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FACILITIES ENGINEERING  
MAINTENANCE AND REPAIR OF  
ARCHITECTURAL AND STRUCTURAL  
ELEMENTS  
OF BUILDINGS AND STRUCTURES

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DEPARTMENTS OF THE ARMY, THE NAVY, AND THE AIR FORCE  
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# FACILITIES ENGINEERING MAINTENANCE AND REPAIR OF ARCHITECTURAL AND STRUCTURAL ELEMENTS OF BUILDINGS AND STRUCTURES

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\*This manual supersedes TM 5-620, dated March 1958.

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# CHAPTER 1

## INTRODUCTION

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### SECTION I—GENERAL

#### 1.1.1 Purpose

This manual provides technical guidance for the maintenance and repair of buildings and structures at military installations. These standards should assist in the economical preservation of structures and insure their continuous and efficient use. Criteria for engineering procedures to cover maintenance and repair work that is within the responsibility of maintenance personnel.

#### 1.1.2 Scope

The military services are required to maintain both recently constructed structures and historic structures which require special techniques to preserve the original appearance. In addition, some installations with temporary World War II era

buildings are maintained only to the degree required to prevent further deterioration. For these reasons, some obsolete products and their maintenance are discussed in this manual although these products are in many cases no longer available. This manual is a technical reference document and procedures and material selections are suggested, not mandated. This manual is not to be interpreted as superseding or negating requirements of other publications.

#### 1.1.3 Restrictive Clauses (US Air Force Only)

This publication contains implied or direct restrictive clauses. Take these clauses as recommendations only.

### SECTION II—DEFINITIONS

"Buildings" and "structures" are defined separately in this section, but throughout this manual the term "structures" will be used collectively to include buildings.

#### 1.2.1 Buildings

A building is a roofed or walled structure intended for use as a dwelling. Building is a broad term which includes troop housing, family housing, dining, training, medical, religious, recreational, community, administrative, technical, industrial, and storage facilities. Specialized buildings such as hangars, maintenance docks, test cells and underground buildings are also included.

#### 1.2.2 Structures

A structure in this manual describes something which is not intended to act as a dwelling for personnel. The broad term includes, sheds, elevated storage tanks, underground storage facilities, flagpoles, towers, walls, fences, gates, swimming pools, and frames that support equipment.

#### 1.2.3 Maintenance

Maintenance is the recurrent, day-to-day, periodic, or scheduled work required to preserve a real

property facility for the effective utilization of its designated purposes. Includes work undertaken to prevent damage to a facility which otherwise would be more costly to restore.

#### 1.2.4 Repair

Repair is defined as the restoration of a real property facility for the effective utilization for its designated purposes, by overhaul, reprocessing or replacement of constituent parts or materials deteriorated by action of the elements or wear and tear in use. Includes the parts and materials and which have not corrected through maintenance.

#### 1.2.5 Installation Engineer

The term "installation engineer" as used in this manual refers to the senior engineering officer (military or civilian) serving as the principal staff officer of the installation commander for maintenance and repair of real property. In each military department, the installation engineer is known under a different title: Navy—Public Works Officer, Air Force—Base Civil Engineer, and Army—Facilities Engineer.

### SECTION III—WORK EXCLUDED

Items which are related to the maintenance and repair of structures but not included in this manual are as follows:

#### 1.3.1 Waterfront Structures

Wharves, quays, piers, bulkheads, quay walls, breakwaters, jetties, groins, and related structures are included in the Tri-Services manual, "Maintenance of Waterfront Structures" (TM 5-622, NAVFAC MO-104, AFP 91-34).

#### 1.3.2 Painting

The selection and application of paints and protective coatings are included in the Tri-Services manual, "Paints and Protective Coatings" (TM 5-618, NAVFAC MO-110 AFP 85-3).

#### 1.3.3 Roofing

The selection, application, maintenance and repair of all types of roofing are included in the Tri-Serv-

ices manual, "Maintenance and Repair of Roofs"(TM 5-617, NAVFAC MO-113 and MCO P11014.9, AFP 91-31).

#### 1.3.4 Bridges and Culverts

The maintenance and repair of all types of bridges and culverts are included in the Tri-Service Manual, "Maintenance and Repair of Surface Areas" (TM 5-624, NAVFAC MO-102, AFP 85-8). Inspection information and ratings for all types of bridges are provided in the manual, "Maintenance Inspection of Bridges," 1978, prepared by the American Association of State Highway and Transportation Officials.

#### 1.3.5 Other Exclusions

Electrical (includes lighting), plumbing, heating, ventilation, and air-conditioning are covered by various Tri-Service manuals.

### SECTION IV—STANDARDS OF MAINTENANCE

#### 1.4.1 General

Desirable maintenance standard is the level at which a facility can be economically maintained to protect the Government's investment and to provide a functional facility. Failure to maintain the facility at this level may result in expensive repair costs.

1.4.1.1 Material which are more durable and provide a longer life may be substituted for original materials provided the economic considerations justify the increased costs.

1.4.1.2 The standards set forth in this manual are for active and inactive installations. Specific maintenance criteria for inactive installations, or parts thereof, are prescribed in pertinent regulations of each military service. See appendix A.

#### 1.4.2 Standards for Structures

1.4.2.1 Permanent, semipermanent, and temporary structures will be maintained to provide substantially

the same capacity, efficiency, and standard of appearance and comfort for which they were originally designed, consistent with their planned use and life expectancy.

1.4.2.2 Structural components, such as foundations, columns, trusses, structural frames and connections, will be maintained regularly and in such a manner as to insure preservation and stability of structures.

1.4.2.3 Exterior and interior surface materials and finishes will be maintained to eliminate defects, to prevent damage, and to keep the facility in good operational and sanitary condition.

1.4.2.4 The maintenance of all structures not scheduled for retention as part of the permanent installation will be commensurate with the planned use and economical life expectancy of such facilities.

### SECTION V—MAPS, PLANS, AND BUILDING NUMBERING

#### 1.5.1 Maps

Installation maps and overlays showing structures, roads, electric services, and utility lines will be maintained in accordance with pertinent regulations of each military service. Maps are to be maintained in a current status by careful revision and addition. Copies of these maps should be readily available to maintenance personnel.

#### 1.5.2 Plans

Original plans and specifications of structures constitute the permanent record of construction and materials. "Record" plans will continually be updated to accurately record changes, additions, and deletions. Copies of these plans should be readily available to maintenance personnel.

### 1.5.3 Building Numbering

Each self-contained structure is assigned a number which is clearly marked in accordance with pertinent regulations of each military department. Then

location and numbering of all structures will be maintained in the basic information folder or facility history file.

## SECTION VI—TIMELY REPAIR

### 1.6.1 General

All maintenance personnel shall be indoctrinated with the importance of not only the method of repair, but also the timely recognition and correction of the basic cause of failure. Some portion of maintenance is necessary due to normal wear and weathering, but many failures may be traced to other basic causes. Correction of these will, over a relatively short period, be justified by decreased maintenance as well as improved factors of use, safety, and appearance.

### 1.6.2 Causes

Premature failure of structural parts, materials, and various components may be caused by some of the following:

- a. *Defective materials or structural parts.*
- b. *Incorrect installation or application.*
- c. *Failure of related, connected, or adjacent components.*
- d. *Unusual or extreme climatic conditions exceeding the design specifications for which the material or structural part was designed.*

### 1.6.3 Investigation

Failures occurring during the normal life expectancy of buildings and structures should be carefully investigated and the fundamental defects corrected prior to superficial repair.

### 1.6.4 Technical Assistance

Unless the cause of failure is immediately discernible and corrective measures are straightforward or standard, the installation engineer, or higher echelons if necessary, should be consulted for advice on corrective measures.

1.6.4.1 Where specific materials are concerned, such as composition flooring and siding, the manufacturer's specifications and instructions may provide sufficient information for corrective measures. Where there is doubt as to the cause of failure, it is advisable for the installation engineer to request assistance from the major command or the manufacturer's agent.

1.6.4.2 In vital structural matters or material failures, beyond the capabilities of or time limitations imposed upon the installation engineering personnel, consultation and advice from qualified, private architects or engineers may be obtained upon approval by appropriate military department authority.

1.6.4.3 Individuals engaged in repair of architectural and structural elements should be aware of electrical (including lighting), plumbing, heating, ventilating and air-conditioning systems as they impact on these repairs. Specific repairs should be coordinated with other elements to insure that repairs do not create adverse conditions in the continuance of service provided by the systems.

## CHAPTER 2

### FOUNDATIONS AND CRAWL SPACES

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#### SECTION I—FOUNDATIONS

##### 2.1.1 General

The foundation of a building or structure transfers the dead and live loads of the superstructure to soil that has enough bearing capacity to support the structure in a permanent, stable position. Footings are used under foundation components, such as columns and piers, to spread concentrated loads over enough soil area to bring unit pressures within allowable limits. Foundation design is determined not only by the weight of the superstructure, but also by occupancy, use, and the load-bearing capacity of the soil at the site. Soil conditions may change over a period of time and introduce maintenance and repair problems even in initially well-designed foundations.

##### 2.1.2 Materials and Types of Foundations

2.1.2.1 *Materials.* Materials for foundations are, in general, concrete (plain or reinforced), concrete masonry units (open or filled cells), bricks, cut stone, rock, and wood. Brick, cut stone, and rock foundations are usually found only in older structures.

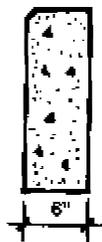
2.1.2.2 *Types of Foundations.* Foundations vary from simple walls and piers with footings to very complex movement-resistant walls and slabs placed without joints. Several basic types may be used in one structure. Due to the broad variety of structures on military installations, maintenance personnel should be familiar with a variety of foundation designs used to meet many conditions. Some typical foundations follow:

*a.* Walls of concrete, masonry units, or brick were sometimes built without footings to support lightweight buildings on soils of high load-bearing capacity. See figure 2-1. Refer to chapter 4, section 4.3 for discussion of concrete walls.

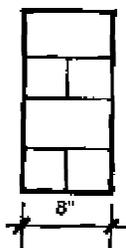
*b.* A separate footing may be used under each column, or a footing may be extended continuously (spread) under a number of columns or a wall. Spread footings are required where imposed loads are great or the soil at the site has a low bearing value. Footings are commonly constructed of concrete, although brick and stone may be found in older construction. Concrete is used plain in mass or reinforced by steel rods, depending on bearing loads. See figure 2-2.

*c.* Spread footings and walls or piers of reinforced concrete poured integrally are used for heavy structures, and where heavy lateral forces are exerted on one side of the wall. Examples are retaining walls, deep basements, and swimming pools.

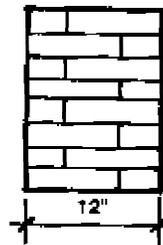
*d.* Spread footings and grade beams of reinforced concrete may be used in large structures without basements. See figure 2-3. The columns transmit the heavy localized loads to the substructure, and the grade beams carry the relatively light, first-story curtain wall. The spread footings are designed and built independently to support both the column loads and the grade beam. Where grade beams are above the frostline, the bottom of the beam may be V-shaped to minimize the upward thrust of frost action on the bottom surface of the beam.



**CONCRETE**



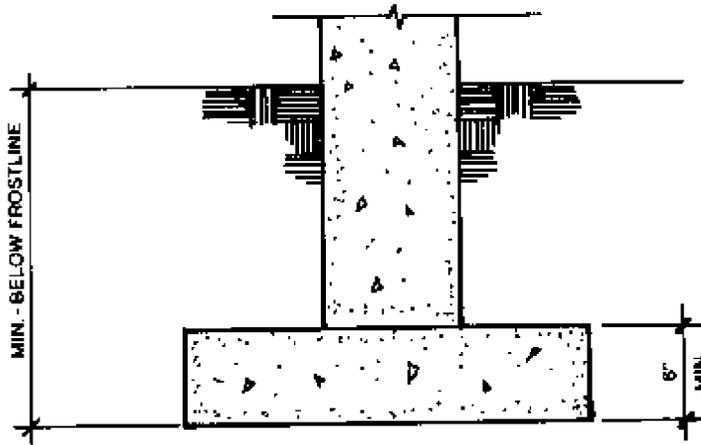
**CONCRETE BLOCK**



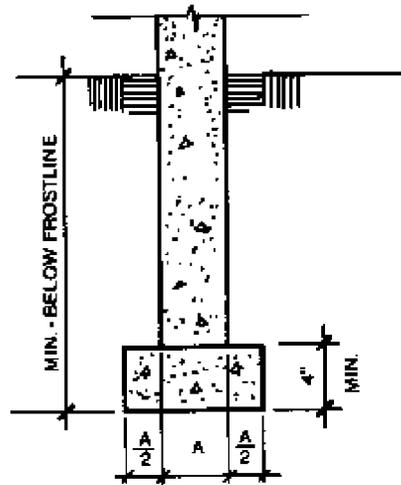
**BRICK**

FOUNDATION WALLS WITHOUT FOOTINGS USED FOR  
LIGHT WEIGHT BUILDINGS  
USUAL DIMENSIONS FOR EACH TYPE ARE INDICATED

*Figure 2-1. FOUNDATION—WALLS WITHOUT FOOTINGS.*

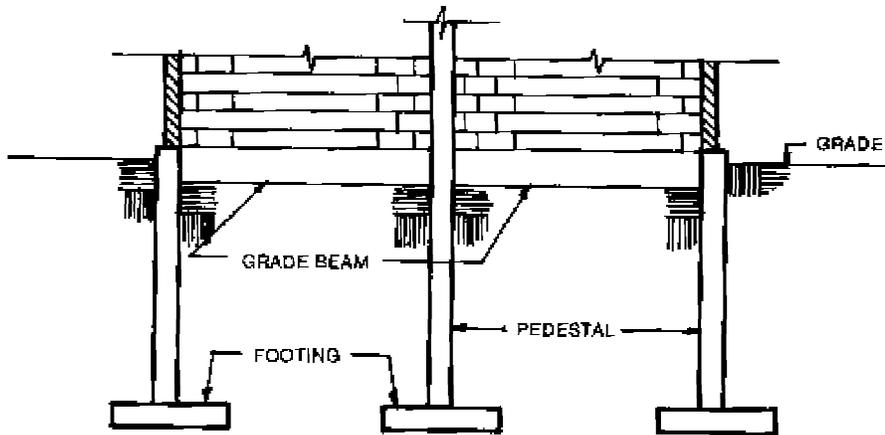


**FOR HEAVY WALLS**



**FOR LIGHT WALLS**

*Figure 2-2. CONCRETE FOOTINGS.*



**GRADE BEAM**

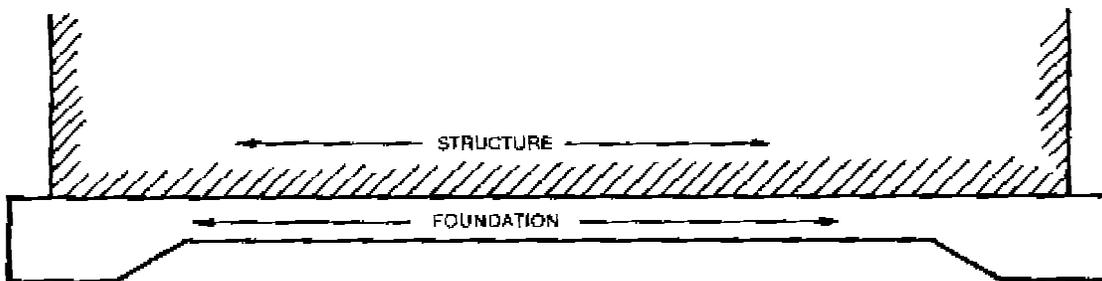
*Figure 2-3. GRADE BEAM.*

e. A mat foundation is one that transmits its loads to the bearing soil by a continuous slab that covers the entire area of the bottom of the structure, e.g., a floor. It is used when the low-bearing value of the Soil results in such large isolated footings that it is more logical to transmit the loads through this slab to the entire area directly under the superstructure. See figure 2-4.

f. There are cases in which it is undesirable to allow any major increase of pressure to the soil. One principle that may be utilized in such cases is that of the "floating foundation." This means that

the estimated weight of the soil removed permanently in order to build the substructure must be equal or less than the dead and live loads of the structure, which is then "floating" by displacing its own weight in the low-bearing value soil. This type of foundation is usually designed for locations where deep and heavy footings or piles are impractical or uneconomical.

g. Brick step footings and walls or piers have been used mostly in old structures. New construction of brick foundations will normally be uneconomical when compared to concrete.



*Figure 2-4. MAT FOUNDATION.*

h. Cut stone foundations are usually constructed of large blocks of hard stone (similar to granite) laid with mortar or dry joints. New construction of cut stone will normally be uneconomical when compared to concrete.

i. Natural or field stone foundations are laid with mortar or dry joints. Where stone is plentiful, it can be used economically for light structures. It can also be used for retaining walls and dry walls.

j. Grill age footings have been used for light loads, where the bearing area required is not larger than the pedestal. See figure 2-5. These footings consist of several layers of beams, normally of wood or steel, with successive layers at right angles to each other and with successively deeper layers having larger beams. However, the rising cost of labor has made these footings uneconomical. Wood Grill age footings are sometimes used to support wood posts, columns, masts, poles, and light temporary structures. Wood used in substructures

is usually pressure-treated with various types of preservatives. Such footings permanently below ground-water level may last indefinitely and require no maintenance.

k. Piles are made of steel, wood, concrete, steel and concrete, and wood with concrete. Piles are usually capped with a reinforced concrete mat or slab. See figure 2-6. Wood piles are usually treated with a preservative and should be totally [and permanently] below ground-water level.

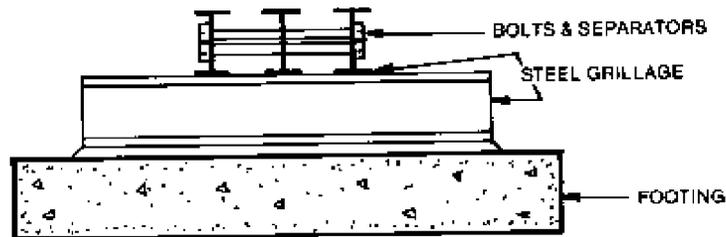
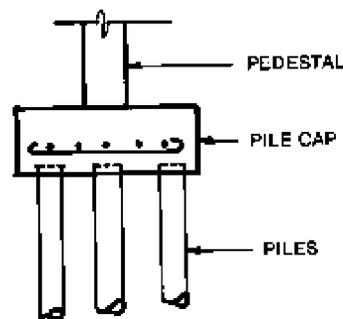


Figure 2-5. STEEL GRILLAGE FOUNDATION.



PILES MAY BE WOOD, STEEL, CONCRETE, OR COMBINATION OF MATERIALS

Figure 2-6. PILE FOUNDATION.

### 2.1.3 Inspection for Distress and Failure

Exposed portions of foundations should be inspected regularly. Inspections should occur more frequently where climate, soil conditions, or changes in building occupancy or structural use present special problems. Evidence of incipient foundation failure may be found during routine inspection of other structural components.

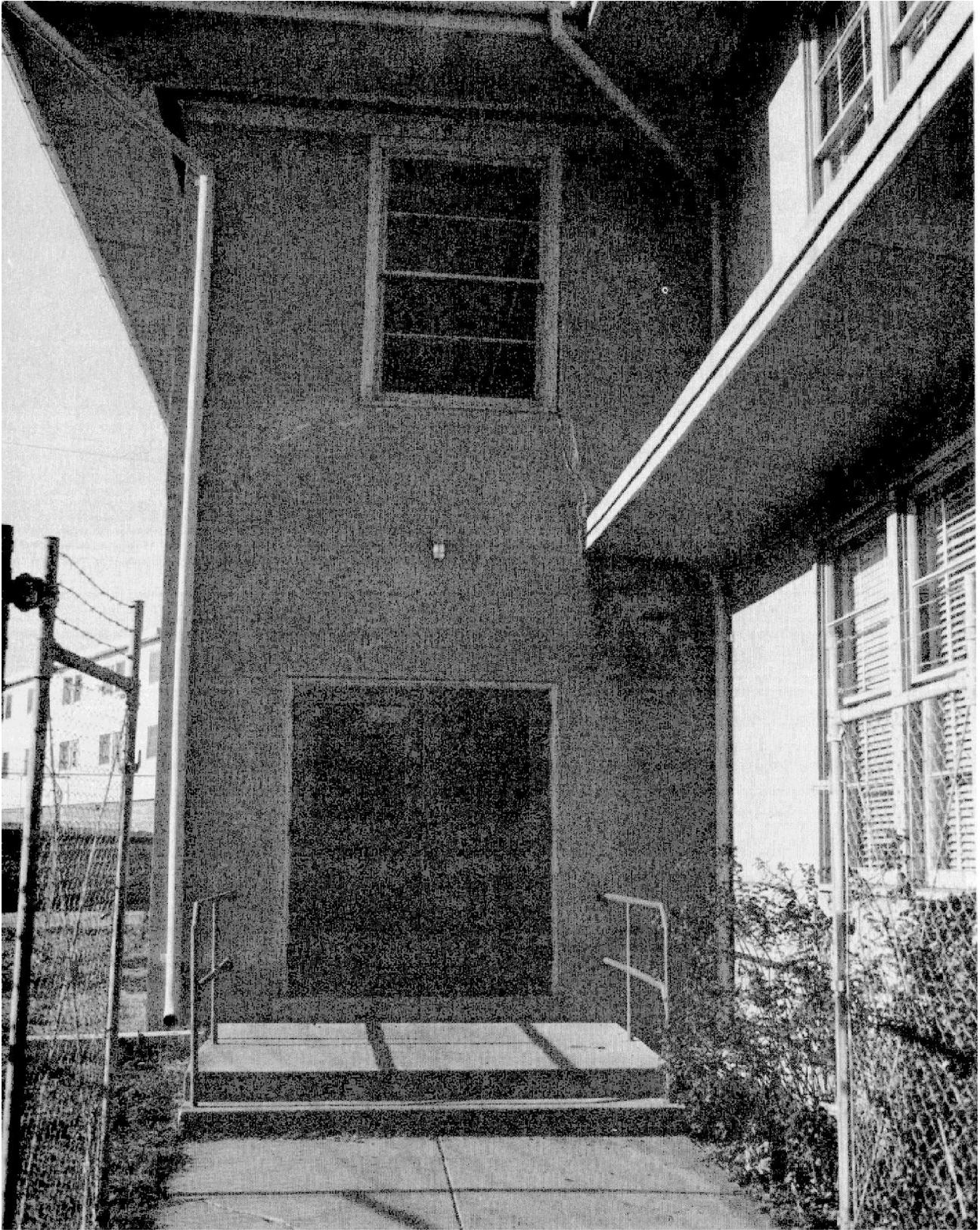
2.1.3.1 *Foundation Displacement.* Foundations should be checked regularly for proper elevation

and alignment. Complete failure in foundations is rare. However, some settling or horizontal displacement may occur. See figure 2-7 and 2-8. Common causes of foundation movement include settlement and differential settlement of the soil caused by inadequate compaction of the soil or improper sizing of the footings; overloading the structure; excessive ground water which reduces the bearing capacity of soil; inadequate soil cover which fails to protect against frost heaving; and

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adjacent excavations that allow unprotected bearing soil to shift from under foundations to the excavated area. Severe, localized foundation dis-

placement may show up in cracked walls, damaged framing and connections, sloping floors, sticking doors, and even leakage through a displaced roof.



*Figure 2-7. CRACKS CAUSED BY FOUNDATION SETTLEMENT—EXTERIOR.*



*Figure 2-8. CRACKS CAUSED BY FOUNDATION SETTLEMENT—INTERIOR.*

2.1.3.2 *Material Deterioration.* Foundations are subject to deterioration, whether from material or construction deficiencies or from environmental conditions. Generally, the deterioration of foundation materials can be determined only by direct observation, unless the effects are severe enough to cause foundation settling. Excessive moisture from surface or subsurface sources is a major cause of timber deterioration, providing the necessary condition for wood decay and encouraging insect infestation. Improperly seasoned wood is subject to cracking, splitting, and deflection. Concrete and masonry are subject to cracking, spalling, and settling, particularly under adverse ground and climatic conditions. Steel and other ferrous metals are subject to corrosion in the presence of moisture and sometimes by contact with acid-bearing soils. Signs of corrosion are darkening of the metal, rusting, and pitting.

#### 2.1.4 Soil Investigation

In all cases of serious foundation settlement, an investigation of the bearing soil should be made as a basis for corrective action. The stability of soils is

derived from their shearing strength (or resistance), which may change with ground conditions at the site. Clay-bearing values, for example, vary with moisture content. A foundation on a clay site that has been laid on the basis of local standards for bearing value may settle when the moisture of the clay increases (and therefore loses shearing strength), when dewatering operations are undertaken in the area, or when an adjacent, deeper excavation drains moisture from the foundation-bearing clay. Clay also loses strength when molded or worked. Frost action is similar in effect to working the clay. Other soil types are subject to change in bearing value or characteristics. Silty soils have greater capillary action than sand and, under severe winter conditions, may absorb enough water to form ice lenses under the footings. The most exposed side of a structure will have the greatest frost action. When the ice thaws, the soil is oversaturated and incapable of supporting a load. The specific maintenance measures given in the following paragraphs provide a partial listing of conditions to be noted during an inspection.

## SECTION II—CONCRETE SLABS ON GRADE

### 2.2.1 General

Concrete slabs on grade may transmit dead and live loads directly to the subgrade independent of the remainder of the structure (floating slab), or they may be structurally integrated with the foundation walls, piers, columns and footings (structural slab), so as to become a part of the structural foundation. Floor slabs on grade are normally separated structurally from the rest of the building. See figure 2-9.

### 2.2.2 Types of Concrete Slabs on Grade

Typically, concrete slabs on grade consist of three principal types:

2.2.2.1 Plain, unreinforced, flat slabs carrying uniformly distributed light loads usually not more than 100 pounds per square foot (lb/ft<sup>2</sup>).

2.2.2.2 Welded wire-mesh, reinforced flat slabs carrying uniformly distributed medium loads, usually not more than 500 lb/ft<sup>2</sup>.

2.2.2.3 Deformed steel bar reinforcing in flat slabs carrying heavy, uniformly distributed, or concentrated loads.

### 2.2.3 Typical Concrete Slab Construction

2.2.3.1 *Subgrade.* Remove all sod and decomposable material; backfill as required; compact and shape the surface. Backfill should be of uniform character, free from large lumps, stones, frozen chunks, or material that will rot. The material selected for backfill should provide a density equal to the natural density of the surrounding soil. Better results and greater densities can be attained by using the backfill material at its optimum moisture content. In large jobs, or particularly important slabs, the optimum moisture content should be determined by laboratory analysis; however, a rough idea of the proper moisture content for ordinary soils (except very sandy soil) can be determined by forming a ball of the soil by hand. Proper moisture content will result in a ball that will hold its shape, but not be plastic or muddy when squeezed. Trenches for pipes, footings, utility lines, etc., must be backfilled in layers not exceeding 6 inches in thickness and each layer tamped so that the backfill will be as dense and strong as the surrounding subgrade.

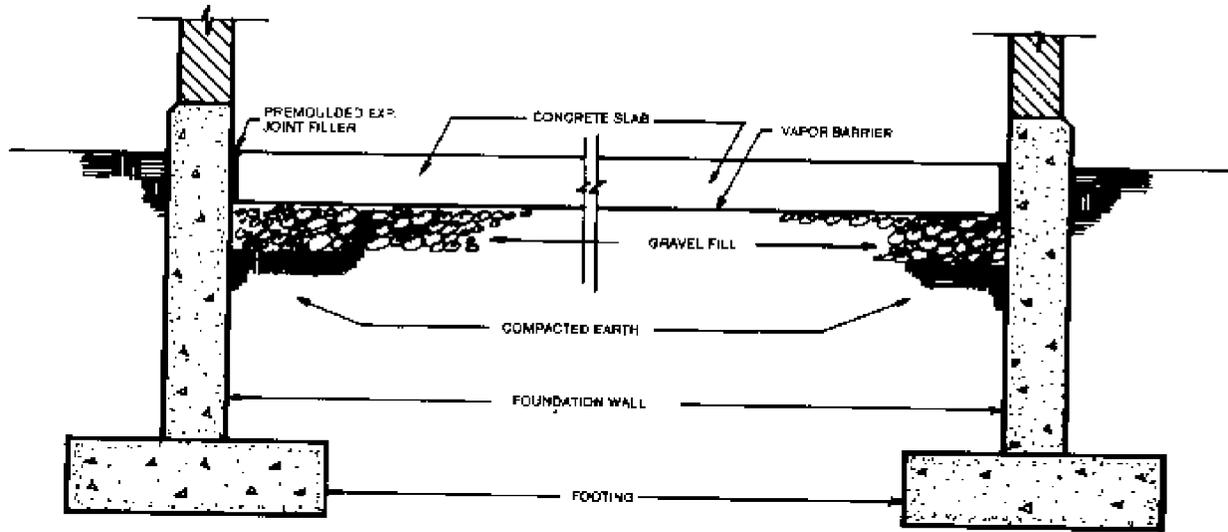


Figure 2-9. FLOOR SLABS ON GRADE.

2.2.3.2 *Gravel Fill.* On the subgrade, place a 4- to 6-inch layer of granular fill and cover with a vapor barrier.

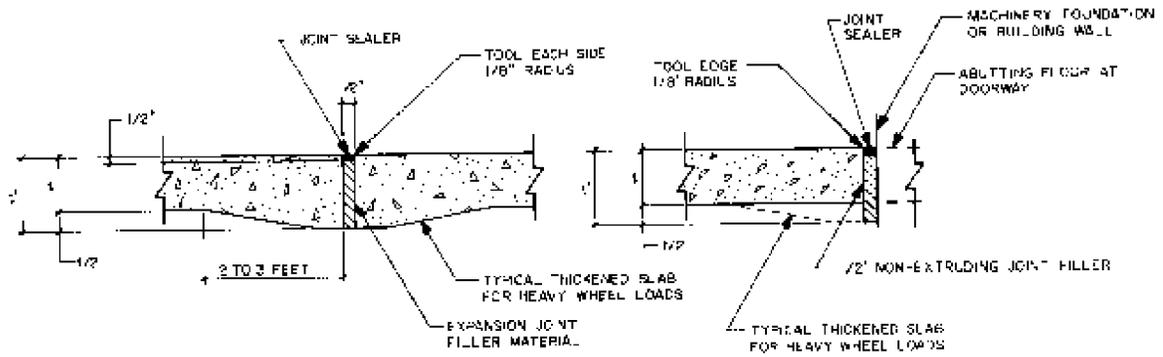
2.2.3.3 *Reinforcement.* Reinforcement in slabs on grade serves primarily to hold the edges of cracks tightly closed and also to distribute loads that contribute to the load-carrying capacity. If control joints are spaced as recommended hereinafter, reinforcement may not be necessary. However, it is preferable to use a nominal amount of reinforcement where the uniformity and strength of the subgrade may be questionable. Such steel supplied should be small bars or welded-wire fabric installed at middepth of slab.

2.2.3.4 *Placement of Concrete.* Concrete for structural slabs should be made with hard, well-graded aggregates and should contain not more than the number of gallons of water specified for each sack of cement. It should be a workable mix which can be placed without honeycombing or permitting excess water to accumulate on the surface. The concrete shall be placed as near to the

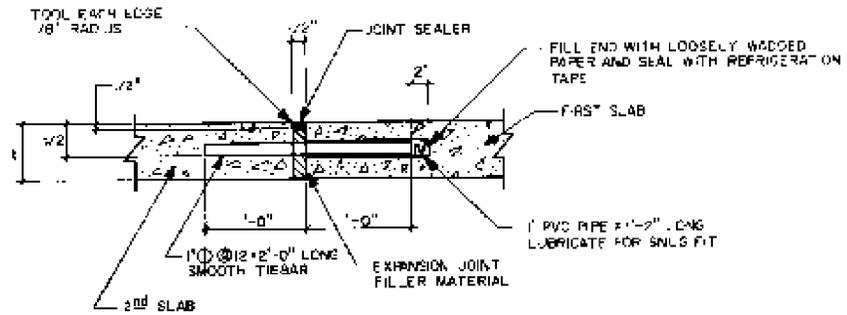
final resting place as possible, thoroughly compacted by vibrating or tamping and spading, and screeded to proper grade for drainage. The minimum practical thickness for a light-duty slab is 4 inches; for medium-duty, 6 inches; for heavy-duty, 8 inches or more.

2.2.3.5 *Joints.* Joints are required in concrete slabs to permit expansion and contraction of the concrete due to temperature and moisture changes, to relieve warping and curling stresses which result from temperature and moisture gradients within the slab, to minimize uncontrolled cracking caused by frost action, and as a construction expedient to separate the areas of concrete placed at different times. There are three general types of joints used in concrete slabs: contraction, expansion, and construction. See figures 2-10 and 2-11.

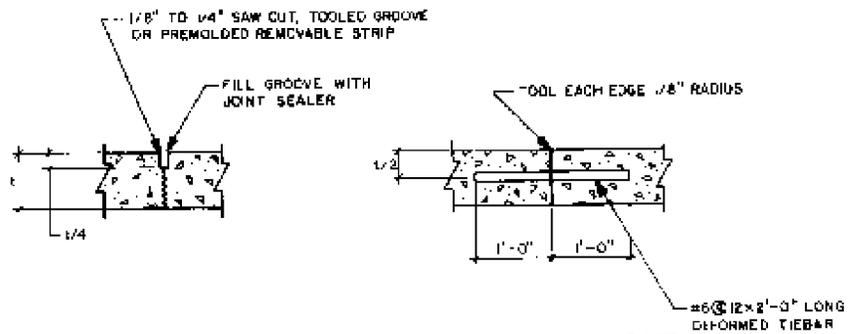
a. *Contraction Joints.* The initial shrinkage of concrete is often greater than subsequent movements of the slab by moisture or temperature



ISOLATION JOINTS



EXPANSION JOINT



CONTRACTION OR CONTROL JOINT

CONSTRUCTION JOINT

Figure 2-10. BUTT JOINTS.

changes. Under normal conditions, joints are placed approximately 15 to 20 feet apart, or on each column line, whichever is less.

*b. Expansion Joints.* Expansion joints are to be installed at walls, columns, and machinery pads, and at 60- to 90-foot intervals. The width of joints varies from  $\frac{1}{4}$  to  $\frac{3}{4}$  inch, depending on the joint spacing and the expected temperature range. Expansion joints at walls, columns, and machinery pads should be designed to allow differential settlement of the floors and footings. Expansion joints will serve as contraction joints, but contraction joints cannot serve as expansion joints.

*c. Construction Joint* Construction joints are provided to separate areas of concrete placed at different times. Insofar as practicable, these joints will be installed at the location of a planned joint.

**2.2.3.6 Joint Filler Material.** Joints are, with a few exceptions, lines of complete separations of the slab. In order to keep the joint clear and free to move, the joint is filled with an expansible material, and may or may not have water seals. The water seals also expand and contract with the movement of the slab. Filler material is generally of two major types:

*a.* Hot or cold asphalt, tar, or other thermoplastic or bituminous compounds, poured, placed or gunned into the joint. Cold joint-sealing compounds, applied under pressure, are more satisfactory for narrow joints,  $\text{C}$  to  $\frac{3}{16}$  inch wide, which cannot be filled by other methods.

*b.* Premolded joint filler strips, manufactured in a wide variety of thicknesses, depths, and lengths, may be composed of wood, fiber, cork, spunglass, rubber composition, felt and other compressible or expansible materials, usually with an asphalt or tar binder (see ASTM D-1751 and D-1752). The filler strip is equal to the width of the joint opening, and a maximum of  $\frac{3}{4}$  inch below the surface of the slab. After the concrete has set, the joint is filled to slab level with poured asphalt (see ASTM D-1850 and Federal Specification SS-S-1401) or other thermoplastic compounds. In areas of expected heavy spillage of diesel fuel, jet fuel, aviation gasoline or lubricants, a jet-resistant sealant conforming with Federal Specification SS-S-1614 or SS-S-200D will be used.

**2.2.3.7 New Joints in Existing Slabs.** Where new joints have to be made in existing slabs, extreme care will be used throughout the operation. The concrete slab will be broken using drills, chip hammers or saws, depending on the extent of the work and the availability of equipment. Joints will be cut cleanly to the desired dimensions. All dust, dirt and

other debris will be removed from the joint before installation of joint material.

#### **2.2.4 Joint Maintenance**

As a general rule, joints in slabs on grades need little or no maintenance. If the joint is in good condition, it should be left undisturbed. The major maintenance is required by the expansion joints where the constant movement (working) of the slab, due to the effects of temperature and moisture, deteriorate the joint material. If maintenance is to be performed, all joint material should be removed. The joint should be swept clean of all debris, and the edges of the joint trimmed to present a clean surface. New joint material of the proper thickness and depth should be installed. New or better joint material may be substituted for the original material if economically feasible.

#### **2.2.5 Special Considerations**

Utility ducts and drainage trenches in slabs on grades may be poured integrally or separately in new construction, or built into existing slabs.

**2.2.5.1 Ducts and Trenches.** Size and location of utility ducts and trenches will be established, in conformance with the construction drawings. Particular care will be taken to see that ducts are thoroughly waterproofed. Drains will be provided to carry off any accumulation of water. These drains will be separate from all other drains leading into a main storm sewer.

**2.2.5.2 Trenches.** Floor drainage trenches will have metal-grating covers and be placed to intercept surface drainage at hangar doors, vehicular entrances, and at other locations as required.

#### **2.2.6 Exterior Slabs on Grade**

Exterior slabs on grade (i.e., vehicular entrance ramps, platforms at pedestrian entrances, transformer or equipment pads) are similar in design and construction to interior slabs on grade except that they must be supported and drained to resist frost action, surface water, ice, snow, and other conditions of the elements. Exterior slabs may be attached to, or be independent from, structures. Brackets, dowels, shelves, and other types of piers may be used for support, or exterior slabs may be poured integrally with the structure foundation to which they are attached. Exterior slabs to be poured independently will rely on a compacted and confined selected fill of crushed stone, gravel, sand, or cinders. In certain locales, due to subsurface water and frost conditions, the fill bed must have adequate drainage to prevent heaving and cracking. This drain may be connected to or be a part of foundation drains.

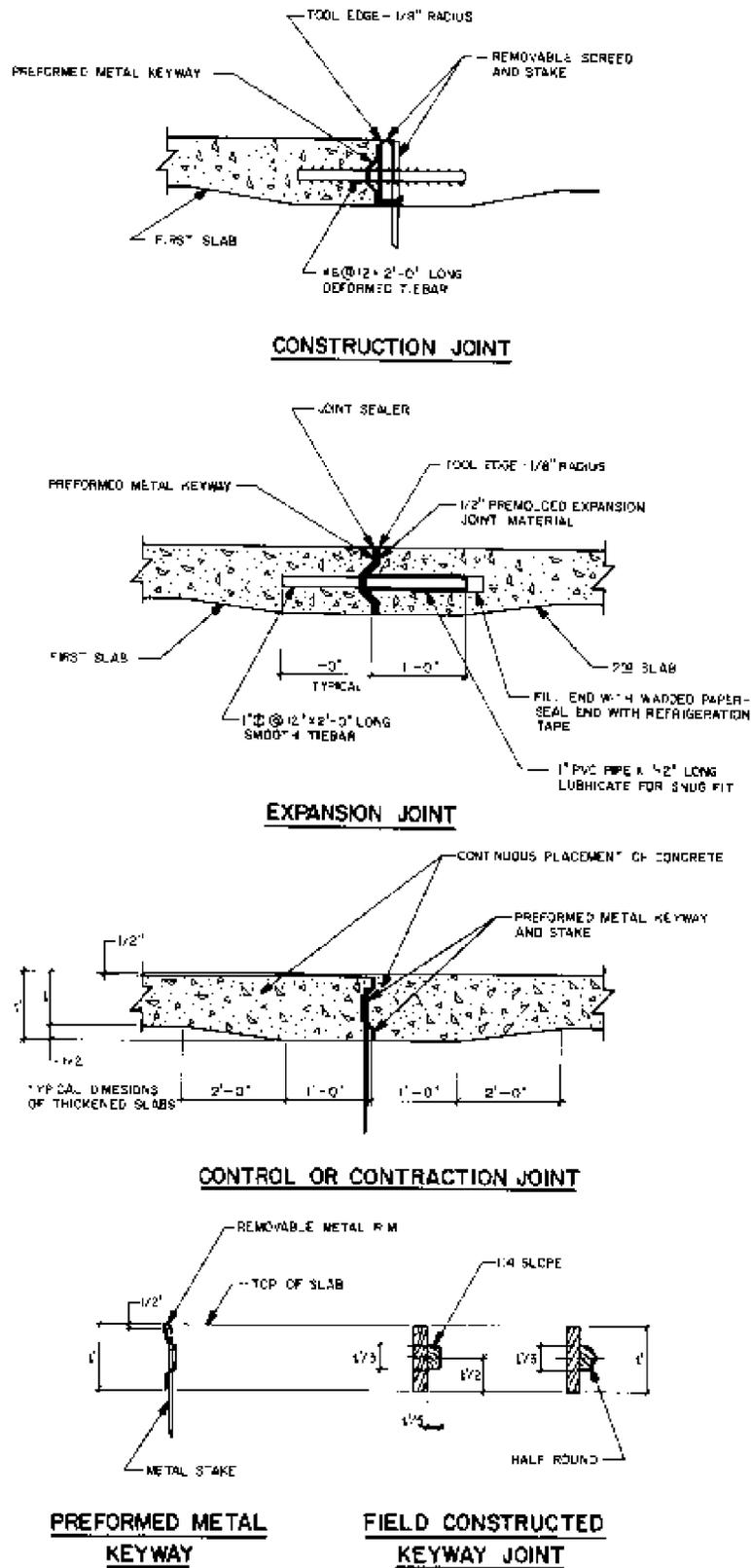


Figure 2-11. KEYWAY JOINTS.

### 2.2.7 Water Seals

Water seals in joints in concrete slabs on grade are usually of copper, other nonferrous metals, rubber compounds or plastic, and are used in conjunction with a mastic material. There are many types and designs, some commercially produced under patents, and others shop-fabricated from detailed designs. Because water seals are of a permanent nature, they require little maintenance. However, failure usually requires complete replacement of the affected section. These joints are used where absolute water tightness is required against a hydrostatic head, such as in swimming pools.

### 2.2.8 Bonding New Concrete to Existing Concrete

Proper bond of new concrete or mortar to existing concrete surfaces is important in producing durable structures. Lack of bond can result in leakage at joints, unsightly incrustations, and failure of structures. Other methods of bonding are discussed in detail under paragraph 2.2.9., Cement-Mortar Concrete Inlay, and paragraph 2.2.10., Epoxy-Resin Grouts, Mortars and Concretes.

**2.2.8.1 Making Construction Joints.** Where construction joints occur, and are not intended to be expansion or contraction points, the surface of the concrete, while still soft, should be swept with a stiff broom or scraped to remove laitance (an accumulation of fine particles on the surface) and roughen the surface. The surface should be left with some coarse aggregate projecting. Before placing the next lift of concrete, the surface should be free of loose particles and debris. Where laitance is not removed before hardening, it must be chipped away until sound concrete is revealed.

**2.2.8.2 Treatment of Bonding Surface.** The bonding surface should be kept constantly wet for at least 1 hour before placing new concrete. Time should be allowed for surface wetness to disappear just before placing new material. The surface will then be damp but slightly absorptive. A layer of concrete containing only one-half the amount of coarse aggregate should be deposited against the hardened concrete to a thickness of at least 2 inches. This is followed by the regular mix, which would be carefully vibrated to prevent honeycombing. Good results can also be secured by saturating the hardened concrete, then spreading a thin layer of dry portland cement about  $\frac{1}{16}$  inch thick over the surface. This should be broomed into the surface and spread uniformly, then left undisturbed to absorb moisture from the base. When it becomes tacky, the new concrete should be placed immediately.

### 2.2.9 Cement-Mortar Concrete Inlay

When concrete slabs become rutted, spoiled or broken, the entire floor should be replaced or resurfaced. In some cases the repair may be limited to the damaged area. A cement-mortar concrete inlay is the usual method of repair. For a detailed discussion of floor repairs and resurfacing, see chapter 6, section 6.3.

**2.2.9.1 Concrete Specifications.** The materials to be used to make the concrete mix will be specified by a qualified engineer. This specification will include the quality of the cement (see ASTM C-94), the gradation of the coarse and fine aggregate, the proportions of the concrete mix, and any additives that might be required. Adjustments of the proportions to make a workable mix will be under the control of a qualified supervisor.

**2.2.9.2 Mixing and Placing Mix** each batch mechanically 2 to 3 minutes, place material on slab, and vibrate, roll, or tamp it firmly into place. A grill-type tamp can be made by nailing strips about  $\frac{1}{2}$  inch wide and  $\frac{1}{2}$  inch deep, spaced about 4 inch apart, to the face of an ordinary tamp. Screed material to designated levels and float surfaces with wood, or preferably a power float. Let stand for 30 to 45 minutes or until pressure from finger ceases to make a dent, then steel-trowel to final finish. Do not sprinkle water on it in finishing. Be careful that finishing does not bring any excess fines to the top. Maintain existing expansion joints.

**2.2.9.3 Curing** Place a suitable covering material (plastic, burlap) or curing compound (spray paint) on the new surface as soon as it has set enough to not be marred.

**2.2.9.4 Reuse of Floor.** If high early-strength cement is used, the floor can be used after 3 days unless temperature has been below 45°F (7.3°C). In that case allow 5 days. Where standard portland cement is used, do not use the floor for traffic loads for 7 days after installation.

### 2.2.10 Epoxy-Resin Grouts, Mortars and Concretes

Three types of epoxy-resin bonding systems are available for application to portland cement concrete and are distinguished in ASTM C-881, Epoxy-Resin-Base Bonding Systems for Concrete. Type I is for use in bonding hardened concrete, steel, wood, brick, and other materials to hardened concrete (see ACI 503.1). Type II is for use in bonding freshly mixed concrete to hardened concrete (see ACI 503.2). Type III is for use in producing skid resistant surfaces on hardened concrete or as a binder in epoxy mortars or epoxy

concretes (see ACI 503.3 and 503.4). For each type of system, viscosity grade, temperature class, and color will be dictated by job requirements as outlined in ASTM C-88 1-78.

2.2.10.1 *General.* Approved epoxy-resin systems provide binding agents particularly suitable for use in the type of work where a high degree of bond in a short period of time is needed. The exceptionally high strengths obtainable in a very short curing time usually permit regular traffic on the slabs within 24 to 48 hours after the repair, depending on temperature conditions. The epoxy systems specified react most favorably when temperatures are in the range of 70° to 100°F (21° to 37.8°C), but satisfactory results can be obtained at temperatures as low as 40°F (4.5°C) if proper conditions are provided. The slab repairs with epoxy materials generally should not be initiated unless the air and slab temperatures are above 40°F and rising.

2.2.10.2 *Approved Epoxy Materials.* Use of epoxy-resin systems in concrete slab repair have been developed and numerous products for this purpose have been marketed under a variety of trade names. In selecting the materials for the work, uniformity is required for obtaining consistently satisfactory results. Therefore, the use of Federal specifications in obtaining or specifying epoxy-resin materials for the subject usages is mandatory. The following issue was current during the preparation of this manual: Federal Specification MMM-A-001993, "Adhesive Epoxy, Flexible, Filled (for Binding, Sealing, and Grouting)." This specification provides for two types of materials according to temperature conditions: type I is for use when slabs, materials, and atmospheric temperatures are between 68° and 104°F (20° and 40°C), and type II is for use when these temperatures are between 40° and 68°F (4.5° to 20°C). The principal difference between "binder" material and "grout" material is that grout contains an inert mineral filler and a thixotropic or jelling agent; the reactive constituents in both materials are identical.

2.2.10.3 *Applications.* The general applications or intended usages of the materials furnished under the Federal specifications are as follows:

a. *Grout.* The grout furnished under Federal specification MMM-A-001993 may be used for cementing dowels in preformed holes, as a bonding agent for hardened portland cement concrete, and for grouting the cracks in pavement.

b. *Binder.* The binder furnished under Federal Specification MMM-A-001993 may be used for re-

pairing spalls with epoxy concretes or mortars, and for filling saw kerfs with epoxy mortars where random cracking has occurred.

2.2.10.4 *Effective Temperatures and Conditioning.* Temperature limitations of the type I and type II grout and the type I and type II binder are mandatory and are repeated here for emphasis: type I is for use when slab, materials, and atmospheric temperatures are between 68° and 104°F (20° and 40°C); type II is for use when pavements, materials, and atmospheric temperatures are between 40° and 68°F (4.5° and 20°C).

a. *Slabs.* If slabs and atmospheric temperatures are less than 70°F (21°C) but not below 50°F (10°C), satisfactory repairs can be obtained without creating an artificial environment, provided the slightly increased cure-out or hardening period required can be tolerated. Further, if the climatic season is such that the pavement becomes hot, with air temperatures above 90°F (32.2°C) and slab surface temperatures possibly plus 120°F (48.9°C), scheduling of repairs should be in the early morning hours, or the areas should be protected from direct sunlight prior to initiating repair operations. When slab temperatures are less than 50°F, a battery of infrared heat lamps, or another suitable heat source, should be placed over the area to be repaired for a period of about 3 hours prior to placement operations. Gentle winds can make the heat lamps ineffective; therefore, temporary windbreaks should be used as necessary. Raising the slab temperature reduces the heat loss into the slab and permits a desirable moderate heat buildup from the exothermic reaction occurring with the combining of the two components of the epoxy system. Although an entirely satisfactory repair can be obtained if this moderate heat buildup does not occur, it may prolong a satisfactory cure-out or hardening and thereby delay reopening to use. Similarly, the cure-out or hardening period for epoxy concretes and mortars can be accelerated during cool weather by the use of heated enclosures over the repaired area. The means of attaining the desired air temperature in the enclosure must be such as to avoid localized heating of hotspots since these may cause bubbling of the liquid epoxies and also induce cracking. The safest method is to provide circulating air with added precautions to insure surface temperatures in the repaired areas of not more than 100°F (37.8°C) during the hardening stage.

b. *Conditioning of Aggregates.* In the preparation of epoxy concretes and mortars it is desirable that aggregates be reasonably dry and conditioned to a temperature of 70° to 85°F (21° to 29.5°C). When the aggregates are cold, two adverse

conditions are created. First, on addition of the epoxy material, the viscosity will be increased with decreased wetting ability; second, low temperatures of the final mixture will be conducive to a reduced hardening rate. If the aggregates are too hot, the epoxy-curing agent reaction will be accelerated, which could make placement and finishing difficult and possibly cause cracking.

*c. Conditioning of Epoxy System Components.*

The viscosity of the two components of the epoxy system increases greatly at temperatures below 70°F prior to mixing with a mechanical stirring device. Although adequate uniformity of the mixture might be obtained at lower temperatures by a prolonged mixing time when epoxy concretes or mortars are being prepared, this could result in overly "rich" mixtures due to the reduced wetting capability.

*d. "Triggering" Curing Chemical Reaction.* To expedite resumption of traffic over a repaired area under low slab and atmospheric temperature conditions, it is possible to appreciably accelerate the early hardening rate of the epoxy binders. This may be accomplished by scalping off the coarser fractions (15 to 25 percent of the total) of the aggregate and heating this portion of the aggregate to about 125° to 150°F (51.7° to 65.6°C). In the preparation of aggregate-epoxy admixtures, the balance of the aggregate is added to the two previously mixed components of the epoxy system. This should give a comparatively rich epoxy concrete or mortar mixture to allow for the addition of the heated aggregates. Immediately prior to placement, the heated scalped portion is added with particular attention to obtaining uniform distribution.

*2.2.10.5 Concretes-Aggregates for Epoxy Concretes and Mortars.*

*a. Concretes.* The aggregates used for epoxy concretes should be clean, dry, washed gravel or crushed stone of a  $\frac{1}{4}$  or  $\frac{1}{2}$ -inch maximum size, uniformly graded from coarse to fine, and of the same quality used for portland cement concrete and bituminous mixtures. Fine aggregate and coarse aggregate of indicated sizes meeting the requirements of the ASTM C-33, "Concrete Aggregates," should be specified for epoxy concrete mixtures.

*b. Mortars.* The aggregate used for epoxy mortars should generally conform to the requirements of the ASTM C-144, "Aggregates for Masonry Mortar." The aggregate should be uniformly graded from coarse to fine, and it is desirable that the materials passing the No.100

sieve be held to a minimum. The permissible maximum size selected will depend on the intended usage of the mortar. For example, in the filling of saw kerfs the normal width of the cut would necessitate using an aggregate with 100 percent passing the No. 8 sieve. In general, for both epoxy concrete and mortar the maximum-sized aggregate should not exceed one-fourth the thickness of the layer being placed or the width of the opening being filled.

*2.2.10.6 Sampling and Testing Epoxy Resin Systems.* All epoxy-resin materials proposed for use must be tested for compliance with the requirements of the Federal Specification MMM-A-001993. The manufacturer's certificates of compliance with the requirements should not be accepted in lieu of tests. The samples required and the minimum quantities necessary for the tests for each manufacturer's lot or batch of materials to be shipped, or retained for use by the Government, or on Government contracts, are stated in section 4 of Federal Specification MMM A-001993.

*2.2.10.7 Trial Batches—Epoxy Mortars and Concretes.* Since variations in aggregate grading and particle shape may affect the proportions required to obtain an economical mixture that has satisfactory placing and finishing characteristics, small laboratory trial batches are desirable prior to field placement operations. Essentially, the same principles which apply for materials produced onsite, such as hot-mix asphaltic concrete and portland cement concrete, will govern. In preparing trial batches the quantity of the cement concrete will govern. In preparing trial batches the quantity of the epoxy binder to which the aggregate is added should be not less than 300 grams. The epoxy-resin binder normally will be a mixture of two components (2 parts epoxy resin and 1 part polysulfide plus curing agent). However, material shipping containers should always be checked for deviations from specified proportions. A suitable capacity metal or polyethylene container having a hemispherical bottom should be used as the mixing vessel. The polysulfide-curing agent component should be added gradually to the epoxy-resin component with constant stirring, and the stirring continued until a uniform mixture is obtained. The rate of stirring should be such that the entrained air is at a minimum. Handmixing is usually unsatisfactory and a power-driven (air- or spark-proof), propeller-type blade should be used. Epoxy concrete proportions by weight may vary from 6 to 10 parts aggregate to 1 part epoxy binder. Aggregate proportions of epoxy concrete normally will consist of about 2 parts fine aggregate to 1 part coarse aggregate by weight. The epoxy mortars

may vary from 3 to 7 parts aggregate to 1 part epoxy binder. The proportions suggested are applicable only to aggregates in the 2.60 to 2.80 specific gravity range. Aggregates having specific gravities above or below these values will probably require adjustment of the suggested proportions. The trial batch procedure will assist inexperienced field personnel in obtaining the proper proportions of aggregate and binder in preparing the larger field batches. Trial batches are not necessary in the use of epoxy grout for filling cracks, placing dowels, and as a bonding medium between plastic and hardened portland cement concrete. The two components of the grout usually will be mixed in the proportions specified by the producer without the addition of fillers or aggregate.

**2.2.10.8 Field Mixing and Batch Size.** Small mechanical mixers of the drum type have been used successfully for mixing epoxy concrete and mortars. However, these mixers are difficult to clean thoroughly, and delayed cleaning can result in buildup of residual material making replacement of the mixer drum necessary. Toluene, the solvent used, also presents problems of toxicity, fires, and possible explosions (toluene has a low flashpoint) due to the confining nature of the mixer drum. Usually the batch size needed will be small, and handmixing using metal pans with other appropriate tools will be advantageous and less hazardous. The maximum batch size will be limited by the manual labor capability to thoroughly mix the epoxy binder and aggregate. Experience has demonstrated that this will range from 200 to 300 pounds total (epoxy binder and aggregate). Prior to starting operations, the immediate onsite availability of all batch-weighted materials and the suitability and adequacy of mixing and placing tools should be carefully checked. A relatively short delay before adding the aggregate to the mixed epoxy binder can mean loss of the binder due to the accelerated chemical reaction. Minor delays can be tolerated provided the mixed epoxy binder is spread in a thin layer, 1 inch or less, in the mixing pan. The container and mixing sequence of the epoxy and polysulfide curing-agent components should be as stated in paragraph 2.2.10.6. The mixed epoxy binder is then transferred to the mixing pan or the drum of the mechanical mixer. The total amount of aggregate incorporated in epoxy concrete may be greater if the aggregates are divided into coarse and fine fractions before being added to the binder. In mixing of epoxy concrete the fine aggregate fraction should be added to just below practicable workability (i.e., a slightly rich mix) and then the coarse fraction added to the carrying capacity of mortar while still retaining

placeability and finishing properties.

**2.2.10.9 Protection of Repaired Areas From Weather and Traffic.** Repaired areas should be protected as follows:

*a. Temperature.* Pavement repairs made when ambient temperatures during the following 24 hours may be 60°F (15.6°C) or lower require limited protection to maintain the epoxy concrete or mortar at temperatures which will provide a reasonably normal hardening rate. The use of tarpaulins supported several inches above the surface of the repaired area will help to maintain the desired conditions provided the temperature difference or drop is not too great. Heated enclosures may also be used to provide effective temperature conditions.

*b. Water.* The formulation of the epoxy-resin grout and binder, described in the Federal specification, is such that moisture in or on the surface of the slab area being repaired does not affect bonding properties; however, free water should not be present. During the early hardening stages, which may vary from 2 to 12 hours depending on weather conditions, the epoxy mortars and concretes should be protected from the rain.

*c. Traffic.* The repaired areas should be barricaded to prohibit traffic of all types until the epoxy concrete or mortar has hardened. The time interval over which protection against traffic should be maintained will vary with weather conditions; but, when appropriate environment is provided or prevails, it will usually be less than 24 hours. [Note: Compressive and flexural strengths of 7,000 and 1,000 pounds per square inch (lb/in<sup>2</sup>), respectively, have been obtained on 1.7 epoxy-aggregate mixes cured at 70°F (21°C) for 20 hours.]

**2.2.10.10 Cleaning of Equipment and Tools.** Due to the nature of the hardened epoxy systems, all tools and equipment must be thoroughly cleaned before the epoxy materials set. Toluene, xylene, or other aromatic petroleum solvents hazard. In the cleaning operations the workmen must wear solvent-resistant gloves; and, since even the vapors will break down natural skin oils, the use of protective creams is desirable.

**2.2.10.11 Safety and Health Precautions.**

*a. General Precautions.* The materials used in the two epoxy systems and the solvents used for cleanup do not ordinarily present a serious health hazard except to hypersensitive individuals. They may be handled with complete safety if adequate precautionary measures are observed. Handle only in well-ventilated areas. Prevent skin contact. Wear protective clothing and goggles when possible

contact is anticipated. Wear goggles to protect eyes from the curing agent in the polysulfide component. This should be mandatory for persons doing the blending and mixing operations but is not so much a hazard for persons engaged in the placing operations. Maintain good housekeeping and personal hygiene standards. Remember the danger—solvents are a fire hazard.

*b. Personal Sensitivity.* The epoxy-resin component presents no hazard from vapor exposure, but a few individuals have developed a rash from skin contact. Therefore, adequate precautionary measures should be exercised. The polysulfide curing-agent component has an obnoxious odor from the polysulfide constituent, which may nauseate some individuals; consequently, inhalation of the vapors should be avoided or kept to an absolute minimum. The amine-type curing agents incorporated in the polysulfide constituent are caustic and may cause tissue damage on direct contact with the skin. Contamination of the eye by the polysulfide curing-agent component can cause severe damage very rapidly, and exposure to high vapor concentrations may also irritate the eyes and mucous membranes.

*c. Personal Precautions.* Although the constituents of the epoxy systems can create some health hazards, proper precautions will reduce these to minimum incidence confined principally to hypersensitive individuals. Wear rubber or other suitable impervious gloves whenever skin contact is possible. When gloves become contaminated, they should be discarded or reconditioned by washing in appropriate solvents, followed by soap and water. Contaminated gloves, clothing, working tools, etc., should not be removed from the work area except for discarding or cleaning. Wear protective clothing, such as coveralls, when engaged in the preparation and usage operations. Wearing of contaminated clothing should be prohibited. Apply protective creams on exposed skin areas when occasional contact occurs or is anticipated. Wear full face shields or goggles whenever droplet contamination is possible, such as during the blending and mixing operations. Restrict blending and mixing operations to open areas, or in buildings, to a well-ventilated hood system. Use disposable paper coverings in the work area where dripping or contamination is expected.

*d. First Aid.* Provide necessities for prompt treatment of accidental skin or eye contact. First-aid procedures in cases of accidental eye contamination consist of immediate and continued washing of the eye for at least 10 minutes with copious quantities of water; bathing the eye with normal saline solution; and referral to a physician if there is

any question of serious eye involvement. Cleanse all skin areas thoroughly with soap and water following accidental or nonpreventative skin contact. If necessary, fresh alcohol, acetone, toluene, or methyl ethyl ketone may be used as a solvent; however, the use of such solvents should be kept to a minimum. In cases of spills, involved clothing should be immediately removed and decontaminated in the manner described herein for gloves.

*e. Removing Source of Contact.* If a workman develops a rash, the source of contact should be determined and eliminated. Treatment of the condition should be handled by a competent physician with full information furnished as to the probable cause.

*f. Moving Hypersensitive Persons.* Remove individuals who are sensitive to any of the epoxy system constituents from exposure until the condition is completely cleared. Limit subsequent contact with materials to a degree which proves to be tolerable. It may be necessary to remove highly sensitive workmen completely from the work area.

*g. Obtaining Further Information on Health Factors.* Some manufacturers of epoxy resins and some health agencies should be able to provide literature and other appropriate guidance on health and safety aspects. The Shell Chemical Corporation, Industrial Hygiene Bulletin SC 106-xx (latest edition) titled "Recommendations for Handling Resins and Auxiliary Chemicals" is an excellent treatise on many aspects of the health factors involved. This bulletin is readily available from any of their offices throughout the United States. Other manufacturers of epoxy resins should also be able to furnish somewhat similar information.

### 2.2.11 Floor Finish

For a detailed discussion of floor finish, see chapter 6, section III.

### 2.2.12 Curing

All concrete should be kept from drying out for at least 5 days (2 days for high early-strength portland cement). For slabs subject to severe wearing conditions and for special toppings, the minimum curing period should be increased to 7 days (3 days for high early-strength cement). Curing may be obtained by covering with waterproof paper sealed at all edges or any suitable method that will prevent the concrete from drying out. Proper curing will increase the strength and resistance to wear and will reduce the shrinkage and tendency to crack.

### 2.2.13 Liquid Hardeners

Liquid hardeners applied over friable, dusting concrete floors protect the surface against abrasion and

shock caused by heavy traffic. Use low-viscosity solutions which penetrate deeply into the concrete.

2.2.13.1 *Preparation of Concrete Floor Surfaces.* Clean all dust, dirt, foreign particles, and oil or grease spots from concrete floors to which a liquid hardener is to be applied.

2.2.13.2 *Materials.* Use one of the following materials or an approved equivalent:

a. *Sodium silicate (water glass):* Commercial, 40° to 42° Baume (Be).

b. *Magnesium fluosilicate* & Crystalline salts plus zinc fluosilicate.

2.2.13.3 *Mixing and Applying Sodium Silicate.* Dilute sodium silicate just before using by adding 4 gallons of water to 1 gallon of sodium silicate. One gallon of this solution covers about 800 square feet of floor surface with one coat. Apply the solution as follows:

a. *First coat* Apply first coat with a mop or broom, brushing solution continuously over floor surface to get even penetration. Allow at least 24 hours for first coat to dry and harden. Scrub dried surface with hot water to remove the glaze which generally appears, then allow 24 to 48 hours for surface to dry completely. If floor is porous enough to absorb first coat without leaving a glaze, hot-water scrubbing can be omitted.

b. *Second coat.* Apply a second coat in the same manner as the first. Allow it to dry, scrub with hot water, and again dry for 24 to 48 hours.

c. *Third coat.* Apply third coat in the same manner. Allow it to dry thoroughly before using floor. Hot-water scrubbing is not needed on this coat.

2.2.13.4 *Mixing and Applying Magnesium Fluosilicate.* To 1 gallon of clean freshwater add a 2-pound mixture of crystalline salts of magnesium fluosilicate and zinc fluosilicate, at least ½ pound being zinc fluosilicate. Fluosilicates can be obtained as prepared solutions or as dry crystals. Dry crystals are more economical and can be mixed at the job with freshwater in wooden vessels. One gallon of this solution covers about 100 square feet of floor surface with one coat. Apply as follows:

a. *First coat.* Dilute the solution by adding 1 gallon of clean freshwater to each gallon of solution, or prepare a new solution of 1 pound of dry crystals to 1 gallon of water. Apply solution with a mop or broom, and brush it continuously over floor surface for several minutes to get even penetration. Allow at least 24 hours for drying before applying second coat.

b. *Second coat* Apply second coat, using

undiluted solution of 2 pounds of crystals to 1 gallon of water. Follow same procedures as for the first coat. Allow at least 24 hours for drying.

c. *Third coat.* If floor is unusually friable or porous, apply a third coat, using same solution and application as for second coat.

2.2.13.5 *Costs.* Sodium silicate materials are cheaper than fluosilicates, but labor cost is greater because of the hot-water scrubbing of each undercoat.

2.2.13.6 *Comparative Effectiveness.* Laboratory experiments and actual use have generally shown little difference in effectiveness between sodium silicate and fluosilicate if both are applied properly. On smooth-troweled floors or dense surfaces, fluosilicate solution is less viscous and penetrates more easily.

a. Penetration of most hardeners, especially sodium silicate, is improved by applying the solution heated to about 170°F (76° F). Both sodium silicate and fluosilicate solutions become about half as viscous at 170°F as at 70° F (21° C). This change in viscosity is greater than that obtained by diluting the solution, which is sometimes recommended for the first coat.

b. Maximum penetration of hardener may not always be desirable. With rough, porous surfaces it is sometimes desirable to retain enough hardener at the surface for adequate reinforcement; use of more concentrated hardeners applied cold will probably give better results. On rough or porous surfaces, 42° Baume sodium silicate solution diluted 1 to 3 or 1 to 2.5 is preferable to fluosilicate solution.

c. Most liquid hardeners sold under trade names have a base of sodium silicate and magnesium fluosilicate, with a small amount of zinc sulfate, or other materials added.

d. Sodium silicate and magnesium fluosilicate with or without added materials are favored because of their availability, ease of mixing and application, ability to harden surfaces satisfactorily, and comparatively low cost.

2.2.13.7 *Varnish Seal Treatment.* A varnish seal is effective to prevent dusting of concrete floors that are subjected to heavy foot traffic. It provides a seal for subsequent waxing of floors in entrances, lobbies, and other areas where appearance is a prime factor. Use a sealer conforming to Federal Specification TT-S-176. Apply the sealer liberally by brushing it into the pores of the concrete. After the sealer has been allowed to dry, buff it with a floor-polishing machine. If certain areas appear lifeless, repeat the process until the pores of the concrete are filled.

SECTION III—MOISTURE CONTROL

2.3.1 Moisture Damage

The backfill around foundations is usually less dense than the surrounding natural, undisturbed earth. Thus, the foundation area has a tendency to be a reservoir of excess surface and underground seepage water, unless it is properly drained. Confined water builds up hydrostatic pressure against foundation surfaces where cracks, porosity, or voids in joints of foundations walls will permit water to seep into the structure and cause wet walls and floors. If drainage is neglected for a long time, overirrigation of the bearing soil may reduce its stability and lead to major dislocation of the foundation. Where the nature of subgrade soil resists, deters, or stops free drainage of subgrade water, waterproofing of usable areas below grade (such as basements, cellars, pools, pits, vaults, igloos, tunnels, utility trenches, and manholes) is

usually necessary. The prolonged neglect of such a condition may cause shifting or rotation of the footings or reduction in the load bearing capacity of the soil under the foundation resulting in serious damage to the structure.

2.3.2 Causes and Control of Ground Water

Although there are several causes and controls for specific ground water conditions, improved drainage is the basic solution to the most common ground water problems. See figure 2-12.

2.3.2.1 *High Water Table.* Moisture in structures caused by a high water table can be drained away from the foundation by installing a drainage system. This is usually the most effective and economical method of maintaining dry foundation walls and slabs on grade. Two drainage systems in general use are described below.

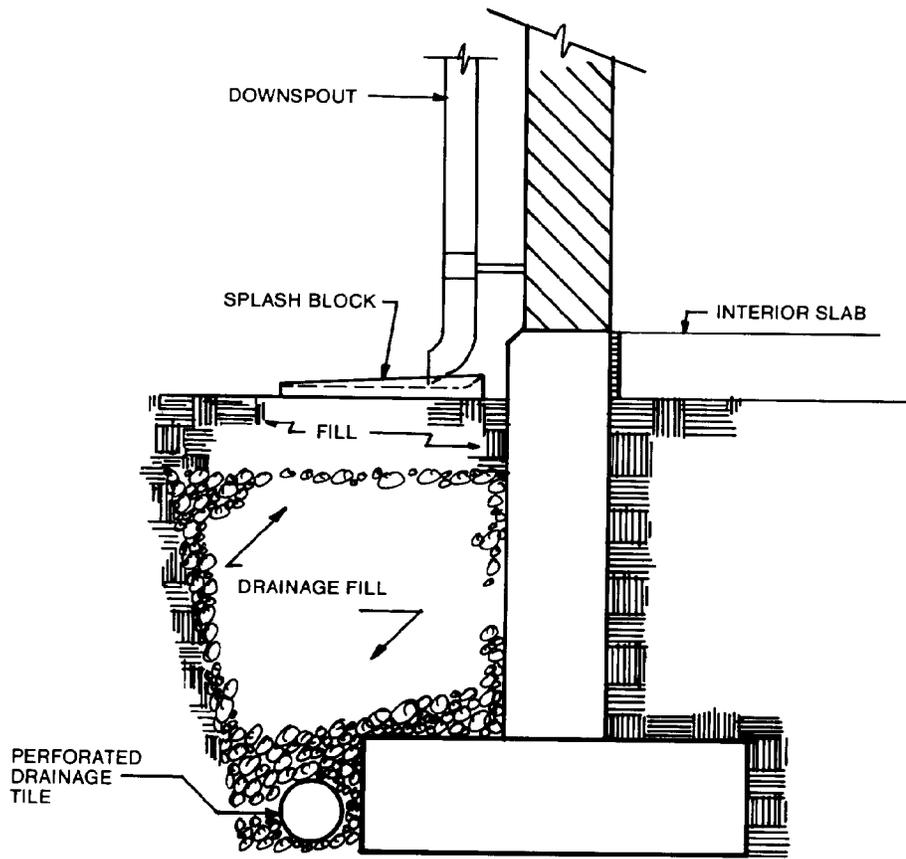


Figure 2-12. FOUNDATION DRAINAGE.

a. *Drainage Pipe.* The earth around the foundation walls is excavated to the bottom of the footing with enough width for working space. See figure 2-13, a foundation wall is to be exposed, care should be exerted to assure that the stability of the wall and the earthbank is maintained. Special care should be taken in loose sand, saturated clay, or a wall having an outward (horizontal) thrust imposed upon it. Perforated or plain tile pipe or perforated plastic pipe such as polyvinylchloride (PVC) is installed next to the bottom of the footing, pitched with minimum slope of  $\frac{1}{2}$  inch in 10 feet in the direction of the intended runoff. Perforated pipe should be laid with closed joints. Plain tile pipe should be laid with open joints having the upper half covered with a bituminous-treated fibrous building paper or suitable plastic film to prevent sand or soil from clogging the drainpipe. To be

effective, a drain should generally be pitched from a high point around the perimeter of the building to a low point below the floor slab where the connection or sump is located. Footing drains connect independently of all other drains into storm sewers, dry wells, or outfalls available for free drainage of water. Drains may also flow into a sump with a float-controlled electric pump. Footing drains that connect to storm sewers or other outfalls should be designed with sufficient drop to assure that the storm sewer does not flood back to the foundation wall. Never connect a storm drain to a sanitary sewer. The drains shall be covered with a bed of at least 1 foot of graded, crushed stone or gravel. Drainpipe sizes and stone drainbed areas (cross section) shall be determined by the estimated volume of water to be drained, the length of run, and the slope of the drain.

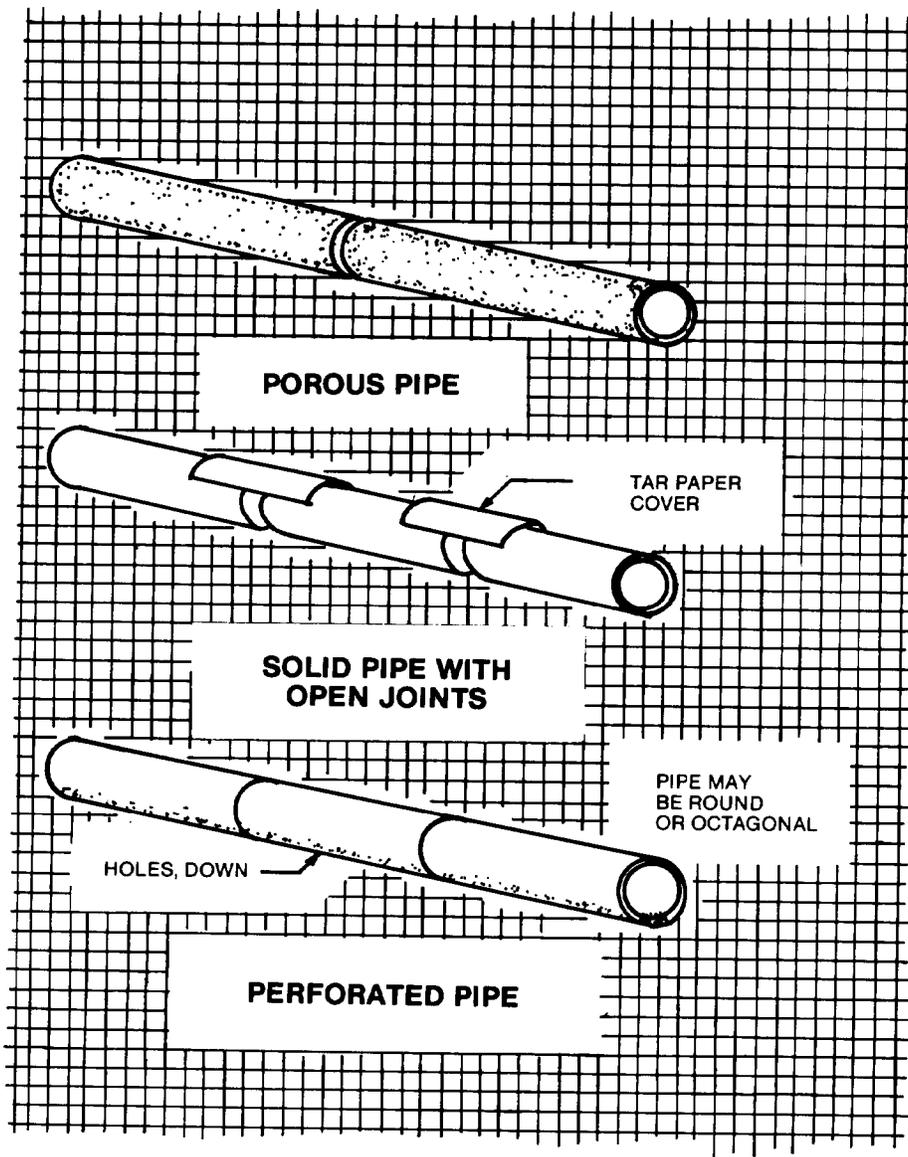


Figure 2-13. DRAINAGE PIPE.

b. *Gravel Drain.* A stone drain bed laid at the bottom of the footings, approximately 2 feet wide and not less than 1½ feet deep, shall be installed similar to the draitile described above.

2.3.2.2 *Roof Drainage.* Where roof drainage causes a foundation water problem, gutters and downspouts should be installed, preferably connected to a storm sewer. Gutters that are improperly hung or allowed to become clogged will overflow and lose their effectiveness. Leaks in gutters should be repaired promptly. Splash blocks or draitile should be installed in the absence of storm sewer connections to prevent pooling of water below downspouts.

2.3.2.3 *Surface Drainage Toward Building* The drainage of surface water toward a building can be reversed by sloping the ground surface away from the foundation wall. Where that is not practical, ditching or installing drains will serve the same purpose. The general grade of crawl spaces should not be lower than the surrounding area, which should be graded to drain way from the building.

2.3.2.4 *Infiltrating Water.* Ground water under hydrostatic head will seep through minor cracks, construction joints, porous concrete, and porous masonry. Direct leaks caused by holes, settlement cracks, complete fracture through walls and slabs, around utility pipes, conduits, ducts and other utility services penetrating foundation walls and slabs

are due to improper installation of sleeves, caulking, or inserts. These leaks must be investigated and repaired in conjunction with other water control measures.

**2.3.2.5 Utility Leaks.** Breaks in water, sewage, heating, and drain pipes should be repaired as soon as discovered. Such conditions will become evident by the improper functioning of the utility involved. However, a thoroughly waterproof foundation of slab may not show any evidence of moisture or the location of such a leak. If a serious break of this nature is not discovered and repaired, it may affect the stability and load bearing capacity of the soil. This will result in serious damage to the structure. When a break is suspected, locating the break may require opening cuts in the slab or excavation of the soil at exploratory points. After locating and repairing the damaged utility, the foundation is to be restored to designed conditions.

### 2.3.3 Condensation

Condensation is caused by humid air coming in contact with cold surfaces. If it is a seasonal condition, the cost of correction might not be justified for the nature of the usage of the space. If the condition is constant and of such extent as to be harmful to the structure or render the space unusable for its designated purpose, the condition should be eliminated.

**2.3.3.1 Condensation in Interior Spaces.** Condensation in interior spaces may be eliminated or alleviated by one or more of the following methods:

- a. Dehumidification of room air by mechanical means.
- b. Insulation of walls including a vapor barrier on the warm side of the insulation.
- c. Ventilation of the room to prevent the air from cooling to the dewpoint.
- d. Where thoroughly dry conditions are required, a special system shall be designed by a qualified engineer.

**2.3.3.2 Condensation in Crawl Spaces.** In crawl spaces or "dead" areas under structures with no basements, moisture-control problems other than building drainage develop from condensation of moisture rising from damp soil. The ideal method of preventing ground moisture from entering the building is to provide an impermeable vapor barrier on insulation in floors and walls. In existing buildings, this is not practical unless it is done during major renovation. The most practical solution is to provide a soil cover of water-resistant material. In the past, 55 pound roll roofing has been the most widely used and successful soil

cover. However, 6 mil (0.006 to 0.5 inch) polyethylene plastic sheeting is more effective and easier to handle. The effective life of these plastic covers when exposed to air or under slabs has not been established. Soil covers may be rolled out on the soil from foundation wall to foundation wall. It is not necessary to form a complete seal over the soil; however, at least 90 percent of the soil should be covered; cracks should be limited to 1 inch. Removal of trash and debris and leveling of sharp dips and mounds in the soil will increase the life of the cover.

### 2.3.4 Moisture Control in Subsurface Structures

Moisture in subsurface structures results from condensation or seepage-or both. Correction may range from simple solutions including dehumidifying or using waterproof paint to drastic measures such as excavation and waterproofing or diverting water sources. Three measures are used to control moisture: plugging leaks, eliminating causative water problems outside the structure, and controlling dampness inside the structure. Correction of condensation-related problems is detailed in paragraph 2.3.3.1.

**2.3.4.1 Moisture Seepage.** Seepage includes the passage of moisture or water through masonry walls or floors from adjacent surfaces. In mild cases, it may resemble condensation and can be tested using a 12-inch square of smooth aluminum foil taped to the masonry wall. If, after several days, moisture appears on the wall side of the foil, seepage is present.

**2.3.4.2 Waterproof Painting.** Unless cracks appear at the source of seepage, moisture control may be established by painting the surface of the walls with a waterproof paint. Ready-mixed paints must be applied to a dry wall which has been prepared by removing dirt and efflorescence with a wire brush, chipping off all loose mortar, and patching holes. The same procedures are followed for dry powder paints, however, the wall must be wetted before painting. Painting is done using a stiff brush. The paint must be carefully worked into all pores of the surface to seal the wall. Two coats are required and the wall should be inspected to insure that all pores are sealed.

**2.3.4.3 Water Leakage.** Leakage occurs from openings in the walls or floors. These may include defective joints, mortar cracks, settlements cracks, or holes resulting from damage or around pipes passing through the wall. In all cases, steps should be taken to seal the opening and eliminate conditions causing the problem.

2.3.4.4 *Repairing Cracks.* Leakage problems associated with cracks may be solved by plugging the crack using patching cement or silicone caulk as discussed in chapter 4, paragraph 4.3.6. Cement should be used only in cases which show little likelihood of continuing shift in the structure. Hydraulic cement must be used in those cracks where running water is present.

2.3.4.5 *Exterior Moisture Control.* In all cases of leakage, steps must be taken to control the source of moisture. This may include control of surface and subsurface water as described in paragraph 2.3.2, or foundation waterproofing as described in paragraph 2.3.4, or both.

### 2.3.5 Foundation Waterproofing

If interior surface maintenance is insufficient to control moisture, excavation and exterior surface waterproofing may be required.

2.3.5.1 *Preparation of Wall Surfaces.* Excavate a trench wide enough for working space around the outside of foundation walls and to the bottom of the footings. Thoroughly clean the exposed surfaces with water, detergents, live steam, or other available agents. Procedures for steam cleaning are detailed in chapter 4, paragraph 4.3.9.4. Carefully examine the exposed surfaces for cracks, holes, fractures, and other damage that would permit moisture to penetrate the walls. Repairing concrete and masonry walls are outlined in chapter 4.

2.3.5.2 *Bituminous Mopped-On Membrane.* Bituminous mopped-on multiple membrane is one of the most positive methods of waterproofing foundation walls subject to considerable hydrostatic pressure. Membranes are of bituminous-saturated felts or fabrics. Roofing-grade, hot coat-tar pitch (conforming to ASTM D-450) or asphalt (conforming to ASTM D-312) is used to mop on the membranes. Five plies of membrane are recommended for hydrostatic pressures of 12 feet. All component materials used in any one application should be the products of one manufacturer, and his application instructions should be followed carefully. Membranes should be applied free from wrinkles and buckles, with each ply coated completely to separate one from another. After the last ply has been placed, the entire surface should be mopped with coat tar or asphalt, according to membrane type (i.e., 70 lbs of coat tar per 100 ft<sup>2</sup> and 60 lbs of asphalt per 100 ft<sup>2</sup> of surface). The final coat should be protected from backfill by a layer of fiberboard embedded in the hot coat. Care should be taken not to rip, scar, tear, or cut the finished membrane during backfilling.

2.3.5.3 *Nonbituminous Sheets.* Membranes of pure plastics, thermoplastics, metal (usually copper or aluminum), and sheathed fibrous building papers are usually applied in more than one layer. They are embedded in portland cement mortar, mastics, plastic cements, or bituminous coatings. All component materials should be products of one manufacturer and used in strict accordance with his instructions.

2.3.5.4 *Cold Asphalt Application.* A primer coat of thin cutback asphalt (conforming to ASTM D-41) should be applied to porous masonry. A heavy coat of asphalt mastic (conforming to Federal Specifications SS-A-694) should be troweled on the primer coat at least  $\frac{1}{2}$  inch thick at the rate of 1 gallon per 12 square feet. Where trowel application is not feasible, two coats of asphalt mastic should be brushed over the primer coat at the rate of 1 gallon per 50 square feet per coat. On concrete, a nonfibrous asphalt emulsion primer diluted with 15-percent cool water should be applied by brush or spray. At least two heavy coats of nonfibrous asphalt emulsion should be brushed or sprayed over the primer coat at the minimum rate of  $1\frac{1}{2}$  gallons per 100 square feet per coat.

2.3.5.5 *Hot Asphalt Application.* A coat of penetrating asphalt primer (conforming to ASTM D-41) should be mopped or sprayed over the surface to be treated. Coverage should be 200 to 400 square feet per gallon, depending on the porosity of the surface. Two coats of hot asphalt (conforming to ASTM D-449) should be mopped or sprayed evenly over the entire surface at the rate of 25 pounds per 100 square feet per coat. The finished coat should be bright, glossy black; and dull areas should be recoated.

2.3.5.6 *Cold Coat-Tar Pitch Application.* A penetrating creosote oil-base bitumen (conforming to ASTM D-43) should be brushed or sprayed evenly over the surface at the approximate rate of 2 gallons per 100 square feet. Application should be repeated until all pores and voids are filled but should not exceed four coats. Each additional coat should be applied at right angles to previous coats to provide full coverage. After the last primer coat has been absorbed and the surface is dry, a complete brush coat of coat-tar bitumen (80° to 100° F or 26.7° to 37.8° C) should be applied at the approximate rate of  $\frac{1}{2}$  gallon per 100 square feet. Areas that are not glossy black should be recoated. The finished coat should be hard and dry before back-filling is begun.

2.3.5.7 *Hot Coal-Tar Pitch Application.* A coat of creosote oil primer (conforming to ASTM D-43) should be brushed evenly over the surface at the

approximate rate of 1 gallon per 100 square feet. Two coats of hot coat-tar pitch (conforming to ASTM D-450, Type A) should be mopped over the primer coat at the approximate rate of 25 pounds per 100 square feet per coat. Pitch should be heated until it is completely liquid but not heated more than 375° F (190.6° C). Backfill should be placed and tamped immediately after the last coat has been applied.

**2.3.5.8 Metallic Type Waterproofing.** Metallic powder may be either mixed with water and applied as a brush or sheath coat, or mixed with cement, sand, and water, and applied as a mortar or plaster coat. The metallic powder oxidizes and expands to fill the voids left by evaporating water. This treatment resists considerable water pressure. Manufacturer's instructions must be carefully followed in preparing and applying the material. Use of metallic waterproofing will be limited to interior applications below grade where temperature differences and surface movement are at a minimum. Where exterior walls are inaccessible and waterproofing must be applied to the interior face, the metallic method is recommended. Metallic-type waterproofing shall consist of finely ground, clean iron of carefully graduated sizes, meeting the standard screen analysis. See table 2-1.

Table 2-1. Mesh sizes for Standard Screen Analysis

Standard screen mesh size	Percentage retained
35 .....	None
40 .....	10
60 .....	35
100 .....	50 to 70
200 .....	80 to 90

The iron shall be mixed with a chemical oxidizing agent that shall be not less than 5 percent or more than 10 percent by volume of the total mixture. The iron-oxide content shall not exceed 5 percent by volume. Material shall not contain dirt, paraffin, or bitumen of more than 0.1 percent by volume. Only enough mortar with metallic material for immediate use should be mixed because it should not be retempered. The wall should first be exposed, cleaned, and roughened to provide a key for the waterproofing materials. Holes, cracks, and other soft or porous places should be cut back to solid material, cleaned, and pointed with mortar. All pipes, bolts, and similar construction should be caulked with lead wool and waterproof cement and made watertight. Surfaces should then be dampened with clean water and given one bonding

coat composed of 1 part cement and 1 part metallic material mixed to a creamy consistency and applied with bristled brushes. The surface should be thoroughly brushed to seal all pores rather than merely provide a surface veneer. This is followed by application of two coats of mortar composed of 1 part portland cement, 3 parts sand, and 25 pounds of metallic material to each bag of cement. This first coat should be troweled on and scratched when partially dry. The second coat, mixed to a heavy brushing consistency, should be brushed on carefully and floated with wood floats. Total thickness of all coats should be approximately  $\frac{5}{16}$  to  $\frac{1}{2}$  inch. After each coat has set but not dried out, surfaces should be wetted down frequently over a period of at least 72 hours. Sufficient time should be allowed between coats to permit thorough oxidation of the material. If rust color is undesirable, cover wall with one or two coats of a waterproof cement-water paint. Do not apply until waterproof coating has completely oxidized and dried out.

**2.3.5.9 Cement Plaster Waterproofing** A method of waterproofing below-grade walls is to plaster exterior surfaces with cement mortar. This mortar may be made plain, or water resistance can be increased by adding calcium stearate, ammonium stearate, or other equivalent water repellent in amounts equal to 3 percent of the weight of the cement. Although the cement plaster method is efficient, its major defect is rigidity. Structural defects which crack the wall may also crack the cement plaster. The method may prove adequate for a wall which is subject only to occasional dampness and not continuous water pressure.

**2.3.6 Waterproofing Underground Structures**

**2.3.6.1 General.** Due to the advent of numerous underground structures (fallout shelters, command posts, missile silos, communication centers, ammunition storage areas) into the military real property inventory, the problem of waterproofing underground structures has become important. A detailed discussion of the waterproofing is presented using the ammunition igloo as the model for the discussion. The ammunition igloo is the underground structure most frequently encountered. However, the principles discussed are valid for any underground structure. Prior to initial repairs, the structure should be carefully examined to definitely establish that the undesirable conditions are caused by leakage and not by condensation or other causes. Modification of storage arrangements or physical plant layout, improved ventilation, dehumidification, or other means to prevent condensation may correct the problem.

2.3.6.2 *Preparation for Waterproofing.* Remove the earth cover from the entire structure to the ledge of the foundation footings, including the rear end wall, and stockpile for replacement. When removing the earth, be careful not to damage the concrete structure or the draitile near the footings. Scrape the concrete structure to remove all dirt, foreign matter, and any loose adherent material. Remove as much as is practicable of the old waterproofing layer if the new waterproofing is not compatible. If the new waterproofing is compatible, only the damaged or loosely adherent portions of the old waterproofing need be removed. Inspect the cleaned surfaces. Remove all sharp edges, ridges, abrupt cleavages, bolts, and severe roughness. Fill all cracks and openings with port-land cement grout. Thoroughly bond the grout to the old concrete, trowel smooth, and allow to cure. Clean all cracks, fill with asphaltic plastic cement (conforming to Federal Specification SS-C-153) and cover with two layers of 30 pound roofing strips (conforming to ASTM D-226) not less than 6 inches wide, embedded in two layers of asphalt plastic cement  $\frac{1}{2}$  inch in thickness, centered over each crack. Cracks  $\frac{1}{4}$  inch or more in width shall, in addition to the above, be covered with sheet-metal strips 7 inches wide, sandwiched between the two roofing strips 8 inches wide, and heavily embedded in asphalt plastic cement. Cracks  $\frac{1}{2}$  inch and larger should be filled with a mix composed of 8 parts asphalt emulsion and 2 parts portland cement (8:2 mix) prior to installing felt strips. Seal the horizontal joint between the foundation and barrel with this 8:2 mix (trowel into the joint and spread 18 inches wide). Firmly embed a 12-inch-wide strip of woven glass fabric conforming to ASTM D-1668 centered over the joint, and coat with a second application of the above mixture. Rough, pitted, honeycombed areas may also be filled with the 8:2 asphalt emulsion, portland cement mixture in lieu of cement grout where conditions warrant. When the concrete is found to be porous and saturated with water, dry out adequately to provide a completely dry surface before the prime coat is applied. Normally, the drying-out period is about 14 days.

2.3.6.3 *Application of Waterproofing Membrane.* Area to be waterproofed will comprise the entire structure, including the barrel, the rear end wall, the front wall cant, the foundations to the footings, and at least 3 inches of the footing ledge. Inspect and repair as required to provide a reasonably smooth surface. Coat the entire surface to be waterproofed with primer (complying with current Federal Specification SS-A-701), applied at not dry for at least 2 days. Apply asphalt emulsion

(complying with current ASTM D-1187, Type A over the prime coat at a rate of not less than  $3\frac{1}{2}$  gallons per 100 square feet. See figure 2-14. Apply two plies of glass cloth fabric, which will cover the entire area to be waterproofed, over the fresh coating of asphalt emulsion. The fabric should be draped vertically over the barrel. Endlaps, when required, should be not less than 12 inches and should be cemented over the lower ply. Sidelaps in each ply should not be less than 2 inches. Lay fabric vertically on the end wall and lap at least 12 inches on the barrel for anchorage, without wrinkles and buckles; firmly pull into the emulsion, smooth by hand to work out wrinkles, and make tight to the lower walls for adhesion to prevent floating as the emulsion is applied. See figure 2-15. Saturate the fabric completely by spraying asphalt emulsion at a rate of not less than 4 gallons per 100 square feet at approximately 80 lb/in<sup>2</sup> pressure. Allow to dry for at least 2 days. Apply the finish coat of asphalt emulsion over the entire area to be waterproofed using not less than 2 gallons per 100 square feet, giving special attention to thin areas and areas in which the fabric is insufficiently coated. See figure 2-16. Inspect the coating after it has dried completely and touch up any bare spots or defects. Dust the waterproofed area with talc or dry portland cement, using not less than 11/2 bags per igloo. Lay the slip-sheet cover (complying with current Federal Specification SSR-501, Class A, 65 lb, Mica Surface) vertically with a lap of not less than 2 inches at the side. Sandbag the sheets to hold in place at the crown lap until the earth cover is replaced. See figure 2-17. Inspect the draitile and verify that tile size is adequate; that the highest point is 1 to 2 feet minimum below floor level; that the tile is properly laid to drain; that it is not obstructed with sediment or other objects, as disclosed by lamping or rodding; that the discharge is to an area with definite slope away from igloos; and that the discharge end of tiles are screened to prevent entrance of rodents. Replace the earth cover carefully in two stages using procedures that will protect the waterproofing from damage. Remove rocks from the earth to the extent that it shall contain not more than 15-percent stone or gravel, all passing a 1-inch sieve. In the first stage, replace the earth halfway up the height of the igloo and allow to settle for about 14 days, or until noticeable compaction has occurred. See figure 2-18. At this stage, examine the slip sheets for possible breaks at the earth line and correct them by splicing and patching. In the second stage, replace the earth to the top of the barrel retaining wall and maintain at the same height the length of the igloo. Maintain a slope of approximately 1.75 on 1, free of vertical and horizontal depressions.

