NATIONAL BUREAU OF STANDARDS REPORT

3994

ROOF MAINTENANCE MANUAL

By

H. R. Snoke and W. C. Cullen

Sponsored by
Repairs and Utilities Division
Office of the Chief of Engineers
Department of the Army

and

Maintenance Division
Bureau of Yards and Docks
Department of the Navy

NBS

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

U. S. DEPARTMENT OF COMMERCE
Sinclair Weeks, *Secretary*

NATIONAL BUREAU OF STANDARDS
A. V. Astin, *Director*

THE NATIONAL BUREAU OF STANDARDS

The scope of activities of the National Bureau of Standards is suggested in the following listing of the divisions and sections engaged in technical work. In general, each section is engaged in specialized research, development, and engineering in the field indicated by its title. A brief description of the activities, and of the resultant reports and publications, appears on the inside of the back cover of this report.

Electricity and Electronics. Resistance and Reactance. Electron Tubes. Electrical Instruments. Magnetic Measurements. Process Technology. Engineering Electronics. Electronic Instrumentation. Electrochemistry.

Optics and Metrology. Photometry and Colorimetry. Optical Instruments. Photographic Technology. Length. Engineering Metrology.

Heat and Power. Temperature Measurements. Thermodynamics. Cryogenic Physics. Engines and Lubrication. Engine Fuels.

Atomic and Radiation Physics. Spectroscopy. Radiometry. Mass Spectrometry. Solid State Physics. Electron Physics. Atomic Physics. Nuclear Physics. Radioactivity. X-rays. Betatron. Nucleonic Instrumentation. Radiological Equipment. AEC Radiation Instruments.

Chemistry. Organic Coatings. Surface Chemistry. Organic Chemistry. Analytical Chemistry. Inorganic Chemistry. Electrodeposition. Gas Chemistry. Physical Chemistry. Thermochemistry. Spectrochemistry. Pure Substances.

Mechanics. Sound. Mechanical Instruments. Fluid Mechanics. Engineering Mechanics. Mass and Scale. Capacity, Density, and Fluid Meters. Combustion Controls.

Organic and Fibrous Materials. Rubber. Textiles. Paper. Leather. Testing and Specifications. Polymer Structure. Organic Plastics. Dental Research.

Metallurgy. Thermal Metallurgy. Chemical Metallurgy. Mechanical Metallurgy. Corrosion.

Mineral Products. Porcelain and Pottery. Glass. Refractories. Enameled Metals. Concreting Materials. Constitution and Microstructure.

Building Technology. Structural Engineering. Fire Protection. Heating and Air Conditioning. Floor, Roof, and Wall Coverings. Codes and Specifications.

Applied Mathematics. Numerical Analysis. Computation. Statistical Engineering. Mathematical Physics.

Data Processing Systems. Components and Techniques. Digital Circuitry. Digital Systems. Analogue Systems.

Cryogenic Engineering. Cryogenic Equipment. Cryogenic Processes. Properties of Materials. Gas Liquefaction.

Radio Propagation Physics. Upper Atmosphere Research. Ionospheric Research. Regular Propagation Services.

Radio Propagation Engineering. Frequency Utilization Research. Tropospheric Propagation Research.

Radio Standards. High Frequency Standards. Microwave Standards.

- Office of Basic Instrumentation
- Office of Weights and Measures

NATIONAL BUREAU OF STANDARDS REPORT

NBS PROJECT **NBS REPORT**

1004-40-4843 March 22, 1955 3994

ROOF MAINTENANCE MANUAL

By

H. R. Snoke and W. C. Cullen

Floor, Roof and Wall Coverings Section
Building Technology Division

Sponsored by
Repairs and Utilities Division
Office of the Chief of Engineers
Department of the Army

and

Maintenance Division
Bureau of Yards and Docks
Department of the Navy

NBS

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

ROOF MAINTENANCE MANUAL

INDEX

ROOF MAINTENANCE MANUAL

******

1. INTRODUCTION

1.1 Purpose and Scope

The purpose of this manual is to provide a guide for an economical system of roof inspections, maintenance, repairs and reroofing. For convenience, each type of roofing is treated in a self-contained section, except for cross references to avoid repetition.

2. GENERAL DISCUSSION

2.1 Importance of Periodic Inspections

The first step in the establishment of a proper roof maintenance program is the adoption of a periodic inspection system. The early discovery and correction of minor defects forestalls major repairs and extends materially the date when reroofing is necessary. Since a large proportion of early roof failures are flashing failures, the regular inspection of flashings is of vital importance.

Regular inspections should be made by competent personnel at least once each year, and always in the Spring. This time is best because it follows the severe winter conditions and is followed by the period best suited for roofing work.

Inspections should be made even though a roof has been exposed for less than one year. The first yearly inspection is of great importance because it frequently discloses minor defects that were not apparent when the roofing or reroofing job was completed.

The roof inspection record should be made a part of the historical file maintained for each structure. This continuing record will be of considerable value in determining the roof treatment that may be necessary. Suggested forms for maintaining historical records and for use in inspections of the various kinds of roofs are shown in Appendix I.

In addition to scheduled inspections, inspections must be made after exposure of the roofs to unusually severe weather conditions such as very strong winds, hail or long-continued rain.

2.2 Maintenance

Roof maintenance, for the purpose of this manual, is defined as the treatment given a roof prior to any actual failure. It may consist in the correction of minor defects in small areas, such as resurfacing bare spots in mineral-surfaced built-up roofs; or it may involve treatment of the entire roof area, such as recoating a smooth-surfaced built-up roof.

The importance of proper roof maintenance cannot be emphasized too strongly. With good maintenance, roofs do not leak, the useful life of the roof is extended many years and the cost per year for roofing is reduced to a bare minimum.

Some types of roofing require more maintenance than others, but every establishment should have a well-trained roof maintenance crew of a size determined by the kinds of roofing and the roof areas involved.

2.3 Repairs

Roof repairs, as distinguished from roof maintenance, are considered to be the treatments given a roof following at least partial failure. These, too, may be minor repairs involving small areas, such as the replacement of broken slate or tile; or they may be major repairs involving the whole roof, such as applying additional layers of felt over a built-up roof.

Minor repairs should be accomplished by the roof maintenance crew. In most cases major repairs should be accomplished by contract with a reliable local roofing contractor.

2.4 Reroofing

Every roof ultimately requires reroofing. While the main purpose of this manual is to serve as a guide for extending the useful life of roofs by proper maintenance and repair methods, of equal importance is the development of criteria for determining the point at which maintenance and repair treatments become unsound economically and reroofing is indicated. Many factors enter into this determination, of which some of the most important are: age of the roofing, unusual exposure conditions such as hail or strong winds, previous maintenance and repair or lack of these, and the current and possible future use of the structure. It is only by weighing all of the pertinent factors that a proper decision can be made.

3. CAUSES OF ROOF FAILURES

3.1 Lack of Maintenance

Failure to recognize and correct minor defects and deterioration in its earliest stages are probably the greatest causes of premature roof failures. Since the whole theme of this Manual is roof maintenance, the simple listing of it as the primary cause of failure suffices here.

3.2 Normal Weathering

All roofing materials deteriorate on exposure to the weather, the rate of deterioration being determined largely by the kind of material and the conditions of exposure.

Some slate roofs in this country are more than 100 years old; the oldest copper roof is more than 200 years; and "tin" roofs exposed 80 or more years are not uncommon. On the other hand, roofs of poor quality slate have been known to fail in 10 years; copper roofs may fail within one year through failure to provide for expansion and contraction, though the metal has not deteriorated; and "tin" roofs deteriorate rapidly when painting is neglected. These are only a few of the examples that might be given. In general, inorganic roofing materials tend to deteriorate less rapidly on exposure than the organic ones. Metal roofs subject to rapid oxidation must be protected.

3.3 Use of Unseasoned Lumber

The use of unseasoned lumber for roof framing and roof decks is a frequent cause of premature roof failure. Figure 1* illustrates roll roofing torn loose from the warped sheathing boards. Movement in the roof deck may cause breakage of rigid roofing materials such as slate, tile and asbestos-cement shingles, and unsightly buckles in roll roofings, asphalt shingles and built-up roofs.

3.4 Storage

Roofing materials, though intended for direct exposure to the weather, may be harmed if exposed before application. Consequently, roofing materials should be stored under cover at all times. Similarly, improper storage such as in direct contact with the ground or in stacks that are too high may damage the roofing material.

3.5 Improper Application of Roofing Materials

Workmanship in applying roofing materials is as important as the selection of the proper materials. Inferior materials applied well will give good service as long as the materials resist weathering, but a roof improperly applied will give poor service from the beginning.

Some of the most common application faults are:

Built-Up Roofs

Failure to apply a layer of building paper over wood decks or other decks with open joints (Figure 2).

Failure to cover knot holes and cracks in wood decks with metal.

Applying built-up roofs in cold or wet weather.

Inadequate nailing of felts in built-up roofs, resulting in the blowing-off and slipping of felts on steeper slopes.

*Illustrations are grouped at the end of this report.

Inadequate moppings of hot bitumen between the plies of felt.

Inadequate application (mopping instead of pouring) of hot bitumen in the construction of slag or gravel surfaced roofs.

Too heavy application of asphalt on the weather surface of smooth-surfaced built-up roofs. See Figure 3.

Failure to broom felts smoothly behind the mop, resulting in poor adhesion, wrinkles and buckles. See Figure 4.

Asphalt Roll Roofings

Failure to cement the seams of roll roofings or to use the proper kind of cement.

Applying roll roofings with exposed nails. See Figure 5.

Nailing roll roofing too close to the edge of the sheet. See Figure 6.

Failure to cut roll roofing into short (12-18 ft.) lengths and failure to permit it to lie flat to lose the "roll".

Failure to cover resinous knots, knot-holes, or wide cracks in the roof deck with sheet metal.

Failure to use metal drip edge at eaves and rake.

Asphalt Shingle Roofs

Nailing asphalt shingles too high. Figure 7.

Failure to cement down the tabs of asphalt shingles with quick-drying cement in windy areas.

Failure to use metal drip edge at eaves and rake.

Failure to use roll roofing underlay over eaves in areas subject to freezing and thawing.

Metal Roofs

Failure to provide adequate side and end laps with corrugated sheet roofings.

Failure to paint tin (terne) roofing.

Failure to provide adequately for expansion and contraction with changes in temperature.

Failure to fasten sheets adequately.

Rigid Roofing Materials (Slate - Asbestos-Cement - Tile)

Nailing too tightly.

Using improper nails.

3.6 Use of Improper Materials

Practically all roofing materials are best suited for a particular type of service and some are definitely unsuited to certain conditions. It is obvious that shingle-type materials serve best on the steeper slopes and that the lower pitched roofs require roofing that will provide a continuous sheet over the entire area.

Shingle-type roofs (asphalt, asbestos-cement, slate, wood) may be used safely on slopes of five inches or more per foot. On slopes lower than five inches, special precautions must be taken.

Asphalt roll roofings, including wide-selvage roofing, may be used on slopes of two inches or more per foot. They should not be used on flatter slopes, not because it is impossible to construct a leakproof roof with them, but because they do not resist weathering well where the roof drainage is poor. Figure 8.

Built-up roofs are best suited to roof decks that range from flat to two inches per foot, though they may be used on steeper slopes.

Metal roofs in sheet form and corrugated asbestos-cement roofs should not be used on slopes lower than three inches per foot. These include special shapes of galvanized and aluminum sheets, protected metal sheets and all batten and standing seam metal roofings.

Soldered seam metal roofs (copper, terne) may be used on flat or nearly flat decks.

3.7 Wind Damage

All roofings are subject to damage from strong winds, and roofs, generally, are not designed to withstand winds of hurricane intensity. However the greatest damage to roofs is not from hurricanes but, rather, from winds of moderate intensity and the gusts that may reach 50 to 75 miles per hour that accompany them.

Asphalt roofings, particularly free-tab asphalt shingles, improperly applied are probably most susceptible to wind damage. Figure 9 illustrates the effect of a gust of wind on such shingles that were nailed too high. Continued flexing of these shingles weakens them and after a number of gusts the shingle tab is blown off. The same is true if these shingles are nailed correctly, but the free tabs are not cemented down and accounts for the many cases where only the exposed tab of a shingle is blown loose. Conventional 210-pound shingles nailed correctly, but not cemented down, have been shown to resist less than 100 gusts in a simulated test. In a similar test with the shingle tabs cemented down they have resisted more than 2000 gusts.

Figure 10 shows another common cause of wind damage to roofs, that is, the partial vacuum caused by wind blowing perpendicularly over the ridge of a roof and causing the roll roofing to tug at its fastenings. This same effect is apparent when wind blows against the side of a building with a flat roof and is one of the most important reasons for the adequate fastening of built-up roofing felts. In the case of built-up roofs it is the constant pull from relatively mild winds that loosen the nails and make the roof susceptible to the first strong wind to which it is subjected.

3.8 Exposed Nails

The tendency of exposed (uncovered) nails to work loose has probably caused most trouble with asphalt roll roofings since a large proportion of these roofings are applied with the nails exposed. See Figure 5. However, exposed nails are always a potential source of trouble with roofing of any type. Nails used to hold down curled wood shingles invariably come loose as do nails in the battens used to deflect water over entrances to buildings.

3.9 Failure of Flashings

Flashings should be designed to furnish at least as long service as the roofing. Many early roof failures are actually flashing failures. This is true particularly of built-up roofs on flat or nearly flat decks. Numerous cases have been observed where reroofing has been requested when repair of the flashings or provision for new flashings was all that was required to make the roof leakproof. See Figure 11.

When it is considered that the function of flashings is to provide a waterproof junction between the roof and other parts of the structure and between roof sections, their importance, and the importance of maintaining them properly cannot be over-emphasized.

4. TYPES OF ROOFING

4.1 Built-Up Roofing

Federal and other specifications for materials used in built-up roofs are listed on page 28 .

4.1.1 Description and General Discussion

Built-up roofing is exactly what the name implies, a membrane built-up on the job from alternate layers of bituminous-saturated felt and bitumen. Since each roof is custom-made, the importance of good workmanship cannot be over-emphasized. Figure 12 illustrates extremely poor workmanship on both roof membrane and flashings.

The bitumen used to saturate the felt and as a plying cement and coating for the saturated felts may be asphalt or coal-tar-pitch. These can usually be distinguished by their odors. Asphalt has a distinctly oily odor and coal-tar-pitch a somewhat pungent, phenolic odor. These odors can be determined best with freshly broken specimens or from the fumes of specimens that have been ignited and freshly extinguished.

Coal-tar pitch is particularly adaptable for use in the construction of the so-called "dead-level" built-up roofs on which water collects and stands. Coal-tar-pitch is more susceptible than asphalt to changes in temperature, that is, roofing grade coal-tar pitch is more fluid at high temperatures and more brittle at low temperatures than comparable roofing grade asphalt. Consequently, asphalt is better suited than coal-tar pitch for built-up roofing on steeper slopes.

The layers of felt in a built-up roof function primarily to hold the layers of bitumen in place. They do not materially contribute to the waterproofness of the roof and are not suitable for prolonged exposure to the weather. Built-up roofs are always designated by the number of plies they contain, for example, 3-ply and 5-ply roofs contain 3 and 5 plies of felt, respectively.

Coal-tar-pitch built-up roofs are always hot-applied. The pitch is melted to a heavy liquid consistency and, except when the felts are laid mechanically, Figure 13, is mopped when used as a cement and poured when used as a surface coating. Because of the susceptibility of coal-tar pitch to changes in temperature, coal-tar-pitch roofs should always be surfaced with slag, gravel, crushed stone, promenade tile laid in a cement grout, or similar material.

Asphalt built-up roofs may be either hot- or cold-applied and may be either surfaced or unsurfaced. Hot-applied asphalt and coal-tar-pitch roofs are applied similarly. Hot-applied asphalt roofs use uncoated, saturated felts; cold-applied roofs use saturated and coated felts and cut-back cements containing a volatile solvent. Some cold-applied roofs are surfaced with emulsified asphalt.

Surfacing materials for built-up roofs serve three important functions. They permit the use of thick surface coatings of bitumen, protect the bitumen from sunlight and heat, and increase the fire resistance of the roofing. The statement heard so frequently that "surfaced roofs are undesirable because it is so difficult to locate the source of a leak on a surfaced roof" is entirely fallacious. A surfaced roof, constructed properly with a thick top pouring of bitumen, will not leak. Built-up roofs, except those surfaced with promenade tile or similar surfacing are not intended to carry much foot traffic. Tile surfacing or wooden walkways should be used on roofs that are subjected to regular traffic.

Built-up roofs are adapted particularly to relatively flat slopes (two inches and less per foot) because they furnish a continuous membrane. They may be applied on slopes steeper than two inches per foot when proper precautions are taken.

Built-up roofs are applied to a variety of deck materials, including wood, concrete, steel and gypsum, with or without insulation.

Built-up roofs suffer by being designated as 10-, 15- or 20-year roofs. Too often these designations are interpreted to mean that the roof will require no maintenance or repair for the stated period. Roofs that are not maintained or repaired will, in all probability, require replacement at the end of the stated period, while those that are maintained properly can be expected to serve well beyond the period.

4.1.2 Roof Decks for Built-Up Roofs

Wood Decks

Should be tongued and grooved or splined.

Should be dry when roofing is applied.

At least two nails per 6 in. width at each rafter, nails driven flush.

Roof deck must be smooth - no irregularities.

Knot holes and cracks wider than 1/4 inch between boards must be covered with sheet metal.

Poured Concrete and Gypsum Decks

Deck must be dry, smooth, free from frost or freezing effects, properly graded to drains and free from loose material.

If deck is uneven, high spots must be removed or low spots filled with portland cement or gypsum mortar.

Nailing strips in concrete, when required, must be treated to resist rot, must be properly keyed into the concrete and must be flush with the surface.

Precast Concrete Units

Deck must be dry, smooth, free from frost or freezing effects.

Use cement mortar to level inequalities and fill cracks in the deck.

Precast Gypsum Units

Protect units stored on the job from rain or snow. Store metal-edge gypsum plank on edge, not more than three tiers high, with ample ventilation.

Permit only that amount of gypsum decking to be applied each day that can be covered with roofing that day.

Use only gypsum mortar to fill cracks and level inequalities in the roof deck.

Steel Decks

Deck must be dry, firm, tight, free from rust, grease or any loose material. All steel decks should be shop coated or painted.

4.1.3 Storage and Handling of Materials

Felts

Felts stored on the job must be protected from the weather. It must be realized that these felts, though they are described as "saturated" with asphalt or coal-tar pitch, will still absorb considerable moisture if exposed to it. Felts that contain moisture are certain to result in blistered built-up roofs. Felt rolls should be stood on end, not in contact with the ground.

When felts are applied, they should preferably be rolled into the hot asphalt or coal-tar pitch that has been applied with a mop not more than three feet ahead of the roll. Sufficient asphalt or pitch should be present between the plies of felt to insure that, in no case, is felt touching felt.

Immediately after the felt is rolled into the hot bitumen, it should be "broomed in" with a stiff bristle broom (Figure 13). Any small blisters or buckles remaining should be slit with a knife and smoothed out with the broom. If blisters or buckles larger than 8 in. in any dimension are present, the felt should be removed and re-laid.

Asphalt and Coal-Tar Pitch

Drums of asphalt and coal-tar pitch should be stood on end and protected from the weather during storage.

Asphalt and pitch should be broken up before placing in the kettle. For safety, pieces should be slipped rather than dropped into melted bitumen.

The inspector should insist that the temperature of the melted bitumen be controlled with a thermometer. Both asphalt and coal-tar pitch are hardened and embrittled by overheating and, consequently, are rendered more susceptible to changes in temperature. Overheating the bitumen may therefore reduce the useful life of a built-up roof. Modern heating kettles are usually equipped with a thermometer, but these are frequently broken or so covered with bitumen as to be illegible. The inspector should be provided with a thermometer, two types of which are available.

Asphalt should not be heated above 425°F and should normally be not lower than 350°F when poured or mopped on a roof. If asphalt with a softening point of 150°F or lower is used, the maximum kettle temperature is 375°F and the minimum temperature for application 300°F.

Coal-tar pitch should not be heated above 400°F and should not be poured or mopped at temperatures under 350°F. Dense yellow fumes from the heating kettle is proof that the coal-tar pitch is too hot.

The final coating of asphalt or coal-tar pitch on mineral-surfaced built-up roofs should always be poured rather than mopped to insure sufficient bitumen for embedding the surfacing. Figure 14.

To determine whether mineral surfacing is embedded properly, the inspector should include a broom as part of his regular equipment. Figure 15.

Surfacing Materials

Surfacing materials for built-up roofs should be dry and free from dust since wet or dusty surfacing materials will not bond well with the bitumen. If wet, they should be dried by piling over a heated metal drum with open ends. If roofing work must be done in cold weather, this method may be used to heat the surfacing material to secure proper embedment. If crushed stone is used for surfacing, the stone should not have sharp edges.

Insulation

Since the application of insulation varies with the different types of decks, the kinds of insulation and the use of the structure, no attempt is made to give detailed instructions here. The inspector should see that insulation is stored under cover and that it is installed strictly according to the standard specifications for new roof construction, with no more installed on a single day than can be covered with roofing on that day. If light-weight concrete is used as an insulating material, it must be dry before the roof membrane is applied.

All decks over which insulation is to be applied must be provided with wood edge strips at least 4 inches wide and of the same thickness as the insulation at all open edges and at walls or curbs if metal base flashings are to be installed.

