
4. A bent needle

10-23. The only compass available for taking bearings has an instrument error. What forward bearing should you use when the compass needle indicates a forward bearing of N22°W and a back bearing of S24°E?

1. S2°E
2. S46°W
3. N46°E
4. N23°W

10-24. You are using a compass that has an instrument error and is graduated for azimuths. What forward azimuth should you record when the compass needle indicates a forward azimuth of 37° and a back azimuth of 219°?

1. 37°
2. 38°
3. 91°
4. 128°

10-25. Which of the following defects is most likely to cause a compass to read incorrectly at both ends of its needle?

1. A bent pivot
2. A warped compass card
3. A bent needle
4. A blunt pivot point

10-26. A compass needle that is weak magnetically should be strengthened by which of the following methods?

1. Placing the magnet in an inductive field
2. Drawing the needle over a magnet
3. Placing the magnet in a shielded box
4. Heating the needle with a lighted match

10-27. A compass needle acts sluggishly although it has retained its full magnetism. Which of the following methods should you use to make the needle act smartly?

1. Sharpen its points
2. Sharpen the point on the pivot
3. Reshape it with a special tool
4. Demagnetize it

10-28. In setting up and leveling a transit, you have followed all of the correct procedures. You discover, however, that the plumb bob is still not quite directly over the station point. Which of the following actions should you take next?

1. Loosen two adjacent leveling screws to free the shifting plate and shift the transit head laterally
2. Replace the plumb bob
3. Adjust the tripod legs
4. Re-level the instrument

10-29. Before taking up a transit, which of the following actions should you take concerning the telescope and the vertical motion clamp?

1. Bring the telescope perpendicular to the vertical axis and firmly tighten the clamp
2. Point the telescope vertically upward and firmly tighten the clamp
3. Point the telescope vertically upward and loosen the clamp
4. Point the telescope vertically upward and lightly tighten the clamp

10-30. In which of the following ways are the horizontal limbs of transits numbered?

1. 0°-360° clockwise
2. 0°-360° clockwise, also 0°-90° by quadrants
3. 0°-360° clockwise, also 360°-0° counterclockwise
4. Each of the above

10-31. When you are turning a 40° horizontal angle by transit, what part will normally point to the number of degrees turned?

1. Zero on the A-vernier
2. Zero on the B-vernier
3. 0°-360° graduation on the horizontal limb
4. 40°-320° graduation on the horizontal limb

10-32. Releasing the upper motion of a transit enables you to take which of the following actions?

1. Hold the telescope in place
2. Rotate and train the telescope
3. Hold the horizontal limb in place
4. Rotate and align the horizontal limb

10-33. Which of the following steps should you normally take when turning a 20° horizontal angle from a reference line with a transit?

1. Clamp the lower motion to hold the telescope in place after training it on the reference line
2. Release the lower motion to rotate the telescope 20°
3. Align the 0°-360° graduation on the horizontal limb with the zero on the A-vernier
4. Align the 0°-360° graduation on the horizontal limb with the zero on the B-vernier

10-34. To fix the exact position of the horizontal limb with respect to the A-vernier, what transit screw, if any, should you use?

1. Telescope clamp screw
2. Upper motion tangent screw
3. Lower motion tangent screw
4. None

10-35. To detect accidental movement when measuring a number of horizontal angles from one setup, you should take which of the following steps?

1. Relevel the instrument and check the readings occasionally
2. Adjust the instrument before and after each reading
3. Train the instrument at some clearly defined object to serve as a reference mark for checking the sizes of the angles
4. Take the mean of the observed angles

10-36. The closing-the-horizon method of checking the accuracy of angular measurements is based on the geometrical fact that the sum of the

1. angles in a triangle are 180°
2. angles around a point are 360°
3. acute angles in a right triangle are 90°
4. interior angles of a closed five-course traverse are 540°

10-37. A vertical angle was recorded at +36°. This angle is a measurement of what type?

1. Inclination
2. Declination
3. Depression
4. Elevation

10-38. You are measuring a 30° angle with a 1-minute transit. To improve the precision of this measurement, you turn the angle a total of four times. If the plate reading after the fourth measurement is 119°59°, what is the size of the angle turned?

1. 29°45′45″
2. 29°59′45″
3. 30°00′15″
4. 30°45′15″

10-39. You have measured an angle using the repetition procedure. If the original measurement was 37°22′ and your sixth and last repeat was 224°12′42″, what is the mean angle?

1. 37°5′7″
2. 37°22′7″
3. 37°10′20″
4. 38°00′57″

10-40. Which of the following procedures is a method for extending a straight line?

1. Repeating angles
2. Averaging sets of backsight points
3. Double centering
4. Jiggling in

10-41. What step in the double-centering procedure is taken just before the instrument is rotated through 180° in the horizontal plane?

1. Plunging the telescope
2. Taking the first foresight
3. Taking the backsight
4. Taking the second foresight

10-42. When double centering results in two different extension points, what procedure should you use?

1. Extend your line through the first point
2. Extend your line through the second point
3. Extend your line through a point midway between the two extension points
4. Ignore both points and start over again

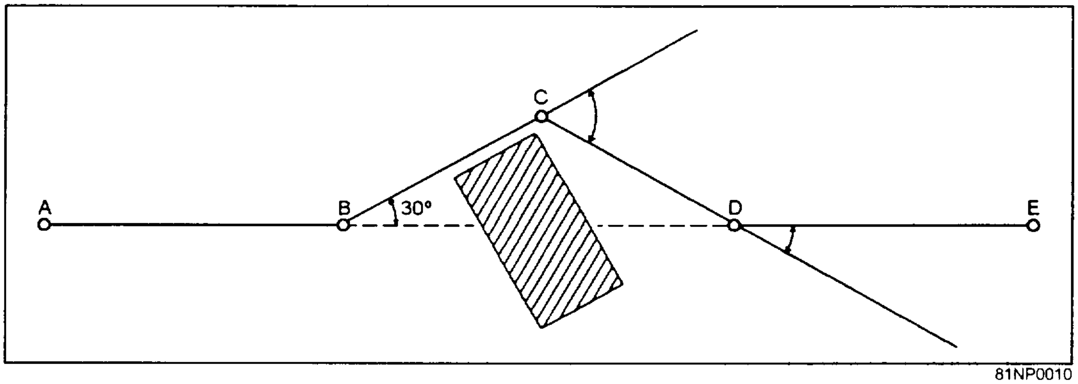


Figure 10F

IN ANSWERING QUESTIONS 10-43 THROUGH 10-46, REFER TO FIGURE 10F. YOU ARE RUNNING THE LINE AE AND THE POWERHOUSE IS IN YOUR WAY. WHILE AT SETUP B, YOU Discovered THAT A 30-DEGREE DEFLECTION ANGLE WILL CLEAR THE OBSTACLE. YOU DECIDED TO USE THIS ANGLE TO BYPASS THE POWERHOUSE.

10-43. What is your next step after recording the deflection angle at B?

1. Take a backsight at A and measure angle ABC
2. Move the instrument to D and measure the deflection angle at D
3. Move the instrument to C and measure the deflection angle at C
4. Move the instrument to A and measure angle BAC

10-44. If you use the angle offset method of bypassing an obstacle, what is the size of the deflection angle at C?

1. 30°
2. 45°
3. 60°
4. 75°

10-45. Which of the following distances is equal to CD?

1. AB
2. BD
3. DE
4. BC

10-46. What is the deflection angle at point D?

1. 30°L
2. 30°R
3. 60°L
4. 60°R

10-47. The angle offset and the perpendicular offset methods are useful in establishing a survey line under which of the following conditions?

1. When the length of the survey line cannot be determined by chaining
2. When the slope becomes great enough to require breaking chain
3. When the line of sight on the chosen survey line is obstructed
4. When the backsiqht distance is much less than the foresight distance

10-48. The “balancing in” process should be used to locate an intermediate point between two control points on a survey line under which of the following conditions?

1. When the distances from the intermediate point to the control points are approximately equal
2. When neither control point is visible from the other, and the other methods of bypassing an obstacle cannot be used
3. When the intermediate point is much closer to one of the control points than it is to the other
4. When the instrument adjustment has a known error

10-49. Moving a transit onto the straight line between two points by a trial-and-error method is referred to by which of the following terms ?

1. Bucking in only
2. Jiggling in only
3. Wiggling in only
4. Bucking in, jiggling in, wiggling in, and balancing in

IN ANSWERING QUESTION 10-50, REFER TO FIGURE 13-19C IN YOUR TEXTBOOK.

10-50. If deflection angles α and β are 4 and 6 minutes, respectively, and distance a equals 4 feet, how far should you set up the instrument from B′ so that it is exactly in line with points A and C?

1. 1.0 ft
2. 1.4 ft
3. 1.6 ft
4. 2.4 ft

10-51. For which of the following situations should the random line method be used?

1. To run a line between nonintervisible end points from an intermediate point from which both end points are visible
2. To run a line between nonintervisible end points when there is no intermediate point from which both end points are visible
3. To establish intermediate stations between nonintervisible end points
4. Both 2 and 3 above

10-52. What tying-in method should you use when locating the configuration of an irregular shoreline from a traverse line?

1. Swing offsets
2. Random lines
3. Range ties
4. Perpendicular offsets

10-53. What meaning is generally given to the term “setting a point”?