Maintain sufficient compaction to avoid appreciable slump, slippage, or shrinkage of the finish grade. Bulldozers and other heavy equipment must not approach closer than about 3 feet of the igloo. Finish to grade, hand-rake, and smooth the earth to provide natural drainage. The earth should be

provided with vegetation of a type consistent with the landscaping plan for the installation. Remove dirt and other foreign materials from the concrete apron of each igloo, and assure that the drainage outlets are exposed and opened.

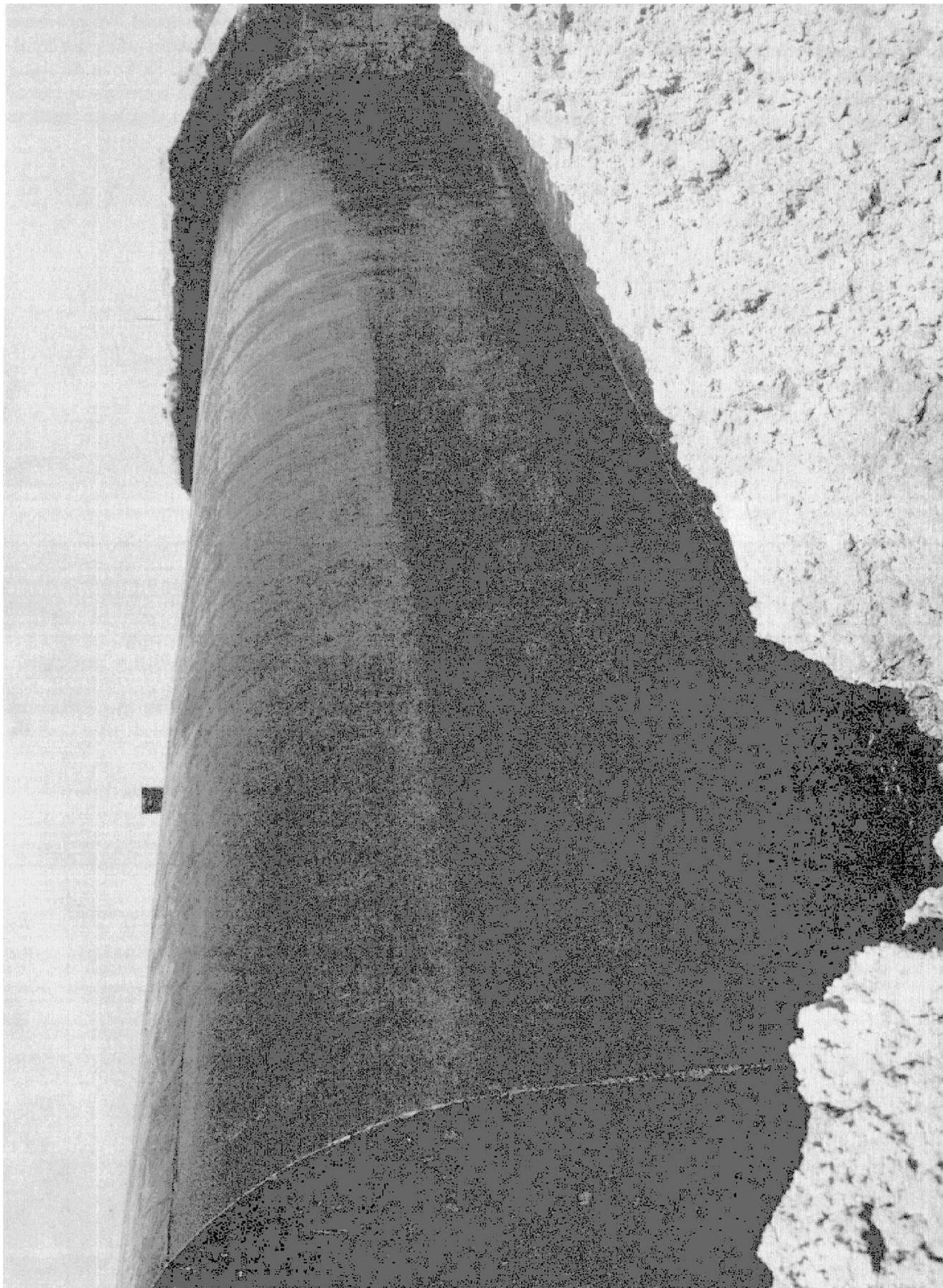


Figure 2-14. WATERPROOFING IGL00—PRIME COAT.

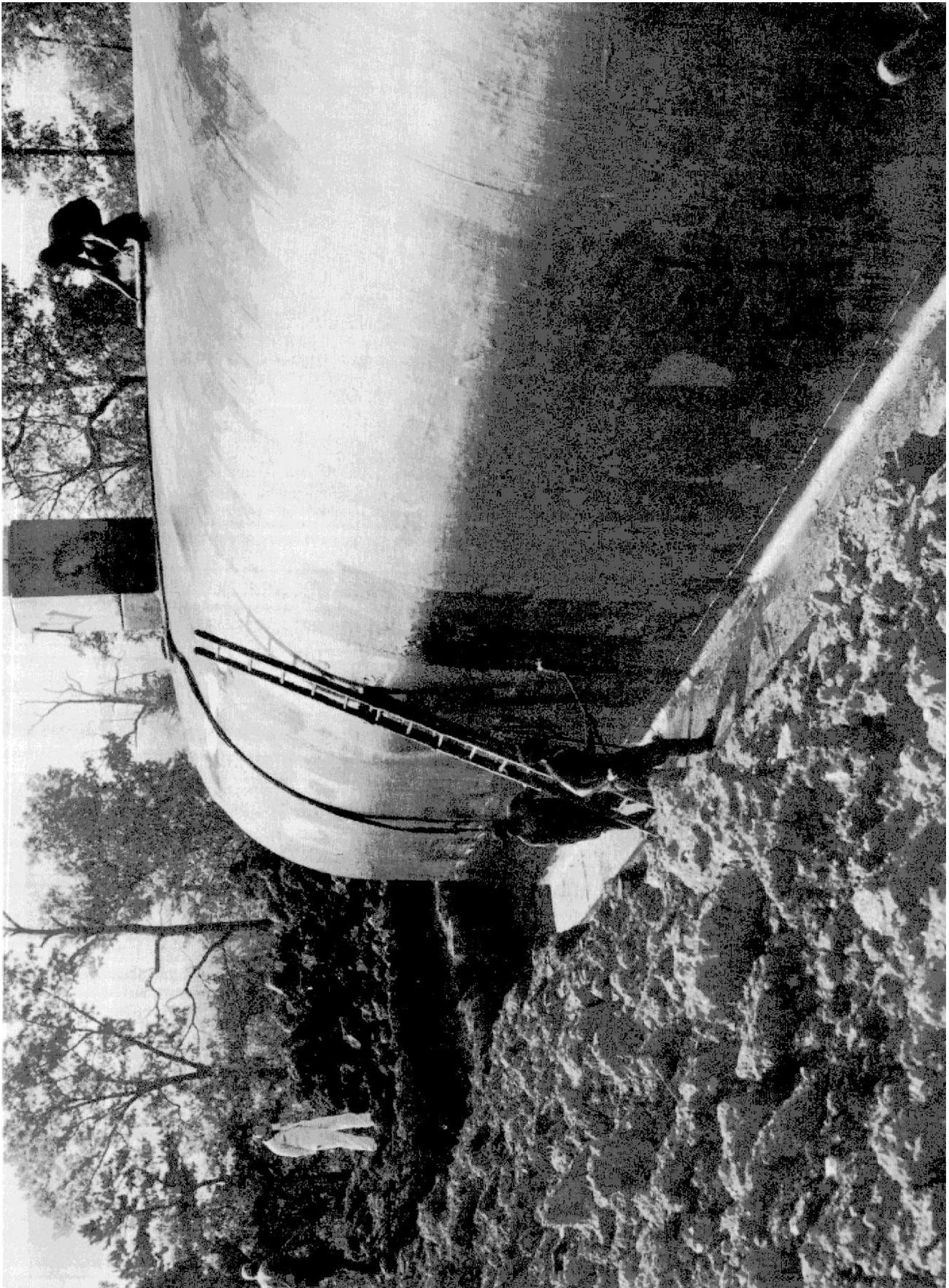


Figure 2-15. WATERPROOFING IGLOO—GLASS FABRIC.

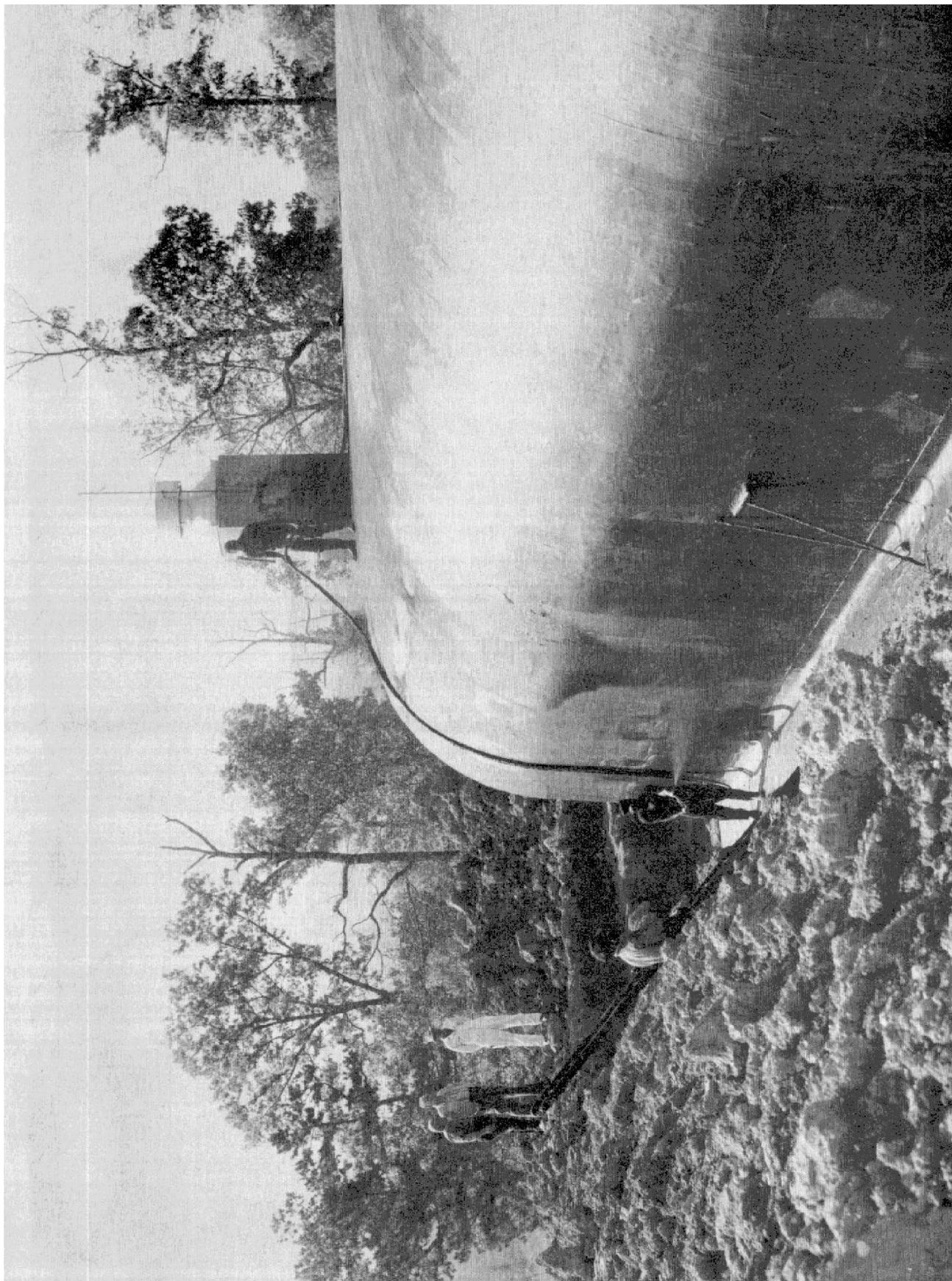


Figure 2-16. WATERPROOFING IGLOO—FINISH COAT.

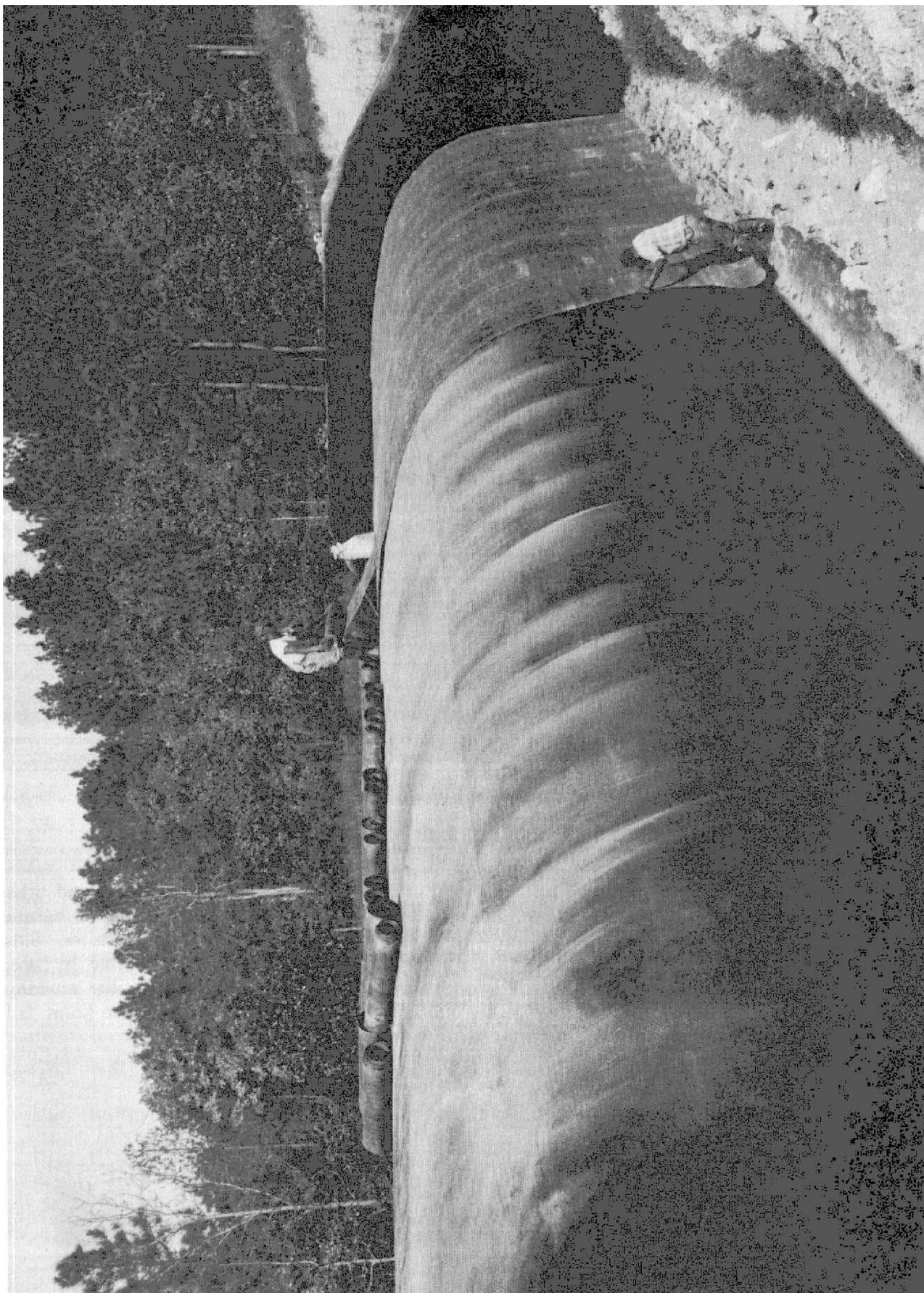


Figure 2-17. WATERPROOFING IGLOO—SLIP SHEET.



*Figure 2-18. WATERPROOFING IGLOO—BACKFILL*

## **SECTION IV—CRAWL SPACES**

### **2.4.1 General**

Considerable deterioration extending from foundation to building superstructure can be caused by neglect of crawl spaces, especially in climates where it is necessary to enclose the space to maintain comfortable floor temperatures. Unventilated crawl spaces contribute materially to rapid absorp-

tion of moisture into structural wood and other materials, and the spaces soon become a natural habitat for fungus growth and termites. Sills, joints, and subflooring may be affected by wood decay. Condensation may occur in the studding spaces above the floor level and cause paint failures.

## 2.4.2 Housekeeping

Routine good housekeeping requires that crawl spaces be kept clean, clear, and accessible. An accumulation of rubbish in the space may provide a natural harbor for insects and rodents, as well as impede access and possibly interfere with drainage. Scrap wood is a clear invitation to termites. Crawl spaces should be checked periodically, and an adequate program of pest control carried out. Disorganized storing of any materials in crawl

spaces should be prohibited. Crawl spaces should be graded to prevent wet areas. Such areas breed mosquitoes, cause fungus growth, and weaken soil-bearing under footings. All ventilation openings should be covered with suitable hardware, cloth, or copper screening to prevent entry of birds and rodents. See figure 2-19. Access doors to crawl spaces should be provided with a suitable padlock and kept closed.

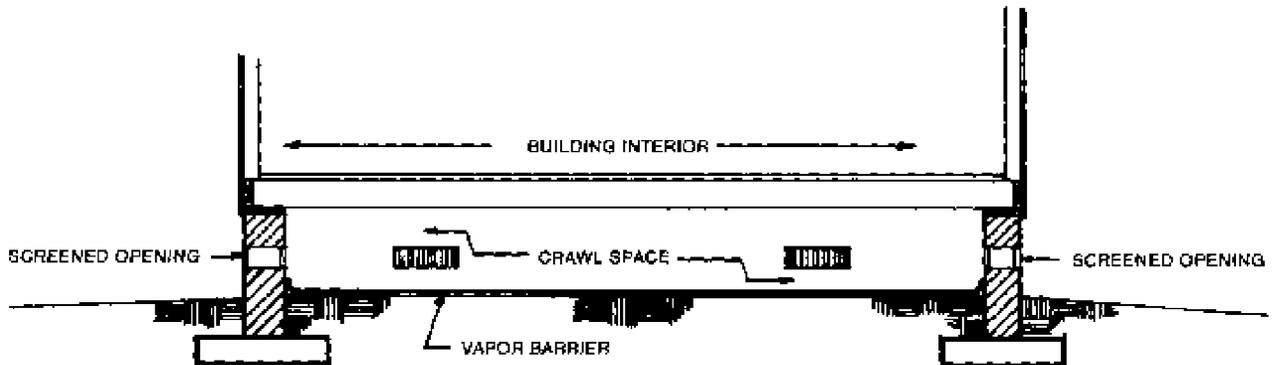


Figure 2-19. VENTILATED CRAWL SPACE.

## 2.4.3 Control of Wood Decay

**2.4.3.1 General.** Decay in wood is produced by organisms known as fungi, which live on wood components. All "dry rot" or "natural deterioration" of wood is caused by living fungi. The term "dry rot" is misleading as fungus cannot live without a regular supply of moisture. All decay destruction can be prevented. Wood-destroying fungi require favorable conditions of moisture, temperature, and access to air. Lack of any one of these essential conditions will inhibit the growth of fungi. Wood presents no decay potential if it has less than a critical moisture content, is maintained at extremely high or low temperatures, or is immersed in water or coated to exclude oxygen. Warm, humid climates or seasonal periods of high humidity provide an environment for growth of wood-destroying fungi. Frequent soaking of wood members, coupled with inadequate ventilation, may produce conditions suitable for fungi growth. Unpainted or untreated wood members, particularly those which touch the ground, are especially susceptible to decay. Some major areas susceptible to fungus attack are wood in contact with masonry foundations, cold-water pipes, or air-conditioning ducts; wood floors laid over concrete without ade-

quate damp-proofing; wood in attics or crawl spaces with inadequate ventilation; all untreated wood in crawl spaces with standing water; lack of flashing around wall openings; wood porches, steps, columns, or posts in contact with the ground, and wooden door and window frames. The presence of decay is usually indicated by one or more of the following conditions: dampness and a musty smell; warped flooring and siding; surface cracks, particularly across the grain; fine, reddish-brown, dusty powder under the building; mildew stains on timbers; a hollow or spongy sound when timber is tapped with a hammer, or when a sharp-pointed tool easily penetrates timber; peeling paint; and swelling joints. Results of decay is illustrated in figure 2-20. If the presence of wood rotting is suspected, contact the pest control shop.

**2.4.3.2 Prevention of Decay.** The best procedure in preventing decay in untreated wood is to keep the wood dry. Air-dried wood does not contain enough moisture to permit the growth of wood-destroying fungi. At moisture content below the fiber saturation point (25 to 30 percent), decay is greatly retarded; below 20 percent, fungus growth is completely inhibited. Wood products used under adverse conditions must have a preservative treat-

**TM 5-620/NAVFAC MO-111/AFP 91-23**

ment. Decay can be prevented by eliminating thecauses. Outlined below are a few of the steps which may be taken to accomplish this goal:

- a.* Provide a protective seal coat to prevent soaking of the wood.
- b.* Seal glass settings with putty and paint.
- c.* Provide tight caulking around wall openings.

*d.* Seal checked lumber, knots, and joints with putty and paint.

*e.* Before assembly, paint the back of all lumber that will not be accessible after assembly, such as window trim, porch decking, and doorheads.

*f.* Provide adequate maintenance and periodic cleaning of rainwater conductors.

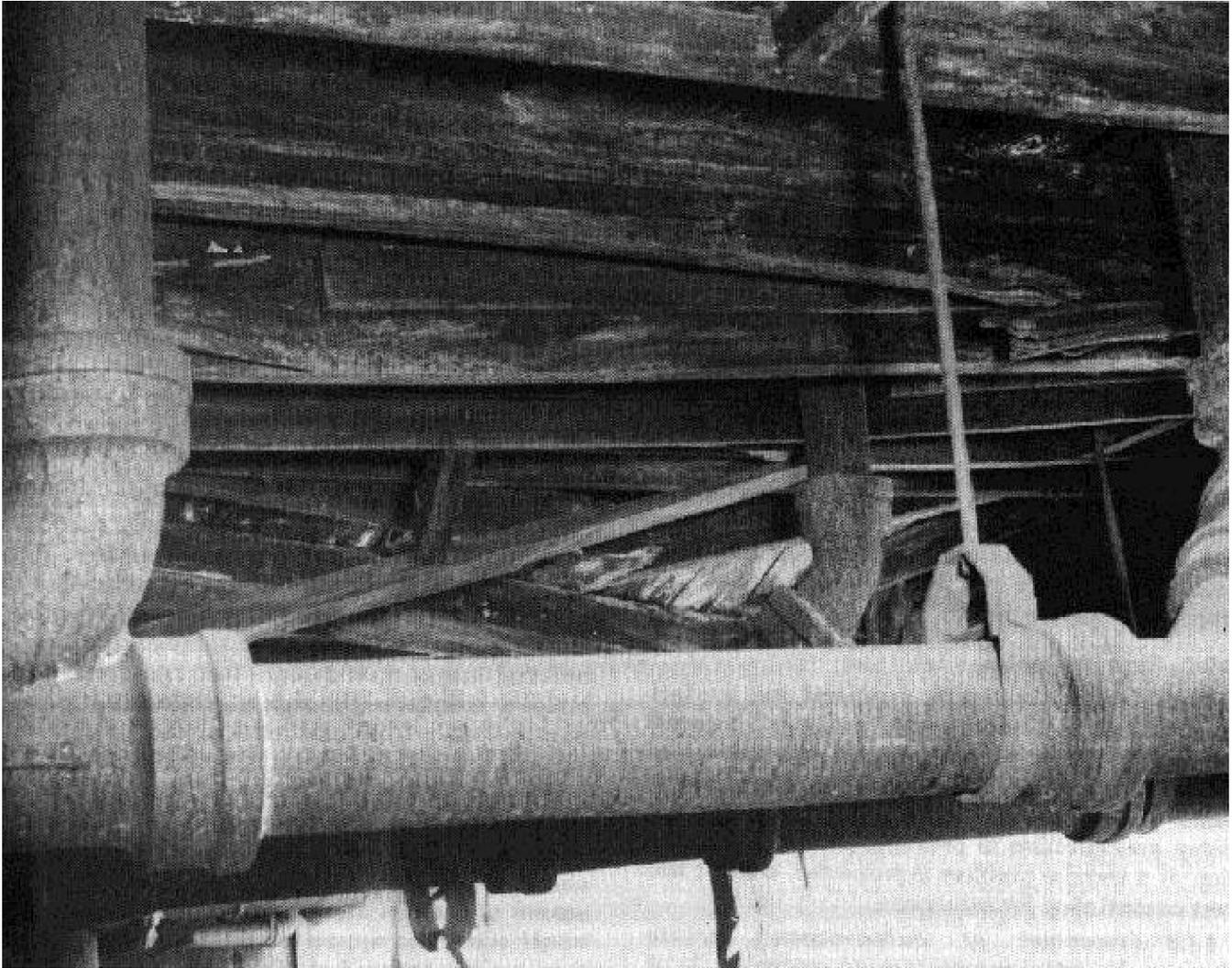


Figure 2-20. CRAWL SPACE DECAY.

g. Separate all wood from earth by resting it above the ground line on solid masonry blocks and vapor barriers.

h. Keep earth and debris away from wood, and slope the earth to drain away from walls.

i. Avoid trapping water on sills by cutting scup-

pers in the bottom rails of screen frame and screen doors.

j. Keep crawl space clear of debris.

2.4.3.3 *Treatment of Decay.* Upon the detection of decay, prompt action will be taken to determine

the extent of damage and the probable causes. If structural members are involved, the advice of an engineer should be obtained to determine the materials and methods to be used in effecting the repair. The infected member may be removed and replaced with a member treated with a wood preservative (see Tri-Services Manual, "Military Entomology Operations Handbook," [TM 5-632, NAVFAC MO-310, AFM 91-16] chapter 8, section 5). Normally, the cause will be traced to excessive moisture or poor ventilation. Provision for the exclusion of moisture and provisions for adequate ventilation should be included as part of the repair. The wood area adjacent to the infected part should be treated to insure against possible spread of the fungus.

2.4.3.4 *Carpenter Ants*. Some insects such as carpenter ants are common in decayed wood. Once the cause for the decay is eliminated, the insect problem disappears but the damage caused by the insect may require repair.

#### 2.4.4 Termite Control

2.4.4.1 *General*. Insects as a general rule are not a major maintenance or repair problem. However, termites are the one exception and constitute a serious problem in areas of infestation. Fortunately, some of the precautions effective against wood decay are, effective in preventing termite infestation. If a termite problem is suspected, contact the pest control shop for assistance.

2.4.4.2 *Prevention of Subterranean Termite Damage*. In subterranean termite control, it is of prime importance to keep untreated wood dry, well ventilated, and removed from contact with the ground. Termites must maintain contact or passage to and from the ground. Mechanical barriers, soil poisoning, and preservative treatment of timber are the major means of combating this menace. Mechanical barriers usually are in the form of termite shields. Unfortunately, unless these shields are properly installed and continually maintained, they provide little or no termite protection. Soil poisoning, also called chemical soil barrier (see Tri-Services Manual, "Military Entomology Operations Handbook," chapter 8, paragraph 8.15.1(8)) offers better protection at a reasonable cost. Chemical solutions are mixed with soil adjacent to foundation walls, piers and under concrete slabs (structures with subslab or intraslab heating/cooling duct shall not be treated until the vents are sealed and the system is reduced away from the soil). This provides long-lasting barriers to termites. Wood installed in suspect or susceptible areas should be pressure impregnated with a wood preservative.

2.4.4.3 *Treatment of Termite Damage*. The treatment of termite damage is similar to treatment of decay. The damaged members are removed and replaced with lumber that has been treated with a wood preservative. The assistance of an engineer may be needed if structural members are involved. Construction to prevent the recurrence of the termite infestation will be part of the repair.

#### 2.4.5 Ventilation.

Adequate ventilation of enclosed crawl spaces is necessary to prevent decay resulting from condensation.

2.4.5.1 *Standards*. Standard guides for meeting ventilation requirements include:

a. For buildings up to 5,000 square feet. Determine linear footage of building perimeter and provide 2 square feet of ventilation per each 100 linear feet. Additionally, determine the total crawl-space ground area and provide ventilation at the rate of  $a$  of 1 percent (0.0033) of the total crawl space ground area. Example: Assume a building size of 4,000 square feet and assume the building is square—the square root of 4,000 square feet is 63.245. This multiplied by the number of sides in the building yields 253 linear feet, or 2.53 when divided by 100.  $2.53 \times 2$  (the number of square feet of ventilation required for each 100 linear feet) yields 5.06 square feet of ventilation required for the perimeter of the building. In the second portion of the equation, crawl-space area would equal the square footage area of the building, or 4,000 square feet. This multiplied by  $a$  of 1 percent (0.0033) yields 13.2 square feet of ventilation required. Combining the two yields, 5.06 and 13.2, 18.26 square feet of ventilation would be required for a building size of 4,000 square feet.

b. For buildings larger than 5,000 square feet, determine the linear footage of the perimeter and provide 2 square feet of ventilation for each 100 linear feet. Additionally, determine the total crawl-space ground area and provide ventilation at the rate of  $\frac{1}{4}$  of 1 percent (0.0025) of the total crawl space ground area. Using the procedures in the above example, and assuming a 6,000-square foot building, 21.2 square feet of ventilation would be required for this building.

c. For interior foundation walls, ventilation is required at the rate of 1 square foot per each 25 linear feet of foundation with the requirement for cross ventilation.

The above requirements may be reduced in arid or semiarid climates. In severely cold temperature zones, operable louvered vents should be closed

during the cold season. Vents shall remain open in temperate and tropical zones or zones with high humidity.

2.4.5.2 *Installations.* Crawl spaces may be ventilated by the installation of gratings or louvers of an adequate size in the foundation walls. Small round louvers, which can be installed by drilling with an expansion bit and tapping into place, are commercially available. Vents through interior walls are equally important. Both types of vents should be installed to insure free air circulation throughout all parts of the underfloor space.

#### **2.4.6 Coordination with Entomology Service**

Close cooperation between the maintenance service and the entomology service must be maintained in areas of mutual interest. Maintenance personnel

should be instructed by the entomology service in recognition and detection of wood decay fungi and termites. This will enable craftsmen to recognize signs of an early fungus attack and to differentiate between the fungus damage and the destructive effects of moisture and weathering. It is advisable to make this recognition and detection part of the inspection checklist where wood structures are concerned. Joint inspections by both services are encouraged. Investigation of damaged areas, determination of probable cause for damage, and agreement on types of repairs are joint functions. Understanding and appreciation of mutual problems will foster a spirit of cooperation, which will improve the overall effectiveness of both services.

## CHAPTER 3

FRAMING—STRUCTURAL COMPONENTS

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## SECTION I—WOOD FRAMING

**3.1.1 General**

The structural components of frame buildings must be strong enough and sufficiently rigid to transfer dead and live loads to the building foundations without excessive deflection or sidesway. Dead loads are those which result from the weight of the structure. Live loads are those induced by external forces such as wind, earthquake, snow, inhabitants, furniture, equipment, or impact. These loads are variable. They are usually not applied over long periods. They could be moving loads or stationary, uniformly distributed or concentrated.

**3.1.2 Framing System**

The major framing systems in use for wooden buildings are known as the balloon frame and the platform frame. There are modifications of these systems; however, the fundamental principles fall into these two categories.

**3.1.2.1 Balloon Frame.** The balloon frame is light, economical, and simple to construct. The sills are laid on the foundation and anchored in place. First-floor joists are spiked in place on the sill, and the cornerposts are set in position on the sill and temporarily braced. See figure 8-1. The studs, which run the full height of the exterior wall from sill to plate, are spiked in position on the sill held near their upper end by temporary boards nailed across them. A horizontal board called a ribbon is set into the studs and cornerposts at the proper height to form a base for the second-story floor joists. The joists are supported in place by the ribbon and nailed to the studs. The tops of the studs and the cornerposts are sawed off level and capped with a plate. The plate joins the top of the studs to form a base for the roof rafters. The exterior sheathing is then nailed in place to brace the frame.

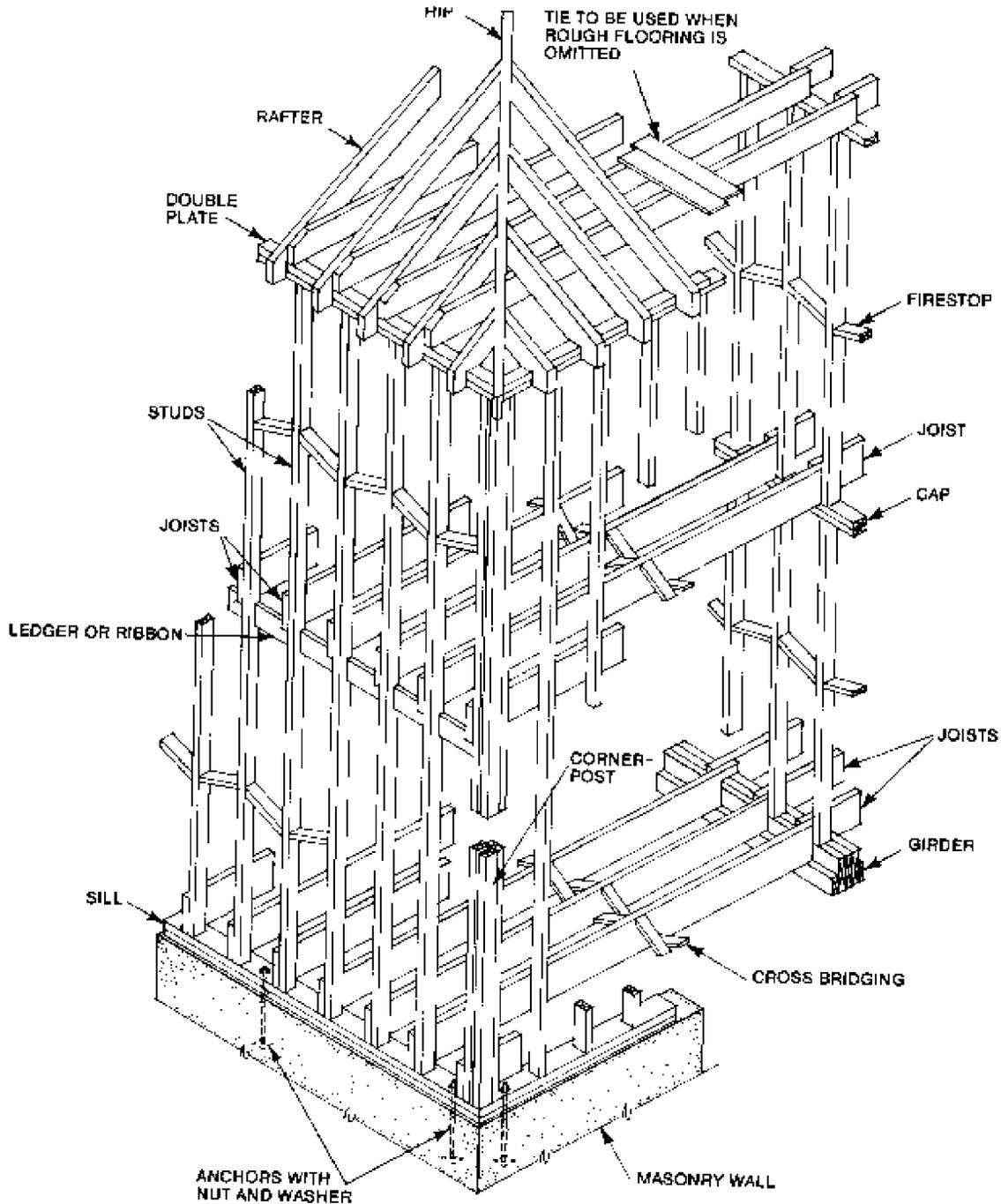


Figure 3 1. BALLOON FRAMING.

3.1.2.2 *Platform Frame.* The platform frame is more rigid and heavier than the balloon frame. Laying the sills and placing the first-story floor joists are accomplished in the same manner as for the balloon frame. A header is placed across the

end of the floor joists, and the subfloor is laid. This forms a platform. Next, a soleplate is laid on the edge of the platform the one-story-high studs capped by a plate are put in place. See figure 3-3. This soleplate, stud, and top-plate unit is normally

assembled in horizontal position on the platform and raised as a unit. Second-floor joists are then spiked in place on the top plate, and the entire sequence is repeated. Sheathing is applied to the exterior face. Due to the panel method of construction used in this system, it lends itself to prefabrication techniques.

3.1.2.3 *Bracing.* Greater rigidity is obtained in both systems by using heavier members, by installing horizontal bridging between the studs, and by

setting diagonal braces into the studs from the sill to the top of the cornerposts to brace the walls.

3.1.2.4 *Sheathing Board.* Diagonal wooden sheathing has been largely replaced by patented sheathing panels. These panels, which can be insulation, vapor barrier, and water repellent combined into one unit, also provide adequate structural bracing when applied as directed by the manufacturer.

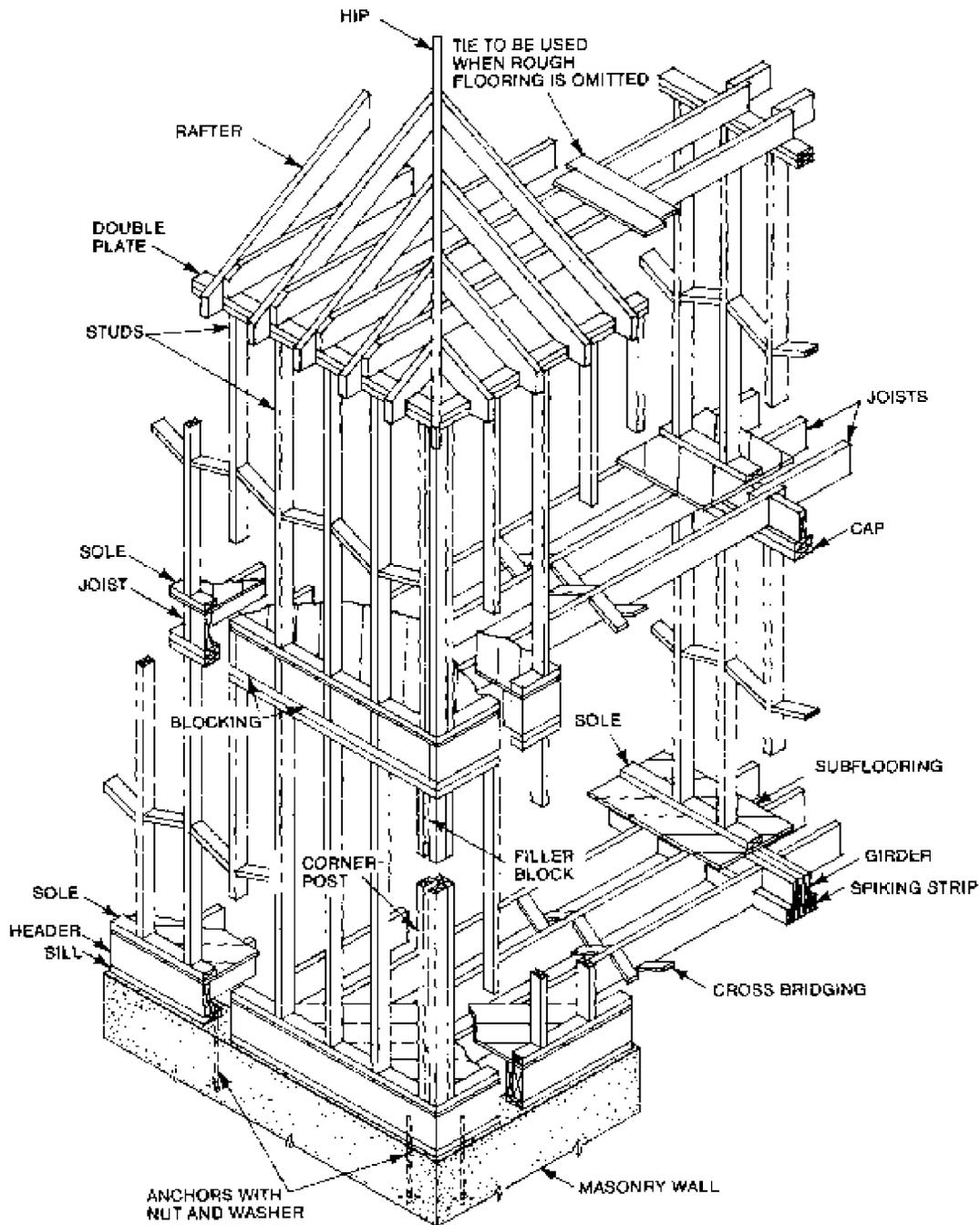


Figure 2-2. PLATFORM (or WESTERN) FRAMING.

### 3.1.3 Sills

The inspection and timely repair of sills set on foundation walls, posts, or columns is an important factor to the maintenance of any structure. As in the case of uneven settlement of foundation, severe

damage can be inflicted on a basic building structure by displacement, deterioration or other things which discount the ability of the sill to maintain the upper components in their fixed, designated positions. Many lesser, but troublesome and expensive repair and replacement problems can

arise, such as wall and ceiling cracks and misaligned doors and windows.

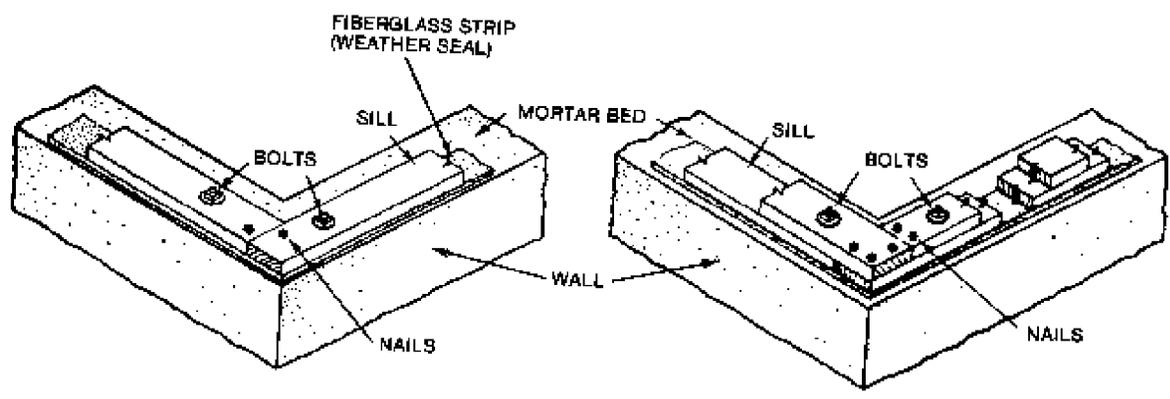
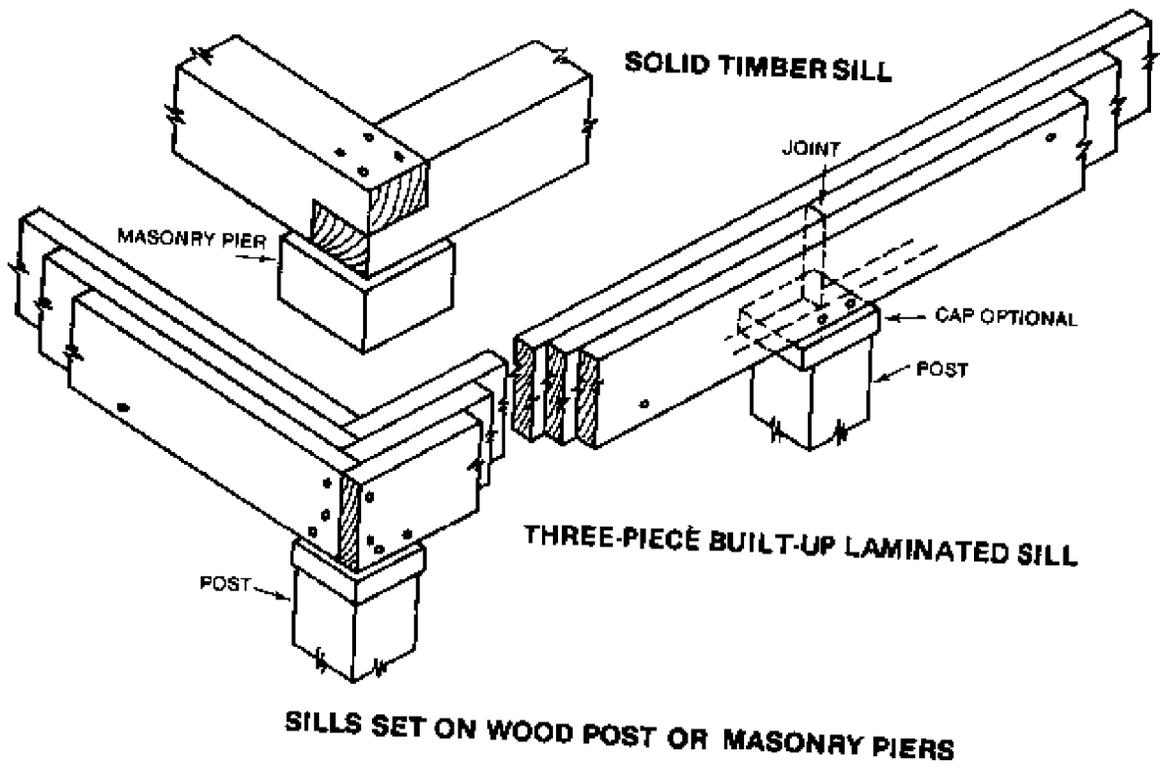
3.1.3.1 *Typical Sills.* Figure 3-3 shows types of sills commonly set on posts, piers, and walls. The imposed loads and pier spacings determine sill sizes. Built-up or laminated sills are made up of two or more members solidly spiked together with joints over supports, always staggered and with corners, as shown in figure 3-3. Note that because dimensions and heights are measured from the in-place sill, it is carefully cut, fitted, and laid level on the piers or wall. On concrete or masonry walls, the sill is placed on mortar and secured with wall anchors. The maintenance personnel should pay special attention to specially framed sill corners, as shown in figure 3-4.

3.1.3.2 *Sill Replacement.* When inspection and engineering consideration dictate that sills should be reinforced, reset, or replaced, good carpentry practices will be followed.

*a. Three-Piece Laminated Sill.* See figure 3-3. Nail from each side with twentypenny nails, two near each end of each piece, with others spaced horizontally not more than 32 inches and staggered near top and bottom from opposite sides; nailing is on 16-inch centers. Stagger all joints over supports. Toenail sills to posts (or caps if used) with two or more nails on each exposed side. Wood caps (when

used) are nailed to tops of posts with at least three or more twentypenny nails. When a four-piece sill is used, the additional member is nailed to the three-piece sill with the same size and spacings as above.

*b. Solid-Timber Sill.* See figure 3-3. Sills of solid timber should be set on posts or piers with halved joints over supports. Nail each lapped joint with three or more nails long enough to penetrate through most of the lower half of joint. Sills are set level on a mortar bed. Butting ends of single sills are toenailed with tenpenny nails. Lap double-sill members at corners, and nail with ten-penny nails. Anchor bolts of the appropriate size and set one near each end of each piece and at intermediate spaces of about 4 feet. Sills are set and secured in place, as shown in figure 3-3. In balloon and braced frame construction, the lower ends of studs extend down and sit on wall sill. Studs are toenailed to place with two eightpenny or larger nails on each wide fence. Joists are toenailed to sills and nailed directly to studs with tenpenny nails. Subfloor is nailed with threepenny nails. In western or platform framing, sills are bedded and anchored as shown in figure 3-4. Joists and headers are set and nailed to sills. Subfloor, laid diagonally, is followed by bottom plate to which studs are toenailed.



**SINGLE AND DOUBLE SILLS SET ON CONCRETE WALL**  
*Figure 3-8. TYPICAL SILLS.*

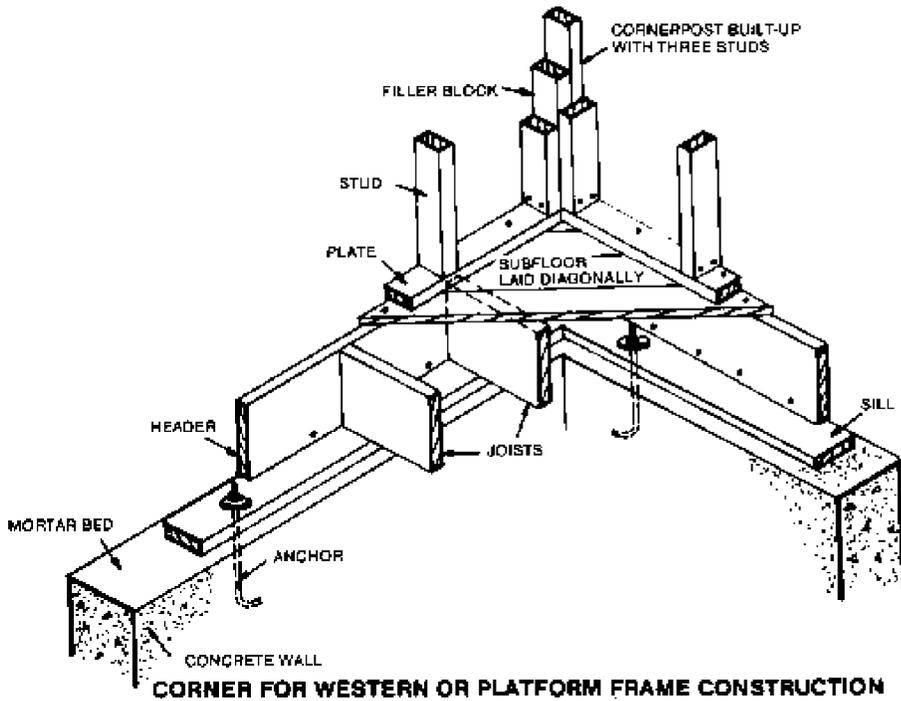
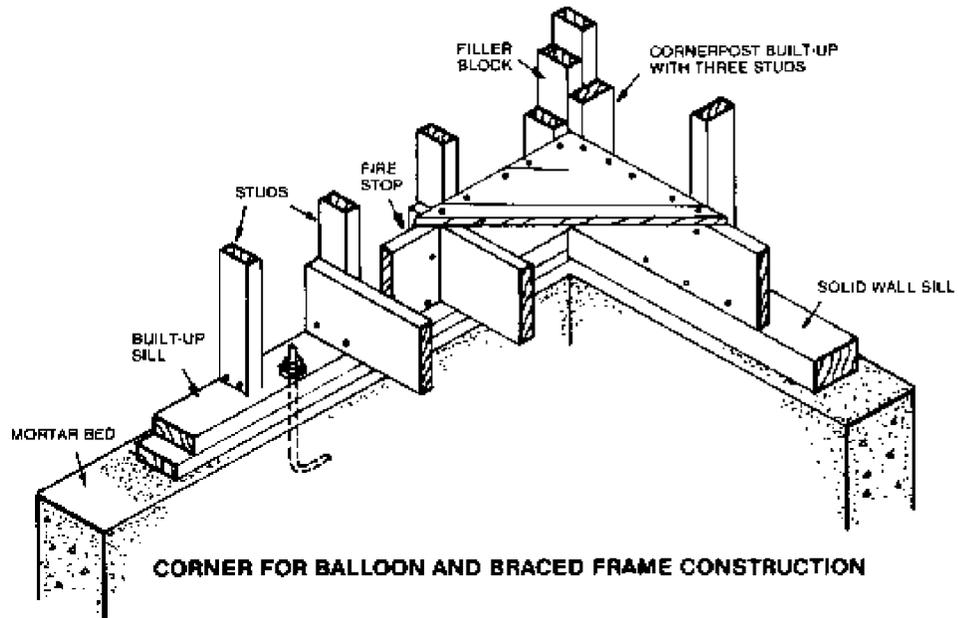


Figure 3-4. FRAMED SILL CORNERS.

3.1.3.3 *Maintenance of Sills.* Inspect wood sills periodically for soundness (see paragraph 3.1.4), rodent and insect damage (see Tri-Services

Manual, "Military Entomology Operation Handbook"), and rot. In addition, they should be kept to correct grade by use of shims and mortar pointing,

and in correct alignment by reinforcing plates, extra tiedowns or other means. Timbers exposed to ground moisture or severe weathering must be treated often enough to prohibit deterioration. Measures for ventilation and other means, as presented in chapter 2 of this manual, for overcoming or offsetting moisture condition must be followed, as well as general good housekeeping and safety procedures.

### 3.1.4 Posts and Columns

Posts and columns are the vertical members which transmit loads directly to the foundations. They are the "legs" of the building and must be strong enough not only to transmit the vertical loads to the foundation (sills) but also to resist lateral or side forces, such as wind and seismic forces if present.

3.1.4.1 *General Maintenance.* Posts and columns below grade or in contact with the earth must be treated with a preservative to resist decay and termite damage. They should be plumb, in good alignment, sound, and free of mold or other fungus growths. Make periodic and thorough inspection of all posts or columns in contact with the ground. Areas under floors which are supported on posts should be well ventilated and drained so that moisture is present only for a minimum period of time.

a. *Columns.* Columns differ from posts only in their length, and usually columns are considered to be above grade for support of second- or upper-story floor and roof loads. In buildings which are finished (covered with plaster, wallboard, sheathing, siding, and other material), it is difficult to inspect and repair damage to columns. When it is obvious that columns are out of plumb and alignment, covering material should be removed and a thorough examination made. Failure or cracks of covering material may occur independently of failure or movements in columns. When the possibility of such a condition exists, sufficient covering shall be removed to examine the columns, beams, and other structural components involved. When a determination has been made, repair and replace covering.

b. *Posts.* Inspection of posts will include a test for soundness by jabbing the post on all four sides with an ice pick or other sharp instrument. The amount of penetration is the indication of its soundness. On most softwood species, such as pine or fir, the pick should not enter more than ½ inch; for hardwood, such as gum or oak, the pick should not go in more than ¼ to ⅓ inch.

3.1.4.2 *Corrective Measure & Corrective measures* for wood posts and columns consist mainly of the following items:

a. *Plumbing and Aligning.* If inspection reveals that posts are out of plumb or alignment, shore the floor above with jacks or other devices. Plumb and realign the post. If foundations are not level because of uneven settling, correction is required before any attempt is made to plumb or realign posts or columns.

b. *Seasoning Checks.* Posts and columns usually are of timber which has not been air- or kiln-dried. This results in seasoning checks which are caused by separation of the wood fibers by drying. Checks are not usually a cause for replacement, but they should be carefully noted as to location, depth, and width of check. If continued investigations indicate these openings or checks are increasing in size, they should be carefully examined by an engineer for possible replacement.

c. *Structural Failure.* When inspection indicates that columns or posts show signs of failure from overloading, examination of the posts of columns should be made by a structural engineer. His recommendations should be incorporated to provide adequate repairs or replacement.

### 3.1.5 Floor Girders, Beams, and Joists

Girders and beams are those structural components of floors which span from column to column or wall to wall, and transmit vertical loads to their bearings. These loads may be introduced into the girders by beams, joists, planks, or other surfaces.

3.1.5.1 *Seasoning Checks.* Large size girders, beams, and joists are made of lumber that is not kiln dried. Consequently, it is normal to expect seasoning checks as the wood loses its moisture. Detailed inspection of these checks should be carefully recorded as to size, location, and depth. If records indicate any increase, stitch bolts may be required. (See paragraph 3.4.10.2 for a discussion of the proper use of stitch bolts.)

3.1.5.2 *Structural Failures.* Beams or joists, which have failed in bending but have sound wood surrounding the failure, may be repaired by fastening adjacent pieces (scabs) to the sides of the failed member.

3.1.5.3 *Repair Consideration.* There are many methods which can be used to reinforce girders, beams, and joists. The selection of the proper methods should be determined by the loads to be carried, the costs, clearances, and accessibility.

3.1.5.4 *Bridging.* Bridging is added to stiffen floor-framing members (joists). Spring floors may

sometimes be stiffened by adding or repairing existing bridging, by adding joist, or by utilizing heavier framing. See figure 3-5.

a. *Open Bridging.* When bridging is in place, it is tightened by driving nails completely through the bridging and into the joist.

b. *Solid Bridging.* Solid bridging must be cut accurately and fitted neatly between the joists to assure resistance to individual movement of the joists. This type of bridging may also be utilized as a fire stop if correctly positioned in the floor (see paragraph 3.1.8).

### 3.1.6 Special Beams

Special beams in floor frames to provide openings are called headers and trimmers. Figure 3-6 illustrates a method of adding structural strength to a floor opening using headers and trimmers.

3.1.6.1 *Framing with Special Beams.* Joists may be framed into these members in several ways:

- a. *Ledger-type framing.* See figure 3-7.
- b. *Metal joist hanger framing.* See figure 3-8.

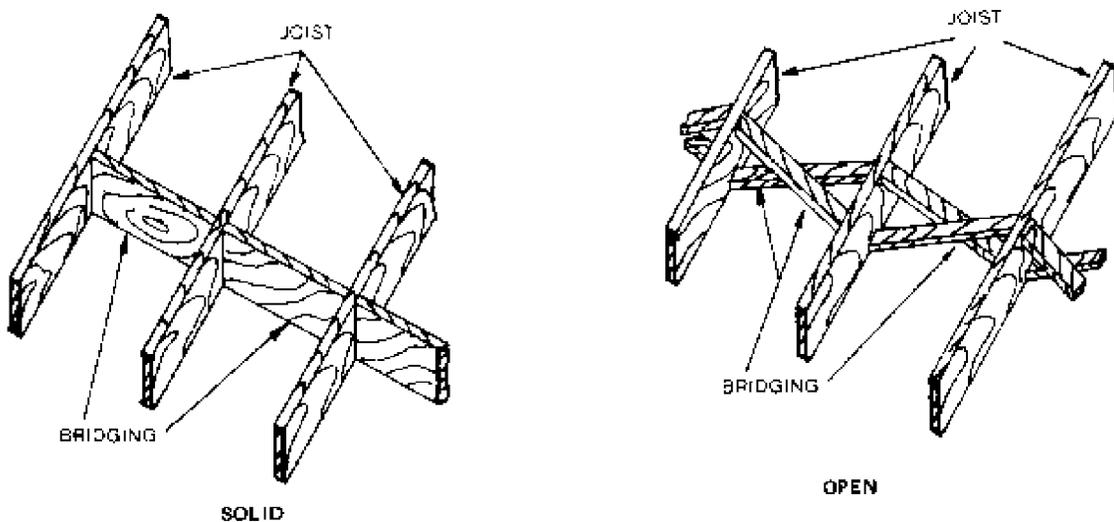


Figure 3-5. BRIDGING (OPEN AND SOLID).

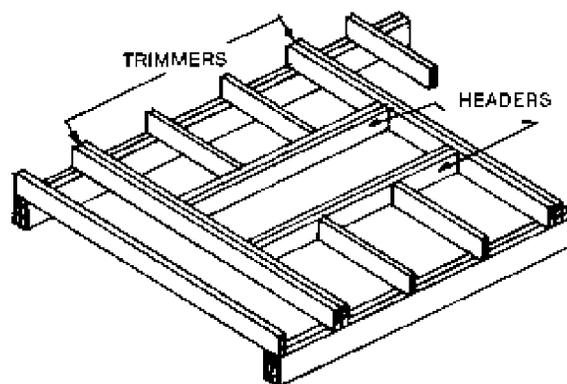


Figure 3-6. SPECIAL BEAMS—HEADERS AND TRIMMERS.

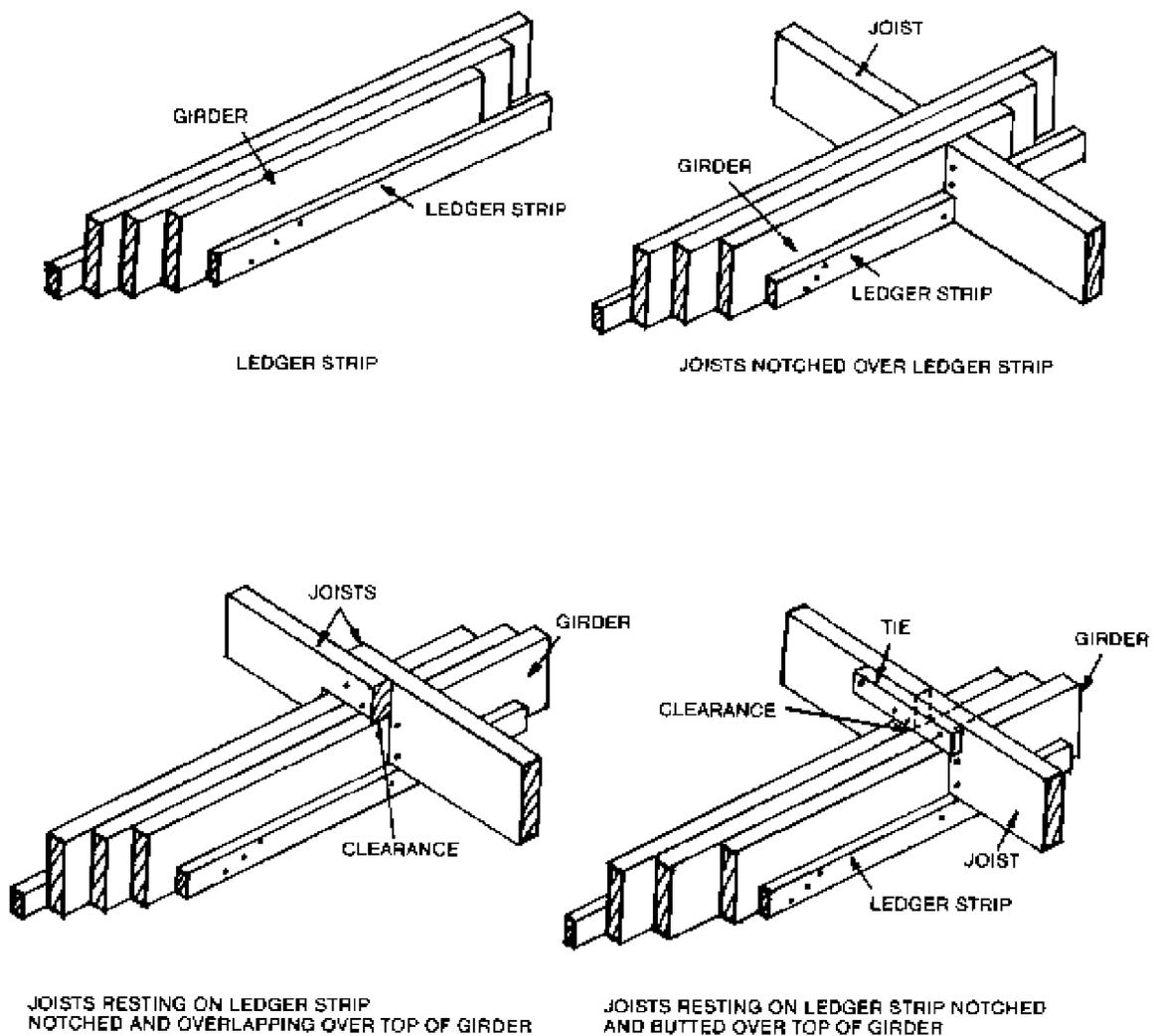


Figure 3-7. LEDGER-TYPE FRAMING.

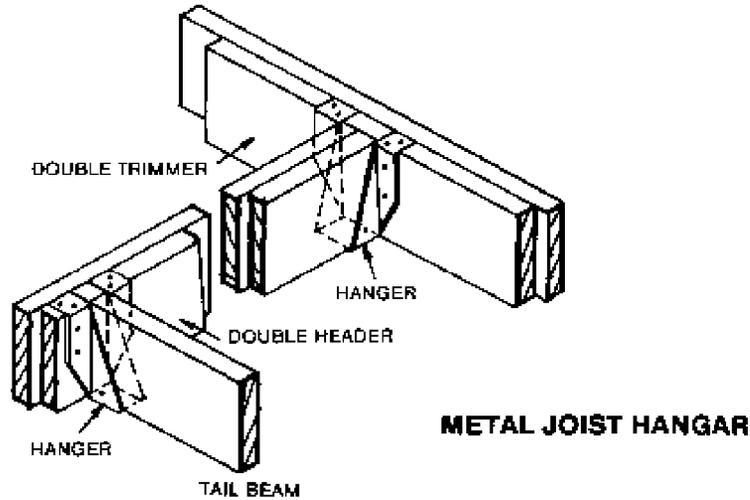


Figure 3-8. METAL JOIST HANGER FRAMING.

c. *Metal anchor framing.* See figure 3-9.

3.1.6.2 *Methods.* Where joists are framed into headers, and headers to trimmers, the connections are determined by the load requirements and care exercised to minimize the effects of unequal shrinkage as much as possible.

a. *Framing Anchors.* Framing anchors, if sufficient for load requirements, will provide the least relative movement due to shrinkage, which is most important if plaster or rigid types of ceiling covers are used. See figure 3-8.

b. *Other Methods.* If other methods are used to frame joists into headers and headers to trimmers, reinforcement and additional load capacity can be secured by adding ledgers, hangers, or framing anchors.

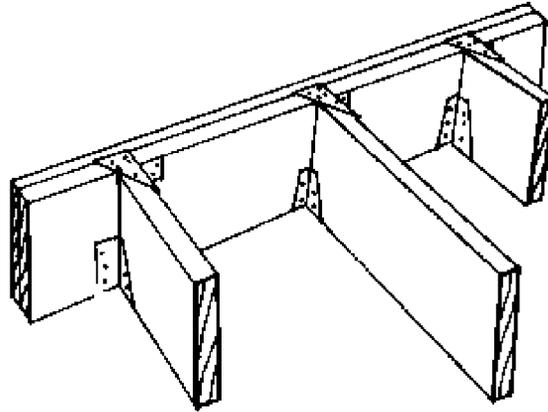
### 3.1.7 Workmanship

When repairs of framing and structural components are necessary, it is extremely important that careful

consideration be given to appropriate methods of jacking and shoring in order to bring all members into proper alignment before corrective or reinforcing methods are applied.

### 3.1.8 Stops

An essential part of construction safety is the maintenance, and where necessary, the installation of fire stops. Fire stops are obstructions deliberately placed in concealed airspaces to block passage of hot gases and flames from one area to another. Sometimes these stops serve a dual purpose, such as for solid bridging, but in any event they must not be inadvertently deleted during repair processes. Fire stops are not confined to wood construction but may also be of concrete, brick, gypsum, mineral wool, or other substances.



**FRAMING ANCHOR FOR JOIST CONNECTION TO HEADER**

*Figure 3-9. METAL ANCHOR FRAMING.*

### 3.1.9 Other Trades

Where addition, alteration, rehabilitation or repair of electrical, plumbing or other utilities involves cutting, notching, or alteration of framing or struc-

tural components, it is important that repairs provide necessary reinforcement as required by the installation engineer.

## SECTION II—WALL AND PARTITION FRAMING

### 3.2.1 General

There are two general types of framing. They are western or platform and balloon frame construction. Basic types of framing are discussed in the preceding section. The major components of wall and partition framing used in each system are similar and are described as follows:

3.2.1.1 *Studs.* The main structural elements of walls and partitions are usually termed studs. The ends of these vertical pieces usually bear on a horizontal bottom plate and are capped by a double top plate, as shown in figure 3-10.

3.2.1.2 *Cornerposts.* Cornerposts, as illustrated in figure 3-11, can be constructed in various ways.

3.2.1.3 *Ledgers and Ribbons.* Second- and third-story joists rest on double plates, ledgers or

ribbons, which are horizontal pieces of wood supported by the studs and cornerposts.

### 3.2.2 Framing Maintenance and Repair

Failure of wall framing is usually related more to major structural faults elsewhere in the construction than to defects in the framing itself. Determining the best repair procedure depends on the use of the building, extent of damage, life expectancy of the structure, and possible future uses. Frequently, it is possible to accept distortion, warping, and settling of the structure, and to make wall framing repairs necessary to overcome cracking of plaster, surface irregularities, sticking of doors and windows, and other localized faults.

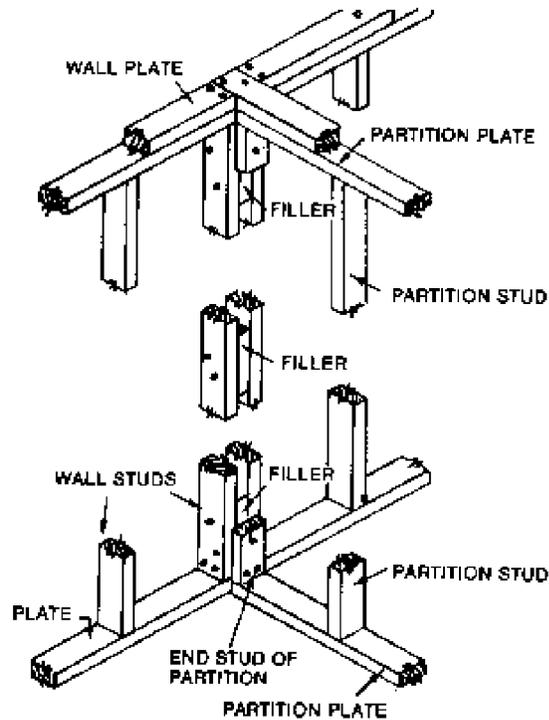


Figure 3-10. WALL CONSTRUCTION, SHOWING STUDS AND PLATES.

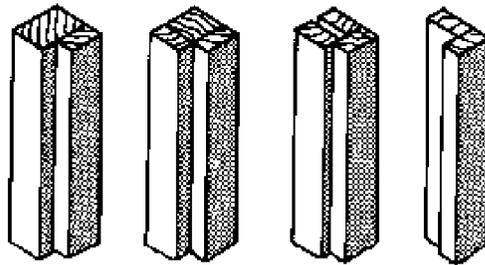


Figure 3-11. TYPES OF CORNER POST CONSTRUCTION.

3.2.2.1 *Locating Dislocated, Warped, or Broken Framing Members.* If some of the evidence listed in the preceding paragraph is apparent, tapping the interior wall surface can be helpful in locating dislocated, warped, or broken framing components. Plaster, dry wall, paneling, or similar interior wall material will be removed and the damaged member replaced or repaired.

3.2.2.2 *Methods of Repair* Warped studs can frequently be returned to original alignment with additional bridging. Headers, lintels, and sills can be returned to horizontal position by proper shimming.

Any major structural repairs or replacements such as the latter should not be undertaken in load-bearing walls without first removing the load from the wall under repair by adequate shoring and jacking. The same precaution would apply in remodeling activities, where new doors, arches, or windows are being made. Framing repairs and replacement techniques for walls and partitions are, in general, similar to the procedures used in correcting floor-support failures. Some of the methods are as follows:

- a. *Trussing and shimming.*

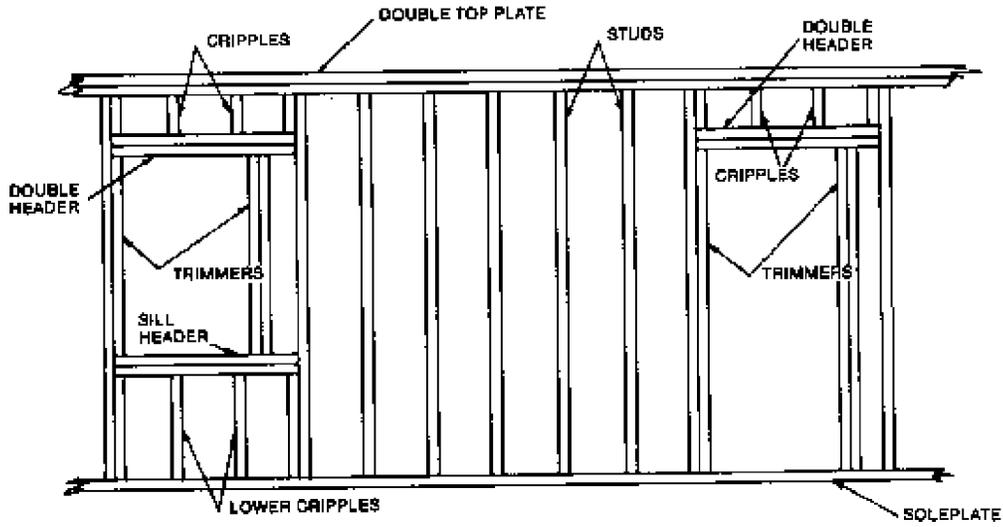
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- b. Split rings and shear plates.*
- c. Yoke angles, clamps, and stitch bolts.*
- d. Bracing and bridging.*
- e. Scabs.*
- f. Splicing*
- g. Tightening bolts and renailing*

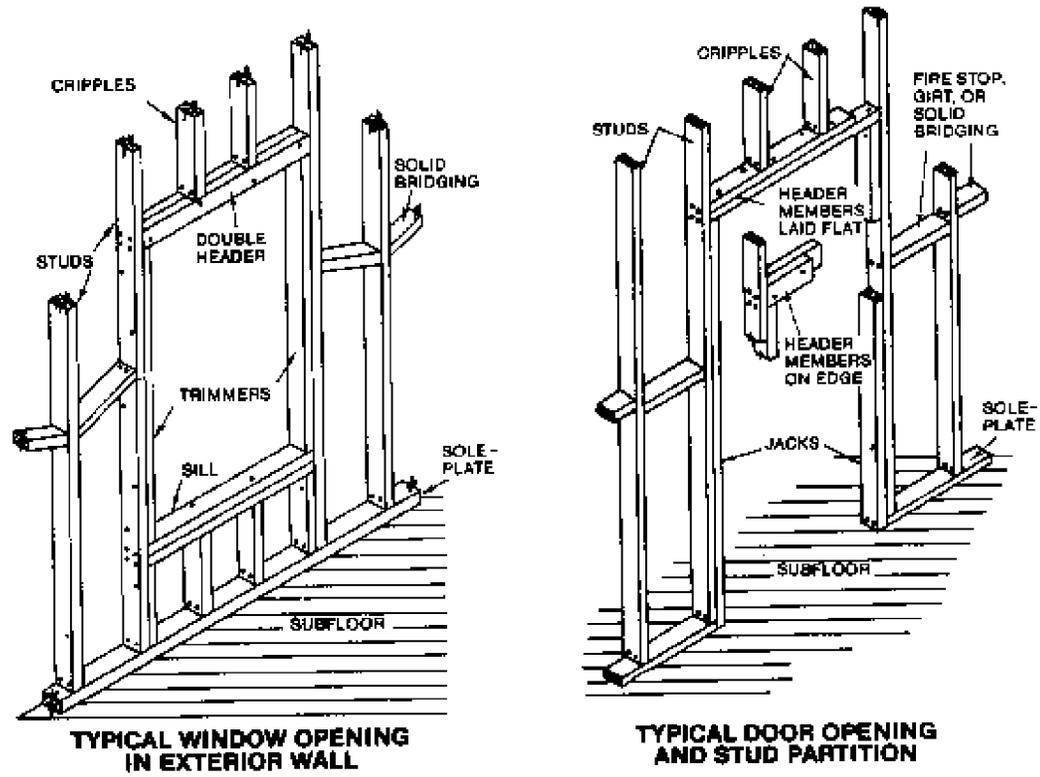
### *3.2.3 Framing Around Openings*

As discussed in the preceding paragraphs, framing

around openings can be directly affected by other structural failures. Figure 3-12 details these framing components to aid in a better understanding of repair and replacement considerations. It is apparent that repair to these sections involves removing trim surrounding wall surfaces, windows or doors, insulation, vapor barriers, and similar building components.



**SIMPLIFIED LAYOUT OF DOOR AND WINDOW FRAMING**



*Figure 3-12. FRAMING AROUND OPENINGS.*

**SECTION III—STEEL FRAMING**

*3.3.1 General*

Some of the advantages of steel framing include ease of construction and freedom from shrinkage, decay, and insect infestation.

*3.3.2 Lightweight Steel Framing*

For smaller buildings, lightweight-steel framing assemblies are in common use. Figure 3-13 shows a typical lightweight steel framing system. Maintenance of this type of framing is primarily concerned

with tightening fittings, preventing corrosion, and checking for deflection and twisting of members.

3.3.3. Structural Steel Framing

Heavy-steel framing is used in many major buildings and related structures. Routine maintenance is limited to regular painting, tightening of fittings,

and periodic inspections to check for deflected, twisted, or damaged structural members. Except for the above procedures, the installation engineer or higher echelons will be consulted prior to instituting maintenance or repair measures on heavy-steel structural systems.

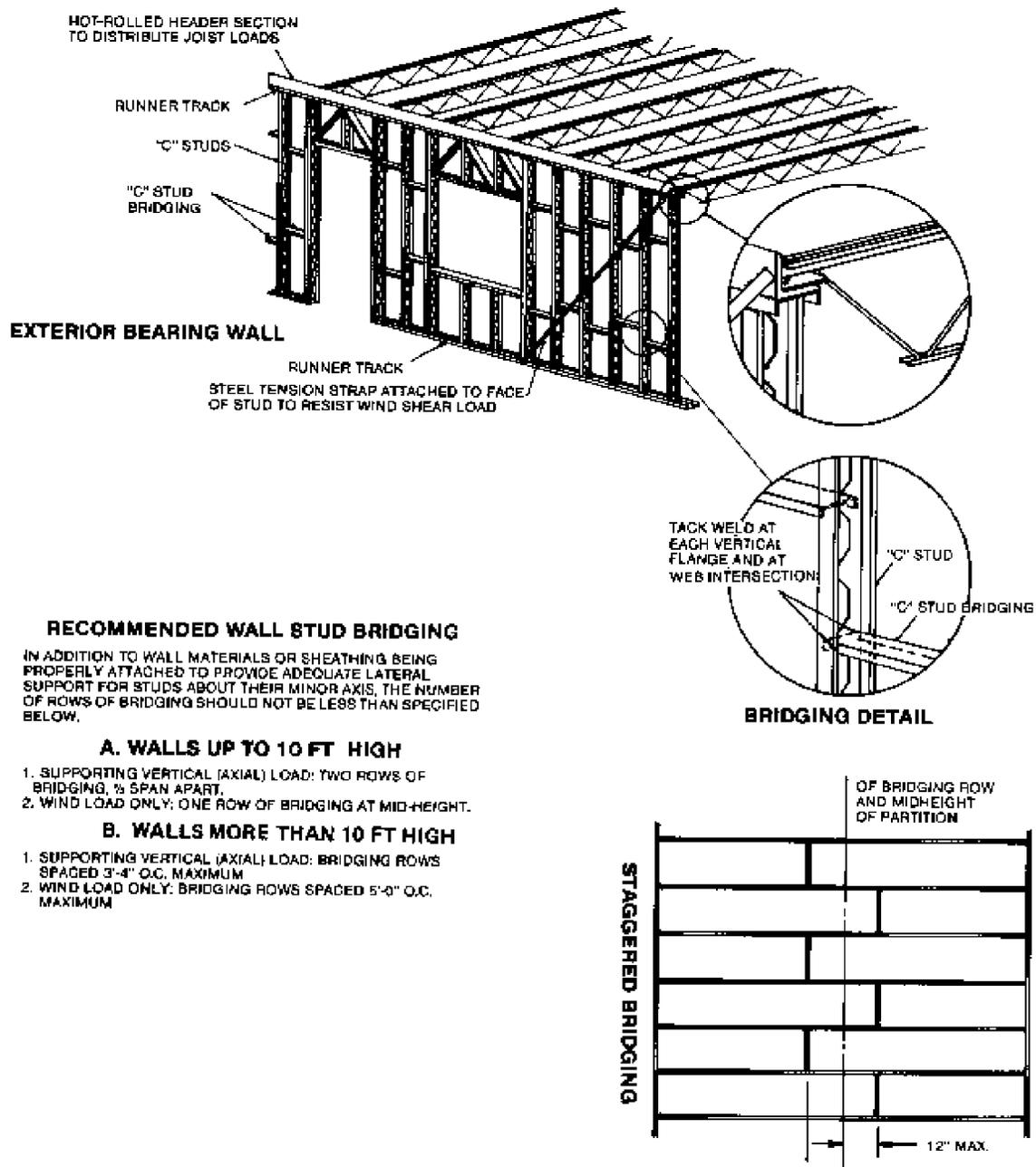


Figure 3-13. METAL FRAMING SYSTEM.

### *3.3.4 Steel Studs*

Steel studs are being used extensively in gypsum board nonload bearing partitions. They compare favorably with wood studs for the same type of construction. However, steel studs offer the additional advantage of being noncombustible. These studs are formed from steel sheets conforming to Federal Specifications QQ-S-698 and QQ-S-700D and are galvanized or provided with a protective coating. Steel studs are C-shaped, formed from material having a minimum nominal thickness of

0.021 inch with a web dimension of not less than 2½ inches. Larger web dimensions are available depending on the partition thickness desired. Steel stud flanges are not less than 1<sup>5</sup>/<sub>16</sub> inches wide, with each flange having a stiffening lip bent parallel to the stud web. Stiffening lips are not less than 1/4 inch wide with turned or folded edges. Some steel studs are fabricated with preformed holes (knockouts) in the web to accommodate utility lines. See figure 3-14.

SECTION IV—ROOF FRAMING

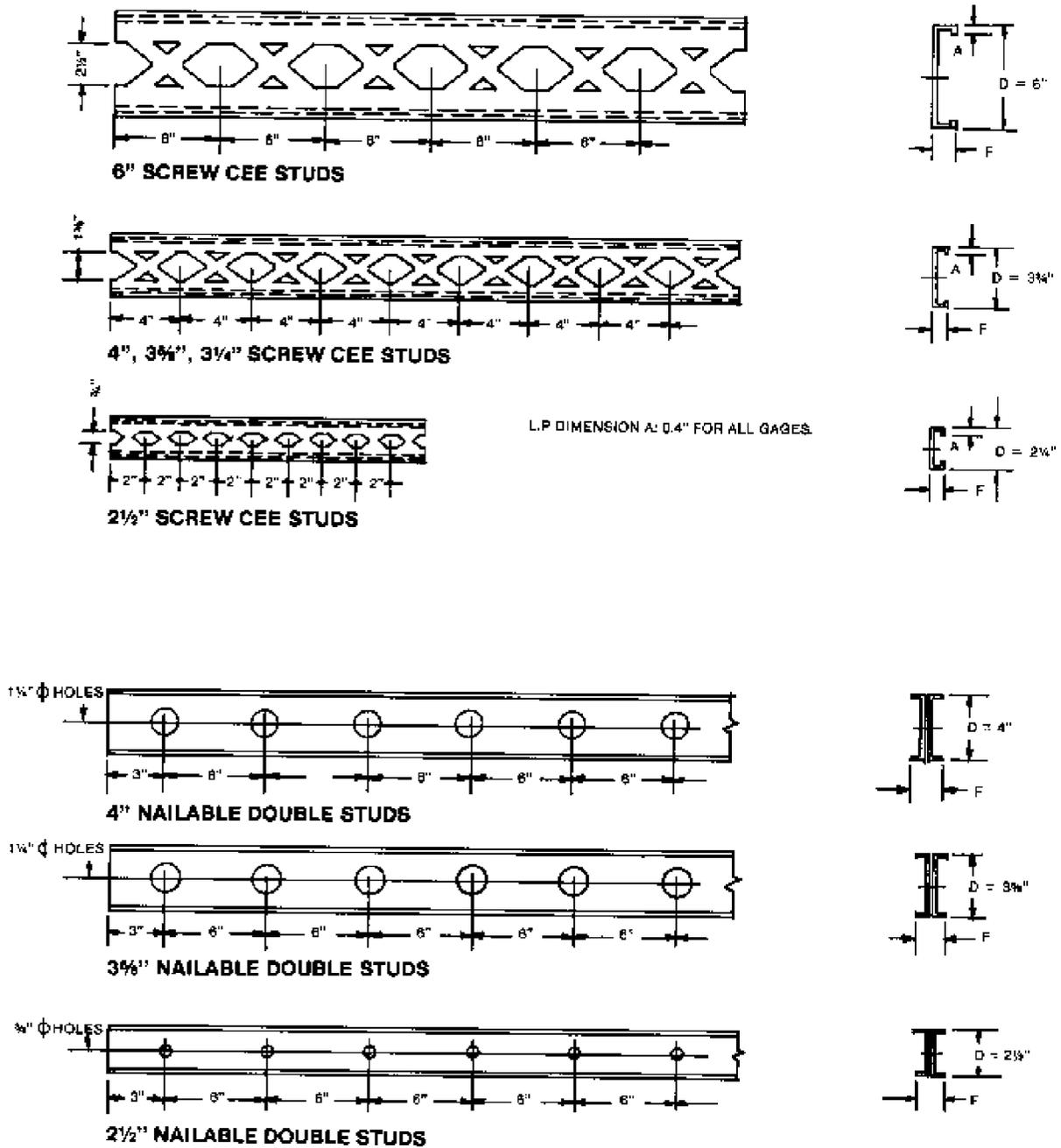


Figure 3-14. FABRICATED STEEL STUDS.

3.4.1 General

Rafters, roof trusses, roof beams, purlins and girders support roof loads in much the same way as joist

beams and girders support floor loads. The notable difference is that pitched roofs must resist lateral forces such as those caused by wind.

### 3.4.2 Types of Roofs

Roofs can be classified in types according to their shapes and also according to their structural limitations. The shapes include flat; pitched (such as shed or lean-to types); curved such as that provided by bowstring trusses or circular arches; or mansard, which is a combination of a steep-pitched and shallow-pitched roof. Roofs which are supported on exterior walls and at a ridge or bearing at some intermediate point are usually referred to as frame roofs: Those that are truss- or arch-supported at

the exterior walls on other trusses or columns are referred to as trussed roofs.

### 3.4.3 Frame Roofs

Rafters are the structural members of a frame roof. Figure 3-15 illustrates the terminology for frame roofs. Frame roofs vary widely, from the simple shed or lean-to type of flat roof to complicated hipped and gabled roofs, which provide for projections in walls which are at right angles to the main gable. Figure 3-16 shows some of the common types of frame roofs.

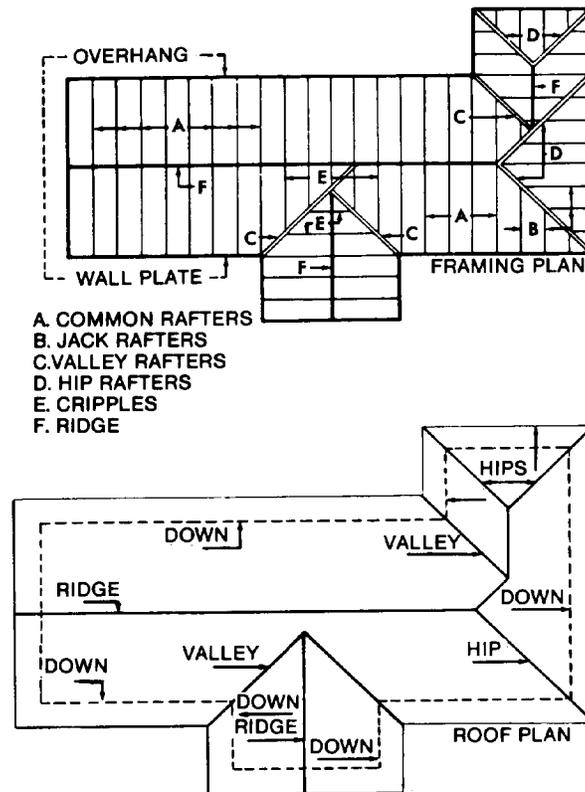


Figure 3-15. ROOFING TERMS AND TYPES OF RAFTERS.

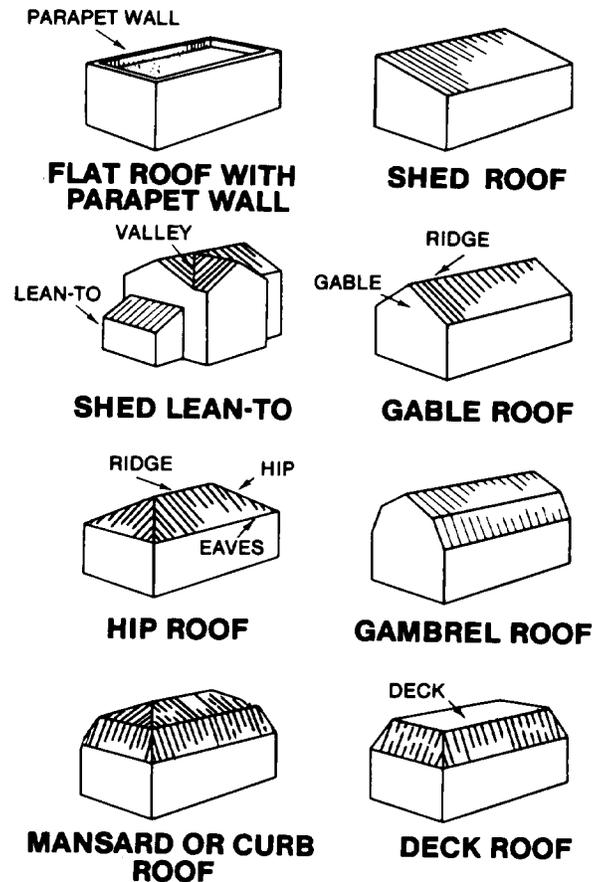


Figure 3-16. FRAME ROOF TYPES.

### 3.4.4 Frame Roof Maintenance

3.4.4.1 *Roof Rafters.* Rafters are generally more accessible to inspection than other structural members of a frame building because they are usually uncovered on the underside where defects and failures can be visually detected. Warped, twisted, or broken rafters can be replaced, or if the roof surface is sound they may be repaired. Warped and twisted rafters can be straightened by adding solid bridging and bracing, while broken pieces can be scabbed without harm to the roof covering.

*a. Rafter Spread.* Sustained overload on pitched roofs is usually manifested in spreading the rafters with the consequent sag in the ridge line. Examination of the connection of rafters to the plate will be included in an inspection of roof framing.

*b. Slippage.* If rafters moved outward on the plate, they can be brought back to line by pulling the ends of the rafters together with rods and turnbuckles or other devices.

*c. Thrust.* The same effect would be noticeable if the exterior walls were moved outward by

thrust from the rafters. This condition can be remedied in the same manner as for slippage.

*d. Anchorage.* Anchorage of the rafters to the top plate is best accomplished by applying framing anchors, such as shown in figure 3-17.

3.4.4.2 *Decay.* Rafters, sheathing and other roof-framing members which are damaged by decay must be replaced. One of the most prevalent causes of extensive roof maintenance is roof-framing failure. Leaky roofs no longer protect the framing, thus allowing weathering and eventual decay. Roofs therefore will be inspected periodically and repairs to surface coverings made immediately upon detection of failure. See Tri-Services Manual, "Maintenance and Repair of Roofs."

3.4.4.3 *Ventilation.* Areas under the roof and above the ceiling will be well ventilated. Air vents will be kept free from obstruction so that condensation does not contribute to decay of the roof members. See paragraph 4.2.5 for information on ventilation.

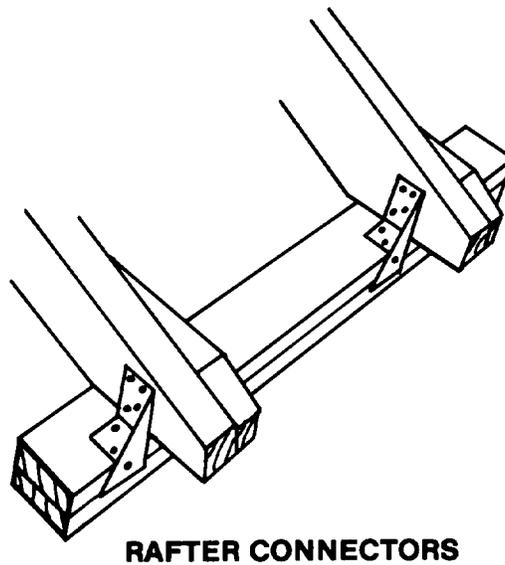
3.4.4.4 *Sheathing.* Sheathing under the roof covering should be inspected for movement, decay,

and warping or cupping. It is sometimes necessary to redrive nails to tighten sheathing and prevent cupping of the individual pieces. Threaded nails of various types are useful since they have more withdrawal resistance than plain shank nails. Where it is necessary to renail sheathing, roof repairs will be made in accordance with Tri--Services Manual,

"Maintenance and Repair of Roofs."

### 3.4.5 Roof Trusses

Figure 3-18 illustrates the more common types of trusses and indicates the character of the stress for typical loadings.



