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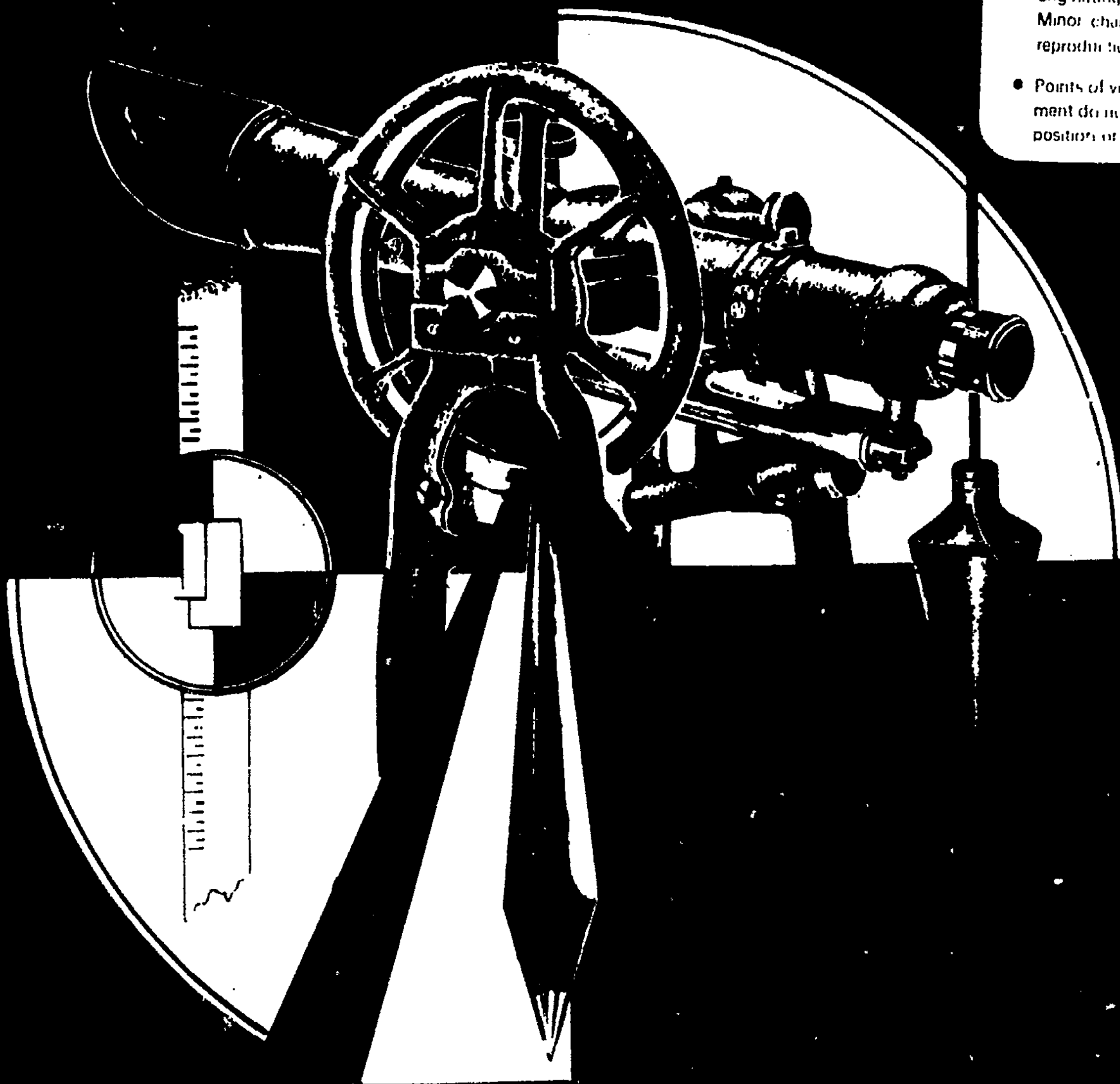
ABSTRACT

Designed for individual study and not formal classroom instruction, this rate training manual provides subject matter that relates directly to the occupational qualifications of the Engineering Aid (EA) rating. This volume contains 10 chapters which deal with: (1) wood and light frame structures (examining the uses, kinds, sizes, and grades of lumber, the various structural members and their functions, and the rough and finished hardware); (2) heavy construction (focusing on wood, steel, and steel frame structures); (3) basic materials commonly used in concrete and masonry construction; (4) materials for mechanical and electrical systems; (5) horizontal construction (examining road and airfield construction terminology, construction methods, and uses of common construction materials); (6) construction drawings; (7) mechanical plans; (8) electrical plans; (9) various types of references used by technical specification writers in the preparation of project specifications (including their format and the terminology used); and (10) typical reproduction equipment and the procedures in maintaining engineering drawing files. (JN)



ENGINEERING AID 3 & 2, VOL. 2

NAVAL EDUCATION AND TRAINING COMMAND

RATE TRAINING MANUAL

NAVEDTRA 10628

Although the words "he," "him," and "his" are used sparingly in this manual to enhance communication, they are not intended to be gender driven nor to affront or discriminate against anyone reading *Engineering Aid 3 & 2, Volume 2*, NAVEDTRA 10628.

Naval Education And Training Program Development Center

ENGINEERING AID 3 & 2, VOLUME 2

NAVEDTRA 10628

1982 Edition Prepared by
EACS Benito C. Bernal, Jr.

PREFACE

The ultimate purpose of training Naval personnel is to produce a combatant Navy which can insure victory at sea. A consequence of the quality of training given them is their superior state of readiness. Its result is a victorious Navy.

This Rate Training Manual and Nonresident Career Course (RTM/NRCC) form a self-study package that will enable Engineering Aids to fulfill the requirements of their rating. In this RTM/NRCC, the emphasis is placed on you, the Engineering Aid, to acquire a basic understanding of the materials, the procedures, the terminology, the specifications, and the construction sequences used in the construction field. With this knowledge and experience, you should be able to develop a quality set of drawings.

Designed for individual study and not formal classroom instruction, the RTM provides subject matter that relates directly to the occupational qualifications of the Engineering Aid rating. The NRCC provides the usual way of satisfying the requirements for completing the RTM. The set of assignments in the NRCC includes learning objectives and supporting items designed to lead the students through the Rate Training Manual.

This RTM/NRCC was prepared by the Naval Education and Training Program Development Center, Pensacola, Florida, for the Chief of Naval Education and Training. Technical assistance was provided by the Naval Facilities Engineering Command, Alexandria, Virginia; the Chief of Naval Technical Training, Millington, Tennessee; the Naval Construction Training Center, Port Hueneme, California; the Naval Construction Training Center, Gulfport, Mississippi; and the Civil Engineer Support Office, Port Hueneme, California.

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THE UNITED STATES NAVY

GUARDIAN OF OUR COUNTRY

The United States Navy is responsible for maintaining control of the sea and is a ready force on watch at home and overseas, capable of strong action to preserve the peace or of instant offensive action to win in war.

It is upon the maintenance of this control that our country's glorious future depends; the United States Navy exists to make it so.

WE SERVE WITH HONOR

Tradition, valor, and victory are the Navy's heritage from the past. To these may be added dedication, discipline, and vigilance as the watchwords of the present and the future.

At home or on distant stations we serve with pride, confident in the respect of our country, our shipmates, and our families.

Our responsibilities sober us; our adversities strengthen us.

Service to God and Country is our special privilege. We serve with honor.

THE FUTURE OF THE NAVY

The Navy will always employ new weapons, new techniques, and greater power to protect and defend the United States on the sea, under the sea, and in the air.

Now and in the future, control of the sea gives the United States her greatest advantage for the maintenance of peace and for victory in war.

Mobility, surprise, dispersal, and offensive power are the keynotes of the new Navy. The roots of the Navy lie in a strong belief in the future, in continued dedication to our tasks, and in reflection on our heritage from the past.

Never have our opportunities and our responsibilities been greater.

CONTENTS

SUMMARY OF ENGINEERING AID 3 & 2 RATE TRAINING MANUALS

VOLUME 1

Engineering Aid 3 & 2, Volume 1, NAVEDTRA 10634-C includes chapters on the Job Ahead; Administration and Organization; Mathematics and Units of Measurement; Drafting: Equipment and Supplies; Drafting: Basic Techniques, Format, and Conventions; Lettering; Drafting: Geometric Construction; and Drafting: Projections and Sketching.

VOLUME 2

Engineering Aid 3 & 2, Volume 2, NAVEDTRA 10628 includes chapters on Wood and Lightwood Frame Structures, Wood and Steel Frame Structures, Concrete and Masonry, Mechanical and Electrical Systems (Materials), Horizontal Construction, Construction Drawings, Mechanical and Electrical Plans, Specifications, and Reproduction and Drawing Files.

VOLUME 3

Engineering Aid 3 & 2, Volume 3, NAVEDTRA 10629 will include chapters on Construction Surveying and Material Testing. The publication date for this Rate Training Manual will be established at a later date.

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CHAPTER 1

WOOD AND LIGHTWOOD FRAME STRUCTURES

To prepare an engineering drawing, regardless of type, you will find it necessary to apply a knowledge of the materials and methods of constructing wood and lightwood frame structures. This chapter ' scribes the uses, kinds, sizes, grades, and other characteristics of lumber; the various structural members and their functions; and the rough and finishing hardware.

WOOD

Of all the different construction materials, wood is probably the most often used as well as the most important. The variety of uses of wood is practically unlimited. Few SEABEE construction projects, whether involving permanent structures or temporary, are built without using wood. Temporary uses include concrete forms, scaffolding, shoring, and bracing. The wood that is used for temporary construction is removed before or after the permanent structure is completed and is normally reusable.

There are many types or species of wood. Each type has its own characteristics and its recommended uses. For most large projects, the type and classification of wood are given in the project specifications. For smaller projects, which do NOT have written specifications, the type and classification of wood are included in the drawings. Engineering Aids should become familiar with the different types of wood that are used for construction. The most common type of wood for this purpose is Douglas fir. It is strong, straight-grained, relatively soft, and easy to work with. In the *Architectural Graphic Standards*, common woods are listed by species, grades, uses, characteristics, and strength factors.

LUMBER

In construction, the terms "wood," "lumber," and "timber" have distinct, separate meanings. WOOD is the hard, fibrous substance which 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 inches. 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 surfaced on two sides only, the designation is S2S (surfaced 2 sides); surfaced on all four sides, S4S (surfaced 4 sides) or S2S2E (surfaced 2 sides, 2 edges). Lumber is ordered and designated on drawings by its nominal size rather than by its dressed dimensions. The difference between the nominal and dressed sizes of lumber is important, not only to the Engineering Aid, but also to the Builder. When actual thicknesses or widths of lumber are not taken into consideration, the overall dimensions of the structures will have cumulative errors. (This problem will be covered in detail later in this manual.) Common widths

Table 1-1.—Nominal and Dressed Sizes of Lumber

Item	Thickness (Inches)		Face Width (Inches)	
	Nominal	Dressed	Nominal	Dressed
Boards	1 1 1/4 1 1/2	3/4 1 1 1/4	2 3 4 5 6 7 8 9 10 11 12 14 16	1 1/2 2 1/2 3 1/2 4 1/2 5 1/2 6 1/2 7 1/4 8 1/4 9 1/4 10 1/4 11 1/4 13 1/4 15 1/4
Dimension Lumber	2 2 1/2 3 3 1/2	1 1/2 2 2 1/2 3	2 3 4 5 6 8 10 12 14 16	1 1/2 2 1/2 3 1/2 4 1/2 5 1/2 7 1/4 9 1/4 11 1/4 13 1/4 15 1/4
Dimension Lumber	4 4 1/2	3 1/2 4	2 3 4 5 6 8 10 12	1 1/2 2 1/2 3 1/2 4 1/2 5 1/2 7 1/4 9 1/4 11 1/4
Timbers	5 & Thicker		5 & Wider	

and thicknesses of lumber in nominal and dressed dimensions are shown in table 1-1.

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 inches 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.

Nominal, rough, green lumber has three general classifications according to size:

1. BOARDS—less than 2 inches thick and 1 or more inches wide. If less than 6 inches wide, they may be classified as strips.

2. DIMENSION—At least 2 inches thick, but less than 5 inches thick and 2 or more inches wide. It may be classified as framing, joists, planks, rafters, studs, and small timbers.

3. TIMBERS—smallest dimension is 5 or more inches. They may be classified as beams, stringers, posts, caps, sills, girders, and purlins.

Lumber classified by extent of manufacture consists of three types:

1. Rough lumber not dressed (surfaced) but sawed, edged, and trimmed to where saw marks show in the wood on the four longitudinal surfaces of each piece for its overall length.

2. Dressed lumber surfaced by a planing machine to attain a smooth surface and uniform size.

3. Worked lumber dressed and also matched, shiplapped, or patterned.

Grading

In accordance with 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. There are even more blemishes in grade D than in grade C. 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, tightknotted stock, containing only a few minor defects. It must be suitable for use as watertight lumber. No. 2 common contains a limited number of significant defects but no knotholes or other serious defects. It must be suitable for use as graintight 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. In addition to the numerical grades, some associations use these: construction, standard, utility, and economy.

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, knots, cross-grain checks, and splits, that affect the strength of 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 a board 1 foot long by 1 foot wide by 1 inch thick. Since the length of lumber is usually measured in feet, the width in inches, and the thickness in inches, the formula for quantity of lumber in board feet becomes:

$$\frac{\text{Thickness (inches)} \times \text{width (inches)} \times \text{length (feet)}}{12} = \text{board measure (board feet)}$$

Example: Calculate the board measure of a 14-foot 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 inch thick is presumed to be 1 inch 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.

PLYWOOD

Plywood is a panel product made from thin sheets of wood called veneers. An odd number of veneers—three, five, seven—is generally used so the grains on the face and back of the panel run in the same direction. Plywood is split-proof, puncture-proof, and pound for pound, one of the strongest materials available. 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. Builders use it for concrete forms, wall and roof sheathing, flooring, box beams, soffits, stressed-skin panels, paneling, partitions, doors, furniture, cabinets, built-ins, shelving, and hundreds of other uses.

Sizes

Plywood is generally available in panel widths of 36, 48, and 60 inches, and in panel lengths ranging from 60 to 144 inches in 12-inch increments. Other sizes are also available on special order. Panels 48 inches wide by 96 inches long (4 by 8 feet), and 48 inches wide by 120 inches long (4 by 10 feet), are most commonly available. The 4- by 8-foot and larger sizes simplify construction, saving time and labor.

Nominal thicknesses of sanded panels range from 1/4 to 1 1/4 inches or greater, generally in 1/8-inch increments. Unsanded panels are available in nominal thicknesses of 5/16 to 1 1/4 inches or greater, in increments of 1/8 inch for thicknesses over 3/8 inch. Under 3/8 inch, thicknesses are in 1/16-inch increments.

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". Occasional knotholes 1/2" 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-Pldg—Improved C veneer with splits limited to 1/8" in width and knotholes and borer holes limited to 1/4" by 1/2".

D—Permits knots and knotholes to 2 1/2" in width and 1/2" larger under certain specified limits. Limited splits permitted.

Figure 1-1.—Plywood veneer grades.

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 repeatedly or otherwise subjected to the weather, exterior plywood retains its glue bond and withstands exposure to the elements. Intérior 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. (See figure 1-1.) 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, split, 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 1-2 shows typical back and edge stamps found on a standard sheet of plywood. It shows all information needed about the sheet, except its actual size.

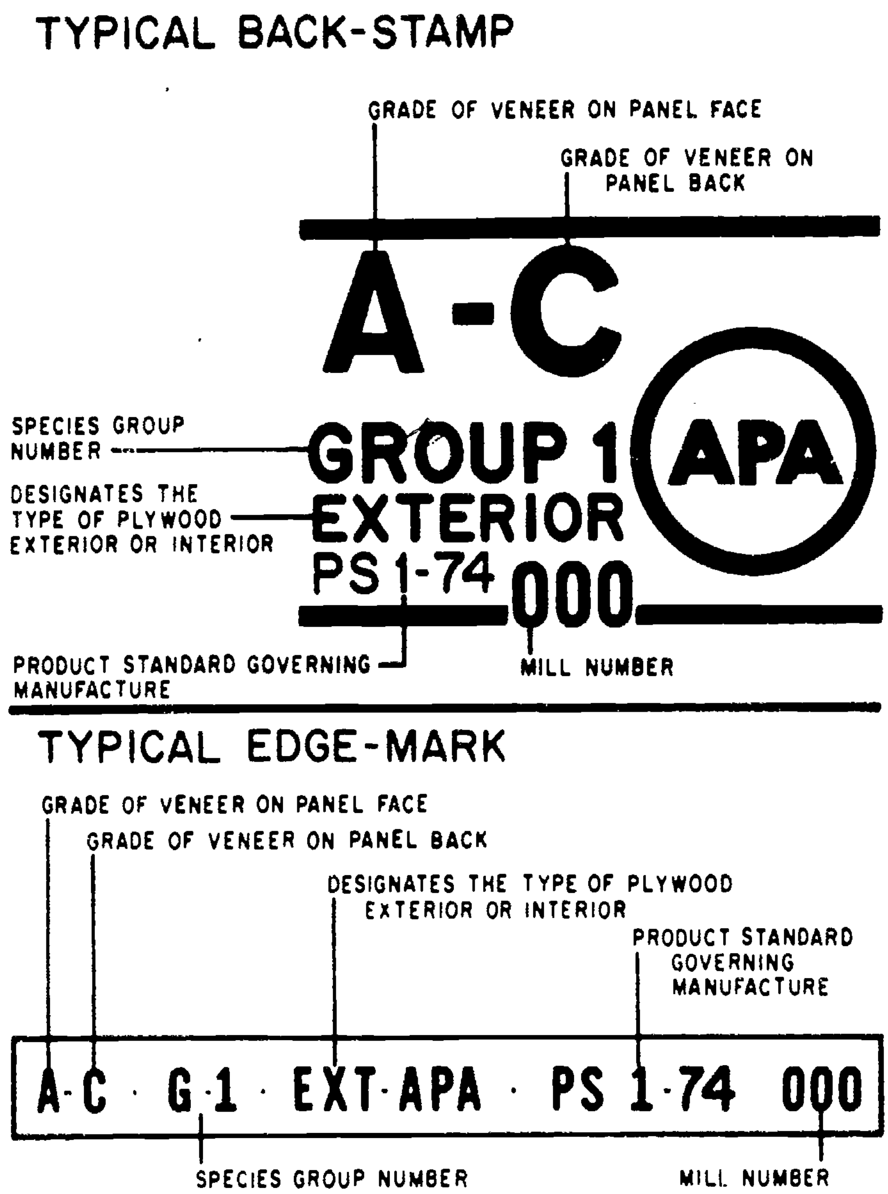

Figure 1-2.—Standard plywood identification symbols.

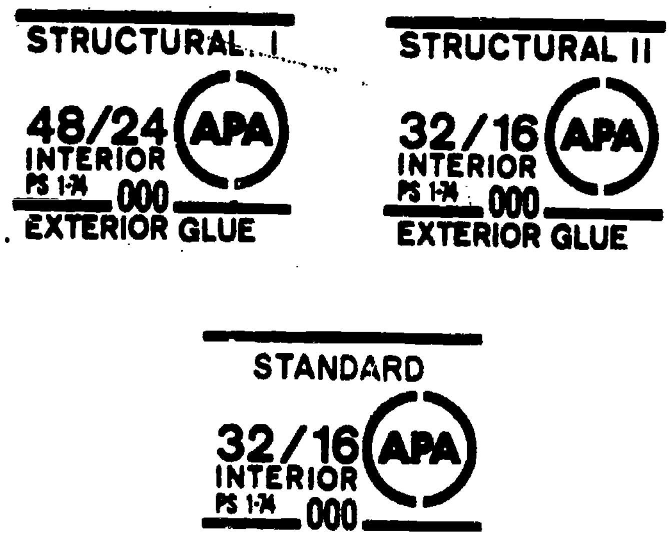

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Figure 1-3.—Structural and sheathing identification symbols.

Figure 1-3 illustrates the stamps found on the backs of structural and sheathing panels. They vary somewhat from the standard stamps. 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 on center spacing of supports for roof decking. The number to the right of the slash is the maximum on center 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 the battalion technical library.

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 geographic 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.

FRAME STRUCTURES

In a frame building, the frame consists mainly of wood or steel 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.

HORIZONTAL WOOD FRAME STRUCTURAL MEMBERS

The lowest horizontal wood frame structural member is the sill—a piece of dimensional lumber which is laid flat on and bolted down to the top of the foundation wall. Actually, it is the wall, not the sill, that supports members joined to the sill. The sill simply provides a nailing base for joining such members.

Horizontal members which support the floors in wood frame structures are called JOISTS or BEAMS, depending on their distance apart. Members less than 4 feet apart are called joists; members placed 4 feet or more apart are called beams. The usual spacing for wood frame floor members is either 16 inches or 24 inches. Joists are usually 2 by 8, 2 by 10, or 2 by 12.

Horizontal members which support joists at points other than along the outer wall lines are called GIRDERS. When the SPAN (horizontal distance between outside walls) 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 which 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 which help to support the outer-wall ends of upper-floor joists in balloon framing. Balloon framing is explained later, in the discussion on sill assemblies. SOLEPLATES are horizontal wood framing members which serve as nailing bases for STUDS in "platform" framing. Studs and platform framing are also explained later.

TOP PLATES are horizontal wood framing members which are nailed to the tops of wall or partition studs.

RAFTERS are framing members which support a roof. For a FLAT roof, they are horizontal; for a PITCHED (sloping) roof, they are inclined. Rafters are similar in cross section to joists, and usually have the same spacing.

A HEADER is a horizontal wood framing member which forms the upper member of a rough door frame, or upper or lower member of a rough window frame, as shown in figure 1-4.

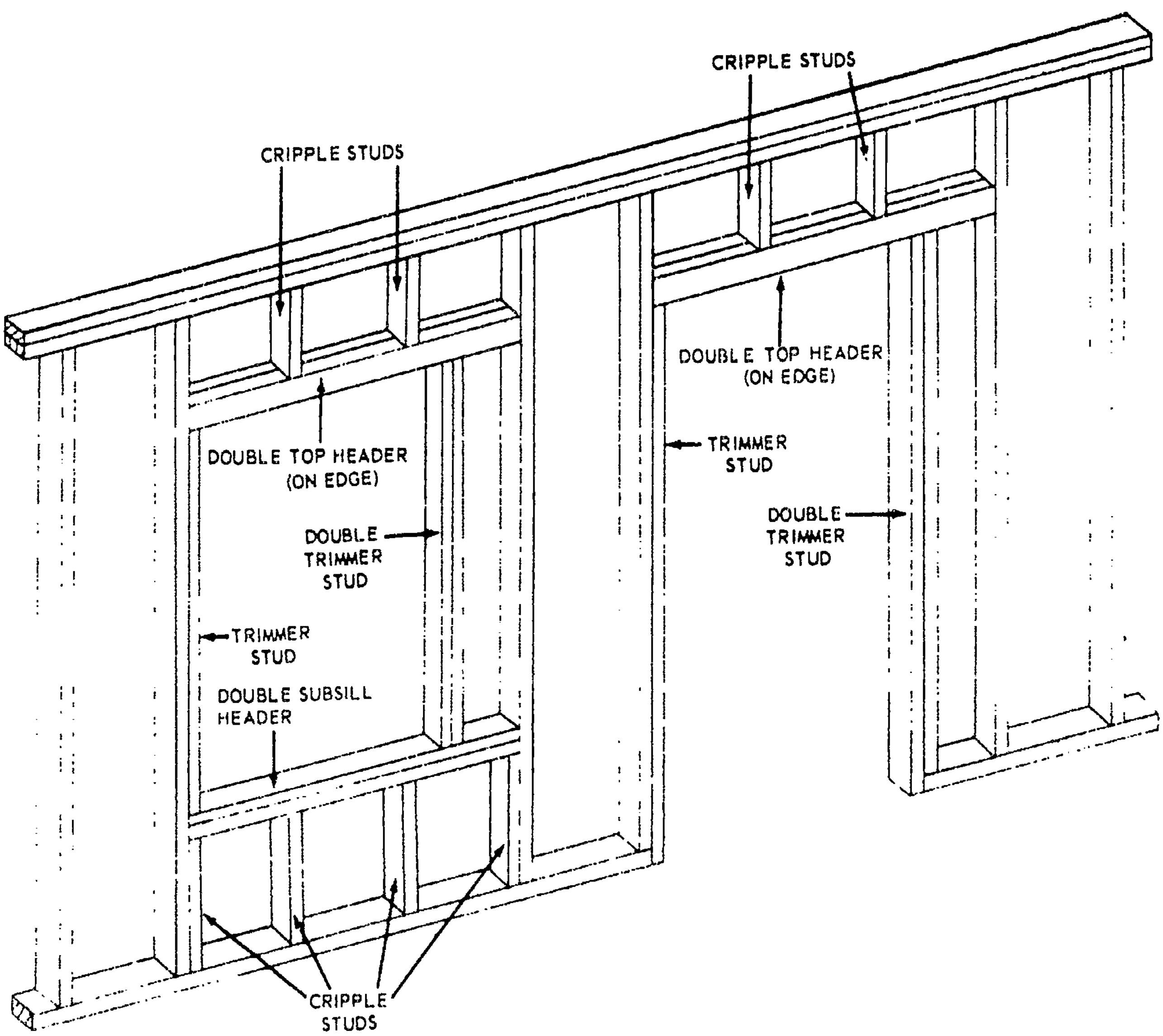

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Figure 1-4.—Part of a wall frame, showing headers.

Similar members which form the ends of a rough floor opening, or of the roof opening for a dormer window or skylight, are also called headers.

A TRUSS is a horizontal member which consists of a framework rather than a single piece. Trusses can be used to span spaces which are too wide for spanning by a single-piece member without intermediate supports. Figure 1-5 shows a roof or rafter truss. Figure 1-6 shows two types of trussed headers. The purpose of trussing a header is to increase its supporting strength when the space to be spanned is too wide to permit the use of a single-member header.

Joists are set on edge, and lateral support for joists on edge is provided by between-the-joist members called BRIDGING. There are two kinds of bridging—CROSS bridging and SOLID bridging—as shown in figure 1-7. Where used over a long span, joists tend to sway from side to side so they

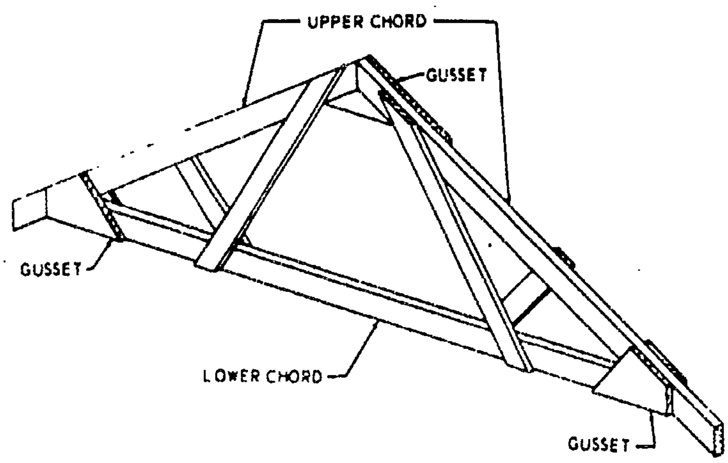

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Figure 1-5.—Roof or rafter truss.

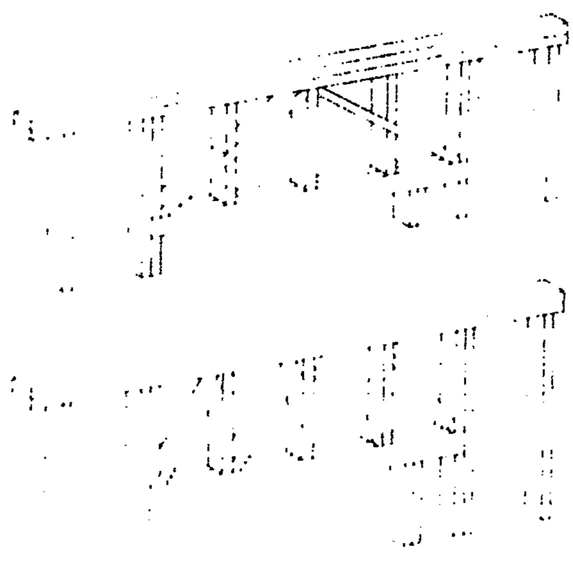

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Figure 1-6.—Trussed headers.

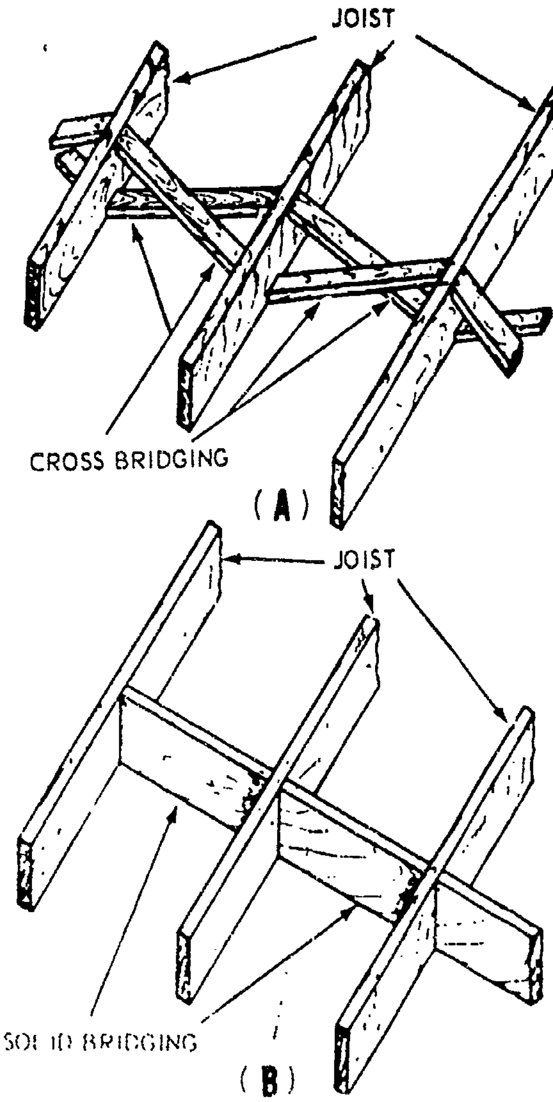

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Figure 1-7.—Cross bridging and solid bridging.

16

are bridged to stiffen the floor frame, to prevent unequal deflection of the joists, and to enable an overloaded joist to receive some assistance from the joist on either side of it.

Joists are covered by a layer (or by a double layer) of boards called the SUBFLOORING. Subflooring boards may be laid STRAIGHT (perpendicular to the joists). Because the subflooring helps to brace the joists, it is considered part of the frame of the building.

VERTICAL WOOD FRAME STRUCTURAL MEMBERS

The principal vertical wood frame structural members are the studs which are usually 2 by 4's. Figure 1-4 shows various types of studs in a wall frame. At a building corner, studs are combined in various ways to form a CORNER POST, as shown in figures 1-8 and 1-9.

Board SHEATHING is nailed to outside-wall studs to form the wall sheathing. Like subflooring, it may be laid either straight or diagonal and is considered part of the frame of the building.

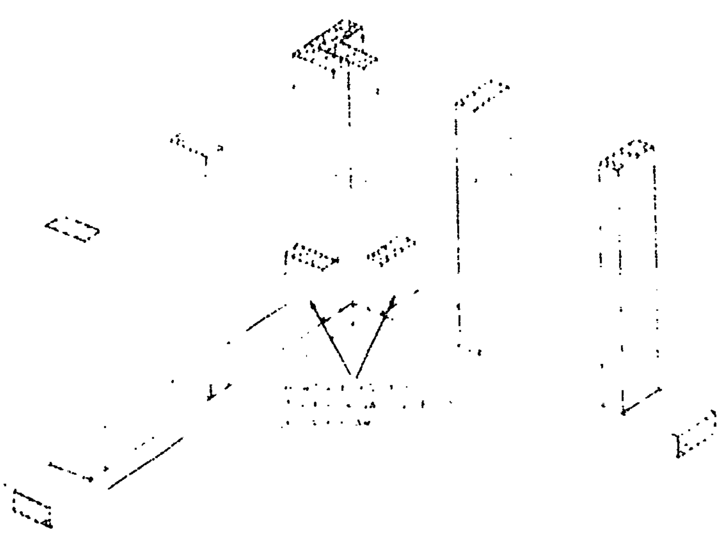

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Figure 1-8.—Simplest type of corner post.

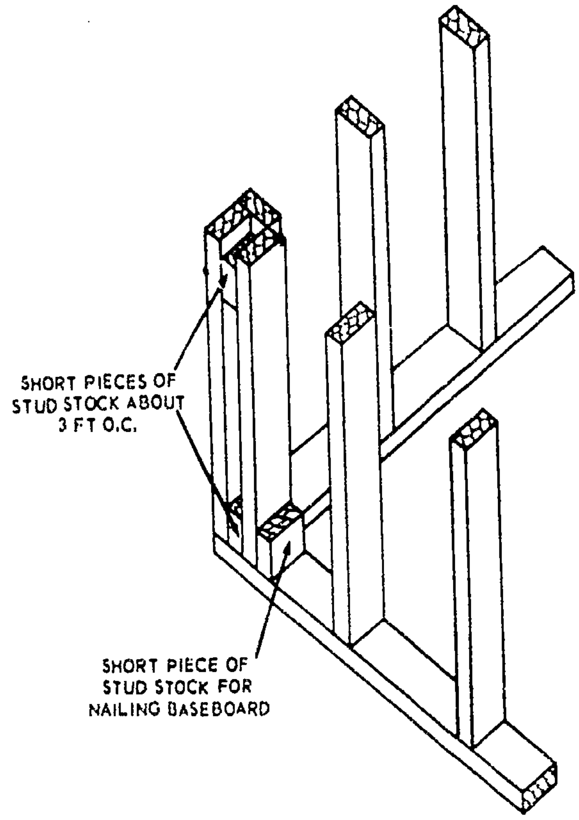

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Figure 1-9.—More solid type of corner post.

SILL ASSEMBLIES

The method of framing the studs to the sill is called a SILL ASSEMBLY. Commonly used sill assemblies are shown in figures 1-10, T-sill; 1-11, Eastern; 1-12, box sill; and 1-13, sill in brick veneer construction. The T-sill and Eastern assemblies are used in what is called BALLOON framing, in which studs are anchored on the sill and are continuous (that is, in one piece) from sill to roofline. The box-sill assembly is used in PLATFORM or WESTERN framing, where studs are cut in separate lengths for each floor and are anchored on soleplates resting on the subflooring. The construction method for a sill assembly using brick veneer as exterior siding is similar to the box-sill assembly method except that the sill is set in the foundation wall to allow enough space for the brick to rest directly on the wall.

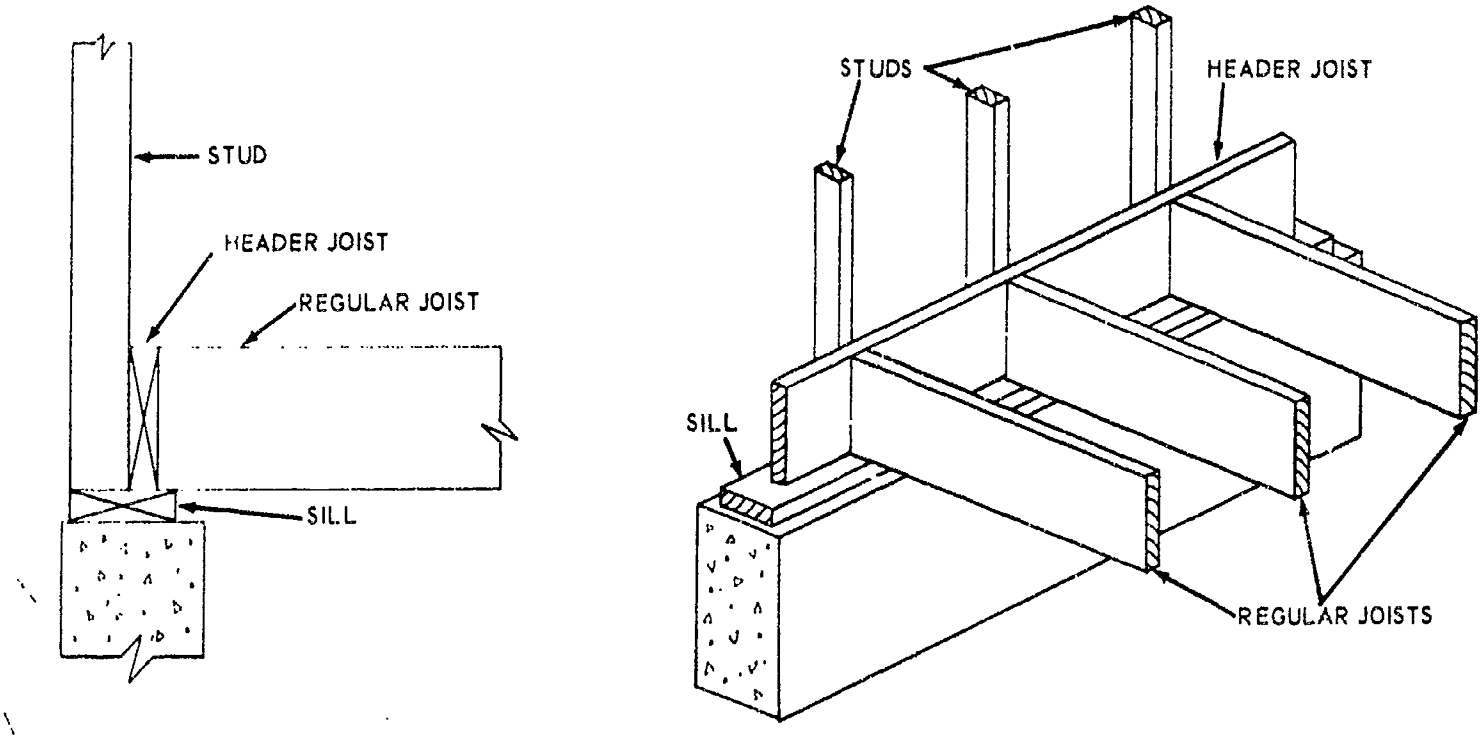

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Figure 1-10.—T-sill assembly.

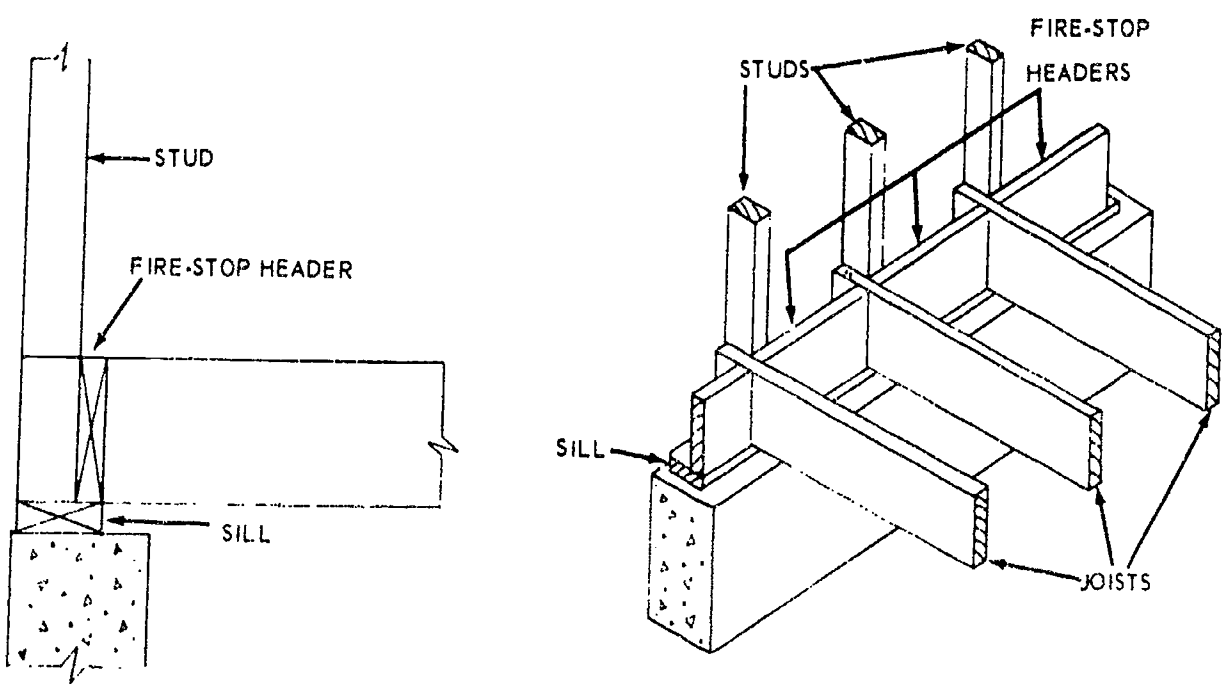

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Figure 1-11.—Eastern sill assembly.

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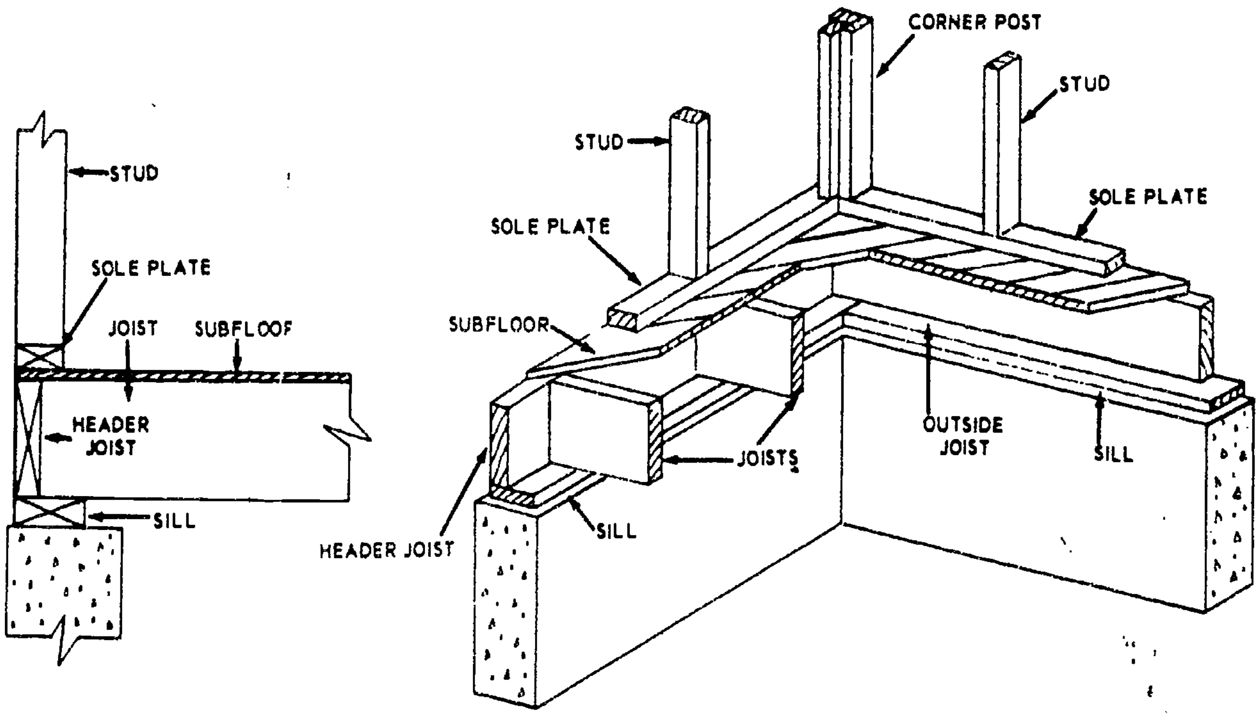

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Figure 1-12.—Box sill assembly.

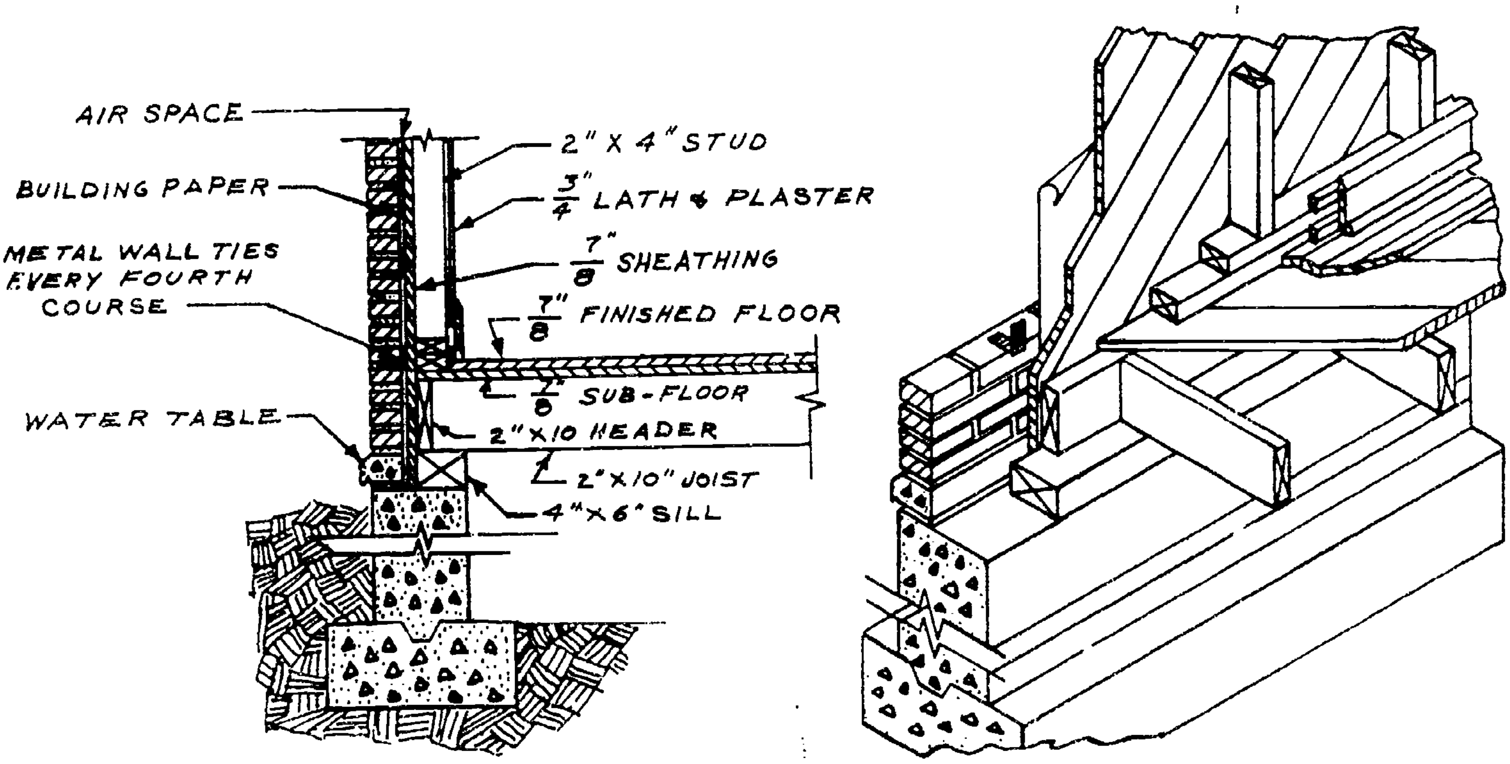

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Figure 1-13.—Sill assembly in brick veneer construction.

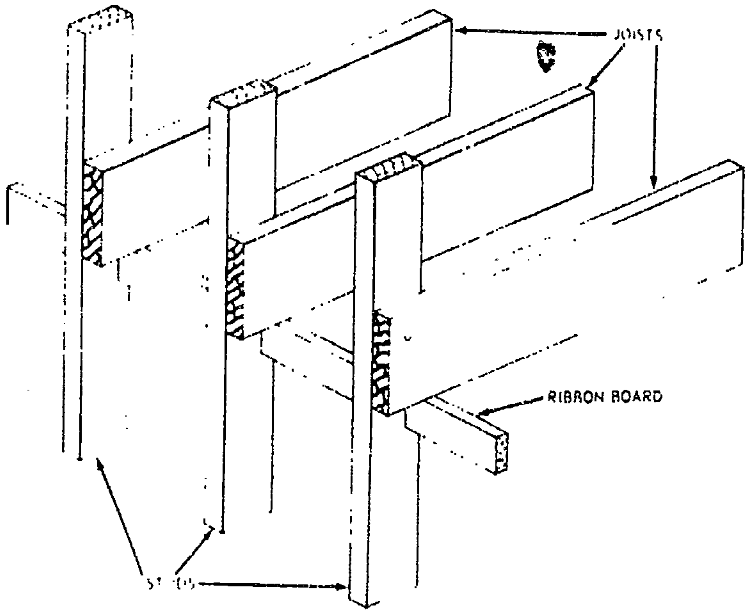

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Figure 1-14.—Method of supporting upper-floor joist ends in balloon framing.

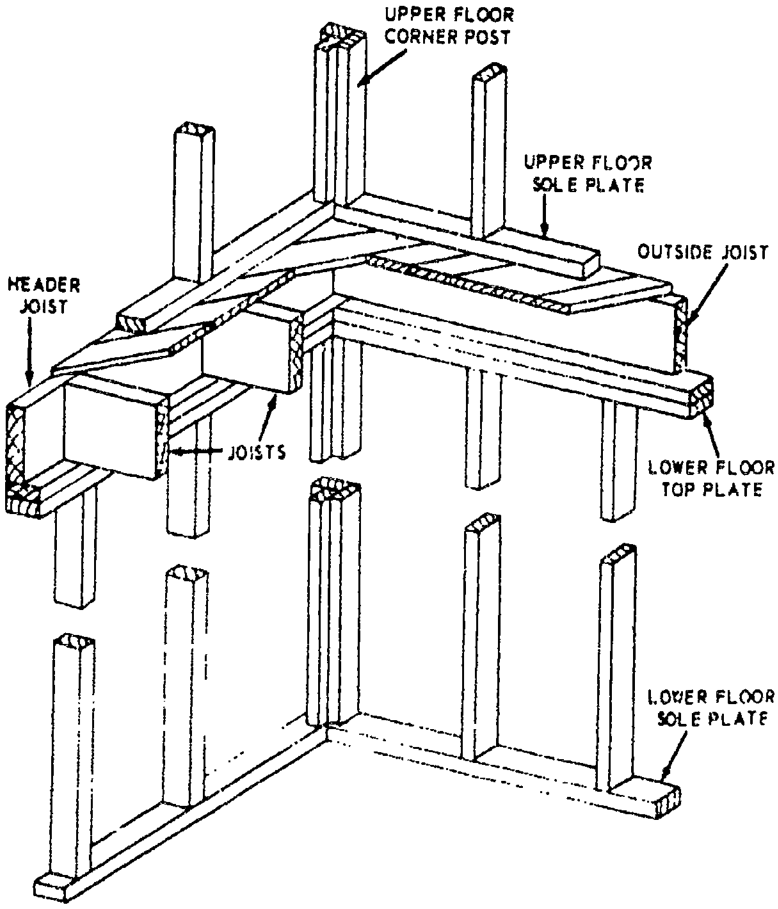

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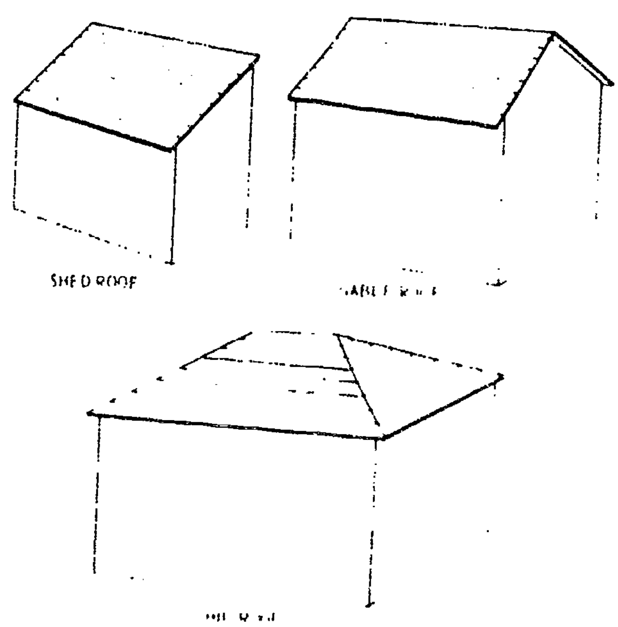
Figure 1-15.—Method of framing upper-floor joists and studs in platform framing.

Figure 1-14 shows how upper-flooring joists are supported by studs and the ribbon board (also called a GIRT or LEDGER) in balloon framing. Figure 1-15 shows how upper-floor joists are supported in platform framing.

ROOF FRAMING MEMBERS

The principal framing members in a roof are the rafters—horizontal in a flat roof, inclined in a pitched roof. When the rafters are placed farther apart, horizontal members, called PURLINS, are placed across them to serve as the nailing or connecting member for the roofing. Purlins are generally used with standard metal roofing sheets, such as 3- by 8-foot corrugated galvanized iron (G.I.) or aluminum sheets. The common practice is to use roofing nails to install metal sheet roofing; however, for a more permanent structure in which heavier gage sheets are used, rivets and metal straps are used instead of nails.

The three most common types of pitched roofs are the SHED or SINGLE-PITCH, the GABLE or DOUBLE-PITCH, and the HIP (fig. 1-16). A shed roof has a single surface, sloping downward from a RIDGE on one side of the structure. A gable roof has two surfaces, sloping downward from a ridge located between



45.449
Figure 1-16.—Common types of pitched roofs.

the sides of the structure—usually midway between them. A hip roof is pitched on the sides like a gable roof, and also on one or both ends. When both surfaces of a gable roof, or all surfaces of a hip roof, slope at the same angle, the roof is an EQUAL-PITCH roof. When the surfaces of the same roof slope at different angles, it is an UNEQUAL-PITCH roof.

Roof Pitch

The PITCH (amount of slope) of a roof is expressed as a FRACTION in which the 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 shown in figure 1-17. 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 the 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 1-17.

On construction drawings, the pitch of a roof is indicated by a small ROOF TRIANGLE like the one shown in the upper view of figure 1-17. The triangle is drawn to scale in which 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.

Roof Additions

Each of the roofs shown in figure 1-16 consists, technically speaking, of only a single roof, even though the gable roof has two surfaces and the hip roof four. A more complicated roof consists of a MAIN roof and one or more ADDITIONS. Figure 1-18 shows a main hip roof plus a gable.

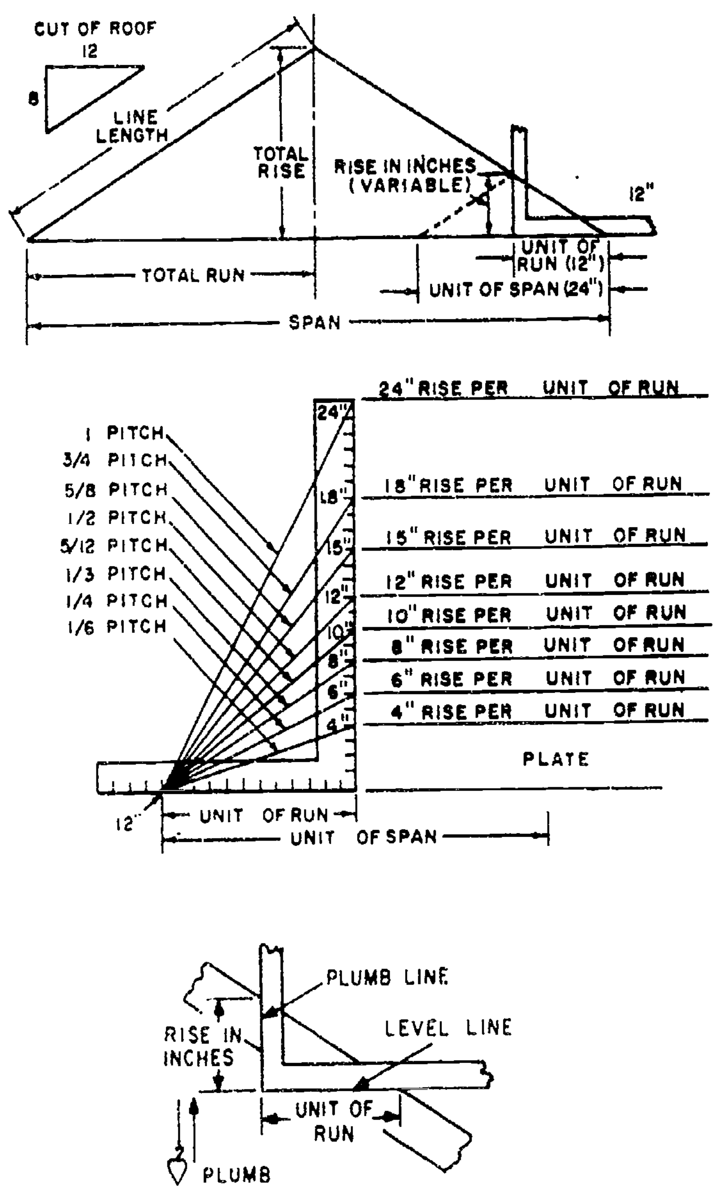


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Figure 1-17.—Roof pitch diagram.

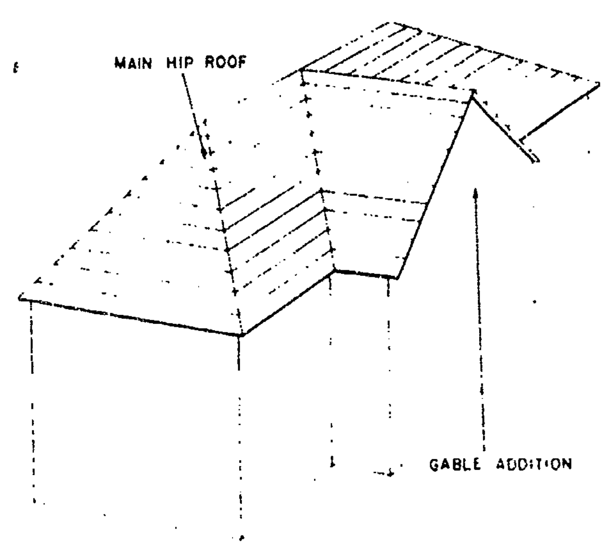

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Figure 1-18.—Main hip roof and gable addition.

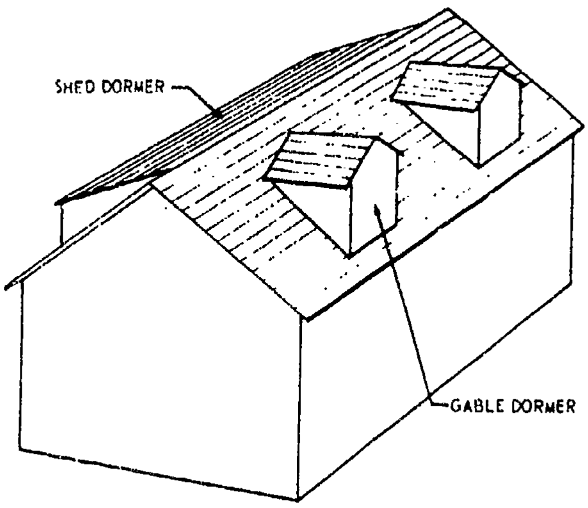

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Figure 1-19.—Dormers.

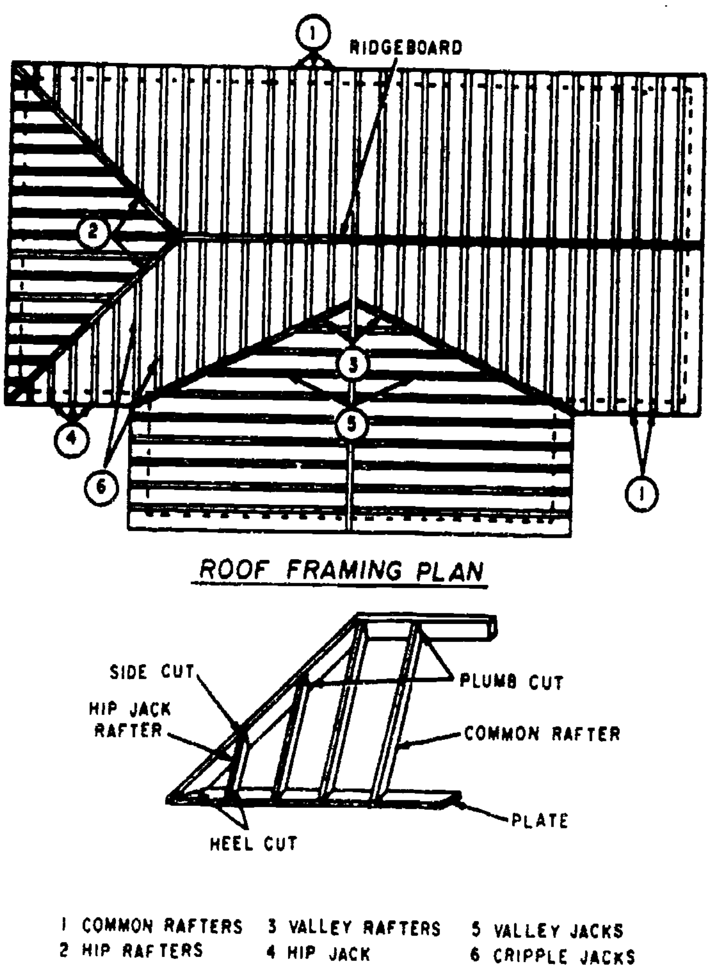

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Figure 1-20.—Rafter terms.

A roof may also contain DORMERS, as shown in figure 1-19. The figure shows a SHED dormer and two GABLE dormers. There are also HIP dormers.

Rafter Nomenclature

As mentioned earlier, the pieces which make up the main body of the framework of all roofs are called rafters. They do for the roof what joists do for the floor and what the studs do for the wall. Rafters are generally inclined members spaced from 16 to 48 inches apart which vary in size, depending on their length and the distance at which 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. 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.

The names of the different varieties of rafters are shown in figures 1-20 through 1-28. Figure 1-20 is a typical roof framing plan. In order to have a better picture of those members that cannot be seen in the plan view shown in figure 1-20, several types of roof framings should be presented in isometric drawings. The following definitions supplement the notes in the drawings.

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.

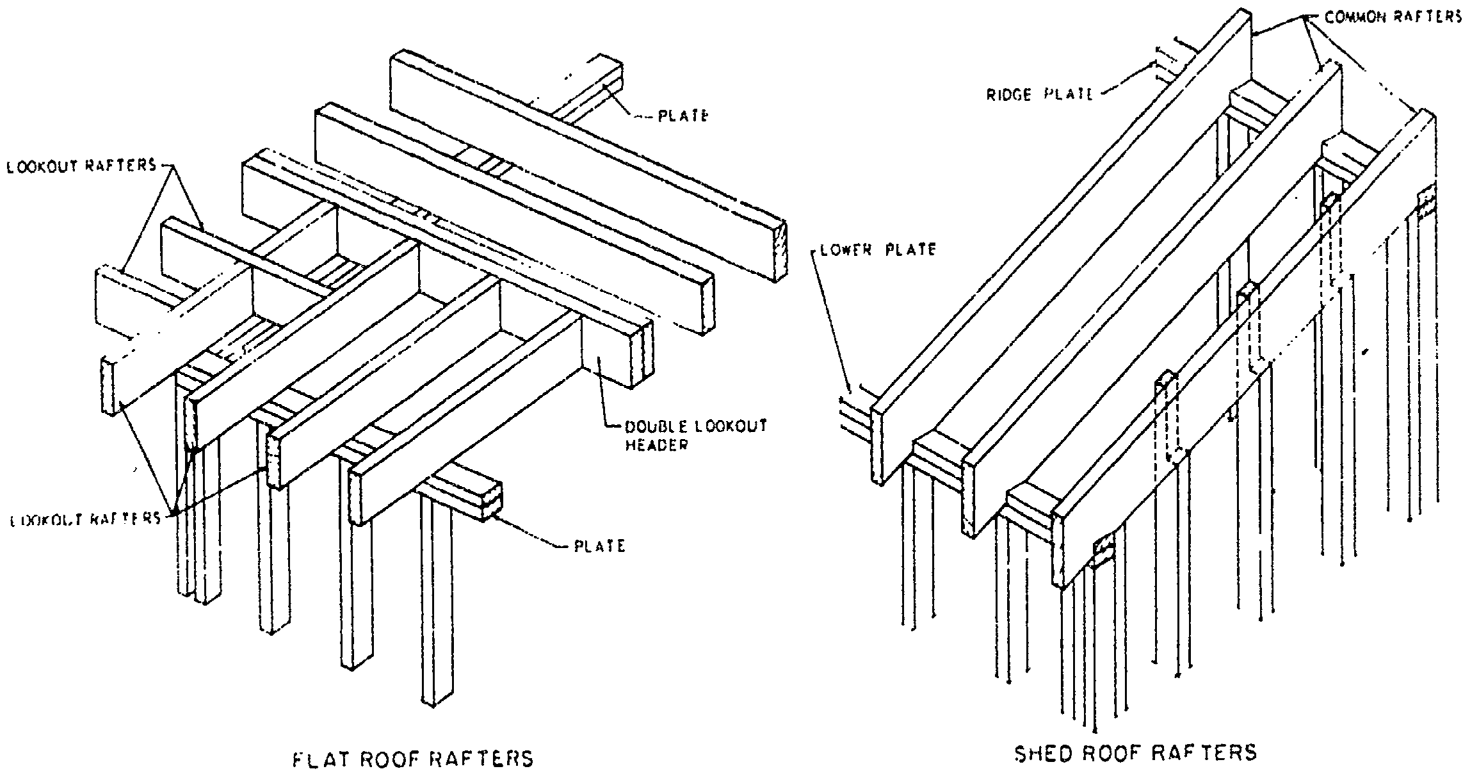

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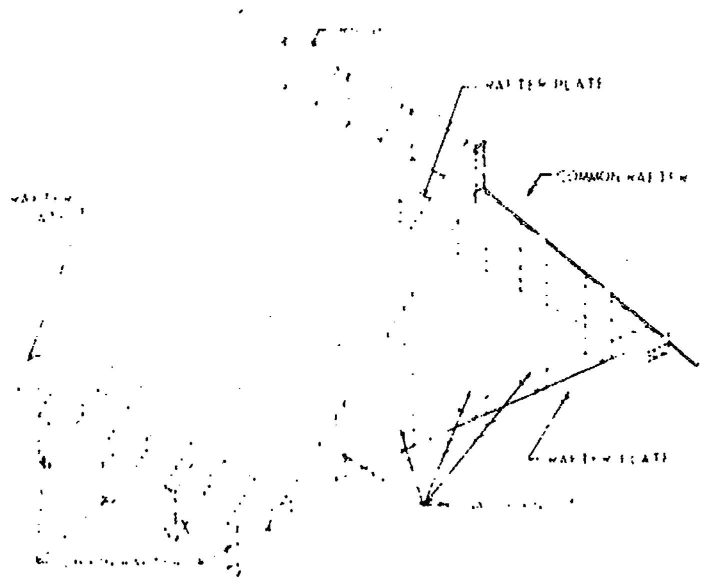
Figure 1-21.—Flat and shed roof framings.



45.455

Figure 1-22.—Gable roof framing.

HIP JACKS—Rafters whose lower ends rest on the plate and upper ends against the hip rafter.

VALLEY JACKS—Rafters whose lower ends rest against the valley rafters and upper ends against the ridgeboard.

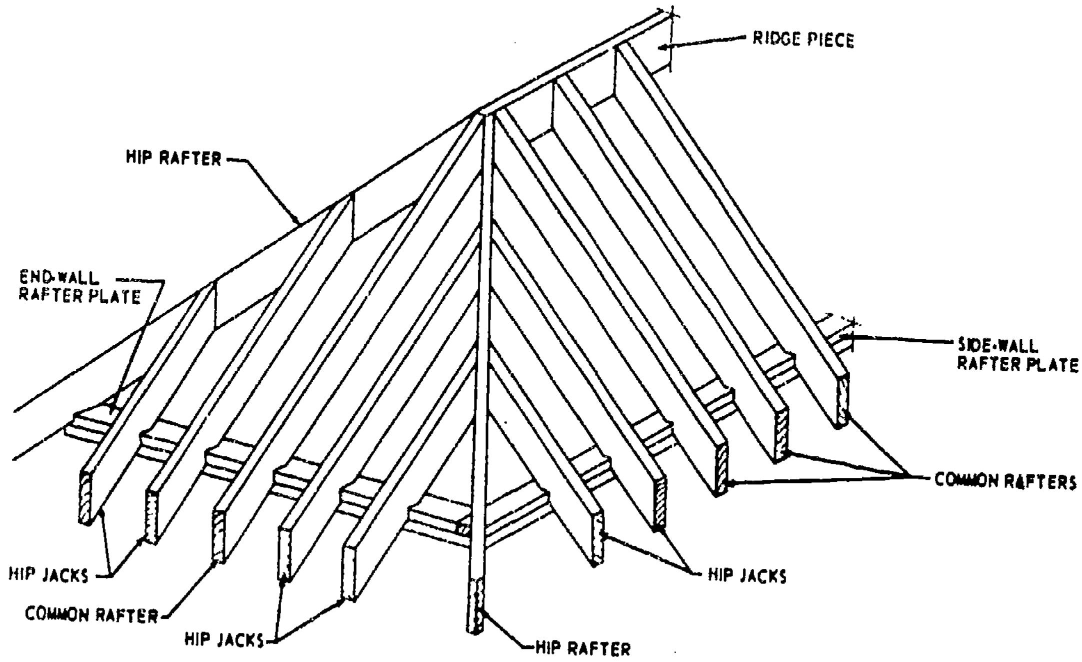
CRIPPLE JACKS—Rafters that are nailed between hip and valley rafters.

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 ridgeboard or, if the ridgeboard is omitted, against the opposite rafters. (See figure 1-20.)

SEAT, BOTTOM, OR HEEL CUT—The cut made at the end of the rafter which 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.



45.456

Figure 1-23.—Equal-pitch roof framing.

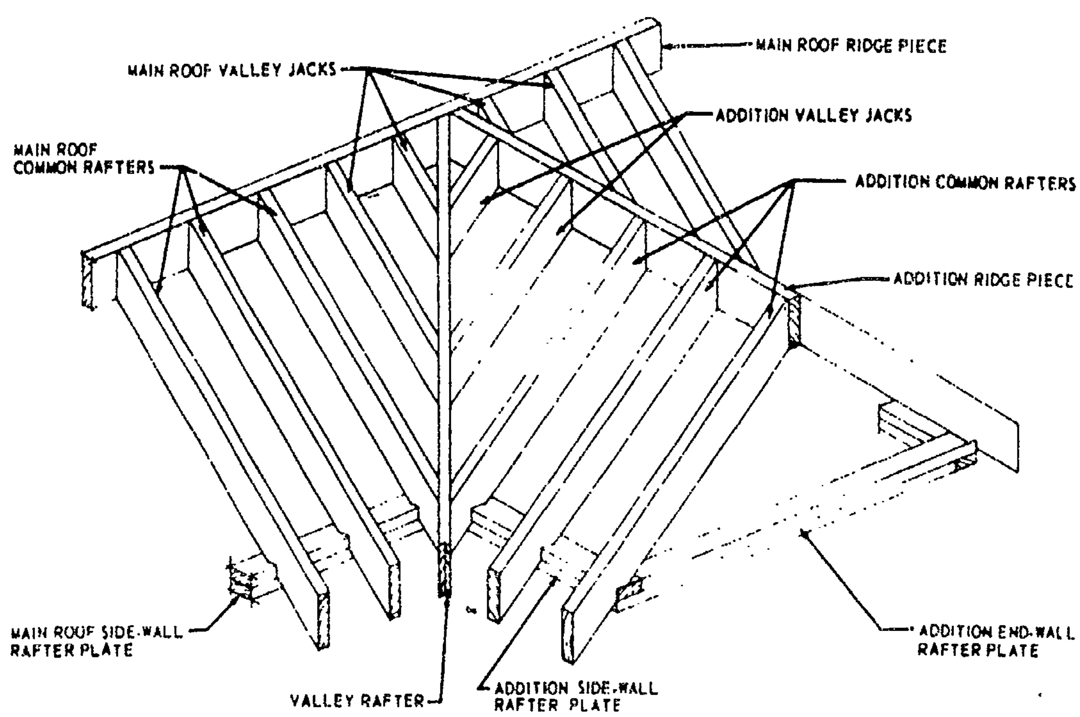


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Figure 1-24.—Addition roof framing.

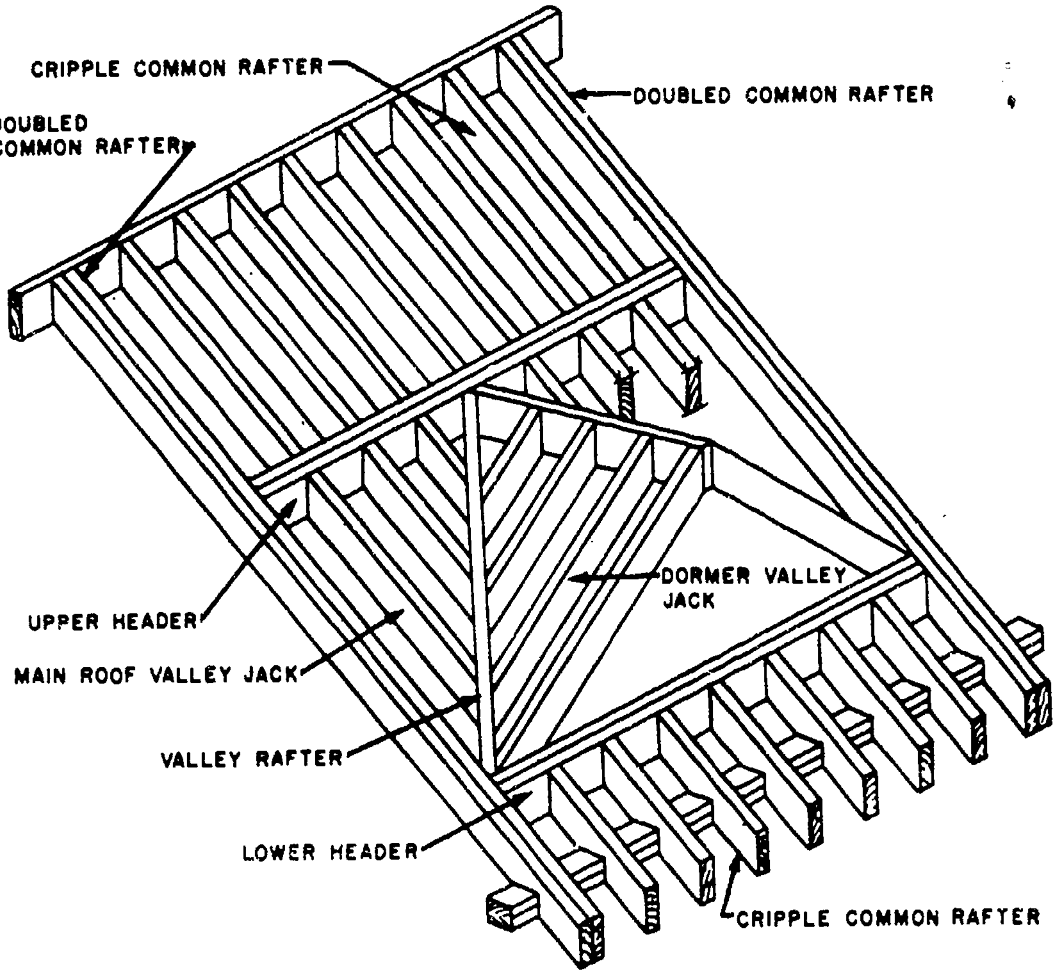

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Figure 1-25.—Framing of gable dormer without side walls.

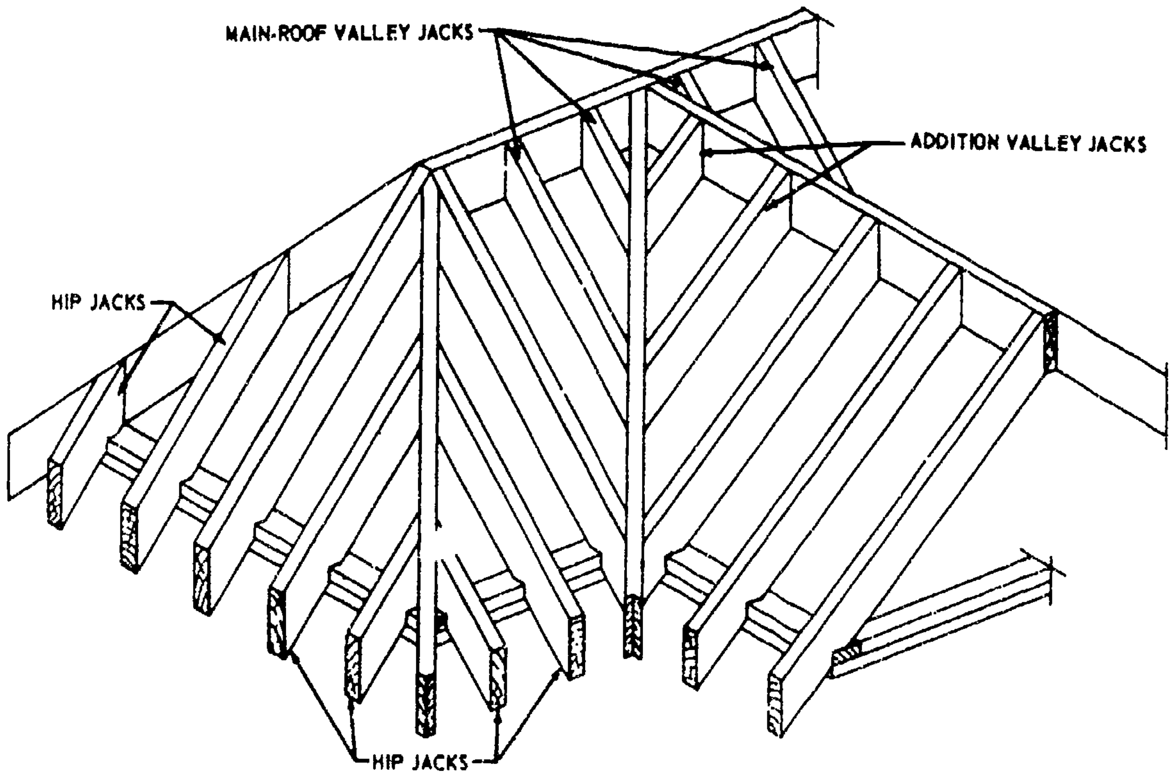

Figure 1-26.—Types of jack rafters.

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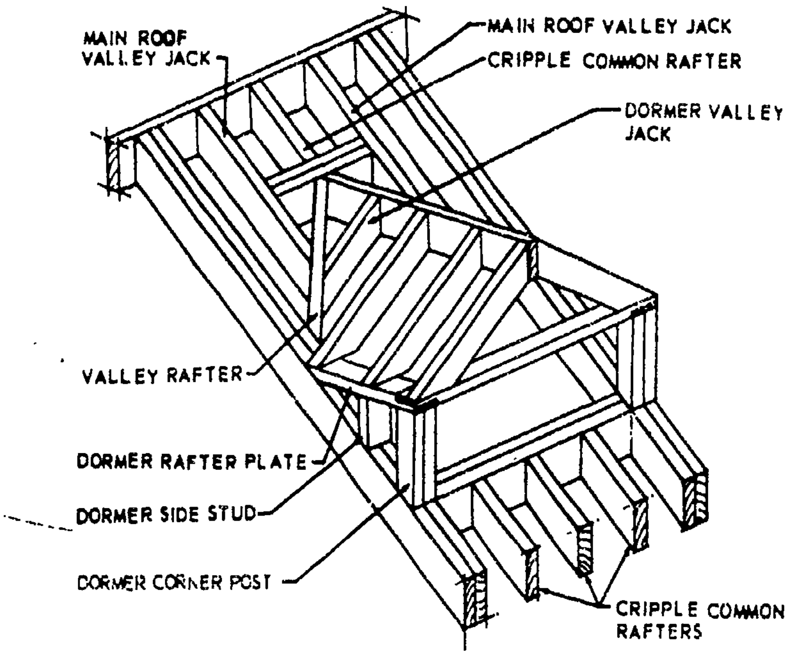

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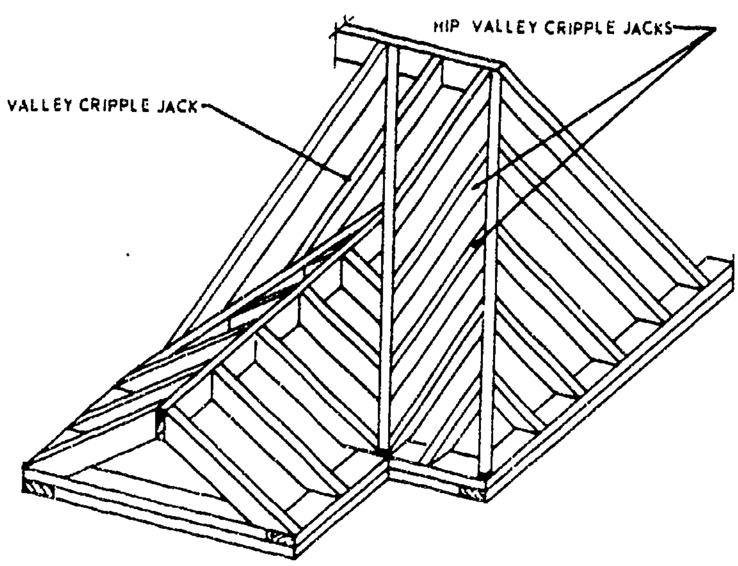
Figure 1-27.—Framing of gable dormer with side walls.



45.460
Figure 1-28.—Cripple jacks.

EAVE OR TAIL—The portion of the rafter extending beyond the outer edge of the plate.

In figures 1-21 through 1-28, you will see that some structural members are doubled. These members are expected to carry a greater load. Examples include plates, headers, rafters at various openings, and rafters that support the roof additions. Doubled members are also used at openings in walls and floors.

BUILDING FINISH

Perhaps the best way to define building finish is to say that most of those parts of a structure which are NOT among the load-bearing members comprise the finish. The finish is divided into "exterior" finish (located principally on the outside of the structure) and "interior" finish (located inside).

EXTERIOR FINISH

The principal items of the exterior finish are the cornices, the roof covering, the door and window finish frames, and the outside-wall covering, if any.

The order in which these principal items are erected may vary slightly, but since the roof covering must go on as soon as possible, and it cannot be put on until the cornices have been constructed, the cornices are usually installed early in the exterior finish. In general, the order in which the exterior finish items are discussed in the following sections is about the order in which they are erected—except, that two or more items may be constructed simultaneously.

Cornices

The rafter-end edges of a roof are called the "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."

The exterior finish constructed at and just below the eaves of a roof is called a "cornice." The practical purpose of a cornice is to seal the joint between wall and roof against weather penetration. Purely ornamental parts of a cornice (or of any other finish, for that matter) are called "trim."

Figure 1-29 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 figures 1-30 and 1-31, or the "closed" or "box" cornice shown in figure 1-32. A short extension of a cornice along the gable-end wall of a gable-roof structure is called a "cornice return" (fig. 1-33). Finish along the rakes of a gable roof is called the "gable cornice trim" (fig. 1-34).

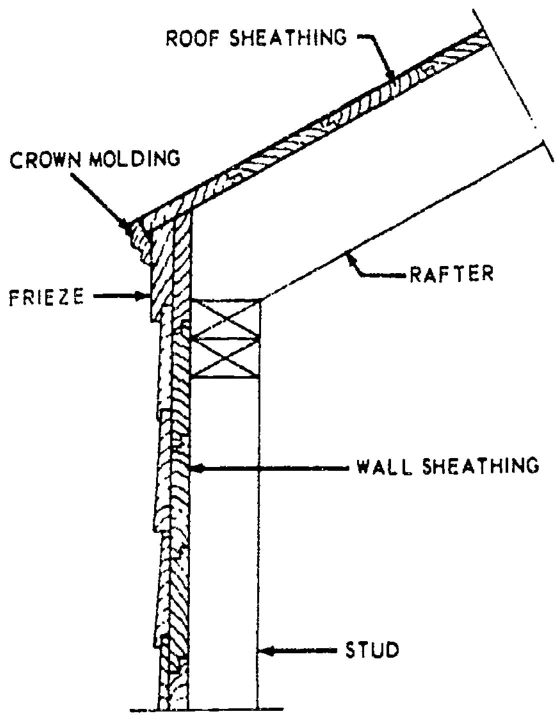


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Figure 1-29.—Simple cornice.

Roof Covering

On pitched-roof Navy-built structures, the roof covering most commonly used is made of asphalt or asbestos-cement. Asphalt roofing comes in rolls (usually 36 inches wide and called roll roofing) and in individual shingles called asphalt strip shingles (fig. 1-35). Asbestos-cement roofing usually consists of individual shingles; the size most commonly used is 12 inches wide by 24 inches long. A shingle 12 inches wide is laid with 5 inches exposed to the weather and 7 inches overlapped by the next higher course of shingles.

On flat or nearly flat roofs, the roof covering is usually built-up. It consists of several layers (called plies) of felt, set in a hot binder of melted pitch or asphalt. A final layer of binder is spread on the top of the uppermost ply of felt, and is usually sprinkled with a layer of gravel, crushed stone, or slag.

The usual number of plies in a built-up roof is five. Felt comes in rolls, usually 36 inches wide. Figure 1-36 shows how five plies of felt are laid on an initial layer of 36-inch wide-building paper. Note how the widths at the starting edge of the roof vary so as to get five-ply coverage

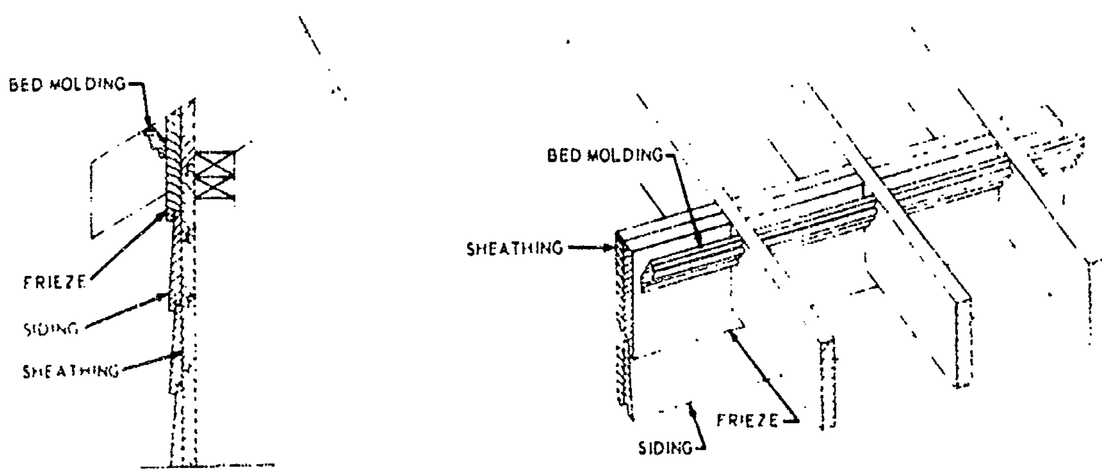

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Figure 1-30.—Open cornice without fascia.

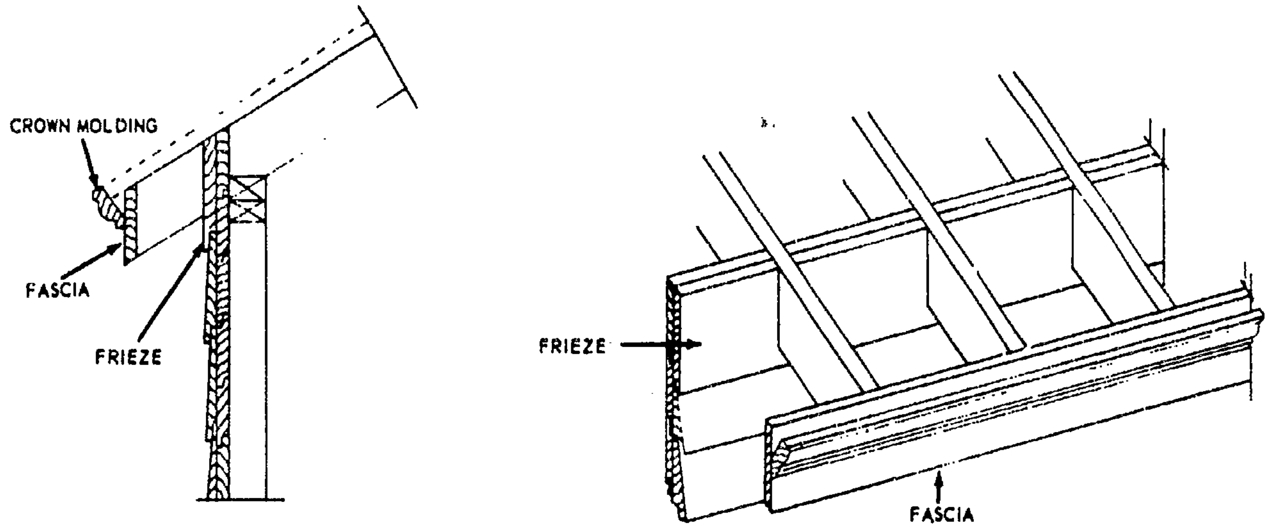

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Figure 1-31.—Open cornice with fascia.

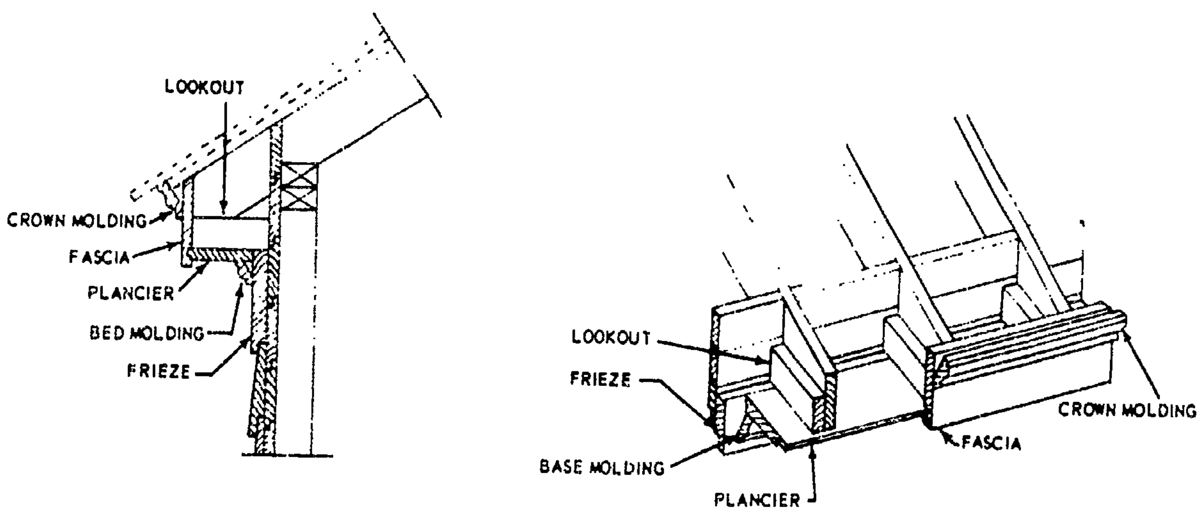

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Figure 1-32.—Closed or boxed cornice.

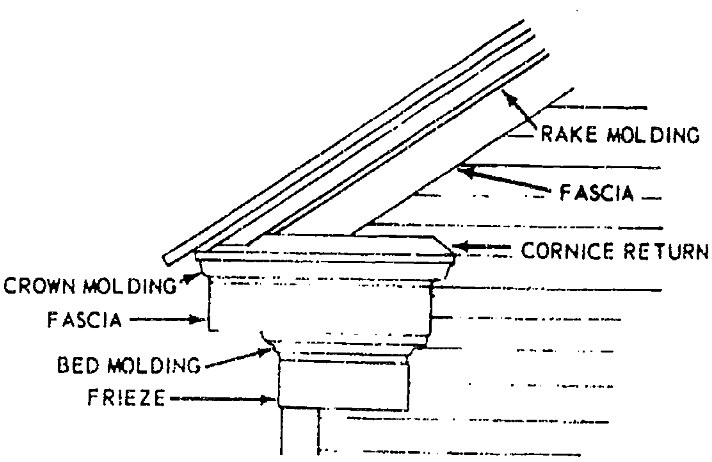

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Figure 1-33.—Cornice return.