1. Establishing a point at a designated location
2. Relocating control points that have been destroyed
3. Locating reference lines for a displaced station
4. Setting the instrument upon a designated point

10-54. You can tie-in a point or set a point to two stations on a traverse by taking which of the following measurements?

1. Its angle and distance from one station
2. Two of its angles, one from each station
3. Its distance from one station and its angle from the other station
4. Each of the above

10-55. Two 50-foot tapes can be used to set a point that is designated by a distance from each of two traverse stations, provided that which of the following conditions exists?

1. The ground is absolutely level
2. The point is not more than 50 feet from either station
3. The tapes are marked off in hundredths of a foot
4. A rough survey is being made

10-56. You are setting a point at given distances from two stations on a traverse. Both distances are longer than your tapes. You could set this point by using which of the following methods?

1. Running the tapes out from both traverse stations and crossing them at the proper point
2. Using a transit and range pole to shoot to the new point
3. Using a transit, rod, and tape to lay off the appropriate distance to the point
4. Solving for one of the interior angles of the triangle and then using a transit, rod, and tape to lay off the appropriate distance to the point

10-57. Surveyors use straddlers for which of the following purposes?

1. To relocate control points that have been destroyed
2. To tie in a new traverse with reference to its angle to an old survey line
3. To tie in a point with reference to its angle from two stations
4. To locate the reference lines for a displaced station

10-58. You must set a marker at a certain point from traverse stations 3 + 00 and 4 + 25. The angle from the traverse line to station 3 + 00 and the distance between the point and station 4 + 25 are given. How should you proceed to set the point?

1. Solve for the other angle from the base line, and the distance of the point from the other station; then, set the point by using transit and tape. Check the distance and other angle from base line
2. Solve for the angle from the base line to the distance line and set the point by the use of transit and tape and check by measuring the base line
3. Lay out the lines to the point with tape and straddlers and check with a transit
4. Lay out the lines to the point with tape and straddlers and check by remeasuring one leg of the triangle

10-59. When tying in a point to a station on a traverse, which of the following conditions should you carefully consider?

1. The selected tie station should not be easily disturbed
2. The tie station must be visible from the point to be tied in
3. Both 1 and 2 above
4. The angle between the tie lines should be no greater than 90°

10-60. A closed traverse was to be 15,000 feet in length. The last course was to be 3,000 feet in length. After you turn the last deflection angle and progress 3,000 feet on the last course, you find that you are 3 feet from the starting point of the traverse. What is the order of precision?

1. First
2. Second
3. Third
4. Fourth

10-61. If precision of 1/20,000 is required, what is the maximum allowable error of closure for a traverse of 10,560 feet?

1. 0.437 ft
2. 0.528 ft
3. 0.759 ft
4. 1.255 ft

IN ANSWERING QUESTION 10-62, REFER TO TABLE 13-1 IN YOUR TEXTBOOK.

10-62. You are running a traverse of nine interior angles, and third-order degree of precision is required. Which of the following sums of the interior angles is acceptable?

1. 1259°59’30”
2. 1259°59’48”
3. 1260°01’ 12”
4. 1260°01’30”

10-63. A temperature correction applied to tape measurements is considered to be a typical precision specification for which of the following surveys?

1. Preliminary surveys
2. Land surveys where the value of the land is high
3. Highway location surveys
4. Both 2 and 3 above

10-64. Which of the following errors in a transit affects both horizontal and vertical angle measurements?

1. The line of sight through the telescope does not coincide with the true optical axis of the telescope
2. The horizontal axis of the telescope is not perpendicular to the vertical axis
3. The axis of each of the plate levels is not perpendicular to the vertical axis of the telescope
4. Each of the above

10-65. Errors that can lead to inaccurate surveying when you use a transit may include which of the following natural errors?

1. Tripod settlement
2. Unequal expansion of transit parts
3. Refraction
4. All of the above

10-66. Which of the following personal errors results in a larger error for inclined sights than for horizontal sights?

1. Failure to focus correctly
2. Failure to center the plate level bubbles exactly
3. Failure to plumb the transit exactly
4. Failure to line up the vertical cross hair with the true vertical axis of the sighted object

10-67. You are having difficulty aligning the transit cross hair with the vertical axis of the sighted object. Which of the following errors is most likely responsible for this difficulty?

1. Improper focusing
2. Not centering the plate level bubbles
3. Plumbing the transit poorly
4. Failure to align the vertical cross hair with the true axis of the object

10-68. Which of the following situations is considered a mistake in transit work?

1. Failure to record the direction in which an angle was turned
2. Turning a deflection angle in the wrong direction
3. Reading the wrong vernier
4. Each of the above

10-69. The carrying case for a transit or a theodolite is specifically designed for which of the following conditions?

1. To protect the instrument from extreme temperatures
2. To serve as a part of the instrument when it is set up for use in the field
3. To prevent excess motion when the instrument is being carried
4. All of the above

10-70. Which of the following actions should you take after an instrument has been exposed to rain and has been wiped down with a clean cloth or chamois leather?

1. Dry it in a heated room
2. Stow it right away in its case
3. Dry it thoroughly at ordinary room temperature

10-71. What is the recommended lubricant for surveying instruments at sub-zero temperatures?

1. Oil
2. Water
3. Petrol
4. Graphite

10-72. Which of the following statements describes the characteristics of an open traverse as compared to a closed connecting traverse?

1. An open traverse has only one previously determined end point, but a closed connecting traverse has two
2. Both types of traverses may not be used for preliminary surveys
3. An open traverse is open at both ends, but a closed connecting traverse forms a loop so that the ends are closed
4. A closed traverse provides fewer checks against error than an open traverse

10-73. In a lower order survey of a road center line, the exact route and station locations are selected so that provisions are made for which of the following conditions?

1. Only the rear station is visible from any station
2. Only the forward station is visible from any station
3. Both stations are visible from any one station and the maximum number of instrument setups can be kept
4. Both stations are visible from any one station and the number of instrument setups can be kept to a minimum

10-74. In double taping between traverse stations, you should use which of the following procedures?

1. Use only tapes that are calibrated
2. Ensure the stations are spaced so that the distance between stations is less than a full-tape length
3. Continue taping until the tie-in control point is reached; then retape all measurements
4. Retape line measurements not within allowable limits

10-75. Which of the following traverse stations may be a point with a known azimuth location?

1. Forward
2. Rear
3. Occupied

ASSIGNMENT 11

Textbook Assignment: "Direct Leveling and Basic Engineering Surveys." Pages 14-1 through 14-25.

11-1. Bench marks (BMs) share what common characteristic?

1. They are permanent
2. They are marked with a known elevation
3. They are constructed only from concrete or brass
4. They are used only for vertical control

11-2. To be used as elevation references in the development or expansion of a permanent naval station, you should establish monumented BMs in which of the following locations?

1. On all important structures, such as buildings and piers
2. At all road intersections
3. In a grid system 1 mile apart
4. In a grid system 1/2 mile apart

11-3. Level nets are established within a prescribed order of accuracy and are tied to what reference?

1. A BM
2. A traverse station
3. A datum
4. A horizontal control point

11-4. Mean sea level (MSL) differs from mean tide level (MTL) in what way?

1. MSL is the mean of tides observed in the open sea; MTL is the mean of inland tidewater observations
2. MSL is the result of averaging tabulated tide readings; MTL is taken from the tidal curve
3. MSL is the mean of a large number of points along a tidal curve; MTL is the mean of only the high and low points along the tidal curve
4. MSL is the datum used primarily in hydrographic surveys; MTL is used as a datum in any type of survey

11-5. The correct way to obtain the MSL value for a month's tide tabulated record is to add all daily sums for the month and to divide this total by the sum of what specific units of time in that month?

1. Minutes
2. Days
3. Hours
4. Weeks

11-6. What datum is generally used for measuring the height of a hill?

1. Mean sea level (MSL)
2. Mean high water (MHW)
3. Mean low water (MLW)
4. Mean low water springs (MLWS)

11-7. Assume you are engaged in a hydrographic survey of the water approaches to Naval Air Station, Adak, Alaska. Your soundings should refer to what datum?

1. MLLW
2. MWL
3. MTL
4. MLWS

11-8. What type of lubricant is recommended for use on engineer's levels in arctic regions?

1. Watch oil
2. Powdered graphite
3. Petroleum jelly
4. Mineral oil

11-9. The proper way to remove an engineer's level from its carrying case is to grasp it firmly by what part(s)?

1. The telescope
2. The footplate
3. The leveling head
4. The wye rings

11-10. When a level setup must be transferred to another point or station, what screws should be loosened slightly?

1. Leg and level
2. Leg and clamp
3. Level and clamp
4. Tangent and clamp

11-11. To help the instrumentman obtain accurate readings, the rodman should take which of the following actions?

1. Clean the top of the point and the rod shoe for a good contact
2. Plumb with both hands
3. Make sure the rod graduations are right side up and facing the instrumentman
4. All of the above

11-12. The proper care of a leveling rod includes which of the following actions?

1. Supporting the entire rod on a flat surface when laying the rod down flat
2. Rinsing any mud off with water and cleaning any grease off with a mild soap solution
3. Wiping it dry before storing it in a dry place
4. All of the above

11-13. On what basis should you select setup points to balance your shots in differential leveling?

1. All setup points are at about the same elevation
2. Backsight distances are about the same as foresight distances
3. All backsight distances are about the same
4. All foresight distances are about the same

11-14. You are setting up an engineer's level on a concrete surface. You mount the instrument on a tripod placed inside a floor triangle. This precaution will protect the tripod from which of the following accidents?