**RAFTER CONNECTORS**

*Figure 3-17. RAFTER ANCHORAGE TO PLATE.*

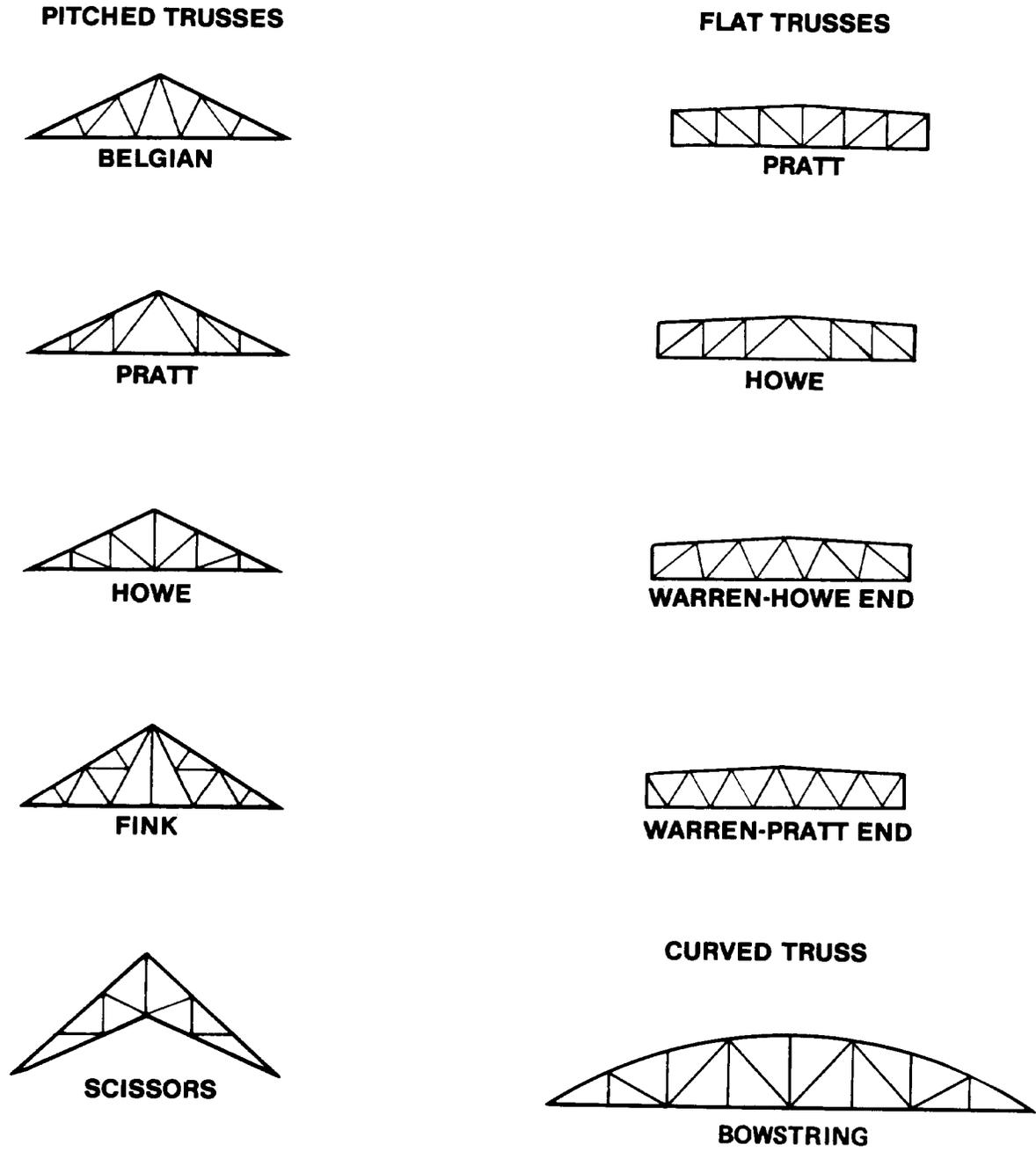


Figure 3-18. COMMON TYPES OF ROOF TRUSSES.

3.4.5.1 *Flat Trusses.* Most commonly used for long spans are the flat-type Pratt trusses, with spans up to 120 feet. Both the Pratt and Warren flat-type trusses, as well as the Howe Truss, are characterized by relatively high stress in the web members in relation to the chord member stresses.

3.4.5.2 *Bowstring or Curved Trusses.* Bowstring trusses are generally found in the smaller hangars, warehouses, and some recreational buildings. These trusses are characterized by relatively high chord stresses with the web members carrying

proportionally lighter stress. The upper chords of bowstring trusses are generally of laminated construction. Failures will be found more often in the chord members. However, this type of truss gives comparatively less maintenance trouble than other types.

3.4.5.3 *Pitched Trusses.* Pitched trusses of the Fink, scissors, and related types are used for short span, usually 60 feet and under. They are found in recreational, chapel subsistence, garage, barracks, and similar type structures.

### 3.4.6 Timber

Expensive and unnecessary repairs or replacements are sometimes made on timber members that, despite extensive seasoning, still retain the full load-carrying capacity for which they were designed. To properly evaluate the effects of seasoning, a full understanding is required of timber behavior during seasoning, timber construction practices, and the designer's allowances for these factors.

#### 3.4.6.1 Definitions.

*a. Check:* A surface opening caused by seasoning, which does not extend through the thickness of the piece and follows the grain. Severe checking appears as a series of discontinuous cracks progressing from one wood-grain layer to an adjacent layer with none of the separations extending to the other side of the piece. A check is not a matter of concern unless there is a possibility of becoming a split in a critical location. Do not refer to checking as "cracking."

*b. Split:* An opening which has separated the wood, extending from one surface through the piece to the opposite surface or to an adjacent surface. A split is of most concern when it extends from the tension face of a beam bottom of beam in beam- and post-type construction); or, if the split passes through the bolt or connector area in a truss member. Do not describe the condition as "splitting."

*c. Shake:* A separation along the grain, most of which occurs between the rings of annual growth. For practical purposes, treat a shake as a particular type of split.

*d. Stitch bolt:* A small bolt (generally  $\frac{1}{4}$ - or  $\frac{1}{2}$ -inch diameter) placed in a member to prevent enlargement of checks or splits. Stitch bolts should never be used to close a check.

*e. Bolt Area:* Area bounded by a line  $\frac{1}{4}$  inch outside the bolthole and extending through the thickness of the wood member, not to be confused with the bolt-bearing area. In bolts without connectors it may be considered as the area covered by the bolthead or nut and washer.

*f. Connector Area:* Area bounded by a line around the bolt equal in diameter to the diameter of the connector and extending through the thickness of the wood member. Since properly installed connectors cannot be seen, reference must be made to structural detail drawings to determine the size. If drawings are not available the size may be determined by loosening nuts and prying members

apart sufficiently to insert a knife or spatula blade and measure them.

*g. Saw Kerf:* An artificial, predetermined split of limited length made by sawing through parallel to the axis of a piece, thus preventing uncontrolled location and direction of a possible natural split or check. Purpose is the same as a contraction joint in concrete.

*h. Compression Member:* For purposes of these data a compression member is defined as a member which is loaded axially in compression.

*i. Tension Member:* A member which is loaded axially in tension.

**3.4.6.2 Lumber Grading.** Lumber is inspected at the mill and strength graded according to visual characteristics, such as knots, shakes, splits, checks, holes, decay, and slope of grain. Working stresses for strength grades are assigned, which include appropriate downward adjustments of clear wood stresses to make allowances for sizes and location of knots, slope of grade, shakes, checks and splits permitted in the particular grade. In general, the working stress for the structural grade of lumber specified has made allowance for checks and splits *normally expected* throughout the life of the piece. These allowable working stresses may be obtained from the "National Design Specifications for Wood Construction," published by the National Forest Products Association.

**3.4.6.3 Seasoning.** Lumber may be either kiln-dried or air-seasoned. Kiln-drying minimizes development of checks and allows selection of pieces with extent of checking predetermined. Kiln-dried dimension lumber in small sizes (4-inch or less thickness) is readily available and usually used. Large-sized (4-inches and up) kiln-dried lumber is usually not available except on special order and after considerable delay. Consequently, large-sized lumber is often installed green and allowed to air-season with large checks and splits being commonplace.

**3.4.6.4 Checking.** Checking most adversely affects the strength of lumber when checks are located at the ends of the piece within the middle third of the depth of a piece used as a beam. Such checking weakens the beam's resistance to horizontal shear. However, horizontal shear only becomes a design consideration in short and relatively thick beams. Another adverse effect occurs when checking is at a steep slope near the tension face of a beam. Such checking reduces the beam's resistance to tension and, if not arrested, could develop into a split. Normally checks are of relatively little importance; their seriousness is a factor only in bending action

or in the probability of developing into a split and the relative importance of a split in that location. Appearance alone should not be the deciding factor. The function of the member is the prime factor. Since most members of trusses are designed for axial loads only and not in flexure, checking may largely be ignored (unless usage or design shows the member to be in flexure). Only splits extending through bolt or connector areas need be evaluated.

3.4.6.5 *Shakes*. Shakes occurring in the connector area which might result in separation of a portion from the rest of the piece should be investigated for repair. Other shakes may be disregarded as such and be evaluated as a check or as a split.

3.4.6.6 *Splits*. Splits occurring in compression members, such as columns, may be serious if there is no probability of slippage from wedging action of connectors or bolts and if the split appears to be dividing the member completely into two parts, thus increasing the length-to-depth (lid) ratio. Splits extending into the bolt or connector area of tension members should be investigated and measure. All measurements of split openings should be made at the distance from the bolt, which is the required end distance for the size of connector used. Excess end distance should be ignored. A single split within the connector area, up to  $\frac{3}{16}$ -inch opening of the splits for a connector of 2e inch or less and a split of  $\frac{1}{4}$  inch for connectors more than 2e inch up to 4 inches, may be disregarded. Splits opened up more than of these widths should receive remedial action to curtail further splitting. If there is more than one split in the connector area, the total opening of the splits should not exceed  $1\frac{1}{2}$  times that for one split. Splits may be repaired by use of stitch bolts provided that the cross-sectional area removed by boring does not exceed the cross-sectional area occupied by the maximum-size knot permitted in the structural grade of timber used. Clamps consisting of small angles and pairs of bolts alongside the member at the split may also be used. Care should be exercised in tensioning both stitch bolts and clamp bolts snugly. No attempt should be made to close a split or a check as this may cause it to extend on the other side of the joint.

3.4.6.7 *Sagging Beam*. Sometimes a sagging timber beam will appear to be overloaded when it is really not overloaded. An inelastic deformation called creep will give an appearance of excessive deflection at the midpoint. Damage might occur if such a beam is jacked back into a level position. The beam should be checked first to find out if there is any evidence of recent motion. In a real overload, there will be fine breaks revealing unex-

posed wood fiber or flaking of paint or other finish material. Measurements should be taken and the beam monitored to determine any additional deflection. If it is determined that creep has occurred and the roof deck must be leveled, it should be accomplished by shimming between the beam and the roof deck.

#### 3.4.7 *Defects*

Discussed below are typical causes of defects usually found in roof trusses. The discussion is mainly concerning wood trusses, since these trusses present the majority of the roof truss problems.

3.4.7.1 *Defective Material*. All lumber incorporated in the trusses should be carefully checked during inspection. A record should be kept of the members containing an excessive number of knots so that particular notice can be made of those members upon subsequent inspections. Specification requirements for structural grade material are that knots will be sound, tight, and not in clusters. The size of the knots should, of course, be limited. It is recommended that the installation engineer acquire, for reference, standard grading rules as published in pamphlet form by the lumber industry for use in determining the quality of material incorporated in the trusses.

3.4.7.2 *Poor Workmanship*. Poor workmanship is evidenced in many ways. Some of the conditions that have been encountered in the past are outlined below for particular emphasis. Lack of precision in drilling boltholes and cutting grooves for timber connectors will cause inadequate gage, edge, and end distances that may reduce the strength of the truss. In some instances the grooves for the timber connectors, although required on one side only, were cut for split rings when it was necessary to use shear plates. Then new grooves were cut which resulted in too much material being removed and the timber not bearing along the exterior rim of the connector. Both the above conditions could weaken the truss and should receive further investigation. Instances were discovered where holes had been drilled for bolts that were never installed. In other cases, bolts of a smaller diameter than the drilled holes were installed. In both the above cases, the correct bolt should be inserted; however, care must be exercised in supporting the truss and binding the joint before removing the undersized bolt. Quite often bolts have been used that were too long or too short. If a bolt is too short, the head of the bolt and the washer may recess into the member, which reduces net area. When a bolt is too long, it may be impossible to tighten the nut enough to obtain a snug connection.

This condition, however, can be remedied by removing the nut and installing additional washers as fillers. Washers on too small an area or thickness have been used between bolthead and timber, resulting in a crushing of fibers or a dishing of the washer. In cases of unusual checking or settlement at particular panel points, an inspection should be made to determine if any timber connectors have been omitted. Conditions may be discovered where timber connector grooves have been cut too deep or too shallow. Both conditions are serious and should be investigated further. Many instances have been observed where the ends of the web members have been cut off flush with the underside of the bottom chord. In some cases this was done so that electric conduits or other mechanical fixtures could be attached to the underside of the chord; in other cases, it was done to increase the ceiling clearance, particularly in garages where the members were in line with entrances where trucks were likely to pass. This reduction of end distance is detrimental to the truss and, in addition to weakening the truss, makes it difficult to repair excessive splitting of the member by installing stitch bolts.

### 3.4.8 Inspection

Timber trusses should be inspected at least once each 2 years. More frequent inspections may be directed by the individual military departments for specific facilities, such as commissaries, theaters, gymnasiums, exchanges, dining halls, and places where large crowds assemble. Appendix B contains several suggested formats which may be used as forms to aid in the inspection process. The first is a data sheet which will remain unchanged until alterations are made to the building. Larger elevation views and photos should be used when necessary to monitor serious defects. A checklist will remind the inspector of items to inspect. A simple form may be used for routine annual inspections with minor defects described on the reverse side. Examples of these non-compulsory formats not requiring reporting are included. Visual inspection from the floor, even with the aid of binoculars, is not enough. The following inspection procedure is suggested.

3.4.8.1 *Checking Existing Construction.* If possible, obtain the latest revision of the structural drawings of the truss and verify if the existing structure conforms with the drawings. Significant deviations or alterations should be reported so that the changes can be analyzed structurally and the record drawings updated. No attempt should be made by the inspector to correct apparent construction deficiencies unless structural analysis indicates that correction is advisable or if subsequent inspection reveals movement indicating that

the truss is in distress and remedial measures are necessary. The structural detail drawings will indicate the existence of timber connectors (which are normally concealed) as well as the type and size, which will aid in evaluating the seriousness of any splits found in the onsite inspection.

3.4.8.2 *Terminology.* The inspector should familiarize himself with the proper timber terminology and use it in his reports. Timber terms are defined in paragraph 3.4.6.1.

3.4.8.3 *Overall inspection of entire truss.* Examine the truss from the floor to determine if there is:

a. Obvious failure of truss, which would make an inspection from the truss itself unsafe.

b. Lateral bowing of upper or lower chords with respect to truss support points. A truss that is laterally bowed indicates that lateral support is either nonexistent or nonfunctioning. Further examinations must be made of bridging, X-bracing, struts, purlins and deck to determine if slippage is occurring in a connection.

c. Vertical sagging of frame (subsequent study will determine if sagging is normal deflection due to loading, long-term creep, or partial failure of an overloaded member).

3.4.8.4 *Detailed inspection.* Examine the truss at close range from a ladder, lift machine or from the truss itself to determine the following:

a. Rupture of any member.

b. Evident separation of sides of members at joints. Nuts should be snug enough to prevent separation of members without embedment into the wood. Loose or absent nuts are detrimental when they permit the timber members to separate and render the shear connectors less effective. Missing nuts should be replaced and all nuts tightened to snugness without embedment into the wood.

c. Noticeable bowing or warping of any member. Bowing could indicate an overloaded compression member; however harmless warping may occur in an unloaded redundant member.

d. Continued development of checks (nonthrough cracks) toward line of bolts. Progressing checks are indicated by freshly exposed wood surfaces at ends of checks. A check progressing toward a bolt or connector area should be monitored so that corrective action can be taken before it becomes a split.

e. Development of splits through a bolt area or connector area of web joints or chord splices.

f. Evidence of leakage such as waterstains, mold, or decay.

g. Wood crushed by overtightening of bolts.

h. Wood fibers freshly exposed by flaking paint or preservative.

3.4.8.5 *Inspection of Ancillary Member.* Examine other members attached at right angles or providing support to the truss to determine if there has been any movement. These may be:

a. Beams or purlins supported on the top of the top chord. These may be secured by nails "toe-nailed" into the top chord of the truss. Any movement will result in the nails bending at the member interfaces and the members may disengage completely. If purlins had been installed with bolted clip angles on top of the truss or recessed into sides of top chord with steel hangers, such movement would have been almost completely eliminated.

b. Struts installed across tops of bottom chord should be examined in the same manner as purlins.

c. X-bracing members serving as sway bracing or bridging should be examined to determine if connections provide positive support to maintain vertical alignment of truss. The truss designer may be provided lateral bracing by another means but, nevertheless, the absence of X-bracing should be noted in reports.

d. Purlins, beams, and struts should be examined for freshly exposed wood where member extends into expansion joint pocket at firewall.

e. Purlins, beams, and struts abutting walls and chord fastened with clip angles or hangers should be examined for bowing or freshly exposed wood fibers indicating member has been subjected to unusual loads.

f. Masonry unit walls, columns or pilasters supporting trusses and concrete piers supporting timber columns must be examined for deterioration. The presence of cracks in brick or mortar adjacent to the bearing plate must be noted. Recent movement is indicated by vertical edges of bricks being out-of-line, corners of brick or concrete broken, cracked brick, and other exposures of unweathered brick or concrete.

g. Timber columns, knee braces and column capital must be examined for damage created by moving vehicles as well as the other defects discussed above. Special note should be made of any large foreign items installed on columns or any notches or cutouts made to accommodate any type of equipment. Many times such attachments conceal deterioration in the column underneath.

### 3.4.9 Timber Roof Maintenance.

The following paragraphs describe maintenance procedures which should be followed for timber roof framing.

3.4.9.1 *Bolt Tightening.* It is important that all truss connections receive periodic tightenings until the moisture content of the lumber reaches a state of equilibrium with the atmosphere. It is also important that, during the first year, the connections be tightened at frequent intervals to prevent the connections from becoming excessively loose, resulting in settlement of the trusses, excessive splitting caused by the introduction of abnormal stresses, and, in extreme cases, failures in truss members. There are a number of corrective methods for repairing damaged members. The types of failures, near failures, and other unsatisfactory conditions encountered vary and require a different approach in practically all cases. Bolts should be snug but not overtightened to the extent to cause damage to the timbers. Listed below are typical repair and maintenance operations as performed under the bolt-tightening program.

a. Truss bolts will be tightened as soon as they become excessively loose. Bolts may be considered loose if, after striking the bolthead a sharp blow with a hammer, the nut can be taken up two full turns or more. Actually, this condition would not cause concern when there are a number of members meeting at a connection, if the actual reduction of bearing area on the connectors were the only consideration. However, a looseness of bolts at all connections reduces the rigidity of the truss as a whole. The character of the timber trusses is such that there is a certain eccentricity to the lines of stress, and such looseness would tend to increase that condition.

b. Climatic conditions determine the rate at which shrinkage occurs. In the northeast, for example, the summer season is warm and moist so very little shrinkage is likely to occur. During the winter months when the air is normally less humid and the buildings are heated, the relative moisture content of the atmosphere is greatly reduced. Consequently, it is unlikely that any appreciable shrinkage will occur from May to October in that area. During the remaining period, a closer check should be kept on trusses. Climatic conditions vary in different sections of the country, but require the same general consideration as outlines above.

c. While performing a routine bolt-tightening operation, the bolts should be checked to determine if there is sufficient thread to tighten the nut. Also check the size of washers; if they are so small that

the truss members cannot be drawn together without embedding the washer, they should be replaced with larger ones. Where it is impractical to remove the bolt to place a new washer next to the bolthead, a square, slotted washer may be inserted between the existing washer and the wood. Wherever slotted washers are used, a nail should be driven into the timber at the edge of the washer, protruding sufficiently to eliminate the possibility of the washer turning and falling off in the event of further shrinkage of the timber. All washers should be at least 1/4 inch in thickness and not less than 2 inches square. When tightening nuts, the bolthead should be struck sharply with a hammer to force the bolt through the truss member and break any adhesion between the bolt and timber resulting from corrosive action.

d. Under those conditions where there is insufficient thread to draw the timber tightly together, a filler washer of some type is required. Usually these bolts extend at least 2 inches beyond the nut. A short compression spring has been used with excellent results as a filler, which, in addition, maintains a tight connection, thus reducing the frequency for future tightenings. These spring washers should, therefore, be considered when preparing for a first tightening of any truss. The bolts should be checked to determine the amount extending beyond the nut after they have been tightened; if the extension is sufficient, the springs should be installed. The springs that have been used are of round edge, 7/16-inch by 1/4-inch section, and of two to three coils. The pressure exerted when fully compressed is approximately 2,800 pounds and there is a straight-line reduction as it expands. This pressure compares favorably with the allowable compression stresses perpendicular to the grain.

e. In many structures, inspection reveals that bolt tightening is required due to shrinkage alone. As a general rule, bolt tightening should be performed if the average takeup on nuts is more than two turns. This, of course, is quite arbitrary and depends greatly on the size of members and length and size of bolts. The importance of keeping bolts tight cannot be overstated. Design values are predicated upon tight connections. In a bolt-tightening operation, care should be exercised to see that the men have safety belts, if necessary, to work from a hazardous height. Spud wrenches of the proper size are used in order that uniform leverage and takeup may be obtained in all bolt-tightening operations. The use of slotted washers is recommended as fillers. It is important that bolts be tight, but too much leverage on the spud wrench may force the washer into the fiber of the wood,

destroying that fiber and cupping the washer. Effective tightening of bolts should be accompanied by tapping on members and boltheads. It is especially important that bolt tightening be performed upon completion of a structure, and that frequent inspection and additional tightening be performed during the year following construction. A few drops of oil placed behind the nut will facilitate tightening of bolts having rusty or dirty threads. It is recommended that each bolt, after tightening, be keel-marked for inspection purposes. It is further recommended that date of tightening be stenciled on one of the trusses of a structure to keep the importance of this maintenance work firmly in the mind of inspectors.

3.4.9.2 *Omission of Ring Connectors and Bolts.* At the time of bolt tightening, it will be noted whether or not the corrective bolts are in the holes drilled for them or whether any bolts have been omitted. In such cases, bolts should be replaced or installed. If timber connectors, such as shown in figure 3-19, have been omitted at any joint or if there is visual evidence of excessive stress at the joint, repairs should be made and the proper bolts and connectors installed while the truss is fully supported at the panel points and clamps are relieving the joint of all stress. The condition of the joint should be recorded and special observations made upon subsequent inspections. Precautions should be taken so that additional loadings, such as hoists and monorails, will not be applied to those panel points.

3.4.9.3 *Roof Settlement.* As roof truss connections become loose, roof settlement occurs. While this settlement might not be of concern to the structural adequacy of the truss itself, problems may develop in other areas requiring remedial action.

a. *Roof Drainage Systems.* On structures containing parallel chord roof trusses, any settlement will seriously affect the roof drainage. Usually a wood truss is fabricated with several inches of camber, a considerable portion of which remains after the installation of the roof deck, roofing, and other dead loads. The roof slope for proper drainage is predetermined, and the roof purlins are set on shims or blocks to acquire that slope. As the truss connections become loose due to shrinkage of the lumber, the trusses sag and drop below the horizontal. This, of course, removes the possibility of rainwater draining from the roof and so increases the live loads to which trusses are subjected. It has proved to be almost impossible to replace a camber in a truss. Consequently, jacking a truss prior to a bolt-tightening operation will be of little value. Instead, the roof purlins must be

raised from the top chord of the truss and shims placed between the purlins and chords. Perform all jacking directly from the truss; otherwise, the removal of the roof loads from the truss will only cause the truss to rise with the roof. In order to jack the purlins, short timbers should be set on the bottom chord of the truss perpendicular to the chord and directly under the purlins to be raised. The purlins should then be jacked cautiously so that there will not be an abrupt rise in the roof to break the roof covering and cause leaks. This work should be performed during the summer season when the roofing is pliable.

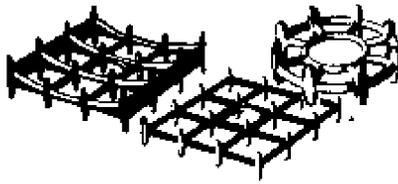
*b. Binding of Doors.* Where roof settlement of a hangar occurs at the door guides, which were originally set with provision for approximately 3 inches of adjustment, a binding of the doors is inevitable. The procedure for adjusting the door guides, of course, depends upon the design of the canopies and guides.

### **3.4.10 Timber Roof Repair**

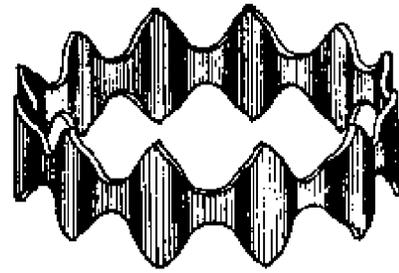
The following paragraphs illustrate and discuss

methods of repair and standards to be used. Typical examples of actual conditions found and repaired are presented.

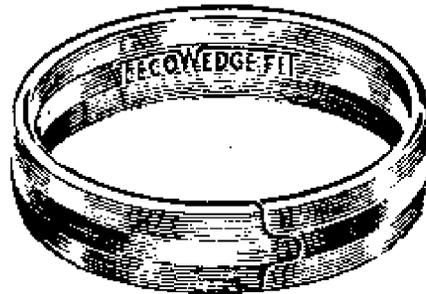
3.4.10.1 *Shoring.* It is frequently necessary to shore trusses to prevent collapse or to provide security while making repairs. Figure 3-20 indicates proper locations for shoring typical trusses. Shores can be placed at all panel points if desired. The methods shown indicate the minimum number of shores necessary to properly support typical trusses. In shoring Warren-type trusses, it is advisable to place a temporary strut to prevent introducing serious secondary stresses in the truss members. Eight-ton jacks may be used under the shores. Shores themselves may be of steel or of seasoned timber. Sufficient planking should be placed under jacks to distribute load on the floor. Trusses should be raised slowly and carefully, jacking each shore in small increments at any one time. Otherwise, additional failures may occur, due to secondary stresses and distortion, and damage may be done to the roof membrane of the structure. Both judgment and experience are required for this operation.



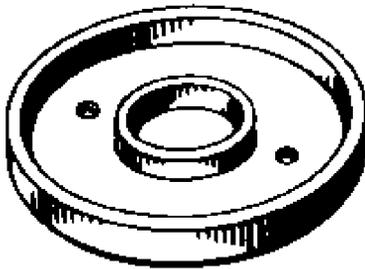
**SPIKE GRIDS**



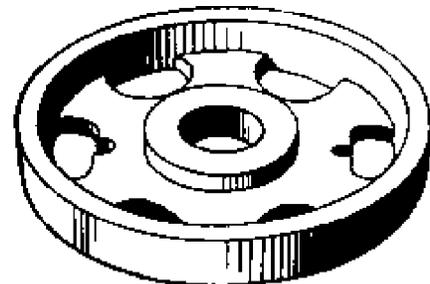
**TOOTHED RING  
(NO LONGER MANUFACTURED)**



**SPLIT RING**



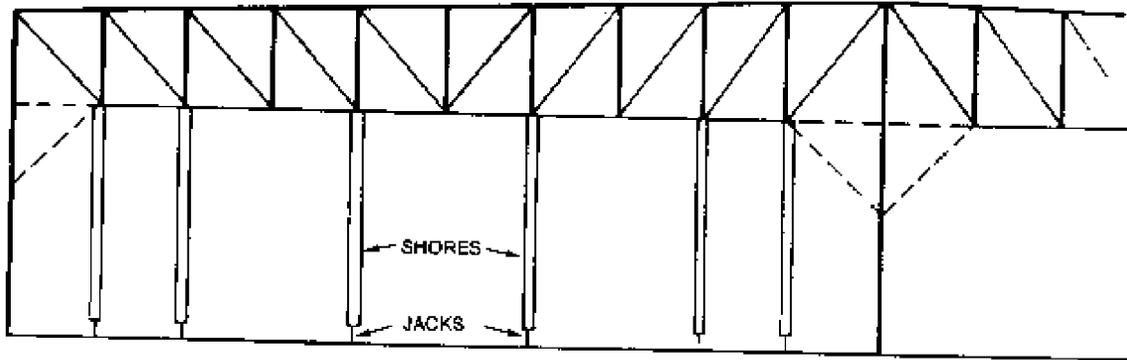
**2 INCH**



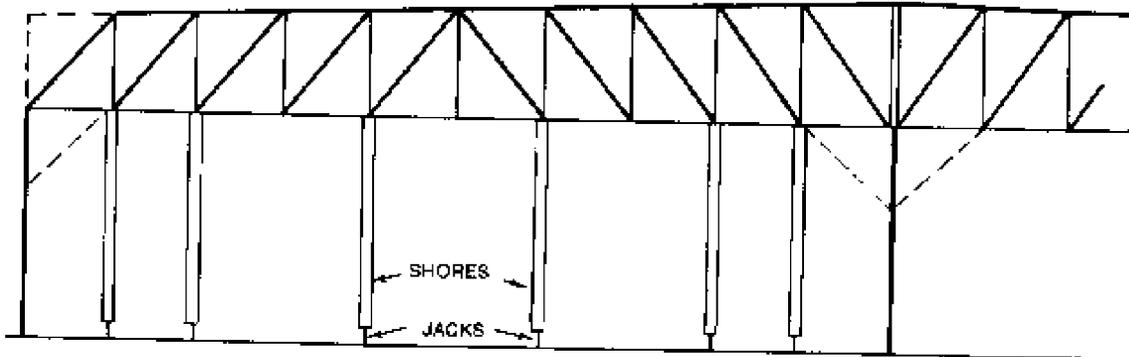
**4 INCH**

**SHEAR PLATES**

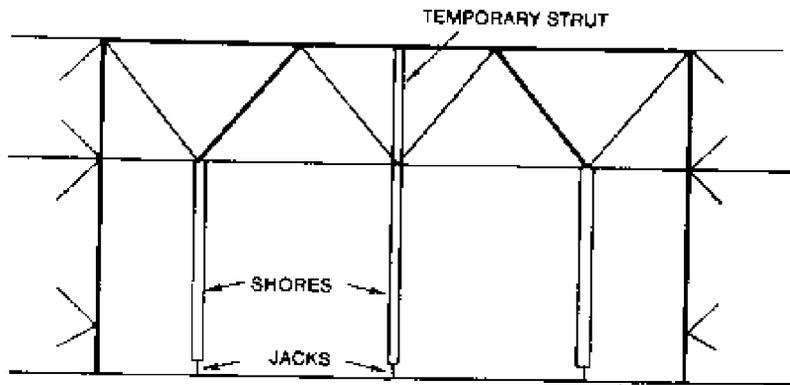
*Figure 3-19. TIMBER CONNECTORS.*



**PRATT TRUSS**



**HOWE TRUSS**



**WARREN TRUSS**

*Figure 3-20. SHORING OF TYPICAL TRUSSES.*

3.4.10.2 *Split and Checked Members.* As previously stated, the standard practice of using unseasoned lumber for trusses invites checks and splits in the members when unseasoned lumber is

used. Checks and splits are normal reactions in most timber as it dries out, and it is more pronounced in certain types of lumber. In those members that have only one row of bolts, any

check or split that occurs is normal and is not likely to be serious. However, if the split passes through the boltholes and continues beyond into the member, it requires attention. The recommended remedy for such splitting and checking is the installation of stitch bolts in the ends of each such member that has split. The bolts used for this purpose are 1/2-inch bolts, threaded on both ends; 9/16 inch holes are drilled 2 to 4 inches from the end of the split member and perpendicular to the axis of the member. The bolt is then inserted and 2-inch, square-cut washers are placed at each end and the nuts are tightened. It is advisable to install the stitch bolts prior to tightening the bolted connection. If the split is serious and continues well into the member, a second stitch bolt should be placed on the opposite side of the connection about 6 to 12 inches from the ring connector. Usually, this operation will not reduce the net area enough to weaken the member. In some cases, when the split passes through the connection but does not pass too far up into the member, it may be stopped by drilling a small hole through the thickness of the member at the end of the split. This hole will relieve any abnormal stresses at that point. Care must be exercised in drilling stitch boltholes so that holes are parallel to the face of the member. Ship auger bits tend to follow the grain and stray from the intended centerline path. Metal-type fluted drill bits with extended shafts are more effective in drilling straight holes.

3.4.10.3 *Damaged Web Members (Tension)*. Quite often an inspection of truss members will indicate that certain members may not be of structural grade material because of the slope of grain is excessive, or the members may contain either an excessive number of unsound knots. These conditions will weaken the members, especially those in tension, and in the case of unsound or excessive knots will reduce the net area of the members. In the event that the condition appears critical or an actual failure has occurred, it will be necessary to reinforce or replace the member.

a. Replacing any truss member can be a costly operation. Unless the building is for permanent use, it is recommended that the member be repaired or augmented rather than replaced. The least complicated procedure is merely to shore the truss directly under the damaged member. This procedure should, of course, be followed only if the floor space is not a consideration.

b. When a tension member fails, settlement may occur in the truss, and the ends of the member at the point of failure may become separate. If the member is to be repaired by splicing, the separated

ends must be returned to their original position. This requires simultaneous shoring of the truss and axial tension jacking of the member.

c. A second and more satisfactory procedure is to prepare steel rods with a steel plate welded to one end and the two rods connected by a turnbuckle. The plate at the end of each rod is drilled in the field to fit the existing bolts at the connections at either end of the damaged member. Grooves are cut into the outer face of the top and bottom chord for shear plates and the connectors and plates installed. CAUTION: Grooves for shear plates are cut with a tool utilizing the existing bolt holes as alignment guides for the groove cutters. Before bolts are removed for this purpose, adequate shoring and tension jacks must be installed. The turn-buckle can then be taken up until the web member is returned to its original position.

d. In cases where checks and splits have occurred in tension members, with excessive slope of grain, it may be possible to close the split or retard further development of the split by placing stitch bolts or clamps along the member at strategic points. Stitch bolts, however, should be installed only after careful consideration, for the excessive use of stitch bolts between connections is not desirable and may weaken the member if installed indiscriminately.

3.4.10.4 *Damaged Web Members (Compression)*. The usual types of failures in compression are either a shear along the fibers when the slope of grain is excessive or a bowing of the member that may or may not result in breaking of the fibers perpendicular to the grain. It is recommended in all cases that the damaged member be repaired by placing a timber of similar width and depth adjacent to the damaged member, connecting them with bolts and split-ring timber connectors. If the failure is close to the panel point, splicing the member may not be practicable. Installing a new member on the same plane would then be advisable, with the chords connecting the new member to the existing bolts with shear plates and steel gusset plates. The new member should then be securely fastened to the damaged member with bolts and split rings.

3.4.10.5 *Damaged Chord Members*. Failures in bottom chord members occur as the result of excessive slope of the grain, knots, or other defects in the material. In most trusses, the chords and most of the web members are made up of at least two timbers. This allows a certain safety factor: if one timber fails, the other will temporarily carry the additional load. It is likely, however, that under that added load the other member would eventually fail

unless the failure is discovered at an early date. Periodic inspections will uncover such conditions before failures occur in adjoining members.

a. Checks usually occur parallel with the grain of the timber. Checks and splits may be more pronounced at panel points containing two rows of bolts that restrain the normal shrinkage action and is further aggravated by the fact that the stresses from the web members are transmitted to the chord in directions perpendicular and at a slope to the chord. If the slope of the grain is excessive, the checks are likely to develop into splits by extending to the edge of the member and may result in failures.

b. Splits often occur in the chord member at the splices where the ends of the timbers butt. There are no sloping forces at those points to aggravate the condition, but occasionally the split continues well into the member, possibly passing through boltholes. Wherever such splits have occurred, it is recommended that stitch bolts be inserted through the depth of the chord member at the splice between the bolts and the end of the chord member. In that way, the split will be kept closed and will not have a tendency to increase.

c. Short members, such as splice plates, are especially susceptible to checks and splits. Quite often, a split develops along the center of the timber parallel to the grain; however, that condition should cause no concern, as splice plates are often designed of two timbers of the same length, but one-half the width. If the split should develop along a row of boltholes, it is recommended that the member be replaced. The splice plates of many trusses are designed so that they contain a row of bolts at either edge and, at each end, one additional bolt which is on the centerline of the member. Under such a condition and when the split occurs along the center of the splice plate, the condition may be corrected by inserting a stitch bolt beyond the last bolt at each end of the splice plate.

d. At panel points when the split in the chord member is very pronounced, even though the split follows a flat grain, it is advisable to install a stitch bolt within 6 to 12 inches of the outer bolt at that connection. A similar bolt may be inserted at the other side of the panel point. However, judgment should be used when installing stitch bolts at such locations, and they should be installed only where splitting is excessive.

e. If an actual failure has occurred in a chord member, that member should be replaced. To do this, the truss should be shored at the panel points along the bottom chord and the damaged member

removed. Using the damaged member as a templet, the new member can be fabricated and installed. The replacements should be of the same material as the truss and of the same moisture content, if possible.

f. If only partial failure has occurred, the chord may be repaired by installing timber splices extending well beyond the ends of the failure. In some cases, steel rods and turnbuckles, similar to those recommended for tension web members, have been used to advantage. However, it is normally more desirable to replace the member and, if possible, to limit the use of steel rods and turnbuckles to locations where it is impractical to shore the trusses. Steel plates should always be used in combination with shear-plate timber connectors when used to reinforce wood members.

### 3.4.11 Heavy Timber Solid Beams and Columns

Periodic inspection and maintenance schedules will not be limited to timber-trussed structures. Many structures of beam and column design have been erected. As these heavier timbers season, severe checking sometimes occurs. In most cases, this checking, although of considerable width and depth, is parallel to the axis of the member and usually requires no attention. An attempt to close such checks with stitch bolts will only aggravate the condition and cause the checks to extend completely through the members. Whenever this checking occurs in cross-grained members, corrective measures must be taken. In extreme cases, the members should be replaced. In some cases, repairs can be effectively made by bolting channel or angle iron parallel to the member and connecting them with bolts and shear plates.

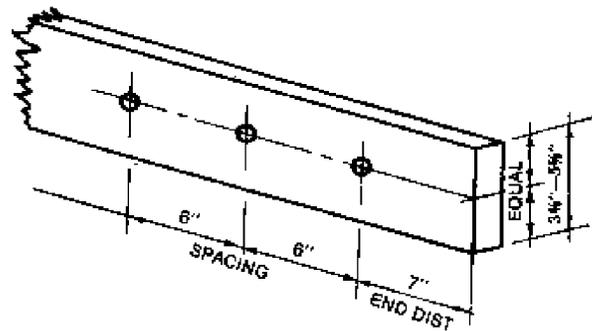
#### 3.4.11.1 *Edge and End Distances and Recommended Spacings.*

a. *Bolt Connections.* Figures 3-21 and 3-22 indicate recommended minimum spacings and edge and end distances for bolts in repair design. Data are based on the use of a  $\frac{3}{4}$ -inch bolt. Three lines of bolts are not always satisfactory and should be used only in large members where spacing can be kept at a maximum. Shrinkage usually occurs at the center of the piece, and a split usually develops along the centerline of bolts.

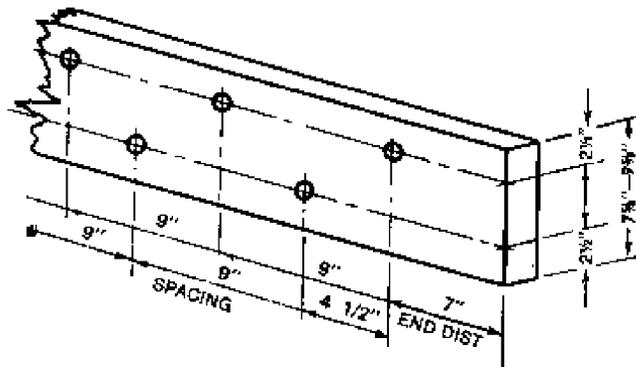
b. *Connector Spacing* Figures 3-23 and 3-24 indicate recommended minimum spacing and edge and end distances for 4-inch shear plates or split rings for use in repair design. For connectors used in lumber not properly seasoned, 80 percent of the tabulated allowable connector loads will apply; spacing and edge and end distances should be in-

creased above the minimum. Installation of the 4-inch connector should be carefully and exactly performed. A large number of present failures are directly traceable to careless workmanship at the time of construction. When 4-inch connectors are used in 1 x 6 members, extreme care should be ex-

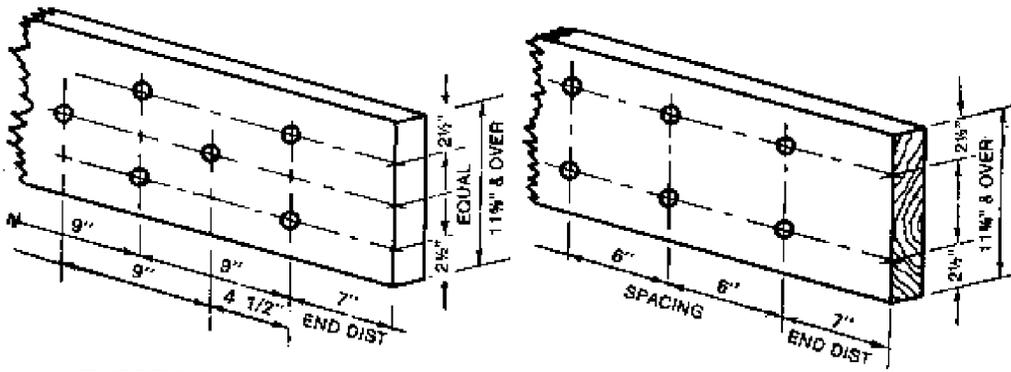
ercised that they be properly grooved, spaced, and located in order to maintain proper edge and end distances. In this connection, consideration will be given to the advisability of substituting larger dimension timber for repair design.



**SINGLE ROW FOR 4" TO 6" MEMBERS**



**TWO ROWS STAGGERED FOR 8" TO 10"**

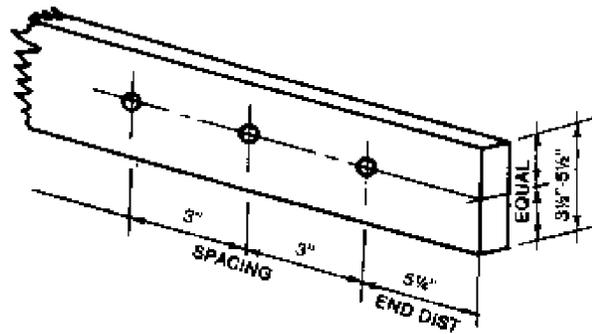


**THREE ROWS STAGGERED**

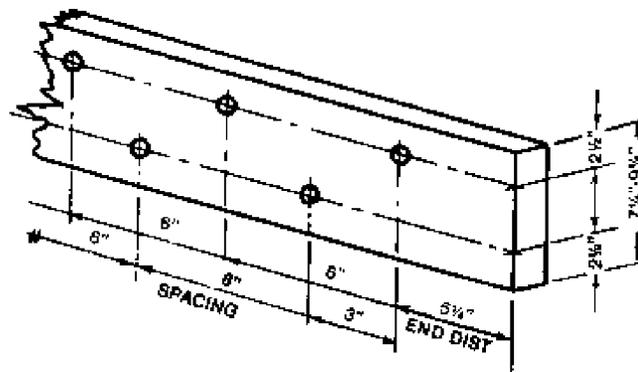
**TWO ROWS IN LINE**

**FOR MEMBERS 12" AND OVER  
LOAD PARALLEL TO GRAIN**

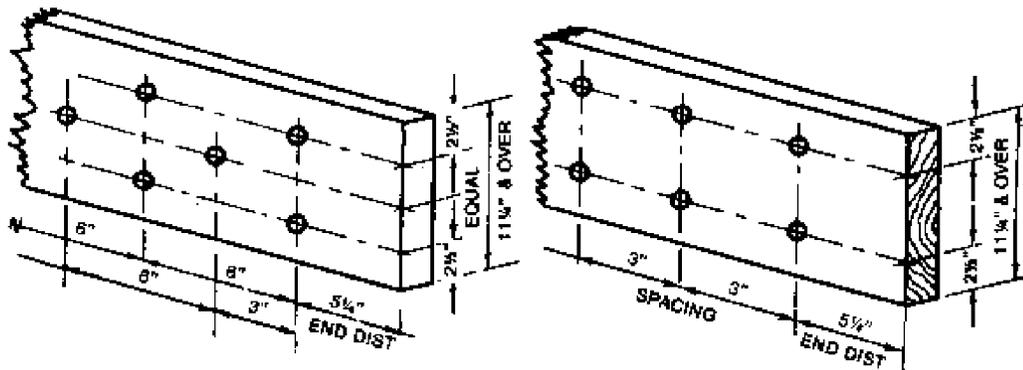
*Figure 3-21. BOLT CONNECTIONS (IN USE PRIOR TO 1970).*



**SINGLE ROW FOR 4" TO 8" MEMBERS**



**TWO ROWS STAGGERED FOR 8" TO 10"**



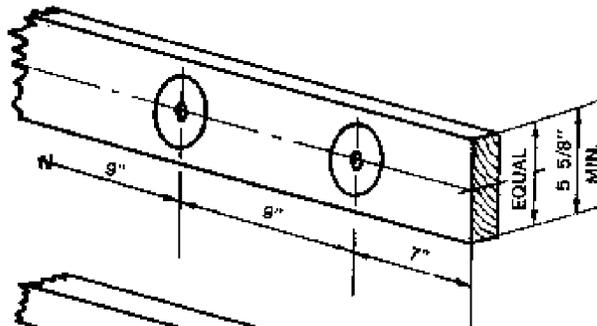
**THREE ROWS STAGGERED**

**TWO ROWS IN LINE**

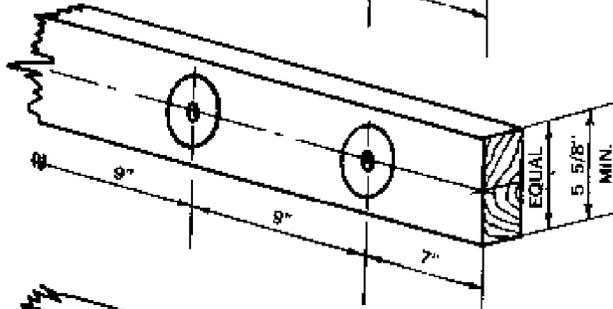
**FOR MEMBERS 12" AND OVER  
LOAD PARALLEL TO GRAIN**

*Figure 3-22. BOLT CONNECTIONS (IN USE AFTER 1970).*

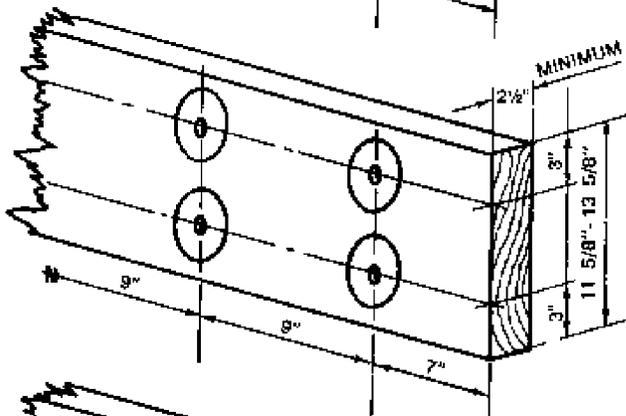
**4-INCH-DIAMETER SPLIT RING  
OR SHEAR PLATE**



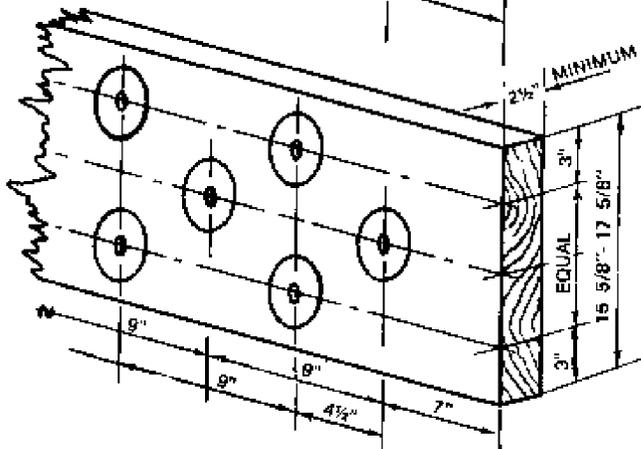
**SINGLE ROW RINGS OR PLATES  
ON ONE FACE FOR MINIMUM  
6" TO 10" MEMBERS**



**SINGLE ROW RINGS OR PLATES ON  
BOTH FACES FOR MIN.  
8" TO 10" MEMBERS**



**DOUBLE ROW RINGS OR PLATES  
ON BOTH FACES FOR  
12" TO 14" MEMBERS**



**THREE ROWS STAGGERED  
RINGS OR PLATES ON BOTH  
FACES FOR 16" TO 18"  
MEMBERS**

Figure 2-23. CONNECTOR SPACING (IN USE PRIOR TO 1970).

**4-INCH-DIAMETER SPLIT RING  
OR SHEAR PLATE**

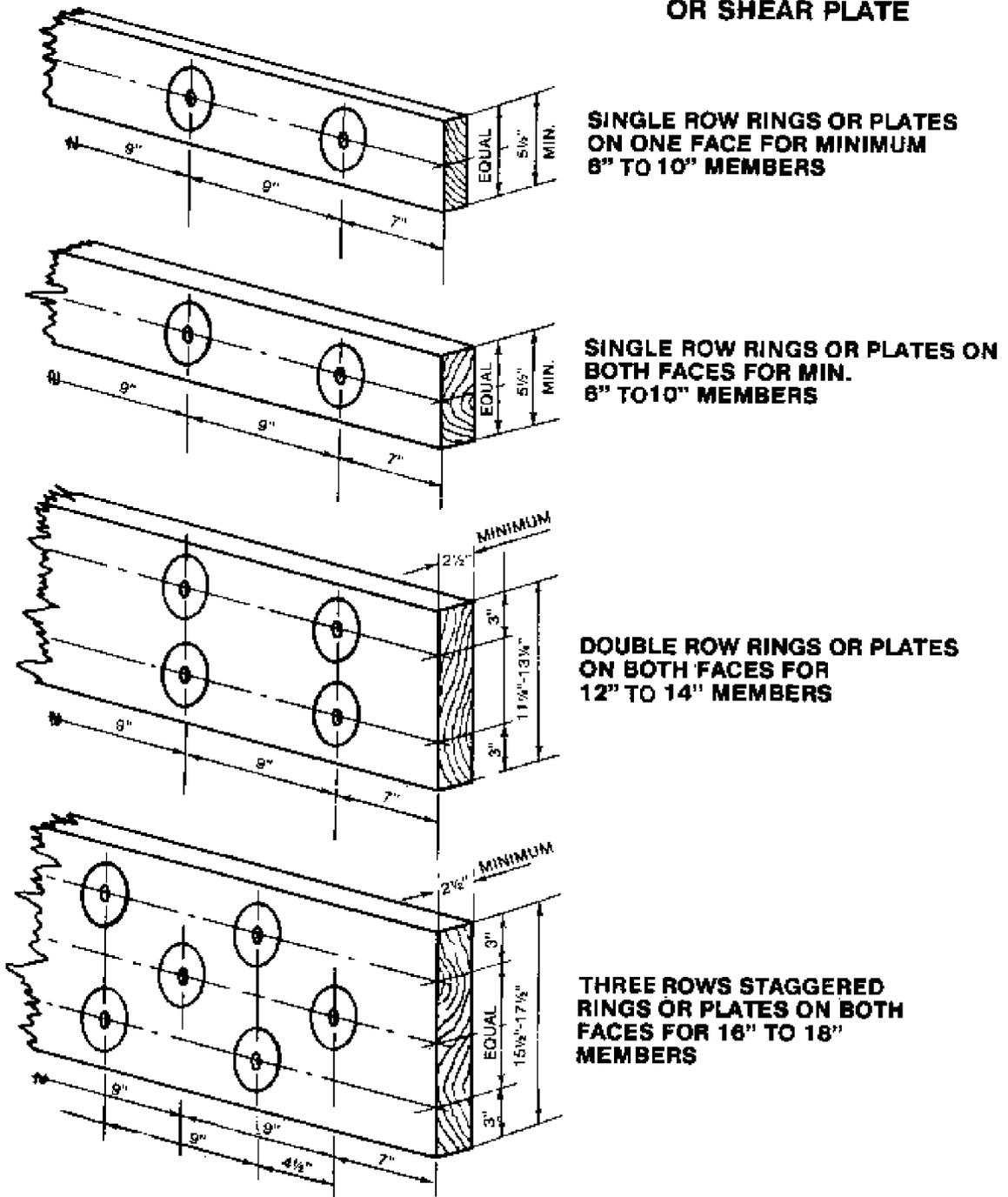


Figure 3-24. CONNECTOR SPACING (IN USE AFTER 1970)

3.4.11.2 Allowable Loads.

a. *Bolts.* For repair purposes, the allowable load in pounds on one bolt loaded at both ends in a three-member connection (double shear) of Douglas fir or southern pine (dense) is given in table 3-1.

Table 3-1. Allowable Loads for One Bolt.

Length of bold in main member (in)	Diameter of bold (in)	Allowable load parallel to grain of well-seasoned lumber (lb)
2½	¾	2,710
3½	¾	3,280
5½	¾	3,350
2½	1	3,680
3½	1	5,000
5½	1	5,930

When a joint consists of two members (single shear) of equal thickness, one-half of the above tabulated loads for a piece twice the thickness of one of the members will apply.

b. *Connectors.* For repair purposes, the allowable load in pounds on one connector is provided in table 3-2.

Table 3-2. Allowable Loads for Connectors.

Type of connector	Diameter of bold (in)	Number of faces of member with connectors of same bolt	Allowable load parallel to grain (lb)
Split Ring 2½	¾	2	3,160
Split Ring 4	¾	1	6,020
Split Ring 4	¾	2	6,140
Shear Plate 2e	¾	2	2,900
Shear Plate 4	¾	2	4,970
Shear Plate 4	f	2	6,720

3.4.12 Timber-Repair Details

3.4.12.1 *Stitch Bolts.* Repair of end splits by stitch bolts is very common and normally is performed when a split opens up at the end greater than ¼ inch. It is particularly important to control the splitting when the end split runs through the line of bolts. It is not advisable to completely close the end split with stitch bolts in the event that such closure will throw excessive stress in the member.

Stitch bolting in this case merely prevents further deterioration of the condition. Stitch bolts to be installed in heavy timber members (nominal four inches or larger) should be 1 inch in diameter and long enough to accommodate the nut and a ¼ inch cut washer at each end. Stitch bolts for use in nominal 3 inch lumber should be 5/16 inch in diameter and those for nominal 2 inch lumber should be 14 inch in diameter. Using larger bolts removes too much wood from the end of the member thus reducing the equivalent end distances. After tightening the existing bolts, install the stitch bolts. See figure 3-25.

3.4.12.2 *Yoke Angles and Clamps.* Figure 3-26 illustrates the repair of a minor split occurring at or near the joint of a chord member. Yoke angles or clamps are preferably used in this case since stitch bolts would reduce the effective area of the chord member. Note the boring of a small hole immediately beyond the termination of a split. This treatment has proved helpful in arresting continued splitting.

3.4.12.3 *Steel Banding.* High strength steel banding such as that used to seal shipping cartons has proved effective in arresting spread of splits. The bands should be of high tensile strength steel 1¼ inch wide and 0.035 inch thick. The strapping should be applied with a Signode Model PH 2 stretcher which has no part remaining under the strapping during tightening to cause slackening on removal of the stretcher. The seals should be No. 34SHOC with fastening accomplished with a model SYC3435. See figure 3-27 for a typical steel banding for arresting splits.

3.4.13 Typical Minor Repairs

3.4.13.1 *Minor Splits by Stitch Bolts.* Figure 3-25 illustrates the use of a stitch bolt in repairing scabs in which end splits have developed. Also shown is a stitch-bolted repair to wood columns in which splitting and deep checking along the grains have occurred. Except in unusual cases, it is not necessary to stitch bolt columns unless the split is developing at an angle of 1 to 14 or greater and if the slope of the grain tends to carry the split to the extreme edge of the column. This type of treatment is effective in solid columns.

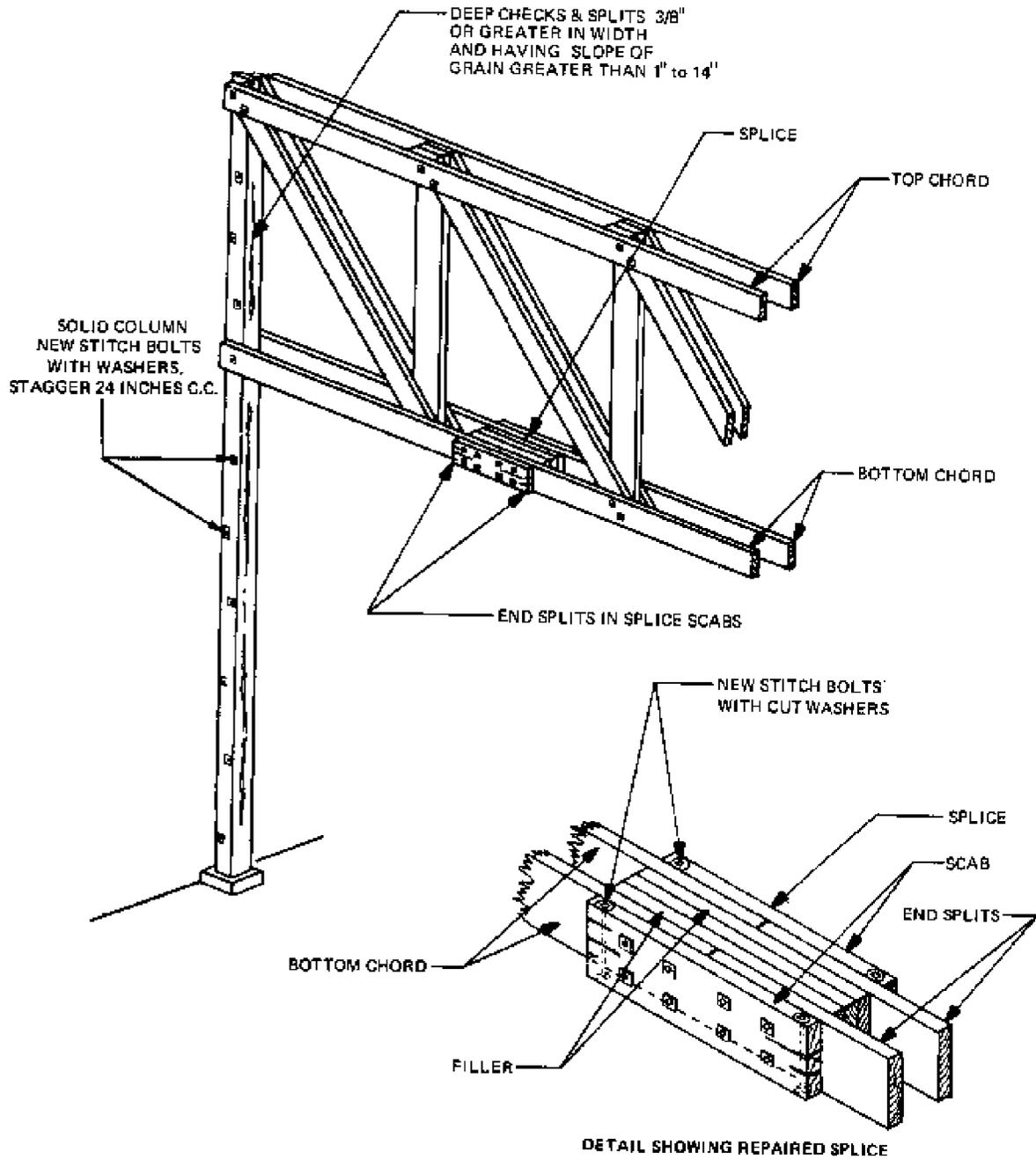


Figure 3-25. MINOR REPAIR OF SPLITS USING STITCH BOLTS.

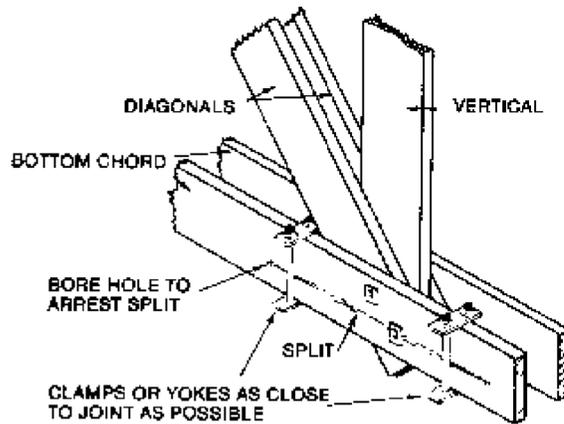


Figure 3-26. TEMPORARY REPAIR WITH YOKE AND CLAMP.

STEEL STRAPPING = 1 1/2" x 0.035" HIGH TENSILE  
 SEALS: NO. 34SHOC  
 SEALER: MODEL SYC 3435

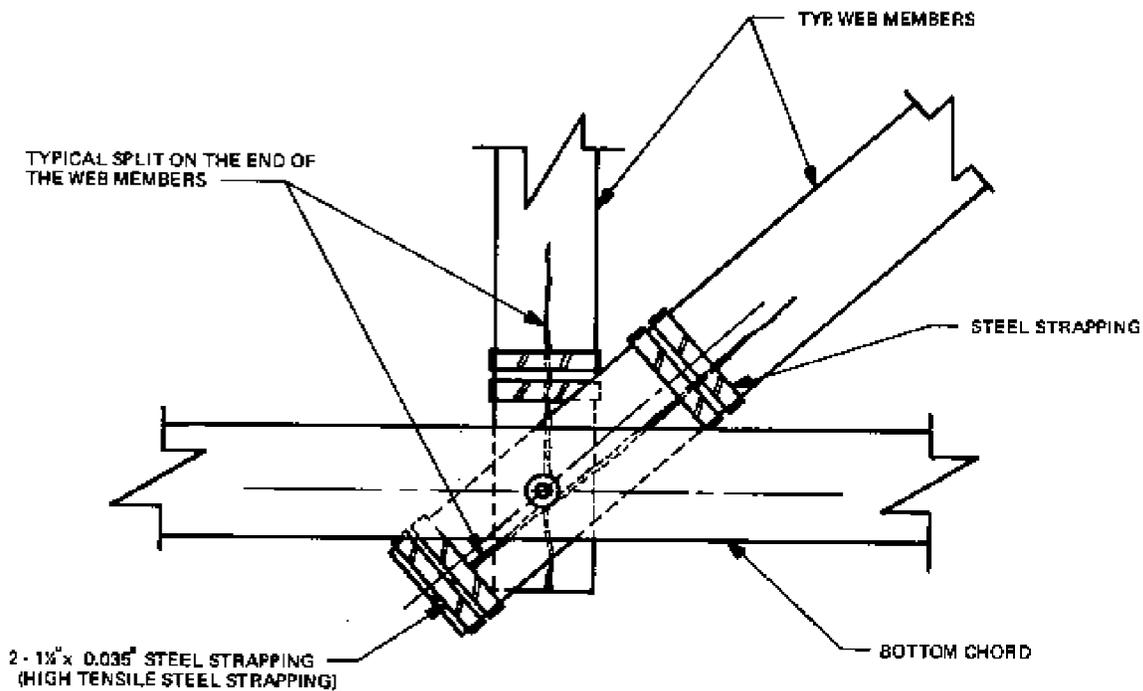


Figure 3-27. TYPICAL STEEL BANDING FOR ARRESTING SPLITS.

3.4.13.2 *Chord Splice Repairs.* Figure 3-28 shows a lower chord splice in which both the splice

members and the chord members were badly warped. This condition usually occurs when trusses

are constructed of light material generally 2 inches thick with depths 8 to 10 inches or greater. The omission of outside splice plates and an inside filler block between the chord was a contributing factor to the conditions shown. The remedy is to install outside splice plates using split rings and the addition of an inside filler block for stiffness, as shown in figure 3-28.

3.4.13.3 *Split Lower Chord.* Figure 3-29 illustrates the repair of a split in a lower chord. The repair is accomplished by adding two splice plates, one on either side of the lower chord and the outside plate carried through the panel point nearest the fracture. The procedure in carrying this splice plate through

the nearest joint is used if there is insufficient room on each side of the fracture to develop the full strength of the member when the splice is bolted in place. Before applying the splice plates, a small hole is drilled ahead of the split to arrest further splitting. Next, a clamp is applied of sufficient size to draw the broken member together. If a member has a thickness greater than 2 inches, a stitch bolt is placed through the member to retain this position. Next, two splice scabs are applied and bolted to the fractured member using sufficient bolts on each side of the break to develop the full strength of the member.

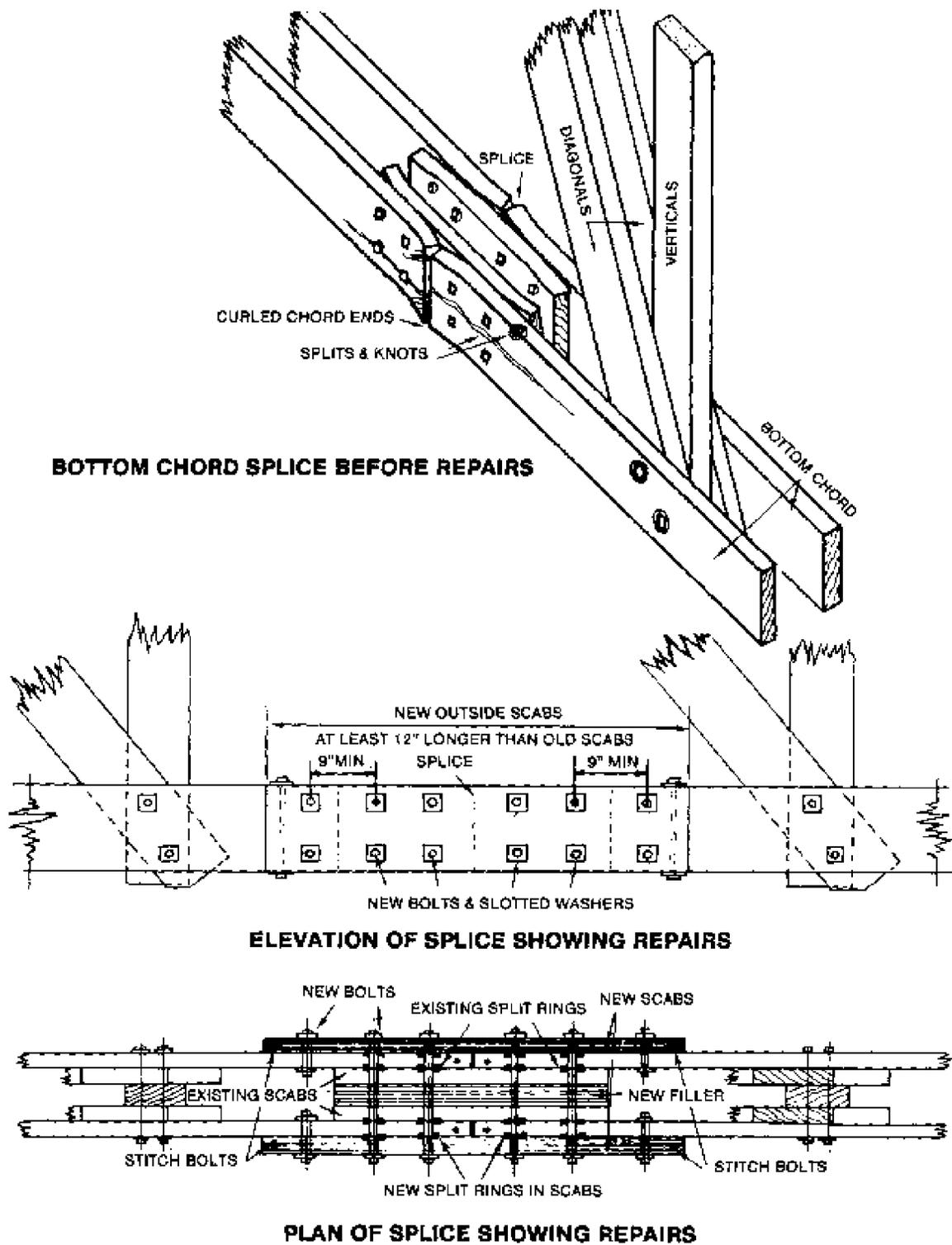


Figure 3 28. TYPICAL CHORD SPLICE REPAIR.

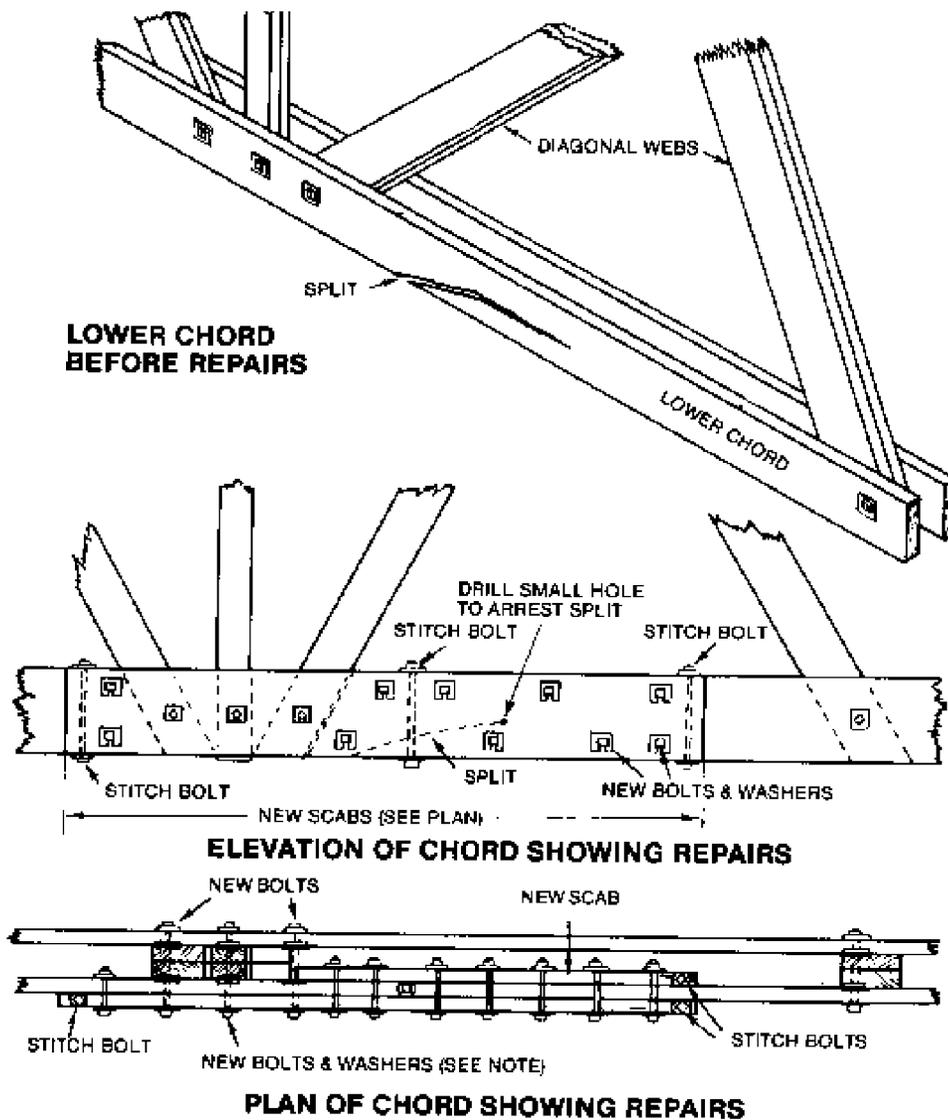


Figure 3-29. REPAIR OF MAJOR SPLIT IN LOWER CHORD.

### 3.4.14 Repair of Complete Breaks.

3.4.14.1 *Lower Chord Using Split Ring Connectors.* In many cases due to extreme knotty conditions and the use of brash (brittle) timber, it will be necessary to repair lower chords when one or more of the members has completely failed. Figure 3-30 illustrates a typical repair for a failure of this type. Note that split rings have been used, permitting the use of fewer bolts and a shorter plate than would be necessary for a bolted connection. However, experience has shown that when such a break appears near a panel point, it is good practice to

carry the splice plates completely through the panel point. The illustration also shows the installation of new filler blocks between the chord members. A break of this type cannot be adequately repaired by adding splice plates to the failed members alone, due to the difficulty in installing split grooves on the inside face of the broken member. Therefore, the splice plate, which would normally be on the inside face of the broken member, is placed on the outside face of the opposite chord member where split rings can be readily installed.

3.4.14.2 *Failed Chords.* Using Bolts Without Con-

nector Rings. Figure 3-31 illustrates an alternate method of repair of the same type of failure as shown. The same principles described in figure 3-32 apply here except that, inasmuch as split ring connectors are not used, the entire repair can be confined to the single broken member. In order to develop the full strength of the failed member, it is

necessary by this method to use a considerably larger number of bolts than required by the former method. It also is necessary to use longer pieces of repair timber. This method is not recommended for large fractures and should only be used when split rings and the equipment necessary for their installation are not available.

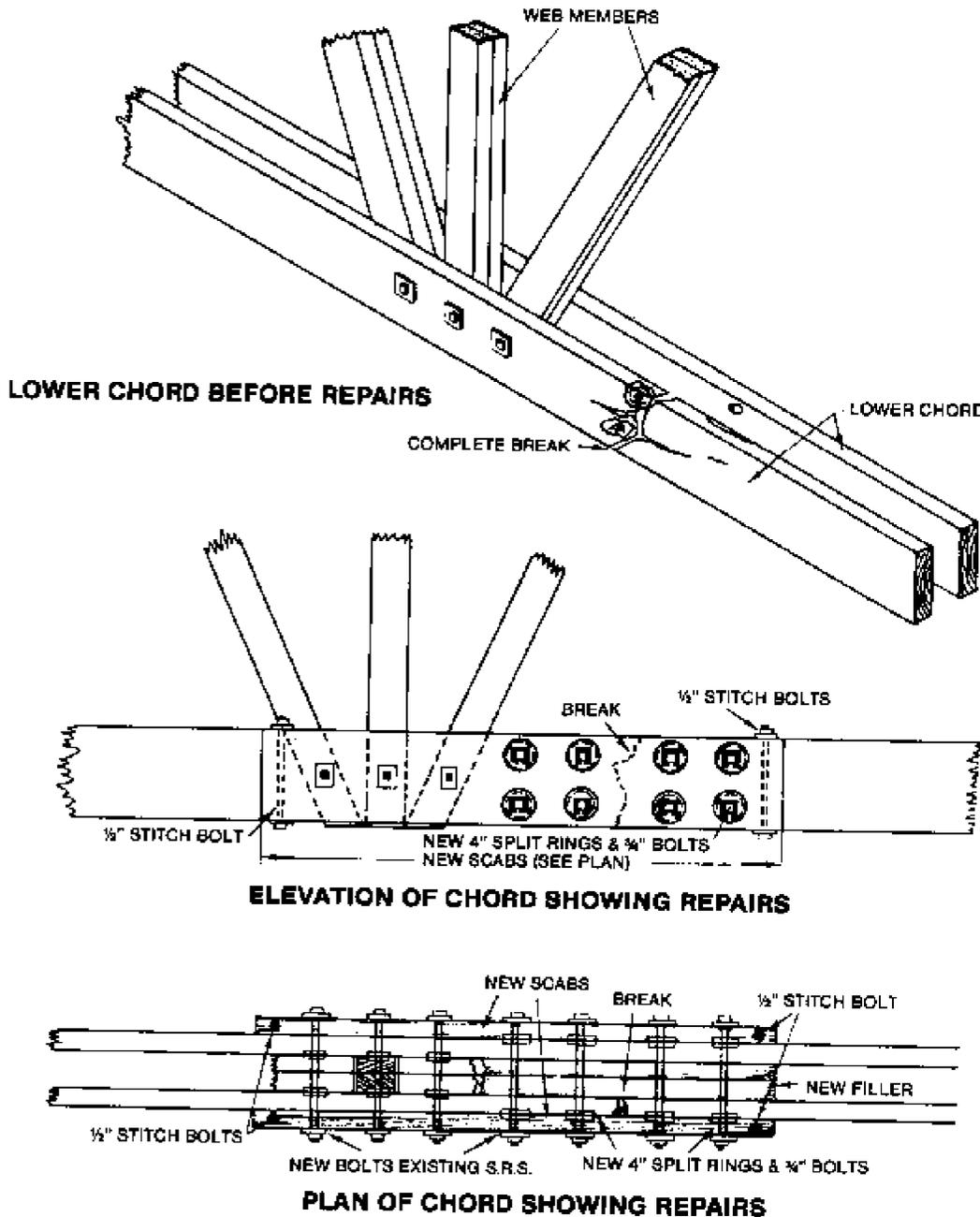


Figure 3-30. REPAIR OF BROKEN CHORD USING SPLIT-RING CONNECTORS.

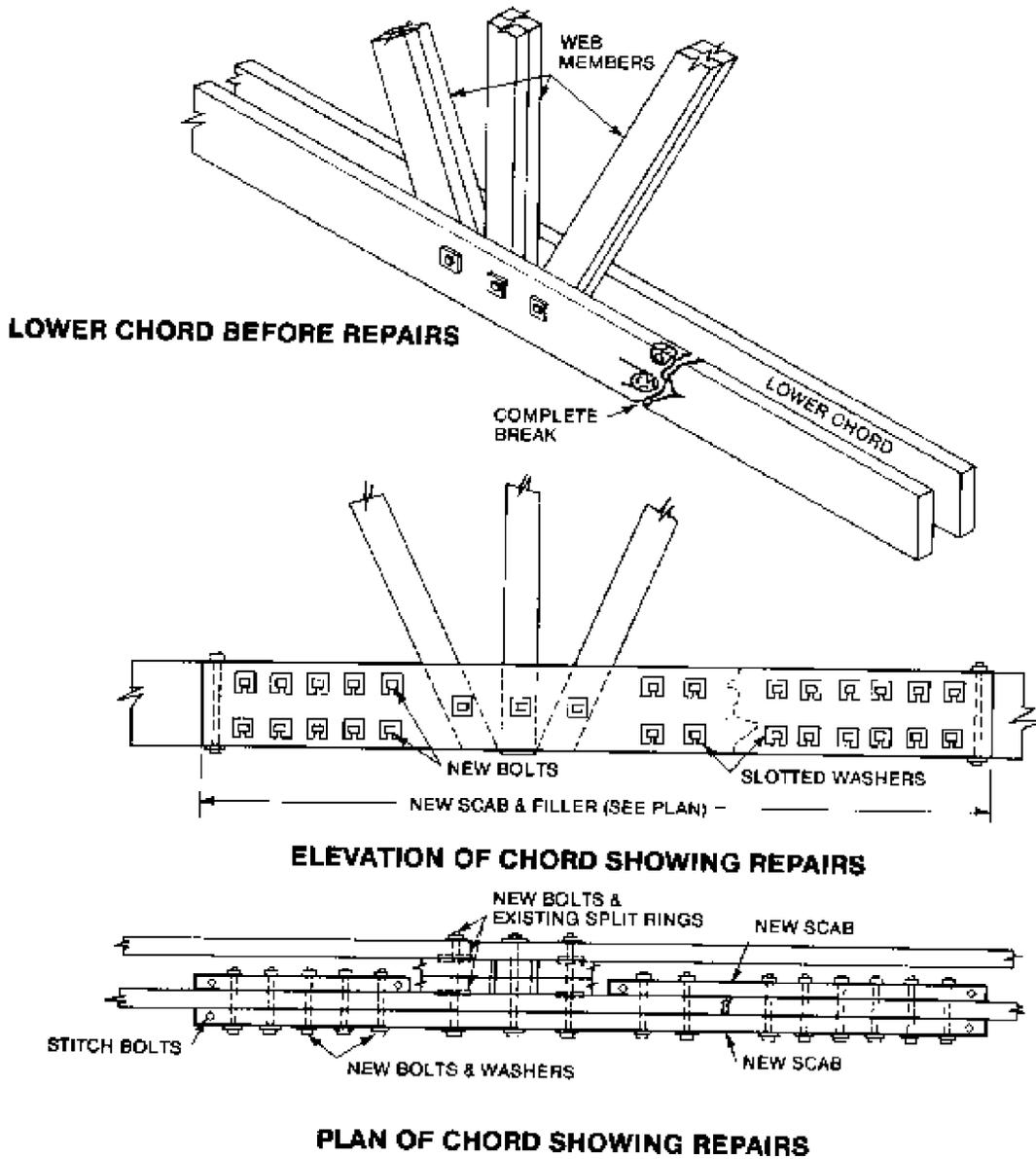
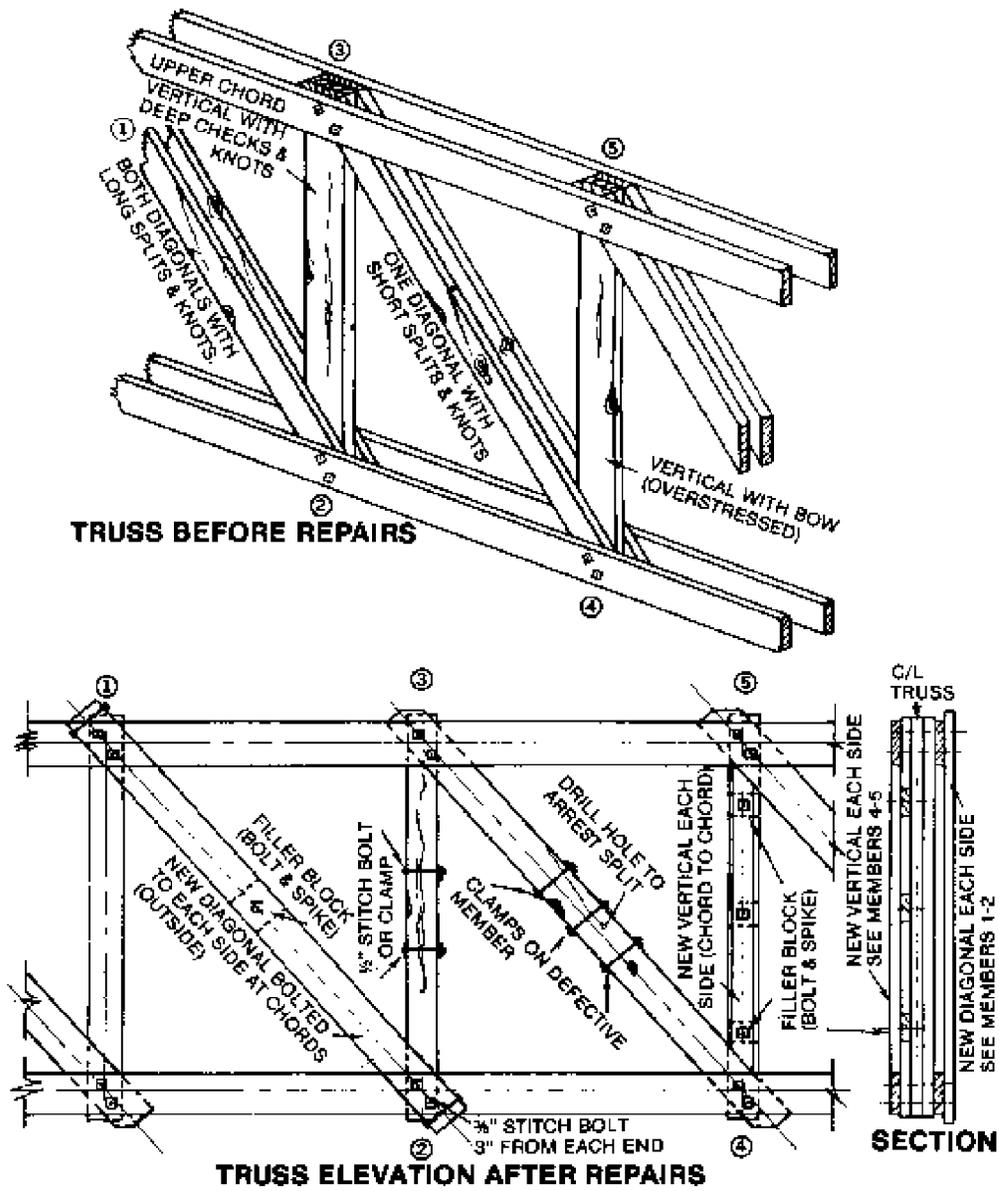


Figure 3-31. LOWER CHORD REPAIR BOLTS.



DIAGONAL 1-2 WITH MAJOR DEFECTS—REINFORCE WITH NEW PIECES  
 DIAGONAL 3-4 WITH MAJOR DEFECTS—REPAIR WITH CLAMPS  
 VERTICAL 4-5 WITH BOW & DEFECTS—REINFORCE WITH NEW PIECES  
 VERTICAL 2-3 WITH MINOR DEFECTS—REPAIRED WITH CLAMPS OR STITCH BOLTS

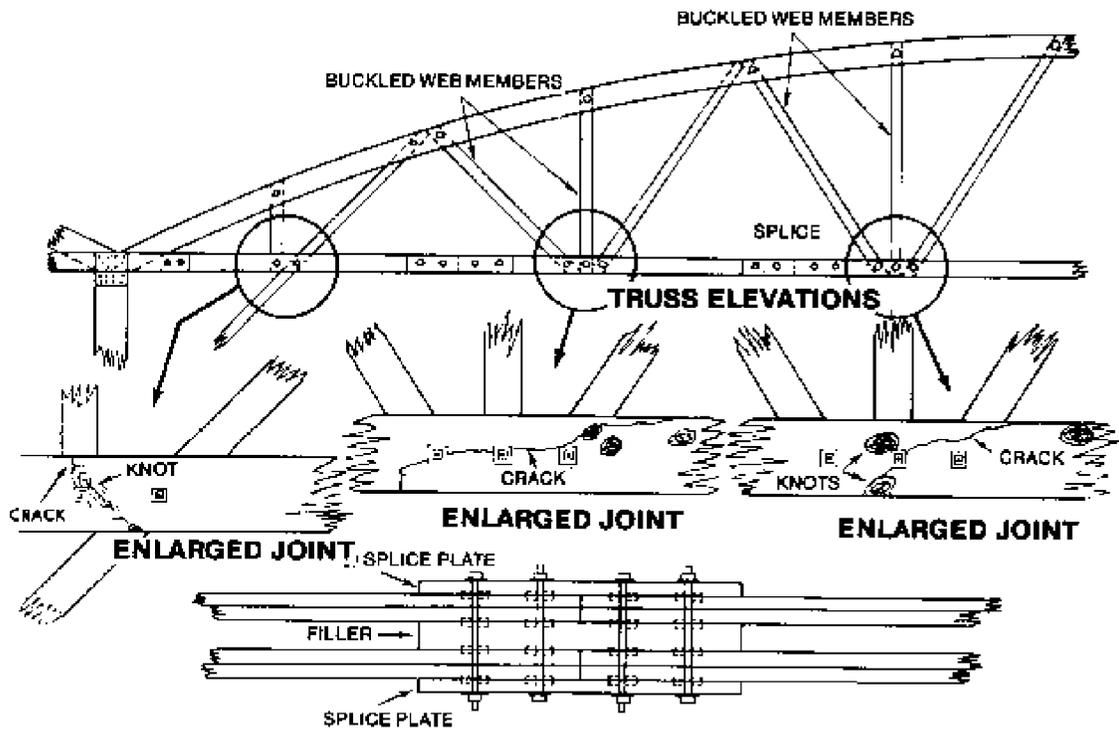
Figure 3-32. TEMPORARY WEB REPAIR.

3.4.14.3 *Web Members*: Figure 3-32 shows a number of typical breaks and defects found in the web members of timber trusses. In the case of member 1-2, where breaks occur in both diagonal members, it has been good practice to install complete new diagonals bolted to each side of the chords, as illustrated in the lower figure for both tension and compression members. For compression members, either verticals or diagonals, repairs can be carried out as illustrated in members 2-3 and 2-4. Neither of these repairs should be used in the case of tension members, which should only be handled by the method shown in 1-2. It is frequently found that vertical compression web members, due to being overstressed, are considerably bowed, as illustrated by member 4-5. This condition is best remedied, as illustrated in the lower figure, by the application of a new vertical

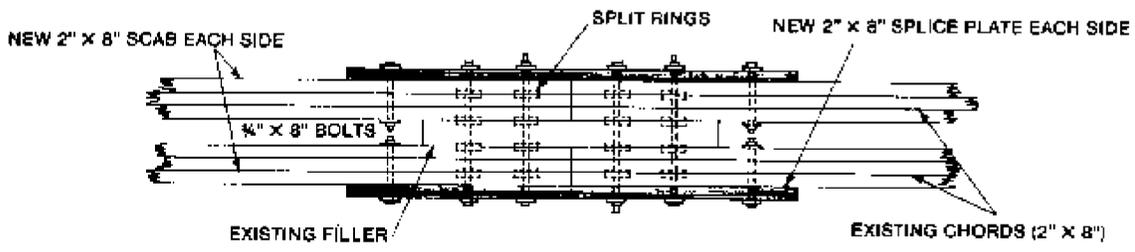
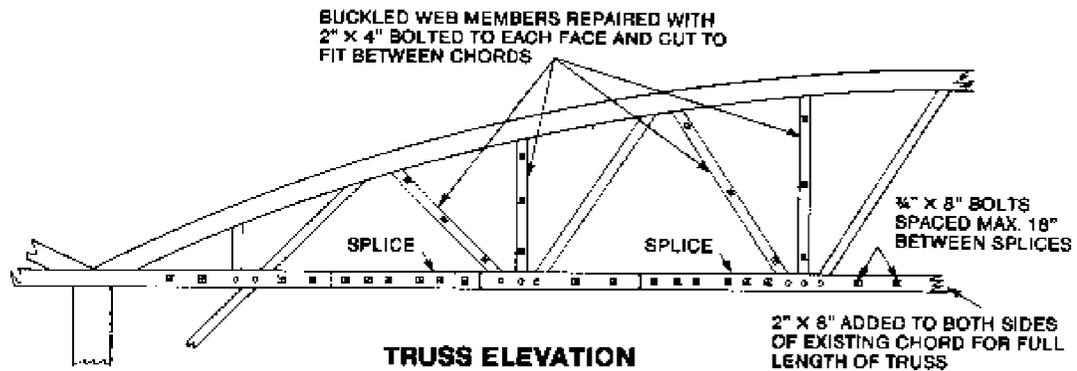
stiffener bolted to each side of the vertical with the necessary filler blocks and through bolts to make a tight connection.

### 3.4.15 Repairs to a Bowstring Truss

To illustrate mass repairs to a truss, figure 3-33 combines typical separate failures examined in a series of trusses. The upper chord, as is generally the case of a bowstring truss, is in good condition; but the web members show signs of lateral deflection and the lower chord has several serious breaks. The lower chord has been repaired by installing new chord members for the full span, using splices as described in paragraph 3.4.13.2 above and illustrated by figure 3-28. The repair of the web members shown in figure 3-32 is described in paragraphs 3.4.10.3 and 3.4.10.4 above.



**TYPICAL BOWSTRING TRUSS IN NEED OF REPAIR**



**SPLICE DETAIL**

**TYPICAL BOWSTRING TRUSS AFTER REPAIR**

*Figure 3-33. TRUSS REPAIR.*

### 3.4.16 Materials Used in Repair

#### 3.4.16.1 Hardware.

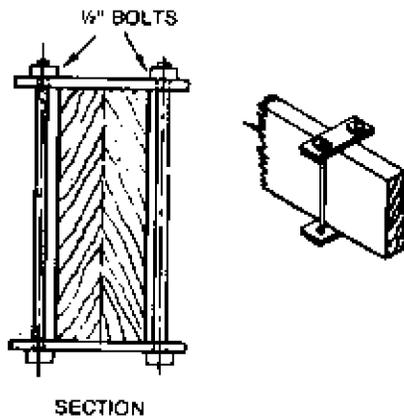
*a. Slotted Washers.* This type of washer can be used as a filler in bolt tightening when the bolts run out of takeup thread. The slotted feature makes it unnecessary in most cases to withdraw bolts from members. The center of gravity of the washer is below the bolt center so that the danger of the washer turning and falling off the bolt is minimized. Slotted washers also can be used in backing up thin-cut washers. Many trusses were originally constructed using cut washers of small diameter. When bolts are tightened, they have a tendency to cup and press into the fiber of the wood. When this condition occurs, a slotted washer or other type of plate washer of proper bearing surface should be placed behind the cut washer before tightening.