On non-combustible decks with inclines that require the nailing of felts, wood nailing strips of the same thickness as the insulation must be provided. Steel decks must be provided with a layer of insulation to serve as a base for the built-up roofing.

A vapor barrier must be provided under insulation to prevent the absorption of moisture by the insulation from the under side. This vapor barrier must be continuous to be effective. Two layers of 15-pound, asphalt-saturated felt mopped solidly between with asphalt or one layer of double-coated felt with edges sealed provide an adequate vapor barrier. Other types of vapor barriers are available.

4.1.4 Determining Treatment for Built-Up Roofs

From the data furnished in the historical record and that listed on the inspection form must come the determination concerning what treatment, if any, the roof shall receive. No matter how detailed these data may be, it is usually necessary to exercise some judgment after considering a number of pertinent factors.

The kind of structure, whether permanent or temporary, its occupancy; the kind of roof, its age, and whether or not leaks occur, are among the most important considerations in determining the treatment.

A roof on a structure designated for temporary occupancy should be given only the minimum maintenance or repair necessary to keep it leakproof during the period of occupancy. A roof on a structure for permanent occupancy should be considered in the light of the prolonged use of the structure and should be given the best maintenance, repair or reroofing possible.

4.1.5 Maintenance Methods - Built-Up Roofs (Treatment Prior to Failure)

Note: Asphalt and asphalt-saturated felt should always be used in the maintenance of mineral-surfaced, asphalt built-up roofs; coal-tar pitch and coal-tar saturated felt in the maintenance of coal-tar pitch, built-up roofs. Asphalt and coal-tar pitch are not compatible so that contact between the two should be avoided whenever possible. In the text that follows, the terms "bitumen" and "bituminous" are used to indicate asphalt when mineral-surfaced asphalt roof maintenance is discussed and coal-tar pitch when coal-tar pitch roofs are discussed.

A. Mineral-Surfaced, Built-Up Roofs

(1) Bare Areas (Small Areas)

(a) Bituminous Coating Exposed (Figure 16.)

Treatment: Brush loose gravel or slag from bare area. Cover the bare area with hot bitumen poured on at a rate of 70 pounds per square and embed fresh gravel or slag. Old gravel or slag may be reapplied if dirt and dust are screened from it. Do not attempt to apply hot bitumen over slag or gravel surfacing since it will not adhere. (Figure 17.)

(b) Felts Exposed

Treatment: If exposed felts appear to be weathered, Figure 18, brush all dust and dirt from the exposed area and, in the case of asphalt roofs, apply one thin coat of asphalt primer meeting Federal Specification SS-A-701. When primer is dry, treat as described for bare areas with the coating exposed. Coal-tar pitch roofs are treated similarly except that no primer is required before the coal-tar pitch is applied.

(2) Small Blisters and Buckles

Treatment: If bare, treat small blisters and buckles as bare areas; otherwise disregard them. (Figure 19.)

(3) Bituminous Coating Weathered Severely Over Entire Roof Area (Figure 20.)

Treatment: Remove bituminous coating and mineral surfacing. Removal is accomplished best in cool weather. When large roof areas are involved, the use of mechanical equipment to remove the bituminous coating and surfacing material is more economical than removal by hand methods. Repair disintegrated felts, damaged areas, blisters and buckles as described under "Repair Methods, Mineral-Surfaced, Built-Up Roofs". Sweep off loose material. Recoat with hot bitumen poured on at a rate of 70 pounds per square and into the hot bitumen embed 400 pounds of gravel or 300 pounds of slag.

B. Smooth-Surfaced, Asphalt, Built-Up Roofs

(1) Organic (Rag) Felt Roofs

(a) Felts Exposed (Small Areas)

Treatment: Same as for mineral-surfaced, built-up roofs, except that 20-25 lb. asphalt should be mopped per square and the mineral surfacing omitted.

(b) Small Blisters and Buckles

Treatment: If felts are exposed, treat as described for exposed felts, mineral-surfaced, built-up roofs, applying 25 lb. asphalt per square and omitting mineral surfacing. If felts are not exposed, disregard small blisters and buckles.

(c) Asphalt Coating Weathered Severely Over Entire Roof Area

General Discussion: Smooth-surfaced, asphalt, built-up roofs, in which the surface mopping is relatively thin and is exposed directly to the weather, usually show definite alligatoring of the surface coating within 3 to 5 years. Alligatoring is always most severe where the asphalt coating is thickest. If allowed to proceed, alligatoring will develop into cracking (Figure 21). Once the surface coating is cracked, water enters the membrane, leaks may appear and the roof deteriorates at a rapid rate. Consequently, maintenance before cracks appear is necessary.

The kind of maintenance selected should depend on the future use of the structure, as indicated below.

c-1. Maintenance For An Expected Use of the Building of Not More Than Four Years

Treatment: Remove all loose dust and dirt by sweeping, vacuuming or air blast. Apply one coat of asphalt primer meeting Federal Specification SS-A-701. A thin coat only is desired, applied preferably by brushing, to avoid excess primer. After primer is dry, apply one of the following:

(1) Asphalt emulsion meeting Military Specification MIL-R-3472, "Roof Coating; Asphalt Base Emulsion", by brush or spray, at a rate of 3 gallons per square.

(2) Asphalt-base roof coating meeting Federal Specification SS-R-451, "Roof Coating; Asphalt, Brushing-Consistency", amended to contain from 8 to 20 percent mineral filler instead of 5 to 25 percent, by brush or spray, at a rate of 3 gallons per square. While many good proprietary roof coatings are available, they usually cost several times as much as coatings purchased under Federal Specification SS-R-451. They may be "guaranteed" for periods up to 10 years or longer, but the guarantees usually provide only for furnishing additional coating if failure occurs. In the absence of any fool-proof test to determine the quality of roof coatings, material purchased under the Federal Specification is adequate for maintaining roofs in this category for an expected use of not more than 4 years.

(3) Fatty-acid-pitch base roof coating meeting Interim Federal Specification SS-C-00560, "Coating Material; Fatty-Acid-Pitch Base, Non-Bleeding, Brushing and Spraying Consistency, Foundations, Roofs, Walls, etc.", at a rate of approximately 3 gallons per square.

(4) Hot-mopping asphalt meeting Federal Specification SS-A-666, "Asphalt for Built-Up Roofing, Waterproofing and Dampproofing", of the same type as used in the original construction, at a rate of 20 to 25 lb. per square.

If the asphalt coating is alligatored but not cracked and the felts are not exposed, the primer may be omitted with the asphalt- and fatty-acid-pitch base coatings. If an emulsion coating is to be applied to such surfaces, dust and dirt may be washed off with a stream of water from a hose. The emulsion may be applied to a damp, but not a wet surface.

The above methods are limited to use on smooth-surfaced, organic-felt roofs of relatively short expected use because of the tendency to alligator and eventually crack of any coating material that is applied over an alligatored or cracked asphalt coating (Figure 22). This tendency increases as the coating thickness is built-up.

c-2. Maintenance for Prolonged Use

Treatment: Clean off all loose dirt or dust by sweeping, vacuuming or air blast. Apply one coat of asphalt primer meeting Federal Specification SS-A-701, applied preferably by brushing, avoiding excess primer. After primer is dry, apply asphalt emulsion meeting Military Specification MIL-R-3472,* except that it need not contain asbestos fibers, at a rate of 2 gallons per square. Immediately after applying the emulsion, while it is still wet, embed strips of fibrous glass mesh, either woven or non-woven, in the emulsion, lapping the strips two inches and using a moistened brush to force the mesh into the emulsion.

*Clay-type emulsion should be used with the glass membrane.

Over the fibrous glass strips, while the first coat of the emulsion is still wet, apply a second coat of emulsion at a rate of 1 gallon per square. Brush this second coat into the mesh with a fiber brush. Allow this second coat of emulsion to set firmly. (At least 12 hours in good drying weather, longer in damp, humid weather.)

Apply a final coat of emulsion at a rate of 2 gallons per square. Fibrated emulsion may be used for the final coat, but its use is not essential.

If the asphalt surface is alligatored but not cracked and felts not exposed, treat as described in the previous section, omitting the asphalt primer.

Figure 23 illustrates the benefit obtained by the use of the fibrous glass strips. The section on the left shows an area of an alligatored roof that was simply coated with asphalt emulsion. The section on the right was coated with the same emulsion reinforced with glass. Both were exposed 2-1/2 years.

This method of treatment is described in detail because it has been used with satisfactory results and it is believed that it provides adequate safeguards against poor workmanship. Variations of this method, in which the glass strips are embedded in a coating of emulsion and a finish coating of emulsion applied, and in which different quantities of emulsion are used, have also given satisfactory results. With any method, workmanship is as important as materials and a satisfactory job will result if the emulsion coatings are fused into a tightly adherent membrane, reinforced with the glass fibers.

(2) Asbestos-Felt Roofs

(a) Felts Exposed (Small Areas)

a-1. Maintenance for An Expected Use of the Building of Not More Than Four Years

General Discussion: Smooth-surfaced, asbestos-felt, built-up roofs may be surfaced originally with hot asphalt or with a cold-applied asphalt-base coating. After four or five years of exposure (sometimes earlier with the cold-applied coatings), light-gray or even white areas appear, indicating that the felts are partly exposed (Figure 24). Since the asbestos felts are constructed mainly of inorganic materials, exposure to the weather is much less serious than with organic felts.

Treatment: For an expected use of not more than 4 years, no treatment is necessary. Disregard small blisters and buckles.

a-2. Maintenance for An Expected Indefinite Use

Treatment: Manufacturers of asbestos felts generally do not recommend recoating asbestos felt roofs at any time. However, recoating with asphalt emulsion meeting Military Specification MIL-R-3472 at a rate of 3 gallons per square, at intervals of four or five years, will prolong their usefulness indefinitely. To be most effective for long periods of maintenance, the initial coating should preferably be an asphalt emulsion or thin asphalt cut-back rather than a hot-applied or conventional asphalt fibrous roof coating.

The use of fibrous glass mesh is not recommended in the maintenance of asbestos-felt roofs.

(3) Cold-Process Roofs (Roofs constructed with coated organic felts cemented to each other and to the roof deck with a special quick-setting cement as recommended by the manufacturer of the felts and surfaced with asphalt emulsion or with a cold-applied coating recommended by the manufacturer.)

(a) Felts Exposed

Treatment: Recoat with asphalt emulsion meeting Military Specification MIL-R-3472 at a rate of 3 gallons per square, or with the material with which they were coated originally. Disregard small blisters or buckles. Large blisters or buckles shall be treated as described under Repair Methods.

4.1.6 Repair Methods - Built-Up Roofs (Treatment following at least partial failure)

A. Mineral-Surfaced, Built-Up Roofs

See note under 4.1.5 Maintenance Methods - Built-Up Roofs.

(1) Felts Exposed and Partially Disintegrated (Small Areas) - Figure 25.

Treatment: Scrape off all surfacing material to a distance at least 2-1/2 feet beyond the area of disintegrated felts. Remove disintegrated felt layers and replace them with new 15-pound bituminous-saturated felts of approximately the same size and mopped in place with hot bitumen. Apply at least two additional layers of 15-pound saturated felt, mopped on with hot bitumen and extending at least 12 inches beyond the area covered by the replacement felts. Apply a pouring of hot bitumen to the repaired area at a rate of 70 pounds per square and into it, while hot, embed fresh gravel or slag. Old gravel or slag may be reapplied if dirt and dust are screened from it.

(2) Roof Membrane Cracked

Treatment: Treat as described for disintegrated felts, except that it is usually only necessary to mop on at least two plies of 15-pound saturated felt, followed by the heavy pouring of bitumen, with slag or gravel surfacing.

(3) Large Blisters or Buckles That Have Cracked to Allow Water to Penetrate. (Blisters or buckles, though large, if intact, will not leak. Only if the felts disintegrate or are cracked should they be repaired.) - Figure 26.

Treatment: Scrape off all surfacing material to a dry felt surface at least 2-1/2 feet beyond the edge of the blister or buckle. Make two cuts at right angles to each other extending 12 inches beyond the edge of the blister or buckle. Fold back the four corners of the membrane and allow to stand until thoroughly dry. When dry, apply a liberal mopping of hot bitumen, fold down the four corners or the membrane and press them firmly into the hot bitumen. Apply at least two additional layers of 15-pound saturated felt mopped on with hot bitumen and extending at least 18 inches beyond the ends of the cuts. Apply a pouring of hot bitumen at a rate of 70 pounds per square and while hot, embed gravel or slag.

(4) Fishmouths or Buckled Open End Laps.

Treatment: Scrape off all surfacing material to a distance at least 12 inches beyond the affected area. Cut the fishmouth or buckled end lap and cement down the loose felts with hot bitumen. Apply at least two layers of 15-pound saturated felt mopped on with hot bitumen and extending at least 8 inches beyond the end of the cut felt and 8 inches below the lap edge. Apply a heavy pouring of hot bitumen and into it, while hot, embed gravel or slag.

(5) Felts Exposed and Disintegrated in Numerous Areas. Figure 27.

General Discussion: Under this category no definite criteria can be established to determine whether the existing membrane should be repaired by adding plies of felt or whether the old membrane should be removed entirely and a new one applied.

The condition of the membrane should largely govern, but the historical record of the roof will be of definite assistance in making a decision.

(a) Cases Where Repairs are Indicated:

Roof has not reached its expected life; that is, roughly, for a 5-ply roof, 20 years; a 4-ply roof, 15 to 20 years; and a 3-ply roof, 10 years.

Base felts are in sound condition and are not waterlogged.

Insulation, if present, is dry.

Leaks that have developed are few in number and are not serious.

(b) Cases Where Reroofing Is Mandatory:

Roof has exceeded its expected life with little or no maintenance.

Felts have disintegrated and disbonded and entire membrane is waterlogged.

Insulation is wet and/or disintegrated.

Numerous leaks of a serious nature have developed in the membrane.

(c) Repairing by Applying Additional Plies of Felt

One cardinal principle in applying additional plies of felt to an existing built-up roof is that the additional felts should never be mopped solidly to an existing membrane. The repair membrane must be isolated from the old membrane by a "dry" felt layer, spot or strip mopped, or nailed, or by one-half inch of roof insulation strip mopped, and if possible, nailed through the old membrane to the roof deck. If the slope of the roof is greater than 1 inch per foot, some provision must be made for fastening the felts and the insulation. The use of insulation is desirable because it effectively isolates the old membrane from the new one and provides a smooth surface free from irregularities for the new membrane.

Another principle, equally important, is that the new membrane should contain not less than three plies of felt.

(d) Preparation of Surface to Receive New Membrane - All Types of Decks:

Remove mineral surfacing, bituminous coating and all loose and disintegrated felts. (Refer to section on Maintenance of Mineral-Surfaced, Built-Up Roofs.)

Repair blisters, buckles, cracks and fishmouths as indicated under "Repairs to Small Areas", omitting final pouring of bitumen and mineral surfacing material.

If new flashings are to be installed, cut off existing membrane flush with the base of fire and parapet walls.

(e) Application of New Membrane to Existing Membrane on Insulated Concrete Decks:

e-1. Saturated Organic Felt with Insulation

Treatment: Mop solidly with hot bitumen one-half inch of roof insulation to the existing membrane. Follow with at least 3 plies of 15-pound saturated felt mopped solidly to the insulation and to each other with hot bitumen at a rate of 25-30 pounds per square, followed with a pouring of hot bitumen at a rate of 70 pounds per square, into which gravel or slag is embedded at a rate of 400 pounds of gravel or 300 pounds of slag per square.

e-2. Saturated Organic Felt Without Insulation

Treatment: Spot or strip mop with hot bitumen one ply of 15-pound saturated felt to the existing membrane. Follow with at least 2 plies of 15-pound saturated felt mopped solidly and finished as described in the preceding paragraph.

e-3. Asphalt and Asphalt-Saturated Asbestos Felt - With and Without Insulation

Treatment: Proceed as described for saturated organic felts using asphalt-saturated asbestos felts, except that the finish coat should consist of asphalt emulsion meeting Military Specification MIL-R-3472, applied at a rate of 3 gallons per square.

(f) Application of New Membrane to Existing Membrane on Wood Decks:

Treatment: Proceed as described for concrete decks except that insulation and felt should always be nailed over wood decks in addition to the mopping recommended when applying a new membrane over concrete. Spot or strip mopping may be omitted when the new membrane is applied directly to the old, the first ply being simply nailed.

(g) Application of New Membrane to Existing Membrane on Gypsum Decks:

Treatment: Treat as described for wood decks. If the roof deck shows cracks on the under side, the use of insulation under the new membrane is mandatory.

(h) Application of New Membrane to Existing Membrane Over an Insulated Roof:

Treatment: First make certain that the old insulation is dry and not disintegrated. If the insulation is not thoroughly dry or if it shows any evidence of disintegration, the existing roofing and insulation should be removed down to the roof deck and a new roof applied.

If satisfied that the insulation is in good condition, apply an additional layer of 1/2-inch insulation, followed by 3 layers of 15-pound saturated felt, mopped on and finished as described for concrete decks.

4.1.7 Reroofing

Reroofing, when necessary, should be accomplished in accordance with standard specifications for new roof construction.

Selection of a specification for a new roof should be made mainly on the basis of the expected future use of a structure.

Preparation of the deck for reroofing: Remove the old membrane entirely.

Restore the deck to as nearly "new" condition as possible.

On wood decks remove all rotted boards, replace with sound boards and renail loose boards.

On cracked concrete or gypsum decks apply at least 1/2 inch of insulation before applying the new membrane.

4.1.8 Federal and Military Specifications Used in Built-Up Roof Construction, Maintenance and Repair. (Military Specifications designated "MIL", all others are Federal.)

Title	Designation
Asphalt; (for) Built-Up Roofing, Waterproofing and Dampproofing. Types I and II, Roofing, Depending on slope of roof.	SS-A-666
Pitch; Coal-Tar (for) Mineral-Surfaced Built-Up Roofing, Waterproofing and Dampproofing. Type I, Roofing.	R-P-381
Felt; Asphalt-Saturated (for) Flashings, Roofing and Waterproofing. Type I - 15-pound. Type II - 30-pound.	HH-F-191
Felt; Coal-Tar-Saturated (for) Roofing and Waterproofing. Type I - 15-pound. Type II - 30-pound.	HH-F-201
Felt; Asbestos, Asphalt-Saturated and Asphalt - Coated for Built-Up Roofing. Class A, 20-pound (one side coated). Class B, 50-pound (both sides coated).	HH-F-182
Felt; Asbestos, Asphalt-Saturated, Uncoated, for Flashings, Roofing & Waterproofing. Type I, Perforated. Class A, 15-pound. Type II, Plain. Class A, 15-pound. Class B, 35-pound.	HH-F-185

Title	Designation
Asphalt Primer (for) Roofing and Waterproofing.	SS-A-701
Cement; Bituminous Plastic. Type I - Asphalt Base. Type II - Coal-Tar Base.	SS-C-153
Roof Coating; Asphalt, Brushing-Consistency.	SS-R-451
Roof Coating; Asphalt-Base Emulsion.	MIL-R-3472
Coating Material; Fatty-Acid-Pitch Base, Non-Bleeding, Brush and Spray Consistency, for Foundations, Roofs, Walls, etc.	SS-C-00560 (Interim)
Surfacing Materials for Built-Up Roofs.	MIL-M-13430

4.2 Asphalt-Shingle Roofing

Federal Specifications:

SS-S-00298 (Interim), Shingles; Asphalt, Mineral-Surfaced, Thick-Butt.

SS-S-00300 (Interim), Shingles; Asphalt, Mineral-Surfaced, Uniform Thickness.
Type I, 4-in. Exposure.
Type II, 5-in. Exposure.

4.2.1 Description and General Discussion

Note: For a more complete description of asphalt shingles, including manufacturing methods and methods of application, it is urged that one or both of the following publications be obtained: National Bureau of Standards Building Materials and Structures Report BMS-70, "Asphalt-Prepared Roll Roofings and Shingles". Copies available from the Superintendent of Documents, Government Printing Office, Washington 25, D. C. "Manufacture, Selection and

Application of Asphalt Roofing and Siding Products", published by the Asphalt Roofing Industry Bureau, 2 West 45th Street, New York 36, N. Y. Available on request to the Asphalt Roofing Industry Bureau.

Asphalt-shingle roofing is manufactured in single or multiple units of roofing felt saturated and coated on both sides with asphalt and surfaced on the weather side with mineral granules. The asphalt coating may or may not contain fine mineral stabilizer.

The surfacing materials on asphalt shingles serve the same functions as those of built-up roofs and, in addition, provide a choice of colors and color blends. The surfacing materials (granules) are either natural products such as slate or trap rock or other mineral products with a ceramic coating. Resistance to light transmission is an important requirement for roofing granules to protect the asphalt coating from solar radiation.

Asphalt shingles are available in a number of forms or shapes, the most common being the square-butt, strip type which, when laid, gives the effect of individual shingles laid by the American or wood-shingle method. Other types are hexagonal strip, individual shingles laid by the American, Dutch lap or hexagonal methods and lock-down shingles of various types.

One of the most important considerations in the selection of asphalt shingles is "coverage", the term used to describe the number of layers of roofing furnished by a particular type of shingle in place. Single-coverage shingles provide but one layer of material over a large proportion of the roof area; double-coverage shingles provide two layers over most of the roof area; triple coverage, three layers, etc. The better the coverage, other considerations being equal, the better the service that may be expected.