1. Turning
2. Moving laterally
3. Tipping over
4. Collapsing

IN ANSWERING QUESTION 11-15, REFER TO FIGURE 14-7 IN YOUR TEXTBOOK.

11-15. In what direction does the level vial bubble move when you turn the level screws as indicated?

1. Up
2. Down
3. Right
4. Left

11-16. The whole foot numbers on a Philadelphia rod are what color?

1. Red
2. White
3. Black
4. Yellow

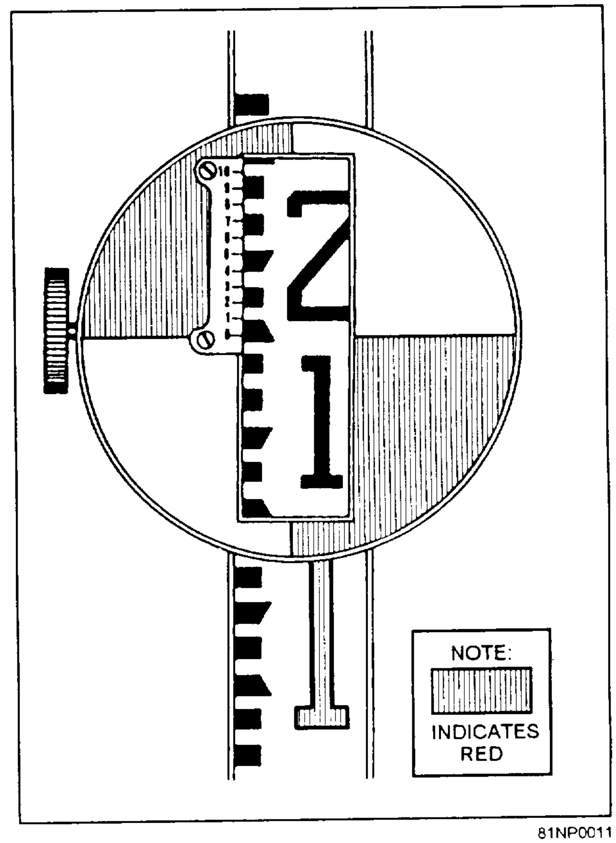


Figure 11A

IN ANSWERING QUESTION 11-171 REFER TO FIGURE 11A.

11-17. What is the target reading?

1. 1.125 ft
2. 1.154 ft
3. 1.5 ft
4. 112.0 ft

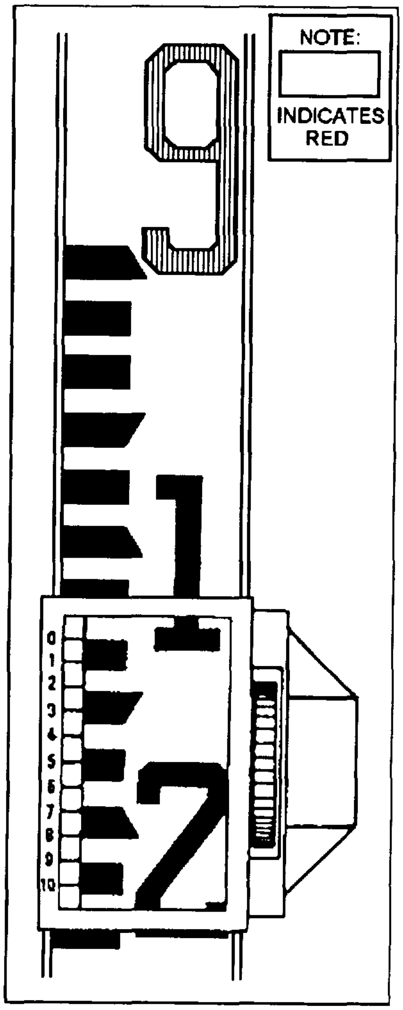


Figure 11B

IN ANSWERING QUESTION 11-18, REFER TO FIGURE 11B.

11-18. What is the target reading?

1. 8.128 ft
2. 9.120 ft
3. 9.128 ft
4. 279.0 ft

11-19. In leveling, which of the following statements best defines height of instrument (HI)?

1. The elevation of the horizontal line of sight
2. The vertical distance from the horizontal axis of the telescope to a point on the ground directly below the instrument
3. The vertical distance between the reference datum and the horizontal line of sight
4. The elevation of the reference datum minus the backsight rod reading

11-20. In determining the elevation of an unknown point, what arithmetic operation should you apply to the HI and FS?

1. Addition
2. Subtraction
3. Multiplication
4. Division

11-21. By using the technique of balancing shots, you can eliminate which of the following effect(s) in differential leveling?

1. Instrumental error
2. Curvature of the earth's surface
3. Atmospheric refraction
4. All of the above

11-22. When turning points are being set up in ordinary precision leveling, what should be the maximum distance between the instrument and a TP?

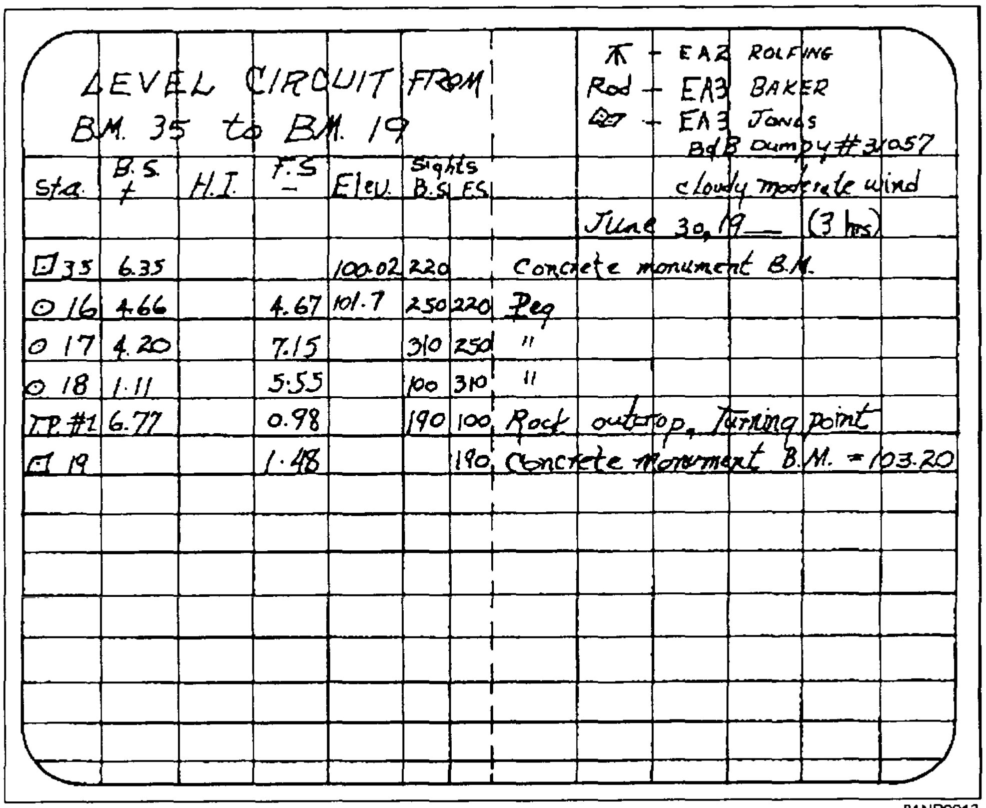
1. 200 ft
2. 300 ft
3. 600 ft
4. 1,000 ft

11-23. When turning points are located in sandy soil, you must set the level rod on a base. Which of the following bases is an acceptable choice?

1. A turning point plate
2. A turning point pin driven into the soil
3. A marlin spike driven into the soil
4. Each of the above

11-24. The original level run is rapidly rerun as a check in what type of leveling procedure?

1. Three-wire
2. Cross-section
3. Profile
4. Flying



LEVEL CIRCUIT FROM BM. 35 to BM. 19

⊼ - EA2 ROLFING
Rod - EA3 BAKER
Rec - EA3 JONES
Bd B Dumpy #31057
cloudy moderate wind
June 30, 19__ (3 hrs)

Sta.	B.S. +	H.I.	F.S. −	Elev.	Sights B.S.	Sights F.S.	
BM 35	6.35			100.02	220		Concrete monument B.M.
○ 16	4.66		4.67	101.7	250	220	Peg
○ 17	4.20		7.15		310	250	"
○ 18	1.11		5.55		100	310	"
TP #1	6.77		0.98		190	100	Rock outcrop, Turning point
BM 19			1.48			190	Concrete monument B.M. = 103.20

81NP0013

Figure 11C

IN ANSWERING QUESTIONS 11-25 THROUGH 11-30, REFER TO FIGURE 11C.

11-25. What is the HI at station 16?

1. 100.02 ft
2. 106.35 ft
3. 106.36 ft
4. 106.37 ft

11-26. What is the elevation of turninq point #1?

1. 97.96 ft
2. 97.99 ft
3. 103.76 ft
4. 104.76 ft

11-27 What is the elevation of BM 19 as computed from the field notes?

1. 101.28 ft
2. 102.38 ft
3. 103.28 ft
4. 104.76 ft

11-28 What is the computed difference in elevation between BM 35 and BM 19?