*b. Stitch Bolts.* Frequently, it is necessary to prevent cumulative splitting of members. Stitch bolts are effective for this purpose, particularly in counteracting minor end splits in compression members. The stitch bolt consists of a relatively small diameter bolt installed the depth of a member with washers at each end. As stitch bolts require the drilling of a hole the depth of the member, with consequent reduction of cross-sectional area, their use in tension sections must be employed with caution.

*c. Yoke Angles and Clamps.* Yoke angles and clamps may also be used to confine splits and

retard cumulative checking and splitting. Details are shown in figure 3-34. Since clamps and yoke angles do not create a reduction in the net section of a member, their use in a tension member is satisfactory. It is particularly important, however, to keep an assembly of this nature constantly tightened.

*d. Ring Connectors and Shear Plates.* Figure 3-35 details the type of 4-inch split rings and 4-inch shear plates currently in use. The assembly of both the shear plate and the split ring is indicated and represents assembly for new or original work. In many cases, it is desirable to replace wooden scabs with steel plates, necessitating the use of shear plates where split rings were originally used. As the shear plate is of smaller diameter than the split ring, some means of adapting this shear plate to the cutout for the split ring must be used. For this purpose, a shear plate bushing has been developed permitting a flush connection without further dapping of the wood member. Additional dapping is costly and may dangerously reduce the net section of the member. This method is illustrated by A and B of figure 3-35. Split rings and shear plates are only effective when properly fitted to the timber. This can only be accomplished successfully through the use of proper tools. Cutterheads and accessories are available through regular supply sources. This procedure is not applicable to the 2½ inch split ring since the comparable shear plate is 2e inches.

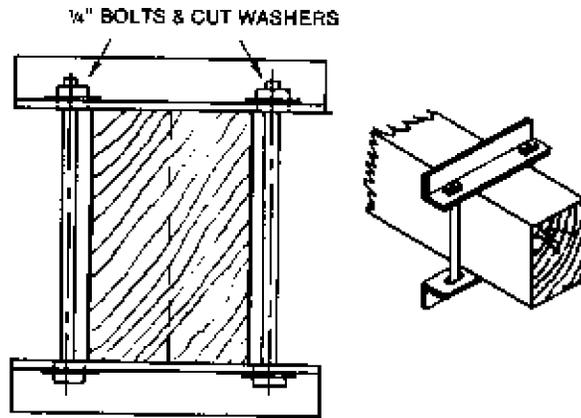


SECTION

**TYPE A**

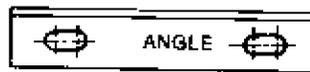


PLAN

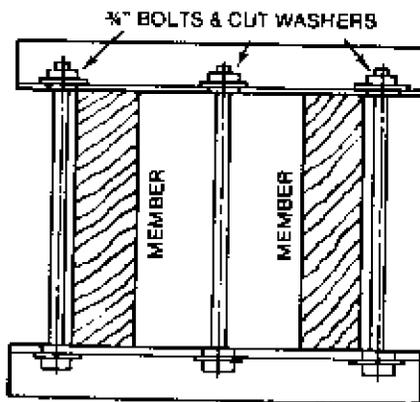


SECTION

**TYPE B**

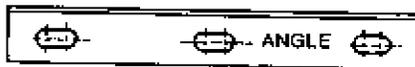


PLAN



SECTION

**TYPE C**



PLAN

**TYPE A**

FOR 1 OR 2 MEMBERS UP TO 4" THICK

**TYPE B**

FOR 1 OR 2 MEMBERS FROM 4" TO 8" THICK

**TYPE C**

FOR DOUBLE MEMBERS SEPARATED FROM 6"-10". FOR TRIPLE MEMBERS USE TWO INSIDE BOLTS

IF MEMBERS ARE SEPARATED OVER 10" USE INDIVIDUAL TYPE "A" CLAMPS

Figure 3-34. TYPICAL YOKE AND CLAMP DETAILS.



#### 3.4.16.2 Timber for Repair Purposes.

a. *Species of Wood.* If inspection reveals that scabbing and reinforcing are necessary, it is of prime importance that mistakes made in original construction are not repeated in repair. Material, design, and workmanship must be carefully considered. Only wood suitable for structural purposes will be used in the repair of timber structures. The most common structural woods are Douglas fir, larch, southern pine.

b. *Grades.* Stress grades of structural woods are specified for all repairs. Generally, acceptable grades to specify for repair purposes are obtained from the latest edition of the "National Design Specifications for Wood Construction" published by the National Forest Products Association. Record plans and original design analysis should be closely studied to determine the original design assumptions and conditions. In the absence of these data, request guidance from the next highest command supervisory authority.

c. *Painting Ends of Members.* Wood dries more rapidly at end-grain than at side-grain surfaces. The tendency to check is, therefore, more pronounced in the end grain. A moisture-resistant end coating is recommended to protect such surfaces from checking during air seasoning. End coatings will be applied as soon as possible to the freshly cut end surface, for end checks, once started, tend to go deeper into the wood as drying progresses. End coatings may be divided into two classes: those that are liquid at ordinary temperatures and can be applied without being heated, and those that are solid at ordinary temperatures and must be applied hot. Two cold coatings being tested at the Forest Products Laboratory, U.S. Department of Agriculture (Technical Note No.186) are phenolic-resin varnish, pigmented with aluminum paste or powder, and filled hardened gloss oil. Both are tough and easily applied. Hot coating materials include pitch, asphalt, resin, and paraffin. The Forest Products Laboratory maintains a list of vendors of these materials.

#### 3.4.17 Repair of Rafters, Purlins, and Bracing

Examine rafters, purlins, and bracing periodically for damage primarily due to roof leaking. If rafters or purlins sag from overload, they are repaired by splicing additional member or members to the existing ones.

#### 3.4.18 Truss Bracing

A common fault of many trusses is the lack of adequate bracing. Trusses require bracing to keep top and bottom chords from bowing from a straight line and to prevent them from tipping from a vertical plane. The primary element for truss bracing is the roof itself; therefore, purlins and joists should be securely fastened to trusses. See figure 3-36. Trusses can be stiffened by adding bracing and it is possible to minimize other repairs through the provision of adequate bracing. The most common types of bracing include the following:

3.4.18.1 *Top Lateral Bracing* Top diagonal bracing is used in the plane of the upper chords. The purlins act as struts. Usually two pairs of crossing diagonals are used in each outside bay on each side of the roof. These diagonals brace the trusses together in pairs. The purpose of this bracing is to stiffen the structure, as the diagonals have no calculated stress. See figure 3-38.

3.4.18.2 *Bottom Lateral Bracing* Bottom lateral bracing, together with the horizontal struts or runners, are attached to the bottom chords of trusses and serve to tie the trusses together. Usually, bottom lateral bracing is not provided for big trusses unless vibration due to heavy equipment or machinery is anticipated. See figure 3-37.

3.4.18.3 *Vertical Sway Bracing.* Vertical sway bracing is usually in a vertical or incline plane, along the centerline, along a sloping plane, or between columns. It is used in connecting the top of one truss to the bottom of the other. It is very useful during erection, and it resists wind pressure on the ends of the building. See figure 3-38.

3.4.18.4 *Knee Bracing* Knee bracing is often used in large structures, and it is used in connecting columns to the trusses. This kind of bracing is used more for rigidity than strength. It is always designed as a compression member, while all other bracings are preferably designed as tension members. See figure 3-39.

#### 3.4.19 Epoxy Repair of Trusses

Repair of trusses using pressure-injected epoxy compounds has been economically and successfully applied in recent years by comparison to conventional repair methods such as replacement, scabbing, and stitch bolting. This method is particularly useful when disruption of work activities below the repair is of concern. The procedure consists of three steps: preparation, placement of injection ports, and epoxy seal injection.

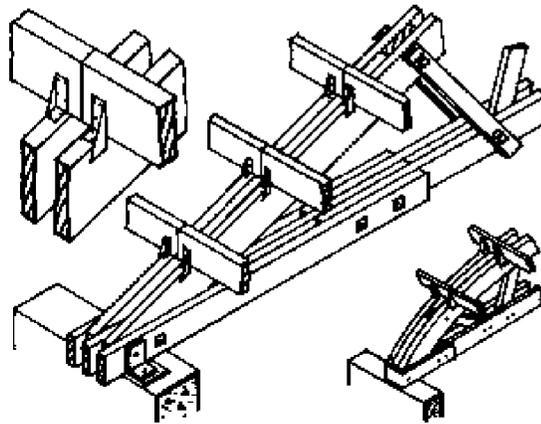
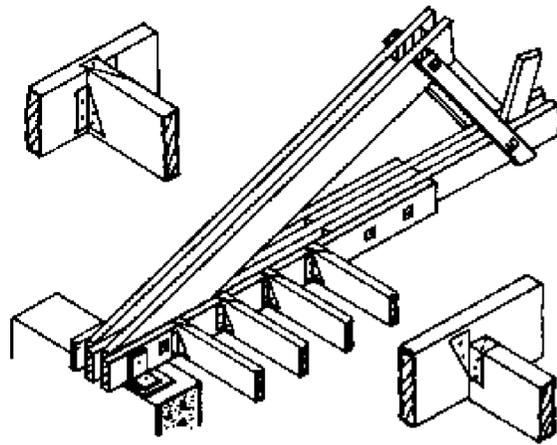


Figure 3-36. JOISTS FASTENED TO TRUSSES.

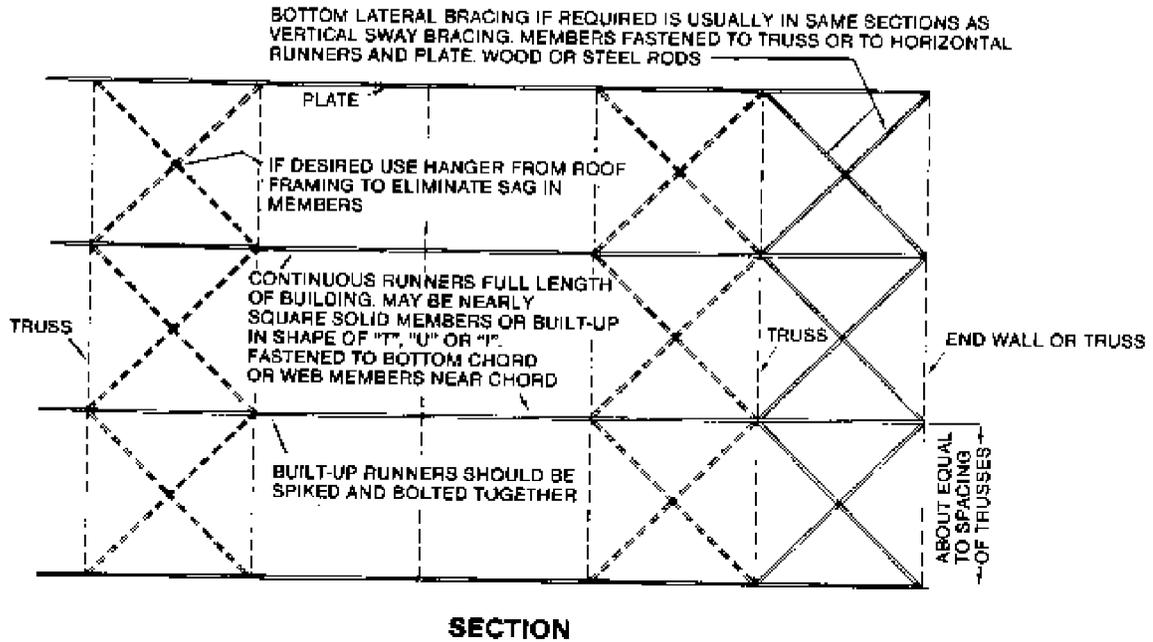
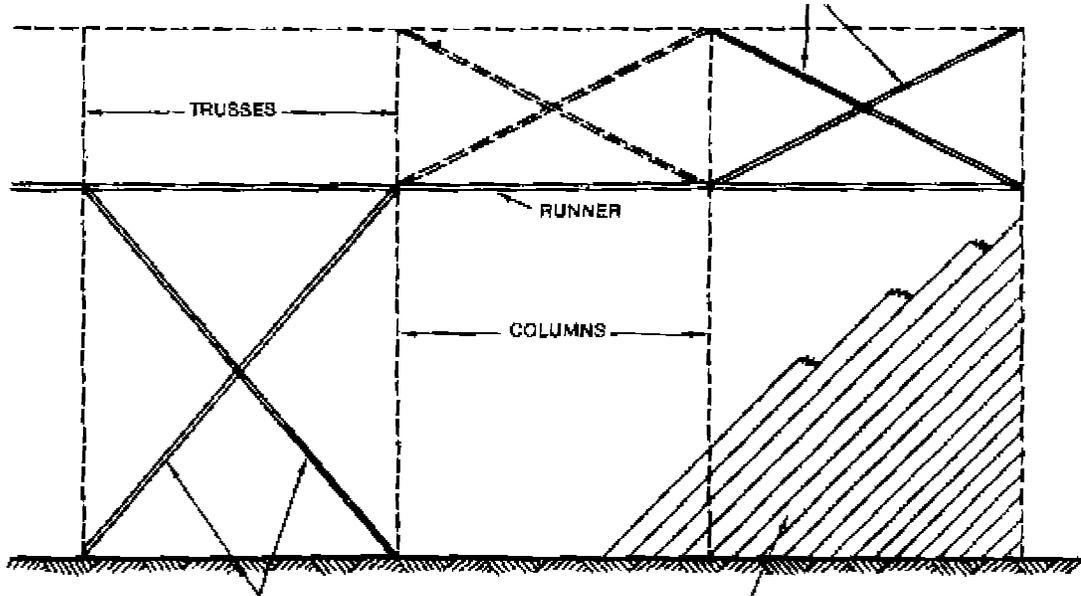


Figure 3-37. BOTTOM LATERAL BRACING.

**TOP LATERAL BRACING**

DIAGONAL ROOF SHEATHING OR TONGUE-AND-GROOVE SHEATHING WELL APPLIED TO JOIST OR PURLINS WHICH ARE IN TURN SECURELY FASTENED TO THE TRUSS IS USUALLY SUFFICIENT FOR TOP CHORD LATERAL BRACING. IN SOME CASES HOWEVER BRACING SIMILAR TO BOTTOM LATERAL BRACING SHOULD BE APPLIED IN THE PLANE OF THE TOP CHORDS.

VERTICAL SWAY BRACING IN END SECTION AS A MINIMUM. POSSIBLY TWO SECTIONS EACH END AND NEAR MIDDLE FOR LONG BUILDING. WOODEN MEMBERS OR STEEL RODS. FASTEN TO TRUSS, ROOF STRUCTURE, OR RUNNERS.



COLUMN AND WALL BRACING WHERE POSSIBLE. DIAGONAL SHEATHING WITH STUDS.

**SECTION**

*Figure 3-38. TOP LATERAL AND VERTICAL SWAY BRACING.*

PURLINS OR JOISTS MUST BE SECURELY FASTENED TO THE CHORD, WHERE POSSIBLE EXTENDS TRUSS WEB MEMBERS TO MAKE CONNECTION.

SCAB OR LAP

SCAB OR LAP

BRIDGING SHOULD BE INSTALLED BETWEEN PURLINS OR JOIST. PURLINS OR JOISTS SHOULD BE LAPPED OR JOINED BY SCABS OVER SUPPORTS. FRAMING ANCHORS MAY BE USED TO FASTEN JOIST TO TOP CHORD OF TRUSS.

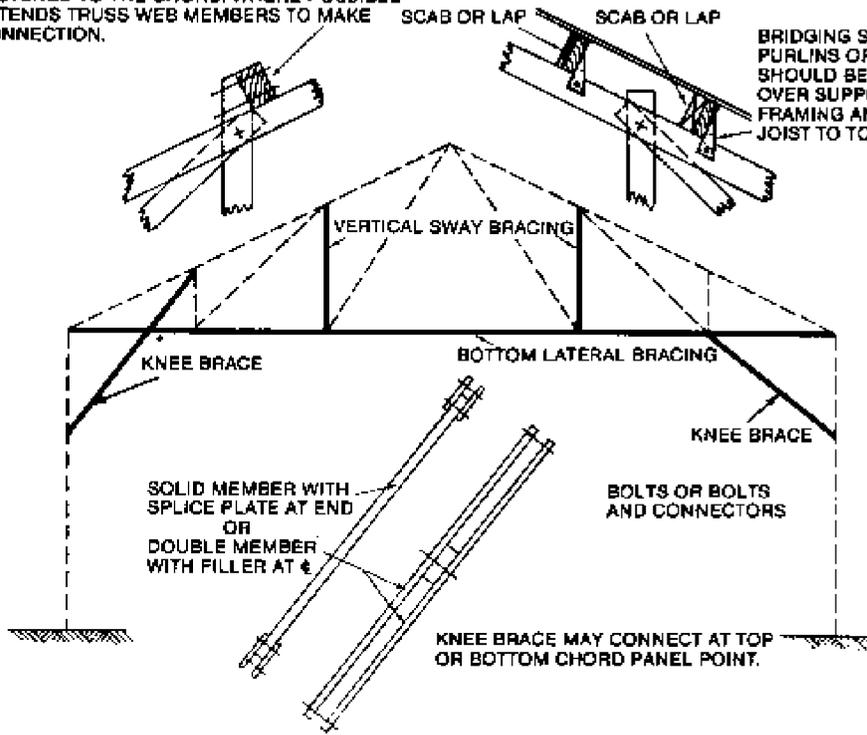


Figure 3-39. KNEE BRACING.

3.4.19.1 *Advantages and Limitations.* There are several advantages to using epoxy repair when repair conditions are favorable. Properly applied, the repaired joint is actually stronger than the original joint before it was damaged. However, this is not true with other repair methods. The second advantage is that epoxy repair requires little shoring. The third advantage is that it is cheaper (as much as 50 percent) than conventional replacement methods. The fourth advantage over other methods is that the epoxy repair can reach inside of the damaged joint. There are two major advantages in the use of epoxy repair. First, temperature can be critical and must be considered before starting repair. When the air temperature is high (125°F or 51.7°C and above), epoxy repair should not be attempted. Second, a determination of whether the entire outside of the joint can be reached for sealing must be made; all cracks and openings must be sealed before injection or the joint will leak and may lose its strength.

3.4.19.2 *Structural and Nonstructural Repair.* Epoxy repair can be divided into two broad types: structural and nonstructural. Nonstructural applications include waterproofing, crack sealing, and cosmetic repairs. Repairs of the nonstructural type are usually quite simple because the goal is to provide a seal. The work effort is successful if the repair prevents leaks. Structural repair can be difficult. Often the total damage is not visible. Cracks may be very small or as large as 1 inch or more. Sealing before injection can be difficult and, for a successful repair, it must be complete. Epoxy must be injected into all voids for the repair to be suc-

cessful. More care and attention to detail are required than for nonstructural repairs.

### 3.4.20 Types of Epoxy Repair:

3.4.20.1 *Type A-1.* Epoxy injection of cracked or split members at truss joints.

3.4.20.2 *Type A-2.* Epoxy injection and reinforcement of decayed wood.

3.4.20.3 *Type A-3.* Splicing and epoxy injection of broken members.

3.4.20.4 *Type B-1.* Epoxy injection of longitudinal cracks and splits away from joints.

3.4.20.5 *Type B-2.* Repair of bearing surfaces using epoxy gel.

### 3.4.21 Strength of Epoxy Repairs.

Among the many factors affecting repair are the many joint types that require repair. Figure 3-40 shows a group of truss joints. As can be seen in the illustration, the number of members, lap area, grain orientation, and number of mechanical connectors will vary. Other important factors are thickness of members, age of wood, and crack width between lapped surfaces. Planning a repair effort should consider the following:

3.4.21.1 *Degree of Damage.* Because epoxy repair is used to provide the shear resistance in lapped members, the degree of damage is usually not important. As long as there are adequate lapped surfaces for bonding, the strength of the joint can be completely restored. The major exception is decay. Repairing a decayed member is difficult and requires special expertise.

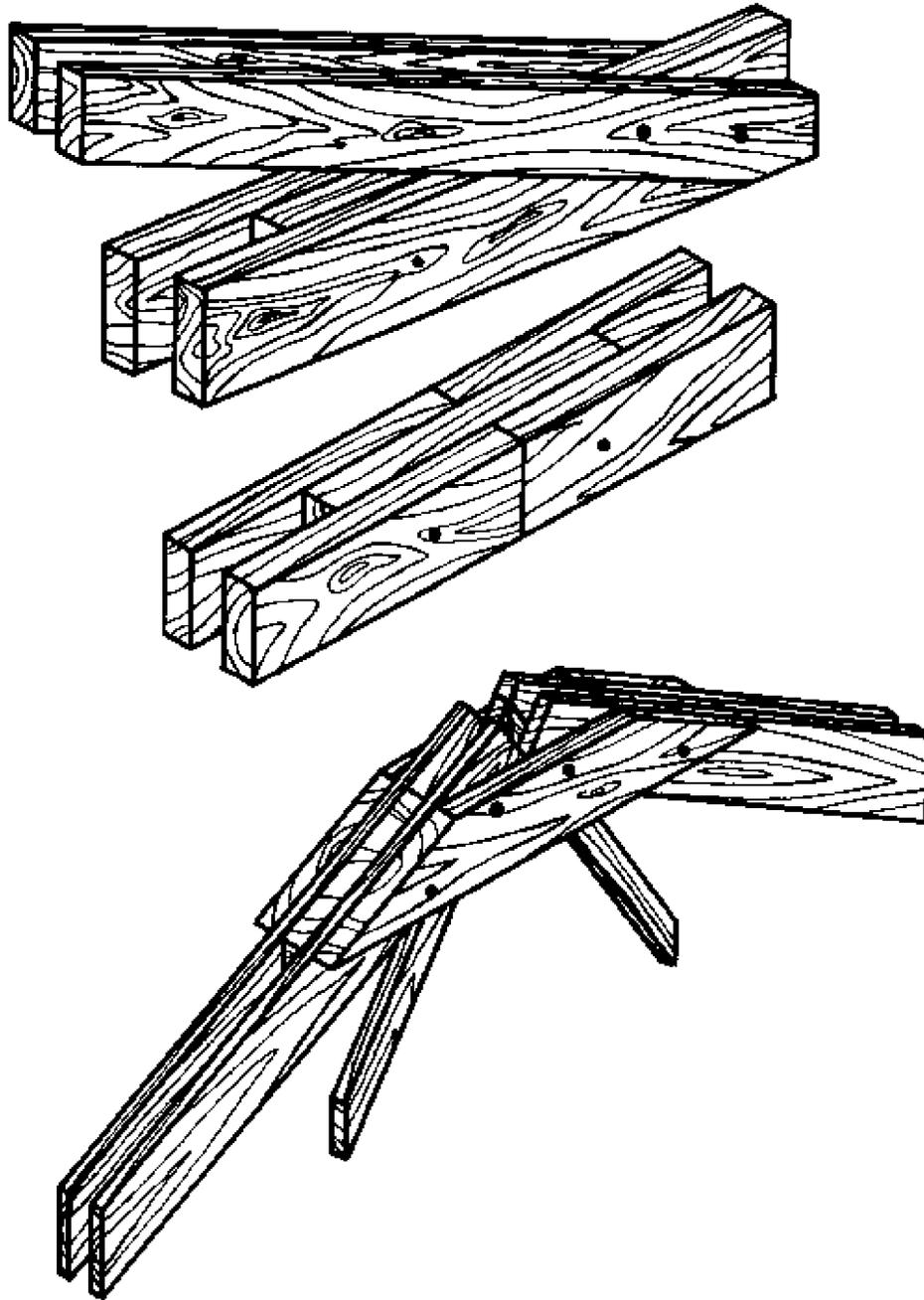


Figure 3-40. TYPICAL JOINTS IN TIMBER TRUSSES.

3.4.21.2 *Effect of Mechanical Connectors.* All joints in wooden trusses must have some sort of connector. In older trusses mechanical connectors such as bolts, split rings, and toothplates have been used. Often it is found that some connectors have been omitted or, if the joint is badly damaged, the connectors may have fallen out. After epoxy repair

the strength of the joint is not affected by a missing connector. A glue line must fail (or deform badly) before the load can be transferred to the connectors. The load required to fail the glue line is usually greater than the connector's ability to carry the load. When the glue line fails, the connector will fail in most cases.

3.4.21.3 *Width of Overlap.* Tests have established that the failure stress of a bonded lap joint is not affected by the width of the overlap.

3.4.21.4 *Length of Overlap.* Bonded double lap-joint strength is directly related to the length of the lap in relation to the thickness of the middle member. Thickness of the lap does not add to the strength of the repair.

3.4.21.5 *Effect of Grain Orientation.* Tests indicate a load-capacity loss of a repaired joint as the grain angle changes from 0° to 90°.

3.4.21.6 *Effect of Glue-Line Thickness.* The effect of the glue-line thickness on joint strength is so small that it can be discounted.

**3.4.22 Characteristics of Epoxy Compounds**

3.4.22.1 *Chemical Grouts.* Chemical grouts consist of two or more chemicals which react to form either a gel or solid. This is in contrast to cement grouts which consist of solid particles suspended in a liquid.

3.4.22.2 *Epoxy Resins.* These resins are two-component systems made of a resin base and a hardener (catalyst). Flexibilizers are sometimes added to prevent cracking of the set glue due to movement of the joint. Epoxy resins are available that cure in high moisture areas. They have the following characteristics:

- a. Ability to resist acids, alkalis, and organic chemicals.
- b. Ability to cure without volatile byproducts.
- c. Ability to cure without external heat.
- d. Ability to accept various thickening agents.

Once hardened epoxy resins will not liquify when heated (thermosetting) but will soften. The required characteristics of epoxy resins to be used in wood structural repair are shown in table 3-3.

*Table 3-3. Mechanical Properties for Resins Used in Repair of Wood Structures*

Characteristics	Low viscosity injection material	High viscosity sealing gel
Pot Life (min) . . . . .	10-60	10-60
Initial cure (hr) . . . . .	1-8	1-8
Final Cure (day) . . . . .	2-5	2-5
Viscosity (c/s) . . . . .	200-500	Nonsagging
Hardness (shore D) . . . . .	80-100	80-100
Modulus of Elasticity (k/in <sup>2</sup> ) . . . . .	0.4-0.6	0.4-0.6
Tensile Stress (k/in <sup>2</sup> ) . . . . .	5-8	5-8
Compressive Stress (k/in <sup>2</sup> ) . . . . .	5-10	5-10

**3.4.23 Steps in Epoxy Repair**

There are four basic steps in the epoxy repair procedure. Each step is described in the following paragraphs:

**3.4.24 Special Member Preparations**

The preparation of the repair area can range from little to extensive. Individual judgment is necessary to determine the preparations required. The following items should be considered prior to any epoxy repair:

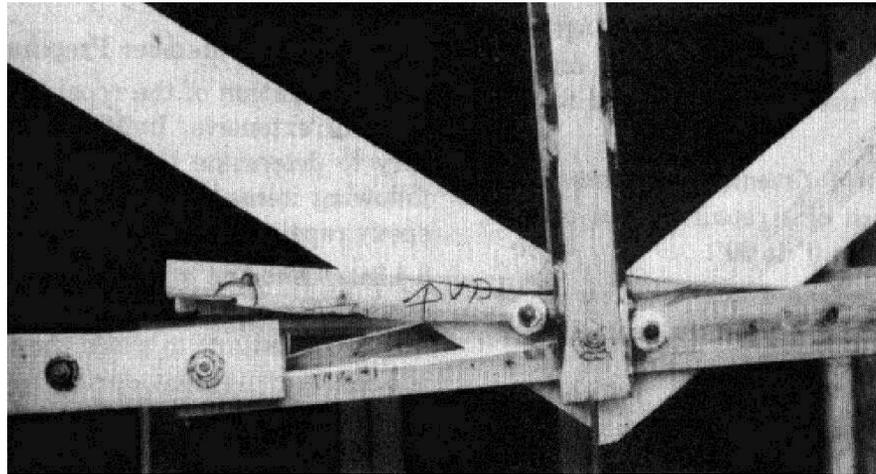
3.4.24.1 *Shoring and Jacking.* In cases where excessive damage or deterioration has occurred, it may be necessary to shore the member to prevent additional movement during repair or to jack the member back to a more normal position. Based on field observations of damaged buildings, jacking has been required only in isolated instances. Three reasons for considering jacking are: (1) to remove excessive sag, (2) to relieve stresses, and (3) to close large cracks. Jacking to relieve stresses is not recommended. Experimental studies have shown that it is difficult to close cracks by jacking and that the size of the crack is unimportant in the epoxy repair process. Therefore, the only reason to jack a truss before repairing would be to remove excessive sag. Only if the sag/span ratio exceeds 1/240, should jacking be considered. If jacking is necessary, extreme caution should be exercised. Stress reversals could cause member failures, especially in the vicinity of the jacking points. The differential movement may also damage attachments such as roofing. In general a structural analysis of the system should be conducted to determine the maximum jacking force permissible. If jacking is necessary, gages to measure the jacking forces should be utilized during the operation.

3.4.24.2 *Addition of Splice Plates.* Some repairs may require the addition of splice plates, e.g., a broken member. The epoxy repair technique is most effective for lapped joints in which the epoxy is injected between the lapped surfaces to provide shear resistance. For broken members, splices are tacked on both sides of the broken member (as shown in figure 3-41) to be later injected with epoxy. Since most failures occur at joints already consisting of lapped members, additional splice plates are generally not necessary.

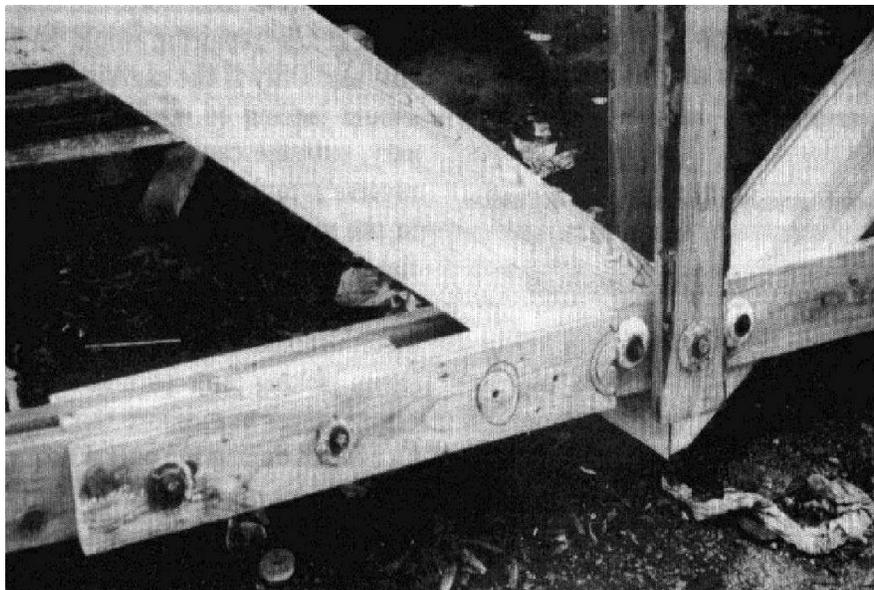
3.4.24.3 *Removal of Moisture Source.* For moist or decayed sections, the moisture source must be eliminated to protect the member from further deterioration. Although most epoxy formulations adhere in moist environments, the moisture may cause the decay to continue in encapsulated or ad-

adjacent areas, and resulting in further deterioration. If the moisture content exceeds 20 percent, the member should be dried out before repair and the

source of the high moisture eliminated. For trusses, the roof should be repaired so that continued leaking will not contaminate the repaired member.



**(A) DAMAGED TRUSS JOINT**



**(B) OLD SPLICE PLATE REMOVED AND LONGER SPLICE PLATE ADDED**

*Figure 3-41. PREPARATION OF MEMBERS BY ADDING SPLICE PLATES.*

3.4.24.4 *Reinforcement.* For severely decayed members, reinforcing elements may be necessary. Holes are drilled and fiberglass reinforcing rods inserted to form either a strong connector pattern between sound and unsound wood, or a stiffening internal truss or frame for increasing load carrying

capacity. See figure 3-42 Epoxy injection will bond the reinforcing members to the surrounding wood to provide increased strength. Since little experimental evidence is available, this procedure should not be used without careful engineering analysis.

3.4.24.5 *Cleaning*. The area to be repaired should be thoroughly cleaned, with all dust and debris cleared to provide a good bonding surface. An air jet from a compressed air source has been found to be very effective for this purpose.

3.4.25 *Joint Sealing*.

The area to be repaired must be completely sealed on the exposed surfaces except for injection and bleeding ports. The success of the repair largely depends on the effectiveness of the sealing. The sealant used should be a high viscosity epoxy with

a puttylike consistency (referred to as a gel). The usual steps in the sealing process are as follows:

3.4.25.1 *Port Setting*. The placing of the ports serves three purposes. First, a means is provided for injecting epoxy into the interior of the damaged area; second, a means is provided for venting the air which is displaced by the epoxy during the injection process; and third, a means is provided for determining the penetration of the epoxy into the damaged area.

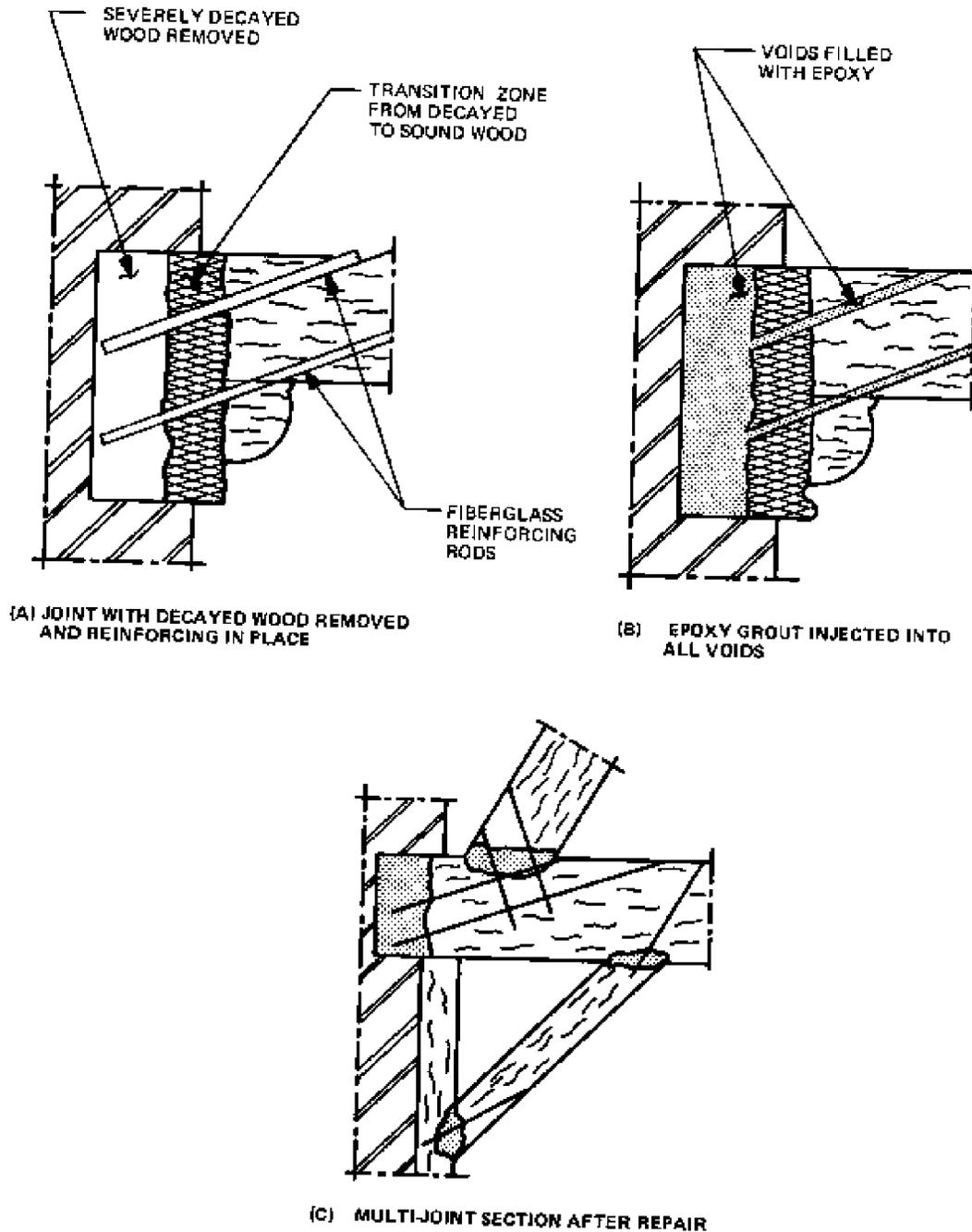


Figure 3-42. REINFORCED EPOXY REPAIR.

*a. Materials.* One of the most common materials used for ports is 1/4-inch-diameter copper tubing. Also frequently used is small diameter (1/4 to 3/8 inch) standard pipe. Plastic tubing has also been successfully used. The primary requirements for port materials are that the part should be bondable with the epoxy gel, and that it can be sealed or closed during the injection itself.

*b. Placement of Ports.* Ports are placed by drilling holes with a diameter identical to the outside diameter of the port. The port is inserted into the hole and sealing gel is applied around the port. The depth of the hole depends on its location and type. Recalling that the key to a successful epoxy repair is insuring penetration into all lapped surfaces, the ports should be placed to maximize

penetration. Alternative placement methods are shown in figure 3-43. One method is to place the port at the juncture of the lapped surfaces as illustrated by port type A in figure 3-43. The hole is drilled at an angle to the surface while insuring that the hole includes the lap area. The depth of the hole should be approximately  $\frac{1}{2}$  inch. The second method is to drill holes perpendicular to the lapped surfaces as illustrated by port type B in figure 3-43. This method allows easier installation and allows the penetration of multiple lap planes by drilling the hole deeper. The hole should be drilled deep enough to penetrate the lapped surfaces desired. For either method the port should only be inserted approximately  $\frac{1}{4}$  inch into the hole. After placement, the port should be sealed with gel. The gel should be built up around the port as shown in figure 3-44. It is important to build up the gel to prevent leaking during injection and capping.

c. *Location and Number of Ports.* The minimum number of ports for single lapped surface is three. Two ports are usually placed at the top and one at the bottom as shown in figure 3-43, however, placement may vary depending on the shape of the lapped surfaces. For members oriented at an angle-to-grain, three ports per lapped surface are usually sufficient. Hence, the total number of ports would be three times the number of lapped surfaces at a joint. However, for parallel-to-grain members such as splices, the lap area may be long enough to justify additional ports. It is recommended that two ports per lapped surface be provided (one top and one bottom) for every 2-foot length of spliced members. Figure 3-45 shows installed ports in place for typical joints. Another location for ports would be the cracks and splits. It is recommended that single ports be placed at the extreme ends of all longitudinal splits with additional ports placed at 3-foot increments.

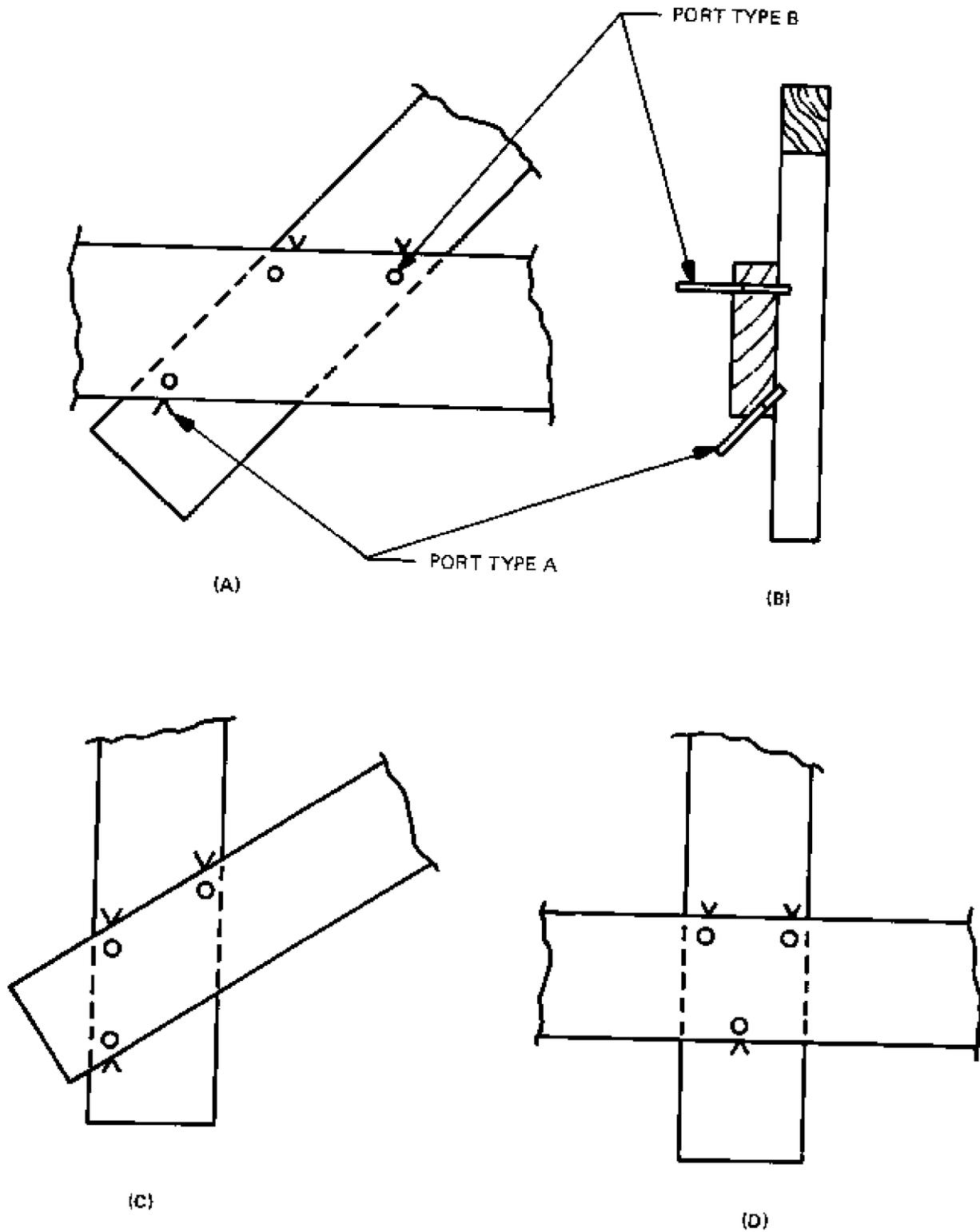


Figure 3-43. ALTERNATE METHODS OF SETTING INJECTION PORTS.

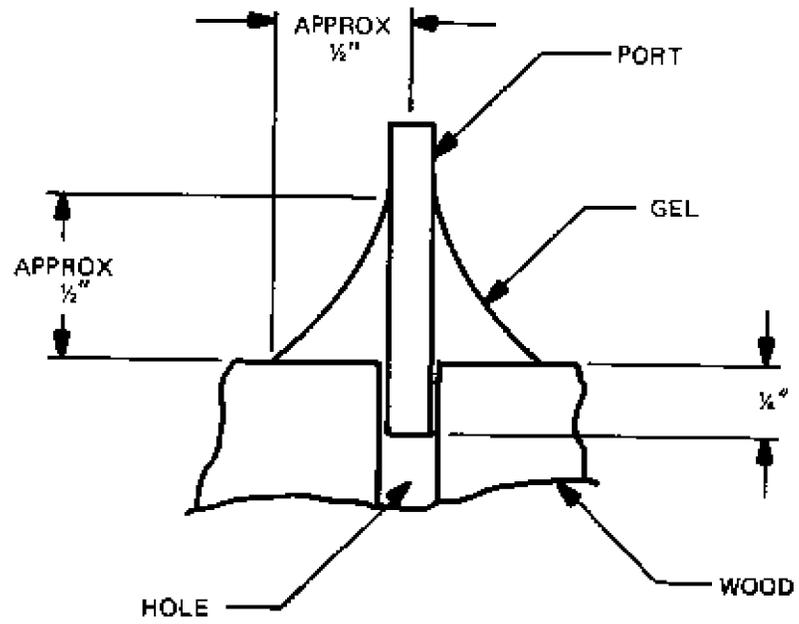


Figure 3-44. CROSS SECTION SHOWING GEL BUILD-UP AROUND PORT.



*Figure 3-45. INSTALLED PORTS IN PLACE.*

3.4.25.2 *Lap Joint and Crack Sealing.* All cracks, lap joints, bolts, holes, and defects must be completely sealed with gel. This sealing is usually performed by hand using putty knives and trowels. The gel must be thick enough to span the openings and withstand pressures of 40 to 80 lb/in<sup>2</sup>. A cross section of a crack covered with gel is shown in figure 3-46. The thickness of the gel at the crack, *h*, should be approximately equal to the crack thickness, *t*. The gel is usually spread ¼ inch on either side of the crack. For cracks wider than ¼ inch, a fiberglass cloth can be placed over the crack and gelled over. This procedure prevents the gel from penetrating too deeply into the crack and provides a stiffening effect once the gel has hardened. Care should be taken to apply the gel to the surface only. Forcing gel deeply into cracks may obstruct the injection epoxy and could prevent the injection epoxy from filling the voids. The gel is

significantly weaker than the injection epoxy and should not be counted on for strengthening the repaired joint. Special care should be taken in sealing the following since experience has shown that leaks often occur at these points.

- a. at sharp corners.
- b. at openings greater than ¼ inch.
- c. around bolts and washers.
- d. around ports.

The entire joint or damaged area must be completely sealed. The injection epoxy has a viscosity similar to thin paint and will seek the path of least resistance when injected. Any small opening will leak enough that the injection cannot continue without sealing the leak. Typical sealed joints are shown in figure 3-47 and typical sealed splices are shown in figure 3-48.

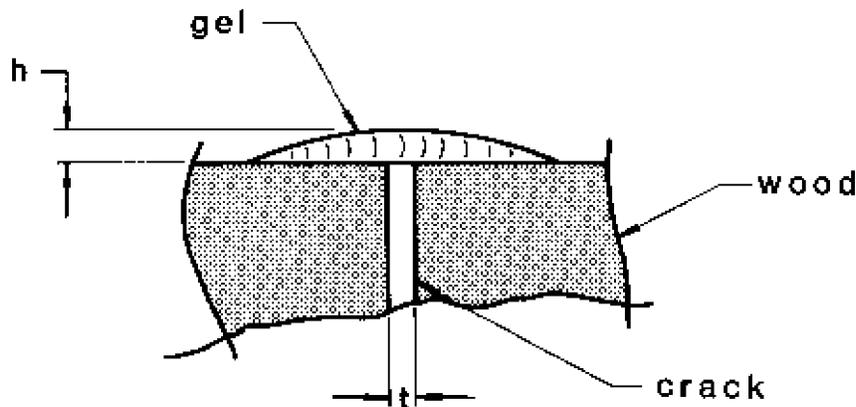


Figure 3-46. GEL APPLIED OVER LONGITUDINAL SPLIT.

3.4.25.3 *Leak Testing.* It is recommended that joints be leak tested before injection. A suitable procedure is to use compressed air. All ports except one venting port and injection port should be temporarily capped. Compressed air (at 25 lb/in<sup>2</sup> pressure) is then forced into the joint. The joint is then coated with a soap film and observed for bubbles. All leaks are marked and repaired after the film has dried. While leak testing may seem tedious, experience has shown that the time spent in leak testing is more than compensated for by expedited injection. In addition, the joint has a higher repaired strength when leaking is minimized.

3.4.25.4 *Hairline Cracks.* In some cases the deterioration has resulted in a number of hairline cracks which are difficult to visually detect. Should leak testing reveal a large number of such cracks, it is recommended that the entire damaged area be

painted with a thick epoxy paint. This application fills hairline cracks and small holes not generally visible.

### 3.4.26 Epoxy Injection.

The next step is to pressure inject a low viscosity two-component epoxy into the sealed joint through the injection ports (figure 3-49). This can usually be done by attaching the nozzle of the injection gun to a single port (usually the lowest) and letting the other ports serve as vents. As epoxy fills the joint, the venting ports leak epoxy and are sealed off. After all ports are sealed, epoxy injection should be continued to insure penetration into the fibers. Care should be taken not to inject with too much pressure or the seal might break. A maximum bozzle pressure of 40 lb/in<sup>2</sup> is recommended.

When possible, the entire joint should be injected from a single port.

**3.4.26.1 *Port Capping.*** Various methods can be used to seal off ports during injection. One method is to lightly tap wooden golf tees into the port. Copper tubing can be bent or squeezed closed with pliers. Wooden dowels can also be inserted. The primary caution is that the seals should not be broken in the process.

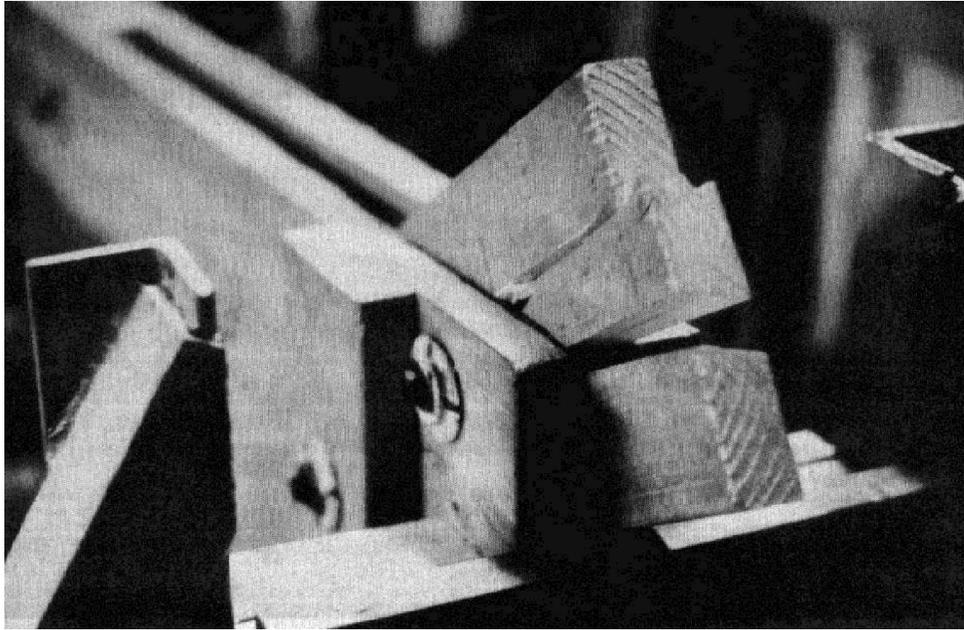
**3.4.26.2 *Leaking During Injection.*** Should a leak develop during the injection, a quick-drying patching cement can be applied. Since it is essential to finish the injection before the epoxy initially sets, a patching cement with a 2- to 3-minute pot life is needed. Hydraulic cements which can be mixed with water work well. Hot-melt glues have also been used successfully. Because of the porous nature of wood, leaking will occur on occasion. No injection should be attempted without a supply of

patching compound on hand.

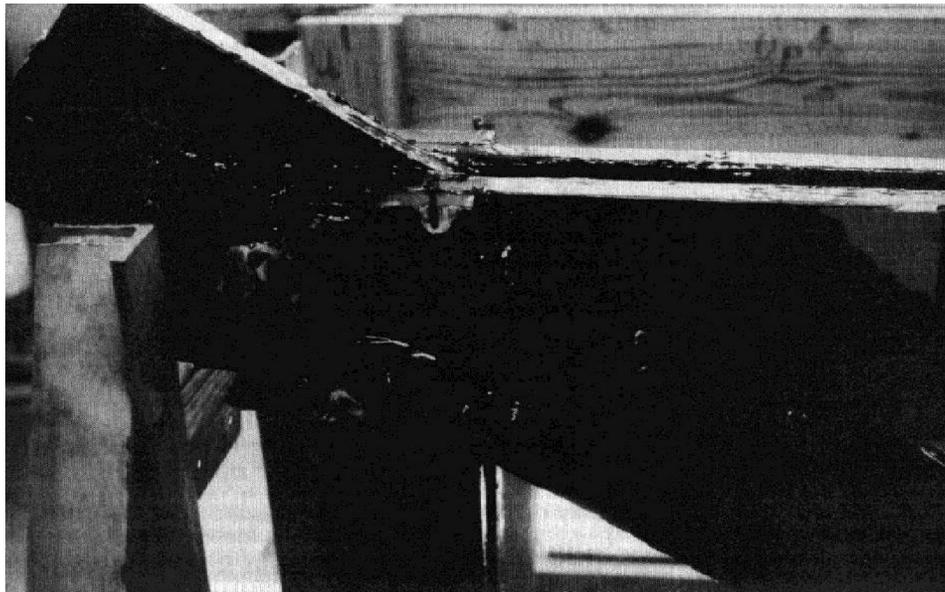
**3.4.26.3 *Injection Equipment.*** Injection is usually accomplished with automatic equipment, although hand equipment can be used. Typically, two positive displacement pumps geared to the specified mix ratio feed the separate components into a nozzle. Mixing is accomplished by forcing the epoxy through static-mixing brushes in the nozzle. As long as the flow is not interrupted for more than a few minutes, injection can progress for hours without damage to the nozzle.

### **3.4.27 Finishing**

The initial cure time for many epoxies is 2 to 5 hours. Final cure is usually accomplished in several days. After final curing, any temporary supports may be removed. If esthetics are important, the injection ports are removed and sealing gel sanded smooth so paint can be applied to finish the repair.



**(A) INITIAL JOINT FAILURE**

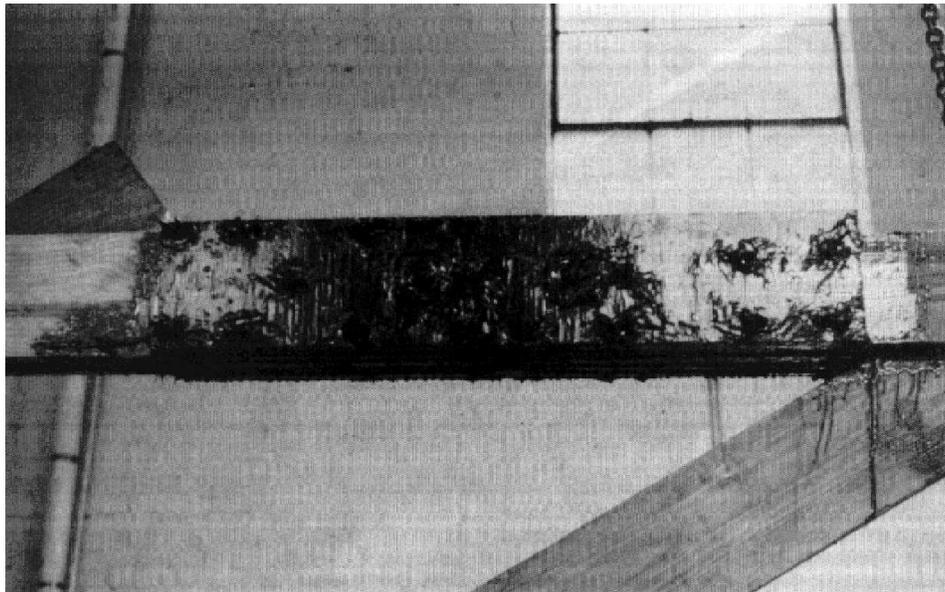


**(B) SEALED JOINT**

*Figure 3-47. TYPICAL SEALED JOINT.*

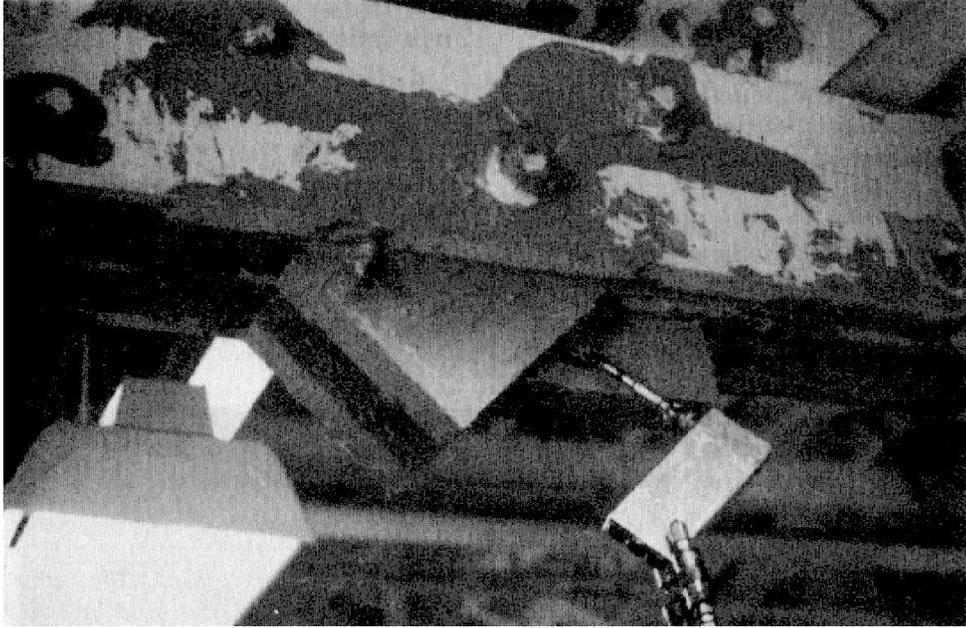


**(A) INITIAL SPLICE FAILURE**



**(B) SEALED SPLICE**

*Figure 3-48. TYPICAL SEALED SPLICE.*



*Figure 3-49. EPOXY INJECTION IN PROGRESS.*

### 3.4.28 Injection Equipment

Although hand injection equipment can be used the utilization of automatic equipment is recommended. Typical equipment is described in the following sections.

3.4.28.1 *Pumping Equipment.* A typical pumping unit is shown in figure 3-50. The specific parts are numbered and described as follows:

- a. Tanks—marked for ease of identification.
- b. Pumps—positive displacement.

- c. Chain drive—geared to provide the correct mix ratio of the two components.

- d. Motor—driving mechanism for pumps.

- e. Feedlines—transfer epoxy components to mixing head.

- f. Check valves—prevents mixed epoxy from penetrating feedline.

- g. Pressure gages—monitor injection flow.

- h. Quick disconnect couplings—attach to mixing head.

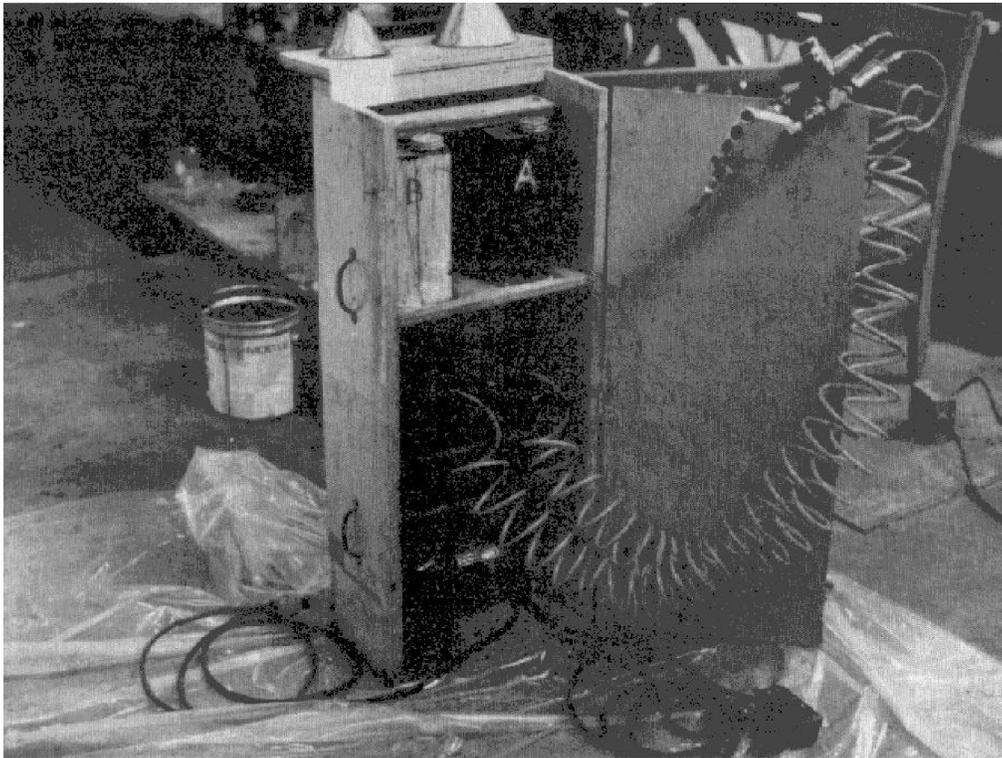


Figure 3-50. EPOXY INJECTION PUMPING UNIT.

3.4.28.2 *Mixing Head.* The mixing head is shown in figure 3-51 with the specific parts numbered. The parts are described as follows:

- a. Feedline inlets—feed epoxy components into mixing head.

- b. Mixing chamber—components mixed.

- c. Mixing brushes—epoxy is forced around brushes for mixing.

- d. Brass petcock—on-off valve for mixed epoxy.

- e. Nozzles.

- (1) Insertion type.

- (2) Ferrule and fitting for positive connection to port.

- f. Hex head sealing plug—remove for cleaning.

### 3.4.29 Quality Control

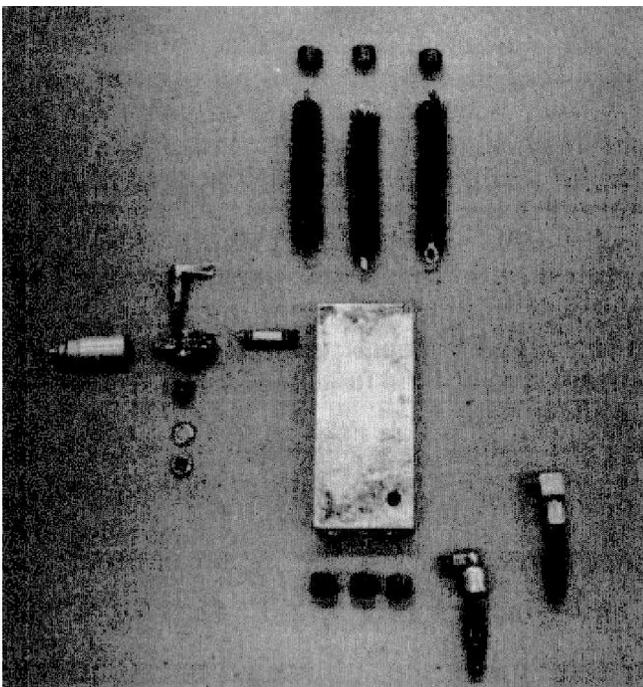
One of the major difficulties associated with the epoxy repair procedure is quality control. Engineering inspection is one measure. However, it may prove difficult to verify whether epoxy has completely penetrated the damaged area. This concern is often emphasized by the fact that workmen may have relatively little experience with wood as opposed to concrete repairs. The following procedures are recommended for insuring a satisfactory epoxy repair.

3.4.29.1 *Epoxy Samples.* In many cases laboratory testing is not possible for wood repair in contrast to concrete repair where test cylinders can be taken. This lack of quality control can result in serious problems for epoxy repaired members. Many

epoxies are very sensitive to mix proportions. The standard injection equipment consists of two positive displacement pumps driven by a single motor geared to obtain the proper mix. The two epoxy components are mixed at the nozzle, thus a fairly continuous flow prevents hardening of the epoxy in the nozzle. However, crimped lines, malfunctioning pumps, or line blockages can sometimes occur. In severe cases the problem may result in soft spots within joints. Frequent collecting of small samples in containers will determine if the epoxy is hardening as expected; this should be routinely done. It is recommended that a sample be taken before the injection of each joint with a notation as

to the specific point being repaired. Should the epoxy not harden properly, the joint should be repaired by an alternative method.

3.4.29.2 *Shear Block Specimens.* The detection of weak but hardened materials is much more difficult. One method is to inject shear block specimens at the beginning of operations and after the repair of every fifth member. A shear specimen is cut into four shear blocks after curing and each is tested in single shear. The failure stress level should be approximately equal to the ultimate strength of the wood (approximately 600 to 800 lb/in<sup>2</sup> for southern pine). This level of shearing strength indicates a high-quality bond.



(A) UNASSEMBLED HEAD



(B) ASSEMBLED HEAD

Figure 3-51. MIXING HEAD OF EPOXY INJECTION UNIT.

3.4.29.3 *Coring.* Another quality control problem is determining epoxy penetration into voids. Coring techniques have been developed, but none have proved completely satisfactory. The coring

devices are either time consuming, thus allowing for only spot checks, or they destroy the sample making it difficult to detect the epoxy.

## SECTION V—GLUED-LAMINATED WOOD FRAMES

### 3.5.1 General

An improvement in the heavy timber construction field is the development of glued-laminated (Glu-Lam) members. Large members are made up from smaller standard dimension pieces of lumber and formed into a variety of shapes and sizes. Glued-laminated members have higher allowable unit stresses than solid timber due to the dispersion of

defects, such as knots, and the kiln-drying of the lumber prior to lamination. One of the most popular types for buildings is the glued-laminated arch. See figure 3-52.

### 3.5.2 Glued-Laminated Wood Beams

Beams built up of smaller pieces can also be shaped to fit architectural and structural requirements in

great variety. Some of these are illustrated in figure 3-52.

#### 3.5.2.1 *Deflection and Camber*

For a given span, deflection is more pronounced in timber members than in steel or concrete. Much more often deflection will be the governing factor in design of timber beams and girders. Designers usually have a camber placed in timber beams and girders, based upon a full dead load and half of a live load. This means that the member will appear to arch upwards at midspan, when the roof has no superimposed load, and flatten out level when it supports a moderate snow load. Under an extreme snow load, usually occurring once every generation, the beam will appear to sag as far downward as it arched upward with no snow. In observing this situation bear in mind that either the top or the bottom of the beam could have been shaped in fabrication to produce a haunch or some other nonconformity. The camber or deflection may be measured from a tight string line held at the same glued surface line from one support to another. However, since members may be shaped after glueing, the only sure way is to consult design drawings where a camber sketch is shown.

3.5.2.2. *Decay.* Designers were originally lead to believe that glue-lam members were water resistant. Consequently, many structures were built with exposed beams and girders. Glue-lam arches were anchored in exposed metal shoes which filled with rain water. These areas are decaying badly and need to be repaired by replacement including full

protection from rainwater provided to the new glue-lam members by complete covers.

#### 3.5.3 **Repair of Glued-Laminated Members**

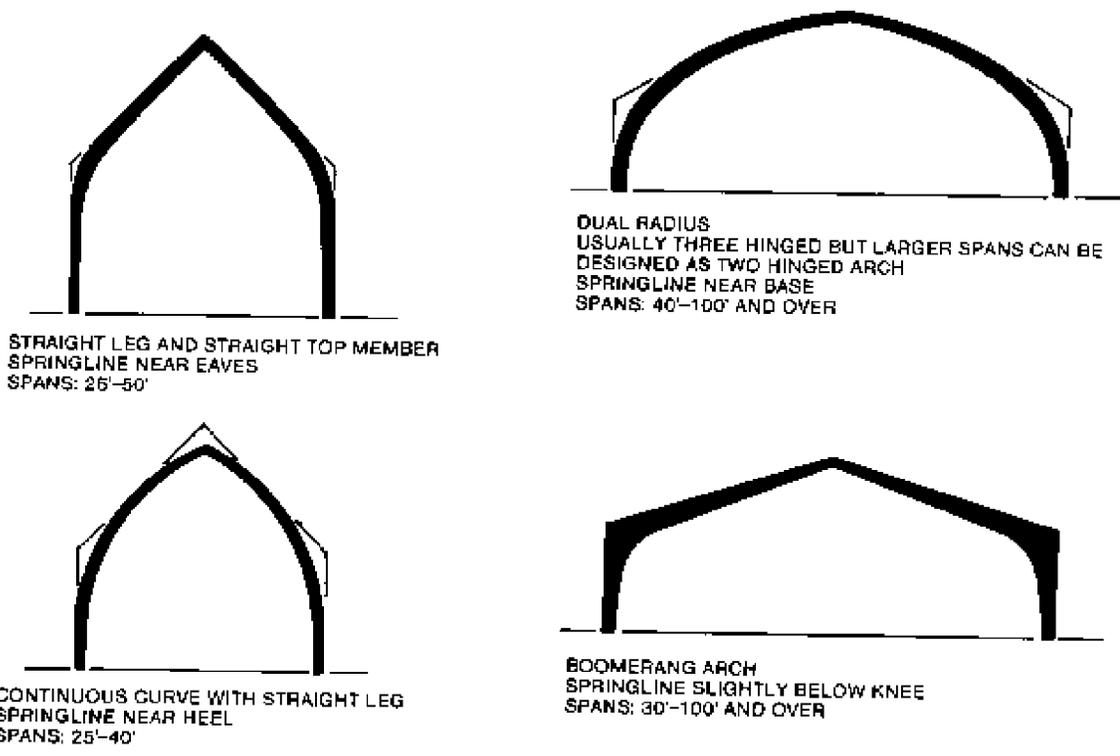
Glued-laminated members, having been kiln-dried before glueing and being of smaller selected pieces, do not ordinarily have the same defects as solid wood members. In arches, periodic inspections should be made to detect any delamination or separating of one piece in the member from another. Minute cracks should be carefully examined; and, if larger than  $\frac{1}{16}$  inch, they should be examined by a competent structural engineer. Arches should be examined for alignment and settling.

#### 3.5.4 **Corrective Measures**

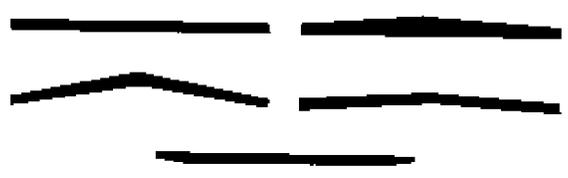
3.5.4.1 *Arches.* Adjustment of tie rods should be made only as directed by a competent structural engineer. Bolts and fasteners at the peak joint should be tightened; however, since the material has been dried, this should not be required as frequently as connections in solid timbers. At the direction of an engineer, steel plates, stitch bolts and spikes may be used to repair arches that have separated or delaminated.

3.5.4.2 *Beams.* Beams may be required in the same way, and lines for detecting sag or deflection should be used.

3.5.4.3 *Purlins and Joists.* Purlins or joists are usually fastened to these members with hangers. Shimming of the purlins in the hangers can be accomplished with small wood wedges or shims.



**GLUED LAMINATED ARCH SHAPES**



**GLUED LAMINATED BEAM SHAPES**

*Figure 3-53. GLUE LAMINATED SHAPES.*

## CHAPTER 4

### EXTERIOR WALLS

#### SECTION I—CLASSIFICATION OF WALLS

##### 4.1.1 Structural Types

Exterior walls may be classified as load-bearing walls (walls that support loads from floors, roof and equipment plus their own weight), nonload-bearing walls (walls that support only their own weight), and curtain walls (walls that have their own weight supported on structural members).

##### 4.1.2 Material Classifications

Exterior walls fall into four general material classifications, with a wide variety of materials and applications:

4.1.2.1 *Wood and Wood Products*: Wood shingles, weatherboard siding, plywood, prefabricated panels.

4.1.2.2 *Concrete and Masonry*: Brick, concrete masonry units, reinforced concrete, precast concrete panels, structural clay tile, stone, exterior plaster (stucco).

4.1.2.3 *Metal*: Corrugated iron and steel, aluminum sheeting, precut sheet metal, enamel-coated, prefabricated steel panels, protected metals, prefabricated panels.

4.1.2.4 *Mineral and Chemical Products*. Asbestos shingles, asbestos-cement sheets (flat and corrugated), prefabricated panels (flat and corrugated), glass block and vinyl.

##### 4.1.3 Finishes and Protective Coatings

As distinguished from exterior wall surfaces themselves, protective and decorative coatings fall into

several general categories. See Tri-Services Manual, "Paints and Protective Coatings," for information regarding their application and maintenance. Exterior plaster (commonly referred to as stucco) is the application of a portland cement plaster to the exterior wall surface. Chapter 5 of this manual discusses the materials and application of interior portland cement plaster in detail. Exterior plasterwork is similar to interior plasterwork except that the exterior plaster finish coat normally contains a waterproofing agent.

##### 4.1.4 Maintenance and Repair

Regardless of the material used in the construction and finish of exterior surfacing, it is necessary that maintenance measures appropriate to the situation be planned and carried out on a regular schedule. Where repair is made to existing types of construction and material, it is best to match the as-built specifications as nearly as possible. Improved construction techniques and materials should be constantly examined to prevent or offset similar failure. Where weathering, normal wear or other reasons dictate a requirement for repair, replacement or refinishing of an exterior wall, consideration must be given to either matching (or duplicating) existing material, replacement of the entire covering, or a completely new finish over the existing surface.

#### SECTION II—WOOD EXTERIORS

##### 4.2.1 Causes of Failure

4.2.1.1 *Moisture*. The most common failure of wood and wood-products exterior siding is caused by moisture. Prolonged weathering, leaks, and cracks, which allow moisture to enter and collect behind exterior coverings, are a source of eventual problems. Condensation within and behind walls also contribute to the problems of maintenance, repair, and rehabilitation. Figure 4-1 demonstrates the mechanics which may produce damaging moisture behind paint and within walls and

illustrates the use of a vapor barrier to avoid these conditions.

4.2.1.2 *Inferior Workmanship and Material*. Inferior materials used in initial construction may allow early warping and cracking, or in instances of green lumber, bleeding of sap. Painting on wet material may cause early scaling, which in turn exposes areas of the wood to severe weathering. Insufficient, loose, and displaced nailing will eventually cause problems.

4.2.1.3 *Structural Failures.* Settlement of foundations, which in turn causes displacement and misalignment of framing members, may crack, misalign and damage facing material. Occasionally, a framing member may fail under loading conditions which exceed those for which it was designed or because of inferior material. This in turn can cause displacement and damage to siding. A fact that is frequently overlooked in maintaining wood siding is that nailing or adhesion methods of fastening sheathing on the framing (studs or furring strips) provide strength to the basic structure, as well as form a covering. It follows that broken or loose siding detracts not only from weatherproofing functions and appearance, but also from the strength of the structures as well.

#### 4.2.2 Maintenance and Repair

4.2.2.1 *Inspections.* Regularly scheduled inspection will determine the need for timely maintenance procedures. Neglect of maintenance and repair measures leads to greater and more costly problems. Painting and surface treatment must be kept in good repair. Specific structural repair and improvement methods are presented below. It is

important to determine the cause of failure and correct it before surface repairs are made.

4.2.2.2 *Causes of Damage.* Siding material may be damaged by normal weathering; severe wind, snow, and ice; falling tree branches; fires; vehicle collisions; spillage of grease, fuels, and chemicals; and vandalism.

4.2.2.3 *Patching, Renailing and Resurfacing.* Make a careful check to determine that existing structural, functional and material conditions warrant repair to the existing wall rather than complete residing, insulation, or other overall repair or rehabilitation. Where existing situations are satisfactory, replace damaged material with like material. Cut out sufficient areas beyond the damaged part to obtain good jointing and sound nailing. Tighten nails in existing material to be left in place. Be sure that material receiving the new nailed pieces of sections are sound and true. (See chapter 3 for framing repair.) Cover replacement wood with finishes or paint matching the original design. When "as-built" plans are available, it is well to examine the original construction detail for assurance that out-of-vision construction and utilities will not be damaged.

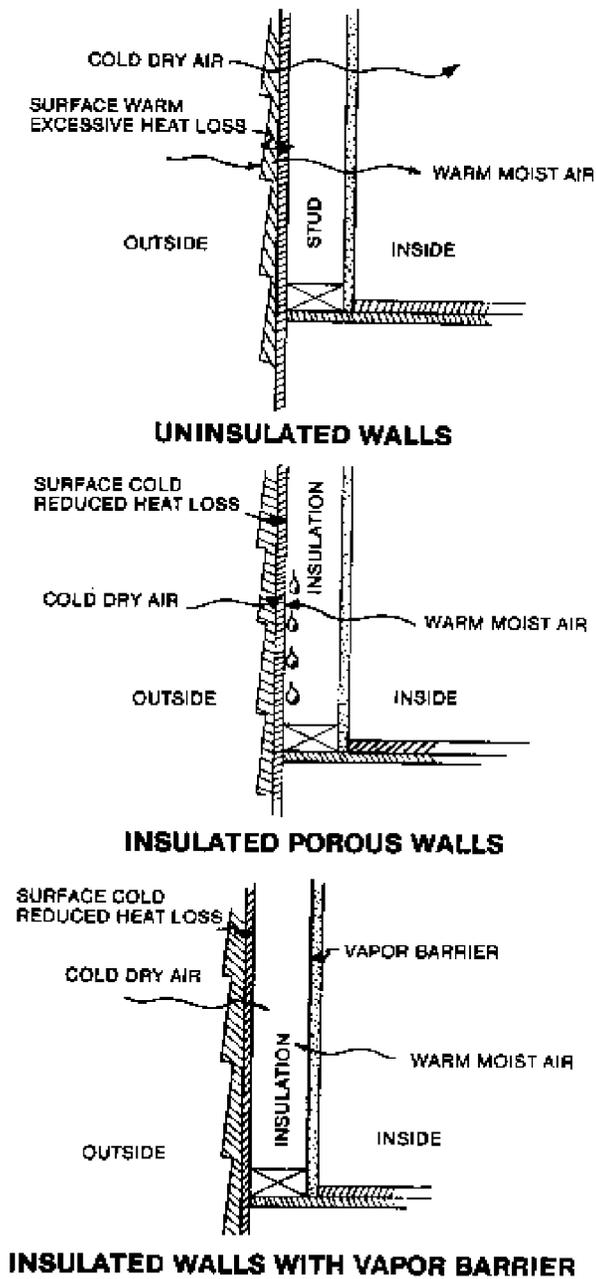


Figure 4-1. MOISTURE CONTROL IN EXTERIOR WALLS.

4.2.2.4 *Repair of Wood Shingles.* Warped, split, or curled shingles should be removed with a ripper and replaced in a similar manner to roofing shingles. See Tri-Services Manual, "Roof Maintenance" (TM 5-617, AFM 91-31, NAVFAC MO-113, and MCO P11014.9)

4.2.2.5 *Repair of Prefabricated Panels.* Panel siding will be periodically checked for looseness

and faulty caulking. It is usually more economical and satisfactory to replace damaged or deteriorated panels rather than to attempt patching.

### 4.2.3 Residing

When existing siding does not meet functional requirements, careful consideration will be given to residing over the existing material. At this time it is

well to consider factors in connection with insulating qualities of the material to be used. If the walls are already suitably insulated within, siding or shingles may suffice. If new or additional insulating qualities are required, careful consideration should be given to the insulating factors of the new material. These considerations include whether present walls are vented or depend on porosity so vapor may reach the outer air, and what effect the addition of material may have on the existence or nonexistence of a vapor barrier within the wall, and the effectiveness of the present airspace in the wall structure. When a qualified engineer has determined what type of material is to be used, the following general rules apply for placing insulating or wood sidings.

4.2.3.1 *General.* The old wall to be recovered will be repaired to provide a sound, substantially smooth, true surface having adequate nail-holding capacity and the ability to hold the new siding firmly.

4.2.3.2 *Over Unusual Construction.* Where structures have thin level siding or similar materials applied directly to studding, which sometimes may be widely spaced, it is appropriate to fasten to the existing wall properly sized wood strips, placed at the nailing location for the new siding. These strips will serve as adequate nailing bases provided they are shimmed to true line and are properly secured.

4.2.3.3 *Over Other Material.* Where it is determined that wood siding should be on a building which has an existing surface, such as asbestos-cement or metal, which will not act as a nailing base, it is necessary to use wood nailing strips which are secured through the existing siding and into the wall studs. Otherwise, all old siding and the old sheathing may have to be removed down to the existing studding and then replaced with new sheathing as well as siding.

4.2.3.4 *Residing Over Stucco.* New siding will not be applied over old stucco. Remove the old stucco, nails, and lath, and apply new siding on existing walls.

4.2.3.5 *Other Considerations.* Whenever siding is replaced or added to existing siding, proper consideration must be given to placement of asphalt-saturated felt underlays, flashing at windows and doors, termite protection, proper surface treatments, and other items pertinent to good construction practices. These considerations will be dependent upon the existing conditions.

4.2.3.6 *Moulding, Flashing, and Caulking* When

residing, the new siding may butt against or overlay the opening trim. If it overlays the trim, it should be finished by an abutting metal or wood staff moulding. If it butts against the opening trim, adequate and appropriate flashing or caulking must be used.

4.2.3.7 *Gutters and Downspouts.* New or rehabilitation work involving the repair or replacement of gutters and downspouts will be phased to insure continual drainage of roof runoff. This will prevent storm water damage to the new work or to the new siding prior to surface treatment, and will prevent water from entering uncovered wall areas.

4.2.3.8 *Underlay.* On residing work where the sheathing or old wall surface is not in sound condition, an underlay of sheathing paper must be applied to prevent the infiltration of wind and moisture. Apply the underlay as the application of the siding progresses, applying only the amount of material which can be covered by the end of each day's work. Use only enough small nails or staples to hold the underlay in place until covered with siding.

#### 4.2.4 Vapor Barriers

A vapor barrier is the best means of preventing condensation by keeping the vapor from reaching a cold surface. When existing buildings have not been provided with a vapor barrier and condensation problems exist, some relief may be obtained by use of vapor-resistant paint on interior wall faces. However, application of a vapor barrier on the inside of the warm side of the exterior wall is preferable. There are a variety of vapor barrier materials, such as impregnated paper, plastics, and metallic sheets. In most instances where a vapor barrier is to be applied within a wall, it is best to use an insulation board, batts, or similar material with an integral factory-applied vapor barrier. This accomplishes the purpose and incorporates insulation at the same time.

#### 4.2.5 Ventilation

Venting of walls, attic, and crawl space to allow escape of vapor to the outside air will help overcome the problem of condensation. Walls may be ventilated by vents which are designed to prevent the entrance of rain or snow and are screened against insects. Vents with screens may also be placed in attic space and crawl space. Vents may be placed in loft spaces, below flat roof decks, in gable walls (louvered), in roofs (by installing insect screens at the eaves), and wall vents in crawl spaces. See figure 4-2.

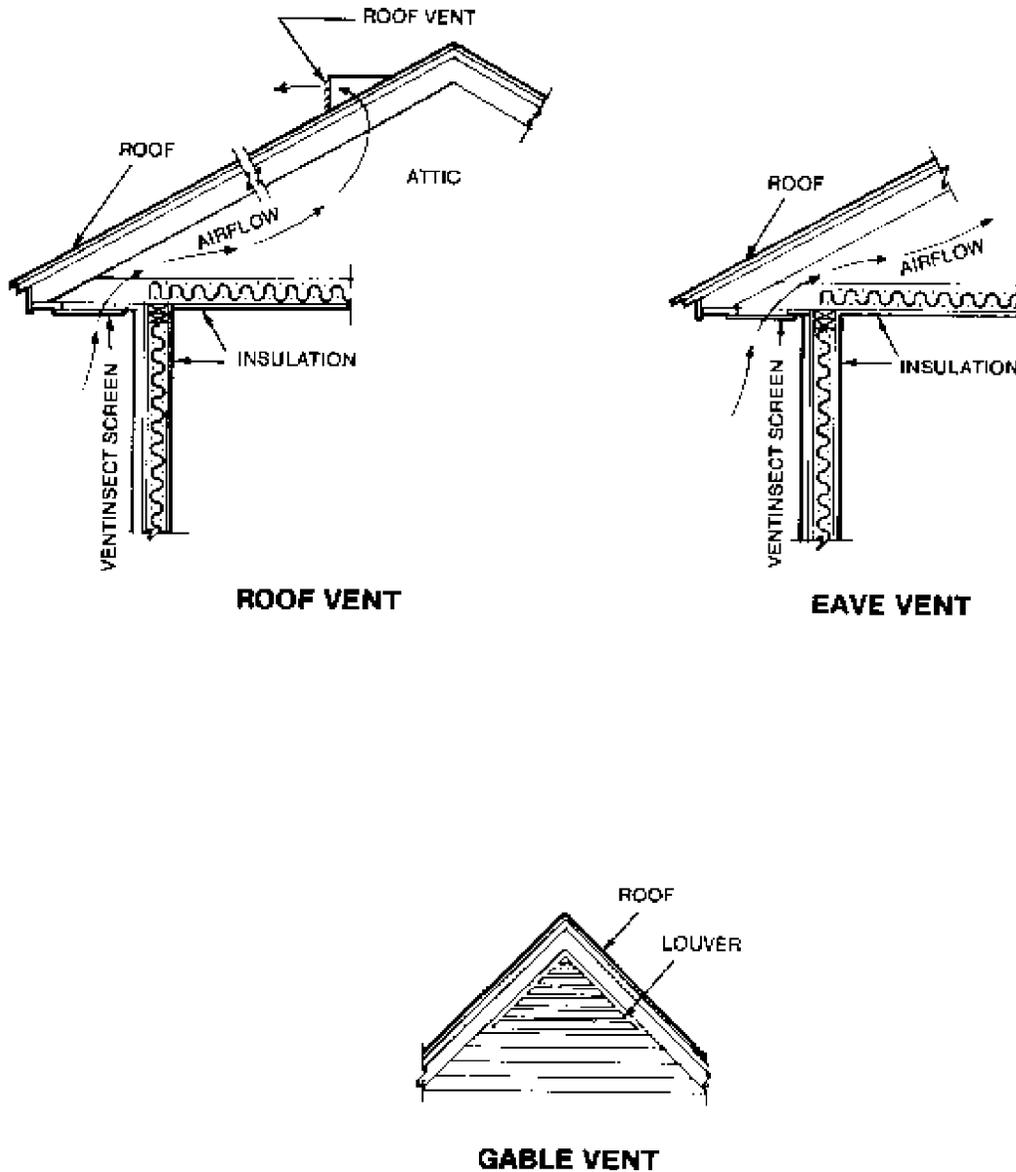


Figure 4-2. TYPICAL METHODS OF ATTIC VENTILATION.

#### 4.2.6 Insulation

Exterior wall insulation has proved its worth many times. In maintenance of structures, questions concerning the sufficiency or deficiency of insulating qualities of walls (as well as ceilings and roofs) often arise. Some of the considerations regarding its use are discussed below.

4.2.6.1 *General.* The use of insulation varies to meet climatic conditions of the area in which a building is located, the use of the building, and the structural features of the building itself. The economic feature of saving and equalizing heat (or air-

conditioning) is of primary importance. A study of the combined conditions cited above will determine the best type and method of application of insulation for a specified use. Fireproofing qualities and condensation control must be considered, as well as the insulating value of the product to be used. For consideration of double-glazing (storm sash) and weather stripping in conjunction with insulating, see chapter 7 of this manual.

4.2.6.2 *Types and Uses of insulation.* Increased insulation reduces annual energy costs and increases initial installation costs and annual maintenance costs. The greater amounts of insulation produce

unusual installation problems and increase the initial costs disproportionately to the energy saving. The optimum amount of insulation can only be determined by complete analysis of costs and savings. See appendix C, paragraph C.2.2.3. According to the DOD Construction Criteria Manual (see appendix A), buildings to be heated to 70°F 21°C) must have a factor in walls of 0.1 either in new construction or in repair renovation work.

a. Roll blankets may be used where access to the space between studs permits their use and fastening. Space must be thoroughly accessible and free of obstacles.

b. Batt blankets may be used in areas similar to those for rolled material.

c. Loose material (pellets or wool) is best suited for areas where access is through a small space. Intrawall areas between the studs and attic spaces may be poured with loose insulation material. It may also be forced in under pressure by compressed air. This form of insulation is particularly adaptable to small areas around windows and doors and in wall utility compartment vents.

d. Other types of insulation include rigid and semi-rigid composition board, which includes stiffening material, such as fiber, to make a material self-supporting. It is used most generally for perimeter insulation, such as around concrete slabs or as sheathing under the siding. Utility batts are formed from insulation, but with no envelope or vapor barrier to break the flow of air through the material. It may be used when no vapor barrier is required or where a separate vapor barrier has been provided.

4.2.6.3 *Placing Insulation.* It is most satisfactory to place roll or batt insulation between the studs of a wall while either the inside or outside surface of a building is uncovered. Thus, when resheathing the outer surface of a wall or replacing the inner surface, consideration should be given to installing insulation. When both wall faces are covered, it is necessary to pour loose insulation from the top or force it in by compressed air from some opening in the wall. In any case, care should be exercised to fill all small crevices and to pack material into confined spaces, particularly around piping and wiring. The vapor barrier side of insulation should face toward the warm side of the wall. In placing any type or kind of insulation, follow the

manufacturer's instructions for proper thickness, form and fastening. Figure 4-3 illustrates application of insulating batts, blankets, and utility batts to standard wood-constructed walls. Figure 4-4 shows methods of placing insulated material on masonry and metal sidewalls.

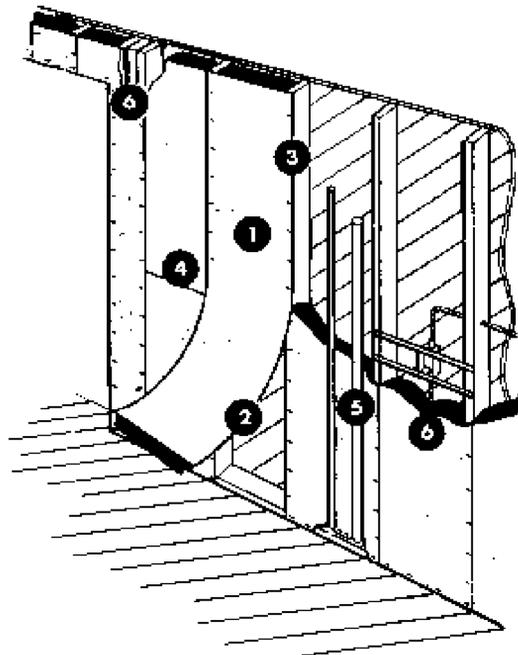
a. *Batts and Blankets.* In figure 4-3, the following steps are demonstrated for batts and blankets: Cut insulation to stud height plus 3 inches for top and bottom, nailing flange exposed. Start at top of stud space and work down if roll blankets are used. Batts can be installed from floor up. Staple or nail flanges to stud at 5- to 6-inch spacing. Make sure vapor barrier faces building interior. Press insulation closely together at joint so that no voids are left. Make sure vapor barrier is not broken by spaces at joints. Insulate with special care on the cold side of pipes and drains. Compress insulation behind pipes where possible or pack with utility batts or pouring wool or scraps from batts or blankets. Cut and apply vapor barrier to provide vapor protection.

b. *Utility Batts.* In figure 4-3 the following steps are described for utility batts: Stack 15 by 10 inch utility bats between studs. If the 15 inch dimension is placed horizontally, batts fit between studs spaced 16 inches on center. With the 15 inch dimension vertical, two batts can be packed into the space between studs on 20 inch center. Tack vapor barrier paper over the insulation to prevent condensation. For complete vapor protection, the vapor barrier must be continuous at joints. Apply roll or batt blankets to furring strips following directions given for wood sidewalls.

c. *Metal Buildings.* See figure 4-4. Attach furring strips to purlins or girts of the metal building on a standard spacing to tack roll blanket insulation. Staple or nail roll blankets to furring strips. Make sure vapor barrier is continuous to prevent condensation on steel sheets. Cover with desired finish.

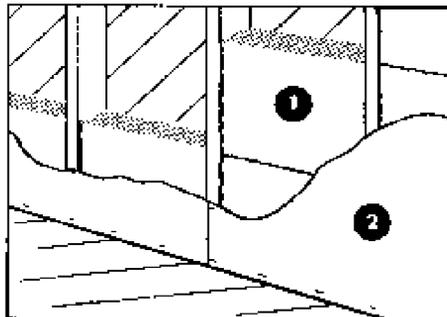
#### 4.2.7 Exterior Steps

Wooden exterior steps are subject to considerable weathering and mechanical abuse. Wood columns and posts supporting exterior steps and platforms should be set in concrete with wood parts no closer than 4 inches to the ground. Ease of access to these structures will make inspection simple and repair uncomplicated.

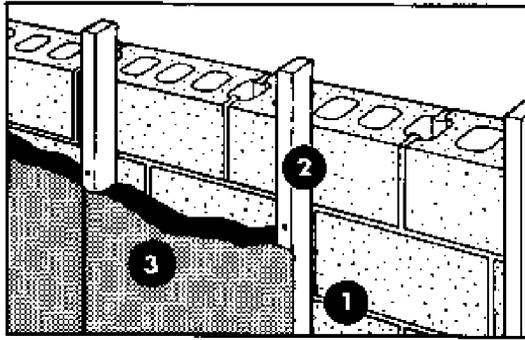


**NOTE:**

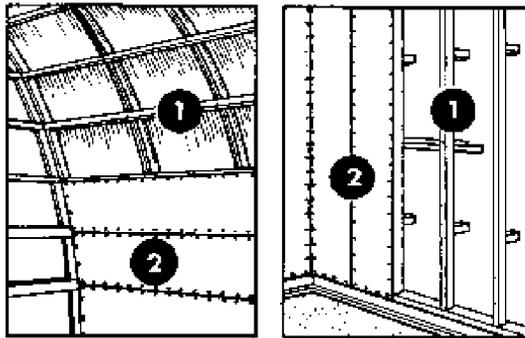
- 1** DENOTE STEP IN THE INSTALLATION OF INSULATION-SEE TEXT FOR EXPLANATION.