Weight is another important consideration in the selection of asphalt shingles. Shingles should weigh at least 210 pounds per square (100 square feet) when applied.

Headlap is important in determining the waterproofness of shingles. Various definitions for headlap have been proposed, one of the most realistic being the distance water must travel upward from the outside to the inside of a roof, assuming there are no breaks in the fabric. With square-butt strip shingles, headlap is the distance a shingle in any course overlaps a shingle in the second course below it. With shingles laid by the Dutch-lap method, it is the distance a shingle overlaps one in the next course below. The greater the headlap, the better the waterproofness.

The exposure of a shingle is defined as the maximum distance the shingle is exposed to the weather, disregarding the space between individual shingles and the cut-out sections of square-tab strip shingles. Coverage, headlap and exposure are interdependent; as the exposure is increased, the headlap and coverage are decreased correspondingly. As the exposure is increased, the possibility of wind damage is increased.

Asphalt shingles generally are eligible for the Class C fire resistance rating of the Underwriter's Laboratories, Inc., which indicates that they are effective against light fire exposures. One proprietary strip shingle is currently available with a Class A fire resistance rating, indicating that it is effective against severe fire exposure. These shingles are herinafter referred to as "Class A".

Shingles covering wide ranges of weight and coverage are available. However, the square-butt strip shingle, 12 by 36 in. in size, with an exposure of 5 in. and weighing approximately 210 lb. per square applied, has come to be the generally accepted asphalt shingle for roofs on structures with slopes of 4 in. or more per foot. Subsequent sections will therefore deal primarily with square-tab strip shingles, though kinds of decks, methods of handling and storage, weathering characteristics, and methods of maintenance and repair apply almost equally to all types of asphalt shingles. The characteristics of representative square-tab shingles are shown in Table 1.

4.2.2 Roof Decks for Asphalt-Shingle Roofs

Wood decks for asphalt-shingle roofs should be of well-seasoned sheathing lumber, nominal 1 in. in thickness, not more than 6 in. wide, preferably tongued and grooved, or of plywood, exterior grade, not less than 1/2 in. thick.

Sheathing boards should be fastened to each rafter with two nails to provide a smooth, even surface. Any knot holes, resinous areas or loose knots should be covered with sheet metal.

The deck should be covered with 15-lb. asphalt-saturated felt prior to laying the shingles.

4.2.3 Storage and Handling of Asphalt Shingles

Asphalt shingles should be handled carefully at all times to prevent damage. Particular care should be exercised during extremes of temperatures. When hot they may be torn rather easily and when cold, the asphalt coating becomes brittle and may be cracked if the shingle is bent. Bundles should be lifted by placing the hands underneath, not by the wires or boards. They should not be thrown or dropped and hooks should not be used.

Shingle bundles stored in warehouses or on the job should not be piled so high that the bottom shingles will be damaged. Two-square bundles should be stored not more than 5 bundles deep and three-square bundles not more than 8 bundles deep. In any case, stacks of shingles should not be more than 3-1/2 ft. high. They should not be stacked directly on the floor of a warehouse or on the ground. They should be stacked on planks spaced so that the shingles do not sag.

TABLE 1. SQUARE-TAB STRIP SHINGLES

Designation	Size in.	Exposure in.	Headlap in.	Coverage, % 1-ply	2-ply	3-ply	Wt. per Square Applied lb.	No. of Shingles per Square	Amt. of Roofing per Square ft^2	No. of Nails per Square
Thick-butt	12 X 36	5	2	2	59	39	210	80	234	480
Uniform Thickness	12 X 36	5	2	2	59	39	210	80	234	480
Uniform Thickness	10 X 36	4	2	3	50	47	210	100	244	400
Heavy	12 X 36	5	2	2	59	39	250	80	234	480

Asphalt shingles stored on the job must be protected from the weather. If water comes in contact with the non-weather surface of the shingles, the thin asphalt coating on that surface may permit some water to be absorbed by the felt base and blistered shingles will result. Contact with oils or solvents must be avoided.

4.2.4 Determining Treatment for Asphalt-Shingle Roofs

Asphalt-shingle roofs that are applied properly usually require no special maintenance or repair treatments. Shingles normally last for a number of years with very little change in appearance. The first indication of normal weathering is the loss of mineral surfacing granules, slight at first, but accelerating as the loss of granules exposes more of the asphalt coating to the weather. Figure 28.

No definite periods can be ascribed for the various phases of weathering because they will vary with the direction of exposure, the climate and the slope of the roof. Weathering is more rapid in hot, humid climates; on southern and western exposures and on low-pitched roofs. Figure 29.

Asphalt-shingle roofs with at least double coverage will usually not leak, even if most of the granular surfacing has disappeared. However, without the surfacing, weathering proceeds rapidly, the shingles become brittle and more vulnerable to wind damage, so that large bare areas are an indication that the roof will soon need attention. Figure 30.

The recoating of weathered asphalt shingles is not recommended for the following reasons. Shingles that have weathered to the stage that recoating would seem to be indicated are probably so brittle that they are likely to be damaged severely by the recoating operation. Figure 31. Further, the unequal weathering of the exposed tabs will result in an unequal absorption of the coating material, thereby causing the coated tabs to curl unless great care is taken to cement tightly all three edges of all exposed tabs. This complete cementing is also important in that if it is not done, otherwise entrapped water may back up above the top of the shingle and cause leaks. Finally, experience has shown also that the cost of recoating and sealing the edges of the shingle tabs in most cases approaches so nearly that of reroofing that reroofing is the more economical procedure.

In asphalt-shingle roofs no such sharp distinction can be drawn between maintenance and repair work as was possible in the case of built-up roofs. Maintenance and repair methods for asphalt-shingle roofs are therefore combined. They will be confined to correcting those defects in application that are susceptible to correction.

4.2.5 Maintenance and Repair Methods - Asphalt-Shingle Roofs

A. Maintaining Roofs Having Improperly Nailed Shingles.

The defect that is found most frequently in the application of square-tab strip shingles is the improper placement of nails, that is, nailing too near the top of the shingle rather than 1/2 to 3/4 in. above a line drawn through the top of the cut-out portions. Figure 32. Because of the reduced thickness of the upper part of thick-butt shingles, shingles of this type are affected more than uniform thickness shingles by too high nailing.

Too-high nailing of shingles should be corrected by placing a spot of quick-setting asphalt plastic cement under the center of each tab and pressing the tab down firmly. The spot of cement should be approximately 1-1/2 in. in diameter when pressed flat. Figure 33. Special quick-setting cements are obtainable from most manufacturers of asphalt roofing products. Approximately 1/3 gallon of cement is required per square of shingles. The shingle tabs should not be bent up farther than necessary to place the cement. No attempt should be made to renail shingles in the proper locations since the bending required may damage the shingle tabs.

B. Maintaining Asphalt-Shingle Roofs in Areas of Strong Winds.

The cement treatment described above should also be used to prevent wind damage to shingles that are nailed correctly but are located in areas where strong winds are prevalent.

C. Maintaining Asphalt-Shingle Roofs Damaged by Hail.

Severe hail storms may damage asphalt-shingle roofs beyond repair, particularly if the shingles have been exposed for a number of years. See Figure 34. With such damage, both layers of shingles are broken, the roof will leak severely and reroofing is mandatory.

Severe damage such as shown in Figure 35, where the asphalt coating and surfacing granules have been removed from numerous small areas, but where the shingles are not broken, will not cause the roof to leak. However, the life of a roof so damaged will be shortened materially. Maintenance is not practicable since the cost would probably equal that of a new roof.

Minor hail damage, where only occasional areas from which the coating and surfacing granules have been loosened may be repaired by covering the bare areas with asphalt-base roof coating or plastic cement, asphalt emulsion, or cotton-seed-pitch base roof coating. (See Section 4.1.5-B.(1)-c-1. for description.)

D. Renewing Rotted Eaves Boards.

The roof sheathing boards at the eaves are frequently rotted before the roof shows any signs of deterioration, because of failure to provide a proper drip edge. In such cases the first three or four courses of shingles should be removed, new sheathing applied, together with a metal drip edge. New asphalt shingles should then be applied, taking particular care not to damage the old shingles when removing nails to join the new roof section with the old one.

E. Installing Drip Edge at Rake.

Cases where shingles have been applied without a proper overhang of 1/4 to 3/8 in. at the rake and where no metal drip edge has been applied may be corrected, before the roof sheathing has deteriorated, by removing carefully any nails holding the shingles at the rake and applying a metal drip edge. The shingles should then be renailed and all of the shingle tabs adjoining the rake cemented as described in 4.2.5-A.

4.2.6 Reroofing with Asphalt Shingles

Asphalt shingles may be used for reroofing over wood- and asphalt-shingle roofs and over smooth- and mineral-surfaced asphalt roll roofing. However, the better practice is to remove the existing roof covering. Among the reasons for removal are: An opportunity is given to correct deficiencies in the roof deck, such as warped or rotted framing and sheathing; better nailing is provided; shingles applied on a smooth surface render better service than on an uneven surface; moisture in the old roofing may enter the new shingles and cause blisters, and the appearance of the reroofing job is better.

In cases where asphalt shingles have been applied over an existing roof, and reroofing is necessary, the two roofs should be removed without question. The reasons for removal given in the preceding paragraph apply with even greater force in such cases.

No attempt should be made to apply asphalt-shingle roofing over existing metal, slate or asbestos-cement roofs because of difficulties in nailing.

A. Preparing Deck for Reroofing with Asphalt Shingles.

(1) When Existing Roofing Is Removed.

Restore the roof deck to as nearly "new" condition as possible, as follows:

Remove all protruding nails and renail sound sheathing where necessary.

Remove rotted or warped sheathing boards or delaminated plywood and install new decking.

Cover all large cracks, knot holes and resinous areas with sheet metal.

Repaint ferrous metal drip edges and other flashings that are in good condition or remove badly corroded metal flashings and install new ones of non-ferrous metal.

Remove old roll roofing flashings. Install new base flashings of non-ferrous metal or roll roofing, and new non-ferrous metal counter flashings.

Fill in with wood strips of the same thickness as the existing sheathing the spaces betwen spaced sheathing to which a wood shingle, slate or tile roof had been applied.

Sweep all loose debris from the roof deck.

(2) When Existing Roofing Remains.

(a) Reroofing Over Asphalt Roll Roofing.

Remove all loose and protruding nails.

Cut all wrinkles and buckles and nail cut edges securely to the roof deck as illustrated in Figure 36.

Repaint ferrous metal drip edges and counter flashings that are in good condition. Install non-ferrous metal drip edges at eaves and rake where none exist, by removing nails, slipping the drip edge under the existing roofing and renailing.

Install new non-ferrous metal or roll roofing base flashings and new metal counter flashings in accordance with new construction specifications where necessary.

Install new non-ferrous metal or roll roofing valley flashings.

Sweep all loose debris from the roof deck.

(b) Reroofing Over Asphalt Shingles.

Remove all loose or protruding nails.

Nail down or, preferably, cut away the butts of all curled or lifted shingles.

Treat flashings as described in (a).

Sweep all loose debris from the roof deck.

(c) Reroofing Over Wood Shingles.

Remove all loose and protruding nails.

Nail down or cut off corners of warped shingles.

Replace decayed or missing shingles with new ones.

Cut back shingles at eaves and rake far enough to apply 1 in. by 4 in. wood strips securely nailed.

Apply beveled wood strips approximately 4 in. wide over each course of wood shingles. The thick side of the strips should be as thick as the butts of the wood shingles, with the other side feathered to negligible thickness.

Treat flashings as described in (a).

Sweep all loose debris from the roof deck.

B. Applying Asphalt-Shingle Roof.

Apply asphalt shingles in accordance with current specifications for new construction except that when an asphalt-shingle roof is applied over an existing asphalt-shingle, roll-roofing or wood-shingle roof, 1-3/4 in. nails should be used. Figure 37.

4.3 Asphalt Roll Roofing

Federal Specifications:

SS-R-501, Roofing, Prepared; Asphalt, Smooth-Surfaced.

SS-R-521, Roofing and Shingles; Asphalt-Prepared, Mineral-Surfaced.

SS-R-511, Roofing; Asphalt and Asbestos-Prepared, Mineral-Surfaced.

4.3.1 Description and General Discussion

Asphalt roll roofing is roofing in sheet form composed of roofing felt saturated, and coated on both sides, with asphalt which may or may not contain fine mineral stabilizer. Asphalt roll roofing, like asphalt built-up roofing, may be smooth-surfaced or mineral surfaced.

Smooth-surfaced roll roofing may be dusted on both sides with fine mineral matter such as talc, mica, or fine sand, to prevent sticking in the rolls. Federal Specification SS-R-501 covers smooth-surfaced roofing in two weights, 55 and 65 lb., the weights indicating the weight per square applied. These roofings are made with organic base felts, commonly referred to in the roofing trade as rag-base felts.

Single-thickness, smooth-surfaced roll roofing should be used only on temporary structures with roof slopes of not less than 4 in. per foot.

Application is usually by the exposed nail method with 2 in. cemented laps. It may, however, be laid by the concealed nail method with cemented laps not less than 3 in. wide.

Mineral-surfaced roll roofing is composed of either organic (rag) or asbestos roofing felt, saturated, and coated on both sides with asphalt which may or may not contain fine mineral stabilizer. It is surfaced on the weather side with mineral granules embedded in the asphalt coating. The non-weather side may be dusted with fine mineral matter to prevent sticking. Mineral-surfaced roll roofing is marketed in rolls 36 ft. long, in the following styles: with the entire surface covered with granules; with a 3- or 4-in. bare lapping edge; and with a 19-in. bare lapping edge, the latter being distinguished as "wide-selvage" roofing. Roofing with the entire surface covered with granules is intended to be laid with a 2-in. lap and exposed nails. Those roofings with bare lapping edges are intended to be laid with cemented laps the width of the lapping edge and with "blind" nailing, that is, with one edge of the sheet of roofing nailed and the other fastened only with cement, the nails being covered by the cemented lap. This method of application is preferred because it largely eliminates the "popping out" common with exposed nails. See Figure 5. The wider the lap, the better the service that may be expected from the roofing.

Mineral-surfaced roll roofings lapped not more than 4 in. should not be used on slopes of less than 4 in. per foot. Wide-selvage roofing may be used on slopes as low as 2-1/2 in. per foot. With all types of roll roofing, the steeper the slope, the better the service that may be expected, both in waterproofness and weather resistance.

Smooth-surfaced asphalt roll roofings weighing at least 55 pounds per square applied and mineral-surfaced roll roofings qualify for the Class C fire resistance rating of the Underwriters' Laboratories, Inc., which indicates that they are effective against light fire exposures. Sheet roofings, composed of multiple plies of asbestos felts and asphalt, with Class A and Class B ratings, are also available. A Class A rating indicates effectiveness against severe fire exposure; Class B, against moderate fire exposures.

4.3.2 Roof Decks for Asphalt Roll Roofing Roofs

Roof decks for asphalt roll roofing roofs should be the same as for asphalt-shingle roofs. See Section 4.2.2.

4.3.3 Storage and Handling of Asphalt Roll Roofing

Asphalt roll roofing should be handled carefully at all times, but particularly during extremes of temperature. It is softened at high temperatures and embrittled at low temperatures.

Asphalt roll roofings stored in warehouses or on the job should be stood on end. If several tiers are to be stored one on top of the other, boards should be placed between the tiers to prevent damage to the ends of the rolls. Roll roofings stored on the job must be protected from the weather.

4.3.4 Determining Treatment for Asphalt Roll Roofing Roofs

Smooth-surfaced asphalt roll roofings, being used normally on temporary structures, should receive only the minimum amount of maintenance or repair that will keep them leakproof.

The first effect of normal weathering on smooth-surfaced roll roofing is the loss of the fine mineral matter used to prevent sticking in the rolls. The coating asphalt, being exposed directly to the weather, deteriorates more rapidly than that of mineral-surfaced roofing. Recoating is usually required within 3 to 5 years. Recoating will be required earliest in hot, humid areas and on buildings such as kitchens and wash-rooms where excessive moisture conditions prevail.

Weathering of mineral-surfaced roll roofing is similar to that of asphalt shingles, that is, normal weathering proceeds slowly and is first evidenced by the loss of granular surfacing. Recoating of mineral-surfaced roll roofing is not generally recommended though it may be used to extend the life of a roof if reroofing does not appear justified.

Leaks at the seams of smooth and mineral-surfaced roll roofings, applied with 2-in. laps and exposed nails, are the most common roll roofing failure. These leaks are caused principally by inadequate lapping, cementing or nailing of the roofing, buckling of the roofing at the seams, and loose nails.

4.3.5 Maintenance Methods - Asphalt Roll Roofing

A. Recoating Smooth-Surfaced Roll Roofings.

<u>NOTE</u>: See Section 4.3.6, following, for methods of making minor repairs before the recoating operation.

Smooth-surfaced roll roofing that has been exposed from 3 to 5 years will usually show one or more of the following conditions that indicate a need for recoating: Asphalt coating alligatored or cracked, small coating blisters cracked and broken and other small breaks in the coating that expose the felt. Minor hail damage, where the asphalt coating is damaged but the felt remains intact, also indicates a need for recoating.

<u>Treatment</u>: Remove all loose dust and dirt by sweeping, vacuuming or air blast. Apply asphalt emulsion, asphalt-base roof coating or fatty-acid-pitch base roof coating as described in Section 4.1.5-B.(1)-c-1, Maintenance Methods - Smooth-Surfaced Built-up Roofs, except that the coating of asphalt primer should be omitted in all but the most severely weathered roofings.

B. Recoating Mineral-Surfaced Roll Roofings.

Because of the protection afforded by the mineral-surfacing granules, mineral-surfaced roll roofing weathers much more slowly than the smooth-surfaced type and, consequently, requires less maintenance. As with asphalt-shingle roofing, by the time deterioration through loss of granules becomes serious, the condition of the roofing will be normally such, through brittleness and general deterioration, that recoating will not be desirable. However, in cases where the future use of a building is in doubt or where funds for reroofing are not available, mineral-surfaced roofs may be recoated as described for smooth-surfaced roofs. Mineral-surfaced roll roofing that has been in place not more than half the period it is expected to serve, but has been damaged by hail, should be recoated if the damage consists of loss of mineral surfacing without breaks in the felt.

4.3.6 Repair Methods - Asphalt Roll Roofings.

Since repair methods for smooth- and mineral-surfaced roll roofings are identical, they are treated in this section.

A. Small Breaks (Nail holes, small breaks caused by hail or other mechanical damage, if limited in number.)

Treatment: Apply asphalt plastic cement complying with Federal Specification SS-C-153, Type I.

B. Large Breaks.

Treatment: Large breaks are repaired as illustrated in Figure 38, by opening the horizontal seam below the break and inserting through it a strip of roofing of the type used originally. Extend the strip at least six inches beyond the edges of the break, with the lower edge flush with the horizontal exposed edge of the covering sheet. Coat the strip liberally with lap cement where it will come in contact with the covering sheet before inserting it. After inserting the strip, press down the edges of the roofing firmly and nail securely with the nails about 3/4 in. from the edges and spaced approximately 2 in. Apply lap cement to the horizontal seam, press down firmly and renail if the original seam was nailed.

C. Large Areas.

Treatment: Where a considerable area has been damaged, but the main area of the roof remains intact, remove the roofing from the damaged area and apply new roofing of the same type, using full-width sheets applied in the same manner as the original roofing.

D. Repairing Leaky Seams of Roll Roofings.

Note: It is assumed other necessary repairs will be made prior to repairing the seams by this method.

Leaks occur most frequently at the seams of roll roofings, caused by inadequate lapping, nailing or cementing, loose nails, fishmouths, etc.

(1) For An Expected Use of Not More Than 1 Year.

Treatment: Sweep the seams to remove accumulated dust and dirt, cut all buckles (fishmouths) which terminate at the seams, and insert a strip of roofing as described in 4.3.6-B. Renail where necessary.

Apply asphalt plastic cement complying with Federal Specification SS-C-153, Type I, to the seams, using a trowel to feather the edge of the cement at the top of the strip. Approximately 6 pounds of cement are required per square of roofing.

(2) For An Expected Use of More Than 1 Year.

Treatment: Permanent repairs to leaky seams of roll roofing roofs are best effected by using a membrane such as cotton fabric or light-weight, smooth-surfaced roll roofing, cemented over the seam and coated with a bituminous compound. A method that has been found to be satisfactory is described here in detail. Modifications of this method, following the same principle, may be satisfactory. With any method, careful workmanship is as important as satisfactory material.

Materials: Four-inch strips of asphalt-saturated fabric (Federal Specification HH-C-581, Woven-Cotton Fabric, Asphalt-Saturated), and asphalt roof coating (Federal Specification SS-R-451, Roof Coating, Asphalt, Brushing Consistency, amended to require at least 10 percent by weight of asbestos fiber in lieu of 5 to 25 percent of mineral filler.

Quantities: Quantities of materials required per square (100 square feet) of roofing area: Asphalt-saturated fabric strips - 39 lineal feet. Asphalt roof coating - approximately 4/5 gallon.

Application: Make repairs in clear mild weather when the outside temperature is 50°F or higher. Sweep the seams to remove accumulated dust and dirt, cut all buckles (fishmouths) which terminate at the seams, and insert a strip of roofing as described in Section 4.3.6-B. Replace all loose and missing nails.