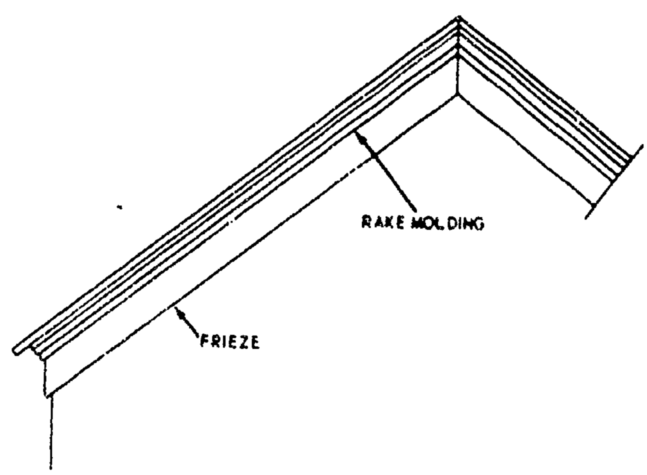

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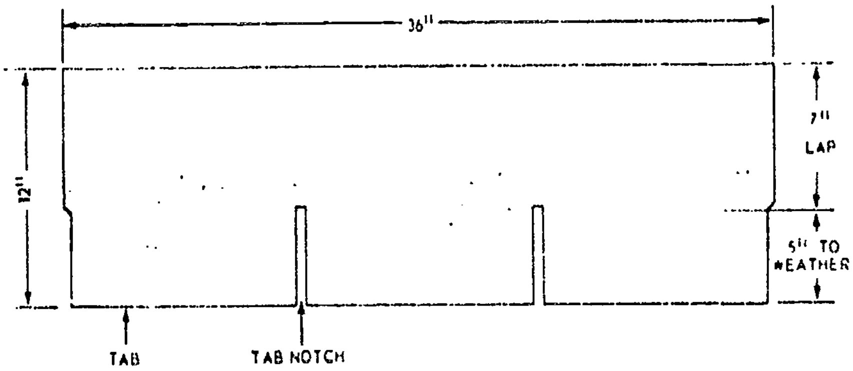
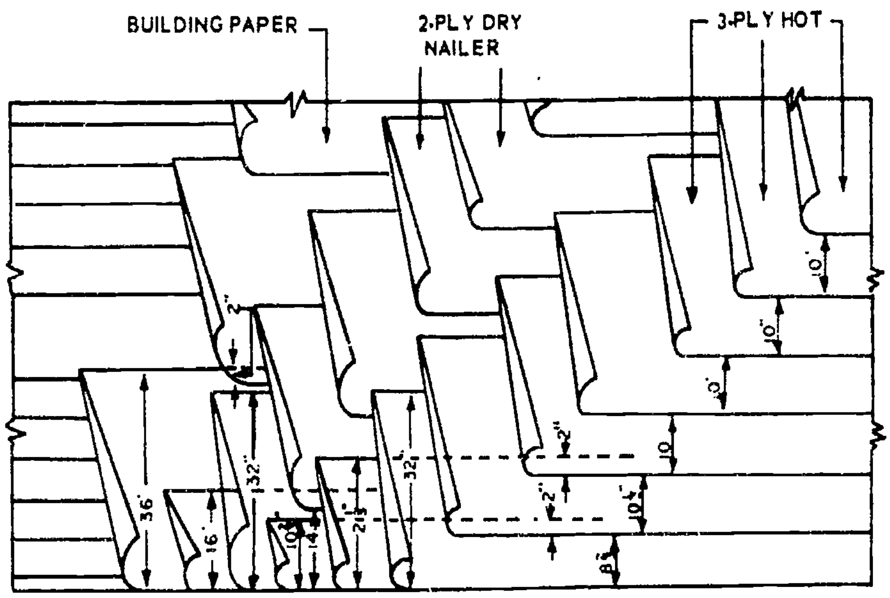
Figure 1-34.—Gable cornice trim.



29.120

Figure 1-35.—Asphalt strip shingle.



45.499

Figure 1-36.—Building paper and felt on five-ply built-up roof.

with 10 inches to the weather all the way up the roof.

Finish Door and Window Frames

Figure 1-37 shows the principal parts of a finish door frame. On an outside door, the frame 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 1-38 shows section drawings of outside-door frame details.

The part of a window which 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 which is hinged at the side is called a casement window—single casement if there is only one sash, double casement if there are two. A window which is hinged at the top or bottom is called a transom window. One with a number of horizontally hinged sashes, which open and

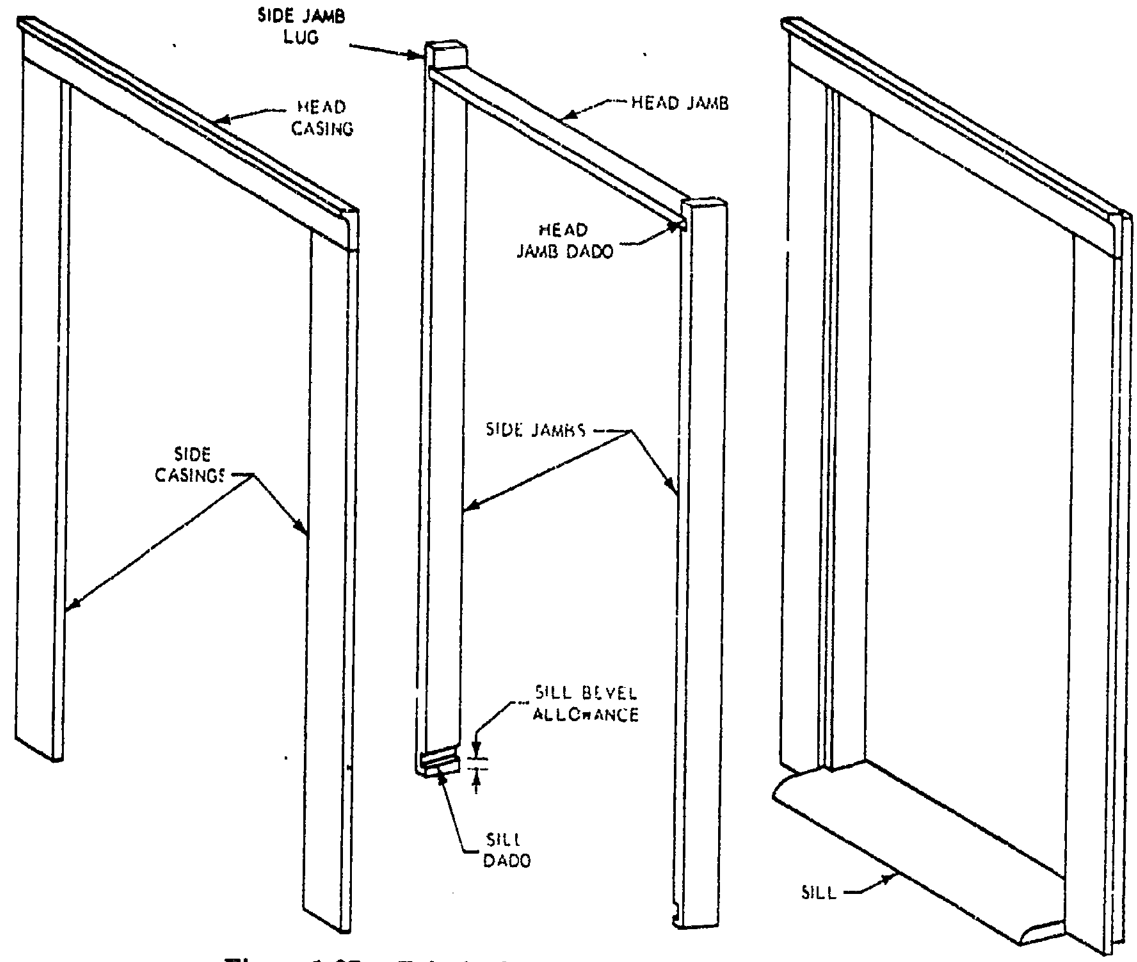


Figure 1-37.—Principal parts of a finish door frame. 45.500

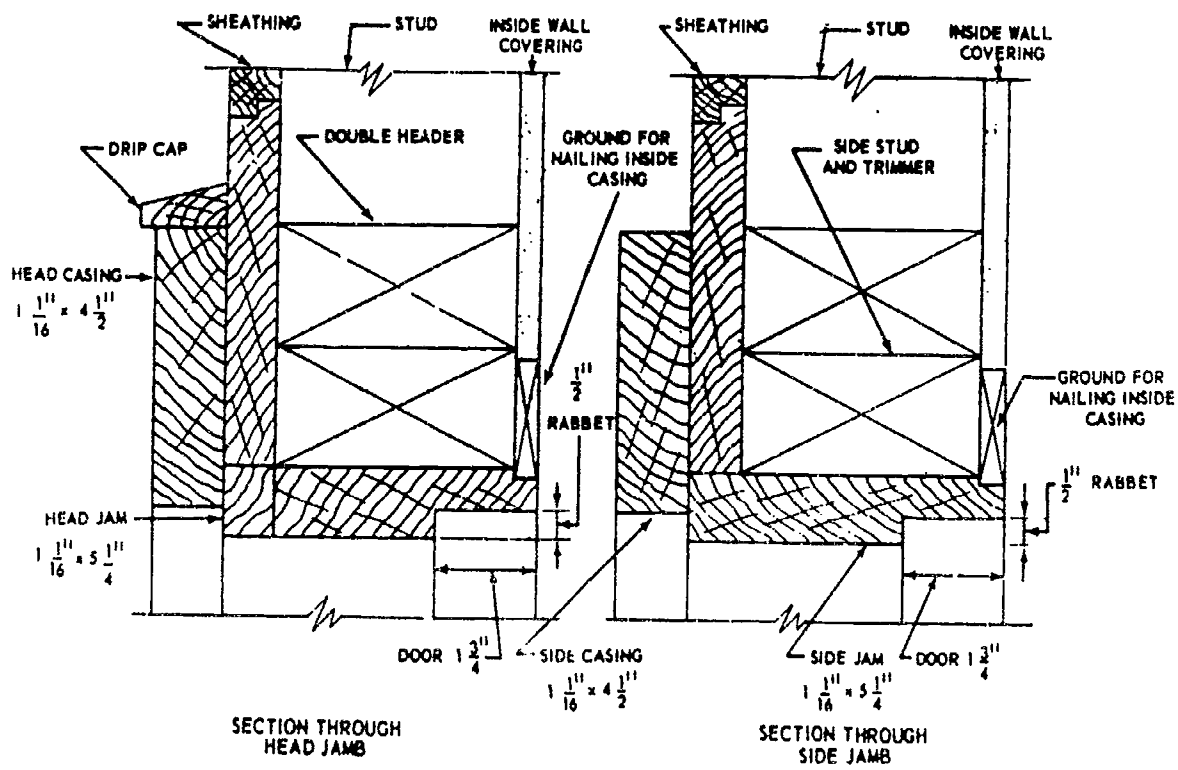


Figure 1-38.—Outside-door frame details. 45.501

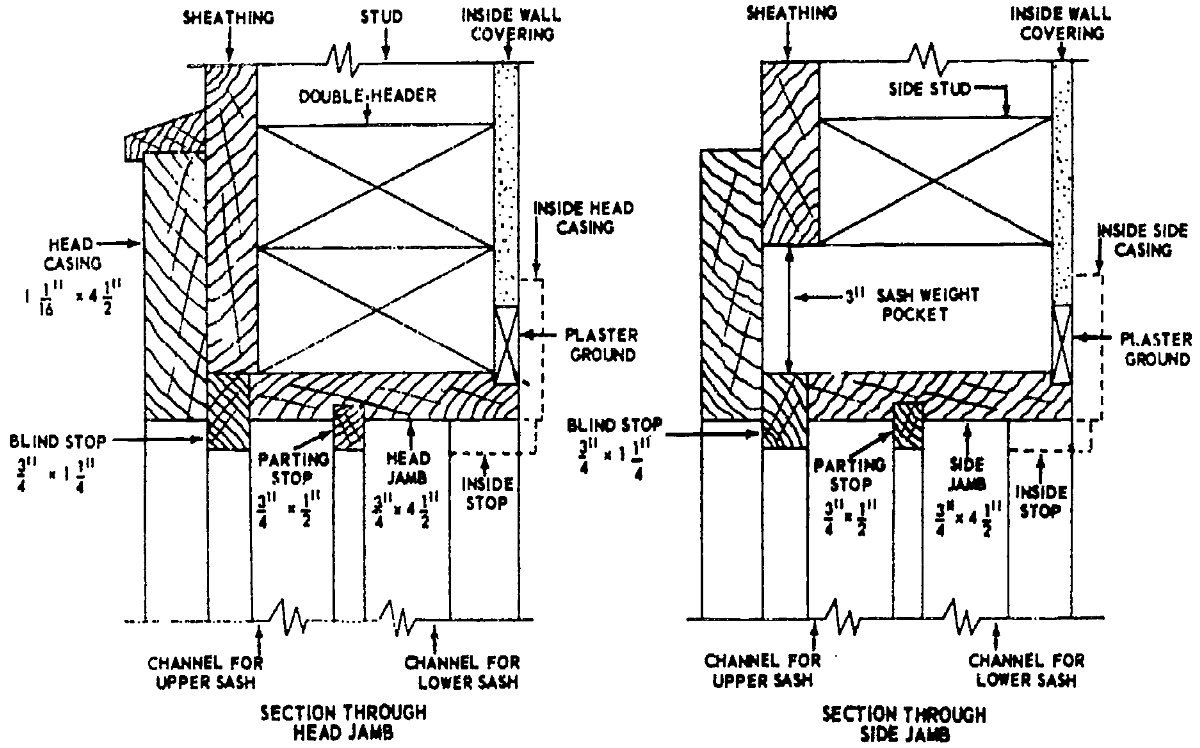


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Figure 1-39.—Head- and side-jamb details for double-hung window.

close together like the slats in a venetian blind, is a jalousie window. A window having two sashes which slide vertically past each other is a double-hung window.

Basically, the finish frames for all these are much alike, consisting principally, like a finish door frame, 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 1-39. Sill details are shown in figure 1-40.

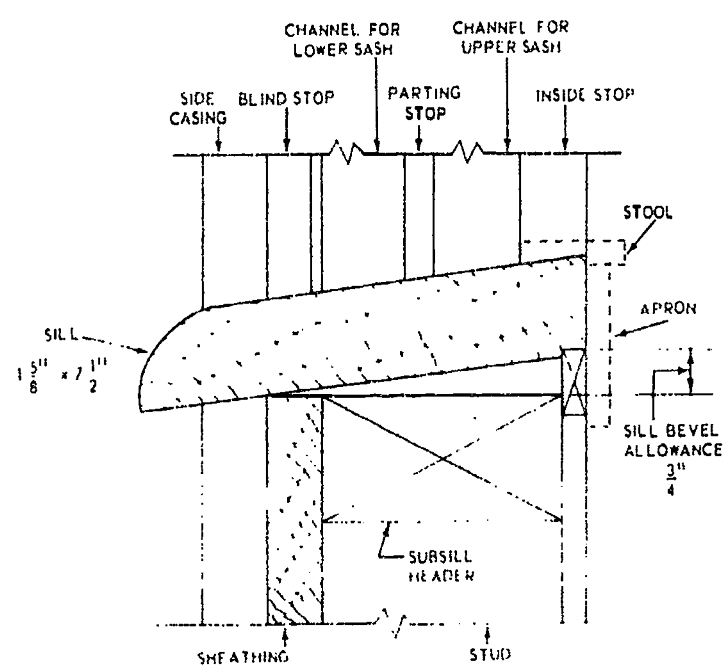

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Figure 1-40.—Sill detail for a double-hung window.

Outside-Wall Covering

The wood sheathing on a frame structure is covered with siding. This may be board siding, or it may consist of sheets of synthetic material, such as plywood, asphalt, asbestos-cement, or "composition." Composition is a general term applied to manufactured sheet materials, such as gypsum board, asphalt felt, fiberboard, and insulation board.

There are two general types of wooden board siding—common siding and drop siding. Common siding consists of boards which overlap each other shingle-wise. Common siding in boards not more than 4 feet long is called clapboard. Common siding in longer lengths but NOT more than 8 inches wide is called bevel siding. Common siding in boards longer than 4 feet and wider than 8 inches is called bungalow siding.

Board siding which is joined edge-to-edge (rather than overlapping) is called drop siding. Figure 1-41 shows three common types of drop siding.

INTERIOR FINISH

The interior finish consists mainly of the coverings applied to the rough inside walls, ceilings, and subfloors. Other interior finish items are inside door frames, doors (both inside and outside), window sash, and stairs.

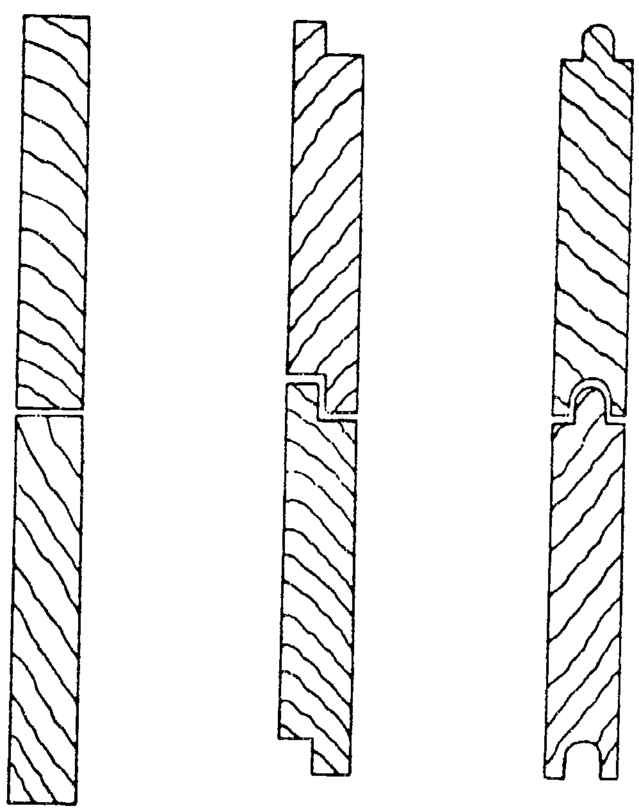


Figure 1-41.—Types of drop siding.

Ceiling and Wall Covering

Ceiling and wall covering may be broadly divided into plaster and dry-wall covering. Drywall covering is a general term applied to sheets or panels of wood, plywood, gypsum, fiberboard, and the like.

A plaster wall and/or ceiling covering requires the prior construction of a plaster base—that is, a plane-surface base to which the plaster can be applied, such as gypsum lath, fiberboard lath, or metal lath. Gypsum lath usually consists of 16- by 48-inch sheets of gypsum board, either solid or perforated with holes for keying. Fiberboard lath is similar, but made of synthetic fibrous material rather than gypsum. Metal lath consists of screen-like sheets of ribbed or meshed metal.

Before lath is applied to walls and ceilings, plaster grounds are installed as called for in the working drawings (refer back to figs. 1-38 and 1-39). These are wood strips of the same thickness as the combined thickness of lath and plaster. They serve as guides to the plasterers, to insure that the plaster around door and window frames will be of correct and uniform thickness behind the casings.

Plastering on metal lath is usually done in three coats, having a combined thickness of about 5/8 inch. The first coat is called the SCRATCH coat, because it is usually scored to improve the adhesion of the second coat. The second coat is called the BROWN coat. The final, finish coat is called the WHITE, SKIM, or FINISH coat.

The basic ingredients for scratch-coat and brown-coat plaster are lime putty and sand, mixed with enough water to attain proper spreading consistency. A finish coat is composed of lime putty plus a dry aggregate which gives a smooth-finish appearance, such as plaster-of-paris, calcium sulphate, or a composition known as Keen's cement.

The most common materials used for drywall finishes are gypsum-board, wood paneling, fiberboard, and ceramic tile.

Gypsum board usually comes 4 feet wide by any length up to 12 feet. It may be applied with the long dimension either in line with or at right angles to joists and studs. A 4-foot sheet applied with the long dimension in line with joists or studs which are 16 inches O.C. (that is, on centers, meaning that the distance from the center of one member to the center of the next is 16 inches) will cover three joists or stud spaces. Gypsum board is nailed on with special cement-coated nails, the heads of which are concealed by countersinking a little below the surface of the board and filling the depression with joint cement. Joints between boards are concealed by cementing on joint tape.

Wood paneling and plywood come in sheets (called panels) of various sizes, for application either horizontally (long dimension at right angles to joist/studs) or vertically (long dimension in line with joists/studs). For horizontal application, lengths of stud or joist stock, called nailers, are set between the studs or joists, along the lines of panel joints, for the nailing of edges.

Fiberboard wall or ceiling covering usually comes in 2- by 8-foot panels, applied (using nailers) crosswise to joists or studs. However, fiberboard also comes in small squares or rectangles called tiles. Common sizes of tiles are 12 by 12 inches, 12 by 24 inches, 16 by 16 inches, and 16 by 32 inches. Tiles can be nailed to studs, joists, and nailers but are more commonly glued to a backing of wallboard.

Ceramic tile is used to cover all or part of the walls, and sometimes the ceilings as well, in bathrooms, shower rooms, galleys, and other spaces subject to a high degree of dampness. In other spaces, it may be used for ornamental purposes. The type most commonly used is glazed interior tile, usually 3/8 inch thick and in 4 1/4- to 6-inch squares. Margins, corners, and baselines are covered with trimmers of various sizes and shapes.

Ceramic tile may be set in a bed of tile cement or in a tile adhesive provided by the manufacturer. For a cement-bed setting against wooden studs or joists, a layer of building paper is laid on first, and metal lath is then applied over the paper. A scratch-and-level coat of tile cement, 1/2 to 5/8 inch thick, is applied to the lath and allowed to dry. The tile is then set in a 1/4- to 1/2-inch cement-bed setting.

For adhesive setting to joists or studs, a backing gypsum lath is nailed on, then the adhesive is applied to the lath.

Concrete or Masonry Wall Covering

Plaster may be applied directly to a concrete or masonry wall. For tile setting, a layer of plaster is usually applied to a masonry wall, allowed to dry, and then the tile cemented to the plaster. For a concrete wall with a good finish, the tile may be cemented directly to the concrete.

Stairs

The two principal elements in a stairway are the treads which people walk on and the stringers (also called springing trees, horses, and carriages) which support the treads. The simplest type of stairway, shown at the left in figure 1-42, consists of these two elements alone.

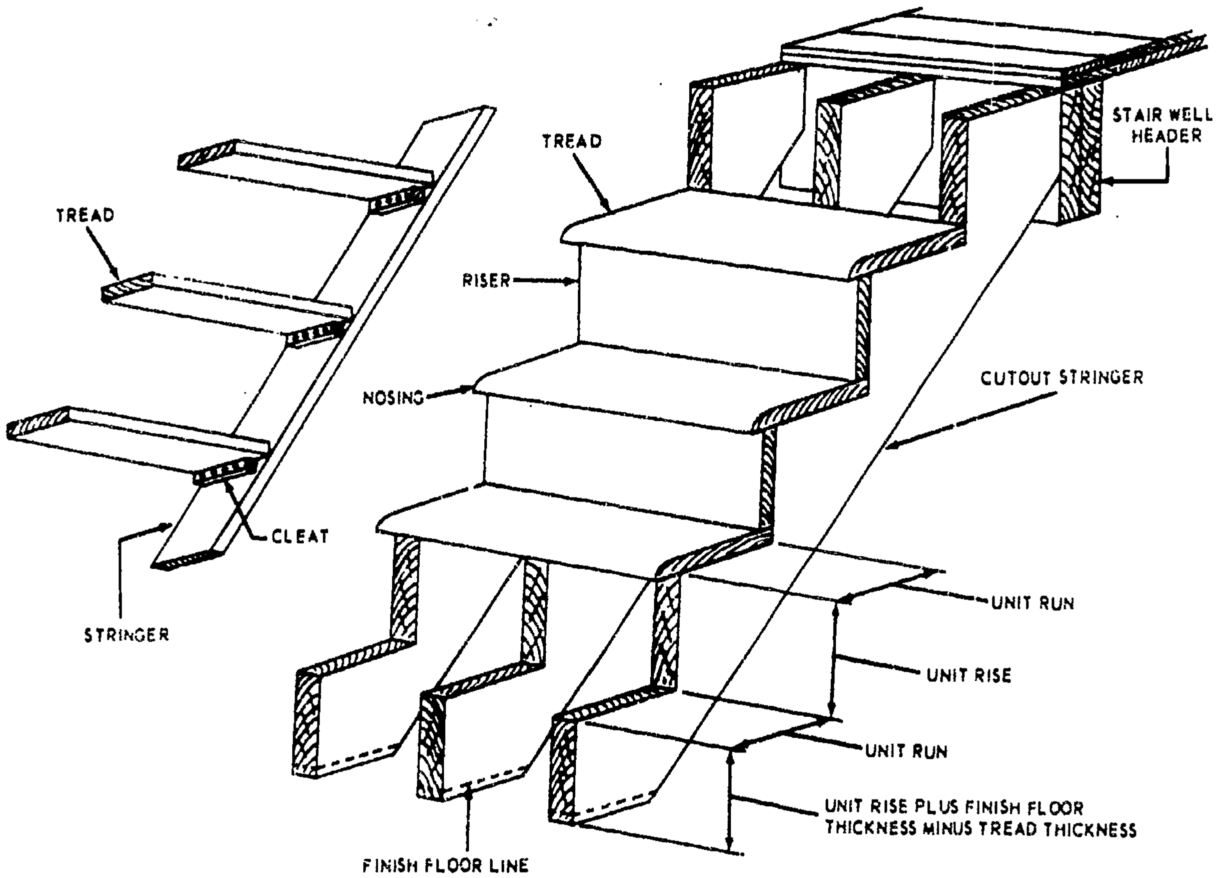
Additional parts commonly used in a finished stairway are shown at the right in figure 1-42. The stairway shown here has three stringers, each of which is sawed out of a single timber. For this reason, a stringer of this type is commonly called a cutout or sawed stringer. On some stairways, the treads and risers are nailed to triangular stair blocks attached to straight-edged stringers.

A stairway which 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 which 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.

Window Sash

A window schedule on the construction drawings gives the dimensions, type, such as casement, double-hung, etc., and the number of lights (panes of glass) for each window in the



45.507

Figure 1-42.—Parts of a stairway.

structure. A window might be listed on the schedule as, for example: No. 3, DH, 2 feet 4 inches by 3 feet 10 inches, 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 feet 4 inches by 3 feet 10 inches 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 inches.

Figure 1-43 shows a double-hung window sash and the names of its parts.

Finish Flooring

Finish flooring is broadly divided into "wood" finish flooring and "resilient" finish flooring. Most wood finish flooring comes in strips which are 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 1-44.

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 a plastic composition called vinyl. With each type of tile, the manufacturer recommends an appropriate type of adhesive for attaching the tile to the subflooring.

Doors

Doors are made in many styles, but the type most frequently used is the "panel" door shown in figure 1-45.

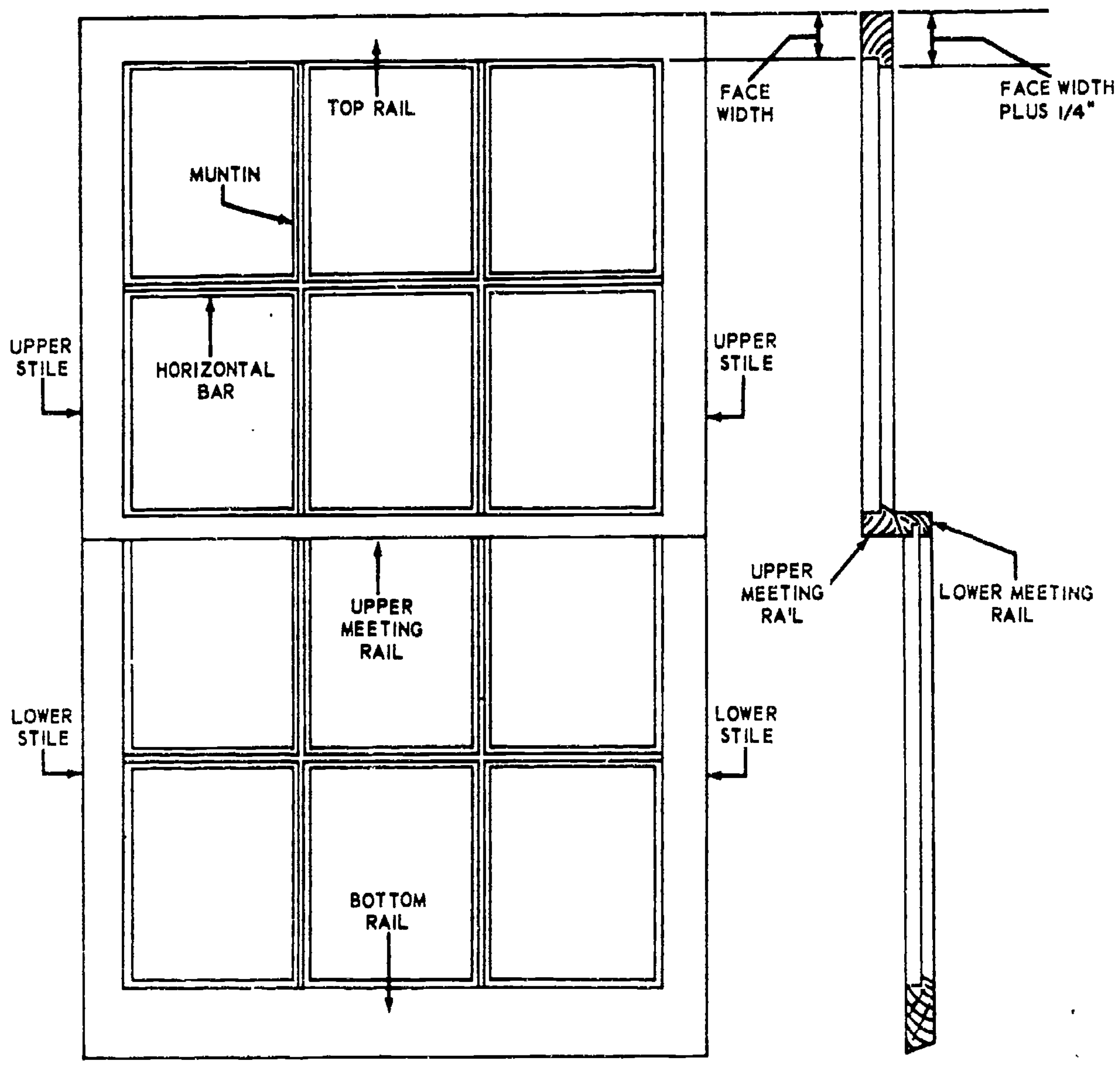


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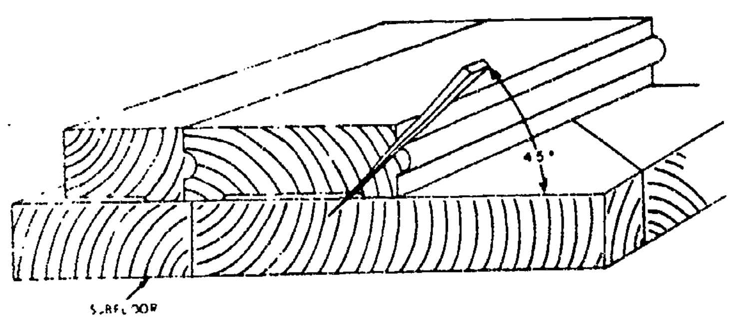
Figure 1-43.—Parts of double-hung window sash.



45.510

Figure 1-44.—Toenailing wood finish flooring.

Interior Trim

The most prominent items in the interior trim are the inside door and 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. 1-46).

HARDWARE

HARDWARE is a general term covering a wide variety of accessories that are usually made

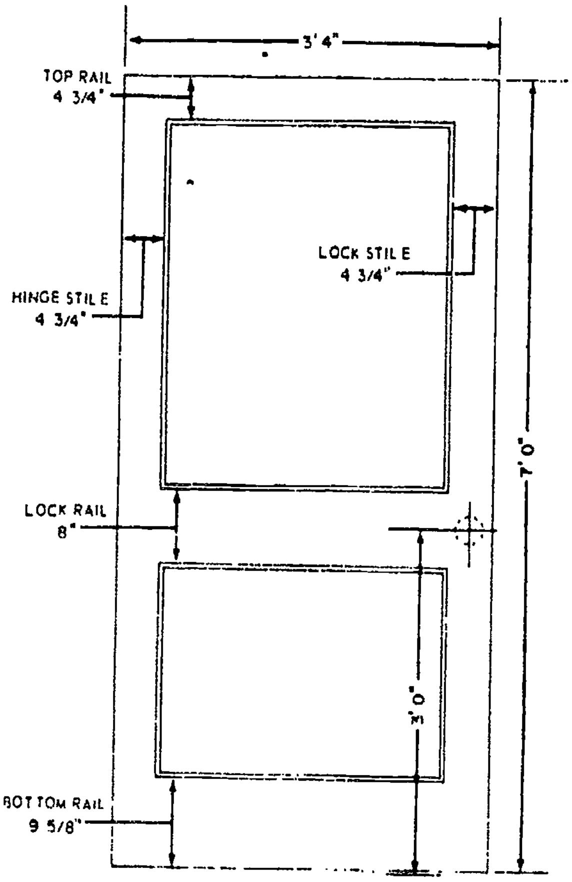


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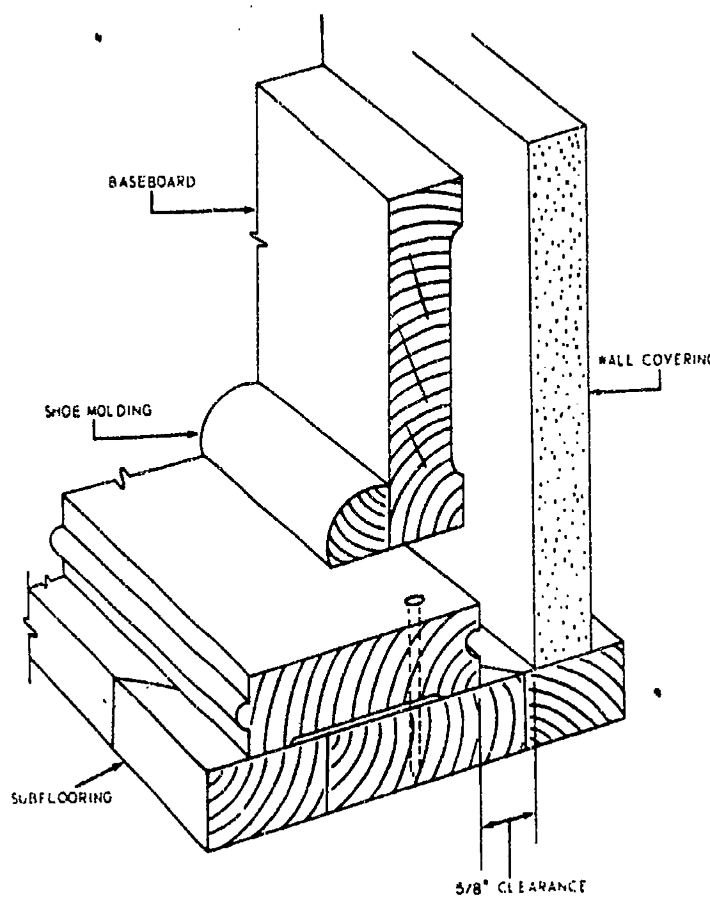
Figure 1-45.—Panel door.



45.512

Figure 1-46.—Baseboard.

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, kick plates, door stops, 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*.

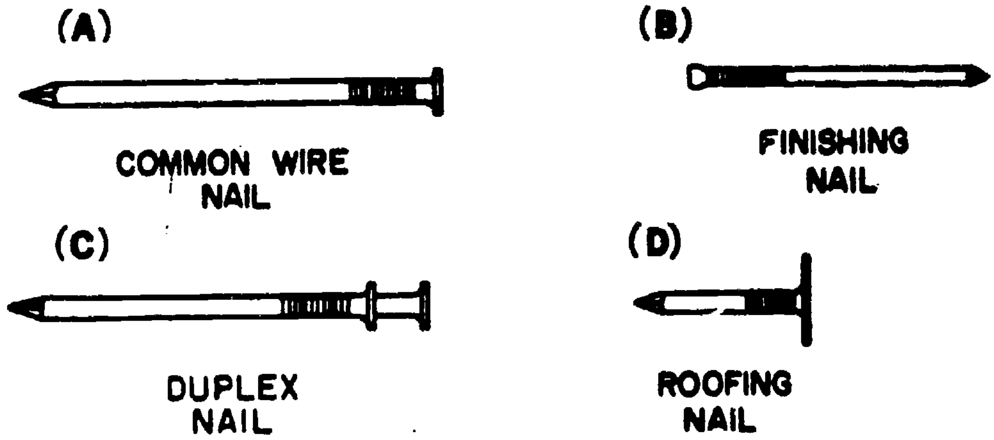
FASTENERS

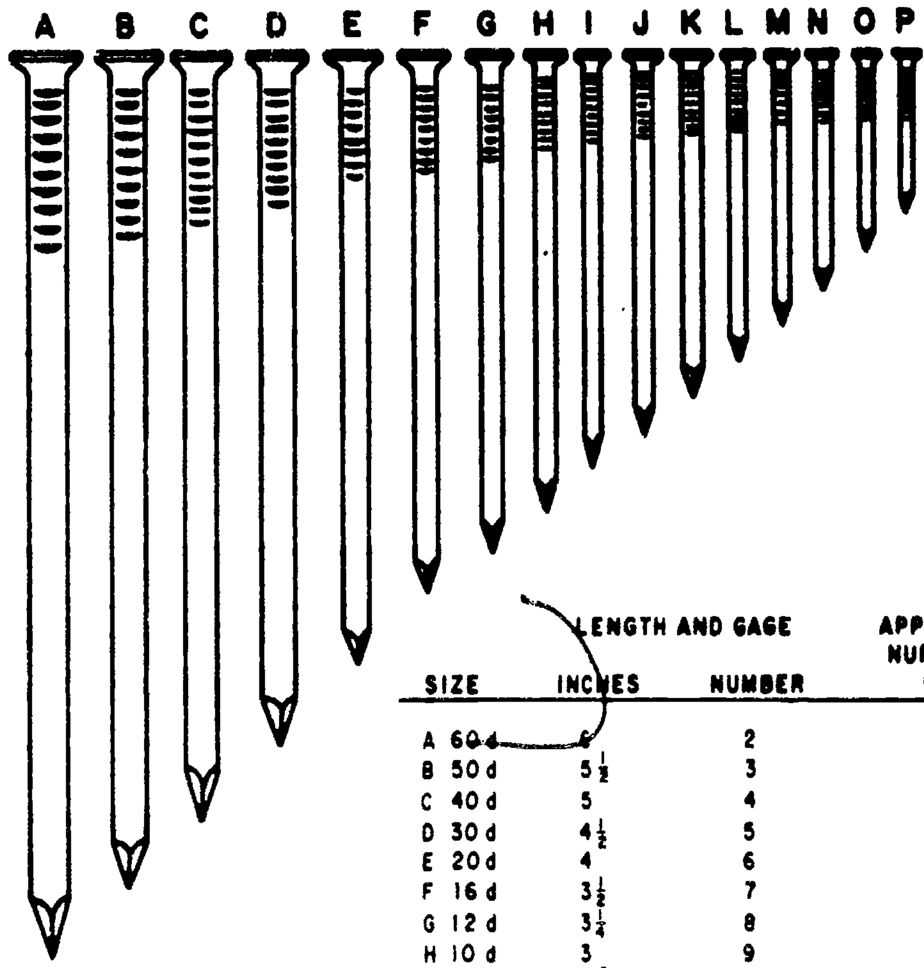
The devices used in fastening or connecting members together to form structures depend on the kinds of material the members are made of. The most common fastening devices are nails, screws, and bolts.

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 (view A, fig. 1-47) are the same, except that the





COMMON WIRE NAILS

SIZE	LENGTH AND GAGE INCHES	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

29.121

Figure 1-47.—Types and sizes of common wire nails and other nails.

3?

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 (view B, fig. 1-47) 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 (view C, fig. 1-47) 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 (view D, fig. 1-47) 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 1-47, there are special-purpose nails. Examples include wire brads, plasterboard nails, concrete nails, and masonry nails. The wire brad has a needle point; the plasterboard nail a large-diameter flat head. The concrete nail is specially hardened for driving in concrete. So is the masonry nail although its body is usually grooved or spiraled.

Sizes of Wire Nails

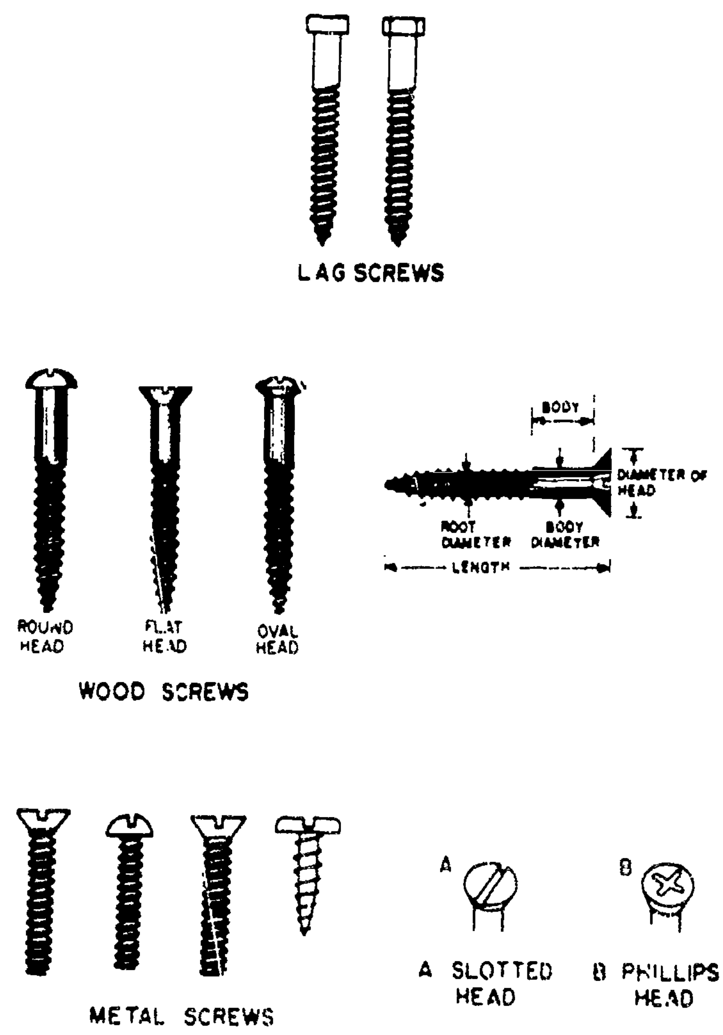
Lengths of wire nails NOT more than 5 inches long are designated by the penny system, where the letter "d" is the symbol for a penny. Thus, a 6d nail means sixpenny nail. The thickness of a wire nail is expressed by number, which relates to standard wire gage. Nail sizes (penny and length in inches), gages, and approximate number of nails per pound are given in figure 1-47. Nails longer than 5 inches (called SPIKES) are not designated by the penny.

Nails in Frame Construction

Rough carpentry joints are nailed with common wire nails. For a joist end which butts against a header joist, twenty-penny nails, two to each end, are driven through the header joist into the joist end. Floor-opening headers are similarly fastened to trimmer joists. Outside floor trimmers are nailed to inside floor trimmers with sixteen-penny nails. Joist ends are toenailed to sills or plates with tenpenny nails, two to each side. Cross-bridging struts are nailed to joists with eightpenny nails.

Members of doubled-stud plates are nailed together with tenpenny nails. Studs are toenailed down to sills or soleplates with eightpenny nails, two to each side. Window headers and subsills are nailed to studs with sixteen-penny nails, driven through the stud into the end of the header.

A common or jack rafter is toenailed to the rafter plate with tenpenny nails, two to each side. At the upper end (as at a ridge piece or a hip or valley rafter), one of the pair of common or jack rafters is nailed to the ridge piece, hip, or valley with two or three tenpenny nails, driven through the ridge piece, hip, or valley. The



29.123

Figure 1-48.—Types of screws.

corresponding rafter of the pair is toenailed at the upper end.

Wall stud bracing is nailed to studs with eightpenny nails, two to each stud crossing. Board sheathing or subflooring is nailed to studs or joists with eightpenny nails; two to each crossing for boards up to 8 inches wide and three to each crossing for wider boards.

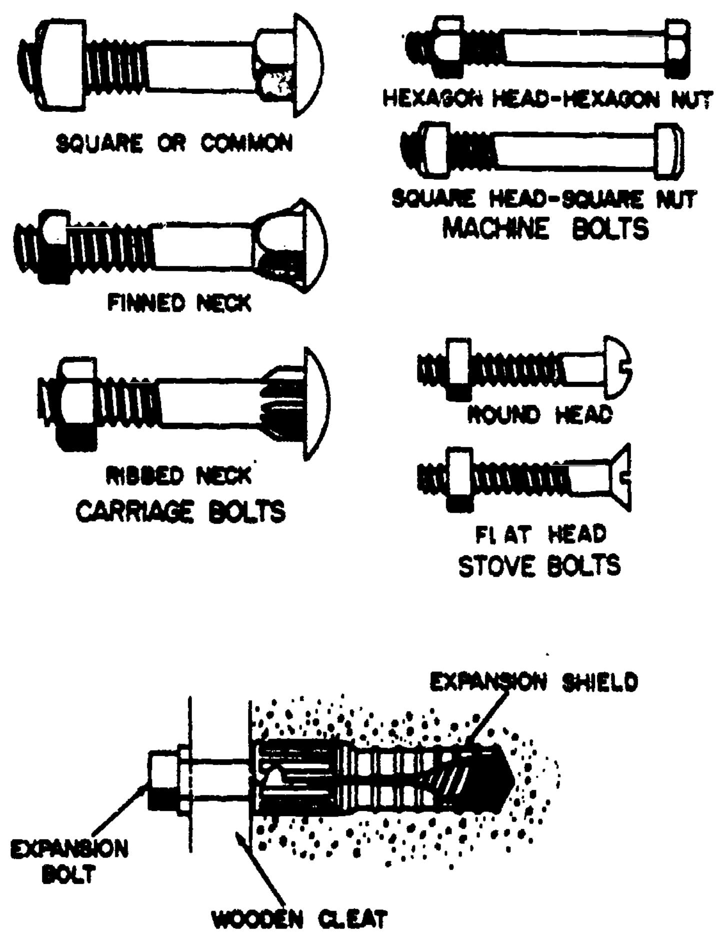
Outside door and window frames are nailed to rough-frame studs and headers with sixteenpenny casing nails driven through the jambs into the studs and headers. Inside door frames are nailed to partition studs and headers with eightpenny casing nails. Wood exterior finish is nailed on with sixpenny finish nails for 1/2-inch material and eightpenny nails for thicker material. Inside casings are nailed to jamb edges with fourpenny casing or finish nails and to studs with eightpenny casing or finish nails.

SCREWS

A wood screw is a fastener which is threaded into the wood. Wood screws are designated by the type of head (fig. 1-48) and the material from which they are made, for example, flathead brass or roundhead 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-inch diameter) to 24 (about 3/8-inch diameter).

Lag screws, called LAG BOLTS (fig. 1-48), 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 inches and in body diameters of 1/4 to 1 inch. 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. 1-48). Sheet metal screws are self-tapping; they can fasten metals up to about 28 gage. Thread-cutting screws are used to fasten metals that are 1/4 inch thick or less.



29.124

Figure 1-49.—Types of bolts.

BOLTS

A steel bolt is a fastener having a head at one end and threads, as shown in figure 1-49. 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 inches and in body diameter from 1/8 to 3/8 inch. 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 inches; in diameter, from 3/16 to 3/4 inch. 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.

CHAPTER 2

HEAVY CONSTRUCTION: WOOD, STEEL, AND STEEL FRAME STRUCTURES

As a general rule, the term "heavy construction" refers to a project in which large bulks of materials and/or extra-heavy structural members are used, such as steel, timber, concrete, or a combination of these materials. In the Naval Construction Force, this would include the construction of bridges or waterfront and steel frame structures.

The SEABEE's construction functions, in support of the Navy's and Marine's Operating Forces, might include designing and construction of these various structures, or their rehabilitation; therefore, you, as an EA, should understand the terminology, the basic principles, and the methodology used in the construction of these facilities. Your knowledge of the methods and materials used in their construction will greatly assist you in the preparation of engineering drawings (original, modified, or as-built).

This chapter will discuss the basic construction methods and materials, their components, and their uses within the structures.

BRIDGE CONSTRUCTION

The spanning structure of a "suspension" bridge is supported from above by cables looped between tall "piers." A bridge other than a suspension bridge is supported from below by piers (specially cantilever truss bridges), or a series of transverse structures called "bents." The two main subdivisions of a "bent" bridge are the "superstructure" (the spanning structure which carries the roadway) and the "substructure" (the bents, plus the foundations on which they are anchored).

TRESTLE AND PILE BENTS

A timber "trestle" bent is shown in figure 2-1. This bent is used on firm, dry ground or on solid bottom in shallow water. A "pile" bent is used in soft or marshy ground, or in water too deep or too swift-flowing for trestle bents. In a pile bent, the "posts" consist of piles driven in the ground, and there is no sill or footing.

ABUTMENTS

The ground points which support the ends of the superstructure of a bridge are called the "abutments." Figure 2-2 shows the abutment excavation, sill, and footing for a timber trestle-bent or pile-bent bridge.

SUPERSTRUCTURE

The principal parts of the superstructure are the decking (roadway or surface of the spanning

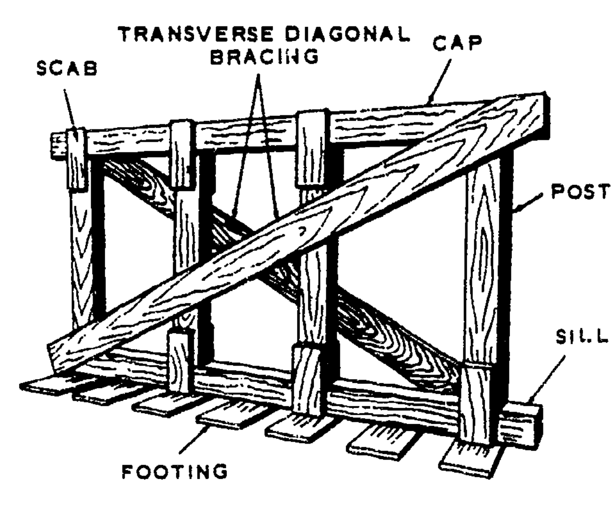


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Figure 2-1.—Timber trestle bent.

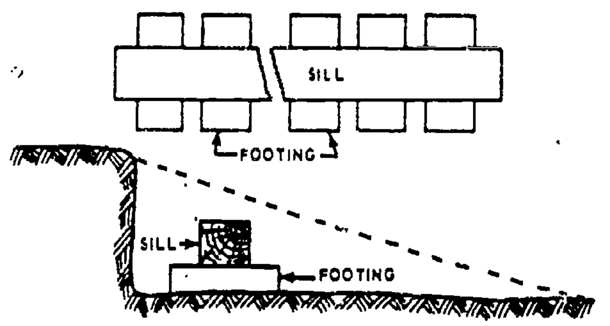

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Figure 2-2.—Abutment sill and footing.

structure) and the girders (horizontal load-bearing members which support the decking). The girders are themselves supported by the caps of the bents. On a timber bridge, the decking consists of a lower layer of timbers, called the flooring and an upper layer, called the treadway. On a timber structure, the girders (each of which extends from the cap on one bent to the cap on the next) are often called stringers. On a concrete structure, steelplate girders, or reinforced-concrete girders are used.

On an advanced base timber bridge or pier, the stringers usually consist of timbers about 10 inches by 16 inches in cross-section, placed about 3 feet 3 1/2 inches O.C. with the long section dimension vertical. Girder length is commonly 14 feet which means that bents on a structure of this type are usually somewhat less than 14 feet apart.

PILE CONSTRUCTION

A pile is a load-bearing wood, steel, or concrete structural member which is driven into the ground. A pile which sustains a downward load is a bearing pile; one which sustains a transverse load is a sheet pile. A bearing pile which is driven, other than vertically, is called a batter pile.

BEARING PILES

Timber bearing piles are usually straight tree trunks with closely trimmed branches with the bark removed. The small end of the pile is called the tip, the larger end the butt. Timber piles range from 16 to 90 feet in length.

A steel bearing pile might be an H-pile (having an H-shaped cross section) or a pipe pile (having a circular cross section). A pipe pile might be open-end (open at the bottom) or closed-end (closed at the bottom).

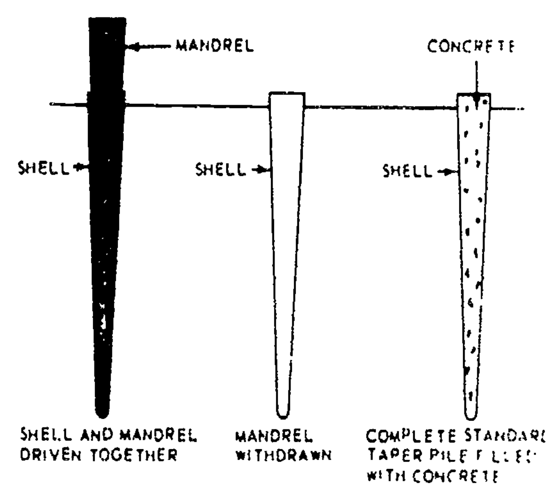
A concrete bearing pile can be cast-in-place or precast. A shell type is constructed, as shown in figure 2-3. For a shell-less type, a hole is made first, either by driving and withdrawing a mandrel (fig. 2-3), or by boring. The concrete for the pile is then poured into the hole and cast against the natural earth.

Precast concrete piles are cast in forms in a casting yard.

SHEET PILES

Sheet piles, made of wood, steel, or concrete, are equipped or constructed for edge-joining, so they can be driven edge-to-edge to form a continuous wall or bulkhead. A few common uses of sheet piles are as follows:

1. To resist lateral soil pressure as part of a temporary or permanent structure. For example, steel sheet piling is widely used to form



45.526
Figure 2-3.—Shell-type cast-in-place concrete pile.

"bulkheads" and "retaining walls" for the lateral or transverse support of soil.

2. To construct cofferdams or structures built to exclude water from a construction area.

3. To prevent slides and cave-ins in trenches and other excavations.

A wood sheet pile might consist of a single, double, or triple layer of planks, as shown in figure 2-4.

The edges of a steel sheet pile are called INTERLOCKS because they are shaped for locking the piles together edge-to-edge. The part of the pile between the interlocks is called the WEB. Steel sheet piles are manufactured in five standard section shapes: (1) DEEP-ARCH, (2) ARCH, (3) STRAIGHT-WEB, (4) Z-SECTION, and (5) CORNER-SECTION.

Sections vary slightly in shape with different manufacturers, each of whom has a particular letter and number symbol for each section they manufacture. (See figure 2-5.)

Concrete sheet piles are cast with tongue-and-groove edges for edge-joining. See *Builder 3 & 2*, NAVEDTRA 10648-G for further discussion of various types of sheet piles.

WATERFRONT STRUCTURES

Waterfront structures may be broadly divided into (1) offshore structures like breakwaters, designed to create a sheltered harbor,

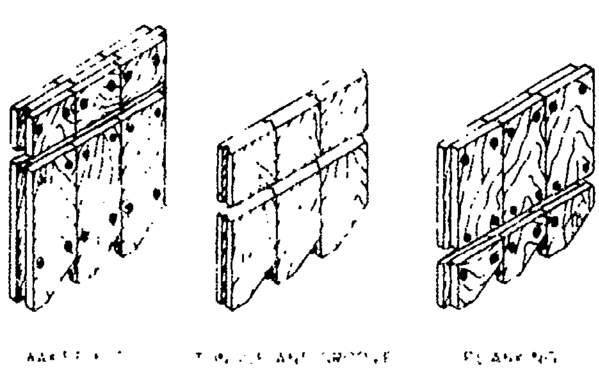


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Figure 2-4.—Wood sheet piles.

(2) alongshore structures like seawalls, designed to establish a definite shoreline and maintain it against wave erosion, and (3) wharfage structures, designed to make it possible for ships to lie alongside for loading and discharge.

HARBOR-SHELTER STRUCTURES

A breakwater is an offshore barrier, erected to break the action of the waves and thereby maintain an area of calm water inside the breakwater. A jetty is a similar structure, except that its main purpose is to direct the current or tidal flow along the line of a selected channel.

The simplest type of breakwater/jetty is the rubble-mound type shown in figure 2-6. Rock for this structure is classified as follows:

Cap rock is the largest rock, placed at the top.

Class A rock is rock in which 85 percent or more consists of pieces weighing more than 2 tons each.

Class B rock is rock in which 60 percent or more consists of pieces weighing more than 100 pounds each, but less than 2 tons (class A).

Class C rock (also called quarry waste) is any rock smaller than class B.

For a deep-water site, or for one with an extra-high tide range, a rubble-mound breakwater may be topped with a concrete cap structure, as shown in figure 2-7. A structure of this type is called a composite breakwater/jetty. In figure 2-7, the cap structure is made of a series of precast concrete boxes called "caissons," each of which is floated over its place of location, and then sunk into position by loading with class C rock. A monolithic (single-piece) concrete cap is then cast along the tops of the caissons.

A groin is a structure similar to a breakwater/jetty, but having still a third purpose. A groin is used in a situation where a shoreline is subject to alongshore erosion, caused by wave or current action parallel to or oblique to the shoreline. The groin is run out from the shoreline (usually there is a succession

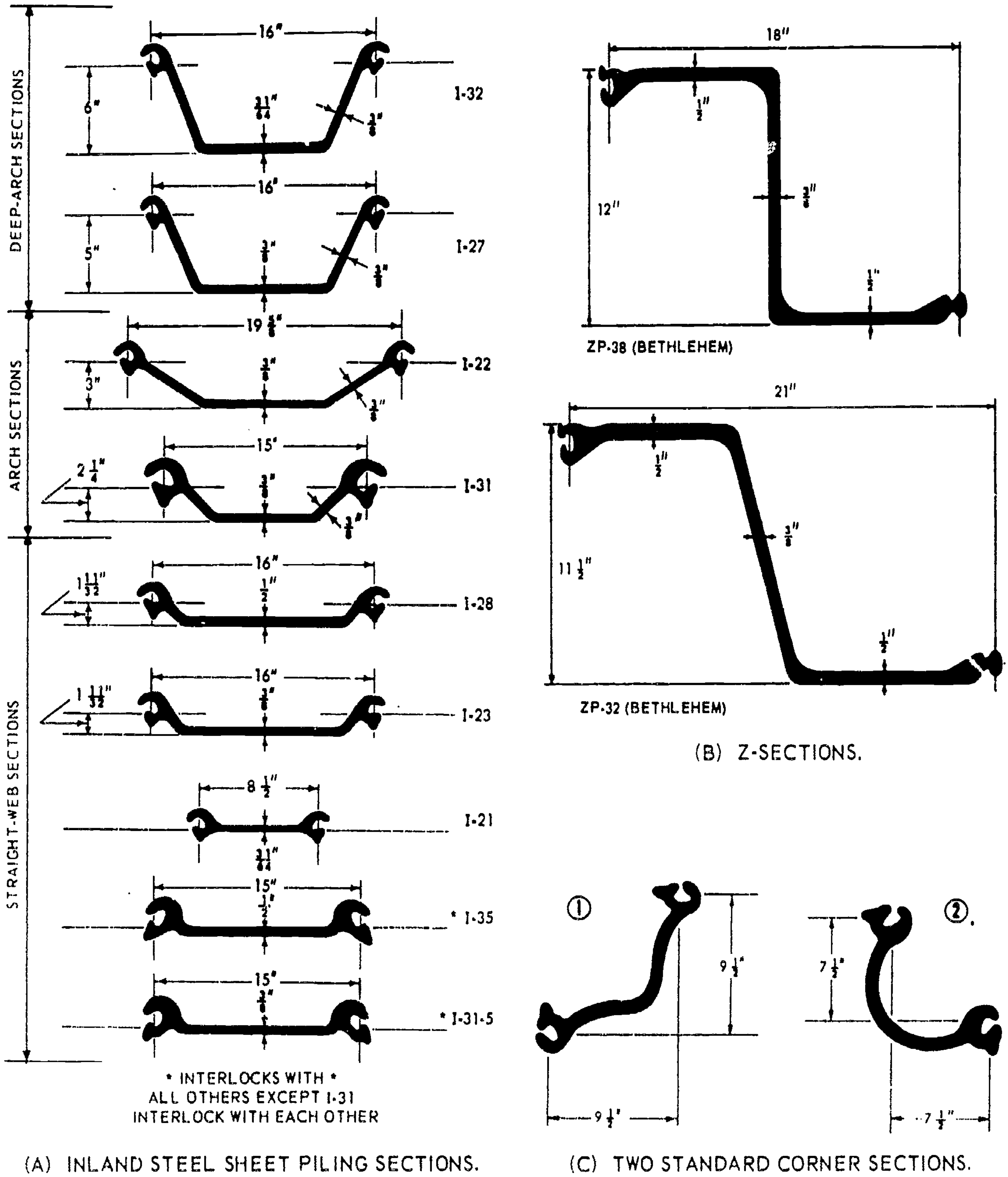

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Figure 2-5.—Standard steel sheet pile sections.

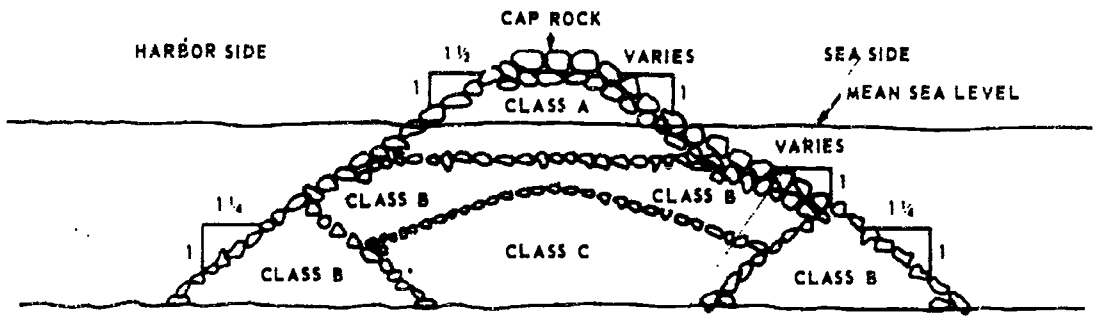

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Figure 2-6.—Rubble-mound or rock-mound breakwater/jetty.

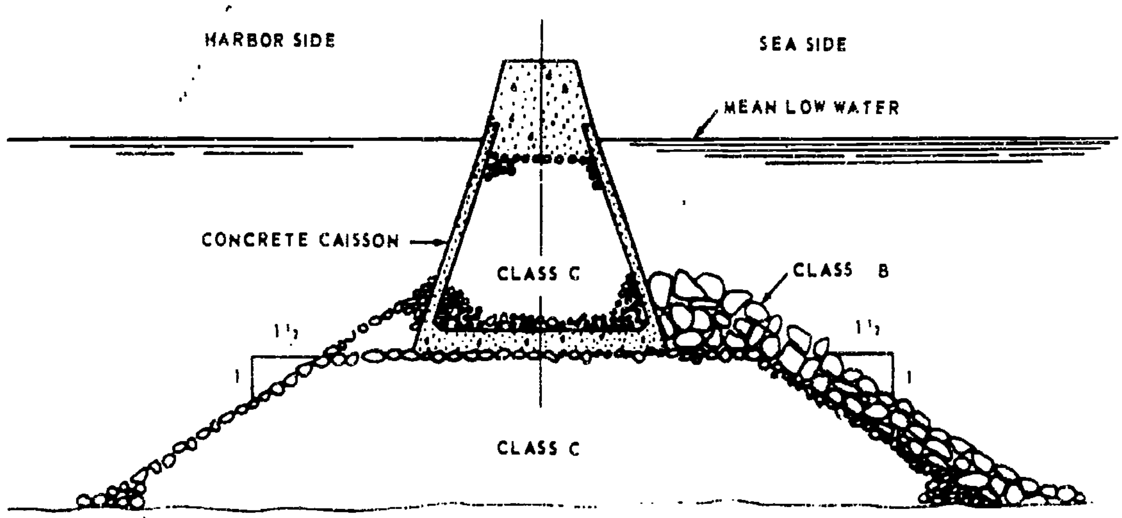

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Figure 2-7.—C .nposite breakwater/jetty.

of groins at intervals) to check the alongshore wave action or deflect it away from the shore.

A mole is a breakwater which is paved on the top for use as a wharfage structure. To serve this purpose, it must have a vertical face on the inner or harborside. A jetty may be similarly constructed and used, but it is still called a jetty.

STABLE-SHORELINE STRUCTURES

These structures are constructed parallel with the shoreline to protect it from erosion and other wave damage.

A seawall is a vertical or sloping wall which offers protection to a section of the shoreline against erosion and slippage due to tide and wave action. A seawall is usually a self-sufficient type structure, such as a gravity-type retaining wall; whereas, a bulkhead is usually a thinner structure which depends partly on wales carried on tie rods extending to buried anchors. Seawalls are classified according to the types of construction. A seawall may be made of riprap or solid concrete. Several types of seawall structures are shown in figure 2-8.

As used in port construction, a bulkhead is a vertical retaining structure used along a shore, or to form the face of a quay (pronounced key)

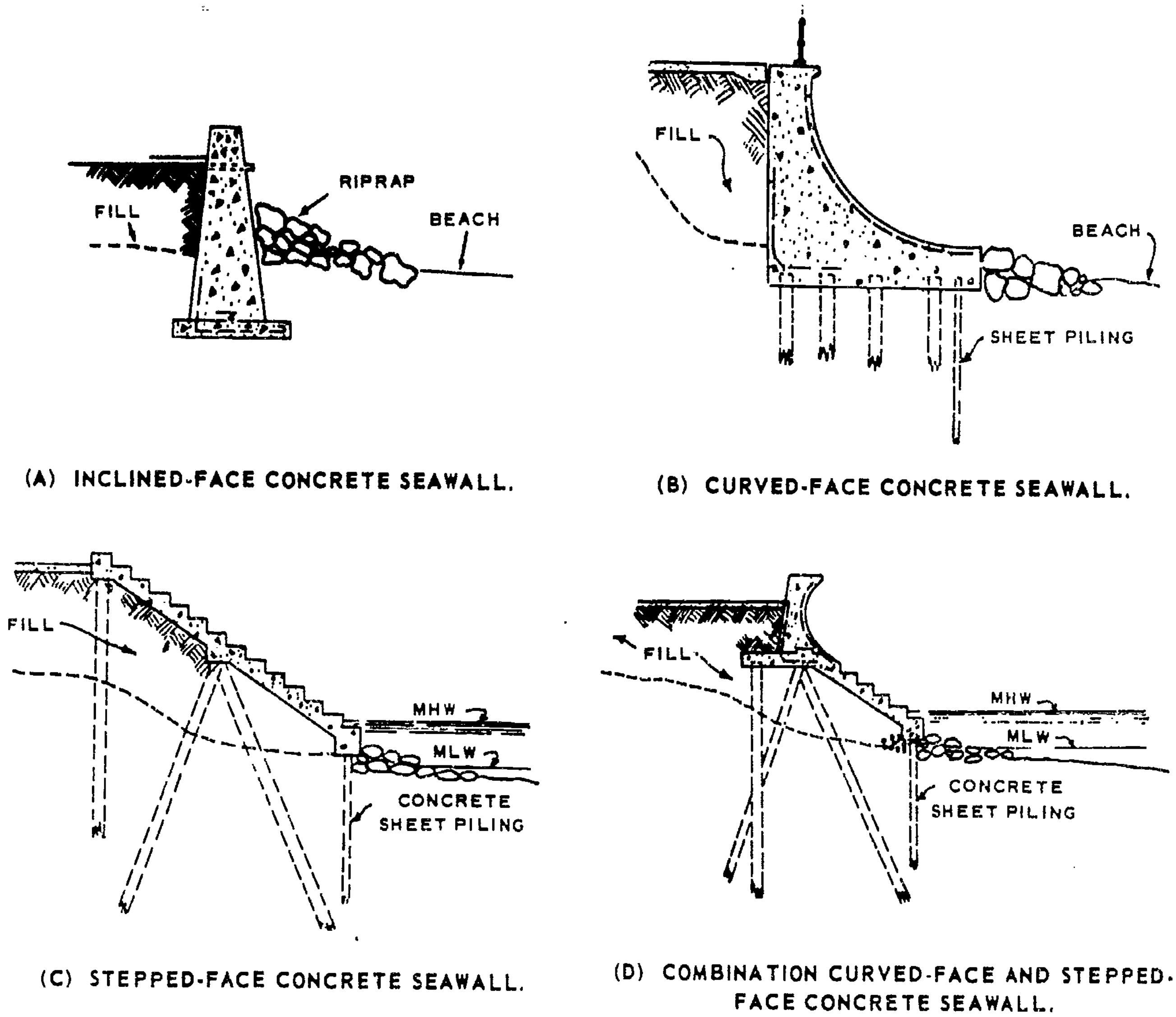

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Figure 2-8.—Various types of seawalls.

or the shore end of a pile wharf or approach. Its purpose is to support and protect an area of shore or fill from erosion. Bulkheads are classified according to types of construction, such as the following:

1. Pile and sheathing bulkhead.
2. Wood sheet pile bulkhead.
3. Steel sheet pile bulkhead.
4. Concrete sheet pile bulkhead.

Most bulkheads are made of steel sheet piles. Figure 2-9 shows a steel sheet pile bulkhead in the course of construction. A working drawing for such a bulkhead is shown in figure 2-10. The plan shows that the bulkhead will consist of a row of deep-arch web piles with a "wale" for anchoring outer ends of the tie rods. The wale will consist of two 12-inch channels back-to-back. The anchorage will consist of a row of arch-web piles with a similar wale for anchoring inner ends of tie rods which is spaced nine feet on center.

The section view shows that the anchorage will lie 58 feet behind the bulkhead. This view also suggests the order of construction sequence. First, the shore and bottom will be excavated to

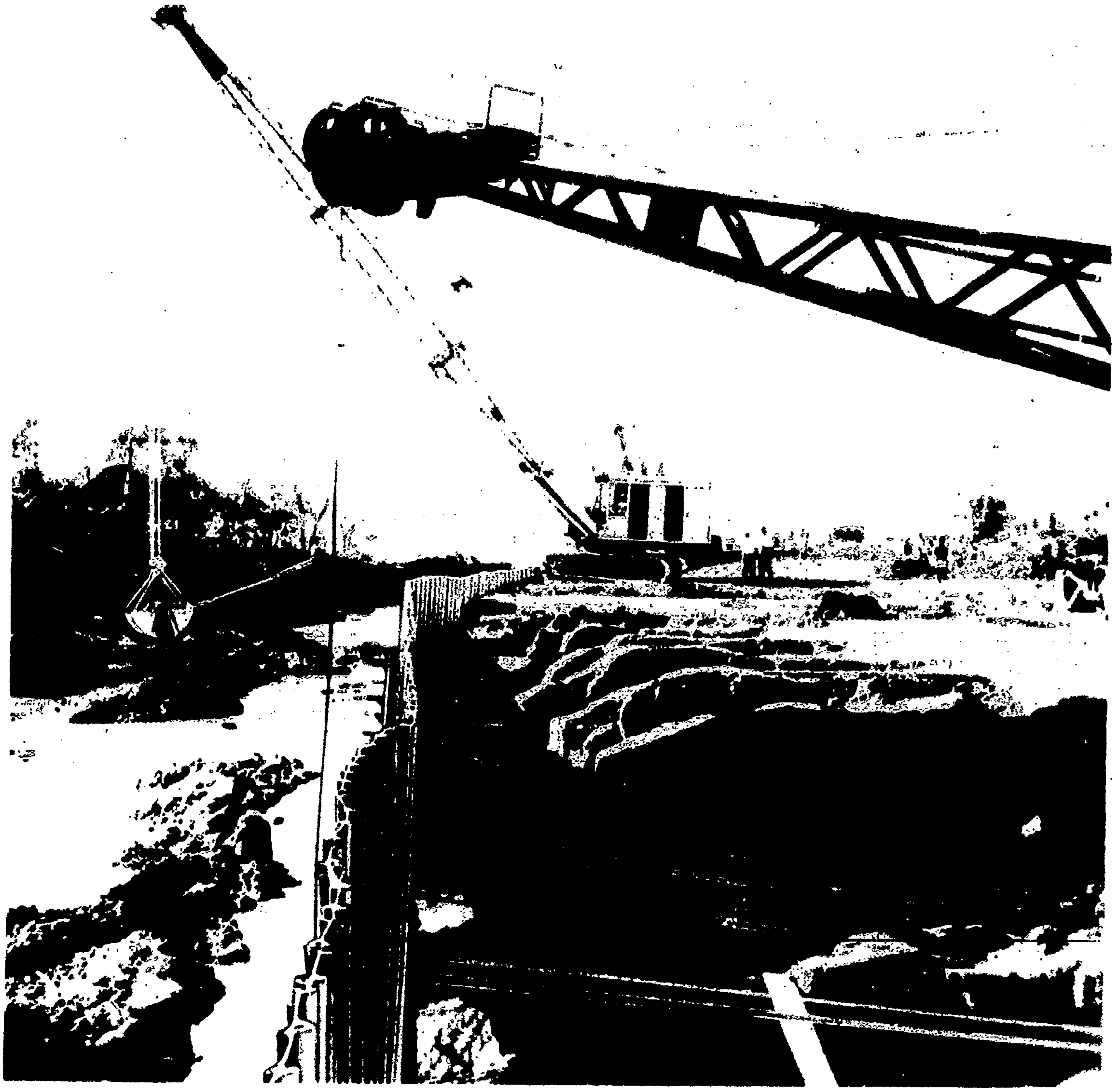

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Figure 2-9.—Steel sheet pile bulkhead.

the level of the long, sloping dotted line. The sheet piles for the bulkhead and anchorage will then be driven. The intervening dotted lines, at intervals of 19 feet 4 inches, represent supporting piles which will be driven to hold up the tie rods. These piles will be driven next, and the tie rods then set in place. The wales will be bolted on, and the tie rods will be tightened moderately (they are equipped with turnbuckles for this purpose).

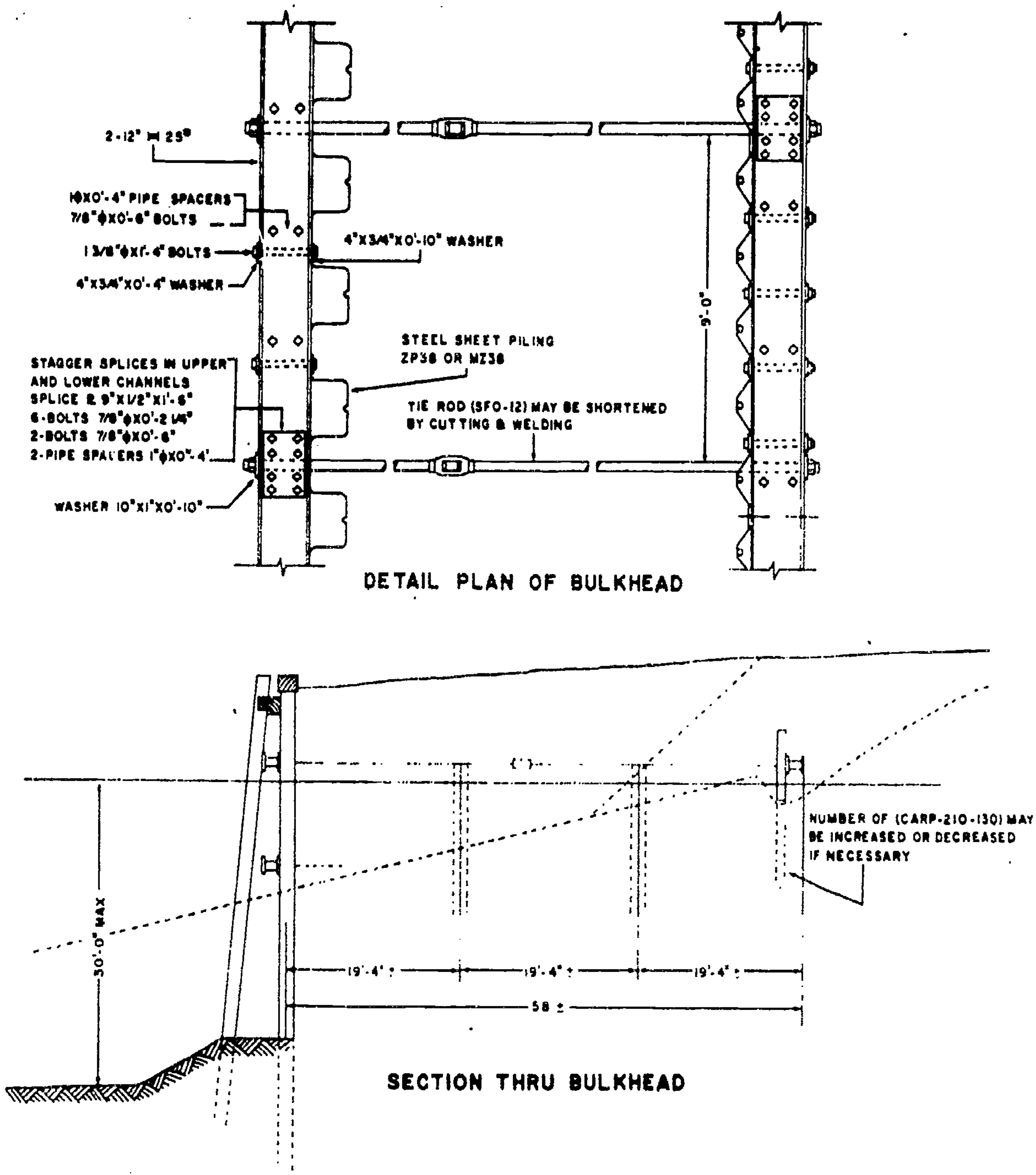

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Figure 2-10.—Working drawing for steel sheet pile bulkhead.

Backfilling to the bulkhead will then begin. The first backfilling operation will consist of filling over the anchorage, out to the sloping dotted line. The turnbuckles on the tie rods will then be set up to bring the bulkhead plumb. Then the remaining fill, out to the bulkhead, will be put in. Finally, outside the bulkhead, the bottom will be dredged to a depth of 30 feet.

To make it possible for ships to come alongside the bulkhead, it will be fitted with a timber cap and batter fender piles, as shown in the detail appearing in figure 2-11.

Fender piles are installed vertically at proper intervals in the waterfront edge of wharfs or quays to serve the following purposes:

1. They cushion a wharf from impact of ships and protect the outer row of bearing piles from damage.

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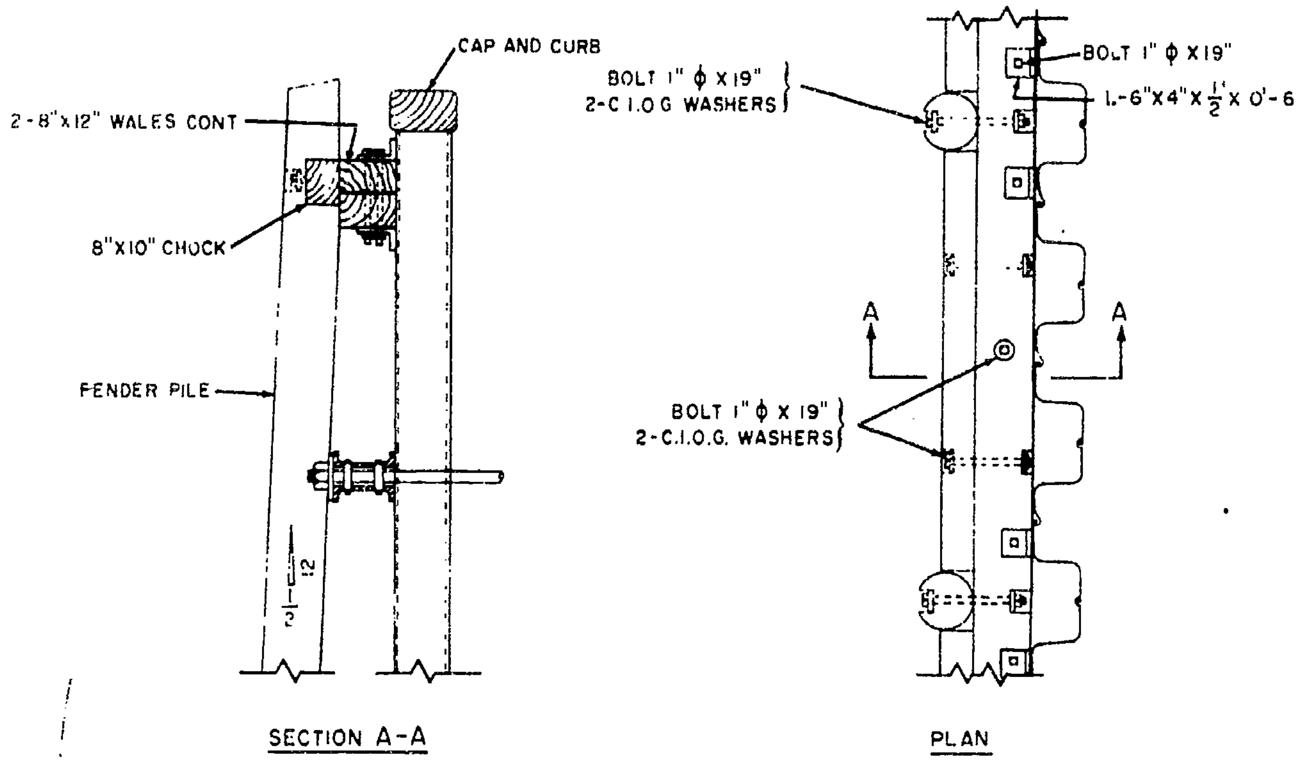

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Figure 2-11.—Cap and fender pile for bulkhead.

2. They protect the outer face of quays from damage due to the impact of ships.

3. They protect the hulls of craft from undue abrasion.

WHARFAGE STRUCTURES

Figure 2-12 shows various plan views of wharfage structures. Any of these may be constructed of fill, supported by bulkheads, and a QUAY is always a structure of this type. However, a pier or marginal wharf usually consists of a timber, steel, or concrete superstructure, supported on a substructure of timber, steel, or concrete-pile bents.

Generally, QUAYS are almost completely rigid structures; sometimes their fender piles are backed up with heavy springs to provide a combination of yielding and resistance. Fender piles are driven at a slight batter beside each outside pile, except on the extreme inshore wharf sections. Every third fender pile may extend 3 to 4 feet above the curb. The others are cut flush with the curb.

Construction drawings for a 20-foot advanced base timber PIER are shown in figures 2-13, 2-14, and 2-15. Figure 2-13 is a general plan view; figure 2-14 is a part plan on a larger scale; figure 2-15 is a section view showing the framing arrangements of one of the bents. A bill of materials (not shown) gives the dimensions of framing members and fasteners. The numbers shown refer to item numbers on the bill of materials; beside each item number, the bill gives a description of the item. From the drawings and the bill of materials, one can derive the following structural data about the pier.

Each length of a pier lying between adjacent bents is called a bay; the length of a bay is obviously equal, then, to the horizontal distance between bents. The general plan shows that the advanced base 20-foot timber pier will consist of one 13-foot outboard bay, one 13-foot inboard bay, ten 12-foot interior bays, and as many more interior bays as are required to reach the shore. The total distance of the outboard bay from the shoreline will depend on how far offshore the water begins to be deep enough to float a ship.

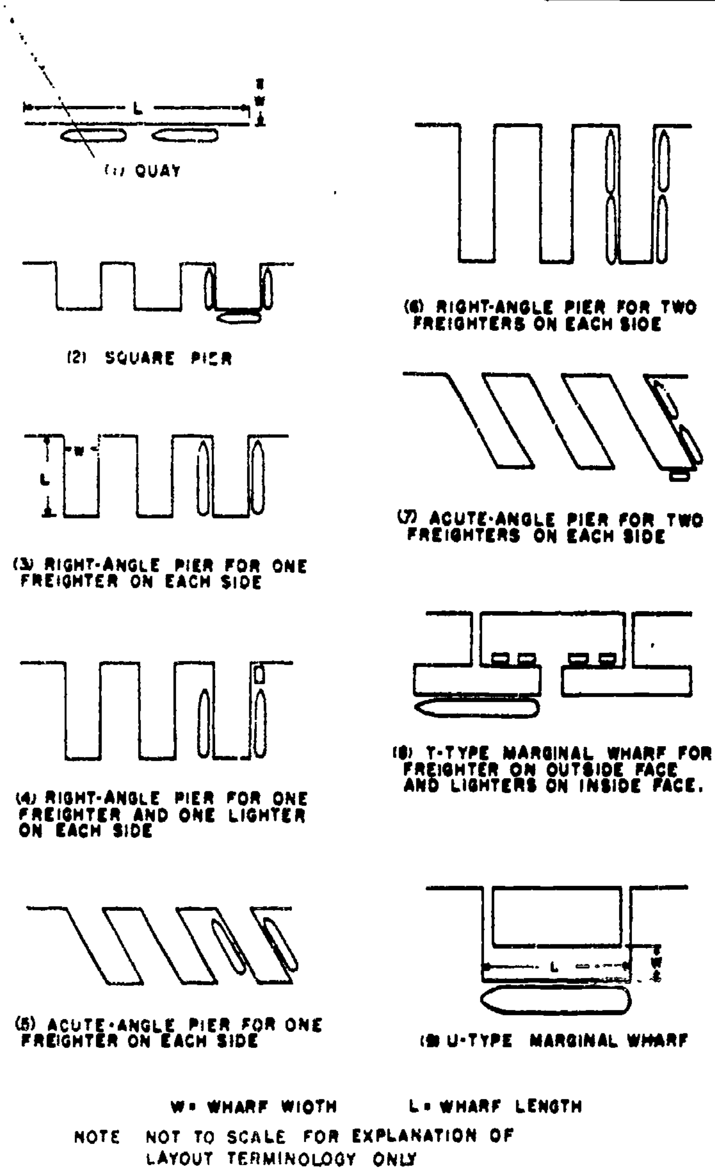

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Figure 2-12.—Types of wharfage structures.

If a bill of materials is taken from the section view (fig. 2-15), it will show that each bent will consist of three bearing piles (No. 1), one on the centerline and the others 7 feet 6 inches from the centerline. The bearing piles will be braced transversely by two 3- by 10-inch by 9-foot diagonal braces (No. 6), bolted on with 1- by 20-inch bolts (No. 21) and 1- by 22-inch bolts (No. 22); also by one 16-foot horizontal brace (No. 5), bolted on with 1- by 20-inch bolts.

Additional, transverse bracing for each bent will be provided by a pair of batter piles (No. 2) with specified batter at 5 run to 12 rise. One pile of each pair will be driven on either side of the bent, as shown. The butts of the batter piles will be joined to 12- by 14-inch longitudinal batter pile caps (No. 7), each of which will be bolted to the undersides of two adjacent bearing pile caps with 1- by 28-inch bolts, in the positions shown in the part plan (fig. 2-14). The batter pile caps will be placed 3 feet inboard of the line of the outer bearing piles of the bents. They will be backed by 6- by 14-inch by 2 foot 6-inch batter pile cap blocks (No. 8), each of which will be bolted to a bearing pile cap with four 1- by 26-inch bolts (No. 35).

Longitudinal bracing between the bents will consist of 14-foot lengths of 3 by 10's (Nos. 19 and 20), bolted to the bearing piles with 1- by 20-inch bolts (No. 21) and 1- by 22-inch bolts (No. 22).

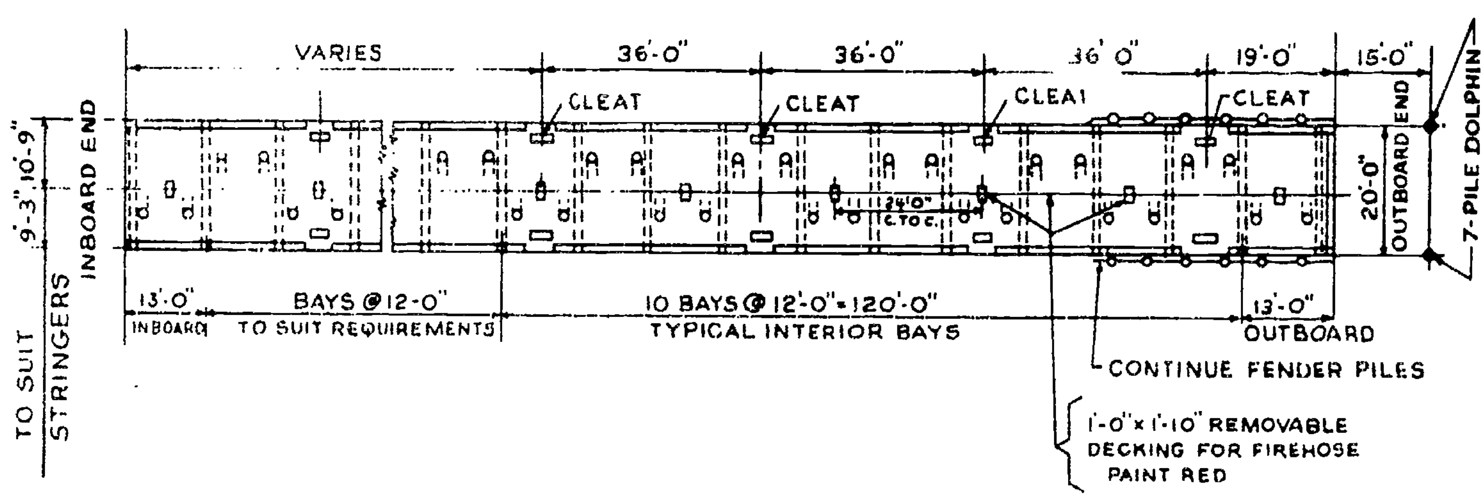

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Figure 2-13.—General plan of advanced base 20-foot timber pier.

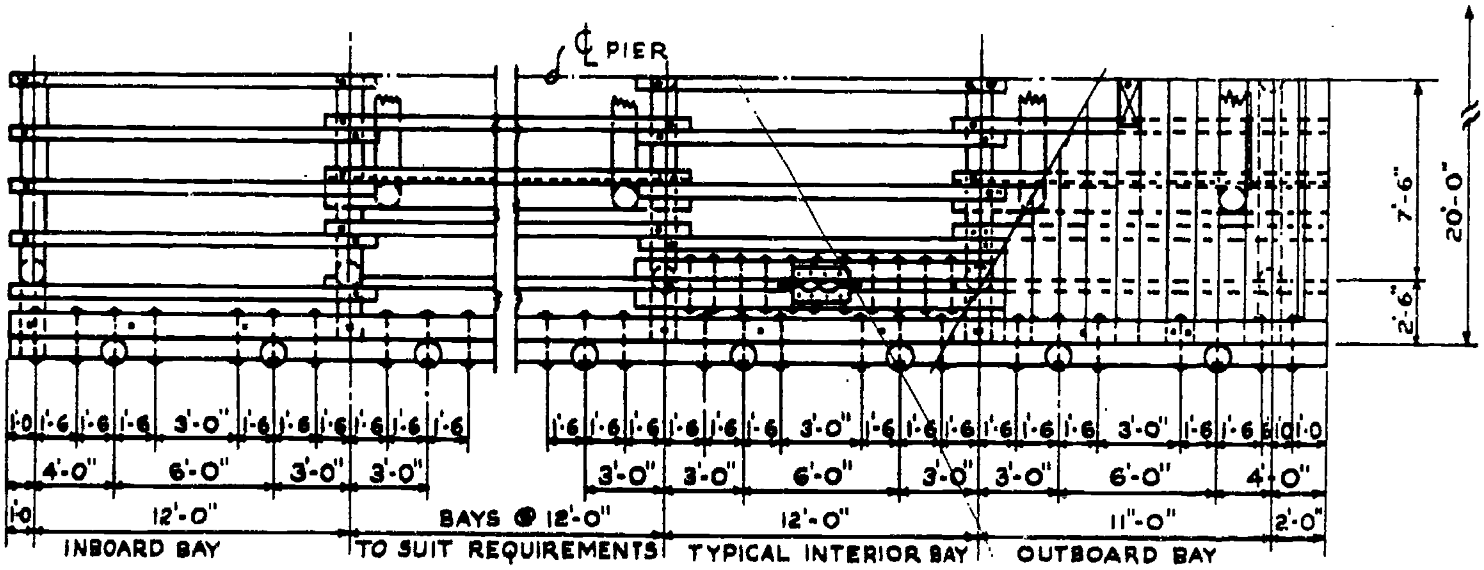

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Figure 2-14.—Part plan of advanced base 20-foot timber pier.

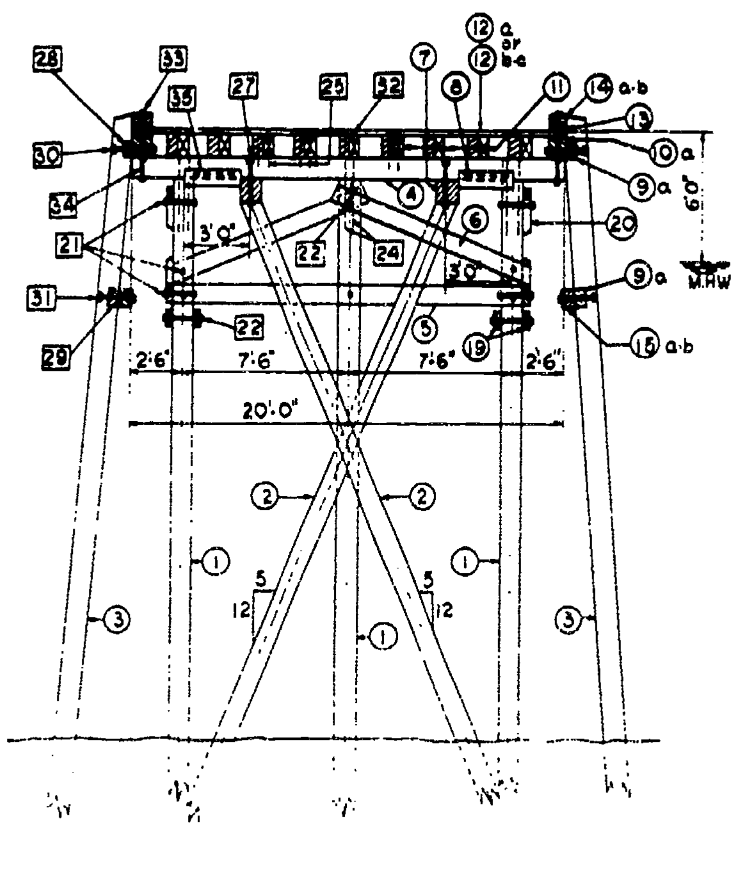

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Figure 2-15.—Section view of advanced base 20-foot timber pier.