1. 2.26 ft
2. 3.26 ft
3. 4.26 ft
4. 4.36 ft

11-29. What is the error of closure of the level circuit?

1. 0.08
2. 0.10
3. 3.18
4. 3.26

11-30. When corrected for error of closure, what is the adjusted elevation of TBM 17?

1. 99.17 ft
2. 99.25 ft
3. 101.67 ft
4. 101.75 ft

11-31. Simultaneous-reciprocal leveling requires which of the following level party personnel?

1. One levelman and one rodman
2. One levelman and two rodmen
3. Two levelmen and one rodman
4. Two levelmen and two rodmen

11-32. In profile leveling, rod readings taken from points that are neither BMs nor TPs are entered under what heading in the field notebook?

1. BS
2. FS
3. IFS
4. Remarks

11-33. You have run a line of levels from an initial BM to a final BM. You compute the elevation of the final BM to be 1,475.77 feet. The elevation of the initial BM is 1,502.36 feet. If the sum of the backlights is 16.32 feet, what is the sum of the foresights?

1. 10.27 ft
2. 26.59 ft
3. 32.06 ft
4. 42.91 ft

11-34. At what point(s) along a proposed highway are cross sections taken?

1. Every 25 ft
2. Every 50 ft
3. At regular stations only
4. At regular stations, at any point where there is a break on the ground, or at any interval desired

11-35. By which of the following methods is the HI in cross-section leveling determined when using a hand level?

1. By adding the instrumentman eyesight height to the center-line elevation from profile field notes
2. By adding the instrumentman eyesight height to a BM elevation
3. By adding the BS reading to a BM elevation
4. Each of the above

11-36. You are doing cross-section leveling for a highway road survey. The profile center-line elevation at station 25 + 00 is 112.5 feet and eye height is 5.3 feet. On a rod held 20 feet from the center line you read 11.2 feet. What is the elevation at this point?

1. 96.0 ft
2. 106.6 ft
3. 118.4 ft
4. 129.0 ft

11-37. What is a form of differential leveling in which a continuous check is maintained on the accuracy of the leveling procedure?

1. Three-wire
2. Double rodding
3. Cross-section
4. Profile

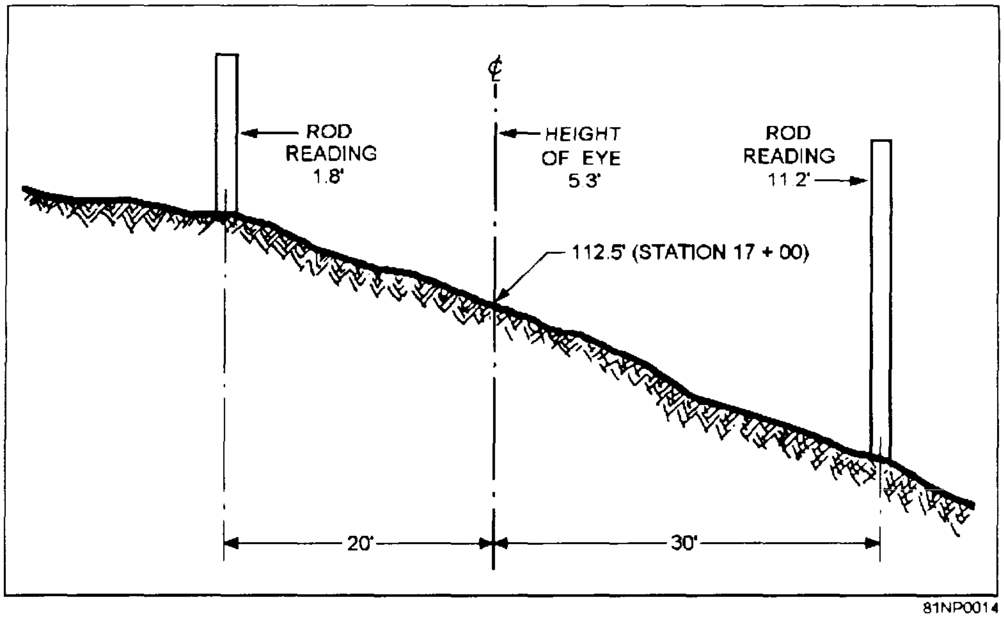


Figure 11D

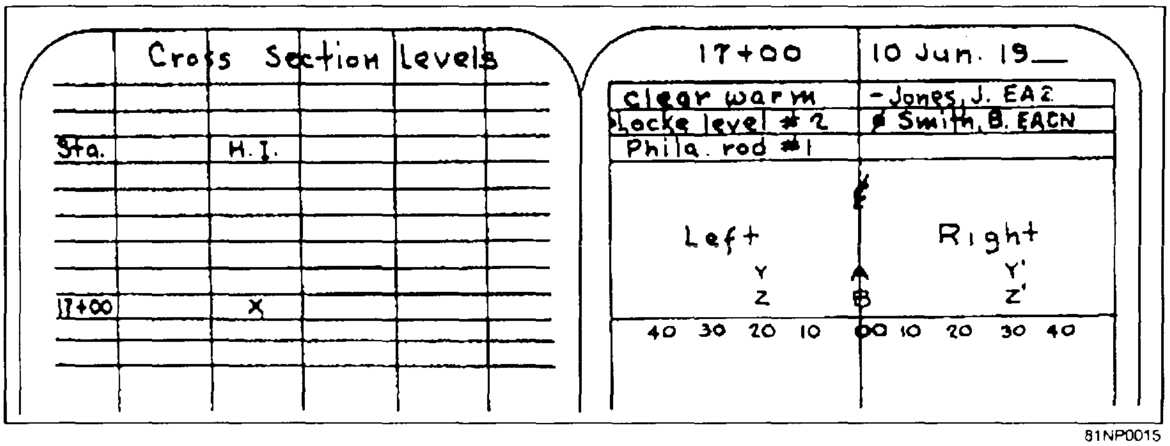


Figure 11E

IN ANSWERING QUESTIONS 11-38 THROUGH 11-41, REFER TO FIGURES 11D AND 11E.

11-38. What numerical values from figure 11D replace the letters A and B, respectively, in figure 11E?

1. 1.8; 11.2
2. 5.3; 112.5
3. 11.2; 1.8
4. 112.5; 5.3

11-39. What numerical value replaces the letter X in figure 11E?

1. 11.2
2. 107.2
3. 112.5
4. 117.8

11-40. What numerical values replace the letters Z and Z′, respectively, in figure 11E?

1. 1.8; 11.2
2. 5.3; 112.5
3. 11.2; 1.8
4. 112.5; 5.3

11-41. What numerical values replace the letters Y and Y′, respectively, in figure 11E?

1. 106.6; 116.0
2. 112.5; 117.8
3. 116.0; 106.6
4. 117.8; 112.5

11-42. If third order accuracy is specified, what is the maximum allowable error of closure for a level loop that is 7,826 feet long?

1. 0.042 ft
2. 0.061 ft
3. 0.608 ft
4. 4.423 ft

11-43. Recording a rod reading in the wrong column in a field book is classified as a

1. mistake
2. standard error
3. personal error
4. natural error

IN ANSWERING QUESTIONS 11-44 THROUGH 11-48, SELECT FROM THE FOLLOWING LIST THE CORRECTIVE MEASURE THAT YOU SHOULD TAKE DURING A LEVELING OPERATION TO AVOID ERRORS RESULTING FROM THE SITUATION GIVEN.

A. BALANCE BS AND FS DISTANCES
B. CALIBRATE ROD LENGTH
C. USE A TURNING POINT
D. AVOID VERY SMALL ROD READING

11-44. Level not in adjustment.

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

11-45. Unstable TP.

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

11-46. Wear and tear evident on the bottom of the rod.

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

11-47. Earth's curvature.

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

11-48. Atmospheric refraction.

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

11-49. Between errors and mistakes, the most importance difference, if any, is that

1. errors can be avoided
2. errors are caused by human negligence
3. mistakes can be avoided
4. there is no difference; the terms are synonymous

11-50. In third-order leveling, the starting and closing BMs must be of which of the following orders of accuracy?

1. First
2. Second or higher
3. Third or higher
4. Fourth or higher

ASSIGNMENT 12

Textbook Assignment: "Direct Leveling and Basic Engineering Surveys." Pages 14-25 through 14-47.

12-1. Fieldwork on the construction of a road being built on a 5-year-old naval air station would very likely begin with what type of survey?

1. Final location
2. Topographic
3. Reconnaissance
4. As-built

12-2. What is the first step in a reconnaissance survey?

1. A field trip to the desired location
2. A study of existing maps and aerial photographs
3. An instrument survey of the desired location
4. An inventory of available construction equipment

12-3. Direct air observation of an area to be reconnoitered offers what main advantage?

1. Acquiring information about the relief of the area
2. Providing a quick means of preparing sketches of the area
3. Speeding subsequent ground reconnaissance of the area
4. Providing a quick means of preparing maps of the area

12-4. A field reconnaissance party follows the route previously marked on a map to verify actual conditions on the ground. Which of the following conditions, relative to an engineering study, should be noted?

1. Soil conditions and washout areas
2. Vegetation and obstacles
3. Quarry sites and sand or gravel deposits
4. All of the above

12-5. Which of the following tasks in constructing a highway is part of the preliminary survey?

1. Establishing final grades and alignments
2. Computing the highway right-of-way
3. Running the traverse
4. Setting grade stakes

12-6. Your survey party is assigned the task of completing a reconnaissance survey of a 3-mile road in hilly, wooded terrain. For this survey, your party should carry which of the following equipment?