Apply the roof coating to the seams in strips approximately 6 inches wide. Use approximately 1 gallon of coating to 80 lineal feet of seam, and work with a three-knot roofing brush or other satisfactory brush. Embed the 4-inch strip of saturated fabric in this coating, pressing it firmly into the coating until it lies flat without wrinkles or buckles; the center of the fabric strip must be directly over the exposed edge of the roofing. Then apply another coat of coating directly over the strip of saturated fabric so the fabric is completely covered and the first and second coatings are continuous. The strips of fabric can be handled most easily if cut into approximately 12-foot lengths.

Treat first the vertical seams of the roofing next to the eaves, extending the cement and fabric 2 inches above the exposed edge of the horizontal seam. Next treat the horizontal seam next to the eaves, placing the fabric directly over the top of the fabric on the vertical seams. Finally treat the vertical seams of the second sheet of roofing, extending the fabric and coating over the fabric on the first horizontal seam to its lower edge. (See Figure 38.) Continue this alternate treatment of vertical and horizontal seams until all seams are repaired.

Roof-coating materials of the type described vary considerably in consistency, composition, setting time, and so on. In some cases, it may be desirable to allow the first coating to become tacky before applying the fabric, or to allow the first coating with the fabric embedded in it to remain for some time before applying the second coating.

<u>Effectiveness:</u> This method is economical, easy to apply, and not difficult to maintain. All the materials used can be purchased under Federal Specifications. The fabric used as a reinforcing material will give to a certain extend with changes in the sheathing boards. Figure 38 illustrates the treatment of seams of roll roofing by this method. Figure 39 is a general view and Figure 40 a close-up of seams treated by this method; the seams having been exposed approximately 18 months since the repairs were made.

Maintain seams treated by this method by recoating them periodically with an asphalt coating of the type used in the original treatment. In warm, humid locations, recoating will probably be necessary after 18 months to 2 years; in other locations, after 2-1/2 to 3 years.

4.3.7 Reroofing With Roll Roofings.

Preparation of the roof deck for reroofing with roll roofings when the existing roofing is removed or over existing roll roofing, asphalt-shingle, or wood-shingle roofs is identical with that described for reroofing with asphalt shingles. See Section 4.2.6, entitled Reroofing With Asphalt Shingles. Roll roofings should be applied in accordance with current specifications for new construction except that, when applying roll roofings over existing asphalt-shingle, roll roofing or wood-shingle roofs, 1-3/4 inch nails should be used.

4.4 Asbestos-Cement Roofing

Federal Specifications:

SS-S-291, Shingles; Roofing, Asbestos-Cement.

SS-R-524, Roofing and Siding; Corrugated, Asbestos-Cement.

4.4.1 Description and General Discussion

Asbestos-cement roofing is composed mainly of portland cement and asbestos fibers. The mixture is formed, while wet, under pressure and is then cured, usually by steam. Since it is composed entirely of inorganic materials, asbestos-cement roofing is extremely resistant to normal weathering. It is quite brittle initially and becomes more brittle on long exposure. Asbestos-cement roofings are produced in various shingle forms and in corrugated sheets. American-method shingles should not be applied on slopes of less than 4 in. per foot; all other types on slopes not less than 5 in. per foot. Corrugated sheets may be used on slopes of 3 inches per foot and steeper.

Shingles laid by the American method are usually about 1/4 in. thick, the weight and number per square varying with the different manufacturers, but in all cases the American method provides greater weight and better coverage than any other type of shingle.

Multiple-unit shingles and shingles laid by the dutch-lap and hexagonal methods are normally about 5/32-in. thick and usually range in weight from 240 to 290 pounds, per square, though dutch-lap shingles laid with a large side lap may weigh as much as 370 pounds per square.

Asbestos-cement shingles that provide two or more thicknesses (American method) over a layer of 15-lb. asphalt-saturated asbestos felt are eligible for the Class A fire-resistance rating of the Underwriters' Laboratories, Inc., which indicates that they are effective against severe fire exposure. Single-coverage shingles (dutch lap or hexagonal methods) over 15-lb. asphalt-saturated asbestos felt are eligible for the Class B rating, indicating effectiveness against moderate fire exposures.

4.4.2 Roof Decks for Asbestos-Cement Roofs

A. Asbestos-Cement Shingles

Wood decks for asbestos-cement shingle roofs should be of well-seasoned sheathing lumber, not less than 1 in. in thickness, not more than 6 in. wide and, preferably, tongued and grooved. The roof deck should be kept dry at all times.

Sheathing boards should be fastened to each rafter with two nails to provide a smooth, even surface.

The deck should be covered with 15-lb. asphalt-saturated felt prior to laying the shingles. This underlayment is necessary to guard against the infiltration of wind and rain. In addition, it provides a cushion for the asbestos-cement shingles.

B. Corrugated Asbestos-Cement Sheets

Corrugated asbestos-cement sheets are normally laid over open wood or steel framing.

4.4.3 Storage and Handling of Asbestos-Cement Roofing

A. Asbestos-Cement Shingles

Asbestos-cement shingles should be kept dry at all times. Exposure to moisture during transportation or storage may cause discoloration of the shingles. Shingles should be stacked on edge, preferably on planks at least four inches from the ground, if stored outdoors. Piles of shingles should be not more than 4 ft. high.

Asbestos-cement shingles should be handled carefully to avoid breakage. If bundles are wired they should not be lifted by the wires.

B. Corrugated Asbestos-Cement Sheets

Asbestos-cement corrugated sheets should be stored and handled with the same care as asbestos-cement shingles. They should always be kept dry. Crated sheets should not be uncrated until needed. When uncrated they should be placed on firm, level supports, preferably on pieces 2 in. by 4 in. spaced 12 to 18 in. and laid at right angles to the corrugations. Sheets should not be stacked more than 4 ft. high. (Some manufacturers recommend 2 ft.)

4.4.4 Determining Treatment for Asbestos-Cement Roofs

Investigation has shown that mechanical damage, such as from hail, traffic, limbs of trees, warping of the roof deck, etc., and failure of fasteners, constitute the principal causes of maintenance and repair work on asbestos-cement roofs.

If only a few shingles or corrugated sheets are broken they should be removed and new ones applied. If a large percentage (25 percent or more) are broken, they should all be removed and a new roof applied. The age and condition of undamaged units should determine whether those salvaged from the old roof should be re-used with new units.

When an asbestos-cement roof fails because of failure of the fasteners, the failure is usually a general one and piecemeal repair is futile. When such failure occurs, normally on a very old roof, it is best to remove the entire roof. Whether the old roofing should be reapplied must be determined by its age and condition. Normally, if the roofing can be removed without damage, it may be reapplied safely.

No sharp distinction can be drawn between maintenance and repair work in asbestos-cement roofings. Maintenance and repair methods are therefore treated under one heading.

4.4.5 Maintenance and Repair Methods - Asbestos-Cement Roofings

A. Asbestos-Cement Shingles

(1) Removing Broken Shingles and Applying New Ones.

(a) Shingles Applied by the American Method.

Follow the method described in Section 4.6.5-A. for replacing a broken slate with a new one. This method is illustrated in Figure 41. The same procedure can be followed with multiple-unit shingles.

(b) Shingles Applied by the Hexagonal Method.

Straighten the anchors, shatter the shingle and remove the broken pieces. Use the nail ripper to cut or draw the nail. Punch a hole in a small piece of copper, galvanized iron or painted tin, place over bottom anchor and nail firmly to the roof deck. Notch a new shingle to pass side anchors. Slide the new shingle into place over the bottom anchor and bend down anchors to hold it in place.

(c) Shingles Applied by the Dutch-Lap Method.

Remove the metal anchor and nails, then remove the broken pieces of shingle. Insert a new shingle with a new anchor. If the nails cannot be withdrawn, notch the new shingle to avoid them.

B. Asbestos-Cement Corrugated Sheets

Broken asbestos-cement corrugated sheets should be replaced with new ones fastened in the same manner as the original sheets. If this is not practicable, toggle bolts with lead or plastic washers may be used. These bolts pass through holes somewhat larger than the bolt and when drawn tight, the washer forms a waterproof seal.

4.4.6 Reroofing with Asbestos-Cement Roofing

A. Asbestos-Cement Shingles

(1) Preparing Deck for Reroofing.

For instructions for preparing the roof deck for reroofing with asbestos-cement shingles when the existing roofing is removed and when asbestos-cement shingles are to be applied over an existing asphalt-shingle, roll-roofing or wood-shingle roof, refer to Section 4.2.6, Reroofing with Asphalt Shingles, except that a 15-lb. asphalt-saturated felt should be applied over the wood-shingle deck. While it is entirely possible to apply asbestos-cement shingles over the roofings mentioned, the long service that is normally expected of asbestos-cement shingles indicates that the better practice is to remove the existing roofing, make the repairs to the deck necessary to bring it to as nearly "new" condition as practicable, and cover the deck with a 15-pound asphalt-saturated felt, laid horizontally, with a 4-in. headlap. End laps should be a minimum of 6 in. except at hips, ridges and valleys, where 12-in. laps are recommended. Nail the felt with sufficient large-headed roofing nails to hold it in place during application of shingles.

(2) Applying Asbestos-Cement Shingle Roof.

Space limitations do not permit inclusion of instructions for applying all types of asbestos-cement shingles. Step-by-step directions for installing multiple-unit shingles are described below. Essentially this same method is used for American method shingles. Detailed instructions for applying other types can be obtained from their manufacturers.

Starter Course

Lift up the edge of underlayment at the eaves and lay a full-size starter shingle. Let it overhand the eaves and gable approximately 1 in. and secure it with four galvanized nails. Apply succeeding starters, spaced 1/16-in. apart, in the same manner until entire course is laid.

First and Succeeding Courses

The first course of the main roof is laid directly over the starter course starting with a half shingle with the vertical edge projecting 1 in. beyond the gable and the butt edge projecting 1 in. beyond the eaves. Fasten each shingle with four galvanized nails. Do not drive nails "home" as in laying wood shingles. Lay the second course with a full-size shingle so that the shoulder coincides with the point of the underlaying course. A 6-in. exposure is automatically obtained. Start the succeeding course with a half-size shingle, then a full-size shingle, alternating with each course.

Hip and Ridge Finish

Lay roof shingles so that they butt closely against furring strips placed at hips and ridges. Cover furring strips with asbestos felt and apply hip and ridge shingles. Start laying the ridge shingles on main roof at the end of the ridge farthest away from prevailing storms. When covering hips, start at the lower end. Fasten each shingle with two nails and point up with slaters cement.

Nails

Large-head, galvanized, needle-point roofing nails should be used. For new roofs, 1-1/4 in. nails are adequate; for application over existing roofs, 2-in. nails should be used.

B. Asbestos-Cement Corrugated Sheets

Asbestos-cement corrugated sheets should be applied in accordance with current specifications for new construction. Manufacturers of asbestos-cement corrugated sheets maintain engineering and estimating services to assist users in determining the quantities of materials required for particular jobs. At least two manufacturers should be consulted.

4.5 Metal Roofing

4.5.1 Description and General Discussion

Metal roofings may be of copper, terne (tin), galvanized steel, aluminum, or so-called protected metal. The various kinds will be discussed separately, but certain factors which apply to all kinds are discussed jointly. For a more detailed discussion of metal roofing, see National Bureau of Standards Building Materials and Structures Report BMS 49, "Metallic Roofing for Low-Cost House Construction".

A. Expansion and Contraction.

All metals used in roofing expand and contract with changes in temperature. This must be taken into account in designing metal roofs. Actually, most metal roof forms owe their design in large part to the necessity for providing for expansion and contraction.

The rate of expansion and contraction differs with each metal. Some idea of the magnitude of the change for which provision must be made is given below, where the figures represent the expansion or contraction of an 8-ft. sheet with a 150°F variation in temperature:

Iron	--	6/64 in.
Copper	--	9/64 in.
Aluminum	--	12/64 in.

Changes in dimensions with changes in temperature result equally in all planes of the metal and are the same regardless of the thickness of the metal. Thus, a 1-ft. square piece of thin copper or aluminum foil will change as much in length and width as a thicker piece of the same size under similar temperature differences.

Because of changes in dimensions with changes in temperature, metal roofs laid in summer require adequate provision for contraction, but little provision for expansion. Conversely, metal roofs laid in cold weather require adequate provision for expansion, but little provision for contraction.

B. Galvanic Action.

In metal roof construction it is frequently impossible to prevent the contact of dissimilar metals, which may result in the corrosion of one of the metals and the protection from corrosion of the metal in contact with it. This is the so-called galvanic action or electrolysis which occurs when metals of different position in the electromotive series are in intimate contact in the presence of an electrolyte. The metals commonly used for roofing are listed in the electromotive series in the following order:

1. Aluminum
2. Zinc
3. Iron
4. Tin
5. Lead
6. Copper

When any two metals in this list are in contact in the presence of an electrolyte, the one with the lower number is corroded. Also, the farther apart the metals are, the greater will be the corrosion. Thus, with iron and copper in contact in the presence of water, the iron would be corroded more than lead in contact with copper under similar conditions. Any means that separates dissimilar metals will protect against this action. Frequently used are layers of waterproof building paper or asphalt-saturated felt, or a coating of asphalt paint.

C. Types of Metal Roofings.

Metal roofings are classified into three general types: Flat sheets, corrugated sheets and unit roofings made in the form of shingles or tiles. Special shapes of some metal roofings are also available.

(1) Flat Sheets.

Flat metal sheets are assembled for roofing purposes by means of various seams, commonly designated as batten seams, standing seams and flat seams.

Batten-Seam Roofing: In batten-seam roofing, metal sheets are formed over ribs or battens, of wood or metal, which divide the roof into small areas and provide adequately for expansion and contraction in the direction perpendicular to the battens. Expansion and contraction in the direction parallel to the battens is provided best by unsoldered flat-lock cross seams. Soldered cross seams are sometimes used with the expectation that allowance for expansion and contraction is made at the eaves and ridge or that the soldered seams so stiffen the sheets that slight buckling within each sheet will occur at elevated temperatures.

Standing-Seam Roofing: Standing-seam roofing is similar to batten-seam roofing in that it divides the roof into relatively small areas and provides for expansion and contraction in the direction perpendicular to the seams. The roofing sheets are fastened to the roof deck by means of cleats spaced not more than 12 in. apart, nailed to the roof sheathing at one end and folded into the seam at the other. Since standing seams are unsoldered, they should not be used on roofs with slopes of less than 2 in. per foot and should preferably be used with slopes 4 in. per foot or greater.

Flat-Seam Roofing: Flat-seam roofing, forming a continuous sheet, is adaptable to low-pitched roofs, preferably not less than 1/2 in. per foot, to insure proper drainage. Small sheets, usually 14 by 20 in., are fastened to the roof deck by means of cleats, one end of which is soldered to the sheet and the other nailed to the roof deck. A flat-lock seam is then formed at the juncture of the sheets and the seams sealed with solder. While the sheets are held in place firmly by the cleats and sufficient elasticity is provided to take care of expansion and contraction, large roof areas covered by this method should have the extremities of the roof covering free or expansion joints should be provided at regular intervals.

Occasionally long sheets of roofing are applied by the flat-seam method.

(2) Corrugated Roofing.

In corrugated roofing, series of parallel alternate ridges and grooves or crests and vales (hills and valleys) are formed in flat metal sheets. These features add stiffness to the sheets, increase the load-carrying capacity and aid in discharging rain water.

(3) Unit Roofings.

So-called metal shingles made to simulate the appearance of slate and forms made to imitate the various kinds of tiles comprise most metal unit roofings. Because of the small size of unit roofings, no provision for expansion and contraction is necessary.

D. Fire Protection.

Metal roofs, generally, are not classified as regards resistance to fire hazards. However, structures with metal roofs usually are eligible for the lowest insurance rates because of the protection afforded from falling sparks and embers.

4.5.2 Roof Decks for Metal Roofings

Metal roofings are applied on solid or open-slat wood decks, or on wood or metal framing (purlins). Solid wood decks may be of well-seasoned, tongued-and-grooved, square-edged or ship-lap sheathing laid to produce a smooth, uniform surface. In open-slat decks, the sheathing boards may be spaced from 6 to 24 in., depending on the rigidity of the roofing to be applied. Only the more rigid sheet roofings, usually corrugated, are laid on purlins without sheathing.

Metal roofing may also be laid over concrete or gypsum roof decks. Some underlay material such as asphalt-saturated felt is usually applied under metal roofing on tight decks. Contact of dissimilar metals should be avoided.

4.5.3 Storage and Handling of Metal Roofing

Metal roofings in storage should be protected from the weather. Although some metal roofings are intended for direct exposure to the weather, some, such as copper, may become stained and others, such as galvanized sttel, may corrode if stored in a damp place. Metal sheets should be stored on edge, not in contact with the ground.

4.5.4 Determining Treatment for Metal Roofs

Since the different metal roofing materials normally require different treatments, they are considered separately in this section.

A. Copper Roofing.

Copper is one of the least chemically active metals used for roofing. Consequently, copper roofings of adequate weight, applied properly, render long service. The weight of copper roofing is designated as ounces per square foot. Sixteen-ounce copper is the generally accepted weight for roofing. Sheets of this weight are approximately 0.022 in. thick and, when applied by the standing-seam method, weigh approximately 125 lb. per square. Copper roofs are usually applied by the flat-seam, batten-seam or standing-seam methods.

When copper roofing is exposed to the atmosphere a green coating known as patina forms on the exposed surface. This coating aids in protecting the metal from further corrosion.

Lead-coated copper is occasionally used for roofing. While this is a case of dissimilar metals in contact, lead and copper are adjacent in the electromotive series so that little action would be expected in any case. Since lead has the lower number, it protects the copper electrolytically as well as physically.

The most common cause of failure in copper roofs is the failure to provide adequately for expansion and contraction, particularly in flat-seam roofing. Broken soldered seams and breaks in the metal at points other than seams indicate inadequate provision for expansion and contraction.

Copper roofs do not normally require maintenance as defined for this manual. Any treatment necessary would be classed as a repair, following failure (leak).

(1) Repairing to Provide Adequate Expansion and Contraction.

(a) Flat-Seam Roofs.

When broken soldered seams indicate inadequate provision for expansion and contraction, new expansion joints sufficient to provide a joint at intervals of not more than ten feet in each direction should be installed.

(b) Batten- and Standing-Seam Roofs.

If soldered horizontal seams on batten- and standing-seam roofs are broken, loose lock seams that permit movement of the sheets should be installed at those points.

(2) Repairing Breaks in Copper Roofing.

(a) Small Breaks

Small holes in copper roofing can be repaired with a drop of solder. In soldering copper, scrape with a sharp instrument or emery cloth until bright metal shows on any surface that is to contact the solder. Then apply zinc chloride or rosin as a flux and tin the surface with a thin coating of solder.

(b) Larger Breaks

Larger breaks, not caused by inadequate provision for expansion and contraction, may be repaired by soldering a piece of copper over the hole.

(3) Reroofing with Copper Roofing.

(a) Preparing Deck for Reroofing with Copper Roofing

Restore the deck to as nearly "new" condition as possible, as follows:

Remove all protruding nails and renail sound sheathing where necessary.

Remove rotted or warped sheathing boards and install new decking.

Cover all large cracks, knot holes and resinous areas with sheet metal.

Repair or replace copper flashings.

(b) Applying Copper Roof

Apply copper roof in accordance with current specifications for new construction.

B. Terne Roofing

Federal Specification QQ-T-201, Terne Plate for Roofing (Roofing Ternes).

Terne (tin) roofing is composed of an iron or steel sheet coated on both sides with a lead-tin alloy. Terne sheets are usually furnished in grades 1C (approximately No. 30 U.S. Gage) and 1X (approximately No. 28 U.S. Gage). The 1C grade, weighing approximately 65 pounds per square, is generally used for flat-seam, batten-seam and standing-seam roofing. The 1X grade, weighing about 25 percent more than the 1C grade, is normally used for flashings, valleys and box gutters.

Sheets are generally available in two sizes, 14 by 20 in. and 20 by 28 in. The larger sheets are normally used in standing-seam construction, the smaller ones in flat-seam construction. Rolls containing 100 sq. ft. in widths of 20 or 28 in. are also available.

The weight of lead-tin coating for terne sheets is designated as "pounds per base box", a base box consisting of 122 sheets, 20 by 28 in. (435.56 sq. ft.). Standard roofing practice calls for a minimum coating of 25 lb. per base box, corresponding to a total of 0.9184 oz. per sq. ft. on both sides of the sheet.

The coefficient of expansion of terne sheets is only about 2/3 that of copper, therefore, expansion and contraction with changes in temperature is less of a problem. In addition, the lighter weights of terne sheets that are used permit slight buckling.

It is necessary to keep terne roofing well painted for long service. The reason is that the lead-tin alloy, while furnishing good physical protection to the iron or steel base, is so placed in the electromotive series that the coating will be preserved at the expense of the ferrous base in cases where pinholes or scratches in the coating expose the base.

The most frequent cause of failure in terne roofs is the lack of regular maintenance painting.

Many leaks in terne roofings are caused by faulty seams.

(1) Maintaining Terne Roofs.

Terne roofs must be maintained by periodical painting. The frequency of painting will vary with different conditions of exposure, but painting should never be put off until rust appears nor should thick coatings of paint be built up by too frequent painting.

Instructions for painting terne roofs are given in current publications.

(2) Repairing Terne Roofs.

(a) Broken Soldered Seams.