The superstructure will consist of a single layer of 4- by 12-inch planks (No. 12), laid on nine 6- by 14-inch by 14-foot "inside" stringers (No. 1) and two 10- by 14-inch by 12-foot "outside" stringers (No. 10). The inside stringers will be fastened to the pile caps with 1- by 24-inch drift bolts (these and other heavy-construction fasteners are described at the end of this chapter). The outside stringers will be fastened to the pile caps with 1- by 30-inch bolts (No. 34).

The deck planks will be fastened to the stringers with 3/8- by 8-inch spikes (No. 32). After the deck is laid, 12-foot lengths of 8 by 10's (No. 14) will be fastened to the outside stringers to form the curb. Lengths of curbings will be distributed, as shown in the general plan (fig. 2-13). You can see that the curbing will be interrupted wherever a "cleat" will be located. Cleats and other mooring hardware are described later. The curbing will be bolted to the outside stringers with 3/4- by 32-inch bolts.

The pier will be equipped with a fender system for protection against the shock of contact with ships coming or lying alongside. Fender piles, spaced as shown in the part plan (fig.

2-14), will be driven along both sides of the pier and bolted to the outside stringers with 1- by 26-inch bolts (No. 3). The heads of these bolts will be "countersunk" below the faces of the fender piles.

An 8- by 10-inch timber fender wall (No. 15) will be bolted to the backs of the fender piles with 1- by 24-inch bolts. Lengths of 8 by 10's, called fender pile chocks, (No. 9) will be cut to fit between the fender piles and will be bolted to the outside stringers and the fender pile wales. Spacing for these bolts is shown in the part plan.

The general plan shows that the fender system will include two 7-pile dolphins, located 15 feet beyond the outer end of the pier. A dolphin is a detached cluster of piles like the one shown in figure 2-16. A similar cluster attached to the pier is called a pile cluster.

Various types of mooring hardware are installed on a wharfage structure for the attachment of mooring lines from ships. As indicated in the general plan, cleats, spaced as shown, are used on the 20-foot timber pier. The bill of materials specifies 42-inch cleats; a 42-inch mooring cleat is shown in figure 2-17. The method of attaching a cleat to the pier is shown in the part plan. Two 10- by 14-inch timbers are bolted to either side of the first inside stringer and the cleat is bolted down to the timbers.

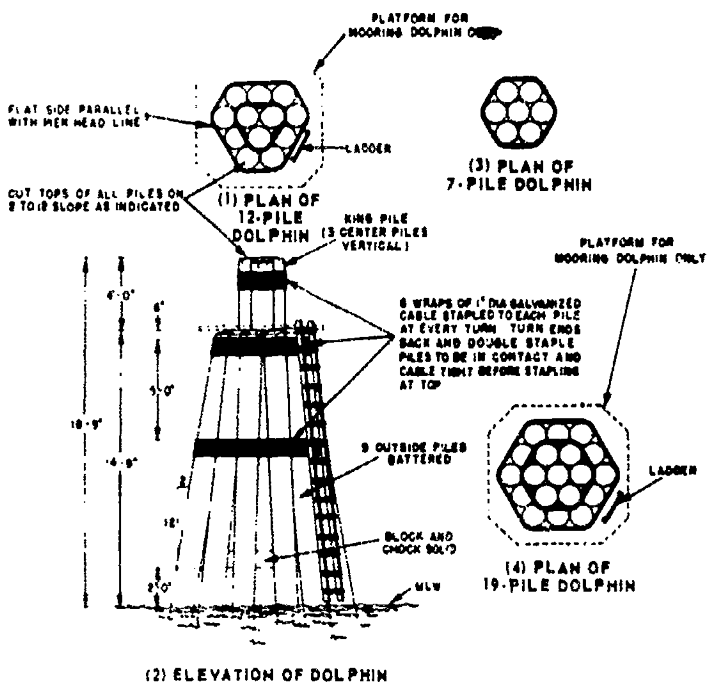

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Figure 2-16.—7-pile, 12-pile, and 19-pile dolphins.

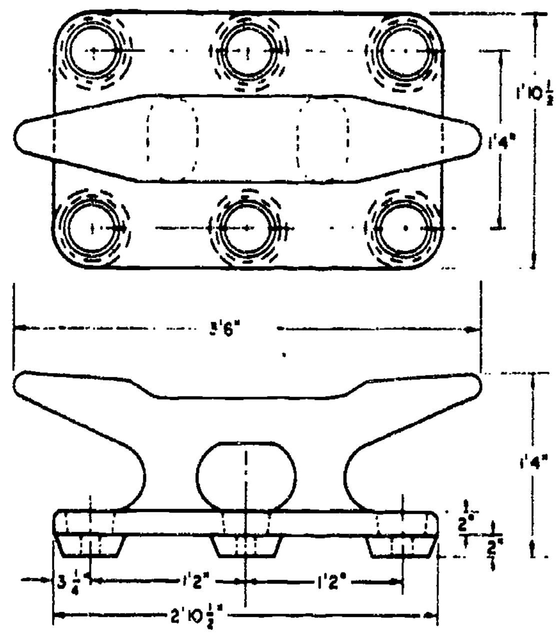

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Figure 2-17.—42-inch mooring cleat.

Another common item of mooring hardware is the bollard shown in figure 2-18. Figure 2-19 shows a method of attaching a bollard to a timber pier.

TIMBER FASTENERS AND CONNECTORS

In working in heavy construction, you will be concerned with the more common types of fasteners used in heavy construction. The next few paragraphs will explain the methods used in attaching these fasteners and connectors.

TIMBER FASTENERS

The BOLTS used to fasten heavy timbers usually come in 1/2-, 3/4-, and 1-inch diameters with square heads and square nuts. A round

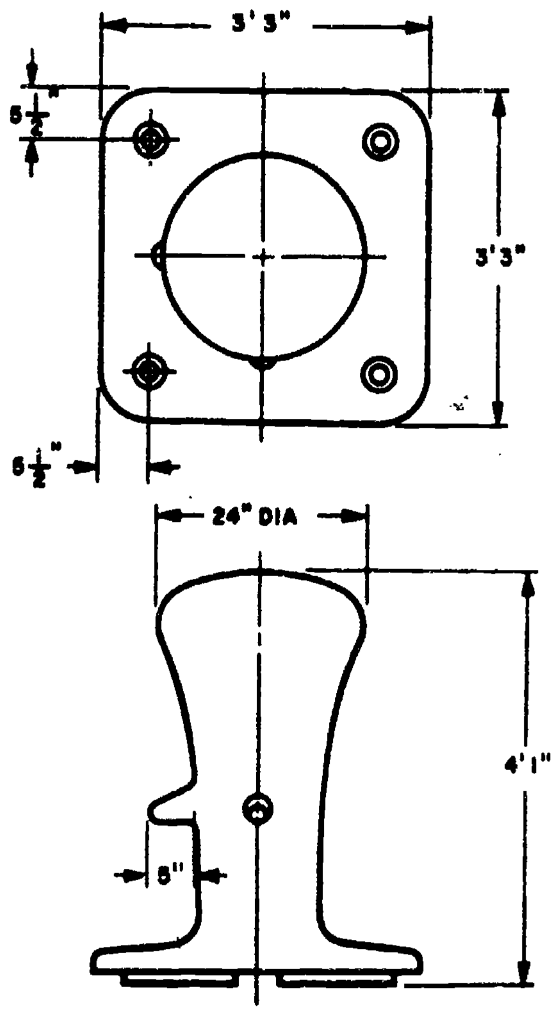

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Figure 2-18.—24-inch bollard.

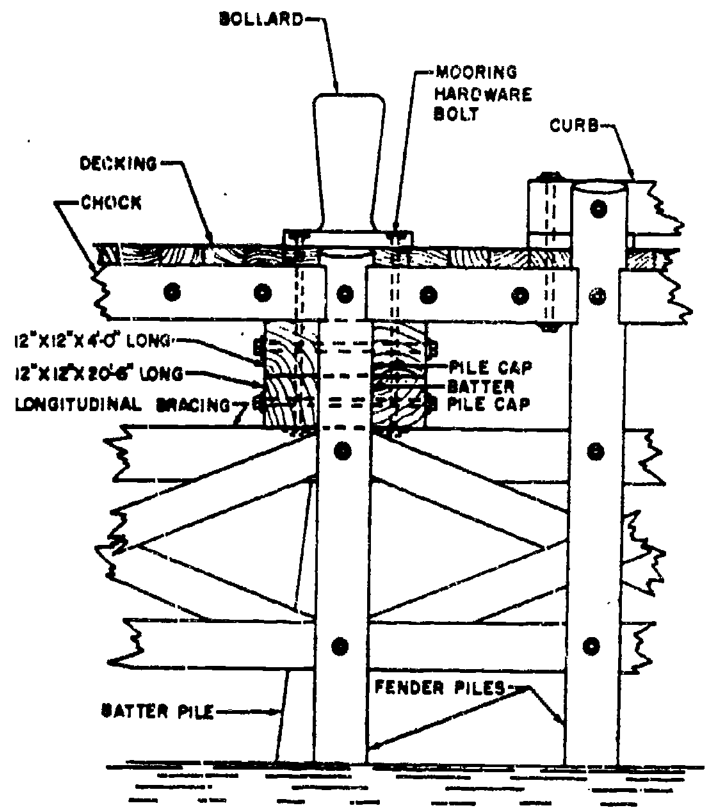

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Figure 2-19.—Method of attaching bollard to timber pier.

steel washer is placed under the head and the nut, and the bolt is tightened until the washers bite well into the wood to compensate for future shrinkage. Bolts should be spaced not less than 9 inches O.C. Edge distance should not be less than 2 1/2 inches, and the end distance should not be less than 7 inches.

Drift bolts, sometimes called drift pins, are bolts used primarily to prevent timbers from moving laterally in relation to each other, rather than to resist pulling apart. They are used more in dock and trestle work than in trusses and building frames. Drift bolts are long, threadless rods, either square or round, and may have square, wedge, or pointed ends. They are driven into a hole bored through the member butted against and into the abutting member. The hole for the drift bolt should be one-sixteenth of an inch larger than the diameter of the drift bolt and about 3 inches shorter. Drift bolt diameters run from 1/2 inch to 1 inch and lengths vary from 18 inches to 26 inches.

Butt joints are also fastened with a SCAB which is a short length of timber that is spiked or bolted to the adjoining members at the joint, as shown in figure 2-20.

TIMBER CONNECTORS

TIMBER CONNECTOR is a general term applied to a variety of devices used to increase the strength and rigidity of bolted-lap joints between heavy timbers. The SPLIT RING, as shown in figure 2-21, is embedded in circular grooves which are cut with a special type of bit in the faces of the timbers which are to be joined. Split rings come with 2 1/4-, 4-, 6-, and 8-inch diameters. The 2 1/2-inch ring takes a 1/2-inch bolt; the others take a 3/4-inch bolt. If

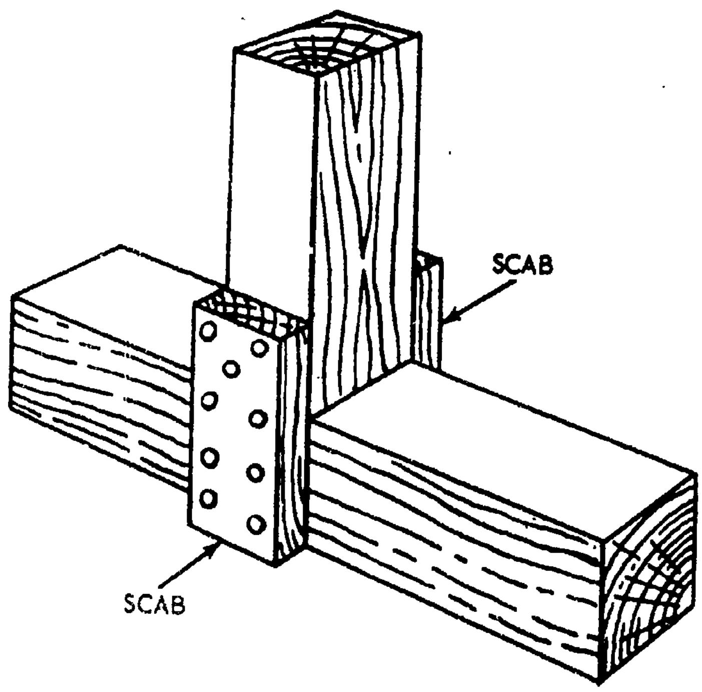

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Figure 2-20.—Scabs.

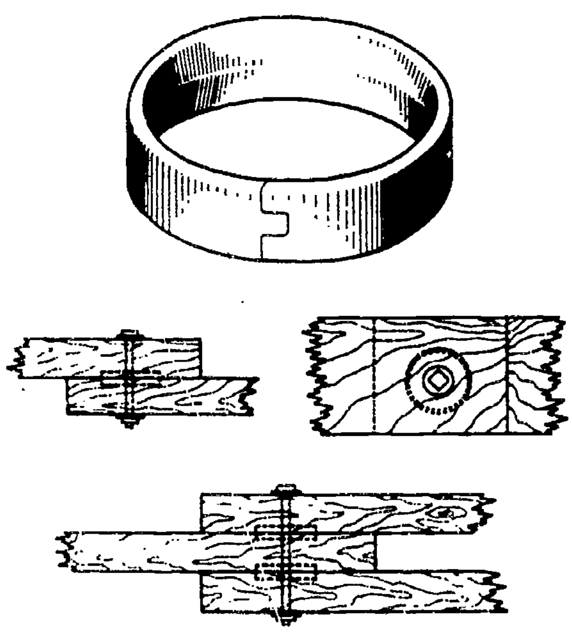

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Figure 2-21.—Split ring and split ring joint.

more than one ring is used at a joint, the minimum spacings center-to-center shall be 9 inches, and at least 2 1/2-ring diameters when the pull on the joint will be parallel to the grain, or 1 1/2-ring diameters when the pull will be perpendicular to the grain. Edge distance which is measured from the center of the ring to the edge of the member should not be less than one-half the ring diameter plus 1 inch. End distance which is measured from the center of the ring to the end of the member should not be less than 7 inches.

The TOOTHED RING (fig. 2-22) functions in much the same manner as the split ring, but it can be imbedded without the necessity of cutting grooves in the members. The toothed ring is embedded by the pressure produced by tightening a bolt of high-tensile strength, as shown in figure 2-23. The hole for this bolt is made one-sixteenth of an inch larger than the bolt diameter so that the bolt may be easily extracted after the ring is embedded. It is then replaced by an ordinary steel bolt.

Toothed rings come with 2-, 2 5/8-, 3 3/8-, and 4-inch diameters. The 2-inch ring takes a 1/2-inch bolt, the 2 5/8-inch ring takes a 5/8-inch bolt, and the others a 3/4-inch bolt. Spacings, edges, and end distances are the same as they are for split rings.

The SPIKE GRID is used as shown in figure 2-24. A spike grid may be FLAT (for joining two flat surfaces), SINGLE-CURVED (for joining

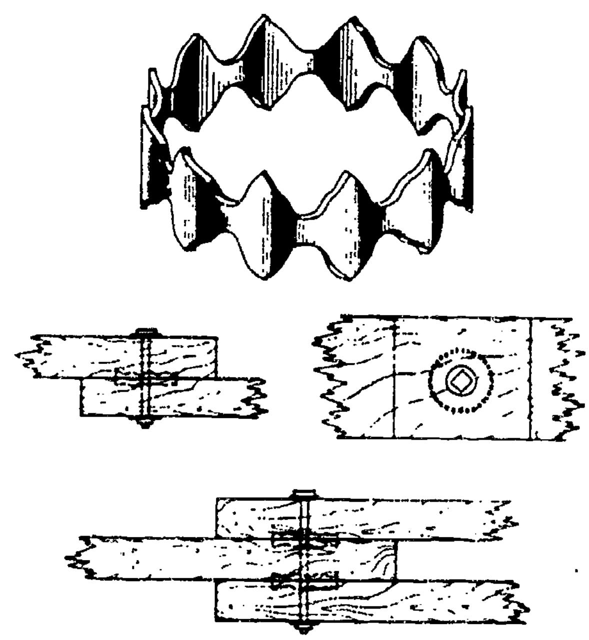

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Figure 2-22.—Toothed ring and toothed-ring joint.

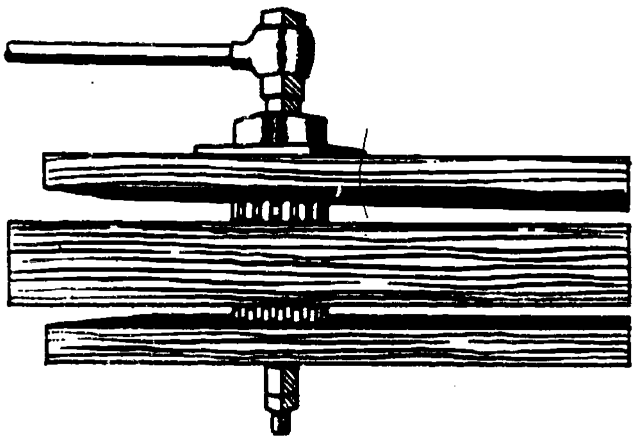

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Figure 2-23.—Embedding toothed rings.

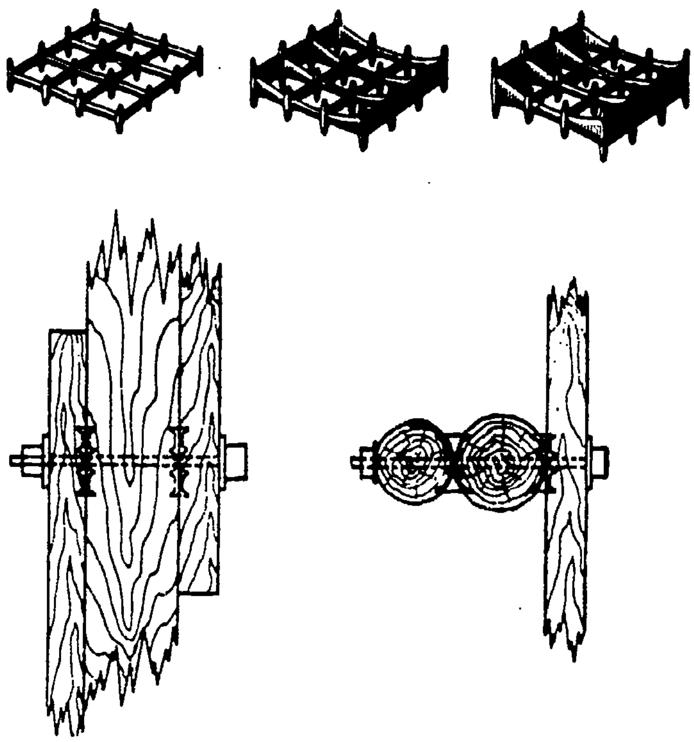

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Figure 2-24.—Spike grids and spike grid joints.

a flat and a curved surface), or DOUBLE-CURVED (for joining two curved surfaces). A spike grid is embedded in the same manner as a toothed ring.

STRUCTURAL STEEL SHAPES

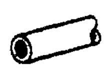
Structural steel forms the framework of many types of structures, such as bridges, piers, hangers, towers, warehouses, and shop buildings. The steel framework of the structure may be visible, as in bridges and towers, or concealed within the walls of various types of buildings. In any case, the steel framework carries the weight of the structure and the applied loads.

The steel structure is a framework of structural steel members. The individual member might be a single piece of steel or several component pieces that are fabricated in the shop and assembled at the jobsite.

A structural steel member which is fabricated in the shop is made from one or more STRUCTURAL STEEL SHAPES. A wide variety of standard shapes of different cross sections are manufactured. Figure 2-25 illustrates many of these various shapes. The three most common types of structural members are the W-shape (wide flange), the S-shape (American Standard I-beam), and the C-shape (American Standard channel). These three types are identified by the nominal depth, in inches, along the web and the weight per foot of length, in pounds. As an example, a W12 × 27 indicates a W-shape with a web 12 inches deep, with a weight of 27 pounds per linear foot. Figure 2-26 shows the cross sectional views of the W-, S-, and C-shapes. The difference between the W-shape and the S-shape is in the design of the inner surfaces of the flange. The W-shape has parallel inner- and outer-flange surfaces with a constant thickness, while the S-shape has a slope of approximately 17° on the inner flange surfaces. The C-shape is similar to the S-shape in that its inner flange surface is also sloped approximately 17°.

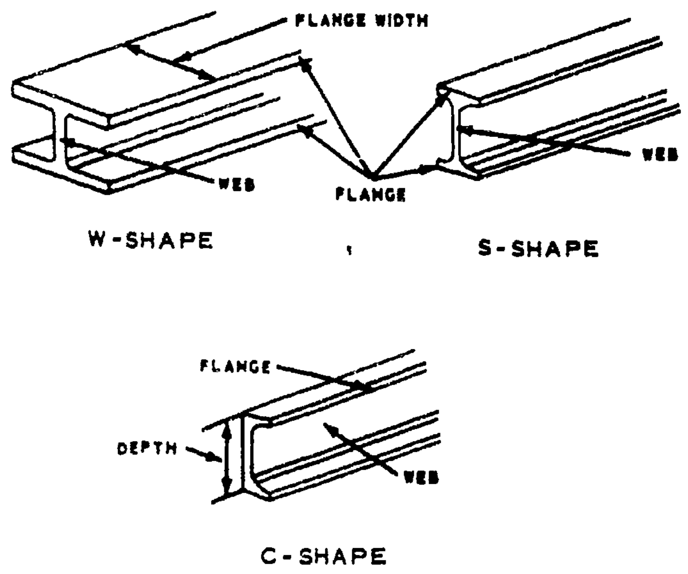
The W-SHAPE is a structural member whose cross section forms the letter H and is the most widely used structural member. It is designed so that its flanges provide strength in a horizontal plane, while the web gives strength in a vertical plane. W-shapes are used as beams, columns, truss members, and in other load-bearing applications.

The BEARING PILE (BP shape) is almost identical to the W-shape. The only difference

OLD SYMBOL	OLD ILLUSTRATED USE	DESCRIPTION	EXAMPLE	NEW SYMBOL	NEW ILLUSTRATED USE
WF	24WF76	W-SHAPE (WIDE FLANGE)		W	W24X76
BP	14BP73	BEARING PILE		BP	BP14X73
I	15I42.9	S-SHAPE (AMERICAN STD I-BEAM)		S	S15X42.9
⊔	9⊔13.4	C-SHAPE (AMERICAN STD CHANNEL)		C	C9X13.4
M	8X8M34.3	M-SHAPE (MISC SHAPES OTHER THAN W, BP, S, & C)		M	M8X34.3
M	8M17				M8X17
Jr	7Jr.5.5				M7X5.5
⊔	12X4⊔44.5	MC-SHAPE (CHANNELS OTHER THAN AMERICAN STD.)		MC	MC12X45
Jr⊔	10Jr⊔8.4				MC12X12.6
		ANGLES:			
L	L3X3X$\frac{1}{4}$	EQUAL LEG		L	L3X3X$\frac{1}{4}$
L	L7X4X$\frac{1}{2}$	UN-EQUAL LEG		L	L7X4X$\frac{1}{2}$
		TEES, STRUCTURAL:			
ST	ST5WF10.5	CUT FROM W-SHAPE		WT	WT12X38
		CUT FROM S-SHAPE		ST	ST12X38
		CUT FROM M-SHAPE		MT	MT12X38
PL	$\mathrm{PL18X}\frac{1}{2}\mathrm{X2'{-}6''}$	PLATE		PL	$\mathrm{PL}\frac{1}{2}\mathrm{X18''X30''}$
BAR	BAR2$\frac{1}{2}$X$\frac{1}{4}$	FLAT BAR		BAR	BAR2$\frac{1}{2}$X$\frac{1}{4}$
O	O6♦	PIPE, STRUCTURAL		⊕	PIPE4 STD
					PIPE 4X-STRG
					PIPE 4 XX-STRG

127.273

Figure 2-25.—Structural shapes and designations.



11.30

Figure 2-26.—Structural shapes.

is that the flange and web thickness of the bearing pile are equal, whereas the W-shape has different web and flange thicknesses.

The S-SHAPE is distinguished by its cross section being shaped like the letter I. S-shapes are used less frequently than W-shapes since the S-shapes possess less strength and are less adaptable than W-shapes.

The C-SHAPE has a cross section somewhat similar to the letter C. It is especially useful in locations where a single flat face without outstanding flanges on one side is required. The C-shape is NOT very efficient for a beam or column when used alone. However, efficient built-up mer·' ers may be constructed of channels assembled together with other structural shapes and connected by rivets or welds.

An ANGLE is a structural shape whose cross section resembles the letter L. Two types, as illustrated in figure 2-27, are commonly used—an equal-leg angle and an unequal-leg angle. The angle is identified by the dimension and thickness of its legs, for example, angle 6 by 4 by 1/2 inch. The dimension of the legs should be obtained by measuring along the outside of the backs of the legs. When an angle has unequal legs, the dimension of the wider leg is given first, as in the example just cited. The third dimension applies to the thickness of the legs which always have equal thickness. Angles may be used in combinations of two or four to form main members. A single angle may also be used to connect main parts together.

STEELPLATE is a structural shape whose cross section is in the form of a flat rectangle. Generally, one of the main points to remember about plate is that it has a width of 8 inches or more and a thickness of 1/4 inch or greater.

Plates are generally used as connections between other structural members or as component parts of built-up structural members. Plates cut to specific sizes may be obtained in widths ranging from 8 inches to 120 inches or more, and in various thicknesses. The edges of these plates may be cut by shears (sheared plates) or be rolled square (universal mill plates).

Plates frequently are referred to by their thickness and width in inches, as plate 1/2 by 24 inches. The length in all cases is given in inches. Note in figure 2-28 that 1 cubic foot of steel weighs 490 pounds. This weight, divided by 12, gives you 40.8, which is the weight (in pounds) of a steelplate 1 foot square and 1 inch thick. The fractional portion is normally dropped and

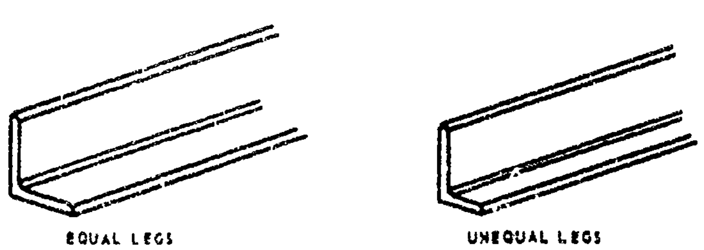


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Figure 2-27.—Angles.

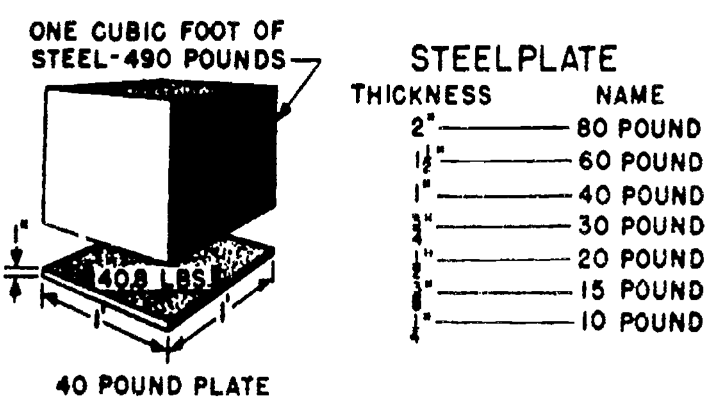

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Figure 2-28.—Weight and thickness of steelplate.

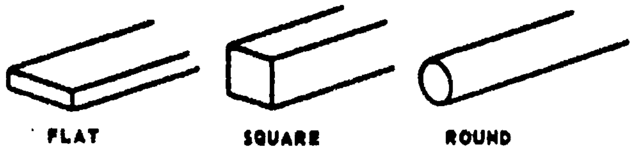


Figure 2-29.—Bars.

1-inch plate is called a 40-pound plate. In practice, you may hear plate referred to by its approximate weight per square foot for a specified thickness. An example is 20-pound plate which indicates a 1/2-inch plate. (See figure 2-25.)

The structural shape referred to as a BAR has a width of 8 inches or less and a thickness greater than three-sixteenths of an inch. The edges of bars usually are rolled square, like universal mill plates. The dimensions are expressed in a similar manner as that for plates; for instance, bar 6 inches by 1/2-inch. Bars are available in a variety of cross-sectional shapes—round, hexagonal, octagonal, square, and flat. Three different shapes are illustrated in figure 2-29. Both squares and rounds are commonly used as bracing members of light structures. Their dimensions, in inches, apply to the side of the square or the diameter of the round.

STEEL FRAME STRUCTURES

Construction of a framework of structural steel involves two principal operations—fabrication and erection. Fabrication involves the processing of raw materials to form the finished members of the structure. Erection includes all rigging, hoisting, or lifting of members to their proper places in the structure and making the finished connections between members.

TYPES OF STRUCTURES

A wide variety of structures are erected using structural steel. Basically they can be listed as buildings, bridges, and towers; most other structures are modifications of these three.

Buildings

The steel framework carries the load of the structure and transmits it to the foundation; therefore, the framework must be strong enough to carry the applied loads and stiff enough so that it will not undergo excessive deflection either during construction or while in service.

In figure 2-30, the vertical members which support the trusses are called COLUMNS. These columns rest on either a concrete foundation or FOOTINGS. The load of the column is usually spread over the top of the footing by a steel-plate connected to the column. The roofing is

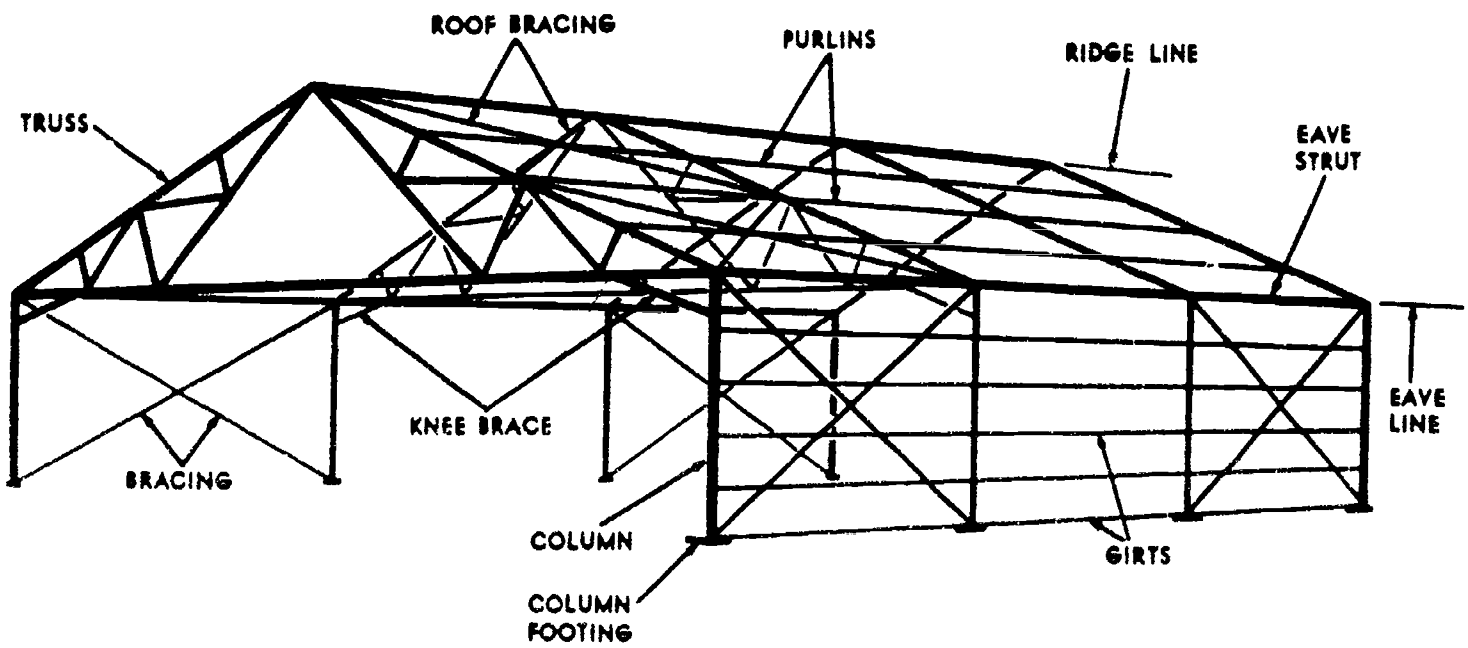


Figure 2-30.—Framework of a typical mill building.

supported by the horizontal members called PURLINS which are fitted between the trusses.

Walls in this type of building may be self-supporting, such as brick or concrete blocks or they may be hung on the framework, as is the case with wood, corrugated metal, or cement-asbestos sheets. Wall sheathing is supported on light horizontal members, called GIRTS. The building frame is made rigid by members in vertical planes, which may be arranged as DIAGONAL BRACES or KNEE BRACES. A diagonal brace joins opposite corners of a quadrangular frame. Usually, diagonal braces are used in pairs. A knee brace does NOT extend all the way across the diagonal of the quadrilateral, but it is made shorter so as to occupy only the knee or corner. A STRUT is any small or secondary member designed to take a load in compression. An eave strut, therefore, is a compression member which extends along the line of the eave of the building. Other bracing members are provided either in the plane of the roof, in the plane of the lower chords of the roof trusses, or both. The frame illustrated is typical of the type of framing known as mill-building construction.

In multistory buildings, floor and roof loads are carried by BEAMS and GIRDERS and supported by columns. A beam-and-column building framework usually is NOT braced with diagonal bracing because such bracing would interfere with windows or doors. Instead, the joints between beams and columns are made rigid by the application of several types of wind bracing methods (designer's choice) that can withstand bending caused by the applied forces. This type of construction is known as SKELETON CONSTRUCTION when the beams are supported by columns (figure 2-31) and as WALL-BEARING CONSTRUCTION when

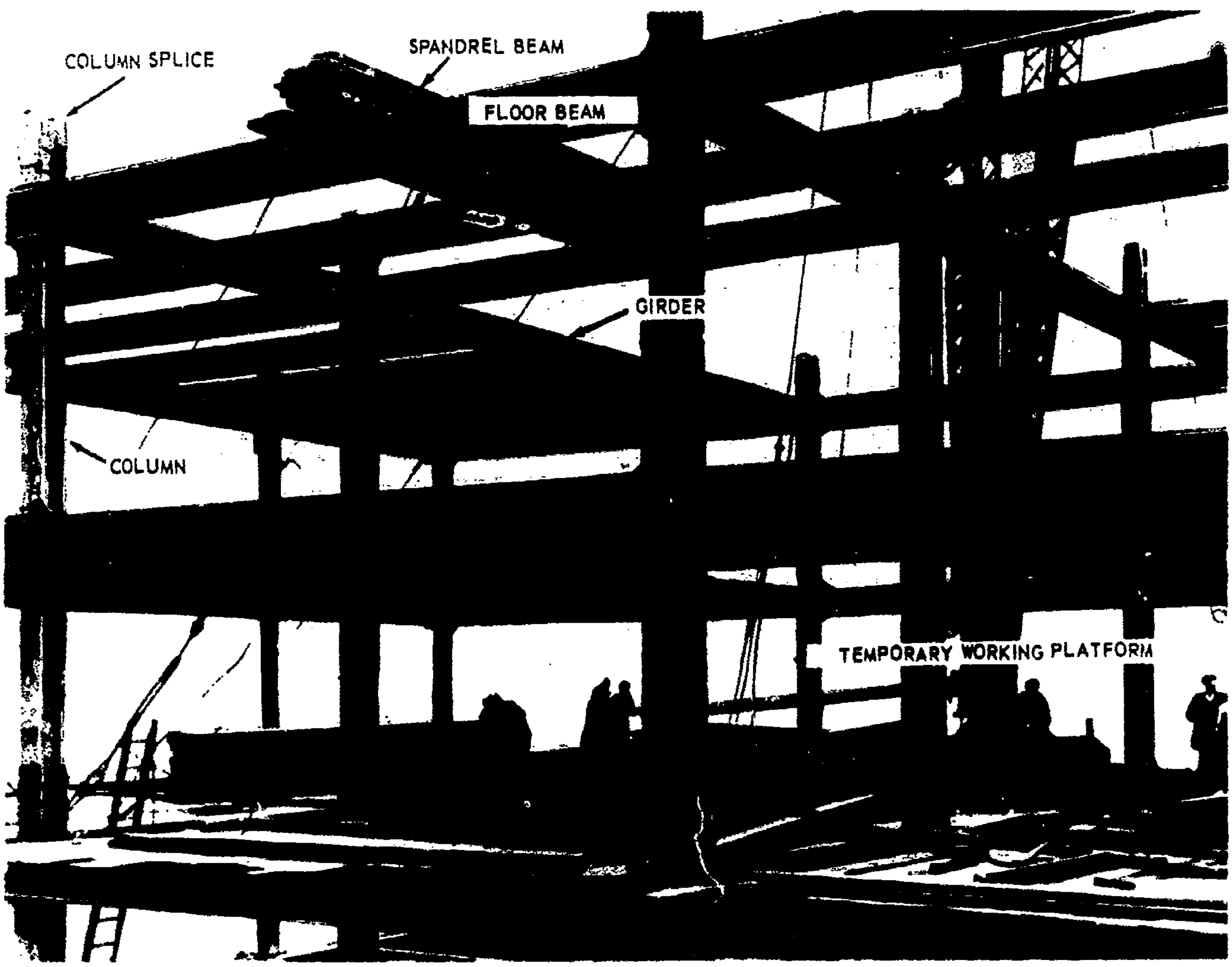


Figure 2-31.—Skeleton structural steel construction. 45.464

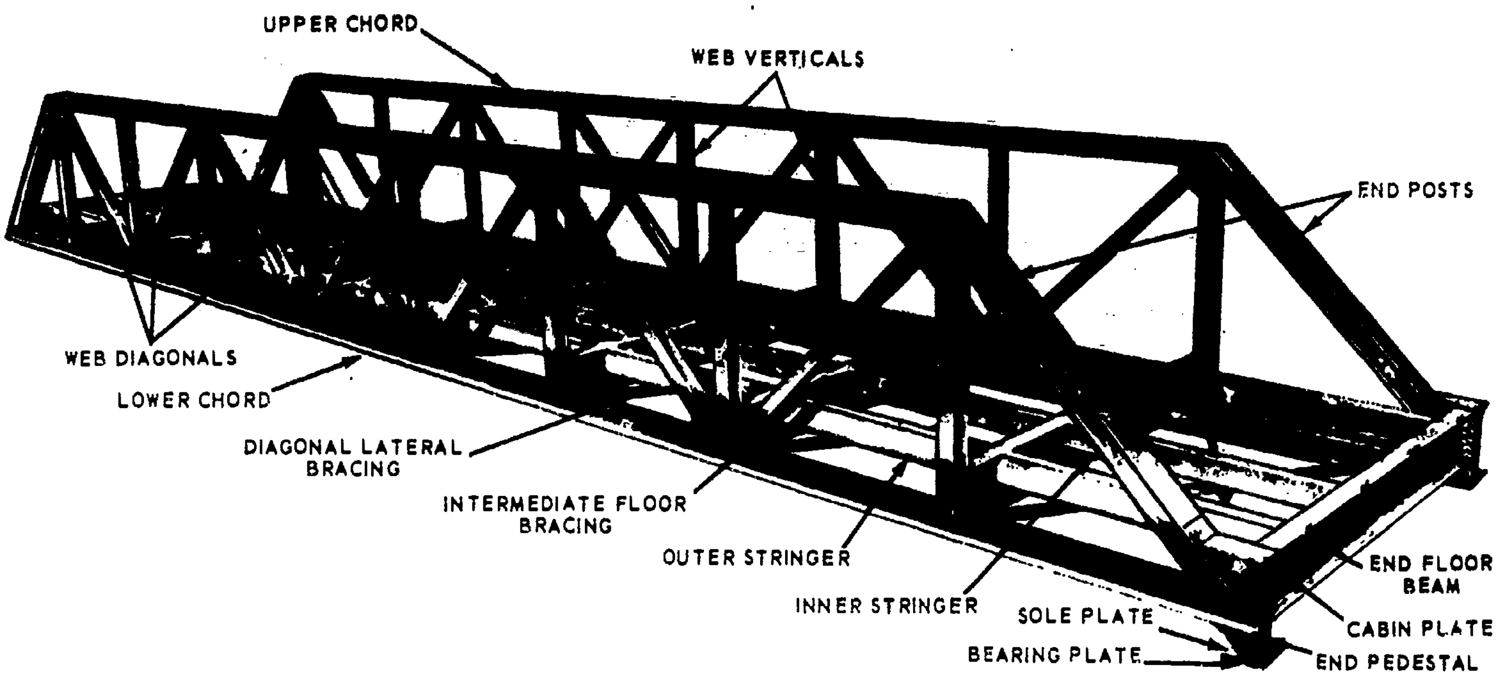


Figure 2-32.—Truss bridge.

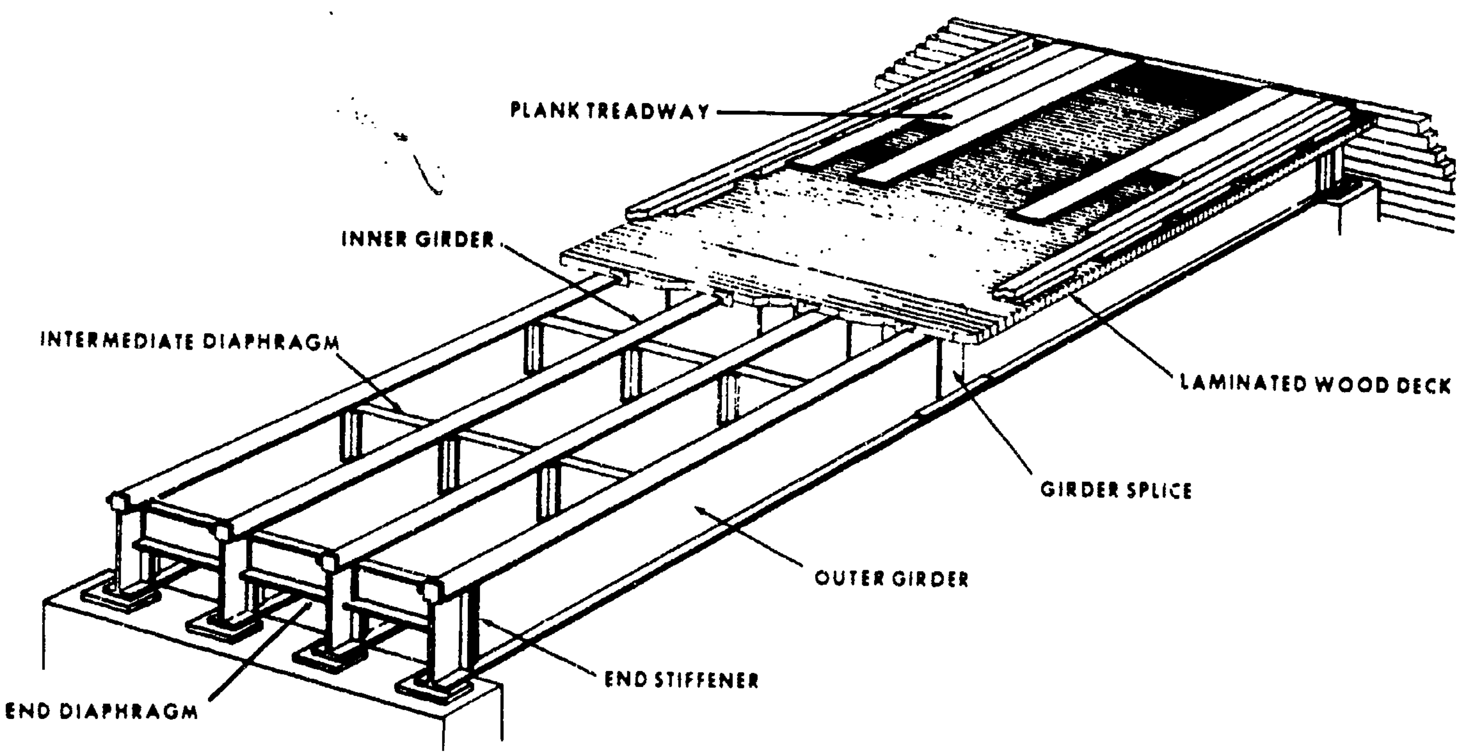


Figure 2-33.—Stringer bridge span.

the beams are supported by masonry walls. In skeleton construction, the portions of the outer walls between windows are supported by SPANDREL BEAMS located within, or parallel to, the walls.

Bridges

A bridge consists of a floor or deck, supports, and necessary bracing. Supporting members for the floor consist of longitudinal stringers supported directly on abutments, or on piers, towers, or a series of bents. The stringers are supported by transverse floor beams which are in turn supported by the main trusses (fig. 2-32). In a stringer bridge span (fig. 2-33), the main members carrying the load take the place of intermediate stringers. Truss members are named according to their location in the truss. The members on the perimeter of the truss are the CHORD MEMBERS. Those in the interior of the truss are the WEB VERTICALS or WEB DIAGONALS, depending on their position. Inclined end members of the chord, adjacent to the abutments, are usually called END POSTS rather than chord members. Bridge spans are known as through spans when the traffic passes through the main trusses and under a top lateral bracing system, as shown in view A, figure 2-34, and as deck spans when the traffic passes above the main members and all bracing, as shown in views B and E, figure 2-34. In pony truss spans, as shown in view C, figure 2-34 and half-through girder spans, as shown in view D, figure 2-34, no top lateral bracing is used because of the small depth of the girders or trusses.

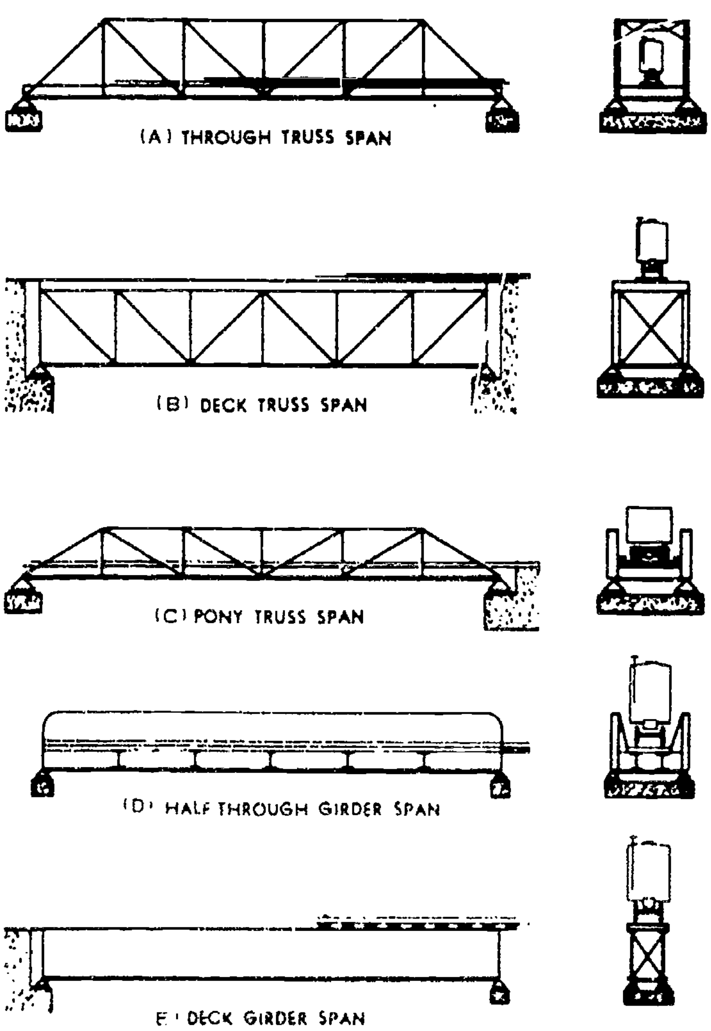


Figure 2-34.—Types of bridge spans.

Towers

Towers are framework structures designed to provide vertical support. They may be used to support another structure, such as a bridge, or they may be used to support a piece of equipment, such as a communications antenna. Since the prime purpose of a tower is to provide vertical support to a load applied at the top, the compression members providing this support are the only ones which require high-structural strength. The rest of the structure is designed to stiffen the vertical members and to prevent bending under load. Primarily, the bracing members are designed to take loads in tension and are based on a series of diagonals. A typical trestle tower used in bridge construction is shown in figure 2-35.

Preengineered Metal Structures

Preengineered metal structures are commonly used in military construction. They are usually designed and fabricated by civilian industry to conform with the specifications set forth by the Armed Forces. Rigid frame buildings, steel towers, communications antennas, and steel tanks are some of the most commonly used structures, particularly at overseas advance bases. Preengineered structures offer an advantage in that they are factory built and designed to be erected in the shortest amount of time possible. Each structure is shipped as a complete kit, including all the materials and instructions needed to erect it. There are many types of preengineered structures available from various manufacturers, such as Pasco, Endure, Butler, and Strand Corporation. Information on nomenclatures and various assemblies is described in the *Steelworker 3 & 2*, NAVEDTRA 10653-F.

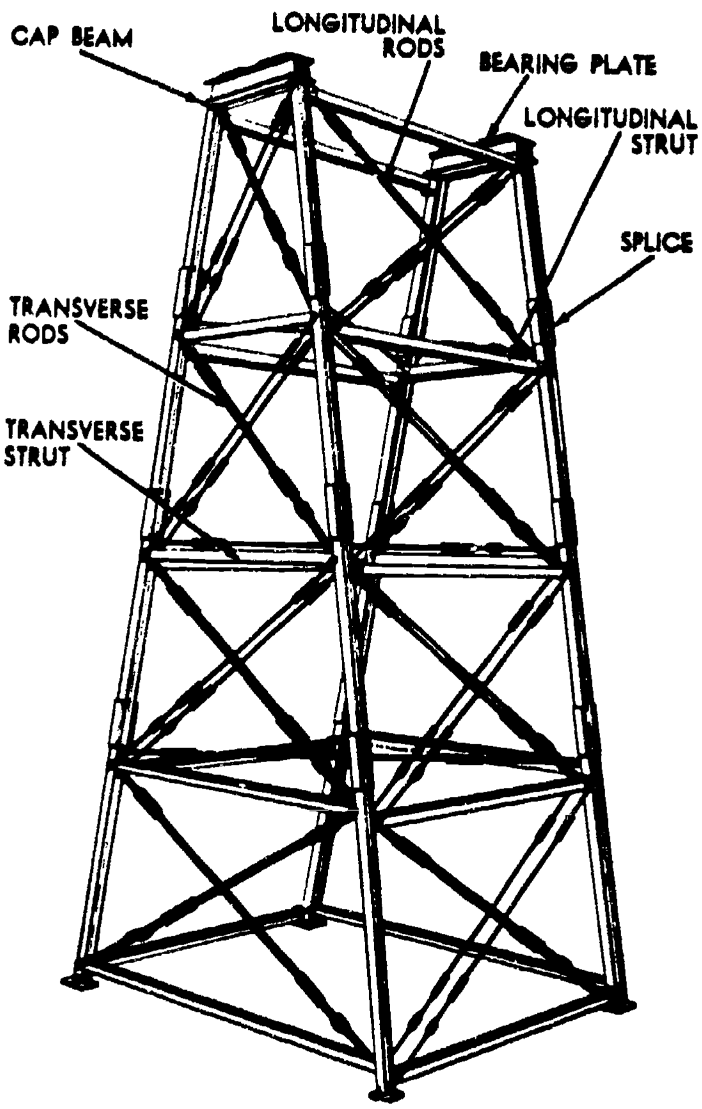


Figure 2-35.—A trestle tower.

STRUCTURAL STEEL CONNECTORS

There are four basic connectors used in making structural steel connections. They are BOLTS, WELDS, PINS, and RIVETS. Bolts and welds are the most common connectors used in military construction. Pins are used for connections at the ends of bracing rods and various support members which require freedom of rotation. Commercial prefabricated steel assemblies may be received in the field with riveted connectors. Types and uses of the four basic connectors will be discussed below.

BOLTS

Bolts are used more than any other type of connectors. They are easy to use and, in contrast to all other types of connectors, require little special equipment. The development of new, higher strength steels and improved manufacturing processes have resulted in the production of bolts which will produce strong structural steel connections.

Specifications for most bolted-structural joints call for the use of high-strength-steel bolts tightened to a high tension. The bolts are used in holes slightly larger than the nominal bolt size. Joints that are required to resist shear between

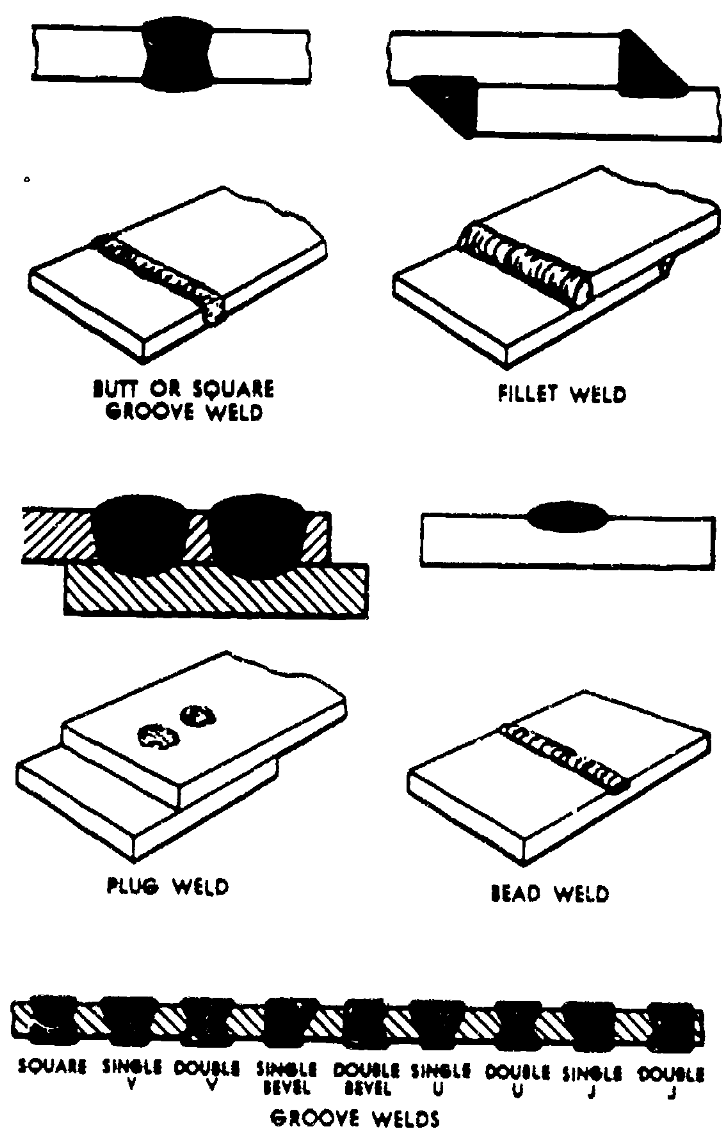


Figure 2-36.—Types of welds.

their connected parts are designated as either friction-type or bearing-type connectors.

Bolted parts should fit solidly together when they are assembled and should NOT be separated by gaskets or any other type of compressible material. Holes should be a nominal diameter, not more than one-sixteenth inch in excess of the nominal bolt diameter. When the bolted parts are assembled, all joint surfaces should be free of scale, burrs, dirt, and other foreign material. Contact surfaces within friction-type joints must be free of oil, paint, or other coatings.

WELDS

Welding is a highly specialized skill that requires technical training in order to insure competence of the operator. Load-bearing parts of a structure that are to be welded should be done only by properly qualified personnel.

The two principal welding processes used in structural work are ELECTRIC ARC WELDING and OXY-MAPP ARC WELDING. In the electric arc welding process, the welding heat is developed by the electric arc formed between a suitable electrode and the base metal. The electrode used is generally steel. Only shielded-arc electrodes should be used. This process of welding is preferred for structural works. In the oxy-mapp gas welding process, heat is obtained by burning mapp gas mixed with oxygen as they are discharged under pressure from a torch designed for this purpose. This process is preferred for thinner metals.

The principal types of welds and welded joints that are suitable for structural work are illustrated in figures 2-36 and 2-37.

PINS

Pins for very large structures are manufactured especially for the type of job and may have diameters of 24 inches or more, and be several feet in length. For most types of jobs, however, pins generally are between 1 1/4 inches and 10 inches in diameters. The two types of pins commonly used are threaded bridge pins and cotter pins (fig. 2-38). THREADED PINS are held in place after insertion by threaded recessed nuts on both ends of the pin. COTTER PINS are held in place by small cotters which pass through holes drilled in the pins. Washers and separators, made from lengths of steel pipe, are used to space members longitudinally on pins.

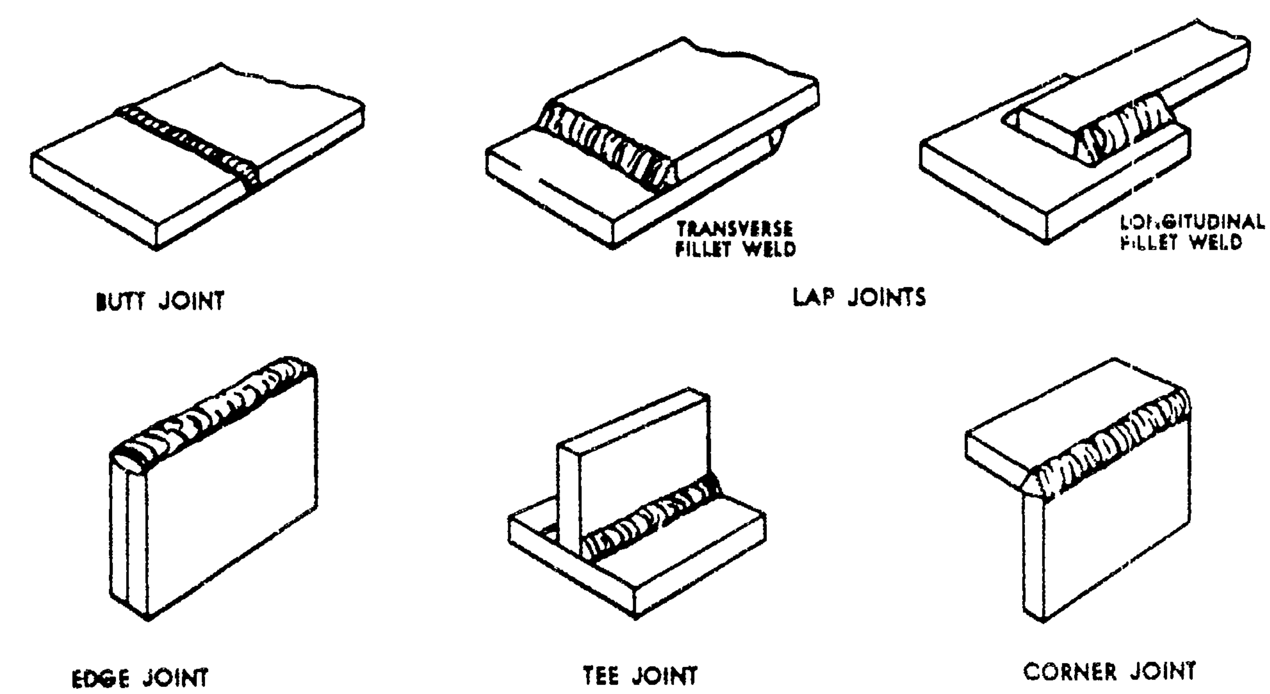


Figure 2-37.—Welded Joints.

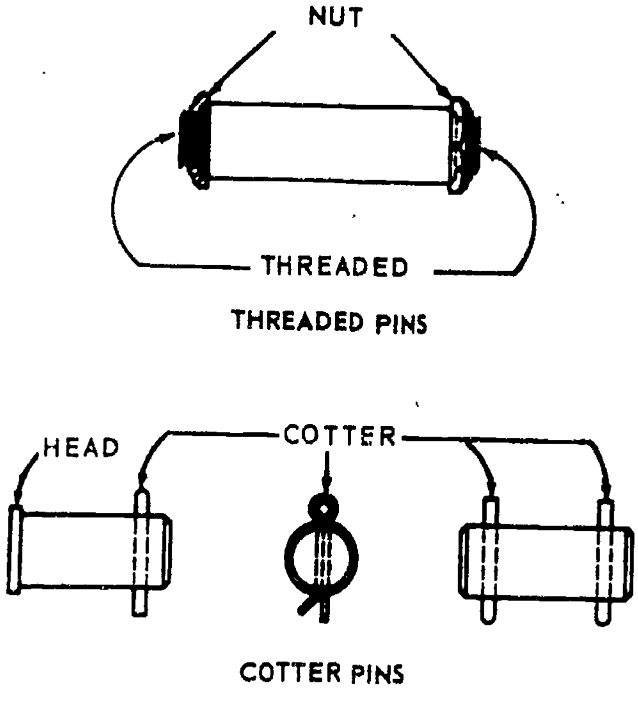


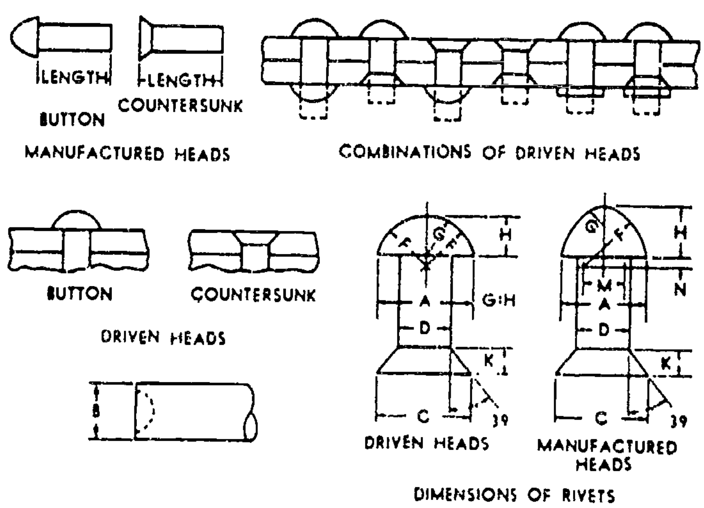
Figure 2-38.—Pins for structural steel connections.

Holes for small pins are drilled; larger pinholes are bored. Engineering practice permits boring holes with a diameter of 1 1/4 inches or more with an adjustable hole cutter. The cotter pinholes are usually bored one thirty-second or one sixty-fourth of an inch larger than the diameter of the finished pin. For bracing connections where adjustable members are used, it is acceptable to drill pinholes one-sixteenth of an inch larger than the pin diameter. The pinholes must be true, smooth, straight, and at right angles to the axis of the member. They should be bored accurately, and all holes in the same member must be parallel.

RIVETS

Rivets are manufactured of soft steel in various nominal sizes and lengths. The sizes used most often in structural work are 3/4 inch and 7/8 inch in diameter. The lengths differ according to the thickness of materials to be connected. Rivets are inserted in the rivet holes while they are red hot; consequently, the holes are drilled or punched one-sixteenth of an inch larger in diameter than the nominal diameter of the cold rivet. Holes for 3/4-inch diameter rivets are drilled thirteen-sixteenths of an inch in diameter and holes for 7/8-inch rivets are drilled fifteen-sixteenths of an inch in diameter.

Rivets are manufactured with one whole head already formed. The rivet shank is cylindrical and the second head is formed by driving it with a pneumatic hammer. The rivet set which is inserted in the end of the hammer has a cavity of the proper shape to form the head of the rivet. Most structural rivets have two full rounded button heads (fig. 2-39). Manufactured heads of rivets may also be obtained in countersunk shape to fit into holes countersunk in the material to be connected. When a driven-countersunk head is to be formed, the rivet is driven with a flat-ended rivet set to fill the countersunk cavity in the material.



11.292

Figure 2-39.—Structural rivets.

CHAPTER 3

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 construction and various 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, and water, without coarse aggregate, is NOT concrete, but MORTAR or GROUT. Never fall into the common error of calling a CONCRETE wall or floor a CEMENT wall or floor. There is no such thing as a cement wall or floor.

The fine and coarse aggregate 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 which 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 buildings 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 which 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 which 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 which is to be exposed to the elements must be watertight and weather resistant. Concrete which 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 which 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. 3-1).

Watertightness

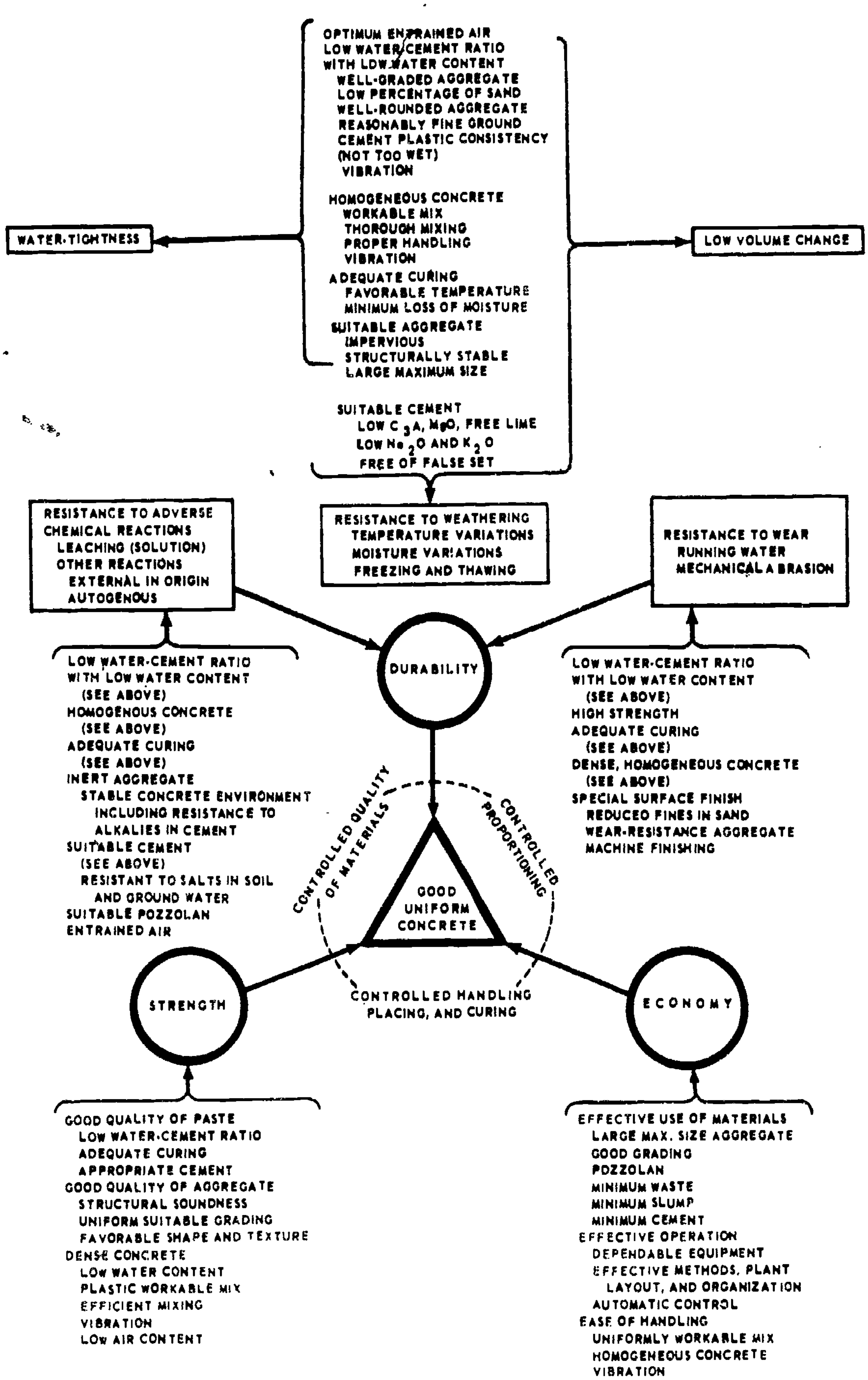
The ideal concrete mix would be one made with just the amount of water required for complete hydration of the cement. This would be a DRY mix, however, too stiff to pour in the forms. A mix which is fluid enough to be poured into forms always contains a certain amount of water over and above that which will combine with 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 usually used in a place where a heavy concentration of



117.83

Figure 3-1.—The principal properties of good concrete.

weight is NOT a factor, such as a sidewalk or a driveway.

REINFORCED CONCRETE

The term "reinforced concrete" refers to concrete containing steel as reinforcement and designed on the assumption that both materials act together in resisting force. Reinforcing steel is used in various types of concrete construction, such as retaining walls, foundation walls, beams, floor slabs, and footings. However, in certain types of construction, such as some pavements and floors, reinforcing steel may not be required.

Concrete is strong in compression but weak in tension. The tensile strength is generally rated about 10 percent of the compression. Thus, concrete works well for columns and posts which are the compression members in a structure. But, when it is used for tension members—for beams, girders, foundation walls, or floors—concrete must be reinforced to attain the necessary strength in tension.

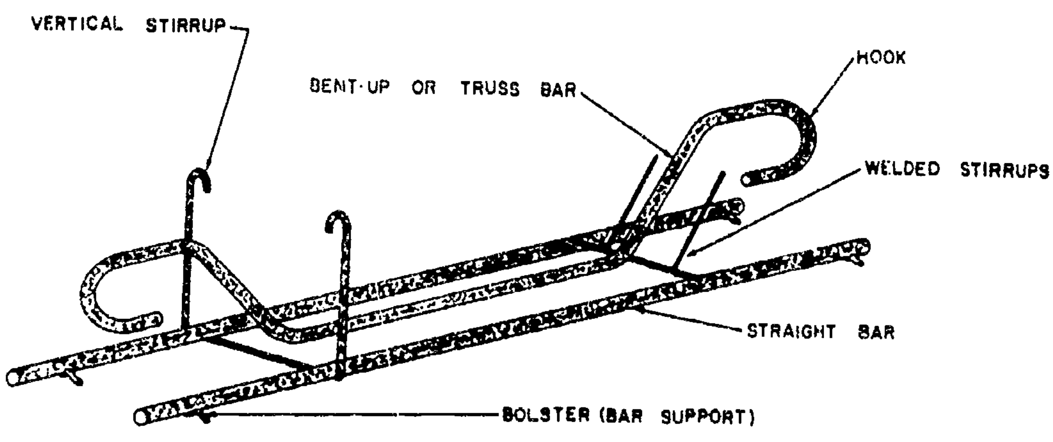
Reinforced Concrete Structural Members

A reinforced concrete structure is made up of many types of reinforced structural members, including beams, columns, girders, walls, footings, slabs, etc.

BEAM REINFORCEMENT.—Several common types of beam reinforcing steel shapes are shown in figure 3-2. Both straight and bent-up principal reinforcing bars are depended on 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.

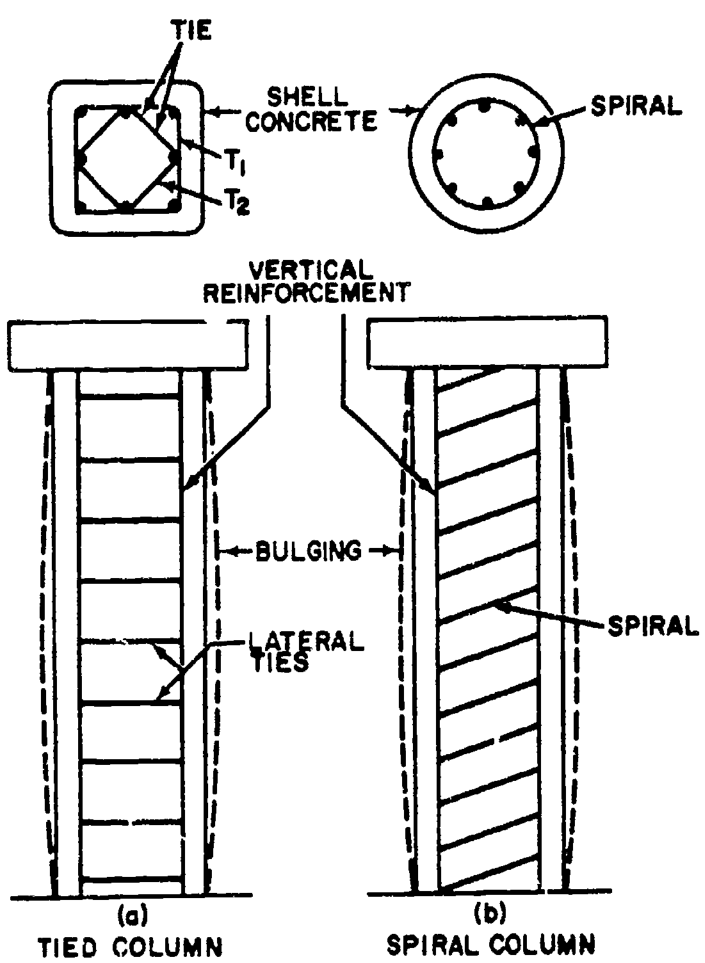
COLUMN REINFORCEMENT.—A column is a slender, vertical member which carries a superimposed load. Concrete columns must always be reinforced with steel unless the height is less than three times the least lateral dimension, in which case the member is called a PIER or PEDESTAL. Most concrete columns are also subjected to bending. Figure 3-3 shows two types of column reinforcement. Vertical reinforcement is the principal reinforcement. Lateral reinforcement surrounds the column horizontally and consists of individual ties (view (a), fig. 3-3) or a continuous spiral tie (view (b), fig. 3-3).

A loaded concrete column shortens vertically and expands laterally. Lateral reinforcement in the form of lateral ties is used to restrain the expansion. The principal value of lateral



45.727

Figure 3-2.—Typical shapes of reinforcing steel.



45.726

Figure 3-3.—Reinforced concrete columns.

reinforcement is to provide intermediate lateral support for the vertical or longitudinal reinforcement. Columns reinforced in this manner are called TIED COLUMNS. If the restraining reinforcement is a continuous winding spiral which encircles the core and longitudinal steel, the column is called a SPIRAL COLUMN. A spiral column is generally considered to be more substantial than a tied column due to the continuity of the spiral reinforcement, as opposed to the many imperfect anchorages at the ends of the individual lateral ties in the tied column. The pitch of the spiral reinforcement can be reduced to provide effective lateral support. The pitch of the spiral, the size, and the number of bars are specified by the engineer.

COMPOSITE AND COMBINATION COLUMNS.—A structural steel or cast-iron column thoroughly encased in concrete and reinforced with both longitudinal and spiral reinforcement is called a COMPOSITE COLUMN. The cross-sectional area of the metal core of a composite column can NOT exceed 20 percent of the gross area of the column. A structural steel column encased in concrete at least 2 1/2 inches thick over all the metal and reinforced with welded wire fabric is called a COMBINATION COLUMN. Composite and combination columns are often used in the construction of large buildings.

The vertical reinforcement in a column helps to carry the direct axial load as the column shortens under load. Vertical bars are located around the periphery of a column for effective resistance to possible bending. Each vertical rebar tends to buckle outward in the direction of least opposition. For this reason, every vertical rebar should be held securely, at close vertical intervals against outward lateral movement. A second system of ties, T_2 (view (a), fig. 3-3) is necessary to confine the four intermediate vertical rebars. If these ties are omitted, the eight-bar group tends to come into a slightly circular configuration under load. The resultant bulging leads to destructive cracking of the concrete shell and failure of the column. A round column has an obvious advantage in this respect.

SHRINKAGE AND TEMPERATURE REINFORCEMENT.—Slabs and walls must not only be reinforced by the principal reinforcement against the applied loads to which they are subjected, but they must also be reinforced in the lateral direction to resist the effects of shrinkage and temperature change. Concrete shrinks as the heat of hydration dissipates. Depending on the extent adjacent construction interferes, this movement of concrete tends to become stressed in tension. A small percentage of steel must be used to resist this force. Similarly, concrete must be allowed to contract with the lowering of temperature. A fall in temperature of about 83 °F causes as much movement as drying shrinkage. The amount of shrinkage and temperature reinforcement usually provided for is approximately 1/5 of 1 percent of the area of the cross section of concrete, as required by the specifications.

Reinforcing Steel

Steel is the best material for reinforcing concrete because the coefficients of expansion of both 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 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 a light, 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.

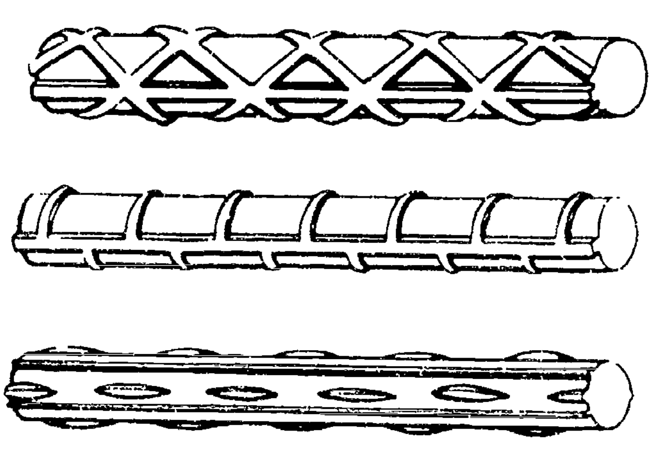
Reinforcing steel may be used in the form of bars or rods which are either plain or deformed or in the form of expanded metal, wire, wire fabric, or sheet metal. Each type is useful for different purposes, and engineers design structures with these purposes in mind.

REINFORCING BARS.—Plain 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 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-corrugated bars. These bars are formed with projections around the surface which extend into the surrounding concrete and prevent slippage. Another type is formed with longitudinal fins projecting from the surface to prevent twisting. Figure 3-4 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 10 standard sizes of reinforcing bars. Table 3-1 lists the bar numbers, weight, and nominal diameter of the 10 standard sizes. Bars #3 through #11, inclusive, are deformed bars. Remember that bar numbers are based on the nearest number of 1/8 inches (3.175 mm) included in the nominal diameter of the bar. To measure rebar, you must measure across the round/square portion where there is no deformation. The raised portion of the deformation is not considered in measuring the rebar diameter.

Frequently, it is required that reinforcing bars be bent into various shapes. There are several reasons for this. First, let us go back to



29.182

Figure 3-4.—Types of deformed reinforcing bars.

Table 3-1.—Standard Reinforcing Bars

Bar Numbers	Weight	Nominal Diameter	
	Pounds Per Foot	Inches	Milli-meters
#2	0.167	0.250	6.3
#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	34.9

the reason for using reinforcing steel in concrete—to increase the tensile and compressive strength of concrete. You might compare the hidden action within a beam 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.

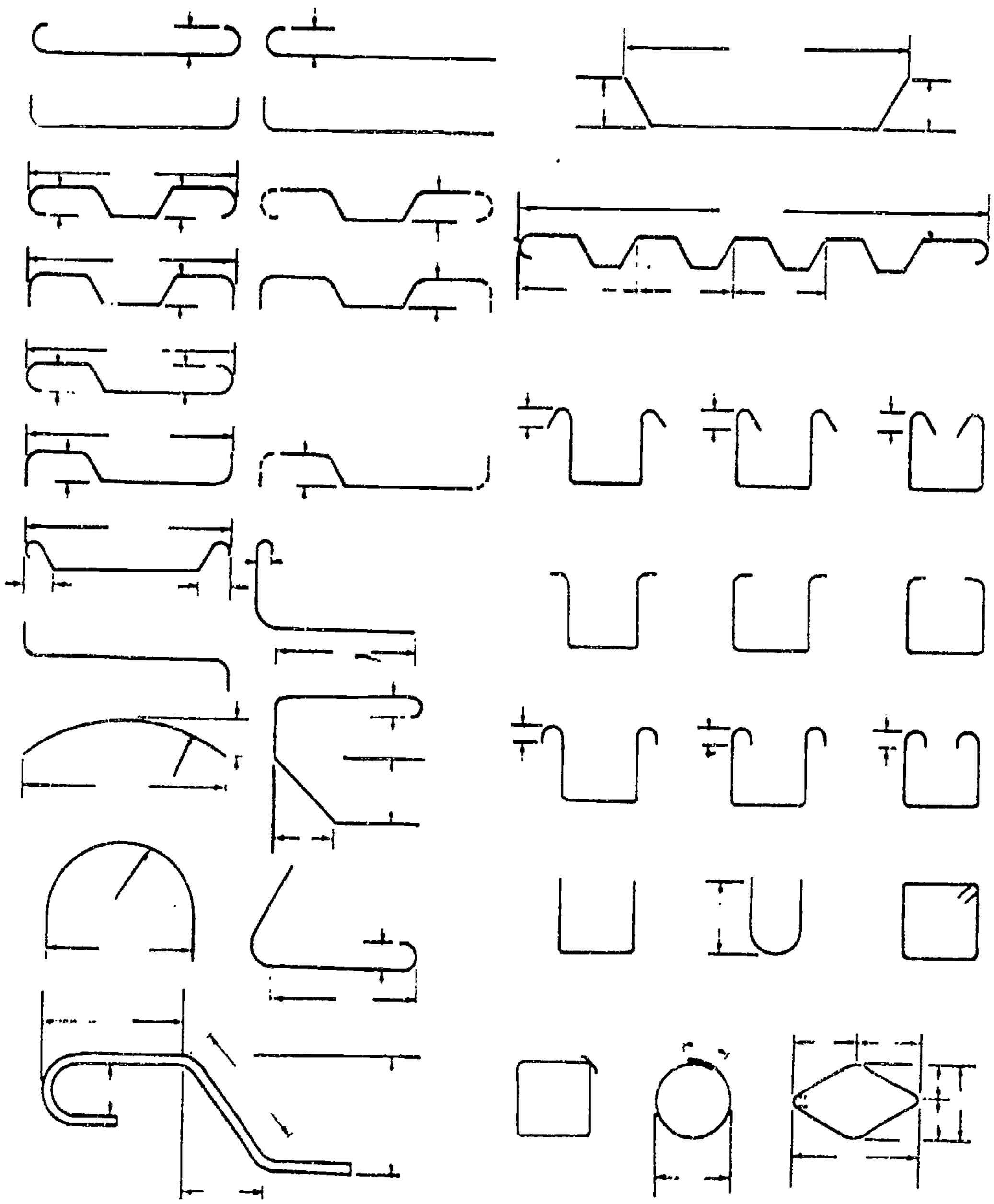
In the case of a continuous beam, it is a little different. The top of the beam may be in compression along part of its length and in tension along another part. This is because a continuous beam rests on more than two supports. Thus, the bending of the beam is NOT all in one direction but is reversed 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 within 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 which you will encounter are shown in figure 3-5.

When reinforcing bars are bent, caution must be exercised to insure the bends are not too sharp. If too sharp a bend is put into the bars, they may crack or may 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 3-6. There are many different types of bends, depending on where the rods are to be placed. For example, there are bends on heavy 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.

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



127.75

Figure 3-5.—Typical reinforcement bar bends.

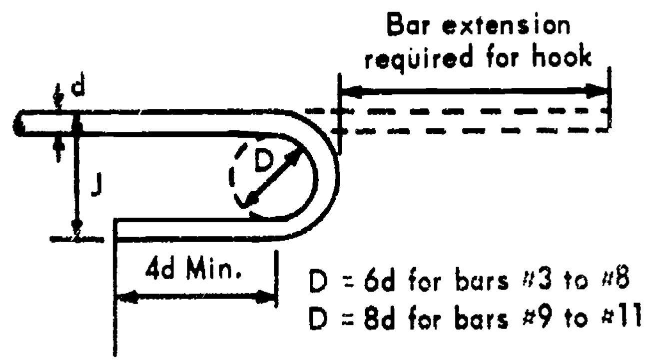
sheet of steel, as shown in view (A), figure 3-7. The sheet steel has been sheared in parallel lines and then pulled out or expanded to form a diamond shape between each parallel cut. Another type is square rather than diamond shaped, as shown in view (B), figure 3-7. Expanded metal is frequently used during plastering operations.

Welded wire fabric is available in both rolls (fig. 3-8) 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 inches to 6 by 12 inches. The square patterns are available in 2 by 2 inches, 3 by 3 inches, 4 by 4 inches, and 6 by 6 inches. Both are furnished in a wide variety of wire gages. The square pattern has the same gage in both directions, while the rectangular type may have the same gage in both direction or the larger gage running longitudinally.

PRECAST CONCRETE

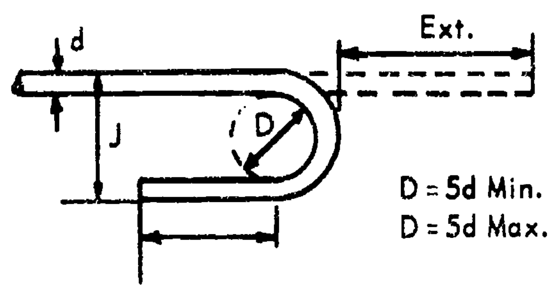
Precasting is the fabrication of a structural member at a place other than its final position

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

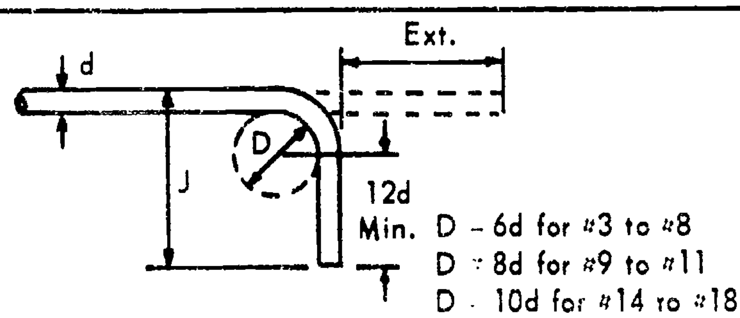
Minimum sizes - 180° hook



Note: Minimum size hooks to be used only for special conditions.

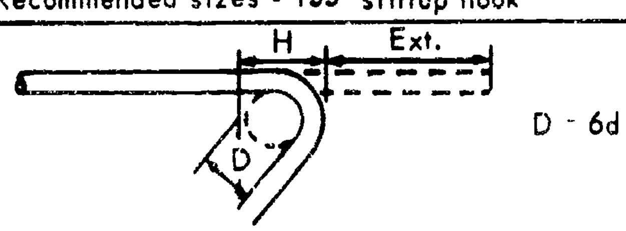
Bar size d	Bar exten.	J
#2	4	1¾
3	5	2¾
4	5	3½
5	6	4¼
6	7	5¼
7	9	6
8	10	7
9	11	8
10	13	9
11	14	10

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



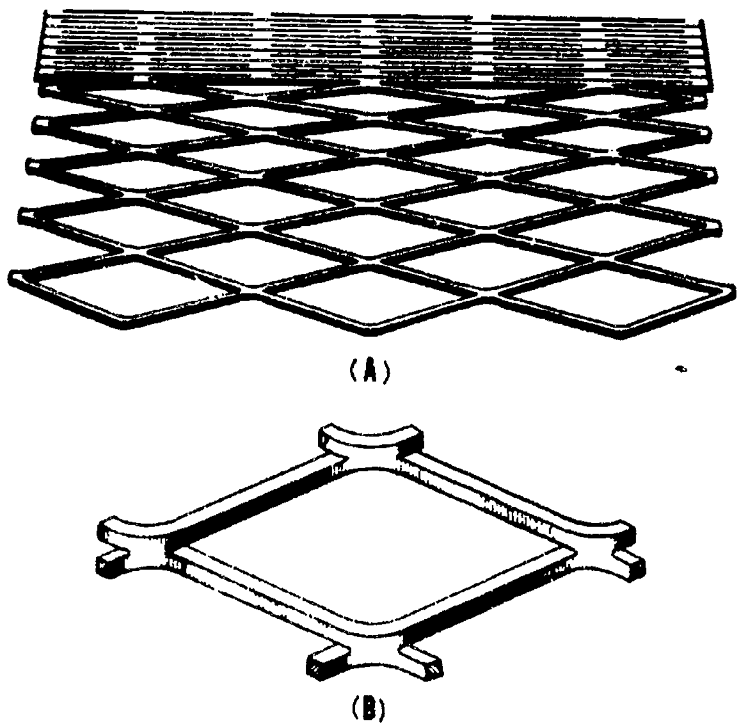
Bar size d	Bar exten.
#2	3½
3	4
4	4½
5	5½

Note: Stirrup hooks may be bent to the diameter of the supporting bars.

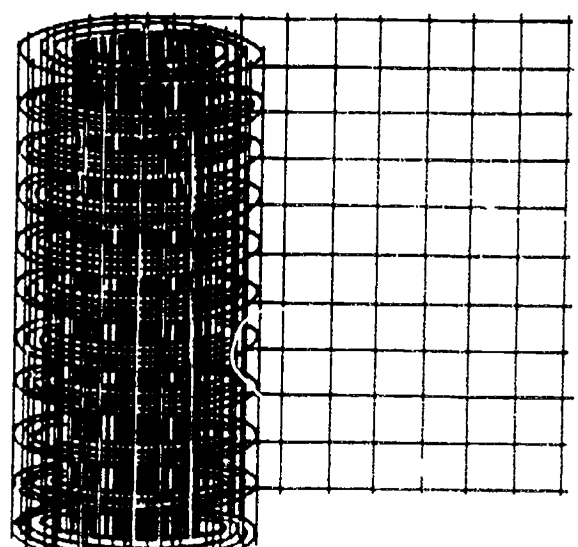
127.79

Figure 3-6.—Standard hook details.

7



127.74
Figure 3-7.—Expanded or diamond mesh steel reinforcement.



29.182
Figure 3-8.—Welded Wire Fabric.

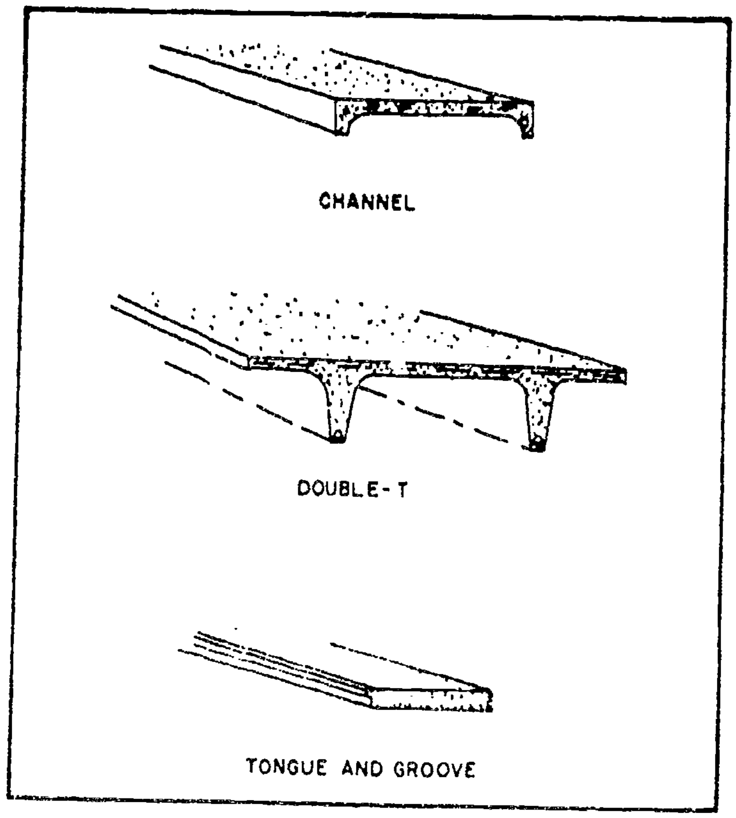
of use. It can be done anywhere, although this procedure is best adapted to a factory or yard. Jobsite precasting is not uncommon for large projects. Precast concrete can be produced in several different shapes and sizes, including piles, girders, and roof members. Prestressed concrete is especially 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 impracticability of transportation makes jobsite casting more desirable.

Precast Concrete Floors and 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. (See fig. 3-9.)

The channel slabs vary in size with a depth ranging from 9 to 12 inches, width 2 to 5 feet, and a thickness of 1 to 2 inches. They have been used in spans up to 50 feet. If desired or needed, the legs of the channels may be extended across the ends and, if used in combination with the top



133.263
Figure 3-9.—Typical precast planks.

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 feet in width and 9 to 16 feet in depth. They have been used in spans as long as 50 feet. When the top-slab size ranges from 1 1/2 to 2 inches in thickness, it should be reinforced with wire mesh.

The tongue-and-groove panel 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.

Welding matching plates are ordinarily 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 position by cranes or by the tilt-up procedure.

Usually, these panels are solid, reinforced slabs, 5 to 8 inches 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 casting on the smooth surface, the casting surface 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 other 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 inches, 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 whenever used in roof construction 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 cardboard 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

It has the greatest advantage when identical members are to be cast because the same forms can be used several times. Other advantages are:

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 condition 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 which contains normal reinforcing in addition to a number of channels through which the prestressing cables or rods may be 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 feet 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. 3-10). When a load is placed on the beam, the camber is forced out, creating a level beam with no deflection.

Those members which are relatively small or which can be readily precast are normally pretensioned. These include precast roof slabs, T-slabs, floor slabs, and roof joists.