1. Lensatic compass
2. Brush hook
3. Hand level
4. All of the above

12-7. As the lead surveyor laying out the final location of a roadway center line, you suspect that the preliminary survey was in error regarding the exact location of the center line. Which of the following actions should you take?

1. Lay out the center line according to the preliminary data
2. Lay out the center line the way you know it should be
3. Lay out the center line and then report the reason for making the necessary change
4. Report the problem and receive authorization before making the location change

12-8. Which of the following details must be shown on a plan view of a proposed highway?

1. Curve design data
2. Gradient
3. Spot elevations
4. Typical cross section of the highway

12-9. When plotting a profile, you should use which of the following (a) horizontal and (b) vertical scales?

1. (a) 1" = 200′ (b) 1" = 20′
2. (a) 1" = 20′ (b) 1" = 200′
3. (a) 1" = 135′ (b) 1" = 15′
4. (a) 1" = 205′ (b) 1" = 20′

12-10. You have just plotted the profile of a road section from station 6 + 00 to station 9 + 81. The elevation of station 6 + 00 is 100.00 feet and that of station 9 + 81 is 93.30 feet. What is the gradient between these stations?

1. +1.76%
2. -1.76%
3. +17.60%
4. -17.60%

12-11. What kind of information is presented in the typical cross section of a proposed highway?

1. Design data for the highway
2. Details of the representative terrain over which the highway will be built
3. Factors establishing a need for the highway
4. Schedule of the office tasks to be performed before the construction of the highway

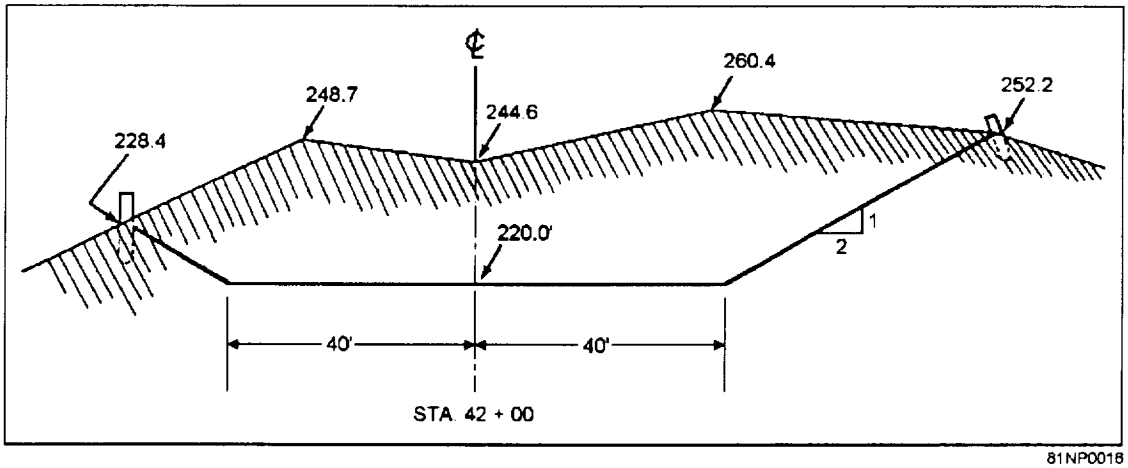


Figure 12A

IN ANSWERING QUESTIONS 12-12 THROUGH 12-15, REFER TO THE CROSS SECTION OF THE PROPOSED HIGHWAY SHOWN IN FIGURE 12A.

12-12. What is the finished grade elevation?

1. 260.4 ft
2. 248.7 ft
3. 244.6 ft
4. 220.0 ft

12-13. How should you write the side slope ratio?

1. 1:2
2. 2:1
3. 1/2
4. 2/1

12-14. What type of cross section is shown?

1. Level
2. Five-level
3. Three-level
4. Four-level

12-15. This cross section may also be called what type of section?

1. Regular
2. Irregular
3. Standard
4. Sidehill

12-16. On the cross-section paper most widely used in surveying offices, the horizontal lines are spaced how far apart?

1. 1/20 in
2. 1/10 in
3. 1/5 in
4. 1/4 in

12-17. After the surface elevations have been plotted on the cross-section paper, the points should be connected in which of the following ways?

1. By freehand curves
2. By freehand straight lines
3. By lines drawn with a straightedge
4. Either 2 or 3 above

12-18. In the plotting of cross sections, the vertical scale relates to the horizontal scale in which of the following manner?

1. The vertical scale must be equal to the horizontal scale
2. The vertical scale must be exaggerated from the horizontal scale
3. The vertical scale may be equal to the horizontal scale, or it may be exaggerated for clarity
4. The vertical scale is usually less than the horizontal scale, but it may be equal or exaggerated for clarity

IN ANSWERING QUESTIONS 12-19 THROUGH 12-21, REFER TO FIGURE 14-29 IN YOUR TEXTBOOK.

12-19. The plotted cross sections are called irregular for what reason?

1. Sections are plotted at a full station and at a section between two full stations
2. The vertical and horizontal scales are different
3. Intermediate elevations are plotted at varying distances from the center line
4. More elevations were plotted for the section at station 11 + 00 than for the section at station 11 + 43

12-20. Notice that the cross-section notes show only two ground elevations to the right of the center line at station 11 + 43. Assume that an additional reading could have been obtained at a point 10 feet to the right of the center line but was not. Refer to the plotted cross section of the station and furnish the entry for this point.

1. $\frac{10}{5.1}$ (80.1)
2. $\frac{10}{8.6}$ (67.0)
3. $\frac{10}{2.4}$ (74.3)
4. $\frac{10}{9.7}$ (67.0)

12-21. The HI for station 14 + 00 is

1. 76.70
2. 78.90
3. 81.60
4. 85.22

12-22. What points are plotted in a three-level section?

1. The roadway edges, slope stakes, and center line
2. The depth of cut or fill and the amount of earth to be moved
3. The left-hand slope stake, right-hand slope stake, and center line
4. The left-hand roadway edge, right-hand roadway edge, and center line

12-23. During what stage of a road construction project are “blue tops” used?

1. Rough grading
2. Clearing and grubbing
3. Final grading
4. Paving

12-24. The natural earth surface below the pavement of a highway is called the

1. final grade
2. finish grade
3. rough grade
4. subgrade

12-25. Which of the following markings on a grade stake indicates a cut of 2.6 feet?

1. C $2^{\underline{6}}$
2. - $2^{\underline{6}}$
3. V $2^{\underline{6}}$
4. Each of the above

12-26. You wish to indicate a cut of 2.6 feet on a stake that is not a centerline stake. You should write the cut information on what part of the stake?

1. Front
2. Back
3. Right side
4. Left side

IN ANSWERING QUESTIONS 12-27 AND 12-28, YOU ARE SETTING GRADE STAKES BY THE PROCEDURE THAT INVOLVES COMPLETING THE NECESSARY COMPUTATIONS WHILE AT EACH STATION.

12-27. You can obtain the grade rod by taking the difference between what two measurements?

1. The HI and the ground elevation
2. The HI and the finished grade
3. The finished grade and the ground elevation
4. The width of the highway and the width of the fill or cut

12-28. You can obtain the amount of cut or fill for a given station by computing the sum of or difference between what two measurements?

1. The HI and the finished grade
2. The ground elevation and the ground rod
3. The ground rod and the grade rod
4. The HI and the ground rod

IN ANSWERING QUESTIONS 12-29 AND 12-30, YOU ARE SETTING A CENTERLINE GRADE STAKE AT A STATION WHERE THE EXISTING GROUND ELEVATION IS 98.6 FEET AND THE REQUIRED ELEVATION IS 110.3 FEET.

12-29. At this station, you obtain a reading of 6.3 feet. What is the (a) grade rod and (b) ground rod?

1. (a) 6.3 (b) 104.9
2. (a) 5.4 (b) 6.3
3. (a) 6.3 (b) 5.4
4. (a) 104.9 (b) 5.4

12-30. What information should you mark on the front of the grade stake?

1. C $5^{\underline{4}}$ and the station number
2. F $6^{\underline{3}}$ and the station number
3. ℄ and the station number
4. F $11^{\underline{7}}$ and the station number

12-31. What is the slope stake distance from the center line if W/2 . 18 feet, h = 6 feet, and the slope ratio is 2:1?

1. 21 ft
2. 24 ft
3. 30 ft
4. 42 ft

QUESTIONS 12-32 AND 12-33 PERTAIN TO THE SETTING OF SLOPE STAKES FOR A CUT SECTION. THE DISTANCE FROM THE CENTER LINE TO THE BEGINNING OF THE SIDE SLOPE IS 22 FEET. THERE IS A CROSSFALL OF 0.5 FEET AND A DITCH 2 1/2 FEET IN DEPTH. THE SIDE SLOPE AND BACK SLOPE RATIO IS 3:1, AND h IS 8 FEET.

12-32. What is the value of W/2?

1. 7.5 ft
2. 22.0 ft
3. 29.5 ft
4. 38.5 ft

12-33. What is the slope stake distance from the center line?