Broken soldered seams should be resoldered, following the precautions given for soldering copper in Section 4.5.4-A.(2)(a).

(b) Leaky Formed Seams.

Repair leaky formed seams by reforming or by calking with a plastic calking material.

(c) Small Breaks.

Repair small holes in terne roofings with a drop of solder.

(d) Larger Breaks.

Larger breaks in terne roofings may be repaired by soldering a piece of terne roofing over the break.

(3) Reroofing with Terne Roofing.

(a) Preparing Deck for Reroofing.

See Section 4.5.4-A.(3)(a), "Preparing Deck for Reroofing with Copper Roofing".

(b) Applying Terne Roof.

Apply terne roof in accordance with current specifications for new construction.

C. Galvanized Steel Roofing

Federal Specification QQ-I-716, Iron and Steel; Sheet, Zinc-Coated (Galvanized).

Galvanized sheets are available in various sizes and in thicknesses ranging from No. 12 to 30 gage and in various weights of zinc coating, the weight of coating being expressed as the total weight of zinc per sq. ft. on both sides of the sheet.

The resistance to corrosion of galvanized sheets increases with increased weights of zinc coating. However, since the sheets are formed after the zinc coating is applied, there are practical limits to the thickness of the coating on formed sheets. The heavier coatings, up to 2.75 lb., are normally applied to the heavier gage sheets. Zinc-coated sheets should be specified by weight in pounds per square foot.

For severe bending or forming, only thin, tightly adherent coatings are used. Zinc is an ideal coating material for iron or steel. From its position in the electromotive series it is obvious that the base metal will be protected electrochemically by the zinc in cases where pin holes or scratches expose it, and it is only when relatively large areas of the base metal are exposed that rusting takes place. Consequently, unlike terne coated sheets, galvanized sheets may be exposed without painting. The length of such exposure depends on the weight of the zinc coating and the conditions of exposure, but painting may be postponed safely until the first sign of base metal corrosion appears. This will be in the form of a rather bright yellow product resulting from the corrosion of the zinc-iron alloy formed on the surface of the base metal.

The common types of galvanized roofing are V-crimp, corrugated, pressed standing seam, rolled roofing and shingles. All but the roll roofing are pre-formed, ready to apply. Other special shapes of pre-formed sheets are also available.

Corrugated galvanized roofing is the lowest in cost of all types of metal roofing and, when properly applied and maintained, it renders very satisfactory service. Since it is the type of galvanized roofing used most frequently on warehouses, sheds, etc., it is taken as representative of the galvanized metal roofings.

Corrugated galvanized roofing may be applied over tight wood decks, with or without underlay, on open-slat decks or on wood or steel purlins. It is available in sheets of different lengths and depths of corrugations.

The most frequent causes of failure in galvanized roofings are improper application and lack of regular maintenance painting. Leaks at seams and fasteners are evidence of improper application.

Galvanized steel sheets should be secured with galvanized steel or aluminum-alloy fasteners in order to avoid galvanic attack on the sheet.

(1) Maintaining Galvanized Steel Roofing.

Galvanized steel roofs need not be painted immediately upon exposure. In fact, without special treatment or the use of special paints, it is better to postpone painting of galvanized steel for several months, at least, to insure adhesion of the paint. Painting may be postponed until the appearance of a bright yellow corrosion product indicating that the zinc coating is no longer protecting the zinc-iron alloy formed on the surface of the base metal. It is much safer to paint prior to the appearance of this product and subsequent regular maintenance painting will prolong the service of the roofing indefinitely.

Instructions for painting galvanized steel roofs are given in current publications on painting.

(2) Repairing Galvanized Steel Roofs.

(a) Leaks at Seams and Fasteners.

Inadequate laps in galvanized steel roofings may be repaired by calking the seams or, in severe cases where calking is impracticable, by stripping the laps as described in Section 4.3.6-D.(2), Repairing Leaky Seams of Roll Roofings for An Expected Use of More Than 1 Year. As stated in this reference, modifications of the method, following the same principle, may be satisfactory. With any method, workmanship is extremely important. It should be realized, also, that repairs of this kind cannot be expected to last as long as the galvanized sheets so that they will require maintenance treatment and probably renewal at intervals.

When exposed fasteners are a part of the lapped seam, the membrane treatment should be applied over them.

(b) Repairing Breaks in Galvanized Steel Roofing.

Breaks in galvanized steel roofing are best repaired by replacing the defective sheet of roofing with a new one.

(3) Reroofing with Galvanized Steel Roofing.

(a) Preparing Deck for Reroofing.

See Section 4.5.4-A.(3)(a), "Preparing Deck for Reroofing with Copper Roofing".

(b) Applying Galvanized Steel Roof.

Apply galvanized steel roof in accordance with current specifications for new construction.

D. Aluminum Roofing

Aluminum roofing materials may be homogeneous, with the entire cross section of the same composition, usually not less than 97 percent of aluminum, or they may be so-called clad materials, with a layer of aluminum or aluminum alloy that is anodic to the core material and which will retard corrosion of the core material if it is exposed. The usual core material is an aluminum alloy, though aluminum-clad steel sheets have been used.

Aluminum roofings are available in essentially the same forms as galvanized steel, namely V-crimp, corrugated, pressed standing seam and shingles. Other special shapes are also available. Sheets are produced in various sizes and thicknesses and in varying degrees of temper.

Aluminum roofing has only recently come into general use, but, when properly applied, it is known to render excellent service. It is similar to copper roofing in that it does not require painting. However, the coefficient of thermal expansion of aluminum is approximately one-third greater than that of copper so that ample provision for expansion and contraction must be supplied when long sheets of aluminum roofing are used.

Contact of aluminum roofing with dissimilar metals must also be avoided, particularly in coastal areas. This precludes the use of bare steel and copper nails, or lead washers, in such areas. Aluminum alloy nails should be used with aluminum alloy roofing to obtain the best results.

(1) Maintaining Aluminum Roofing.

Aluminum roofing, properly applied, does not normally require maintenance. However, if evidence of severe atmospheric corrosion occurs, the roofing may be preserved by regular maintenance painting. Instructions for painting aluminum are given in current publications.

(2) Repairing Aluminum Roofing.

Failures in aluminum roofing that are due to improper application are essentially the same as those encountered with galvanized steel roofing and are repaired similarly. See Section 4.5.4-C.(2), "Repairing Galvanized Steel Roofs".

(3) Reroofing with Aluminum Roofing.

(a) Preparing Deck for Reroofing.

See Section 4.5.4-A.(3)(a), "Preparing Deck for Reroofing with Copper Roofing".

(b) Applying Aluminum Roofing.

Apply aluminum roofing in accordance with current specifications for new construction.

E. Protected Metal Roofing

Protected metal roofing takes its name from the fact that it consists of a steel base sheet that is protected from the weather by a factory-applied covering. In one type, the covering is an asphalt-saturated, asbestos felt bonded to the steel core on both sides and coated with a waterproof coating. In the other type, the covering is simply an asphaltic compound that is applied to both sides of the sheet and surfaced with fine mineral matter.

Protected metal roofing is available in sheets of different size and unit weight, depending upon the gage of the metal core and the type of covering. It is also available in different shapes, though the corrugated form is in most general use.

Protected metal roofings are definitely proprietary materials with only limited sources of supply. Consequently, with these materials, the recommendations of the manufacturer should be followed as regards storage and handling, application, maintenance and repair.

With materials of this kind, it is practically impossible to avoid some breaks in the protective covering during application. To cover such breaks and to renew the protective coating when exposure makes a renewal necessary, only materials furnished by the manufacturer should be used in order to insure that the new material is compatible with the old.

4.6 Slate Roofing

Federal Specification SS-S-451, Slate; Roofing.

4.6.1 Description and General Discussion

Slate is a natural rock which was formerly much more widely used as a roofing material than at present. Consequently, most slate roofs that are encountered are old ones, on permanent structures. Some of the oldest roofs in the country are of slate, slate roofing having been produced for more than 200 years.

Slate colors are designated Black, Blue Black, Gray, Blue Gray, Purple, Mottled Purple and Green, Green (fading and unfading) and Red.

Most roofing slate has been produced in two counties in eastern Pennsylvania, although the colored slates from western Vermont and eastern New York and the gray (Buckingham) slates from Virginia have also been used widely. The quarries that produced the earliest, and possibly the most enduring, slates on the Pennsylvania-Maryland border (Peach Bottom) are no longer operated for roofing slate.

The eastern Pennsylvania slates are classed as "fading" slates, in that they change color on long exposure, the most common form of fading being that where the sides and bottom of the exposed portion of the slate changes to a light gray or tan, which will eventually spread over the entire exposed surface. This change may start in a relatively short time, 10 to 12 years, with slates of poor quality. It is usually accompanied by a partial disintegration of the faded portion. However, many such roofs that have rendered from 50 to 60 years of satisfactory service are known.

The New England and Virginia slates generally render excellent service, roofs of these slates more than eighty years old being not uncommon.

Roofing slate is quite brittle and becomes more brittle on exposure. It is produced in a variety of sizes and is usually laid by the American method. Roofing slate is normally 3/16-in. thick, but on monumental jobs may range in thickness from 3/16 to 2 in. for architectural effect. Slate roofs may vary in weight per square from 650 to 8000 lb., depending upon the thickness.

Roofing slate is not classified as to fire resistance by the Underwriter's Laboratories, Inc., but a reasonable classification would be one similar to that for asbestos-cement shingles.

4.6.2 Roof Decks for Slate Roofs

Wood decks for slate roofs should be of well-seasoned sheathing lumber, not less than 1 in. in thickness, not more than 6 in. wide and, preferably, tongued and grooved. Specifications formerly suggested 8 or 10 in. widths, but the narrower boards cause less breakage.

Sheathing boards should be fastened to each rafter with two nails to provide a smooth, even surface.

The deck should be covered with a 30-lb. asphalt-saturated felt prior to laying the slates. The roof deck should be kept dry at all times.

4.6.3 Storage and Handling of Slates

Roofing slates should be handled carefully to avoid breakage. They should be stacked on edge, preferably on planks, to give a firm, level support. Tiers of slate should be separated by wooden lath placed 1 in. from the outside edges of the slates. Slates should normally not be stored more than 6 tiers high. When stored outdoors they should be covered, particularly in freezing weather.

4.6.4 Determining Treatment for Slate Roofs

As with asbestos-cement roofing, mechanical damage, such as that from hail, traffic, limbs of trees, warping of the roof deck, etc., and failure of fasteners, constitute the principal causes of maintenance and repair work on slate roofs.

Actual failure of the slate due to weathering will occur eventually. With slate of poor quality this may happen in less than 25 years. With slate of good quality it may be after more than 100 years of exposure and usually after the slates have been relaid because of the failure of the original fasteners.

If only a few slates are broken they should be removed and new ones applied. If a large percentage are broken (25 percent or more), they should all be removed and a new roof applied. The age and condition of the undamaged slates should determine whether those salvaged from the old roof should be re-used.

No definite criteria can be given for determining whether a slate should be re-used. However, if the part that has been exposed is not faded appreciably and shows no evidence of disintegration; if the unexposed portion, either side, shows no disintegration; and if the slate gives a sound "ring" when it is held between thumb and finger by one corner as lightly as possible and struck a sharp blow by the knuckles, it may be safely re-used.

When the failure of a slate roof is due to failure of the fasteners, the failure is usually a general one, and, as with asbestos-cement roofing, piecemeal repair is futile, and it is best to remove the whole roof. Whether the old slate should be reapplied must be determined by its age and condition. A case is known where slate applied originally about 1870 were removed because of failure of the nails and successfully re-applied during World War II.

No sharp distinction can be drawn between maintenance and repair work in slate roofing. Maintenance and repair methods are therefore treated under one heading.

4.6.5 Maintenance and Repair Methods - Slate Roofs

A. Removing Broken Slates and Applying New Ones

Remove the broken slate and cut the nails with a ripper. Insert a new slate of the same color and size as the broken one and nail it through the vertical joint of the next course above, driving the nail about 2 inches below the butt of the slate in the second course above. Force a 3- by 6-inch or larger strip of copper under the course above the nail and bend the strip slightly concave to hold it in place. The strip usually will extend about 2 inches under this course and will cover the nail and extend 2 inches below it. (See Figure 41.)

4.6.6 Reroofing With Slate

A. Preparing Deck for Reroofing.

For instructions for preparing the roof deck for reroofing with slate when the existing roofing is removed and when slate is to be applied over an existing asphalt-shingle, roll-roofing or wood-shingle roof, refer to Section 4.2.6, "Reroofing with Asphalt Shingles", except that a 30-lb. asphalt-saturated felt should be applied over a wood-shingle roof before applying the slates. When slate is used to replace a lighter material or when it is applied over another material, the roof framing should be checked to determine whether it has adequate strength. As with asbestos-cement shingles, the long service that is normally expected from a slate roof indicates that the better practice is to remove the existing roofing, make the repairs to the roof deck to as nearly "new" condition as practicable and cover with a 30-lb. asphalt-saturated felt laid horizontally with a 4-in. headlap and 6-in. end laps. Secure the felt with large-headed roofing nails as necessary to hold it in place until covered by slate.

B. Applying Slate Roof.

<u>Starter Course</u>

Apply a cant strip of suitable thickness, depending upon the thickness of the slate, at the eaves. Lay the starter course over the cant projecting 2 inches at the eaves and 1 inch at the gable. Fasten each slate with two large-headed slating nails. Drive the nails so that their heads just touch the slate. Do not drive nails "home". The length of the starter course may be found by adding 3 inches to the exposure being used on the regular slate, while the thickness depends upon the thickness of the slate.

First and Succeeding Courses

Apply the first course of slate over the starter course with the butts of both courses flush and the joints broken. Fasten each slate with a minimum of 2 large-headed slating nails. Apply the second and succeeding courses with a headlap of 3 inches and joints broken. Bed all slates on each side of hips and ridges within 1 foot of the top and along rakes within 1 foot of the edge in approved elastic cement and cover all exposed nail heads with elastic cement. Lay slate roofs with open valleys.

Nails

Nails for slating should be of non-ferrous metal and of proper size. Large-headed copper nails are satisfactory. For commercial standard slates, 18 inches or less in length, use 1-1/4-in. nails; for longer slates, 1-1/2-in. nails should be used. A good rule to use in determining the proper size nail is to add 1 inch to twice the thickness of the slate. Two-inch nails should be used on hips and ridges.

4.7 Tile Roofing

4.7.1 Description and General Discussion

Most roofing tiles are clay or shale products that are burned to a hard, dense structure, with or without a glazed exposure surface. A few cement tiles have been produced.

Several types of tiles are used for sloping roofs, namely, shingle, Spanish, mission and interlocking, but in these general types there are many variants in size, form and color.

The so-called promenade tiles used for surfacing flat, built-up roofs that are subjected to traffic are usually square-edged shale tile not less than 3/4 in. thick.

Tile roofs are extremely heavy, ranging in weight from 800 to 1800 lb. per square; consequently, they require very strong framing to support them. Tiles, except promenade tiles, should not be laid on slopes of less than 4 in. per foot.

Roofing tiles are not classified as to resistance to fire by the Underwriters' Laboratories, Inc., but since they are fireproof they should be rated at least equal to asbestos-cement and slate roofings.

4.7.2 Decks for Tile Roofs

A. Sloping Decks.

Wood decks for tile roofs should be of well-seasoned sheathing lumber, preferably tongued-and-grooved and not more than 6 in. wide.

Sheathing boards should be fastened to each rafter with two nails to form a smooth, even surface.

The roof deck should be covered with 30-lb. asphalt-saturated felt prior to laying the tiles.

Concrete decks with nailing strips and nailable concrete decks are also used.

B. Flat Decks.

Promenade tile on flat decks are laid over a conventional asphalt or coal-tar-pitch built-up roof, usually 5 ply, with a final mopping of 25 pounds of asphalt or coal-tar pitch instead of the usual heavy pouring of bitumen specified for roofs surfaced with slag or gravel.

Promenade tiles should be laid in a bed of cement mortar (1 to 3) approximately 1 in. thick. Joints should be 3/16 to 1/4 in. wide, filled flush with cement mortar (1 to 2). Expansion joints, 3/4 in. wide, filled with a joint-sealing compound, should be provided on 15-ft. centers and at skylights, curbs and walls. Expansion joints should extend from the top of the tile through the cement mortar to the bituminous membrane.

4.7.3 Storage and Handling of Tiles

Store and handle roofing tiles as described in Section 4.6.3, "Storage and Handling of Slates".

4.7.4 Determining Treatment for Tile Roofs

A. Sloping Roofs.

Mechanical damage, such as that from hail, traffic, tree limbs, etc., and failure of fasteners constitute the principal causes of maintenance and repair work on tile roofs.

The principles that determine the treatment for sloping tile roofs are essentially the same as those for determining the treatment of slate roofs, except that occasionally, after very long periods of service, tile roofs that are in otherwise satisfactory condition may leak because of the disintegration of the felt underlayment.

B. Flat Roofs with Promenade Tile.

The most frequent cause of maintenance or repair work on a promenade tile roof is that necessitated by too few expansion joints between the promenade tile or by permitting the expansion joints to become filled with non-resilient material. Maintenance and repair methods for the built-up roof membrane are discussed under Built-Up Roofing.

Maintenance and repair methods for tile roofs are treated under one heading since no clear-cut distinction can be made between them.

4.7.5 Maintenance and Repair Methods - Tile Roofs

A. Sloping Roofs.

Replace broken shingle tiles with new ones by the method described for replacing broken slates, Section 4.6.5-A. Replace broken Spanish tiles by troweling portland cement mortar on the new tile surface that will be lapped by the tile in the course above and on the surface that will lap the tile in the course below. Fasten the new tile in place with copper wire. Interlocking tiles use special fastenings and are replaced easily. It is sometimes impossible to match the exact shape or color of very old tiles. When a number of buildings are roofed with the same kind of old tiles, it may be necessary to re-roof the first with new tiles that match the old as nearly as possible, keeping sound tiles salvaged from the first roof to patch the other roofs and to replace tiles broken when the other roofs need to be reroofed.

B. Promenade Tile on Flat Decks.

When insufficient expansion joints cause raising of the promenade tile, new joints should be installed. Expansion joints on 10-ft. centers and at skylights, curbs and walls are considered adequate.

If expansion joints have become filled with non-resilient material or if the expansion joint material has deteriorated, it should be raked out and new material installed.

4.7.6 Reroofing with Tiles

A. Sloping Roofs.

(1) Preparing Deck for Reroofing.

Existing roofing should be removed and the roof deck restored to as nearly "new" condition as practicable by removing rotted or warped sheathing boards and replacing them with new ones, and applying a 30-lb. asphalt-saturated felt horizontally, with a 4-in. headlap and a 6-in. side lap. Secure the felts along laps and exposed sheets with large-headed roofing nails as necessary to hold it in place until covered by tile.

(2) Applying Tile Roof.

(a) Mission and Spanish Tiles.

Before starting to lay tiles, mop the wood nailing strips with hot asphalt and fill spaces back of cant strips with asphaltic cement. Lay tiles with open valleys. Set eaves closures back 3 inches from the lower edge of eaves tiles. Lay pan tiles with uniform exposures to the weather. Lay cover tiles in a uniform pattern, except where otherwise necessary to match existing roofs. Give all tiles a minimum lap of 3 inches and extend pan tiles 1 inch over rear edge of gutter. Cut tiles to meet projections with finished joints and point up with roofer's cement. Waterproof the spaces between field tiles and wood nailing strips at ridges and hips with a fill of roofer's cement. Fit all tiles properly and then secure them with nails long enough to penetrate at least 1 inch into the wood base. Fill spaces between pan and cover tiles in first row at eaves solid with cement mortar composed of 1 part portland cement, 3 parts fine sand, and enough clean water to form a plastic mix. Wet all tiles before applying mortar, and then press them firmly into the mortar bed. Match the tile courses on dormer roofs with those on the main roof. Cut surplus mortar off neatly. Point up all open joints. Remove loose mortar from exposed surfaces.

Where winds of hurricane intensity can be expected, consideration should be given to reinforcing tile roofs by laying all field tiles in portland cement mortar. To do this, fill the ends of tiles at eaves, hips, ridges, rakes, and spaces beneath ridges, solid with cement mortar and fill the full width of laps between the tiles, both parallel and perpendicular to the eaves, with cement mortar.

(b) Slab Shingle Tiles.

Lay slab shingle tiles with a 2-in. headlap and secure each tile with two large-head roofing nails. Double the tiles at the eaves and project them 1 inch over the rear edge of gutters. Lay all tiles within 1 foot of hips, ridges, and abutting vertical surfaces in roofer's cement. Lay 10- or 12-in. tiles with 1-in. headlap on sides of dormers. Match the tile courses on dormer roofs with those on the main roof. Lay tile roofs with open valleys.

4.8 Wood-Shingle Roofing

4.8.1 Description and General Discussion

Wood-shingle roofs are usually of red cedar, cypress or redwood shingles. Wood shingles are available in three "Grades"; however, the description that follows applies only to the No. 1 grade.

Only heartwood should be used in making wood shingles, cut so that the annual or growth rings form an angle no greater than 45° from the perpendicular when a shingle is laid flat. This defines "edge-grain" shingles and distinguishes them from flat-grain shingles which are less resistant to splitting and warping than the edge-grain shingles.

Thickness is the most important dimension of wood shingles. It is measured at the butt ends and is designated according to the number of pieces that are necessary to constitute a specific unit of thickness. Thus, 5/2 indicates that the butts of five shingles measured together will give a total thickness of 2 in.