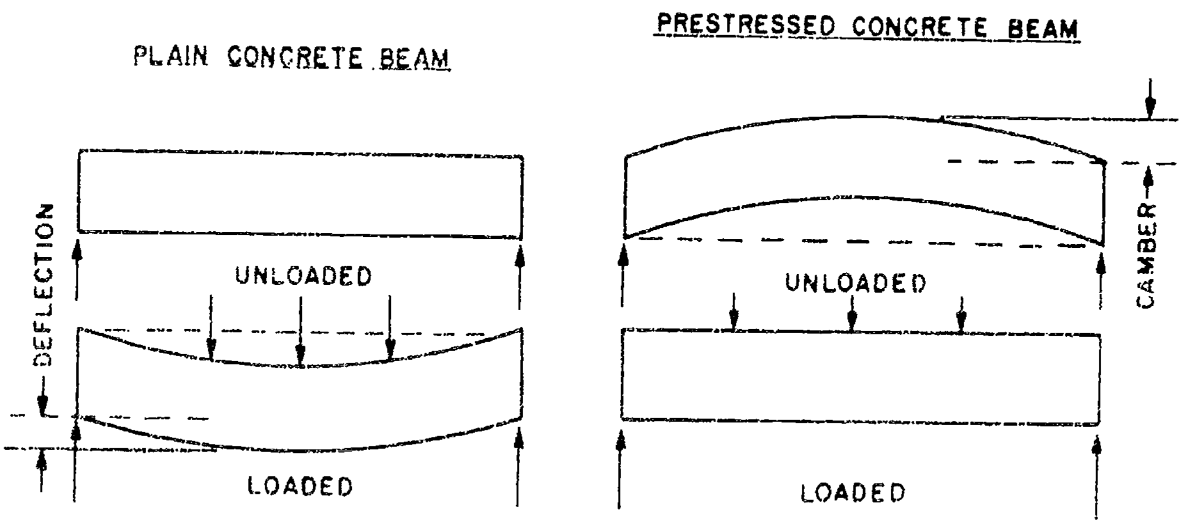


Figure 3-10.—Comparison of plain and prestressed concrete beams.

LIGHTWEIGHT CONCRETE

Conventional concrete weighs approximately 150 pounds per cubic foot. Lightweight concrete weighs 20 to 130 pounds per cubic foot, depending on its intended use. Lightweight concrete can be made by using either gas-generating chemicals or lightweight aggregates, such as expanded shale, clay, or slag. Concrete containing aggregates, such as perlite and 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.

Insulating lightweight concrete has a unit weight ranging from 20 to 70 pounds per cubic foot, and its compressive strength seldom exceeds 1,000 psi.

Structural lightweight concrete has a unit weight up to 115 pounds per cubic foot and a 28-day compressive strength in excess of 2,000 psi.

Similightweight concrete has a unit weight of 115 to 130 pounds 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.

The first extensive use of lightweight concrete was for concrete block. Present uses of lightweight concrete include structural applications, such as cast-in-place and precast walls, floors, roof sections, and insulation applications, such as fireproofing.

The general principles of concrete proportioning may be applied to lightweight concrete aggregates. But when the aggregates are highly absorptive, some modifications are required. The uniformity and quality of lightweight concrete depend primarily on the uniformity of the moisture content of the aggregate.

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 insure 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 insure 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 PICK-UP 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 pick-up inserts is extremely important. There are engineering manuals which 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 insure 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, utilizing 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 which 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 a waterproof joint. To accomplish this, expansion joint material is used whenever necessary.

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 FORMS

Most structural concrete is made by placing (called CASTING) plastic concrete into spaces enclosed by previously constructed FORMS. The plastic concrete hardens into the shape outlined by the forms, after which the forms are usually removed.

Forms for concrete structures must be tight, rigid, and strong. If the forms are NOT tight, there will be a loss of paste which may cause weakness or a loss of water which may cause sand streaking. The forms must be strong enough and well braced enough to resist the high pressure exerted by the concrete.

Forms, or parts of forms, are often omitted when a firm earth surface exists which is capable of supporting and/or molding the concrete. In most footings, for example, the bottom of the footing is cast directly against the earth, and only the sides are molded in forms. Many footings are cast with both bottom and sides against the natural earth. In this case, however, the specifications usually call for larger footings. A foundation wall is often cast between a form on the inner side and the natural earth surface on the outer side.

Form Materials

Form material should be of wood, plywood, steel, or other approved material, except that forms for concrete pavement other than on curves should be metal, and on curves, flexible or curved forms of metal or wood may be used. Wood forms, for surfaces exposed to view in the finished structure and requiring a standard finish, should be tongue-and-groove boards or plywood. Forms for surfaces requiring special finishes should be plywood or tongue-and-groove boards, or should be lined with plywood, a nonabsorptive hard-pressed fiberboard, or on other approved material.

Foundation Forms

Foundations vary according to their use, the bearing capacity of the soil, and the type of material available. The material may be cut stone, rock, brick, concrete, tile, or wood, depending upon the weight which the foundation is to support. Foundations may be classified as wall or column (pier) foundations.

WALL foundations are built solid, the walls of the building being of continuous heavy construction for their total length. Solid walls are used when there are heavy loads to be carried or where the earth has low supporting strength.

These walls may be made of concrete, rock, brick, or cut stone, with a footing at the bottom.

The combined slab and foundation, sometimes referred to as the THICKENED-EDGE slab, is useful in a warm climate where frost penetration is not a problem and where the soil condition is especially favorable. It consists of a shallow perimeter-reinforced footing poured integrally with the slab over a VAPOR BARRIER. The bottom of the footing should be at least 1 foot below the natural gradeline and supported on solid, unfilled, and well-drained ground.

When the ground freezes to any appreciable depth during the winter, the wall of the building must be supported by a foundation or piers which extend below the frost-line to a solid bearing on unfilled soil. In such construction, the concrete slab and the foundation wall are usually separate. There are three typical methods which are suitable for for such conditions (figs. 3-11, 3-12, and 3-13).

The most desirable properties in a vapor barrier to be used under a concrete slab are: a good vapor-transmission rating; resistance to damage by moisture and rot; and the ability to withstand normal usage during pouring operations. Such

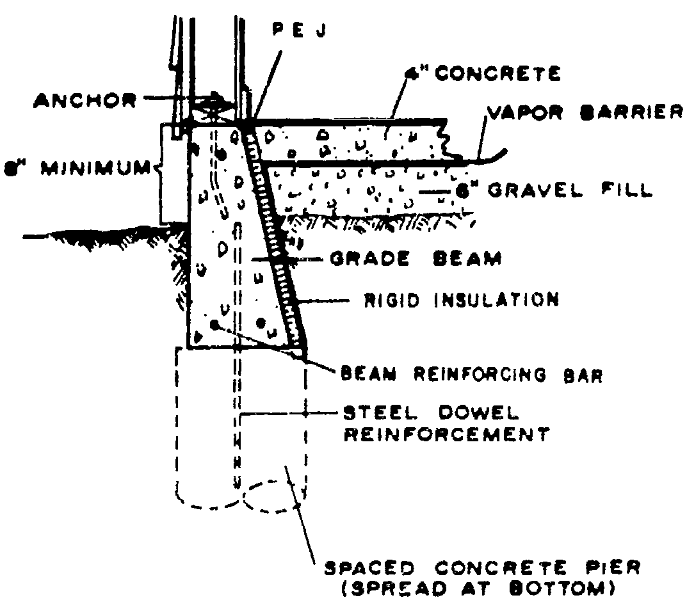


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Figure 3-11.—Reinforced grade beam for concrete slab. Beam spans between concrete piers located below frost-line.

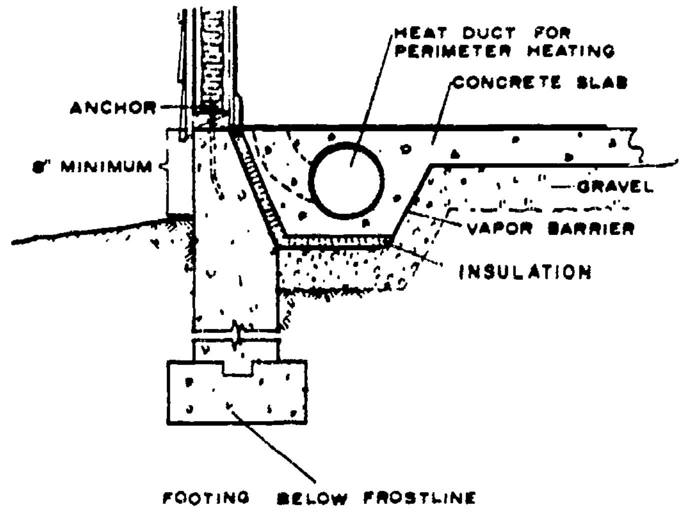

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Figure 3-12.—Full foundation wall for cold climates. Perimeter heat duct insulated to reduce heat loss.

properties are included in the following types of materials:

1. Fifty-five pound roll roofing or heavy asphalt-laminated duplex barriers.
2. Heavy plastic film, such as 6-mil or heavier polyethylene, or similar plastic film laminated to a duplex-treated paper.
3. Three layers of roofing felt mopped with hot asphalt.

Wall Forms

Wall forms are made up of five basic parts. They are: (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 alined 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. 3-14).

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

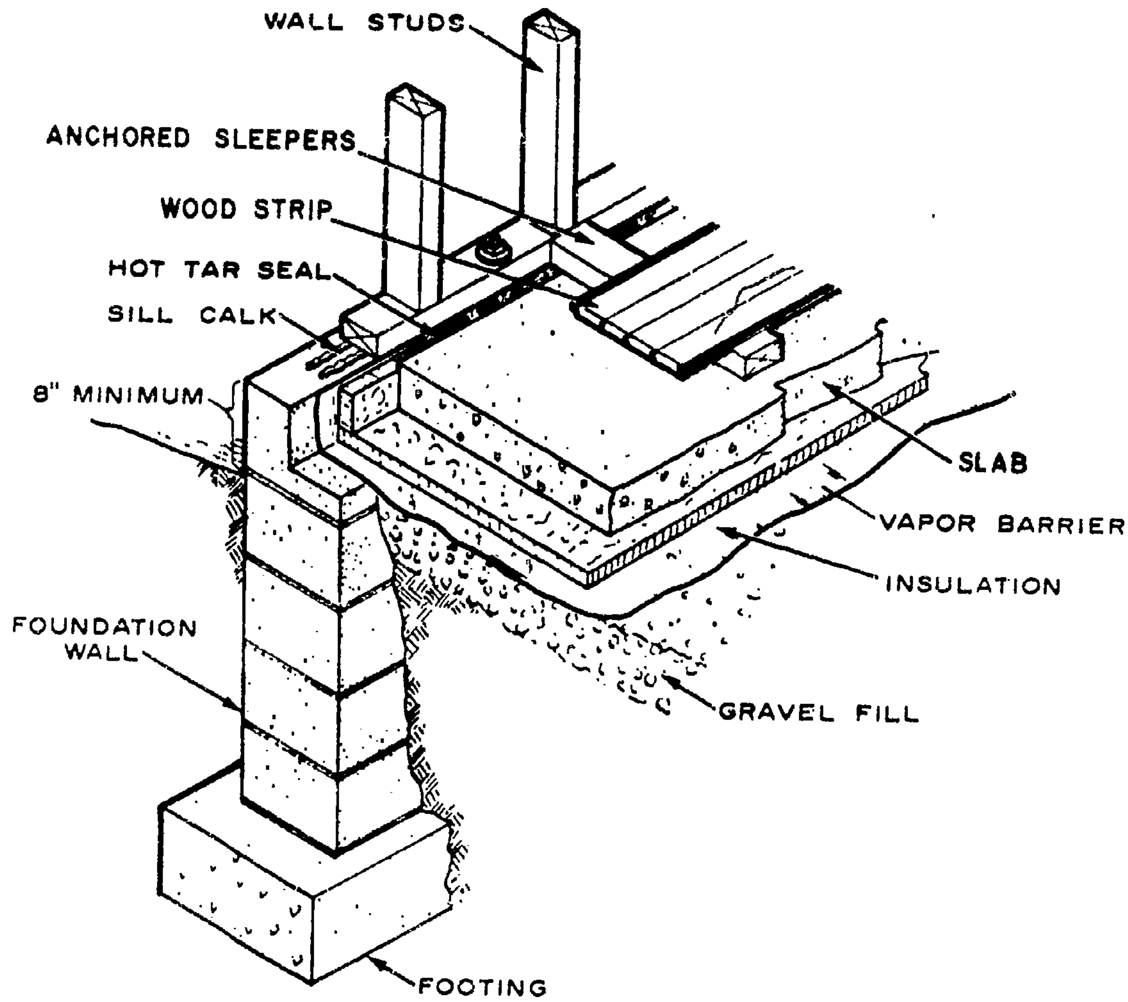

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Figure 3-13.—Independent concrete floor slab and wall. Concrete block is used over poured footing which is below frostline. Rigid insulation may also be located along the inside of the block wall.

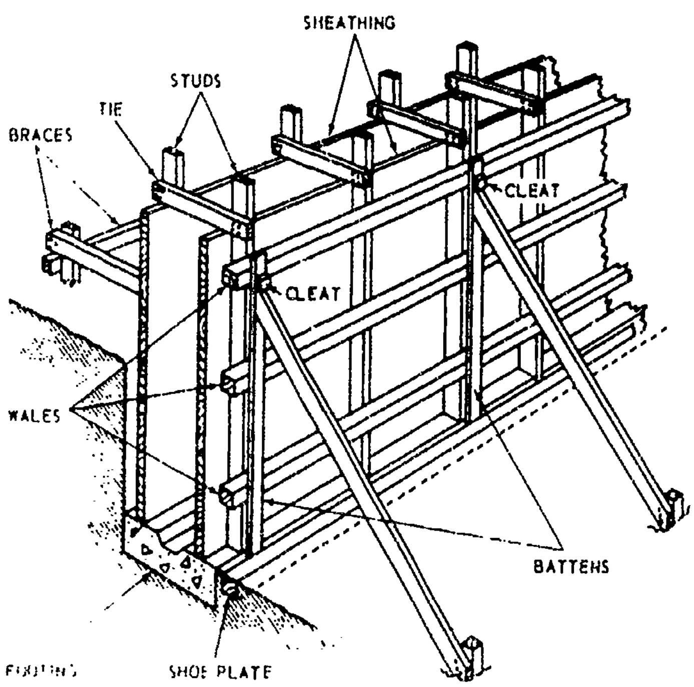

Figure 3-14.—Parts of typical wall form. 29.128

simple wire ties, used with wood SPREADERS, are shown in figure 3-15. 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 which 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 which combine the function of the tie and spreader. Figure 3-16 shown 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

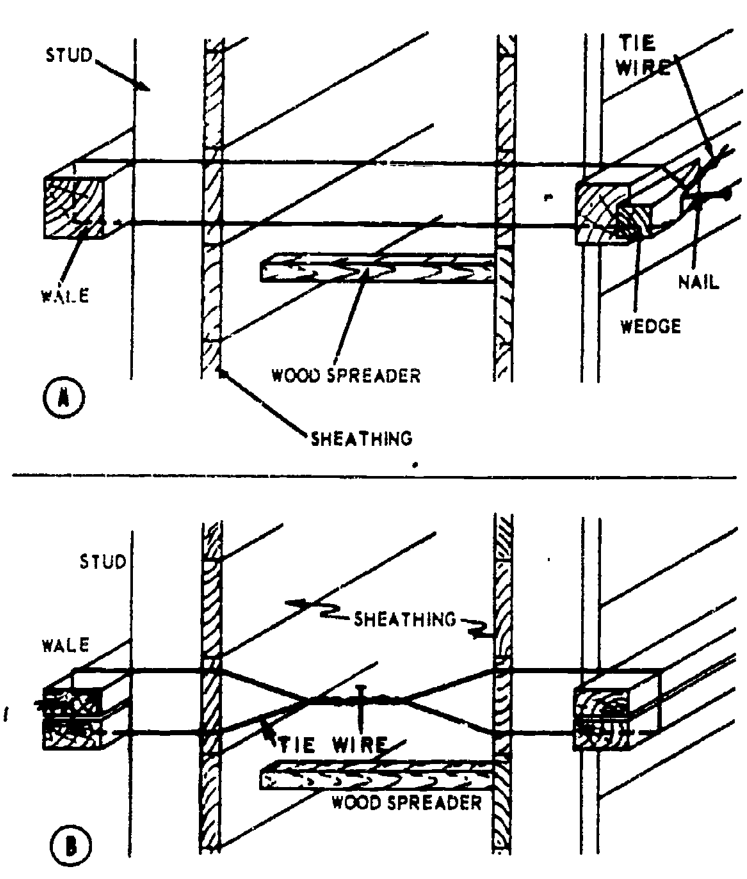

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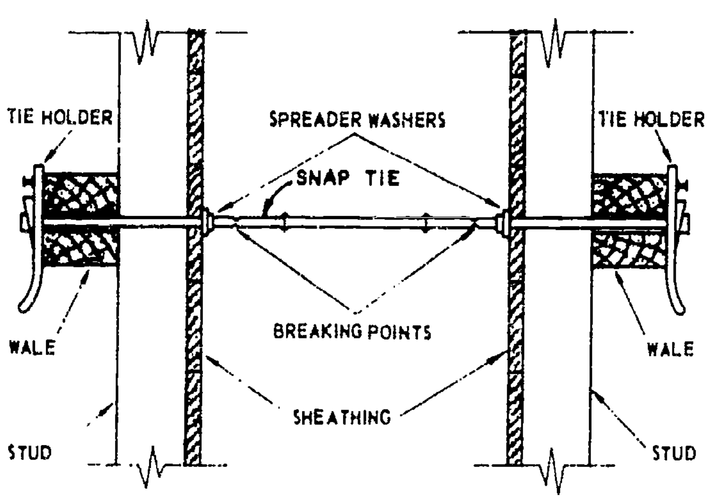
Figure 3-15.—Wire ties for wall forms.

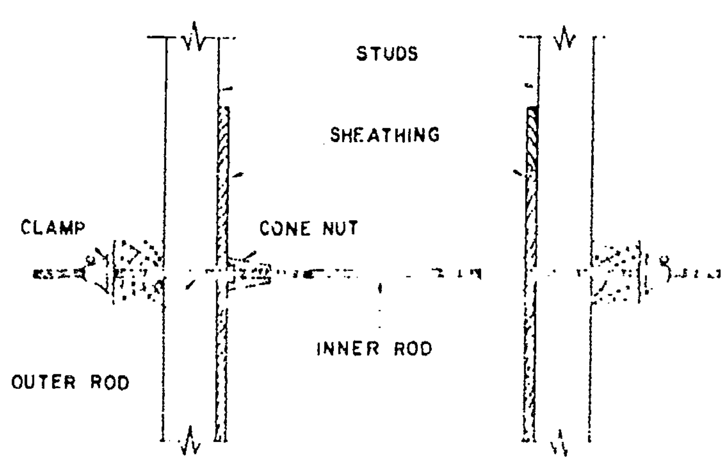


45.470
Figure 3-16. Snap tie.

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 inch 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 3-17. 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 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 and reduce the time and labor required for erecting forms on the site.



45.471
Figure 3-17.—Tie rod.

Many types of prefabricated form panels are in use. Contractors sometimes build their own panels from wood framing covered with plywood sheating. The standard size is 2 feet by 8 feet, 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, etc. Panels are held together by patented panel clamps. Flat bar ties (which lock into place between panels) eliminate the need for spreaders. Forms are alined by using one or more doubled rows of 2 by 4's, secured to the forms by a special device which is attached to the bar ties.

Form panels made completely of steel are also available. The standard size is 24 by 48 inches, 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.

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

Figure 3-18 shows a column form. Since the rate of placing in a column form is very high and since the bursting pressure exerted on the form by the concrete increases directly with the rate of placing, a column form must be securely braced by the yokes shown in the figure. Since the bursting pressure is greater at the bottom of the form than it is at the top, the yokes are placed closer together at the bottom than they are at the top.

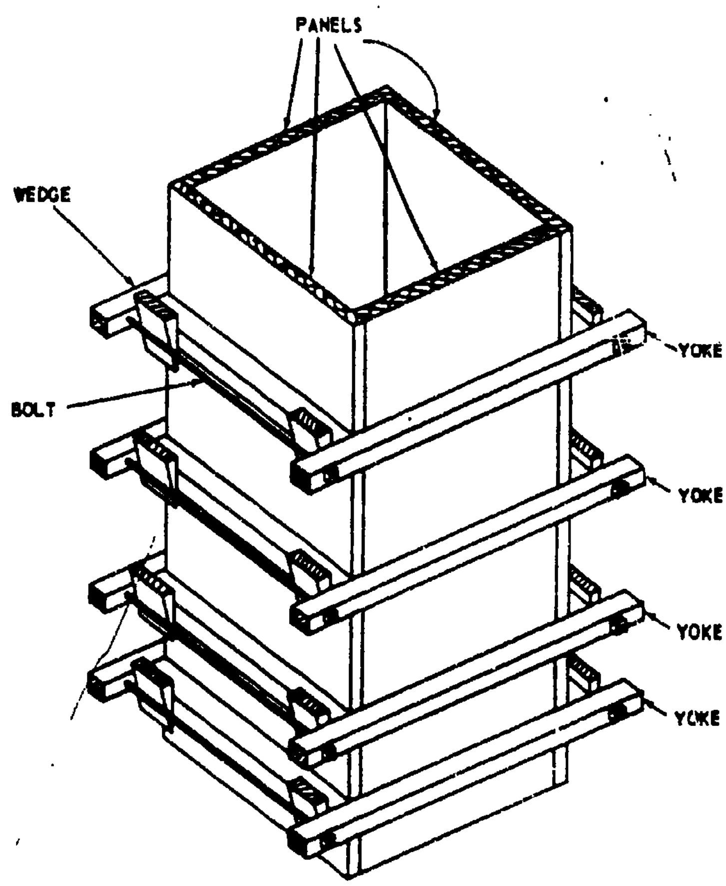


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Figure 3-18.—Column form.

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 beam form is preferred, and details for this type are shown in figure 3-19. 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 3-20 shows a typical interior beam form with slab forms supported on the beam sides. This drawing indicates that 3/4-inch plywood serves as the beam sides and that the beam

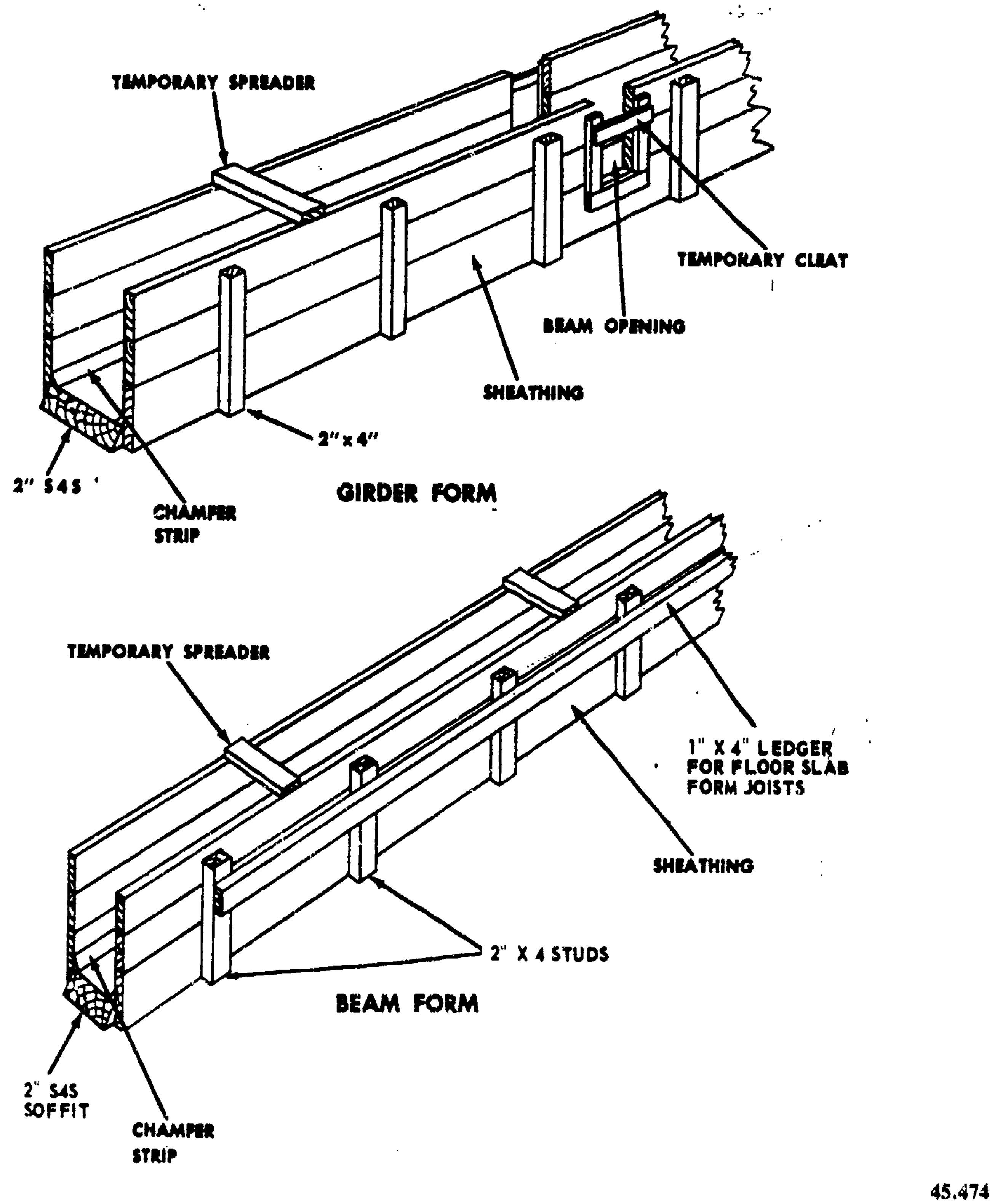

Figure 3-19.—Typical beam and girder forms.

bottom is a solid piece of 2-inch dimension lumber supported on the bottom by 4- by 4-inch 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.

Overhead Floor and Roof Slabs

Concrete used for floor and roof slabs may be either precast units or cast-in-place concrete, in accordance with the design of the structure. If

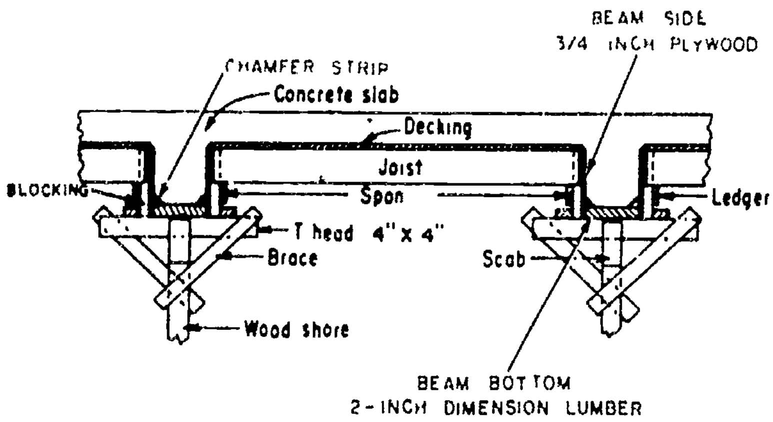

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Figure 3-20.—Typical components of beam formwork with slab framing in.

precast units are to be used, the columns, beams, and girders are formed as previously described. The use of cast-in-place concrete for overhead floors and roof slabs requires much more forming and shoring. Shoring refers to the temporary construction used to support the forms. The supporting columns may be poured and allowed to cure and used for support along with the shoring, or they may be poured with the slabs and beams.

Whenever concrete is cast in place for overhead floors and roof slabs, its weight should be kept to a minimum while maintaining the designed strength. This is accomplished in a variety of ways. One is a BEAM-AND-SLAB floor. Here the slab is supported by a series of parallel beams. Another type is known as a FLAT-SLAB floor. There are no beams in this type of construction, but the slab is supported by thickened sections over the columns known as DROP PANELS. Increased support is provided at the column by enlarging its top end into what is known as a COLUMN CAPITAL. A third type is a RIBBED SLAB. It consists of a series of concrete joists or ribs, containing the reinforcement, cast monolithically with a relatively thin slab. The ribs, in turn, frame into supporting girders. The main purpose of using a ribbed-slab floor is to reduce the dead load by concentrating the reinforcement in the ribs and leaving out most of the concrete between them. A variation of the ribbed slab is made by running ribs in two directions, at right angles to one another, thus producing what is commonly referred to as a WAFFLE floor.

Another method of reducing the weight of floors is to produce a series of voids. This may be done by laying cardboard tubes with sealed ends in rows, by using egg-crate type cardboard core forms, or by using a type of lightweight block, laid in rows, to replace the concrete.

MASONRY

MASONRY is that form of construction composed of stone, concrete, brick, gypsum, hollow clay tile, concrete block, 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

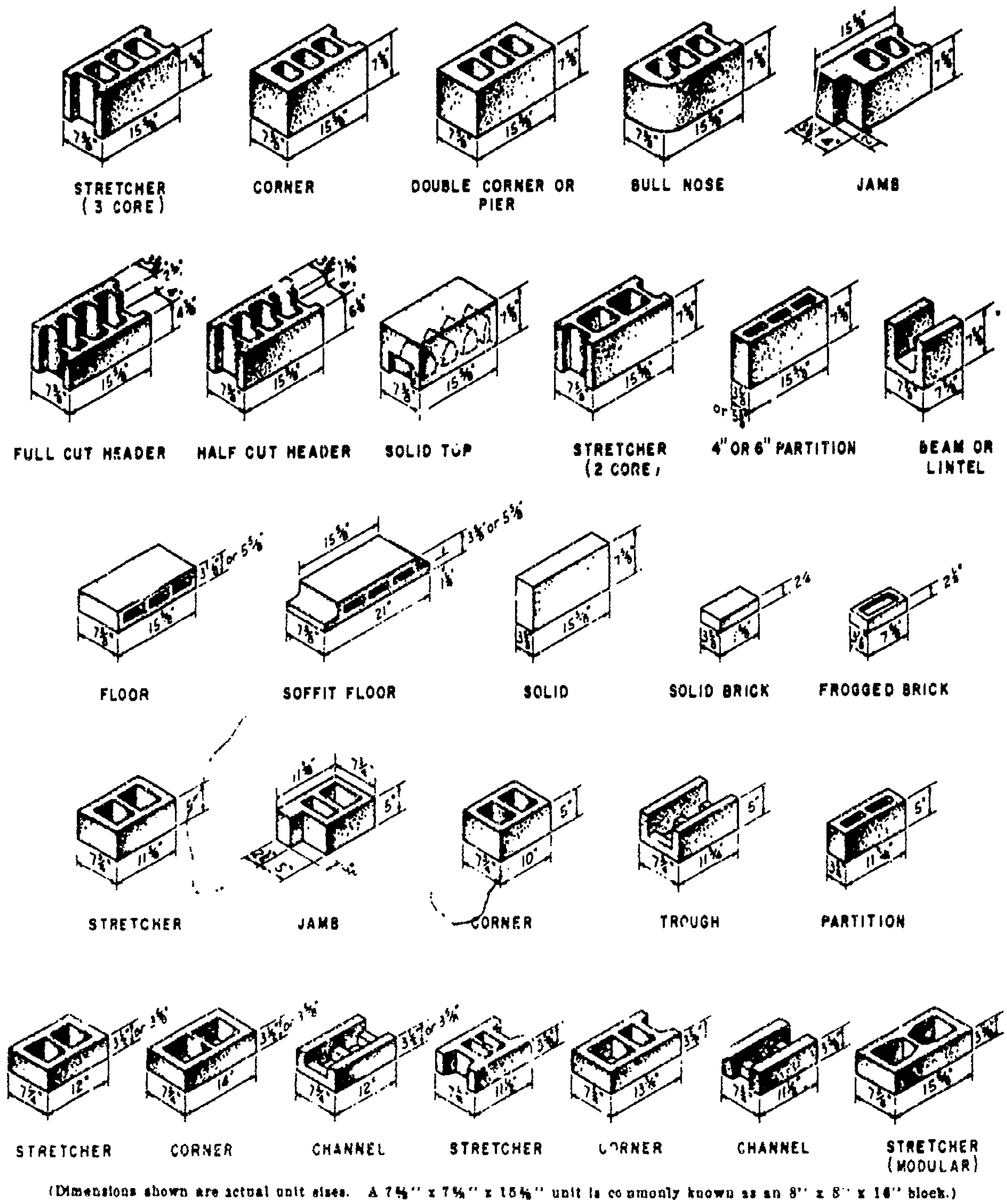
Concrete masonry has become increasingly important as a construction material. Important technological developments in the manufacture and utilization of the units have accompanied the rapid increase in the use of concrete masonry. Concrete masonry walls properly designed and constructed will satisfy 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 utilize 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 sufficient[illegible] 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 in figure 3-21. Concrete unit sizes are usually



29.142

Figure 3-21.—Typical sizes and shapes of concrete masonry units.

referred to by their nominal dimensions. A unit measuring 7 5/8 inches wide, 7 5/8 inches high, and 15 5/8 inches long is referred to as an 8- by 8- by 16-inch unit. When it is laid in a wall with 3/8-inch mortar joints, the unit will occupy a space 16 inches long and 8 inches high. Besides the basic 8- by 8- by 16-inch units, the illustration shows a smaller partition unit and other units which are used much as cut brick are in brick masonry.

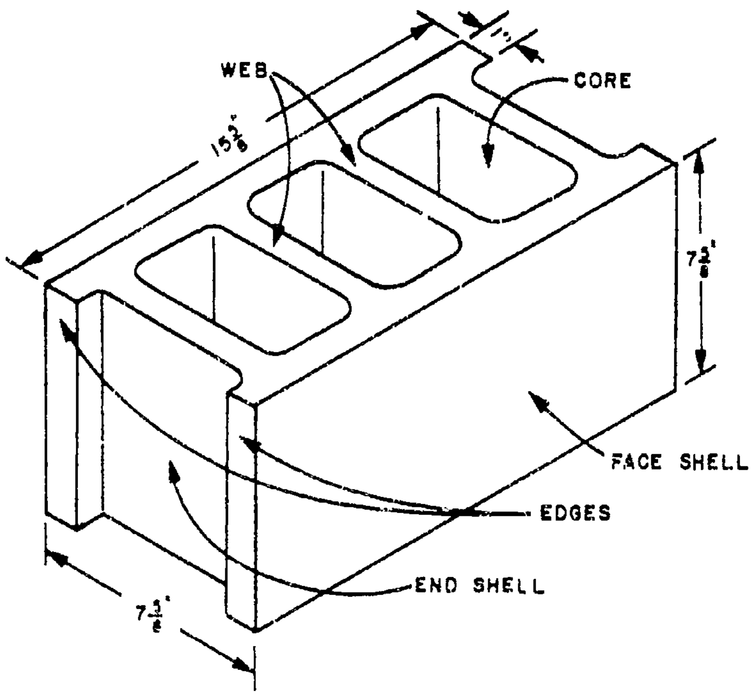


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Figure 3-22.—Concrete block.

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 specials shown are self-evident. Besides the shapes shown in figure 3-21, 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. 3-22). The material which 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 3-23 illustrates but a few of the wall patterns that can be developed using various pattern bonds and block sizes. Commercial

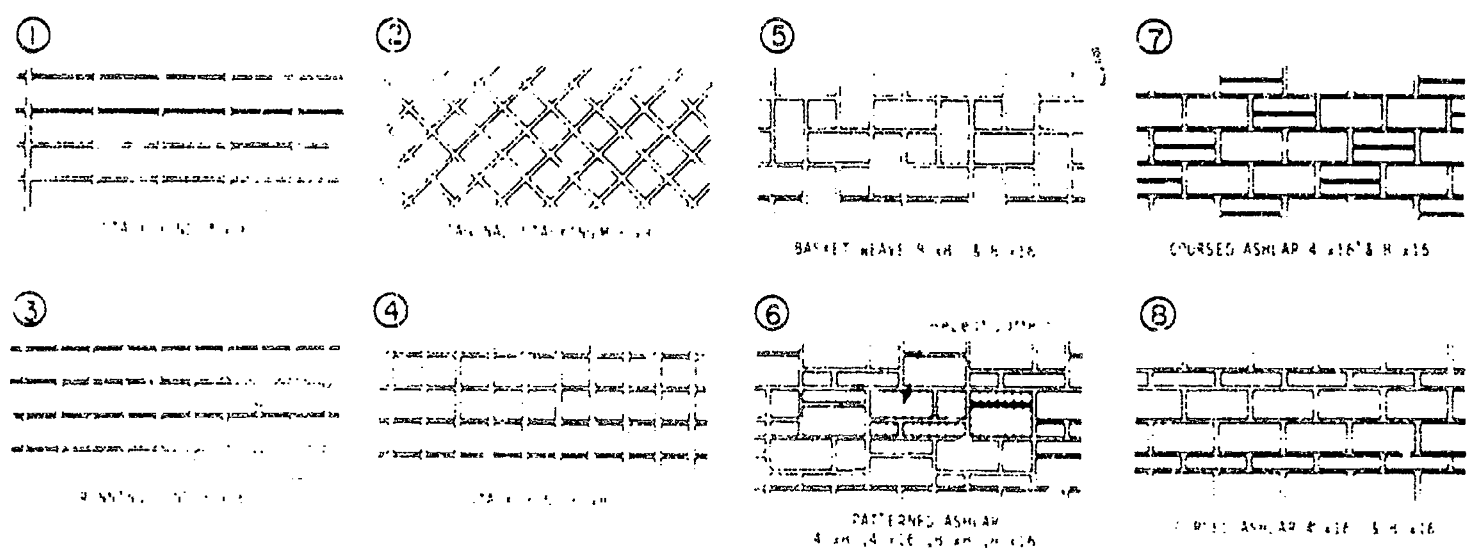

Figure 3-23.—Wall patterns.

publications from the Portland Cement Association illustrate many more. Figure 3-24 shows some of the styles of SCREEN BLOCKS (blocks with patterned holes). This type of block is used to make a decorative wall called a PIERCED or SCREEN wall. Other architectural effects can be achieved by laying some block in relief (fig. 3-25) or by varying the type of mortar joint.

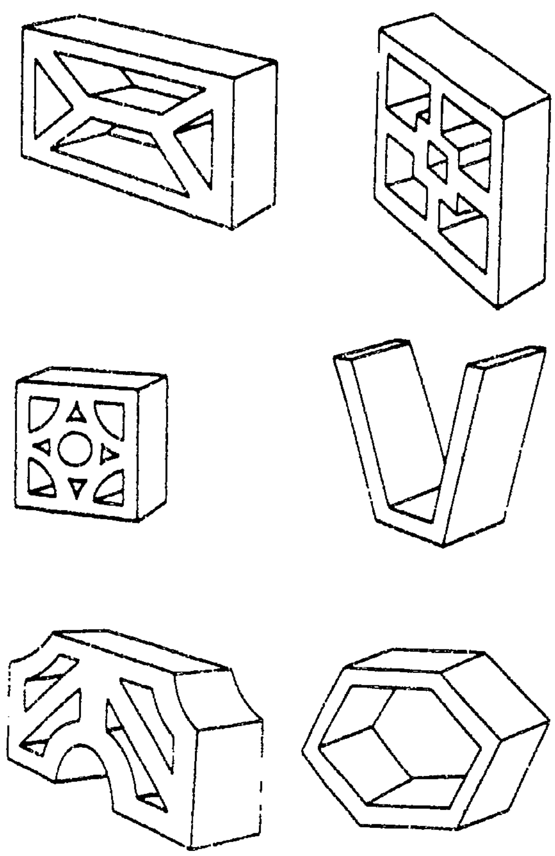

Figure 3-24.—Screen block designs.

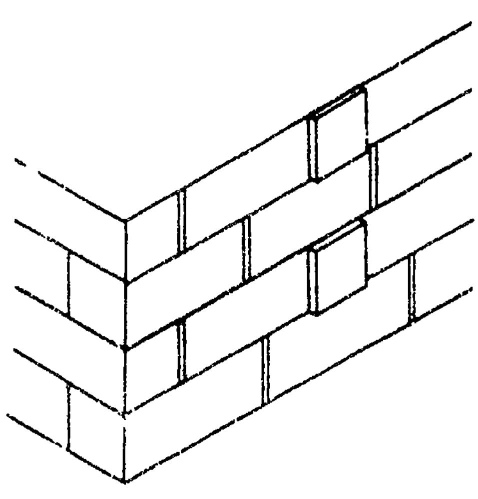

Figure 3-25.—Blocks laid in relief.

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. 3-26). This procedure assumes that window and door frames are of modular dimensions which 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 inches. Table 3-2 lists nominal lengths of concrete masonry walls by stretchers, and table 3-3 lists nominal heights of concrete masonry walls by courses. When units 8 by 4 by 16 are used, the horizontal dimensions should be planned in multiples of 8 inches (half-length units) and the vertical dimensions in multiples of 4 inches. 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, 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 which 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 which is laid on one of its shell faces is called a SIDE-CONSTRUCTION tile; one

Table 3-2.—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 3-3.—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".

which is laid on one of its web faces is called an END-CONSTRUCTION tile. Figures 3-27 and 3-28 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 pounds per square inch based on the gross section may be expected. The tensile strength of structural clay tile masonry is small. In most

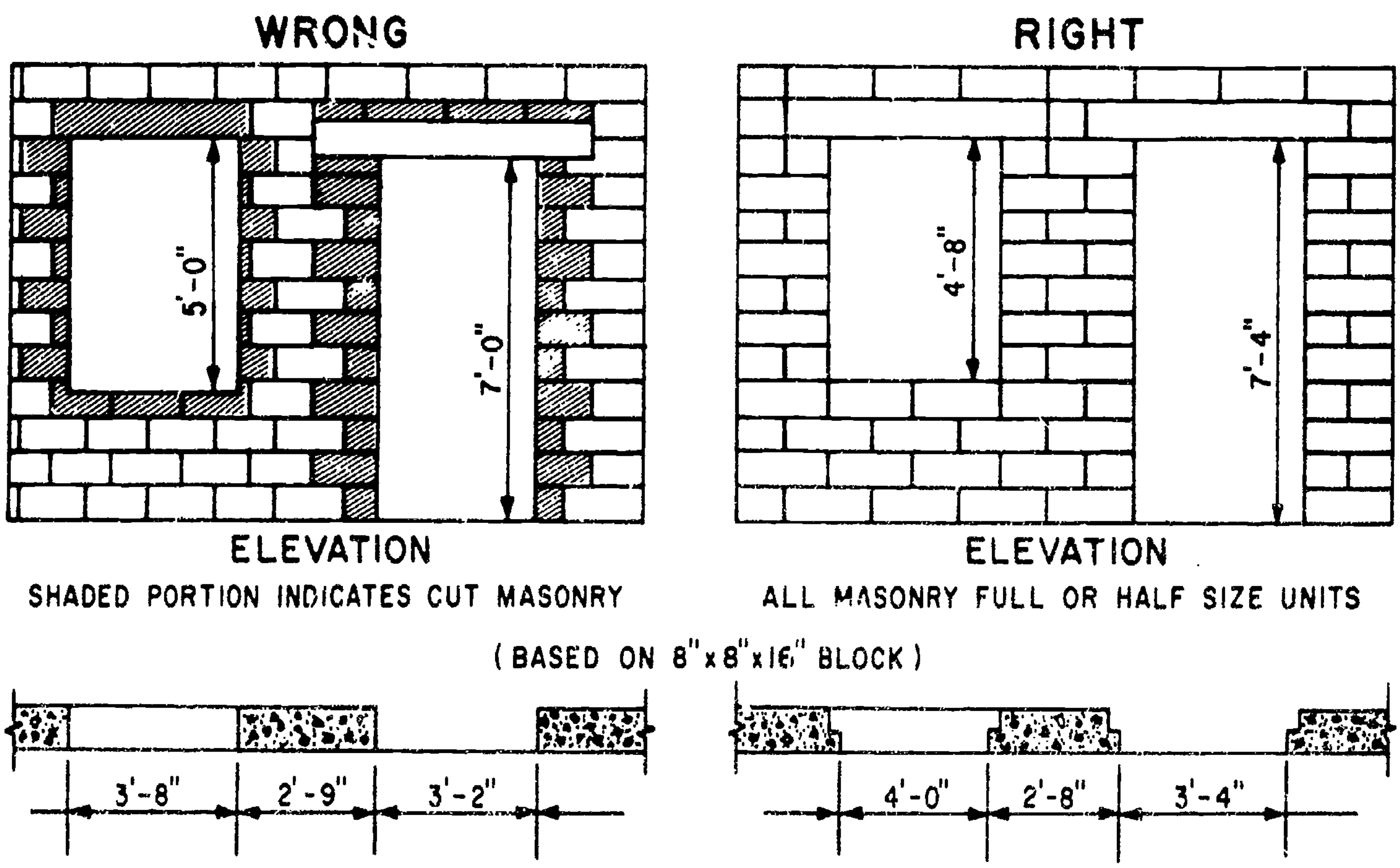

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Figure 3-26.—Planning concrete masonry wall openings.

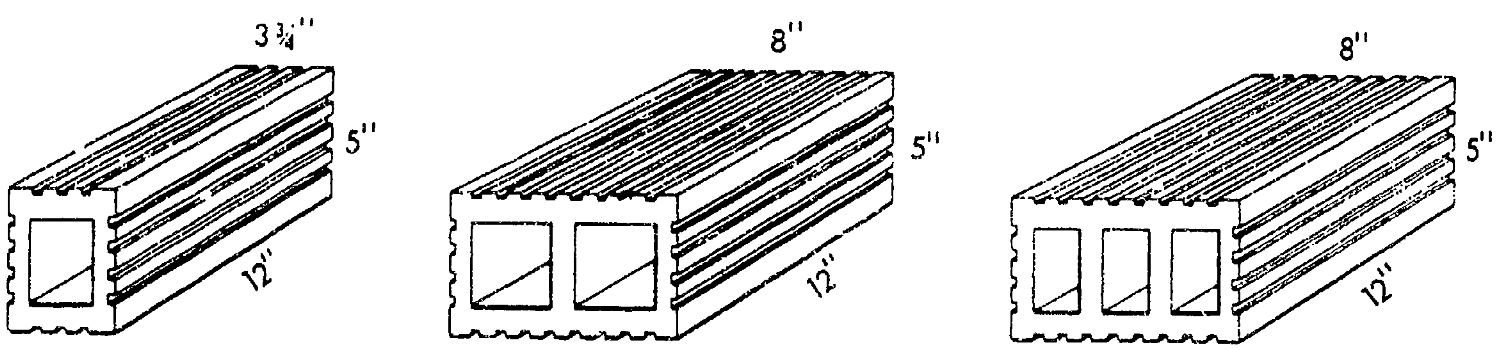

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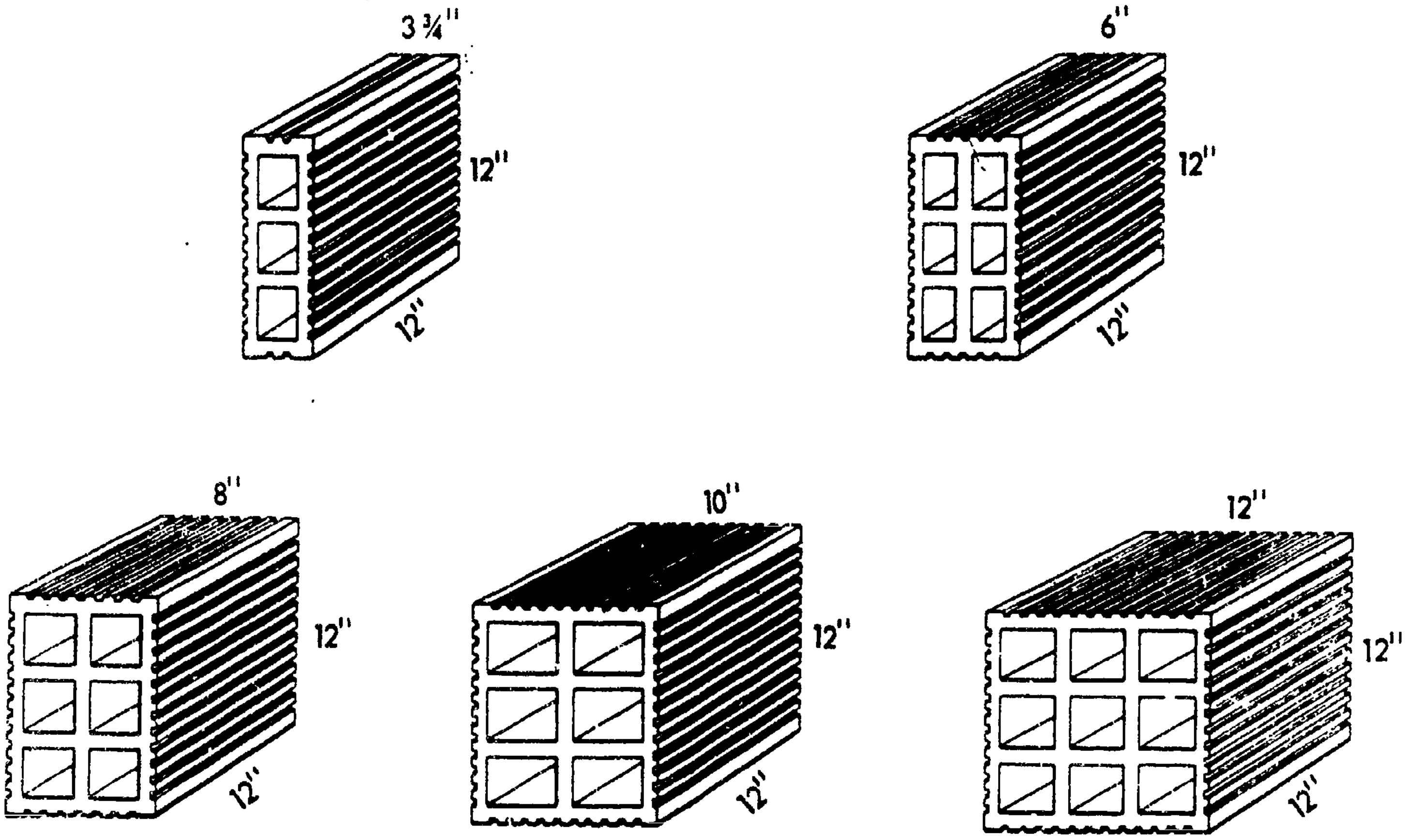
Figure 3-27.—Standard shapes of side-construction building tiles.

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



29.144

Figure 3-28.—Standard shapes of end-construction building tiles.

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, due to 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 inches thick will resist a fire for 1 hour provided the fire produces a temperature of not more than 1,700°F.

The solid material in structural clay tile weighs about 125 pounds 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-inch tile wall weighs approximately 30 pounds per square foot, while a 12-inch weighs approximately 45 pounds 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-inch 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 4- to 12-inch 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 3-29 illustrates the use of structural clay tile as a back unit for a brick wall.

Figure 3-30 illustrates the use of 8- by 5- by 12-inch tile in wall construction. To avoid exposure of the open end of the tile, a thin tile called a SOAP is used at the corner.

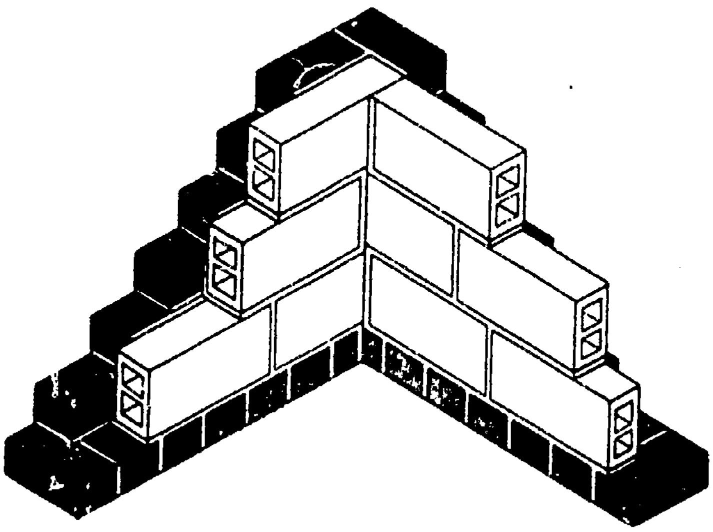


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Figure 3-29.—Structural tile used as a backing for brick.

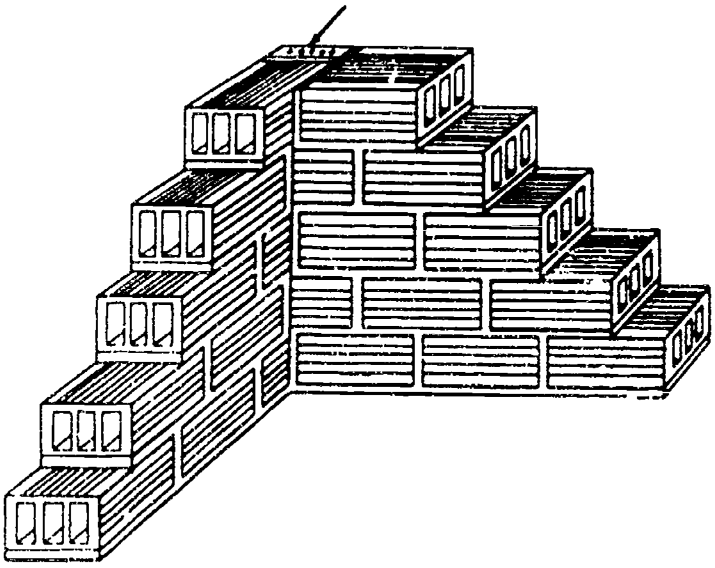

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Figure 3-30.—Eight-inch structural clay tile wall.

STONE MASONRY

Stone masonry is masonry in 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 which 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 stones in courses, as shown in figure 3-31. Each layer must contain bonding stones that extend through the wall, as shown in figure 3-32. 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 is assembled of roughly squared stones in such a manner as to produce approximately continuous horizontal bed joints, as shown in figure 3-33.

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 more commonly found stones that are suitable

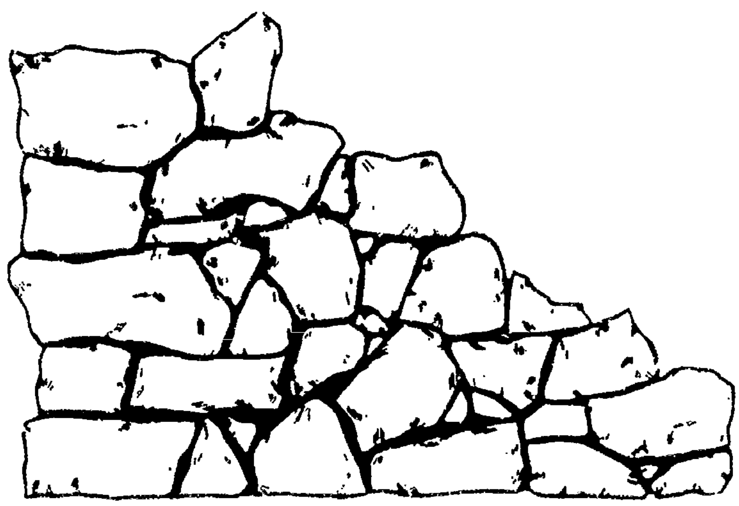

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Figure 3-31.—Random rubble masonry.

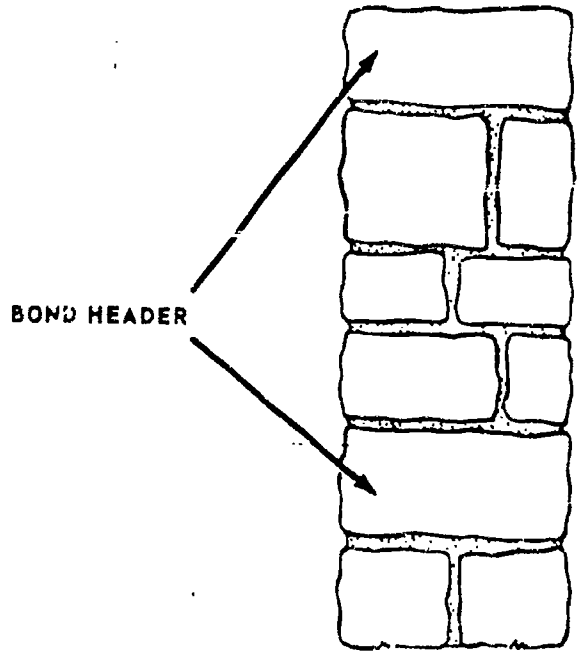

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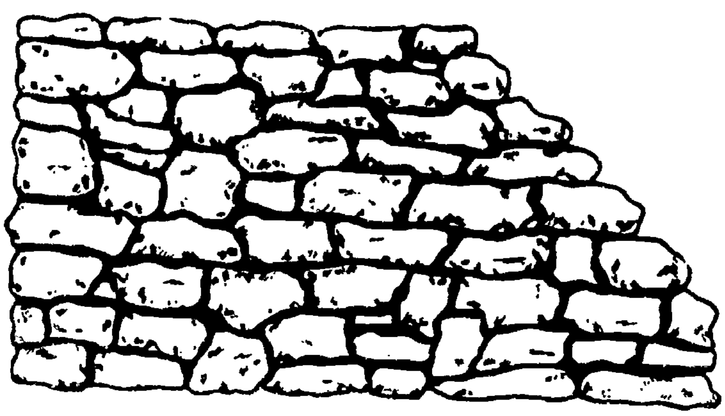
Figure 3-32.—Bond stones.



133.45
Figure 3-33.—Coursed rubble masonry.

are limestone, sandstone, granite, and slate. Unsquared stones obtained from nearby ledges or quarries or even field stones may be used. The size of the stone should be such that two people can easily handle it. A variety of sizes is necessary in order 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

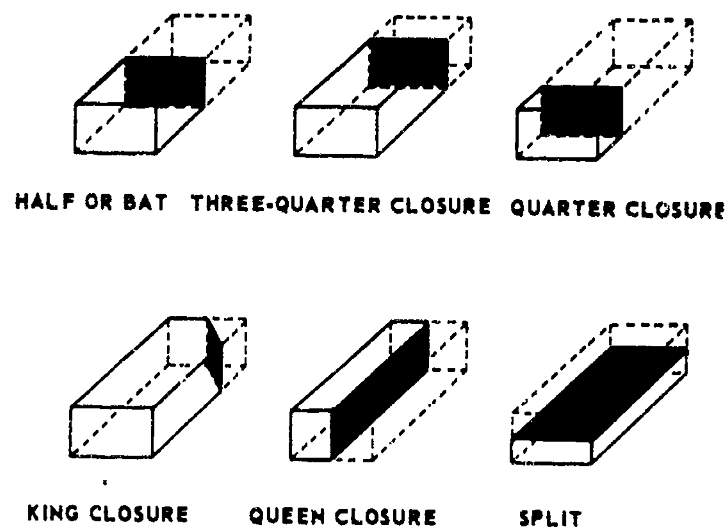


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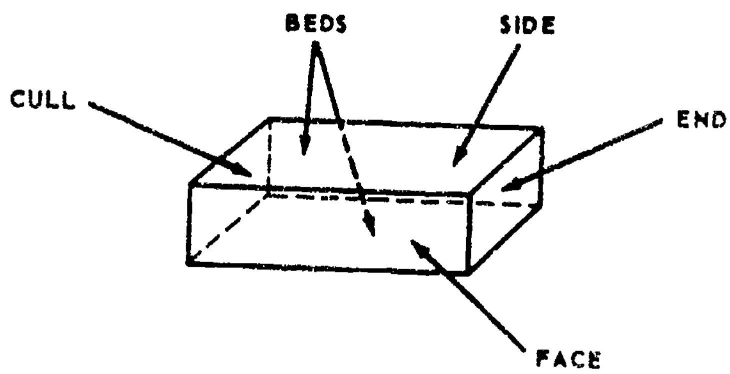
Figure 3-34.—Nomenclature of common shapes of cut brick.



29.141
Figure 3-35.—Names of brick surfaces.

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 hardnesses. In some regions, pits are opened and found to yield clay or shale which, 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 3-34. 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 face, the side, the cull, the end, and the beds, as shown in figure 3-35.

Masonry Terms

Specific terms are used to describe the various positions of masonry units and mortar joints in a wall (fig. 3-36). These are:

Course. One of the continuous horizontal layers (or rows) of masonry which, bonded together, form the masonry structure.

Wythe. A continuous single vertical wall of brick.

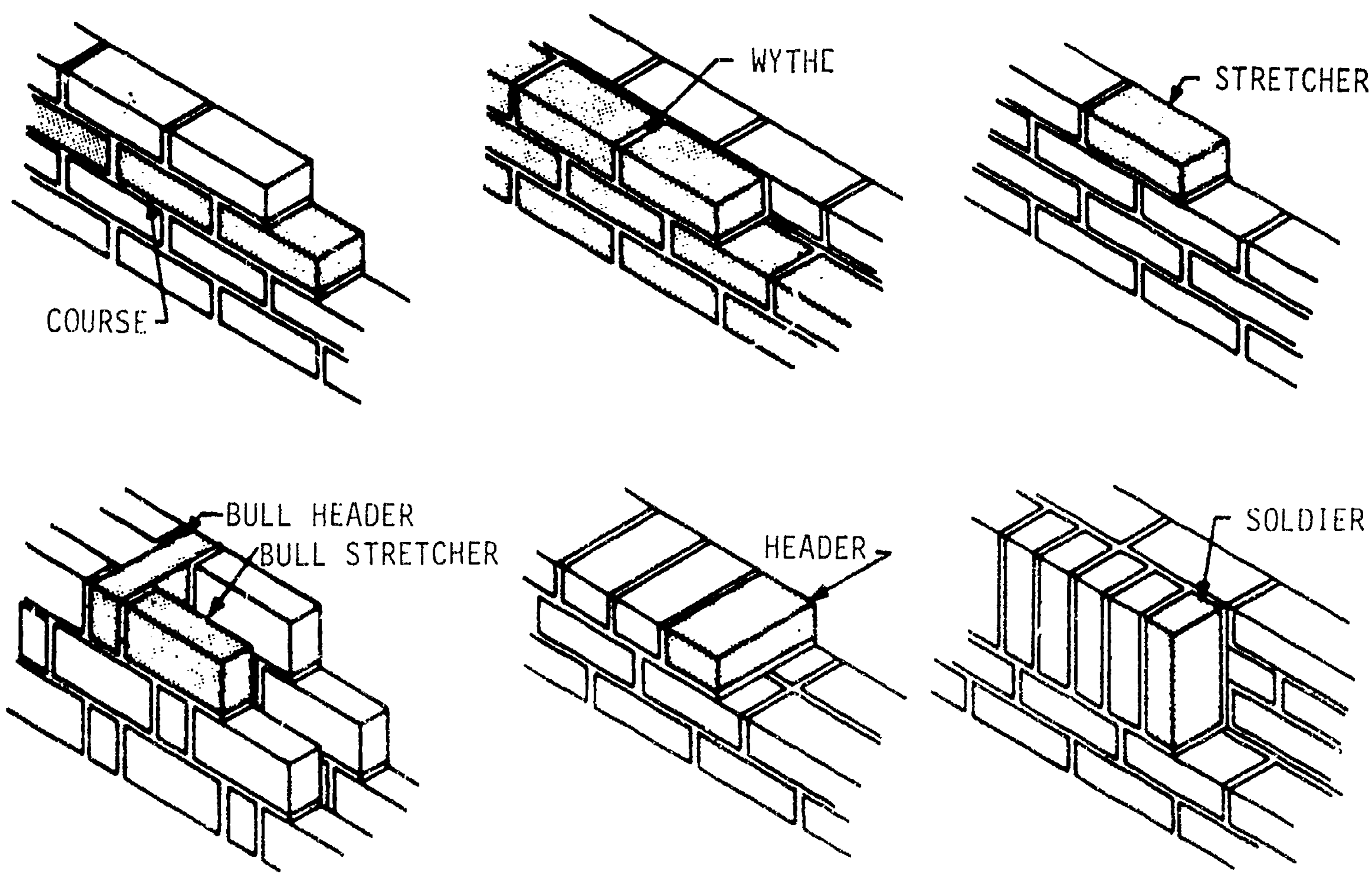


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Figure 3-36.—Masonry units and mortar joints.

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.

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. Common brick is brick which 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 which 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 which is inferior in quality even to common brick. Brick which 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 in accordance with 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 may be 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 inches.

Types of Brick

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:

BUILDING brick, formerly called 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. Building brick is also known as hard- and kiln-run brick. It is used generally for the 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 which 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 which 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 is necessary.

FIREBRICK is made of a special type of fire clay which 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 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 imbedded 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. There are five basic pattern bonds in common use today, as shown in figure 3-37. These are the 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 very 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 alined. Usually, this pattern is bonded to the backing with rigid steel ties, but when 8-inch-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 alinement requires dimensionally accurate units, or carefully prematched units, for each vertical joint alinement. 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

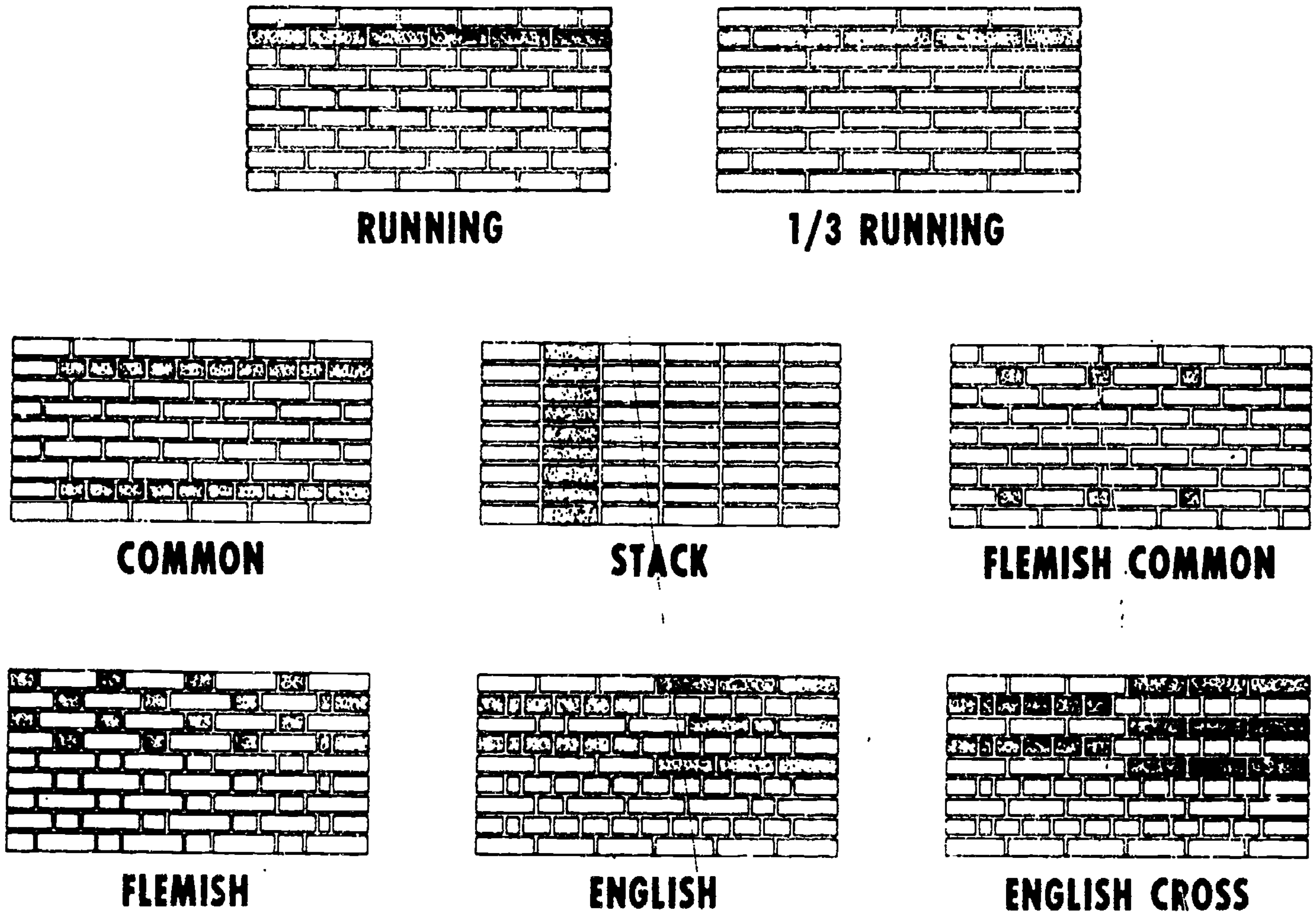

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Figure 3-37.—Some types of brick masonry bond.

in the intervening courses. Where the headers are not used for the structural bonding, they may be obtained by using half brick, called blind-headers. There are two methods used in starting the corners. Figure 3-37 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 inch 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 which 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.

CHAPTER 4

MECHANICAL AND ELECTRICAL SYSTEMS (MATERIALS)

In order to prepare workable construction drawings, Engineering Aids should be able to recognize and describe the materials used in mechanical and electrical systems and understand their use and function.

In this chapter, only the plumbing and drainage portions of the mechanical systems and the various materials used will be discussed. We will also present the different types of materials used in electrical systems associated with the installation of electrical power within buildings.

MECHANICAL SYSTEMS

The plumbing systems installed by the SEABEES are divided into the WATER DISTRIBUTION SYSTEM and the DRAINAGE SYSTEM. The water distribution system consists of the pipes and fittings which supply hot and cold water from the building water supply to the building fixtures, such as lavatories, water closets, washers, and sinks. The drainage system consists of the piping and fittings required to remove the water supplied to the fixtures from the building and out into the sewer lines or disposal field. You, as an EA, will not be expected to design the system; however, you might be called upon to prepare construction drawings from sketches and specifications. Therefore, your basic knowledge of the different types of piping materials and fittings used in each system will help you in the preparation of workable mechanical drawings.

WATER DISTRIBUTION SYSTEM

As just stated, the purpose of a water distribution system is to carry water throughout a building to where it is needed. This system (fig. 4-1) consists of the water service pipe, water distribution pipe, connecting pipe, fittings, and the control valves. The water service pipe begins at the water main. The water distributing pipe starts at the end of the service pipe and carries the water throughout the building. There are several types of pipe and fittings used in water distribution systems, but only the most common types used in the SEABEES will be discussed.

Copper Tubing

For water distribution pipes, copper tubing is one of the most widely used materials. 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 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.

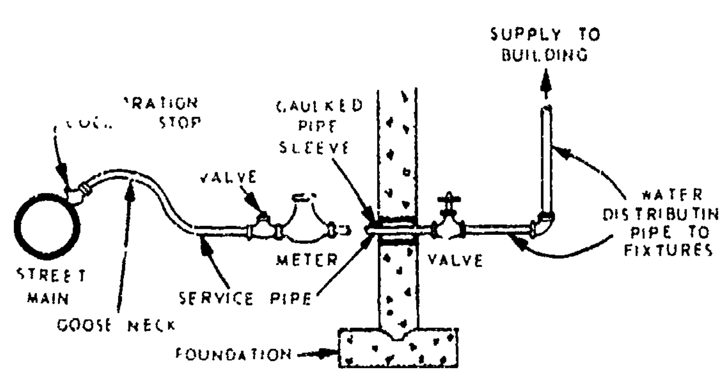

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Figure 4-1.—Water supply and distribution system.

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-foot coils, while hard temper tubing comes in 12- and 20-foot 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 feet. 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.

Plastic Pipe

Plastic pipe has been extensively used in NAVY construction. Its economy and ease of installation make it increasingly popular for use in either water distribution systems or sewer drainage systems. Available in 10-foot lengths, 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 above or below ground. Plastic fittings are available which are similar in appearance to those used with metal piping. Plastic pipe can also be adapted to metal pipe fittings. Valves used with plastic pipe are usually made of brass.

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-foot lengths rather than 5-foot 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 only used on small diameter pipe.

The three major types of fittings used with cast-iron water pipe are tees, elbows, and couplings. They are similar in appearance to the fittings used with cast-iron soil pipe (to be discussed later).

Galvanized Steel Pipe

Galvanized steel 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 20-foot lengths and to resist corrosion, it is GALVANIZED (coated with zinc) at the factory, both inside and outside. 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.

Common types of fittings used with galvanized steel pipe are shown in figure 4-2. The STRAIGHT COUPLING is used for joining two lengths of pipe in a straight run which 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 has two female (inside) threads of different sizes with different centers so when they are joined, the two pieces of pipe will NOT be in line with each other, but can be installed so as to provide optimum drainage of the line.

A NIPPLE is a short length of pipe (12 inches or less) with a male (outside) thread on each end. It is used to make an extension from a fitting and is available in many precut sizes. The TEE is used for connecting pipes of different diameters or for changing direction of pipe runs. The 90° and 45° ELBOW (or ELLS) are used to change direction of the pipe either 90° or 45°. Regular elbows have female threads at both outlets. In a close space where it is impossible or impractical to use a regular elbow and nipple

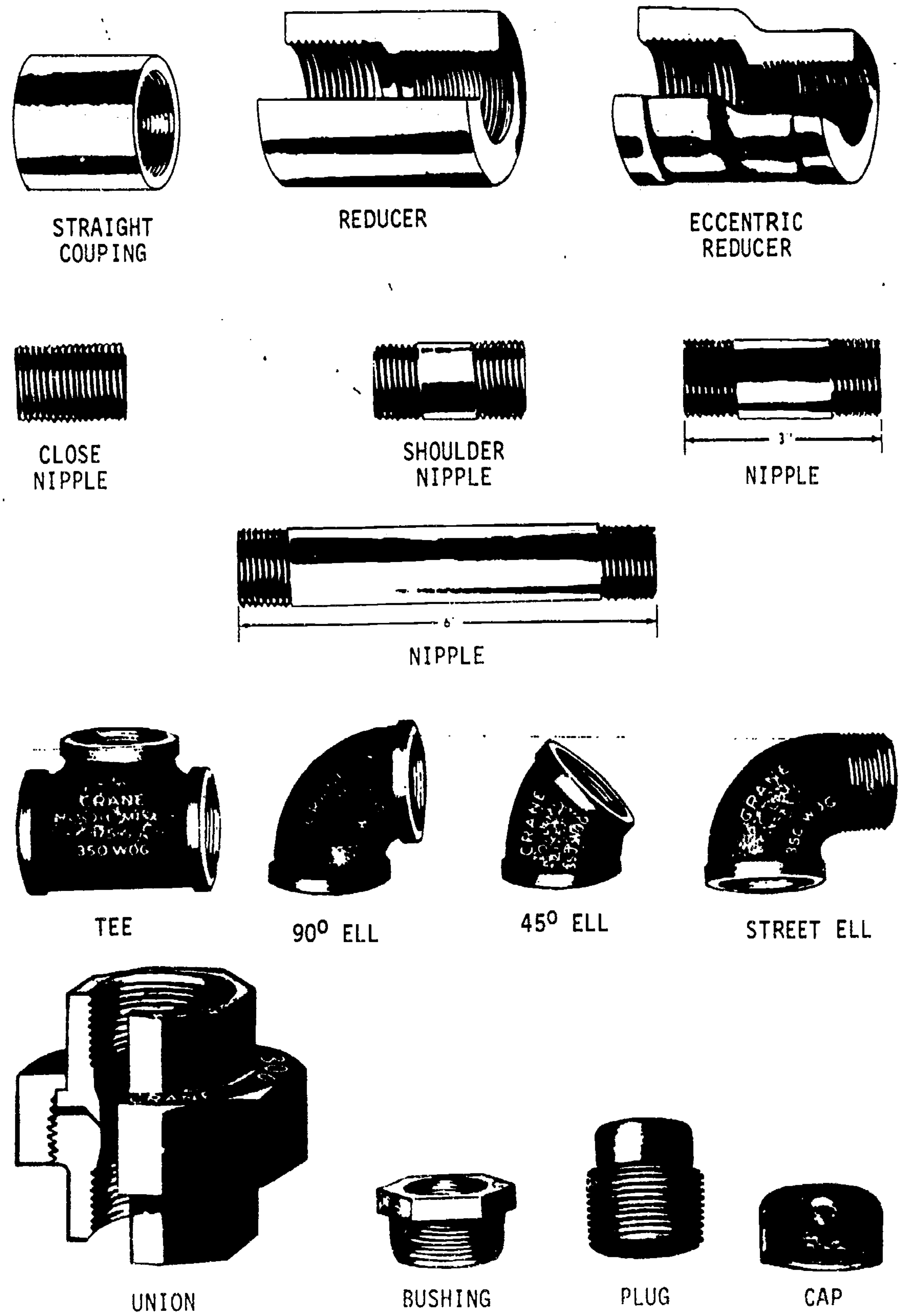

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Figure 4-2.—Types of pipe fittings.

together, the STREET ELBOW or ELL is used to change direction. Unlike a regular elbow, it has one female and one male threaded outlet.

To join straight runs of pipe, UNIONS and COUPLINGS are used. A clamp on the coupling allows for easy disconnection without disturbing the pipes themselves. A pipe BUSHING is a specialized fitting with a male thread on the outside and a female thread on the inside. Bushings may be used to reduce the size of openings of fittings and valves to a smaller diameter. Pipe PLUGS are fittings with male threads screwed into other fittings to close openings. Pipe plugs have various types of heads, such as square, slotted, and hexagon. A pipe CAP is a fitting with a female thread and it is used for the same purpose as a plug, except that the pipe cap screws on the male thread of a piece of pipe or nipple.

Fittings are identified by the sizes of pipe which are connected to their openings. For example, a 3- by 3- by 1 1/2-inch tee is one that has two openings for a 3-inch run of pipe and a 1 1/2-inch reduced outlet. If all openings are the same size, only one nominal diameter is designated. For example, a 3-inch tee is one that has three 3-inch openings.

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 disc or plug which can be tightly pressed against a seating surface around or within the opening. Figure 4-3 shows three kinds of valves used in plumbing systems. They are the gate, globe, and check valves.

The GATE VALVE has a wedge-shaped, movable plug, called a gate, which fits tightly against the seat when the valve is closed. When the gate is open an unrestricted flow passage is provided. The gate valves are operated either fully open or closed, never in any other position to adjust the rate of flow.

GLOBE VALVES, so called because of their globular-shaped body, are used for regulating flow by means of throttling (adjusting rate of flow).

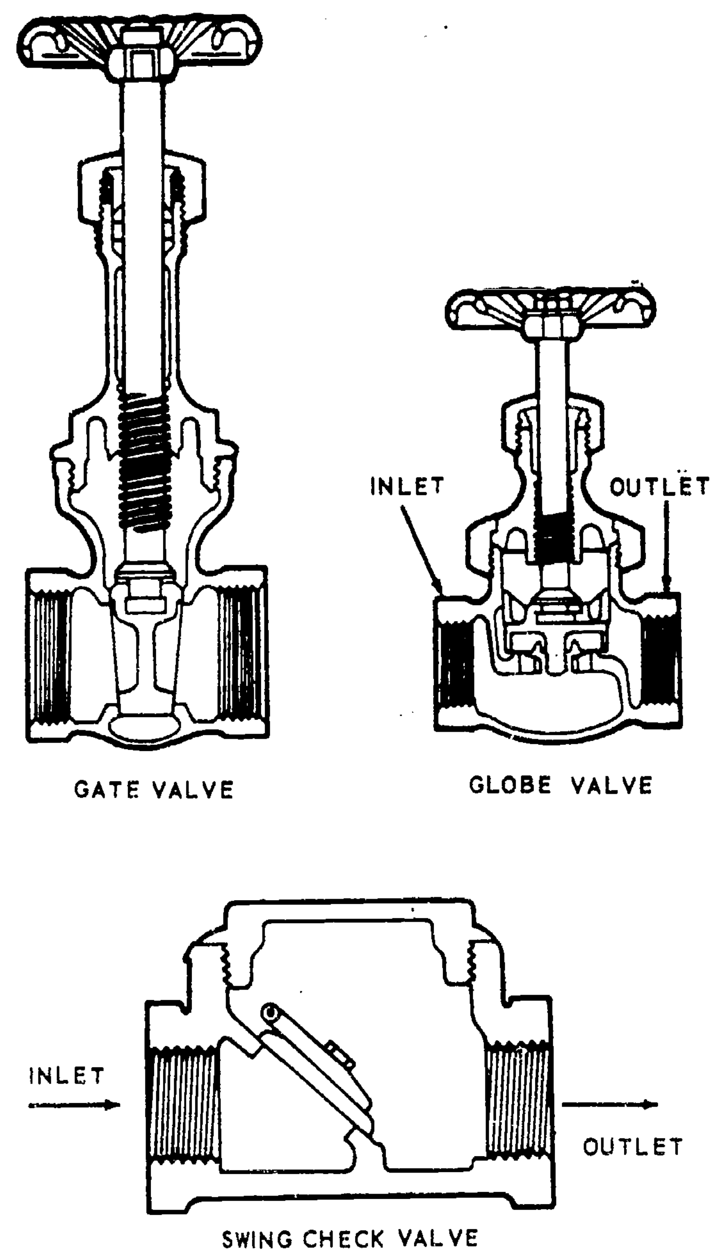

Figure 4-3.—Types of valves.

CHECK VALVES are principally used to automatically prevent backflow in pipelines. The SWING CHECK VALVE, shown in figure 4-3, is used where an unrestricted flow is desired.

The direction of flow is usually indicated by the manufacturer on globe and check valves. Gate valves are installed without regard to flow direction.

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—we will discuss only the latter which is the most common drainage system installed by the SEABEES.

Sanitary Drainage System

The SANITARY DRAINAGE SYSTEM carries sanitary and domestic wastes and terminates at a sewage treatment facility. Surface and ground waters must be excluded from this system to prevent an overload of the sewage treatment facilities.

Cast-iron and galvanized-steel pipes and fittings are used most often in the installation of a sanitary drainage system. However, 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 materials might also govern the type of pipe actually used. Below, we will discuss some of the material used in a sanitary drainage system.

CAST-IRON PIPE AND FITTINGS.—Cast-iron soil pipe and fittings are composed of gray cast iron made of compact, close-grain, 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 feet from the building. Here, it connects into a concrete or clay sewerline. Cast-iron soil pipe is also used when going 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-foot and 10-foot lengths, with nominal inside diameters of 2, 3, 4, 5, 6, 8, 10, 12, and 15 inches. It is available as single-hub or double-hub in design, as indicated in figure 4-4. 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 both ends. Hubs or bells, of cast-iron soil pipe are enlarged sleeve-like fittings, which are cast as a part of the pipe to make water- and pressure-tight joints with oakum and lead. Cast-iron soil pipe fittings are used for making branch connections or changes in direction of a line. Common types of fittings are described below and shown in figure 4-5.

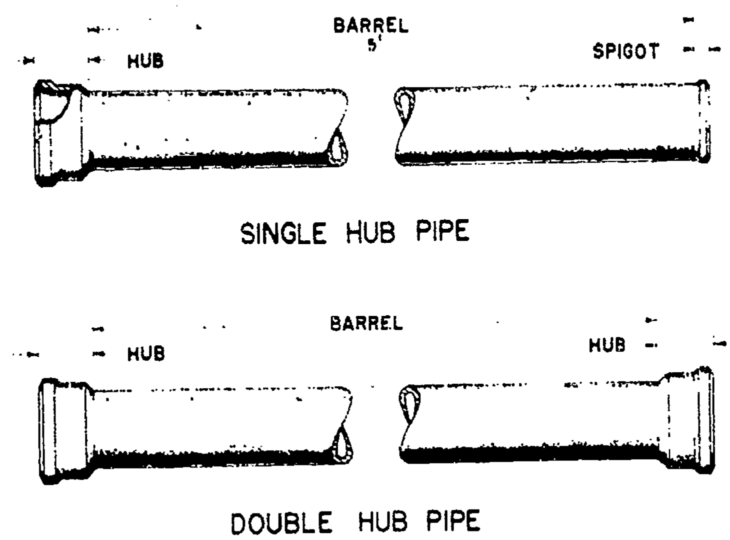

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Figure 4-4.—Single-hub and double-hub cast-iron soil pipe.

Bends. The 1/16 bend is used to change the direction of cast-iron soil pipe 22 1/2°. A 1/8 bend changes the direction 45°. 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 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 soil pipe branch.

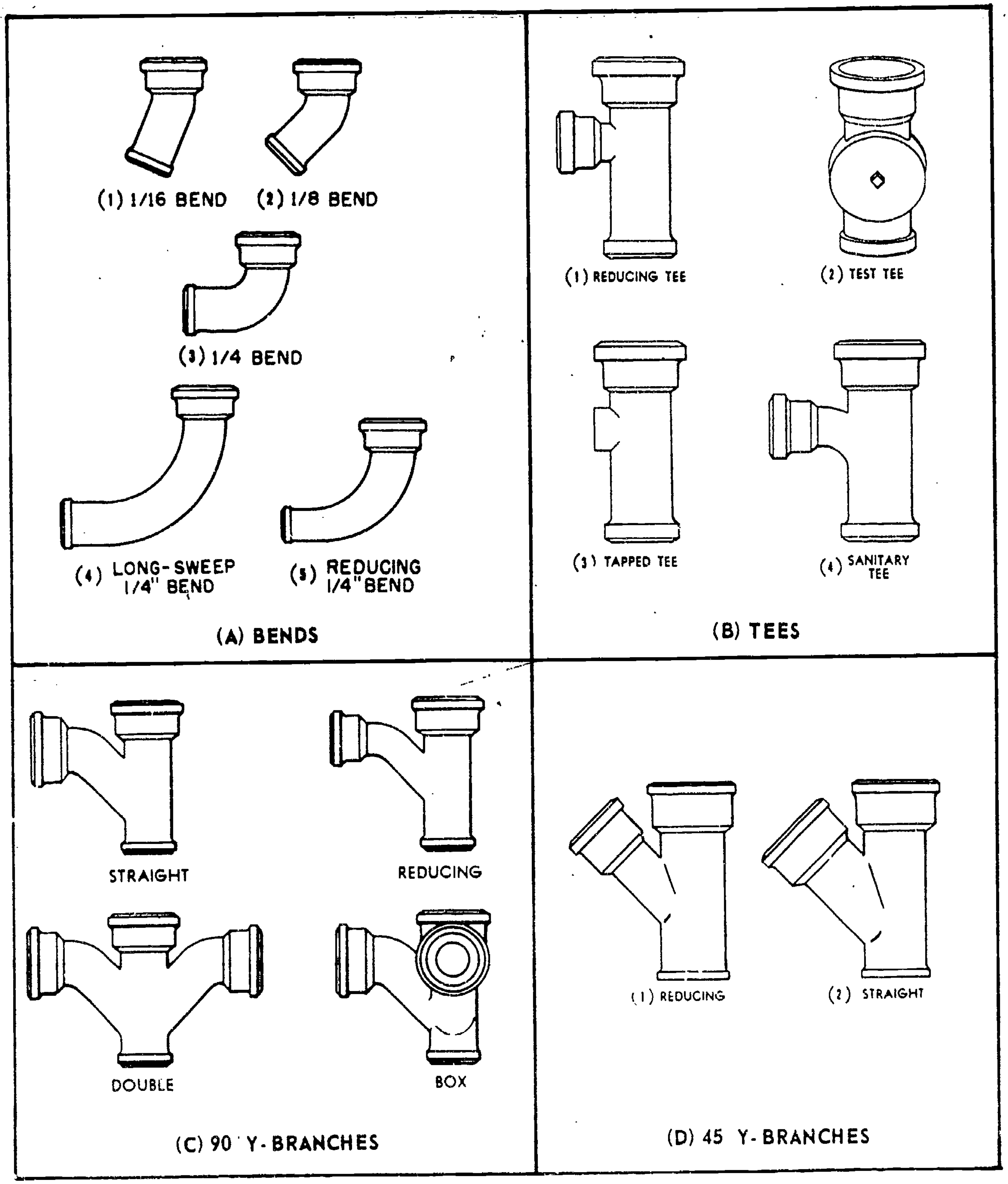

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Figure 4-5.—Common cast-iron soil pipe fittings.

Ninety Degree Y-Branches. Four types of cast-iron soil pipe 90° Y-branches generally used are illustrated in figure 4-5. These are normally referred to as COMBINATION Y AND 1/8th 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 1/8th BEND) is easy to recognize since there is a 45° 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 90° from each other.

Forty-Five Degree Y-Branches. The two types of 45° Y-branches 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.

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 feet, and in diameters ranging from 4 to 42 inches. Like cast-iron soil pipe, it has a bell end and a spigot end to facilitate joining. Vitrified clay pipe is used for house sewerlines, sanitary sewer mains, and storm drains. The types of fittings for clay pipe are few: bends and T- and Y-branches, primarily.

Precast concrete pipe may be used for sewers in the smaller sizes—those less than 24 inches. This pipe is not reinforced with steel. Dimensions of concrete pipe are similar to vitrified clay pipe.

Figure 4-6 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

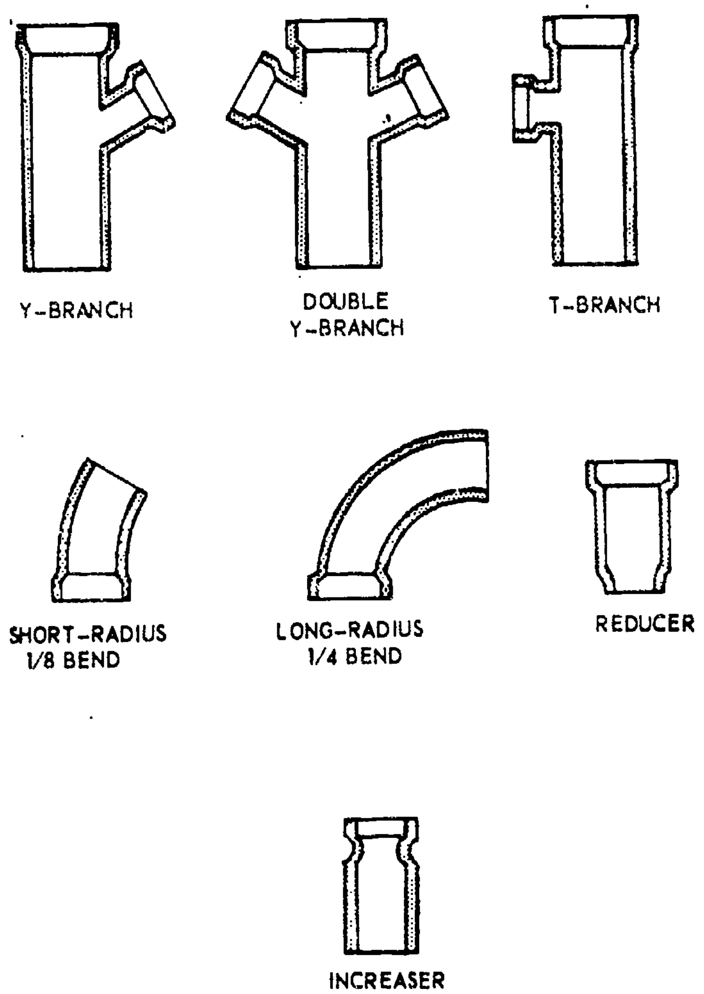

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Figure 4-6.—Cross section of clay or concrete fittings.

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.

ABOVEGROUND DRAINAGE PIPING.—Aboveground sewage piping within buildings consists of either one or a combination of the following: brass or copper pipe, copper tubing, extra heavy or service-weight cast iron, galvanized wrought iron, galvanized steel or lead, or plastic pipe. However, galvanized steel pipe is the most often used pipe.

UNDERGROUND DRAINAGE PIPING.—Underground piping outside of buildings may be cast iron, concrete, vitrified clay, asbestos cement, or rigid plastic, but cast-iron soil pipe, concrete, and vitrified clay are the most common. Underground piping within buildings is usually cast-iron soil pipe; however, galvanized steel, lead, or copper is sometimes used.

TRAPS.—A trap is a device which catches and holds a quantity of water, thus forming a seal which prevents the gases resulting from sewage decomposition from entering the building through the pipe. Traps (fig. 4-7) must be installed on fixtures, such as lavatories, sinks, and urinals, with the exception of a water closet which is made with the trap as an integral part of it.

Traps may be made of copper, plastic, steel, wrought iron, or brass, with brass being the most commonly used. Traps in water closets are made of vitreous china and are cast right into the fixture. Since the trap may occasionally need to be cleaned, there should be a plug in the bottom which may be removed or the trap should have screwed connections on each end for easy removal.

VENTS.—Vent pipes allow gases in the sewage drainage system to discharge to the outside. They allow 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 other fixture traps as it goes through the pipes. This means that the vent piping must serve the various fixtures, or groups of 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 stack (fig. 4-8) or the stack vent which goes to the exterior. Vent piping may be copper, plastic, cast iron, or steel.

A vent stack is that portion of the vertical sewage drainage pipe which extends above the highest horizontal drain that is connected to it. It extends through the roof to the exterior of the building. A vent stack is used in multistory buildings where a pipe is required to provide the flow of air throughout the drainage system. The vent begins at the soil or waste pipe, just below the lowest horizontal connection, and may go through the roof or connect back into the soil or waste pipe.

For more information on plumbing drainage systems, refer to the latest edition of *Utilitiesman 3 & 2*, NAVEDTRA 10656.