1. 24.0 ft
2. 29.0 ft
3. 44.0 ft
4. 62.5 ft

```
    As rodman, you are setting
slope stakes at station 7 + 00,
and the instrumentman is 100
yards away.  You have obtained
the following information from
notes and plans:

W/2 = 20 FEET
SLOPE RATIO = 2:1
FINISHED GRADE ELEVATION AT
CENTER LINE = 156.3 FEET
GROUND ELEVATION AT CENTER
LINE = 160.8 feet
HI = 165.0 FEET
```

Figure 12B

IN ANSWERING QUESTIONS 12-34 THROUGH 12-38, REFER TO FIGURE 12B.

12-34. What is the cut at center line?

1. 4.2 ft
2. 4.5 ft
3. 4.8 ft
4. 8.7 ft

12-35. What should the rod reading be at the center line?

1. 4.2 ft
2. 4.5 ft
3. 4.8 ft
4. 8.7 ft

12-36. What should your initial estimate of d be?

1. 20.0 ft
2. 28.4 ft
3. 29.0 ft
4. 40.0 ft

12-37. As you walk to the initial estimate of d, you observe a drop of approximately 3 feet in the ground elevation. Your second estimate of d is

1. 23.0 ft
2. 25.4 ft
3. 32.0 ft
4. 47.0 ft

12-38. At the second estimate of d, the rod reading is 7.2 feet. You know your second estimate of d is

1. correct
2. 0.5 ft short
3. 0.5 ft long
4. 1.0 ft long

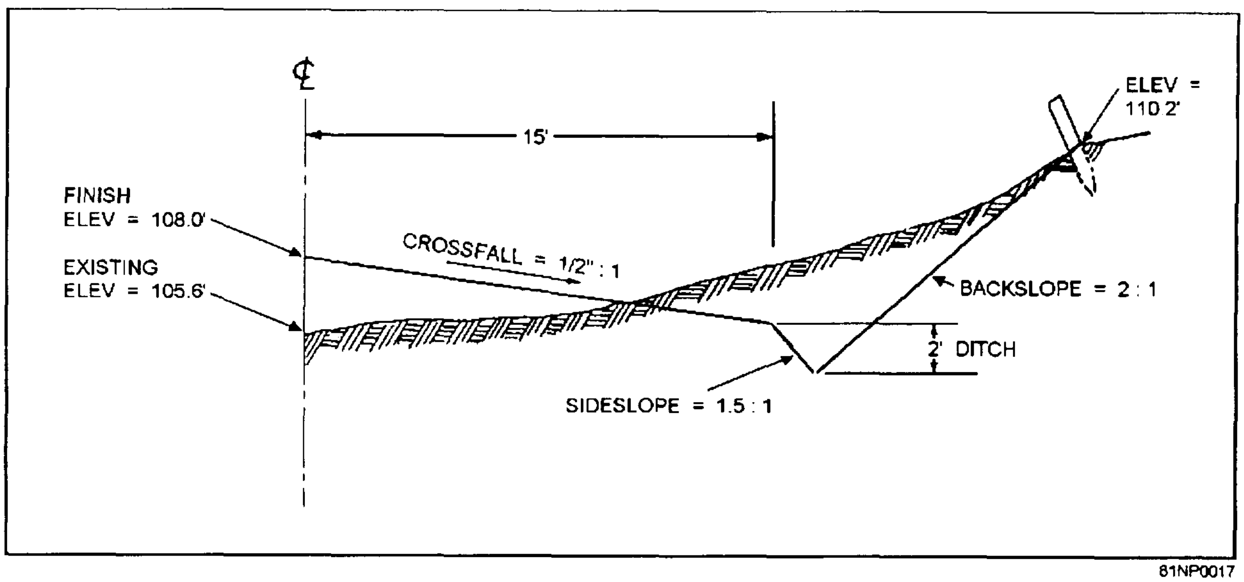


Figure 12C

IN ANSWERING QUESTIONS 12-39 AND 12-40, REFER TO FIGURE 12C.

12-39. What type of cross section is shown?

1. Level
2. Three-level
3. Five-1evel
4. Sidehill

12-40. What is the distance from the center line to the slope stake?

1. 25.4 ft
2. 27.4 ft
3. 27.6 ft
4. 32.4 ft

12-41. In curb construction, construction crews should obtain line and grade from which of the following sources?

1. Center-line stakes
2. Blue tops
3. Shoulder stakes
4. Offset hubs

12-42. Pavement stakeout is primarily dependent upon which of the following factors?

1. The type of instruments used to perform the stakeout
2. The type of equipment used for paving
3. The finish grade elevations
4. The directions from the construction crew leader

12-43. In checking the accuracy of a 9- by 12-foot rectangular layout by means of the Pythagorean theorem, you should find the diagonal to measure what distance?

1. 15 ft
2. 18 ft
3. 20 ft
4. 25 ft

12-44. The batter boards should be placed how far from the building lines so as not to interfere with construction?

1. 1 to 2 ft
2. 2 to 3 ft
3. 3 to 4 ft
4. 4 to 5 ft

12-45. When batter boards are used to preserve building lines, horizontal and vertical controls are provided by

1. cords stretched between the top edges of the batter boards
2. the side edges of the batter boards
3. the vertical edges of the batter boards
4. the top edges of the stakes that hold the batter boards

12-46. The invert elevation of an underground sewer pipe is taken at what point on the pipe?

1. Lowest outside surface
2. Highest inside surface
3. Lowest inside surface
4. Highest outside surface

12-47. For any construction project, what is the optimum time for the as-built survey to begin?

1. During the layout survey
2. As soon as stakeout is completed
3. Upon final project completion
4. During construction as the individual features are completed

12-48. Red flagging should be used on the legs of your instrument when you are surveying in the vicinity of which of the following areas?

1. Airstrips
2. Excavations
3. Logging operations
4. Blasting operations

12-49. Which of the following actions should you take when you are running a tape-transit traverse that crosses electric wires?

1. Stretch the tape above the wires
2. Ground one end of the tape
3. Break chain at the wires
4. Wear rubber gloves

12-50. Excavations that are what minimum depth, in feet, must be suitably braced and shored to prevent cave-ins?

1. 5
2. 2
3. 3
4. 4

ASSIGNMENT 13

Textbook Assignment: "Materials Testing: Soil and Concrete." pages 15-1 through 15-39. "Administration." Pages 16-1 through 16-14.

13-1. Which of the following substances is/are enclosed by the mineral grains in a soil mixture?

1. Air or gases only
2. Water only
3. Organic matter only
4. Voids containing air, gases, water, and organic matter or any combination of these

13-2. Rock is classified into how many groups?

1. One
2. Two
3. Three
4. Four

13-3. What type of rock is formed from the accumulation and cementing of plant and animal remains?

1. Metamorphic
2. Sedimentary
3. Igneous
4. Organic

13-4. By what process are residual and transported soils formed?

1. Disintegration
2. Weathering
3. Decomposition
4. Atmospheric exposure

IN ANSWERING QUESTIONS 13-5 THROUGH 13-7, SELECT THE KEY WORDS OR PHRASES THAT BEST MATCHES THE TYPE OF SOIL LISTED.

A.	FRESHWATER LAKE
B.	ESKERS
C.	LOESS
D.	IN-PLACE WEATHERING

13-5. Residual soil.

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

13-6. Lacustrine soil.

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

13-7. Glacial soil.

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

13-8. According to the Unified Soil Classification System, materials retained on the No. 200 sieve and passing the No. 4 sieve are classified as

1. coarse grained
2. sands
3. fines
4. medium fines

13-9. Which of the following bulky particle shapes is considered to be the most desirable for construction purposes because of its interlocking characteristic?

1. Rounded
2. Subrounded
3. Subangular
4. Angular

13-10. A well-graded soil consists of which of the following particle sizes?

1. Only intermediate sizes
2. Large and small sizes only
3. Uniformly graded sizes
4. A good representation of all sizes

13-11. A well-graded soil provides which of the following conditions?

1. Maximum displacement of particles
2. Maximum density and stability of particles
3. Minimum displacement of voids
4. Each of the above

13-12. In most inorganic soils, the specific gravity of the solid substance has what minimum to maximum range?

1. 2.60 and 2.65
2. 2.60 and 2.80
3. 2.65 and 3.00
4. 3.00 and 3.50

3-13. In which of the following ways can water enter a layer of soil mass?

1. By gravitational pull
2. By capillary action
3. By absorption
4. Each of the above

13-14. When soil is subjected to loading, what soil property has the greatest effect upon its behavior?

1. Specific gravity
2. Moisture content
3. Gradation
4. Plastic and liquid limits

13-15. Which of the following descriptions best defines the term "hygroscopic moisture"? (Hint: Your textbook contains a glossary.)

1. Soil water absorbed by the atmosphere
2. Absorbed moisture in soil at any time
3. Adsorbed moisture in air-dried soil
4. Thin films of water that freely move through soil

13-16. The term "moisture content" refers to which of the following factors?

1. The amount of free water in a soil sample
2. The proportion of the weight of water to the weight of wet soil expressed as a percentage
3. The amount of hydroscopic moisture in a soil sample
4. The proportion of the weight of water to the weight of dry soil expressed as a percentage

13-17. Which of the following properties of a fine-grained soil permits clay to be rolled into thin threads at a certain moisture content without crumbling?

1. Liquidity
2. Plasticity
3. Cohesiveness
4. Consistency

IN ANSWERING QUESTIONS 13-18 THROUGH 13-20, SELECT THE TERM THE THAT BEST MATCHES THE DESCRIPTION LISTED.