Wood shingles should be not less than 16 in. long. Maximum width is 14 inches; minimum width of shingles less than 24 inches long is 3 in. and for those 24 in. long and longer, it is 4 inches.

Wood shingles are sold in bundles, with shingles packed flat in courses, the butts of shingles in alternate courses facing in opposite directions, giving a "square pack". The number of courses at each end of a bundle are indicated so that a bundle designated 13/14 means one with 13 courses at one end and 14 at the other. Each course of shingles in a bundle averages 18-1/2 "running inches", that is, the actual width of the shingles in a course in a bundle. Given this information and the desired exposure, it is easy to calculate the number of bundles of shingles that will be required to cover a square of roof surface.

The treatment of wood shingles with creosote preservative materially lengthens the life of a wood-shingle roof. The creosote tends to exclude moisture; to prevent warping and splitting of the shingles; to retard rot or decay and to decrease surface weathering. In addition, shingle nails last longer with shingles that have been given a creosote treatment.

Commercial Standard 31-52, "Wood Shingles (Red Cedar, Tidewater Red Cypress, California Redwood) issued by the Department of Commerce and available from the Government Printing Office, discusses general and detail requirements for No. 1 Grade wood shingles and gives a glossary of terms used in connection with wood shingles. Another reference is the "Certigrade Handbook of Red Cedar Shingles", published by the Red Cedar Shingle Bureau, Seattle, Washington.

4.8.2 Roof Decks for Wood-Shingle Roofs

Roof decks for wood-shingle roofs may be of solid or open sheathing. Solid decks should be of well-seasoned sheathing lumber, nominal 1 in. in thickness, either tongued-and-grooved or with straight sides, or of plywood, exterior grade, not less than 1/2 in. thick. When open or spaced sheathing is used the sheathing boards (1 by 3, 1 by 4 or 1 by 6-in.) are spaced the same distance as the anticipated shingle exposure and each course of shingles is nailed to a separate sheathing board; or 1 by 6-in. boards are spaced twice the distance of the anticipated shingle exposure. By the latter method, two courses of shingles are nailed to each sheathing board. No underlay material is required for wood shingles.

4.8.3 Storage and Handling of Wood Shingles

Wood shingles should preferably be stored under cover to maintain a uniform moisture content. If outdoor storage is necessary, bundles should be piled on planks to prevent contact with the ground and they should be covered to protect them from the weather.

4.8.4 Determining Treatment for Wood-Shingle Roofs

Wood-shingle roofs of good quality shingles applied correctly normally render long and satisfactory service. Failures in wood-shingle roofs usually occur because of warping or splitting of the shingles, decay, normal weathering, or failure of the shingle nails.

Warping and splitting are found most frequently with flat-grain shingles. They occur usually on the portion of the shingle that is exposed to the weather. Neither warping or splitting is likely to affect the waterproofness of the roof because a wood-shingle roof should have three layers of shingles throughout. Splits in shingles, however, may shorten the life of a roof by permitting water to reach the nails in the shingles underneath and hasten their deterioration.

Decay in wood is caused by minute organisms that thrive best in moist wood. Therefore, it is found most frequently in low-pitched and shaded roofs that remain moist for long periods.

Normal weathering proceeds slowly in wood shingles. Factors in normal weathering are wind-driven rain, snow, hail, or sand and alternate freezing and thawing in winter. Very old wood-shingle roofs usually show the exposed shingle butt just below the area protected by the overlying shingle much thinner than the protected area.

Failure of shingle nails is most frequently caused by the splitting of shingles or the improper placement of nails.

The effects of all of the deteriorating factors mentioned are lessened appreciably by impregnating the shingles with creosote oil. Impregnation by dipping or by pressure process before the shingles are applied is much more effective than treatment after application.

Maintenance and repair work for wood-shingle roofs will be treated under the same heading.

4.8.5 Maintenance and Repair Methods - Wood-Shingle Roofs

A. Warped Shingles.

Warped shingles do not usually cause leaks and, except for appearance, are not immediately objectionable. Warped shingles will probably crack eventually, in which case they should be removed. Warped shingles should never be face nailed except in preparation for reroofing. The nailing is likely to crack the shingles and the nails will work loose, permitting the roof to leak.

B. Removing Cracked or Rotted Shingles and Applying New Ones.

Broken wood shingles can be removed by the methods described for removing broken slates (Section 4.6.5-A.), except that at least four nails must be cut. After the broken shingle is removed, insert a new one of the same size and nail it through the exposed butt, preferably with thin copper nails. Also nail the shingle immediately above through the exposed butt.

C. Treating Shingles with Creosote or Shingle Stain.

Wood-Preservative, Coal-Tar-Creosote, Crystal-Free, for Brush, Spray or Open-Tank Treatment, under Federal Specification TT-W-560, is an excellent preservative for wood-shingle roofs. Application by brush, while more laborious, is likely to be more effective than application by spray because of better penetration.

If a colored roof is desired, pigmented stains containing creosote oil or its derivatives should be used in preference to those without creosote.

The frequency of treatment varies with the kind of wood, pitch of the roof and any pre-treatment the shingles may have been given prior to application.

Drying-oil paints should not be used on wood-shingle roofs because unequal absorption and subsequent drying of the paint may cause the shingles to warp and curl.

4.8.6 Reroofing with Wood Shingles

Wood shingles may be used for reroofing over wood- and asphalt-shingle roofs and over smooth- and mineral-surfaced asphalt roofing. However, as with other materials, the better practice is to remove the existing roof covering.

No attempt should be made to apply wood shingles over metal, slate or asbestos-cement roofs because of difficulties in nailing.

A. Preparing Deck for Reroofing with Wood Shingles.

(1) When Existing Roofing is Removed

Proceed as described under Section 4.2.6-A., "Preparing Deck for Reroofing with Asphalt Shingles", (1) "When Existing Roofing Is Removed".

(2) When Existing Roofing Remains.

(a) Reroofing Over Wood Shingles.

Remove all loose and protruding nails. Replace decayed or missing shingles with new ones. Nail down or cut off corners of curled and warped shingles and reanil loose shingles.

Cut back shingles at eaves and rakes far enough to apply 1- by 4-in. strips securely nailed.

Remove weathered shingles at the ridge and replace them with a strip of beveled siding, thin edge down, to provide a solid base for nailing the ridge shingles. Treat hips the same as ridges.

Fill open valleys with wooden strips level with the shingle surface.

Install new non-ferrous metal valley flashings.

Install new non-ferrous metal base and counter flashings, in accordance with new construction specifications, where necessary. Sweep all loose debris from the roof deck.

(b) Reroofing Over Asphalt Roll Roofing.

Inspect carefully all sheathing boards at the eaves and replace rotted boards with new ones.

Remove all loose or protruding nails. Cut all blisters and buckles and nail cut edges to the roof deck as illustrated in Figure

Repaint ferrous metal flashings that are in good condition.

Install new non-ferrous metal base flashings and new metal counter flashings in accordance with new construction specifications, where necessary.

Install new non-ferrous metal valley flashings.

Sweep all loose debris from the roof.

(c) Reroofing Over Asphalt Shingles.

Proceed as described in (b), Reroofing Over Asphalt Roll Roofing and, and in addition, nail down or cut away the butts of all curled or lifted shingles.

B. Applying Wood Shingle Roof.

Apply a double course of wood shingles at the eaves, with the butts of the shingles overhanging the eaves 1-1/2 in. Space all shingles in the same course 1/4 in. and nail each shingle in these and subsequent courses with two nails placed 1 to 1-1/2 in. above the butt line of the succeeding course of shingles and not more than 3/4 in. from the edge of the shingle on each side.

Break the joints between the shingles in successive courses at least 1-1/2 in. and apply the shingles so that the joints in alternate courses are not in line.

The exposure of wood shingles depends on the slope of the roof and on the length of the shingles. For slopes of 5 in. per foot and greater, the standard exposures are as follows:

Length of shingle, in.	Exposure, in.
16	5
18	5-1/2
24	7-1/2

For slopes less than 5 in. per ft., these exposures should be 3-3/4, 4-1/4 and 5-3/4 in. respectively.

Use only hot-dipped galvanized nails, either round or square cut, for applying wood shingles. Use 1-1/4 in. nails for 16- and 18-in. shingles and 1-1/2-in. nails for 24-in. shingles in new construction. When wood shingles are applied over an existing roof, use 1-3/4-in. nails for 16- and 18-in. shingles and 2-in. nails for 24-in. shingles. Nail heads should not be driven into the wood.

5. FLASHINGS AND APPURTENANCES

5.1 Wall, Chimney and Monitor Flashings

5.1.1 General Discussion

The function of a flashing is to provide a water-tight junction between the roofing material and other parts of the structure, and between roof sections. Flashings may be defined as the most vulnerable part of any roof since the majority of leaks result from failures at these vital areas. There are numerous causes of flashing failures, the most common resulting from inadequate or faulty construction. Many roof and flashing failures could be eliminated by constant and painstaking inspection by competent inspectors during installation. Some common causes of flashing failures are:

1. Weathering resulting from insufficient or lack of protective coating.
2. Punctures usually resulting from the omission of a cant strip. (Figure 42.)
3. Open laps or seams.
4. Separation of flashing from vertical surface. (Figure 11.)

5. No allowance made for expansion and contraction of metal flashings.

In many instances, leaks have been attributed to flashing failures where no such failures were evident. The actual cause may result from open joints in a masonry wall or chimney, into which the water enters, works its way down behind the flashing and into the roofing. In masonry walls, this condition may be eliminated by "through the wall" flashings.

Flashings may be differentiated into two main classes, namely, base and cap or counter flashing.

The base flashing is the actual junction between the roofing material and the vertical wall, projection, etc., and should be considered as a component part of the roof construction. The base flashing may be either of plastic or metallic construction. For the purpose of this manual, the term plastic flashing includes all types other than metal.

The cap or counter flashing is usually constructed of metal and serves as a protecting cover for the base flashing. This flashing should extend a minimum of 8 in. and a maximum of 12 in. above the roof line and should be set into a reglet extending into the wall at least 4 in., although through-wall flashings are preferable. The function of the cap or counter flashing is to overlap the base flashing so that all flashing strips and nails are completely covered. In some instances, a cap flashing of felt or fabric is employed. This system usually consists of a 4 to 6 in. strip of saturated felt or fabric, embedded in plastic cement and placed 2 to 3 in. above and 2 to 3 in. below the top edge of the base flashing so that all nail heads are completely covered. A uniform coating of a plastic flashing cement is then troweled to a feather edge over the felt or fabric strip.

5.1.2 Inspection Procedures

For convenience, the inspection form for flashings is incorporated with the inspection forms for various types of roofing in Appendix I.

A. Plastic Base Flashings.

A thorough inspection of flashings, at least once every year, is essential since numerous failures attributed to the roofing material are frequently flashing failures. These areas should also be the first to be inspected when leaks are reported in a structure. A good procedure to follow is to first make a careful inspection of the roofing material near the flashings for signs of moisture. In built-up roofs, blisters in this area are a sure indication that moisture has found its way beneath the membrane. If blisters are evident and the membrane seems intact, a flashing failure, however small, is indicated. Following the inspection of the roofing material, the entire base flashing should be inspected for punctures, broken laps or seams, separation of flashing from vertical surfaces and signs of deterioration. If a cant strip is present, it can usually be detected by gently tapping the flashing in the area mid-way between the roof and the vertical surface with a solid object. The areas in question should be clearly marked for future maintenance and repair.

B. Metal Base Flashings.

The common failures which occur in a metal base flashing are cracks, broken joints, and deterioration of ferrous metal flashing due to lack of paint. The inspector should pay particular attention to exterior and interior corners, which areas are most vulnerable. Usually no cant strip is employed when base flashing is of metal. The inspection procedure is similar to that described under plastic base flashings.

C. Plastic Cap or Counter Flashings.

During the inspection of plastic cap flashings, the most likely causes of failure will be:

1. Separation of flashing from the vertical surface and/or from base flashing.
2. Deterioration due to lack of protective coating.

D. Metal Cap or Counter Flashings.

The common failures in metal cap flashings are:

1. Location of the flashing too high or too low above the roof deck.
2. Deterioration of ferrous base flashings due to lack of paint.
3. Cracks and broken joints due to expansion and contraction.
4. Separation of the flashing from the vertical surface.

5.1.3 Maintenance and Repair Methods

In the case of flashings, no definite distinction can be drawn between maintenance and repair methods. Consequently, the two are combined in this section.

A. Plastic Base Flashings.

(1) Punctures. (Figure 42.)

Punctures are usually caused by traffic or by falling objects striking a base flashing where a cant strip has been omitted.

Treatment: For temporary repair, make puncture watertight by coating with plastic flashing cement and embedding into the cement a saturated felt or fabric, following with a trowel coat of plastic flashing cement.

For permanent repair, remove the broken flashing, install a cant strip and reflash in accordance with standard specifications for new roof construction.

(2) Vertical Laps of Flashing Open.

Treatment: Smooth laps back in place and re-cement with plastic flashing cement. Recoat entire lap with plastic flashing cement.

(3) Separation or Sagging of Base Flashing from Wall, Chimney or Monitor.

Treatment: Refasten the base flashing to the vertical surface by nailing or cementing. Recoat with a plastic flashing cement and replace appropriate counter flashing.

(4) Surface Coating of Plastic Base Flashing Disintegrated.

Treatment: Brush off all loosely adhering coating and apply a trowel coating of asphalt or coal-tar plastic cement as used for the original coating.

B. Metal Base Flashings.

(1) Lack of Protective Coating of Paint. Metal Not Severely Deteriorated.

Treatment: Remove all rust, moisture, loose scale, grease, dirt, etc., and apply fresh coating of paint. Instructions for painting metal are given in current publications.

(2) Lack of Protective Coating of Paint. Metal Severely Deteriorated, i.e., Holes, Punctures, Etc.

Treatment: Remove and discard deteriorated area of flashings and re-flash in accordance with standard specifications for new roof construction.

(3) Vertical Joints of Base Flashing Open.

Treatment: Straighten the metal flashing and put it in place. Re-solder open joints. Install additional expansion joints where necessary.

(4) Separation of Metal Base Flashing from Wall, Chimney or Monitor.

Treatment: Treat as described under maintenance and repair of plastic base flashings.

C. Plastic Cap or Counter Flashings.

(1) Separation of Plastic Cap Flashing from Vertical Wall and/or Base Flashing.

Treatment: Re-cement plastic cap flashing with a plastic flashing cement and apply a trowel coat of flashing cement.

(2) Deterioration Due to Lack of Protective Coating.

Treatment: Brush off all loosely adhering coating and apply a trowel coating of plastic flashing cement.

D. Metal Cap Flashings.

(1) Lack of Protective Coating of Paint. Metal Not Severely Deteriorated.

Treatment: As described under maintenance and repair of metal base flashings.

(2) Lack of Protective Coating of Paint. Metal Severely Deteriorated.

Treatment: As described under maintenance and repair of metal base flashings.

(3) Metal Cap Flashing Located Too High or Too Low to Function Properly.

Treatment: Remove the loose flashing and trim off flush with the wall any flashing metal left in the joint. Make necessary repairs to the vertical surface and re-flash in accordance with standard specifications for new roof construction into a new reglet at least 2 in. above the old one.

E. Repair Methods of Flashings When Repairs Involve Application of a New Membrane.

<u>Treatment</u>: Remove existing flashing and cut old membrane flush with base of vertical surface. An exception may be made with the metal counter flashing that is in good condition, well fastened to the wall, and which will stand bending up for the application of new base flashing and bending down after base flashing is installed.

Install new base flashing after repair membrane is applied in accordance with standard specifications for new roof construction.

F. Repair Methods for Parapet Walls.

<u>Note</u>: It is poor practice to coat parapet or fire walls with an impervious coating.

(1) Mortar Joints Deteriorated.

<u>Treatment</u>: Rake out all loose mortar and repoint with a 1:1:6, portland cement, hydrated lime and sand mortar, proportioned by volume.

(2) Joints in Coping Open.

<u>Treatment</u>: Rake out all loose material and repoint with portland cement or a caulking compound complying with Federal Specification TT-C-598.

5.2 Vent Flashings

5.2.1 General Discussion

The majority of vents are constructed of metal and consequently are subject to expansion and contraction. For this reason, it is poor practice to attempt to flash up the sides of such projections as this type of flashing is subject to early failure. Vents are usually of two types, namely, the flat flange vent and the curb vent. The former being the most common. The flat flange vent is placed directly upon the last ply of roofing while the curb vent is constructed to fit over a wooden or concrete curb. Each type is supplied with a component flashing flange by which the vent is connected to the roofing. In the case of the flange vent, asphalt, pitch, or plastic cement is used generously beneath and above the metal flashing flange which is securely nailed to the roof. The flange is stripped with two plies of felt, not less than double the width of the flange, cemented solidly together and to the flashing flange with asphalt, pitch or plastic cement. The flashing flange of the curb vent is secured to the curb after the flashing is brought up and over the curb.

5.2.2 Inspection

All vents and vent flashings should be carefully inspected during the periodic roof inspection and at such times that leaks are reported in the structure. An inspection should also be made from the underside of the roof. Damp areas or stains near the vent indicate a flashing failure. Common failures to look for in vents and vent flashings are:

(1) Broken seams caused by expansion and contraction.

(2) Exposed nails that have worked loose causing separation of metal flashing flange from roof (Figure 43).

(3) Omission of felt stripping over edge of flange.

(4) Standing water around vent or stains on adjacent roofing (Figure 44).

(5) Deterioration of metal caused by lack of protective coating of paint.

5.2.3 Maintenance

A. Broken Seams Caused by Expansion and Contraction.

Treatment: Re-solder broken seams and install additional expansion joints if necessary.

B. Separation of Flashing Flange from Roof Caused by Exposed Nails Working Loose (Figure 43).

Treatment: Raise flashing flange high enough to force plastic cement beneath it and redrive loose nails. Apply two plies of felt or fabric cemented to each other and to the flange with asphalt, pitch, or plastic cement. The outer edge of the first ply of felt or fabric should extend not less than 3 in. beyond the flange and of the second ply of felt or fabric not less than 6 in. Apply finished surfacing similar to roof surfacing.

C. Omission of Felt Stripping Over Flashing Flange.

Treatment: Treat edges by applying two layers of felt or fabric as described in B. above.

D. Standing Water Around Vent or Water Stains on Adjacent Roofing (Figure 44).

Treatment: (Treat only if leakage occurs.) Remove old flashing and reflash in accordance with instructions given in B. above.

In severe cases re-installation of the vent may be called for.

E. Lack of Protective Coating of Paint With or Without Deterioration of Metal.

Treatment: Remove all rust, moisture, loose scale, grease, dirt, etc., and apply fresh application of paint. Instruction for painting metals are given in current publications.

In cases where metal is seriously deteriorated, removal and replacement with new vent may be called for.

5.2.4 Repair During Reroofing

Metal vents and the flashing flanges should be carefully inspected for signs of deterioration. If deterioration is serious, remove old vent and install new vent in accordance with standard specifications for new roof construction.

If the present vent is deemed serviceable, proceed as follows:

1) Flange vent - If the flashing flange is securely fastened to the old roof, the new membrane should be cut to fit around the vent and applied over the flashing flange.

2) Curb vents - Raise the vent and re-flash so that the new flashing can be brought up and over the curb and replace and refasten vent to the curb.

5.3 Valley Flashings

5.3.1 General Discussion

Roof valleys are formed when two sloping roof sections join to form a V. Since water from both sections is concentrated in the valley, valley flashings are of extreme importance.

Valley flashings on tile, slate, asbestos-cement shingles, wood shingles, metal and similar roofs are usually constructed of metal, while those on mineral-surfaced asphalt roll roofing and asphalt shingles are constructed either of metal or mineral-surfaced roll roofing. Valleys on smooth-surfaced roll roofing roofs are usually of smooth-surfaced roll roofing.

A. Metal Valley Flashings.

Metal valley flashings may be of 20-ounce copper or similar material and are applied in sheets not exceeding 8 ft. in length, free from longitudinal seams and of sufficient width to extend not less than 4 in. under the roof covering on each side. The exposed portion is approximately 4 in. wide at the top and increases 1 in. in width for each additional 8 ft. in length. Each section is lapped not less than 6 in. (8 in. where the slope of the valley is less than 4-1/2 in. per foot) in the direction of flow and the upper end is fastened to the roof deck.

With slate or tile roofing, 24-oz. copper is generally used in place of the 20-oz., and where valleys are installed with clay or cement tiles, the exposed valleys have a uniform width of 4 in. in place of the increasing width of 1 inch per 8 feet.

B. Mineral-Surfaced Asphalt Roll Roofing Valley Flashings.

Mineral-surfaced asphalt roll roofing is satisfactory for flashing valleys of both asphalt-shingle and mineral-surfaced asphalt roll roofing roofs. The valley is lined with two thicknesses of the material. The first ply is 18 in. in width and centered in the valley with surfaced side down. The second ply, 36 in. in width, is applied over the first strip, centered into the valley, nailed and cemented with surfaced side up. The width of the valley is 6 to 8 in. wide at the top and will diverge at the rate of 1 inch per each 8 feet of the valley.

5.3.2 Inspection

Valleys must be kept clean to function properly. Ice dams and debris blocking valleys may cause water to back up beneath the roofing or laps of the valley. The valley incline should be checked for smoothness and uniformity to assure a rapid run-off of the water.