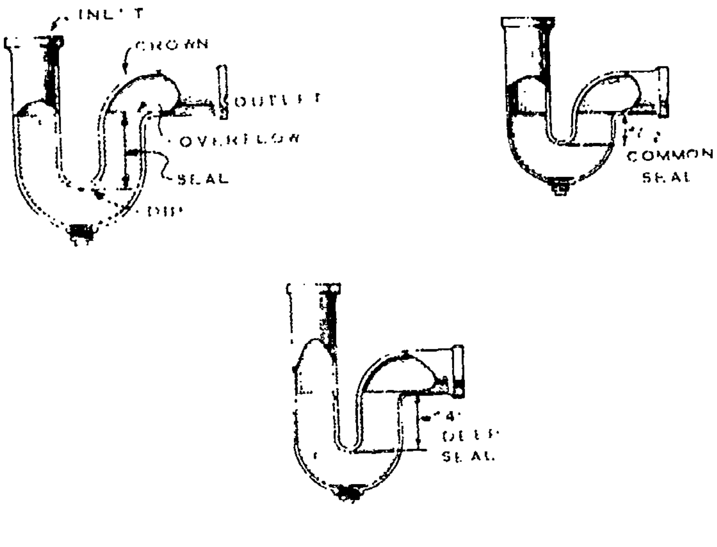

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Figure 4-7.—Traps.

ELECTRICAL SYSTEMS

All buildings require an electrical system to provide power for the lights and to run various appliances and equipment. At all Navy bases, the electrical system consists of three parts: the powerplant that supplies the electrical power, the distribution system that carries the electrical current from the generating station to the various buildings, and the interior wiring system that illuminates the building and feeds the electrical power to the appliances and equipment within a building.

In this section, we will discuss a variety of materials and fittings that are used in the installation of electrical wiring. For more information, refer to the latest editions of *Construction Electrician 3 & 2*, NAVEDTRA 10636, *Architectural Graphic Standards*, *Army Technical Manuals*, and the *National Electrical Code* (NEC).

CONDUCTORS

Electrical conductors generally consist of drawn copper or aluminum formed into wire.

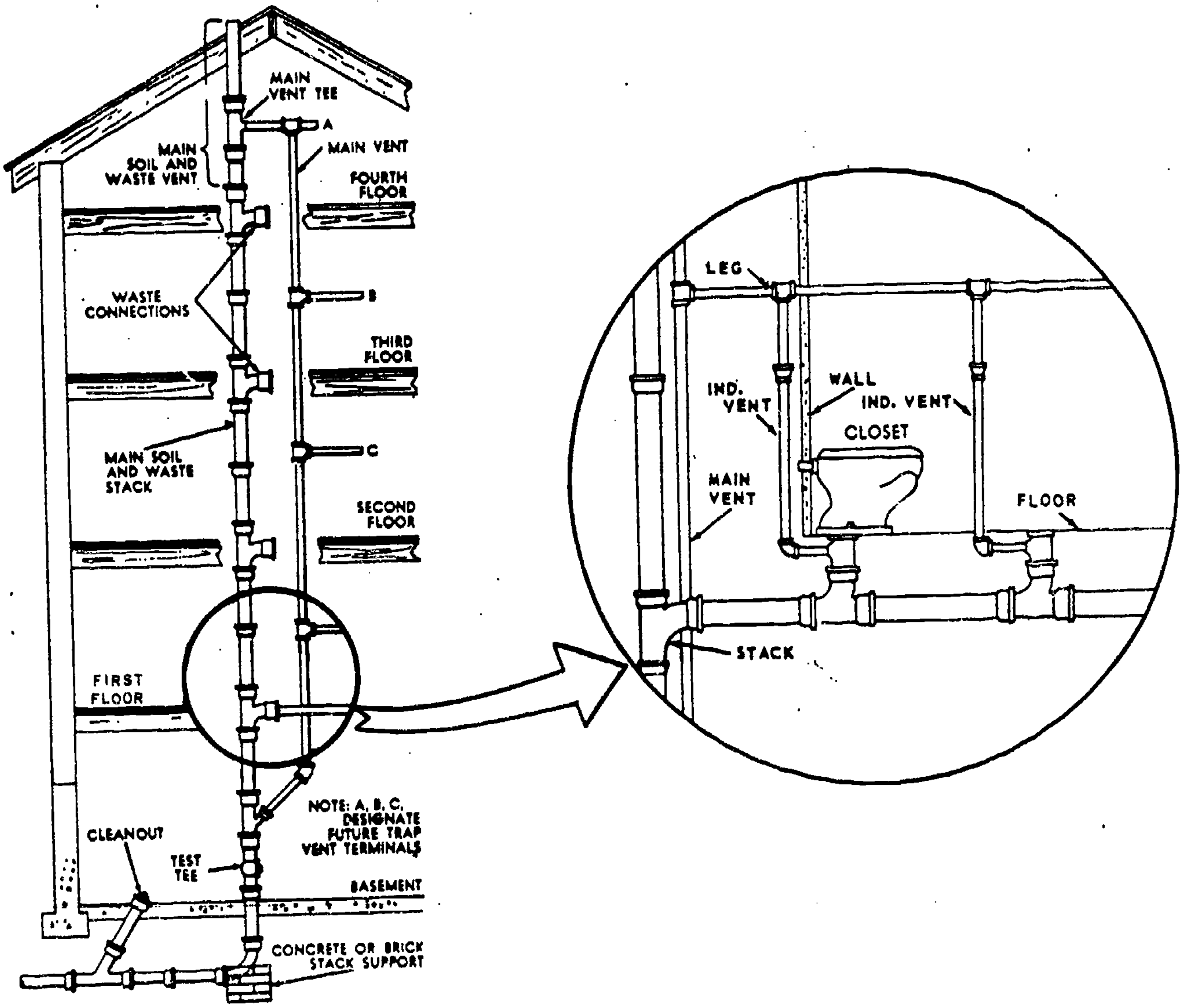

Figure 4-8.—Typical stack and vent installation.

They provide paths for the flow of electrical current. Conductors are usually covered with insulation material to minimize the chances for short circuits and for the protection of personnel.

Single Conductors

A single conductor might consist of one solid wire or a number of stranded, uncovered, solid wires which 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 4-9.

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 4-10 shows a comparison of ½ actual wire diameters to their AWG numerical designations. Notice that the wire gage 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

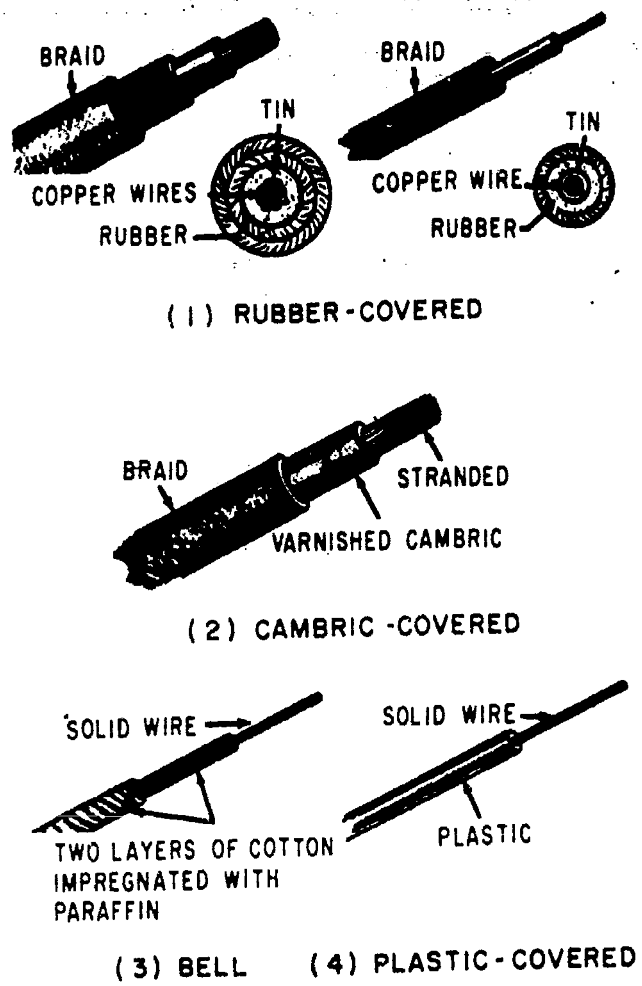

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Figure 4-9.—Types of single conductors.

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

45.871

Figure 4-10.—Comparison of standard wire gage numbers to wire diameters.

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" which has been factory installed with the lighting fixture. It is stranded for flexibility and is usually size 16 or 18 AWG.

Multiwire 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 4-11 shows common types of multiwire conductors.

Nonmetallic-sheathed cable (NMC) 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 insure the grounding of all metal boxes in the circuit, and also furnishes the ground for the grounded-type convenience outlets which are required in Navy installations. Romex is NOT authorized to

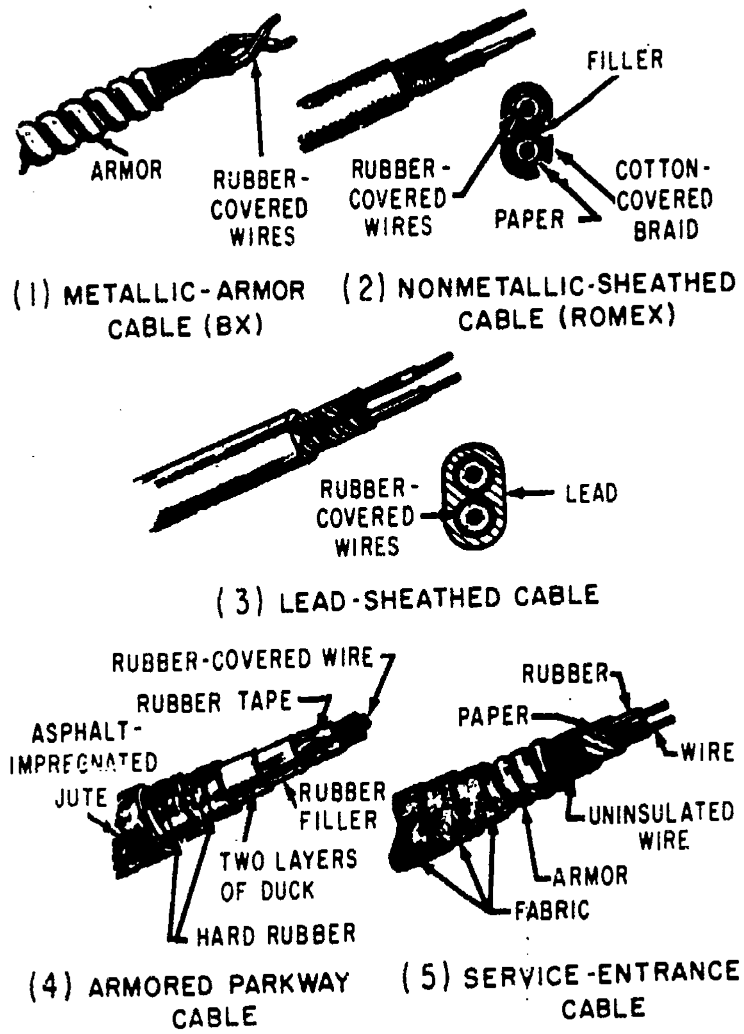

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Figure 4-11.—Types of multiwire conductors (cables).

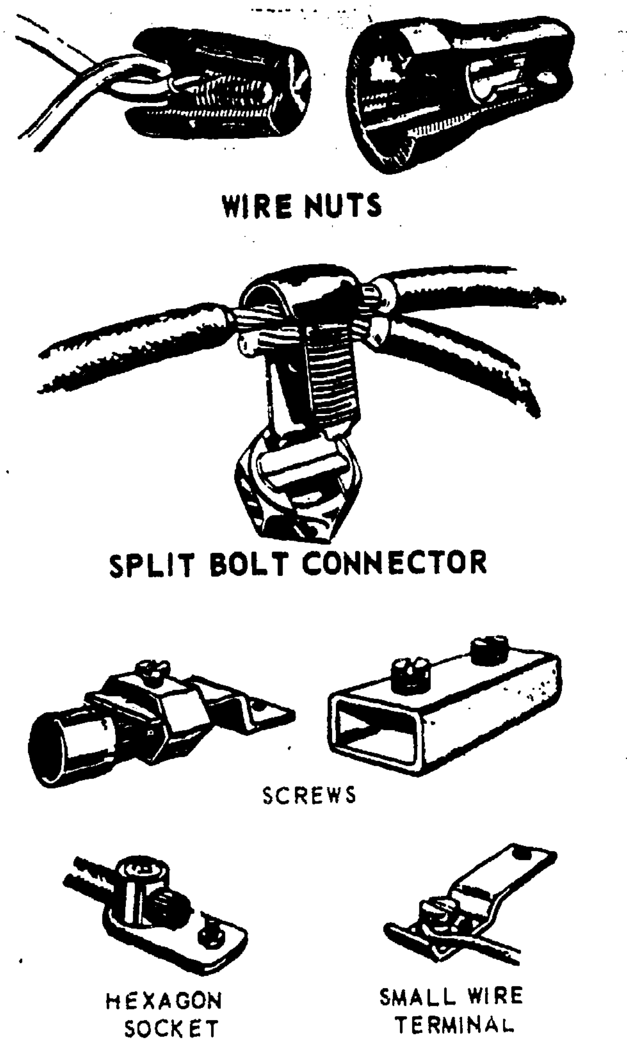

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Figure 4-12.—Cable and wire connectors.

be used as service entrance cable, in garages, in storage battery rooms, imbedded in poured concrete, or in any hazardous area.

Nonmetallic-sheathed cable is used for temporary wiring in locations where the use of conduit would be unfeasible.

WIRE CONNECTORS

Figure 4-12 shows various types of connectors which 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 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 4-13.

An outlet box is simply a metal container, set flush or nearly flush with the wall, floor, or

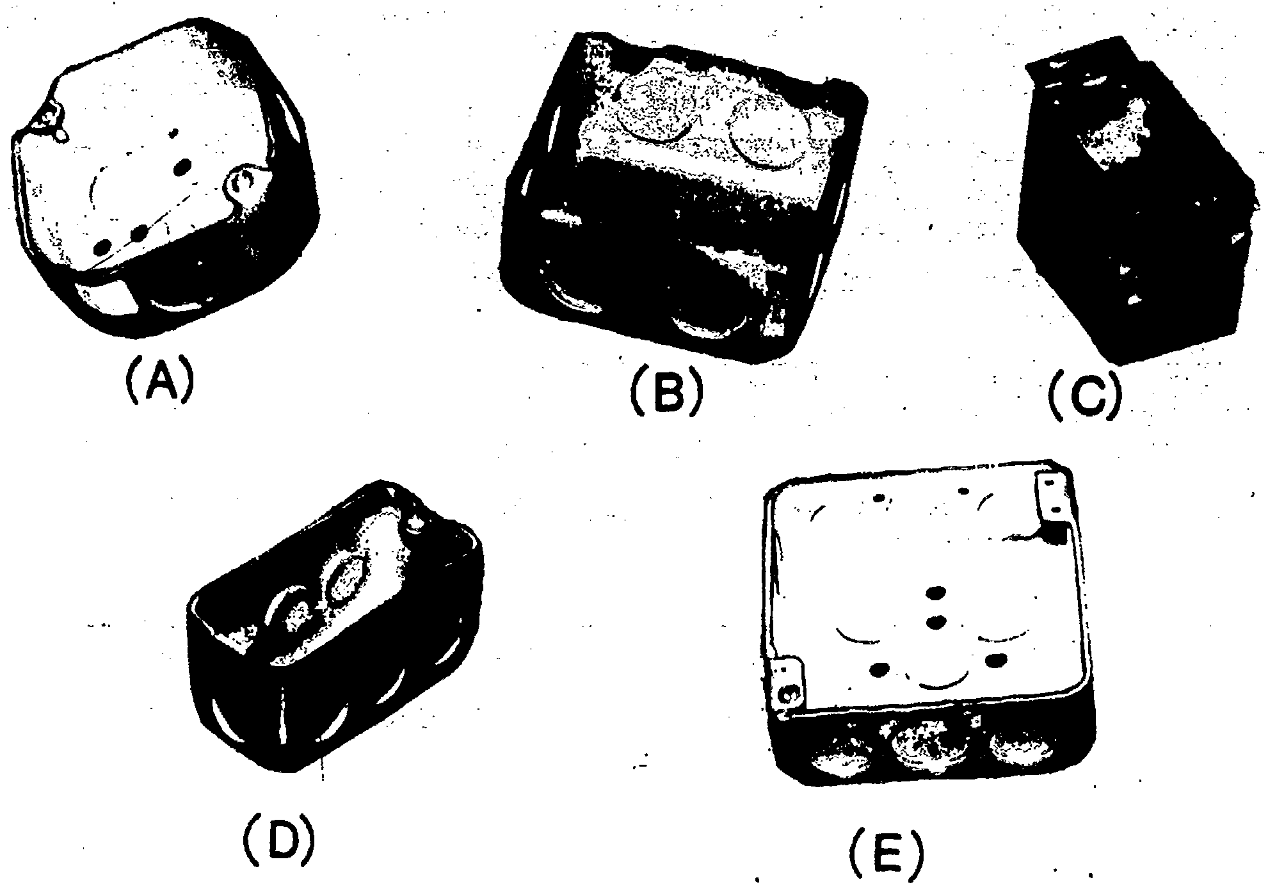

Figure 4-13.—Types of outlet boxes.

ceiling, into which the outlet, receptacle, or switch will be inserted and fastened. Figure 4-13 (box A) is a 4-inch octagon box used for ceiling outlets. This box is made with 1/2- or 3/4-inch KNOCKOUTS—indentations which can be knocked out to make holes for the admission of conductors and connectors. Box B is a 4 11/16-inch square box used for heavy duty, such as for a range or dryer receptacle. It is made with knockouts up to 1 inch in diameter. Box C is a sectional or GEM BOX used for switches or receptacles. By loosening a screw, the side panel on the gem box can be removed so that two or more boxes can be GANGED (combined) to install more than one switch or receptacle at a location. Box D is a UTILITY BOX, called a handy box, made with 1/2- or 3/4-inch knockouts and used principally for open-type work. Box E is a 4-inch square box with 1/2- or 3/4-inch 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 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 made to fit.

CONDUIT 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 are 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 conduits. The three types of conduit and their associated fittings are shown in figure 4-14.

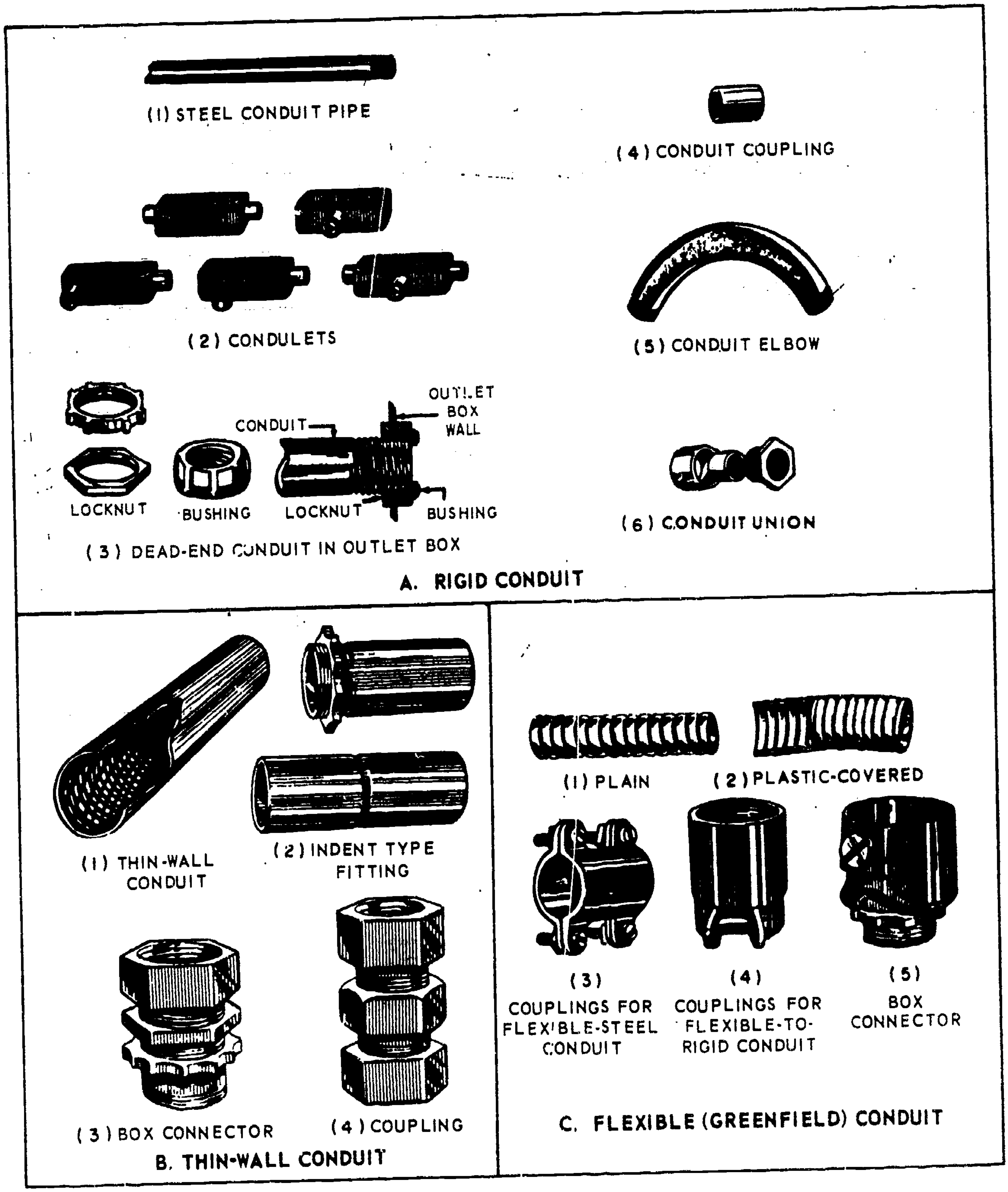

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Figure 4-14.—Types of conduit and their associated fittings.

Rigid Conduit

Rigid galvanized steel or aluminum conduit is made in 10-foot lengths. It is threaded on both ends and comes with a coupling on one end. It comes in sizes from 1/2 inch to 6 inches in diameter. Various fittings used for connecting rigid-metal conduit are shown in figure 4-14.

Another type of rigid conduit has recently been approved by NAVFAC. This is rigid plastic conduit which is specially suitable for use in areas where corrosion of metal conduits has been a problem. 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 inches in diameter. To change direction in the line, they are either bent or connected to junction boxes. Elbow fittings may also be used.

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, and is made in sizes from 1/2 to 2 inches in diameter. Thin-wall conduit cannot be threaded; therefore, special types of fittings, as shown in figure 4-14, must be used for connecting pipe-to-pipe to boxes.

Flexible Conduit

Flexible conduit (fig. 4-14) 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 be impossible to install and requires no elbow fittings. It is made in sizes from 1/2 to 3 inches in diameter.

SWITCHES

For interior wiring, single-pole, 3- or 4-way toggle switches are used. Most of the switches will be single-pole, but occasionally a 3-way system is installed, and on rare occasions, a 4-way system.

A single-pole switch is a one-blade, on-and-off switch which may be installed singly or in multiples of two or more in the same metal box.

In a 3-way switch circuit, 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 4-way switch is an extension of a 3-way circuit by the addition of a 4-way switch series.

Note that 3- and 4-way switches can be used as single-pole switches, and 4-way switches can be used as 3-way switches. Some activities may install all small-wattage, 4-way switches for all lighting circuits to reduce their inventories. However, 3- and 4-way switches are usually larger than single-pole switches and take up more box room. The size of a switch depends on its ampacity (rated maximum amperage). The ampacity and maximum allowable voltage are stamped on the switch.

RECEPTACLES

A convenience outlet (fig. 4-15) is a duplex receptacle with two vertical or T-slots and a

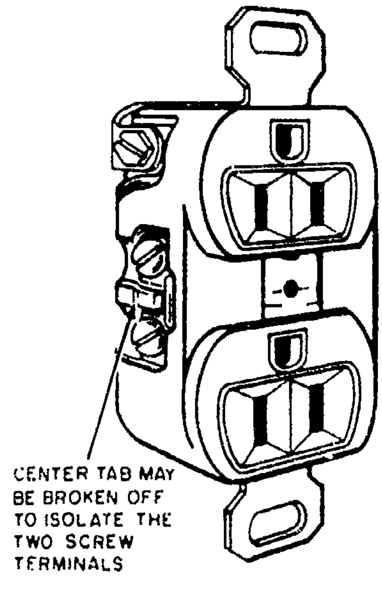

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Figure 4-15.—Duplex convenience outlet.

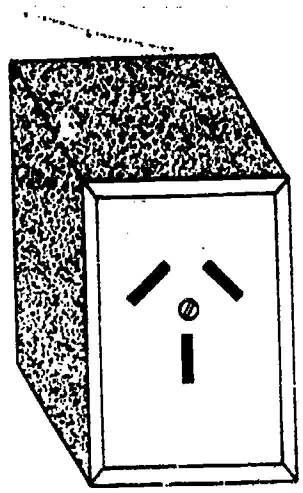

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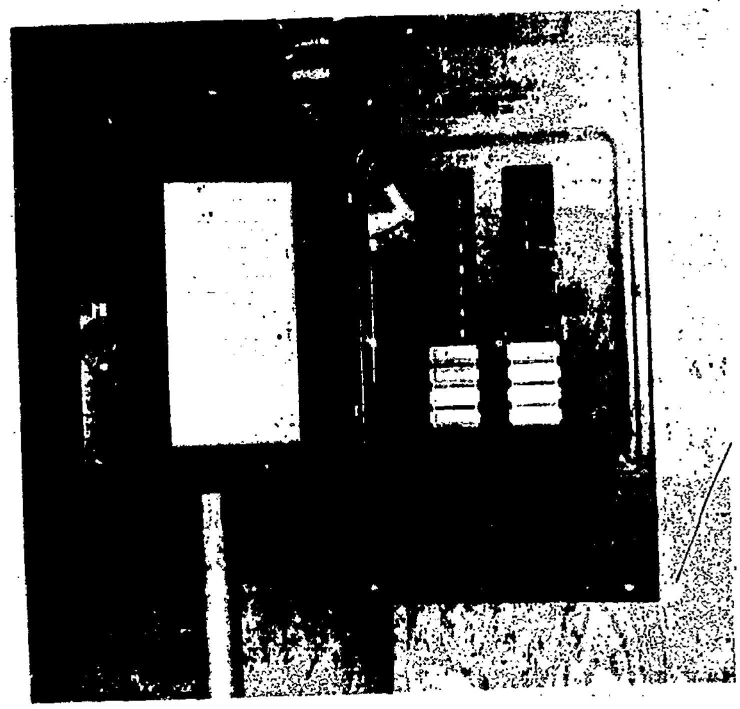
Figure 4-16.—Range receptacle.



73.11

Figure 4-17.—Lighting panel.

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. 4-16) might be either a surface type or a flush type. It has two slanted contacts and one vertical contact and is rated at 50 amps. Receptacles for clothes dryers are similar but are rated at 30 amps. Range and dryer receptacles are rated at 250 volts and are used with three-wire, 115/230 volts, two hot wires and a neutral. A receptacle for use with an air-conditioner taking 230 volts is made with two horizontal slots and one round contact for the ground.

DISTRIBUTION PANELS

A panelboard is defined by the *National Electric Code* (NEC) as "a single panel or group of panel units designed for assembly in the form of a single panel, including buses (buses and busways are explained in articles 364 and 384-21 of the NEC). 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 cutout box and placed in or against a wall or partition and is only accessible from the front."

As an Engineering Aid, the electrical layout of breaker panels for both light and power is your main concern. (See fig. 4-17.) The breaker panel uses a thermal unit built into the switch with the breaker being preset at the factory to open automatically at a predetermined ampere setting. It may be reset to the ON position after a short cooling-off period.

Lighting panels are normally equipped with 15-amp single-pole automatic circuit breakers, while the power panels may have 1-, 2-, or 3-pole automatic circuit breakers with a capacity to handle the designated load. Figure 4-18 shows a typical layout for an entrance switch, a lighting panel, and a power panel.

In most buildings, the entrance switch and panelboards should be mounted close to each other.

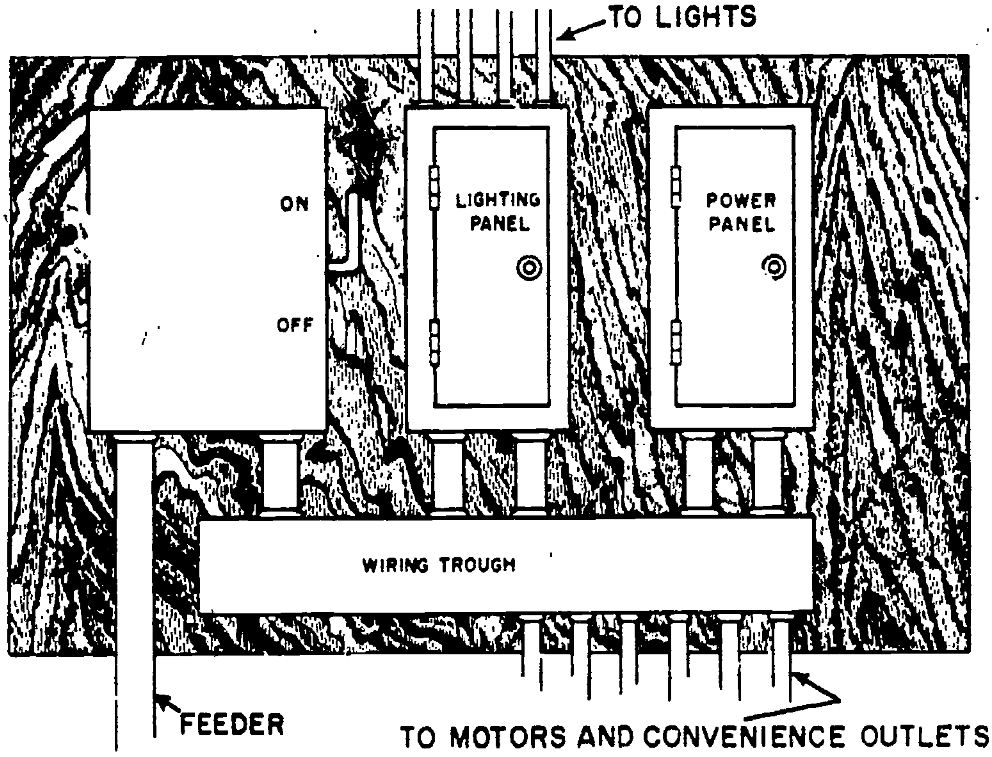


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Figure 4-18.—Typical layout for entrance switch, lighting panel, and power panel.

CHAPTER 5

HORIZONTAL CONSTRUCTION

The success of a military operation often depends on rapidity of movement and maintenance of supply lines. In turn, both depend on routes or lines of travel; that is, roads, railways, sea routes, and air lanes. Parts of these routes are usually constructed by the SEABEES; example, a road for automotive vehicles or a FIELD FOR AIRCRAFT.

It is easy to see that road construction and airfield construction have much in common—method of construction, equipment used, sequence of operations, and the like. Each road or airfield requires a subgrade, base course, and surface course. The methods of cutting and filling, grading and compacting, and surfacing all are similar. The responsibility for designing and laying out lies with the same person--the engineering officer.

As an Engineering Aid reporting to a SEABEE unit for duty, you can expect an assignment in the Engineering Division, which is directed by an engineering officer. To be able to carry out this assignment, you must learn the terminology of road and airfield construction, methods of construction, and uses of common construction materials.

The principles of plotting points and drawing layouts for roads and airfields will be discussed in a later volume which is under development.

ROADS

A military road is defined as any route used by the military for transportation of any type. This includes everything from a superhighway to a simple path through the jungle. The type of road required depends mainly upon the missions of the units that use it. In forward combat zones, the requirements are usually met by the most expedient road; that is, one that will get the job done with no attempt for permanency. In the rear zones, however, the requirements usually call for some degree of permanency and relatively high construction standards.

NOMENCLATURE

When assigned to the Engineering Division, you may help prepare the working plans for the construction of roads and airfields; example, a 2-lane, earth, gravel, or paved-surface road. Figures 5-1 and 5-2 show the basic parts of a road. The following are definitions of terms that you are likely to use when preparing the working plans for a road.

a. CUT. (1) An excavation through which the road passes. (2) The vertical distance the final grade is below the existing grade.

b. FINAL, OR FINISHED GRADE. The elevation to which the road surface is built.

c. SURFACE. That portion of the road which comes into direct contact with traffic.

d. EXISTING GRADE. The undisturbed earth before construction begins.

e. FILL. (1) Earth that has been piled up to make the road. (2) The vertical distance the final grade is above the existing grade.

f. SUBGRADE. The foundation of a road which can be either undisturbed earth (for a cut) or material placed on top of the existing grade.

g. BASE. Select material (crushed stone, gravel, etc.) placed in a layer over the subgrade for the purpose of distributing the load to the subgrade.

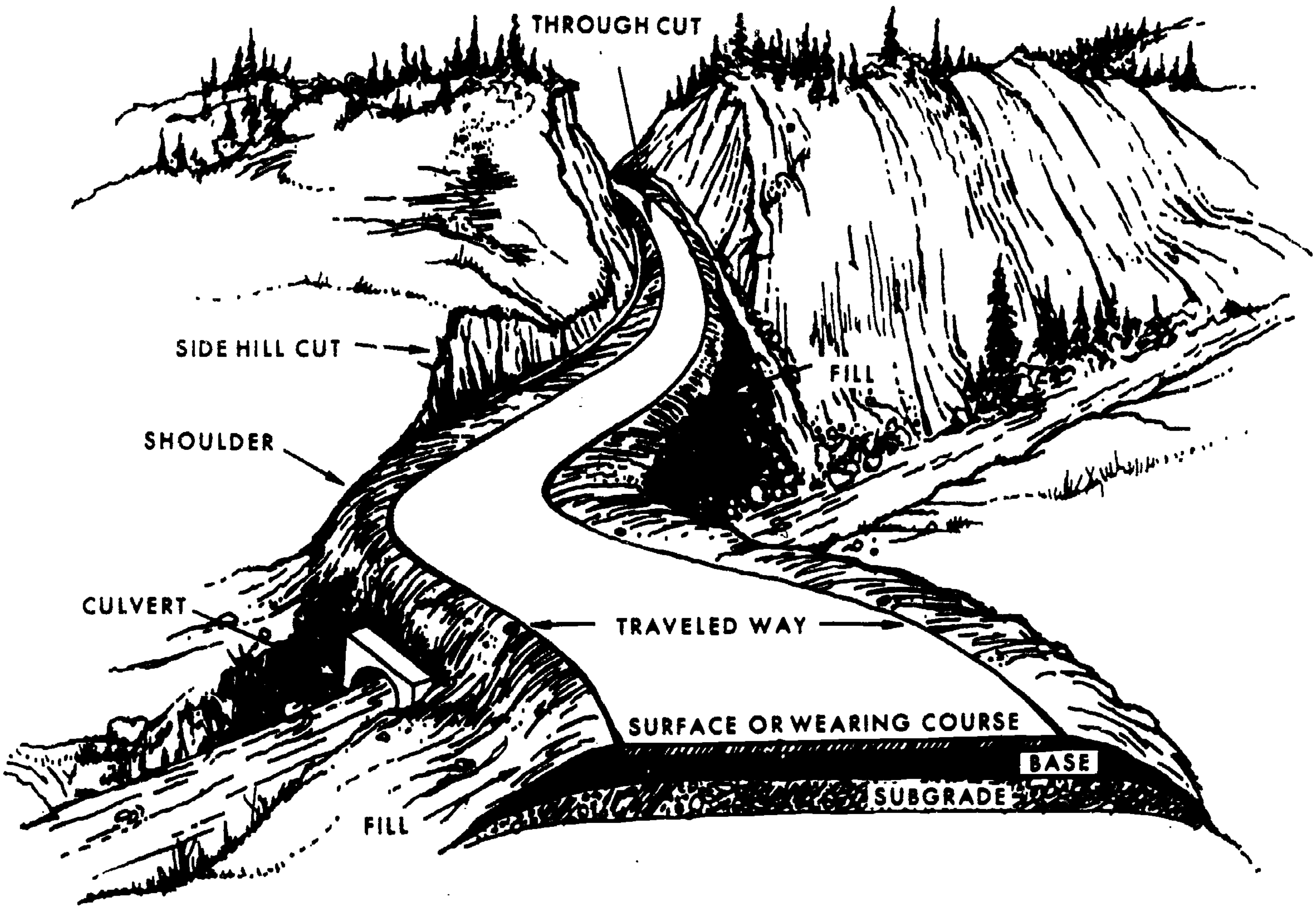

Figure 5-1.—Perspective of road illustrating road nomenclature. 45.873

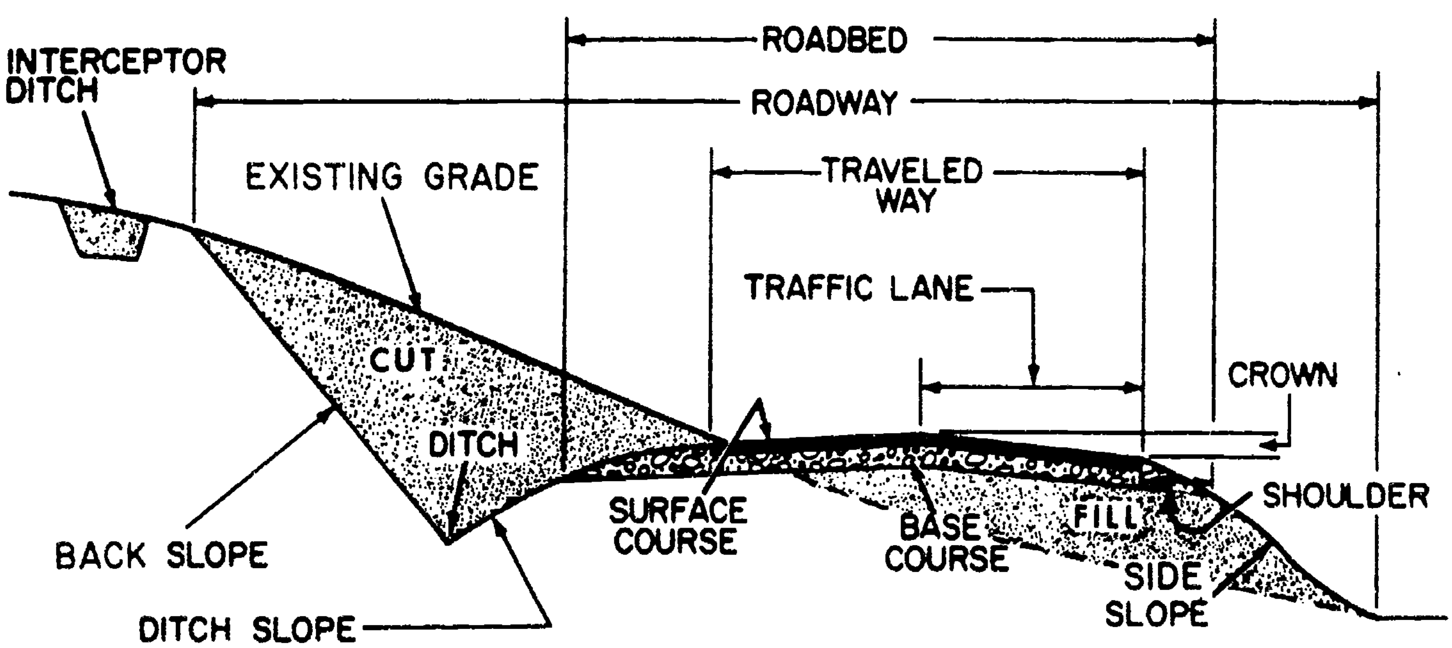

Figure 5-2.—Typical cross-section illustrating road nomenclature. 45.874

h. TRAFFIC LANE. Portion of the road surface over which a single line of traffic traveling in the same direction will pass.

i. TRAVELED WAY. That portion of the roadway upon which all vehicles travel (both lanes for a 2-lane road).

j. SHOULDERS. The additional width immediately adjacent to each side of the traveled way.

k. ROADBED. The graded portion of a highway usually considered as the area between the intersections of top and side slopes upon which the base course, surface course, shoulders, and median are constructed.

l. ROADWAY. The portion of a highway, including shoulders, for vehicular use.

m. ROADWAY DITCH. The excavation, or channel adjacent and parallel to the roadbed.

n. DITCH SLOPE. The slope which extends from the outside edge of the shoulder to the bottom of the ditch.

o. BACK SLOPE. The slope from the top of the cut to the bottom of the ditch.

p. SIDE SLOPE. The slope from the outside edge of the shoulder to the toe of the fill.

q. TOE OF SLOPE. The extremity of the fill (where the existing grade intercepts the fill).

r. INTERCEPTOR DITCH. (1) A ditch cut to intercept the water table or any subsurface drainage. (2) A ditch cut along top of fills to intercept surface drainage.

s. WIDTH OF CLEARED AREA. The width of the entire area that is cleared for the roadway.

t. SLOPE RATIO. A measure of the relative steepness of the slope, expressed as the ratio of the horizontal distance to the vertical distance.

u. CENTERLINE. The exact center, or middle, of the roadbed; the symbol for centerline is ℄.

v. BLANKET COURSE. A 1- or 2-inch screening spread upon subgrade to prevent mixing of base and subgrade.

w. CROWN. The difference in elevation between the centerline and the edge of the traveled way.

x. SUPERELEVATION. The difference in elevation between the outside and inside edge of the traveled way in a horizontal curve.

y. STATION. A horizontal distance generally measured in intervals of 100 feet along the centerline.

z. STATION NUMBER. The total distance from the beginning of construction to a particular point, (example, 4 + 58 is equal to 458 feet).

SURVEY

When it is decided that a road is needed through a particular area, the first and logical step is to determine a route for it to follow. This route may be chosen by the use of maps, aerial photographs, aerial reconnaissance, ground vehicle reconnaisance, or by walk-through reconnaissance, or any combination of these. Once the route is chosen, a surveying crew makes the preliminary survey.

The preliminary survey consists of a series of straight lines, called traverse lines, connecting a series of selected points, called traverse stations.

A survey party will stake in each traverse station, determine the distances between them, and the direction of the straight lines connecting them. The line direction is known as the bearing and is measured by the number of degrees a line deviates from the North-South direction. From this information, an Engineering Aid will draw the point of intersections (PI) and the connecting lines. Then an engineer will compute the horizontal curves at each point of intersection, and an EA will draw the curves and mark the stationing. This is the proposed centerline. This drawing is given to a final location party who stakes in the centerline and curves. The party chief may make changes in alinement with the approval of the engineer, but the changes must be recorded. Once the final location is determined, all information and changes pertinent to the location are used to prepare a second and final drawing showing the final centerline location, construction limits, all curves and curve data, station marks, control points, natural and manmade terrain features, trees, buildings, and anything that is helpful in construction. This drawing is a "bird's-eye view" of the road and is actually what you see from a position directly above. This is known as a road plan (fig. 5-3). It is drawn on plan-and-profile paper. The plan is

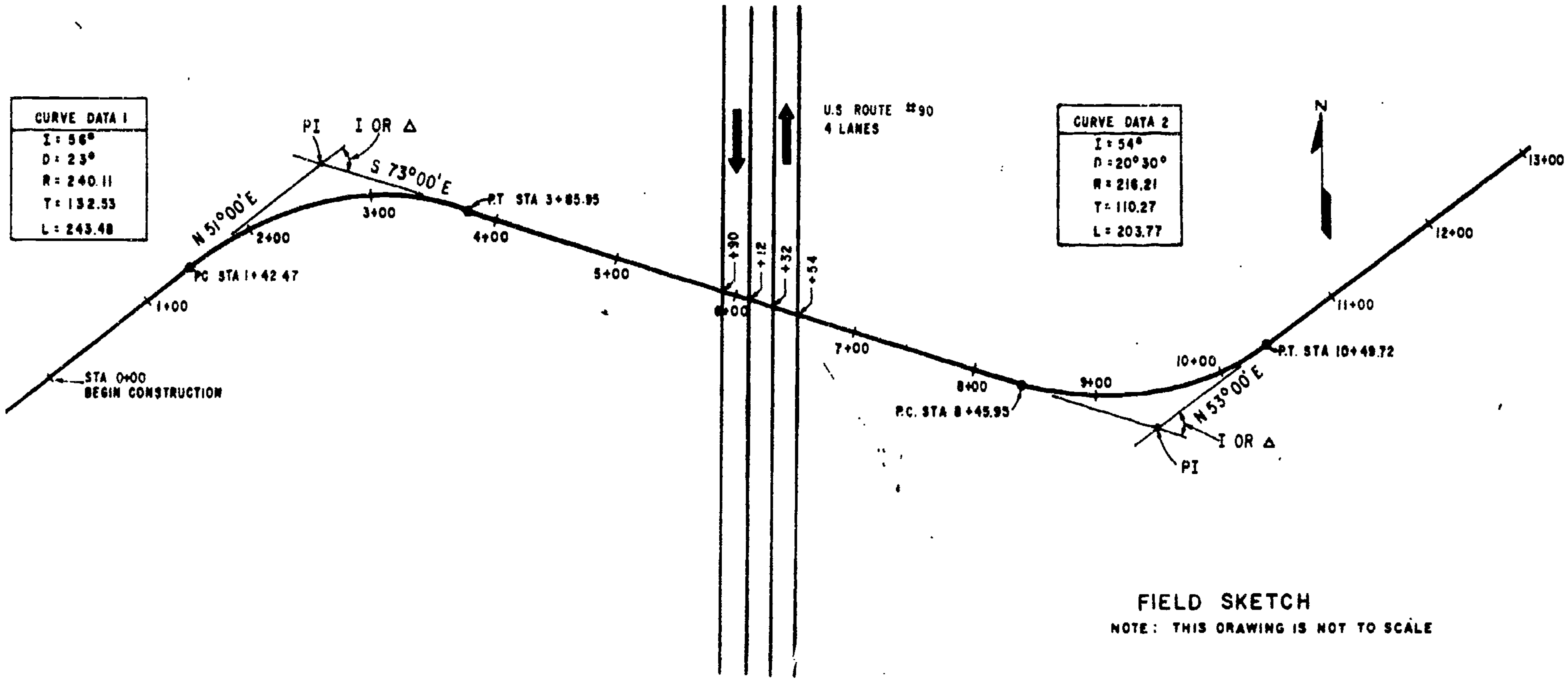

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Figure 5-3.—The road plan.

drawn on the upper portion to any scale desired. The bottom portion is composed of grid lines and is used for the road profile.

ROAD PLAN

The road plan, or plan view, shows the actual location and length of the road measured along the centerline. The length is determined by the stations. The beginning of the road is normally given the station number 0 + 00 and would be noted on the plans in this manner:

sta. 0 + 00

Begin construction

The numbers on the left side of the plus sign (+) are station numbers which show the number of full stations from the beginning of the project to the point in question. The numbers on the right show the fractional parts of one station.

Example 1:

sta. 36 + 79 means 36 full stations and $\frac{79}{100}$ of one station. This point would be 3,679 feet from the beginning of the road.

Example 2:

$119 + 26^{80}$

This point is 11,926.80 feet from the beginning. A full station represents 100 feet, and a plus station represents any distance between full stations. Full stations are shown on the plans as a 1/4-inch hash mark through the centerline. Plus stations are shown by shorter hash marks on the upper side of the centerline. The hash marks are always drawn perpendicular to the centerline. The station numbers themselves are put on the plan in a horizontal position and centered on the hash marks.

All manmade and natural objects, such as trees, buildings, fences, wells, and so on, are also plotted on the plan if they are in the right-of-way or construction limits. (Right-of-way is the land acquired for the road construction.) These objects and their location are taken from the surveyor's notebook. Their location is determined by a station number and their distance from ℄. All measurements and distances are made perpendicular to the ℄ of the particular station unless otherwise noted.

Horizontal Curves

The road centerline consists of straight lines and curves. The straight lines are called tangents, and the curves are called horizontal curves. These curves are used to change the horizontal direction of the road. All information necessary to draw a curve should be furnished by the engineer or surveyor's notebook. The necessary information is known as curve data. Below is the data for a curve and the explanation of the terms.

$$\triangle = 56°13'$$
$$D = 18°42'$$
$$T = 163.39'$$
$$L = 300.62'$$
$$R = 307.76'$$

(a) The symbol △ (Delta) represents the deflection angle made by the tangents where they intersect, and is known as the intersection angle and may also be represented by the symbol I (fig. 5-3).

(b) D is the degree of curvature, or degree of curve. It is the angle subtended by a 100-foot arc or chord (fig. 5-3).

(c) T is the tangent length and is measured from the PI to the point of curvature (PC) and the point of tangency (PT). The PC is the beginning of the curve, and the PT is the end of the curve.

(d) L is the total length of the curve measured in feet along the arc.

(e) R is the radius of the curve, or arc. The radius is always perpendicular to the curve tangents at the PC and the PT.

(f) A horizontal curve is generally selected to fit the terrain. Therefore, some of the curve data will be known. The following formulae show definite relationships between elements and allow the unknown quantities to be computed.

(g) To find the radius, R, or degree of curvature, D:

$$R = \frac{5729.58}{D} \quad , \quad D = \frac{5729.58}{R}$$

(h) For T, the distance between PC and PI and PI and PT:

$$T = R \operatorname{Tan}\frac{\triangle}{2}$$

(i) To find L, the length of curve

$$L = \frac{100}{D} \triangle \text{ (D and } \triangle \text{ in degrees)}$$

(j) The PC and PT is designated on the plan by a partial radius drawn at each point and a small circle on the centerline. The station number of the PC and PT is noted as in figure 5-3. The length of the curve, L, is added to the PC station to obtain the station of the PT. The curve data is noted on the inside of the curve it pertains to and is usually between the partial radii.

Since horizontal curves have superelevation (SE), there must be a transition distance in which the shape of the road surface changes from a normal crown to a superelevated curve. The transition length (TL) is generally 150 feet and starts 75 feet before the PC is reached. The same is true in leaving curves. The transition begins 75 feet before the PT and ends 75 feet beyond. The beginning and end of the superelevation is noted on the plan.

Control Points

Control points are points from which the ℄ of the road may be reestablished when the original points have been destroyed by construction equipment. These points may be a PT, PC, POT (point on tangent) or PI. To relocate them, reference by setting two or more points on a common line. The angle the line makes with the centerline and the distance to the points is measured and recorded (fig. 5-3). This information is taken from the surveyor's notebook. Reference the control points by driving iron pins at right angles to the point on each side of the centerline and measure the distance. If room allows, draw the references directly on the plan opposite the control point. If not, show the control points and references on a separate sheet, called a reference sheet.

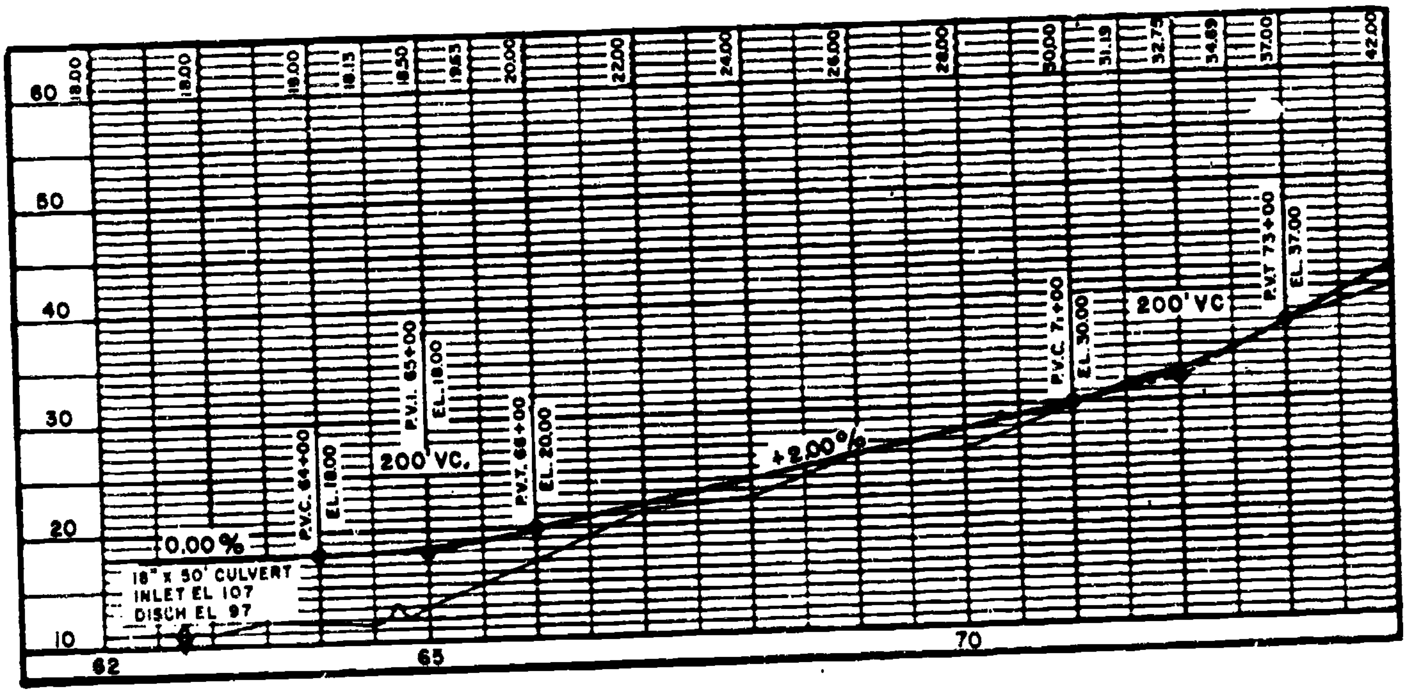
ROAD PROFILE

As stated before, the road profile is drawn on the lower section of the plan-profile paper. Profile is defined as the representation of something in outline. When applied to roads, this means the outline of the original ground taken along the centerline. The profile is nothing more than a side view of the earth made by a longitudinal cutting plane along the centerline and always viewed perpendicular to the centerline (fig. 5-4).

The profile is drawn from information in the surveyor's notebook. The ground elevations are normally taken every 50 feet along the centerline and at major breaks in the terrain. The shots may be every 100 feet if the ground slope is constant.

The station numbers are lettered across the bottom of the paper in a horizontal position and on a heavy grid line. The heavy grid lines, both horizontal and vertical, are usually 2 inches or 2 1/2 inches apart, and are further subdivided. The horizontal scale normally used is 1 inch = 50 feet or 1 inch = 40 feet. The vertical scale is exaggerated, or blown up, and is generally 10 times greater than the horizontal scale. Therefore, vertically, 1 inch = 5 feet or 1 inch = 4 feet. After the proper scale is selected, datum elevations are lettered along the left (and sometimes right) border on the heavy horizontal grid lines. These elevations range below and above the lowest and highest profile elevations, respectively, on that sheet. For example, the highest profile elevation is 537.2 and the lowest is 514.7. The lowest datum elevation would be 510.0. On the next heavy grid above would be lettered 520.0, the next 530.0. The highest would be 540.0.

The elevations given in the surveyor's notebook are plotted above their respective stations. To plot an elevation, make a dot and then



45.876

Figure 5-4.—Road profile.

lightly circle it. Connect the elevation points with straight-dashed lines of medium length. Do not miss a point.

A road gradeline is also drawn on the lower portion of the plan-profile paper and is represented by a heavy solid line. The gradeline is also a longitudinal section along the centerline or side view and shows the elevations to which the road is built (fig. 5-4). The gradeline is normally the centerline elevations of the finished surface, but may be the centerline elevations of the subgrade. If the subgrade was used, make a special note of it.

The gradelines are a series of straight lines (tangents) connected by curves, called vertical curves. The lines may be level or sloped. If the lines slope upward, the grade is positive; if downward, the grade is negative. The slopes are in reference to the direction of increasing stations. The amount of slope is lettered above the gradeline and is usually indicated as the percent of slope. In figure 5-4, the slope from sta. 66 + 00 to 71 + 00 is + 2.00 percent. This means the centerline grade rises 2 feet in 100 feet horizontal distance. If the slope is − 1.50 percent, the grade would fall 1.50 feet in 100 feet horizontal distance.

The point at which the straight lines intersect is the PVI (point of vertical intersection). This point is comparable to the PI of horizontal curves.

Vertical Curves

If the road is to offer safe, comfortable driving, the point of vertical intersection (PVI) must not break sharply. The length of the curve depends upon the steepness of the intersecting grades. In most cases, a vertical curve is symmetrical; its length is the same on both sides of the PVI. The length is horizontal as opposed to the length along the curve. The station on which the curve begins or ends is called the point of vertical curvature (PVC) or point of vertical tangency (PVT), respectively. Unlike horizontal curves, vertical curves are parabolic; they have no constant radius. Therefore, the curves are plotted, usually in 50-foot lengths, by computing the offsets from the two tangents. A vertical curve at the crest or top of a hill is called a SUMMIT CURVE or OVERVERTICAL; one at the bottom of a hill or dip is called a SAG CURVE or UNDERVERTICAL.

Gradelines

The gradeline is drawn using the same horizontal and vertical scale as the profile. This allows the amount of cut or fill for a particular point to be measured. If the gradeline is higher than the profile, fill is required. If lower, it is cut.

The profile and gradeline drawings also show the relative locations of drainage structures, such as box culverts and pipe. Only the vertical scale is used to draw these structures. The heights of the structures are accurately plotted using the horizontal scale. The widths cannot be accurately drawn due to the large vertical scale, so the structures are drawn just wide enough to indicate the type structure. A box culvert would show as a high, narrow rectangle and a round pipe as a high, narrow ellipse.

ROAD DIMENSIONS

The type of dimensioning used for road plans is a variation of the standard dimensioning. In road dimensioning, numerical values for elevations, cuts, fills, and stations are considered dimensions also.

a. STATION NUMBERS. Most road dimensions appear on the profile-gradeline drawing. The station numbers are lettered horizontally below the profile-gradeline and are centered on the appropriate vertical grid line.

b. ELEVATIONS. At the bottom of the sheet the profile and gradeline elevations for each station are lettered vertically. The gradeline elevations are lettered just above the profile elevations. Any station numbers other than full stations are noted as plus stations vertically just outside the bottom border (fig. 5-5).

c. CUTS AND FILLS. Above the profile and gradeline elevations are lettered the cuts and fills (fig. 5-5). They are also in a vertical position. The gradepoints, or points where the profile crosses the gradeline, are also noted in this row. They are designated by the word "GRADE" lettered vertically above the gradepoint station.

d. DITCHES. There are two steps in the procedure for dimensioning ditches.

(1) Extension lines are drawn from the ends of a ditch, or any point in the ditch where the ditch grade changes. These lines are extended downward, and dimension lines drawn, with heavy arrowheads. These extension and dimension lines should be heavier than normal so they may be distinguished from grid lines.

(2) The information necessary to describe the ditch is lettered above the dimension line. If the lettering is crowded, the space below the line may also be used. The information furnished is the percent of grade of the ditch, depth relative to centerline, type, and width of ditch. The elevation and station are given at the ends of the ditches and at changes of grade (fig. 5-5).

e. VERTICAL CURVES. Each vertical curve on the gradeline is also dimensioned. Extension lines are drawn upward from the PVC and PVT. A dimension line and arrowheads are drawn and the length of the curve lettered above. The station and elevation of the PVC, PVI, and PVT are lettered vertically over these points and above the dimension line.

f. CORRELATION WITH PLAN. All points on the profile-gradeline coincide with centerline points on the plan. The beginning and ending of construction of the plan view are also shown on the gradeline as beginning and end of construction. The elevations at these points are also noted.

g. DRAINAGE STRUCTURES. All drainage structures, such as pipes and culverts, are dimensioned by notes. The station number, size of opening, length of pipe, and flow line elevation are noted.

h. TITLE. The title, "PROFILE AND GRADELINE" is lettered below the ditch dimensions. Below this are noted the horizontal and vertical scales.

SEQUENCE OF CONSTRUCTION

In constructing a road, there is a sequence to follow. First, the area through which the road must pass is cleared of trees, stumps, brush,

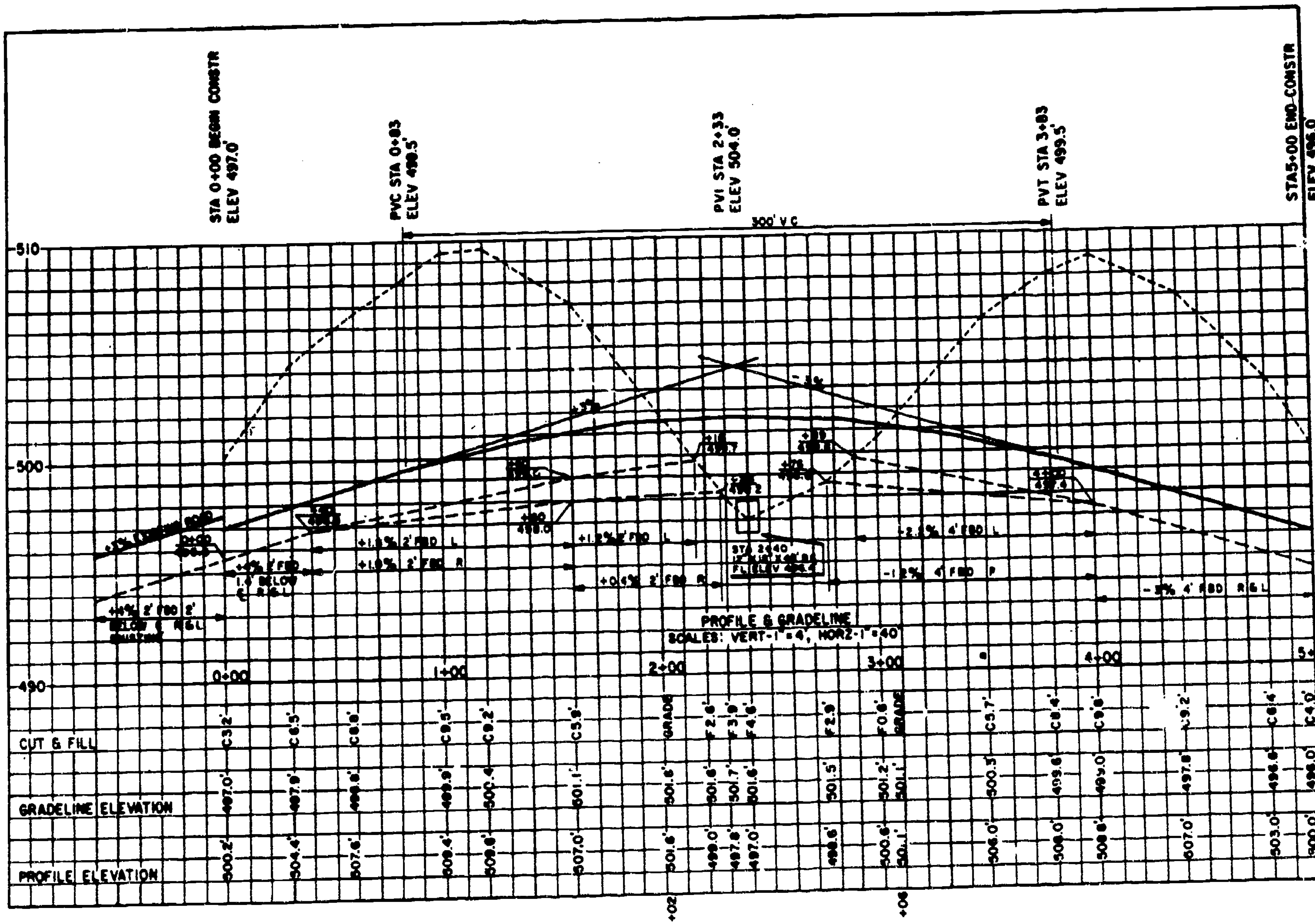


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Figure 5-5.—Profile and gradeline.

boulders, and other debris. The width of the clearing varies greatly but is always at least 12 feet greater than the roadway width. That is, there must be a minimum of 6 feet cleared behind the construction limits of each side of the road.

The next step is the laying of cross-drain pipes and grading operations. The culverts are placed at a predetermined location, positioned, and sloped, as shown on the roadway plans. The grading operations are carried on until the subgrade is brought up in layers and compacted. In cuts, the excavation is carried on until subgrade elevation is reached; the earth is then compacted.

After grading is complete, a base course is placed on the subgrade. This material can be gravel, sand, crushed stone, or more expensive and permanent materials. A surface course is placed over the base. This material can be sand-asphalt, blacktop, concrete, or similar materials.

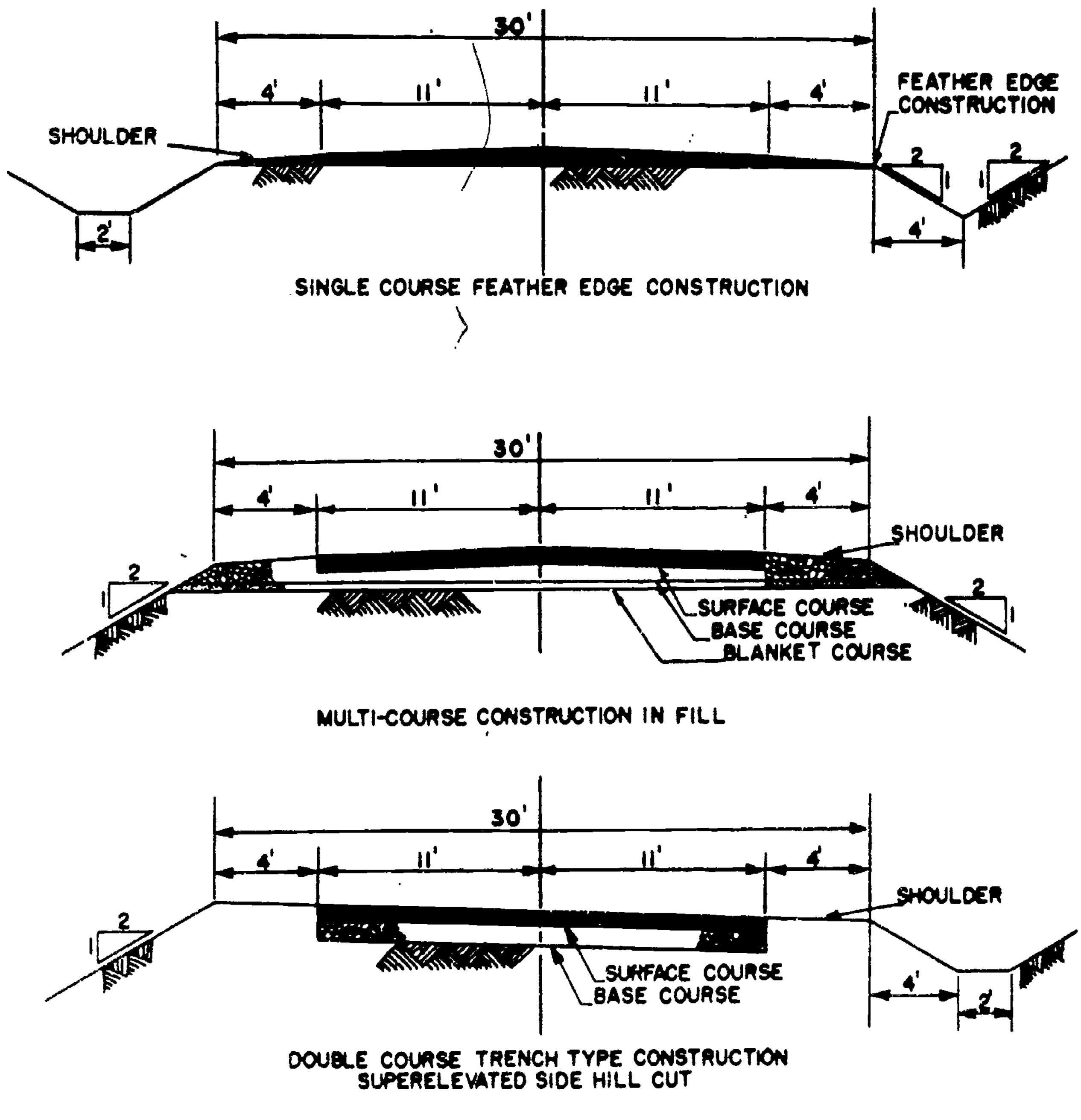

Figure 5-6.—Typical section.

In some cases, traffic may be allowed to travel over the subgrade itself. In others, traffic may require only a gravel or stone surface. But a base and a hard durable surface must be built for a high-speed road.

SECTIONS

In the construction of a road, there are certain conditions or requirements that must be met. One requirement is that the shape and features of the road be as uniform as possible. This and other requirements are stipulated in the typical section for the road. (See figure 5-6.)

To get a clear concept of what a typical section is, remember the meanings of section and typical. A section is a view of an object that has been cut by an imaginary plane perpendicular to the line of sight. Typical means having the essential characteristics. Here, the section is a view showing the road cut perpendicular to the line of sight which is parallel to the road centerline. To be typical, the section must show the type and thickness of base and surface material, the crown, superelevation, ditch slope, cut slope, fill slope, and all horizontal widths of the road components, such as surface, shoulders, and ditches. In other words, the typical section shows what the road would look like if it were cut at any point by a plane. Since in practice there will be slight discrepancies, a tolerance in construction is allowed. However, the shape and construction of the road should conform to the typical section as closely as possible. (For requirements and design criteria, refer to DM-5.)

The typical section for a curved road must also be shown if there are any curves throughout the length of the road. The only change would be the shape of the roadbed. The pavement would be a plane surface instead of crowned and would be superelevated to account for the centrifugal force encountered in curves. The outside shoulder slope is the same as the superelevated pavement slope, but the inside shoulder slope is either the same or a greater slope. (Inside shoulder refers to the shoulder closer to the center of the arc, or curve.)

Curves are also widened on the inside to allow for the "curve straightening" effect of long wheelbase vehicles. The back wheels of the trailer in a tractor-trailer rig would not follow in the tracks of the tractor wheels. They would run closer to the inside edge on the inside lane and closer to the centerline on the outside lane. This presents a safety hazard when two vehicles meet in curves. Curve widening partially eliminates this hazard.

Figure 5-7 is a superelevated section showing curve widening; table 5-1 lists the widening for various degrees of curvature. The angle, in degrees, is subtended by an arc or chord of 100 feet. Notice that the minimum curve widening is 2 feet, but it increases to 3 feet in sharper curves.

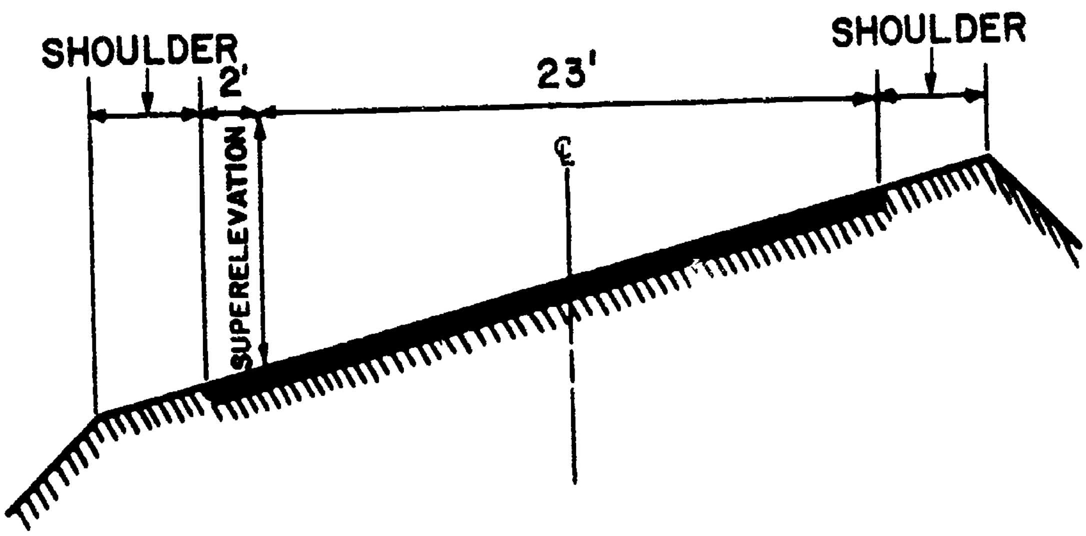

Figure 5-7.—Curve section.

Table 5-1.—Curve Table

Degree of curvature (degrees)	Radius of curvature (feet)	Superelevation (inches per foot)	Widening of two-way roads on curve (feet)
1°00'— 4°00'	5,730—1,432	1/4"/ft	2
5°00'— 7°00'	1,146— 819	3/8"/ft	2
8°00'— 9°00'	716— 637	5/8"/ft	2
10°00'—11°00'	572— 521	3/4"/ft	2
12°00'—13°00'	447— 441	7/8"/ft	3
14°00'—16°00'	409— 359	1"/ft	3
17°00'	337	1 1/4"/ft	3

CROSS SECTIONS

To determine how closely a road has been built to conform to the typical section, road cross sections are taken. Cross sections are usually taken 50 feet apart, on each station and half station, and on points which warrant them, such as entrances or side-road approaches. Cross sections, like typical sections, are views showing the road cut by a plane perpendicular to the line of sight which is parallel to the road centerline. Cross sections show the actual shape of the road, the horizontal width of components and their distances from centerline, the constructed elevations, and the extremities of the cut and fill. They also show the slopes of the surface, ditch, shoulders, cut, and fill. Known as FINAL CROSS SECTIONS, they are taken after the road is completed.

ORIGINAL CROSS SECTIONS are usually taken after the roadway has been cleared but may be taken before. If taken before, the thickness of the sod to be stripped off is normally deducted from the elevations. An original cross section shows the elevations of the natural, or original ground. They are taken on the same stations as the final cross sections.

The cross sections use the same horizontal and vertical scale in order to eliminate distortion. The scale is usually 4 or 5 feet to 1 inch, but it can vary. Distances given in cross section notes are always horizontal, and are plotted horizontally. The existing grade elevations given in the surveyor's notebook are correct to the nearest tenth (0.1) of a foot. (Example: 539.6 may actually be anywhere between 539.56 or 539.64.) Final elevations on finished pavement, however, are taken to the nearest hundredth (0.01) of a foot. (Example: 539.60.) The elevations and distances supplied by the surveyor's notebook should be plotted as accurately as possible. The only data needed for plotting are station numbers, elevations of the points, and their distances from centerline. The stations are given in the first column, and the elevations obtained by subtracting the figures above the horizontal slash in the figures on the right page, from the height of instrument (HI). The distances—left and right of the centerline are the numbers below the horizontal slashes. Figure 5-8 is an example of a cross section plotted from surveyor's notes.

To designate the point at which the section is taken, the station number of the section is given. If the section is in fill, the station number goes above the station and is centered on it. If it is cut, or cut and fill, the station number goes below and is centered.

DRAINAGE

Drainage is a major problem in the location, construction, and design of roads. A route should never be located where the drainage presents a problem that cannot be handled or would be too costly to handle. A route may have to be relocated because there is not enough material available to build a particular type of road. It could be due to a swamp or underground spring or high flood waters that can

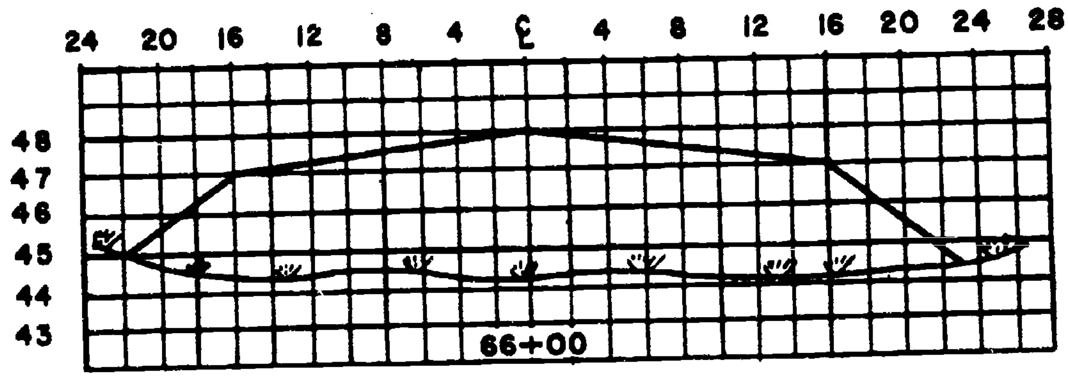

Figure 5-8.—Cross section.

cover the road, or flash floods that can completely wash out the road. These are some of the reasons for planning alternate routes. During construction, the problem of drainage is mainly one of preventing standing puddles on the roadway. This problem is solved by slanting the worked surface of the road so that water can run off quickly or by cutting ditches, called bleeders, so that the water may be carried away as it accumulates.

Subsurface drainage problems are solved by raising the gradeline of the road or lowering the water table. In either case, the distance between the water table and the top of the subgrade should be as great as possible. There are several ways of lowering the water table. In one way, deep open ditches are set back beyond the roadway limits. These ditches intercept the water table, allowing ground water to seep through the sides. The water then flows along the bottom and out the end of each ditch.

In another way of lowering the water table, a deep trench is dug exactly where the finished roadway ditch would be. The trench is then backfilled to a designated depth with rocks or large gravel of varying size, with the larger size at the bottom. The rocks are capped with a layer of branches or straw, and the remainder of the trench backfilled with soil and compacted. This trench is called a French drain (fig. 5-9). A tile drain is the same as the French drain, except that a perforated pipe or tile is placed in the bottom of the trench. The trench is then backfilled with gravel to the desired depth. The minimum pipe grade is 0.3 percent with the maximum varying to meet conditions.

Surface drainage involves water from direct precipitation, surface runoff, rivers, and streams. (Surface runoff is rainfall that is not absorbed by the soil, but runs off a surface in sheets or rivulets.) Rainfall has an immediate effect upon a roadway. Obviously, rainwater would cause safety hazards or weak spots on the roadway if it were allowed to stand. Water that falls upon the surface, or traveled way, is drained by crowning the surface. That is, constructing the traveled way so that the middle is higher than the edges.

The traveled way in curves is drained by superelevating the surface. That is, constructing the traveled way so that the inside edge of the curve is lower than the outside edge.

The water which drains from the surface continues over the shoulders. The shoulders always have a slope greater than, or at least equal to, the surface slope. This slightly increases the speed of the draining water and therefore increases the rate of drainage. The water then flows from the shoulder down the side of the fill, if in a fill section of roadway. If the section is in a cut, the water flows into a roadway ditch. Roadway ditches are not normally in a fill section.

Roadway Ditches

The functioning of a roadway ditch is the most important factor in roadway drainage. If this ditch, which runs alongside the roadway, becomes obstructed or is inadequate for the volume of water, then the roadbed becomes

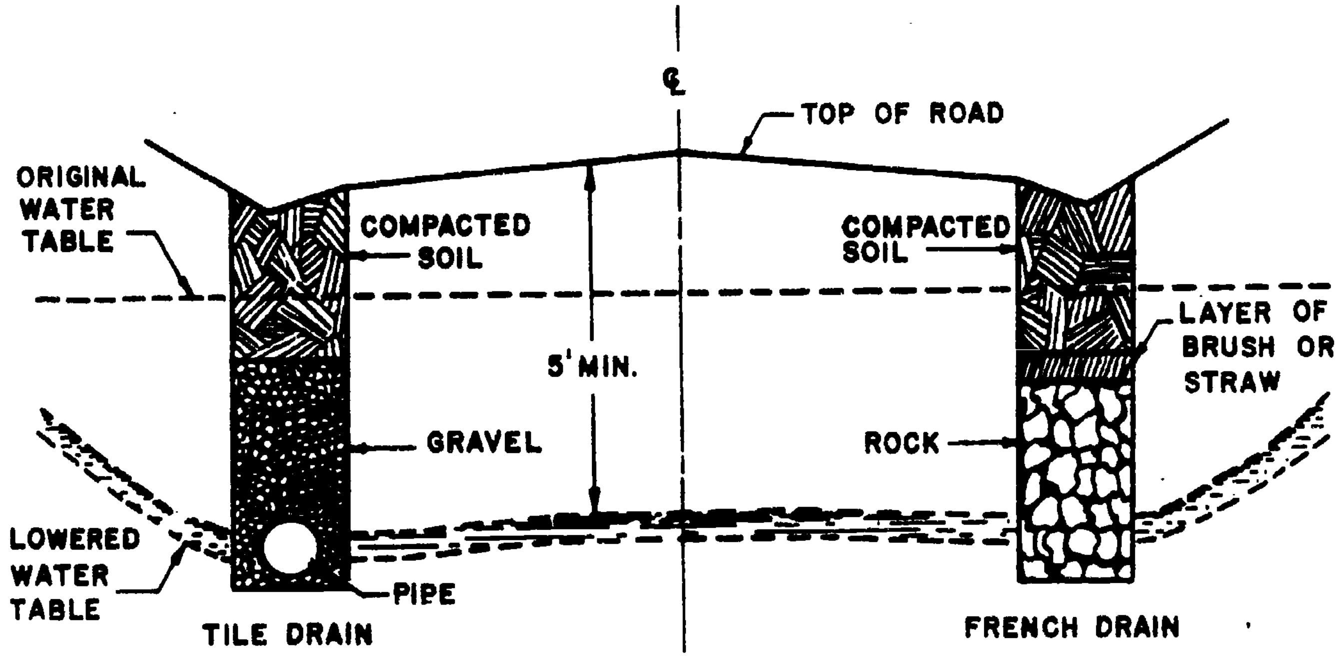

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Figure 5-9.—Subsurface drainage.

flooded. Not only can this block traffic, but it can also wash away surface and shoulder material.

There are several factors to consider in determining the size and type of roadway ditches: volume of water to be carried, the slope of the backslope, soil types, the "lay of the land," and the maximum and minimum ditch grades.

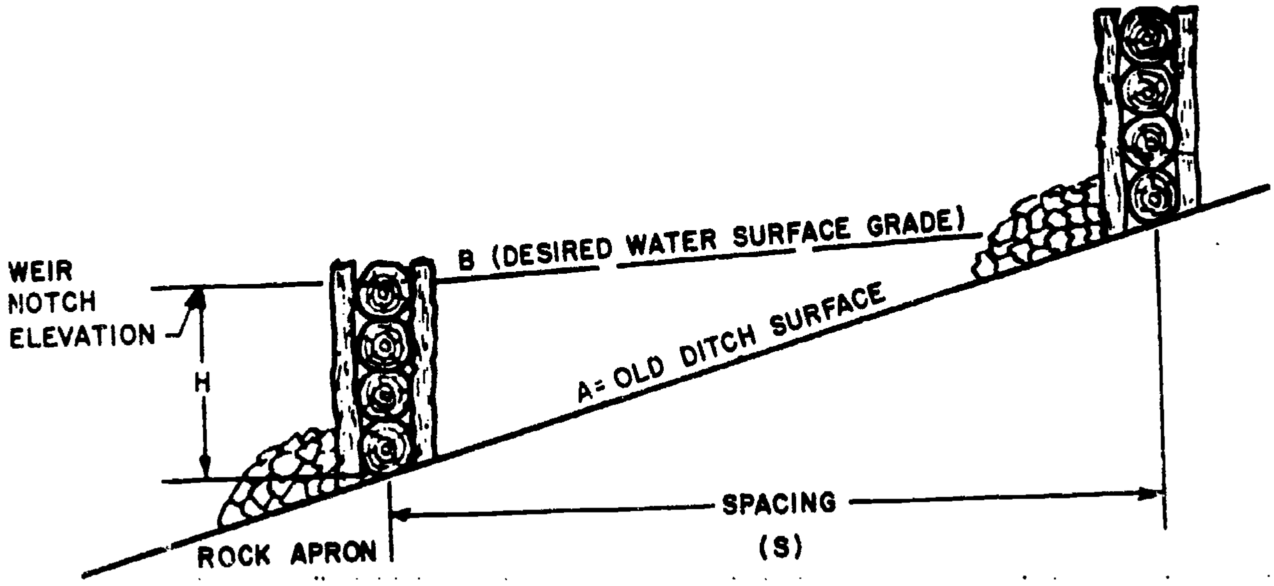
The slopes of the surface, shoulders, and backslopes affect the volume. A steep slope would increase the RATE of runoff, thereby causing a greater instantaneous volume of water in the ditch. On the other hand, a lesser slope would decrease the rate of runoff, but would expose more surface area on the backslope, which would increase the AMOUNT of runoff.

The choice of slopes to be used would be governed by other factors, however. The foremost are whether the additional excavation is needed in the roadway construction and the type of soil. A lesser slope would be required if the cut is in sand instead of clay or rock. The STANDARD CUT slope, or backslope, is 1 1/2:1 (1 1/2 foot horizontal, 1 foot vertical). This slope may be decreased for sandy soil, or greatly increased for rock cuts. The STANDARD DITCH slope, from the shoulder to the bottom of the ditch, is 3:1 (3 foot horizontal, 1 foot vertical). All these soil types have different amounts of runoff. The runoff from a sandy soil is small, but from a clay soil or solid rock, it is large.

An important design factor is the ditch grade itself. The minimum grade is 0.5 percent, and the desirable maximum grade is 4 percent. A grade greater than 4 percent would cause excessive erosion due to the greater velocity of the water. In this case, low dams of wood or stones, called check dams, (fig. 5-10), are built across the bottom of the ditch to slow the water down. In general, a moderate velocity is desirable because it prevents excessive erosion and can offset the ponding effect of slower moving water.

One factor involving the volume that cannot be controlled is the rainfall itself. The more intense the rainfall and the longer the duration, the greater the volume of water the ditch will have to carry. Local residents are sometimes helpful in determining the heaviest rainfall to expect in a particular area, as well as high-water marks along streams.

Besides the factors involving the volume of water, design of the ditch itself must be considered. Two common types of ditches are the



$$S = \frac{100\ H}{A\text{-}B}$$

Where H = height of checkdam in feet, measured from bottom of weir notch to bottom of ditch.

A = % grade of existing ditch.
B = desired % grade of proposed water surface.
(H can vary from 1 to 3 feet. A is usually known
B should be between 0.5% and 4%– desirably, 2%).

45.880

Figure 5-10.—Check dams.

V-bottom ditch and the flat bottom, or trapezoidal ditch (fig. 5-11). Under similar conditions, water flows faster in a V-bottom than in a trapezoidal ditch. The side slope for a shallow V-bottom is 4:1 or greater. For a deep V-bottom, the side slope is 3:1, 2:1, or 1:1. The side slope for a trapezoidal ditch is 3:1, 2:1, or 1:1. The flat bottom is generally 2 feet wide, but can range from 1 foot to 6 feet or more.

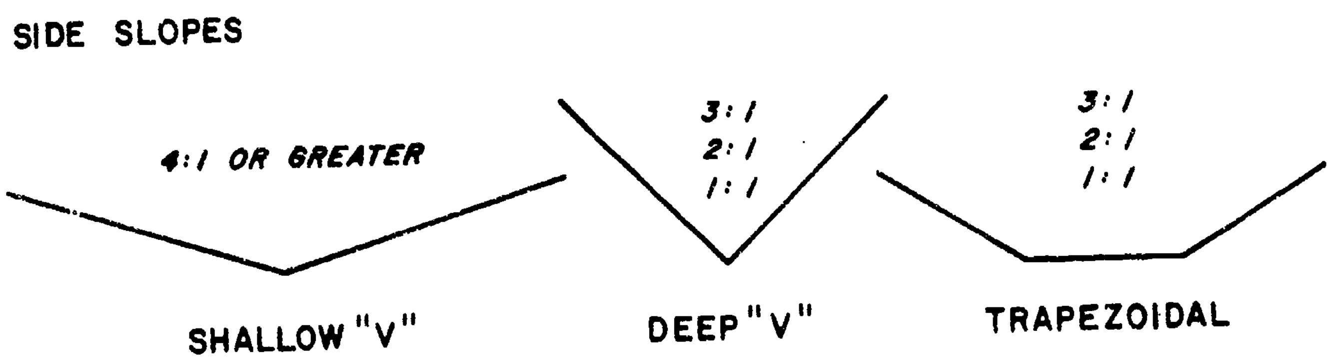


Figure 5-11.—Types of ditches.

Interceptor Ditches

The volume of water draining into a roadway ditch can be decreased by the use of shallow ditches that extend around the top of the cut and intercept the water draining from the original ground toward the roadway. An interceptor ditch (fig. 5-12) is dug 2 or 3 feet behind the backslope limits. Its size depends on the original ground slope, runoff area, type of soil and vegetation, and other factors relating to runoff volume.

Diversion Ditches

As it leaves the cut, water from the roadway ditches cannot be allowed to pond in the ditches or against the roadway fill. Therefore, diversion ditches are dug to carry the water away from the roadway to natural drains. These drains can be rivers, streams, gullies, sinkholes, natural depressions, or hollows.

Culverts

Sometimes it is necessary to have the water flow from one side of the road to the other or have the road cross a small stream. This is done with cross drains. They are called culverts if 10 feet or less in width. Over 10 feet wide, they are called bridges. Culverts are made of many materials, such as corrugated metal, concrete pipe, timber, logs, and open-ended oil drums.

The most desirable, under normal conditions, is the corrugated metal culvert. It is lightweight, easy to handle and assemble, compact for shipping, and relatively economical. The metal pipe comes in 2-foot half sections,

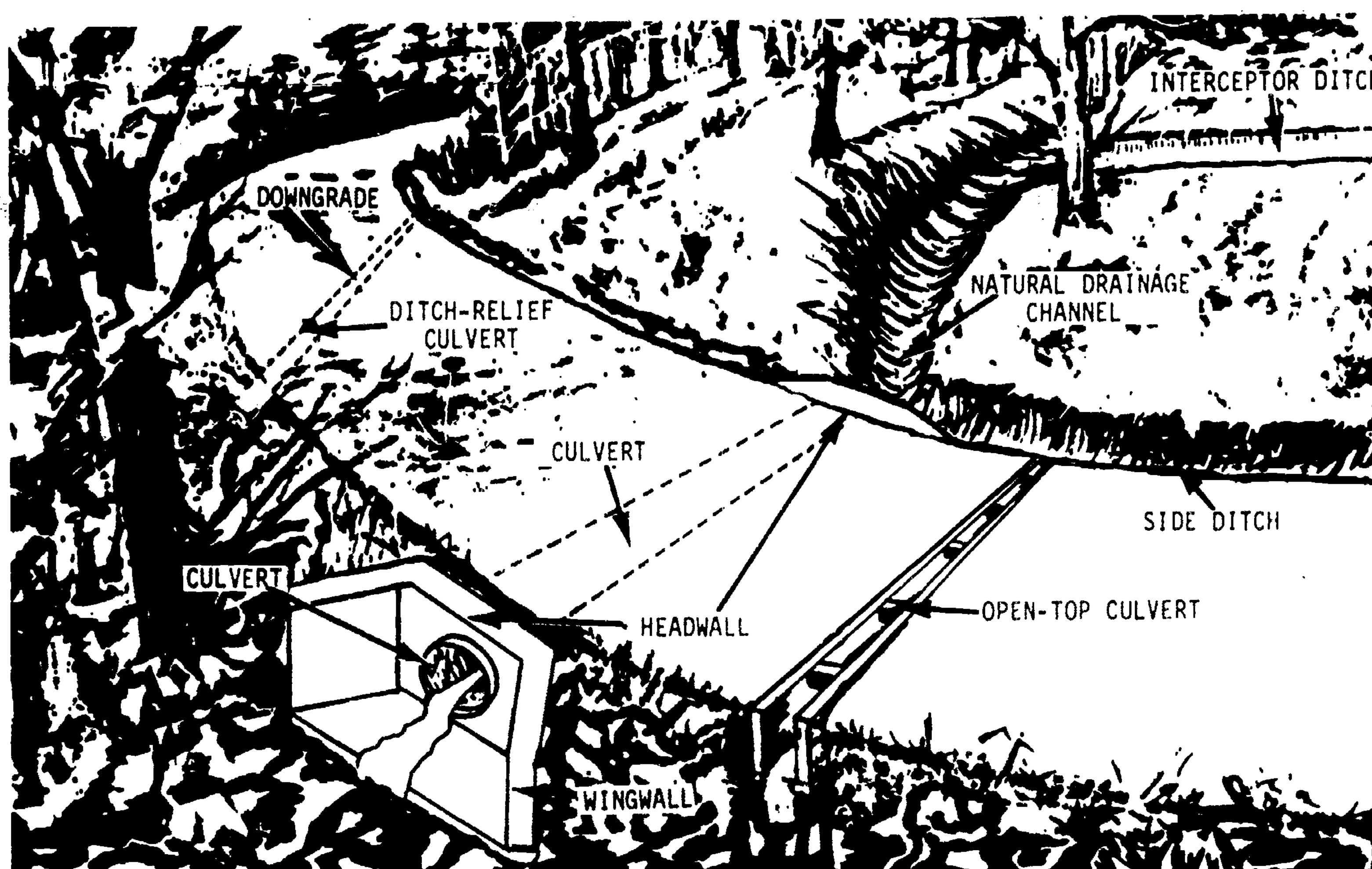


Figure 5-12.—Drainage systems.

with longitudinal flanges for bolting (view A, fig. 5-13). These sections are assembled to obtain the required length of culvert, so the culvert length has to be in even feet. In assembly, the top and bottom half sections are staggered in much the same manner as two courses of brick. At one end of the pipe, there will be 1 foot extending from the bottom on the other end, due to this staggering of sections. The metal is of different thicknesses, or gages, ranging from 8 to 14, with 8 being the thickest. The sizes range from 8 inches to 84 inches in diameter.

Concrete pipe is the strongest and most durable of the materials used in making culverts. The shell thickness and length depend on the pipe diameter. (The larger the diameter, the thicker the shell and longer the section.) Pipe diameters are nominal dimensions, that is, only the inside dimension. They do NOT include the thickness of the walls.

Timber culverts may be box culverts, with rectangular cross sections (view B, fig. 5-13), or log culverts (view C, fig. 5-13).

Sometimes the walls of a culvert are used only to contain the flow of water and support no load. For nonload supporting walls, sand bags, peat blocks, soapstone, or almost any material available can be used (view D, fig. 5-13).