A.	LIQUID LIMIT
B.	PLASTIC LIMIT
C.	PLASTICITY INDEX
D.	SHRINKAGE LIMIT

13-18. The boundary in moisture content between the solid and semisolid state of the soil.

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

13-19. The moisture content corresponding to the arbitrary limit between the liquid and plastic states of consistency of a soil.

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

13-20. The moisture content at the arbitrary limit between the plastic and semisolid state of a soil .

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

13-21. Which of the following constructions would be least affected by soil moisture?

1. An asphaltic-cement road laid on a sand-clay admixture
2. A concrete building foundation laid on a base of fine-grained soil
3. A concrete building foundation laid on a gravel base
4. An asphaltic-cement runway laid on a gravel-clay admixture

13-22. In the Unified Soil Classification System, what category of soil is identified by the presence of large amounts of organic material?

1. Coarse grained
2. Fine grained
3. Peat
4. Sand

13-23. When less than half of the coarse portion of a soil sample is retained on a No. 4 sieve, the sample is classified as what type of soil?

1. Sand
2. Gravel
3. Silt
4. Clay

13-24. When you dig test holes with the hand auger, the samples may be completely disturbed, but they are satisfactory for determining which of the following information?

1. Compaction capabilities
2. Moisture content
3. Soil profile
4. All of the above

13-25. A soil sample tagged CB-P3-1 was taken from which of the following locations?

1. Project CB, bag No. P3, pit No. 1
2. Project CB, pit No. 3, location No. 1
3. Construction battalion pit No. 3, area No. 1
4. Construction borrow pit No. P3, bag No. 1

13-26. Disturbed samples are satisfactory for use in which of the following tests?

1. Unconfined compression
2. Mechanical analysis
3. Specific gravity
4. Both 2 and 3 above

13-27. YOU are taking a moisture content sample that you know will be tested within the next 4 hours. At a minimum, what action, if any, should you take to prevent the evaporation of moisture from the soil?

1. Seal the canister with friction tape
2. Dip the canister in paraffin
3. Wrap the canister with a paraffin coated cloth
4. None, since the test will be performed within 1 day

13-28. Soil samples obtained by samplers are used for the testing of which of the following soil properties?

1. In-place density
2. Shear strength
3. Compressive strength
4. All of the above

13-29. A chunk sample would be best suited for sampling which of the following soil types?

1. Highly plastic
2. Cohesionless
3. Slightly plastic
4. Moderately cohesive

13-30. YOU are obtaining an undisturbed soil sample using the CBR mold. After removing the CBR mold and sample from the hole, which of the following steps should you take next ?

1. Trim out a ½-inch recess in the top of the mold
2. Coat the top of the sample with paraffin
3. Remove the upper collar of the mold
4. Trim out both ends of the mold before sealing the sample ends with paraffin

13-31. One way to be certain that a soil sample used is representative of the whole sample is by using which of the following methods?

1. Straining
2. Soaking
3. Halving
4. Quartering

13-32. When quartering a sample, what quarter(s), if any, should you discard?

1. Any single quarter
2. Two adjacent quarters
3. Two diagonally opposite quarters
4. None

13-33. For a complete soil test, identify the logical sequence of the following procedures.

A. Determine the specific gravity of representative samples.
B. Determine the moisture content of representative samples.
C. Determine moisture-density relationship.
D. Determine grain size and distribution.
E. Determine the field moisture content.
F. Determine Atterberg limits.

1. A, B, F, C, E, D
2. B, C, A, D, F, E
3. B, D, A, F, C, E
4. B, D, C, A, E, F

TEST	NATURAL SOIL MOISTURE CONTENT					
RUN NUMBER	1	2	3			
TARE NUMBER	6	7	9			
A. WEIGHT OF TARE + WET SOIL	196.4	187.3	209.6			gm
B. WEIGHT OF TARE + DRY SOIL	176.8	169.9	190.2			gm
C. WEIGHT OF WATER, W_w = (A - B)						gm
D. WEIGHT OF TARE	43.6	44.0	46.4			gm
E. WEIGHT OF DRY SOIL, W_s = (B - D)						gm
WATER CONTENT, w	%	%	%	%	%	

81NP0018

Figure 13A

IN ANSWERING QUESTIONS 13-34 THROUGH 13-37, REFER TO FIGURE 13A WHICH IS A TABLE OF VALUES FOR THREE MOISTURE CONTENT TESTS ON A TYPICAL SOIL SAMPLE. COMPUTE THE WATER CONTENT OF EACH RUN.

13-34. What is the dry weight of the soil in run number 1?

1. 176.8 g
2. 152.8 g
3. 143.6 g
4. 133.2 g

13-35. What is the weight of water in run number 2?

1. 17.4 g
2. 17.6 g
3. 18.4 g
4. 18.6 g

13-36. What is the water content of run number 3?

1. 13.0%
2. 13.2%
3. 13.5%
4. 17.4%

13-37. What is the average moisture content of the three runs?

1. 13.4%
2. 14.0%
3. 31.1%
4. 41.9%

13-38. The results of a sieve analysis shows 100% passing the 1 3/4-, 1½-, and 1¼-inch sieves and 99% passing the l-inch sieve. What should be the first sieve size entered on the data sheet?

1. 1
2. 1¼
3. 1½
4. 1 3/4

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SIEVE ANALYSIS DATA

SIEVE ANALYSIS DATA			DATE: 11 July 19—
PROJECT		EXCAVATION NUMBER: 2	SAMPLE NUMBER: FT-P1-1
DESCRIPTION OF SAMPLE: 25 lb. bag sample			PREWASHED: ☐ YES ☒ NO
WEIGHT ORIGINAL SAMPLE (gm): 1632.8	WEIGHT AFTER PREWASHING[1] (gm)		WASHING LOSS[1] (gm)

SIEVE OR SCREEN a	WEIGHT RETAINED ON SIEVE (gm) b	PASSING SIEVE WEIGHT (gm) c	PASSING SIEVE PERCENT d
*	0		100
3/4		1632.8	100.0
1/2	394.8	1238.0	
3/8	217.3	1020.7	
No. 4	176.2	844.5	
10	189.4	655.1	
20	362.1	293.0	
40	108.3	184.7	
100	140.2	44.5	
NUMBER 200	23.8	20.7	

A. WEIGHT SIEVED THROUGH NO. 200 (gm): 18.3	ERROR (Original weight − total weight of fractions) (gm)
B. WASHING LOSS[1] (gm)	$(\frac{\text{Error (gm)}}{\text{Original weight (gm)}} \times 100) =$
C. TOTAL PASSING NO. 200 (gm) (A + B): 18.3	PERCENT ERROR
TOTAL WEIGHT OF FRACTIONS (Total of all entries in Col. b + c)	$(\frac{\text{Error (gm)}}{\text{Original weight (gm)}} \times 100) =$

REMARKS

TECHNICIAN (Signature)	COMPUTED BY (Signature)	CHECKED BY (Signature)

[1] For prewashed samples only. * Maximum particle size

86NP0009

Figure 13B

IN ANSWERING QUESTIONS 13-39 THROUGH 13-42, REFER TO FIGURE 13-B.

13-39. What percentage of the material tested passed the No. 40 sieve?

1. 17.9%
2. 11.3%
3. 10.2%
4. 2.7%

13-40. What is the percentage of error in the soil sample?

1. 1.5%
2. 1.4%
3. 0.15%
4. 0.14%

13-41. The soil sample predominantly consists of what type of material?

1. Cobbles
2. Gravel
3. Sand
4. Fines

13-42. What is the percentage of gravels contained in the sample?

1. 48.3%
2. 51.7%
3. 62.5%
4. 88.7%

13-43. A sieve analysis data sheet shows that the original weight of a test sample exceeds the total weight of fractions, resulting in a percentage error that is smaller than the maximum permissible error. Which of the following actions should you take?

1. Disregard the value of the error
2. Rerun the test
3. Add the value of the error to the largest amount retained by any sieve
4. Add the value of the error to the smallest amount retained by any sieve

13-44. When is it necessary to prewash a sample before proceeding with a normal dry sieve analysis?

1. When the sample contains a surplus of superfine materials
2. When the sample has an undesirable water content
3. When the sample is too dry
4. When the sample contains too little superfine materials

13-45. During a sieve analysis, 2% of the material passed the No. 200 sieve. What subsequent test, if any, should you perform on the sample to determine this soil's susceptibility to frost?

1. Hydroscopic moisture content
2. Hydrometer analysis
3. Specific gravity
4. None

13-46. After a sieve analysis has been performed, which of the following materials should be tested for specific gravity of solids?

1. Only those larger than the No. 40 sieve
2. Only those retained on the No. 4 sieve
3. Only those passing the No. 4 sieve
4. Materials passing the No. 200 sieve

W_s	=	102.3
W_{bw}	=	536.1
W_{bws}	=	600.5
K	=	0.9975
G_a	=	2.58
G_m	=	2.58

Percent Gravel = 60%
Percent Sands and Fines = 40%

Figure 13C

IN ANSWERING QUESTIONS 13-47 AND 13-48, REFER TO THE DATA IN FIGURE 13C.

13-47. Find the specific gravity of solids.

1. 2.67
2. 2.69
3. 2.71
4. 2.73

13-48. Find the composite specific gravity.

1. 2.42
2. 2.52
3. 2.62
4. 2.64

13-49. Which of the following errors will have the greatest negative impact on the accuracy of a specific gravity test?