*Figure 4-3. PLACING BATTS, BLANKETS AND UTILITY BATTS IN WOODFRAME WALLS.*



**MASONRY SIDEWALLS**



**METAL SIDEWALLS**

**NOTE:**

**1** DENOTE STEP IN THE INSTALLATION OF INSULATION-SEE TEXT FOR EXPLANATION.

*Figure 4-4. PLACING INSULATION INSIDE MASONRY AND METAL SIDEWALLS.*

4.2.7.1 *Treating Porch and Walkway.* Flooring Treated lumber should be used if available. However, if it is not available, immediately upon delivery at the building site, treat all matched or square-edged flooring and planking to be used on the exterior with a preservative sealer before it is exposed to the weather. Immerse boards fully for not less than 15 minutes in a slow-drying wood sealer. After treatment, carefully stack lumber and protect it until ready to use. Before installation, dip or brush-coat all cut ends of flooring with sealer; after installation, apply a brush coat of sealer to any surfaces which have been abraded, planed, scraped, or sanded. Square-edged material laid with open joints should be used for open walkways in hospitals and other installations where open joints are not objectionable.

4.2.7.2 *Repairs.* Normally, the component members may be repaired by replacing the damaged parts in kind. Use sound material, 2 or 3 inches thick, for stringers, and space them more than 24 inches on centers. Cut stringers to form treads, using planks of sufficient width to provide at least

5 inches of uncut lumber along and parallel to the bottom edges of the stringers. Maintain uniform tread widths and riser heights throughout the run. Treads are formed of 2 x 4's or 2 x 6's or a combination of the two sizes spaced ¼ to ½ inch apart. Risers are left open. Set lower ends of the stringer on concrete footings at least 4 inches above the ground.

4.2.7.3 *Replacements.* Expected utilization of the building and extent of damage are the determining factors as to which of the following methods may be the more economical for complete replacement:

- a. Replacement in kind using salvageable material supplemented with new material.
- b. Concrete steps and platforms with metal pipe railings.

**4.2.8 Porches**

The same maintenance generally applies to porch flooring and supporting members as for framing. Treatment of material and procedures are as dis-

cussed in paragraph 4.2.7.1 above. Care will be taken to maintain porch flooring and rails in good condition.

#### 4.2.9 Loading Platforms

Particular attention must be given to inspection and maintenance of loading platforms due to the consideration of constant application of changing live loads to the floor surface. Movement of large quantities for heavy materials, the impact of falling loads, and the constant hazard of vehicles colliding with the platform framing call for frequent inspection and maintenance. Framing is generally

replaced or reinforced to match the existing structure.

#### 4.2.10 Canopies

Repair of existing canopies or construction of new canopies will be restricted to areas and conditions as prescribed by the installation engineer. Repairs are usually made by replacing the damaged part or parts in kind. New canopies, when permitted, will be of the most economical construction consistent with the expected utilization of the building concerned.

### SECTION III—CONCRETE AND MASONRY

#### 4.3.1 General.

The frequency of maintenance for masonry and concrete exterior walls is less than that for most other exterior materials. Leakage through concrete walls is caused by cracks in the concrete and, in rare cases, porosity of the concrete. Most defects that cause appreciable problems, such as leakage, are due to the expansion and contraction of the structural members. Other common causes are settlement, excessive floor loadings, and poor workmanship in the original construction.

#### 4.3.2 Mortar

4.3.2.1 *General.* Mortar made from good-quality material, mixed and placed under proper weather conditions and in a workmanlike manner helps produce weather-resistant, durable masonry.

4.3.2.2 *Defects and Damage.* Weathering may cause a spalling of mortar joints under the best conditions. Poor mortar mixes are usually at fault when the face of the masonry walls is marred by stains and efflorescence. Impure water containing acids or organic matter and improper sand in the mortar mix not only cause stains through bleeding (spillage of water over a masonry surface during construction or curing), but also accelerate weathering of the mortar joints.

#### 4.3.3 Repointing

Repointing with the best materials and skill workmanship will correct the most common fault, defective mortar joints.

4.3.3.1 *Removing Old Mortar.* Since removing mortar by hand with hammer and chisel is difficult and expensive, most masons who specialize in repointing use portable electric-driven grinding wheels to simplify the job. Cut out cracked or open mortar joints to a depth of at least  $\frac{1}{2}$  to  $\frac{3}{4}$  inch.

Remove all dust and loose material with brushes, compressed air, or water jet. If water is used, no further wetting of the joints may be needed unless the work is delayed.

4.3.3.2 *Recommended Mix.* Use mortar of about the same density as the original mortar, or use a prehydrated mortar mix in the following proportions by volume: 1 part of portland cement, 1 part of lime putty or hydrated lime, and 6 parts of sand. Prehydrate the mortar by mixing it about 2 hours before use, adding only about half the mixing water, to eliminate excessive original shrinkage and volume change.

4.3.3.3 *Application.* At the end of the 2-hour curing period, work the mortar, adding enough additional mortar to make the mixture plastic, but not enough to make it run. Be sure the joints are damp, and then apply the mortar by packing it tightly into the joints in thin layers. Tool the joints to smooth, compact, concave surfaces. If openings in the mortar are small, cutting out the joints is unnecessary, and following procedure may be used. Mix grout in proportions by volume:  $\frac{1}{2}$  sand, **d** portland cement, **c** limestone flour, powdered flint, or fine hydrated lime. Wet the joints, and apply two coats of grout, brushing it vigorously into the joints.

4.3.3.4 *Protection.* Protect all fresh repointing from direct exposure to hot sun and drying winds until it has set hard.

#### 4.3.4 Efflorescence

4.3.4.1 *General.* The source of efflorescence of walls can be found if close inspection is made when it first appears. The immediate remedy to prevent recurrence of efflorescence is to check causes of excessive moisture that contacts the wall, such as defective flashings, gutters, downspouts, copings, and mortar joints. If it appears at the edges of the

masonry unit, the mortar probably is at fault. Efflorescence at the center of the unit indicates that the masonry unit and mortar may be responsible.

4.3.4.2 *Cause of Efflorescence.* Efflorescence on masonry usually appears as a light powder or crystallization and always indicates trouble. Aside from its unsightly appearance, it is evidence that enough moisture may be penetrating the wall to cause disintegration of the masonry. The two conditions which generally produce efflorescence are the presence of water-soluble salts (in masonry units, mortar, or both) and moisture which deposits salts on the wall surface when water evaporates. This latter may be excess moisture caused by extra soaking of units before laying, or moisture taken up during storms after erection of the wall.

4.3.4.3 *Water-Soluble Salts.* Soluble salts may be present in brick, hollow tile, concrete blocks, or mortar. Tests have shown that only a small percentage (probably not more than 10 percent) of well-burned clay and sand-lime brick and hollow clay tile contributes to efflorescence. Secondhand brick, because of its uncertain origin and previous contact with mortar and plaster of unknown composition, may cause efflorescence. Concrete blocks are often made of materials containing efflorescing salts. Portland cements, limes, and sands used in mortars often contain soluble salts that cause efflorescence. The Wick Test for efflorescence, as described in ASTM C-67, is recommended for determining the presence of soluble salts in masonry units and mortar ingredients.

4.3.4.4 *Excessive Moisture.* Since moisture is necessary to carry soluble salts to exterior masonry surfaces, efflorescence is evidence that construction faults have permitted moisture to enter the wall. Excessive moisture in walls may be caused by defective flashings, gutters, downspouts, copings, or improperly filled mortar joints. Location of efflorescence does not always mean that water is entering the wall at that point. Streaks on the wall from the top down or patches some distance from the top might indicate defective gutters or copings. Patches of efflorescence are sometimes caused by opened mortar joints or projecting brick courses without enough wash (upper surface of the brick which is sloped to shed water). Water may also enter openings at windowsills and around window and door frames. Efflorescence close to the ground may indicate ground water drawn up by capillary action.

4.3.4.5 *Efflorescence Analysis.* The following checklist is helpful in determining causes of efflorescence:

a. *Age of Structure.* Determine the age of structure at the time the efflorescence appeared. If the structure is less than 1 year old, the source of the salts is probably the cement in the mortar, and the source of the water is usually construction water. However, if the structure is more than 2 years old, construction details should be examined for possible leaks in the wall or the adjacent construction. The sudden appearance of efflorescence on an established building previously free of efflorescence is normally attributed to a new entry of water into the construction assembly.

b. *The Location of the Efflorescence.* The location both on the structure and on the masonry unit or mortar joint should be carefully noted. The location of the salt crystals on the joints or the masonry units may help in determining the source of the salts. The recent use or occupancy of the building should also be noted. Has the building been vacant for some time? Has it been altered, expanded or modified?

c. *The Condition of the Masonry.* Careful examination of the profile of the mortar joints, the condition of the mortars, the type of workmanship, the condition of caulked joints, the condition of flashing and drips, and deterioration or eroding of mortar joints in coping or in sills should offer clues as to the entry paths of moisture into the construction.

d. *Other Source of Water.* If the usual sources of moisture have been eliminated, consideration should be given to other sources, such as condensation on the walls, leaking pipes, faulty drains, and condensation on heating and plumbing lines. It should be emphasized that these are rare and unusual sources of moisture for efflorescence. The principal sources of moisture should be thoroughly examined before these secondary sources are considered.

### 4.3.5 Types of Cracks

4.3.5.1 *Horizontal Movement.* Cracks in this category are usually long cracks in the mortar joints. They generally occur along the line of the floor or roof slab or along the line of the lintels over windows and doors, resulting from horizontal movement of the slabs involved. Where these cracks turn a corner they frequently rack down (or up) as shown in figure 4-5. Racked-down corners are discussed in paragraph 4.3.8.4 below.

4.3.5.2 *Settlement.* This usually results in diagonal cracks that reach from the lintel of one window or door to the sill of an adjacent window. These cracks generally follow the mortar joint with an

occasional break through the masonry units.

4.3.5.3 *Deflection.* Vertical and diagonal movement cracks usually occur in lintels and beams

and are the result of excessive deflection, or sometimes shrinkage. See figure 4-6.

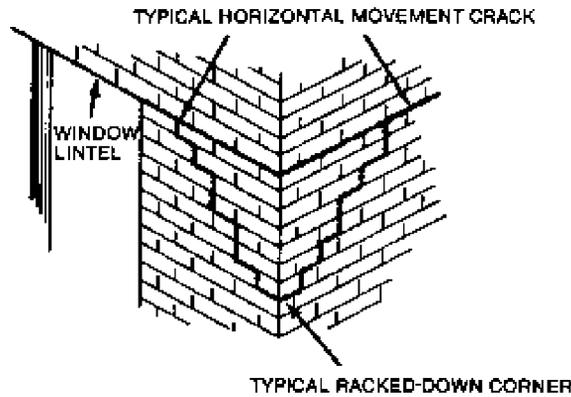


Figure 4-5. HORIZONTAL MOVEMENT AND RACKED DOWN CORNER.

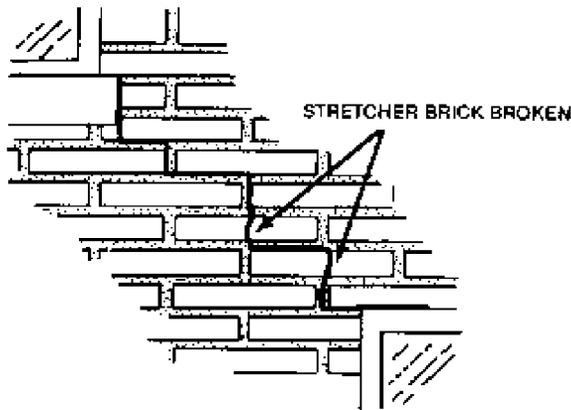


Figure 4-6. DIAGONAL MOVEMENT CRACK.

4.3.5.4 *Shrinkage.* Haphazard cracks in mortar as well as in concrete, resembling a road map, are the result of shrinkage. These cracks seldom amount to more than hairline cracks, and seldom are a cause for concern.

4.3.5.5 *Miscellaneous.* Various combinations of the cracking discussed may occur or may be combined singly or collectively with other failures, such as excessive short-term loading from the elements; external damage from vehicles or objects; failure of

support through deterioration; failure attributed to uncalculated secondary stresses such as creep, vibration or impact; or progressive minor failures resulting in a major failure.

#### 4.3.6 Repair of Cracks

4.3.6.1 *General.* Before any attempt to repair a crack is made, an engineering investigation shall be made to determine the cause of the crack. The cause should be corrected first. Repairs to cracks

in masonry have often resulted in an unsightly appearance. Cases exist where fine hairline cracks were chiseled out and repointed with mortar when such work was entirely unnecessary. In exposed walls, it is extremely difficult, if not impossible, to chisel out a joint and repoint it without producing a repaired area noticeably different from the surrounding masonry. The repaired joint in such work will be noticeable from an appreciable distance, whereas the hairline crack is barely visible. A few instances exist where the pointing mortar was left recessed below the surface of the block, thus actually defining and calling attention to the crack. Another erroneous practice in repair is to fill the crack with plastic caulking compound or a bituminous material having a color dissimilar to that of the masonry surface, resulting in an objectionable appearance. In considering the repair of cracks in concrete masonry walls, the following precautions should be observed.

a. Do not attempt to repair cracks as soon as they appear. Observe the crack periodically over a period of time to determine whether further cracking or widening of the crack will occur. Determine the cause of the crack and correct. No attempt should be made to repair cracks in a new wall, unless such action is absolutely necessary to prevent the entry of water, or for similar reasons.

b. Do not attempt to repair a fine crack by chiseling out a deep groove and repointing. Repair fine cracks by filling or bridging over with a cement-based wash or paint.

c. Do not caulk cracks above grade with light plastic or dark bituminous caulking compounds which will contrast with the wall finish. If such materials must be used, seal the caulking by coating with shellac or aluminum paint and then paint to match the surrounding area.

d. In filling joints with cement-sand mortar, size the sand to the width of the crack. Be sure to moisten the old concrete or mortar surrounding the crack to develop good bond and cure the new mortar by keeping it damp for 2 or 3 days. Do not apply waterproofing above or below grade until the pointed wall has dried (set).

e. Seal cracks below grade to prevent moisture from entering or passing through the wall.

4.3.6.2 *Determination of Method of Repair.* If the cracked masonry units to be repaired are in a wall of some prominence, where patching would be an eyesore, the cracked masonry units shall be removed and replaced. If the final appearance of the wall is of little consequence, the cracked masonry units may be patched in a manner similar

to the repair described for cracks in joints, using any procedure determined feasible and economical.

#### 4.3.7 Concrete Repairs

4.3.7.1 *Routing and Sealing.* Repair large cracks by first cutting them out to a depth of about 1 inch and a width of  $\frac{1}{4}$  inch. Remove all dust and loose material with brushes or compressed air. If the cracks have been caused by initial shrinkage or expansion of the structure, fill them with mortar. If they are caused by an accepted recurrent movement of the structure, fill them with caulking material. Before applying mortar, wet the crack and adjoining surfaces thoroughly. Then neatly apply a slurry of portland cement and sand. Use 1- to 3-mix cement-sand mortar. To reduce shrinkage, prehydrate the mortar by mixing it about 2 hours before using it, adding only about half of the mixing water. At the end of the 2-hour curing period, rework the mortar and add enough water to make the mortar plastic, but not enough to make it run. Pack the mortar in the crack in fairly thin successive layers and tool it to a smooth surface, slightly in front of the adjoining surfaces. Shrinkage will be further reduced by keeping the patched portions damp for 48 hours. Caulking material should conform to Federal Specification TT-C-598. Use Grade 1 for gun application and Grade 2 for knife application. Grade 2 will shrink less than Grade 1. Before applying the caulking material, swab the cracks with a cloth moistened with turpentine or mineral spirits. *Do not use thinners in the caulking material* Do not apply primers. They usually stain the concrete and seal the pores, preventing a good bond. To place caulking compounds in cracks or expansion joints that have previously been filled with caulking, first remove the old caulking to a depth of  $\frac{3}{4}$  inch.

4.3.7.2 *Repairs Using Epoxies.* The use of epoxies for bonding broken surfaces is the most successful method for sealing cracks in concrete.

a. Cracks as narrow as 0.003 inch can be sealed with epoxy compounds. Wide cracks in horizontal surfaces may often be sealed by pouring the epoxy compound into them; but in vertical surfaces and in the narrowest cracks in horizontal surfaces, applying the sealant by pressure is necessary. The usual practice is to drill holes approximately  $\frac{3}{4}$  inch deep and  $\frac{3}{4}$  inch in diameter into the crack from the face of the concrete at 6- to 12-inch centers and inject a solvent to flush out the defect. Valve stems or other types of entry ports are fastened in these holes with an epoxy compound. The smaller the cracks, the closer the valve stems should be placed. The surface crack

between the valve stems is sealed with a high viscosity epoxy or other compound that will contain the pressure of the injection process.

*b.* The injection process begins by pumping a low viscosity epoxy compound into the valve at the lowest elevation until the epoxy level reaches the adjacent valve. All valves in the circuit are then capped. The highest pressure used safely without causing relative movement between parts of the structure is applied to force the epoxy compound into hairline cracks. The pressure should approach 100 lb/in<sup>2</sup> if possible and should be maintained from 1 to 10 minutes or more. The pressure is then released, and more epoxy compound is pumped through the same valve until the succeeding valve is capped; the process is repeated with successive valves until the crack has been completely filled, pressurized, and all valves capped. If larger quantities of grout than anticipated are required, further investigation is necessary. Cores are often taken later to check penetration and strength.

**4.3.7.3 Chemical Grouting.** Chemical grouts consist of solutions of two or more chemicals that react to form a gel or a solid precipitate, as opposed to cement or clay grouts that consist of suspensions of solid particles in a fluid. Cracks as narrow as 0.002 inch have been sealed in concrete with chemical grout. The advantages of chemical grout include applicability to a moisture environment, wide limits of control of gel time, and application on very fine fractures. Disadvantages are high cost, high degree of skill and expertise for satisfactory use, and shelf-life considerations and safety precautions required for successful use.

*a.* The ultimate goal of grouting is to place a certain grout at some predetermined location. Down-hole grout placement can be accomplished by several means. The simplest grouting situation is to pump or pour the grout directly on a surface or into an open hole or fracture. The simplest down-hole method using pressure for placement would be the use of one packer to prevent the grout from coming back up the hole while it is being pumped.

*b.* Selective down-hole grouting for an appreciable hole can be accomplished by placing two packers, one above and one below the area to be treated, and then injecting the grout. Another selective grout placement method is by use of "tubes a manchettes." This method entails using a tube with a smooth interior that is perforated at intervals and sealed into the grout hole. The perforations are covered by rubber sleeves, "manchettes," which act as one-way valves. Selective grout placement is obtained by a double packer arrangement that straddles the perforations.

The annular grout sleeve is designed to burst under pressure which permits grout to flow into the formation.

*c.* A slotted or perforated pipe may be driven into a formation and then grouted, or an open-end pipe may be driven to a desired elevation and then grout. The open-end pipe can be kept open by plugging the open end with a rivet or bolt during driving. When the desired elevation is reached the pipe is raised several inches to allow the rivet or bolt to work free from the open end when pressure is applied by grouting. The pipe may also be unplugged by placing a smaller rod inside the injection pipe to total hole depth and slightly beyond.

*d.* Using the two-solution process, drive a perforated pipe a certain distance and inject the grout solution. This process is continued until total depth is reached and then grout solutions of the remaining chemicals are injected to complete the reaction as the pipe is extracted.

*e.* Selective placement of grout can be accomplished without the use of packers. This involves grouting a pipe in place, lowering a gun perforation unit that contains either shaped, charged projectiles, or a special jet charge, and firing the projectiles or jets to penetrate the pipe some distance into the formation. Either of these methods gives access to previously grouted formations and virgin formations. Elevation and direction can be dictated by this operation.

**4.3.7.4 Small Cracks in Concrete.** Repair small cracks by thoroughly wetting and then brushing cement-sand grout into them. Mix grout in proportions, by volume or equal parts of portland cement and dry sand, passing a No.50 sieve. Liquid shall be added to produce a mix suitable for brushing. Cement and sand shall be selected to produce a shade of grout that matches existing concrete. Brush the grout vigorously into the cracks. After the cracks have been filled, keep them damp for about 36 hours.

**4.3.7.5 Large Broken Areas.** Repair large broken concrete areas by cutting out enough loose concrete to expose the metal reinforcement. Remove all dust and loose materials. Wet the existing surfaces thoroughly and then coat them with a neat cement-sand slurry, as recommended for large cracks. Then apply the new concrete of a mix corresponding to that of the existing concrete. Mixing and application should conform to the applicable requirements. After the concrete is applied, keep it damp for 48 hours.

**4.3.7.6 Precast Concrete Walls.** Most precast slabs and panels are of dense, high-strength

concrete. Webs are usually thin. Repair large cracks in monolithic concrete. *Do not attempt to cut channels in precast slabs or panels.* Repair small cracks as indicated in paragraph 4.3.7.2.

4.3.7.7 *Concrete Spalling.* Repair concrete spalling using a 2-part polymeric mortar system. Remove all loose and unsound concrete by hammer and chisel. Remove small concrete pieces with a wire brush. Remove loose rust scale and all nonadherent rust from any exposed reinforcing by chipping with handtools and by wire brush. Clean all dust, oil, or other bond-inhibiting materials from patch area. Be sure depth of patch area is compatible with patching material. Before placing the patching material, thoroughly clean, dampen, and brushcoat the area to be repaired. Mix only the amount of mortar that can be used during the pot life of the specific product. Patch area with polymeric repair mortar. All surface preparation, mixing, and placing must be in strict accordance with the manufacturer's printed instructions. All work must be finished plumb, smooth, and neat to match adjacent existing areas. Protect the repair and keep it damp for the curing period specified by the manufacturer.

4.3.7.8 *Structural Concrete Patching.* Repair defective or discolored concrete with a 2-part polymeric mortar system. Remove concrete in question to a depth of no less than 1 inch. Make all cuts perpendicular to the concrete surface. Remove all loose concrete pieces with a wire brush. Before placing patching material thoroughly clean, dampen, and brushcoat the area to be repaired. Mix only the amount of mortar than can be used during the pot life of the specific product. Patch area with polymeric repair motar. All surface preparation, mixing, and placing must be in strict accordance with the manufacturer's printed instructions. All work must be finished plumb, smooth, and neat to match adjacent existing areas. Protect patch and keep it damp for the curing period.

4.3.7.9 *Grouting Bolts.* Grouting bolts into existing concrete beams, walls, and slabs using a 2-part epoxy grouting compound with an added aggregate. Remove dust, grease, standing water, and all other deleterious materials from bolthole. Remove dirt and grease from the bolt and dry it sufficiently. Mix only the amount of grout that can be used during the pot life of the specific product. Fill the bolthole to a predetermined depth with epoxy grout. Set the bolt in the hold and work it up and down, lightly tapping it to insure complete embedment. Check the bolt projection and plumbness and secure in position using a template to insure proper location. Pack or pour additional

grout into the hole, if required. Allow grout to set for time period specified by manufacturer before applying load. Use a heavy liquid grout for horizontal surfaces and a gel consistency grout for vertical and overhead surfaces. All surface preparation, mixing, and application of grouting compound must be in strict accordance with the manufacturer's printed instructions.

4.3.7.10 *Bonding Toppings to Existing Concrete.* Use a 2-part epoxy concrete adhesive to bond concrete toppings to existing concrete floors. Remove all dust, laitance, oil, and other deleterious material from the existing concrete slab by sandblasting or other means of abrasive cleaning available. Remove all standing water from the area to be covered. Mix only the amount of adhesive that can be used during the pot life of the specific product. Apply the adhesive with airless sprayer, roller, brush, or squeegee evenly to the surface at the coverage specified by the manufacturer. All surface preparation, mixing, and application of the adhesive must be in strict accordance with the manufacturer's printed instructions.

4.3.7.11 *Concrete Floor Overlays.* Refinish existing concrete floor slabs using a 2-part polymeric mortar overlay. Prepare surface to be covered to the required profile of the specific product to be used. Remove all deteriorated concrete and existing toppings, dirt, oil, and other bond-inhibiting materials by sandblasting, scabber, or other available means. Sweep or vacuum dust off entire surface. Repair all cracks in the existing slab with a low viscosity epoxy grout. Wash entire surface prior to overlay application and allow it to air dry. Apply overlay mortar to the surface and finish to the desired final surface condition. All surface preparation, mixing, placing, and finishing must be in strict accordance with the manufacturer s printed instructions. Provide joints in the overlay topping in the exact location of joints in the exiting slab. Saw-cut joints immediately after overlay has set or preform joints by inserting steel or plastic strips in the existing joints. Preformed joint strips shall not project above the top of the overlay and shall be removed after the overlay has stiffened. Tool a **C**-inch radius edge after the joint strip is removed. Protect the new overlay and keep it damp for the curing period specified by the manufacturer.

4.3.7.12 *Surface Sealants.* Protective surface coatings are used primarily to improve the durability of concrete by preventing or inhibiting the intrusion of moisture, chemicals, or waterborne salts but can also be used to lengthen the life of repair. Typical materials employed as protective surface coatings include boiled linseed oil generally mixed with

mineral or petroleum spirits or turpentine), petroleum oil, silicones, epoxy-resin coatings, asphalt materials, rubber and rubberized asphalt, or curing compounds. Epoxy coatings are the most effective under sustained exposure because they do not require replacement as frequently; but they are more expensive. Impervious coatings such as epoxy-resin coatings should never be applied to the surface of concrete slabs on grade that may be subsequently exposed to freezing unless it is certain that the concrete can resist frost action in a critically water-saturated condition.

*a. Methods of Application.* Sealers may be applied to old surfaces by airless spray, roller, brush, lamb's wool applicator or trowel, depending on the product. High viscosity sealers such as bituminous applications for below-grade concrete exteriors are generally applied with brush or trowel and may require reinforcing mesh to enhance resistance to tear or rupture. Some epoxy, rubber, and acrylic sealants may be applied by airless spray equipment. Most sealants may be applied by brush or lamb's wool application. The manufacturer's recommended applications should always be followed.

*b. Surface Preparation.* Sealants require clean surfaces for proper penetration. Surfaces should be free of existing coatings, dirt, oil, grease, or other contaminants. The type of sealant selected will determine the appropriate method for cleaning. Particular care must be taken in cleaning surfaces for application of epoxy sealants or films, which require water or sandblasting. The manufacturer will identify the appropriate cleaning methods which are detailed in paragraph 4.3.9.

#### 4.3.8 Brick Repairs

4.3.8.1 *Mortar Preparation.* Lay new brickwork in mortar mixed in the proportions by volume of 1 part portland cement, 1 part lime paste, and 6 parts sand, or of 1 part masonry cement and 3 parts sand. Add sand so that it is distributed uniformly throughout the mass. Then add water gradually until the mortar is plastic enough for use. Portland cement and masonry cement (type II) should conform to ASTM Specification C-270. Lime paste should be made with pulverized quicklime or with hydrated lime that has been allowed to soak for at least 72 hours before use. However, hydrated lime processed by the steam method should be soaked not less than 12 hours before using it. Pulverized quicklime should conform to Military Specification MIL-L- 14519C. Ten percent should pass a No.20 sieve, and 90 percent should pass a No.50 sieve. The chemical composition and fineness of hydrated lime should conform to Federal Specification SS-L-

351 and should not contain more than 8-percent free (unhydrated) calcium oxide and magnesium oxide. Lime paste, after soaking as recommended herein, should pass the plasticity test for Type F lime given in Federal Specification SS-L-351. Sand should be sharp, clean, and free from dirt, silt, organic matter, and other impurities. Mixing water should be clean freshwater and free from excess acids, alkalies, and other deleterious matter.

4.3.8.2 *Bricklaying.* Handle bricks so that their faces and edges will not be damaged. Be sure that masonry beds are clean and properly wetted. Porous soft brick should be wetted before laying in hot, dry weather to reduce the rate of absorption of water from the mortar. The amount of wetting is determined by the type of brick and the weather conditions. Glazed brick has little or no absorption; therefore, it should be laid dry. Lay the brickwork in the bond that matches the adjoining existing work. Use batts only for closures. *Completely fill all joints between bricks with mortar.* Form bed joints with a thick, smooth layer of mortar. Avoid furrows. Form cross joints by applying a full coat of mortar to the entire side or end of the brick to be laid, as the case requires, and then shove the mortar-covered end or side tightly against the bricks already in place. *Do not merely butter the corners of the brick to be laid and then attempt to fill the empty mortar joints after the brick is in place.* Form longitudinal joints as recommended for cross joints or apply a full thickness of mortar to the bricks laid previously, and then shove the next brick in place. Lay closure bricks with full-bed, longitudinal, cross joints, placing the bricks carefully without disturbing the bricks already in place. *Do not allow any dry or butt joints.* Build in metal fasteners, flashing, etc., as the work progresses. Keep joints uniform in thickness, aligning and tooling them to match joints of existing work. Remove all loose and excess mortar.

4.3.8.3 *Brick Walls.* Common defects in brick walls are open vertical joints, cracking, spalling, and porosity. Efflorescence and leakage of rain-water through the walls usually result from such defects. Inadequate or improperly designed and constructed flashings also cause serious leakage. Open, vertical joints result from failure to fill the joints with mortar in laying the brick. Cracking may result from settlement, expansion and contraction, misalignment, or some other serious structural defect in the building. Spalling results if bricks are soft or tend to powder and crack, or when moisture freezes within the masonry. Porosity in brick walls is rare and can result only from the use of porous brick or mortar. Mortar containing large aggregate or poor-quality brick may produce this porous

condition. An engineering investigation of the causes of structural defects should govern the nature and extent of major repairs. Cracked and open mortar joints should be repaired as recommended. Where masonry cracks appear at windows, doorways, offsets, and like places, an expansion joint or control joint should be provided at those locations to minimize the effect of foundation movement.

4.3.8.4 *Racked-Down Corners.* On masonry projects having concrete floor or roof slabs,

buildings may have sections of masonry damaged or loosened at the corners. This occurs where the horizontal movement cracks along the side and end of a building meet. Frequently, the horizontal crack not only continues around the corner, but also forms a diagonal crack in a downward direction that meets a similar crack from the other side, forming a "V." The masonry units inside this V are loosened and must be reset. See figure 4-7. The following procedure may be used to accomplish the repair:

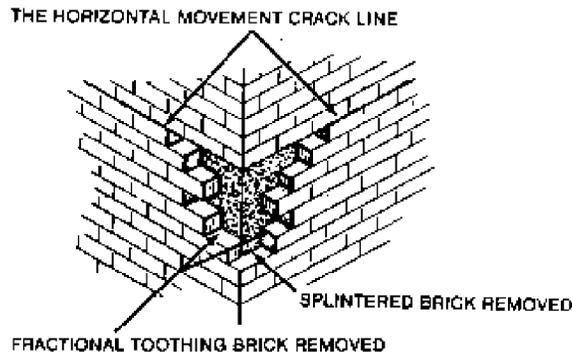


Figure 4-7. DAMAGED BRICK REMOVED.

a. Remove all the bricks inside this V, including any masonry units that have been broken. See figure 4-7. This forms regular sides and helps to hold or key the new masonry units in place.

b. After the masonry units are removed, the good masonry units should be cleaned and as many new matching ones obtained as necessary. Relay the bricks in mortar up to and even with the horizontal crack running along the side and end of the building. Making all joints the same width as the original joints matching the old mortar will result in a very presentable job. As the masonry units are relaid, the backup masonry units should be coated with mortar, so that the newly laid masonry units will be bonded to them.

c. Partially fill with mortar the top joint that is on line with the horizontal crack. This can be done by pushing the mortar into the joint with a narrow pointing trowel. When about half the depth of the joint is filled, fill the remainder with sealing compound. This system of mortaring only half a joint supports the brick above but forms a weak plane along the top of the racked-down areas. If movement occurs the mortar joint break but the relaid bricks remain in place. The sealing compound keeps the joint watertight.

4.3.8.5 *Parapet Creep.* Unequal expansion of roof slabs and masonry parapets sometimes causes parapet corners to creep. When this happens, the horizontal mortar joint at the top of the slab (or the nearest through-wall flashing) usually shears open. The corner parapet will then extend beyond the face of the wall below. If creeping continues to the point that cracks extend through the parapet and concrete spalls from the spandrel beam, and both brick and mortar begin to break off, an engineering investigation for major repairs is necessary. In most cases, approximately 20 feet of the parapet, beginning at the corner, must be removed. A new section of parapet, doweled into the wall below, is then laid. A vertical expansion joint, 1 inch wide, is provided at the juncture with the existing parapet. Through-wall metal flashing and a continuous seal of bituminous plastic cement must be provided at the bottom of and in the expansion joint. Plastic cement should conform to Federal Specification SS-C-153.

#### 4.3.9. Cleaning Masonry and Concrete Walls

4.3.9.1 *General.* The appearance of many structures has been irreparably marred by improper cleaning methods. A cleaning method that works well on hard surfaces can be harmful to soft stone

and glazed finishes. A method that cleans marble or glazed surfaces may be entirely unsatisfactory on rough-textured surfaces. Cleaning methods safe for a masonry surface may cause damage to the mortar joints. If the surface to be cleaned has more than one kind of masonry, one cleaning method may not be safe or effective on all. The material to be cleaned and the type of stain to be removed will determine the cleaning process to be used.

4.3.9.2 *Concrete.* Many chemicals can be applied to concrete without causing injury. Chemicals having an acid reaction must be handled with caution. Even weak acids may roughen the concrete surface if left for long periods of time. Stains caused by iron, copper, bronze, aluminum, fire, and oil are discussed below. Old long-neglected stains may require repeated treatments. Deep staining may be removed with a poultice or by the "bandage" treatment.

4.3.9.3 *Masonry.* Masonry units of low absorption and those with smooth (or glazed) surfaces generally respond readily to proper cleaning methods and resume their original appearance. Highly absorbent or rough-surfaced units are more difficult to clean. When the staining material fills the pores of the unit, attempts to remove the stain may remove part of the surface, destroy its texture, or change its appearance. The principal methods of cleaning masonry structures are with steam and water, sandblasting, and various liquids and pastes.

4.3.9.4 *Steam Cleaning.* Cleaning with high-pressure steam and water, sometimes called cold-steam cleaning, is effective and economical. It removes grime from surfaces of concrete and masonry building without harming the surfaces. After steam cleaning, masonry surfaces retain their original finish and natural color tones without the roughened surfaces and dulled edges caused by sandblasting or the dead, bleached tone caused by acid cleaning.

*a. Equipment.* Use proper equipment for steam cleaning. Much of it can be improvised, but the needs of an installation may make buying or renting equipment advantageous.

(1) *Steam Supply.* A continuous supply of high-pressure steam must be assured before cleaning operations begin. A truck-mounted portable boiler, together with its accessories, is generally a satisfactory source. Steam pressure for cleaning old buildings is preferably 150 lb/in<sup>2</sup> and never less than 140 lb/in<sup>2</sup>. For cleaning new work 120 lb/in<sup>2</sup> is preferred; however, never less than 100 lb/in<sup>2</sup> is needed. Boiler capacity of about 12 horsepower for

each cleaning nozzle is necessary. The pressure with which the steam and water mixture is driven against the wall, not volume of discharge, is important in steam cleaning.

(2) *Nozzle.* The cleaning nozzle is a most important accessory; it should be a mixing type, having a water control valve and automatic steam shutoff. One efficient type has a very narrow opening 4 inches long and can deliver an extremely fine spray at a high velocity. Operating two cleaning nozzles from each length of scaffold is good practice.

(3) *Water Supply Hose.* An ordinary garden hose is suitable for carrying water from the source to the mixing nozzle.

(4) *Steam Supply Line.* Use high-pressure steam couplings and hose, or suitable pipe and fittings, or a combination or both, to convey steam to the mixing nozzle.

(5) *Rinsing Hose.* In addition to the hose supplying water to the steam-cleaning nozzle, have another hose with ordinary garden-type nozzle and shutoff to flush the walls with water occasionally.

*b. Procedure for Steam Cleaning.* Cleaning is done by high-velocity projection of a finely divided spray of steam and water against the masonry surface. The mixture of steam and water spray entering minute surface depressions and openings dissolves and dislodges grime, soot, and other extraneous matter, which is later flushed down the wall by the rinsing hose. Experimentation with the cleaning equipment quickly shows the operator the best angle and distance to hold the nozzle from the wall and proper regulation of steam and wet values for most effective work. Work on one 3-foot-square space at a time. Pass the nozzle back and forth over the area; then flush with clear water before moving to the next space. Alkalines, such as sodium carbonate, sodium bicarbonate, and trisodium phosphate, are sometimes added to the cleaning water to speed the cleaning action. Although they aid cleaning, some salts are retained in the masonry and may appear on the wall later as efflorescence. To cut down the amount of salts retained, wet wall units thoroughly with clear water before beginning the cleaning operation. Immediately after cleaning, wash the wall with enough clear water to remove all possible salts from the wall face. Removal of surface dirt sometimes reveals stains. A mild acid wash may be necessary to remove them. After the stains are removed, steam the treated surface again and flush with water from the rinsing hose to remove all trace of acid wash. Steel scrapers or wire brushes may be necessary to remove hardened

deposits that cannot be removed by steam cleaning. Use scrapers sparingly and carefully to avoid damage to masonry surface. Use brushes of fine spring-steel wire to grind off the hard deposit without digging into or scratching the masonry surface. After hard deposits have been removed by scraping or wire brushing, flush off surface with water, treat it with the steam-cleaning nozzle, and flush again to remove any loose dirt which might cause future streaking or discoloration.

**4.3.9.5 Sandblast Cleaning.** Sandblasting cleans rust and scale from structural steel and many other metal surfaces efficiently. When used on masonry surfaces, it eliminates mortar smear, acid burn, efflorescence (which is inherent in acid cleaning), and chemical stains. Do not use this method on marble, terra cotta, glass, or units with glazed or other special surfaces or textures. Although it cleans effectively, it often destroys the original surface of the masonry unit. It tends to dull sharp edges (arrises), to blur ornamental detail and caring, and to roughen surfaces. Stone cleaned by sandblasting, especially limestone, appears whiter, but this whiteness is caused partly by the fact that the stone surface has been abraded.

*a. Equipment Used for Sandblasting* Use a ¾-inch hose if maximum air and sand pressure is required, or a 1-inch hose if volume, rather than pressure, is required. For use against brick, a pressure in the range of 60 to 120 lb/in<sup>2</sup> through a ¼-inch sandblast nozzle is recommended. The quality of sand needed varies with the depth of cutting to be done and the type of material to be cleaned. Fine, white urn sand, which is rounder and cuts less than sharp sand, is recommended for use on brick. Placing a canvas screen around the scaffold keeps sand from scattering and makes it possible to salvage about 75 percent of the sand. Usually, four men are required in a sandblasting crew: one attends the air compressor, one at the nozzle, and two on the ground to handle the hose, scaffold, sand, etc.

*b. Procedure for Sandblasting* In sandblasting, compressed air forces sand through a nozzle against the surface to be cleaned. The sand removes accumulated grime and a layer of the surface. The thickness of the layer removed depends on the type of sand used, the air pressure, the volume of sand applied, the nearness of the nozzle to the surface, and the length of time that the sand is applied to one area. Sandblasting can be used safely on hard brick by an experienced operator using caution, and on sand finish with extreme caution. The nozzle operator should experiment with his equipment on a small, secluded area to

determine how far to stand from the wall, which pressure is best, and the angle at which sand will clean the surface, but not etch it. The operator should concentrate on hitting the brick surfaces, and not the mortar joints. When hardness between masonry units and mortar joints differs widely, sandblasting may cut deeply into the mortar. If this occurs, joints must be repointed. Roughened surfaces produced by sandblasting gather soot and dirt quickly; therefore, the application of a transparent waterproofing is desirable. This coating fills surface pores, tends to make the wall self-cleaning, and prevents rapid soiling of surface by smoke and dust.

#### **4.3.10 Chemical Cleaners**

**4.3.10.1 General.** Acid and caustic concentrations and space mixtures are used to clean many interior and exterior surfaces. The cleaning material used depends on the texture of the surface to be cleaned, the age of the structure, the material or stain to be removed, and the capabilities of the cleaning crew. The most satisfying results will be obtained by balancing all the above factors and observing a trial application on a sheltered area. Many burned-clay surfaces, concrete surfaces, and glazed (or polished) surfaces of tile, marble, and glass can be cleaned by hand-scrubbing with a white soap powder dissolved in soft water, using ordinary fiber scrub brushes. Rinse surfaces thoroughly with clear water after scrubbing them.

**4.3.10.2 General Precautions in Using Acids.** Do not use acid solutions to clean limestone and similar materials unless experienced operators and expert supervision are available. Acid washes tend to eat into stone surfaces and pit them. They usually bleach, producing an unnatural appearance, and may cause yellow stains to appear later. If acid solution is not thoroughly washed from the masonry pores after cleaning, the destructive action continues for some time. When mixing acid solutions, always *pour acid into water*. Handle acid solutions carefully because they are harmful to the skin and especially to the eyes. When working with acid cleaners, wear goggles, gloves, and protective clothing, and keep a supply of running water at hand. Use only wooden containers and fiber brushes when cleaning with acids. Do not use metal containers or wire brushes and steel wool to scrub the walls because small steel particles become lodged in crevices, producing rust spots and stains.

**4.3.10.3 Removing Mortar Stains.**

*a. General Cleaning Procedure.* Make the cleaning operation one of the last phases of the job. Do not start before the mortar is thoroughly set and

cured. Remove large particles of mortar with wooden paddles and scrapers before wetting the wall. In some cases it may be necessary to use a chisel or wire brush. Presoak the wall. Saturate the masonry with clean water and flush off all loose mortar and dirt. Protect the area below the surface being cleaned. Keep all masonry below soaked with water and flush off all acid and loose mortar. Protect ornamental shrubs and pedestrians, as required. Clean only a small area at a time (approximately 10 to 20 square feet). It may be necessary to reduce this area when heat, sunlight, warm masonry, or warm winds increase the reaction rate of the acid or accelerate drying. Rinse the wall thoroughly with plenty of clean water after scrubbing.

*b. Cleaning Dark- and Light-Colored Brick with Nonacid Solution.* Follow directions outlined in paragraph 4.3.10.3(1), General Cleaning Procedure. Scrub wall with a solution of ½-cup trisodium phosphate and ½-cup household detergent, dissolved in 1-gallon clean water. Use stiff fiber brush only.

*c. Cleaning Dark Brick with Acid Solution.* Acid cleaning should be used only in difficult cases. Follow directions outlined in paragraph 4.3.10.3(a), General Cleaning Procedure. Mix 1 part clean, stain-free commercial-grade, hydrochloric acid (muriatic) with 9 parts clean water in a nonmetallic container. *Pour acid into water; never pour water into acid.* Apply and scrub the brick with a long-handled fiber brush having no metallic parts.

*d. Cleaning Light Brick with an Acid Solution.* Use the same procedure as for cleaning dark brick, except mix 1 part of the highest grade acid (chemically pure) available to 15 parts clean water; then neutralize the acid immediately after cleaning. Neutralizing can be accomplished by flushing the wall with a solution of potassium hydroxide or sodium hydroxide, mixed at the rate of ½ pound of hydroxide in 1 quart of water (2 lbs/gal). Allow this solution to remain on the wall for 2 or 3 days. The white salts left on the wall by the hydroxide may be hosed off or will be removed by a heavy rain.

*e. Cleaning Glazed Brick and Tile.* Glazed brick and tile should be carefully wiped clean with a soft cloth within a few minutes after laying. A final cleaning with a soft sponge or brush and ample water will usually do the job. In more difficult cases, use the same procedures as used for cleaning dark- and light-colored brick with nonacid solutions, paragraph 4.3.10.3(b); do not use metal cleaning tools, brushes, or abrasive powders. A

second method for cleaning is the method described for cleaning light brick with an acid solution, paragraph 4.3.10.3(d), using no more than 1 part high-grade acid (chemically pure) to 25 parts clean water. *Never use acid to clean salt-glazed or metallic-glazed masonry units.*

*f. Efflorescence Stains.* Follow the steps outlined in paragraph 4.3.10.3(a), General Cleaning Procedures. Efflorescence can frequently be removed by water applied with a stiff scrubbing brush. In those cases where the water procedure does not remove all the stain, the surface can be scrubbed with a solution of hydrochloric (muriatic) acid mixed at the rate of 1 part commercial-grade acid to 9 parts water.

*g. Vanadium Stain.* Green stains are usually caused by salts of vanadium and can be removed by the method for neutralizing described in paragraph 4.3.10.3(d).

#### 4.3.10.4 *Paints and Similar Coatings.*

*a. Whitewash, Calcimine, and Cold-Water Paints.* To remove whitewash, calcimine, or cold-water paints, wash the surface with an acid solution of 1 part muriatic acid and 5 parts water. Scrub vigorously with a fiber brush as the solution foams. When coating has been removed, wash the wall with water from an open hose until all traces of acid are removed. If a paint film is old, crumbling, and flaking, scraping with wire brushes and metal scrapers may be necessary. While this method is effective, it may leave metal particles, which later cause rust stains in the wall surface.

*b. Oil Paint, Enamels, Varnishes, Shellacs, and Glue Sizings.* Remove oil paint, enamel, varnish, shellac, or glue sizing by applying a paint remover that is left on until the softened paint can be scraped off with a knife or flushed off with water. After the paint is removed, wash the wall thoroughly to remove all traces of acid. Efficient paint removers include:

- (1) Commercial paint remover.
- (2) Trisodium phosphate — 2 pounds to 1 gallon of hot water.
- (3) Caustic soda—2½ pounds to 1 gallon hot water.
- (4) Sodium hydroxide—1 part dissolved in 3 parts water and added to 1 part mineral oil. Stir mixture until emulsified; then stir in 1 part sawdust or other inert material.
- (5) Soda ash and quicklime—equal parts mixed with enough water to form a thick paste. Leave this mixture on the wall for 24 hours before

scraping off. If the oil-paint is very thick and hard, this method may fail, in which case sandblasting or burning may be the best way to remove it.

4.3.10.5 *Iron Stains.* Iron stains can usually be recognized by their resemblance to iron rust or by their proximity to steel or iron members in the building. Large areas of concrete or cement stucco may be stained if curing water contains iron. This stain can generally be removed by mopping the surface with a solution of 1-pound oxalic acid dissolved in 1-gallon water. After 2 or 3 hours, rinse with clean water, scrubbing at the same time with stiff brushes or brooms. Some spots may require a second mopping and scrubbing. For older, deeper stains the following methods are recommended:

a. *Method 1.* Dissolve 1 part sodium citrate in 6 parts lukewarm water. Mix thoroughly with 7 parts lime-free glycerin. Add to this solution enough whiting (chalk powder) or kieselguhr to make a paste poultice stiff enough to adhere to the surface when applied with a putty knife or trowel to a thickness of  $\frac{1}{2}$  inch or more. Allow a minimum of 2 days for drying. Scrape off and wash thoroughly. If the stain has not disappeared, repeat the treatment. This treatment has no injurious effects, but its action may be too slow for bad stains. Ammonium citrate produces quicker results, but may injure a polished surface slightly, making a repolishing necessary.

b. *Method 2.* The sodium hydrosulphite combination "bandage practice" method is more satisfactory for removing deep, intense iron stains. Make a solution by dissolving 1 part sodium citrate crystals in 6 parts of water. Dip white cloth or cotton batting in this solution, place the cloth over the stain, and leave it there for 15 minutes. On horizontal surfaces, sprinkle a thin layer of hydrosulphite crystals over the stain being treated with sodium citrate, moisten with water, and cover with a paste of whiting and water. Give vertical surfaces the sodium citrate treatment. Place layer of whiting paste on plasterer's trowel, sprinkle on a layer of hydrosulphite crystals, moisten slightly, and apply to stain. Remove treatment after 1 hour. If left on longer, a black stain may develop. Wash treated surface with clean water. If inspection shows incomplete removal of the iron stain, repeat the cleaning operation, using fresh materials.

4.3.10.6 *Fire and Smoke Stains.*

a. *Method 1.* Fire and smoke stains can sometimes be removed by scouring with powdered pumice or a grit scrubbing powder. After removing the surface stain by scouring, the deep-seated stain can be removed by applying the trisodium-phos-

phate-chlorinated-lime solution. Fold a white cotton flannel cloth to three or four thicknesses, and saturate with the liquid. Paste this saturated cloth over the stain, and cover with a slab of concrete or sheet of glass, making sure the cloth is pressed firmly against the stained surface. If the surface is vertical, devise a method to hold the saturated cloth firmly against the stain. Resaturate the cloth from time to time. Wash surface thoroughly at end of treatment.

b. *Method 2.* Make a smooth stiff paste of trichlorethylene and powdered talc and apply as a troweled-on poultice. Cover poultice with glass or pan to prevent rapid evaporation. Allow time to dry. Scrape off and wash away all traces of treatment material. Trichlorethylene gives off harmful fumes; therefore, see that closed spaces are well ventilated when using this stain remover.

4.3.10.7 *Copper and Bronze Stains.* Copper and bronze stains are usually green, but may be brown in some cases. Mix 1 part dry ammonium chloride (sal ammoniac) and 4 parts powdered talc, add water, and stir to a thick paste. Trowel  $\frac{1}{4}$ -inch layer of paste over the stain and leave until dry. When working on polished marble or similar fine surfaces, use a wooden paddle to scrape off dried paste. An old stain may require several applications.

4.3.10.8 *Oil Stains.* Oil penetrates most concrete readily. Oil spilled on horizontal surfaces should be immediately covered with a dry powdered material such as hydrated lime, fuller's earth, or whiting. Sweep up the powdered material, taking as much of the oil as possible. Scrub with a 10 percent acid solution (phosphoric or muriatic) containing a detergent, and wash with water. If treatment is made soon enough, there will be no stain. However, when oil has remained for some time, one of the following methods may be necessary:

a. *Method 1.* Mix 1 pound trisodium phosphate in 1 gallon water, and add sufficient whiting to make a stiff paste. Spread a layer of  $\frac{1}{2}$ -inch thickness over the surface to be cleaned. Leave paste until it dries (about 24 hours), remove and wash surface with clear water.

b. *Method 2.* Saturate white cotton flannel in a mixture of equal parts of acetone and amyl acetate and place it over the stain. Cover the cloth with a slab of dry concrete or sheet of glass. If stain is on a vertical surface, improvise means to hold cloth and covering in place. Keep the cloth saturated until the stain is removed. Covering saturated cloth with glass tends to drive the stain in, while the slab of dry concrete will draw out some of the oil.

## 4.3.10.9 Ink Stains.

a. Blue or Black Ink & Stains from different types of inks require different treatments. Because of their acid content, ordinary writing inks may etch concrete. To remove a stain of this type, make a strong solution of sodium perborate in hot water. Mix it with whiting to form a thick paste. Apply it in a ¼-inch layer, and leave until it is dried. If some of the blue color is visible after the poultice is removed, repeat the process. If only a brown stain remains, treat it by Method 1 recommended for iron stains. Sodium perborate may be obtained from any druggist. Some blue inks contain Prussian blue, a ferrocyanide of iron. These stains cannot be removed by the perborate poultice, Javel water, or chlorinated lime poultice. They yield to treatment by ammonia water applied on a layer of cotton batting. A strong soap solution applied in the same way may also be effective in some cases.

b. *Bright-Colored Inks.* Many red, green, violet, and other bright-colored inks are water solutions of synthetic dyes. Stains made by this type of ink can usually be removed by the sodium perborate poultice that is recommended for ordinary writing ink stains. Often the stain can be removed by applying ammonia water on cotton batting. Javel water, conforming to Federal Specification O-S-602, may be used in the same way as ammonia water, or mixed to a paste with whiting and applied as a poultice. A mixture of equal parts of chlorinated lime and whiting reduced to a paste with water can also be used effectively as a poulticing material. Use a chlorinated lime conforming to the requirements of Federal Specification O-C-114 for Type II, Grade A chlorinated lime.

c. *Indelible Inks.* Many indelible inks consist entirely of synthetic dyes. Stains may be treated as recommended for that type; however, some indelible inks contain silver salts, which cause a black stain. This stain can be removed with ammonia water applied by bandage. Several applications are usually necessary.

4.3.10.10 *Tobacco Stains.* The following method is usually effective in removing tobacco stains. Dissolve 2 pounds of trisodium phosphate crystals, conforming to Federal Specification O-S-642, in 1 gallon of hot water. In a shallow, enameled pan, mix 12 ounces of chlorinated lime, with enough water to make a paste. Add the water slowly and mash the lumps as they form. Pour this mixture and the trisodium phosphate solution into a 2-gallon stoneware jar, and add water until the jar is full. Stir well, cover the jar, and allow the lime to settle. Add some of the liquid to powdered talc until a

thick paste is obtained. Apply it with a trowel as a ¼-inch poultice. To apply the paste with a brush, add about a teaspoon of sugar to each pound of powdered talc. When it is dry, scrape it off with a wooden paddle or trowel. This mixture is a strong bleaching agent and is corrosive to metals. Care should be taken not to drop it on colored fabrics or metal fixtures. If the stain is comparatively light, use a scrubbing powder as a poulticing material. Stir the powder into hot water until a mortar consistency is obtained. Mix it thoroughly, and then apply the mixture to the stained surface in a ½-inch layer. Permit it to dry. In most cases, make two or more applications, if necessary.

4.3.10.11 *Urine stains.* To remove urine stains, use the method recommended for tobacco stains. If the stains remain, saturate cotton batting in the liquids recommended, and paste it over the remaining stains. Resaturate the cotton, if necessary.

4.3.10.12 *Rotten Wood Stains.* Damp rotten wood will produce a chocolate-colored stain that is readily distinguished from most other stains. The treatment recommended for fire stains is best. Removal of the stain will be accelerated if the surface is first scrubbed thoroughly with glycerin diluted with four times its volume of water.

4.3.10.13 *Coffee Stains.* Coffee stains can be removed by applying a cloth saturated in glycerin that is diluted with four times its volume of water. Javel water of the solution used on fire stains is also effective.

4.3.10.14 *Iodine Stains.* Iodine stains gradually disappear; however, they may be removed quickly by applying alcohol and covering the spot with whiting or powdered talc. If the stain is on a vertical wall, it may be removed by applying some alcohol to the stain and covering it with a paste of talcum and alcohol.

4.3.10.15 *Perspiration Stains.* Secretions from the hands or oil from the hair may produce stains on concrete. The stain is brown or yellow and may be mistaken for an iron stain. The best treatment is the one recommended for fire stains. Deep stains may require several treatments.

#### 4.3.11 Glass-Block Masonry

4.3.11.1 *General.* Glass-block panels require little maintenance other than occasional cleaning and periodic inspection of joints. The glass-block panels can be seriously damaged by superimposed loads transmitted through excessive deflections in beams and lintels, differential settlement of foundations, or by impact. The cause of serious damage must be investigated and corrected prior to making repairs.

4.3.11.2 *Materials.* The following materials are used in glass-block masonry:

a. Glass block is a hollow, partly evacuated block constructed of translucent, pressed glass, which is formed of two halves fused together at a high temperature. The exposed faces are a nominal 6-inch (5¾ inches), 8-inch (7¾ inches) and 12-inch (11¾ inches) square with a nominal 4-inch (3f inches) thickness.

b. Mortar should conform to N-type mortar as described in ASTM C-270. A waterproofing mixture approved by the glass-block manufacturer may be used with the mortar.

c. Oakum shall be a nonstaining type treated to prevent mildew and dry rot.

d. Premolded expansion strips shall be of d-inch-thick fibrous glass material or other material recommended by the glass-block manufacturer.

e. Joint reinforcement shall be fabricated of galvanized wire consisting of two 9-gauge parallel wires spaced 2 inches on centers with a 14-gauge cross wire welded at not more than 8 inches on centers.

f. Wall anchors shall be perforated (hot-dip galvanized after perforation), 20-gauge, steel strips.

g. Asphalt emulsion shall be the type and manufacture recommended by the glass-block manufacturer.

#### 4.3.11.3 *Installation of Glass Blocks.*

a. General. Good workmanship is essential to obtain watertight glass-block panels. Manufacturer's instructions and recommendations should be carefully studied. Minor deviations are permissible but should be for a good, valid reason.

b. *Procedure.* The sill area to be covered with mortar shall receive a heavy coating of asphalt emulsion not less than 1/16 inch thick. When the emulsion coating is thoroughly dry, place a full mortar-bed joint. Do not furrow the mortar bed. Place the expansion strip in the jamb and head using asphalt emulsion as an adhesive. Set the first course of block. All joints must be full and not furrowed. Do not use steel tools to tap blocks into position. Blocks shall be laid in a regular straight-line pattern with vertical and horizontal joints continuous. Horizontal joint reinforcing shall be installed where indicated, or in accordance with the following General rule:

— For blocks 6 inches square, one tie every fourth course.

— For blocks 8 inches square, one tie every third course.

— For blocks 12 inches square, one tie every second course.

Reinforcing ties shall be spaced so as not to occur in the top joint of panels. Place the lower half of the mortar-bed joint. Press the reinforcing tie into place. Cover the panel reinforcing with the upper half of the mortar bed and trowel smooth. Panel reinforcing must run from end to end of the panel. Endlaps shall not be less than 6 inches. Reinforcing must not bridge expansion joint. Wall anchors for anchoring the glass block to the masonry or concrete construction shall be spaced not more than 2 feet on centers, vertically. Panels up to 2 feet high may have a single anchor in each jamb. All panels more than 2 feet high shall have at least two anchors in each jamb. Anchors shall be crimped at jambs to provide for expansion and contraction. Anchors shall extend not less than 10 inches into the structural jamb and 1 foot into the glass-block joint and shall be completely bedded in the center of the mortar joint. While mortar is still plastic, joint shall be raked back a sufficient depth to expose the edges of the block as sharp, clear lines. While mortar is still plastic and before final set, the joints shall be tooled slightly concave and smooth. The recess left between the face of the glass-block panel and the structural jamb (or head openings) shall be rammed full with oakum to within e inch of the exposed surface of the glass block. The recess grooves left in front of the oakum shall be fully caulked on both interior and exterior to provide a watertight and weatherproof joint. Rake out other spaces requiring caulking to a depth equal to the width of the space. Remove surplus mortar from the faces of the glass block and wipe dry.

4.3.11.4 *Repair of Glass-Block Masonry.* Glass-block masonry panels require little maintenance other than occasional cleaning and periodic inspection of joints, except when damaged. The causes of damage must be corrected before repairs are made. To repair panels, use the following methods:

a. Remove cracked and broken glass blocks.

b. Chip off fragments of broken glass adhering to undamaged blocks, taking care not to damage wall ties and anchors.

c. Clean old mortar from exposed wall tiles and anchors and from mortar-bearing edges of adjoining blocks.

d. Replace panels using materials and methods that match existing work as closely as possible.

Mortar will be proportioned with 1 part portland cement and 1 part lime putty and 4 parts sand. Two parts mortar cement may be substituted for portland cement and lime. Mix the mortar to stiff but workable consistency. Mortar for glass block masonry should be drier than for brick masonry.

## SECTION IV—METAL SIDING

### 4.4.1 General

The type of material used for metal siding may vary; but, generally speaking, each type requires similar maintenance and repair measures. Under conditions of foundation settlement, heavy wind and snow loading, heavy falling objects, and collision by vehicles, it is possible for metal buildings to sag, lean, or become damaged. In the event of settlement and subsequent misalignment of structural members and displacement or bending of siding, it is necessary to correct the basic problems as outlined in Chapter 2 of this manual. Where severe wind conditions or vibrations affect the stability of metal siding, it may be necessary to place additional bracing and fasteners. This should be done as directed by a structural engineer or as outlined in the siding manufacturer's instructions on sheeting and fasteners.

### 4.4.2 Routine Maintenance

Measures must be taken to keep all bolts, clips, rivets, nails, and other ties and fasteners tight and in place. Where corrosion has destroyed the effectiveness of a fastener, treat or replace it immediately. Where stresses may have damaged the siding connection with the fastener, patch as necessary with matching material and replace the connector to assure a positive connection. Use stainless steel or aluminum nails and neoprene washers to assure trouble-free service. They not only waterproof the joint, but also prevent corrosion. It is often advantageous from the standpoint of maintenance to use double-headed nails in placing corrugated metal siding. Where sections of metal siding have been bent badly or cut, remove and straighten the section, making neat and workmanlike patches where expedient. Where damage is severe, replace

the panel with a matching substitute. Buildings that are subject to damage from vehicles should be provided with bumper guards to prevent vehicles or forklifts from striking the siding. Where metal buildings have interior insulation, take care not to damage existing construction and utilities when repairing or replacing metal wall coverings. Keep ventilators in metal buildings clean and clear of obstruction. Keep door-sliding devices and locks in adjustment and tightly fastened.

### 4.4.3 Steel Siding

4.4.3.1 *General.* Steel siding with protective coatings is designed to give reasonably long service. Damage from abrasion may expose the steel core to corrosion or reduce the thickness of protective coatings. Unless the damaged areas are repaired, touched up, or recoated as necessary, serious damage may result. If structural changes to a building make it necessary to cut existing steel siding, treat the affected areas to prevent corrosion. Protected steel siding is of the standard corrugated (or deep corrugation types) with the steel core protected at the factory with coatings or a combination of coverings and coatings. See figure 4-8. The sheets are resistant to flame spread. The surface is weather resistant, water repellent, and resistant to fumes, chemicals, and corrosion. The color coats are stable to heat and light and resistant to chalking. Siding sheets are furnished, complete with all flashings, fastenings, and accessories. Interior and exterior surfaces of the sheets are provided with a bituminous (black) or colored synthetic-resin, factory-applied weather surfacing. Protective coverings or coatings are applied by one of the following methods.

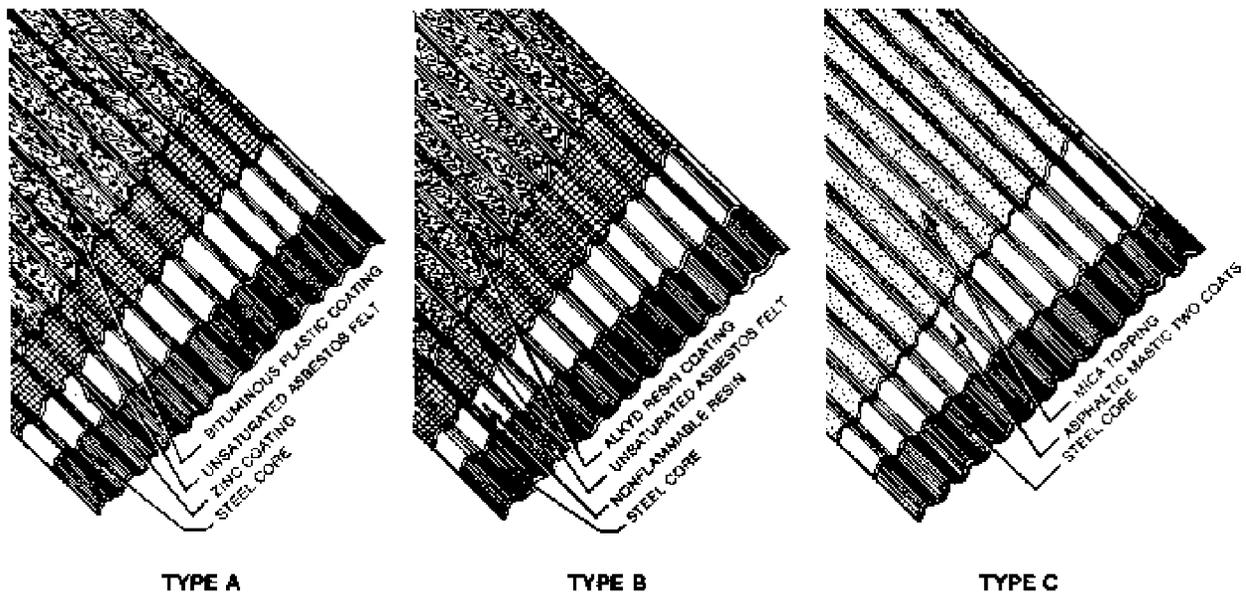


Figure 4-8. TYPES OF PROTECTED METAL.

a. *Type A (felt protected, zinc-adhesive).* The cleaned steel core is dipped in a bath of molten zinc, fusing the zinc to the steel. While the zinc is in a molten state, a layer of unsaturated felt is pressed over it, on each side of the sheet, squeezing the felt fibers into the zinc. The exterior or interior surface is finished with a heavy bituminous compound or a color coating of synthetic resin.

b. *Type B (felt protected, plastic-adhesive).* The cleaned steel core is given a phosphatising treatment, coated with a rust inhibitive primer, and a resinous adhesive. A layer of impregnated felt is rolled onto both sides of the sheet with the application of heat and pressure. The sheet is then given a protective coating of bituminous compound or alkyd-resin color compound.

c. *Type C (Asphalt-protected, mineral-coated).* The cleaned steel core is coated on all surfaces with a rust-inhibitive coating. The sheet is then heated and coated with adhesive. After the coated sheet has been cured, two separate coats of bituminous compound are applied. After application of the second coat, a layer of mineral mica is applied to both sides of the sheet by heat and pressure. A synthetic-resin color coating may be applied over the bituminous-compound coatings.

4.4.3.2 *Cleaning of Steel Siding.* Before repairing, touching up, or recoating, clean the affected areas. Remove all flaked coating and rust with a stiff fiber brush. Remove dust, chemical deposits, grease, and dirt. Scrape off thick deposits of grease with a trowel, putty knife, or wooden spade before using the detergent cleaner. Remove rust with a wire brush. The coatings for protected steel are petroleum asphalt compounds. They can be softened or dissolved by organic cleaners and solvents. *Do not use naphtha, bensol, xylol, gasoline, or carbon tetrachloride for cleaning protected steel.* If asbestos felt is encountered, refer to paragraph 4.5.3.

4.4.3.3 *Repair of Steel Siding.* To insure compatibility, recoating compounds conforming to the manufacturer's specification should be used in recoating protected steel. Recoating procedure is as follows:

a. *Type A and B Materials.* For small areas (under 10 square inches) of steel core exposed, coat the exposed steel, including a width of about 1 inch of the adjoining asbestos felt- and bituminous-covered surfaces, with asphalt primer. Allow the primer to dry for at least 24 hours and then apply bituminous plastic cement. Build up the plastic cement to form a continuous plane with

adjoining surfaces. When the cement has been exposed to the weather for at least 24 hours, apply a coat of bituminous compound. Thin the compound to brushing consistency with a suitable solvent and apply it at the rate of about 1 gallon to 125 square feet. Overlap adjoining area about 1 inch. For large areas (10 square inches or more) of steel core exposed, prime the metal surfaces and about 1 inch of the adjoining areas as recommended for small areas. Then apply a brush coat of bituminous compound, using about 1 gallon for each 75 square feet. While the compound is still wet, apply 48- by 48-mesh, unbleached muslin weighing 4 ounces per linear yard, or a porous, tough mat of fiberglass reinforced with random continuous glass yarns and bonded with a resinous binder compatible with bituminous coatings. Before using muslin, soak it in clean water until all sizing has been removed, and hang it up until it is damp dry. Apply the damp muslin or the fibrous glass mat firmly and evenly into the bituminous compound. Provide a continuous pleat in the muslin in the center of and parallel with each low corrugation of the protected metal roofing and siding. At side or end laps, pleat the muslin or the glass at the edges of the overlapping sheets of protected steel and tuck the muslin or glass into the crevice between the sheets. Immediately after the muslin or glass is installed, apply a brush coat of the bituminous compound recommended for the first coat. Cover the muslin or glass completely. Allow this coat to dry for at least 24 hours. Then apply a final coat of the bituminous compound at the rate of 1 gallon for each 75 square feet over the repaired area.

*b. Type C Material.* For small areas (under 10 square inches) of steel core exposed follow the treatment recommended for Type A and B materials, except that the final coat should be of asphalt-base emulsion. While the coating is still tacky, cover it completely with 160-mesh mica topping. For large areas (10 square inches or more) of steel core exposed, prime the steel surface, including a width of about 1 inch of the adjoining bituminous covering, as recommended for smaller areas. Then apply a brush coat of asphalt-base emulsion at the rate of 1 gallon for each 75 square feet. While the emulsion is still wet, apply muslin or fibrous glass mat as recommended for Type A and B materials. Immediately after the muslin or fibrous glass is installed, apply a brush coat of the asphalt emulsion, covering the muslin or fibrous glass completely. Allow the emulsion to dry for at least 24 hours. Then apply a final coat of the emulsion at the rate of 1 gallon for each 75 square feet. While this coat is still tacky, apply an overall coat of 160-mesh mica topping.

4.4.3.4 *Rusted and Loosened Fasteners.* Replace corrosion-weakened bolts and screws with new bolts or screws. If the old holes are too large for the new fasteners, drill new holes in an adjoining solid portion of the sheet. Use stainless-steel, sheet-metal screws for fastening sheets to each other, and use stainless-steel self-tapping screws to fasten sheets to structural steel. Clean the rust from old holes, cover them with muslin or fibrous glass patches, and recoat them as recommended for repairing large areas of exposed metal core.

4.4.3.5 *Caulking Side and End Laps.* If water is entering the building through the laps, caulking of the laps is usually necessary. Before caulking, however, be certain that all fasteners in the vicinity of the leaks are tight. Remove all dirt and debris from the laps. Using a caulking gun, lay a continuous bead of plastic cement along the edge of the protected steel siding. Then force the cement into the lap with a putty knife or a small pointed trowel. After the cement has been worked into the lap, smooth off the exposed cement and remove any excess cement.

4.4.3.6 *Painting.* Recoat or paint protected metal if the existing coatings are dry and brittle and re-coating or painting will extend the life of the protected metal for several years. Recoating or painting should be done during warm weather. It should not be done while it is raining or when the surfaces are wet. Be sure the surfaces are clean. Type C material cannot be painted or recoated unless the surface mica is removed or has disappeared. Refer to Tri-Services Manual, "Paint and Protective Coatings" (TM 5-618, NAVFAC MO-110, AFM 85-3).

4.4.3.7 *Unpainted Surfaces.* If the existing surfaces have not been painted, coat them with bituminous compound conforming to DOD Specification DOD-C-2687B. Before applying the compound to dry and brittle surfaces, apply a coat of asphalt primer conforming to Federal Specification SS-A-701. Allow the primer to dry for at least 24 hours. Thin the bituminous compound to brushing consistency with a suitable solvent. Use 4-inch paint brushes with coarse, stiff bristles to apply the coating.

4.4.3.8 *Painted Surfaces.* If the existing protected steel siding has been previously painted with aluminum paint that has deteriorated or flaked off, repaint it with aluminum paint. Be sure to remove all loose and blistered paint before repainting. For repainting, use aluminum paint mixed in the proportions of 2 pounds of aluminum paste-pigment, Type II, Class B, to 1 gallon of Type 1, Class B, mixing varnish for aluminum paint. Apply the paint

at the rate of about 1 gallon to 140 square feet. Best results are obtained by spray applications rather than brushing. The use of brushes may cause bleeding of the bituminous coating underneath. If local conditions make brushing rather than spraying necessary, use a 3- or 4-inch, soft long-bristled brush. Lay the paint on the surface, working in one direction only. Work rapidly, do as little brushing as possible, and do not brush the paint into the surface. Follow the applicable portions of the Tri-Services Manual, "Paint and Protective Coatings," in applying the paint. Be sure that all areas are covered. Aluminum paint has a tendency to "leaf" immediately after it has been applied. Touching up an insufficiently painted area usually results in a spotty job.

#### 4.4.4 Aluminum Siding

4.4.4.1 *General.* Aluminum siding material coated with factory-laminated, polyvinyl-fluoride film is available as a protected metal siding. Aluminum unbacked lap siding 0.024 inch thick is bonded at the factory with a laminated, polyvinyl-fluoride film finish not less than 1.5 mils thick on the face side.

The back coating is a factory-applied, corrosion-inhibiting coating.

4.4.4.2 *Cleaning of Aluminum Siding.* Before repairing, touching up, or recoating, clean affected areas. Remove all loose or torn asbestos felt, flaked coating, and rust with a stiff fiber brush. Remove dust, chemical deposits, grease, and dirt. Use synthetic detergent cleaner to remove chemical deposits and grease. Thick deposits of grease can be scraped off before using cleaner. The coatings of most protected metal are petroleum asphalt compounds that can be softened or dissolved by organic cleaners and solvents. Do not use naphtha, benzol, oxydol, gasoline, or carbon tetrachloride for cleaning protected metal. For further information on cleaning aluminum surfaces, refer to the Tri-Services Manual, "Paint and Protective Coatings."

4.4.4.3 *Repair of Aluminum Siding.* Minor repairs to the polyvinyl surface can be made with an enamel paint recommended by the siding manufacturer. Extensively damaged siding should be replaced.

## SECTION V — MINERAL AND CHEMICAL PRODUCTS

### 4.5.1 General

Developments in combining chemical and mineral elements have produced hard-surfaced, weather-resistant materials for exterior wall finishes. These materials require little maintenance except to keep fasteners secure and to remove stains acquired from other sources. According to manufacturer's instructions, painting could be accomplished; however, military regulations prohibit doing it unless exception to policy is obtained.

### 4.5.2 Asbestos-Cement Siding

Asbestos fibers have been found to be injurious to health when breathed under certain conditions. As a result, some products such as asbestos fiber insulation and asbestos cement shingle siding have been removed from the market and laws exist restricting their usage. Although these high visibility products have been discontinued, asbestos and asbestos products continue to be manufactured and sold under their trade names. Usage of these products is considered perfectly safe provided some caution is exerted, particularly with disposal. Any operation such as sawing, cutting, or pulverizing, which might create dust, should be avoided. Limited cutting may be done when the operator wears a dust mask and disposes of the residue without permitting it to become windborne. Since many military installations have large numbers of buildings

covered with asbestos-cement shingles which must be retained, the following paragraphs pertaining to its handling are contained in this manual. At such time that the appearance and usage makes replacement advisable, new siding of aluminum, steel, or vinyl with insulation should be installed as outlined in appendix C.

### 4.5.3

Asbestos containing materials are found in varying degrees and locations in structures built through 1979. With the passing of the Clear Air Act, the use of sprayed on asbestos-containing friable materials was banned in new construction. Much non-friable and encapsulated materials continued to be used and still remain in place with little hazard.

Asbestos-cement, for example, was used in the manufacture of water pipe and roof and siding products. The laws pertaining to the repair, removal and disposal of asbestos-cement and other ACM continue to change. Operation and Maintenance personnel are referred to Service manuals, regulations or other guidance on asbestos control and abatement and to publications of the Environmental Protection Agency, the Occupational Health and Safety and Administration and applicable State and local agencies.

#### 4.5.4 Translucent Structural Panels

Siding produced from combining polyester resins, fiberglass, and plastics may be encountered in some new construction. As is the case with other flat and corrugated sidings, it is important to keep fastening devices tight and replace broken panels. Replacement fasteners will be similar to those recommended by the manufacturer of the product involved. It is obvious that siding material should match that existing in the building. Cleaning of translucent siding is paramount because it is used for lighting and decoration. Choice of detergents and chemical cleaning solutions must be within limitations of the manufacturer's recommendations, or severe damage may result.

#### 4.5.5 Solid Vinyl Siding

Solid vinyl siding is a pigmented polyvinylchloride compound, extruded into 0.035-inch-thick shapes and is available in both vertical and horizontal patterns. The material is highly durable and available with long-term guarantees for useful appearance life.

4.5.5.1 *Maintenance.* Painting is usually not required until after 20 years of installed life. The surface is easily cleaned with a mild detergent and water.

4.5.5.2 *Repair.* Damage to the panels is not normally anticipated, but should it occur the manufacturer's recommendation for replacement should be followed. This requires use of the manufacturer's special tool to disengage the panel at the top or end of the panel where it overlaps a flashing. Disengage the top of the damaged panel using the tool to disengage the locks. Remove the nails at the top of the damaged panel, and remove it. Install the replacement by hooking it into the top lock of the panel immediately below the repair and nail the top of the panel into place. Use the manufacturer's tool to lock the panel above the repair into the top lock of the replacement panel by slipping the tool across the top of the replacement panel.

### SECTION VI—EXTERIOR INSULATING SYSTEM

#### 4.6.1 General

A variety of exterior insulating systems have been recently developed and used in new construction or added to existing structures. These systems employ a layering of insulation board, reinforcing fabric, synthetic plaster, or copolymer adhesive and synthetic plaster or copolymer finish. Most can be installed directly onto masonry, concrete, metal and wood frame structures. Most products are relatively maintenance-free; however, they are susceptible to damage. Repair and maintenance information for two types of commercial products is as follows.

#### 4.6.2 Dryvit

4.6.2.1 *Maintenance.* No routine maintenance is required. Under normal conditions there should not be any cracking or peeling. The surface may be washed with detergent or painted with an exterior latex paint if a color change is desired.

4.6.2.2 *Repairs.* Repairs should be attempted only when the ambient temperature is above 40°F (4.5°C) and rising, and has been at least 40°F or above for at least 24 hours. The manufacturer's recommended repair procedure for heavily damaged areas is as follows:

a. Using a disk grinder, expose the smooth base-coat Primus layer approximately 2 to 3 inches all around damaged area. Use an aluminum oxide disk of No.48 grit.

b. Cut all components of the Dryvit system out of the damaged area. This includes the finish coat, the base coat, the reinforcing fabric, and the insulation board. Clean the exposed substrate of any old Primus adhesive. Cut a piece of Dryvit insulation board to fit neat and snug and rasp for precise fit. Apply Dryvit mixed Primus adhesive fully over the back of the Dryvit insulation board to a thickness of about  $\frac{1}{4}$  inch.

c. Apply the Dryvit insulation board to the substrate. Cut Dryvit reinforcing fabric so that it will cover patch area lapping on to exposed base-coat layer.

d. Apply Primus adhesive mix to the face of the insulation board. With a margin trowel, embed Dryvit reinforcing fabric into the mixed Primus adhesive. The reinforcing fabric should be covered with Primus adhesive to produce a uniform base-coat surface.

e. Using masking tape, mask off the area exposing approximately  $\frac{1}{4}$  inch of the existing finish. After approximately 24 hours, the finish coat can be applied.

f. Trowel on a new finish coat over the new and existing base coat.

g. Allow the Dryvit finish to set up for approximately 10 minutes, depending on weather conditions. Remove tape from the wall.

*h.* Feather edges of patch to blend inconspicuously with texture of surrounding areas. After patch has dried there will be a slight color variation between the patch and the surrounding area. This should become less conspicuous in the time as environmental conditions blend the color of the patch to the surrounding area. In order to be sure of proper color, Dryvit finish should be matched to the original batch number of the existing Dryvit finish. Where the Dryvit insulation board is not heavily damaged, it does not have to be replaced.

### 4.6.3 Sto

4.6.3.1 *Maintenance.* No routine maintenance is required. The finish is permanent, colorfast, and scrubbable.

4.6.3.2 *Repair.* The manufacturer lists the following repair procedures for puncture, damaged corners, and patching finishes. The minimum ambient temperature is 38°F (3.4°C) for at least 12 hours. It is easier to repair a large area than a small one. Make patch large enough to work with.

*a.* Scrape off the Sto finish from the wall approximately 2 inches around the damaged area. Be careful not to damage the ground coat and mesh in this area.

*b.* Carefully cut the Sto reinforcing fiberglass mesh to approximately 1 inch from the outer perimeter of the existing finish.

*c.* Remove the damaged area by cutting out a plug around the puncture leaving a strip of good polystyrene between the mesh and the damaged area.

*d.* Scrape any remaining adhesive off the face of the substrate.

*e.* Cut a piece of polystyrene to fit the opening in the system. Make sure the fit is precise to avoid any thermal breaks.

*f.* Rasp plug to match thickness of existing polystyrene if needed before applying to substrate.

*g.* Apply adhesive to the back of the polystyrene and put in place with firm pressure making sure the plug is adhered to the substrate.

*h.* Cut a piece of mesh to butt existing mesh. Apply reinforced plaster over area where mesh is to be placed.

*i.* Embed mesh in reinforced plaster, keeping same thickness of existing ground coat. Allow reinforced plaster to dry before applying finish.

*j.* After reinforced plaster has set, prepare area to receive finish. Using masking tape, cover existing finish around patched area.

*k.* Apply finish and float out to match texture of wall.

*l.* Remove masking tape and use paintbrush to blend wet finish into the dry finish.

*m.* In repairing corners, the polystyrene must be replaced back far enough on the wall to allow proper adhesion of polystyrene used to replace damaged area. Make sure corner is double wrapped with Sto reinforced fiber mesh at least 2½ inches.

*n.* To repair patching finish only, scrape off the Sto finish approximately 1 inch around the damaged area. Using masking tape, cover existing finish around patched area. Apply finish and float out to match texture of wall. Remove masking tape and using a paintbrush, blend wet finish into dry finish.

## CHAPTER 5

## INTERIOR WALLS, PARTITIONS, AND CEILINGS

## SECTION I—INTRODUCTION

**5.1.1 General**

This chapter considers the various types of interior walls, partitions and ceilings and describes methods and procedures for their maintenance and repair. In addition to the requirements for strength, color, durability, and other qualities for construction purposes, properties directly affecting safety, acoustical characteristics and thermal insulation value of the finish material must be considered.

**5.1.2 Types of Interior Walls and Partitions**

Interior walls and partitions are usually constructed of wood studs, metal studs, blocks, or structural clay tile with a plaster, gypsum board or ceramic tile finish. Others are constructed of glazed structural units, brick, block (painted or unpainted), metal, or glass.

**5.1.3 Types of Ceilings**

Ceilings are usually gypsum board, plaster, acoustical tile, or metal, either applied directly to the underside of the floor or roof framing or supported by a suspended grid system.

**5.1.4 Interior Finishes**

5.1.4.1 *Plaster.* The various types of plaster are similar in composition and application but are designed for specialized uses.

*a. Gypsum Plaster.* Gypsum plaster is most generally used in ordinary construction because it can be readily applied to furred and lathed surfaces of exterior masonry and directly to interior masonry. It can be applied over metal lath and gypsum products. High-grade, high-strength gypsum plaster is generally limited to use in neuropsychiatric sections of hospitals. Gypsum plaster should conform to ASTM C-631 and C-28.

*b. Lime Plaster.* Lime plaster, found in many older buildings, is similar in application to gypsum plaster but should not be used in conjunction with gypsum products. Lime plaster should be repaired with like material.

*c. Keene's Cement Plaster.* Keene's cement plaster produces a hard, moisture-resistance surface, suitable for spaces given hard use,

particularly wainscots, and areas subject to continued moisture, such as baths, kitchens, and certain hospital areas. Keene's cement plaster should be applied only over a gypsum plaster base and should conform to Federal Specification SS-C-161A.

*d. Portland Cement Plaster.* Portland cement plaster may be applied directly to interior masonry walls and over metal lath; it should never be applied over gypsum products. It is recommended for use in plastering walls and ceilings of large, walk-in refrigerators and other cold-storage spaces, basement spaces, toilets, showers, janitorial closets, and similar areas where Keene's cement plaster is not economically justifiable.

*e. Insulating Plaster.* Insulating plaster differs from other plasters in that lightweight vermiculite and perlite are used as an aggregate instead of sand. It is lightweight, provides some thermal insulation, and gives a fire-retardant surface, to a degree determined by its composition and method of application.

5.1.4.2 *Tile.* Ceramic tile, structural clay tile, glazed structural units, and similar water-resistant materials are commonly used for interior walls and wainscoting where moisture conditions and cleanliness are factors. Structural clay tile is used primarily for interior partitions and for backup for brick walls. Tile finishes and wainscoting are used in toilets, baths, kitchens, and certain hospital spaces.

5.1.4.3 *Wallboard.* Gypsum wallboard should conform to ASTM C840 or C-36. It is composed of a gypsum core encased in a heavy manila-finished sheet on the face side, and a strong liner paper on the back. Hard-pressed fiberboard may be used as wainscoting only when backed with noncombustible material, such as gypsum wallboard. Structural-type fiberboard should conform to Federal Specification LLL-B-810. Where moisture resistance or extra strength is required, Class II or Class IV treated fiberboard should be used; otherwise, Class I is satisfactory. Wallboard, in general, is used where conditions of occupancy do not subject it to severe services.

5.1.4.4 *Metal.* Interior walls, partitions, or ceilings of metal (steel, aluminum, etc.) are normally used in industrial and office-type buildings and structures to withstand hard use or to contain hazardous operations. Other common uses of metal include office partitions, toilet partitions, and sleeping cubicles.

### 5.1.5 Functions and Characteristics

5.1.5.1 *General.* In the maintenance and repair of buildings and structures, care should be taken to maintain the effectiveness of interior finishes as to fire resistance, insulation and acoustical functions.

5.1.5.2 *Fire Resistance.* Conventional wall construction materials, such as gypsum block surfaced with plaster of the required thickness, brick, concrete, hollow tile, and concrete block, are considered nonhazardous and noncombustible. Partitions or ceilings constructed of assemblies of wood or metal studs or joists, or of metal, gypsum, or wood lath, surfaced with cement, lime, or vermiculite plaster, are considered nonhazardous. A sheet-metal covering applied directly to wood joists or over old plaster ceilings, although superior to highly combustible materials, offers little resistance to fire and increases the effort required to extinguish fires in concealed spaces, such as between joists.

5.1.5.3 *Insulation.* Noncombustible materials used for insulation of buildings and structures against heat or cold, such as mineral or glass wool, have a secondary effect of increasing fire resistance, if they stay in place and do not settle to create voids. Rigid insulating boards of polyurethane and perlite are also used on walls.

5.1.5.4 *Noise Control.*

*a. Sound Absorption.* Acoustical materials applied on walls, partitions, and ceilings absorb noise and aid hearing by reducing echoes and reverberation. Porous or low-density materials, similar to those used for thermal insulation, are commonly applied in theaters, auditoriums, and other areas where good acoustics are required. The materials should be noncombustible or fire-resistant, such as mineral and glass wool and laminated gypsum wallboard attached to the framing with resilient clips.

*b. Exterior Sound.* Insulation from exterior noise is sometimes part of the interior sound-absorption problem. The best resistance to noise penetration usually can be obtained with heavy rigid walls and floors, or multiple-layer construction separated by airspaces. Such construction keeps out sound by preventing the vibration of wall or floor. Any mechanical connection across the intervening airspace in a

structurally separated wall increases sound transmission. For hollow walls not structurally separated, such as ordinary wood-stud partitions, a fill of noncombustible material between the studs slightly improves the sound insulation.

5.1.5.5 *Cleanability.* In general, ceramic tile, glass, glazed-faced masonry, and similar hard-surfaced materials are more easily cleaned and are more resistant to moisture and staining than plaster, wood, and metal.

### 5.1.6 Accessory Materials

5.1.6.1 *Lath.* Metal lath should conform to Federal Specification QQ-L-101. It may be expanded metal, woven wire mesh, or woven wire fabric, with a paper or other backing. Gypsum lath or rock lath, conforming to Federal Specification SS-L-30D, is available in solid, perforated, and insulating types. Expanded metal lath should be used to replace wood lath in all rehabilitation work. It should be placed with the long side of the sheet perpendicular to the supports, and then be nailed or stapled to wood supports and wired to metal supports. In hanging laths for ceilings, the joints should be broken so alternate sheets run through, to avoid plaster cracks. When gypsum lath is used, all joints should be staggered so that joints do not meet on the same stud or at the ceiling line.

5.1.6.2 *Furring.* Furring consisting of wood or metal strips serves as a framework for lath; it may be used to level uneven wood partitions or ceiling framing or masonry wall surfaces, or to provide a dead airspace in walls for insulation.

### 5.1.7 Plastering Accessories

To obtain a satisfactory plaster surface, a number of accessories are required.

5.1.7.1 *Grounds.* Grounds are wood strips of uniform thickness installed around all openings, at the bottom of walls near the floor, at the top of wainscots, at chair-rail heights, and other places where trim is required. They serve as a guide in bringing the plaster to a uniform thickness for an even surface, form a stop against which the plaster is finished, and furnish means for fastening the interior trim to the walls. Temporary wood grounds are often used in gauging the thickness of the scratch and brown coats of plaster.

5.1.7.2 *Base Screeds.* Base screeds, like plaster grounds, serve as a guide to gauge the plaster thickness and as plaster stops. Screeds are used at the bottom of plaster walls where the plaster joins the floor base, or where it joins the wainscot in walls with tile or other similar materials used as bases or wainscots.

5.1.7.3 *Corner Beads.* Corner beads should be installed at all external plaster corners. They serve a dual purpose: as a plaster stop gauge for acquiring a uniform surface finish, and as a reinforcement to strengthen plaster corners to prevent them from being broken off. Corner beads are manufactured in two all-metal styles: the bullnose bead, which is a wide-radius bead and is designed especially for corners receiving unduly hard use; and the standard bead, which has a very small radius and is designed to provide sharp, clean corners. A corner bead suitable for installation on plasterboard (dry wall) corners is a fabricated product consisting of a  $\frac{3}{4}$ -inch hard metal strip, formed to a right angle and glued under pressure to a 2-inch strip of fabric or tough, treated paper. Specially constructed beads are available for forming arches and other irregular corners.

5.1.7.4 *Corner Lath.* The corner lath is an angle-shaped strip of lath with 2- or 3-inch legs, usually installed at an interior vertical or horizontal plaster corner as a reinforcement to prevent cracking of

the plaster. Corner laths may be procured in preformed strips or be cut from metal lath sheet and formed on the job to fit the particular corners in which they are to be installed. Corner laths should be fastened at the edges, with staples used over wood and lath and wire over metal lath. Corner laths should not be fastened by nailing through into the framing because stresses in the structure will then be transmitted directly into the plaster, causing a crack.

5.1.7.5 *Strip Lath.* A strip lath, as the term indicates, is a strip of metal lath, 4 or more inches wide, intended for application over joints of dissimilar plaster-base materials where the surfaces to be plastered lie in the same plane and cannot be effectively bonded or tied together without the help of metal lath strips. Each corner of a door, window, or other opening in a plastered surface will have a 12- by 24-inch strip of metal lath fastened over the plaster base at an angle in relation to the opening of approximately  $45^\circ$ . Such additional reinforcing is not required over metal lath.

## SECTION II—REPAIR AND MAINTENANCE OF PLASTER AND TILE

### 5.2.1 Application of Plaster

5.2.1.1 *Preparation.* Before plastering is started, the plaster base, whether masonry or lath, and the grounds should be inspected. The existence and location of plumbing, heating, and electrical outlets should be checked.

5.2.1.2 *Bond.* A secure bond between plaster and base is necessary to develop strength and resistance to damage in walls and ceilings. A "mechanical" bond is formed when plaster is pressed through the mesh of metal lath or the holes of perforated board lath, forming keys on the other side. A "suction" bond is formed when plaster is applied over nonperforated gypsum or insulation board lath and over a masonry base. In suction bonding, the small, needlelike plaster crystals penetrate the surface pores of the base by suction; when the plaster sets, the base and plaster become "welded" together. When perforated board lath is used, both mechanical and suction bonds are developed.

5.2.1.3 *Plaster System.* Plaster is applied in a series of coats called scratch, brown, and finish. Application and mixes vary to meet conditions imposed by original construction on which the plaster is applied and by the area of use. Three-coat work is generally advisable over metal lath while two-coat work often suffices over masonry and gypsum lath and gypsum partition tile. Consideration will always be given to the use of light plaster aggregate, such as perlite and vermiculite, for

insulation value and to materials with fireproofing characteristics, such as gypsum board, metal lath and other components, for wall surfaces under repair. Proper drying and settling of one coat before another coat is applied is necessary for good plastering. Adequate ventilation is required for good drying. If the entire building is enclosed and heated, fans may be used to eliminate dead air-spaces and facilitate drying.

a. *Scratch Coat.* The scratch coat consists of a mixture of sand or lightweight aggregate and plaster. The sand or aggregate is increased for a scratch coat over masonry. Sufficient material and pressure must be applied to form full keys on metal lath or a good bond on masonry. The scratch coat is left with a rough surface to accept the next coat.

b. *Brown Coat.* The brown coat is similar to the scratch coat except that sand or aggregate content is increased. It is applied after the scratch coat has set firm and hard. The brown coat is laid flush to the grounds, straightened to form a true surface and left rough.

c. *Finish Coat* Float or sand finish is achieved by using a rubber or carpet float. The float finish of gypsum vermiculite should be placed only on base coats of gypsum lightweight aggregates. Recommended proportions for this finish coat are 1 part gypsum gauging plaster, 5 parts lime putty, **a** to **b** part fine, white sand or lightweight aggregate fines.

## 5.2.2 Causes and Signs of Plaster Damage

Cracks, holes and looseness in plastered surfaces are signs of excessive internal or external stresses. They may be caused by poor workmanship, such as improper proportions or application of the plaster, imperfect lathing, and poor atmospheric conditions during plastering; or by moisture infiltration or an excess of moist air generated inside a building frame. External stresses that cause plaster damage should be investigated and corrected before repairs are made to the plastered surfaces themselves.

## 5.2.3 Plastering Equipment

Equipment for making minor repairs consists of a spatula or putty knife, a small diamond-shaped pointing trowel, a sharp chisel, a linoleum knife, a hammer, and a shallow mixing pan.