A. Metal Valleys.

Copper valley flashings usually require little maintenance if properly installed, while terne and galvanized valleys should be inspected for lack of paint and signs of rust. The inspector should look for separations at the end laps and for openings in the metal due to corrosion.

B. Mineral-Surfaced Roll Roofing Valley Flashings.

The inspector should look for signs of normal weathering which will most likely appear in this area first since water concentrates in the valley. The first indication is the loss of granules, slight at first, but accelerating as the loss of granules exposes mor of the asphalt to the weather. Separation of end laps and separation of the roof proper from the valley flashings often result in leaks.

5.3.3 Maintenance and Repair

A. Metal Valley Flashings.

Valleys must be kept clean to function.

(1) Leakage Occurring at Laps.

Treatment: Do not attempt to solder laps. Treat seam or lap with a white lead paste consisting of basic lead carbonate and 8% boiled linseed oil.

(2) Small Holes in Copper Flashings.

Treatment: Clean surface around hole with emery cloth, apply a flux of zinc chloride or rosin and repair with a drop of solder.

(3) Large Holes in Copper Flashings.

Treatment: Prepare surface as in (2) above and solder a piece of copper over the hole.

(4) Holes in Galvanized Metal Flashings.

Treatment: Replace the smallest unit of the flashing.

(5) Lack of Protective Coating of Paint on Terne or Galvanized Metal Valleys.

Treatment: Painting should never be put off until rust appears. Should rust appear, remove all rust, moisture, loose scale, grease, dirt, etc., and apply new application of paint. Instructions for painting metals are given in current publications.

B. Mineral-Surfaced Roll Roofing Valley Flashings.

Valley must be kept clean to function properly.

(1) Loss of Granules Due to Normal Weathering and Water Concentrating in Valley.

Treatment: Remove all loose granules, dust, and dirt by sweeping, vacuuming or air blast and apply one thin coat, by brushing, of asphalt primer (SS-A-701). After primer is dry, apply one of the following: 1) a coating of asphalt emulsion (MIL-R-3472) by brush at a rate of 3 gallons per square; 2) Asphalt-base roof coating meeting Federal Specification SS-R-451, by brush, at a rate of 3 gallons per square; 3) Fatty-acid-pitch base roof coating at a rate of 3 gallons per square, available in natural, green, buff, or red colors.

(2) Separation of End Laps.

Treatment: Lift upper lap high enough to force a liberal amount of plastic cement between plies and press top lap firmly in place.

(3) Separation of Roofing or Shingles from Flashing.

Treatment: Gently lift separated shingle or area, force plastic cement beneath it, and press shingle or roofing firmly into the cement.

5.4 Drainage Systems

5.4.1 General Discussion

The drainage system includes all gutters, leaders, drains, scuppers, crickets, etc. The primary function of this system is to remove water from a roof as quickly as possible and to prevent the storage of water on the roof. Every roof must have some provision for drainage, including the so-called "dead-level" decks. It is important that drainage areas be kept free from debris which will interfere with proper drainage (Figure 45). Many roof failures can be traced both directly and indirectly to inadequately designed or improperly installed drainage systems.

5.4.2 Inspection

A suggested check list for inspectors is as follows:

1) Check deck incline. It should be smooth and uniform.

2) Look for low areas. Standing water or water stains are signs of low areas.

3) Check gutters, leaders, etc., for obstructions which will hinder the run-off of water.

4) Check size, locations and number of drains, gutters and leaders.

5) Look for broken or clogged drains.

6) Look for standing water around drains. This indicates drain is set too high or not in correct location.

7) Look for defective flashing around drains. Drains are usually equipped with a flashing flange which should be securely fastened to the roof deck and double felt stripped as in the case of vent flashings.

8) Check gutters for defective hangers and straps.

9) Check gutters for holes, rust or other signs of deterioration.

5.4.3 Maintenance and Repair

A. Drains.

Must be kept clean to function properly (Figure 46).

(1) Broken Drains.

Treatment: Remove broken drain and install new drain in accordance with specification of new roof construction.

(2) Separation of Flashing Flange from Roof.

Treatment: As described in Section 5.2.3-B.

(3) Standing Water Around Drain.

If drain is clean, this condition indicates drain is not at a low point of the area or is set too high.

Treatment: Re-install or re-locate the drain.

B. Gutters and Leaders.

Must be kept clean to function properly.

(1) Rusting or Corrosion of Gutters and Leaders.

Treatment: 1) Metal not deteriorated: Remove all rust, moisture, loose scale, grease, dirt, etc., and apply new coat of paint. Instructions for painting metals are given in current publications.

2) Metal severely deteriorated: Remove defective section and replace with new material in accordance with standard specications for new roof construction.

(2) Defective Straps and Hangers.

Treatment: Replace and re-align defective straps and hangers.

C. Low Areas, Permitting Water to Stand (Figure 47).

Failures of this type are usually the result of poor design or structural failure. Building up the roof covering with felt and hot bitumen or any type of fill is not recommended since the materials only add weight to an already weakened area.

Treatment: Before repair or re-roofing is started, the low area should be corrected by raising the sunken joists or installing new joists. Where little can be done to correct such a failure, the relocation of the drain to the low area will be of value.

5.5 Gravel Stops and Metal Edge Strips

5.5.1 General Discussion

The primary function of gravel stops (slag or gravel surfaced roofs) and metal edge strips (smooth-surfaced built-up roofs) is to finish off all exposed edges and eaves in order to prevent wind from getting under the edges causing blow-offs. Another important function of the gravel stop is to prevent the loss of gravel or slag from areas near the edge of the roof. The flashing flange of the gravel stop or edge strip is placed over the last ply of felt and should extend at least 4 inches on the roof. It should be nailed securely to the roof deck and double felt stripped, after which the finished coat of bitumen and surfacing or cap sheet is applied. The lip of the gravel stop should protrude a minimum of 3/4 inch above the roof deck while the lip of the edge strip should be a maximum of 1/2 inch above the deck. Both should be securely fastened to the facia board.

Many structures have been observed where gravel stops or edge strips have been omitted. In lieu of this practice, the roofing membrane was bent over the edge and fastened to the facia board with wooden battens as shown in Figure 48. Figure 49 shows a section of this roof after repair and the installation of a metal gravel stop.

Numerous failures or potential failures have occurred at these vital areas due to severe weathering of the roofing material and to the deterioration of the wood battens and the facia boards which in turn renders the roof membrane susceptible to wind damage.

5.5.2 Inspection

The gravel stops and edge strips should be inspected during the annual inspection of the roof. The inspector should examine carefully the entire edge of the roof, paying particular attention to:

1) Rotted or rusted gravel stops and edge strips,

2) Damaged or rotted overhangs and facia boards,

3) Separation of flashing flange from the roof,

4) Bitumen flowing under gravel stop and down facia board,

5) Omission of gravel stops and edge strips.

5.5.3 Maintenance and Repair

A. Rotted or Rusted Gravel Stops and Edge Strips.

Treatment: Not Seriously Deteriorated - Remove all rust, moisture, loose scale, grease, dirt, etc., and apply fresh coating of paint to ferrous metal. Instructions for painting ferrous metals are given in current publications.

Seriously Deteriorated - Remove and discard section containing deteriorated area and replace in accordance with standard specifications for new roof construction after damaged overhang and facia boards are repaired or replaced with new ones.

B. Damaged, Rotted or Deteriorated Facia Boards and/or Overhangs.

Treatment: Remove and discard all deteriorated metal. Repair and replace facia boards and overhangs and install new gravel stop or edge strips in accordance with standard specifications for new roof construction.

C. Separation of Flashing Flange from Roof Membrane.

Treatment: Scrape off gravel or slag at least 12 inches from gravel stop and lift flange high enough to force plastic cement beneath it. Re-nail in place and apply two layers of felt stripping, the top one overlapping the lower one 2 to 3 inches. Pour hot bitumen over bare area and while hot, embed clean, dry slag or gravel as used for the roof.

D. Bitumen Flowing Beneath Gravel Stop and Down Facia Boards.

This type of failure, more common in the coal-tar pitch roof, is usually due to original design or construction and very little can be done to correct it after installation of the roof. However, it can be prevented by a simple means, by installing the roof as follows:

1) Extend the first two plies of felt at least 6 inches beyond the edge of the roof.

2) Cut the next 2 or 3 plies even with the edge.

3) Turn the extension of the first two plies back and over the other plies forming an envelope.

4) Install gravel stop in usual manner over this.

E. Omission of Metal Gravel Stop or Metal Edge Strip.

Treatment: These areas should be inspected at frequent intervals (every 6 months) and at first indication of failure, gravel stops or metal edge strips should be installed in accordance with standard specifications for new roof construction. This practice will prevent costly blow-offs.

5.6 Other Projections

5.6.1 General Discussion

The projections included in this section are pipes, stacks, ladder struts, flag poles, bracings for signs, etc., which penetrate the roofing. No attempt should be made to flash around these projections with felts, as any expansion, contraction or other movement in these members will crack the felts and a leak will develop. All such projections should be flashed with a metal sleeve flashing with flange or, on built-up roofs, a pitch pocket with flange (Figure 50).

5.6.2 Inspection

The flashing at the projections should be inspected during the periodic inspection.

5.6.3 Maintenance and Repair

A. Defective Flashings at Projections.

Treatment: Cut away old felt flashings and install a metal sleeve flashing with flange or a pitch pocket with flange. The flashing flange should be placed on the last ply of felt and securely nailed and cemented to it. The flange then should be stripped with two layers of felt, the top one overlapping the bottom one by 2 to 3 inches, and cemented with hot bitumen. In the case of the pitch pocket, the cup is filled with hot bitumen. On wood decks, a layer of concrete, one inch in thickness, is poured in the pitch pocket and allowed to set prior to the hot bitumen.

6. SAFETY MEASURES

6.1 General Discussion

Construction work generally is inherently hazardous. Roof work, whether it be new construction, maintenance or repair, because of its nature, ranks high in the incidence of accidents. While it is true that accidents may occur in spite of measures taken to prevent them, a well-defined program to prevent accidents always pays dividends.

Accident prevention is closely tied in with efficiency. The contractor whose equipment is always in order; who attempts to predetermine the hazards of each particular project and plans accordingly for the prevention of accidents, will not only encounter fewer accidents, but will also operate more efficiently.

While this is not intended to be a complete manual on safety precautions in roofing, observance of the following suggestions will go far to prevent common accidents.

Good reference works on safety in the construction field are:

"Manual of Accident Prevention in Construction", published by the Associated General Contractors of America, Inc., Munsey Building, Washington 4, D. C.

"American Standard Safety Code for Building Construction", A.S.A. A10.2-1944, published by the American Standards Association, 70 E. Forty-Fifth Street, New York 17, N. Y.

6.2 Storage and Handling of Materials

Segregate materials as to kind and size and place them in neat, orderly piles that are safe against falling. (See instructions under each type of roofing material.

Place warning signs in daytime and red lights on and around materials stored in walkways or streets at night.

6.3 Ladders

Test all ladders to determine whether they are strong enough to carry the intended loads.

Construct wood ladders of straight-grained materials free from defects. Avoid painted ladders since the paint may serve to conceal defects.

Mark metal ladders with signs cautioning against use around electrical equipment.

Provide ladders with non-slip bases and fasten at the top when possible.

Place the foot of a ladder not more than one-fourth its length away from the vertical plane of its top support.

Extend ladders leading to landings or walkways at least 36 in. above the landing and fasten so that they cannot slip. Avoid splicing ladders whenever it is possible.

Construct "chicken" ladders or crawling boards at least 10 in. wide and 1 in. thick, to which are nailed cleats, 1-1/2 in. wide and 1 in. thick, extending the width of the board.

The board should extend the full length from the ridge to the eaves and should be fastened securely to the ridge so that it cannot become loose.

Make each section of double boards as a single board, with the two sections hinged or bolted together. Use double boards with the sections straddling the roof, with the hinge bolt resting on the ridgepole.

Provide a catch platform or life line on roofs pitched more than 3 in. per foot.

6.4 Scaffolds

Design scaffolds to take the maximum loads to which they will be subjected.

Protect the edges of all scaffolds with railings and toe boards.

Do not use scaffolds for the storage of material except that being used currently. Clean scaffolds daily of all rubbish.

6.5 Roof Brackets

Form triangular roof brackets from three pieces of 2 by 4 in. lumber, with the diagonal member sloped to match the pitch of the roof, and the horizontal member level to support the roof plank.

Support roof brackets by ropes fastened to a hook securely hooked over the ridgepole of the roof, or to roof members on the other slope of the roof, or by means of pointed projectors driven their full length into the roof framing or deck.

Provide a catch or scaffold platform, extending at least 2 ft. beyond the eaves and equipped with a guard rail, on roofs without parapet walls, where the slope is greater than 3 in. per foot and the distance from ground to eaves is more than 20 feet. A life line of manila rope securely fastened to a safe anchorage may be substituted for the platform.

6.6 Heating and Handling Bituminous Materials

Mount heating kettles on firm, level, non-combustible foundations. Keep them at least 3 feet from any combustible materials, and keep one or more suitable fire extinguishers within 50 feet of each kettle. See that kettles in use are constantly attended and adequately protected from personnel, vehicles, and other equipment.

Provide each kettle with a close-fitting lid which can be closed at once if the heated material flames. A temperature-recording device to help prevent material from being heated above safe temperatures should also be used.

Material must be thoroughly dry before it is added to heated contents of kettles. Add material by sliding it into kettles, not by dropping it.

Do not add any inflammable substance to thin or dilute material being heated. Shut down kettle burners when refueling, and if heated material bursts into flame.

In handling hot substances, use hoisting gear heavy enough for the loads imposed. Brace all gear securely. In hoisting and handling hot substances, be careful not to endanger workmen nearby or below.

Require all persons handling hot substances to use proper foot and leg protection, gloves, goggles, and any other necessary personal protective equipment.

APPENDIX I.

HISTORICAL RECORD FORMS

AND

INSPECTION FORMS.

HISTORICAL RECORD - BUILT-UP ROOFS

BUILDING ____________________ USED FOR ____________________

Permanent _____ Temporary ____ Year Roof Was Applied _______

Kind of Roof Deck: Wood ____ Concrete slab ____ Concrete block ____ Gypsum slab ____ Gypsum plank ____ Steel ____

Slope of Roof: Flat ____ In. per foot ____

Area of Roof: Squares _______ (one square equals 100 sq. ft.)

Type of Built-Up Roof:

Asphalt: Surfaced ____ Unsurfaced ____ Cold process ____

Wide selvage ____

Coal-Tar Pitch _____

Kind of Surfacing: Slag ____ Gravel ____ Crushed stone ____ Promenade tile ____ Slate slabs ____ Mineral-surfaced cap sheet ____ Smooth-surfaced cap sheet ____ Other surfacing (name) ____________________

Number of Plies of Felt: 2 ____ 3 ____ 4 ____ 5 ____

Kind of Felt: Organic (Rag) ____ Coated _____ Uncoated _____

Asbestos _____ Coated ______ Uncoated _____

Insulation: Yes ____ No ____ Thickness ____________________

Type of insulation ____________________

Where placed ____________________

Vapor seal: Yes ___ No ___ Type of vapor seal ______________

Flashings:

Base flashings: Metal ____ Kind of metal ____________________

Composition ____ Kind ____________________

Other (describe) ____________________

Counter or cap flashings: Yes _____ No ______

Through wall: Yes _____ No _____ Metal _____ Kind of metal ____________ Composition ____ Kind _______________

Other (describe) ____________________

Flashing block: Yes _____ No _____

Previous Maintenance: (Describe briefly with dates.)

Roof membrane: ____________________

____

Flashings: ____________________

____

Previous Repairs: (Describe briefly with dates.)

Roof membrane: ____________________

____

Flashings: ____________________

____

HISTORICAL RECORD - ASPHALT-SHINGLE ROOFS

BUILDING ________________________ USED FOR ________________________

Permanent _____ Temporary _____ Year Roof Was Applied _____

Kind of Roof Deck: Sheathing boards ____ Thickness, in. ______

S.S. ____ T & G ____ Plywood ____ Thickness, in. ___________

Underlayment: None ____ Saturated felt ____ Paper ____ Asphalt shingles ____ Wood shingles ____ Other ________________________

Slope of Roof, in. per ft. ________ Area of roof, squares _____

Type of shingles: Strip shingles ____ Exposure, in. __________

Individual shingles ____ Exposure, in. _________

Strip shingles: Square butt ____ Hexagonal ____

Square butt shingles: Thick butt ___ Standard weight ____ Heavy weight ____ Class A _____

Hexagonal shingles: Standard weight ___ Heavy weight ____

Individual shingles: Standard weight ___ Heavy weight ____

Method of laying: American ___ Dutch lap ___ Hexagonal ___

Lock down _____ Exposure, in. ______

Color of Roofing Granules: ____________________

Flashings:

Valley flashings: Roll roofing ___ Asphalt shingles ____

Metal ___ Kind of metal ________________

Drip edge: Roll roofing ___ Asphalt shingles ___ Metal ____

Kind of metal _______________________

Vent flashings: Roll roofing ____ Metal ____ Kind of metal

____

Chimney flashings: Roll roofing ____ Metal ____ Kind of metal ______________________________

Previous Maintenance: (Describe briefly with dates.)

Asphalt shingles: ____

____

Flashings: ____

____

Previous Repairs: (Describe briefly with dates.)

Asphalt shingles: ____

____

Flashings: ____

____

HISTORICAL RECORD - ASPHALT ROLL-ROOFING ROOFS

BUILDING ______________________ USED FOR ________________________

Permanent _____ Temporary _____ Year Roof Was Applied _____

Kind of Roof Deck: Sheathing boards ___ T & G ___ S.S. ____

Thickness, in. ____ Plywood ____ Thickness, in. _____

Underlayment: None ____ Saturated felt ____ Paper ____ Asphalt shingles ____ Wood shingles ____ Other ___________________

Slope of Roof, in/ft. _______ Area of roof, squares __________

Type of Roll Roofing: Mineral surfaced ______ Smooth-surfaced _____ Wide selvage _____

Method of Laying: 2-in. lap ______ 4-in. lap _____ 19-in. lap _____ Concealed nails ____ Exposed nails ______.

Type of Lap Cement: Hot applied _____ Cold applied ______

Color of Roofing Granules: ____________________________

Flashings:

Valley flashings: Roll roofing ____ Asphalt shingles ____ Metal ____ Kind of metal __________________________________

Drip edge: Roll roofing ____ Asphalt shingles ____ Metal ___ Kind of metal ____

Vent flashings: Roll roofing ____ Metal ____ Kind of metal ____

Chimney flashings: Roll roofing ___ Metal ___ Kind of metal ____

Previous Maintenance: (Describe briefly with dates.)

Asphalt Roll Roofing: ______________________________

____

Flashings: ______________________________________

____

Previous Repairs: (Describe briefly with dates.)

Asphalt Roll Roofing: ______________________________

____

Flashings: ______________________________________

____

HISTORICAL RECORD - ASBESTOS-CEMENT ROOFS

BUILDING ________________ USED FOR ________________

Permanent _____ Temporary _____ Year Roof Was Applied _____

Type of Roof: Corrugated sheets ____ Shingles _____

Type of Shingle: Dutch lap _____ Hexagonal _____

American _____ Multiple Unit _____

Type of Deck:

Shingle: Wood _____ Other ________________

Corrugated: Wood _____ Other ________________

Purlin Spacing ____________ in.

Slope of Roof: ____________ in. per foot

Area of Roof: Squares __________ (one square equals 100 sq.ft.)

Type of Underlayment:

Asphalt-saturated asbestos felt ______ Asphalt-saturated organic felt ____ Other ________________

Weight of felt, lbs. ___________

Kind of Fasteners: Shingles: Nails ___ Other ___ Size _______

Corrugated sheets: Clips ___ Type ________________

Screws _____ Size _________ Bolts ___ Size _________

Nails ____ Size _________ Other ___ Size _________

Flashings:

Valley flashings: Metal __ Kind of Metal _______ Other _____

____

Vent flashings: Metal __ Kind of metal ________ Other ______

____

Drip edge: Metal __ Kind of metal _________________

Chimney flashings: Metal __ Kind of metal _________

Other ____

Previous Maintenance: (Describe briefly with dates.)

Asbestos-cement roofing: ___________________________________

____

Flashings: ____

____

Previous Repairs: (Describe briefly with dates.)

Asbestos-cement roofing: ___________________________________

____

Flashings: ____

____

HISTORICAL RECORD - METAL ROOFING

BUILDING ______________________ USED FOR ________________________

Permanent ____ Temporary ____ Year Roof Was Applied _______

Kind of Roof Deck: Wood _____ Metal _____ Other ______________

Solid ____ Open _____ Purlins _____ Purlin spacing _______in.

Slope of Roof: ________________________ in./ft.

Area of Roof: Squares ___________(One square equals 100 sq.ft)

Kind of Metal: Terne (tin) ___ Wt. coating ___________

Copper ____ Wt. ft.^{2} ________ Galvanized steel _____ Wt.

coating ___________ Aluminum ____ Gage _______ Protected

metal ____ Kind of protected metal __________________________

Type of Metal Roof: Flat sheets _______ Corrugated sheets ____

Special shapes ___________ Shingles or tiles ________________

Type of Seams: Batten ______ Standing ____ Other _____________

Flat _____ Soldered: Yes _____ No _____

Type of Fasteners: Nails ____ Bolts ____ Clips ____ Screws____

Cleats ____ Other ____

Flashings:

Valley flashings (describe) ____________________________

____

Vent flashings (describe) ______________________________

____

Chimney flashings (describe) ______________________________

____

Previous Maintenance: (Describe briefly with dates.)