1. Loss of material
2. Misreading the thermometer by 1°
3. Not soaking a clean, sandy soil before exhausting the air from the volumetric flask
4. Failing to apply the correction factor (K)

13-50. What should be the surface appearance of a saturated-surface-dry soil sample?

1. Very wet
2. Damp
3. Very dry

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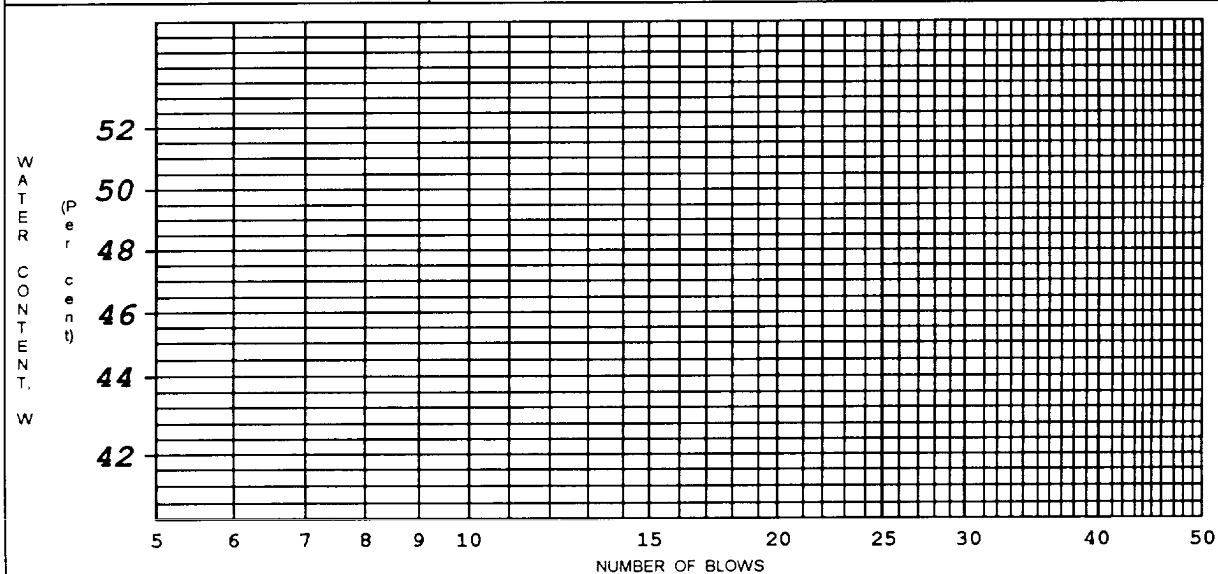
ATTERBERG LIMITS DETERMINATION			DATE
PROJECT		EXCAVATION NUMBER	SAMPLE NUMBER

LIQUID LIMIT, W_L						
RUN NUMBER	1	2	3	4	5	6
TARE NUMBER	41	42	43	44	45	46
A. WEIGHT OF WET SOIL + TARE	43.96	41.78	43.92	41.51	43.38	43.73
B. WEIGHT OF DRY SOIL + TARE	41.07	38.84	40.92	38.45	40.23	34.16
C. WEIGHT OF WATER, W_W *(A - B)*						
D. WEIGHT OF TARE	34.04	32.06	34.29	31.88	33.76	34.16
E. WEIGHT OF DRY SOIL, W_S *(B - D)*						
WATER CONTENT, $w = (\frac{W_W}{W_S} \times 100)$						
NUMBER OF BLOWS	49-50-51	39-41	32-34	29-29	23-24-25	18-19

W_L	W_P	I_P $(W_L - W_P)$
LL =	PL = 42.0	PI =



PLASTIC LIMIT, W_P					NATURAL WATER CONTENT
RUN NUMBER					
TARE NUMBER					
F. WEIGHT OF WET SOIL + TARE					
G. WEIGHT OF DRY SOIL + TARE					
H. WEIGHT OF WATER, W_W *(F - G)*					
I. WEIGHT OF TARE					
J. WEIGHT OF DRY SOIL, W_S *(G - I)*					
WATER CONTENT, $w = (\frac{W_W}{W_S} \times 100)$					
PLASTIC LIMIT, I_P *(Average w)*					

REMARKS		
TECHNICIAN *(Signature)*	COMPUTED BY *(Signature)*	CHECKED BY *(Signature)*

DD Form 1209, AUG 57 86NP0010

Figure 13D

IN ANSWERING QUESTIONS 13-51 THROUGH 13-54, REFER TO FIGURE 13D.

13-51. What is the water content of run number 1?

1. 30.3
2. 38.5
3. 41.1
4. 43.2

13-52. What are the coordinates of run number 2?

1. 39 and 41.0
2. 39 and 41.1
3. 40 and 43.4
4. 41 and 43.4

13-53. What is the liquid limit of this soil sample?

1. 47.1
2. 48.0
3. 49.2
4. 49.8

13-54. What is the plasticity index of this soil sample?

1. 5.1
2. 5.5
3. 6.0
4. 7.2

13-55. The slump test measures what property of concrete?

1. Workability
2. Strength
3. Durability
4. Compressibility

13-56. To ensure a slump test specimen is a good representation of the concrete batch, you must take samples at two or more regularly spaced intervals during discharge from which portion of the batch?

1. First only
2. Middle only
3. First and middle
4. Last

13-57. In a slump test, each layer of concrete is rodded how many strokes?

1. 10
2. 15
3. 25
4. 30

13-58. When a slump test is performed, the entire procedure from the beginning of the sampling process through the removal of the slump cone from the specimen should NEVER exceed what maximum number of minutes?

1. 7½
2. 17½
3. 20
4. 22½

13-59. To what extent do the sampling procedures for cylinder specimens differ from those for slump tests?

1. Much different procedures are used
2. The same procedures are used
3. Nearly the same procedures are used, except that the samples are taken from the discharge of the first portion of the batch

13-60. When preparing standard size cylinder specimens, you should (a) fill the mold with what total number of layers, and (b) rod each layer with a total of how many strokes?

1. (a) 2 (b) 25
2. (a) 2 (b) 50
3. (a) 3 (b) 25
4. (a) 3 (b) so

13-61. When the maximum size of coarse aggregate is 3 inches, what should be the minimum cross-sectional dimensions of the beam specimen?

1. 6 in by 6 in
2. 6 in by 9 in
3. 9 in by 9 in
4. 9 in by 12 in

13-62. While the functions of all the other SEABEE ratings relate to the whole of a construction project, the EA's functions are related to only the site preparation and layout phases.

1. True
2. False

13-63. The responsibilities of an NMCB engineering division include which of the following tasks?

1. Providing as-built copies of drawings to customer activities
2. Maintaining construction project status boards
3. Both 1 and 2 above

13-64. The responsibilities of a battalion's monitoring/reporting division include which of the following tasks?

1. Maintaining project status records
2. Timekeeping and labor analysis
3. Preparing project completion letters
4. All of the above

13-65. The components of a PWD engineering division include which of the following branches?

1. Planning and estimating branch
2. Civil branch
3. Both 1 and 2 above
4. Inspection branch

13-66. A crew leader/supervisor who asks questions relative to assigned tasking is demonstrating weak leadership.

1. True
2. False

13-67. You are informed that your survey crew is not being efficient in performing assigned survey tasks. Which of the following conditions may be an underlying cause of this inefficiency?

1. Crew members were not properly briefed as to the scope of their assigned tasks
2. Each crew member did not understand his assigned responsibilities
3. The importance of assigned tasks in relation to overall mission of the unit was not emphasized
4. All of the above

13-68. Prints that are smaller than size B should be stored in a standard deep-drawer cabinet in which of the following ways?

1. On edge
2. Flat
3. Rolled
4. Folded

13-69. What is the final folded size of prints in accordion-pleat type of folds?

1. 8 3/8 by 10 7/8 inches
2. 8 1/2 by 11 inches
3. 8 3/4 by 11 inches
4. 9 by 11 inches

13-70. For easy reference, prints or drawings for active projects should be stored in which of the following ways?

1. In folders
2. In stick files
3. In deep-drawer cabinets
4. Rolled

13-71. Which of the following shore activities generally use the Standard Subject Identification Codes System for the filing of drawing records?

1. Public Works Centers
2. Naval Construction Battalion Centers
3. Naval Construction Regiments
4. All of the above

13-72. Which of the following information should always be recorded on the index card for your drawing files?

1. Drawing title and number
2. Cross-referenced correspondence relating to the drawing(s)
3. Name of agency that made the drawing
4. All of the above

13-73. As the librarian for the Engineering Technical Library, you are responsible for which of the following tasks?

1. Ensuring that the publications are all in their proper location
2. Maintaining an efficient check-out/check-in system
3. Taking action, as necessary, to ensure that any lost or missing required publications are obtained
4. All of the above

13-74. As an Engineering Aid, which of the following references should you consult to find all the requirements that you must satisfy for advancement to the next higher paygrade?

1. NAVEDTRA 10696
2. NAVFAC P-485
3. NAVEDTRA 71365
4. OPNAVINST 5110.4

13-75. Which of the following information does the Personnel Readiness Capability Program provide?

1. Information of skills of each crew member
2. Detailed personnel skill information to all levels of the Naval Construction Forces
3. Information to be used for better command and planning in matters of readiness, capability, training, and logistical support at all levels
4. All of the above