## 5.2.4 Patching

5.2.4.1 *Structural Cracks.* Generally, two coats of patching material are required to repair wide structural cracks.

a. The first coat may be a job mix composed of 1 part fibered gypsum plaster and 2½ parts plastering sand, by volume, mixed with clean water to a uniform color and workable consistency.

b. Material for the second coat may be either a neat gypsum plaster or a mix of 1 part hydrated lime and ½ part calcined gypsum mixed with water to a suitable consistency.

c. A small amount of casein glue added to the above mix insures easier application because it tends to retard the setting time of the mix. The addition of glue also prevents shrinking of the mix and helps form a better bond with the old plaster.

d. In lieu of the mixes described in (a) and (b) above, a commercial patching plaster may be used. This material, known as spackling compound, is a mixture of plaster of Paris and powdered glue, which is mixed with clean water to the consistency of soft putty.

e. The quantity of any patching material must not exceed that which can be applied within 30 minutes after mixing. Plaster material should not be retempered (by adding water) once it has begun to dry out and harden. Retempered plaster placed on the wall will dry and become soft and crumbly.

5.2.4.2 *Map Cracks.* Best patching results in the repair of medium-width map cracks are usually obtained by use of the spackling compound described in (d) above.

5.2.4.3 *Hairline Shrinkage Cracks.* One method of

filling hairline shrinkage cracks is to mix spackling compound to a thin paste and scrub it into the cracks.

## 5.2.5 Repair of Gypsum and Lime Plaster

Identification of failures in gypsum and lime plaster surfaces, possible causes, failure and methods of repair are discussed below.

5.2.5.1 *Structural Cracks.* Structural cracks are easily identified because they are usually large and well defined, extending across the surface and entirely through the plaster. They generally develop during the first year after completion of construction and, in most cases, can be successfully and permanently repaired. However, before repairs are initiated, the cause of the failure should be determined from an engineering standpoint and necessary precautions taken to prevent recurrence of the failure. Structural cracks may extend diagonally from the corners of door and window openings, run vertically in corners where walls join, run horizontally along the junction of walls and ceilings, or occur in walls where two unlike materials join.

a. *Causes.* Structural cracks may be caused by one or more structural defects, such as foundation settlement; failure of masonry wall section by shrinkage or cracking; sagging, warping, or shrinkage of wood frame members; insufficient bracing of wood frame members, or use of undersized or improperly spaced wood frame members.

b. *Repair.* To repair a structural crack, use a linoleum knife or chisel to cut out and remove loose material. The crack must be formed to a V-shape to provide adequate keying action by making the surface opening narrower than the bottom of the crack. Care should be exercised to widen the crack only enough to insure a good bond between patching plaster, old plaster, and lath. Expanded metal or wire lath should be cleaned and the mesh opened so that, when patching plaster is forced into the opening, a good key is formed. Break out the key between wood lath so that a new key can be formed when patching material is forced into place. Thoroughly wet wood lath before applying patching plaster. Brush out all loose material, remove all grease or dirt from surrounding surface areas, and wet the edges of the groove. Press the first coat of patching plaster firmly into place, filling the groove nearly to the surface; allow it to set until nearly dry but not hard; then complete the patch by applying a coat of finish plaster, strike off flush, and trowel smooth. If the edges of the old plaster and the wood lath are not thoroughly wetted, they serve as a wick to draw the water

from the fresh plaster, causing it to dry out, remain chalky, and crack around the edges of the patch. In applying the plaster, special attention should be given to the edges of the patch to insure a firm, solid bond between old and new plaster.

#### 5.2.5.2 *Map Cracks.*

*a. Map cracks* are less noticeable than structural cracks. They penetrate through the plaster but do not extend entirely across the surface and generally occur as a series of irregular cracks running at various angles, embracing areas 6 inches or more in width and up to several feet in length. Map cracks are generally caused by improper bonding between the plaster and lath or masonry base and indicate inferior workmanship, the use of poor quality materials, or a combination of the two.

*b. Repair.* Normally map cracks are repaired in much the same manner as described for shrinkage cracks. Where large areas are badly cracked, the repair method for loose plaster, described in paragraph 5.2.5.4a, may be used.

#### 5.2.5.3 *Shrinkage Cracks.*

*a. Shrinkage cracks* are sometimes referred to as crazing and resemble map cracks in appearance but are ordinarily confined to the finish coat. They do not extend entirely through the plaster surface, and cover a much smaller portion of the wall or ceiling surface. Shrinkage cracks generally result from careless workmanship, too rapid drying of the surface, insufficient troweling, troweling while the surface is still too wet, or by not troweling until the surface had become too dry.

*b. Repair.* Normally shrinkage cracks are repaired by filling with spackling compound. Where shrinkage cracks penetrate the base course and are of such extent that they will not retain such a paint mixture, they should be cut out and repaired in the same manner as described for structural cracks.

5.2.5.4 *Holes.* Holes are repaired in the same manner as structural cracks. Cutting out the loose plaster surrounding the hole requires extreme care not to loosen an unnecessary amount of sound plaster.

*a. Loose Plaster.* Loose plaster is indicated by bulging and cracking of large areas of the plaster surface. The extent of loosened plaster can be determined by lightly tapping the surface with a small hammer, with the resulting sounds indicating the extent of the loose area. Loose plaster may result from excessive moisture caused by leaks in the roof, seepage through an exterior wall, plumbing leaks, or heavy condensation. This excessive moisture causes the plaster to loosen. In some cases, the plaster may bulge or sag but continue to hang in this condition quite a long time before

falling, held together only by the hair or fiber in the base coat. Occasionally moisture causes the fastenings holding the lath to the structural frame to corrode, permitting both the lath and plaster to bulge or sag. Another cause of bulging plaster is the use of incompletely hydrated lime in the plaster mix. In localities where high humidity is prevalent, moisture causes a continued hydration of the lime, which weakens the plaster and destroys the bond between plaster and base. This condition usually occurs in the spring and summer months, starting from the first to third year after plastering and continuing indefinitely.

*b. Repair.* Before repairing the damaged plaster, it is necessary to locate and eliminate the source of moisture. To prevent loose plaster from falling until permanent repair can be accomplished, temporary repair may be made by securing the loose plaster with a section of wallboard nailed securely to the wall or ceiling over the area affected. Nails should be of sufficient length to penetrate through the plaster and obtain a firm bearing in the studs or joists. Repairs of a permanent nature should be made as soon as practicable. Remove all loose plaster around the break, working back in the surrounding area to a point where solid plaster (well keyed to the lath, which, in turn, is solidly secured to the structural frames) is reached. Remove defective lath and replace with suitable plaster backing, such as metal lath or plasterboard, and securely refasten all lath that has become loosened.

5.2.5.6 *Old Plaster Surfaces.* Old, worn, crumbling plaster is repaired in the same manner as loose plaster. However, in the attempt to repair old plastered surfaces, the operation of removing the affected areas sometimes causes areas of apparently sound plaster to fall. This is evidence that the entire plaster surface has deteriorated to the extent that replastering of the whole area is necessary.

### 5.2.6 **Repair of Keene's Cement Plaster**

Keene's cement plaster is much harder and less susceptible to damage from moisture than gypsum and lime plasters and therefore requires much less maintenance and repair. Keene's cement plaster is normally used in areas subject to excessive moisture conditions, such as showers, toilets, baths, galleys, laundries, machinery and equipment rooms, and similar spaces. When repairs of Keene's cement plaster surfaces are necessary, the same principles described above for repair of gypsum plaster apply, with the exception that Keene's cement plaster should be used, in accordance with manufacturer's instructions, instead of patching plaster and gypsum plaster.

### 5.2.7 Repair of Portland Cement Plaster

Surfaces subjected to hard use or exposed to moisture, such as walls and ceilings of large walk-in refrigerators and cold storage spaces, exterior surfaces such as undersides of canopies and marquees, and other locations where, for economical reasons, Keene's cement plaster is not justifiable, are often coated with portland cement plaster. The types of failures and methods of repairing portland cement plaster are basically the same as described above for gypsum plaster. In patching small areas, the edges of the surface surrounding the defective area must be thoroughly and continuously wetted for at least 1 hour before application of the patching material. Just prior to applying the patch, dust the entire edge of the exposed plaster with a light coat of portland cement. Press the first coat of portland cement plaster, composed of 1 part portland cement, 3 parts plastering sand, and ¼ part lime putty, firmly into the groove or hole nearly to the surface, using particular care to insure that no voids are left around the perimeter of the patch. Scratch or roughen the surface of the patch with a wire brush or nail to make a base for receiving the finish coat. Thoroughly cure the patch by keeping it moist for at least 72 hours; then let it dry thoroughly, for not less than 7 days, prior to applying finish coat. Just prior to applying of the finish coat, moisten the patch thoroughly and firmly press the plaster into the remaining cavity, float to a smooth, even surface, and then trowel to the same texture as the surrounding surface. Keep the patch moist for at least 3 days.

### 5.2.8 Material Handling Precautions

All material in bags or bundles should be stacked, blocked, interlocked, and limited in height so that the pile is stable and secure against sliding or collapse. Judgment must be used in stacking and storing materials in any structure. Concentrated loads of stored materials can exceed the allowable uniform live load by 100 percent, if the loads are stacked adjacent to outside walls or over beam and column supports. *Never stack materials in the center of joist spans.* When material is placed in or encroaches on passageways, it should be located to present the least possible hazard. Limits of allowable loads will be determined through consultation with structural personnel of the installation engineer organization.

#### 5.2.8.1 Cement and Lime.

a. Bags of cement and lime should not be stacked more than 10 bags high without stepback, except when restrained by walls of appropriate strength.

b. The bags around the outside of the stack should be placed with the mouths of the bags facing the center of the stack.

c. During unstacking, the entire top of the stack should be kept nearly level and the necessary step-backs maintained.

d. Handle cement and lime in paper bags with care to prevent bags from breaking.

e. Store lime and cement on off-the-floor platforms in dry spaces. Lime must be kept dry in storage to prevent possible premature slaking, which could cause fire.

5.2.8.2 *Personal Protective Measures.* Workmen will observe the following precautions:

a. Wear heavy gloves when handling metal lath.

b. Wear goggles for eye protection when handling cement and lime.

c. Wear shirts with closed neck and wristbands and insure that exposed parts of the body do not come in direct contact with lime.

d. Avoid wearing clothing that has become stiff and hard with cement or lime; such clothing irritates the skin and may cause infection.

e. Personal cleanliness and frequent washing are effective preventives of skin ailments.

### 5.2.9 Replacement Application of Ceramic Tile

5.2.9.1 *Scratch Coat.* A scratch coat for application as a foundation coat must be not less than ¼ inch thick and composed of 1 part cement to 3 parts sand, with the addition of 10-percent hydrated lime by volume of the cement used. While still plastic, the scratch coat is deeply scored or scratched and cross-scratched. The scratch coat should be protected and kept reasonably moist during the seasoning period. All mortar for scratch and float coats must be used within 1 hour after mixing. The retempering of partially hardened mortar should not be permitted. The scratch coat must be applied not more than 48 hours, nor less than 24 hours, before starting the setting of tile.

5.2.9.2 *Float Coat.* The float coat should be composed of 1 part cement, 1 part hydrated lime, and 3½ parts sand. It must be brought flush with screeds or temporary guide strips, well placed to give a true and even surface at the proper distance from the finished face of the tile.

5.2.9.3 *Setting Wall Tile.* Wall tile should be thoroughly soaked in clean water before it is set. It is set by neatly troweling a skim coat of portland cement mortar on the float coat, or applying a skim coat to the back of each tile unit, and immediately floating the tile into place. Joints must be straight,

level, perpendicular, and of even width not exceeding  $\frac{1}{16}$  inch. Wainscots are built of full courses, which may extend to a greater height, but in no case more than  $1\frac{1}{2}$  inches lower than the specified or figured height. Vertical joints must be maintained plumb for the entire height of the tile work.

5.2.9.4 *Grouting.* All joints in wall tile should be grouted full with a plastic mix of neat white cement immediately after a suitable area of tile has been set. The joints should be tooled slightly concave and the excess mortar cut off and wiped from the face of tile. Any interstices or depressions in the mortar joints after the grout has been cleaned from the surface should be roughened at once and filled to the line of the cushion edge before the mortar. All joints between wall tile and plumbing or other built-in fixtures should be made with a lightcolored caulking compound. Immediately after the grout has had its initial set, tiled wall surfaces should be given a protective coat of noncorrosive soap or other approved protection.

### 5.2.10 Application of Tile in Existing Construction

Wall tiles installed over existing and patched or new plaster surfaces in an existing building are completed as described in paragraph 5.2.9, except that such wall tiles are applied by the adhesive method.

5.2.10.1 *Priming.* Where wall tile is to be installed in areas subject to intermittent or continual wetting, the wall areas should be primed as recommended by the manufacturer of the adhesive used.

5.2.10.2 *Adhesive Application.* Wall tile may be installed either by the floating method or by the buttering method. In the floating method apply the adhesive uniformly over the prepared wall surface, using quantities recommended by the adhesive manufacturer. Use a notched trowel held at the proper angle to insure a uniformly spread coating of the proper thickness. Touch up thin or bare spots by an additional coating of adhesive. The area coated at one time should not be any larger than that recommended by the manufacturer of the adhesive. In the buttering method, daub the adhesive on the back of each tile in such amount that the adhesive, when compressed, will form a coating not less than  $\frac{1}{16}$  inch thick over 60 percent

of the back of each tile.

5.2.10.3 *Setting Tile.* Joints must be straight, level, plumb, and of even width, not exceeding  $\frac{1}{16}$  inch. When the floating method is used, one edge of the tile is pressed firmly into the wet adhesive, the tile snapped into place in a manner to force out all air, then aligned by using a slight twisting movement. Tile should not be shoved into place. Joints must be cleaned of any excess adhesive to provide for a satisfactory grouting job. When the buttering method is used, tile is pressed firmly into place, using a "squeegee" motion to spread the daubs of adhesive. After the adhesive partially sets, before it is completely dry, all tiles must be realigned so that faces are in same place and joints are of proper width, with vertical joints plumb and horizontal joints level.

5.2.10.4 *Wainscots.* Wainscots are built of full courses to a uniform height. The wainscot height may be adjusted somewhat to accommodate full courses, but the adjustment should not exceed  $1\frac{1}{2}$  inches from the norm.

5.2.10.5 *Grouting* The adhesive should be allowed to set for 24 hours before grouting is done. Joints must be cleaned of dust, dirt, and excessive adhesive, and should be thoroughly soaked with clean water before grouting. A grout consisting of portland cement, lime, and sand, or an approved ready-mix grout may be used, but the grout must be water resistant and nonstaining.

5.2.10.6 *Caulking* Nonstaining caulking compound should be used at all joints between built-in fixtures and tile work, and at the top of ceramic tile bases, to insure complete waterproofing. Internal corners should be caulked before corner bead is applied.

### 5.2.11 Repair of Ceramic Tile

Cracked and broken tile should be replaced promptly to protect the edges of adjacent tile and to maintain waterproofing and appearance. Timely pointing of displaced joint material and spalled areas in joints is necessary to keep tiles in place.

### 5.2.12 Cleaning

Newly tiled surfaces should be cleaned to remove job marks and dirt. Cleaning should be done according to the tile manufacturer's recommendations to avoid damage to the glazed surfaces.

## SECTION III—REPAIR AND MAINTENANCE OF DRY-WALL CONSTRUCTION

### 5.3.1. General

Dry-wall construction usually consists of a gypsum wallboard finish. However, other manufactured

sheet materials and wood products are also used to provide interior wall construction other than wet plaster. When the following items are used, the

item used should be in conformance with the Federal Specification or Standard cited: gypsum board (AA-L-30); hardboard (LLL-B-810); particle board (ASTM C-208); plywood (Product Standard PS-1-66 or Commercial Standard CS-35-61); acoustical unit prefabricated (SS-S-118A). This chapter deals with the maintenance and repair of these types of dry-wall construction.

#### 5.3.1.1 Repair.

a. *Fixed-Wall Construction.* Maintenance and repair of interior wall boarding generally requires that nails, screws, and other fasteners be kept in a secure condition. Cracks in plaster-type boards may be repaired in a manner similar to plaster repair. Joints which fail in dry-wall construction must be recemented and taped. Broken panels usually are best repaired by replacement of a complete panel. When repairs are completed, finish to match the adjoining area. All fastening, such as nailing, screwing, or gluing, must be at least equal to the "as built" construction.

b. *Nonload-Bearing Partitions.* Nonload bearing partitions carry no load other than their own weight and are used under floors or roofs that are trussed or framed with beams and girders to carry the superimposed load to the structural frame. Nonload bearing partitions can be less substantial than load-bearing partitions and are usually placed after structural frame, roof, and floors are in place. Periodic inspection of these partitions will be made for marks, dents, scratches, cracks and other surface damage. These nonload-bearing partitions can be repaired, strengthened, plumbed, and aligned without regard to the structural frame or ceilings and may be removed to provide other interior arrangements of space.

c. *Trim and Wainscot.* Trim and wainscot material will vary to suit design requirements for different interiors. Wood trim and wainscot must be kept nailed, screwed or otherwise secured. When broken areas occur, they should be repaired or replaced with like material and fastening devices. Ceramic tile may occasionally be patched with plaster or plastic materials, but it is usually more suitable to extract the broken piece and replace it with a new one. Joints should be kept in good repair, and new joining material placed where severe spalling occurs. Synthetic moldings must be kept securely fastened to the wall so moisture and dirt do not collect between them and the wall. Mastic of the type used in the original construction should be used for repair or replacement of moldings and wainscots of this type.

### 5.3.2 Single-Thickness Gypsum Wallboard

5.3.2.1 *Nailing.* Secure gypsum wallboard to supports with 1 $\frac{1}{4}$  inch by 0.101-inch, blued, helically threaded, tapered screw nail with medium diamond point. Space nails not less than  $\frac{1}{2}$  inch from edges, 5 to 7 inches apart on ceilings, and 6 to 8 inches apart on walls. Drive nails with heads slightly below the surface, but do not use a nail set.

5.3.2.2 *Finish Joints.* Square-edge sheets are recommended for temporary construction. Sheets with  $\frac{1}{2}$ - to  $\frac{3}{16}$ -inch bevel on the long edges are used where the joint is featured. The recessed-edge sheet is used where a concealed reinforced joint is desired. Finish of recessed joint consists of filling the recess with cement, into which a perforated tape is imbedded. A thin covering coat of cement is applied over the tape. Second and third coats of cement are applied after preceding coats are dry. When the last coat of cement is dry, the joint should be sandpapered smooth and level with the rest of the wall.

5.3.2.3. *Gypsum Backing* For backing glazed or other wallboard linings and wainscots, use gypsum plasterboard, conforming to Federal Specification SS-L-30. Install boards horizontally with joints staggered. Secure to supports with 13-gage, blued or cement-coated, 1  $\frac{5}{16}$ -inch flathead nails, spaced about 4 inches apart on all bearings.

5.3.2.4 *Limitations.* Maximum spacing of bearings should not exceed 24 inches. Gypsum board should not be installed in damp places such as showers and bathrooms. Do not use gypsum board as a base for attaching tile or other materials with adhesives.

### 5.3.3 Double-Thickness Gypsum Wallboard

5.3.3.1 *Planning* A double thickness of gypsum wallboard is produced on the job by laminating two thicknesses of  $\frac{1}{2}$ -inch gypsum wallboard, using a special adhesive to bond the layers. The resulting walls are strong, can stand heavy abuse, and are very resistant to cracking and sound transmission. On walls not more than 8 feet 3 inches in height, the first layer is applied vertically, with edges centered on and nailed to studs. The second layer of wallboard is then applied horizontally across the studs. Where the ceiling is between 8 feet and 8 feet 3 inches, the gap is filled in with scrap strips and concealed by the baseboard. Where wall lengths exceed 12 feet, vertical end joints are staggered to fall between, not on, framing members. Use wood cleats on the face of the board to hold the ends in place until the adhesive has set, and then remove them. Use 12-foot panels, wherever practical, to minimize end joints. Where

walls exceed 8 feet 3 inches in height, it is more practical to apply the first layer of wallboard horizontally, breaking all end joints between studs, where 12-foot boards will not span the wall length. The face layer is then applied vertically, with full-length boards extending from floor to ceiling, eliminating all the joints. Where joints in the first and second layers are parallel, they should be offset at least 10 inches. Edges of the face layer should be centered on and temporarily nailed to the studs.

**5.3.3.2 Application.** Make a thorough inspection of the framing before applying the first layer of wallboard. Studs and joists should be in true alignment. Soil pipes, bridging, fire stops, etc., must not protrude beyond framing members. To insure proper application of the second or face layer of wallboard, a definite plan for erection should be formed before the first layer of the board is applied. Ceiling height will determine whether the base layer is vertical or horizontal. Apply the base layer with 1 $\frac{1}{4}$ -inch by 0.101-inch blued, helically threaded, tapered screw nails with medium diamond point spaced 8 inches on centers. Cut the face layer panels to correct size. Prepare the laminating adhesive cement in accordance with the wallboard manufacturer's recommendations. Using a notched spreader blade, spread the mixed cement uniformly over the entire back surface to the extreme edges of the board. After the board is in place, wipe away any cement forced out along the edges. When the face layer is applied horizontally, apply the first sheet to the upper wall. With temporary nailing, secure the board in place until the cement has set. Secure long edges by nailing wherever they occur on or across framing members. On walls, space nails in the center of the board 16 to 24 inches on centers. Following application of the upper panels, place the lower face panels. Butt the top and lower panels closely together.

**5.3.3.3 Finishing Nail Holes and Joints.** All temporary nails should be countersunk at least  $\frac{1}{4}$  inch with  $\frac{5}{32}$ -inch nail set. This is done after the face layer has been in place long enough for the cement to dry. Cement dries in 24 hours, but under adverse conditions, allow 48 hours. Fill nail holes with a joint cement mixed to a puttylike consistency. For tapered joints, spot nail holes with joint cement and then finish as normal tape-reinforced, recessed joints. Butt or square-end joints are treated the same as tapered-edge joints. However, finishing coats of joint cement are feathered wider (approximately 24 inches) because there is no taper in which to embed the tape.

**5.3.3.4 Spreader Blade.** A metal cement spreader blade is recommended. With blades made of other materials, the cement tends to accumulate in the notches and dry, preventing proper spreading action. Stainless steel or galvanized steel make the best spreaders. The spreader should have the approximate stiffness of a plaster trowel blade. The blade should be kept reasonably clean at all times. A 10-inch blade is most effective for spreading the cement.

### 5.3.4 Cement-Asbestos Wallboard

Cement-asbestos board is no longer used.

### 5.3.5 Insulation Board

Make all joints between boards over solid bearings and bring edges of board into moderate contact, but do not spring into place. Nail boards with 1 $\frac{1}{2}$ -inch, blued plasterboard nails spaced 6 inches on centers along edge bearings and approximately 12 inches on centers at intermediate bearings.

### 5.3.6 Hard-Pressed Fiberboard

This type material may only be used as wainscoting when backed with noncombustible material, such as gypsum wallboard. When a structural-type fiberboard is required, use  $\frac{5}{16}$ -inch material conforming to Federal Specification LLL-B-810. Where moisture resistance or extra strength is required, install Type II fiberboard; otherwise, Type I is suitable. Installation is similar to that described previously for insulation board. Make certain that material is preexpanded before installing Type II fiberboard in areas subject to moisture or steam, or in very humid localities. To do this, scrub the fiberboard on the screen side with a stiff broom and cold water until it turns a very dark brown (chocolate), or a decided black in the case of the black-treated board. Following this, stack the wetted boards face to face and wetted back to back, and allow them to remain in this position overnight or preferably for 36 hours.

### 5.3.7 Glazed Wallboard

Glazed wallboard suitable for wainscots consists of a base material with a factory-applied finish. It may only be used when backed by noncombustible material. The base may be made of asbestos fiber and cement formed under pressure into dense, monolithic sheets, a structural-type fiberboard, or a hard-pressed gypsum sheetrock. Finish on exposed face is a factory-applied gloss coating. A variety of colors are available, such as white, ivory, yellow, peach, green, blue, red, and black. In addition to these colors, other finishes give the appearance of several woods, such as walnut, mahogany,

knotty pine, oak, and red gum. Most boards are made in 4-foot widths and lengths of 4 to 12 feet. Thickness range from **c** to **d** inch. The **d**-inch-thick boards can be applied by nailing over furring strips, in which case make all joints over solid bearings and secure with 1¼ inch, 18-gage brads, driven ¼ inch from edges on 4- to 6-inch spacings and about 12-inch spacings through the body of the board. An alternate method of installation consists of spreading an adhesive over a smooth, solid backing of noncombustible material such as gypsum wallboard. Cut and fit glazed boards to a close fit. Lay the board on the adhesive-coated wall or ceiling and push firmly into place. Do not spring into place. Clean off any excess adhesive that may appear at joints, using cleaner recommended by the board manufacturer for that purpose. Immediately after setting the board in position, insure solid contact with backing by placing previously prepared braces. Leave the braces in place until the adhesive sets, usually overnight. For some applications, brads may be used to support the boards while the adhesive sets. The nails may be either countersunk or withdrawn and the holes filled with material matching the board finish. Panel effect, if desired, is obtained by installation of moldings over board joints and around openings. These moldings are available in a variety of sizes, colors, and materials, such as wood, plastic, metal alloys, and stainless steel.

### 5.3.8 Plywood Linings

Plywood acceptable for interior wall and ceiling linings will be equal to or better than three-ply softwood plywood, interior grade, not less than ¼ inch thick, manufactured in accordance with the requirement of Product Standards PS 1-66. It may be used when backed with noncombustible materials. Face veneer may be Douglas fir or other softwood or hardwood with smooth surface suitable for painting or staining. The economical procedure generally calls for the installation of the larger size sheets. Before starting the installation, see that stud, furring and ceiling joist spacings do not exceed 24 inches on centers. Make all joints, including end joints, over solid bearings. Fit panels close but do not force into place. Secure with six-penny nails spaced 6 inches on centers on intermediate bearings. Plywood for wainscots is usually set with the grain running horizontally. Plywood for wall lining is set with the grain running vertically. Grain of plywood on ceiling should be parallel with the long dimension of the room.

### 5.3.9 Furring in Walls

5.3.9.1 *Placing* When applying interior surfacing materials, install furring strips vertically, spaced not more than 2 feet on centers. It is also advantageous to place other furring strips so that each sheet of surfacing material is supported horizontally at distances of about 4 feet on centers. Wood furring strips supporting metals lath and plaster are spaced 16 inches on centers. Furring strips are also installed around all openings or wherever proper installation of wall, partition, or ceiling lining requires their use.

5.3.9.2 *Fastening* Furring strips may be secured to masonry walls by the methods given below.

a. Cut or case-hardened nails placed on 2-foot centers provide a simple and satisfactory way to fasten furring strips to walls or ceilings. The wedging action of a cut nail gives additional holding power. Furring strips are leveled or plumbed by inserting wooden wedges under the nailing point.

b. The same procedures used for nailing are used for bolting. Toggle bolts or butterfly bolts can be used to attach furring strips to hollow-core masonry material. The use of bolts requires drilling a hole in both the strip and the masonry. This method is slower than nailing and should be used only when the superior holding power of a bolt is required.

c. Powder-Actuated Tools. The development of powder-actuated tools has provided a means of fastening any construction material to steel or concrete with great speed and ease. A wide variety of pins and studs are available to suit the needs of the job at hand. The pins are placed in the tool, similar to a handgun, and fired into place by a special powder charge. These tools can be used to fasten furring strips to masonry, as well as for a variety of other uses. The tool requires a trained operator and observation of prescribed safety procedures.

### 5.3.10 Furring in Ceilings

5.3.10.1 *General.* Ceilings are furred to obtain straight surfaces and to correct any difference in level on the underside of the joist. Furring strips, spaced 12 to 16 inches on centers, are run perpendicular to the underside of the floor or ceiling joists and secured with 10-d nails. These strips are brought to even surface by working from leveled furring strips extending around the perimeter of the ceiling.

5.3.10.2 *Fastenings.* Furring strips intended to support plaster or acoustical materials on the ceilings should be nailed and tied securely by 16-gage

wire to the underside of the joists. When wooden joists are used, convenient hangers are formed by driving 10-d nails into each side of the joists. A wire extending from one nail to another, looped and drawn taut across the furring strip, forms a

secure anchor. When open-web joists are used, nailing is accomplished by means of metal nailing grooves or wooden nailers. Wire loops, encircling the furring strips and the lower chord of the joists, can be spaced as required.

## SECTION IV—FIRE PROTECTION

### 5.4.1 General

In the course of necessary repairs to buildings and structures, fire protection features will be reexamined and any deficiencies corrected promptly. Adequate fire protection is a function of design, but such changing conditions as additions to buildings and structures, change in occupancy, or introduction of increased operational hazards may require upgrading of protective features or additions to them. In any case, the effectiveness of fire protection features depends on regular inspection, care, and maintenance. (Fire protection standards may be obtained from the National Fire Protection Association (NFPA) Standards.) (Air Force Standards are found in AFM 88-15.) The extremely rapid flame spread that occurs on the surfaces of commonly used materials has been the cause of many catastrophes. In view of the past record, the use of combustible wall and ceiling finishes (including wallboard and acoustical units) having high flame-spread ratings is prohibited. Certain interior finishes that have a rapid flame-spread rating were widely used in the past and remain in use in some buildings. The generation of smoke and fumes resulting from the combustion of material must also be taken into consideration. Interior wall and ceiling finishes are applied over structural framing of a building and cover a considerable portion of the individual walls or ceilings. Such materials include decorative finishes, acoustical corrections, and surface insulation. Surface coverings of wallpaper, not exceeding 0.025 inch thick, or a material with no greater fire risk than wallpaper, do not contribute significantly to fire hazards when applied over a noncombustible base. Generally, plaster finishes have been accepted by building codes, and wallpaper or paint finishes over noncombustible surfaces are considered nonhazardous if any coatings are not applied one over the other.

**5.4.1.1 Noncombustible Interior Finishes.** Fire resistance and flame spread are different properties of construction materials. Fire-resistant ratings have been established for wall, partition, and ceiling construction by responsible and extensive laboratory tests. Conventional wall construction, such as brick, concrete, hollow tile, and concrete or gypsum block units surfaced with plaster of the required thickness, is considered nonhazardous and

noncombustible. Similarly, partitions or ceilings constructed of assemblies of wood or metal studs and joists, or of metal, gypsum, or wood lath surfaced with cement, lime, or vermiculite plaster have nonhazardous interior surfaces and, depending on the assembly, the required fire rating. Sheet-metal covering applied directly to wood joists or over old plaster ceilings, although superior to highly combustible materials, offers little resistance and increases the effort required to extinguish fires starting in concealed spaces between the joists.

**5.4.1.2 Insulation and Sound Control Materials.** Insulation and sound control problems are similar, principally because the same materials (treated and untreated) are often used for insulating buildings for heat or cold (thermal insulation) and for sound control (acoustical correction).

**5.4.1.3 Fire Resistance.** Noncombustible insulating material, such as mineral or glass wool, may increase fire resistance if it will stay in place and not settle and produce voids. Standard fire tests have shown that mineral wool in the hollow spaces between studs increases the fire resistance of metal lath and sand gypsum plaster on wood stud partitions by about 30 minutes. For gypsum board facing on wood stud, the fire resistance is increased by 10 to 20 minutes.

### 5.4.2 Alterations

When alterations are necessary to existing buildings, the fire protection features should be reexamined to correct deficiencies and provide such additional measures as the new use requires. The following features are most important.

**5.4.2.1 Firewalls.** Firewalls are protection against the horizontal spread of fire only if they are intact, and if openings were permitted, are properly protected against passage of smoke or heat. Interior finish repairs must be accomplished without damage to firewalls, and finishes applied should have a flame spread rating equal to finishes used on other interior walls for a particular occupancy. When hazards are increased in existing buildings and structures, firewalls should be added as needed to subdivide the space into suitable limited fire areas; this can often be done economically by increasing the fire resistance of existing walls and

installing fire doors. If area limitations require firewalls through combustible roof structures, the walls should be parapeted.

5.4.2.2 *Vertical Openings.* The enclosure of vertical openings is most important in preventing the vertical spread of fire. In fact, it is probably the largest factor in connection with life and property safety in multistory buildings. If masonry walls cannot be placed around open stairways or elevator shafts in an existing building, metal lath and plaster, or other lightweight construction of equal fire resistance, may be used. Any enclosure is preferable to open stairs or elevator shafts.

5.4.2.3 *Horizontal Openings.* All wall openings will have fire protection features appropriate to the occupancy of the building and structure. This is especially important for areas where hazardous processes are carried on or hazardous materials are stored in buildings or structures with a large total floor area. The adequacy of horizontal opening protection should be checked and preserved in the course of interior repairs. If swinging fire doors are used to replace sliding doors, such doors must swing in the direction of the emergency exits.

5.4.2.4 *Concealed Spaces.* Concealed spaces exposed in the course of repairs will be checked for

the presence of combustible debris. Materials used for insulation will be noncombustible. Any draft stop helps slow the spread of fire, but complete fire stopping may be difficult in open-joint channels and stud-spaced wood construction. Fire stops should be used between the wood joist and sills. The use of fire-retardation paint or solution may be helpful in particular cases, but this provides only a temporary measure of protection.

5.4.2.5 *Skylights.* Skylights and other small structures on the roofs of buildings should have a fire-resistance rating appropriate to the construction and occupancy. Skylights should be maintained to insure their effectiveness in preventing the entrance of fire and venting interior fire or explosion.

5.4.2.6 *Ventilation Ducts.* Ventilation or exhaust and intake ducts extending through roofs or walls should be of noncombustible materials. Ducts should be cleared of obstructions as required. Ventilation hoods, ducts, and filters in kitchens should be periodically cleaned to remove grease accumulation that may cause fire. Devices to prevent the entrance of sparks or brands, such as baffle plates, vanes, dampers, and metal screens, should be checked regularly for proper setting and good condition.

## SECTION V—ACOUSTICS

### 5.5.1 Acoustical Problems

Acoustical materials applied on walls, partitions and ceilings of theaters, auditoriums, and many other occupancies absorb noise and aid hearing by reducing echoes and reverberation. Two acoustical problems are to be considered. One is the treatment of a room or building to keep out exterior sound, and the other is the treatment of a room interior to eliminate echo and reverberation by sound absorption or diffusion to reduce objectionable noise levels.

5.5.1.1 *Exterior Sound.* Insulation from exterior noise is sometimes part of the interior sound-absorption problem. The best resistance to noise penetration usually can be obtained with heavy rigid walls and floors, or multiple-layer construction separated by airspaces. Such

construction keeps out sound by preventing the vibration of the wall or floor. Any mechanical connection across the intervening airspaces in a structurally separated wall increases sound transmission. For hollow walls not structurally separated, such as ordinary wood stud partitions, a fill of noncombustible material between the studs slightly improves the sound insulation.

5.5.1.2 *Sound Absorption.* For best results, sound absorption requires porous or low-density materials, but it is impossible to set rules applying equally to every installation. However, it is necessary to use only noncombustible materials that do not have surface flame-spread characteristics and will not add fuel to a fire that may occur in the treated spaces.

## CHAPTER 6

### FLOORS AND STAIRS

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#### SECTION I—GENERAL

##### 6.1.1 Types of Floors and Coverings

Floor materials found in buildings and structures for various occupancies include wood, concrete, terrazzo, magnesium oxychloride, clay tile (quarry and ceramic mosaic), mastic, metal, cork, and rubber. Conductive floors are normally peculiar to operating rooms and delivery suites in hospitals and dispensaries. Spark-resistant floors shall be placed in ammunition storage areas, where explosives are stored. Common floor coverings include linoleum, vinyl tile, vinyl-asbestos tile, asphalt tile, cork tile, rubber tile, and resinous coatings for monolithic floors. Floor structures, finishes, and coverings should be suitable for the operations conducted on them. All components should be maintained in such a manner that the complete floor will give satisfactory service. No operations which might impair the floor structure, covering or finish should be conducted until suitable modifications or protective measures have been undertaken.

##### 6.1.2 Types of Stairs

Maintenance instructions are provided herein for interior and exterior stairs of wood, concrete, terrazzo, metal, and composition materials.

##### 6.1.3 Inspection of Floors, Floor Covering, and Stairs

6.1.3.1 *Floors.* Wood floors should be checked quarterly for loose nails; warped, cupped, or loose boards; raised ends; splinters; cracks; loose knots; raised nails; and water or other damage from improper cleaning, condensation, and wood decay. Concrete floors should be inspected annually for dusting, spalling, cracking, and settling. Terrazzo floors should be inspected annually for loose or broken segments and damage from improper cleaning. Magnesium oxychloride floors should be checked annually for water and other damage from improper cleaning. Clay tile floors should be inspected annually for missing, loose, or broken tiles, open joints, and damage from improper cleaning. Mastic-topped floors should be checked annually for damage from improper cleaning. Conductive floors should be tested for conductivity with an ohmmeter at least quarterly or after repair,

and a permanent log should be maintained. Conductive flooring will meet the conductivity requirements of the National Fire Protection Association (NFPA) Standards. Metal floors should be inspected annually for corrosion.

6.1.3.2 *Floor Coverings.* Floor coverings should be checked annually. Asphalt and vinyl tile coverings should be inspected for missing, loose, and broken tiles, or open joints; serious indentations; burns; and damage from improper cleaning. Linoleum and other flexible sheet coverings should be inspected for loose seams, buckling, serious indentations, and damage from improper cleaning.

6.1.3.3 *Stairs.* Interior and exterior stairways should be inspected at least quarterly for adequacy of support and safe condition of components. Stairways should be checked, as appropriate, for cracked, weathered, or rotted wood framing; for settled, cracked, or spalled concrete; and for rusted or loose metal supports or parts or loose nails on wood stairs. Treads should be inspected for loose or broken tread nosing, excessive wear, paint or tread covering deterioration, and loose, eroded, or slippery tread surfaces. Exterior treads should be sloped (or drilled) so as to drain properly. Handrails should be inspected for loose fastening and material deterioration. Newel posts and balusters should be checked for looseness and missing parts.

##### 6.1.4 Custodial Services

Proper and timely custodial care will materially prolong the life of floors and finishes. The Military Custodial Tri-Services Manual (TM 5-609, NAVFAC MO-125, AFP 91-30 and 92-1) provides Commanders at DOD installations with methods of accomplishing custodial services and establishes cleaning standards.

##### 6.1.5 Safe Floor Loads

**CAUTION:** Do not load floors beyond their designed safe load capacity. Permanent and easily read signs or placecards, conspicuously showing the safe load capacity in lb/ft<sup>2</sup> of the floor, should be placed on each floor of a building. Such posting

is also necessary for slab-on-ground floors in warehouses, equipment shops, etc, when imposed loads

on them are likely to exceed the bearing capacity of the underlying soil.

## SECTION II—WOOD FLOORS

### 6.2.1. Wood-Strip and Parquet Floors

Strip flooring is usually of oak, pine, maple, beech, pecan or birch and is generally laid over a wood subfloor. Strip flooring should be of tongue-and-groove material and be blind-nailed. Parquet flooring may be solid block or laminated block in the hardwood species and may be nailed or installed in adhesive on concrete slab, plywood subfloor, or hardwood underlay. For gymnasiums, squash and handball courts, and ballrooms, special application methods are used as specified in guide specifications for military construction and in accordance with the manufacturer's instructions.

### 6.2.2 Reconditioning

6.2.2.1 *Defects in Wood Floors.* Some of the defects found in wood floors and the causes of these defects are listed below:

a. Wide cracks between strips and at end joints, caused primarily by use of unseasoned wood for floorboards and understructures.

b. Raised flat grain and excessive splintering, caused by oversanding or improper cleaning with excessive water and strongly alkaline soap or other damaging cleaning agents.

c. Irregular holes in floor where upended segments have been torn out during mopping or removed to prevent accidents.

d. Unevenness at joints, caused by inadequate nailing or loosening of nails under heavy traffic during the shrinking period.

e. Wood decay, frequently caused by condensation under the floor.

f. Failure to provide for expansion at room perimeter, causing floor to buckle.

6.2.2.2 *Reconditioning Methods.* Floors that have become appreciably worn, cut, gouged, indented, or stained or that have splintered, loose, or warped strips or planks should be refinished or covered. Pine- or hardwood-strip flooring can be sanded about  $\frac{3}{16}$  inch or nails are exposed before replacement or overlaying is needed.

### 6.2.3 Refinishing

6.2.3.1 *Floor Preparation.* Perform the following corrective work before removing old finish, refinishing, or covering floors:

a. Renail all loose and warping boards.

b. Remove all tacks and set nail heads well below the floor's surface.

c. Scrape or machine-sand all high joints to make them level with adjacent floorboards.

d. Remove and replace boards that are damaged beyond reconditioning.

e. Remove loose splinters and fill all holes and large cracks with crack filler.

f. Remove grease, oil, and other foreign matter.

6.2.3.2 *Refinishing Areas with Worn Finish.* Areas where wood-floor finishes are worn may sometimes be reconditioned as follows:

a. If possible, clean the floor by the drycleaning methods, or use a commercial-type "finish renewer" available from most flooring contractors. Most wood-flooring manufacturers recommend that no water be used on the maintenance of wood floors. However, if scrubbing is necessary, use a mop dampened in all-purpose synthetic detergent solution.

b. Liberally apply a varnish-type sealer that conforms to Federal Specification TT-S-176. Spread or spray it along the grain of the wood.

c. After the sealer has dried completely, buff the floor with a floor-polishing machine, using No.1 steel wool pads. If portions of the floor look lusterless, dry, or dead after the buffing, continue sealing and polishing until the floor surface has a uniform appearance.

d. Apply spirit-type liquid or paste wax. Buff the wax after each application.

### 6.2.3.3 Sanding

a. *Equipment.* Power-operated sanding machines are the most satisfactory means of preparing wood floors for refinishing. The operator should wear an approved respirator or dust mask while sanding. Abrasive paper, commonly called sandpaper, is made with paper or fabric backing. For machine use, a fabric-backed or fabric-reinforced paper backing is recommended. The mineral cutting agent glued to the face of the paper may be flint (Federal Specification P-P-105), garnet (Federal Specification P-P-121, waterproof), or silicon carbide (Federal Specification P-P-101, waterproof). Cutting surfaces are designated close coat (cutting grits covering the entire face) or open coat (grit covering about half the cutting surface). Open-coat paper is recommended for sanding materials, such as paint and varnish, that tend to clog spaces between the grits. Flint papers are made in 12 grades. Flint (sand) papers having glue

binders must not be stored where they will be subject to oil, moisture, or extreme heat and cold. Old brittle paper can be softened by dampening the backing. The following table (table 64) is a guide to sandpaper selection for floor finishing:

TABLE 6-1: Guide to Sandpaper Selection for Floor Finishing

Grade	Type	Use
3½	Open	Preliminary removal of stubborn varnish, shellac, floor oil, wax, and deep-penetrating filler compounds. Not to be used for cutting into wood surfaces.
3	Open	Used in place of No.3½ for surfaces of less resistance; is preferred if it does the required work.
2½	Open	Preliminary removal of floor finishes such as shellac, wax, floor oils, alcohol stains, and lacquered surfaces.
2	Close	Use instead of No. 2 and No.2½ open coat where surface permits cutting without gumming. Closed coat should be used in preference to open coat whenever practicable.
1½	Close	Use as a first paper on all new floors.
1	Close	Use as followup for No.2 and No.2½ in all cases.
1	Close	Use the same as No. 1 open coat to provide a smooth floor finish.
½	Close	Use as final finish on most floor work.
1/0 & 2/0	Close	Use as final finish on best hardwood floor work.
3/0 & 4/0	Close	Use for finishing fine woodwork such as furniture and for rubbing down paint and varnish finishes.

*b. Procedure.* Old varnish, shellac and wax material should be removed from the floor with the proper type of abrasive paper. First, go over the floor twice diagonally with coarse paper, avoiding deep abrasive marks in the wood; then finish with fine paper or steel wool parallel with the grain. See figure 6-1. No attempt should be made to cut wood

in the removal operation. Edges that cannot be reached by a sanding machine should be hand-scraped. The floor should then be sealed and waxed as described in paragraph 6.2.3.2. The final sanding for parquet flooring must be with a disk sander. Additional information on floor sanding may be found in the Tri-Services Manual, "Paints and Protective Coatings."

6.2.3.4 Use of volatile Liquids.

*a. Safety Precautions.* In exceptional cases, when old floor finishes cannot be removed by sanding or scraping with an abrasive, highly volatile liquids may be used. These liquids, as well as those used in floor refinishing, include paint and varnish remover, varnish, liquid paint, and shellac, which have flashpoints as low as 40° F (4.5° C). Refinishing should be done only under expert supervision, with attention to the following precautions:

- (1) Use rubber gloves and face masks (respirators) when working with highly volatile liquids, varnish, varnish remover, liquid paint, and shellac.
- (2) Remove from the area all personnel not engaged in the work.
- (3) Provide all possible natural ventilation.
- (4) Disengage the main electric switch for the entire building and work under natural light. If this is not practicable, disconnect all electric appliances in the vicinity, including such equipment as water coolers and soft-drink dispensers, before applying volatile liquids. Do not reconnect the appliances until the liquids have completely dried on the floor.
- (5) Shut off the main gas valve for the building. If this is not practicable, extinguish the pilot lights on all gas equipment and do not relight them until the volatile liquids have completely dried.
- (6) Prohibit smoking and the use of open flames during application of the liquids and for 1 hour after they have completely dried.
- (7) Clean only a small area of floor at a time.
- (8) Restrict the amount of liquid on hand to that needed for the immediate operation; immediately return any unused liquid to its proper storage place. Do not use open containers for storage.
- (9) Provide covered metal containers for used cleaning rags. Remove the cans before securing the building.
- (10) Place the residue from sanding machines in cans, wet it down, and promptly remove the cans from the building.

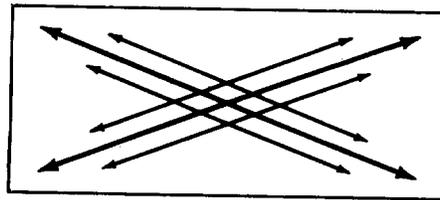
(11) Notify the fire department before operations are started, and observe any additional pre cautions fire officials may require.

*b. Application.* Old varnish and paint finishes may be removed from a floor by application of an organic-solvent remover conforming to Federal Specification TT-R-251. The remover is brushed on and allowed to stand until the varnish or paint softens. The old finish is then scraped off with a steel blade scraper or rubbed off with steel wool or excelsior. Oil finishes may be removed by a water solution of trisodium phosphate, washing soda, or commercial cleaner. The liquid is applied to the floor, a small area at a time, allowed to stand for a few minutes, and then scrubbed off with a stiff brush. The floor should be scrubbed and mopped to a dry or slightly damp surface. Old shellac may be

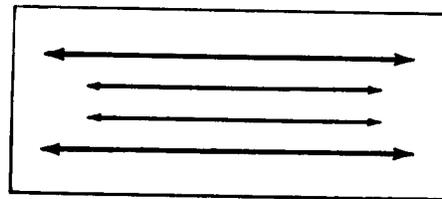
removed by the use of steel wool saturated with turpentine.

### 6.2.4 Replacement of Wood Floors

6.2.4.1 *Preparation.* Before laying finished wood floors, inspect wood subfloors, replace defective or otherwise damaged boards, and renail boards that do not have a firm, tight bearing. Broom-clean subfloors of plaster, dirt and other foreign matter. When the subfloor is judged to be clean and dry, put down a layer of asphalt-saturated felt conforming to Federal Specification HH-R-595. Lap edges and ends of felt 4 to 6 inches and turn up under baseboard not less than 3 inches. Finished flooring will not be brought into building until plaster and masonry is thoroughly dry.



STEP 1



STEP 2

Figure 6-1. PROCEDURE IN SANDING FLOORS

6.2.4.2 *Laying Wood Flooring.* Cut all boards to eliminate knotholes, loose knots, and damaged portions. Blind nail all dressed and matched flooring with straight shank cut steel, or spiral or screw-type shank flooring nails. For 25/32-inch flooring use eightpenny nails. For face nailing, use 8-d finishing nails and set the heads. Normally, flooring should be laid perpendicular to the joists. Nails should extend through the subfloor into the joist. Strip flooring overlying existing strip flooring should be laid perpendicular to the existing

flooring. The first strip along the wall must be straight and parallel to walls for it affects direction of succeeding strips. Drive each strip tight against previously laid strip before nailing. End-matched joints may be made random. Make square end joints occur over bearings. Stagger all end joints so there are at least two continuous boards on each side of board joints. Set heads of all exposed nails. Leave an expansion space of not less than 1/2 inch on all sides next to walls, but not wider than will be covered by the base shoe, quarter round, or door

threshold. Finish flooring by machine sanding. Hand scrape around edges and other surfaces not accessible by machine.

### 6.2.5 Patching Wood Floors

6.2.5.1 *Procedure.* If floor damage requires re placement of strips or planks, the following procedure should be observed:

a. Make two longitudinal cuts in the damaged strip or plank. See figure 6-2, detail A.

b. Remove the section between the two cuts by cutting the strip with a chisel at midpoint. See figure 6-2, detail B.

c. Remove the remainder of the damaged strip, taking care not to damage the tongues and grooves of adjoining boards. See figure 6-2, detail C.

d. Remove the lower part of the groove of the new closure strip or plank. See figure 6-2, detail E.

e. Insert the tongue of the closure into the groove of the adjoining board for face nail with two eightpenny, annular-ring finishing nails. When possible, the end joints should be located so the nails will enter the joist. In new closure areas of flooring laid in mastic on concrete, remove the existing mastic and apply new mastic of the type recommended by the flooring manufacturer before installing the new closure.

f. Set exposed nails. See figure 6-2, detail D.

g. Dress the new portion to the level of the adjacent floor by sanding both areas to a continuous, smooth plane.

h. Dry-sweep the area to remove all particles of dust.

i. On open-grained woods, brush on a paste filler conforming to Federal Specification TT-F-336. After the filler has partially dried, rub it into the pores of the wood with a circular motion using excelsior or burlap. Wipe the surface lightly to remove any surplus filler. Inadequate filling is indicated by pockmarks and results from wiping off too much of the filler or from unusual absorption by the wood. Eliminate such deficiencies by repeating the filler application.

j. Seal and wax the floors as described in paragraphs 6.2.3.2 and 6.2.3.3 or finish to match existing.

### 6.2.6 Creaking Floors

Creaking in an old floor may be the result of one or more causes such as shrinking or warping of the boards, insufficient initial nailing, loosening of the subfloor, warping of joints, or the presence of building settlement which throws the floor out of level. If the boards have lifted from the joists, place a wood block on the loose spot and drive down with a heavy hammer or maul. A piece of old carpet or other material placed under the block will prevent marring the finished floor. If floor will not stay down, drive several nails through both finish and subfloor into the joists to draw the floor down tight. Drive nails heads to within ¼ inch of floor, then finish driving and set with nail set. Fill holes over nail heads with putty or plastic wood, colored to match floor finish.

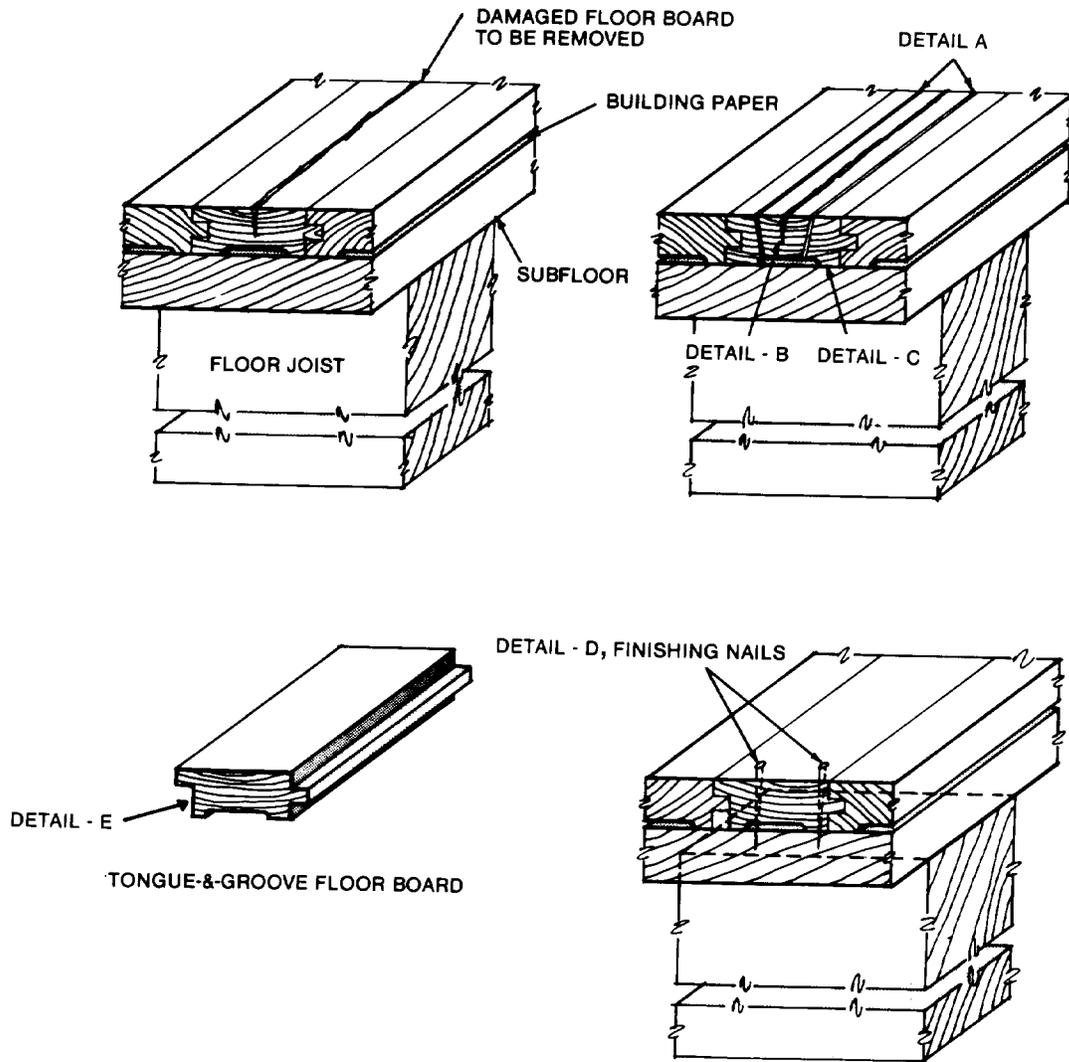


Figure 6-2. METHOD OF REPLACING TONGUE-AND-GROOVE FLOORING.

### 6.2.7 Preparation for Rug or Carpet Covering

Wood floors that are to be covered with rugs must be sealed to prevent damage from dust that seeps through the covering. Refer to paragraph 6.2.3.2, reconditioning areas with smooth finish, except omit wax coat. Provide padding or underlays to protect rugs from dust seepage and to prolong rug life.

### 6.2.8 Overlaying of Wood Floors with Resilient Flooring

When wood floors can no longer be resanded and it is not desirable to replace them, they may be overlaid with resilient flooring. Procedures for the overlaying of wood floors with resilient flooring are outlined in Section 6.9, Resilient Floor Covering.

### 6.2.9 Industrial Wood-Block Floors

6.2.9.1 *Description.* Wood-block flooring is usually of southern yellow pine, oak, western larch, western hemlock, and Douglas fir. Wood-block flooring should be pressure treated with preservative. It usually shows all end grain on the wearing surface. Blocks are made in sizes ranging from 1½ to 4 inches wide, from 3½ to 8½ inches long, and from 2 to 4 inches thick. Grooves are usually cut into the sides and ends of individual blocks, or the vertical corner surfaces are beveled to permit easy penetration of binder into the joints surrounding each block. Blocks are usually laid individually in an adhesive mastic and the joints filled; however, factory-assembled strips of blocks laid in mastic may be used.

6.2.9.2 *Maintenance.* Sweeping wood-block floors with a stiff bristle broom or a power sweeper should keep them dirt-free. In areas where accumulation of dirt and oils requires more than normal sweeping, the floor may be scraped with a metal scraper or cleaned with a power buffing machine equipped with a wire-bristle brush or coarse steel wool pads. Oil or water spills should be removed immediately and the area covered with an oil- and water-absorbing compound conforming to Federal Specification P-S-865. The compound should be swept up after it has absorbed the oil or water. Do not use water on wood-block flooring. Water enters the pores of the blocks or the cracks between them and causes the floor to warp or buckle.

6.2.9.3 *Repair.* Wood-block floors are generally repaired by replacement of splintered, cracked, and loose blocks with new blocks, matching the original materials as closely as possible. Methods of repairing floors are as follows:

*a. Large Areas.* When large areas or the entire floor surface must be replaced, the new floor should be installed according to specifications for the original floor. If the materials originally specified cannot be obtained, they should be matched as closely as possible, and the manufacturer's recommendations followed. Both coal-tar pitch and asphalt products are used in the installation and treatment of industrial wood-block floors. Materials of the respective types used in the original installation should be used for replacement. Coal-tar pitch and asphalt are not compatible and must not be in contact with each other. Test existing materials to determine their composition. Concrete may be used to replace large areas of deteriorated blocks where operational conditions permit and where the weight of the concrete will not exceed the design limitations of the structure. Concrete provides the hardness and toughness necessary to resist heavy loadings but does not provide the resiliency needed for foot comfort or for protection

of tools or parts that may be dropped. Repair woodblock floors with concrete as follows:

- (1) Lay out the area to be repaired in rectangular lines and include all defective and loose blocks.
- (2) Remove all blocks within the rectangular area.
- (3) Clean the subfloor of all loose particles, dust, oils, and grease.
- (4) Proportion, place, and finish the new concrete as described in paragraph 6.3.4.
- (5) Replace all expansion joints and install new expansion joints in the concrete every 20 feet in both directions.

*b. Small Areas.* Small areas of wood-block floors are repaired by replacement of deteriorated or loose blocks with small blocks, matching existing materials as closely as possible.

- (1) Remove all deteriorated and loose blocks in the area.
- (2) Thoroughly clean the subfloor, removing all loose particles, dust, oil, and grease.
- (3) Be certain that the subfloor and surrounding blocks are thoroughly dry. Then, apply one coat of the floor manufacturer's recommended primer to the subfloor and sides of the surrounding wood blocks.
- (4) When the primer is thoroughly dry, apply a coat of coal-tar pitch or plastic bituminous cement, as suitable to the subfloor in the quantities necessary for permanent adhesion between the subfloor and wood blocks.
- (5) Fit the individual blocks or strips of blocks into place, matching the existing floor lines as closely as possible. Fill any voids of less than one full block with a section of a block cut to fit. Retain existing expansion joints.
- (6) Fill the joints and finish or seal the floor, as necessary, according to the manufacturer's recommendations.

### SECTION III—CONCRETE FLOORS

#### 6.3.1 Maintenance

Concrete floors of proper composition, installation, and curing require comparatively little maintenance unless they are exposed to the following: severe abrasion and heavy vehicle loads from industrial traffic; the deteriorating effects of grease, oils, and food acids such as are encountered in kitchens, sculleries, bakeries, meat-cutting plants, and similar food preparation spaces; or caustic soaps and solutions. The corrosive agents in highly acidic or alkaline liquids attack concrete floors and cause

spalling, pitting and other deterioration; such floors may be overlaid with resinous (epoxy, polyester) industrial (tru-welded-on) type topping or with resinous terra 330. When trucking is done over concrete floors, as in aisles of warehouses, trucks should be fitted with wide-faced wheels with rubber tires. If vehicle abrasion and shock continue to raise maintenance demands, the application of heavy-duty topping to the concrete should be considered. CAUTION: Avoid painting concrete floors except for functional requirements, such as marking safety

lanes or similar areas. Painting for appearance is unjustified and impractical. Traffic areas on painted floors will wear first, making the floor unsightly and presenting a difficult cleaning problem. Cost of repainting constitutes an unnecessary expenditure of maintenance funds. Much useful information on concrete floors can be found in publications by and available from the Portland Cement Association and in the "Concrete Manual" published by and available from the Bureau of Reclamation, U.S. Department of the Interior. Also refer to pavement manuals.

### 6.3.2 Repairs

Concrete floors should not be repaired until causes of defects have been determined and preventable causes have been eliminated.

#### 6.3.2.1 Cracks.

*a. Causes and Corrections.* Cracks in concrete floors may be caused by shrinkage, expansion or contraction due to temperature changes, settlement, or lack of rigidity of supporting beams or other structural members. When such movements are recurrent and can be eliminated only by major structural changes, little can be done except to keep the cracks filled with a mastic material. In many cases, comparatively small cracks may be filled with varnish or resin. Although the cracks will remain visible, they will not leak or gather dirt. When the cause of large cracks has been determined and corrective measures taken to eliminate further cracking, the cracks can be permanently repaired by filling them with nonshrinking cement mortar. Patching will not permanently correct cracks in slabs on grade caused by vertical movement resulting from exceeding the design load of the slab, inadequacy of the base, or insufficient bearing capacity of the soil. Slab failure under these circumstances may sometimes be corrected by mud jacking. Following completion of mud jacking, cracks should be cleaned and filled with an epoxy resin preparation, which should be used only in accordance with the manufacturer's recommendations. Complete replacement of slab-on grade floors is often the only feasible method of repair.

*b. Procedure for Repairing.* Chip or rout out cracks to be repaired. Form a channel of at least 1 inch deep, with vertical sides. If the crack extends through the structural slab, cut a V-shaped groove, at least 2 inches deep, in the bottom of the channel, resulting in a total depth of 3 inches. If the crack does not extend through the base and if the top course is less than 3 inches thick, chip the V-shaped groove only to the depth of the wearing

course. Clean out all loose material with a stiff brush and compressed air. First saturate the area to be patched and the adjoining surface with water. Keep them wet for at least 4 hours. Mop up the excess water. Spread a thin layer of neat port land cement on the sides and bottom of the crack. Broom the cement into the surface of the concrete. As soon as the cement has absorbed enough water to form a sticky paste, place the new mortar. Tamp the mix into the crack and with a screed, bring it to a level slightly higher than the adjoining floor. Let it set for about 1 hour. Tamp it hard and trowel it to the level of the adjoining floor. Keep the new concrete wet and protect it from traffic for about 7 days (3 days if high early strength is used).

#### 6.3.2.2 Patches.

*a. Preparation.* Lay out patches in rectangular lines to include all defective surfaces. The edges of the areas to be patched should be saw cut. Chip out the old concrete to a depth of at least 1 inch or until sound concrete is reached. Roughen the chipped surfaces and provide vertical sides. Clean out all the loose particles and dust. Saturate the prepared areas and adjoining surface with water and keep them wet for at least 4 hours. Remove any pools of water that may accumulate on the roughened area, neatly spread a layer of portland cement uniformly, and thoroughly broom it into the surface. As soon as the cement has absorbed enough water to form a sticky paste, apply the patching mixture.

*b. Patching* Prepare a patching mixture consisting of 1 part portland cement, 1 part well-graded sand, and 2 parts pea gravel or crushed rock, graded from **c** to **d** inch. Mix the dry ingredients of the concrete thoroughly. Use no more than 4½ gallons of mixing water for each sack of cement. Continue the mixing for at least 1½ minutes after all the ingredients, including water, are in the mixture. The concrete, after being placed on the slab, should be vibrated, rolled, or tamped in place. Screed to proper level and float. Steel trowel to a hard finish. Cover the new concrete with wet burlap or another approved method (spray paint), protect it from traffic, and keep it wet for 7 days (3 days if high-early strength cement is used).

### 6.3.3 Refinishing by Grinding

Improperly constructed floors that have topping finish may be roughened by traffic or pitted by heavy impacts. Such floors can be restored to satisfactory condition by grinding off the roughened surface. If the concrete is of such poor quality that the surface will soon be roughened or pitted again, it would be more economical to resurface or

replace it with concrete of the proper quality. Concrete surfaces often have numerous hairline cracks and crazes as a result of improper curing. If the cracks are not too deep, they may be eliminated by grinding the floor. Concrete floor surfaces are ground by the method used in finishing terrazzo floors, which requires highly skilled labor under adequate supervision.

### 6.3.4 Resurfacing

6.3.4.1 *Suitability of Floors.* Wearing surfaces of concrete floors that are spalling or abrade easily under foot traffic should be resurfaced or covered. Old floors that have been subjected to service too severe for the quality of the surface can be resurfaced with a heavy-duty topping. If the floor design load permits and if raising the floor level is not objectionable, a new topping can be placed directly on the old slab.

6.3.4.2 *Preparation.* All dust, paint, grease, oil, and loose materials should be cleaned from the old floor before it is resurfaced. Areas that have the original troweled finish should be roughened with a pick or grinding tool. Expansion and construction joints should be retained. Whenever practicable, the new topping should be at least 2 inches thick and reinforced with 2- by 2-mesh galvanized welded wire fabric, 21 pounds per 100 square feet, placed approximately in the middle of the thickness of the new concrete.

6.3.4.3 *Concrete Mixture.* New concrete should consist, by volume, of 1 part portland cement, 1 part graded sand, and 2 parts pea gravel or crushed rock, graded from **C** to **D** inch. It should be of the stiffest consistency practicable so that the strike-off board or straightedge may be used in a sawing motion. Not more than 4 gallons of mixing water, including the moisture in the aggregates, should be added for each sack of portland cement. Use not more than 5 gallons when floating is done by hand. The concrete should be mixed for at least 1½ minutes after all ingredients, including the water, are in the mixer.

6.3.4.4 *Application of Finish.* Keep the base slab thoroughly moist for a 24-hour period before placing the finish, but allow no pools of water to remain when the wearing course is placed. Broom a thick coat of neat cement grout into the surface of the slab for a short distance ahead of the topping. Before the grout has hardened, place the wearing course and bring it to the established grade with a straightedge. Compact the wearing course by rolling with weighted rollers or tamping with iron tampers. Float the surface with a wood float or power-floating machine, making sure no water

remains on the finished surface. Test the surface with straightedge to detect high and low spots and eliminate them. Finish the surface with a steel trowel. Allow the concrete to become hard enough that mortar will not accumulate on the trowel. In the final troweling, a ringing should be produced as the trowel is drawn over the surface. Do not sprinkle dry cement or a mixture of dry cement and sand on the wearing course to absorb moisture or stiffen the mix. This will make the surface weak and produce cracks and crazes. Cover the concrete with wet burlap as soon as it has hardened enough not to be damaged by the covering, and keep it wet for at least 7 days.

### 6.3.5 Heavy-Duty Floors

Concrete floors in receiving rooms, loading platforms, and other locations that are subjected to impact from falling objects, heavily loaded steel-tired trucks, or sliding loads usually require protection, such as steel floor grilles or surface treatment.

6.3.5.1 *Grilles.* Steel floor grilles are set in concrete, with openings between the grilles filled with concrete. Grilles should be installed according to the manufacturer's recommendations. The top surfaces of the grilles should be level with the finished floor.

6.3.5.2 *Surface Treatment.* Metallic monolithic surface treatment consists of a factory-prepared mixture containing iron aggregate, suitable for application as a part of a new concrete topping by the dusted-on method. The mixture should be free from nonferrous metal particles, oil, grease, and soluble alkaline compounds. It should be water-absorbent and contain not more than 0.075 percent of water-soluble material. A cement-dispersing agent and a pozzolanic material that will combine with free lime to form a water-insoluble compound should be combined with the metallic aggregate. In applying the finish to the topping, strike off the topping true and screed it to the finished elevation. Apply the dry mixture over the freshly screeded concrete at a uniform rate of 60 pounds per 100 square feet of surface. After the mixture has absorbed water to a uniform appearance, rod it with a straightedge to a uniformly true surface. When absorption is complete, compact the finish by rolling with heavy rollers or by floating with motor-driven floats of the metal disk type. Add material to low spots until a uniform appearance is obtained. Follow the compaction with troweling by hand or machine to produce a smooth, hard, and impervious surface. Cure heavy-duty floors as recommended in paragraph 6.3.4.4.

### 6.3.6 Nonslip Floors

A nonslip floor is required in certain areas. In resurfacing floors in such areas, nonslip aggregates may be mixed with the concrete or sprinkled on the surface of the wearing course just before final troweling. More aggregate is required when it is mixed with the concrete, but distribution on the aggregate is usually more uniform. Nonslip aggregates should be particles of aluminum oxide, emery ore, or ceramically bonded abrasive, such as Carborundum, ranging in size from  $\frac{1}{32}$  to  $\frac{1}{4}$  inch. If mixed with the concrete,  $\frac{3}{4}$  to 1 pound of aggregate is required for 1 square foot of floor when topping is  $\frac{3}{4}$  to 1 inch thick. If sprinkled on the surface,  $\frac{1}{4}$  to  $\frac{1}{2}$  pound of aggregate is required for 1 square foot of floor. To apply the aggregate directly to the floor, dampen the abrasive aggregate thoroughly before spreading, and tamp it flush with the unhardened surface with a steel trowel. Be careful not to bury the chips. Cure the floor as recommended in paragraph 6.3.4.4. After curing, scrub the floor with a floor machine, using steel wool pad (or rub it with an abrasive brick and water) to remove cement film and slightly expose the nonslip aggregate.

### 6.3.7 Waterproofing

6.3.7.1 *Causes of Seepage and Damage.* Concrete floors that must resist the percolation of water applied on the upper surface are usually waterproofed during construction. Improper waterproofing or building settlement may require remedial action. Floors usually leak at the line where the floor joins the wall, through cracks that may be very small, and through porous concrete. If the surface of a concrete floor can be raised, the floor can be waterproofed with a bituminous membrane waterproofing.

6.3.7.2 *Waterproofing Methods.* Application of bituminous membrane waterproofing (felt and coal-tar pitch or asphalt) is similar for concrete floors and masonry walls. If coal-tar pitch is used, coat the concrete base uniformly with hot pitch conforming to Federal Specification R-P-381, Type II (also ASTM D-450). Use not less than 40 pounds per 100 square feet, and lay over this two or four layers (depending on extent of leakage and hydrostatic pressure) of coal-tar pitch-saturated felt conforming to either ASTM D-173 cotton-fabric felt, or ASTM D-1327 burlap-fabric felt, or ASTM D-1668 glass-fabric felt. Lap each layer 24½ inches for 36-inch-wide material (22 inches for 32-inch material) over the preceding layer, and make end-laps not less than 6 inches. Mop hot coal-tar pitch at the rate of 25 pounds per 200 square feet for the

full 24½ inches on each sheet, so that the felt does not touch felt in any place. Mop the top surface of the top layer with hot pitch at the rate of 25 pounds per 100 square feet. As far as practicable, extend the waterproofing up vertical surfaces not less than 8 inches. If asphalt felts and moppings are used, coat the concrete with asphalt primer conforming to Federal Specifications SS-A-701, at the rate of 1 gallon of primer per 100 square feet. Allow primer to dry and then apply hot asphalt at the rate of 30 pounds per 100 square feet. Lay either two or four layers of asphalt-saturated felt conforming to Federal Specification HH-R-590, Type I (also ASTM D-173 cotton-fabric felt, ASTM D-1327 burlap-fabric felt, ASTM D-1668 glass-fabric felt), as recommended for coal-tar pitch felts except that moppings should be at the rate of 20 pounds per 100 square feet, using asphalt that conforms to Federal Specification SS-A-666.

#### 6.3.7.3 *Concrete Topping over Waterproofing*

When bituminous-membrane waterproofing is applied, a 3-inch concrete topping should be provided over the waterproofing. A 2-inch concrete topping should be provided over metallic-type waterproofing. Topping should be applied as recommended for resurfacing in paragraph 6.3.4. Extreme care should be exercised to prevent damage to the waterproofing membrane.

### 6.3.8 Surface Treatment

6.3.8.1 *Selection.* The application of a surface treatment that tends to increase the density and protect the wearing surfaces of concrete is usually desirable. The selection of the surface treatment should be governed by the nature of the operations normally conducted on the floor. The selection, preparation, and application of surface treatments are covered in detail in paragraph 2.2.13 of this manual.

### 6.3.9 Reconditioning Concrete Floors to Receive Coverings

6.3.9.1 *General.* Coverings are primarily used on faulty wood floors. However, occasions may arise when it is necessary to lay coverings over new or old concrete floors. In such cases, the following procedures are recommended.

6.3.9.2 *Preparation of Concrete Floors.* To be suitable for covering, concrete floor surfaces must be smooth, fully cured, dry and free of oil, grease, dirt, lime coating, and other substances that will prevent proper bonding between floor and covering. Score with a wire brush. A single coat of paint that is dry and well bonded to the concrete may be removed. Where there are two or more coats of paint, varnish or other finishes, or where there is

scaling and looseness, remove all coats by one or more of the methods described for cleaning wood floors.

6.3.9.3 *Roughness.* Old concrete floors that are rough, spalled, rutted, cracked, or in otherwise unsatisfactory condition, must be repaired before laying a flexible floor covering. Frequent repairs or replacements are necessary when coverings are laid over deteriorated floors, especially those subjected to wheeled traffic. Use complete concrete patches, cement grout, quick-set patching cement, crack filler, or other suitable materials and methods, to obtain a smooth surface. See chapter 2 for details on concrete-slab repairs. If the concrete floor is in such condition that patching is impracticable, a trowel-on type of underlay should be installed.

6.3.9.4 *Alkalinity.* Concrete floors are usually alkaline and may be coated with free lime. This can be detected by applying a 1-percent solution of phenolphthalein in alcohol (obtainable at any drugstore) to the concrete surface. Dampen several spots on the concrete with water and apply a few scattered drops of the phenolphthalein. If the concrete is alkaline, the drops will turn red or purple. Test the suspected floor at several points. Floors shown to be alkaline and floors on which strong caustics or alkali solutions have been used to remove paint, varnish and similar materials are neutralized by washing with a 10-percent solution of muriatic acid and water. Rinse the floor to remove acid and lime. Allow enough time to dry thoroughly before applying the covering cement.

6.3.9.5 *Dampness.* All types of flexible floor covering can be laid over suspended concrete floors which have underfloor ventilation. Allow sufficient time (2 or 3 months may be required, depending on the weather) for a new floor to dry before covering is applied. Open windows for natural ventilation during daytime, but close them at night to shut out damp air. Concrete with a hand-troweled surface treated with a hardener also dries slowly. If boxes, mats, or other objects with large flat-bottom surfaces have been on the concrete floor for a long time, they should be moved and the area inspected for wet spots, which indicate that moisture may be coming up through the concrete. This moisture is usually not seen on exposed areas because it evaporates as fast as it reaches the surface. When

dryness of floors is in doubt, one or more of the following tests should be performed:

a. *Flat Sheet Test.* Place pieces of flat glass, rubber, or other waterproof sheets at several points on the floor. Remove the covering after about 24 hours. It may be assumed that the floor is dry if no moisture shows on the concrete. If moisture shows, allow additional time and apply heat and ventilation to assist in drying.

b. *Putty Ring Test.* Form rings of putty about 6 inches in diameter and ½ inch high at several points on the concrete. Inside each ring drill one or two ¼- to ½-inch-diameter holes about 1 inch deep. These holes will allow any moisture in the slab to escape. Place a level teaspoonful of granulated, anhydrous calcium chloride in a small dish in each putty ring and cover with a piece of flat glass, pressing the glass down on the putty to keep out all outside air. If the floor is damp, beads of moisture will appear on the glass cover in 24 to 48 hours and the calcium chloride will be partly or completely dissolved. If dampness is noticeable, repeat the test at weekly intervals until the calcium chloride does not dissolve.

c. *Adhesive Patch Test.* Spread patches of adhesive about 2 inches square in each corner and at several spots elsewhere on the floor. After 24 hours, test the adherence of adhesive with a putty knife. If the adhesive peels off, moisture is rising too rapidly for a satisfactory installation of any cemented-on covering. Allow additional time for drying.

6.3.9.6 *Preparation of Floor for Rug or Carpet Coverings.* Concrete floors that are to be covered with carpets or rugs should be sealed to prevent damage from the dust that seeps through the coverings. Prepare the floor by the following process:

a. Thoroughly clean the floor, exposing the true wearing surface so as to disclose any defects. Patch honeycombed areas and fill cracks with mastic.

b. Apply proper surface treatment as described under the applicable portions of paragraph 2.2.13.

c. If nailing strips for fastening the carpet to the floor were not installed when the floor was constructed, provide suitable fasteners in the concrete surface.

## SECTION IV—TERRAZZO FLOORS

### 6.4.1 General

Terrazzo traditionally has been a form of mosaic flooring made by embedding small pieces of marble in mortar and polishing. Today, this traditional material is obtained by combining selected marble

chips in a matrix of portland cement or, more recently, in synthetics or resinous matrices.

6.4.1.1 *Cementitious Terrazzo.* Generally, cementitious terrazzo is a mixture of marble chips and portland cement. These terrazzo floors are usually

laid on concrete slabs and may or may not be bonded directly to the concrete. When structural movement or vibration is anticipated, a "floating" terrazzo floor is usually installed. The concrete slab is overlaid with a layer of sand, which is covered with a waterproof membrane such as bituminous felt, and a cement mortar underbed is installed on the felt. The finished terrazzo surface,  $\frac{1}{8}$  to  $\frac{3}{4}$  inch thick, is then laid over the underbed. The total thickness of underbed and terrazzo surface is usually 2 to 3 inches. To guard against further cracking, terrazzo areas are limited to 4 by 4 feet, with dividing strips of nonferrous metal set in the mortar bed and extending to floor level. Terrazzo floors may be bonded to the concrete without sand or felt between or may be integral with the prepared slab.

6.4.1.2 *Installation of Topping* After the underbed has hardened sufficiently, the terrazzo is laid and then compacted with heavy rollers. The wearing surface is ground and polished after it has hardened.

6.4.1.3 *Resinous (Thin-Set Terrazzo)*. This noncementitious type of surface is made by embedding marble chips in a matrix of resin such as epoxy, polyester, latex, or polyacrylate. Latex terrazzo may be as thin as  $\frac{1}{8}$  inch while the others may be as thin as  $\frac{1}{4}$  inch.

#### 6.4.2 Cleaning New Floors

Terrazzo appears to be dense and very hard, but the cement is sensitive to harsh soaps and cleaners, which can cause the floor to be pitted, rough, and permanently susceptible to dusting and trapping of dirt. Sweeping compounds containing oil will penetrate and permanently discolor terrazzo. Newly installed floors should be scrubbed with a synthetic detergent cleaner two or three times a week and mopped on alternate days. The floor should be rinsed thoroughly after each washing. After 2 or 3 months of this treatment, the floor will acquire a natural sheen and require only routine maintenance,

including the regular application of a sealer. Sealing of new terrazzo prolongs the slow-drying process of the cement, making the floor denser and assuring longer life. The use of a sealer on old terrazzo retards the penetration of stain-carrying water into the marble and cement mixture. Sealing also prevents dusting and blooming.

#### 6.4.3 Discoloration of Terrazzo

When areas of a terrazzo floor become yellow while adjacent slabs retain their original color, the discoloration is generally due to the way the floor was originally finished. Poulticing with grit scrubbing powders will remove most discoloration caused by improper finishing. The powders should be stirred slowly into a pail of hot water until a thick paste of mortar consistency is obtained. Discoloration can also be removed by scrubbing the surface with Javell water. Javell water is a strong bleaching material and should not be used for general-purpose cleaning. If not available from stock, Javell water may be prepared and applied to the floor as follows: Dissolve 3 pounds of washing soda in 1 gallon of water. Mix 12 ounces of chlorinated lime and water to a paste in a shallow, enameled pan, adding the water slowly and mashing the lumps. Add the paste to the soda solution making a maximum of 2 gallons by adding water, and place the mixture in a covered stoneware jar to settle. Use the clear liquid, diluting it with six times its volume of clear water. Rinse the surface with clear water and then use the Javell water as a soap or scrubbing solution.

#### 6.4.4 Repairs

Repairs to a terrazzo floor should be made in accordance with the specification for new floors. Only floor specialists who are capable of the class of workmanship necessary should be entrusted with the work.

### SECTION V—MAGNESIUM OXYCHLORIDE FLOORS

#### 6.5.1 Installation and Repairs

Experienced personnel are essential in installing and repairing magnesium-oxychloride (often called Magnesite) flooring and the manufacturer's recommendations should be followed closely. Floor failures are usually caused by improper installation or use. This type of floor is not recommended for kitchens, bakeries, warehouses, and other buildings where floors are subject to spillage of food, oil, grease, and considerable amounts of water or areas subject to the abrasive and shock action of truck

wheels. If magnesium-oxychloride floors are mopped dry after each wetting, they will withstand daily scrubbing. The flooring can be installed over prepared wood and concrete floors in thickness of  $\frac{3}{4}$  inch or more as conditions require. It should never be applied over asphalt tile, linoleum, cork, rubber, or other flexible coverings.

6.5.1.1 *Specifications*. The following table lists specifications prepared by the American National Standards Institute Association. See table 6-2. They are offered as a guide to the many

requirements that must be observed in mixing and laying oxychloride-type flooring.

Table 6-2. — Specifications Prepared By American Standards Institute Association.

ANSI designations	Title
A88.1 . . . . .	Preparation of subfloors for Oxychloride-Composition Flooring.
A88.2 . . . . .	General Purpose, Oxychloride-Composition Flooring and Its Installation.
A88.3 . . . . .	Heavy Duty, Oxychloride-Composition Flooring and Its Installation.
A88.4 . . . . .	Basecoat, Oxychloride-Composition Flooring.
A88.5 . . . . .	Nonslip, Oxychloride-Composition Flooring and Its Installation.
A88.6 . . . . .	Terrazzo, Oxychloride-Composition Flooring and Its Installation.
A88.7 . . . . .	Industrial Granolithic, Oxychloride-Composition Flooring and Its Installation.
A88.8 . . . . .	Oxycement Underlay and Its Installation.

6.5.1.2 *General-Purpose Type (A 88.2)*. General-purpose type, most commonly used, is usually mixed and laid in a solid color through the full thickness of about 1/2 inch. This general-purpose flooring, when troweled to a dense, smooth, semiglossy wearing surface, results in a floor with a wearing hardness only slightly less than that of Tennessee pink marble.

6.5.1.3 *Heavy Duty (A 88.3)*. Hard, coarse aggregates give a wearing surface suitable for heavier service required in light industrial plants and other areas subjected to hard usage. This flooring is generally laid to a thickness of not less than 1/2 inch.

6.5.1.4 *Industrial Granolithic (A 88.7)*. This is a terrazzo type since the aggregate is crushed granite, trap rock or similar hard stone chips. This floor, usually laid to a thickness of 3/4 inch, is finished by mechanical grinding but not such as will produce a polished surface. The finished floor is extremely tough and durable and will meet the demands of extra hard usage.

6.5.1.5 *Nonslip (A 88.5)*. This flooring is furnished in two types: Type I, General Purpose Nonslip, and Type II, Heavy Duty Nonslip. Crushed rock is replaced in part with an abrasive aggregate to produce a nonslip surface. Other types of oxychloride flooring may be made nonslip by use of abrasive materials in the wearing surface.

6.5.1.6 *Terrazzo (A 88.6)* Oxychloride terrazzo is produced by the use of marble or other chips of

varying size and color and a matrix of contrasting color.

6.5.1.7 *Preparation of Subfloors (A 88.1)*. This specification describes the preparation of new and old concrete, wood, brick, stone, metal and ceramic tile subfloors prior to the application of an oxychloride floor.

**6.5.2 Materials**

Refer to manufacturer's standard specification for information relative to dry-mix compositions, aggregates, gaging solutions, water, metal anchoring mediums, liquid bonding mediums, division strips, and other components necessary to insure a proper cementitious flooring installation.

**6.5.3 Miscellaneous Requirements**

6.5.3.1 *Preparation*. Prior to the start of any flooring operations, all pipe rails, radiators, space heaters, water coolers, and other items of equipment that will interfere with the installation of the floor should be disconnected and removed from the work area. Check the present floor framing to see that it is of such design, structural strength, and rigidity to withstand, without appreciable deflection or movement, the maximum service to which the finished floor will be subjected. When resetting the removed equipment, necessary provision must be made in all connections to accommodate the increased thickness of the new flooring.

6.5.3.2 *Insulation*. All new and existing pipes which will pass through the floor should be separated from the flooring by being wrapped with at least two turns of asphalt-saturated felt leaving sufficient clearance to permit free movement of the pipe. Trim the insulating felt flush with the finished flooring. Retard the possible passage of smoke or fumes by loosely packing the space between flooring and pipe with glass wool, rock wool or other fire-resistant material. Metal surfaces, such as knothole covers, which will be in contact with the composition flooring should be given a coating of bituminous paint.

6.5.3.3 *Fitting Doors*. Doors which swing over the new flooring should be removed and sufficient material cut from the bottom edge to provide about 1/4-inch clearance. The cut edges should be given a coat of spar varnish or paint before the doors are rehung.

6.5.3.4 *Thresholds*. Thresholds of hardwood should be provided at all interior and exterior doors. Thresholds will have a vertical surface abutting the new flooring and a 30° bevel on the exterior.

6.5.3.5 *Temperature.* In areas where composition flooring is to be laid, the room temperature should not exceed 95° F (35° C) until final set is attained. The temperature at time of installation should be maintained substantially uniform and should not decrease more than 20° F (-6.7° C) for at least 24 hours after completion of the floor. Composition floorings should not be laid when the work-area temperature is less than 50° F (10° C). Heating should not be accomplished by means of salamanders. Warm air should not be blown across freshly laid composition flooring. During the installation and curing period, doors and windows to the work area should be kept closed or so arranged as to prevent harmful circulation of air.

6.5.3.6 *Additional Requirements.* Check the manufacturer's standard specification relative to the floor to be laid for additional installation requirements.

#### 6.5.4 Preparation of Surfaces

Subfloors of both wood and concrete should be dry and thoroughly cleaned free of mud, grease, wax, plaster, paint, asphalt and any other foreign substances.

6.5.4.1 *Concrete Subfloors.* The term concrete includes lightweight concrete, cinder concrete, and concrete fill or grout. The surface glaze should be completely removed by sandblasting, bushhammering, or other manner approved by the installation engineer. In addition to removing the glaze, the floor should be adequately roughened. If a bush-hammer is used, not less than 70 percent of the surface should be roughened, with the hammer marks distributed uniformly. If a pick is used, the pickmarks should be not less than  $\frac{1}{4}$  inch deep, not less than 2 inches in diameter, and be evenly spaced at intervals not exceeding 6 inches on centers. Rapid scarifying may be accomplished by use of a power-driven machine equipped with a cylindrical cage fitted with a series of hardened steel cutters. The cutters are mounted to provide a flailing, scoring hammermill action which results in a diagonal or crosslatched pattern in the concrete surface. Cracks in old concrete should be cut out sufficiently to permit removal of loose chips and dust and then grouted flush.

6.5.4.2 *Wood Subfloors.* Place on the cleaned wood floor a covering of 15-pound, asphalt-saturated felt or an equivalent waterproof building paper. Lay the felt or paper free of wrinkles or bulges and with all edges lapped not less than 1 inch. A coating of emulsified asphalt of such consistency that it will not pass through cracks in

the wood floor may be used in lieu of the felt of paper. A mechanical anchoring medium consisting of meta lath or metal mesh should be laid over the fel with lapped and wired edges so as to cover completely the surface which is to receive the flooring mix. The anchoring medium should be secured by means of nails and staples, placed about 6 inches apart in two directions. The fastenings should be driven in such a manner that the anchoring medium is nowhere embedded in the felt and Sc that a gage [1/18] inch thick will just fit between the felt and the anchoring medium. Nails should extend through not less than seven-eighths of the wood floor's thickness and in case of a double floor should extend into the lower layer.

6.5.4.3 *Base.* Where wood-stud walls to receive a composition base adjoin an existing wood floor, the felt and metal lath on the floor should be turned up the walls to within  $\frac{1}{2}$  inch of the top of the base and be secured by nailing into the studs and backing. Where wood-stud walls to receive composition base adjoin an existing concrete floor, the walls should be covered with a strip of asphalt felt and metal lath to about base height. Bend the strip lath to about base height. Bend the strip lath to lap 2 inches onto the concrete floor and secure with concrete stub nails spaced about 6 inches apart. Secure top edge of metal lath by nailing into the studs and backing.

6.5.4.4 *Flashing Areas* subject to water spillage which are situated on upper floors should be provided with adequate perimeter flashing to prevent leakage to space below.

6.5.4.5 *Installation Procedures.* Refer to manufacturer's standard specifications for information relative to slump test, applied thickness, placing the composition mix, troweling, curing, sealing, and protection.

#### 6.5.5 Cleaning

The finished floor should not be scrubbed or flooded with water for at least 15 days after installation. Where tests for electrical conductivity are required, they should not be made until the floor has completely cured, usually a period of 30 to 60 days. Properly formulated composition floors, when cured and sealed, offer considerable resistance to gasoline, turpentine, animal, mineral and vegetable oils, and greases. However, good housekeeping and safety require speedy removal of these materials when spilled on the floor. The use of a solvent to remove oil and grease usually will not harm the floor though it may remove the easily replaced wax coat.

## SECTION VI—CLAY TILE FLOORS

### 6.6.1 Ceramic Tile

Ceramic tile is glazed or unglazed, manufacture in small squares, hexagonal, rectangular, and circular shapes about 1/4 inch thick, and is often arranged in mosaic patterns. The pieces are usually factory-assembled on paper sheets in the required pattern, laid on a mortar setting bed, pressed firmly on the mortar, and tamped true and even with the finished floor line. Grout is then force( into the joints, filling them completely, and is finished flush and level with the floor line.

### 6.6.2 Quarry Tile

Quarry tile is unglazed and manufactured in square and rectangular shapes, ranging from 2-3/4 to 9 inches wide, and 2-3/4 to 12 inches long, with varying thicknesses. Tiles are laid individually or a mortar setting bed with joints about 1/2 inch wide.

### 6.6.3 Repair of Tile Floors

Replace broken or badly stained tiles and reset loose tiles in the following manner:

6.6.3.1 Remove the damaged or loose tiles.

6.6.3.2 Clean the mortar from the edges of the surrounding tile.

6.6.3.3. Roughen the concrete underbed to provide a good bond for the new setting cement.

6.6.3.4 Dampen the underbed and edges of the

surrounding tile and place the setting mortar mixed in the proportion of 1 part portland cement to 3 parts sand.

6.6.3.5 Set the tile, tamping it to the level of the finished floor.

6.6.3.6 Fill the joints with grout or pointing mortar, matching the color and finish of the joints of the original floor as closely as practicable. If the mortar in the existing joints has deteriorated, cracked, or crumbled, thoroughly clean the joints of all loose mortar and repoint them with grout or pointing mortar. Grout joints  $\frac{1}{8}$  inch or less wide with neat portland cement grout of the consistency of thick cream. Point joints  $\frac{1}{8}$  to  $\frac{1}{4}$  inch wide with pointing mortar consisting of 1 part portland cement to 1 part pointing sand. Point joints wider than  $\frac{1}{4}$  inch with pointing mortar consisting of 1 part portland cement to 2 parts pointing sand.

6.6.3.7 In locations such as food preparation areas, where the floor is directly exposed to the effects of corrosion agents, use acid-resistant joint material to fill the joints. The acid-resistant mortars are proprietary products and should be mixed in accordance with the manufacturer's recommendations. They are composed of both powdered and liquid resin cement and should be resistant to the effects of oils, fats, greases, organic and inorganic acids, salts, alkalies, and mineral solvents.

## SECTION VII—MASTIC FLOORS

### 6.7.1 Description and Use

Mastic coatings applied on concrete or rigid wood floors provide a resilient floor finish that is suitable for a variety of uses. Mastic topping, when hard and cured, forms a tough, dustless flooring that is highly resistant to abrasion and shock from vehicles. Neoprene-type coating similar to that used in mothballing equipment can be obtained in a variety of colors and makes an excellent resilient floor finish. The mastic topping should be finished to a thickness of not less than 1/4 inch above the highest section of existing floor, with additional thickness as required. Free edges should be feathered.

### 6.7.2 Preparation of Floor

The concrete floor to be topped should be cleaned of all dust, dirt, and other foreign matter by vigorous sweeping, airblasting (operators must wear safety glasses), or other suitable means. Oil or

grease can be removed with a solution of 1/4 pound of common household lye or trisodium phosphate dissolved in 1 gallon of hot water. The hot solution should be applied to the greasy surface and allowed to remain for about 10 minutes. Then the area should be scrubbed with a stiff bristle, fiber, or wire brush. The area should be mopped, flushed with clean water, and mopped again. This action should be repeated until all the cleaning compound is removed. Care must be exercised to keep the cleaning compound away from skin and eyes. After the concrete has been cleaned and is still damp, a specially prepared emulsified asphalt primer is applied and allowed to dry to a tacky state. Then, the floor is topped with either cold or hot mastic.

### 6.7.3 Cold-Laid Mastic

Cold-laid bituminous mastic floors are usually laid in layers. Coatings consist of a fibrous mastic. The mastic material is similar to the primer but is ground with enough asbestos and finely powered

siliceous material fillers to make a very thick, pasty, fibrous mass. When a coating is dry, succeeding thin coats are applied until the desired thickness is obtained. The total thickness of cold-laid mastic floors is usually  $\frac{1}{4}$  to  $\frac{1}{2}$  inch.