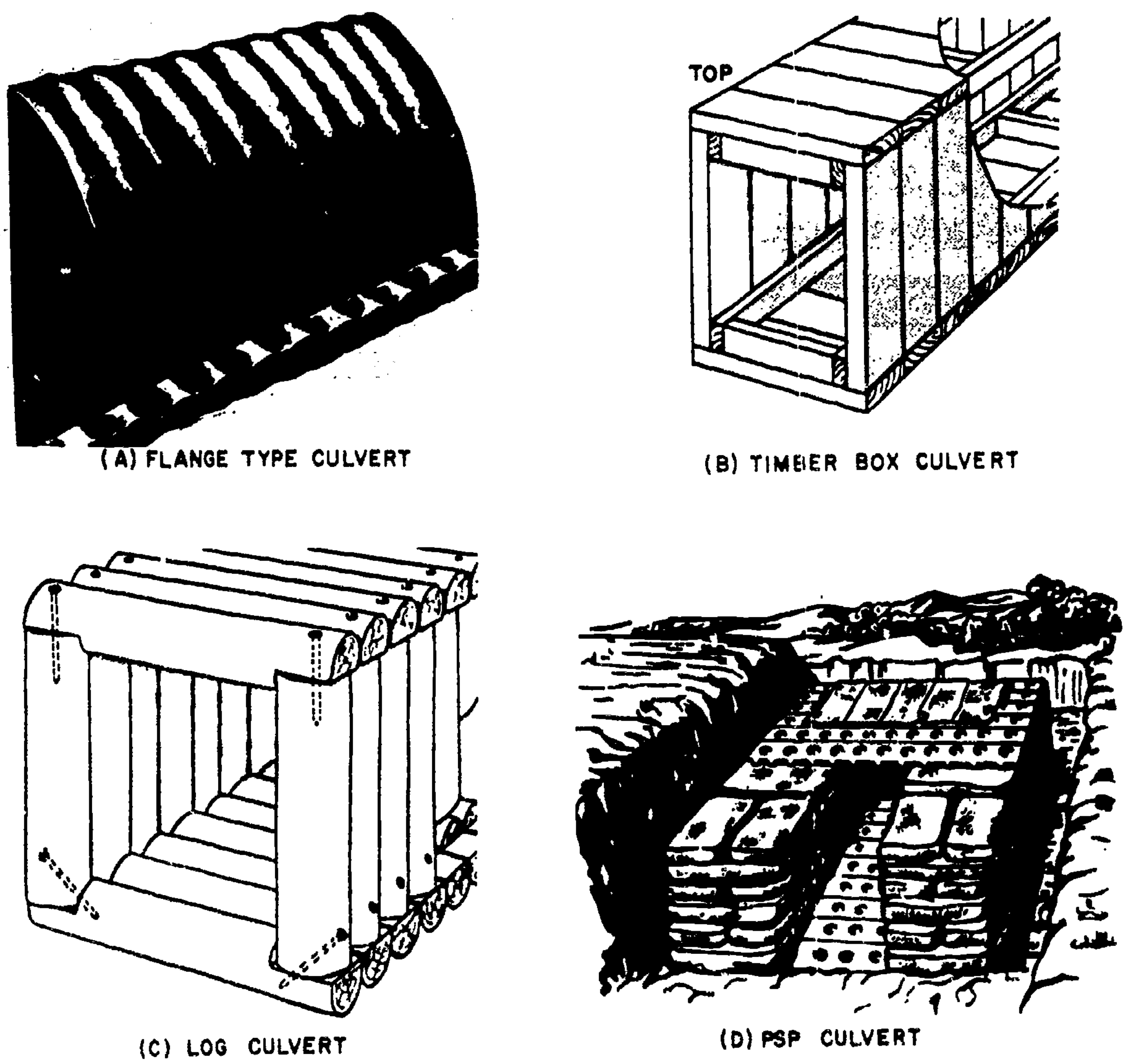


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Figure 5-13.—Types of culverts.

AIRFIELDS

An AIRFIELD is a group of facilities designed for takeoff, landing, servicing, fueling, and parking of fixed-wing and rotary-wing aircraft. Airfields are classified by the mission of the activity they support or by the types of aircraft for which facilities are provided. Regardless of the classification, the basic components of airfields and methods of construction are the same.

ELEMENTS OF AN AIRFIELD

The elements composing the airfield include runways, taxiways, aprons, and hardstands. Each element normally consists of a paved surface placed on a stabilized or compacted subgrade; shoulders and clear zones, normally composed of constructed inplace materials; and approach zones and lateral safety zones, which require only clearing and the removal of obstructions projecting above the prescribed glide and safety angle. These and other elements are defined below or shown in figure 5-14.

ANGLE, GLIDE. A small vertical angle measured outward and upward from the end of the flightstrip, above which no obstruction should extend within the area of the approach zone. It also indicates the safe descent angle for various types of aircraft and is expressed as a ratio horizontal distance to rise.

APPROACH ZONE. A trapezoidal area extending outward from each end of a flightstrip, within which no natural or manmade object may project above the glide angle.

APRON, PARKING. A prepared area used in place of hardstands for the parking of aircraft. It is also referred to as a conventional apron.

APRON, WARMUP. A stabilized or surfaced area used for the assembly or warming up of aircraft, usually located at both ends of the runway adjacent to and with the long axis parallel to the connecting taxiway.

CLEAR AREA. A rectangular area located adjacent to and outside of the runway shoulders, in which tree stumps are cut close to the ground, boulders removed, and the general area roughly graded to the extent necessary to reduce damage to aircraft in the event of erratic performance in which the aircraft runs off the runway.

CLEAR ZONE. A cleared area located at each end of the runway.

FLIGHTSTRIP. Includes entire area of the runway, shoulders, clear area, overruns, and clear zones.

FLIGHTWAY. Includes flightstrip area together with the two approach zones.

HARDSTAND. A stabilized or surfaced area provided to support standing aircraft. Hardstands are normally dispersed at intervals along each side of a taxiway.

LATERAL SAFETY ZONE. A transitional surface located between the runway clear area or runway edge when no clear area is provided and the clearance lines limiting the placement of building construction and other obstacles with respect to the runway centerline. The slope of the transitional surface is 7:1 outward and upward at right angles to the runway centerline.

OVERRUN. A graded and compacted portion of the clear zone, located at the extension of each end of the runway to minimize risk of accident to aircraft due to overrun on takeoff or undershooting on landing. Its length is normally equal to that of the clear zone, and its width is equal to that of the runway and shoulders.

ROAD, ACCESS. A two-way road, normally improved, connecting the airfield with the existing road system of the vicinity.

ROAD, SERVICE. A road connecting the access road and the bomb and fuel storage areas with all hardstands and aprons for the purpose of refueling, rearming, and servicing aircraft.

RUNWAY. A stabilized or surfaced rectangular area located along the centerline of the flightstrip on which aircraft normally land and take off.

SHOULDER. A graded and compacted area on either side of the runway to minimize the risk of accident to aircraft running off or landing off the runway.

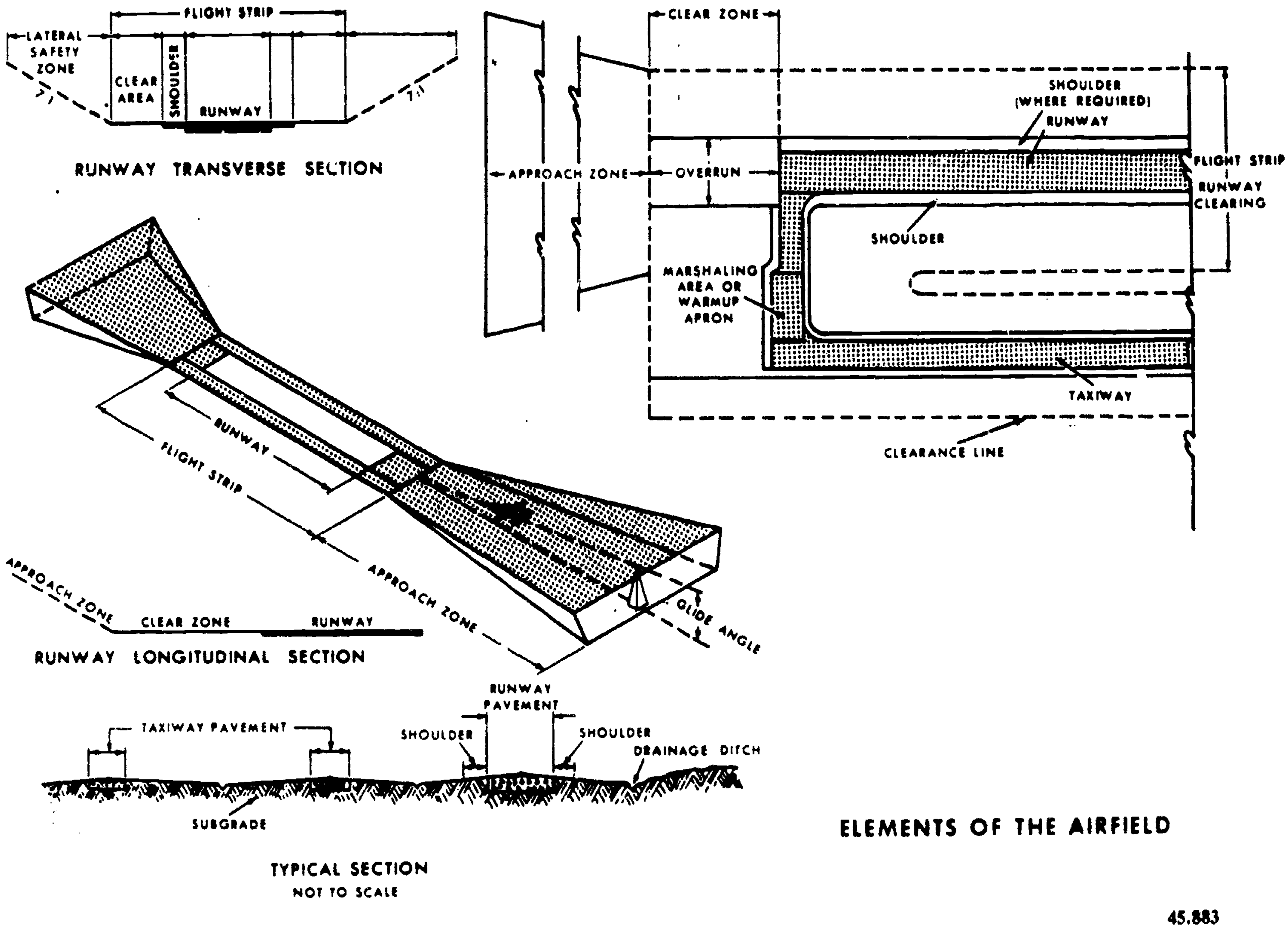

Figure 5-14.—Elements of the airfield.

TAXIWAY. A prepared strip for the passage of aircraft on the ground to and from the runway and parking areas. The width of the taxiway includes a stabilized, surfaced, or paved central strip.

TOUCHDOWN AREA. That portion of the beginning of the runway normally used by aircraft for primary contact of wheels on landing.

RUNWAY ORIENTATION

Normally, runways are oriented in accordance with the prevailing winds in the area. Particular attention should be paid to gusty winds of high velocity in determining the runway location. The established runway direction should insure 95 percent wind coverage. This requirement alone, however, should not cause rejection of a site which is otherwise favorable. Where dust may be a problem, orient the runway at an angle of about 10° to the prevailing wind so that dust clouds produced by takeoffs will blow diagonally off the runway. Wind data must be obtained indicating directions, velocity, and frequency of such occurrence. Wind data should normally be based on the

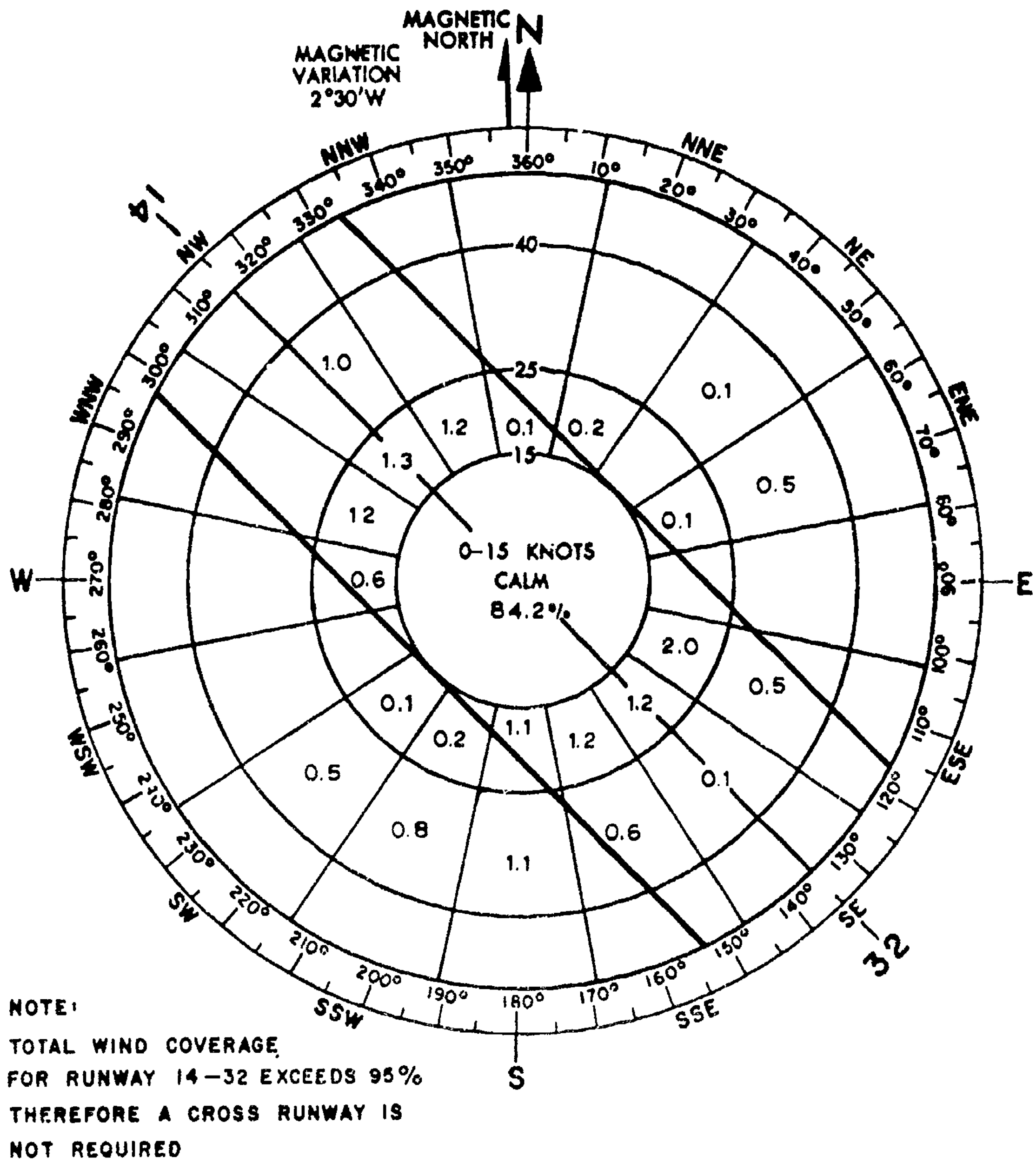

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Figure 5-15.—Wind rose (15-knot crosswind component).

average weather conditions for at least the last 5 years.

Such information usually can be found for all populated areas of the world, on both military and civilian maps, especially those prepared by marine or aeronautical agencies. If no observations are available for a particular site, observation of the nearest point should be adjusted to changes that will result locally from the topography or other influencing factors. Figure 5-15 shows a typical wind rose diagram (relative frequency and average strength of winds from different directions) components, and supporting data. To determine desirable runway orientations with respect to wind coverage, figure 5-16 shows tabulated wind coverage and the standard procedure. See figure 5-17 for allowance variations of wind direction.

Vertical Alinement

Airfield construction normally specifies a minimum length of each gradeline, or a minimum distance between the gradeline intersection points. Although the specification varies with the type of aircraft involved and the standard of construction desired, the most common minimum is 400 feet between points of vertical intersection. The vertical curve design for airfields is the same as that for roads. The only point of difference may occur where the curve is longer than the runway itself. In this case, the runway will be a segment of the curve and the PVC and PVT will be off the airfield. Care must be taken to avoid confusion in the stationing.

Airfield Layout

Figures 5-18 and 5-19 illustrate the typical dimensions and grade requirements for single and dual runway systems. Figure 5-20 shows a typical section, detail and grade requirements for both runways. Figures 5-21 and 5-22 show profiles and grade requirements for different types of end zones for fleet support and training airfields.

SUBBASE AND BASE COURSES

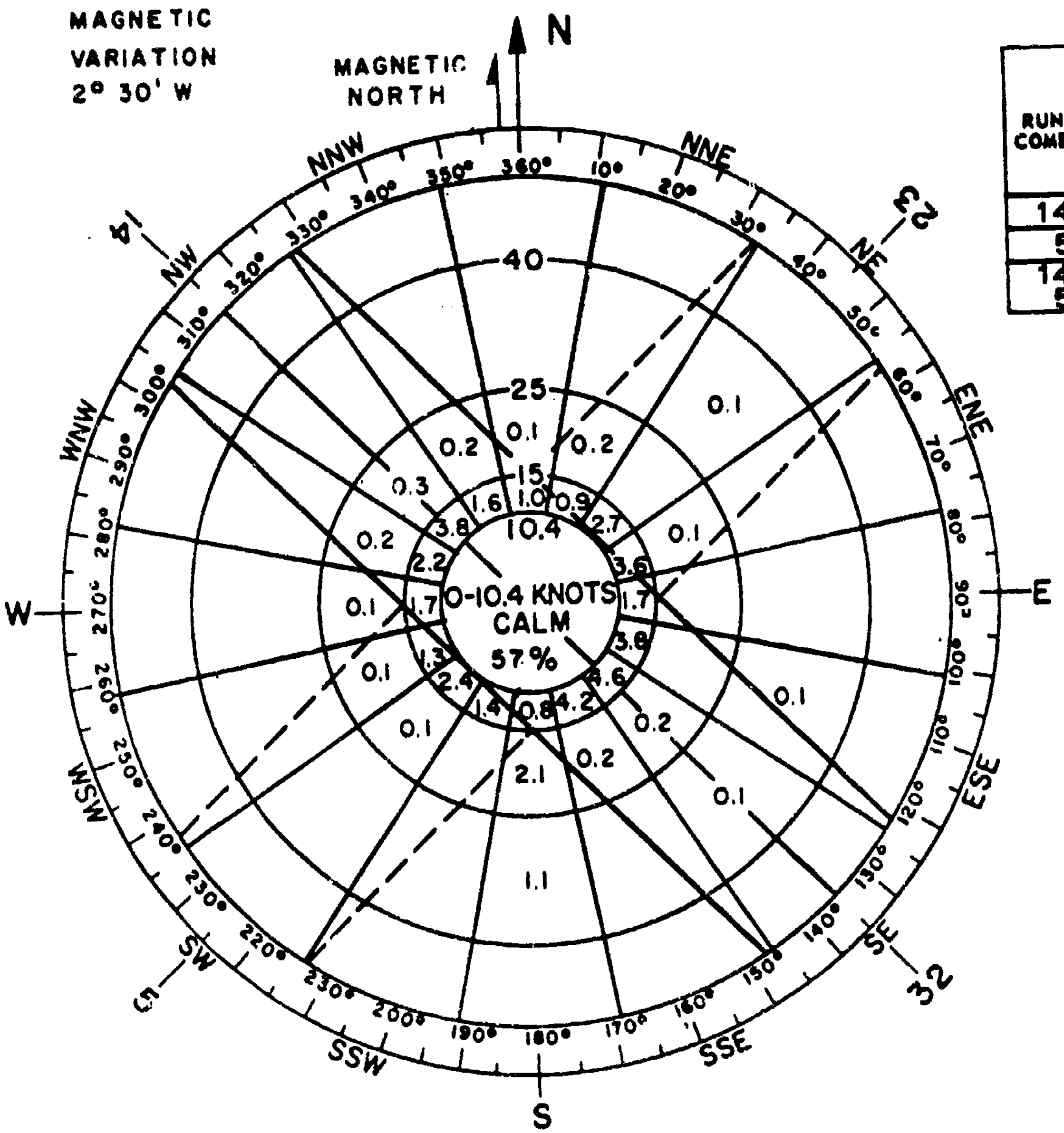
Pavements (including the surface and underlying courses) may be divided into two classes—rigid and flexible. The wearing surface of a rigid pavement is constructed of portland-cement concrete. Its flexural strength enables it to act as a beam and allows it to bridge over minor irregularities in the base or subgrade upon which it rests. All other pavements are classified as flexible. Any distortion or displacement in the subgrade of a flexible pavement is reflected in the base course and upward into the surface course. These courses tend to conform to the same shape under traffic. Flexible pavements are used almost exclusively in the theater of operations for road and airfield construction since they adapt to nearly all situations and can be built by any construction battalion unit in the NAVAL CONSTRUCTION FORCE.

FLEXIBLE PAVEMENT STRUCTURE

A typical flexible pavement is constructed as shown in figure 5-23, which also defines the parts or layers of pavement. All layers shown in the figure are not present in every flexible pavement. For example, a two-layer structure consists of a compacted subgrade and a base course only. Figure 5-24 shows a typical flexible pavement utilizing stabilized layers. (The word "pavement" when used by itself refers only to the leveling, binder, and surface course, whereas "flexible pavement" refers to the entire pavement structure from the subgrade up.) The use of flexible pavements on airfields must be limited to paved areas NOT subjected to detrimental effects of jet fuel spillage and jet blast. In fact, their use is prohibited in areas where these effects are severe. Flexible pavements are generally satisfactory for runway interiors, taxiways, shoulders, and overruns. Rigid pavements or special types of flexible pavement, such as tar rubber, should be specified in certain critical operational areas.

MATERIALS

Select materials will normally be locally available coarse-grained soils, although fine-grained soils may be used in certain cases. Limerock, coral, shell, ashes, cinders, caliche, disintegrated granite, and other such materials should be considered when they are economical.



10.4-KNOT CROSSWIND COMPONENT WIND ROSE

RUNWAY OR COMBINATION	WIND COVERAGE TABULATION					PERCENT COVERED
	PERCENT COVERED					
	0 TO 10.4 KNOTS	10.4 TO 15 KNOTS	15 TO 25 KNOTS	25 TO 40 KNOTS	40 & OVER KNOTS	
14 - 32	57.0	26.0	1.1	0.1	–	84.2
5 - 23	57.0	18.4	0.5	0.1	–	76.0
14 - 32 5 - 23	57.0	37.7	1.6	2.0	–	96.5

PROCEDURE

To determine desirable runway directions an overlay consisting of three parallel lines is used on the wind rose. The distance between the two outer lines of the overlay is equal to the diameter of the innermost circle of the wind rose. The third line is the centerline and represents the runway centerline.

Place centerline of overlay across center of wind rose and rotate until sum of percentage appearing between outer two lines, including fractional portions of segments, becomes a maximum. In this example a single runway direction (solid overlay lines) provides only a maximum of 84.2% wind coverage. Since the total wind coverage is less than the 95% required for an airfield, a secondary or crosswind runway is required.

Place overlay (dashed lines) to form the preferred 90° angle with primary runway, 60° is the minimum allowable, and total the wind coverage provided by both runways which is 96.5%.

Above example uses the wind rose with crosswind component of 10.4 knots which is criteria for airfields with conventional gear aircraft operations. Using wind rose with 15 knot crosswind component, see Figure 5-15 which is the allowable for aircraft with tricycle gear.

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Figure 5-16.—Determination of runway direction using wind rose.

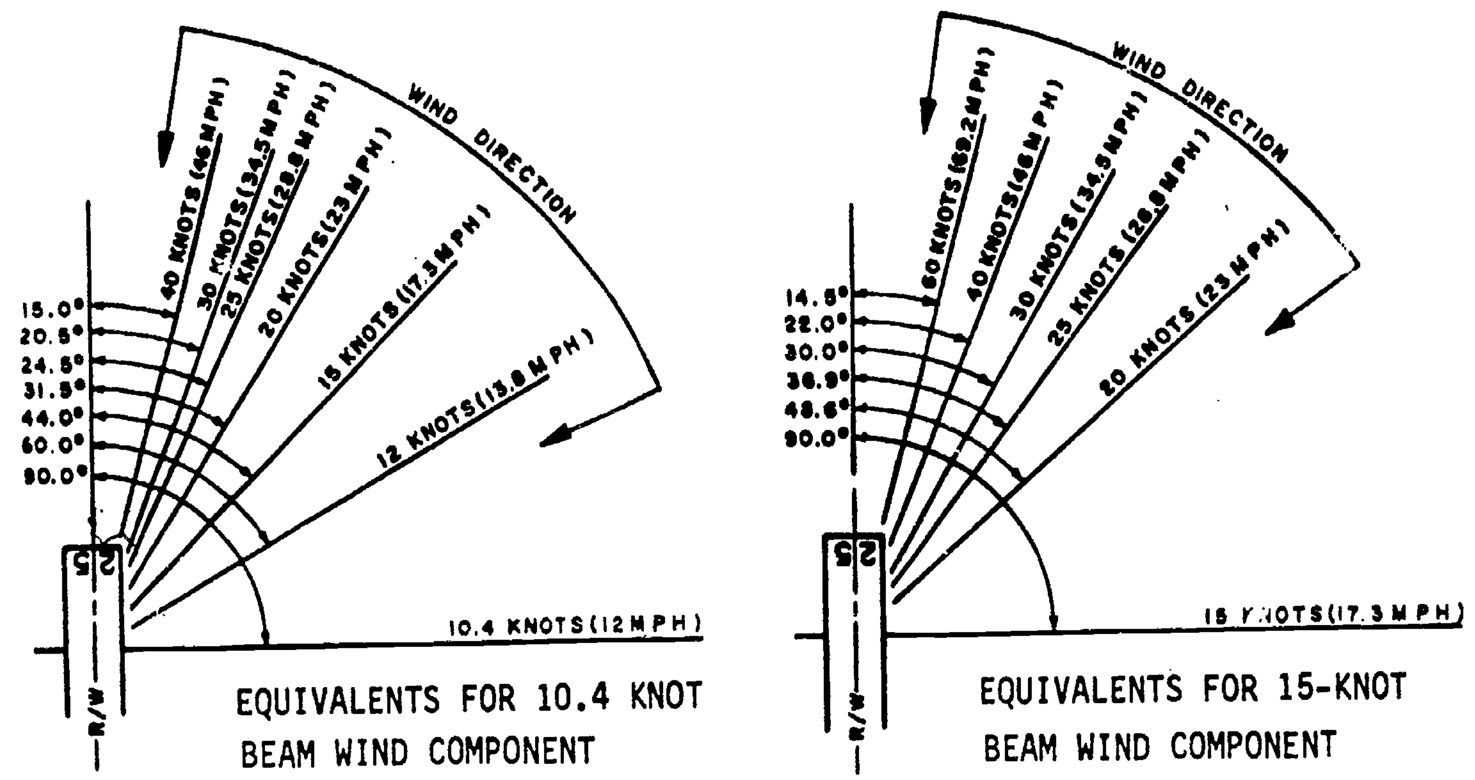

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Figure 5-17.—Allowable wind variations for 10.4 and 15-knot beam wind components.

Subbase

Subbase materials may consist of naturally occurring coarse-grained soils or blended and processed soils. Materials, such as limerock, coral, shell, ashes, cinders, caliche, and disintegrated granite may be used as subbases when they meet area specifications or project specifications. Materials stabilized with commercial admixes may be economical as subbases in certain instances. Portland cement, cutback asphalt, emulsified asphalt, and tar are commonly employed for this purpose.

Base Course

A wide variety of gravels, sands, gravelly and sandy soils, and other natural materials such as limerock, corals, shells, and some caliches can be used alone or blended to provide satisfactory base courses. In some instances, natural materials will require crushing or removal of the oversize fraction to maintain gradation limits. Other natural materials may be controlled by mixing crushed and pit-run materials to form a satisfactory base course material.

Many natural deposits of sandy and gravelly materials also make satisfactory base materials. Gravel deposits vary widely in the relative proportions of coarse and fine material and in the character of the rock fragments. Satisfactory base materials often can be produced by blending materials from two or more deposits. A base course made from sandy and gravelly material has a high-bearing value and can be used to support heavy loads. However, uncrushed clean-washed gravel is not satisfactory for a base course, because the fine material which acts as the binder and fills the void between coarser aggregate has been washed away.

Sand and clay in a natural mixture may be found in alluvial deposits varying in thickness from 1 to 20 feet. Often there are great variations in the proportions of sand and clay from

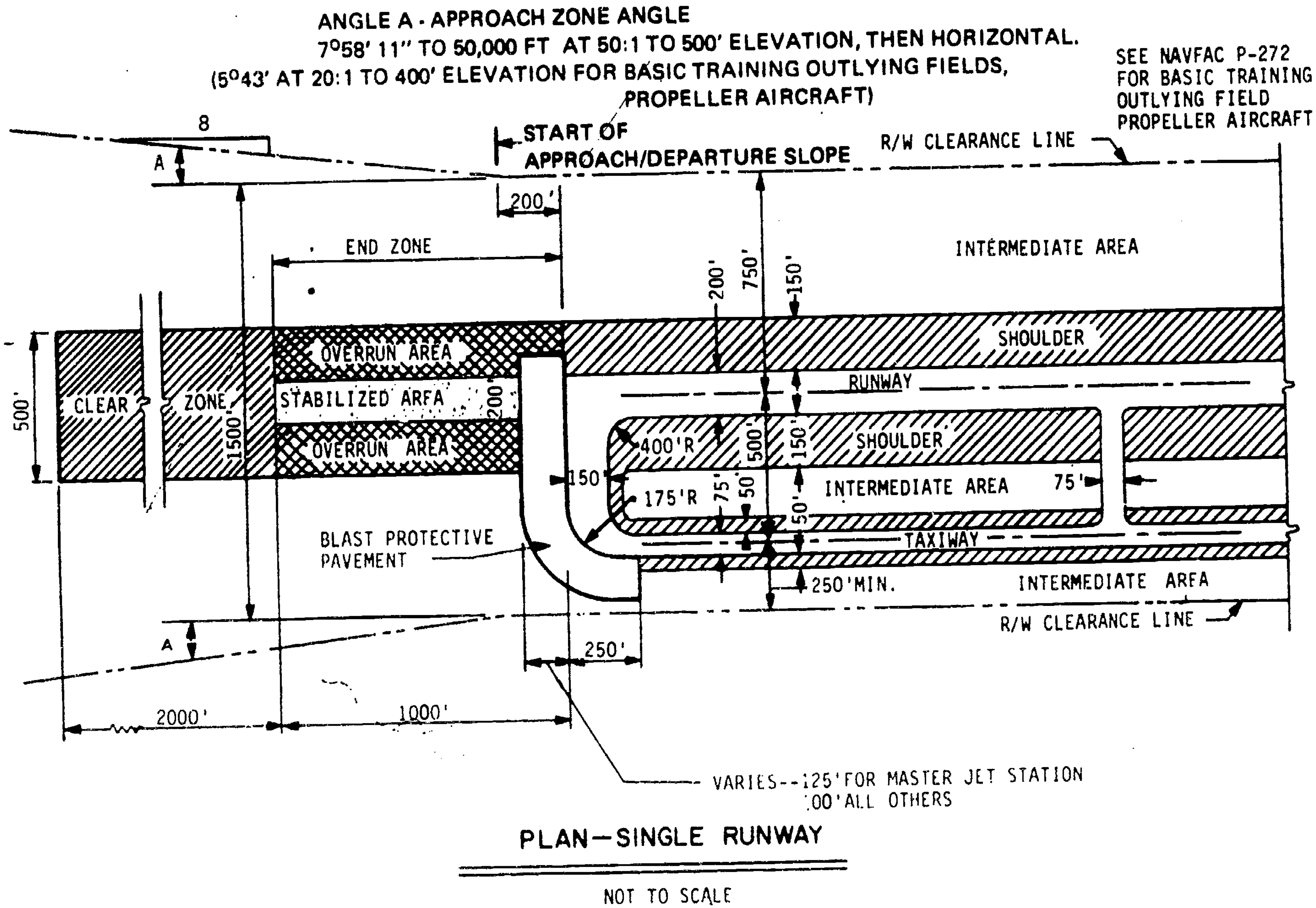

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Figure 5-18.—Plans—single runway.

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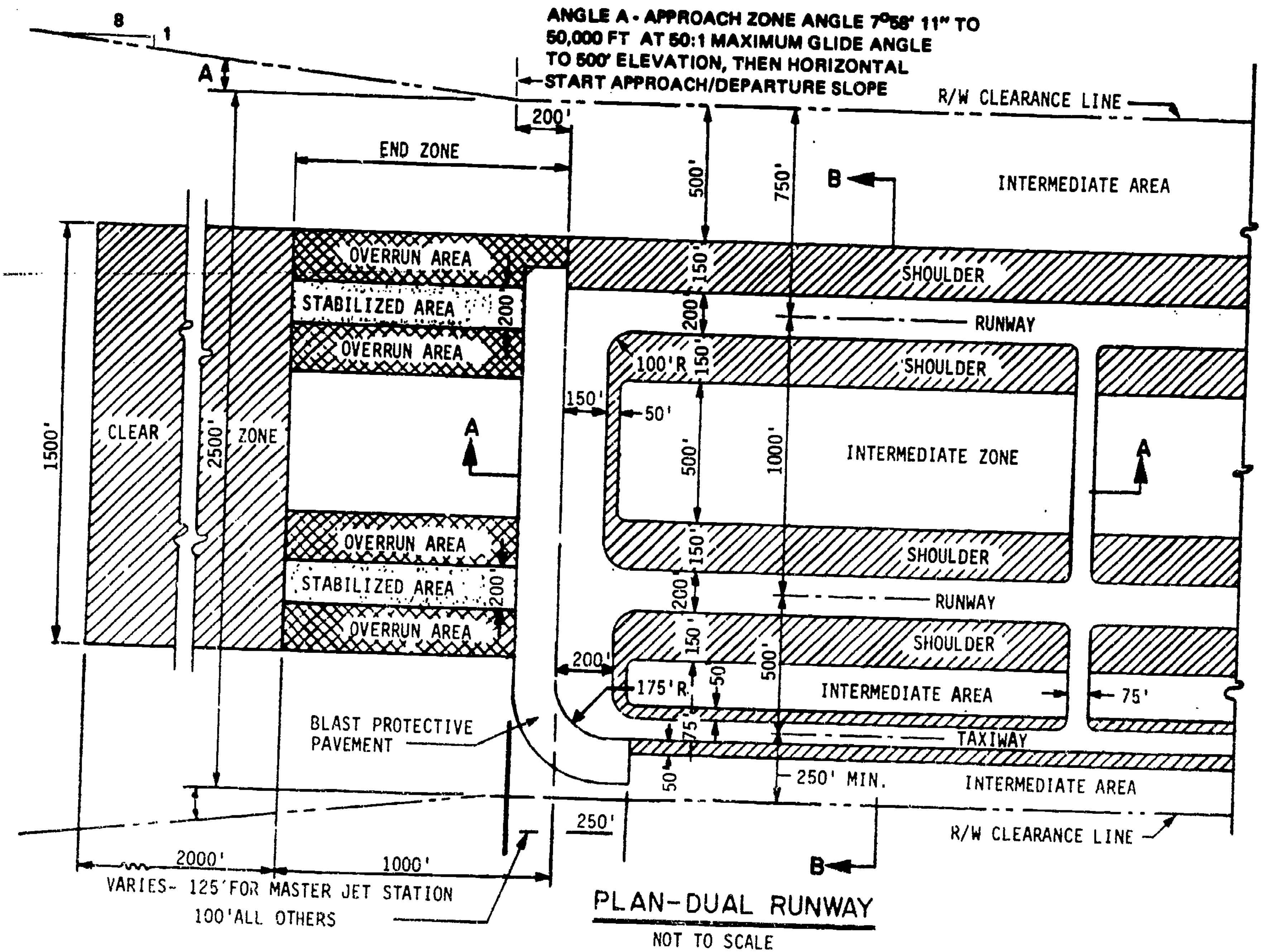

Figure 5-19.—Plans—dual runway.

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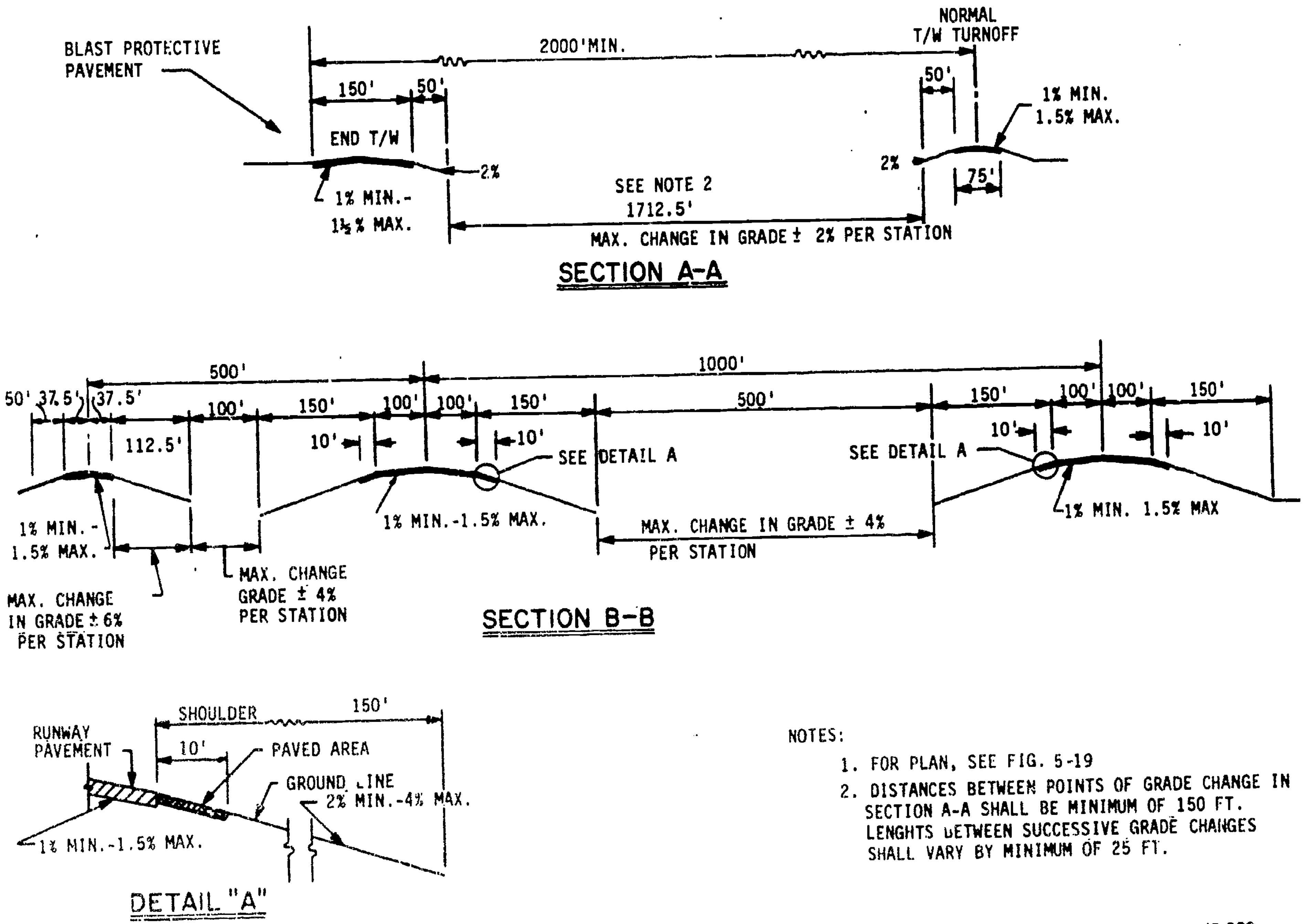

Figure 5-20.—Single and dual runways (sections and details).

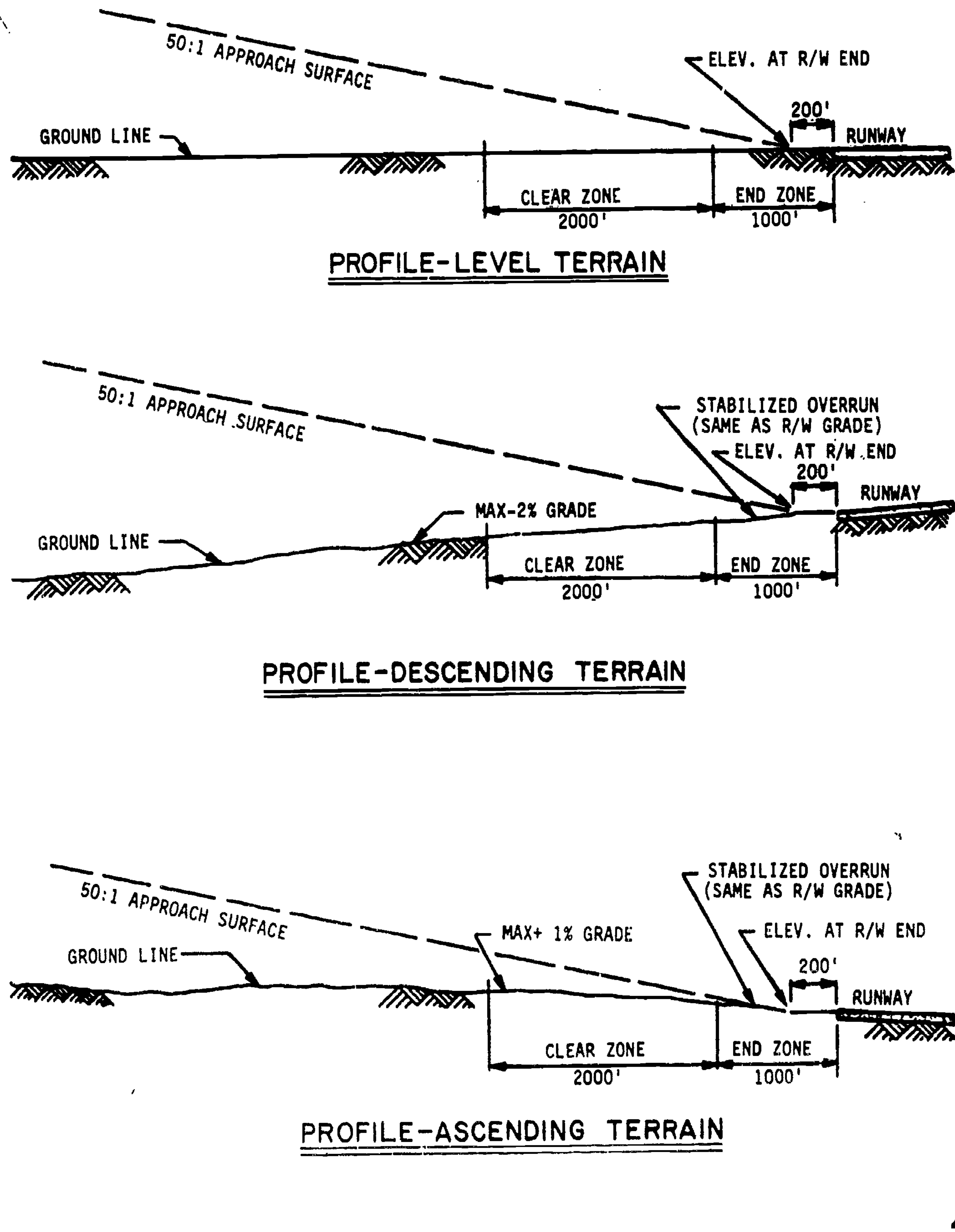

Figure 5-21.—Longitudinal end zone grades (fleet support and advanced training airfields).

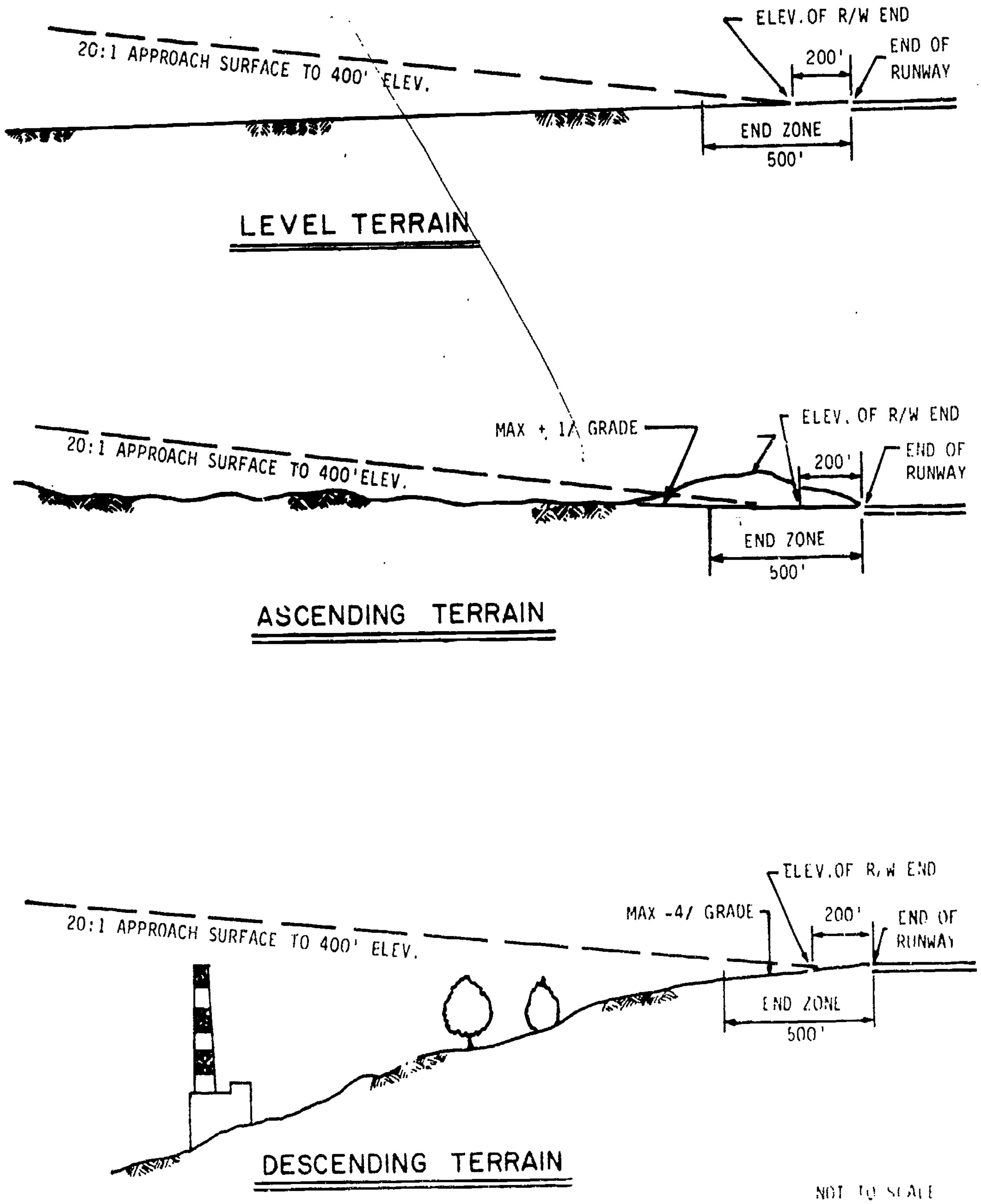

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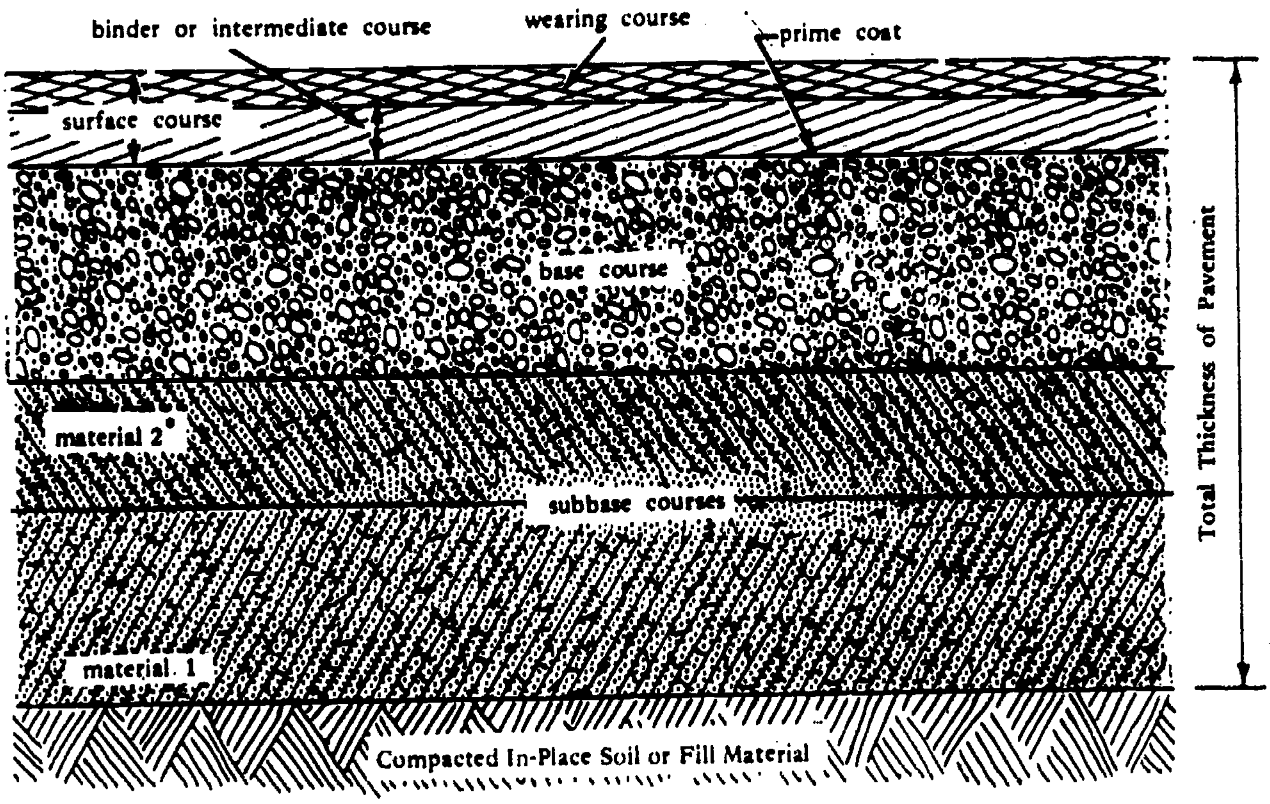
Figure 5-23.—Longitudinal end zone grades (basic training outlying fields, propeller aircraft, only).



*Material 2 is of a higher quality than material 1.

PAVEMENT	Combination of subbase, base, and surface constructed on subgrade
SURFACE COURSE	A hot mixed bituminous concrete designed as a structural member with weather and abrasion resisting properties. May consist of wearing and intermediate courses.
PRIME COAT	Application of a low viscosity liquid bitumen to the surface of the base course. The prime penetrates into the base and helps bind it to the overlying bituminous course
SEAL COAT	A thin bituminous surface treatment containing aggregate used to waterproof and improve the texture of the surface course
COMPACTED SUBGRADE	Upper part of the subgrade which is compacted to a density greater than the soil below
TACK COAT	A light application of liquid or emulsified bitumen on an existing paved surface to provide a bond with the super imposed bituminous course
SUBGRADE	Natural in-place soil, or fill material

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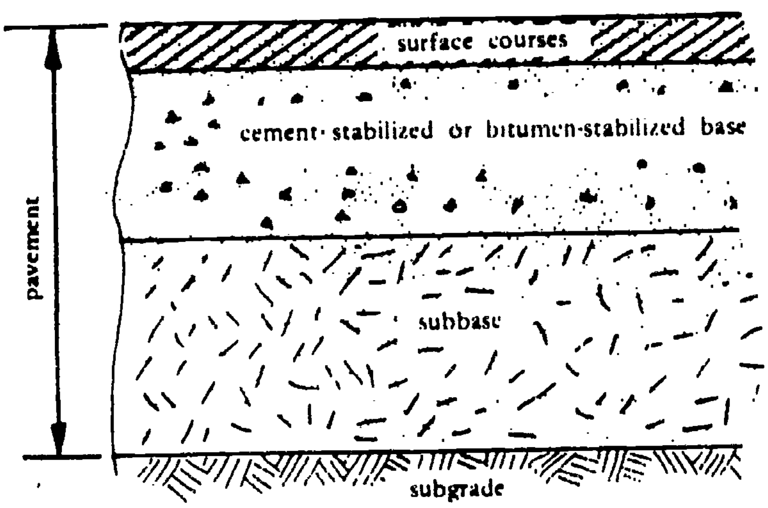
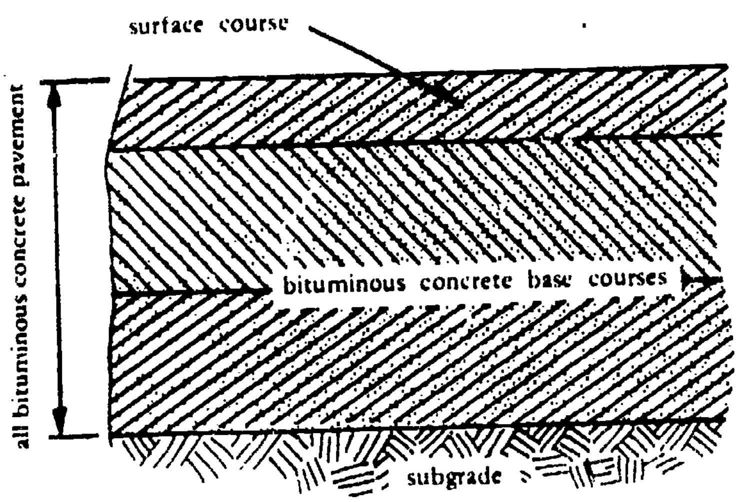
Figure 5-23.—Typical flexible pavement and terminology.



STABILIZED BASE SECTION



ALL BITUMINOUS CONCRETE PAVEMENT

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Figure 5-24.—Typical pavements utilizing stabilized layers.

the top to the bottom of a pit. Deposits of partially disintegrated rock consisting of fragments of rock, clay, and mica flakes should not be confused with sand-clay soil. Mistaking such material for sand clay is often a cause of base-coarse failure because of reduced stability due to the mica content. With proper proportioning and construction methods, satisfactory results can be obtained with sand-clay soil. It is excellent in construction where a higher type of surface is to be added later.

Processed materials are prepared by crushing and screening rock, gravel, or slag. A properly graded crushed-rock base produced from sound, durable rock particles makes the highest quality of any base material. Crushed rock may be produced from almost any type of rock that is hard enough to require drilling, blasting, and crushing. Existing quarries, ledge rock, cobbles and gravel, talus deposits, coarse mine tailings, and similar hard, durable, rock fragments are the usual sources of processed materials. Materials which crumble on exposure to air or water should not be used. Nor should processed materials be used when gravel or sand-clay are available, except when studies show that the use of processed materials will save time and effort or when they are made necessary by project requirements. Bases made from processed materials can be divided into three general types—stabilized, coarse graded, and macadam. A stabilized base is one in which all the material ranging from coarse to fine is intimately mixed either before or as the material is laid into place. A coarse-graded base is composed of crushed rock, gravel, or slag. This base may be used to advantage when it is necessary to produce crushed rock, gravel, or slag on site or when commercial aggregates are available. A macadam base is one where a coarse, crushed aggregate is placed in a relatively thin layer and rolled into place; then fine aggregate or screenings are placed on the surface of the coarse-aggregate layer and rolled and broomed into the coarse rock until it is thoroughly keyed in place. Water may be used in the compacting and keying process. When water is used, the base is a waterbound macadam. The crushed rock used for macadam bases should consist of clean, angular, durable particles free of clay, organic matter, and other objectionable material or coating. Any hard, durable crushed aggregate can be used, provided the coarse aggregate is primarily one size and the fine aggregate will key into the coarse aggregate.

Other Materials

In a theater of operations where deposits of natural sand and gravel and sources of crushed rock are not available, base courses are developed from materials that normally would not be considered. These include caliche, limerock, shells, cinders, coral, iron ore, rubble, and other select materials. Some of these are primarily soft rock and are crushed or degraded under construction traffic to produce composite base materials. Others develop a cementing action which results in a satisfactory base.

CORAL.—Uncompacted and poorly drained coral often results in an excessive moisture content and loss of stability. The bonding properties of coral, which are its greatest asset as a construction material, vary with the amount of volcanic impurities, the proportion of fine and coarse material, age, length of exposure to the elements, climate, traffic, sprinkling, and method of compaction. Proper moisture control, drainage, and compaction are essential to obtain satisfactory results.

CALICHE.—A variable material which consists of sand, silt, or even gravel, when saturated with water, compacted, and allowed to settle, can be made into high quality base courses. Especially, caliches which are cemented with lime, iron oxide, or salt. Caliches vary, however, in content (limestone, silt, and clay) and in degree of cementation; therefore, it is important that caliche of good uniform quality be obtained from deposits and that it be compacted at optimum moisture.

TUFF.—A porous rock, usually stratified, formed by consolidation of volcanic ashes, dust, etc., and other cementitious materials of volcanic origin may be used for base courses. Tuff bases are constructed the same as other base courses except that after the tuff is dumped and spread, the oversize pieces are broken and the base compacted with sheepsfoot rollers. The surface is then graded, compacted, and finished.

RUBBLE.—It may be advantageous to use the debris or rubble of destroyed buildings in constructing base courses. If so, jagged pieces of metal and similar objects are removed.

Bituminous Base

Bituminous mixtures frequently are used as base courses beneath high-type bituminous pavements, particularly for rear-area airfields which carry heavy traffic. Such base courses may be used to advantage when aggregates locally available are relatively soft and otherwise of relatively poor quality, when mixing plant and bituminous materials are readily available, and when a relatively thick surface course is required for the traffic. In general, a bituminous base course may be considered equal on an inch-for-inch basis to other types of high-quality base courses. When a bituminous base course is used, it will be placed in lifts not exceeding 3 1/2 inches in thickness. If a bituminous base is used, the binder course may be omitted and the surface course may be laid directly on the base course.

CHAPTER 6

CONSTRUCTION DRAWINGS

The construction of any structure or facility is described by a set of related drawings which gives the crew 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 graphic and printed instructions for each phase of construction. Generally, construction drawings are categorized according to their intended purposes: preliminary drawings, presentation drawings, shop drawings, and working drawings.

PRELIMINARY DRAWINGS

The preliminary drawings are the initial drawings prepared by the designer or A and E firm (architects and engineers) 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 as a basis for the preparation of the finished working drawings.

Most of the design work incorporated in the preliminary drawings includes the majority of the architectural, structural, electrical, and mechanical ideas and concepts. A set of preliminary drawings will usually contain only a site plan, floor plan, one or two elevations, and a typical wall section.

Because they are no longer useful after the working drawings are prepared from them, only a few sets of preliminary drawings are normally prepared.

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 usually consist of perspective views complete with colors and shading. Since presentation drawings are actually used to "sell" an idea or design, 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 some portion of the work prepared by the construction contractor, subcontractor, manufacturer, distributor, or supplier. Samples are physical examples which illustrate materials, workmanship or equipment and establish standards by which the work will be judged. Product data, such as brochures, illustrations, standard schedules, performance charts, and other information are furnished by the contractor or the manufacturer to illustrate a material, a product, or a system for some portion of the work. As an EA, you will be required to draft shop drawings for minor shop and field projects. They may include shop items, such as doors, cabinets, and small portable buildings: (prefabricated berthing quarters, and modifications of existing structures) or from portions of design drawings, specifications, or from freehand sketches given by the design engineer.

WORKING DRAWINGS

A working drawing is any drawing that furnishes the information required by the craftsmen to manufacture a machine part or 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 so that the builder who uses them will require no further information. A complete set of drawings consists of DETAIL DRAWINGS, ASSEMBLY DRAWINGS, and must include a BILL OF MATERIALS.

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 from the dimensions of the detail drawings, which provide a check on the accuracy of the design and detail drawings and often discloses errors.

Depending on the space available on the drawing sheet, the bill of materials may be incorporated in the drawing; otherwise, it is listed in a separate sheet. The bill of materials lists the quantities, types, sizes, and units of the materials required to construct the object presented in the drawing.

Actually, working drawings are drawn for the guidance of the supervisors and contractors who do the actual construction. Most of them consist of orthographic projections, though sometimes details may be shown in isometric or cavalier projections. "General" drawings consist of "plans" (views from above) and elevations (side or front views) drawn on a relatively small scale.

In general, working drawings include all of the drawings necessary for the different SEABEE ratings to complete a building. These are the drawings that show the size, quantity, location, and relationship of the building parts. Generally, working drawings may be divided into three main categories: architectural, mechanical, and electrical.

Regardless of the category, working drawings serve several functions:

—they provide a basis for making material, labor, and equipment estimates prior to construction.

—they give instructions for construction, showing the sizes and location 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.

Since mechanical and electrical plans will be discussed in chapters 7 and 8, we will only cover the architectural plans in this section. But, before we discuss these drawings in detail, we will go over the standard conventions, abbreviations and symbols used in the working drawings. You, as the EA, must be able to recognize and interpret them in order to draw and understand the plans.

SITE PLANS

A site (plot) plan (fig. 6-1) is a plan view that shows the contours, boundaries, roads, utilities, trees, structures, and any other significant physical features on or near the construction site. The location of the proposed structure is shown in outline form. The reference lines are shown on the plot plan which can be located at the site. Thus, the site plan furnishes the essential data for laying out the building lines. By showing both existing and finish contours, the Equipment Operator (EO) is able to landscape the area.

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" = 10' or 1" = 20'.

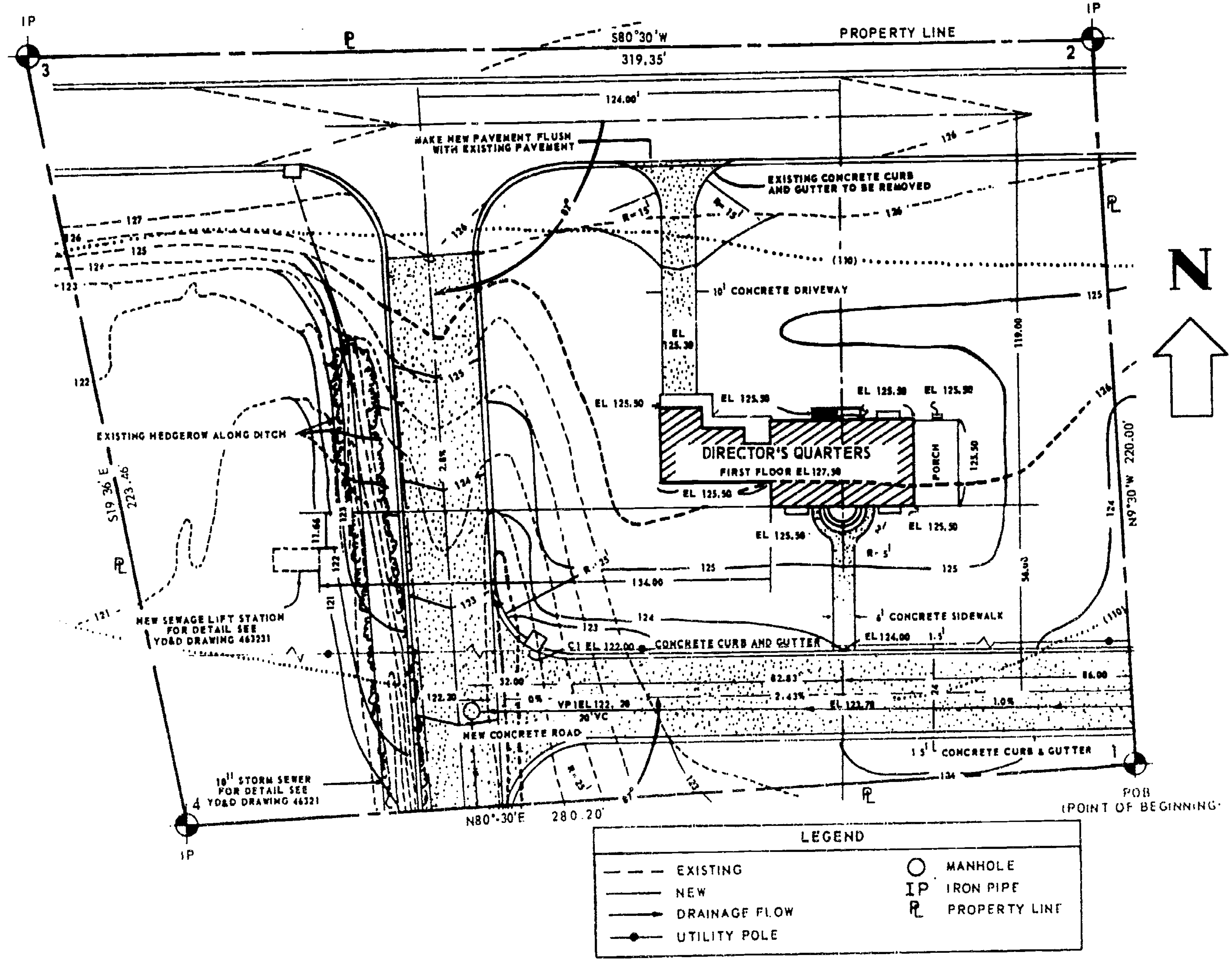

Figure 6-1.—Site plan.

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This means that 1 inch on the drawing is equal to 10 or 20 feet, whatever the case may be on the ground. Since the engineer's scale is the chief means of making scaled site plans, you, as an EA, should be thoroughly familiar with its uses.

In most cases, when the battalion is tasked with a construction project, the drawings have been prepared by a civilian firm or architects and engineers (A and E) that are under contract with the government; but in some instances, where the

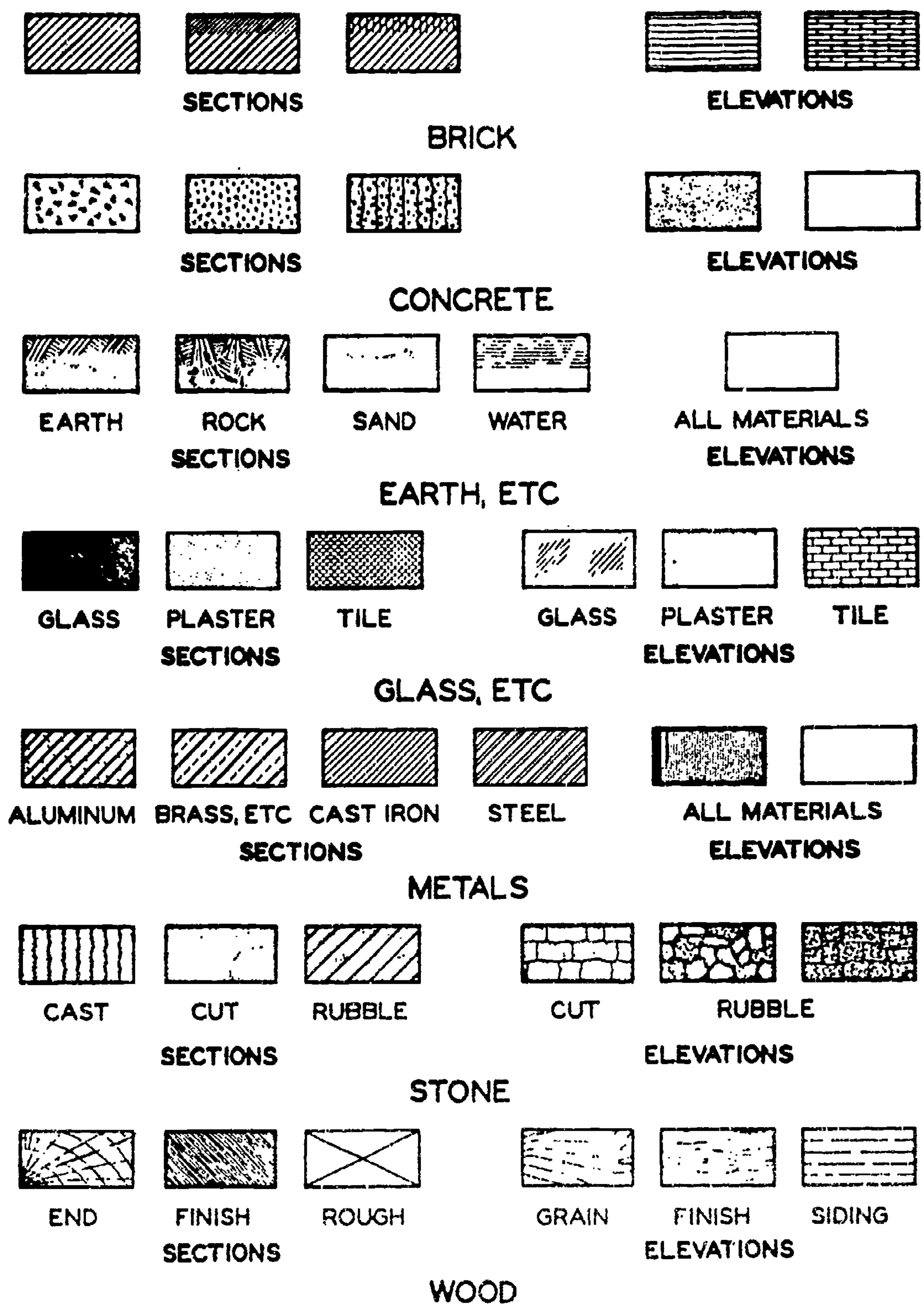

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Figure 6-2.—Architectural symbols for plans and elevations recommended by the American Standards Association. (Note: Symbols may vary according to section or elevation drawings.)

government has just acquired a site for a building in some remote area, the Engineering Division may be assigned the responsibility of furnishing the designer (Civil Engineer) with property and topographic surveys. These surveys, which will be discussed in detail in a later volume, will show (1) property lines with their lengths obtained from a deed description of the property as if the property were perfectly flat; (2) existing utilities and their location on or near the property, such as sanitary sewer, electrical lines, gaslines, water supply lines, storm sewer, manholes, telephone lines, and all other existing features on the property, manmade or natural; and (3) the physical characteristic of the land by using notes, contour lines, and symbols which includes the direction of the land slope and whether the land is flat, wooded, hilly, and any other features of its physical nature.

All of the information stated above is necessary so that the engineer can place the buildings in their proper orientation. This information is also needed by the designer to locate existing utilities (mechanical, electrical) and to route new services to the building.

DRAWING SYMBOLS

Standard drawing symbols are the means by which you will convey the intended function of your drawing. Nonstandard symbols must be explained by notes or in the legend. Most of these symbols you will learn through constant usage, so do not try to memorize them. The main thing is to know the information source for a particular symbol. The military drawing standards (MIL-STDS) are your main source. Consult them before you refer to other references. Structural standard symbols will be presented in this chapter (mechanical and electrical symbols are presented in other chapters).

Architectural Symbols

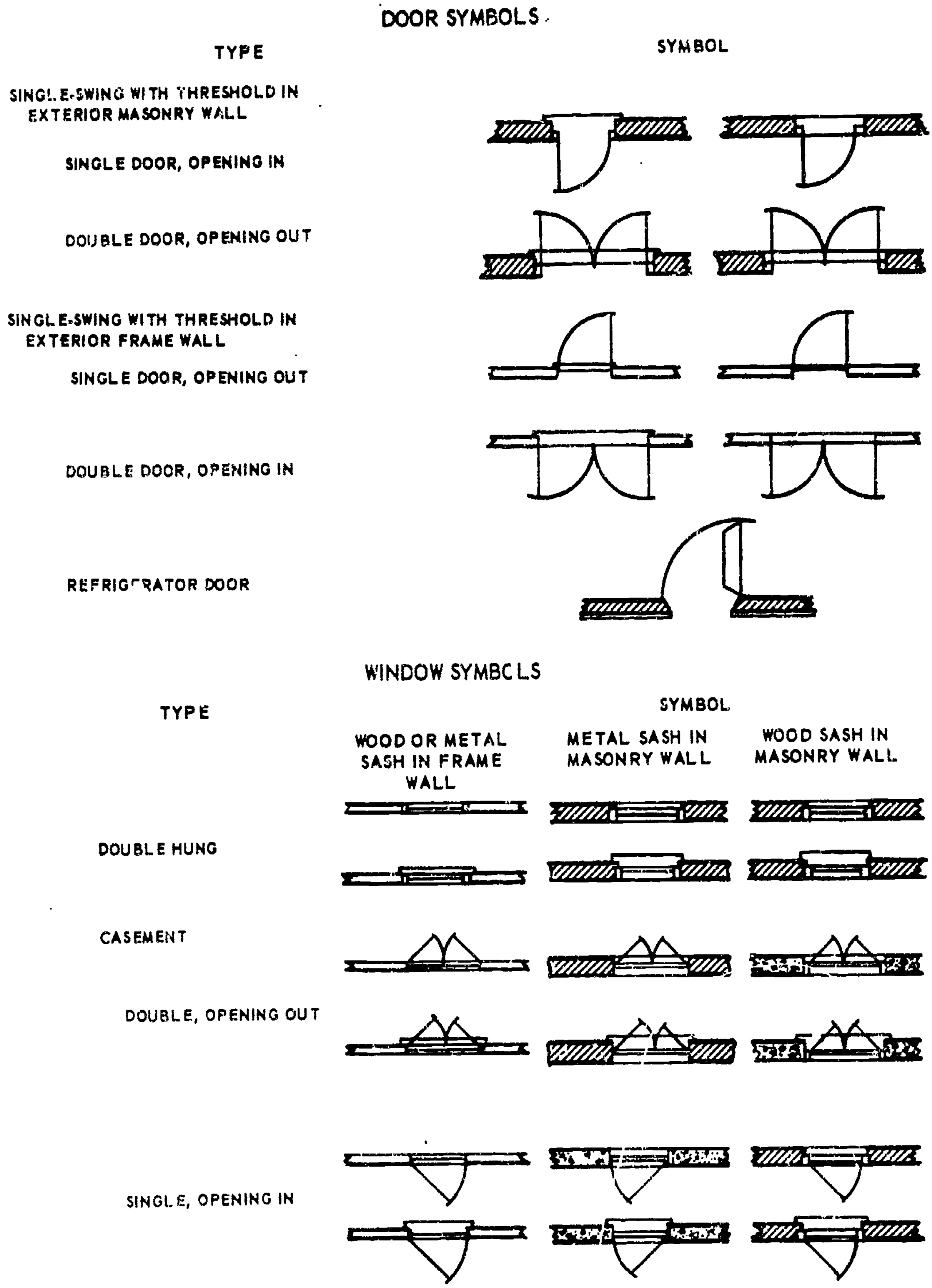
As an EA, you must be prepared to make drawings of advanced bases and airfield structures and other architectural and structural drawings, as assigned. Although NAVFAC has prepared standard drawings for most of these structures, there are times that you may be required to prepare original drawings or modify the existing ones. In doing this, you could be working from notes and sketches; but generally, these notes and sketches would not be complete as far as the correct final appearance of the drawing is concerned. You will supply the correct symbols used to properly depict the parts of a structure. Your knowledge of existing architectural and structural symbols will greatly assist you in accomplishing the job correctly and promptly, and above all, with confidence.

Some of the architectural symbols that you may use are shown in figures 6-2 and 6-3. You are responsible for researching or devising symbols for construction materials not found in this training manual or found in one of the MIL-STDS.

Welding Symbols

Welding is a method of making a permanent joint between two metal parts, and its wide use has brought about a whole language of symbols for use on drawings. The symbols and terms used are discussed in *American Welding Society Standard for Welding Symbols*, AWS/A2.4-79. The basic welding symbol, as shown in view A, figure 6-4, is simply a reference line forming an arrow, with one or more angle bends behind the arrow head which points to the location of the weld. All information required to indicate the welding process to be used, the location and type of weld, the size, finish, and the like, are located in specified positions on or near the welding symbol, as shown in view B, figure 6-4.

To provide identification, welds are classified as ARROW SIDE (near side) or OTHER SIDE (far side). A weld on the near side of the joint, parallel to the drawing sheet and toward the observer, is called the ARROW SIDE; it is on the same side as the symbol, and the arrow points to its face. The OTHER SIDE is on the opposite side of the joint away from the observer, and its face is away from the arrow. (Examine fig. 6-4 closely.)



65.112

Figure 6-3.—Architectural symbols (doors and windows).

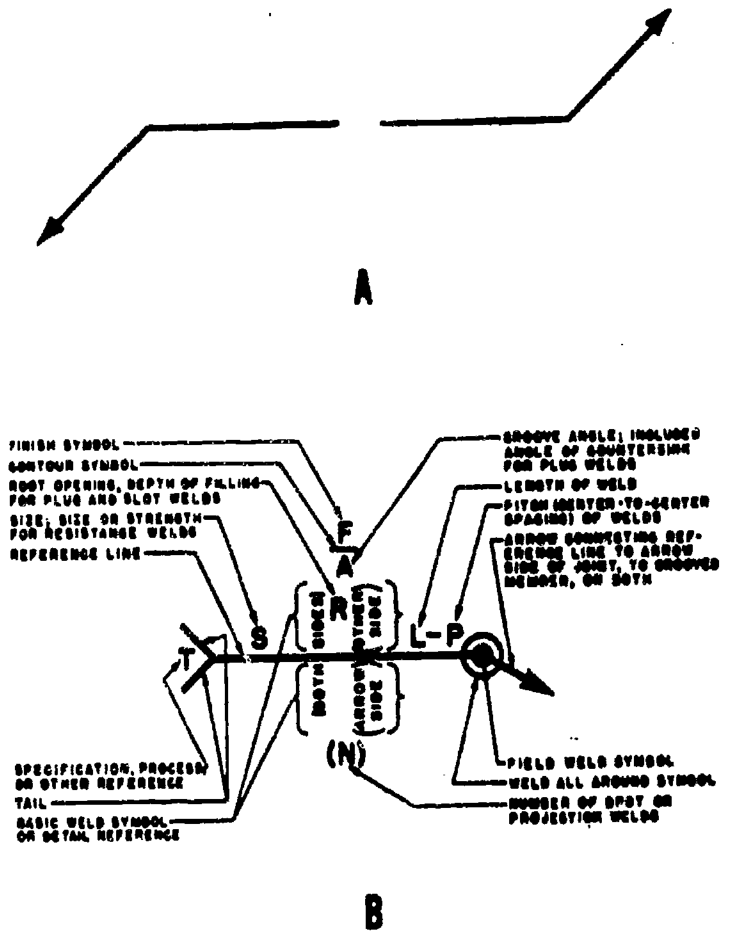


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Figure 6-4.—Welding symbols.

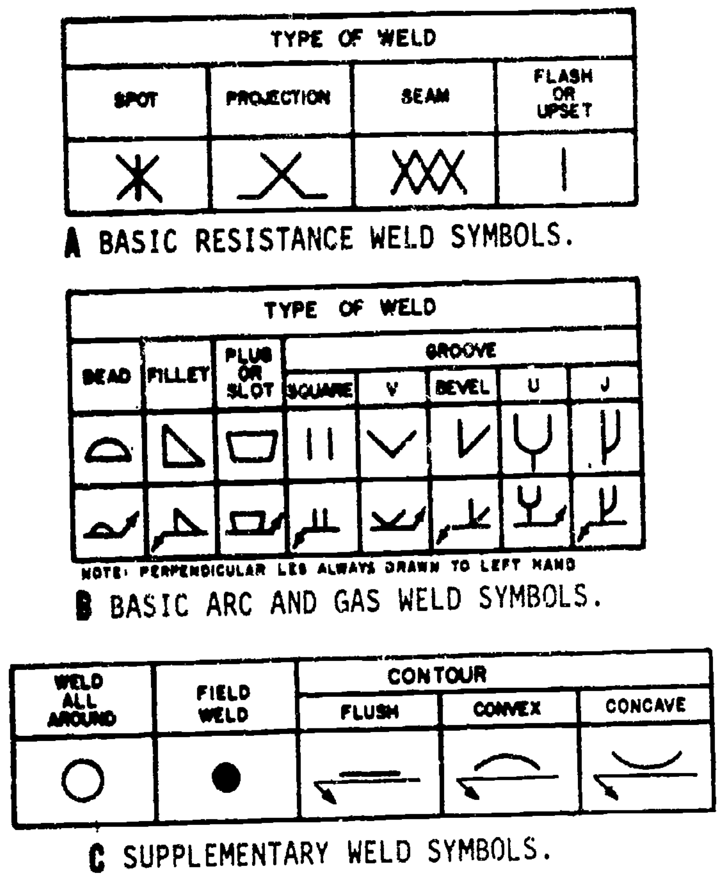

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Figure 6-5.—Weld symbols.

Symbols used to indicate the type of weld are called BASIC WELD SYMBOLS to differentiate them from the WELDING SYMBOL, or ARROW. (See weld symbols shown in figure 6-5.) View A, figure 6-5, shows resistance weld symbols; view B, shows arc and gas symbols, and view C, some supplementary weld symbols. Figure 6-6 shows the types of welded joints and some applications of the welding symbols.

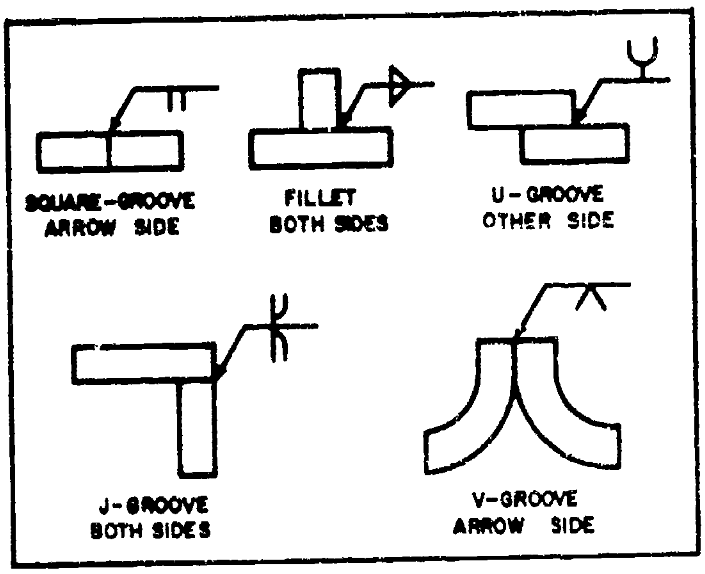

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Figure 6-6.—Application of the welding symbol.

ARCHITECTURAL DRAWINGS

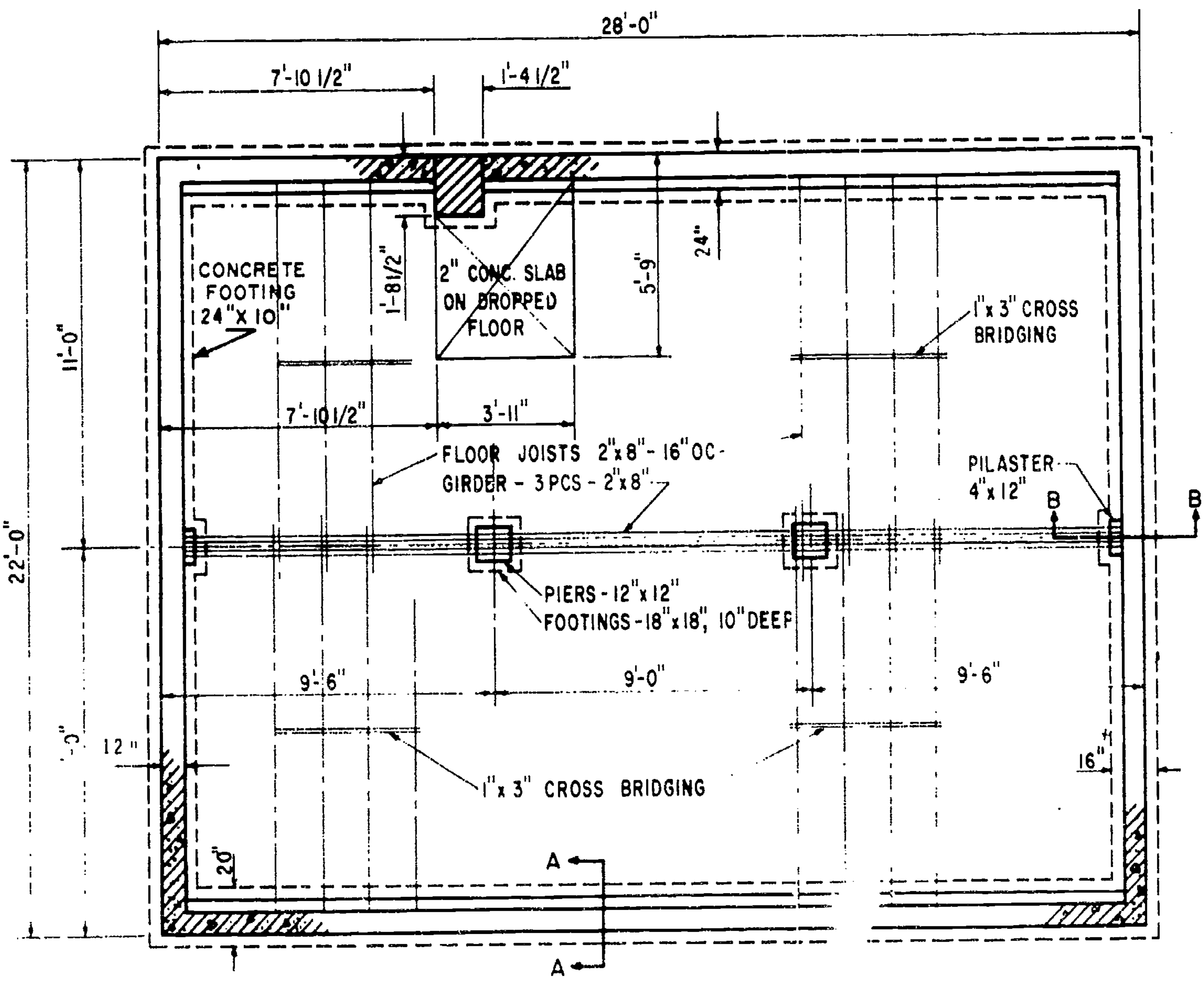
Architectural drawings consist of all the drawings which describe the building's structural members and their relationship to each other; this includes foundation plans, floor plans, framing plans, elevations, sections, details, schedules, and bill of materials (B.M.)

Foundation Plans

The FOUNDATION PLAN is used mainly by the building crew who will construct the foundation of the structure; and like any other plan views, it is a horizontal section view cut through the walls of the foundation, showing all relative information. In most SEABEE construction, foundations are built with concrete masonry units (CMU's), poured concrete, and solid brick.

Figure 6-7 illustrates a plan view of a structure as it would look if projected into a horizontal plane which passed 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-inch and 8-inch concrete masonry unit (CMU's) walls measuring 18 feet lengthwise and 22 feet crosswise. The lower portion of each lengthwise section of wall will be 12 inches thick, to provide a concrete ledge 4 inches wide.

A girder running through the center of the building will be supported at the ends by two 4- by 12-inch concrete pilasters which will butt against the end foundation walls. Intermediate support for the girder will be provided by two 12- by 12-inch concrete piers, each supported on



45.513

Figure 6-7.—Foundation plan.

157

18- by 18-inch spread footings, 10 inches deep. The dotted lines around the foundation walls indicate that these walls will also rest on spread footings.

Floor Plans

In the building construction trades, the term "plans" are frequently used. To define this term more accurately, a plan is a horizontal section through a building showing the outline or arrangements of a floor; hence, it is commonly called a floor plan. Figure 6-8 shows the manner in which a floor plan is developed. Imagine that after the 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 6-9 shows a typical masonry construction architectural floor plan. It gives the lengths, thicknesses, and character of the outside walls and partitions at the particular floor level. It also shows the number, dimensions, and arrangement of the rooms, the widths and locations of the doors and windows, and the locations and character of the bathroom, kitchen, and other utility features. Study figure 6-9 carefully! In dimensioning floor plans, it is very important to check the overall dimension against the sum of the partial dimensions of each part of the structure.

Framing Plans

FRAMING PLANS show the size, number, and location of the structural members (steel or wood) constituting 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. Wall framing plans show the location and method of framing openings and ceiling heights so that studs and posts can be cut. 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 details are shown.

FLOORS.—Framing plans for FLOORS are basically plan views of the girders and joists. The unbroken double-line symbol is used to indicate joists, which are drawn in the positions they will occupy in the completed building. Double framing around openings and beneath bathroom fixtures is shown where used.

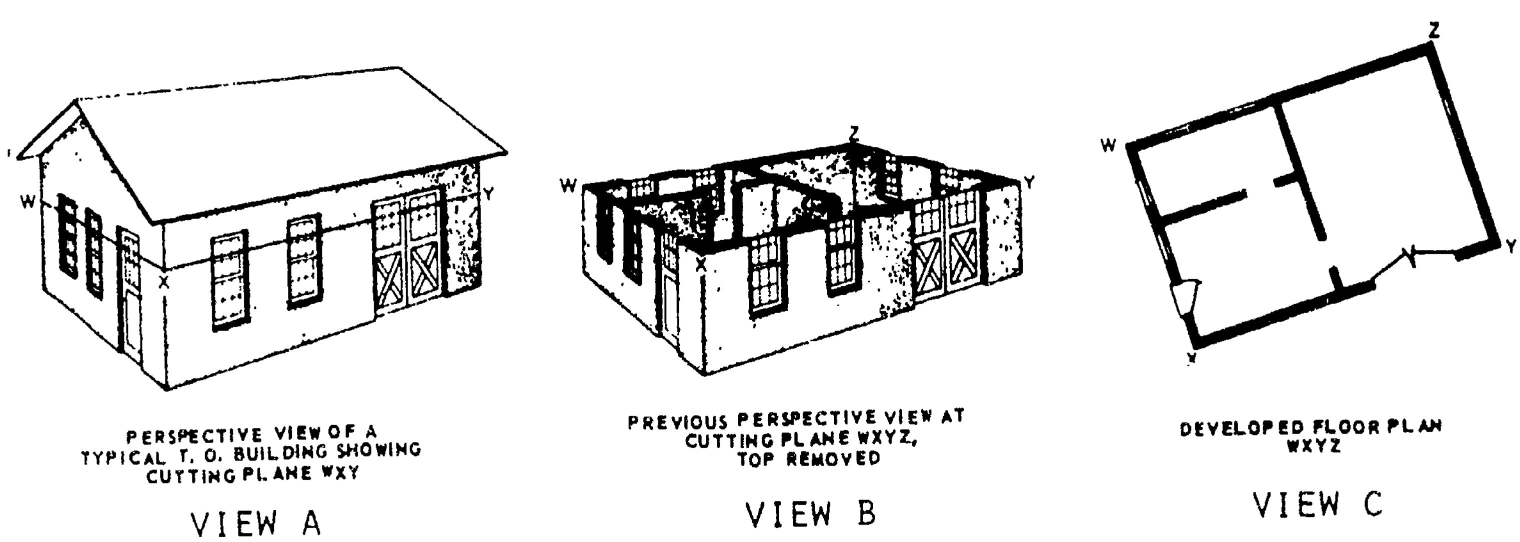


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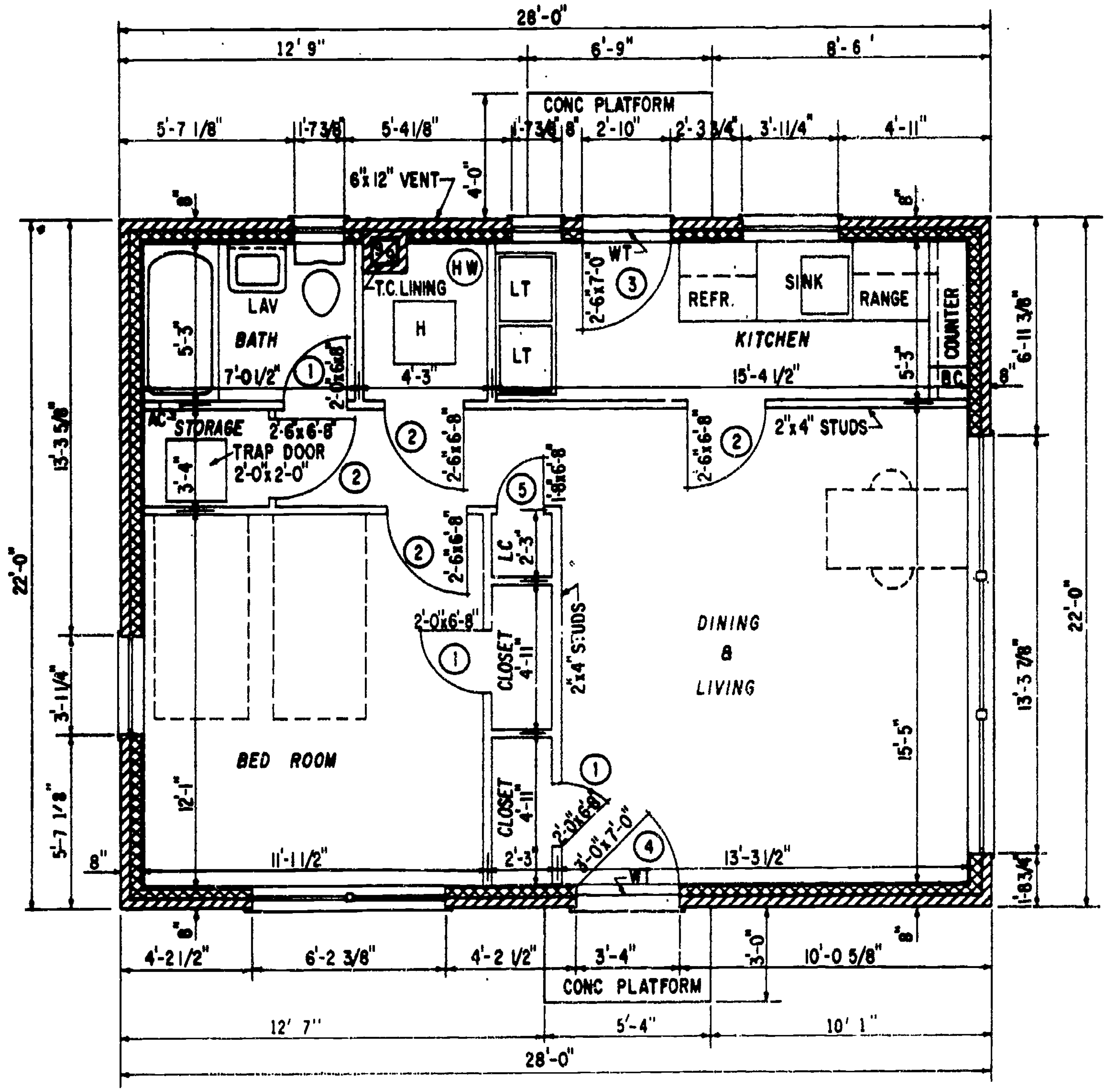
Figure 6-8.—Floor plan development.



DOOR SCHEDULE

(1) - 2'-0 x 6'-8" (2) - 2'-6" x 6'-8" (3) - 2'-6" x 7'-0"

(4) - 3'-0" x 7'-0" (5) - 1'-8" x 6'-8"

Figure 6-9.—Floor plan. 45.515(54)A

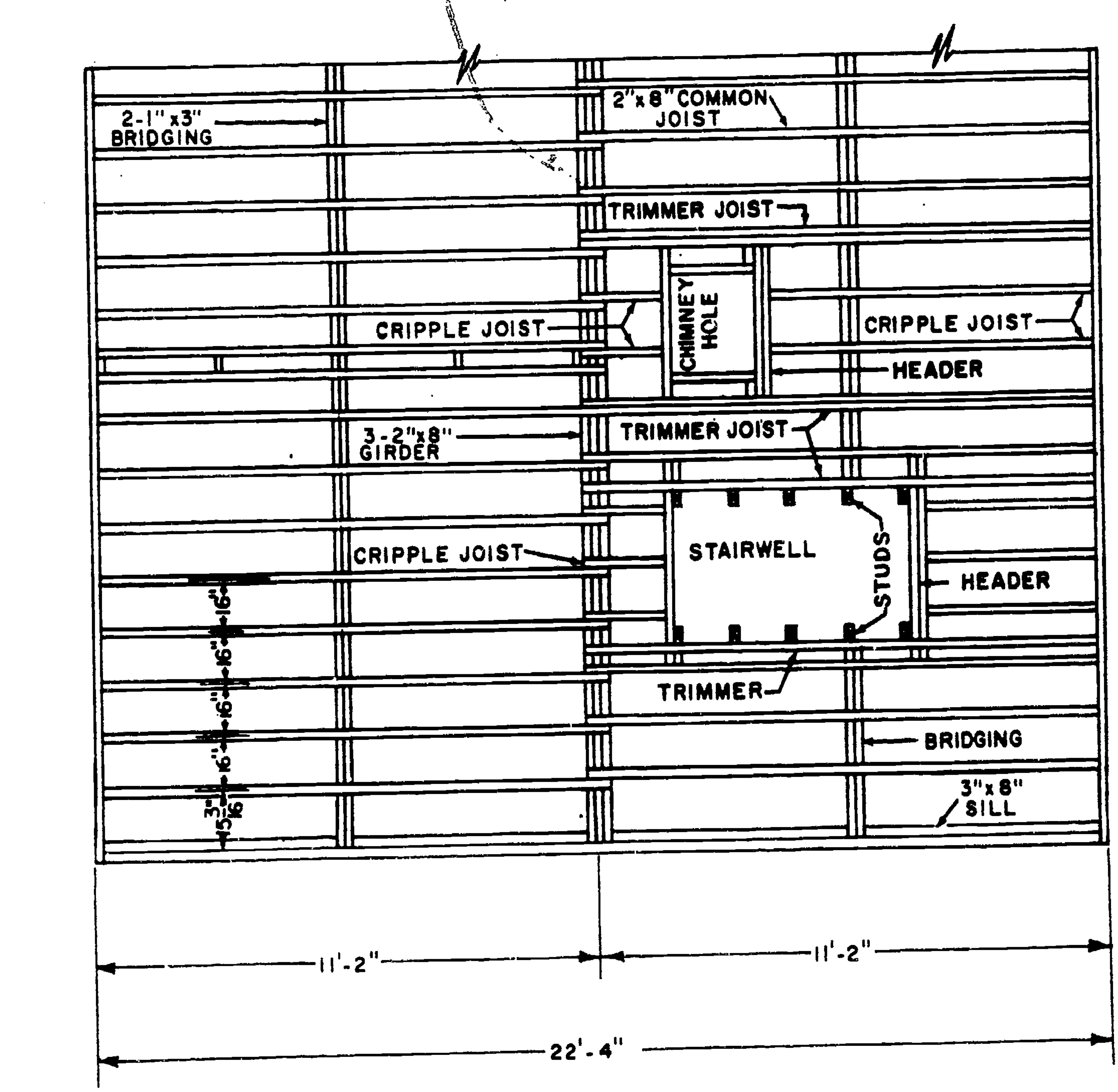


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Figure 6-10.—Floor framing plan.

Figure 6-10 shows the manner of presenting floor framing plans.

Bridging is also shown by a double-line symbol which runs perpendicular to the joist. The number of rows of cross bridging is controlled by the span of the joist; they should not be placed more than 7 or 8 feet apart. A 14-foot span needs only one row of bridging, but a 16-foot span needs two rows.

Notes identify floor openings, bridging, and girts or plates. Use nominal sizes in specifying lumber.

Dimensions need not be given between joists. Such information is given along with notes. For example, 2" by 6" joists @ 2'-0" c.c., indicates that the joists are to be spaced at intervals of 2 feet 0 inches from center to center. 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.

ROOFS.—Framing plans for ROOFS are drawn in the same manner as floor framing plans. The draftsman should always visualize the plan as looking down on the roof before any of the roofing material (sheathing) has been added. Rafters are shown in the same manner as joists.

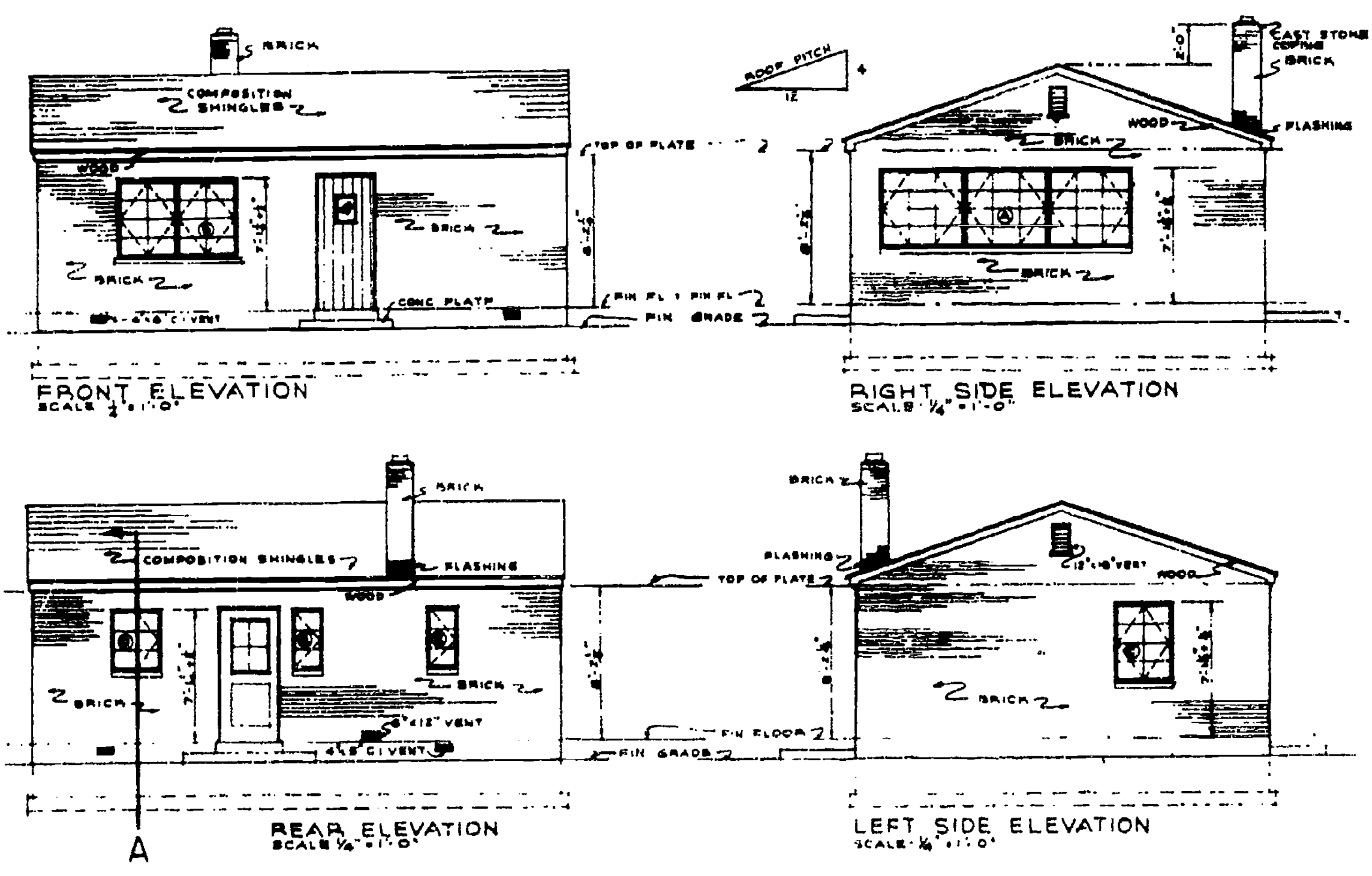
Elevations

ELEVATIONS are the drawings that show the true exterior appearance of the structure. They are drawn to scale. Usually they are the same as the plan, but occasionally space requirements on the drawing sheet restrict the use of the same scale, and elevations are shown at a smaller scale than the plan. Nevertheless, their relationship is the same, so be very careful and observe the scale of the drawings, before orienting various views.

Doors, windows, shapes of roof, chimneys, and exterior materials are shown, providing the contractor with an exterior finished appearance. Few dimensions are given on these views, only those vertical dimensions that cannot be shown on the plan.

Basically, four elevations are needed in a set of drawings to complete the exterior description of a structure: the front, rear, and two sides of a structure, as they would appear projected on vertical planes.

Elevations for a small building are shown in figure 6-11. They show that the wall surfaces of this house will consist of brick and roof covering of composition shingles. The top of the rafter plate will be 8 feet 2 1/4 inches above the level



45.518

Figure 6-11.—Elevations.

of the finished first floor, and the tops of the finished door and window openings 7 feet 1 3/4 inches above the same level. The roof will be a gable roof and will have 4 units of rise for every 12 units.

Each window shown in the elevations is identified by a capital letter. Figure 6-12 shows a window schedule applying to the same building. The schedule shows the dimensions of the finished opening and the character and dimensions of the lintel for each window. For window A, for example, the lintel will consist of an angle combined with a channel; for each of the other windows, the lintel will consist of two angles. The schedule indicates that the sash will be metal casement sash. The dotted lines on the elevations show how each section of sash will swing.

SCHEDULE FOR METAL CASEMENT SASH		
SYMBOL	SIZE	LINTEL
A	3-4'5/8" X 4'-2 5/8"	JL 9" [3" X 3½" X ¼" L
B	2-3'-1" X 4'-2 5/8"	JL 2L's 4" X 3" X ¼"
C	1-3'-1" X 4'-2 5/8"	JL " " "
D	1-3'-1" X 3'-2"	JL " " "
E	1-1'-1 7/8" X 3'-2"	JL " " "

45.519

Figure 6-12.—Window schedule for building shown in figure 6-11.

Sections

SECTIONS provide important information as to height, materials, fastening and support systems, and concealed features. They show how a structure looks when cut vertically by a cutting plane. The cutting plane is not necessarily continuous, but, as with the horizontal cutting plane in building plans, may be staggered to include as much construction information as possible. Like elevations, sectional views are vertical projections. Being detail drawings, they are drawn to large scale. This facilitates reading and provides information that cannot be given on elevation or plan views. Sections are classified as TYPICAL and SPECIFIC. Figure 6-13 shows the initial development of a section. A typical section taken from the foundation plan is illustrated in figure 6-14 and figure 6-15.

Typical sections represent the average condition throughout a structure and are used when construction features are repeated many times. Figure 6-14 shows wall section A-A of the foundation plan in figure 6-7. It shows the construction details which are repeated at regular intervals throughout the building. Study figure 6-14 very closely. You can see that it gives a great deal of information that is necessary for those performing the construction of the building foundation and part of the floor.

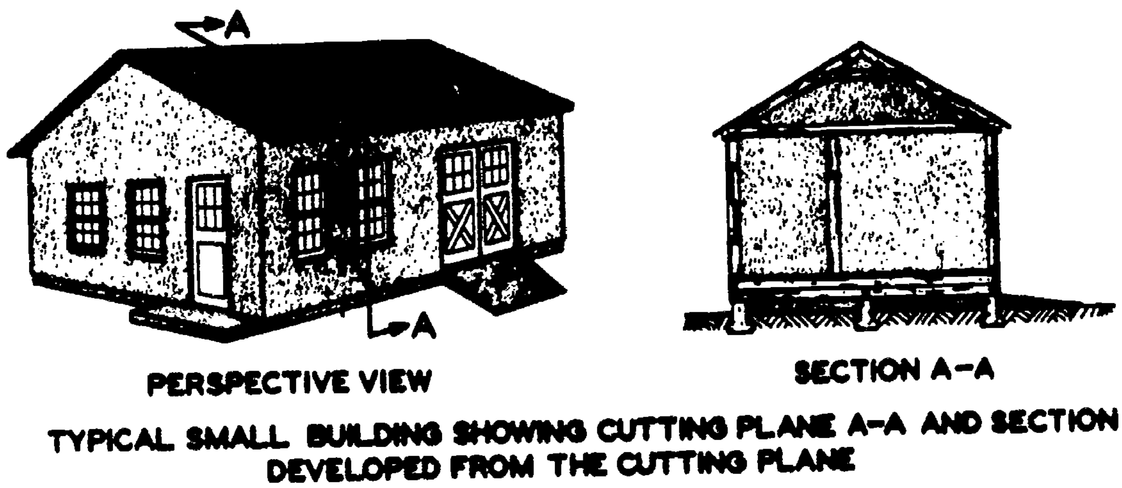


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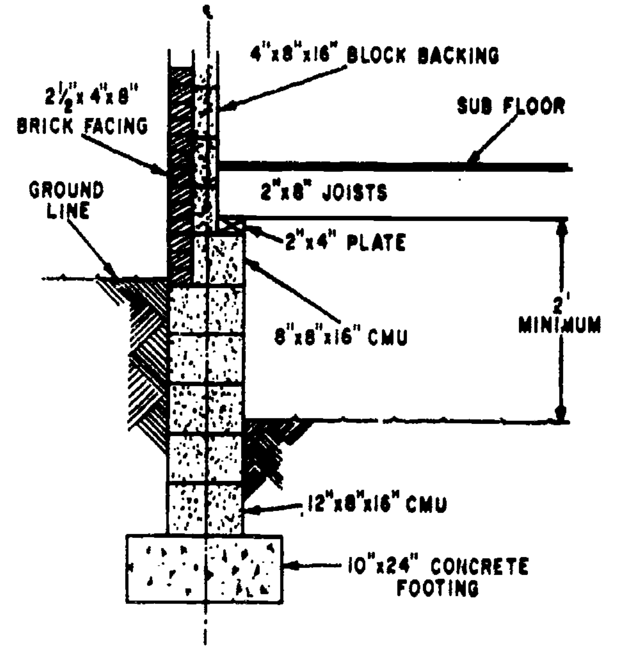
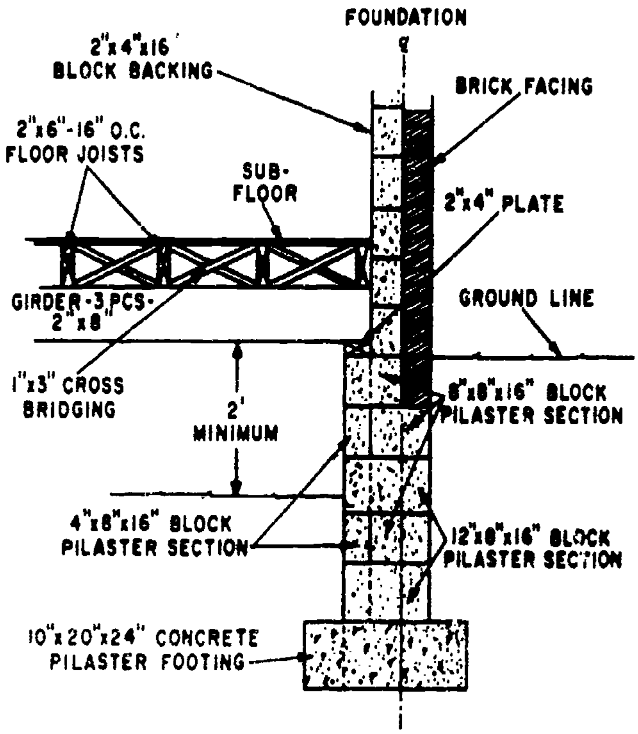
Figure 6-13.—Development of a section view.



SECTION A-A

133.420
Figure 6-14.—Section A-A illustrates a typical section of a masonry building.



SECTION B-B

133.421
Figure 6-15.—Wall section B-B shows a pilaster, a specific section of a concrete masonry unit wall.

The foundation plan shown in figure 6-7 shows that the main foundation of this structure will consist of a 22- by 28-foot concrete block rectangle. Figure 6-14, which is section A-A of the foundation plan, shows that the front and rear portions of the foundation (28 foot measurements) are made of 12- by 8- by 16-inch CMU's centered on a 10- by 24-inch concrete footing to an unspecified height. These are followed by 8-inch CMU's which form a 4-inch ledger for floor joist support on top of the 12-inch units, and serve to form a 4-inch support for the brick facing which is to begin an unspecified depth below ground level. The main wall is then laid with standard 2 1/2- by 4- by 8-inch face brick backed by 4- by 8- by 16-inch CMU's.

The foundation plan shown in figure 6-7 also shows that both side walls (22-foot measurements) are 8 inches thick centered on a 16-inch concrete footing to an unspecified height. Section B-B (fig. 6-15) illustrates the PILASTER, a specific section of the wall to be constructed for support of the girder. It shows that the pilaster is constructed of 12- by 8- by 16-inch CMU's alternated with 4- by 8- by 16-inch and 8- by 8- by 16-inch CMU's. The hidden lines (dashed lines) on the 12-inch wide units indicate that the thickness of the wall beyond the pilaster is 8 inches thick. Note how the extra 4-inch thickness of the pilaster provides a center support for the girder, which in turn will support the floor joists.

Figure 6-16 represents a complete wall section for both masonry and wood frame structures, usually taken from the elevation views. This section is necessary for clarity, because they show the construction details from the foundation to the roof. Construction methods and materials may vary, but once you are familiar with one type of construction drawing, you will be able to do the others—notwithstanding whatever type of construction methods and materials used.

When a particular construction feature occurs only once, and is not shown clearly in the general drawing, a cutting plane is passed through that portion. (See fig. 6-17.) The cutting plane indication is used and identified with the same letter at

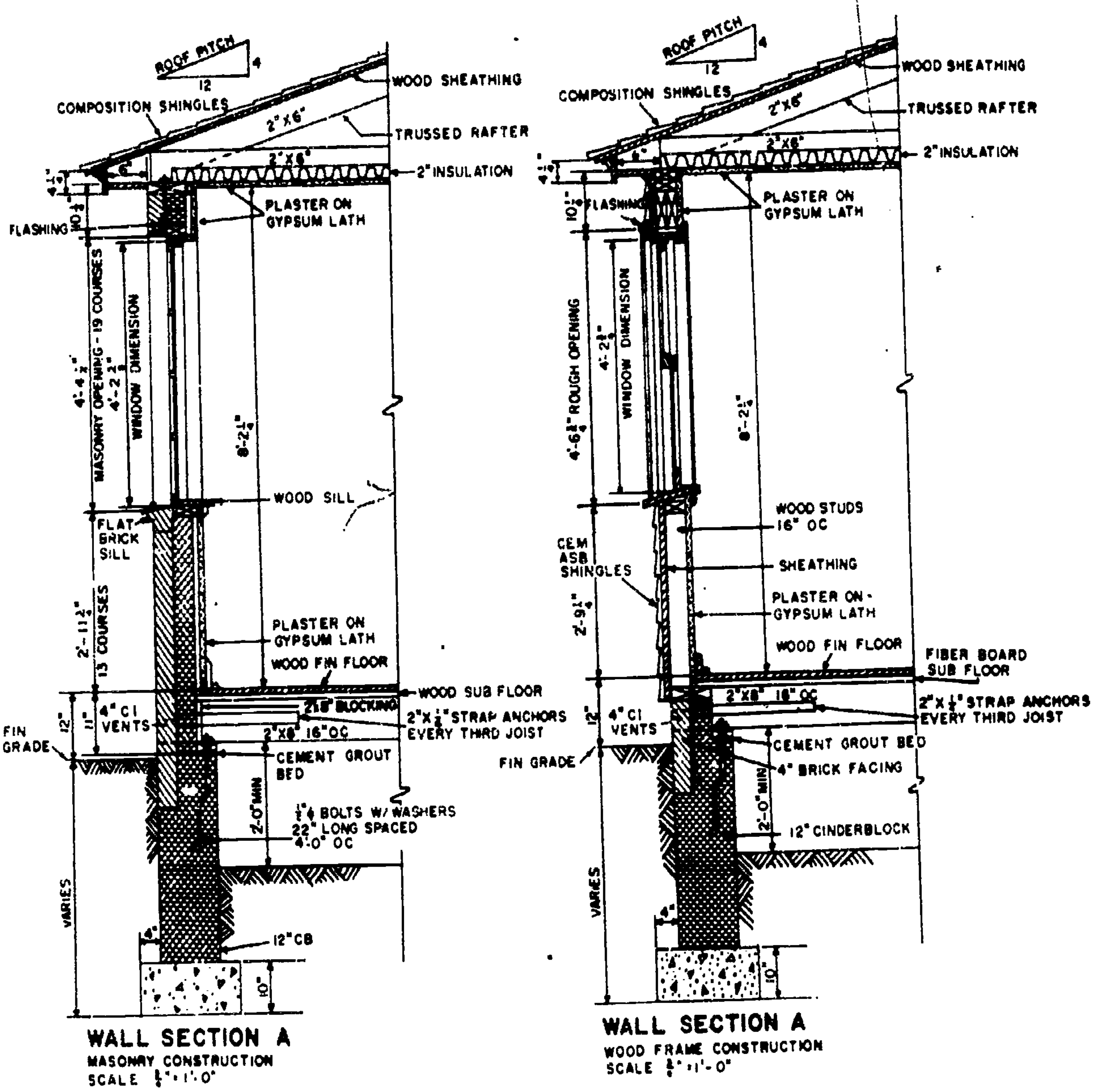


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Figure 6-16.—Wall sections.

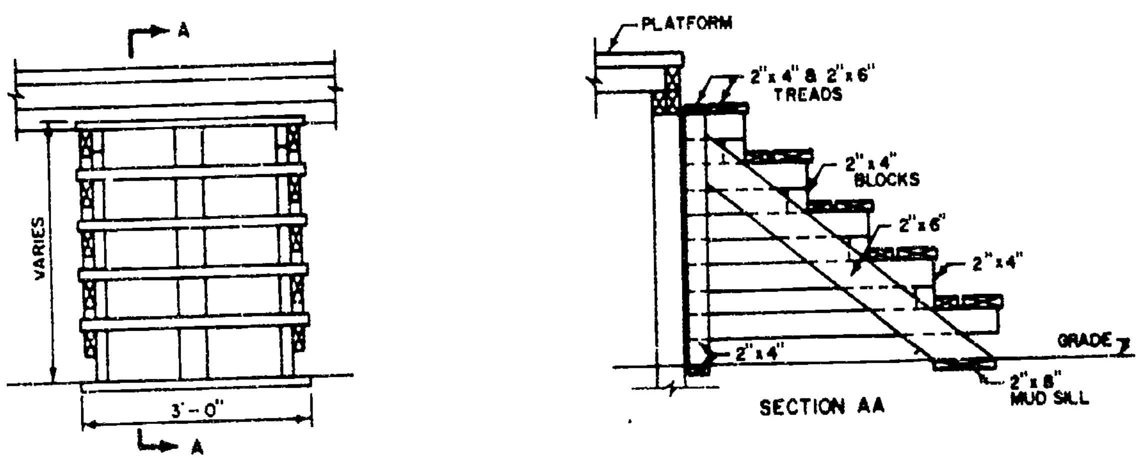

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Figure 6-17.—Outside steps.

either arrowhead. These letters then become part of the title; for example, Section A A of the outside steps shown in figure 6-17. The cutting plane line indicates the extent of the portion through which the section is taken. The arrows indicate the direction of viewing.

Details

DETAILS are large-scale drawings showing the builders of a structure how its various parts are to be connected and placed. Details do not use the cutting plane indication, but they are closely related to sections, because sections are often used as parts of detail drawings. The construction of doors, windows, and eaves is customarily shown in detail drawings of buildings. (See fig. 6-18.) Detail drawings are used whenever the information provided in elevations, plans, and sections is not clear enough for the builder on the job. They are usually grouped so that references may be made more easily from the general drawing.

Schedules

General notes usually are grouped according to materials of construction in a tabular form and are called a SCHEDULE. As used in this training manual, the category, General Notes, refers to all notes on the drawing not accompanied by a leader and an arrowhead. Item schedules for doors, rooms, footings, and so on are more detailed. Typical door and window schedule formats are presented below.

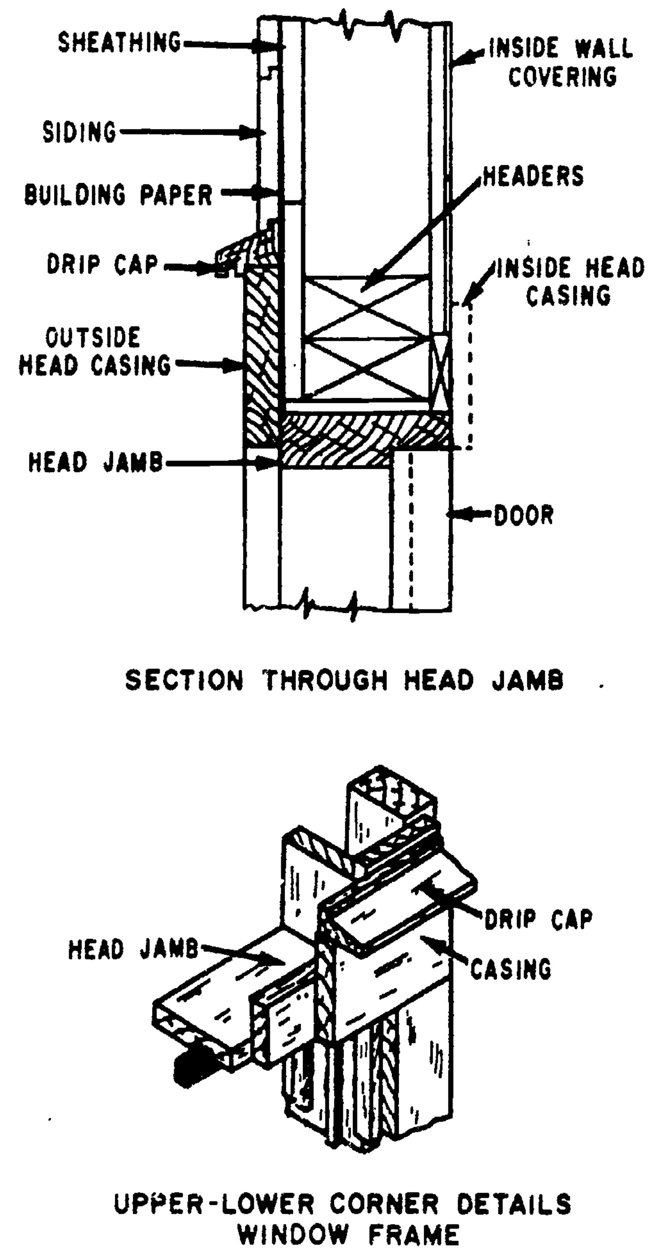

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Figure 6-18.—Door and window details.

1. Door Schedule. The doors, shown by a symbol in a plan view, may be identified as to size, type, and style with code numbers placed next to each symbol. This code number, or mark, is then entered on a line in a door schedule and the principal characteristics of the door are entered in successive columns along the line. The No. column allows a quantity check on doors of the same design, as well as the total number of doors required. By using a number with a letter, the mark can serve a double purpose. The number identifies the floor on which the door is located, and the letter identifies the design of the door. For example, mark 1-D would mean door style D on the first floor. The sequence of door sizes is written in width by height by thickness. The description column allows identification by type (panel, flush), style, and material. The remarks column allows reference to the appropriate detail drawing. The schedule is a convenient way of presenting pertinent data without making the Builder refer

to the specifications. A typical door schedule follows:

No.	Mark	Size	Description	Remarks
6	1-D	5 × 7	Flush—	Double door hinged
9	2-D	2 1/2 × 7	Panel—	Single door hinged

2. Window Schedule. A window schedule is similar to a door schedule. It provides an organized presentation of the significant window characteristics. The code mark used in the schedule is placed next to the window symbol that applies on the plan view or elevation view. (See figs. 6-11 and 6-12.) A similar window schedule follows:

No.	Mark	Size	Description	Remarks
16	W-1	5 × 9	Double Hung	Slide from bottom to top and top to bottom
12	W-2	4 × 7	Casement	Hinged at top

Bill of Materials (B.M.)

A BILL OF MATERIALS is a tabulated 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 each will contain similar information. Actually, a bill of material is a grouped compilation based on takeoffs and estimates of all 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.

Most NAVFAC drawings will contain a bill of materials incorporated within the drawings. But, there are times when you are directed to tabulate materials needed for a new project that has been designed in-house for cost estimate and funding. Figure 6-19 shows a typical example of a completed form of a B.M.

SHIP APRIL 19-

BILL OF MATERIAL
1180-CBC-4815/2 (2-75)
0900-LL-P81-3020

PROJECT: INTERIM WATER SYSTEM REINDEER STATION (CANTONMENT AREA) BM NO. DIW 112

AUTHORITY | PAGE | OF

ROUT IDENT	M&S	SERV & REQNR	DMD	SERV & SUPP ADDRESS	SIG	FUND CODE	D	PROJECT	PRI	RDD	JOB ORDER	ACCOUNTING DATA	RDS
P96	2	N62583	N	Y1W112	A	TN	W	ZM9	05	094	4K6404		

DOC IDENT	FSC	STOCK NUMBER NIIN	UNIT OF ISSUE	QUANTITY	DOCUMENT NUMBER DATE SERIAL	COS	ADV	L/I	CRIT FLAG	DESCRIPTION/SPECIFICATION/VENDORS	UNIT COST	TOTAL COST	LOCATION	QTY/DATE RECD	QTY/DATE ISSUED
ADE			SH	69	4081 7903			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"X4"X16' 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	

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Figure 6-19.—Typical bill of materials.

CHAPTER 7

MECHANICAL PLANS

Mechanical plans, as used in this chapter, include all drawings and notes which refer to the water supply, sewage and drainage, heating and air-conditioning, refrigeration, and other like systems. In the Navy, these systems may vary, depending on whether they are aboard ship or shore based. As an EA, your main concern will be with 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 cheapest materials which will serve the purpose are normally used.

This chapter will discuss the purpose and the development of a mechanical plan in the context of plumbing, heating, and air-conditioning.

PLUMBING SYSTEMS

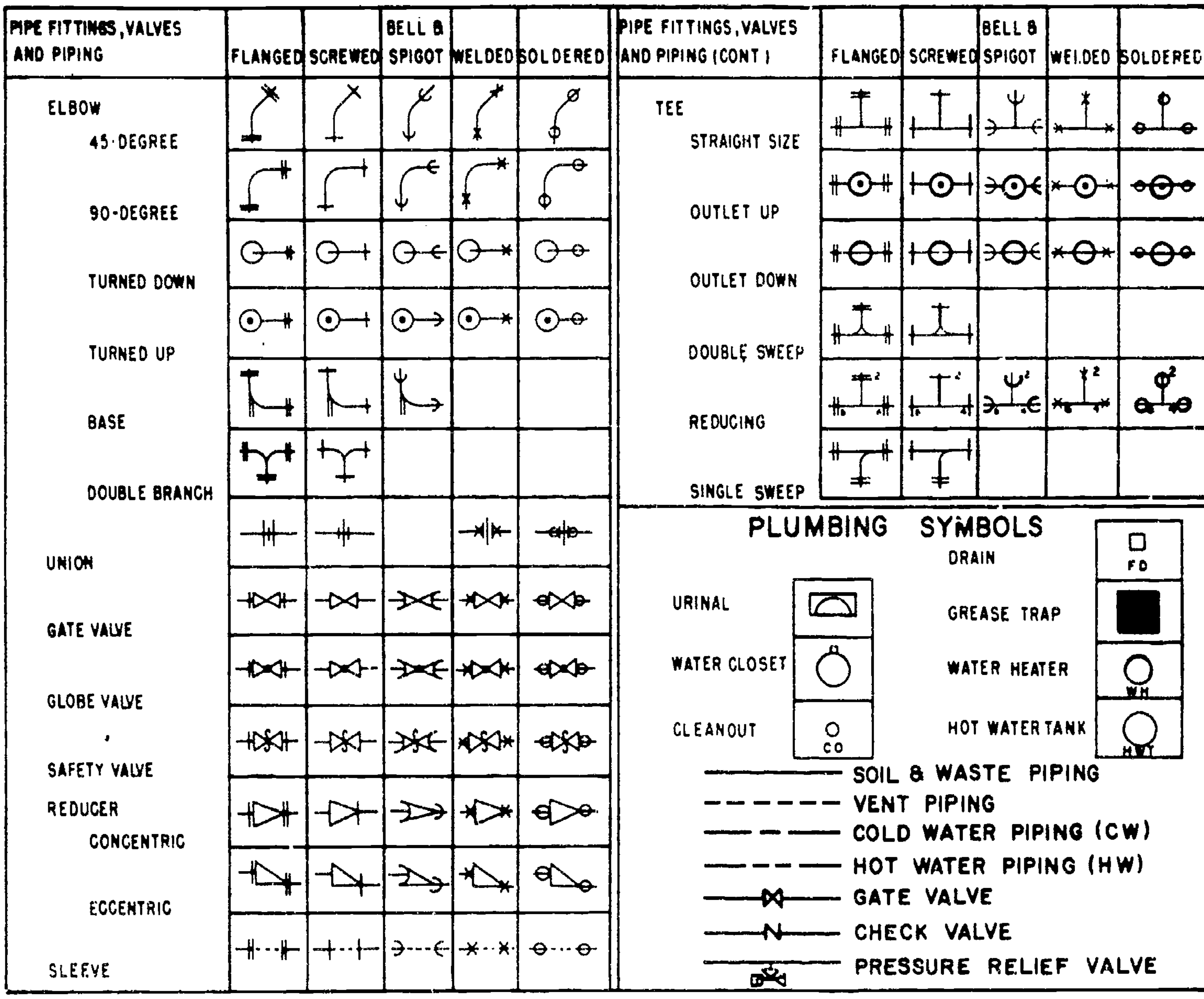
In general, plumbing refers to the system of pipes, fixtures, and other apparatus used inside a building for supplying water and removing liquid and waterborne wastes. In practice, the term also includes storm water or roof drainage and exterior system components connecting to a source, such as a water main and a point of disposal, such as a domestic septic tank or cesspool.

The purpose of plumbing systems is, basically, to bring into, and distribute within a building a supply of safe water for drinking, washing, and cooking and to carry off the discharge of waste material from various receptacles on the premises to sewers, leech basins, etc. without causing a hazard to the health of the occupants. Codes, regulations, and trade practices define the plumbing specifications which vary from state to state, but the *National Plumbing Code* is widely accepted as a guideline for the minimum requirements for plumbing designs. As stated earlier in the previous 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.

MECHANICAL SYMBOLS

As a rule, the 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 in accordance with the specifications and good plumbing and construction practices. Generally, plumbing plans consist of four types of symbols: piping, fittings, valves, and fixtures. (See fig. 7-1.)

Piping symbols indicate the type and location of the piping that should be indicated on the plans by using solid or dashed lines. The size of the required piping should be noted alongside each route of the plan. Piping up to 12 inches in diameter is referred to by its nominal size which is approximately equal to the inside diameter (ID). The exact inside diameter will depend on the classification of the pipe. Because their wall thickness is greater, the heavy types of piping have smaller inside diameters. Piping over 12 inches in diameter is referred to by its outside diameter (OD).



11.330(54)

Figure 7-1.—Mechanical symbols.

Fitting symbols are shown by the basic line symbols for pipes when used in conjunction with the symbology of pipe fittings or valves. They will define not only the size of the pipe and the method of branching and coupling, but also the use to which the pipe will be put. This is important because the type of material from which the pipe is made determines how the pipe should be used.

In regard to valve symbols, the type of material and their size are normally NOT noted on drawings, but must be assumed from the size and material of the connected pipe. However, when specified on the bill of materials or plumbing takeoff, valves are called out by size, type, material, and working pressure; for example, 2-inch check valve, brass, 175-pounds working pressure.

Fixture symbols are known as general appurtenances, such as drains and sumps, but other fixtures, such as sinks, water closets, and shower stalls are indicated 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 which closely resemble the actual fixtures or obtain mechanical symbol templates that are available commercially. These templates come in various sizes (scale). Get the size that will match the common scales you use in your architectural drawing, such as 1/4 inch equals 1′-0″.

PLUMBING LAYOUT

Figure 7-2 shows a typical plumbing layout. You can see how the outlines of walls, partitions, and water utilities features were taken

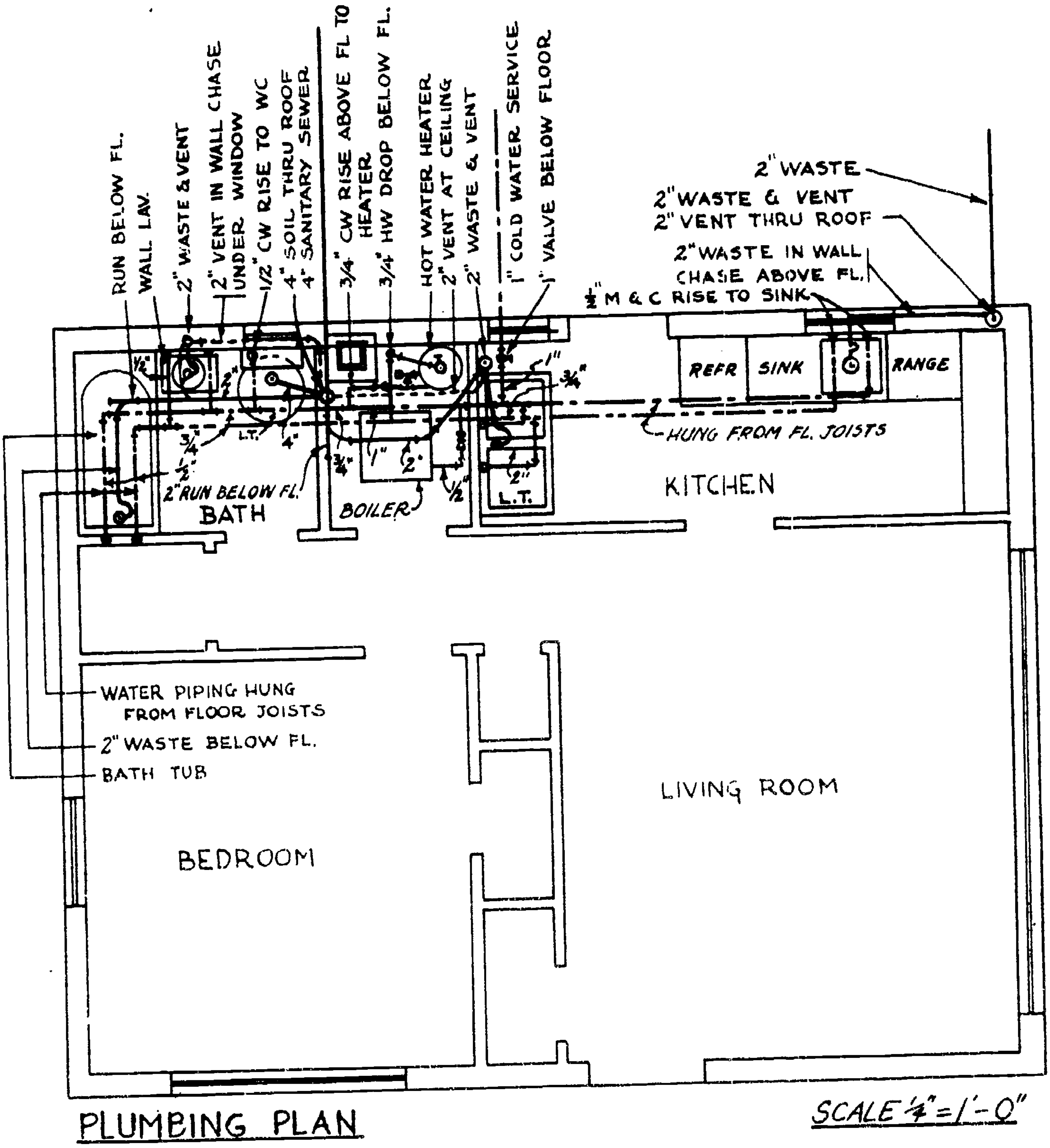


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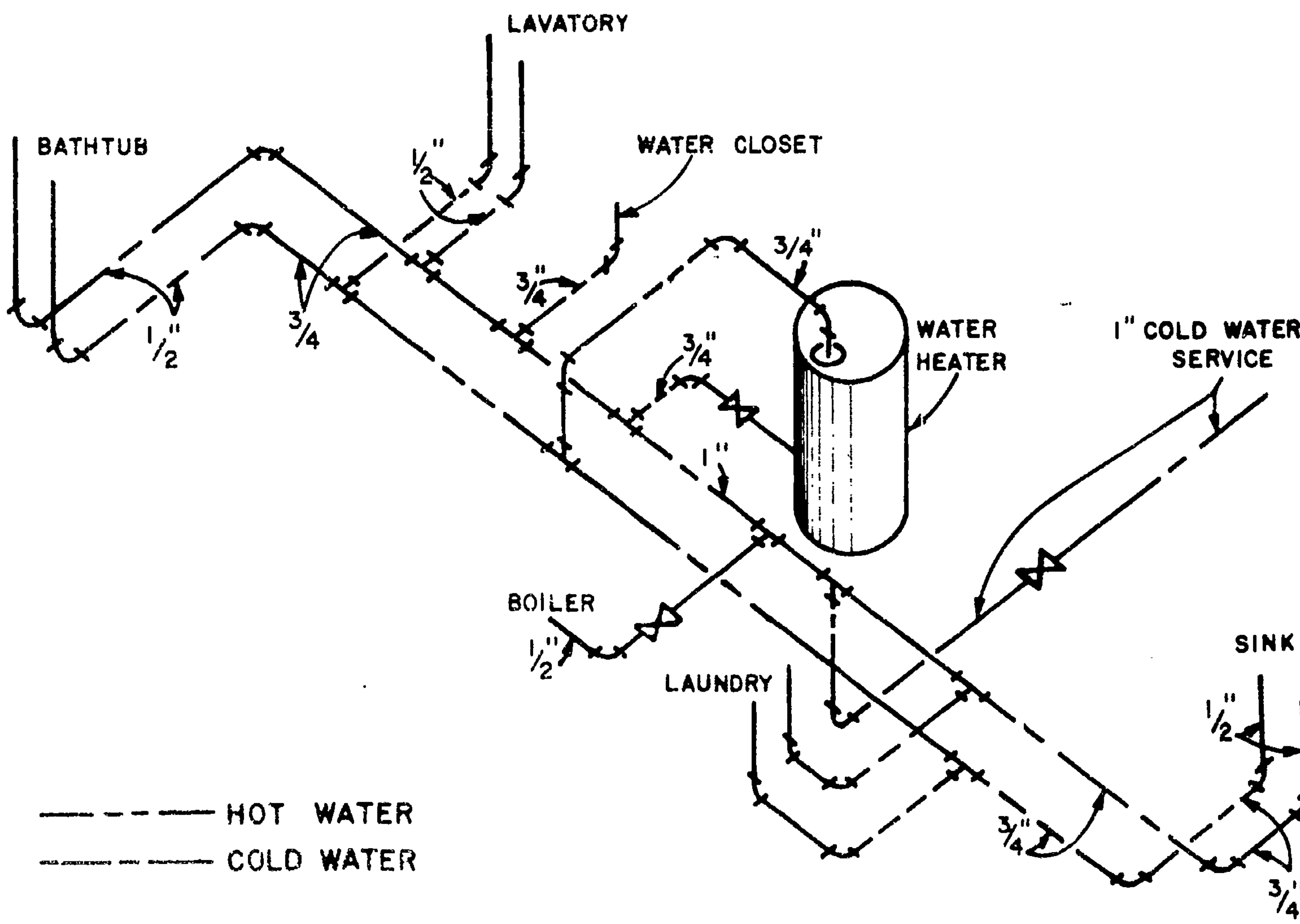
Figure 7-2.—Typical plumbing layout for a small house.

from the floor plan. The reproduction is, unfortunately, too small to be easily studied, but you can see that it utilizes the mechanical symbols. Refer to ANSI Y32.4-1977. 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-inch 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 boiler 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.



45.894

Figure 7-3.—Hot and cold water risers diagram.

to the 4-inch 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-inch pipe running through the roof; the sink waste line vents through a 2-inch pipe running up through the roof.

The figure shows the plan view of the lines, fittings, and fixtures locations. For an experienced Utilitiesman (UT), this may be the only drawing needed to install the system, but on the other hand, a shortage of personnel may be a factor, and an inexperienced Utilitiesman may be assigned for the plumbing project. In order to convey your ideas clearly as to how the system is connected, an isometric drawing is needed. This drawing is a method of visualizing or showing a three-dimensional picture of the pipes in one drawing.

Figure 7-3 shows the risers diagram for hot and cold water service lines and how they are connected to feed the fixtures.

Figure 7-4 shows the waste and soil pipes diagram and the associated fitting symbols. The arrows represent the direction of flow. If you notice, all the pipes are sloping towards the building drain.

Figure 7-5 shows the basic layout of a drainage system. The terminology and function of each part are defined below:

a. The fixture branches are horizontal drain pipes connecting several fixtures to the stack.

b. A fixture drain is the drain from the trap of a fixture to the junction of that drain with any other drainpipe.

c. The soil and waste stacks are fixture branches which feed into a vertical pipe, referred

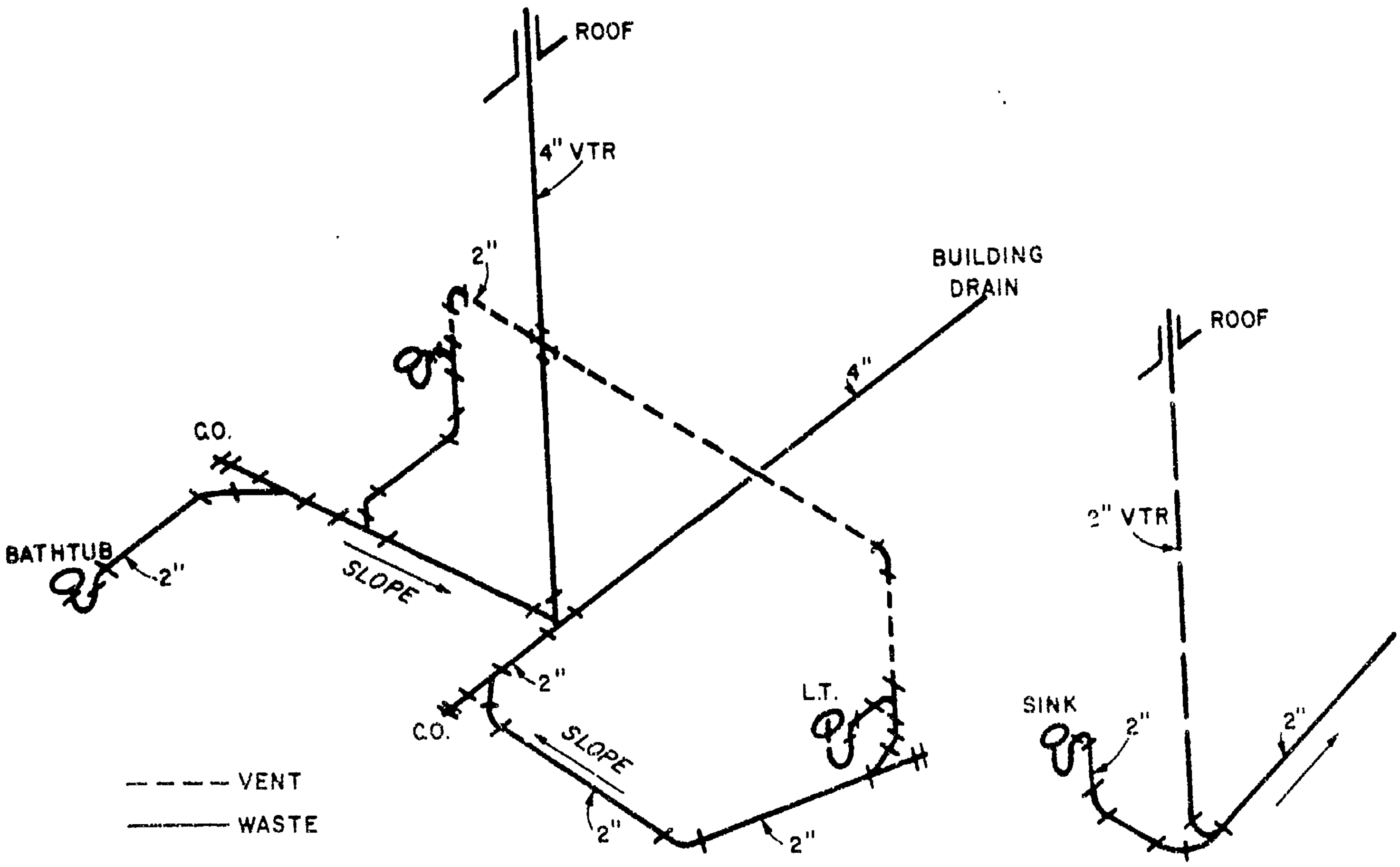


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Figure 7-4.—Waste and soil risers diagram.

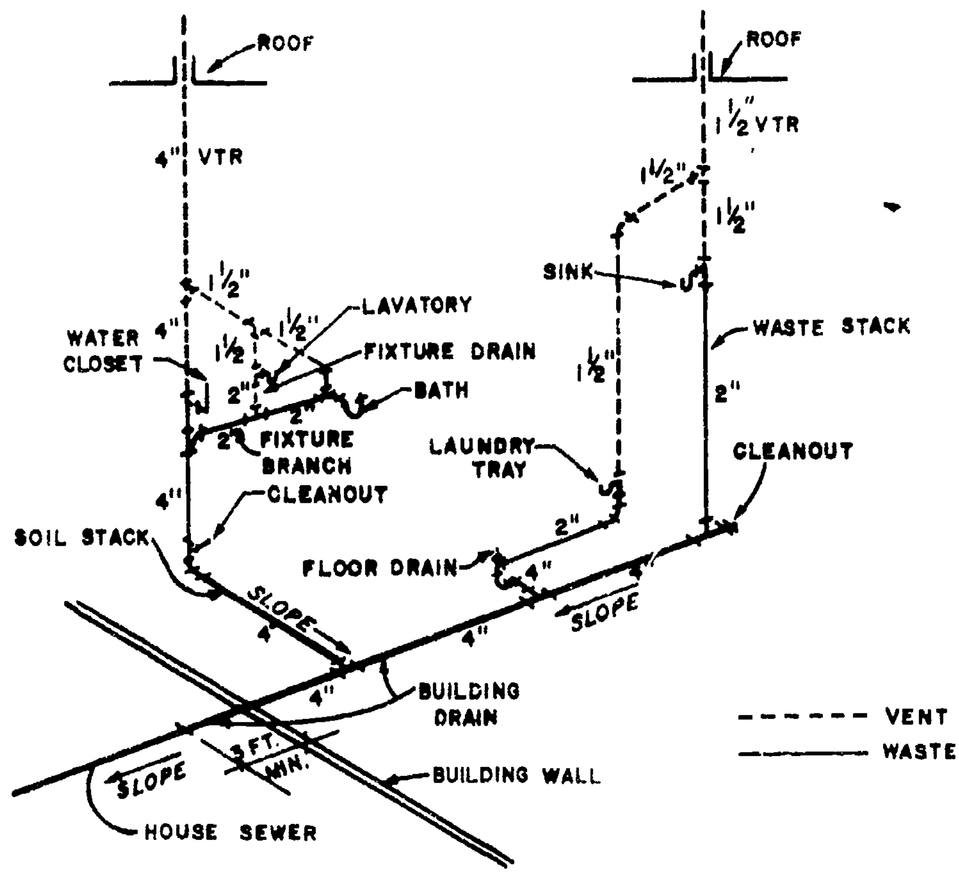

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Figure 7-5.—Basic layout of a drainage system.

to as a stack. If the waste that is carried by the fixture branches includes human waste (coming from water closets or from fixtures that have similar functions), the stack is called a SOIL STACK. If a stack carries all waste except 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.

d. The building drain (also referred to as 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 feet outside the building wall. (Most local codes require that the house drain extend at least 3 feet beyond the building wall, but a few local requirements range from 2 to 10 feet.)

e. The building sewer is that part of the horizontal piping of a drainage system which extends from the end of the building drain. It conveys the waste to the community sewer or a private disposal tank.

f. The 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.

g. The cleanout is a unit with a removable plate or plug which provides access into plumbing or other drainage pipes for cleaning out extraneous material.

HEATING, AIR-CONDITIONING, AND VENTILATING SYSTEMS

As with plumbing system layouts, the layouts for heating, air-conditioning, and ventilating systems are usually done on architectural floor plan outlines, using the appropriate symbols from ANSI Y32.4-1977. The draftsman makes the layout of a mechanical system on the basis of notes and sketches provided by the design engineer. To do this, the draftsman must know how these systems function. Described below are some of the most common heating, air-conditioning, and ventilating systems.

STEAM

These systems may be one-pipe or two-pipe air-vent (gravity), vapor (gravity), or vacuum systems, and they may be upfeed or downfeed. One-pipe systems are not used in permanent structures. Low-pressure steam, circulating through radiators or convectors, is used for heating most office buildings. Medium-pressure steam from unit heaters is used for heating bakeries, laundries, hangars, and industrial buildings. High-pressure steam is used mainly for process work and for conveying through a distance from a central heating plant.

In a one-pipe air-vent system, air which could cause a cushion ahead of the steam and prevent the flow is removed by means of air valves installed on the radiators. In a one-pipe system, the radiators may be placed above the pipe (upfeed) or below it (downfeed), and it always employs a gravity return. That is, the condensate gravity flows back to the boiler, rather than being mechanically forced back. Most of the gravity return systems are one-pipe, and they are seldom used for permanent Navy buildings.

In vapor systems, the design is intended to reduce steam pressure in the boiler and the amount of heat emitted from the radiators in mild weather, and to maintain boiler pressure and increase radiator heat in cold weather. A vapor system of the two-pipe type is shown in figure 7-6. The radiator may be of the hot water type. It operates with very low-steam pressures. Since air valves on the radiators on the two-pipe system are eliminated, foul air or water cannot be discharged into the occupied spaces.

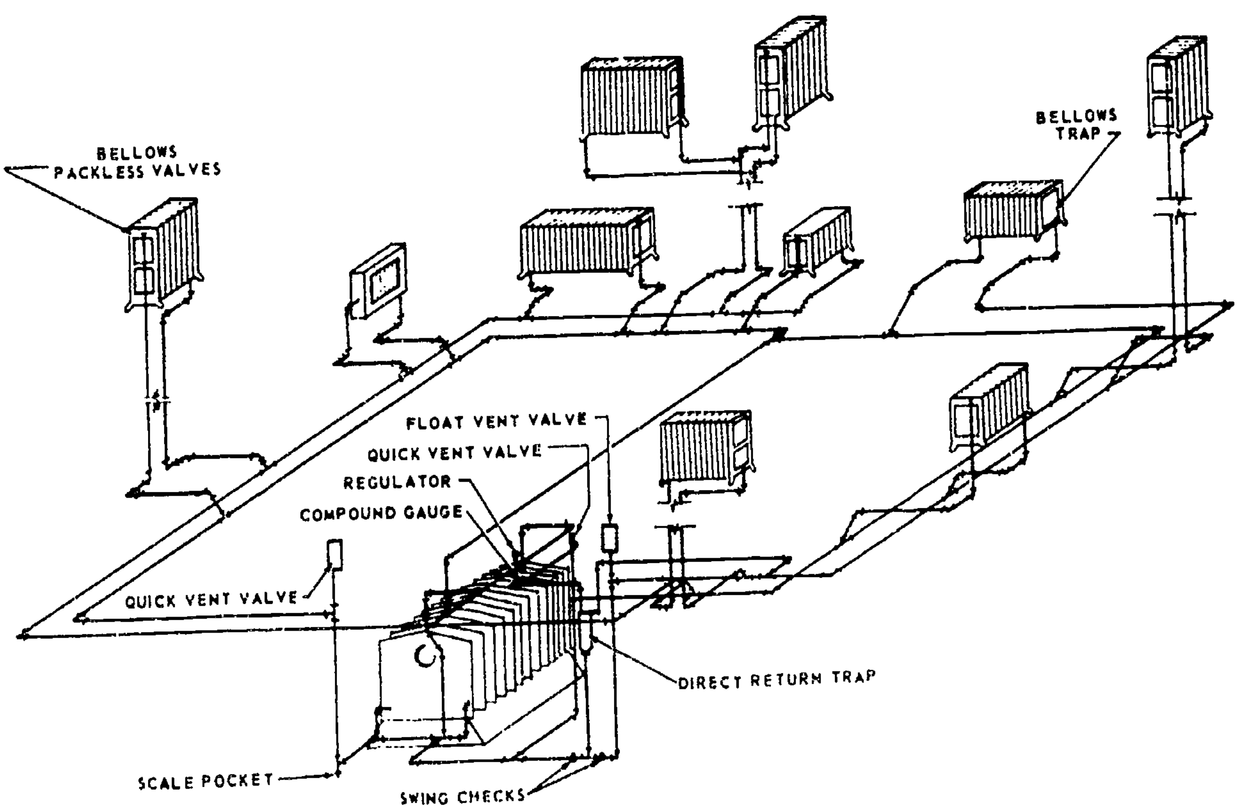

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Figure 7-6.—Vapor heating system.

The steam enters at the top tapping of the radiator, through a graduated control valve, rather than at the bottom tapping as in the one-pipe air-vent system. The temperature of the room may be controlled by the amount of steam admitted. Condensed steam and air are discharged through a thermostatic trap, located at the lower tapping of the radiator, into the dry return piping. One of these traps is designed to pass air and water, but not steam. An air vent and check and an automatic return trap that vent the air from the system, but prevent outside air from entering, are installed in the return main.

In a two-pipe vacuum system, a pump is used to draw air and condensate from the return lines. This creates a partial vacuum and helps the circulation in the system. This type of system is better for large buildings than either of the other two types because of the pressure drop which may be expected in long runs of pipe. The radiators are equipped with graduated valves and traps like those in vapor systems. The vacuum pump on the return contains an air liberating tank with a float-controlled air vent.

HOT WATER

These systems provide for the circulation of water from a heater through pipes to radiators or convectors and back to the heater. A gravity system of return is seldom used today; instead, a pump is used to keep the water circulating.

The most common types of hot water heat for small buildings are the one-pipe and two-pipe systems. A one-pipe system is shown in figure 7-7. Hot water is carried in a single main around the system and diverted to each radiator in turn. A two-pipe system is shown in figure 7-8. In this system, the main carries hot water, and the cooled water is returned through a separate return pipe.

HOT AIR

These systems distribute heated air through a duct system. The air is usually heated in a coal-, gas-, or oil-fired hot air furnace, but it may be heated by passing over steam- or hot-water-heated coils. The air circulation is provided by fans.

Figure 7-9 shows a hot air system. Note that this drawing is an isometric drawing; this is a method of portrayal often used for design drawings of heating, ventilating, and air-conditioning systems.

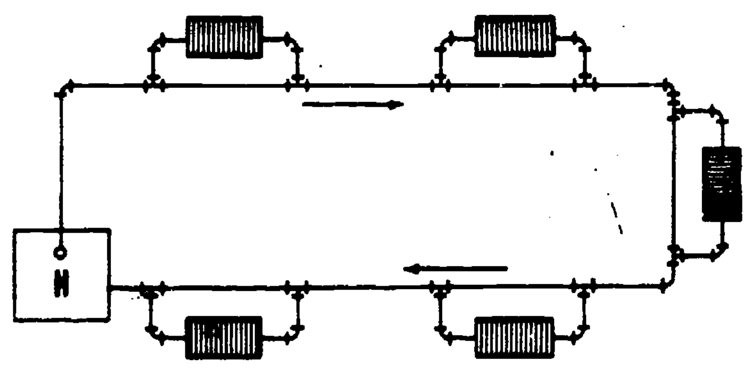

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Figure 7-7.—One-pipe hot water system.

A

B

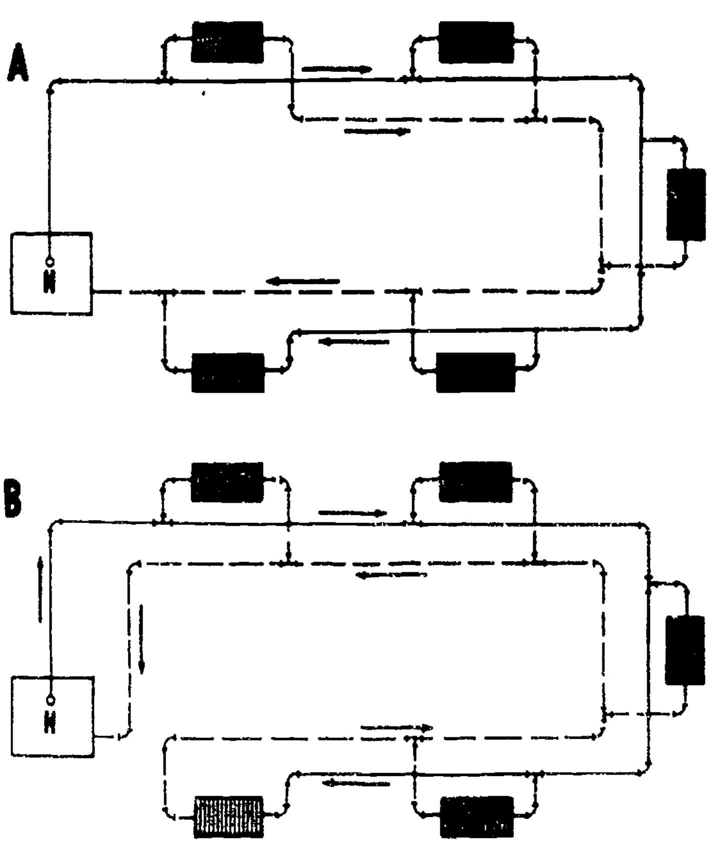

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Figure 7-8.—Two-pipe hot water heating systems: A. Direct return; B. Reverse return.

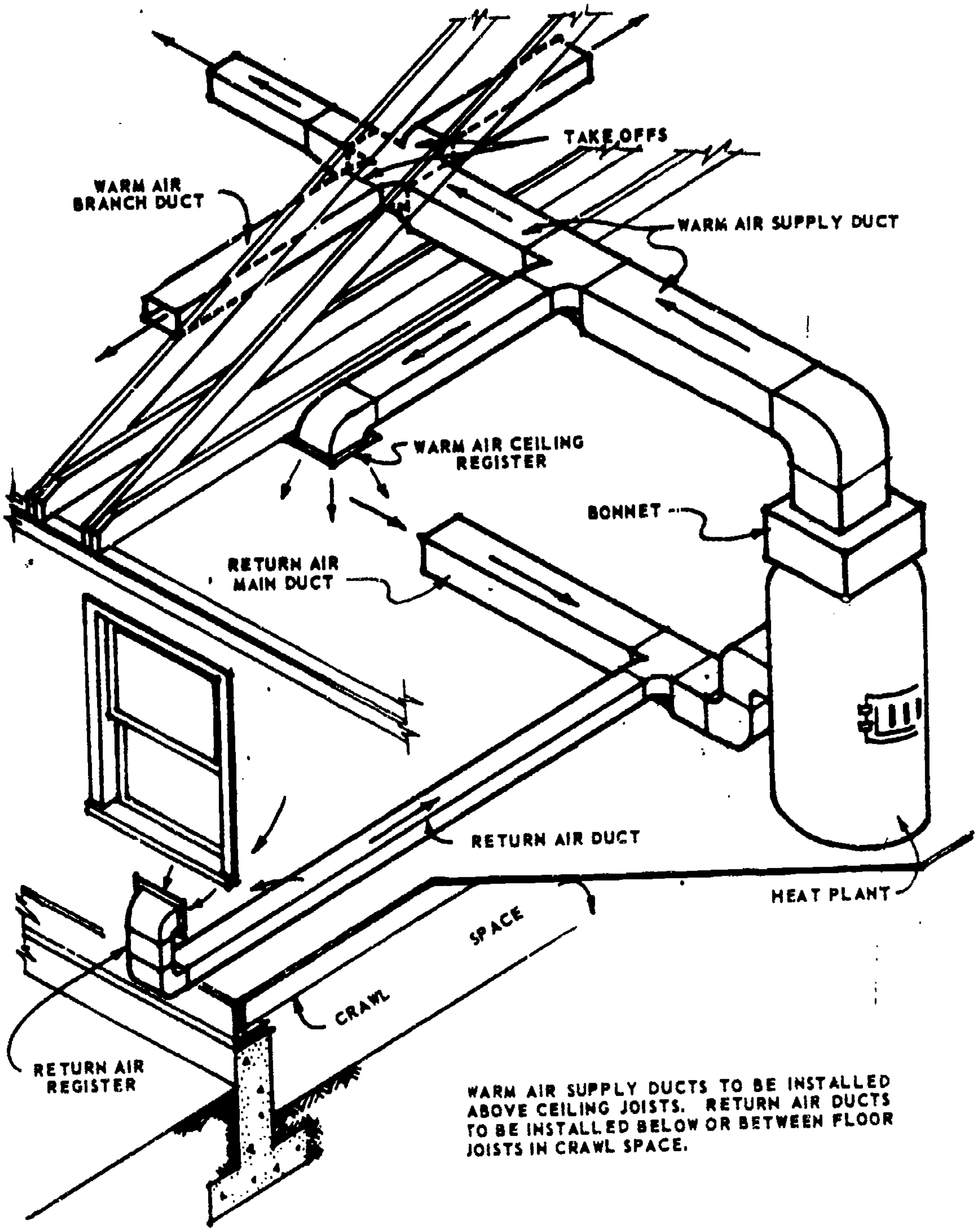

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Figure 7-9.—Hot air heating system.

RADIANT

RADIANT heating (also called PANEL heating) is a system in which the heating units (which may be hot air pipes, hot water pipes, or electric coils) are embedded in walls, floors, and/or ceilings.

AIR-CONDITIONING

An air-conditioning system maintains the temperature, moisture content, movement, and the quality of the enclosed air in a structure within desirable limits.

In all systems of air-conditioning, air is the exchange medium that conveys heat to or from the space to be kept conditioned and the cooling or heating equipment. Air also has the capacity to absorb and carry water vapor. When air holds all the water vapor it is capable of absorbing, it is called SATURATED air. This is air of the maximum possible HUMIDITY. Summer air is usually too humid for comfort; therefore, a summer air-conditioning system is designed to dehumidify as well as cool the air. Artificially heated air, on the other hand, is usually too dry for comfort; therefore, in artificially heated premises, the air-conditioning system both heats and humidifies the air.

Air-conditioning may be effected by individual room or space units, or by a central system. A schematic drawing of an air-conditioning unit is shown in figure 7-10. The FAN at the right draws air into the supply duct; this air consists of recirculated air from inside, plus (when desired) a regulated amount of air from outside. From the SUPPLY DUCT, the air passes through a FILTER into the mixing or treating chamber. There it is first warmed by passing over a bank of low-pressure (LP) steam coils called the PREHEATER. This preheating prevents the moisture in the air from freezing when it enters the sprayer.

The SPRAYER, fed with cold water (CW), next cools the preheated air; it also dehumidifies or humidifies it, depending upon whether the original humidity of the air is above or below that desired. The sprayer also functions as an air washer. After passing through the sprayer, the air passes first a filter and next a second bank of steam coils called the REHEATER. The reheater heats the conditioned air to the desired temperature.

The pipe marked CR in figure 7-10 is the CONDENSATE RETURN, carrying steam condensate from the heater and reheater back to the boiler. That marked CWR is the COLD WATER RETURN, carrying used spray water back to the tank of the spray pump.

Figure 7-11 (a foldout at the end of this chapter) shows a heating and air-conditioning layout for a hospital. You can see that the air-conditioning plant consists of four separate self-contained units, three of which are located in the mechanical equipment room, and one on the porch of the ward. Note the cooling towers,

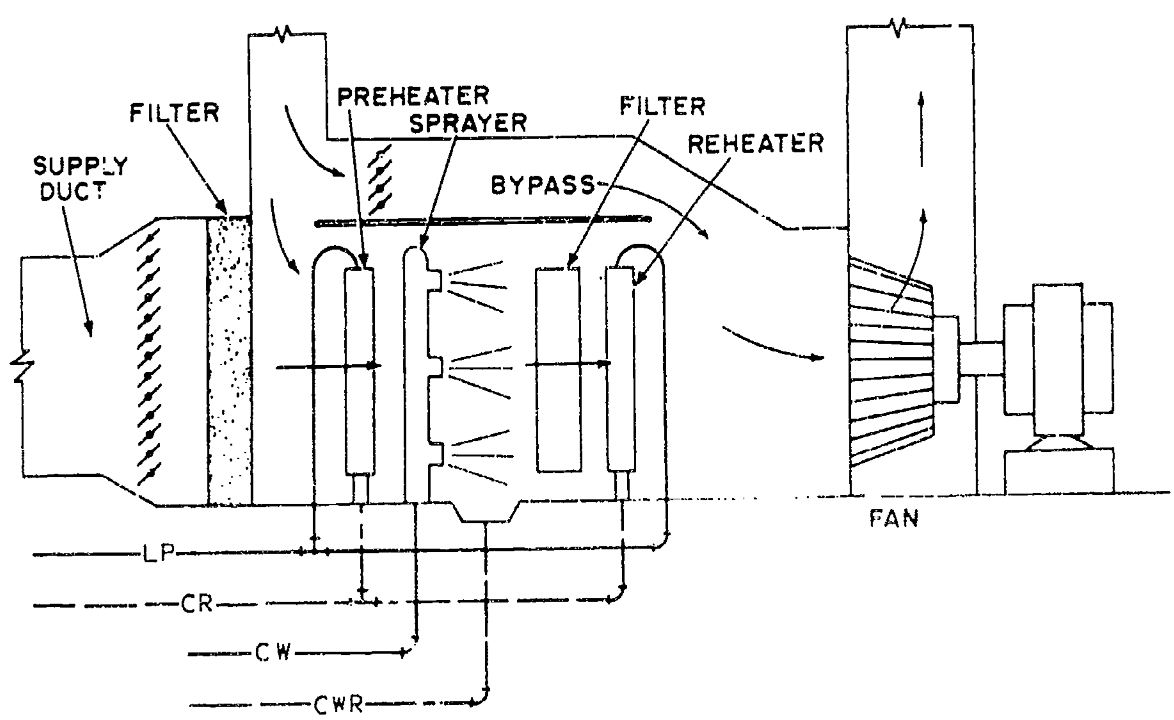

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Figure 7-10.—Air-conditioning unit.

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which have not previously been mentioned. The function of one of these is to cool the spray water returned by the cold water return from the sprayer; after cooling in the tower, this water goes again into the CW line to the sprayer.

You can see the line of air-conditioning ducts, running from each of the air-conditioning units. Note that the section dimensions of each length of a specific size are inscribed on the drawing; note, too, that these dimensions decrease as distance away from the unit increases.

Note that some spaces are heated, not by the air-conditioning system, but by radiators. These are spaces (all the toilets, for example) which may contain odors or gases which would make it inadvisable to connect them with the air-conditioning duct system. On each of the radiators, the heating capacity, in British thermal units (BTU's), is inscribed. In each space not communicating with the air-conditioning system, you can see an exhaust fan (for ventilation) shown. On each fan the air capacity, in cubic feet per minute (CFM), is inscribed.

In each air-conditioned compartment, you see a circle (or more than one circle) on the duct, indicating an outlet for air-conditioned air. These outlets are called DIFFUSORS, and the capacity of each diffusor, in CFM, is inscribed thereon. Note that this capacity varies directly with the size of the space serviced by the outlet.

Steam lines from the boiler in the mechanical equipment room to the air-conditioning units and radiators appear as solid lines. Small diagonal lines on these indicate that they are low-pressure steam lines. Returns appear as dash lines.

In the upper left corner, the details are set down to show the valve arrangement on the steam and condensate return lines to each of the air-conditioners. (Normally, the fittings, as shown in the drawing are not numbered. For use in this training manual, the fittings are numbered to simplify the explanation.)

Referring to the symbols specified in ANSI Y32.4-1977, the detail indicates that in the steam line, the steam headed for the unit passes (A) a gate valve, (B) a strainer, and (C) an electrically operated modulating valve. This last reduces the pressure to that for which the unit coils are designed.

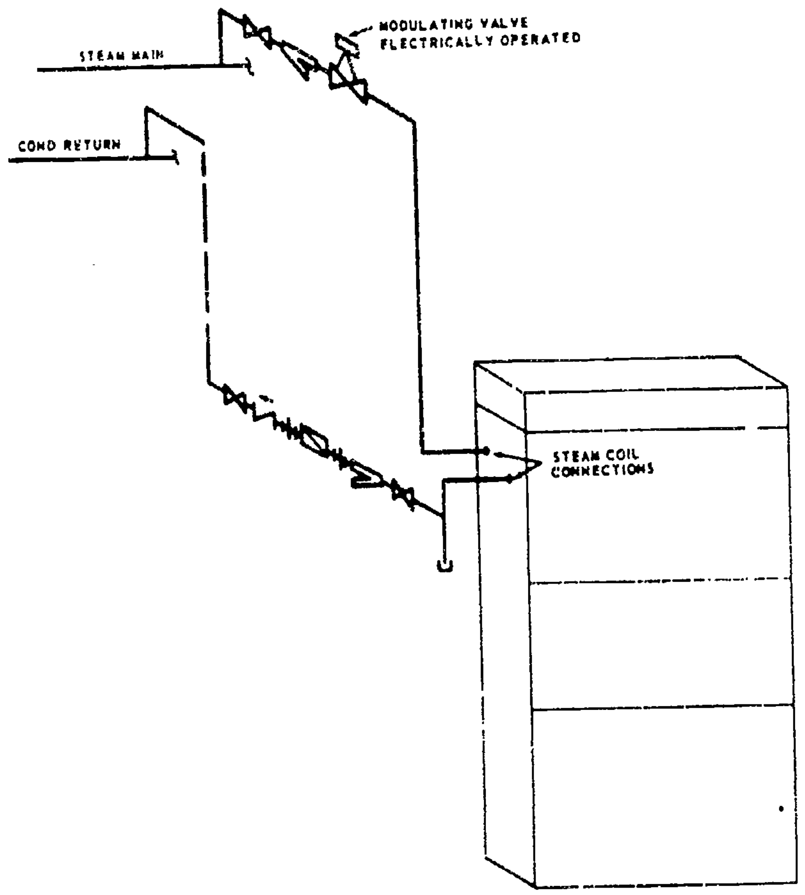
The steam condensate leaving the unit first passes (1) a gate valve, (2) a strainer, (3) a union, and (4) a steam trap. This trap is a device which performs two funct- -s: (1) it provides a receptacle in which stea.. · ..denses into water, and (2) it contains an automatic valve system which periodically releases this water into the rest of the return lines.

Beyond the steam trap, there is another union; next comes a check valve, and finally another gate valve. A check valve is a one-way valve, permitting passage in one direction and preventing backup in the opposite direction.

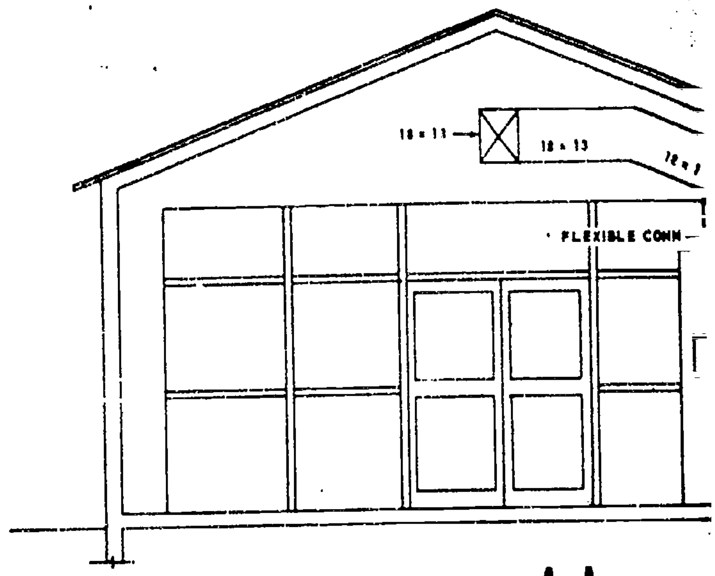
VENTILATING

Most VENTILATING SYSTEMS take advantage of the natural environment. The ventilating system is designed to use the natural forces of wind and interior-exterior temperature differences to cause circulation, and maintains a continuous freshening of the internal air. In general, air is permitted to enter through openings at or near the floor level, and allowed to escape through openings high on the walls or in ceilings and roof.

In mechanical ventilation, air circulation is induced by mechanical means—usually by fans, which may be combined with supply and exhaust duct systems.

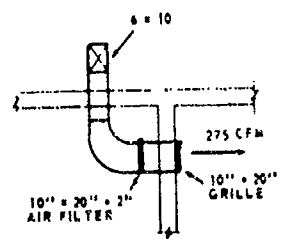


TYPICAL STEAM & COND RETURN CONN
TO AIR CONDITIONING UNIT
NO SCALE



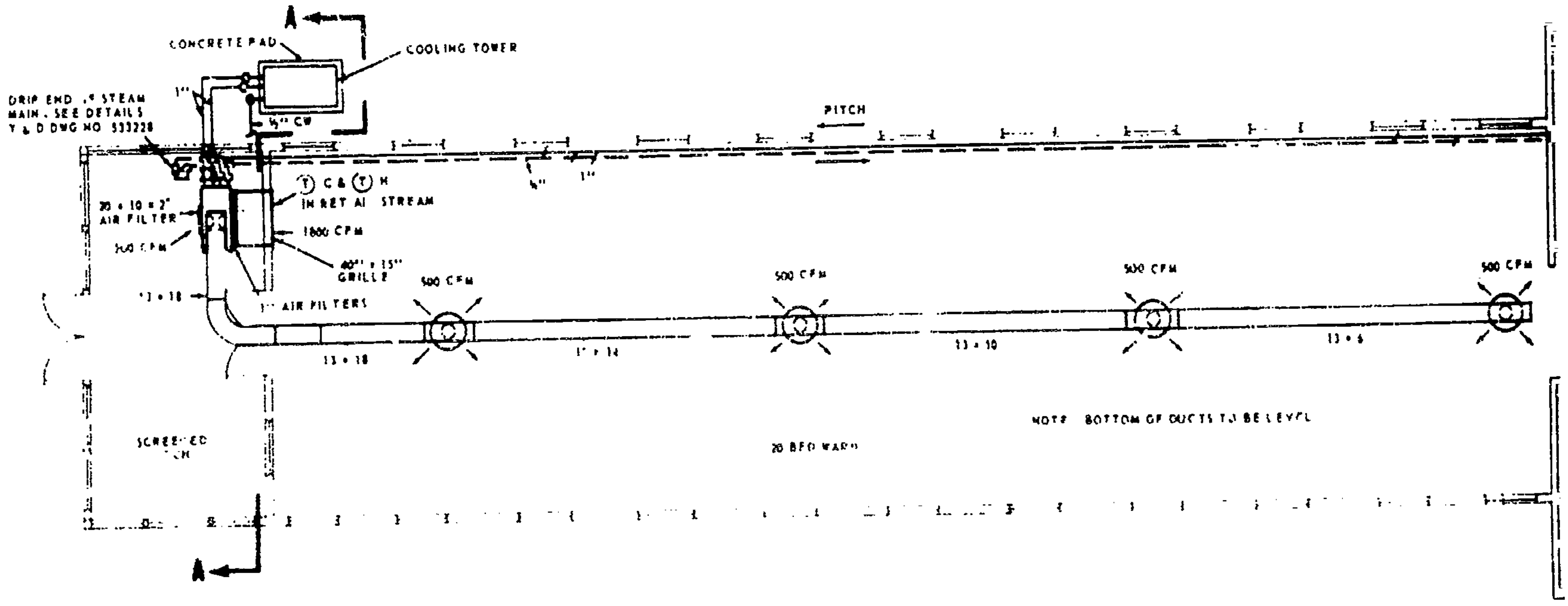
SECTION A—A

SCALE 1/4" = 1'-0"



SECTION B—B

SCALE 1/4" = 1'-0"



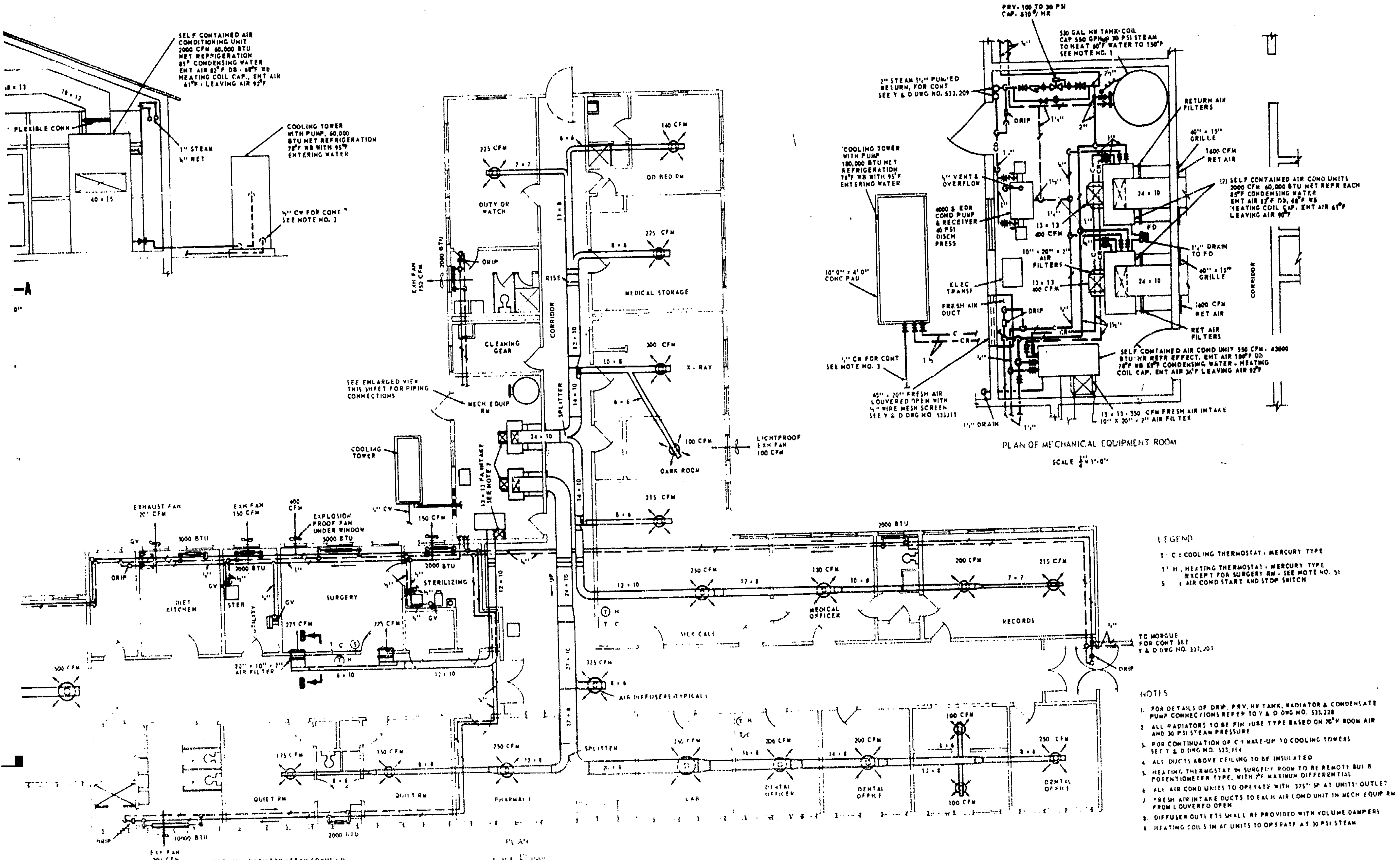


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Figure 7-11.—Heating and air-conditioning layout.

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CHAPTER 8

ELECTRICAL PLANS

The electrical information and layouts in construction drawings, just like the mechanical plans are generally super-imposed on the building plan and the plot plan.

In this chapter, we will address electrical plans as the drawings which pertain to the electrical distribution system that indicate outside powerlines and appurtenances for multibuilding installations and the Interior Wiring System (any electrical wirings installed inside a building).

As an EA3 or EA2, 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 electrical drawing methods, the symbols, and the nomenclature, as well as the basic functions of the components associated with the electrical distribution systems, circuit hookups, and in addition, be able to apply that knowledge in drawing electrical plans.

ELECTRICAL SYMBOLS

The most common types of symbols used in electrical drawings are shown in figure 8-1. For special or additional symbols, refer to ANSI Y32.9-1972. Except for the details which require more time, because they are generally shown in different views and sections, or in a pictorial form, ordinary electrical drawings for structures are easy to make.

To draw in electrical symbols in an electrical drawing, as in drawing a plumbing plan, it is best to use templates. The wire is generally drawn as a single line, but with slanting "tick marks" to indicate the number of wires in an electrical circuit.

ELECTRICAL DISTRIBUTION SYSTEMS

Electrical distribution is defined as the delivery of power to building premises, on poles or placed underground, from the powerplant or substation through feeders and mains.

Within this system, the Construction Electrician (CE) may refer to it as the power system which is a general term that covers the large-capacity wiring installations and associated equipment for the delivery of electrical energy from the point of generation to the point of use. 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 times, in small power systems, which will be discussed later in this chapter, 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 power outlets.

Before proceeding to the study of this section, you should have a basic understanding of the use of the transformer in the electrical power system.

TRANSFORMERS

A transformer is simply a device for increasing or reducing the voltage in an electrical circuit. It ranges in size from a portable one (those used for appliances inside the building) to heavy ones that are mounted permanently in platforms or hung with crossarm brackets attached to an electric pole. Ask one of the CE's

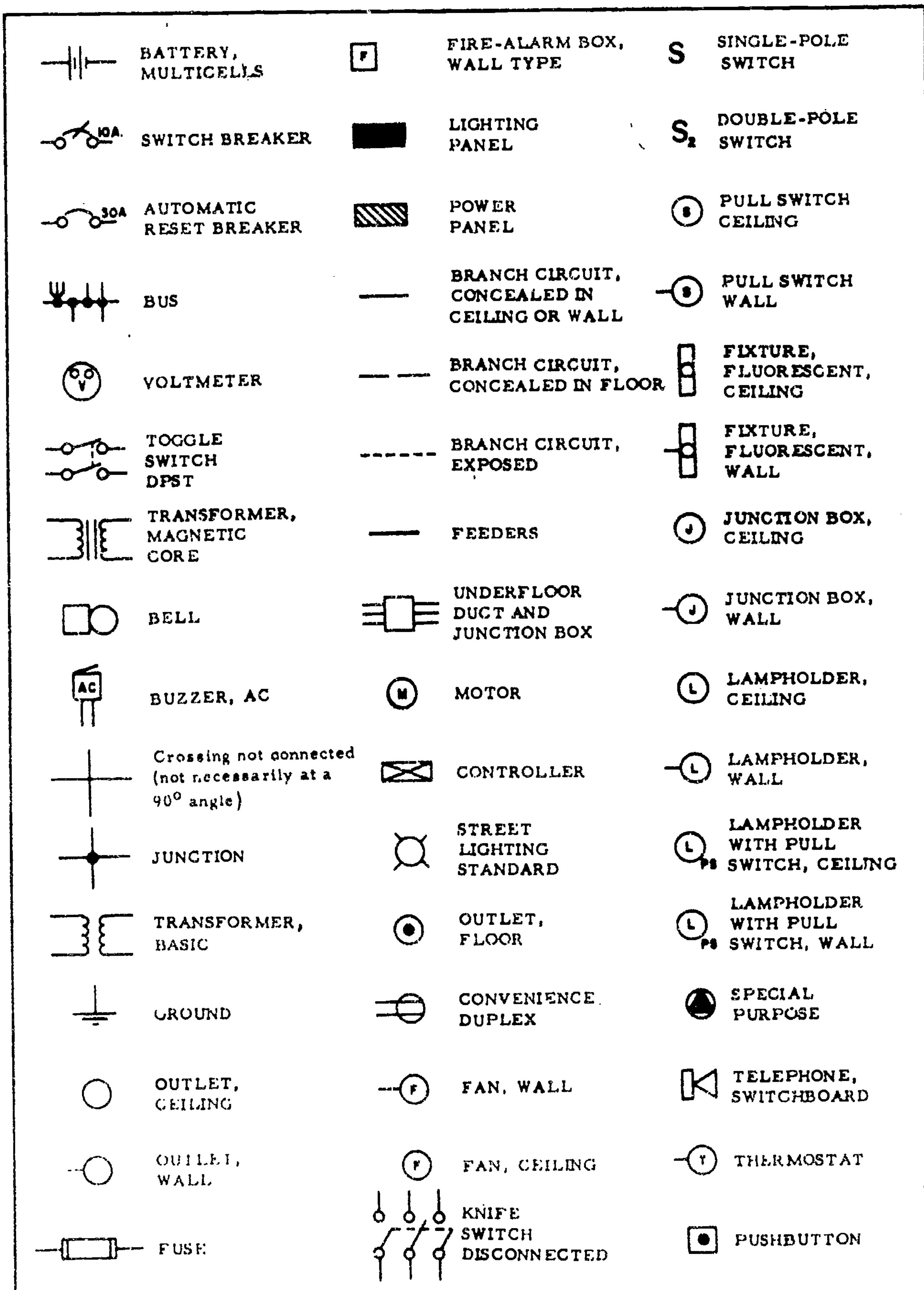

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Figure 8-1.—Electrical symbols.

to show you a transformer, and it is very probable that there is one not far from your barracks.

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; this time 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,

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

(See chapter 3, *EA 3 & 2, Vol. 1.*)

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, the VOLTAGE or ELECTROMOTIVE FORCE (E) must also be increased 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.

POWER DISTRIBUTION SYSTEMS

Most land-based power systems use alternating current rather than direct current, principally because the use of transformers is possible only with alternating current. An a.c. distribution system usually contains one or more generators (technically known as ALTERNATORS in an a.c. 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 system may be a THREE-WIRE OR A FOUR-WIRE system, depending upon whether the alternators are connected DELTA (Δ) or

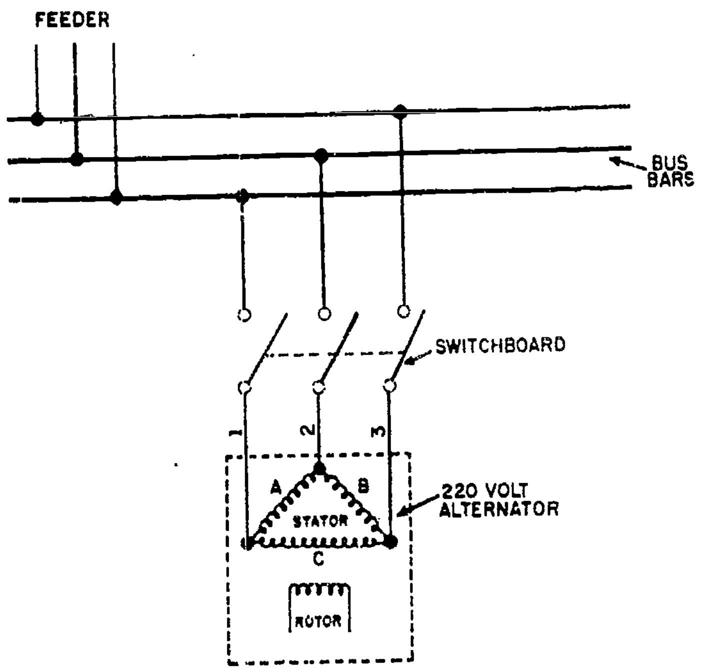

Figure 8-2.—Delta-connected alternator.