#### 6.7.4 Hot-Applied Mastic

Hot-applied bituminous mastic floors are similar to

the mixtures used in sheet asphaltic pavements, but they contain more asphaltic binder so that they can be troweled into place when heated to a fluid condition. The mastic is usually applied in layers  $\frac{3}{4}$  inch or more thick. The mastics used should be applied according to the manufacturer's recommendations.

### SECTION VIII—CONDUCTIVE FLOORS

#### 6.8.1 Description and Use

Conductive floors made of terrazzo or other suitable materials are required to prevent accumulation of electrostatic charges. Conductive floors are used in hospital and dispensary operating and delivery suites where explosive anesthetics are used, in ammunition inspection and manufacturing areas, and in areas where electrical equipment is tested.

#### 6.8.2 Testing

Conductive tests should comply with requirements in the National Fire Protection Association Standard, Recommended Safe Practice for Hospital Operating Rooms, which prescribes the method of installation. The floor should be tested for conductivity immediately before the first use.

6.8.2.1 *Schedule.* The following schedule is recommended for subsequent testing of hospital operating rooms.

- a. Test at least once a month.
- b. Test after each alteration or repair of the floor.
- c. Test after each waxing has dried and again about 24 hours after the waxing.

6.8.2.2 *Conditions.* Make the tests only under the following conditions:

a. When the room is free of explosive gas mixtures.

b. When the floor is completely dry, i.e., at least 4 hours after cleaning or waxing.

c. When the relative humidity of air in the room is the same, or as close as possible, to that at the operating level (55 to 60 percent, when controllable).

#### 6.8.3 Repairs

Conductive floor repairs should be accomplished by matching the existing material and workmanship as closely as practicable, following the floor manufacturer's recommendations. A test for conductivity must always be made after the repair has been completed. (See paragraph 6.8.2 for test procedure.)

#### 6.8.4 Maintenance

Conductivity floors must be both sanitary and conductive. Improper cleaning methods that allow a film to cover the floor, thereby prevent conductivity, will render the floor useless in preventing explosions from static electricity. Custodial services are discussed in the Tri-Services Manual, "Military Custodial Services Manual" (TM 5-609, NAVFAC MO-125, AFM 91-2)

### SECTION IX—RESILIENT FLOOR COVERINGS

#### 6.9.1 General

Resilient floor coverings generally used include linoleum, vinyl plastic tile, vinyl asbestos tile, asphalt tile, cork tile, and rubber tile. Floor coverings should be selected carefully and laid according to the manufacturer's recommendations. If felt lining is necessary, it is cemented to the floor, and the resilient covering is bonded to the felt. In other cases, the covering may be bonded directly to the floor. Any cement paste or primer used directly on the floor should effectively seal the pores in the floor.

#### 6.9.2 Protection of Coverings

Heavy furniture or equipment should not be

dragged across resilient floors. Suitable rests should be provided on furniture and equipment such as lockers, files, and cots to distribute the weight when such objects are placed permanently on the floor. The maximum static load limit per square inch for asphalt tile is approximately 25 pounds; for cork tile, 40 pounds for composition tile, 50 pounds for linoleum, 75 pounds; and for rubber tile, 200 pounds. Chairs, desks, and other movable equipment should be fitted with flat-faced gliders not less than  $1\frac{1}{2}$  inches in diameter. Chair-roller, wheels or casters should be at least 2 inches in diameter and have a  $\frac{3}{4}$ -inch-wide face; the whole caster should revolve freely. Most flexible floor coverings are designed for interior use and should

not be installed where they are exposed regularly to sun and rain, extremes in temperature, hot water or steam, and damaging solvents, greases, and oils.

### 6.9.3 Care of Installed Equipment

Before covering is laid, all pipe rails, radiators, space heaters, water coolers, and other equipment that will interfere with installation of the covering should be disconnected and removed from the work area. When the equipment is reset, necessary provisions should be made in all connections to accommodate the increased thickness of the floor. Pipe passing through the flooring should be wrapped with at least two turns of asphalt-saturated felt and the space between pipe and flooring loosely packed with glass wool or similar fire-resistant material.

### 6.9.4 Adhesives

Adhesives for use with felt- or fabric-backed flexible floor coverings should conform to the floor-covering manufacturer's recommendations. Under dry conditions, most linoleum pastes show high adhesive strength, but few have sufficient resistance to moisture to suitably bond floor coverings to subfloors in humid locations. Lignin paste is suitable for bonding linoleum and felt-backed materials in dry locations only. Cumar resin and resin-oil cements show fair resistance to moisture. Cements and primers for use above grade floors with asphalt-saturated flexible floor coverings should be of the asphalt-emulsion type or as recommended by the floor-covering manufacturer.

### 6.9.5 Underlayments on Wood Floors

Lining felts and floor coverings may be applied directly to wood floors providing there are no cracks or ridges. Otherwise, plywood, hardboard, or other underlayment may be required.

6.9.5.1 *Rigid and Semirigid Board Types.* Plywood should be laid face side up to receive the finish floor. It should be three-ply sheathing grade conforming to commercial standard CS 45-55 and be a minimum of ¼ inch thick with exterior glue. Increased thickness may be necessary, depending on the structural adequacy of the subfloor or to achieve uniform alignment with adjacent existing finish floors. Whenever possible, plywood should be laid so that the face plies are at a right angle to the wood subfloor. When the subflooring is laid diagonally, the face plies should be laid at a right angle to the joist or sleepers. Hardboard is less desirable as underlayment than plywood. If used, it should be laid with the back or rough side up, to receive the bonding paste. Plywood and hardboard underlayment should be face-nailed to the existing floor, with 1¼-inch hardened screw-type or ring-

grooved underlayment nails placed 6 inches on center at the edges and 12 inches on center in the middle of the sheet. Nails should be driven flush with the surface of the board. Staples should never be used as underlayment fasteners.

6.9.5.2 *Troweled on Types.* When using underlayments of the troweled-on type, follow the manufacturer's recommendations for mixing, application, and curing.

### 6.9.6 Crack Fillers for Wood Floors

All holes or cracks in wood floors or underlayments should be filled with a suitable crack filler before flexible coverings are laid. Crack fillers should adhere tightly to crack surfaces, have minimum shrinkage, and resist crumbling or powdering under traffic. Factory-prepared commercial fillers should be applied according to the manufacturer's recommendations. Job-mixed fillers are composed of 90 parts fine sawdust and 10 parts a fast-drying organic vehicle, such as lacquer, shellac, or an approved commercial shellac substitute. Filler is made by adding the vehicle to the sawdust until a medium-stiff, easily worked paste is obtained. Only the amount that can be used in approximately 80 minutes should be mixed at one time. The filler should be worked into holes and cracks, smoothed off flush with the surface of the floor or underlayment, and allowed to dry for at least 1 hour before the floor covering is laid.

### 6.9.7 Vinyl Sheet Flooring

6.9.7.1 Vinyl sheet flooring is available in a wide variety of product characteristics including color, texture, and resilience. They may be used in a variety of environments based on the thickness of wear layer and conditions of the floor structure. Flooring should conform to Federal Specifications L-F-475 or L-F-1641. Installation practices and maintenance as specified by the manufacturer should be followed in all cases.

#### 6.9.7.2 Job Preparation.

a. *Job Inventory.* The room should be measured wall to wall in at least two locations each for length and width, making allowances for doorways. An additional 3 inches should be included in each measurement. When more than one width of material is to be used, an additional allowance of 3 inches is required per run for fitting the first and successive sheets. Length allowance must consider pattern repeat characteristics of the flooring. Some flooring patterns require sheet reversal at the seams which must be considered prior to cutting.

b. *Removing Old Sheet Flooring.* CAUTION: Most sheet vinyl floorings contain asbestos or other inert fibers which may cause serious bodily harm.

Do not remove backing or lining felt by sanding or grinding or any method which will create dust. Have a sample of the old sheet flooring tested for asbestos. If asbestos is present, special removal procedures will be required. If the existing floor covering is well bonded, several products may be laid directly on the existing surface. If removal is required, the recommended method is to cut the wear layer into narrow strips of 4 to 18 inches wide, depending on the product. The covering may be split from the backing and pulled at a sharp angle or core-rolled. The remaining felt will normally have a surface smooth enough to accept the new floor. Removal of the felt backing must be done in strict compliance with the manufacturers' recommended procedures.

6.9.7.3 *Installation.* Sheet flooring containing asbestos should not be used. Sheet flooring may be applied to either concrete or wood floors under certain conditions. Both types of floors must be free of moisture at all times or the floor covering may warp or become damaged.

a. *Concrete floors.* Concrete subfloors on or below grade must be tested for moisture. The floor should be cleaned by thorough sweeping with a wire brush to remove all loose particles, followed by priming or sizing in accordance with the manufacturer's recommendations. The floor may be tested for moisture by installing small panels throughout the floor area. This test should include areas of the subfloor which are least subjected to drying conditions. If the panels are securely bonded after 72 hours, it may be concluded that the floor surface is dry and sufficiently clean of foreign particles to permit installation. All holes, cracks, and joints in subfloors must be filled using products recommended by the manufacturer of the floor covering. Prior to installation, the floor should be swept or vacuumed clean of all dirt and debris.

b. *Loose-Lay of Floor Covering.* If only one width of flooring is to be installed, it should be unrolled and laid out and marked with the room diagram using a wax pencil. Allowance for excess material (1½ inches per side) must be considered. The covering can then be cut using a utility knife to the oversized dimensions of the room and transported to the room. It is a good practice to allow the covering to lay full unrolled, flat on the floor, in a warm room (70° F) or (21° C) for about 24 hours before cementing it into place. The covering can be trimmed with a utility knife. Door jams and corners must be trimmed carefully to avoid miscuts which may be exposed or provide a poor fit.

c. *Bonding.* Adhesives will be specified by the floor covering manufacturer based on type of subfloor or underlayment and floor covering material. Adhesives should be warmed at 70° F for 48 hours prior to installation and should be applied using a notched trowel.

d. *Seams.* If seams are required, advance planning must avoid placing a seam within 6 inches of joints in the underlayment. After the first sheet is flattened to the floor, the second sheet should be overlapped so that the design matches exactly. The sheets should be taped together to avoid slippage. A scrap piece may be laid under the overlapping pieces to provide a better fit and to allow a better cut of the lower sheet without damaging the underlayment. The cut should be made using a sharpened blade and metal straightedge through both layers of the overlap. The knife must be kept straight to avoid a beveled edge which cannot be sealed properly. The sheets may then be folded back and the adhesive applied to the underlayment. Insure that no excess adhesive is left which may ooze up into the seam. The flooring should be rolled into the adhesive using a weighted roller.

e. *Seam Sealing.* Use seam sealers recommended by the manufacturer only. Insert the vertical metal fin of the seam sealer applicator into the joint at one end of the seam and apply very light pressure to lay out a bead of sealer. The sealer will weld the vinyl core and the wear layer. Care should be exercised to avoid spilling the seam sealer. If this happens, no attempt should be made to remove it. Seams should not be disturbed for 24 hours after completion to allow welding process to be complete.

## 6.9.8 Asphalt Floor Tile

6.9.8.1 *General.* Asphalt flooring tile is suitable for installation on most wood and concrete subfloors above grade and concrete floors in contact with the ground. Asphalt-tile is made of a blended composition of asphaltic or resinous binders, asbestos fibers, plus insert fillers or pigments, formed and cut to size under heat and pressure. This material is one of the few resilient floor coverings that can be used to advantage on concrete slabs on ground where some resistance to moisture is necessary. Asphalt tile, available in many plain and marbelized colors, not only presents an attractive appearance but offers other important advantages. It is quiet, comfortable, safe to walk on, extremely durable, and highly resistant to abrasive action of foot traffic and common abuses such as scuffing and cigarette burns. It is an odorless, nonabsorbent covering which does not originate dust; it is easy to clean and has a low

maintenance cost. All these factors make it particularly desirable for use when high sanitary standards must be maintained. When exceptional abuse or severe accident makes repair necessary, new units to replace the damaged ones can be inserted easily.

6.9.8.2 *Characteristics of Asphalt Tile.* The following are important characteristics of asphalt tile:

a. *Color Variations.* Asphalt tile is manufactured mainly by converting batches of several raw materials into units of the finished product. Due to the human element involved and variances of raw materials, such a process naturally results in slight variations in tile colors. These color variations, which are characteristics of the product, are not noticeable in designs and patterns of two or more colors. Differences in shade are generally noticeable when floors are laid in solid colors. However, the effect can be minimized by mixing the tile from several cartons as the tiles are applied.

b. *Effect of Grease and Oil.* Since asphalts and asphaltic resins are soluble in oil and grease, it is obvious that ordinary asphalt tile is not adapted for use in kitchens, gas and oil stations, machine shops and adjacent office areas, behind meat market counters, or in mess halls.

c. *Effect of Acids.* Although asphalt tile has considerable resistance to acid, it is destroyed by high concentrations and is not recommended for use on floors exposed to strong acid solutions. It may be used satisfactorily in laboratories if spilled acids are normally removed immediately.

d. *Effects of Temperature and Sunlight.* Asphalt tile is not adapted to outdoor locations exposed to the sun or to use on floors subjected to continued or intermittent extremes of cold and heat.

e. *Effect of Moisture.* Although asphalt tile is not affected by the normal dampness in concrete slabs on ground or by moisture resulting from normal maintenance, it is not recommended for floors constantly exposed to wet conditions. It is not suitable for use in shower stalls or adjacent floor areas or for open porches and other outside locations. Continued exposures to water impairs the cement at joints, eventually shrinking the tile so that it loosens from the subfloor.

6.9.8.3 *General-Purpose Asphalt Tile.* General-purpose asphalt tile and base should conform to requirements of the Federal Specification SS-T-312. A preferred size is the standard 9 x 9 inches. Other available regular sizes are 12 x 12 and 18 x 24 inches. Other sizes in square and rectangular shapes are made by one or more manufacturers but

are not always carried in stock. Several sizes in octagon and hexagon shapes and half tiles for diagonal installations are available at extra cost. Asphalt tile is available in C- and  $\frac{3}{16}$ -inch thickness, weighing approximately 1 and 2 pounds per square foot, respectively. The C-inch-thick tile is recommended for most installations. Straight and cove-bottom types of base are furnished in heights of 4 and 6 inches. General-purpose asphalt tile is divided into Groups A, B, C, and D, according to color and cost. Group A colors, plain and very dark, are most economical in cost. Group B, at a slight additional cost, covers the dark plain and marbelized colors. Group D colors are light, plain and marbelized, and the most expensive. It should not be inferred that the more expensive tile is of better quality, but simply that because of special pigments and resins the manufacturing cost of light-colored tile is greater than for dark-colored tile. Grease-resistant tile and base is obtainable in two classes: Class I, which is resistant to edible oil and alkali; and Class II, which is resistant to mineral oil and alkali. Class I is recommended for installation in dining spaces of mess halls and areas where oil spillage may occur. Grease-resistant tile is more expensive than any of the general-purpose tiles.

6.9.8.4 *Preparation of Sub/Floors.* Refer to preceding paragraphs for descriptions of wood and concrete floor preparation and the installation of underlayments.

6.9.8.5. *Lining Felt.* Lining felt for application over new or reconditioned wood-strip floors should be an asphalt-saturated asbestos fiber or rag felt of a type made specially for use under asphalt tile. A dry felt is not satisfactory because it gives too soft a cushion under the tile and permits excessive indentation of tile under loads of chairs and other pieces of furniture. Also, a dry felt may split and crawl when subjected to moving traffic. Procedures for laying felt are described in paragraph 6.9.7.3.1. Felt is not required when asphalt tile is laid over plywood, hardboard or smooth concrete.

6.9.8.6 *Adhesives.* Use only adhesives approved by manufacturer of the asphalt tile.

a. *Linoleum Paste.* Linoleum paste is used to secure lining felt to wood-strip flooring.

b. *Asphalt Base Primers.* Primers for use on concrete floors and mastic underlay shall be of the following types:

(1) *Emulsion-Type Primers.* This primer is a homogeneous emulsified asphalt of such consistency that when mixed with water it can easily be brushed to full coverage on the floor. This type of primer should be used only on suspended concrete floors that have heated or well-ventilated spaces underneath.

(2) *Cutback-Type Primers.* This primer is composed of an asphaltic base and a suitable light, volatile solvent. Consistency should be such as to afford easy brushing on the floor. This type primer is required on concrete subfloors on or below grade and on new concrete subfloors which may contain concealed moisture. It is optional for use on suspended concrete subfloors which have heated or well-ventilated spaces underneath.

c. *Asphalt Base Cements.* Asphalt cements made specifically for bedding and fastening asphalt tile shall be of a heavy consistency which can be applied and spread effectively with a standard toothed trowel.

(1) *Emulsion-Type Cement.* This cement is a homogeneous emulsified asphalt suitable for use without the addition of other ingredients. See Federal Specification MMM-A-1 15.

(2) *Cutback-Type Cement.* This cement is composed of an asphaltic base and suitable volatile solvents. See Federal Specification MMM-A-110.

(3) *Cove Base Cement.* Cove base cement should be a semi-waterproof type made specifically for use with asphalt tile.

6.9.8.7 *Use of Asphalt Cements.* Asphalt tile may be secured to most types of subfloors with an emulsified asphalt cement. However, a moisture-resistant, cutback asphalt cement is always necessary for securing asphalt tile to concrete subfloors which rest directly on the ground. Asphalt cements are used as adhesives and never in place of underlayments for smoothing rough surfaces. Too much adhesive is usually applied when attempting to fasten asphalt tile over rough or uneven subfloors, and this results in "bleeding." In addition, the tile does not have sufficient contact with the subfloor to make a satisfactory bond and eventually loosens. An excess amount of the cutback-type cement not only results in bleeding but prevents early evaporation of the solvents. This may soften the asphalt tile and lower its resistance to indentation. Cutback cements must not be used with asphalt-saturated felt or asphalt-type underlays, since the solvent in the cutback will be absorbed into any asphaltic base and soften it. This causes the adhesive to lose its bonding effectiveness, and the tile may loosen and curl. The solvents in cutback asphalt adhesives are flammable and volatile and must not be exposed to open flame. Adequate ventilation must be provided to take off fumes. See that fire extinguishers are conveniently located. Keep the asphalt cement containers tightly closed in storage as evaporation of solvent will cause the cement to become too thick for proper application.

Some asphalt cements freeze at low temperatures. When freezing occurs, thaw the cement in a warm room for several days, keeping container tightly closed. Stir thoroughly before using. Delivery of adhesives in the manufacturer's sealed containers with the labels intact and seals unbroken should be required.

6.9.8.8 *Installation of Asphalt Tile.* Installation of asphalt tile should conform generally to the manufacturer's printed recommendations. Tile is cemented directly to cleaned and prepared concrete slab, plywood or hardboard underlay. Tile laid over wood-strip flooring is usually cemented to lining felt previously cemented to the reconditioned flooring.

a. *Layout.* Before tile is laid, the floor area must be squared and the best method of laying determined. This will depend on the shape of room, location of fixed furniture and doorways, and the tile design selected. Definite and specific instructions that will apply in all cases cannot be given. Asphalt tile should be laid parallel to walls which are at right angles in order to eliminate unnecessary cutting of the field tile and borders. Always start at the center of the room and work toward the walls so that border widths can be adjusted accordingly.

b. *Temperature.* Temperature of the cement, asphalt tile, room and subfloor must be maintained at 70° to 80° F (21° to 26.7° C) for at least 24 hours before and 24 hours after the laying process. Never apply cold tiles because condensation may form on the underside and break down the bond of the cements. If any tiles are warped when removed from the shipping cartons, pile them on a flat surface near a radiator or in a very warm room until they become flat. Adequate ventilation is important because it hastens drying and maintains the adhesive properties of cement by preventing condensation of moisture.

c. *Spreading Cement.* Stir the asphalt tile cement to uniform consistency in container. Spread cement evenly over the floor ahead of tile laying, using a notched trowel. Allow the cement to dry for approximately 30 minutes or until a tacky condition is produced before setting the tile. If tile is applied too soon, the unevaporated solvent in cutback cements may soften the tile, leading to possible excessive indentation later. If the interval between cement spreading and tile laying is too long, a poor bond will result.

d. *Laying Asphalt Tile.* When the cement has become sufficiently dry, lay tile according to predetermined design and layout. Field tile should be laid first. Cut and fit the border tile accurately against

walls, built-in equipment, and other permanent projections and recesses. Lay so that joints fit closely and form straight lines. Avoid squeezing the joints, as tile will expand and buckle with an increase in temperature. Embed each tile firmly to prevent movement under traffic. When heated, asphalt tile can be cut with a linoleum knife or scored deeply to give a clean break. Apply heat slowly to back of tile to prevent blistering. Asphalt tile cutters are recommended for making straight cuts. A pin vice fitted with a steel phonograph needle is a convenient tool for scoring. Make a pencil mark at each end of the piece to be cut, place a straightedge between the two marks, and score a deep scratch along the straightedge. Snap off the piece of tile, making sure to start the pressure at one end of the scratched line rather than at the center of the piece. This method of cutting can be done only with the grain, never diagonally or across the grain. Exposed job-cut edges should be sandpapered smooth.

*e. Cove Base.* The installation of a 4-inch-high cove base as part of the asphalt tile flooring may be desirable. However, in areas where cove base is subject to frequent bumping by furniture or floor-furnishing equipment, rubber tile appears more durable than asphalt tile. Vinyl cove base may also be used. Some base materials are furnished in prefabricated outside corners which are easy to install and give a neat appearance to outside corner work. Instructions furnished by the manufacturer of the base material used should be followed in the selection of materials and fitting the base in place.

*f. Removing Asphalt Cement Spots.* If asphalt cement oozes up at joints or is smeared on tile surfaces during the setting, scrap off immediately with a putty knife and rub with a cloth saturated with a mild neutral soap. If this does not remove all trace of the cement, use 00 steel wool and a wet scouring powder, rinse off the clear water, and dry the surface.

**6.9.8.9 Finishing** Improved appearance and longer useful life will result if asphalt tile floor is cleaned and waxed before being put into use. Cleaning, especially wet washing, and waxing should be postponed until tile has properly bonded to subfloor or underlay. Should water or wax get under tile before cement has hardened, the bond may be destroyed and the tile will curl and break. As a precautionary measure, tile should not be cleaned or waxed for 2 weeks after setting. If floor must be used during this period, protect tile with a covering of paper, fabric, or wood walkways.

*a. Prewaxing at Factory.* Factory-waxed tiles eliminate the necessity of waxing after the tile is

laid. Prewaxing also protects the surface of tiles against damage during transportation and installation. However, even factory-waxed tiles must be protected if tile is laid before construction is completed. Cover tile floors with building paper, fabric or boards, especially at entrances and along traffic aisles.

*b. Initial Waxing* Water-emulsion waxes, free from oils and volatile organic solvents and conforming to Federal Specification P-W-155, are safest for use on asphalt tile floors. Do not use paste or liquid waxes containing solvents such as gasoline, benzine, turpentine, or oils. Such solvents will soften asphalt tile and cause the colors to run. Best results are obtained by initial application of two thin coats of water-emulsion wax. Allow approximately 30 minutes for each coat to dry to a hard, medium-bright finish. Drying time depends to a large extent on room temperature, humidity and ventilation. A higher gloss is produced by use of a power-driven buffer. Wax must be dry when buffed.

**6.9.8.10 Radiators on Asphalt Tile.** A radiator or other heavy fixture on legs should not be set directly on asphalt tile. The weight of the radiator, together with the softening effect of heat, may cause the legs to sink into tile, resulting in bulges and breaks. If tile is laid before the radiators are set, cut holes in the tile and insert a hard material to form bases for the legs. Ceramic tile, iron washers, or other metal disks of the same thickness as the tile make satisfactory bases. A piece of 1-inch pipe, ground on the outside to form a die punch, is helpful in cutting holes for radiator leg bases. When tile is laid over concrete, ball bearings can be used for leg bases instead of the materials suggested above. Heat asphalt tile and tap the ball bearings down with a hammer. In the event radiators have been set before tile is laid, raise the radiator, slide tile underneath, and place a heated ball bearing under each leg. Weight and added heat of the radiator will force the ball bearing down to the concrete subfloor.

**6.9.8.11 Tile on Stair Treads.** Do not leave asphalt tile with unprotected edges on stair treads and landings. Suitable metal, plastic, or wood edgings must be fastened to the tread nosing to protect tile edges and eliminate the tripping hazard. Do not use edging strips which have concealed horizontal flanges because the tile may crack at the rear edge of flange.

**6.9.8.12 Precautions.** Preparation of new subfloors and the reconditioning of old subfloors should be given special attention before laying tile. Asphalt tile floors should not be installed until

other trades have completed their work. When necessary to install the asphalt tile floor before other trades have completed their work, protect the finished floor with building paper or other suitable material. See that temperature of room and all materials is maintained at 70° to 80° F (21° to 26.7° C) for 24 hours after installation. Install asphalt tile only over subfloors that are smooth, firm, and free from oil, grease, and other foreign matter. Do not lay asphalt tile over any resilient floor such as cork tile, rubber tile, linoleum, or dry felt. Asphalt tile should not be laid over a below-grade wood floor or one that is springy or has loose boards. Legs of lockers, desks, cases, cots and other items of furniture not subject to frequent moving will be provided with suitable furniture resets or wood blocks to prevent excessive indentation. Do not install asphalt tile where it will be exposed to excessive water, such as in open porches, kitchens, dish-wash rooms, shower compartments and adjacent dressing spaces. Use the type of adhesive recommended by the tile manufacturer for each particular installation. Directions for use of adhesives are usually on the labels of the containers. Never use sweeping compounds containing free oils, sand, or other abrasives. Avoid as far as possible, the use of gasoline, turpentine, benzene, and similar solvents as cleaning agents. Should it be necessary to use one or more of these materials, keep the room well ventilated, and see that no open flame is nearby. Use safe water-emulsion-type waxes. Do not use waxes known to contain oils or other solvents. Asphalt tile in toilet rooms should not be waxed, especially around urinals, as uric acid dissolves the wax and will leave a spotty appearance. Frequent damp mopping is the best method of cleaning. Before using a new cleaner or wax on the asphalt tile floor for the first time, moisten a white cloth with a material and rub over the surface of one or two tiles. If tile color shows on the cloth, a solvent has dissolved part of the tiles' surface and the material is not safe for use on asphalt tile. A safe procedure is to get the advice of the asphalt tile manufacturer before purchasing an unknown cleaner or polishing material.

### 6.9.9 Vinyl-Asbestos Floor Tile

6.9.9.1 *Material.* Vinyl-asbestos tile conforming to the requirements of Federal Specification SS-T-312 consists of thoroughly blended composition of a thermoplastic binder, asbestos fibers, mineral fillers, and pigments. The binder consists of a PVC resin or a copolymer resin compounded with suitable plasticizers and stabilizers. Tile shall be 9 or 12 inches square and  $\frac{1}{8}$  inch thick.

6.9.9.2 *Recommended Installations.* Vinyl-asbestos tile may be installed over and above grade subfloors directly or with a lining felt depending on the condition of the floor. Normally, a lining felt is used with strip flooring, and direct application is used over plywood and hardboard. Vinyl-asbestos tile is not applied on or below grade subfloors. The one exception is a concrete floor which has a membrane waterproofing. Vinyl-asbestos can be bonded directly to metal or concrete stairs.

6.9.9.3 *Preparation of Subfloors.* Refer to the preceding paragraphs and use vinyl manufacturer's recommendations for descriptions of wood and concrete subfloor preparation and the installation of underlayments.

6.9.9.4 *Installation of Tile.* Conditioning the materials and work area and laying vinyl tile is accomplished in much the same manner as described for asphalt tile in paragraph 6.9.8.8. Additional specific recommendations of the vinyl tile manufacturer relative to lining felt, adhesive, and installation procedures will be followed closely.

6.9.9.5 *Maintenance After Installation.* Vinyl floor tiles are one of the easiest floors to maintain. After installation is completed, the floor will be allowed to set for 4 or 5 days before beginning maintenance. This will allow the adhesive to set and become thoroughly hard. A sufficient first cleaning action can be accomplished by use of lukewarm water and a mild soap or other cleaner recommended by the tile manufacturer. Rinse with clean water and mop dry. Never leave any standing water. If the floor has become badly soiled during installation, it should be given a machine buffing with 00 or 000 steel wool, after which steel wool particles and dirt are removed by vacuum cleaner or soft broom sweeping. A machine buffing with a soft bristle brush immediately after the first washing or steel wool treatment should bring back the original gloss. Initial waxing should be accomplished when the floor is laid and cleaned. After installation is completed, allow at least 24 hours before heavy furniture or other equipment is moved on the floor. The weight of fixed and movable furniture and other equipment often causes indentations in resilient floor coverings. Legs of chairs, desks, tables, etc., should be fitted with wide-diameter, flat-faced metal or composition gliders or cups specially designed for the purpose. Where the design of the equipment does not permit the use of gliders or cups, blocks of wood of ample size will be placed under the bearing corner.

### 6.9.10 Cork Tile

Cork tile may be laid on wood or concrete floors that are not in direct contact with the ground. Tiles are made of raw cork and resins, are unbacked, and are **C** inch thick. They have good durability but only fair resistance to grease and alkalis. Tiles should be laid according to the manufacturer's recommendations.

### 6.9.11 Rubber Tile and Sheet

Rubber-tile flooring may be laid on concrete floors in direct contact with the ground if the floor is not below grade. Slabs on grade must be membrane-waterproofed to receive rubber tile and sheet. Rubber tiles are equal in durability and maintenance requirements to linoleum and vinyl tiles. For slip-resistant floors, rubber-sheet floor coverings are made with a wearing surface of a compound of natural, synthetic, or reclaimed rubber, with or without a backing of cotton or fabric. Rubber sheeting conforms to Federal Specification ZZ-M-71d. Finished surfaces have longitudinal, diamond-, pyramid-, or knob-shaped corrugations. Thicknesses range from **C** to ¼ inch and widths from 24 to 42 inches. Rubber tiles and sheets are laid according to the manufacturer's recommendations.

### 6.9.12 Repair of Resilient Floor Coverings

6.9.12.1 *Repairing Linoleum.* Repair comparatively small areas of damaged linoleum by laying out the area along rectangular lines and laying an oversized section of new linoleum over the damaged area. Cut through the two layers simultaneously to insure a tight fit. Remove the damaged

section and clean the exposed underfloor of adhesive, dust, and dirt. Replace damaged felt lining. Apply a linoleum adhesive to the exposed surface and fit the new linoleum in place. Roll the area with a linoleum roller and place weights of suitable size on the patch to assure proper adhesion.

6.9.12.2 *Repairing Resilient Tile.* Repair resilient tile by removing the damaged section and replacing it with new material. Tile is more easily replaced than linoleum because of its smaller size. After removing damaged tile, scrape the exposed area level, and clean off all mastic, dust, and dirt. Replace damaged felt lining. Install new tile in suitable cement or mastic in accordance with the manufacturer's recommendations.

6.9.12.3 *Resurfacing Cork Tile.* Improve the appearance of cork tile after abuse of long service by sanding the tile with No.1-½ sandpaper, followed by finish sanding with No.00 paper. After each sanding, sweep the floor to remove cork dust. After the final sanding, wash the floor with a synthetic detergent cleaner, rinse it by damp-mopping with clean water, and dry it. Apply two or three coats of water-emulsion wax suitable for cork tile. Buff the wax with a polishing machine after each coat has dried.

### 6.9.13 Maintenance of New Resilient Floor Coverings

Newly installed resilient floor covering should be maintained in accordance with Tri-Services Manual "Military Custodial Services Manual" (TM 5-609, NAVFAC MO-125, AFM 91-30).

## SECTION X—RESINOUS FLOOR FINISHES

### 6.10.1 General

Resinous floor finishes (also known as seamless coating systems) are a relatively new development. As such, only very limited experience has been gained in the selection, installation, maintenance, and repair of these floor systems. The resinous floor system is composed of the resins, hardener, and fillers. The resin is the binder which holds the mass together and bonds the floor coating to the base floor. The hardener converts the liquid resin into a solid. The filler, which can be any material fairly inert to chemicals, adds to impact strength and brings the coefficient of thermal expansion of the resin closer to that of the base floor. Despite convenient classifications into generic types of resin binder, chemical analysis by the National Institute of Science and Technology indicates that there is

not always a clear distinction between these types. No matter what the generic type (epoxy, polyester, polyurethane), the prepolymer and catalyst (hardener) must be chemically designed for the particular floor coating. The properties and performance of the combination of materials will vary widely with the particular formulation. The resin binders may also be combined with other ingredients, such as aggregates, to provide a wearing surface.

### 6.10.2 Materials

Outlined below are the components for the resinous floor. It must be stressed that these components must be from the same manufacturer and formulated for the particular resinous floor covering. Materials must be stored for at least 24 hours at a temperature of not less than 50° F (10° C).

Methyl methacrylate (MMA) based acrylic reactive resin systems generally cure down to 24° F (4.5° C) (and lower) and do not require special storage before use.

6.10.2.1 *Primer*. Primer, a material recommended by the manufacturers of the resin, will penetrate into the pores of the substrate (base floor). The primer must blend with the topping to form a permanent monolithic floor-covering system.

6.10.2.2 *Resinous Binder*. This is the basic resinous material which will constitute the major ingredient in the floor-covering system.

6.10.2.3 *Catalyzers (Hardeners)*. A catalyzer is a product which will catalyze or harden the resin binder when added in the correct proportions and thoroughly mixed.

6.10.2.4 *Fillers*. This material is composed of inert mineral or cellulosic ingredients best suited for the resin binder. Normally, fillers are used to impart the color and physical characteristics to the floor covering.

### 6.10.3 Types

Resinous floor coverings are classified by generic type of resin binder and subclassified by method of application. Some resinous floor coverings are generally known as decorative, brush-on or roll-on, monolithic flooring. This type of covering is closely related to floor enamel. Another type of covering is mixed with the aggregate in a concrete mixer and is troweled on in the same manner as a concrete topping. A third type also resembles a concrete floor topping, but the aggregate is decorative, usually marble chips, and after hardening it is ground with a grinder.

6.10.3.1 *Epoxy*. Epoxy coverings may be brushed-on (rolled-on), troweled-on industrial or thin-set terrazzo.

6.10.3.2 *Polyester*. Polyester coverings may be troweled-on industrial or thin-set terrazzo.

6.10.3.3 *Polyurethane*. Polyurethane coverings may be brushed-on (or rolled-on) or troweled-on industrial.

6.10.3.4 *Methyl Methacrylate*. MMA-based reactive systems are used from brushed-on (rolled-on) coatings to self-leveling and troweled-on decorative industrial and commercial type floors. They can generally be trafficked 1 to 2 hours after application.

In addition to the types mentioned above, it is expected that advances in technology will develop new seamless floor (and wall) covering systems which will consist of layers of different generic types such as an epoxy base and a polyurethane finish.

### 6.10.4 Floor Systems Selection

The selection of the particular floor system depends on the ability of the system to withstand exposure conditions. Polyesters are suitable for resistance to detergents but not for exposure to strong alkaline solutions like sodium hydroxide. Epoxies should not be used where resistance to oxidizing acids or resistance to temperature more than 130° F (54.5° C) are required. MMA-based systems are excellent against heat shock, mechanical impact, salts, alkalies, organic and inorganic acids but should not be used where solvents are spilled regularly. Where doubt exists as to the suitability of a particular resinous material, inquiries should be directed to the next highest echelon of command.

### 6.10.5 Preparation of Substrate

This is the most critical phase of the installation of resinous floor-covering systems. Most bond failures have been traced to improper preparation of the substrate surfaces. In the case of newly poured concrete surfaces, the concrete must be a minimum of 28 days old. A distinction should be made between new concrete and existing slabs that need rehabilitation work. New slabs are prepared by sandblasting and abrasive, steel shot blasting. Old slabs should be prepared mechanically by sandblasting or abrasive blasting, scarifying or scabbling. The substrate surface must be swept clean and must be free of paint, oil, grease, or any other material that will affect the bonding or the smoothness of the applied floor covering. In the case of a concrete slab, the surface should be etched with a 10-percent solution of muriatic acid applied by mopping or brooming. Allow the acid to remain about 10 minutes or until the bubbling ceases. Thoroughly wash the surface with clean water, removing all residue. Allow the surface to thoroughly dry. Cracks or uneven areas of the substrate must be patched or repaired with materials recommended by the resin manufacturers.

6.10.5.1 *Priming* When the surface is thoroughly dry, the primer is applied insuring that the entire surface is coated without flowing and collecting in depressions.

6.10.5.2 *Application*. The interval between priming and application of the resinous floor covering is in strict accordance with the manufacturer's instructions. The coating is applied to the finished thickness depending on the type of resin, the exposure of the floor covering, and the decoration desired. Thicknesses range from  $\frac{3}{16}$  to  $\frac{5}{16}$  inch. Cove bases are normally cast-in-place, resinous, covering

material with a 1-inch radius curve and are from 4 to 6 inches high.

**6.10.5.3 Finishing.** Brush-on (or roll-on) types are finished with a sealer if required by the manufacturers. Troweled-on types are troweled to a uniform smooth finish. After curing, in accordance with the manufacturer's directions, a sealer coat is applied. Thin-set terrazzo must have the exposed surface ground smooth after the curing is completed. Grout is applied and worked into pinholes and other voids. Excess grout must be removed as soon as possible. After the grout has cured, the surface should be ground to a smooth uniform finish. After the final grinding, the surface must be washed with a neutral cleaner and rinsed with water. When the surface is thoroughly dry, the sealer coat is applied.

**6.10.5.4 Protections.** All completed work should be protected until the floor is placed in service. This is especially true when other construction operations are in progress.

### 6.10.6 Maintenance and Repair

Resinous floors are maintained the same as terrazzo floors. Normal custodial services provide the necessary maintenance. Due to the recent use of these floor covering materials, few floors have been repaired. When repairs have been made, MMA- and polyester-based systems have proved to be the most successful because the new resins bond monolithically to the existing systems without leaving cold joints. The damaged area and 6 inches adjacent to the damaged area are completely removed down to the substrate (base floor). The substrate is prepared as for a new floor (see paragraph 6.10.5). The resinous material is leveled with the existing floor covering. Aggregate or decorative chips are added if required. When curing is completed, some systems may require grinding the edges smooth. Present practice indicates that the preparation of the substrate is the key to successful resinous floor repairs.

## SECTION XI—STAIRS

### 6.11.1 Repairs

**6.11.1.1 Wood Stairs.** Exterior wood stairs are subject to weathering and mechanical abuse. Normally, damaged components should be removed and replaced in kind. Maintenance on interior wood stairs usually involves treads. Squeaks indicate loose treads, which can be corrected by driving finishing nails through the treads into the riser or carriages, or by removing the molding under the tread overhang, driving wood wedges between the tread and riser, re-nailing the tread tightly, and replacing the molding. In open string stairs, a tread that is worn but not split or broken may be removed and reversed. Split, broken, or otherwise seriously damaged treads should be replaced with new boards. Housed treads that cannot be removed may be repaired by leveling the worn surface with asphaltic mastic or other suitable plastic materials and covering the tread with a suitable floor covering. Plain and nonslip nosing of steel, brass, bronze, aluminum, and molded hard rubber are commercially available and should be applied according to the manufacturer's recommendations.

**6.11.1.2 Concrete Stairs.** Concrete stair treads that are cracked, chipped, or spalled may be patched according to recommendations in para-

graph 6.3.2.

**6.11.1.3 Terrazzo Stairs.** Terrazzo stairs, because of the nature of the material and general conditions of use, usually require limited maintenance. Cleaning for removal of discoloration may be necessary and should follow the procedure recommended in paragraph 6.4.3.

**6.11.1.4 Metal Stair & Metal Stairs,** especially when exposed to the weather or corrosive agents, should be given a coat of rust-resistant paint. Rusted fasteners should be replaced and properly secured.

### 6.11.2 Application of Coverings

The elimination of hazards may require the application of slip-resistant coverings on treads of exterior or interior stairways. Some types of bituminous-base coverings are furnished with a slip-resistant wearing surface, which makes them efficient materials for use on stair treads. A mineral-surfaced, nonslip covering, consisting of silicon carbon grains coated on a heavy, tough semisaturated fabric, is also available commercially. The fabric has a backing of pressure-sensitive adhesive. Rubber mattings may also be applied to treads to reduce slipping hazards.

## SECTION XII—CARPET

## 6.12.1 General

Carpeting is a common authorized floor covering for uses in quarters and select administrative, recreational, and education facilities. Guidelines on the selection and characteristics of authorized carpeting may be found in Engineer Technical Letter 1110-3-323, "Carpet in Army Facilities," NAVFAC Design Manual 14.2, "Carpet Selection Guide," and Air Force Design Manual.

6.12.1.1 *Care and Maintenance.* Routine custodial care and maintenance of carpets should be maintained to avoid excessive wear caused by surface soil penetrating to the lower pile and backing. Procedures for care and maintenance are in the Tri-Service Manual (TM 5-609, NAVFAC MO-125, AFM 91-2 Military Custodial Services).

## 6.12.1.2 Repairs

a. *Spot Repairs.* Small repairs to carpet pile may be made by resetting individual tufts in the affected area. This procedure may be used in cases of small burns or serious stains where the carpet backing is unaffected. Carpet pile should be cut down to the backing and stubs removed. New individual tufts should be stripped from a piece of scrap carpet or from an inconspicuous part of the existing carpet by unraveling the edge of the scrap. Prepare the area to be repaired with a thin coat of latex adhesive and install individual tufts, doubled, into the carpet backing using a tuft-setting tool. The tufts should be installed from the edge or corner of the repair and as close together as possible. Trimming or gentle pulling of the tufts will provide a smooth surface.

b. *Plug Method.* Larger repairs or repairs involving damage to the backing may require the removal of a portion of the carpet and replacement with a matching plug. A piece of matching carpet should be placed over the affected area and aligned to insure that the pattern and direction matches exactly. The carpet may be temporarily tacked in place while cutting. Using a sheet-metal disk plug or metal straightedge, cut both layers of carpet being careful not to fray the edges or damage tufts. Avoid cutting into the carpet padding. Replace the damaged area with the new plug to insure a proper fit. Seams should be taped with 4-inch-wide carpet seaming tape as recommended by the carpet manufacturer. The tape should be bonded with carpet seam adhesive. Insert the patch insuring a proper fit and allow the area to dry, undisturbed, for a minimum of 6 hours.

## 6.12.2 Replacement

If carpeting is to be removed and replaced, the floor should be inspected and prepared by removing and replacing deteriorated or loose underlayment or subflooring. Large cracks in concrete floors should be repaired as outlined in paragraph 6.3.9.6.

6.12.2.1 *General Installation.* Install carpeting after other finishing operations, e.g., painting, have been completed. Room humidity and temperature must be within limits recommended by the manufacturer and no less than 60° F (15.6° C), for 24 hours before and after installation. Planning for the replacement should minimize the number of seams with no seams occurring perpendicular at doorways.

6.12.2.2 *Installing Carpet Guards.* Carpet guards should be installed wherever the edge of carpet is exposed to traffic. This should be precut to the exact dimensions of all openings except where another device, such as expansion joint cover systems or thresholds, are located with an integral carpet binding bar.

6.12.2.3 *Installing Tackless Carpet Stripping.* Standard tackless carpet stripping should be installed around the perimeter of the room at a distance of not more than ¼ inch from the wall base.

6.12.2.4 *Installing Carpet Cushion.* Carpet cushion is usually laid with the slip-resistant face down; however, check with the cushion manufacturer for the recommended method. The cushion should be cut approximately 6 inches longer than required to butt to the tackless strip and trimmed in place after it is secured. The cushion may be secured using tacks spaced 6 inches apart around all edges, taped with 4-inch-wide tape as recommended by the manufacturer, or spot cementing to the subfloor. All seams should butt tightly and run in the opposite direction of any carpet seams. NOTE: In large rooms or when excess shifting of carpet is anticipated during installation, the carpet may be laid out in the room prior to installing the cushion and turned back to allow installation of the cushion. Once the cushion is secured in place it should be trimmed to butt with the tackless strips and edge guards.

6.12.2.5 *Installing Carpet.* Carpet is cut not less than 3 inches larger than the net room size. Installation begins in one corner of the room away from openings. Stretching the carpet onto the tackless strip is done with a knee kicker or power stretcher which have been adjusted to insure that the teeth

do not become exposed through the backing of the carpet. To start the installation, the carpet should overlap the walls approximately 1½ inches in the starting corner. The carpet should be kicked onto the tackles strips and trimmed 6 inches in each direction from the corner. The carpet should be kicked onto the tackles strips for up to 3 feet from the corner angling the kicker slightly away from the corner.

6.12.2.6 *Length Stretch.* With the beginning corner set, the carpet should be stretched in length by installing the second corner. This should be the corner farthest from the beginning along an adjacent wall, not opposite. The length stretch should use a power stretcher with a head placed three inches from wall. The carpet is held on the tackles strip with a spreader which is released slowly to allow the carpet to hook onto the strip. A kicker is then used to install the corner in the same way as the beginning corner and the entire starting wall between the two corners.

6.12.2.7 *Width Stretch.* The width stretch is performed in the center of the wall opposite the two corners previously installed. The carpet is secured to the strips in the same manner as the length stretch. Instead of using a kicker, the power stretcher is used to secure the entire half of the wall beginning at the point of stretch halfway toward one corner and then the other. The base of the power stretcher should not move during the width stretch installation.

6.12.2.8 *Completing the Stretch.* The installation should continue along the wall opposite the beginning wall using the power stretcher with no angle to the tubes. This is followed by both end walls, also using the power stretcher in a straight stretch.

6.12.2.9 *Cutting.* Excess carpeting along walls should be trimmed with a trimmer or sharp utility knife with approximately ¼-inch excess. The excess is then pressed into the gully between the tackles strip and the wall.

## CHAPTER 7

## DOORS, WINDOWS, AND BUILDERS' HARDWARE

## SECTION I—MAINTENANCE AND REPAIR OF DOORS

**7.1.1 General**

Exterior doors are more subject to abuse and weathering than interior doors, but, in general, defects and corrective measures are similar.

**7.1.2 Periodic Inspection**

Doors should be inspected quarterly for poor fitting, including loose or broken battens; deteriorated or damaged frames; paint deterioration; material damage; cracked or broken glass; split or cracked wood panels; warped or dented metal; warped or broken screening; broken or inoperative hardware (locks, hinges, and sliders).

**7.1.3 Wood Doors****7.1.4 Butt-Hinged Doors**

Mechanical injury to mullions, headers, jambs, or hardware usually causes trouble with large wood-batten framed and braced doors. Decay, resulting from exposure to weather or shrinkage of door members, also causes distortion or failure. Frequently, the free edge of the door sags and causes the door to bind at the bottom and open at the top.

*7.1.4.1 Checklist for Repair*

Effective remedies may be determined by first checking the following:

- a. Examine the jamb opening to see that the hinge and lock sides are plumb and parallel.
- b. Check the doorhead to see that it is level.
- c. Check anchorage of the jamb.
- d. Check anchorage of hinges.
- e. Check lock faceplates for projection beyond the face of the door.
- f. Check all members for swelling, shrinking, or warping.

*7.1.4.2 Repairs.* The following procedures apply when the door itself has shrunk or is warped, swollen, or sagged.

- a. When a door shrinks, remove the hinge leaves and install a filler (cardboard or metal shim) at the outer edge of the jamb and hinge mortice.

This forces the door closer to the jamb at the lock edge. If the hinge pins do not bind, the door will operate satisfactorily. Each hinge should be shimmed equally to prevent the door from becoming hinge bound. When the door has swelled, place shims in the inner edge of the hinge mortice as shown in figure 7-1.

- b. Restore a warped door to its normal shape by removing it and laying it flat. Weighting it down may also be necessary. If it is still warped after a reasonable length of time, battens screwed to the door help restore it to true plane. Screw eyes, rods, and turnbuckles help straighten a door by gradually pulling it into place.

- c. Install a diagonal batten brace from the top of the lock side to the bottom of the hinge side to repair a sagging door permanently. The diagonal brace must cover the joint between rail and stile and be securely fastened to both members, at top and bottom, and other intermediate rail members. Temporary repair is made by installation of a wire stay brace equipped with turnbuckles and placed diagonally in the reverse direction from a batten brace.

- d. Doors or door members may require rebuilding because of neglect or abuse. Remove the door to a flat surface and replace the damaged member. Carpenter's clamps assist in holding door members square while nails or screws are driven.

- e. Trim the door when the preceding methods fail to correct the trouble. However, do not cut doors immediately following rain or damp weather. When dry, the door may fit too loosely.

**7.1.5 Wood Panel Doors**

Failures in panel doors are similar to those in large wood doors. In addition, doors are subject to binding at the hinge edge, friction between the dead bolt and strike plate, or between the latch-bolt and strike plate.

*7.1.5.1 Locking.* Trouble with the locking apparatus is generally caused by defective knobs or locks. Check the knob to determine whether the spindle is worn or only loose. Where a lock does not move

smoothly, replacement may be necessary, although repair of worn parts or lubricating with graphite frequently overcomes the difficulty.

7.1.5.2 *Rattling*. An excess of space between the door and stop head causes the door to rattle. Removal and refitting of the head stop while the door is closed remedies this difficulty. The door may also rattle because of too much play between the latchbolt and strike plate. Correct this condition by moving the plate back toward the stop.

7.1.5.3. *Loose Hinges*. Hinges become loosened if a door is *too* tight on the hinge edge and binds against the hinge jamb. If the door has plenty of clearance on the lock side and the entire pin seems to move slightly when the door is closed, loosen both hinges at the frame and insert card-board under the jamb leaves along the outer edges. To make a uniform space between the jamb and the door, insert a strip of cardboard under the inner edge of the top hinges in the leaf which is fastened to the jamb. This usually corrects the trouble by pulling the upper part of the door closer to the jamb. However, considerable space above the door and along the outside (lock edge) may result. In that case, loosen the screws in the leaf of the bottom hinge, which is attached to the jamb, and insert cardboard under the other edge. If the hinge has been pulled loose and the wood screws have damaged the wood fibers on either the door or jamb, the holes may be plugged with wood plugs or filled with plastic wood.

7.1.5.4. *Warping*. A warped door that has spring inward or outward at the hinge edge is impossible to close without considerable pressure against the bulging part. This trouble is generally overcome by placing an additional hinge midway between the other two to hold the door straight. If another hinge cannot be obtained, temporary repair is made by shifting the hinges outward or inward on the jamb, as shown in figure 7-1. Adjust stops according to the position of door when closed and latched.

7.1.5.5 *Settling and Shrinkage*. Settling of the foundation or shrinkage and deflection of framing members often causes trouble at door openings. When the greatest settlement is on the hinge side of a door, the door will tend to become floor-bound at the lock side. When settlement is greatest on the lock side, the door will bind at the head jamb. As a result, the bolt in the lock will not be in alignment with the strike plate, making it impossible to lock

the door securely. Vertical settlement and horizontal deflection will cause the jamb opening to become out of square. On most wood doors, the simple correction is to plane as required at either the top or bottom rail for proper clearance. Another method, more complicated but producing better results, is to lift off the strike plate and nail or screw a wood strip extending up and down the entire length of the door frame, as shown in figure 7-2. It is necessary to cut a hole in this strip for the latchbolt. An alternate method is to remove the hinges from the door and screw a wood strip to the door, extending the entire length. Countersink all nails or screws, and place putty over all holes.

7.1.5.6. *Latching*. When the latch does not operate because of poor alignment with the strike plate (figure 7-3), enlarge the hole in the strike plate by filing. If the bolt strikes squarely on the plate and requires removal of as much as  $\frac{1}{8}$  inch of metal, remove the strike plate and raise or lower it as necessary.

7.1.5.7 *Uneven Side Margins*. It is seldom necessary to plane a door if trouble is caused by loose or improperly morticed hinges. However, if planing is necessary because side margins are uneven and the door strikes at top or bottom because of settlement of the frame or similar causes, locate the points of friction. It is easier and less noticeable to plane the hinge edge. Bevel the lock edge of the door about  $\frac{1}{8}$  inch to facilitate closing. If the door still strikes along the lock edge, plane the hinge edge and cut in the hinge leaves flush with the surface, if necessary.

7.1.5.8 *Sticking* Damp weather often causes a door to stick. Absorption of moisture results in swelling of the framework and door. If the door has an even margin along the top and bottom edges and if the hinges are firm, the hinge edge must be planed. It is best to plane the hinge edge because hinges are more easily removed and remorticed than the lock. Take care not to plane off too much wood. When it is necessary to trim a door for better fitting, carefully mark the amount to be planed, allowing clearance on all sides of approximately the thickness of a dime. To determine the correct amount of wood to be removed, set the door hard against the hinge side, wedge it plumb, and scribe the desired thickness of material to be planed off. When planing or cutting is completed, repaint the edges before rehanging the door.

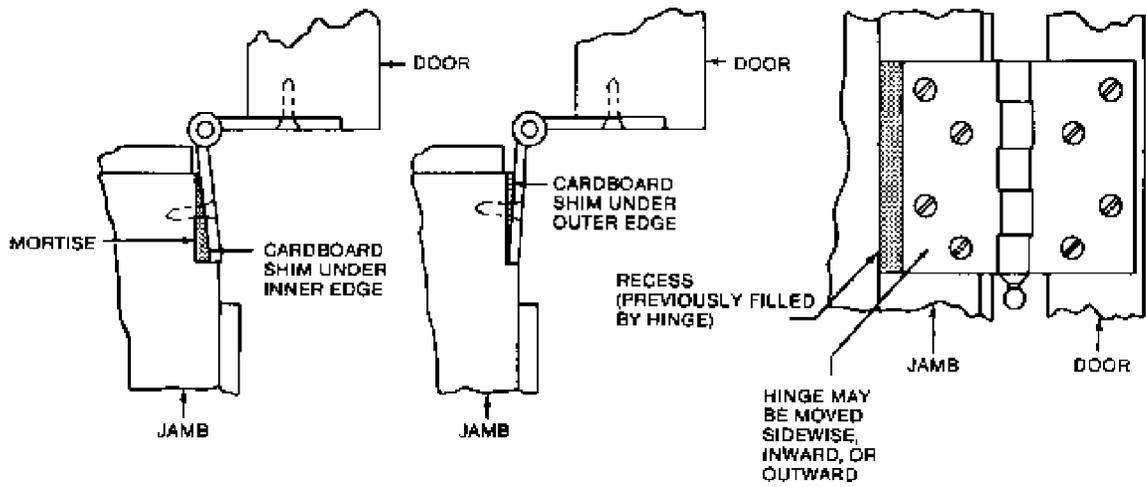


Figure 7-1. HINGE ADJUSTMENT FOR BINDING OR STICKING DOORS.

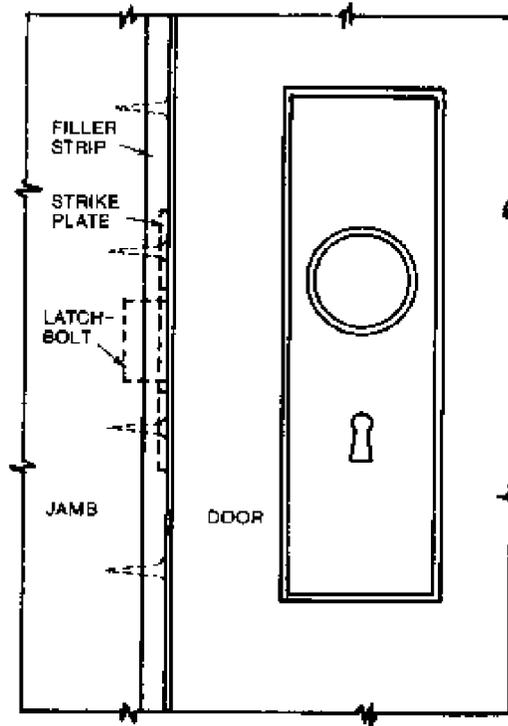


Figure 7-2. VIEW OF DOOR JAMB SHOWING FILLER STRIP.

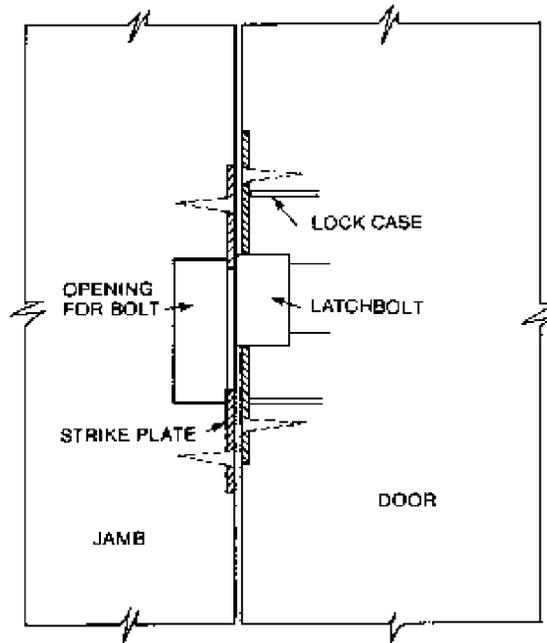


Figure 7-3. POOR ALIGNMENT OF LATCHBOLT WITH STRIKER PLATE.

7.1.5.9 *Bevel.* Proper bevel for wood doors of 2 feet 8 inches to 3 feet in width is about  $\frac{1}{16}$  inch per 1 inch of door thickness. On doors of smaller width that are of equal thickness, the bevel should be increased proportionately to the decreased width of door. On wider doors, the bevel can be decreased proportionately to the increase in width of the door. See figure 7-4.

### 7.1.6 Metal Doors

7.1.6.1 *Types.* Metal doors, commonly used in warehouses, hangars, stockrooms, mess halls (galleys) and other areas where hard service or industrial operations require them, are of various types: metal, clad, hollow metal, and solid metal, with variations including interchangeable glass and screen panels.

7.1.6.2 *General Maintenance.* Because most metal doors and fittings are shop designed and fabricated, it can be assumed that they will maintain their shape and mechanical operating abilities provided hinges, locks, and other fittings remain secure in their fastenings. This is accomplished by checking screens, nuts and bolts, and special fasteners and operating devices regularly and keeping them tight and in good order. Building settlement, mechanical failure, and collision may require investigation and corrective measures for a basic cause of misalignment in the structure framing itself. Frames must be plumb and corners square so that the door

fits its opening with proper clearances. Weatherproofing and caulking must be maintained in a workmanlike manner. Mechanically operated doors must be removed and straightened, repaired, or replaced. Repair material and finishing should match the existing material. Shop repair of metal doors should meet acceptable standards for welding, riveting, and sightliness. Replacement of surface metal on fireproof, metal-clad wood doors must be weathertight and of material of the same gage as originally provided. Service doors in mess halls (galleys), stockrooms, and other areas where personnel pass in and out frequently with arms loaded should be provided with kick plates and with bumper protection to prevent slamming against walls.

### 7.1.7 Fire Doors

Fire doors are specifically designed and installed to restrict the spread of fire and smoke in facilities. They are usually of metal, metal clad, or wood construction with or without lights as described below and are classified in accordance with NFPA Standard 252 or other approving authorities.

7.1.7.1 *Types of Doors.* The most common types of doors, as described in NFPA Standard 80, "Fire Doors and Windows," are composite doors of wood, steel or plastic bonded to a solid core; hollow metal doors; metal-clad doors of metal over wood cores; sheet metal doors; rolling steel doors;

curtain-type doors; and wood core doors of wood or plastic bonded to wood core. Doors with lesser

fire protection spread ratings may include wired glass lights.

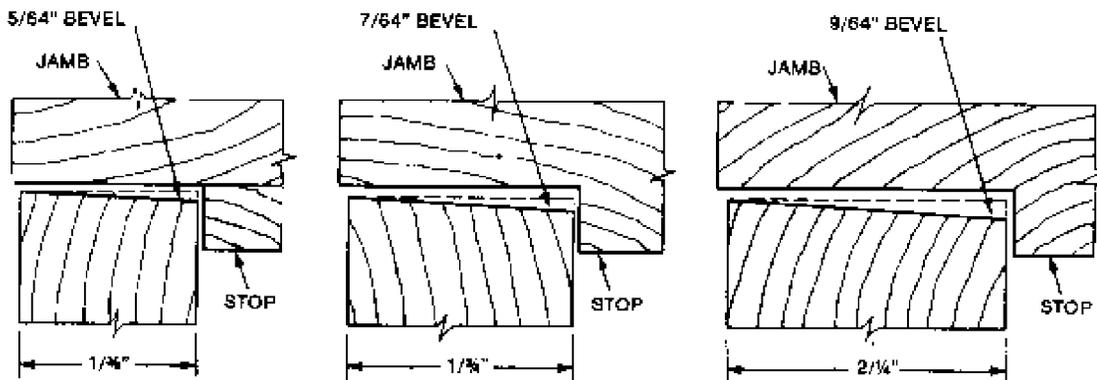


Figure 7-4. DOOR BEVEL FOR NORMAL WIDTH OPENINGS.

7.1.7.2 *Inspections.* Doors must be kept operable at all times and should be kept closed. Maintenance includes frequent inspection of hinges, catches, closers, latches and stay rolls. Lights, if any, and door face coverings, chains or cables, should also be inspected. In addition, metal- and tin-clad doors should be inspected for dry rot. Areas surrounding doors should be inspected for blockage and doors inspected for tampering such as wedges to keep the door open or devices which inhibit their opening.

7.1.7.3 *Maintenance.* NFPA Standard 80 and the manufacturer's recommended maintenance should be followed. Lubricate guides and bearings and adjust chains and cables on counterbalanced doors as needed to insure proper operation. Replace worn hardware immediately. Broken light panels should be replaced with at least 1/4-inch-thick wire glass. Faults in face coverings should be immediately repaired as described in paragraph 7.1.5.2.

### 7.1.8 Hangar and Warehouse Doors

Doors used in hangars and warehouses are commonly of the rolling type and motorized; they impose extreme loads on the narrow bearing surface of supporting rails. They require specialized maintenance in accordance with the manufacturer's recommendations. If major warping or displacement of sliding panels occurs, engineering personnel should be consulted on repair. Settling or failure of roof trussing can cause displacement of overhead rails and guides, imposing stresses on the panels. Maintenance of large metal areas of doors is similar to that for metal sidings, as recommended in chapter 4. Complicated devices for operating

large doors should be maintained according to the manufacturer's recommendations.

#### 7.1.8.1 *Minor and Routine Maintenance.*

- a. Keep rails, guides, springs, and rollers secure and free from dust, dirt, corrosion, and obstruction.
- b. Keep upper rails and rollers lubricated according to the manufacturer's recommendations.
- c. Check and maintain alignment of rollers and rails.
- d. Check guides for security and alignment. Straighten bent guides.
- e. Repair damaged glazed sections promptly.
- f. Inspect and lubricate motors as recommended by manufacturer.
- g. Keep hinges and springs free from dirt, debris, and corrosion, and lubricate them regularly. Replace sprung or broken hinges and springs and other door fittings.
- h. Keep locks and latches lubricated and in good repair.

7.1.8.2 *Adjustment to Hangar Door Guides.* The methods used in adjusting door guides depend on the type of door mechanisms involved. The detailed procedures explained herein are for a particular type of construction. However, the principles applied in the adjustment of this door can be used on many types of door and truss configurations. The causes of binding of sliding hangar doors in timber truss-type hangars are discussed in paragraph 3.4.9.3.

- a. Considerable difficulty has been encountered in hangars containing Pratt trusses with a span of

120 feet. Usually the trusses over the doors carry considerable additional loads, for the door canopy and guides are cantilevered out beyond those trusses. The 120-foot trusses are usually erected with a 4- to 6-inch camber, and the door guides are adjusted for a fixed distance from the deck. The distance between truss chords and door guides will, therefore, vary, the greatest differences being at the center of the span.

*b.* A practical means for adjusting the door guides is to raise the outriggers at their point of contact with the bottom chord of the door trusses. This is accomplished by driving oak wedges between the outriggers and chords. Before raising the outrigger, it will be necessary to notch the sills supporting the bulkhead; otherwise, the entire bulkhead will be raised with the outrigger. It may be necessary to raise the canopy to relieve the strain when driving the wedges. One jacking tower, made up of 6 x 64-inch timbers, and suitable cross bracing, should be constructed for this purpose. By setting the tower under each outrigger, in turn, and jacking it to its predetermined height, the wedges can be installed and the jack removed. All bolts connecting the outrigger to both trusses should be loosened while performing this operation.

*c.* In some hangars, the arrangement of outriggers and door guides is somewhat different. These guides are bolted to the underside of the outriggers, with a spacer timber between the flange of the "T" guide and the underside of the outrigger. The guides can be adjusted in this case by removing the spacer timber, and, in its place, installing a correct number of shims or blocks to bring the guides to the proper grades. Where corrections are made in this manner, it will be possible to readjust the guides at a later date, if necessary, by removing some of the shims. The only equipment required for this work, other than the usual mechanic's tools, will be a portable scaffold of sufficient height to reach the canopy.

*d.* When making adjustments to the doors, the wheel adjustment should be taken up as much as possible and the wheels well greased. Check the rails and chip away any concrete rubbing against the flange of the wheels. The door rails should be kept clean at all times. It is recommended that the operation forces be instructed to sweep out the tracks daily. Exercise extreme caution when adjusting door guides, for the guides have only a few inches bearing on the door at the top; and, if the guides are raised too much, the doors will tumble over, probably with disastrous results. Adjustments to door guides should not be made by cutting material from the stem of the "T" rails, as this only reduces the bearing surface of the guides.

### **7.1.9 Cold-Storage Doors**

Doors in cold-storage rooms, including meat track doors, should be checked for tight closing. Latches should be adjusted if necessary. Hinges and latch mechanisms should be lubricated regularly. Gaskets should be cleaned and checked for necessary replacement. Special attention should be given to low-temperature installations, where nonfreezetype (electrical resistant) gaskets are used. Doors should be inspected for damage or deterioration, and bumper guards checked. Ceilings and walls should also be inspected for loose insulation, cracks, or other defects in wood, cement, or mastic finishes. Wall and corner guards should be checked for condition. Meat tracks should be secure. To reduce deterioration, tracks should be cleaned and repainted as necessary.

### **7.1.10 Detention Doors**

Detention doors should be inspected regularly for security of locking devices. Breakout alarms attached to door locks should be checked for operational readiness. Electrical or pneumatic controls for simultaneous locking and unlocking of doors in large, cell-block installations should be checked by qualified personnel. Locking devices and hinges should be lubricated regularly.

### **7.1.11 Storm Doors**

Storm doors are commonly made of wood or aluminum, with appropriate glazing. Wood storm doors should be maintained and repaired according to the manufacturer's recommendations.

### **7.1.12 Screen Doors**

Screen doors, usually made with wood or aluminum frames, should be fitted with wire guards and wood or metal push bars on the inside to avoid pressure on the screening in opening them. Doors should be sized or trimmed to allow proper clearance at the head, jambs, and bottom. Too much clearance will defeat the purpose of excluding insects, but doors should not stick or bind, which causes damage to the frames under traffic. A sagging screen door can be straightened by the use of a metal rod with a tumbuckle. One end of the rod is fastened to the face of the frame, at the center of the intersection of the bottom rail and the outer vertical rail. The other end is fastened as high on the face of the hinge rail as it will reach. The tumbuckle is then turned to shorten the rod and thus lift the bottom rail. Doorframes are maintained as recommended in paragraph 7.1.3. Screen maintenance should conform to recommendations in paragraph 7.2.8.

## SECTION II—MAINTENANCE AND REPAIR OF WINDOWS

### 7.2.1. Periodic Inspection

Windows should be inspected for loose-fitting or damaged frames, illfitting or broken sashes, cracked or broken glass, deteriorated putty, broken or worn sash cords, and missing or broken hardware. If atmospheric conditions cause ordinary putty to crumble quickly, plastic glazing compound should be substituted. Leaks may be caused by material shrinkage. Frames and cover molds of wood windows should be inspected, along with sills, jambs, and heads of metal windows. Open joints should be caulked. A slight shrinkage of putty away from the glass can often be corrected by needle glazing with a soft plastic compound. Rust spots on metal sashes and frames should be wire-brushed or sandpapered, cleaned with a rag saturated with mineral spirits, and then spot-painted.

7.2.1.1 *Types of Windows.* The following discussion is extracted from *Building Construction, Materials and Types of Construction* by Whitney Clark Huntington and Robert E. Mickadet, courtesy of John Wiley and Sons, New York. The usual types of windows, regardless of materials in their construction, are illustrated in figure 7-5. The glass areas in these examples are subdivided in various ways which may have no significance to the type of window illustrated. Some windows may include only a single pane of glass. Subdivisions may be made to permit the inclusion of ventilating units, for convenience in cleaning, to limit glass size for safety, for architectural effect, or for other reasons. Various types of windows or sashes are often combined as a single window opening.

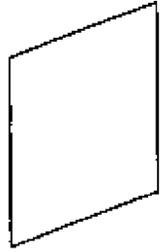
7.2.1.2 A fixed window (figure 7-5(A)) makes no provision for natural ventilation.

7.2.1.3 For double-hung window (figure 7-5(B)), both sashes slide vertically, with the weight of each

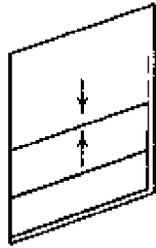
counterbalanced by sash weights, spiral spring balances, or tape spring balances similar to clock springs. The sash is easily operated and edge friction will hold it in any set position. For a single-hung window, only the lower sash operates. Some types are arranged so that the sash can be removed from the inside.

7.2.1.4 One or both sashes for a horizontal-sliding window (figure 7-5(C)) may be arranged to slide. Some types are also arranged so that the sash may be removed from the inside. Heavy sashes are often provided with nylon rollers for ease in operation. Sashes are sometimes suspended from rollers operating on overhead tracks.

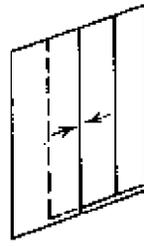
7.2.1.5 In general, any hinged window is a casement window. It may swing out or in and may be hinged at either side, the top, or the bottom but the term is usually applied only to side-hinged windows. An outswinging casement window with two sashes is shown in figure 7-5(D). Each sash swings on extension hinges attached to the hanging stile of the sash and the jamb of the frame. The extension provides an open space between the hanging stile and the jamb to facilitate cleaning the outside. For an inswinging casement window (figure 7-5(E)), extension hinges are used to make the sash swing clear of the inside surface of the wall. One or more casements of either type may be included in a single opening. For example, three sashes could be included by providing a mullion between a single sash and a pair of sashes. Outswinging casements are more widely used than inswinging. The folding window (figure 7-5(F)) is a form of outswinging casement window with the two sashes hinged together on their meeting stiles rather than each to its outside stile. Projection arms are arranged so that the sash operate symmetrically.



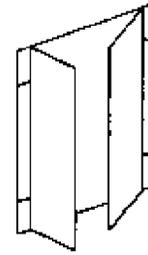
**(A) FIXED**



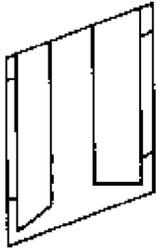
**(B) DOUBLE-HUNG**



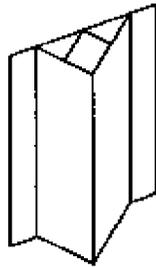
**(C) HORIZONTAL SIDING**



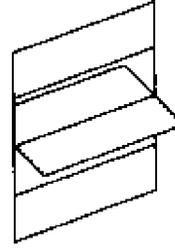
**(D) OUTSWINGING CASEMENT**



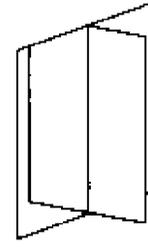
**(E) INSWINGING CASEMENT**



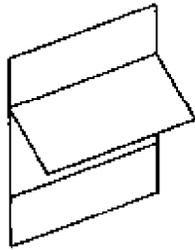
**(F) FOLDING**



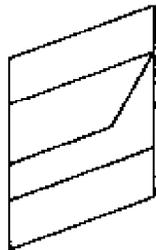
**(G) HORIZONTAL PIVOTED**



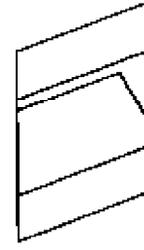
**(H) VERTICAL PIVOTED**



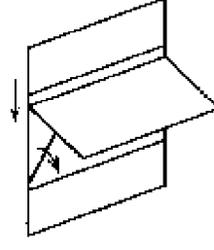
**(I) TOP-HINGED OUTSWINGING**



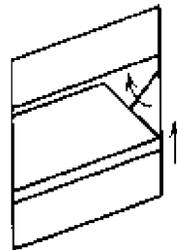
**(J) TOP-HINGED INSWINGING**



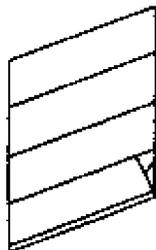
**(K) BOTTOM-HINGED INSWINGING**



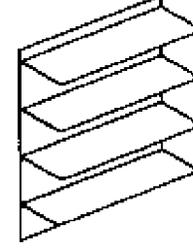
**(L) OUTWARD PROJECTING**



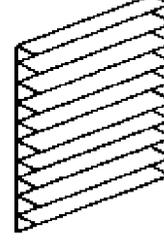
**(M) INWARD PROJECTING**



**(N) HOPPER**



**(O) AWNING**



**(P) JALOUSIE**

FIGURE COURTESY OF JOHN WILEY & SONS, INC.  
FROM BUILDING CONSTRUCTION BY  
WHITNEY CLARK HUNTINGTON AND ROBERT E. MICKADET

*Figure 7-5. WINDOW TYPES—OUTSIDE VIEWS FOR OPEN POSITIONS.*

7.2.1.6 A horizontal-pivoted sash (figure 7-5(G)) is pivoted at the center. Such sashes are often arranged in a row to form a continuous or ribbon window located in a sawtooth roof or monitor and are operated in unison from the floor by a mechanical operator.

7.2.1.7 A vertical-pivoted sash (figure 7-5(G)) is often arranged to swing in a full circle.

7.2.1.8 Sashes may be top-hinged and outswinging, top-hinged and inswinging, or bottom-hinged and inswinging (figure 7-4 (I), (J), and (K)).

7.2.1.9 Projected windows have ventilation sashes which operate like the outward-projecting window shown in figure 7-5(L). The ends of the arms are pivoted to the stile of the sash and to the frame. Shoes are attached to the top rail of the sash and move vertically along the stiles, guided by tracks attached to the vertical members at the sides of the opening. An inward-projecting window is shown in figure 7-5(M). If the latter is located at or near the bottom of a window, it is called a hopper ventilator (figure 7-5(N)). If several outward-projecting ventilators are located vertically adjacent to each other and are arranged to be operated simultaneously by a single operator, the window is called an awning window (figure 7-5(O)). Fixed meeting rails sometimes are provided between adjacent sashes. The downward movement of the top rail of the projected sash provides an opening through which the outside of the outward-projecting sash can be cleaned.

7.2.1.10 A jalousie window (figure 7-5(P)) is similar to an awning window except the ventilating units are heavy glass slats from 3 to 8 inches wide with metal end supports to which the operator is attached. Adjacent edges of the slats overlap  $\frac{1}{2}$  inch or more to exclude rain and reduce air infiltration. There is considerable air leakage when closed, and they are usually used only for enclosed porches or where air leakage is not objectionable.

## 7.2.2 Wood Windows

7.2.2.1 *Causes of Failure.* Window failures may result from various causes, the most common being weathering. Weathering causes loss of putty and paint with subsequent deterioration and rotting of wood members; binding of parting or stop heads; windows forced out of shape by settling, shrinking, or twisting of the building frame; swollen or improperly fitted sashes; broken or uneven sash cords; and sashes stuck from paint in the pulley stile.

7.2.2.2 *Binding.* When it is determined that the sash in a double-hung window binds because of pressure against the parting bead, thorough waxing

of parts in contact prevents much unnecessary labor. Binding of horizontal sliding sashes is also relieved by this procedure. When the inside stop beads of a double-hung window press too tightly against the sash, reduce the thickness of beads by planing, sanding, or scraping along the edge adjacent to the sash, or move the beads farther from the sash. Carefully plane the top or bottom rail to relieve binding in horizontal-sliding sashes. After planing, coat the sash with linseed oil and wash it when the oil has dried.

7.2.2.3 *Settlement.* Careful nailing frequently restores the shape of frames that are forced out of shape by settling, shrinking, or twisting of the building. Cutting the sash is not recommended as a remedy.

7.2.2.4 *Swelling.* Do not cut any window that will resume its original size when properly dry. Cut or plane a sash or frame that is swollen by moisture only when it is determined that the member is too large, even when dry. Remove and plane a sash when the vertical edge binds against the pulley stile or running face of the window frame. To locate high spots on the sash, rub the sash stile with chalk and then slide the sash from closed to open position two or three times. High spots on the sash are indicated at points where the chalk has rubbed off.

7.2.2.5 *Bowing.* Occasionally a parting bead becomes too long, causing a bow in the middle. In this case, remove the bead from the frame and cut  $\text{C}$  to  $\frac{1}{4}$  inch from one end.

7.2.2.6 *Broken Cords.* Broken or missing cords call for careful removal of the stop bead. Remove the lower sash from the frame. Knot the cords to prevent them from running through the pulley after the window is detached. Remove the parting bead to remove the upper sash. Install new cord, then replace the upper sash, parting bead, lower sash, and stop bead, in that order. An economical and efficient substitute for a broken cord or pulley is the sash control spring. This spring can also be used in lieu of barrel bolts and other devices for the control of a nonbalanced sash. Proper sash operation requires that the combined clearance of the two edges be  $\text{C}$  to  $\frac{3}{16}$  inch. When installing a control spring on a new sash or old sash removed from the frame, nail a spring to each edge of the sash so that the top of the spring is 6 inches below the top rail of the upper sash, or 6 inches below the check rail or lower sash. Use two 16-gage,  $\frac{1}{4}$ -inch-long brads for each spring. When installing the spring on an in-place sash, raise the lower sash at the high point and hold the spring with prongs toward the frame. Push the spring up between sash and frame, using enough pressure to flatten the top

spring curve to permit it to slide upward. Install the spring on the opposite side of the sash in the same manner. Lower the upper sash to the low point and follow the same installation instructions as above, except push the spring downward. No nails or screws are required.

**7.2.2.7 Balancing Adjustment.** When a sash with spiral or pullman-type balances is out of balance, follow the manufacturer's directions for balance adjustment. Attempts to repair such sashes without compliance with prescribed directions may result in further damage.

### **7.2.3. Metal Windows**

Maintenance and repair of metal windows is usually considerably less than that for wood. General repair is similar to that for metal doors. Rusting, warping, and sticking of operating devices are the most common failures. It is important to lubricate mechanisms regularly and to keep fastening devices secure. Problems of alignment caused by building settlement must be adjusted in conjunction with overall corrective measures, which may involve stabilizing the foundation and framing. Caulking must be maintained in good order to prevent leakage of moisture and air.

### **7.2.4 Vinyl Windows**

Vinyl windows have frames and lineal components of solid PVC or PVCclad wood or aluminum or other combinations of PVC and metals. These windows can have low coefficients of heat transmission and air infiltration which give them an advantage over some other types of windows; however, they can be more expensive and their selection must be based on lifecycle cost analysis similar to that described in appendix C for vinyl siding. Vinyl windows are low maintenance by comparison to wood types. The vinyl used is resistant to cracks, peeling, blisters or other surface defects. Painting is unnecessary for vinyl; however, vinyl clad wood may require painting to the interior surface.

### **7.2.5 Venetian Blinds**

Venetian blinds, when permitted by criteria, should conform to Federal Specification AA-V-00200B. Head boxes, usually installed between the reveals of jambs, should be set level on brackets designed to allow convenient removal and replacement without damage to the blinds or adjacent surfaces. Brackets should be secured in place with screws,

nails, or other fasteners. Replacement of worn tapes and cords is the major maintenance problem with venetian blinds. A check for broken or bent slats should be made when cords or tapes are replaced, since slats can only be replaced by removal of the cords.

### **7.2.6 Caulking and Sealing**

**7.2.6.1 General.** Caulking and sealing compounds are used to seal and waterproof exposed joints around wood and metal frames that are built into exterior concrete and brick, stone, concrete block, glass block, and other masonry. This includes control joints in masonry construction. Caulking compounds are used in wood construction for sealing joints around door and window frames. See figure 7-6. Factors which influence joint design and choice of joint sealant are briefly discussed so that these principles may be applied with understanding to the maintenance program.

**7.2.6.2 Joint Designs.** In movable joints, the elements to consider in the design are their spacing, sizes, and shapes. Since the ability to expand and contract varies a great deal with different sealants, the percentage of expansion required generally determines the sealant to be used. It is therefore necessary to calculate the anticipated expansion and contraction of the joint due to temperature changes. The coefficients of thermal expansion of the building material to be sealed, and the spread between the winter low and summer high temperatures will be used in the design and shape of movement. The type of sealant can be selected, based on service conditions and movement. The maximum strain that a particular sealant can endure can be determined in the laboratory by testing to failure at different temperatures. Reputable manufacturers will supply dependable data. The maximum working elongation in movable joints will be 10 percent for caulking compounds and a single-component elastomer, and 25 percent for rubber-base sealants. For example, a joint is calculated to move ¼ inch in width during the period between the high and low inservice temperatures. Using the maximum working elongation of 25 percent for rubber-base sealants, the joints would be 1 inch wide. Then following the rule of thumb that the joint sealant should be one-half the width of the joint in depth, the joint would be 1 inch wide by ½ inch deep.

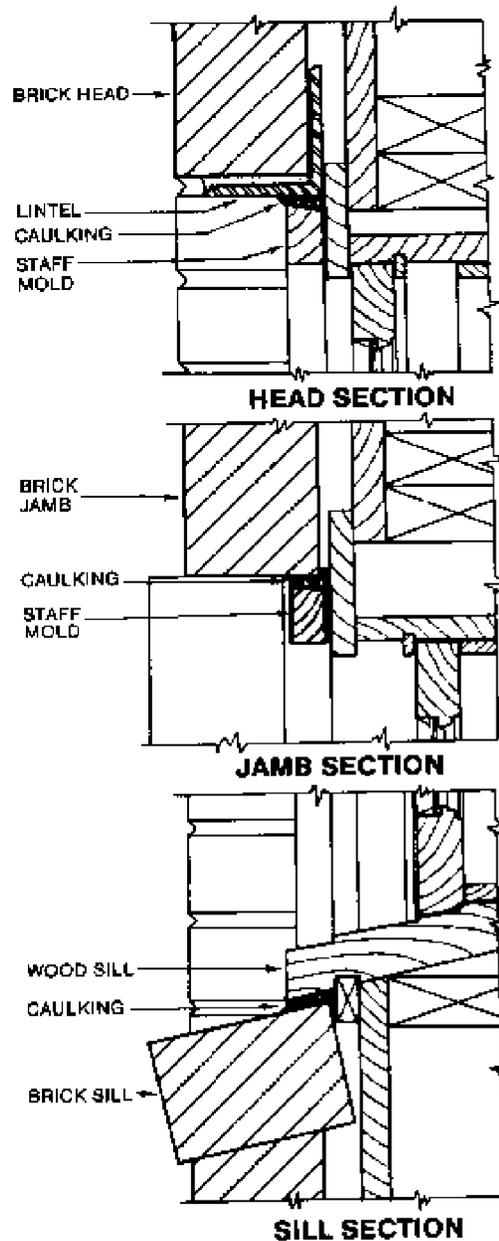


Figure 7-6. REQUIRED CAULKING AROUND WOOD WINDOW FRAME.

### 7.2.6.3 Sealing Aid and Techniques.

*a. Appearance.* Well-designed joints have a good exterior appearance, provide economical maintenance, and assure weathertight joints.

*b. Backup.* Backup material is used to control depth of sealant in a deep joint cavity. This material should be flexible enough to allow the sealant to assume the shape in compression or tension as indicated in figure 7-7.

A nonmoisture-absorbing backup material should be used. Of the resilient materials, the extruded closed-cell flexible foams and sponge rubber will be used for expansion and control joints. Tubes or beads of polychloroprene or butyl may also be used.

*c. Primer.* A primer is required on the sealant contact surfaces of porous construction materials. Depending on weather conditions, primers will dry in approximately 1 hour; coverage will average

about 200 square feet per gallon, depending on porosity of the material to be primed.

*d. Cleaning Solvents.* Solvents will not be allowed to air dry without wiping. Perchloroethylene is used for removing waxes from surfaces to be sealed. VMP-naphthlene is used for cleaning in acrylic glazing and for edges of shatterproof glass. Recommended solvents from glass manufacturers also should be considered. Use a mixture of equal parts of xylene and acetone or toluene or methyl ethyl ketone for cleaning the glazing surfaces of aluminum curtain-wall sashes. Ammonium bifluoride or muriatic acid may be used to clean masonry surfaces receiving the sealant. After the surfaces

are cleaned, neutralize the muriatic acid with a dilute solution of household ammonia, wash the joint cavity with clean water, and allow to dry.

*e. Joint Accessibility.* Where practical, a joint should be designed to be accessible for inspection and repair. When a joint becomes inaccessible after construction has been completed, the sealant should be a more permanent type considered than that which would be used for the accessible joint.

*f. Tip Size.* Select the proper tip size for the gun so that the sealant will extrude and fill the joint cavity in one pass.

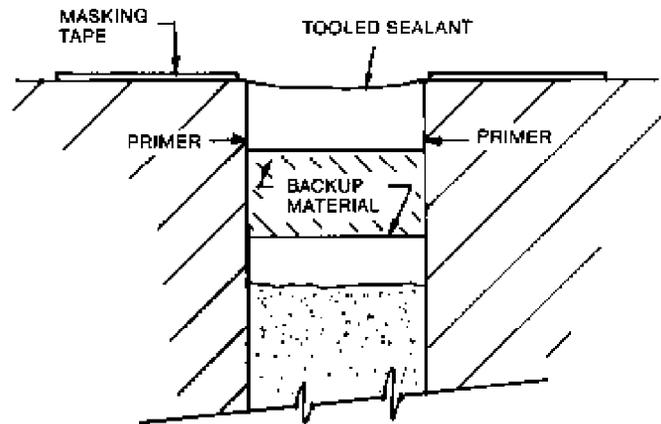


Figure 7-7. RAKED MORTAR JOINT CAVITY.

*g. Tooling.* Tooling the sealant forces the sealant into the joint cavity, insures good surface contact, and finishes off the exterior surface of the joint. Tooling white or light-colored sealants should be done with a dry or water-wet tool only. Solvents, detergents, or soapy solutions frequently used by applicators to allow the tool to slip freely, may discolor sealant surfaces.

*h. Masking.* Masking either or both surface edges of the joint cavity provides a straight line to the joint, protects wall surfaces from smears, and allows sealant to overlap slightly on the wall, providing a better surface seal. Application is suggested prior to priming, especially on light-colored masonry or other porous surfaces. Most primers discolor somewhat with age or weather exposure. Staining is easily noticeable in areas at ground level, entrance ways, steps, etc. Fresh sealing compound smears can be removed from masonry by scraping smears off immediately and rubbing clean with methyl ethyl ketone, acetone, or

a similar solvent.

#### 7.2.6.4. Surface Preparation.

*a. Steel Surfaces of Movable Joints.* The surfaces in the joint cavity to be in contact with the sealant will be cleaned of all permanent or temporary protective coatings before the sealant is applied.

*b. Steel Surfaces to Tight or Nonmovable Joints.* The sealant may be applied over the permanent coating. Temporary protective coatings will be removed to bare metal before applying the sealant.

*c. Aluminum Surface of Movable or Nonmovable Joints.* The aluminum surfaces in contact with sealants will be cleaned of the temporary protective coating. Solvents, when used for cleaning, will be as recommended by the applicators of the coating, and the solvent will be the nonstaining type. Lintless paper towels should be used for wiping off the solvent cleaner and coating. The use of rags tends to be too long,

which results in the surfaces not being well cleaned or wiped of. Masking tape is also used for temporary protective cover on the area to be in contact with the sealant. This tape should be removed just prior to the application of the sealant.

*d. Contact Surfaces of Joint Cavities.* Joint cavity contact surfaces that have come in contact with mold-release agents, curing compounds, silicon water repellents, floor hardeners, and other surface treatments will require prior cleaning preparation before sealants are installed. Wire brushing, sandblasting, masonry saw cutting, or other similar preparation may be required to clean the joint cavity in wood, concrete or masonry construction.

**7.2.6.5. Sealants.** The following general requirements and intended uses will be considered in selecting sealants. When colors are required, they should be those standard with the supplier. For unusual conditions, the purchaser and the supplier should agree on an acceptable color when cured. Painting over a cured sealant is permissible, but the supplier should again be consulted. The paint material should have some flexibility when covering movable joints.

*a. Basic Types.* The basic types of joint sealants are the so-called caulking compounds, the one- and two-component rubber-base sealants, the one-part elastomeric sealants (also tapes and beads), and preformed gaskets. Each type is manufactured in several different materials. No one material or joint design will satisfy all conditions for a good sealant installation. Each type of sealant has its limitations. Combinations of sealants make some of the most effective seals. Poor joint design, use of inappropriate sealants, and poor workmanship in preparing surfaces and applying the sealants will cause failure of the joints and sealants.

*b. Bulk-Type Compounds.* Broadly classified, sealing and caulking materials are the bulk type, supplied in cartridges, cans, or drums and applied either by gun or knife, or the preformed types, supplied in extruded shapes, tapes and beads.

(1) The principal ingredients of oil- and resin-base caulking compound are vegetable, hydrocarbon or drying oil, and resins mixed with asbestos fibers and other inert ingredients. It is ready-mixed for immediate use and can be applied under ordinary building conditions, 40° to 100° F (4.5° to 37.8° C). It is for use in wood or metal fixed joints and in very limited movable joints. It has a short life expectancy unless used where it will be regularly painted, coated, or have other protective coverings.

(2) Two-component types that are rubber

base and chemical curing are liquid polysulfide polymers and polyurethane polymers. The ambient temperature at the time of application will be 40° to 80° F (4.5° to 26.7° C), and the inservice temperature will be -60° to 200° (-51.1° to 93.3° C). They require accurately controlled premixing and careful application and cure to a rubbery material with high adhesion. Their intended uses includes expansion and movable joints in concrete, masonry, and metal; perimeter sealing of metal frames in exterior walls; curtain-wall construction as joint sealer, and beading and settling of glass and panels. The self-leveling type is used for joints in horizontal surfaces, and the nonsag type for joints in vertical surfaces.

(3) Single-component types that are rubber base and chemical-curing include sulfides, silicones, and polyurethanes. The ambient temperature at the time of application will be between 50° and 100° (10° to 37.8° C), except that the silicone type will be between 0° and 120° F (-17.8° to 8.9° C). The inservice temperatures will be from -20° to 200° F (-28.9° to 93.3° C), except that the silicone type will be from -80° to 350° F (-62.2° to 176.6° C). The sealants are premixed and ready for immediate application. They require careful handling and storage and have a relatively long curing time. They are intended for use in locations similar to those for the two-component compounds although the curing times, application temperatures, and other factors will dictate which compound will best serve the joint.

(4) Nonskinning compounds, which are polybutenes or blends of polybutenes and polyisobutylenes (butyl) mixed with asbestos fibers or other inert ingredients, are ready-mixed for immediate use. Ambient temperature at time of application will be from 0° to 10° F. Inservice temperature range will be from -60° to 200° F. The material is nondrying and the exposed surfaces are tacky. It is to be used in fixed and unmovable joints between metals or glass, as bedding compounds, in interior joints in protected locations, and in glazing metal curtain-wall construction. This type of sealant may be used below grade.

### **7.2.7. Glazing**

**7.2.7.1 General.** Glazing repair consists of sash reconditioning and replacement of broken glass. Maintenance often involves only replacement of loose, deteriorated, or missing putty. Glazing items in buildings and structures generally should be replaced using the same type of materials used in the original work. The quality of replacement materials should be improved only when justified by obvious inadequacy of the failed materials, and when

planned future use of the buildings or structure warrants it. Consideration may be given to providing double-pane insulating window glass where it can be economically justified. It should be noted that glass size is sometimes specified by the so-called "united inches method," which is the sum of the length and width of the size specified, i.e., one-half the perimeter. Example: Glass size of 12 inches wide by 15 inches long would be specified as 27 united inches.