WYE (Y). Figure 8-2 is a schematic drawing illustrating a delta connection. The coil marked 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 8-3 shows a Y-connected alternator (3-phase, 4-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 delta-connected system has only a single voltage rating (220 volts in fig. 8-2). However, in a Y-connected system, the voltage developed in different combinations of wires is different. In figure 8-3, you can see that lines 1 and 2 take power from 2 stator coils (A and C). The same applies to lines 1 and 3 (power from coils B and C), and line numbers 2 and 3 (power from coils A and B). However, the neutral (N) and line 2

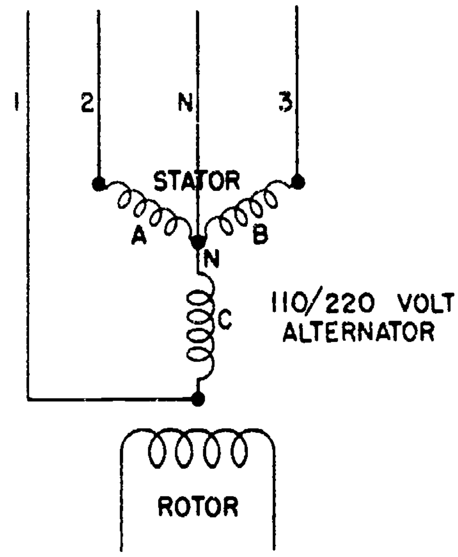

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Figure 8-3.—Y-connected alternator (3-phase, 4-wire).

takes 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

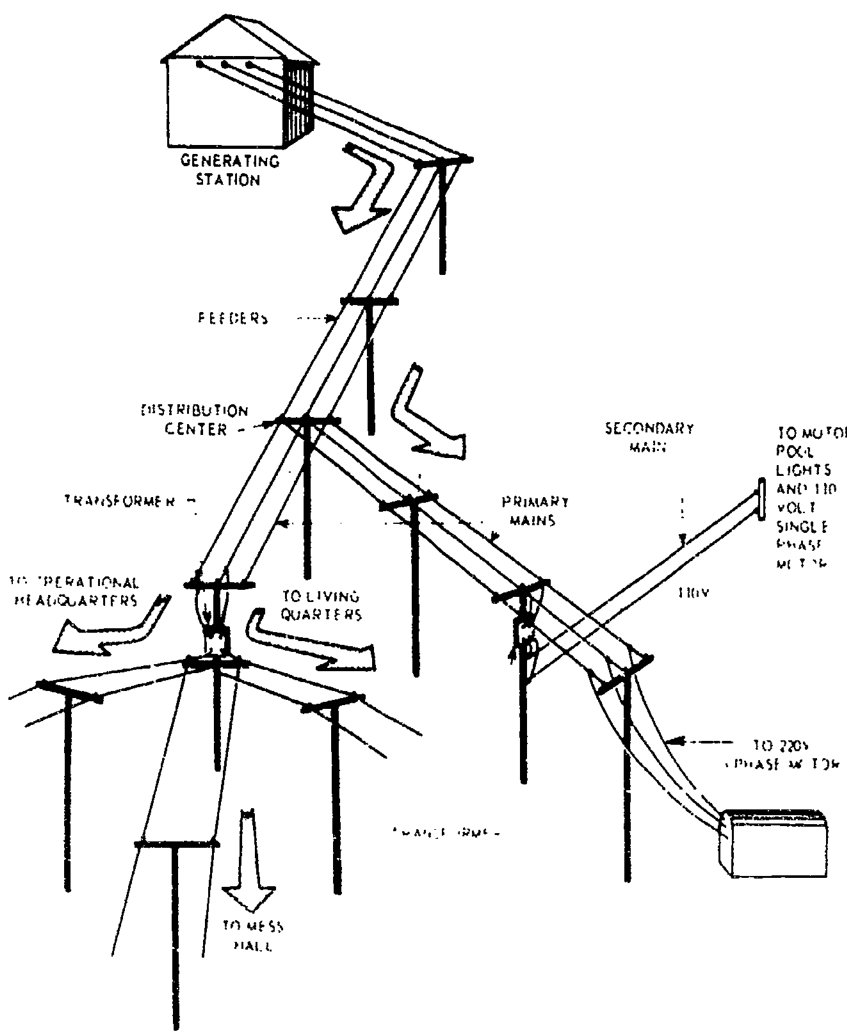

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Figure 8-4.—Three-wire distribution system, pictorial view.

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 8-4 illustrates a three-wire distribution system. This system has a delta-connected alternator, generating 240 volts. From the generating station, three-wire feeders carry the power overhead to the distribution center, from which two primary mains branch off. One of these carries power to a lighting system and single-phase motor in a motor pool, both designed to operate on 110 volts, and to a three-phase motor designed to operate on 220 volts. The 220-volt three-phase motor is connected directly to the 220-volt three-phase primary main. For the lighting system and 110-volt motor, however, two wires in the primary main are tapped off to a transformer which reduces the 220-volt primary main voltage to 110 volts. The use of two wires creates 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 volts and converted to single phase.

Figure 8-5 shows how the system illustrated in figure 8-4 is represented in a WIRING DIAGRAM.

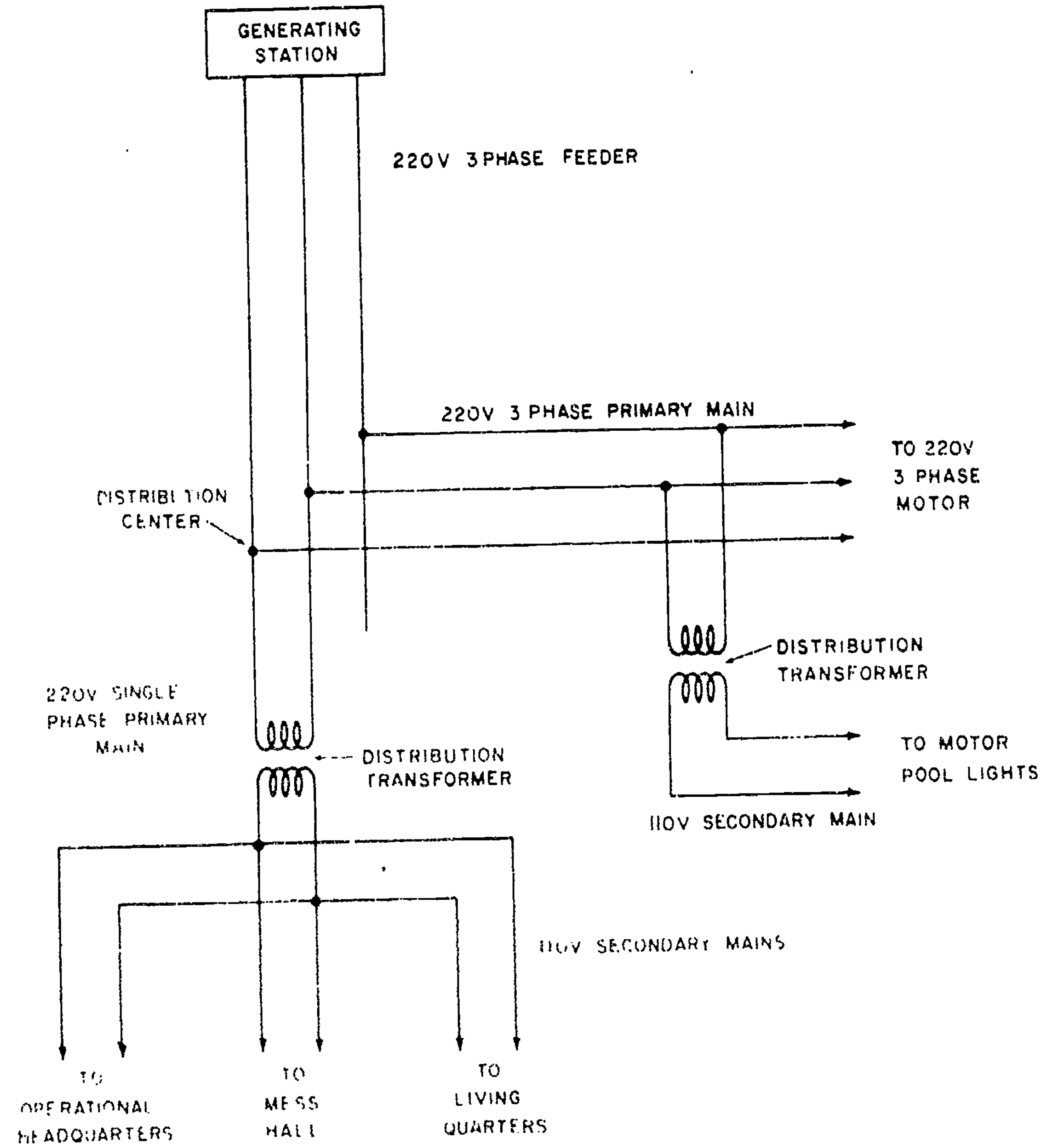

Figure 8-5.—Three-wire distribution system, wiring diagram. 82.72

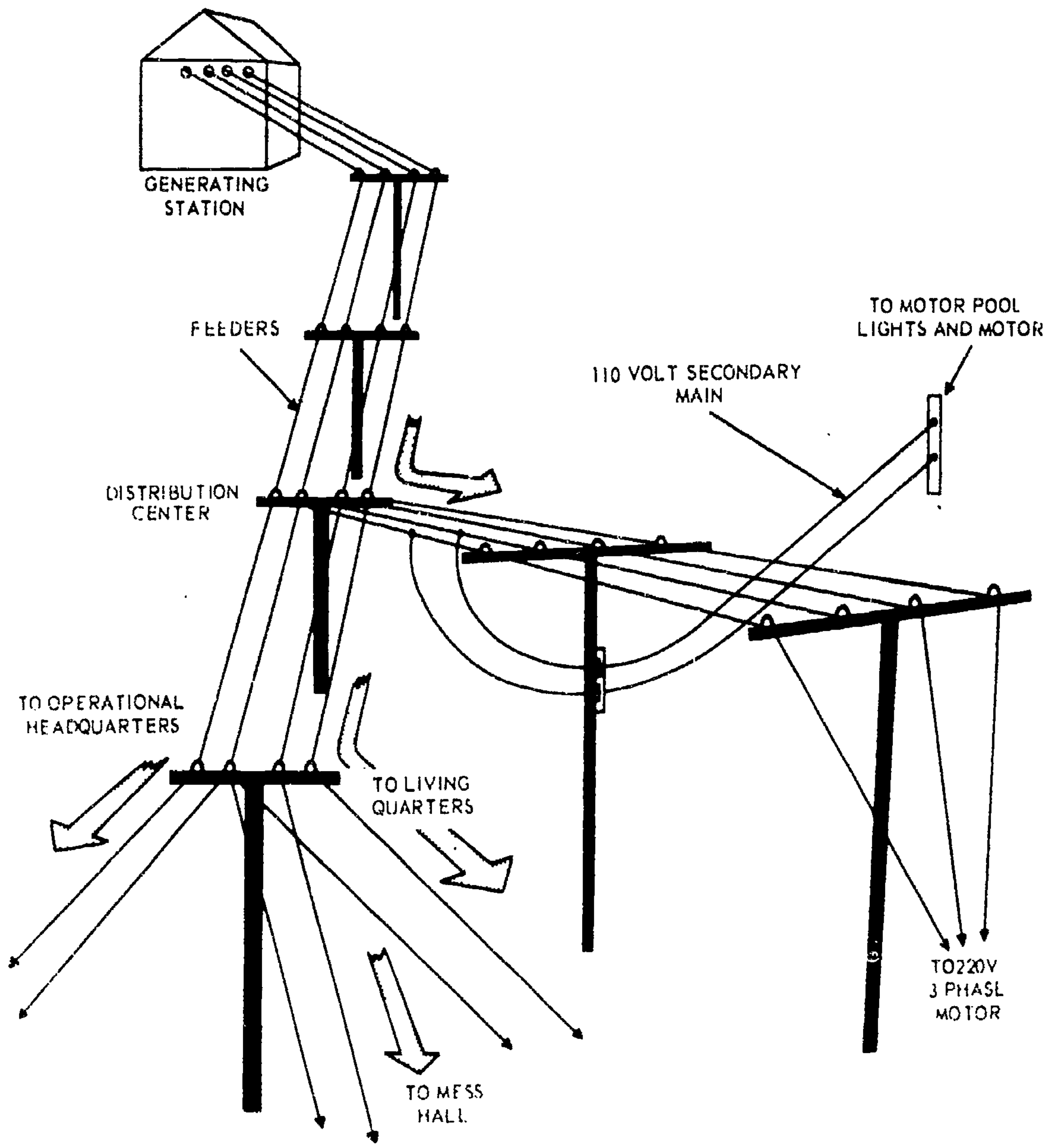

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Figure 8-6.—Four-wire system, pictorial view.

Figure 8-6 shows a four-wire system serving the same facilities. Here there is a Y-connected alternator rated at 110/220 volts. You can see that to get 110 volts 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-volt three-phase motor is tapped into the three hot wires which develop 220 volts three-phase. You can see that the neutral wire in a 4-wire system exists to make it possible for a lower voltage to be used in the system.

Figure 8-7 shows a wiring diagram for the system illustrated in figure 8-6.

Exterior Electrical Layout

Figure 8-8 is a plot plan showing six buildings which are to be supplied with electricity for power and lighting. The dotted line at the bottom of the drawing indicates underground ducts containing cable already laid. The design engineer has decided to tap the cable at manhole (M.H.) 22, and run lines from there overhead to dead end at the rear of building 126. Lines are to

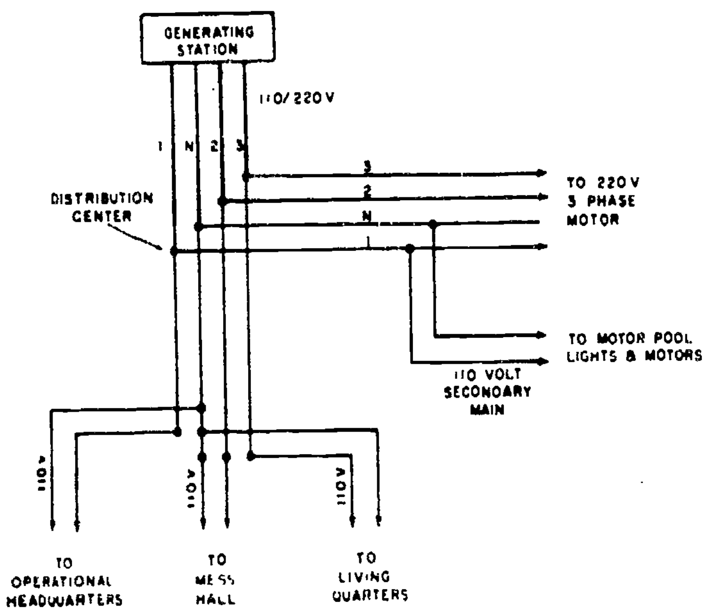

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Figure 8-7.—Four-wire system, wiring diagram.

be run underground from M.H. 22 to the first pole, up the pole to a POTHEAD (See fig. 8-12.) and from the pothead to conductors on the pole crossarms. At building 126, lines are to be carried down the pole, re-gathered through a pothead into conduit again, and run underground to a concrete slab, and out through another pothead to a transformer bank.

Figure 8-9 shows the same plot plan, with the electrical layout superimposed. General notes for the drawing are shown in figure 8-10. Figure 8-11 shows the detail A indicated in figure 8-9. Figure 8-12 shows the section A-A indicated in figure 8-11. The term 1-3/C #1/0 VCL means "one three-conductor number 1/0, varnished cambric lead covered cable." Note the 5-kilovolt pothead shown in figure 8-12.

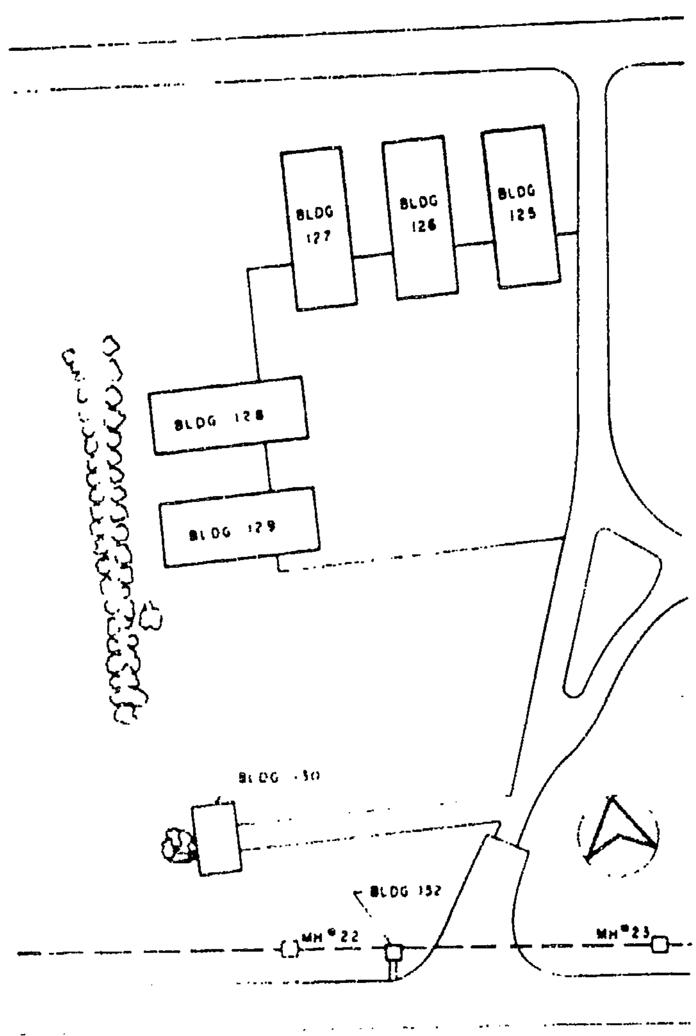

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Figure 8-8.—Plot plan without electrical layout.

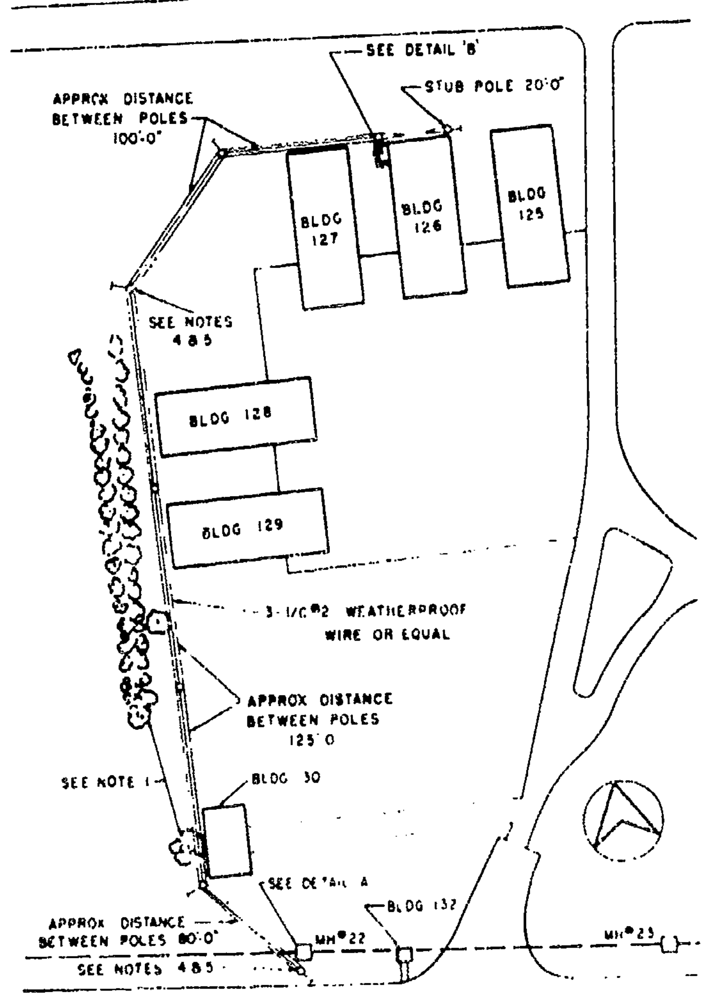

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Figure 8-9.—Plot plan with electrical layout.

GENERAL NOTES

1 - TREES OBSTRUCTING POLE LINE TO BE TRIMMED OR REMOVED AS DIRECTED BY CONSTRUCTION OFFICER

2 - PROVIDE LIGHTNING ARRESTERS, AT EACH END OF POLE LINE, ON ALL THREE OVERHEAD WIRES GROUND LIGHTNING ARRESTERS WITH SUITABLE BARE WIRE CONNECTED TO DRIVEN GROUND ROD

3 - INSULATORS TO BE PORCELAIN, PIN TYPE, INSULATOR PINS TO BE LOCUST WOOD OR EQUAL

4 - TERMINAL POLES, AND POLES AT POINT OF CHANGE IN LINE DIRECTION, TO HAVE DOUBLE CROSS-ARMS ALL OTHER POLES, SINGLE CROSS-ARM. CROSS-ARMS TO BE STANDARD 4 PIN, 5'-7" x 3 1/2" x 4 1/2", PIN SPACING 3'-0" ON CENTERS AND 14 1/2" ON SIDES

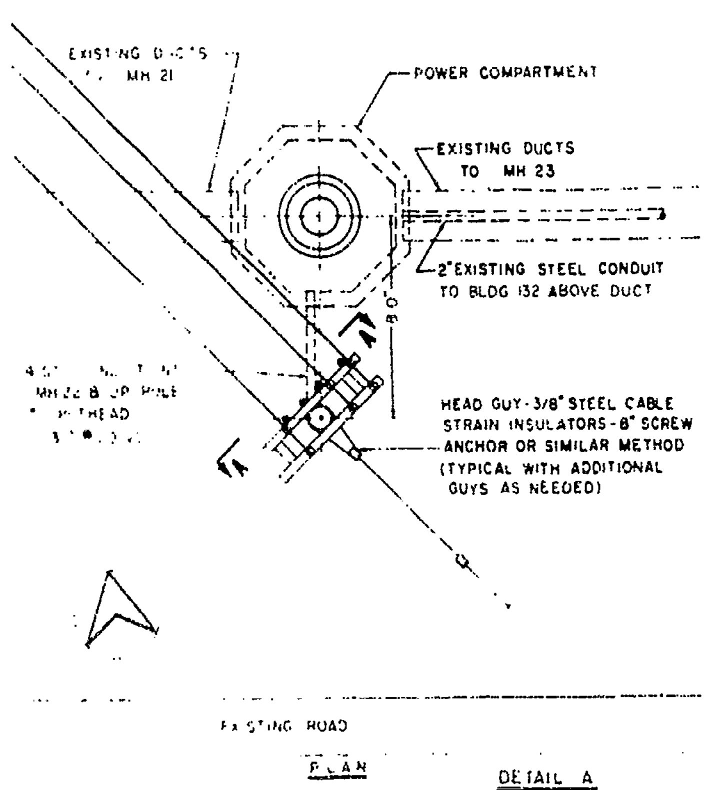
5 - TERMINAL POLES TO HAVE ONE GUY, POLES AT POINT OF CHANGE IN LINE DIRECTION TO BE GUYED ACCORDING TO STANDARD PRACTICE EACH GUY LINE TO HAVE TWO PORCELAIN STRAIN INSULATORS, THE LOCATION AND SPACING OF STRAIN INSULATORS AND GUY ANCHORS TO BE IN ACCORDANCE WITH STANDARD PRACTICE

6 - MATERIAL AND WORKMANSHIP SHALL CONFORM TO ALL STANDARD CODES, REGULATIONS AND SPECIFICATIONS

82.75

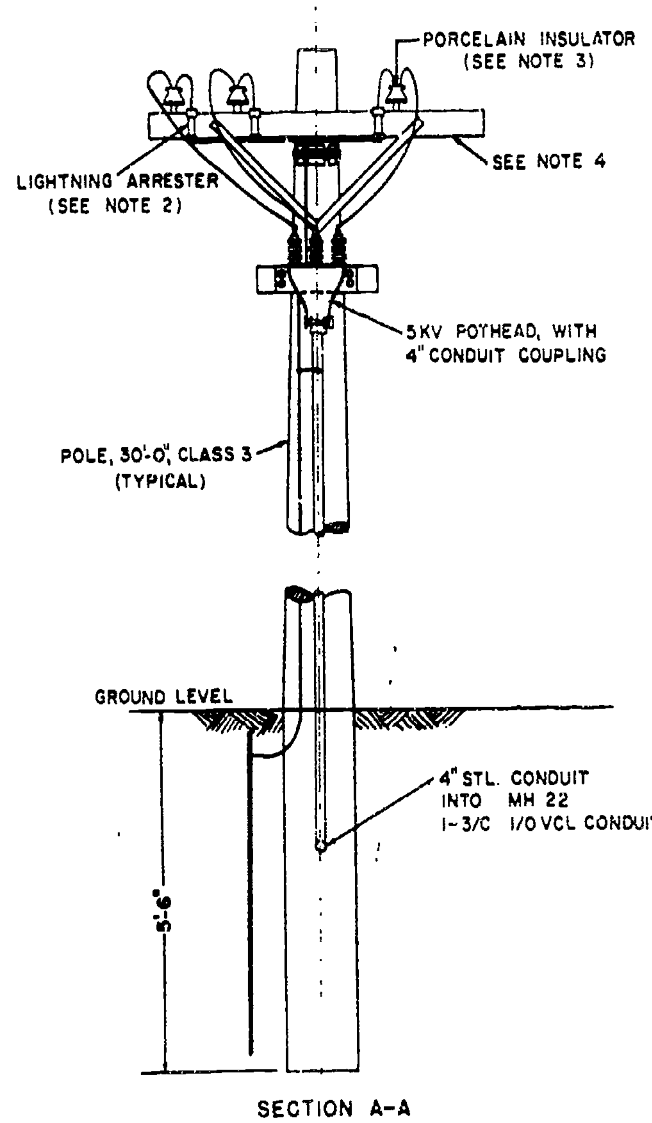
Figure 8-10.—General notes for layout shown in figure 8-9.

Figure 8-13 shows the detail B indicated in figure 8-9. This represents the installation behind building 126, where the overhead line terminates. The last pole in the system is shown in the lower left corner. From the pole to the transformer bank, the underground conduit is indicated by dotted lines. The conduit runs



65.66

Figure 8-11.—Detail for layout shown in figure 8-9.



65.67

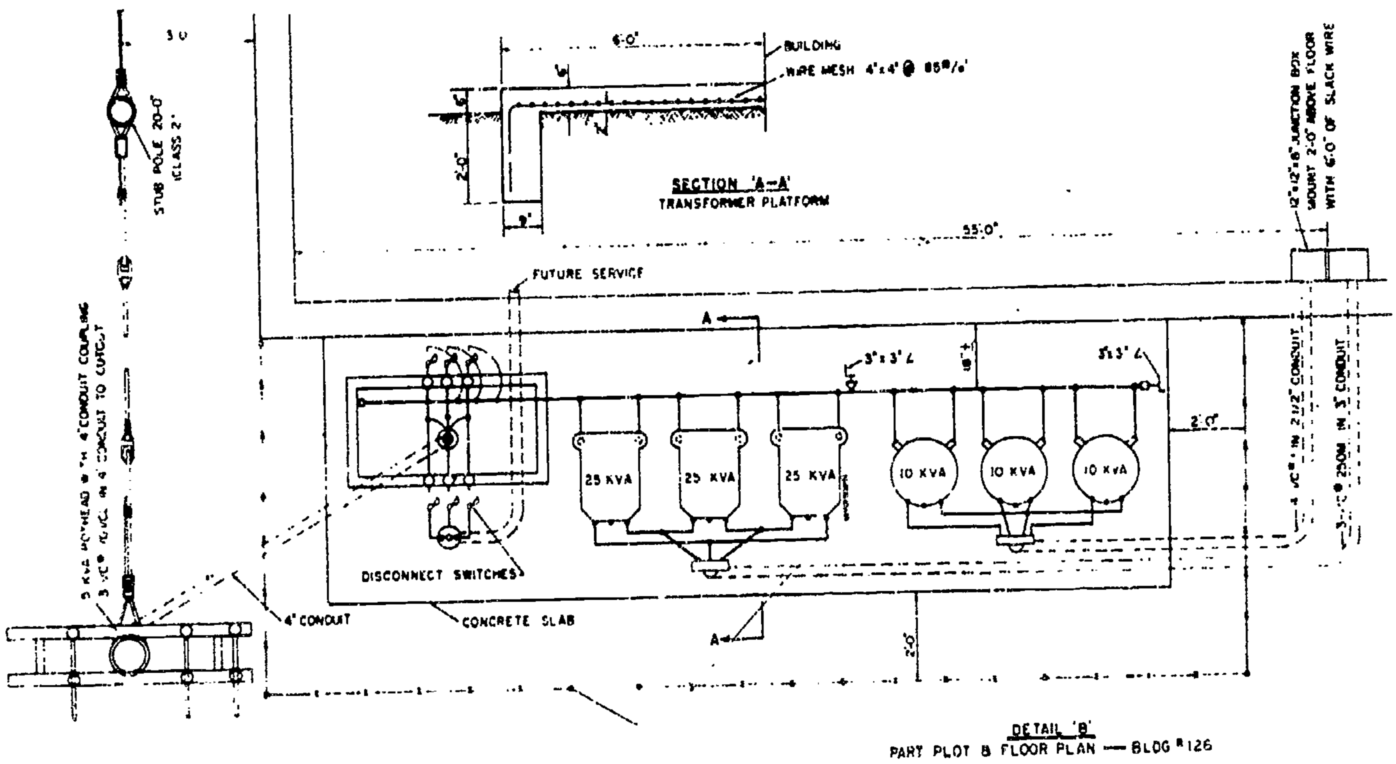
Figure 8-12.—Section A-A indicated in figure 8-11.

under the concrete slab on which the transformers rest. Section A-A gives construction details of this slab.

The angle-iron symbol with the dimensions 3 by 3 inches indicates that the BUS (connecting conductor) running along the transformer primaries will be supported on posts made of 3- by 3-inch angles. From the transformer secondaries, underground conduits (indicated by dotted lines) will run to the junction box on building 126.

Interior Electrical Layouts

Electrical power is brought into a building through a service entrance by OVERHEAD or



65.69

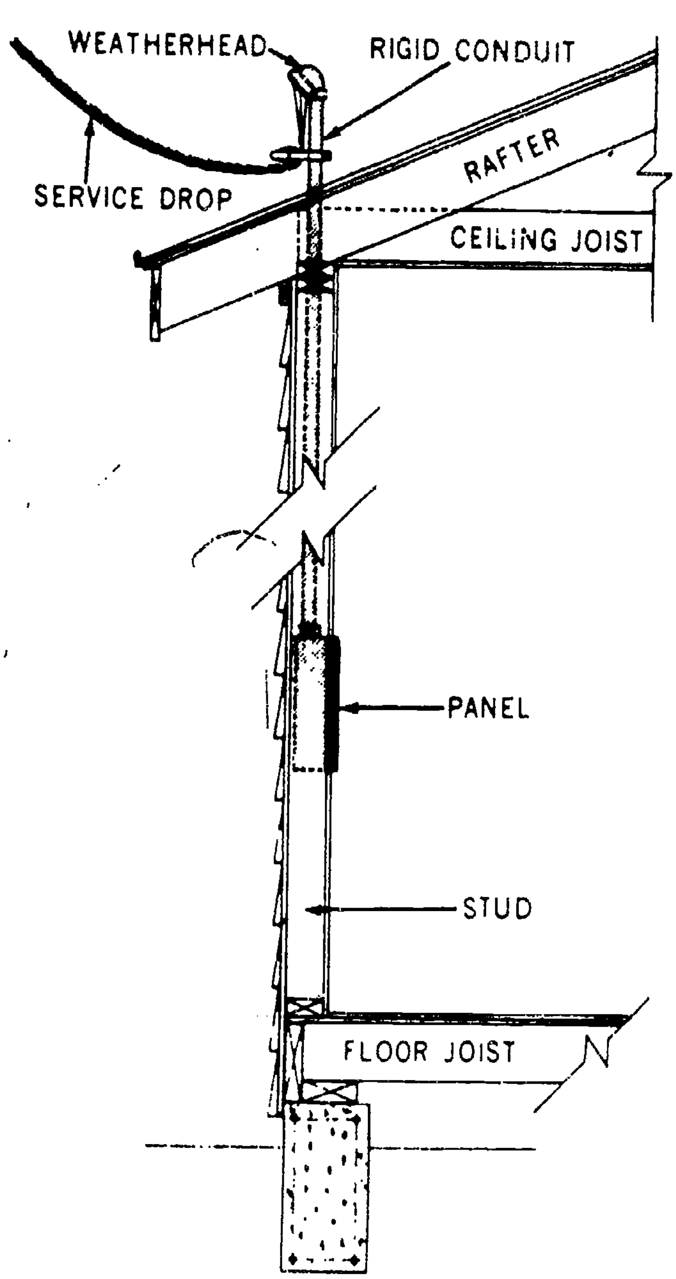
Figure 8-13.—Detail B indicated in figure 8-9.

UNDERGROUND SERVICE. Figure 8-14 shows an overhead service entrance which brings power from the service drop to a panelboard inside the building. Naturally, one of the components of the service entrance is the conductor through which the current flows. This conductor may consist of individual wires which run through a protective raceway, such as rigid metal conduit, electrical metallic tubing, or rigid nonmetallic conduit. The raceway provides the conductors with protection from both physical and weather damage. At other times, service entrance cable is used. This cable does not need raceway protection unless it is likely to be physically damaged by abrasion or from being struck by passing equipment.

A service head, also called a weather head, is used with a raceway to provide an entrance for the conductors into the raceway and is designed to prevent the entrance of rain into the raceway and bushed to reduced abrasion on the insulation. Figure 8-15 illustrates an UNDERGROUND SERVICE that brings power into a building. The conductors, corresponding to the service drop which bring the power to the building, are called the "service lateral." These conductors may be tied to an overhead distribution system, and 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 metal or nonmetallic or it can also be installed with underground service entrance cable (USE). The figure shows the layout of an underground service lateral run from the transformer to the junction box and to the service equipment.

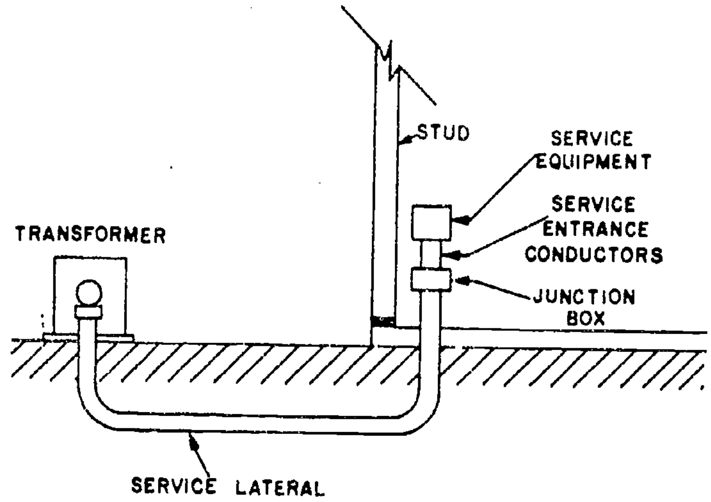
Figure 8-16 shows an electrical layout, once again superimposed on an outline taken from an architectural floor plan. The service entrance



45.897
Figure 8-14.—Overhead service entrance.

bringing power into the house is a three-wire line in 1 1/4-inch conduit. However, the fact that the line voltage is 110/220 indicates that these three wires must be two hot wires and a neutral wire from a four-wire system, the third hot wire not being brought into the building.

The service line runs by way of a service switch to a lighting panel, from which two BRANCH CIRCUITS run to the lighting fixtures and convenience outlets in the rooms. The



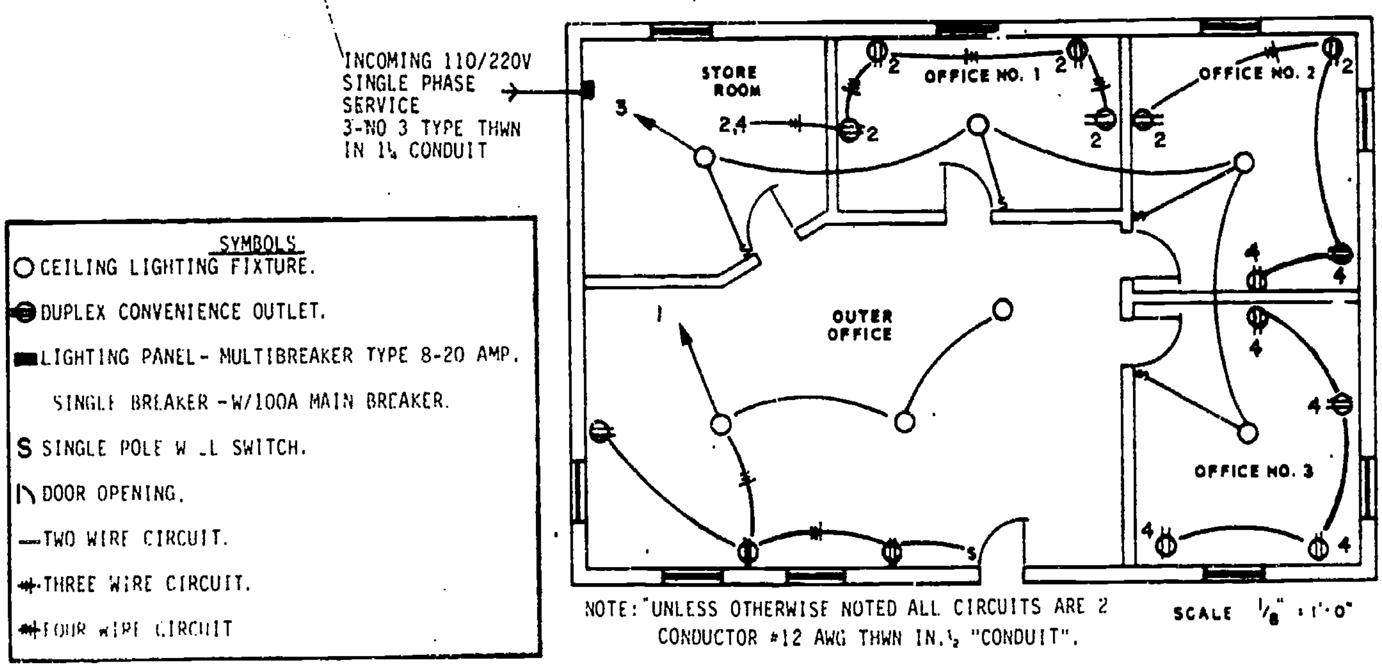
45.898
Figure 8-15.—Underground service to building.

character of these fixtures and outlets, and of the service switch and the lighting panel, is shown under "symbols."

Figure 8-17 is a wiring diagram showing the connections for the layout shown in figure 8-16. After entering the building, the two hot wires (black) in the service lead are connected to a 100-amp, 2-pole main circuit breaker, while the neutral wire bypasses the switch and runs to the NEUTRAL BAR in the panel board, with a branch off to a water pipe ground. Beyond the main circuit breaker, the two hot wires run to vertical BUS BARS in the panel board.

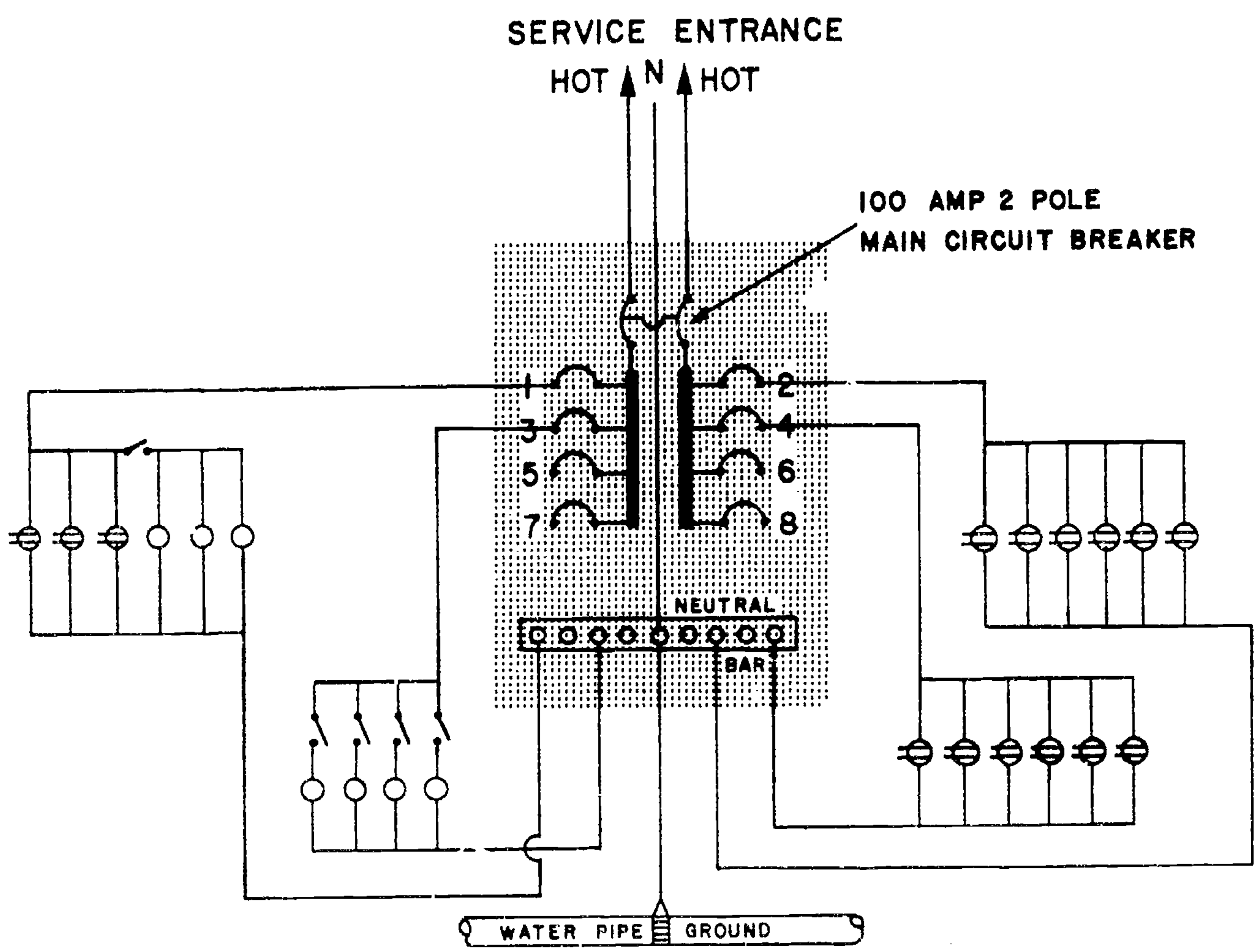
The panel board is equipped to handle eight circuits, although there are only four shown in the diagram. Consider branch circuit No. 1. This circuit contains two wires, a hot wire running out from the bus bar in the panel board, and a neutral (white) wire running back to the neutral bar in the panel board. This circuit contains only a single switch, which turns all the lights in the circuit on or off simultaneously, but has no effect on the flow of power to the convenience outlets.

Circuit No. 3 also contains a hot wire out from the bus bar and a neutral wire back, and tied into the solid neutral bar. Each of the lights in this circuit has its own switch, which controls the flow of power to the light only. Like circuit No. 1, circuit No. 3 has a hot wire out from the panel board bus bar, and a neutral wire back to the neutral bar.



45.515(65)

Figure 8-16.—Interior electrical layout.



82.76

Figure 8-17.—Wiring diagram for layout shown in figure 8-16.

As mentioned earlier, the electrical information on small residential working drawings is generally shown in the regular floor plan. However, there are times when more information is needed to convey the designers ideas that can not be contained in a single drawing. Therefore, a separate electrical drawing will be required. In order to develop this drawing and be understood by the electrical contractors, and for the (CE) who will install and plan the local circuits requirements to meet the local code and specifications, the following basic steps are suggested: (a) Show the location of the service panel and its rating (125 amps); (b) Show all wall and ceiling outlets; (c) Show all special purpose outlets, such as telephone, communications, doorbells, etc.; (d) Show all switches and their outlet connections; (e) Show convenience outlets; and (f) If required, complete a schedule of electrical fixtures, symbol legends, and notes necessary to clarify any special requirements in the drawing that are not stipulated in the specifications.

CHAPTER 9

SPECIFICATIONS

Even well-drawn construction drawings cannot be entirely adequate in revealing all the aspects of a construction project. There are many features that cannot be shown graphically. For instance, how can anybody show on a drawing the quality of workmanship required for the installation of doors and windows or who is responsible for supplying the materials, except by extensive hand-lettered notes. The standard procedure then is to supplement construction drawings with written descriptions. These detailed written instructions, commonly called SPECIFICATIONS (SPECS), define and limit the materials and fabrication according to the intent of the engineer or the designer. The specifications are a very important part of the project, because they eliminate possible misinterpretation and insure positive control of the construction.

This chapter will explain various types of references used by technical specification writers in the preparations of project specifications, their general format, and the terminology used.

NAVFAC SPECIFICATIONS

NAVFAC SPECIFICATIONS are prepared by the Naval Facilities Engineering Command which sets forth the standards of construction for the Naval Construction Force and all work performed under the jurisdiction of the Naval Facilities Engineering Command. When NAVFAC specifications are used in the preparation of project specifications, they must be consistent with the conditions of usage mentioned in them. Major deviations in these specifications should NOT be made without prior NAVFAC Headquarter's approval.

Design Criteria Used In Contracts For Public Works, NAVFAC P-34, is a publication that lists current NAVFACENGCOM guide specifications and Federal, Military, and special specifications and standards cited in those guide specifications and the Design Manuals and related publications promulgated by NAVFACENGCOM as design criteria.

GUIDE SPECIFICATIONS

GUIDE SPECIFICATIONS in the Type Specifications (TS) series and the design criteria contained in the NAVFAC design manuals (DM) and NAVFAC P publications (P-) are mandatory for use in the design of Naval Shore Facilities. These publications and manuals define, describe, and establish the minimum criteria for the design and construction of various specialties. They are the NAVFAC specifications and references in project specifications that are most commonly used by the SEABEES. They may be modified by taking exceptions or amplified by additional requirements.

EXAMPLE: "Concrete construction shall conform to the applicable requirements of the American Concrete Institute (ACI-301 and ACI 318), except as otherwise specified."

EXAMPLE: "Protection and curing of concrete piles shall be in accordance with ACI-308; however, the side forms can be removed approximately 48 hours after the concrete is placed."

TYPE SPECIFICATIONS (TS-SERIES)

TYPE SPECIFICATIONS must not be referenced in project specifications. They may be used as manuscripts for project specifications. Portions of type specifications that are not applicable to a project must not be incorporated into the project specifications. When portions of a project are not covered by a type specification, amplify, where necessary, using language and form similar to that of the type specification.

STANDARD SPECIFICATIONS (S-SERIES)

STANDARD SPECIFICATIONS are written for a small group of specialized structures, which must have uniform construction to meet rigid operational requirements. NAVFAC standard specifications contain references to Federal, Military, other command and bureau, and association specifications. NAVFAC standard specifications are referenced or copied in project specifications. When it is necessary to modify requirements of a standard specification, it must be referenced and exceptions taken.

EXAMPLE: "The magazine shall be Arch, Type I, conforming to Specifications S-M8E, except that all concrete shall be Class F-1."

COMMERCIAL SPECIFICATIONS AND STANDARDS

Where the quantity of material is small and does not require testing, a suitable standard commercial product may be used. Manufacturers' standards, however, cannot be referred to or copied verbatim in project specifications.

Technical Society and Association Specifications

These specifications—for example, those published by the American National Standards Institute (ANSI), American Society for Testing and Materials (ASTM), Underwriter's Laboratories (UL), and American Iron and Steel Institute (AISI)—should be referenced in project specifications, when applicable.

Manufacturers' Standards

These specifications should not be referenced in project specifications. They may be used to aid in preparing the requirements for project specification, but must not be copied verbatim. Do not base requirements on standards of several manufacturers.

FEDERAL AND MILITARY SPECIFICATIONS

FEDERAL SPECIFICATIONS cover the characteristics of materials and supplies used jointly by the Navy and other government agencies. Federal Specifications do not cover installation or workmanship for a particular project, but specify the technical requirements and tests for materials, products, and/or services. Figures 9-1, 9-2, and 9-3 are excerpts from Federal Specifications FF-N-105B (nails, spikes, staples, etc.) which dictate the minimum requirements, acceptable for use of all Federal agencies. For example, suppose the project specifications, which will be discussed later, states that "for all carpentry, nails shall conform to Federal Specification FF-N-105B Type II." To further identify the nails required, it will be necessary to refer to Federal Specification FF-N-105B to define the different styles under Type II before proper selection of the nails may be made. The engineering technical library should contain all of the commonly used Federal Specifications pertinent to SEABEE construction.

MILITARY SPECIFICATIONS are those specifications that have been developed by the Department of Defense. Like Federal Specifications, they also cover the characteristics of materials. They are identified by "DOD" or "MIL" preceding the first letter and serial number, such as MIL-L-19140C (lumber and plywood, fire-retardant treated) and DOD-STD-100C (engineering drawing practices).

PROJECT SPECIFICATIONS

Construction drawings are supplemented by written PROJECT SPECIFICATIONS. Project specifications give detailed information regarding materials and methods of work for a particular construction project. They cover various factors relating to the project, such as general conditions, scope of work, quality of materials, standards of workmanship, and protection of finished work.

Fed. Spec. FF-N-105B

FEDERAL SPECIFICATION

NAILS, BRADS, STAPLES AND SPIKES:
WIRE, CUT AND WROUGHT

This specification was approved by the Commissioner, Federal Supply Service, General Services Administration, for the use of all Federal agencies.

1. SCOPE AND CLASSIFICATION

1.1 Scope. This specification covers wire and cut nails and spikes, wire brads and staples, and wrought spikes.

1.2 Classification.

1.2.1 Types and styles. Nails, brads, staples and spikes shall be of the following types and styles, as specified (see 6.2).

Type I - Brads

Type II - Nails
- Style 1 - Asbestos Shingle
- 2 - Barrel
- 3 - Boat
- 4 - Box
- 5 - Broom
- 6 - Casing
- 7 - Coolers
- 8 - Sinkers
- 9 - Corkers
- 10 - Common
- 11 - Concrete
- 12 - Double-Headed
- 13 - Fine
- 14 - Finishing
- 15 - Flooring

FSC 5315

82.240

Figure 9-1. - Page 1 from Federal Specifications FF-N-105B.

FF-N-105B

Style 16 - Lath
17 - Masonry
18 - Pallet
19 - Gypsum Wallboard
20 - Roofing
21 - Shingle
22 - Siding
23 - Slating
24 - Rubber Heel
25 - Underlayment
26 - Square Barbed
27 - Masonry Drive
28 - Escutcheon

Type III - Staples
Style 1 - Fence
2 - Poultry Netting
3 - Flat Top Crown
3a - Round or "V" Crown
4 - Preformed

Type IV - Cut Nails
Style 1 - Common
2 - Basket
3 - Clout
4 - Trunk
5 - Cobblers
6 - Extra-Iron Clinching
7 - Hob

Type V - Spikes
Style 1 - Common (Cut)
2 - Gutter
3 - Round
4 - Barge and Boat

1.2.2 Sizes. Nails, brads, staples and spikes shall be of the sizes listed herein or as otherwise specified (see 6.2).

2. APPLICABLE DOCUMENTS

2.1 The following documents of the issue in effect on date of invitation for bids or request for proposal, form a part of this specification to the extent specified herein.

Federal Specifications:

NN-P-71 - Pallets; Materials-Handling, Wood (General Construction Requirements).
QQ-Z-325 - Zinc Coating, Electrodeposited, Requirements For.
MMM-A-250 - Adhesive, Water-Resistant (For Closure of Fiberboard Boxes).
PPP-B-566 - Boxes, Folding Paperboard.
PPP-B-601 - Boxes, Wood, Cleated-Plywood.
PPP-B-621 - Boxes, Wood, Nailed and Lock-Corner.
PPP-B-636 - Box, Fiberboard.

82.241

Figure 9-2.—Page 2 from Federal Specifications FF-N-105B.

FF-N-105B

Uniform Classification Committee, Agent:

Uniform Freight Classification.

(Application for copies should be addressed to the Uniform Classification Committee, Tariff Publishing Officer, Room 202 Union Station, 516 W. Jackson Blvd., Chicago, IL 60606.)

National Motor Freight Traffic Association, Inc., Agent:

National Motor Freight Classification.

(Application for copies should be addressed to the National Motor Freight Traffic Association, Inc., Agent, 1616 P Street, N.W., Washington, DC 20036.)

(Technical society and technical association specifications and standards are generally available for reference from libraries. They are also distributed among technical groups and using Federal agencies.)

3. REQUIREMENTS

3.1 Material. Nails, brads, staples and spikes shall be of the following materials, as specified (see 6.2).

3.1.1 Steel wire. Steel wire shall be of good commercial quality, entirely suitable for the purpose and sufficiently ductile to insure that the finished product shall withstand, without fracture, cold bending through 180 degrees over a diameter not greater than the diameter of the wire. Except as specified in 3.1.2, the cold bend test will not be applied to barbed nails, or nails having mechanically formed or deformed shanks.

3.1.2 Hardened steel. Hardened steel nails shall be heat treated to a minimum hardness of Rockwell C37. The finished product shall withstand, without fracture, cold bending through 20 degrees over a diameter not greater than the diameter of the wire.

3.1.3 Medium-carbon steel sheet. Cut nails (Type IV) and cut spikes (Type V, style 1) shall be sheared from medium-carbon steel sheet of good commercial quality, entirely suitable for the purpose. The finished product shall withstand, without fracture, cold bending through 90 degrees over a diameter not greater than the thickness of the sheet.

3.1.4 Copper. Copper nails shall contain a minimum of 98 percent pure copper. Copper nails shall withstand, without fracture, cold bending through 180 degrees over a diameter not greater than the diameter or thickness of the nail.

3.1.5 Copper-clad steel wire. Copper-clad steel wire shall be not less than 20 percent copper by weight. The average thickness of the copper shall be not less than 10 percent of the radius of the finished wire; the minimum thickness shall be not less than 8 percent of the radius of the finished wire. The finished product shall withstand cold bending through 180 degrees over a diameter not greater than the diameter of the wire without fracture and without separation of the copper from the steel.

82.242

Figure 9-3.—Page 4 from Federal Specifications FF-N-105B.

The drawings, together with the project specifications, define the project in detail and show exactly how it is to be constructed. Usually, any set of drawings for an important project is accompanied by a set of project specifications. The drawings and project specifications are inseparable. The drawings indicate what the project specifications do not cover; and the project specifications indicate what the drawings do not portray, or they clarify further details that are not covered amply by the drawings and notes on the drawings. Whenever there is conflicting information on the drawings and project specifications, the project specifica'' s take precedence over the drawings.

The Naval Facilities Engineering Command has developed a format for use in the preparation of project specifications. This format is described in NAVFAC Type Specification TS-M129 (latest revision), *Format and General Paragraphs for the Preparation of Manuscripts of Specifications for Public Works*. The format is patterned generally after the Construction Specifications Institute's format for Construction Specifications.

The General Requirements are usually the first specifications listed for the structure, stating type of foundation, character of load-bearing members (wood-frame, steel-frame, concrete), type or types of doors and windows, types of mechanical and electrical installations, and the principal function of the building.

The SPECIFIC CONDITIONS come next which must be carried out by the constructors. These are grouped in divisions under headings applying to each major phase of construction, as in the following typical list of divisions:

DIVISION

2. SITE WORK
3. CONCRETE
4. MASONRY
5. METALS
6. CARPENTRY
7. MOISTURE CONTROL
8. DOORS, WINDOWS, AND GLASS
9. FINISHES
10. SPECIALTIES
11. EQUIPMENT

DIVISION

12. FURNISHINGS
13. SPECIAL CONSTRUCTION
14. CONVEYING SYSTEMS
15. MECHANICAL
16. ELECTRICAL

Sections under one of these general categories generally begin with GENERAL REQUIREMENTS for that category. For example: under DIVISION 6.—CARPENTRY, the first section might read:

> 6.—01.—GENERAL REQUIREMENTS.—All framing, rough carpentry, and finishing woodwork required for the proper completion of the building shall be provided. All woodwork shall be protected from the weather, and the building shall be thoroughly dry before the finish is placed. All finish shall be dressed, smoothed, and sandpapered at the mill, and in addition, shall be hand-smoothed and sandpapered at the building, where necessary, to produce proper finish. Nailing shall be done, as far as practicable, in concealed places, and all nails in finishing work shall be set (meaning to drive heads slightly below the surface with a hammer-driven tool called a "nail set").

All lumber shall be S4S; all materials for millwork (doors, window sash, and the like) and finish shall be kiln-dried (meaning: dried or "cured" in heated kilns, rather than simply air-dried); all rough and framing lumber shall be air- or kiln-dried (meaning: absolutely no "green" lumber to be used).

Any cutting, fitting, framing, and blocking necessary for the accommodation of other work shall be provided. All nails, spikes, screws, bolts, plates, clips, and other fastenings and rough hardware (here is a whole list of items too small or too numerous to be shown on the drawings) shall be provided. All finishing hardware shall be installed in accordance with the manufacturer's instructions. Caulking and flashing (thin sheets of metal or other material, installed around window openings, chimney openings, and at other places where leakage might occur) shall be provided where indicated or where necessary to provide weathertight construction.

Subsequent sections under division 6.—CARPENTRY would specify various quality criteria and standards of workmanship for the various types of rough and finish carpentry, as, for example:

6.—07.—STUDDING for walls and partitions shall have doubled plates and doubled caps. Studs shall be set plumb and not to exceed 16 inches on centers and in true alinement. They shall be bridged with one row of 2 by 4 pieces, set flatwise and fitted tightly, and nailed securely to each stud. Studding shall be doubled around openings, and the headers for openings shall rest on the inner studs. Openings more than 4 feet wide in partitions shall have trussed headers. Studs shall be trebled at corners to form corner posts.

DIVISION 15, under Mechanical the Specs may read:

15.01. GENERAL REQUIREMENTS.—The work consists of a complete plumbing system including the sanitary soil, waste, and vent piping; cold and hot water supply piping, watermeter (if required), plumbing fixtures, hot water heater, and other necessary appurtenances. The system shall be inspected, tested, and approved by local government plumbing codes before burying, concealing, or covering the various piping systems. Each system shall be complete and ready for operation except as specified or indicated otherwise.

15.02. SANITARY SEWER, below ground level, shall be of extra heavy cast-iron soil piping and fitting of the bell-and-spigot type, extending not less than 5 feet beyond the foundation wall and sloped not less than 1/8 inch per foot. The joint shall be made from a good grade of twisted oakum uniformly and well tamped into the joint and with the 1-inch depth of hot poured lead, made in one pouring, and caulked tight. All horizontal soil connections to the system shall be accomplished by Y-fittings or combination Y-and 1/8 bends and all changes in direction greater than 1/8-bends shall be of the long sweep pattern. Lines shall be well supported to eliminate sagging. Backfilling shall be well tamped in 6-inch layers.

15.03. SANITARY SEWER, above ground, shall be as specified for below ground, except wastelines and vent piping above ground shall be of zinc coated, standard weight, screwed-end pipe steel and cast iron, recessed, long radius, screwed drainage fittings, graded not less than 1/8 inch per foot. The sanitary sewer vent shall extend full size through the roof for a distance of not less than 12 inches, where it shall be flashed with suitable corrosion resistant metal before the roofing is installed. A 4-inch cleanout shall be provided just above ground elevation at the base of the soil stack. All male screw ends shall be coated with a good grade pipe joint compound before entering into fittings. The bath tub trap shall be provided with a 3/4-inch brass, screw drain plug; all lines shall be properly supported from the floor joints with suitable hangers. Closet-bowl floor connections shall have a cast-iron closet-bowl floor flange with provisions for anchoring the brass closet-bowl bolts and an approved type of horn gasket. The finished joint shall be absolutely leakproof and the bowl shall sit squarely on the finished floor.

DIVISION 16, ELECTRICAL, will follow the same line of thought, except that the requirements will be those that follow closely the Electrical Code or sound electrical engineering practices.

The moment your battalion or unit receives orders to undertake a major construction project, watch for the arrival of sets of drawings and specifications that are usually provided well in advance of the deployment period. These drawings and specifications will also be the basis for the P & E (Planning and Estimating) and scheduling. Take a look at the specifications; once you advance in rate, especially if you are concerned with P & E, it will be your responsibility to study the applicable specifications thoroughly.

NAVFAC has prepared specifications which cover practically every subject on Naval construction. These specifications are the standards followed by the Naval Construction Forces—above all other specifications that may be available.

CHAPTER 10

REPRODUCTION AND DRAWING FILES

Usually, one draftsman is assigned the responsibilities of drawing reproduction, maintenance of reproduction equipment, and maintaining drawing files. However, all EA's should be familiar with the aspects of performing these duties.

This chapter discusses the typical reproduction equipment commonly used by the SEABEES and also discusses the procedures used in maintaining engineering drawing files. Each command will have different equipment and maintain different types of filing systems, depending on their mission and the size of their engineering division. When you are assigned reproduction and filing responsibilities, you will be given additional on-the-job training.

DRAWING REPRODUCTIONS

Complete drawings and tracings of drawings are used only for making reproductions; these are usually called PRINTS. Prints are exact copies reproduced on inexpensive, but fairly durable, paper by the most economical process available. Original drawings and tracings are removed from protected files (discussed later) only by the Engineering Aid, who is working as a draftsman, to make changes or to make reproductions. Therefore, the EA can provide workable copies or prints to estimators, supervisors, field crews, and others who must work from information provided on the original drawings.

This section discusses the various aspects of operating and maintaining typical reproduction machines, as well as the materials associated with drawing reproduction.

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, and then they are 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.

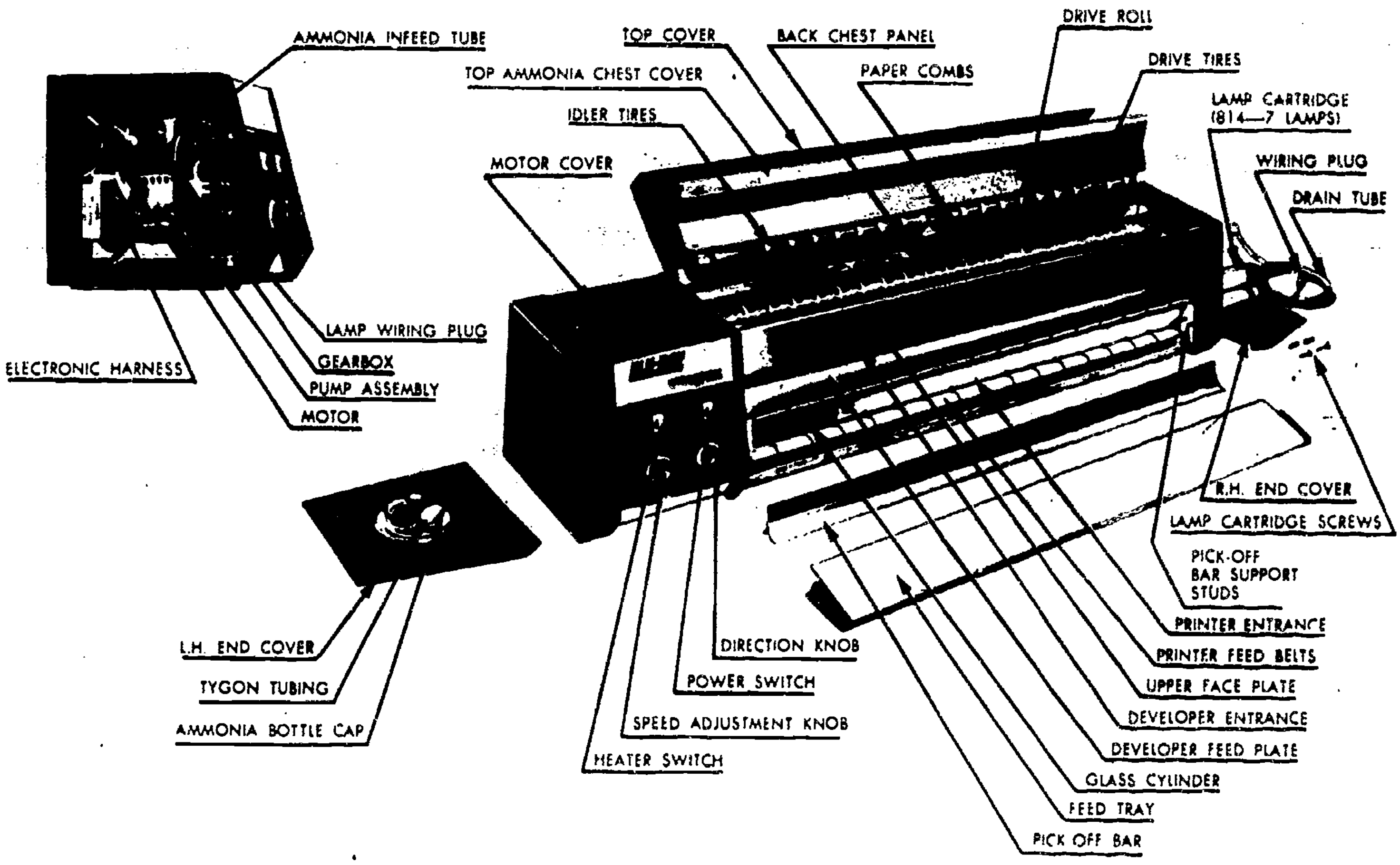
Diazo process reproduction machines are made by several manufacturers, such as BLU-RAY Inc. and General Analine Film Corp. (GAF). Machines formerly made by GAF were called Ozalid. The machines presently made are no longer called Ozalid, only labeled GAF. However, old Ozalid equipment is still serviced and repaired by the GAF Corp.

The basic difference between the various types of diazo machines is the size of paper that they can accommodate. Paper which is 9 inches wide can be used on the smallest machine, and paper which is 54 inches wide can be used on the largest machine.

Blu-Ray Rotary Diazo Whiteprint machines are currently being used in battalion engineering offices. Ozalid or GAF machines are usually found in shore activity engineering divisions.

Blu-Ray Whiteprinter Model 842

The Blu-Ray Model 842 Whiteprinter, shown in figure 10-1, has most of the capabilities of



45.866

Figure 10-1.—Exploded view of the blu-ray Whiteprinter Model 842.

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 EA's 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.

GENERAL INSTRUCTIONS.—Ammonia vapors produced by the Blu-Ray diazo process machine are very toxic and may be extremely uncomfortable to anyone working in the area where the machine is located. Therefore, the room or area used for reproduction must be properly vented and equipped with exhaust fans. Preferably, the machine should be located in a separate room, used only for reproduction. The machine should be located as close as possible to an electrical outlet of adequate power supply (electrical specifications are given in the operation manual).

After the machine has been assembled and set up in accordance with 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.

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 recommend 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.

OPERATING INSTRUCTIONS.—A pilot-lighted switch marked POWER on the instrument panel turns the Blu-Ray machine on and off, actuating the main drive motor, the ammonia pump motor and fan, and 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 over 12 feet per minute in both directions.

The knob marked SPEED gives the speed range by manually turning to a number that experience has shown to be proper for the type 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 WARMUP 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 side up (yellow). 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 while this is being done.

When removing jammed paper from the ammonia chest, do NOT bend or scratch any of the mechanical parts in the chest.

It is important, due to described qualities of the aqueous ammonia, that a NITE-SHEET be run in the developer section when the machine is not in operation for a period of time. (Nights, week-ends, 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, insuring 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 should be obtained through your supply system. This applies to any other parts needed.

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. For complete drainage, raise the motor end of the machine a few inches for a moment.
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 takeup brackets.
6. Loosen the two screws in both brackets, and press down approximately 1/4 inch 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 pivot and then lifting it off the machine. The back chest panel can independently be removed 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 infeed 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 a pin and slot connector to the drive shaft, and lift the assembly up and out of the chest.

After 600 hours 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 from the edge of the panel. Back off the locking screw 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 when it is removed the new tube can be properly placed.

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 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 re-attach 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 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 troubleshooting 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 blocked.
3. Machine not level, preventing proper drainage.
4. Ammonia bottle improperly capped.
5. Ruptured pump tubing.

Wrinkled prints from developer jamming

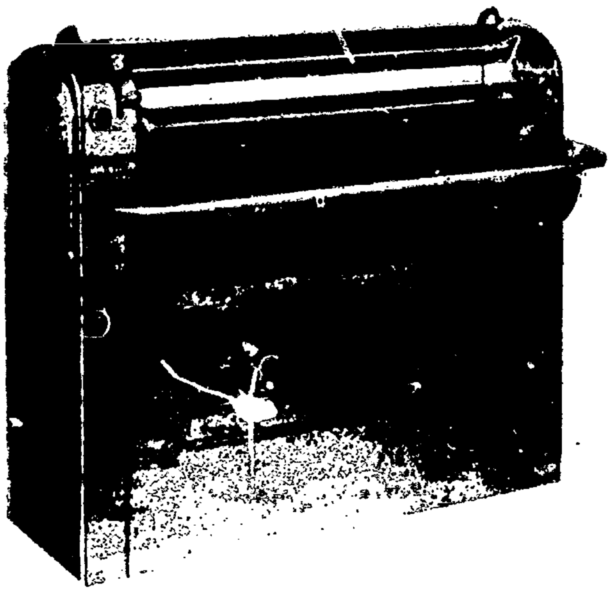
1. Condensation in ammonia chest.
2. Did not use nite-sheet
3. Sensitized paper damp before using, due to humid storage.
4. Paper placed in developer chamber against the grain.
5. Foreign material in developer chamber.
6. Exit not clear.

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.



45.296

Figure 10-2.—Ozalid machine.

2. Sensitized paper old or exposed.
3. Ammonia pump not operating properly—infeed tube kinked or pinched.
4. Cold ammonia in supply bottle.

Ozalid

The Ozalid machine, shown in figure 10-2, will be discussed in this section. It is normally used in shore activity engineering divisions and is a part of the battalion's Table of Allowances.

Every EA should have a basic understanding of the various functions of the Ozalid; therefore, printing and developing are discussed, as well as the operating principles of the cooling and exhaust system. Information is also given on machine operation, adjustments, and maintenance.

PRINTING SECTION.—Figure 10-3 illustrates 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 feedboard, 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 the printing cylinder by the pickoff assembly, and directed towards the developing section.

After pickoff, 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 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 original and 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 which 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.

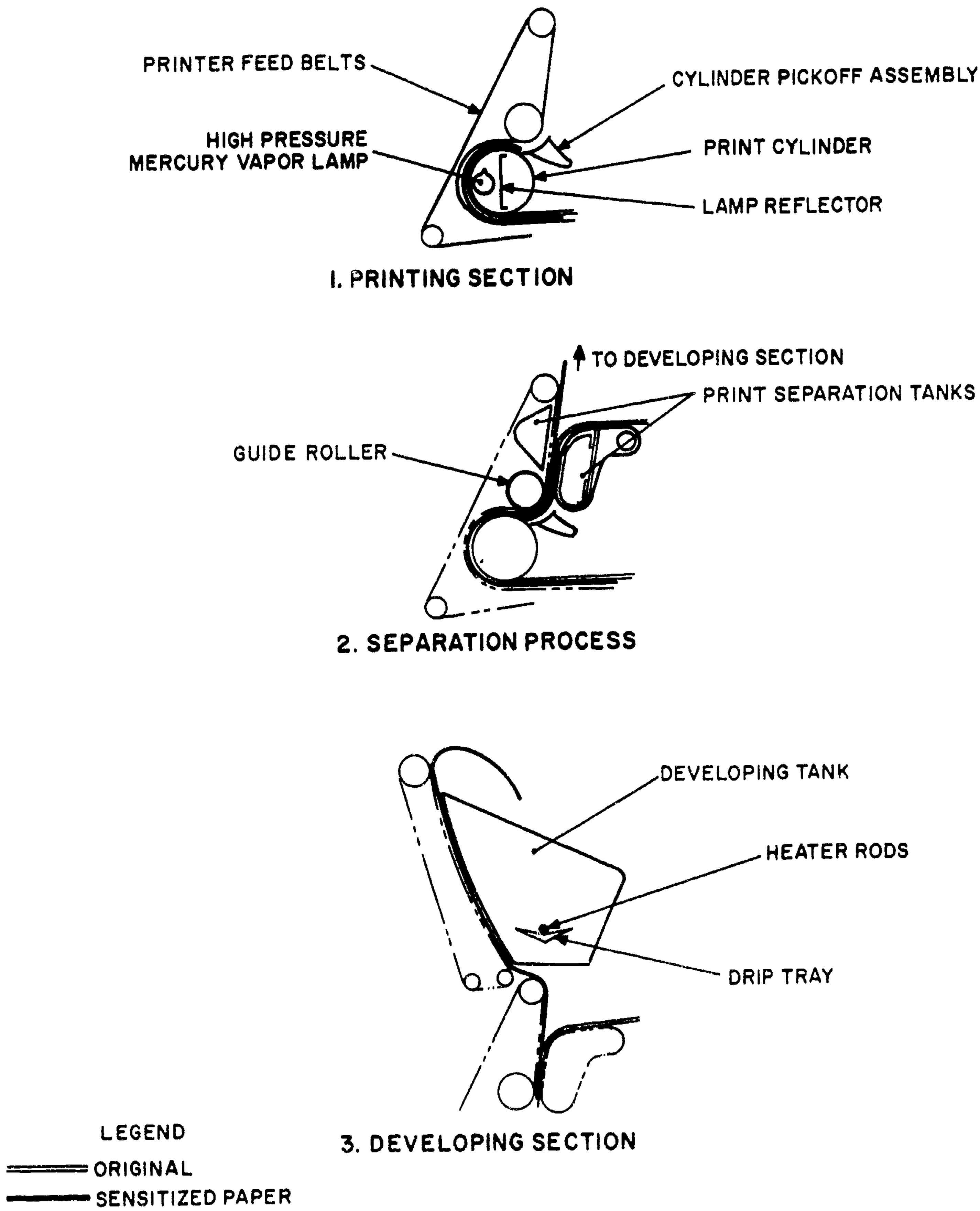


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Figure 10-3.—Principles of operation.

DEVELOPING SECTION.—The developing section consists of a perforated stainless steel developing tank. This tank is continuously supplied with ammonia from an ammonia supply tank through a gravity-feed system (fig. 10-4). 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 thermoswitch controlled heater located 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 developing tank. Thus, a semipermanent 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 valve shuts automatically when the machine is secured and is automatically opened when the machine is turned on, thereby reemitting 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

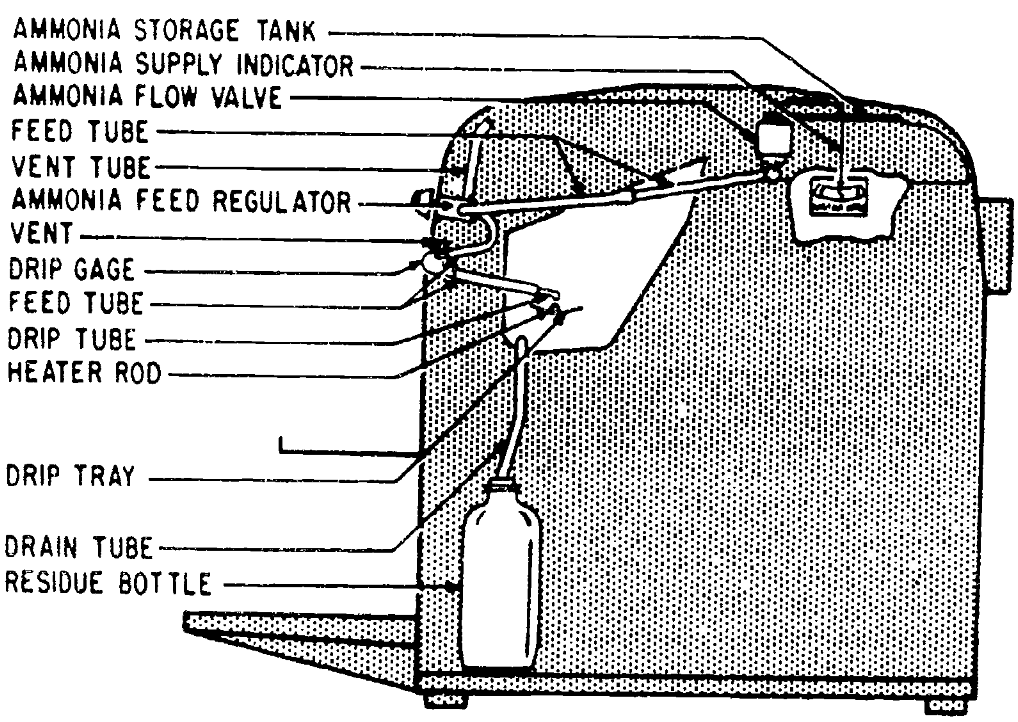

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Figure 10-4.—Ammonia flow system.

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expended cylinder tightly by turning it clockwise. Bleed off all pressure remaining in the feedline 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. Insure 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, re-tighten the connections.

A uniform flow of ammonia is maintained by a pressure gage located between the cylinder and the developing section. In addition, the pressure gage indicates the amount of available ammonia left in the cylinder. A new cylinder will have a gage reading of 150, while an empty cylinder will indicate a reading of 50.

After passing through the pressure gage, 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 warmup and periods of idling or nonuse.

To aid in the distribution of the ammonia vapor within the developing tank, a water supply is used. 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 waterflow to 60 drops per minute, and insure 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 which 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 insuring 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 warmup 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. 10-4). Then, fill the storage tank with ammonia. If bubbles are encountered in the feed system due to increased temperature or high altitude, the ammonia should be diluted 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 feet per minute and above), 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 due to excessive heat.

After a short warmup period, the machine is ready for operation. The machine should be run for approximately 20 minutes or until the operating temperature is between 180° to 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 the 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 slow 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 inches 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 due to atmospheric changes which may cause shrinkage or expansion of some of the belts. These adjustments should be performed in accordance with the manufacturer's instructions and only then by qualified personnel.

Maintenance is required on a daily, weekly, monthly, semi-annually, 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 re-use 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:

a. Clean the inside of the cylinder when the machine is COLD using the following procedure:

(1) Open the door at each end of the lamp housing.

(2) Remove the lamp connector from each end.

(3) Swing the triangular stop aside and withdraw the lamp assembly.

(4) 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.

(5) Wipe the lamp assembly with a DAMP cloth.

(6) Re-install 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:

a. Lubricate the bearings and drive chain assembly sparingly with No. 10 motor oil.

4. Semi-annual requirements:

a. 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 due to dirt accumulations on the perforated side.

PAPER MATERIAL

Material is available from various sources under different trade names and designations, but basically all diazo products are materials that have been coated with a light-sensitive dye that will develop when exposed to ammonia. The two types of paper commonly used for reproduction drawings are blueprint paper and sepia line intermediates.

Blueprint Paper

Standard weight 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 inches to 34 by 44 inches, or in rolls that range in widths from 11 to 42 inches with lengths of 50 or 100 yards.

Colored paper provides black or blue images on blue, green, pink, or yellow stock.

Plastic-coated papers are now available which 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. Using 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 ultra-violet light rays. Base materials may be a vellum base treated with a plastic transparentizer which allows the passage of the light rays. Sheet and roll sizes are similar to those of the standard paper. Corrections can be made on the sepia prints by using a solution of intermediate corrector to remove the image, then adding the pencil or ink correction.

FILING DRAWINGS

For our purposes here, the term "filing" means (1) the protected stowage of a large number of items with the greatest possible economy of space and in a manner which makes it possible for any single item to be readily located; and (2) the maintenance of a file record in which all items on file are recorded and in which the record of any single item (including its location in the file) may also be readily located.

Every important technical drawing is identifiable by a drawing number. The number is assigned by the agency which made the drawing, and the agency insures that there are no duplications of numbers. The first major file breakdown for drawings, then, is a breakdown into separate files for the different agencies which 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.

ORIGINALS

The following sections discuss the matter of filing under quite ideal conditions—especially with regard to equipment. Therefore, the equipment mentioned here may or may not be available.

Original drawings, tracings, and negatives are filed flat—NEVER folded. For large items, there are shallow-drawer file cabinets of the type shown in figure 10-5. There is usually a deep drawer at the bottom in which very large drawings, tracings, or negatives, rolled and placed in cylindrical cartons called "map cartons," may be stowed.

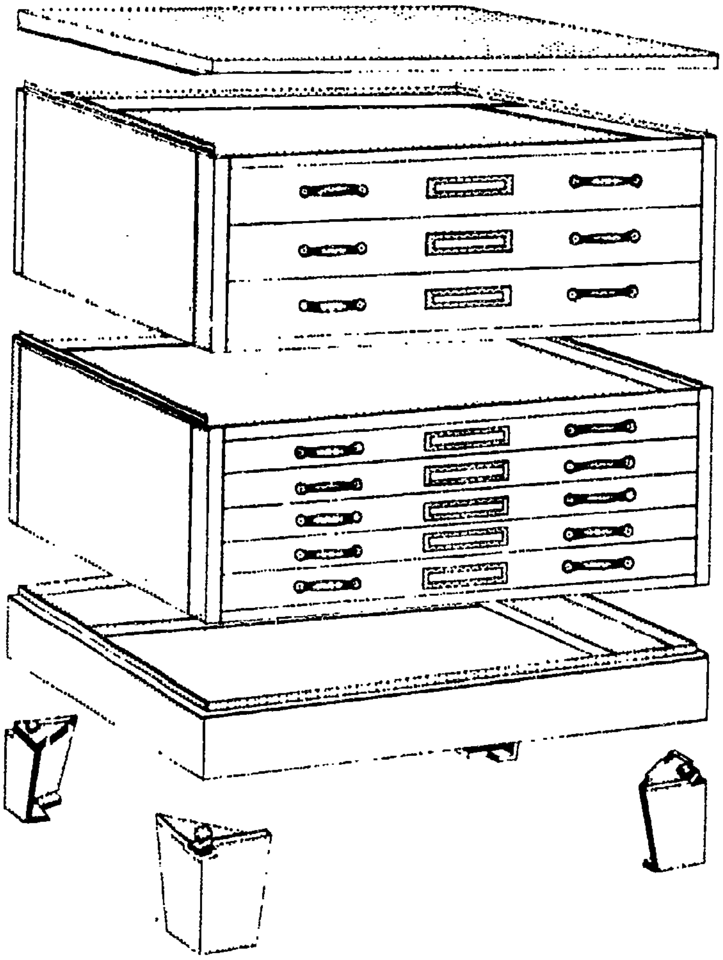

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Figure 10-5.—Shallow-drawer type cabinet for filing large, original drawings, tracings, and negatives.

Smaller items (up to size B, 11 by 17 inches) are stowed on edge in the standard deep-drawer type of cabinet, as shown in figure 10-6. 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.

PRINTS

Prints, regardless of size, are stowed on edge in the standard deep-drawer type of cabinet. Prints larger than size B must be folded. A print is folded in accordion-pleat type folds in such a manner as to insure that the drawing number is outside after the print has been folded. Final folded size should be 8 1/2 by 11 inches. You should make yourself a plastic or plywood 8 3/8- by 10 7/8-inch "folding guide," or procure a ready-made one. The steps in folding a large print are as follows:

1. Fold the print into 10 7/8-inch lengthwise accordion-pleat folds first. Lay the print facedown, and start by turning up the edge containing the drawing number, using the folding guide, as shown in figure 10-7. 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 10-8. Continue turning over and folding until the width of the drawing is used up.

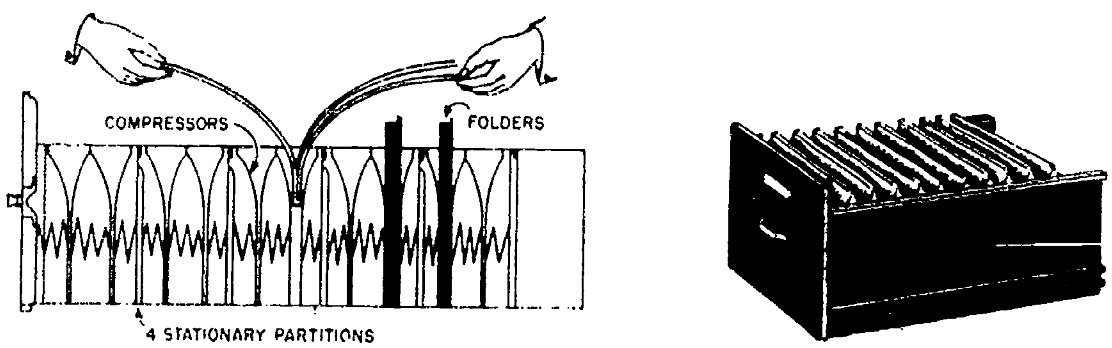

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Figure 10-6.—Drawer of cabinet used for filing small, original drawings, tracings, and negatives.

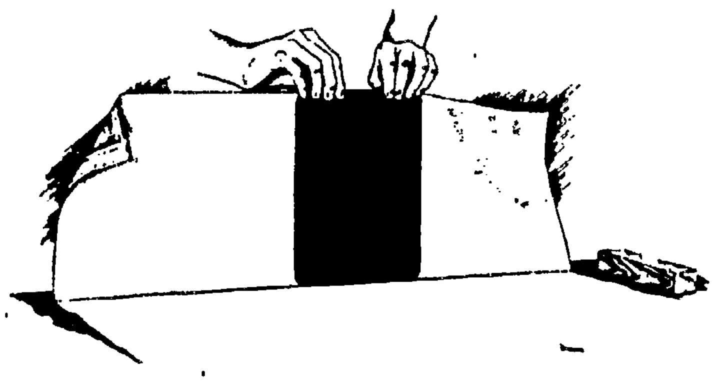

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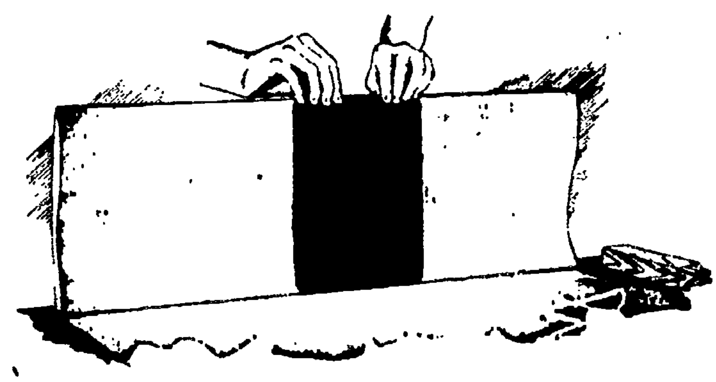
Figure 10-7.—Making first lengthwise fold in a large print.



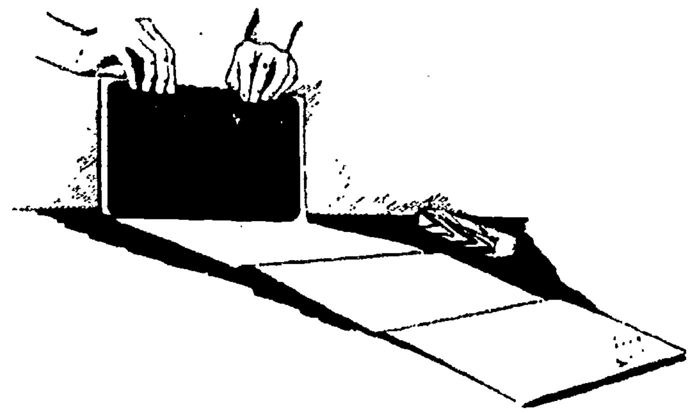
45.301
Figure 10-8.—Making second lengthwise fold in a large print.

3. Place the lengthwise-folded drawing so that the side on which the drawing number appears is down. Begin at the end which contains the drawing number, and make the first 8 1/2-inch crosswise accordion-pleat fold, using the folding guide, as shown in figure 10-9.
4. Turn the print over and make the next fold. Continue until the length of the drawing is used up.

Folded prints are stowed in the same type of deep-drawer cabinet used for stowing small originals. Prints of drawings for active projects are generally placed on STICK FILES for easy reference.

DATA

Data relating to drawings, such as correspondence, should be filed in accordance with



45.302
Figure 10-9.—Making first crosswise fold in a large print.

SECNAVINST 5210.11B (described later), 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 maintained, such data must be filed in that folder.

FILE RECORD

A record of each drawing should be kept on an index card in a suitable file drawer. The different agencies which produce drawings prepare their own types of index cards. A type of card which could be used is shown in figure 10-10. A brief description of the information which would be entered in each of the numbered spaces shown in this card is as follows:

1. The "numerical subject identification code" and/or the "name-title subject identification code." These classification codes are prescribed in the Department of the Navy *Standard Subject Identification Codes Manual*, SECNAVINST 5210.11B. A copy of this instruction is available in the personnel office and in the 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.

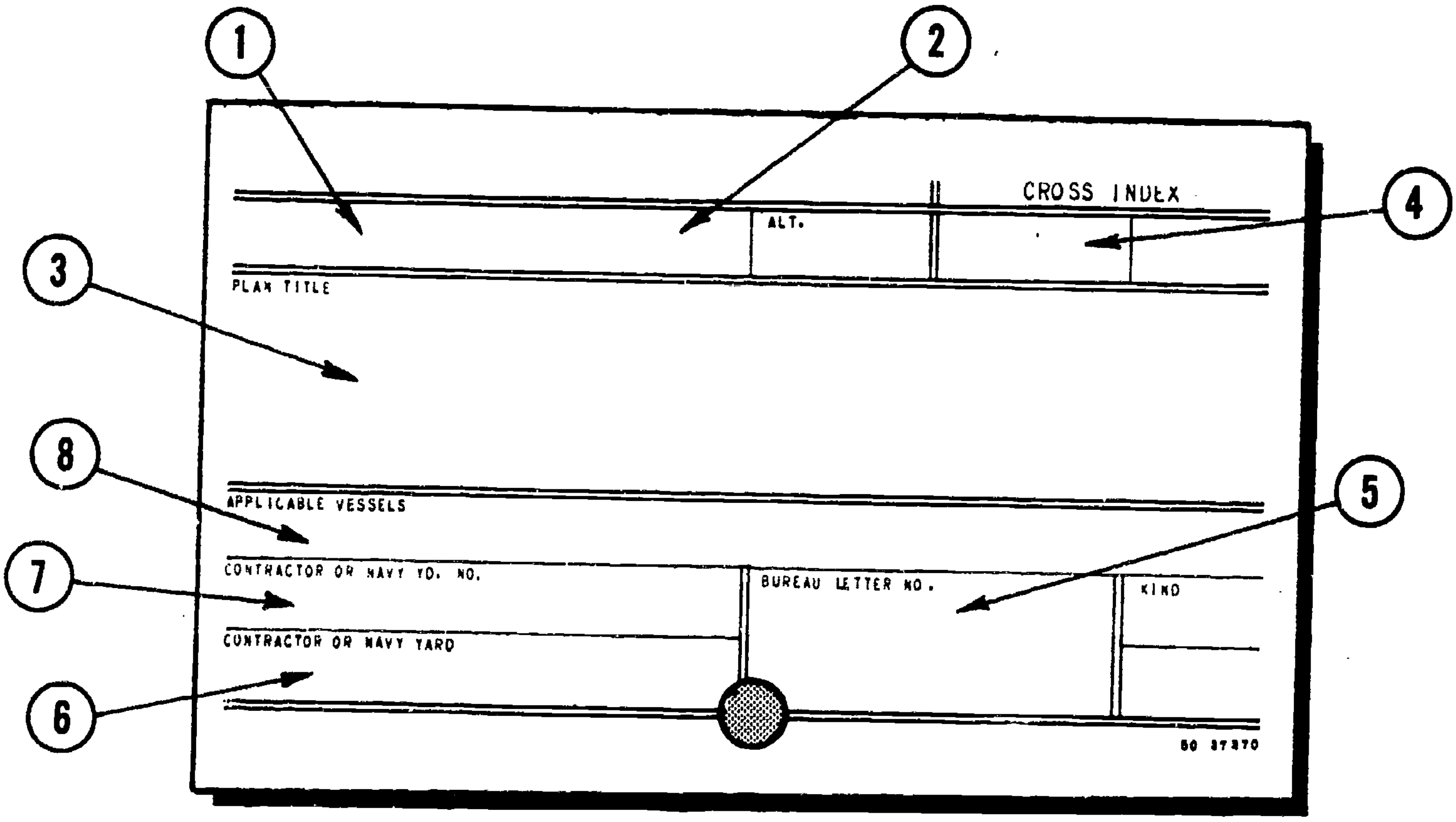


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Figure 10-10.—Drawing file index card.

The Standard Subject Identification Codes System is generally employed by large shore activities, such as Public Works Departments, Naval Construction Battalion Centers, or Brigade Headquarters. For smaller mobile units, such as the Battalion, the EA in charge of the drafting room or the Operations Chief may devise their own indexing system for the filed drawings that suits the volume of records handled by the unit.

2. The drawing number. NAVFAC calls it the "NFEC Drawing Number."

3. The title of the drawing, taken from the title block.

4. Cross-index references to any correspondence or data which may be on file relating to the drawing.

5. Number of the Bureau letter, if any, which was forwarded with the drawing.

6 & 7. The number and name of the A & E firm, contractor, naval shipyard, or other agency which actually made the drawings.

Again, if a separate folder or drawer file is maintained for each project, a notation must be 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.

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