7.2.7.2 *Flat Glass.* Flat glass used for glazing sash, doors, and other uses will conform to requirements of current Federal Specification DD-G-1403.

a. *Clear Window Glass.* Clear window glass, Type II, Class 1, Quality 96, is recommended for replacements in hospitals, administration buildings, and other similar structures. The use of Quality 96 in quarters and service buildings will afford a savings in material costs. The following schedule may be used as a guide for thickness and size of installed clear window glass: Single-strength glass should be used in sheets 400 square inches to 7 square feet in area; above that limit, glass  $\frac{3}{16}$  inch thick should be used where plate glass is not required.

b. *Polished Plate or Float Glass.* Polished, clear-vision plate or float glass is used around prominent entrances, in large openings, for air deflectors, shelving, bulletin board doors, and projection booth observation ports. Polished plate glass should be Type 1, Class 1, Quality 96, and have a nominal thickness of  $\frac{1}{4}$  inch.

c. *Wire Glass.* There are two kinds of wire glass, Type III, Class 1: A (flat) and B (corrugated). Flat wire glass, usually  $\frac{1}{4}$  inch thick, is used in doors, windows, fixed sidewall sashes, and some sky-lights. Corrugated wire glass,  $\frac{5}{16}$  inch or more thick, is used mostly in skylights. Clear, flat wire glass, polished on two sides, is used in windows and doors of detention, storage, and other buildings where security and clear vision are necessary.

d. *Obscured Glass.* Figured glass, Type III, Class 1, Kind A, Form 3, Quality 911, Finish F1, not less than  $\frac{1}{2}$  inch thick, is used where clear vision is not necessary or is undesirable. Such locations would include windows and doors in toilets, baths, dressing rooms, operating rooms, surgical dressing rooms, shops, garages, and warehouses. Figured or ribbed glass, smooth on one side, is desirable for use in doors and windows of buildings such as shops, garages, and warehouses where clear vision is not required.

e. *Heat-Absorbing Glass.* Heat-absorbing glass, Type 1, Class 2, Style A (or Style B), is

installed in the sash of control towers and other spaces where occupants are exposed to direct or reflected rays of the sun. This glass is generally  $\frac{1}{4}$  inch thick, clear, ground, and polished. Its solar-heat-reflecting and luminous-transmittance qualities are described in current Federal Specification DD-G-1403. Where clear vision is not required, the rolled figured, blue-green, obscure glass should be used.

f. *Light-Diffusing Glass.* Figured glass, Type I, Kind A, Form 5, Quality 911, Finish F2, is usually not less than  $\frac{1}{4}$  inch thick. The surface design may be a series of cylindrically shaped lenses on each side of the glass, with the lenses on one side running at right angles to the other. An alternate design is a series of parallel rows of circular lenses one each side, with the centers of the lenses on one side halfway between centers of the lenses on the opposite side. Depending on the manufacturer's standards, circular lenses may be spaced  $\frac{1}{4}$  or  $\frac{1}{2}$  inch on centers. This lens-type glass is especially desirable for use in borrowed-light partitions and in spaces where an even distribution of light in all parts of the room is necessary.

g. *Colored Glass.* Sheet glass, Type II, Class I, Quality 95, is acceptable for use in the exterior sashes of chapels. It is a hammered or figured-pattern sheet not less than  $\frac{1}{2}$  inch thick. Generally, it is amber in color. Several other colors are available.

h. *Shatterproof Glass.* Shatterproof glass is installed to advantage in observation windows in engine-test rooms, detention rooms, and other places requiring a high resistance to breakage. Glass may be tempered or laminated, not less than  $\frac{1}{4}$  inch thick, and polished on both sides. Tempered glass is made by reheating the glass until it is somewhat soft, and then cooling it quickly in a bath of oil or against a metallic surface. It withstands heavy impacts and great pressures, but a comparatively light blow with a pointed object on or near the edge may break it because of internal stresses resulting from sudden cooling. This type of glass may fly apart violently when broken. Laminated glass gives protection against flying pieces of broken glass. The glass is built up in the manner of a sandwich, with a sheet of transparent adhesive bond between two sheets of glass. If a break occurs, the plastic stretches, serves as a cushion, and holds the sharp fragments.

i. *Insulating Glass.* Double-pane and triple-pane insulating glass, each of the same nominal thickness, is separated by not less than  $\frac{3}{16}$ -inch dehydrated airspace and hermetically sealed at the factory. Dehydration should be guaranteed for a period of not less than 10 years. Glazing techniques

for insulating glass may be found in paragraph 7.2.7.10.

**7.2.7.3 Putty.** Putty for wood-sash glazing must conform to current Federal Specification TT-P-00791. Types I and II may be used interchangeably, but Type II is recommended for filling holes and cracks where a harder material is desirable. Putty and compound for metal-sash glazing must conform to current Federal Specification TT-G-410. Types I and II are both suitable for interior and exterior work. Type I is an elastic glazing compound that dries on the surface but remains slightly soft and plastic underneath. It is recommended for use, in addition to wood or metal beads, on doors, transoms, and skylights, where repeated shock or vibration may be encountered. Oil or other adulterants should not be added to putty or compound on the job. Putty or glazing compound should be stocked in relatively small quantities so that it will be fresh when used. A 30-day supply is suggested as sufficient for ordinary installation needs. One gallon of putty or compound will normally bed and face glaze approximately 100 linear feet of ¾-inch rabbet, 150 linear feet of ½-inch rabbet, or 200 linear feet of ¼-inch rabbet.

**7.2.7.4 Glazier's Points and Clips.** Glazier's points for wood-sash glazing should be standard zinc triangles of approximately ½-inch equilateral. Wire slips for metal windows vary by type of window. A reserve supply for maintenance work should be available at all times.

#### 7.2.7.5 Paint

*a. General.* Painting is mentioned here only to serve as a reminder that it must be accomplished prior to glazing or reglazing. The selection and application of paints and other protective coatings are covered in detail in a separate Tri-Services manual, "Paints and Protective Coatings" (TM 5-618, NAVFAC MO-110, AFM 85-3).

*b. Wood-Sash Primer.* Good maintenance and repair practice requires that wood-sash glass rabbets be primed or sealed before the glass is set. Shellac and quick-drying varnish should not be used as primers because they dry to hard glazed surfaces that may prevent a tight putty bond.

*c. Wood-Sash Finish Paint.* Surfaces of jambs, stop beads, and sashes in sliding contact may be finished with penetrating sealer in lieu of paint.

*d. Metal Sash.* Metal should be cleaned and primed before glazing or reglazing is done. Red lead-base, ready-mixed paint is suitable for touch-up or complete priming.

**7.2.7.6 Glasscutting.** Insofar as possible, glass should be purchased and stocked in sizes that can

be used without cutting. Glass of special sizes is cut in the shop. For glass sizes, measure all four sides of the sash and deduct  $\frac{1}{16}$  to  $\frac{1}{8}$  inch in the pane size for irregularities in the sash. Minimum equipment required for glasscutting consists of a table, a common wood or metal T-square, and a glasscutter. The table should be about 4 feet square with front and left edges square. Mark off the surface of the table vertically and horizontally in inches. A thin coating of turpentine or kerosene on the glass line to be cut is helpful in lubricating the action of the cutter wheel. A sharp cutter must be carefully drawn only once along the line of the desired cut. Additional strokes of the cutter may result in breakage. Allow about 5 percent for breakage in cutting and setting. When extensive cutting is anticipated, a commercially manufactured cutting board is available that incorporates the above-mentioned minimal equipment plus a spring-loaded grip for the glasscutter that slides along the bar, assuring good, clean glasscutting. This board is used in a vertical position and occupies very little floor space.

#### 7.2.7.7 Preparation Before Glazing.

*a. Old Wood Sashes.* Clean all putty runs of broken glass fragments and glazier's points. Remove loose paint and putty by scraping. Wipe the surface clean with cloth saturated in mineral spirits or turpentine, prime the putty runs, and allow them to dry.

*b. New Wood Sashes.* Remove dust, prime the putty runs, and allow them to dry. All new wood sashes shall be pressure-treated for decay protection (see Tri-Services manual, "Military Entomology Operations Handbook," Chapter 8, Section 5, NAVFAC MO-310, TM 5-632, AFM 91-16).

*c. Old Metal Sash.* Remove loose paint or putty by scraping. Use steel wool or sandpaper to remove rust. Clean the surfaces thoroughly with a cloth saturated in mineral spirits or turpentine. Prime bare metal and allow it to dry thoroughly.

*d. New Metal Sash.* Thoroughly clean the sash with a cloth saturated in mineral spirits or turpentine to remove dust, dirt, oil, or grease. Remove rust with steel wool or sandpaper. If the sash is not already factory-primed, prime it with rust-inhibitive paint and allow it to dry thoroughly.

**7.2.7.8 Setting Glass.** Do not glaze or reglaze exterior sash when the ambient temperature is 40° F (4.5° C) or lower unless absolutely necessary. Sash and door members must be thoroughly cleaned of dust with a brush or cloth dampened with turpentine or mineral spirits. Lay a continuous  $\frac{1}{16}$  inch thick bed of putty or compound in the putty run. See figure 7-8. The glazed face can be

recognized as the side on which the glass was cut. If the glass has a bowed surface, it must be set with the concave side in. Wire glass is set with the twist

vertical. Press the glass firmly into place so that the bed putty will fill all irregularities.

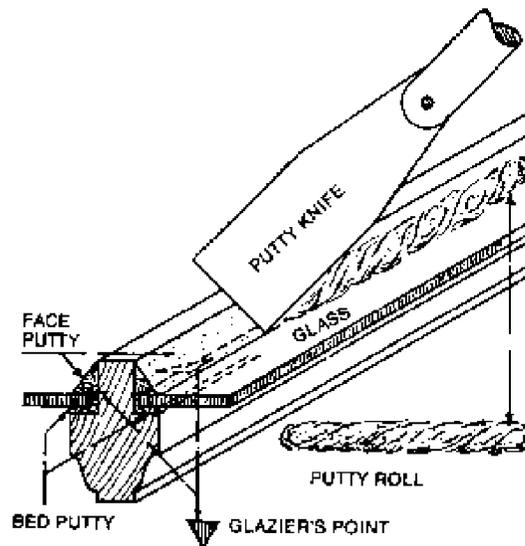


Figure 7-8. SETTING GLASS WITH GLAZIER POINTS AND PUTTY.

a. *Glazier's Points.* When glazing wood sash, insert two glazier's points per side for small lights and about 8 inches apart on all sides for large lights. When glazing metal sash, reuse the wire clips or metal glazing beads. See figure 7-9.

b. *Putty.* After the glass has been bedded, lay a continuous bead of putty against the perimeter of the glass-face putty run. Press the putty with a putty knife or glazing tool with sufficient pressure to insure its complete adhesion to the glass and sash. Finish with full, smooth, accurately formed bevels with clean-cut miters. Trim up the bed putty on the reverse side of the glass. When glazing or reglazing interior sash and transoms, whether fixed or movable, and interior doors, use wood or metal glazing beads. Exterior doors and hinged transoms should have glass secured in place with inside

wood or metal glazing beads bedded in putty. When setting wire glass for security purposes, set wood or metal glazing beads, secured with screws, on the side facing the area to be protected. Wood sash putty should be painted as soon as it has surface-hardened. Do not wait longer than 2 months after glazing. Metal sash, Type I, elastic compound, should be painted immediately after a firm skin forms on the surface. Depending on weather conditions, the time for skinning over may be 2 to 10 days. Type II, metal sash putty, can usually be painted within 2 weeks after placing. This putty should not be painted before it has hardened because early painting may retard the set. The paint should completely cover the putty and extend approximately 1/8 inch onto the glass surface to serve as a seal.

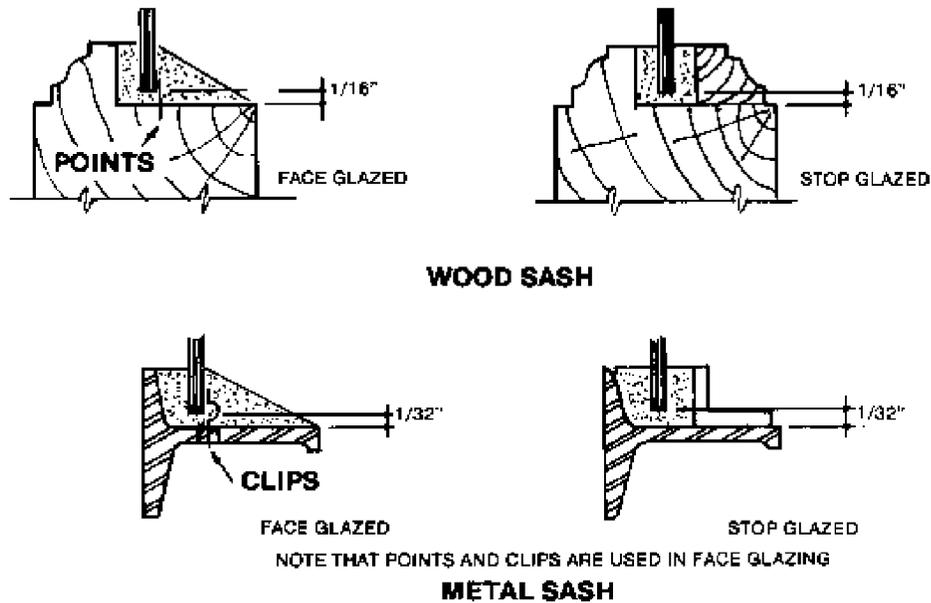


Figure 7-9. WINDOW GLAZING.

7.2.7.9 *Cleaning.* Clean the glass on both sides after painting. A cloth moistened with mineral spirits will remove putty stains. Ammonia, acid solutions, or water containing caustic soaps must not be used. When scrapers are used, care should be exercised to avoid breaking the paint seal at the putty edge.

7.2.7.10 *Insulating Glass.* Two major types of insulating glass are currently manufactured which are designed to improve the U-value of the glass unit. These are double- and triple-pane units with hermetically sealed airspaces separating the panes. The panes are separated by a desiccated spacer, which absorbs moisture from the airspace, and are permanently sealed.

a. Preparation of sashes and frames should follow the same procedures outlined in paragraph 7.2.7.7. The sash must be of sufficient width to accommodate the size unit to be installed.

Sufficient allowance must include a glazing leg minimum of  $\frac{3}{4}$  inch.

b. Two setting blocks spaced at the quarter points should be of neoprene or lead construction with manufacturer's recommended hardness and length.

c. Unit must be installed square.

d. A weep system should be incorporated into any insulating glass installation to drain excess moisture away from the unit. Weep holes should be a minimum  $\frac{1}{4}$ -inch thickness and installed three per unit.

e. Glazing methods are illustrated in figure 7-10. The tape method utilizes a high-quality rubber material suitable for specific installations with a release paper on one side. The tape is fitted to the

opening with corners butted, not overlapped, joints sealed, and the paper removed just prior to installation. Constant pressure is maintained against the tape from proper stop design. The tape and wet seal method utilizes the same procedure as the tape method except that a  $\frac{1}{8}$ -inch clearance is allowed between the top of the tape and the top of the stop which is filled with an elastomeric sealant of polysulfides, silicones, urethanes or acrylics. The edge of the sealant should be leveled to improve weatherproofing. The wet glazing method requires the use of space shims on the face of the stops at intervals of 18 inches on center maximum. The sealant is forced into the existing space using a caulking gun or power equipment. Putty and glazing compounds should not be used with insulating glass. Several structural glazing gaskets are also available for installing insulating glass as shown in figure 7-10.

f. Glazing systems which apply pressure to the edge of glass for waterproofing should be maintained at a pressure of 4 to 10 pounds per linear inch of perimeter or as recommended by the manufacturer. Avoid pressure on the marginal edge ( $\frac{1}{8}$ -inch) of the unit.

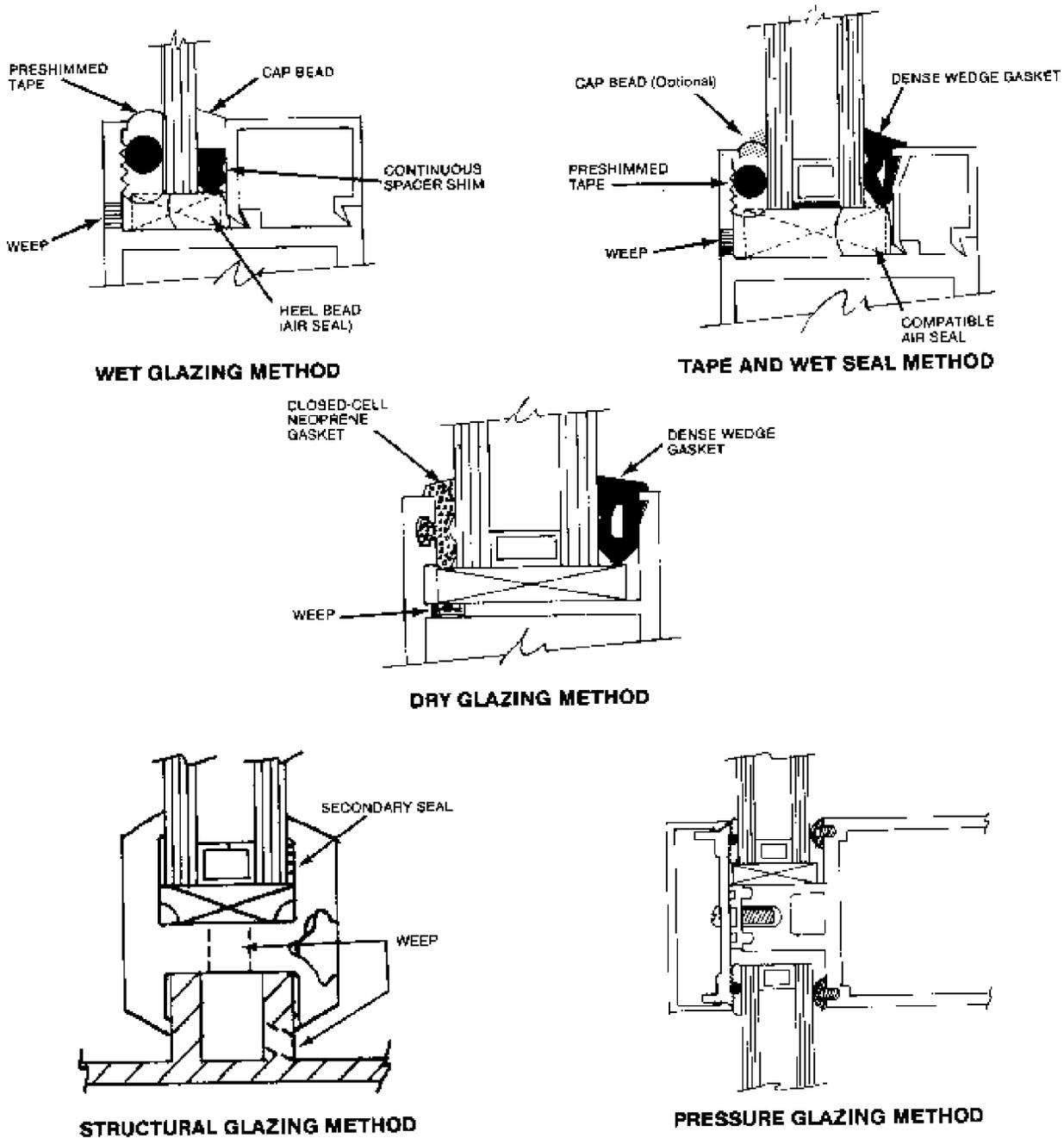
7.2.7.11 *Safety Requirements.* Handling and cutting glass creates a serious cutting hazard. Appropriate gloves and other personal protective equipment must be provided. Adequate procedures for the disposal of cuttings and broken glass should be established.

## 7.2.8 Window Screens.

Included in this category are half-length sliding window screens, full-length window screens, and fixed porch screens.

7.2.8.1 *Screen Cloth.* Mesh screening in current use is made of comparatively short-lived steel or iron wire, either painted or galvanized. Continued use of such painted or galvanized screen cloth is not recommended for other than planned, short-use buildings. Do not use steel or iron wire screening in tropical zones. The use of corrosion-resistant material, such as copper, bronze, aluminum or plastic, is recommended for most screening needs. Bronze wire is recommended for installation in barracks, dining facilities, and similar buildings where rough usage may be expected. Commercial bronze, better known as brass, is not recommended for use in areas subject to excessive condensation and salt air. Shipments of screening delivered on requisitions for bronze should be tested to see that brass has not been substituted.

7.2.8.2 *Wire and Mesh Sizes.* The diameter of metal or plastic strands and the size of the openings are important. Screen cloth having mesh openings no larger than 0.0475 inch is recommended for all installations. Screen cloth suitable for most locations is the 18 x 18 mesh per inch made with 0.011-inch-diameter strands. Screen cloth recommended for tropical areas is type with the 0.015-inch-diameter strands, with opening sizes no greater than 0.0475 inch.



COURTESY, FLAT GLASS MARKETING ASSOCIATION - GLAZING MANUAL

Figure 7-10. INSULATED GLASS GLAZING TECHNIQUES.

7.2.8.3 *Replacing Broken Screen Cloth.* A too large, free screen area is one of the causes of early screen failure. A screen area between supports will be no more than 2 x 3 feet, if possible. Window screens eventually require repair of screen cloth,

refastening of screening, or repainting. When screen is broken and replacement is necessary, cut a piece of screen cloth large enough to permit tacking to frame. Tack new screening along one end completely, holding it tight as tacking

proceeds. Then tack opposite end, pulling wire from end to end, as well as along the side which is being tacked. Finally, tack along other two sides which should require practically no pulling. Do not pull mesh out of shape, and keep strands parallel to sides of frame. Then replace molding which, when fastened down firmly, takes up any remaining slack in the wire. Prompt repair of tear will often preclude replacing entire screen. To repair a screen, cut a piece of screen cloth slightly larger than the torn opening. Bring the edges of the tear back to their original position as nearly as possible, and cover with the patch piece. Sew edges of patch to existing screen with fine wire or monofilament fishline.

7.2.8.4 *Screen Protection.* Push-bars and hardware cloth guards are screen savers, especially where

traffic is heavy. Fasten wood or metal push-bars approximately 45 inches above the floor. Hardware cloth guards extend from lock rail to bottom rail and may be either ½-inch-square mesh, 19-gage steel wire of 1-inch, diamond mesh woven from 16-gage steel wire. Guards should be given black finish. They should be set close against the screen and firmly secured at all edges.

7.2.8.5 *Screen Storage.* Removable window screens should be taken down in the fall and stored in a dry place during the winter months. Do not store screens on a concrete floor or on the ground. Inspect screen frames and screen cloth before placing them in storage. Make necessary repairs and paint frames. Patch or replace damaged screen cloth. If signs of rust or corrosion are detected, brush clean and apply a protective coating.

## SECTION III—BUILDERS' HARDWARE

### 7.3.1 Metals and Finishes

7.3.1. *General.* The composition of materials in builders' hardware is of fundamental interest. It often affects the ability of the product to maintain appearance and durability and can have an important bearing on the worth of a product under a particular circumstance. Except for the few instances where plastics, woods, and ceramics are used, builders' hardware is made of metal. Selection of the base metal and finish depends on such factors as use, exposure to elements, and appearance desired. Also, hardware in a room should harmonize in design and finish. In this discussion "base metal," which is the material out of which the basic portions of the hardware item are manufactured, is differentiated from "finish," which denotes the surface characteristics of the product. The finish may be simply the result of treatment of the basic metal, or it may be achieved by the addition of a second metal or other product.

7.3.1.2 *Base Materials.* Basic metals used in builders' hardware are brass, bronze, iron, steel, stainless steel, aluminum, and zinc. Competition between producers of the various metals, which may be cast, extruded, forged, or wrought, is frequently keen, especially with changes in production capacity and technology. Although not metal, plastics are being used in a manner similar to a base metal in manufactured hardware products.

*a. Cast Metal.* Cast metal is produced by pouring molten alloy into premolded forms. This method results in a versatile shape which can be machined, etched, or carved to yield a great variety of designs. It is very durable, withstands considerable abuse, and will take a fine finish in

brass and bronze. However, castings are costly to produce and thicknesses are not as uniform as forging and extensions.

*b. Extrudes.* Extruded shapes are produced by forcing or drawing semimolten metal through dies, like a chef uses a pastry bag. Designs having linear characteristics are possible. Extrusions are very durable but limited in application due to restrictions of cross sections that can be designed or formed. Generally, extrusions are limited to brass and aluminum.

*c. Forged Metal.* Forged metal is hammered, pressed, or rolled into shape. A smooth, dense product results from this process, the value of which relates to the thickness of the metal. Forged metal has considerable tensile strength due to the uniform denseness of the metal. It has excellent finishing and machining capabilities. Many items that were formerly cast are now forged. Material with thickness greater than 0.080 inch is acceptable in lieu of cast material.

*d. Wrought Metal.* Wrought metal is rolled into flat sheets or stripes. The products are formed by punching or diecutting into the desired forms. It may be thick, as in a hinge, or thin, as in a push-plate.

*e. Brass and Bronze.* Brass and bronze are metal alloys, the greatest portion of which are copper and those containing smaller amounts of other metals, notably lead and zinc. Bronze differs from brass in that it contains some tin. Differences in color result from the proportions of the various metals included. Cast brass has a yellowish color, while cast bronze has a reddish hue.

*f. Steel.* Steel is widely used in builders' hardware. It is stronger than iron. Ordinary carbon steel contains not only iron but portions of other elements such as carbon, manganese, phosphorus, and sulfur. Exposed to the weather, carbon steel is likely to rust. Its wide use results largely from its strength and lower cost. Most of the builders' hardware items made of wrought steel are formed in flat sheets by dies in heavy presses.

*g. Stainless Steel.* Stainless steel is an iron product of which there are about 40 standard types. Each contains substantial amounts of chromium and small quantities of a number of other elements. A majority of types also contain appreciable percentages of nickel. Because it is highly rust-resistant, has a higher luster finish, and is easily maintained, stainless steel is prized as a builders' hardware material. The popularity of this metal has increased; most manufacturers now provide a large range of stainless-steel products, such as locks, trim, door-closure arms, butt hinges, kick plates, push- and pull-plates. It is very desirable when extreme, rugged use is expected.

*h. Aluminum.* Aluminum is now in many ways in builders' hardware. It is usually alloyed with about 4 percent of other elements. Cast, forged, and wrought products are obtained by much the same processes as are other metals. Pressure-cast aluminum is frequently used as a substitute for cast iron in miscellaneous items, such as door-stops, handrail brackets, and hooks.

*i. Powdered Metal.* Powdered metal is pressed into shape and then sintered in a furnace. For additional strength, it may be sintered again. The process is employed to form a range of products from various metals..

*j. Cast Iron.* Cast iron's characteristics are its long-wearing qualities, natural lubrication, brittleness, low tensile strength, and tendency to rust. Cast iron contains 92 percent iron and small quantities of such other elements as carbon, manganese, silicon, phosphorus, and sulfur. The metal is poured into sand molds to achieve the desired shape.

*k. Malleable Iron.* Malleable iron is cast iron treated by baking or annealing to make it tough and shock-resistant. When properly cast and annealed, malleable iron can be bent and even knotted without breaking. Many manufacturers use malleable iron in items like pulls and closure arms to reduce the possibility of breakage and provide resistance to stress.

*l. Forged Iron.* Forged iron's greatest use in builders' hardware is in the manufacture of specialized or decorative trim often imitative of early-

American, hand-forged items. Iron forgings are produced by hammering a red-hot bar of iron into the desired shape. Forged iron is almost pure iron, with only about 1 percent of other elements.

*m. Zinc.* Zinc has long been used in builders' hardware as a coating over iron and steel, since it resists rust. Many products are made using die-cast zinc as a base metal. It is easily cast, machined, and plated.

*n. Plastics.* The rapid advance of plastic technology has led to the development of durable and serviceable materials such as Bakelite, nylon, delrin, lexan, lucite, and formica. Although plastics are becoming more widely used, they have many shortcomings and are not as acceptable as metal. However, plastics have been successfully used for kick plates, mop plates, door-edging lock mechanisms, knobs, pulls, and hand levers.

*7.3.1.3 Finishes.* Natural finishes take the color of the base metal in the product and may be either high or low luster. Applied finishes result from the addition by plating of a second metal, a synthetic enamel, or other material.

*a. Finishes.* Finishes for builders' hardware have undergone tremendous changes in recent years. New techniques and finishes have been introduced, changes in popularity have taken place, and some finishes have been dropped. The preparation given base materials prior to finishing consists generally of machining, buffing, and polishing. Polished brass and bronze finishes are produced by buffing or polishing the metal to a high gloss before applying a synthetic coating. Satin brass and bronze natural finishes are obtained by dry-buffing or scouring, and the resultant finish is then coated. Uncoated finishes of brass or bronze are used where natural oxidation of the entire exposed surface yields the desired result. Oil rubbing of uncoated bronze produces a dark oxidized finish suitable for some decors. The chromiums, polished and satin, are brass, bronze and nickel plating of builders' hardware has been done for scores of years, usually by means of an electrolytic process. Oxidizing is also used, especially where the designs are ornamental.

*b. Coatings.* Coatings are used to prevent tarnishing or oxidation of plated brass and bronze finishes. The original color and sheen of natural metals can be maintained for a long time with the use of modern, synthetic coating treatments.

*c. Anodizing.* Anodizing forms a protective and uniform oxide on aluminum, giving it a hard, tough skin. A variety of color anodized finishes, such as black and oxidized bronze, are available.

d. *Finish Standards.* Although the National Institute of Science and Technology, U.S. Department of Commerce, some years ago prepared product standards for the finishes used with builders' hardware, the Door and Hardware Institute (DHI) has updated the standards, consistent with current practices in the industry. DHI Standard 1301, *Finish Standards*, lists 96 standard finishes and their nearest U.S. equivalents. Samples of selected standard finishes may now be obtained from DHI.

### 7.3.2 Hands of Doors

The dictionary lists no less than 91 connotations of the word "hand." This well demonstrates the specialized language of builders' hardware and the need to understand the language. In the builders' hardware industry the position of the hinges on a door, in terms of right or left, as viewed from the outside of a building, room, or space to which the doorway leads, determines the hand. The hand of a door is a term used to indicate the direction of the swing of the door. See figure 7-11. The outside is the side from which security is necessary. In a series of connecting rooms (as in a hotel suite) the outside will be the side of each successive door approached from the entrance. For two rooms of equal importance with a passage between, the outside is the passage side. Strictly speaking, the door itself is only right or left hand; the locks and the latches may be reverse bevel. However, it is necessary to include the term reverse and to specify in accordance with the conventions shown here. This will prevent any confusion as to which side is the outside. This is especially important when different finishes are desired on the opposite sides of the door. Although the hardware items specified may be reversible, or even universal, it is good practice to identify the hand completely, in accordance with the convention here stated. For a person standing outside, the rule is that an inswinging door is regular bevel and an outswinging door is reverse bevel. Hardware in general may be:

7.3.2.1 *Universal.* Used in any position (e.g., a surface bolt).

7.3.2.2 *Reversible.* Hand can be changed by revolving from left to right, or by turning upside down or by reversing some part of the mechanism (e.g., many types of locks and latches).

### 7.3.3 Hinges

7.3.3.1 *General.* There are four basic applications of hinges: full mortise, half mortise, full surface, and half surface. See figure 7-12. Within each type there are various styles, each designed for a particular situation. In addition to these there are other design types, such as olive knuckle, modern paumelle and pivots. Hinges are further classified by such characteristics as mounting or movement control. A butt hinge is a type designed for mortising into the butt edge of the door and into the rabbet of a door frame. A spring hinge contains one or more springs to move the door into a closed position. See figure 7-13. It may be either single or double acting. A checking floor hinge is a device which combines top and bottom points for hanging the door with a controlled-speed closing mechanism. Top, intermediate, and floor pivots make possible installations to solve special design problems and to enable transfer of weight from the jamb to the floor.

7.3.3.2 *Elements of Hinges.* Swaging is a slight offset of the hinge at the barrel, which permits the leaves to come closer together and improves the operation and appearance of the door. A leaf is one of the two attaching plates, which, when fastened together by the hinge pin, form a complete hinge. Bearings (ball, oil-impregnated, or antifriction) offer the highest qualities in ease of operation and durability. Nonrising pins are a feature of quality hinges. Close tolerances, especially in the pin, prevent excessive wear, and are an important characteristic of high-quality, heavy-duty hinges. Hinges are available in brass, bronze, stainless steel, and carbon steel.

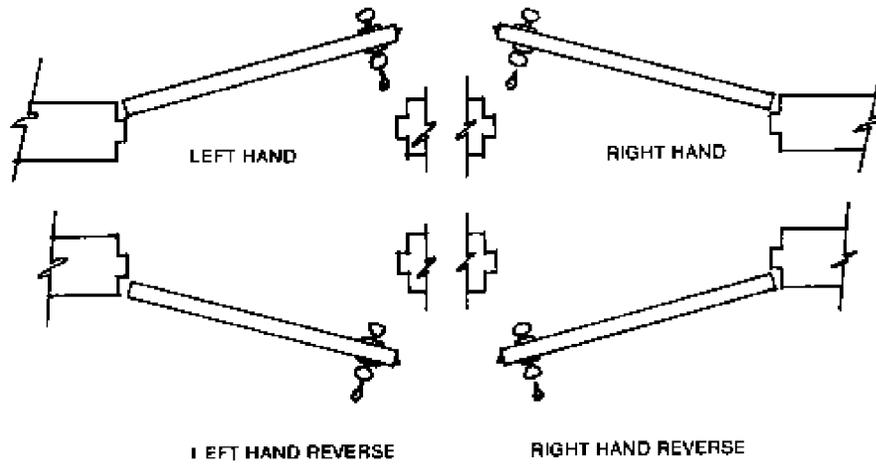
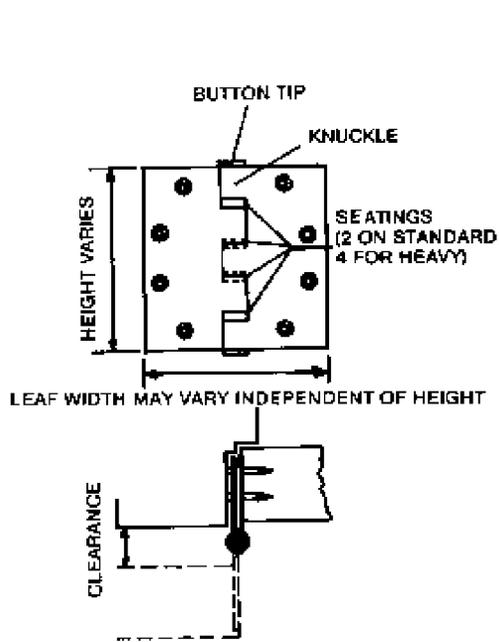
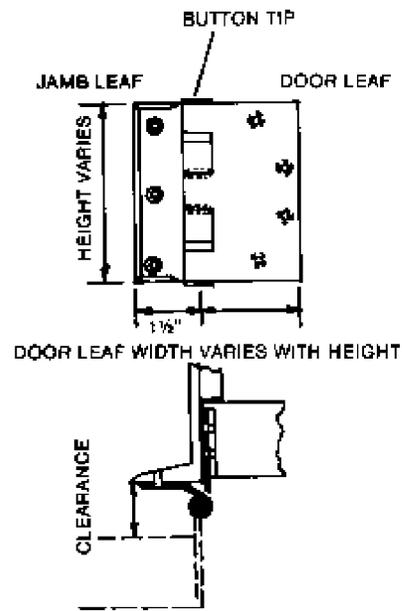


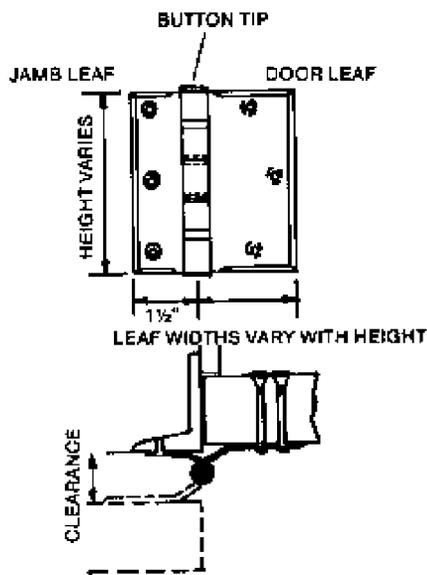
Figure 7-11. HANDS OF DOORS.



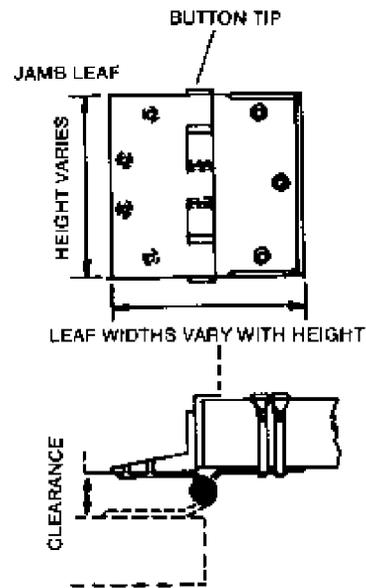
**FULL MORTISE**



**HALF MORTISE**



**FULL SURFACE**



**HALF SURFACE**

Figure 7-12. HINGE TYPES.

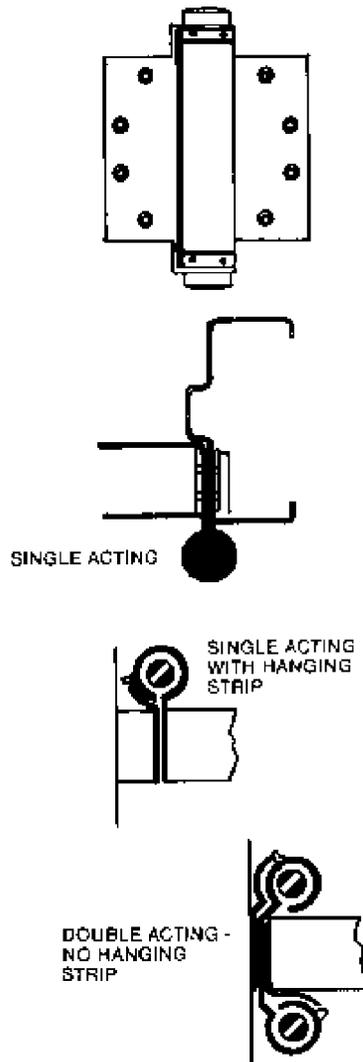


Figure 7-13. SPRING HINGES.

7.3.3.3 *How to Specify Hinges.* Hinges are specified by number (in pairs); either ball, oil-impregnated, or antifriction bearings; type of tips; type of screws; type of hinge; metal; height-width (required only for full mortise hinges); weight (standard or heavy); and finish. The number of hinges per door varies with the height of the door. Generally, a minimum of three per door is recommended, but two may suffice for doors to 5 feet high. Three are required for doors up to 7 feet 6 inches high. One additional hinge is required for every additional 30 inches. Template hinges are made to standard templates (in accordance with Government standards) to insure exact matching of hinges and

their screw holes with doors and jambs, either metal or wood, made by other manufacturers.

7.3.3.4 *Screws and Fastenings.* It is the custom to supply as regular packing all machine screws and wood screws or combination screws which can be used with both wood or metal. Through-bolts and grommet nuts, where so indicated, are furnished regularly for application of half-surface or full-surface door leaf, along with machine screws for jamb.

7.3.3.5 *Size and Gage.* It is important that the size of the hinge and the gage of metal are adequate for the job and are consistent with the size, weight, and frequency of use of the door. In sizing hinges, the

first dimension is that taken at the leaf. This is the vertical height of the hinge, which is the first numeral on full-mortise hinges, not including the tip. Table 7-1 provides a helpful tabulation for determining size and gage.

TABLE 7-1. — HINGE GUIDE

Door		Minimum Hinge Height (in)
Thickness (in)	Width (in)	
f or 1	Any	2½.
1c	To 36	3.
1d	To 36	3½.
1d	>36	4.
1¾	To 41	4½
1¾	> 41	4½ Heavy.
1¾ to 2¼	Any	5 Heavy.

Use proper width of hinge if trim clearance is required. Hinges should be heavy weight for heavy doors or doors of high frequency and unusual stress. Heavy-weight hinges should have a minimum width of 4½ inches when used for doors 1¾ inches thick. On all exterior doors opening out and reverse bevel interior doors with locks, a pin which cannot be removed when the door is closed or an interlocking leaf feature should be specified. Ball, oil-impregnated, or antifriction bearing hinges should always be specified for doors equipped with door closures.

**7.3.4. Locks**

7.3.4.1. *General.* One of the most important categories of builders' hardware is locks. The names used for locks were originally selected to identify either the type of construction or installation. Considering the great variety of functions, types, sizes, weights, security and convenience features of locks, considerable experience is fully required to select the proper lock for a particular use. The locks most commonly used in all types of construction are described below. See figure 7-14.

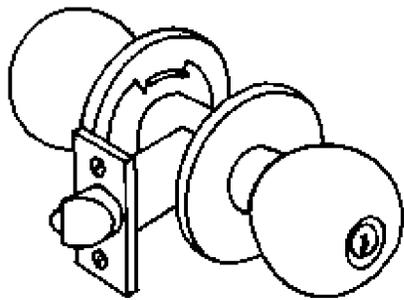
7.3.4.2. *Bored Type.* These types of locks are installed in a door having two round holes at right angles to one another, one through the face of the

door to hold the lock body and the other in the edge of the door to receive the latch mechanism. When these two are joined together in the door, they comprise a complete latching or locking mechanism. Bored-type locks have the keyway (cylinder) and locking device, such as push or turn buttons, in the knobs. They are made in three weights-heavy, standard, and light duty. The assembly must be tight on the door, without excessive play. Knobs should be held securely in place without screws and a locked knob should be removable. Roses should be threaded or secured firmly to the body mechanism. The trim has important effects in this type of lock, because working parts fit directly into the trim. Regular back-set for a bored lock is usually 2¾, but it may vary.

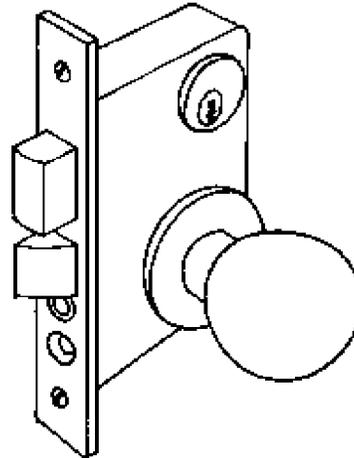
7.3.4.3. *Preassembled Type.* The preassembled-type lock is installed in a rectangular notch cut into the door edge. This lock is one that has all the parts assembled as a unit at the factory, and when installed little or no disassembly is required. Preassembled-type locks have the keyway (cylinder) in the knobs. Locking devices may be in the knob or on the rose or excutcheon. Regular back-set is 2¾ inches. The lock in available only is heavy-duty weight.

7.3.4.4. *Mortise type.* A mortise lock is installed in a prepared recess (mortise) in a door. The working mechanism is contained in a rectangular-shaped case with appropriate holes into which the required components, cylinder, knob and turn-piece spindles are inserted to complete the working assembly. Regular backset is 2¾ inches. These locks are available in heavy-duty and standard-duty weight. Armored fronts are available. In order to provide a complete working unit, mortise locks, except for those with deadlock function only, must be installed with knobs, levers, and items of trim.

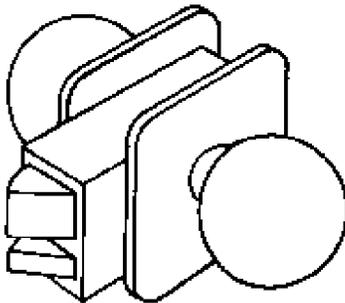
7.3.4.5. *Integral Type.* An integral lock is a mortise lock with a cylinder in the knob. It is installed in a prepared recess (mortise) in a door. A complete working unit consists of the lock mechanism and selected trim (knob, rose, escutcheon). Roses or escutcheons are bolted together through the lock case. Regular backset is 2¾ inches. This type is available only in heavy-duty weight.



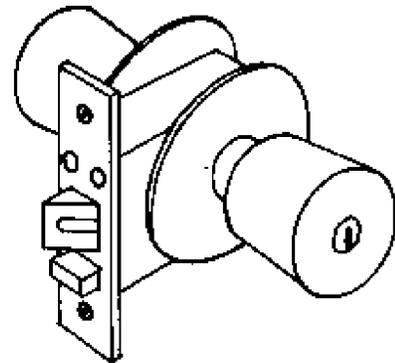
**BORED**



**MORTISE**



**PREASSEMBLED**



**INTEGRAL**

*Figure 7-14. LOCK TYPES*

7.3.4.6 *Details.*

*a. Bolts.* The lock achieves its function by means of various types of bolts. The bolt is a bar of metal, which projects out of the lock into a strike prepared to receive it.

*b. Latchbolts.* The function of a latchbolt is to hold the door in a closed position. A latchbolt is spring actuated and is used in all swinging-door locks except those providing dead-bolt function only. It has a beveled face and may be operated by a knob, handle or turn. It is recommended for the

heavy-duty bored, mortise, preassembled, and integral types that some kind of antifriction provision be incorporated. The throw of the latchbolt must not be less than ½ inch. "Throw means the projection of the latchbolt beyond the lock face. Friction occurs when a latchbolt hits the lip of the strike. An antifriction feature is recommended to insure easy closing of the door. This is particularly desirable when door-closing devices are used. This device may be a split latchbolt, a plastic insert in the bolt or in the strike, a pivoted bolt, or a self-lubricating bolt.

*c. Auxiliary Deadlatch.* An auxiliary deadlatch is a security feature and should be required on all locks used for security purposes, unless a dead-bolt function is specified. This feature deadlocks the latchbolt automatically and makes it virtually impossible to depress the latchbolt when the door is closed.

*d. Dead bolt.* A dead bolt is a bolt having no spring action and is activated by a key or by a turn. It must be manually operated. Dead bolts provide security. When hardened steel inserts are used, the security is greater. The minimum throw should be ½ inch. A dead bolt may be specified with certain functions or mortise, preassembled, and integral locks.

*e. Lock Strikes.* A lock strike is a metal plate mortised into the doorjamb to receive and to hold the projected latchbolt. It is sometimes called a "keeper." The proper length lip should be specified

so that the latchbolt will not hit the doorjamb before the strike. A wrought box should be installed back of the strike in the jam. This box will protect the boltholes from the intrusion of plaster construction debris or other foreign material, which would prevent the bolt from projecting properly into the strike. Standards covering installation dimensions for locks have been issued by the American National Standards Institute. These include dimensions for strikes, the use of which provides uniformity in frame preparation.

*f. Electric Strike.* This is an electromechanical device which replaces an ordinary strike and makes possible remote electric locking and unlocking of a door. A control mechanism actuates the electric strike and allows the door to be opened and relocked without a key. Optional features available include accommodation for dead bolt, automatic unlocking if power fails, and built-in provision to indicate the door is not locked. There are various designs of electric strikes for use with numerous types of locks and exit devices.

*g. Cylinders.* The cylinder of a lock is the cylindrical-shaped assembly containing a tumbler mechanism and the keyway, which can be actuated only by the correct keys. For servicing, such as keying, all cylinders may be removed. In some types it is also possible to remove the keyway assembly but only by means of a control key. To provide greater security, special cylinder collars are available.

## SECTION IV—MAINTENANCE AND REPAIR OF HARDWARE

### 7.4.1 Bolts and Screws

All bolt and screw heads should be carefully inspected, and any that show rust discoloration or rust scale should be thoroughly wire-brushed. If any bolts or screws have corroded to the extent that they lack good fastening strength, they should be removed and replaced. When the holes where bolts or screws are removed are too large for new fasteners, new holes should be drilled and new fasteners of the drive-screw or self-tapping type provided in an adjoining solid portion of the metal.

### 7.4.2 Door and Window Hardware

Interior and exterior hinged, sliding, and rolling doors of every type, including storm and screen doors, should be checked for faulty installation and lack of maintenance. The operation and condition of hinges, lock assemblies, closers, tracks, hangers, and other hardware items should be checked. If parts are rusted, they should be cleaned and a light

coat of oil applied. The same procedure applies to the mechanical operator for monitor sash and skylights. Available keys should be fitted for proper lock operation. Brass and bronze surface plates and knobs should be cleaned as described in paragraph 7.4.11.

### 7.4.3 Door-Closing Devices

The first thing to check on any closing device is proper installation according to the manufacturer's instruction sheet. Often closers are applied too near or too far from the hinge jamb, which affects operation as well as shortening the life of the closer. It is imperative that the closer and its arm be in their correct places and firmly fastened. Familiarization with the adjustment features of the devices to be maintained is necessary for a proper understanding of their functions. The manufacturer's instruction sheet should be valuable for this. Closing devices that have hydraulic controlling action, such as liquid door closers and checking

floor hinges, must be refilled with the correct type of fluid at regular intervals. Keeping closers full of liquid is one way to prolong their lives as well as insure smooth operation. Finally, all closing devices should be overhauled periodically, which involves complete disassembly and cleaning in the shop. Floor-type closers for exterior doors in locations subject to ice and snow are usually difficult to maintain and should always be installed on the inside of outswinging doors. To simplify maintenance, concealed-type door closers should be limited to locations where they are necessary for operational reasons.

#### 7.4.4 Locksets

The basic function of a lockset is to lock or latch a door in its closed position; therefore, the first order of maintenance should be to determine whether the lock is in alignment with its strike. The latch-bolt should set easily into the strike without any binding or scraping. The dead bolt, when projected by action of key or turn, should also seat without cutting away wood or other material behind the strike. In the operation of knobs, set screws must be tight. Before tightening, however, the knob action should be tested to see if it is free. If not, the setscrews should be loosened in the shank and knob turned counterclockwise, just enough to permit easy action without binding. Then the setscrews should be retightened. Make sure they bear against a flat side of the spindle rather than on a corner. If the knobs have "screwless" or "clutch" fastenings, a spanner wrench will be needed to make adjustments. The wrench should be used to loosen the inside knob shank, and this knob or its shank component threaded up or down the spindle, depending on the adjustment necessary. The lubricating agent for locks and cylinders is dry graphite. Do *not* use grease or oil. To free gummed or corroded parts, kerosene or penetrating oil may be used, but this should be allowed to evaporate before reassembly. Bored or unit types of locksets represent a somewhat different problem in that they have knobs and roses assembled in an integral part of the lock mechanism. Adjustment features differ greatly among the various makes; therefore, it is recommended that the manufacturer's instructions be consulted before any attempt is made to correct poor installations.

#### 7.4.5 Thresholds

Loose fastenings are often a source of trouble with thresholds. At each inspection, screws should be tightened, and loose anchors and expansion shields replaced. Check for dirt and gravel, particularly in interlocking types. The door strip should be set in

the interlock. Replacement thresholds should always be placed in new caulking bases.

#### 7.4.6 Sliding-Door Equipment

The various types of hangers have both vertical and lateral adjustment. Find how these work and consult the manufacturer's specifications to attain the utmost efficiency in keeping the doors sliding easily. Bottom tracks and guide channels should be kept free of debris.

#### 7.4.7 Panic-Exit Devices

Particular care must be taken to insure proper operation of exit devices. Under no circumstances should bars, chains, padlocks, or auxiliary locks be used on exit doors. Familiarization with these devices will enable personnel to keep them functioning to lock against ingress while still permitting unimpeded egress. This involves keeping strikes aligned and free of debris so that latches will hold. Crossbars that are loose or flabby in action indicate that service is needed. Check for worn springs, pivots, or spindles. When astragals are present, they should be adjusted to keep center clearance at a minimum. See discussion of fire doors, paragraph 7.1.6.

#### 7.4.8 Security Fences and Gates

To maintain stability and to correct alignment, connections for gates, posts, braces, guys, and anchor on security fences should be tightened. Hinges, latches, locking devices, and other hardware should be cleaned and lubricated for easy operation.

#### 7.4.9 Skylights

Skylights made of multiple supporting members and panes are often a source of leaks. As a rule, maintenance consists only of replacing sealing strips, cushion strips, and skylight compound at joints between glass sheets. When glass, metal flashings, and joint cappings must be replaced, materials and methods should be similar to those used in the original installation. Wood or steel structural frame members that have deteriorated should be replaced.

#### 7.4.10 Vents

Metal vents should be inspected for deterioration caused by lack of protective paint or inadequate paint coverage. Vents should not be exposed to standing water. They should be equipped with a flashing flange to prevent early flashing failure because of expansion and contraction of the vents. For metal flashing, roof-drainage devices, gravel

stops and edge strips, see Tri-Services manual, "Maintenance and Repair of Roofs," (TM 5-617, NAVFAC MO-113. AFP 91-31, MCO P11014.9).

#### **7.4.11 Cleaning and Maintenance of Aluminum**

7.4.11.1 For routine cleaning of aluminum, the mildest method will usually work easily and well. However, conditions vary, and if the surfaces have been neglected for a long time, it may be necessary to experiment with small areas before selecting a method. Three methods of routine cleaning are:

*a.* Wash with clean water and dry thoroughly. Wash with a synthetic detergent cleaner, rinse, and dry. Use a nonetching chemical cleaner according to the cleaner manufacturer's directions.

*b.* If the aluminum has accumulated a thick coating of dirt, it is usually easier to remove the heavy dirt with a solvent cleaner. Then try one of the following operations: a wax-base polish cleaner with a clean, soft rag or pad, following the manufacturer's directions; a nonwax-base polish cleaner with a clean, soft rag or pad, following manufacturer's directions; or a mild abrasive cleaner (scouring powder) on a damp, clean cloth. Rinse well and dry after any of these operations.

*c.* If the results of methods (a) and (1)) are unsatisfactory, use a stainless-steel wool pad of fine texture with a liquid wax or one of the cleaners mentioned under method (b). Mild steel wool can also be used; however, any remaining particles will rust-stain the aluminum and should be removed.

7.4.11.2 In the process of waxing aluminum, the aluminum should be cleaned thoroughly with a solvent cleaner. The wax should be applied with a soft, clean cloth; polishing should be done with another soft cloth. Before lacquering an aluminum surface, old lacquer that is worn off in spots should be stripped completely with a lacquer remover. The

surface should be cleaned with a solvent-type cleaner. For good lacquer adhesion, it is preferred that a good "tooth" on the surface be attained by using an etching type of cleaner. After 3 to 5 minutes, the surface should be rinsed with clean water, and then a thorough wet coat of lacquer applied by paint spray equipment, if available. Otherwise, a clean paintbrush should be used, and the lacquer thinned as the manufacturer recommends. The first coat should be allowed to dry, and then a second coat applies in the same manner. To protect aluminum from stains and other damage, the use of strong cleaners should be avoided and the aluminum padded against scraping or denting by heavy loads.

#### **7.4.12 Brass and Bronze Finishes**

Natural brass and bronze finishes age quite well and contribute to the beauty of a building. No attention to this hardware is required other than wiping it with a damp cloth until the original lacquer begins to wear off. When abrasion of the lacquer becomes apparent, the best appearance will be achieved by use of a lacquer thinner or some nonacid agent to remove all remaining lacquer coating. Then the piece may be polished with brass polish. In time, the latter will impart an attractive, soft luster, characteristic of old brasses and bronzes.

#### **7.4.13 Miscellaneous**

There are many types of builders' hardware items not specifically mentioned in this manual. All of them must be examined periodically if they are to function properly. Tight fastenings and proper lubrication will keep most of them working. The applicable hardware manufacturer's instructions for assembly and parts should be available for the proper maintenance of hardware items.

APPENDIX A

REFERENCES

**Government Publications**

29 CFR 1910.1001 Public Law—Code of Federal Regulations, Title 29, Part 1910 1001.

Department of Defense Manuals

DOD Construction Criteria Manual 4270.1 M

*Tri-Services Manuals*

TM 5-609, NAVFAC MO-125, AFP 91-2 . . . . Military Custodial Services

TM 5-617, NAVFAC MO-113 and MCO

P11014.9 AFP 91-31. . . . . Maintenance and Repair of Roofs

TM 5-622, NAVFAC MO-104, AFP 91-34 . . . Maintenance of Waterfront Structures

TM 5-618, NAVFAC MO-110 AFP 85-3 . . . . Paints and Protective Coatings

TM 5-632, NAVFAC MO-310 AFP 91-16 . . . Military Entomology Operational Handbook

TM 5-624, NAVFAC MO-102 AFP 85-8 . . . Maintenance and Repair of Surfaced Areas

TM 5-695, NAVFAC MO-117 AFP 91-37 . . . Maintenance of Fire Protection System

*Department of Navy Technical Publications*

NAVFAC Design Manual 14.2 . . . . Carpet Selection Guide

*Department of Air Force Technical Publications*

Air Force Design Manual . . . . Interior Finish Materials

*Federal Specifications*

AA-L-30 . . . . Gypsum Board

AA-V-00200B . . . . Venetian Blinds

CS-35-61 . . . . Plywood

DD-G-1403 . . . . Glass Plate (Float), Sheet Figured and Spandrel Heat-Strengthened and Fully Tempered)

HH-R-590 . . . . Roofing Felt (Asbestos, Asphalt-Saturated)

HH-R-595 . . . . Roofing Felt, Coal-Tar and Asphalt-Saturated Organic Felts, Rolls

LF-475 . . . . Floor Covering, Vinyl

L-F-1641 . . . . Floor Covering, Sheet Vinyl

LLL-B-810 . . . . Building Board, (Hardboard) Hard Pressed, Vegetable Fiber

LLL-F-1238A . . . . Floor Covering Linoleum

MMM-A-110 . . . . Adhesive Asphalt, Cut-Back Type (for Asphalt and Vinyl Asbestos Tile)

MMM-A-115 . . . . Adhesive, Asphalt, Water-Emulsion Type (for Asphalt and Vinyl Asbestos Tile)

MMM-A-001993 . . . . Adhesive, Epoxy, Flexible Filled for Binding Scaling and Grouting

O-C-114 . . . . Calcium Hypochlorite, Technical

O-S-602 . . . . Sodium Hypochlorite Solution

O-S-642 . . . . Sodium Phosphate, Tribasic, Technical, Anhydrous, Dodecahydrate and Monohydrate

P-P-101 . . . . Paper Abrasive, Silicon Carbide, Waterproof

P-P-105 . . . . Paper Abrasive, Flint

P-P-121 . . . . Paper Abrasive, Garnet

P-S-865 . . . . Oil and Water Absorbing Compounds

PS-1-66 . . . . Plywood

P-W-155 . . . . Wax, Floor, Water Emulsion: w/gpl Supplements

QQ-L-101 . . . . Lath, Metal, (and Other Metal Plaster Bases)

**TM 5-620/NAVFAC MO-111/AFP 91-23**

QQ-S-698 .....	Steel, Sheet and Strip, Low Carbon
QQ-S-700D .....	Steel Sheet and Strip, Medium and High Carbon
R-P-381 .....	Ptich, Coal-Tar: (for) Aggrate-Surfaced Built-up Roofing, Waterproofing, and Dampproofing
SS-A-666 .....	Asphalt, Petroleum (Built-up Roofing, Waterproofing, and Dampproofing)
SS-A-694 .....	Asphalt, Petroleum (Coating, Brushing and Spraying Consistency)
SS-A-701 .....	Asphalt, Petroleum (Primer, Roofing and Waterproofing)
SS-B-755 .....	Building Board, Asbestos-Cement: Flat and Corrugated
SS-C-153 .....	Cement Bituminous Plaster Type-i, with Asphalt Saturated Felts and Type II with Coal-Tar Saturated Felts
SS-C-161A .....	Cement: Keen's
SS-L-30D .....	Lath, and Board Products, Gypsum
SS-L-351 .....	Lime: Hydrated (For) Structure Purposes
SS-R-501 .....	Roofing Felt, Asphalt-Prepared, Smooth Surfaced
SS-S-118A .....	Sound Controlling Blocks and Boards (Prefabricated Acoustical Tiles and Panels
SS-S-200D .....	Sealing Compounds, two component, Electronic, Polymer Type, Jet Fuel Resistant, Cold Applied
SS-S-1401 .....	Sealing Compound, Hot Applied, For Concrete and Asphalt Pavements
SS-S-1614 .....	Sealing Compound, Jet Fuel Resistant, Hot Applied, One Component, For Portland Cement and Tar Concrete Pavements
SS-T-312 .....	Title, Floor: Asphalt, Rubber, Vinyl, Vinyl Asbestos
TT-C-598 .....	Calking Compound, Oil and Resin Base Type (For Masonry and Other Structures)
TT-F-336 .....	Filler, Wood Paste
TT-G-410 .....	Glazing Compound, Sash (Metal) for Back Bedding and Face Glazing (not for Channel Stop Glazing)
TT-P-00791 .....	Putty: Pure Linseed Oil (for Wood Sash Galzing)
TT-R-251 .....	Bemover, Paint (Organic Sovent Type)
TT-S-176 .....	Sealer, Surface-Varnish Type, Floor, Wood and Cork
ZZ-M-71d .....	Sheeting, Rubber
ZZ-M-71E .....	Matting, Rubber and Vinyl
<i>Department of Defense Specifications</i>	
DOD-C-2687B .....	Notice 1, Compound, Battery Sealing (Metric)
<i>Military Specifications</i>	
MIL-L-14519C .....	Limestone, Pulverized
<i>Military Standards</i>	
MIL-STD-865A .....	Notice 2, Selective (Brush Plating) Electrodisposition
<i>US. Department of Commerce, Product Specifications</i>	
PS 1-74 .....	Construction and Industrial Plywood
PS51-71 .....	Hardwood and Decorative Plywood

*U.S. Department of Interior Publications*  
 Concrete Manual, Bureau of Reclamation  
*General Services Administration Publications*  
 A-A-373A .....

Glazing Compound, Sash (Metal) for Back Bedding  
 and Face Glazing (Not for Channel or Stop Glazing)

**Non-Government Publications**

*American Society for Testing and Materials*  
 (ASTM), 1916 Race Street, Philadelphia, PA  
 19103

ASTM C-28-80 .....	Specification for Gypsum Plastic
ASTM C-33-80 .....	Specification for Concrete Aggregates
ASTM C-36-80 .....	Specification for Gypsum Wallboard
ASTM C-67-81 .....	Brick and Structural Clay Tile, Sampling and Testing
ASTM C-94-80 .....	Specification for Ready-Mixed Concrete
ASTM C-144-76 .....	Specification for Aggregate for Masonry Mortar
ASTM C-208-72 .....	Structural Insulating Board Made from Vegetable Fibers
ASTM C-220-77 .....	Specification for Flat Asbestos-Cement Sheets
ASTM C-270-80a .....	Specification for Mortar for Unit Masonry
ASTM C-631-70 .....	Specification for Bonding Compounds for Interior Plastering
ASTM C-669-75 .....	Specification for Glazing Compounds for Back Bedding and Face Glazing Metal Sash
ASTM C-840-79 .....	Specification for Application and Finishing of Gypsum Board
ASTM C-881-78 .....	Epoxy-Resin Base Bonding System for Concrete
ASTM D-41-78 .....	Primer for use with Asphalt in Dampproofing and Waterproofing
ASTM D-43-73 .....	Specification for Cresosote for Priming Coat with Coas-Tar Ptich in Dampproofing and Waterproofing
ASTM D-173-80 .....	Specification for Woven Cotten Fabric Saturated with Bituminous Substance for Use in Waterproofing
ASTM D-226-77 .....	Asphalt-Saturated Roofing Felt for Use in Waterproofing and in Constructing Built-up Roofs
ASTM D-312-78 .....	Asphalt for use in Constructing Built-up Roof Cover- age. Type Depending on Slope of Roof
ASTM D-449-73 .....	Specification for Asphalt Used in Dampproofing and Water Proofing
ASTM D-450-78 .....	Specification for Coal-Tar Pitch for Roofing, Damp- proofing and Waterproofing
ASTM D-1187-66 .....	Specification for Asphalt Base Emulsions for Use and Protective Coating for Metal
ASTM D-1327-78 .....	Specification for Bitumin-Satruated Woven Burlap Fabrics Used in Roofing and Waterproofing
ASTM D-1668-80 .....	Specification for Woven Glass Fabric Treated with Bituminous Substance for Use in Waterproofing
ASTM D-1751-73 .....	Specification for Preformed Expansion Joint Fillers for Concrete Paving and Structural Construction (Nonextruding and Resilient Bituminous Types)

**TM 5-620/NAVFAC MO-111/AFP 91-23**

ASTM D-1752-67 .....	Specification for Preformed Sponge Rubber and Cork Expansion Joint Filler for Concrete Paving and Structural Construction
ASTM D-1850-74 .....	Specification for Concrete Joint Sealer, Cold-Application Type
<i>National Fire Code Standards</i>	
National Fire Protection Association, Batterymarch Park, Quincy, MA 02269	
1 .....	Fire Prevention Code
80 .....	Fire Doors and Windows
220 .....	Standard Types of Building Construction
252 .....	Fire Doors
<i>NFPA Publications</i>	
National Forest Products Association, 1619 Massachusetts Ave., NW., Washington, DC 20036	
National Design Specification for Wood Construction Design Values for Wood Construction	
<i>PCA Publications</i>	
Portland Cement Association Publications, Old Orchard Road, Skokie, IL 60076	
ACI-318 .....	Building Code Requirements for Reinforced Concrete
<i>DHI Publications</i>	
Door and Hardware Institute, 7711 Old Springhouse Road, McLean, VA 22102	
DHI-1301 .....	Finish Standards
<i>Shell Chemical Co. Publication</i>	
Shell Chemical Co., P.O. Box 2463, Houston, TX 77002	
SC 106-84 .....	Recommendations for Handling Resins and Auxiliary Chemicals
<i>John Wiley and Sons Publications</i>	
John Wiley and Sons., Inc., 605 3rd Avenue, New York, NY 10158	
"Building Construction, Materials and Types of Construction" by Whitney Clark Huntington and Robert E. Mickadeit.	
<i>F. G.M.A. Publications</i>	
Flat Glass Marketing Association, 3310 Harrison Street, Topeka, KS 66611.	

APPENDIX B.  
SAMPLE FORMAT

1. Check List For Inspecting Timber Trusses

Inspector \_\_\_\_\_ Date \_\_\_\_\_

Building and Truss Data	Building Number					
	Truss Number					
	Type of Truss					
	Truss Span					
	Truss Spacing					
	Truss Clear Height					
Overall Inspection of Entire Truss	Truss Laterally Bowed					
	Truss Vert. Sagging					
	Truss Long. Racking					
Detailed Inspection of Truss Joints and Members	Member Ruptured					
	Members Separated					
	Member Bowed					
	Severe Checking					
	Critical Splits					
	Mold, Decay & Stain					
	Bolt Head Crushing					
	Gusset Plate Condition					
Inspection of Ancillary Members	Bridging & X-Bracing					
	Exp. Joint Pocket					
	Purlin & Connection					
	Strut & Connection					
	Truss End Bearing					
	Lower Chord Stays					
	Columns or Pilasters					

SAMPLE FORMAT

2. BUILDING DATA FOR INSPECTING ROOF FRAMES

Building Number	Roof Slope	Frame Type
Clear Low	Monitor	Year
Height: Roof	Roof	Built
Building Width: _____ panels, each _____ = _____ x _____ frames = _____		
Building Length: _____ frame spaces, each _____ = _____		
Deck: Exposed _____ Concealed _____	Frame: Exposed _____ Concealed _____	Column: Exposed _____ Concealed _____
Deck Material _____	Frame Material _____	Column Material _____
Roof Insulation _____	Ceiling Insulation _____	Wall Insulation _____

PLAN AND CROSS-SECTION SKETCHES

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	
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## APPENDIX C

### Example of Typical Cost Analysis

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This appendix provides a method for evaluating the economic advantages of using one material and/or method in lieu of others. The approach presented here may be used, with little modification, to evaluate the relative economic advantages of any selection of building or structure maintenance alternatives.

This example analysis is a life cycle cost study of painting existing wood siding versus overlaying existing siding with new prefabricated siding and insulation. It is divided into four parts. Paragraph C.1 discusses general factors impacting on the study. Paragraph C.2 compares continuing the present system, but with insulation added to the outside and protected by new siding-any kind of siding. Paragraph C.3 compares four types of factory prefinished siding with sufficient insulation added to provide each type with the same degree of thermal energy conservation. Paragraph C.4 provides the cost data source for all the figures used in C.2 and C.3 and a generic description of the four fictional materials used as siding overlayment.

#### **C.1 General**

##### **C.1.1 Purpose**

To provide an evaluation of the economic advantages of installing new exterior prefabricated siding and insulation over wood siding in lieu of repainting the existing wood siding.

##### **C.1.2 Consideration of Useful Life**

Only those maintenance alternatives which have a useful life shorter than, or equal to, the remaining useful life of the structure should be evaluated. Generally, major repairs should be accomplished on only those facilities identified on the approved installation master plan as being approved for long-term retention and utilization.

##### **C.1.3 Estimating Useful Life**

The estimate of remaining useful life should be based on sound engineering judgment considering the total facility, including all necessary structural, mechanical, and functional elements necessary to realize the remaining useful life.

##### **C.1.4 Life Cycle Costing**

Life cycle costing is the evaluation of the total of all costs and savings identified with a particular

alternative throughout the useful life of that alternative. Life cycle costs can be compared by equating all costs to their present value cost. When comparing life cycle costs, care must be taken that the life cycle considered is for the same length of time for each alternative and does not exceed the expected retention time for that facility.

##### **C.1.5 Present Value Cost**

Present value cost is the sum of money that will grow at a prescribed interest rate to either a specified sum in one particular year or will grow to annual equal expenditures over a specified number of years. It is the amount of money, if put into an interest-bearing account, will be just sufficient to cover each cost as the cost arises. The account's rate of interest would be the current discount rate adjusted by the projected rate of inflation. The discount rate is prescribed by the appropriate regulation for each service, and is used at 10 percent in the examples that follow below.

##### **C.1.6 Selection of Alternative**

The alternative with the lowest present value cost, including any initial cost, is the most economical. A final selection based upon features not expressible in monetary terms and not shown to be most economical must be justified.

##### **C.1.7 Estimating Costs**

Cost estimates for life cycle costing should be made using known comparable costs whenever possible. These may be obtained from local facility records, records at other facilities, higher commands, and current commercially published and nationally recognized estimating manuals. The source of all cost estimates should be documented and cost estimate computations should be included with the cost analysis.

##### **C.1.8 Recurring Costs**

All costs recurring annually or at intervals must be escalated to the time expenditure is made. Energy Conservation Investment Program procedures and other regulations provide guidance for escalation rates of usual construction, maintenance and repair costs, and energy types. Energy escalation costs vary depending on the energy source (see table C-1).

TABLE C-1. — Escalation Rates

Type	Rate (pct)
Coal .....	5.0
Fuel Oil .....	8.0
Natural or Liquid Petroleum Gas .....	8.0
Electricity .....	7.0

The escalation rate and discount rate are combined into cost factors in table C-2. Costs recurring at intervals must use the "one-time cost factors" in the first column of each table.

The accumulative total cost shown in the second column may be used when the basic cost item occurs each year. In the absence of better information, escalation rates for replacement, repair, and maintenance costs may be taken at 5 percent. If any future costs are forecast by more accurate means, such as an appropriate regulation, the present value is obtained by using the estimated future cost and the 0 percent rate as shown in table C-2 Rate A. In all four tables in table C-2, the discount rate is 10 percent.

Table C-2 — Differential Escalation Discount Factors

The one-time cost factors are likely to be applied to one-time costs occurring in isolated years after the program year. Recurring *benefits/cost* factors are to be applied to identical annually recurrent cash flow. \* These factors are to be applied to cost elements which are anticipated to escalate at the same rate as the general price level.

Economic life years	Rate A		Rate B	
	Differential inflation rate—0%* Discount rate—10%		Differential inflation rate—5%* Discount rate—10%	
	One-time cost factors	Recurring benefits/cost factors	One-time cost factors	Recurring benefits/cost factors
1 .....	0.954	0.954	0.977	0.977
2 .....	0.867	1.821	0.933	1.910
3 .....	0.788	2.609	0.890	2.800
4 .....	0.717	3.326	0.850	3.650
5 .....	0.652	3.977	0.811	4.461
6 .....	0.592	4.570	0.774	4.461
7 .....	0.538	5.108	0.739	5.974
8 .....	0.489	5.597	0.706	6.680
9 .....	0.445	6.042	0.673	7.353
10 .....	0.405	6.447	0.643	7.996
11 .....	0.368	6.815	0.614	8.610
12 .....	0.334	7.149	0.586	9.196
13 .....	0.304	7.453	0.559	9.755
14 .....	0.276	7.729	0.534	10.288
15 .....	0.251	7.980	0.509	10.798
16 .....	0.226	8.209	0.485	11.284
17 .....	0.208	8.416	0.464	11.748
18 .....	0.189	8.605	0.443	12.191
19 .....	0.172	8.777	0.423	12.614
20 .....	0.156	8.993	0.404	13.018
21 .....	0.142	9.074	0.385	13.403
22 .....	0.129	9.203	0.368	13.771
23 .....	0.117	9.320	0.351	14.122
24 .....	0.107	9.427	0.335	14.458
25 .....	0.097	9.524	0.320	14.777

Economic life years	Rate C		Rate D	
	Differential inflation rate—7%* Discount rate—10%		Differential inflation rate—8%* Discount rate—10%	
	One-time cost factors	Recurring benefits/cost factors	One-time cost factors	Recurring benefits/cost factors
1 . . . . .	0.986	0.986	0.991	0.991
2 . . . . .	0.959	1.946	0.973	1.964
3 . . . . .	0.933	2.879	0.955	2.919
4 . . . . .	0.908	3.787	0.938	3.857
5 . . . . .	0.883	4.670	0.921	4.777
6 . . . . .	0.859	5.529	0.904	5.681
7 . . . . .	0.836	6.364	0.888	6.569
8 . . . . .	0.813	7.177	0.871	7.440
9 . . . . .	0.791	7.968	0.856	8.296
10 . . . . .	0.769	8.737	0.840	9.136
11 . . . . .	0.748	9.485	0.825	9.961
12 . . . . .	0.728	10.212	0.810	10.770
13 . . . . .	0.708	10.920	0.795	11.565
14 . . . . .	0.688	11.608	0.781	12.346
15 . . . . .	0.670	12.278	0.766	13.112
16 . . . . .	0.651	12.930	0.752	13.864
17 . . . . .	0.634	13.563	0.739	14.603
18 . . . . .	0.616	14.180	0.725	15.329
19 . . . . .	0.600	14.779	0.719	16.041
20 . . . . .	0.583	15.363	0.699	16.740
21 . . . . .	0.567	15.930	0.687	17.427
22 . . . . .	0.552	16.482	0.674	18.101
23 . . . . .	0.537	17.019	0.662	18.762
24 . . . . .	0.522	17.541	0.650	19.412
25 . . . . .	0.508	18.049	0.638	20.050

**C.1.9 Applicability**

The policy and method outlined herein are applicable to all buildings with siding problems, including family housing.

**C.1.10 Designation of Siding as Repair**

If the existing siding has deteriorated or will not successfully hold paint for the minimum period presented in the appropriate regulations, re-siding may be classified as repair when life cycle costing proves re-siding to be the most economical alternative.

**C.2 Insulation Comparison**

**C.2.1 Options Considered**

Two options were considered: Option I — Sandblasting and repainting; or Option II — Overlayment residing. Various types of siding coupled with various types and thicknesses of insulation should be considered to arrive at an optimum combination. Factors to be considered are:

**C.2.1.1 Initial Construction Costs.** Re-siding costs should include the finish and trim material around doors, windows, vents, utility service, and mechanical equipment. These trim costs will vary with the various thicknesses of insulation selected and the greater thicknesses may require extensive reworking of jambs, sills, and heads.

**C.2.1.2 Annual Maintenance Costs.** In spite of manufacturers' claims, siding is not maintenance free. An estimate must be made of the amount that has to be replaced each year due to abuse and accidental damage.

**C.2.1.3 Energy Savings.** Increases in thickness of insulation will produce increases in fuel savings with diminishing savings until an optimum is reached. Some sidings provide R values as an inherent characteristic while others such as unbacked aluminum, steel, and vinyl provide negligible values. The U factor of the complete system must be considered in the analysis.

**C.2.1.4 Appearance Life Expectancy of Siding.** After a number of years all brands of siding exhibit some color shift. Eventually there will be a damaged panel replaced with new material which will differ significantly in color from the existing. When the color differences become unsightly, it will be necessary to paint the entire wall even though the original finish is sound.

**C.2.1.5 Life Expectancy of Substrate.** All substrates will eventually wear out. Excessive moisture, corrosive atmosphere and sunshine will cause siding to rust, corrode or shatter requiring complete replacement.

**C.2.2 Life Cycle Energy Cost Comparison**

Increased insulation reduces annual energy costs

and increases initial installation and annual maintenance costs. Greater amounts of insulation may produce unusual installation problems and increase the initial costs disproportionately to the energy saving. The optimum amount of insulation can only be determined by complete analysis of costs and savings. According to table 9-2, DoD Construction Criteria Manual 4270.1M, buildings to be heated to 65° F (18.4° C) must have a U-factor in walls of 0.1 Btu/hr-ft<sup>2</sup>-F either in new construction or in repair renovation work. While a U-factor of 0.1 may not represent the optimum value it is the maximum requirement and will serve as a basis for comparing energy costs with the existing wall.

C.2.2.1 Example assumptions:

Exterior Building wall Area . . . . .	=	4000 ft <sup>2</sup>
Fuel Oil Cost Escalation Factor . . . . .	=	8 et
Electricity Cost Escalation Factor . . . . .	=	7 et
Construction Cost Escalation Factor . . . . .	=	5 pet
Differential Inflation Discount Rate . . . . .	=	10 pet
Retention Time of Building . . . . .	=	5 yrs
Design Heating Temperature Difference . . . . .	=	48°F (8.9°C)
Equivalent Cooling Temperature Difference . . . . .	=	35°F (1.7°C)

C.2.2.2 Comparison Analysis:

Item	Unit cost	Cost source *	PV factor	Cost
<i>OPTION I —</i>				
<i>Continue Existing System</i>				
Repaint . . . . .	1365	C.14.4.1	1.0	\$1,365
Repaint . . . . .	455	C.14.4.1	4.461	2,030
Heat . . . . .	1606	C.14.4.1	4.777	7,672
Cool . . . . .	288	C.14.4.1	4.670	<u>1,345</u>
Total Cost . . . . .				\$12,412
<i>OPTION II —</i>				
<i>Insulated to U= 0.1 with siding overlayment</i>				
Reside . . . . .	5925	C.14.4.3	1.0	\$5,925
Repair . . . . .	38	C.14.4.3	4.461	167
Heat . . . . .	703	C.14.4.2	4.777	3,358
Cool . . . . .	126	C.14.4.2	4.670	<u>588</u>
Total Cost . . . . .				\$10,038

\*Paragraph number of cost data source.

C.2.2.3 Conclusions. Adding insulation to a relatively uninsulated building is cost effective and becomes even more cost effective as fuel prices rise. The optimum thickness of insulation may be determined by using realistic costs and retention time of building. It appears that adding insulation with new siding overlayment would not be cost effective for retention times of less than 5 years. For the balance of this illustrative

example it is assumed the optimum U-factor is 0.10 Btu/hr-ft<sup>2</sup>-F.

C.3 Siding Comparison

C.3.1 Life Cycle Siding Costs

Having determined that adding insulation will be cost effective for the building retention time, comparisons with continuing existing siding may be eliminated. The justification for one type of siding over others will depend on current installed costs of siding; effective life expectancy of the siding substrate before complete replacement is required; effective life expectancy of the siding finish material before cyclical repainting is required; and retention time of building. In the example that follows four types of siding are selected, all obtaining the same U factor by adding appropriate amounts of insulation. Building retention time is not determined in order to illustrate the impact retention time has on final decision.

C.3.2 Example assumptions

Building will be the same as in C.2 except building retention time is unspecified and siding characteristics are as follows:

C.3.2.1 Siding Material "A"—A heavy duty siding with a factory-bonded high-quality film finish material. The siding requires ¾ inch of rigid polystyrene insulation board to obtain the required U-factor. The finish material is estimated to require 4-year cyclical painting starting in the 21st year, with complete replacement of the substrate in the 31st year.

C.3.2.2 Siding Material "B"—A light-duty siding with a factory-applied paint finish. The siding requires ¾ inch of rigid polystyrene insulation board to obtain the required U-factor. The finish material is estimated to require 4-year cyclical painting starting in the 13th year, with complete replacement of the substrate in the 25th year.

C.3.2.3 Siding Material "C"—A heavy-duty siding with a factory applied enamel paint finish. The siding requires ¾ inch of rigid polystyrene insulation board to obtain the required U-Factor. The finish material is estimated to require 4-year cyclical painting, starting in the 13th year with complete replacement of the substrate in the 31st year.

C.3.2.4 Siding Material "D"— wood fiberboard having a factory-applied paint finish. The siding has inherent insulative value requiring ¼ inch of additional rigid polystyrene board insulation to achieve the required U-factor. The finish material is estimated to require 3-year cyclical painting, starting in the 9th year, with complete replacement of substrate in the 15th year.

**C.3.3 Comparison Analysis**

Since U-factors are equal for all cases, the fuel costs will be equal and may be eliminated from

the analysis. Present value costs, in the year occurring, are tabulated in table C-3.

TABLE C-3. -Present Value Costs of Sidings

Year	Siding material								Yr
	"A"		"B"		"C"		"D"		
	P.V. of M&R costs*	Accum. total costs	P.V. of M&R costs*	Accum. total costs	P.V. of M&R costs*	Accum. total costs	P.V. of M&R costs*	Accum. total costs	
0	6725	6725	5925	5925	6125	6125	4825	4825	0
5	126	6851	122	6047	324	6449	20	5028	5
9	104	6955	101	6148	269	6718	594	5622	9
12	—	6955	—	6148	—	6718	752	6374	12
13	87	7042	442	6590	581	7299	—	6374	13
15	—	7042	—	6590	—	7299	2456	8830	15
17	72	7114	552	7142	668	7967	—	8830	17
20	—	7114	—	7142	—	7967	101	8931	20
21	306	7420	458	7600	554	8521	—	8931	21
24	—	7420	—	7600	—	8521	296	9297	24
25	382	7802	1896	9496	461	8982	—	9227	25

\*Present Value of Maintenance and Repair costs is obtained by multiplying current cost data presented in paragraph C.14.4 by the Recurring Benefits/Costs factors for the year the cost will be incurred as shown in table C-2.

**C.3.4. Conclusion**

The foregoing tabulation of costs indicates that for retention periods of less than 11 years, siding overlayment material "D" should be used. For 12 to 16 years-siding overlayment material "B" should be used, and for periods of 17 years or greater, siding overlayment material "A" should be selected.

Using:

$$U_{av} = \frac{S}{100} (U_s) + \left\{ 1 - \frac{S}{100} \right\} (U_i) \text{ EQ. 9}$$

(1977 ASHRAE Fundamentals Handbook, pg. 22.5)

**C.4 Cost Data**

**C.4.1 Wall U-values Option I-Existing:**

Wall component	R-value	
	Through Wall	Through Framing
Outside Air Film (15-mph wind)	0.17	0.17
3/4-inch shiplap siding	1.05	1.05
3/4-inch solid wood sheathing	0.94	0.94
3-1/2-inch airspace	1.01	—
Nominal 2" x 4" wood stud	—	4.38
1/2-inch gypsum wall board	0.45	0.45
Inside air film	0.68	0.68
R=	4.30	7.67
TOTAL U = 1/R	0.233	0.13

Where:

- U<sub>av</sub> = Average U-value for building section
- U<sub>i</sub> = U-value for area between framing members
- U<sub>s</sub> = U-value for area backed by framing members
- S = Percentage of area backed by framing members

Assume 20 percent framing.

$$U_{av} = \frac{20}{100} (0.13) + \left\{ 1 - \frac{20}{100} \right\} (0.233)$$

$$= 0.21 \text{ Btu/hr-ft}^2\text{-F}$$

Option II—Overlayment re-siding with insulation:

Wall component	R-value	
	Through Wall	Through Framing
Existing . . . . .	4.30	7.67
New siding with 1/2 inch insulating board/foil-backed . . . . .	1.82	1.82
3/4-inch rigid polysterene . . . . .	4.16	4.16
R= . . . . .	10.28	13.65
TOTAL U = 1/R . . . . .	0.097	0.073

$$U_{av} = \frac{S}{100} (U_s) + \left( 1 - \frac{S}{100} \right) (U_f) =$$

$$U_{av} = \frac{20}{100} (0.073) + \left( 1 - \frac{20}{100} \right) (0.097) = 0.092 \text{ Btu/hr-ft}^2\text{-F}$$

The differences in R-value between the most common types of siding — steel, aluminum, and solid vinyl are negligible. However, some sidings are themselves significantly insulative or are manufactured with an integral insulation backer layer and the U-values of these types should be calculated independently. Various thicknesses of insulation impact on fuel savings. A separate preliminary analysis should be made of differing thicknesses of insulation to determine the thickness and corresponding U-value for optimum savings over the life of the building. Included should be the variable costs of finishing around doors, windows, etc., and special means of support and attachment for the greater thicknesses of insulation. In this example the optimum thickness of insulation is assumed to be 3/4 inch of rigid polystyrene which produces a U-value lower than the maximum of 0.10 required by DOD regulations in new or rehabilitative work.

**C.4.2 Heating and Cooling Loads**

C.4.2. 1 Use the equation  $Q = U_{av}A(t_i - t_o)$  to determine the heat gain and loss in Btu per hour.  $U_{av}$  is the coefficient determined in C.4.1. above, A is the wall area, and  $(t_i - t_o)$  is the difference

between the design interior and design exterior temperature in ° Fahrenheit.

Heating:

Existing  $Q = (0.21)(4,000)(65-17) = 40,820$  Btu/hr  
 With Overlayment  $Q = (0.092)(4,000)(65-17) = 17,664$  Btu/hr

C.4.2.2 Use the equation  $Q = U_{av}A(CLTD)$ . Assume frame wall, each exposure having equal area, i.e., 1,000 ft<sup>2</sup> on north, east, south, and west walls. The average Cooling Load Temperature Difference (CLTD) = 35°F @ 1,400 hr, ASHRAE Fundamentals Handbook, Table 7,1977, p.25.9. (Calculations are made on transmitted sensible heat gain only. Other heat gains are not affected by siding modifications.)

Cooling:

Existing  $Q = (0.21)(4,000)(35) = 29,400$  Btu/hr  
 With Overlayment  $Q = (0.092)(4,000)(35) = 12,880$  Btu/hr

**C.4.3 Energy Consumption Estimates**

Heating: Using eq. 1 on p. 43.8 of the 1976 ASHRAE Systems Handbook for calculating energy consumption by the Modified Degree Day Method:

$$E = \left( \frac{H_L \times D \times 24}{t \times V} \right) C_D C_F$$

- E = Fuel consumption for the estimate period
- HL= Design heat loss, Btu/hr
- D= Degree days; assume 3865 F—Day
- t = Temperature difference = (65 — 17)
- = Rated efficiency; assume 70 pct
- V= Heating value of fuel; 138,700 Btu/gal for distillate fuel oil
- C<sub>D</sub> = Correction factor for heating effect vs degree days
- C<sub>F</sub> = Part load correction factor
- Table 3\*, assume 40 percent oversizing, CF= 1.79

Table 2\*, 17°F design temperature C<sub>D</sub> approx. = 0.86

\*1976 ASHRAE Systems Handbook, p.43.8

C.4.3.1 Existing Siding, H<sub>L</sub> = 40,320 Btu/hr

$$E = \left( \frac{40,320 \text{ Btu/hr} \times 3865 \text{ F} \cdot \text{Day} \times 24 \text{ hr/day}}{48 \text{ F} \times 0.70 \times 138,700 \text{ Btu/gal}} \right)$$

$$(0.86)(1.79)$$

E = 1,235 gal  
 Cost = 1,235 gal x \$1.30/gal  
 Cost \$1,606/year

C.4.3.2 Siding Overlayment, H<sub>L</sub> = 17,664 Btu/hr

$$E = \left( \frac{17,664 \times 3865 \times 24}{48 \text{ F} \times 0.70 \times 138,700} \right) (0.86)(1.79)$$

E = 541 gal  
 Cost = 541 gal x \$1.30/gal  
 Cost \$703

C.4.3.3 Cooling: Use Equivalent Full Load Hour Method. Assume 1200 full load hours of operation of equipment. Using Table 4 on p.43.9 in the 1976 ASHRAE Systems Handbook, and assuming central air conditioning unit; power input is approximately 1.63 kW/ton.

a. Existing Siding:

$$E = \frac{29,400 \text{ Btu/hr} \times 1.63 \text{ kW/ton} \times 1,200 \text{ hr}}{12,000 \text{ Btu/hr/ton}}$$

$$= 4,792 \text{ kWh}$$

Cost = 4,792 kWh x \$0.06/kWh = \$288/yr

b. Siding Overlayment:

$$E = \frac{12,880 \text{ Btu/hr} \times 1.63 \text{ kW/ton} \times 1,200 \text{ hr}}{12,000 \text{ Btu/hr/ton}}$$

$$= 2,099 \text{ kWh}$$

Cost = 2,099 kWh x \$0.06/kWh = \$126/yr

C.4.4 Construction Costs:

a. Existing Siding

Paint wood siding (primer + 1 coat) 0.26/ SF x 4,000 SF	=	\$1,040
Paint wood trim (primer + 1 coat) 0.44/ SF x 200 SF	=	88
Windows and doors (primer + 1 coat) 0.25/ SF x 500 SF	=	125
Repair of Siding 2.80/SF x 40 SF	=	<u>112</u>
Total — Initial and M&R costs		
each 3 years	.....	\$1,365
Average annual cost ÷ \$1,365-		
3	.....	= 455

b. Sliding Overlayment—Material "A"—Life expectancy of substrate is 30 years and finish is 20 years. Repainting will start in 21st year with complete replacement of siding in 31st year.

Install new siding overlayment 1.15/ SF x 4,000 SF	=	\$4,600
Bead-board backer 0.10/SF x 4,000 SF	=	400
3/4" polystyrene foam insulation 0.40/ SF x 4,000 SF	=	1,600
Paint windows and doors (as above) 0.25 SF x 500 SF	=	<u>125</u>
Total — Initial Cost and Replacement Cost in 31st Year		
	.....	<u>\$6,725</u>
Replace damaged siding 3.00/SF x 10 SF	=	\$30
Paint windows and doors (as above) 0.25/ SF x 500SF	=	<u>125</u>
Total — M&R Costs (5th yr and each 4 yrs thereafter)		
	=	\$155
Paint without priming (1 coat) 0.16/ SF x 4,000SF	=	<u>640</u>
Total — M&R Cost in 21st year		
	.....	\$795
Repaint Siding: Add prime coat 0.10/ SF x 4,000SF	=	<u>400</u>
Total — M&R Cost after 21st year		
	=	\$1,195

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*c. Siding Overlayment—Material "B"—Life expectancy of substrate is 24 years and finish is 12 years. Repainting will start in 13th year with complete replacement of siding in 25th year.*

Install new siding overlayment 0.95/ SF × 4,000 SF . . . . .	=	\$3,800
Bead-board backer (as above) . . . . .	=	400
3/4-inch polystyrene foam insulation (as above) . . . . .	=	1,600
Paint windows and doors (as above) . . . . .	=	<u>125</u>
Total — Initial Cost and Replace- ment Cost in 25st Year . . . . .	=	<u>\$5,925</u>
Replace damaged siding 2.50/SF × 10 SF . . . . .	=	\$25
Paint windows and doors (as above) . . . . .	=	<u>125</u>
Total — M&R Costs (5th yr and each 4 yrs thereafter) . . . . .	=	\$150
Average annual M&R cost 150:×4 . . . . .	=	38
Paint without priming (as above) . . . . .	=	<u>640</u>
Total — M&R Cost in 13th year . . . . .	=	\$790
Repaint Siding: Add prime coat (as above) . . . . .	=	<u>400</u>
Total — M&R Cost after 13th year . . . . .	=	\$1,190

*d. Siding Overlayment-Material "C"—Life expectancy of substrate is 30 years and finish is 12 years. Repainting will start in 13th year with complete replacement in 31st year. Although the life expectancy of this siding substrate is quite long it is highly susceptible to damage therefore annual maintenance costs are high.*

Install new siding overlayment \$1.00/ Sfx4,000 SF . . . . .	=	\$4,000
Bead-board backer (as above) . . . . .	=	400
3/4-inch polystyrene foam insulation (as above) . . . . .	=	1,600

Paint windows and doors (as above) . . . . .	=	<u>125</u>
Total—Initial Cost and Replace- ment Cost in 3th year . . . . .	=	<u>\$6,125</u>
Replace damaged siding 2.75/SF× 100 SF . . . . .	=	\$275
Paint windows and doors (as above) . . . . .	=	<u>125</u>
Total—M&R Costs (5th yr and each 4 yrs thereafter) . . . . .	=	\$400
Paint without priming (as above) . . . . .	=	<u>640</u>
Total—M&R Cost in 13th year . . . . .	=	\$1,040
Repaint Siding: Add prime coat (as above) . . . . .	=	<u>400</u>
Total—M&R Cost after 13th year . . . . .	=	\$1,440

*e. Siding Overlayment-Material "D"—Life expectancy of substrate is 14 years and finish is 8 years. Repainting will start in 9th year with complete replacement of siding in 15th year.*

Install new siding overlayment 0.95/ SF× 4,000 SF . . . . .	=	\$3,800
3/4 inch rigid polystyrene insulation 0.25/ SF× 4,000 SF . . . . .	=	1,000
Paint windows and doors (as above) . . . . .	=	<u>125</u>
Total--Initial Cost and Replace- ment Cost in 15th year . . . . .	=	<u>\$4,825</u>
Replace damaged siding 2.50/SF× 50 SF . . . . .	=	\$125
Paint windows and doors (as above) . . . . .	=	125
Total—M&R Costs (5th yr and 20th yr) . . . . .	=	\$250
Paint without priming (as above) . . . . .	=	<u>640</u>
Total—M&R Cost in 9th and 24th yr . . . . .	=	\$890
Repaint Siding: Add prime coat (as above) . . . . .	=	<u>400</u>
Total—M&R Cost in 12th year . . . . .	=	\$1,290

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