Metal roofing: ______________________________

____

Flashings: ______________________________

____

Previous Repairs: (Describe briefly with dates.)

Metal roofing: ______________________________

____

Flashings: ______________________________

____

HISTORICAL RECORD - SLATE ROOFING

BUILDING ____________________ USED FOR ________________________

Permanent ____ Temporary ____ Year Roof Was Applied _____

Type of Slate: ___________________ Approx. thickness, in. ____

Color of Slate: ___________ Approx. wt./square, lbs. __________

Slope of Roof: ______________ in. per foot

Area of Roof: Squares ________ (One square equals 100 sq. ft.)

Roof Deck: Wood ___ Thickness, in. _______ Width, in. _______

Other (explain) ____

Underlayment: Asphalt-saturated asbestos felt ________________

Weight _________ Asphalt-saturated organic felt ____________

Weight _________ Other (explain) ___________________________

Type of Fasteners: Nails ____ Size ______ Other ______________

Flashings:

Valley flashings: Metal ___ Kind of Metal ___________ Other

____

Vent flashings: Metal ___ Kind of Metal __________ Other ___

____

Drip Edge: Metal ___ Kind of Metal _______________

Chimney flashings: Metal ___ Kind of Metal _________________

Other _________________________

<u>Previous Maintenance</u>: (Describe briefly with dates.)

Slate roofing: ____

____

Flashings: ____

____

<u>Previous Repairs</u>: (Describe briefly with dates.)

Slate roofing: ____

____

Flashing: ____

____

HISTORICAL RECORD - TILE ROOFING

NOTE: For Promenade Tile on Flat Decks, Use Historical Record for Built-Up Roofs.

BUILDING ____________________ USED FOR ______________________

Permanent ____ Temporary ____ Year Roof Was Applied ______

Type of Tile: Shingle ___ Spanish ___ Interlocking ___ Other

________________ Thickness _______ in. Wt. per square ____

Color ________________

Slope of Roof: __________ in. per square

Area of Roof: Squares _________ (One square equals 100 sq.ft.)

Rood Deck: Wood ____Thickness, in. _______ Width of sheathing

boards, in. ________ Other __________________________________

Underlayment: Asphalt-saturated asbestos felt ___ Weight _____

Asphalt-saturated organic felts ______ Weight _______ Other

(explain) ____

Type of Fasteners: Nails ____ Size ______ Other ______________

Flashings:

Valley flashings: Metal ___ Kind of Metal ___________ Other

____

Vent flashings: Metal ___ Kind of Metal ______________Other

____

Drip edge: Metal ___ Kind of Metal ________________

Chimney flashings: Metal ___ Kind of Metal ____________________

Other ____

Previous Maintenance: (Describe briefly with dates.)

Tile roofing: ____

____

Flashings: ____

____

Previous Repairs: (Describe briefly with dates.)

Tile roofing: ____

____

Flashing: ____

____

HISTORICAL RECORD - WOOD-SHINGLE ROOFS

BUILDING ____________ USED FOR ____________

Permanent _____ Temporary _____ Year Roof Was Applied _____

Kind of Rood Deck: Sheathing boards: ____ T & G ____ S.S. _____

Thickness, in. ____ Shingle lath: ____ Width of spacing, in. _____ Thickness, in. ____ Plywood: ____ Thickness, in. ______

Underlayment: None ____ Saturated felt ____ Paper ____ Wood shingles ____ Asphalt roll roofing ____ Asphalt shingles ____

Other ____________

Slope of Roof, in/ft. __________ Area of roof, squares ________

Kind of Shingles: Cedar ___ Cypress ___ Pine ___ Other ________

Thickness of Shingles: 4 butts/2 in. ____ 5 butts/2 in. ______

Other, define ____________

Exposure: _________ in. Shingles pre-stained: Yes ___ No _____

Flashings:

Valley flashings: Metal ___ Kind of Metal ____________ Wood shingles ____ Other ____________

Vent flashings: Metal ___ Kind of Metal ____________ Other ____________

Drip edge: Metal ___ Kind of Metal ____________ Wood shingles ____ Roll roofing ____

Chimney flashings: Metal ___ Kind of Metal ____________

Other ____________

Previous Maintenance: (Describe briefly with dates.)

Wood shingles: ____________________

____

Flashings: ____________________

____

Previous Repair: (Describe briefly with dates.)

Wood shingles: ____________________

____

Flashings: ____________________

____

INSPECTION FORM: ANNUAL INSPECTION OF BUILT-UP ROOFS

BUILDING ______________ DATE OF INSPECTION ______________

Roofing Membrane

General Appearance: Good _____ Fair _____ Poor _____

Water Tightness: No leaks _____ Leaks with long-continued rain _____ Leaks every rain _____

Reported Cause of Leaks: Weathering of roofing material _____ Faulty material _____ Faulty design _____ Faulty construction _____ Wind damage _____ Hail damage _____ Traffic on roof _____ Other mechanical damage (describe) __________ ______________________ Low spots (water ponding) ____ Failure of flashings _____ Failure of gravel stops _____ Other causes (describe) ______________ ______________________________

Adhesion of Mineral Surfacing to Bitumen:[1/] Good ___ Fair ___ Poor ___

Bare Areas: (Give approximate percentage of total roof area below.)

Bituminous coating exposed[1/] _____ Condition of coating: Smooth ____ Alligatored ____ Cracked _____ Felts exposed ____

[1/] Surfaced roofs only.

Felts disintegrated _____ Edges of felts curled ______

Blisters _____ (Give size range and approximate number per square if numerous.) ____

Cracked to allow water to enter: Yes ______ No ______

Buckles ____ Cracked to allow water to enter: Yes ___ No __

Cracks in membrane ____ Through to roof deck: Yes ___ No ___

Fishmouths _____

General Condition of Roof Membrane: __________________________

____

Treatment Recommended: _______________________________________

____

Flashings:

Base Flashings:

Metal:

Deteriorated ____ Vertical joints open ____ Flanges of base metal flashing loose: Yes ___ No ___ Due to: Inadequate nailing ____ Not properly sealed with felt strips_____

Plastic:

Sagged or separated from parapet wall ____ Buckled ____
Cracked ____ Failure of base flashing: Weathering _____
Mechanical _____ Surface coating disintegrated: Yes ____
No ____ Vertical laps not cemented properly: Yes __ No __

Cap Flashings:

Metal:

Firmly embedded into vertical wall: Yes ___ No ___

Deteriorated ____ Vertical joints open ____ Not covering base flashing adequately: Yes ____ No ____

Plastic:

Surface coating disintegrated ____ Flashing felt disintegrated ____

Flashing Block:

Groove pointed sufficiently: Yes _____ No _____

Recommended Treatment: ____________________________________

____

Parapet Walls:

Mortar joints deteriorated ____ Settlement cracks in walls ____ Joints in tile coping open ____ Concrete coping cracked ____ Other defects (describe) _____________

____

Recommended Treatment: ____________________________________

____

INSPECTION FORM: ANNUAL INSPECTION OF ASPHALT-SHINGLE ROOFS

Note: Asphalt-shingle roofs should never be wakled upon directly. When it is necessary to get on a roof, ladders or boards with cleats nailed to them should be used to distribute the weight.

BUILDING ____________________ DATE OF INSPECTION ______________

Asphalt Shingles

General Appearance: Good ______ Fair ______ Poor ______

Water Tightness: No leaks ____ Leaks with long-continued rain ____ Leaks every rain ____

Reported Cause of Leaks: Weathering of shingles _____

Faulty material ____ Faulty design ____ Wind Damage _____

Faulty application: a. Nailed too high ____ b. Too few nails ____ c. Exposure too great ____

Hail damage ____ Traffic on roof ____ Other mechanical damage (describe) ____

Failure of flashings ____ Other causes (describe) ___________

____

Condition of Shingles: Apparently unchanged ____ Buckled _____

Blistered ____ Loss of Granules: Slight ____ Medium ________

Severe (bare areas) ____ Curled ____ Tabs Missing _________

Asphalt coating damaged (hail, etc.) ____ Coating alligatored or cracked ____ Other defects (describe) ___________________

____

General Condition of Asphalt-Shingle Roof: ____________________

____

Treatment Recommended: ____

____

Flashings: (Describe condition if defective.)

Chimney Flashings:	Satisfactory	_______	Defective	__________
Wall " :	Satisfactory	_______	Defective	__________
Ridge " :	Satisfactory	_______	Defective	__________
Vent " :	Satisfactory	_______	Defective	__________
Valley " :	Satisfactory	_______	Defective	__________
Edge " :	Satisfactory	_______	Defective	__________

Drainage System: (Describe condition if defective.)

Gutters:	Satisfactory	____	Defective	____________________
Downspouts:	Satisfactory	____	Defective	____________________

Treatment Recommended: ____

____

INSPECTION FORM: ANNUAL INSPECTION OF ASPHALT ROLL ROOFING ROOFS

Note: Asphalt roll roofing roofs should not be walked upon directly. When it is necessary to get on a roof, ladders, or boards with cleats nailed to them, should be used to distribute the weight.

BUILDING ____________________ DATE OF INSPECTION ______________

Asphalt Roll Roofing

General Appearance: Good _______ Fair _______ Poor _______

Water Tightness: No leaks ____ Leaks with long-continued rain ____ Leaks every rain _____

Reported Cause of Leaks: Weathering of roofing _______

Faulty material ____ Faulty application: Insufficient lap ____ Lap not cemented ____ Exposed nails loose ____

Inadequate nailing ____ Wind damage ____ Hail damage ____

Traffic on roof ____ Other mechanical damage (describe)

____

Failure of flashings ____ Other causes (describe) _____________

____

Condition of Roofing: Apparently unchanged ____ Buckled ____

Blistered ____ Loss of Granules: Slight ____ Medium ____ Severe (bare areas) ____

Asphalt coating damaged (hail, etc.) ____ Coating alligatored or cracked ____ Other defects (describe) ____________________

____

General Condition of Roll Roofing Roof: ______________________

____

Treatment Recommended: ____

____

Flashings: (Describe condition if defective.)

Chimney flashings: Satisfactory ____ Defective ______________

Wall " : Satisfactory ____ Defective ______________

Ridge " : Satisfactory ____ Defective ______________

Vent " : Satisfactory ____ Defective ______________

Valley " : Satisfactory ____ Defective ______________

Edge " : Satisfactory ____ Defective ______________

Drainage System: (Describe condition if defective.)

Gutters: Satisfactory ____ Defective ____________________

Downspouts: Satisfactory ____ Defective ____________________

Treatment Recommended: ____

____

INSPECTION FORM: ANNUAL INSPECTION OF ASBESTOS-CEMENT ROOFS

Note: Asbestos-cement roofs should not be walked upon directly. When it is necessary to get on a roof, ladders, or boards with cleats nailed to them should be used to distribute the weight.

BUILDING ____________________ DATE OF INSPECTION ______________

Asbestos-Cement Roofing

General Appearance: Good ______ Fair _______ Poor ________

Water Tightness: No leaks _____ Leaks with long-continued rain ____ Leaks every rain _____

Reported Cause of Leaks: Weathering of roofing materials _____ Faulty material ____ Faulty Design ____ Faulty construction ____ Wind damage ____ Hail damage ____ Other mechanical damage (describe) ____ Faulty underlayment ____ Failure of flashings ____ Insufficient side lap ____ Insufficient end lap ____ Other causes (describe) ____

Condition of Roofing: Apparently unchanged _____ Loose shingles or sheets (%) _____ Broken or cracked shingles (%) ______ Broken or cracked corrugated sheets (%) _____ Apparent cause of breakage: Nailed too tightly ____ Mechanical damage _____ Other (describe) ____ Failure of fasteners: Yes (%) _______ No ______

General Condition of Asbestos-Cement Roof: ____________________

____

Treatment Recommended: ______________________________________

____

Flashings: (Describe condition if defective.)

Chimney flashings: Satisfactory ____ Defective ____________

Wall " : Satisfactory ____ Defective ____________

Ridge " : Satisfactory ____ Defective ____________

Vent " : Satisfactory ____ Defective ____________

Valley " : Satisfactory ____ Defective ____________

Edge " : Satisfactory ____ Defective ____________

Drainage System: (Describe condition if defective.)

Gutters: Satisfactory ____ Defective ____________

Downspouts: Satisfactory ____ Defective ____________

Treatment Recommended: ______________________________________

____

INSPECTION FORM: ANNUAL INSPECTION OF METAL ROOFS

BUILDING ____________________ DATE OF INSPECTION ______________

Kind of Metal: ____

General Appearance: Good _______ Fair _______ Poor _______

Water Tightness: No leaks _____ Leaks with long-continued rain _____ Leaks every rain _____

Reported Cause of Leaks: Corrosion _____ Faulty design _____ Faulty construction _____ Insufficient lap _____ Defective fasteners _____ Broken seams _____ Faulty seams _____ Failure of flashings _____ Other causes (describe) _________

____

General Condition: Rust or corrosion: None ____ Slight ____ Severe ____ Percent of total area evidencing corrosion _____ Condition of protective coating (if any): Good ___ Fair ___ Poor ___. Seams: Broken - Yes ___ No ___ If yes, location ________________________________ Number ____________________

Breaks (not in seams): Yes ___ No ___ Location _____________ Number __________ Size ___________

Holes: Yes _____ No ______ Location ____________________ Number ____________ Size ______________________________

Expansion joints: Too few _____ Sufficient number ________

If too few, indicate where needed____________________________

Treatment Recommended: ____

____

Flashings: (Describe condition if defective.)

Chimney flashings: Satisfactory ____ Defective ____________

Wall " : Satisfactory ____ Defective ____________

Ridge " : Satisfactory ____ Defective ____________

Vent " : Satisfactory ____ Defective ____________

Valley " : Satisfactory ____ Defective ____________

Edge " : Satisfactory ____ Defective ____________

Drainage System: (Describe condition if defective).

Gutters: Satisfactory ____ Defective ________________

Downspouts: Satisfactory ____ Defective ________________

Treatment Recommended: ____

____

INSPECTION FORM: ANNUAL INSPECTION OF SLATE ROOFS

Note: Slate roofs should not be walked upon directly. When it is necessary to get on a roof, ladders, or boards with cleats nailed to them, should be used to distribute the weight.

BUILDING ______________________ DATE OF INSPECTION ____________

Slate Roofing

General Appearance: Good _______ Fair _______ Poor _______

Water Tightness: No leaks _____ Leaks with long-continued rain _____ Leaks every rain _____

Reported Cause of Leaks: Weathering of slate _____ Faulty material _____ Faulty design _____ Faulty construction ____ Wind damage _____ Hail damage _____ Failure of flashings _____ Other mechanical damage (describe) ______________ __________________ Faulty underlayment ______ Other Causes (describe) ____

Condition of Slate: Apparently unchanged _____ Slate disintegrated: Slight ____ Severe ____ Broken or cracked slate (%) ____ Apparent cause of breakage: Nailed too tightly _____ Mechanical damage _____ Other (describe) ____________________ ____

Failure of fasteners: Yes (%) ______ No ______ Other failures (describe) ____

General Condition of Slate Roof: ______________________________

____

Treatment Recommended: ____

____

Flashings: (Describe condition if defective.)

Chimney flashings: Satisfactory ____ Defective ____________

Wall " : Satisfactory ____ Defective ____________

Ridge " : Satisfactory ____ Defective ____________

Vent " : Satisfactory ____ Defective ____________

Valley " : Satisfactory ____ Defective ____________

Edge " : Satisfactory ____ Defective ____________

Drainage System: (Describe condition if defective.)

Gutters: Satisfactory ____ Defective ________________

Downspouts: Satisfactory ____ Defective ________________

Treatment Recommended: ____

____

INSPECTION FORM: ANNUAL INSPECTION OF TILE ROOFS

Note: For Promenade Tile on flat decks use Inspection Form for Built-Up Roofs.

BUILDING ____________________ DATE OF INSPECTION ____________

Tile Roofing

General Appearance: Good ______ Fair ______ Poor ______

Water Tightness: No leaks ______ Leaks with long-continued rain ______ Leaks every rain ______

Reported Cause of Leaks: Weathering of tile ____ Faulty material ____ Faulty design ____ Faulty construction ____ Wind damage ____ Hail damage ____ Failure of flashings ___ Other mechanical damage (describe) ________________________ Faulty underlayment ____

Condition of Tile: Apparently unchanged ____ Broken or cracked tiles (%) ____ Apparent cause of breakage: Nailed too tightly ____ Mechanical damage ____ Other (describe) ____

____

Failure of Fasteners: Yes (%) _______ No _______

Other Failures (describe): ________________________________

General Condition of Tile Roof: ____________________________

____

Treatment Recommended: ____________________________________

____

Flashings: (Describe condition if defective.)

Chimney flashings: Satisfactory ____ Defective ______________

Wall " : Satisfactory ____ Defective ______________

Ridge " : Satisfactory ____ Defective ______________

Vent " : Satisfactory ____ Defective ______________

Valley " : Satisfactory ____ Defective ______________

Edge " : Satisfactory ____ Defective ______________

Drainage System: (Describe condition if defective.)

Gutters: Satisfactory ____ Defective ____________________

Downspouts: Satisfactory ____ Defective ____________________

Treatment Recommended: ______________________________________

____

INSPECTION FORM: ANNUAL INSPECTION OF WOOD-SHINGLE ROOFS

BUILDING ________________ DATE OF INSPECTION ____________

Wood Shingles

General Appearance: Good ______ Fair ______ Poor ______

Water Tightness: No leaks ____ Leaks with long-continued rain ____ Leaks every rain ____

Reported Cause of Leaks: Weathering of shingles____ Cracked shingles ____ Curled shingles ____ Failure of shingle nails __ Failure of flashings ____ Other causes (describe) __________

____

Condition of Shingles: Apparently unchanged ____ Cracked (%) __ Curled (%) _____ Loose (%) _____

General Condition of Wood-Shingle Roof (describe): __________

____

Treatment Recommended: ______________________________

____

Flashings: (Describe condition if defective.)

Chimney Flashings: Satisfactory ____ Defective ___________

Wall " : Satisfactory ____ Defective ___________

Ridge " : Satisfactory ____ Defective ___________

Vent " : Satisfactory ____ Defective ___________

Valley Flashings: Satisfactory ____ Defective ______________

Edge " : Satisfactory ____ Defective ______________

Drainage System: (Describe condition if defective.)

Gutters: Satisfactory ____ Defective ____________________

Downspouts: Satisfactory ____ Defective ____________________

Treatment Recommended: ______________________________________

____

Figure 1. Warping of unseasoned sheathing boards.

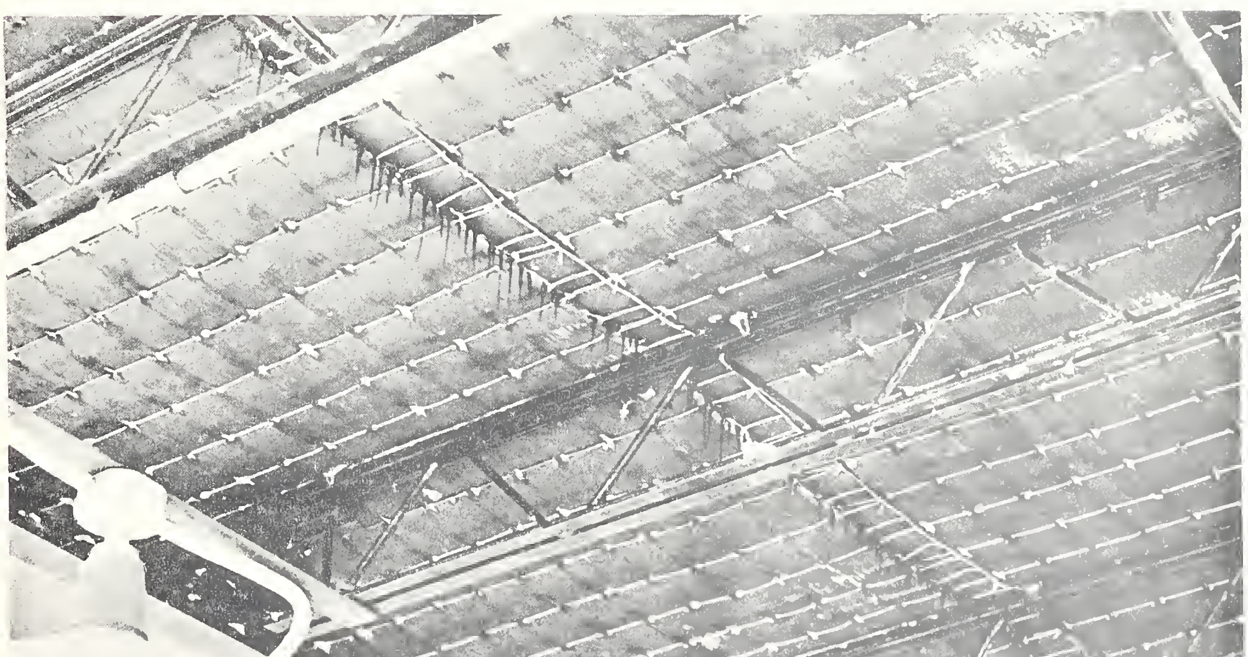

Figure 2. Bitumen flowing between open joints.

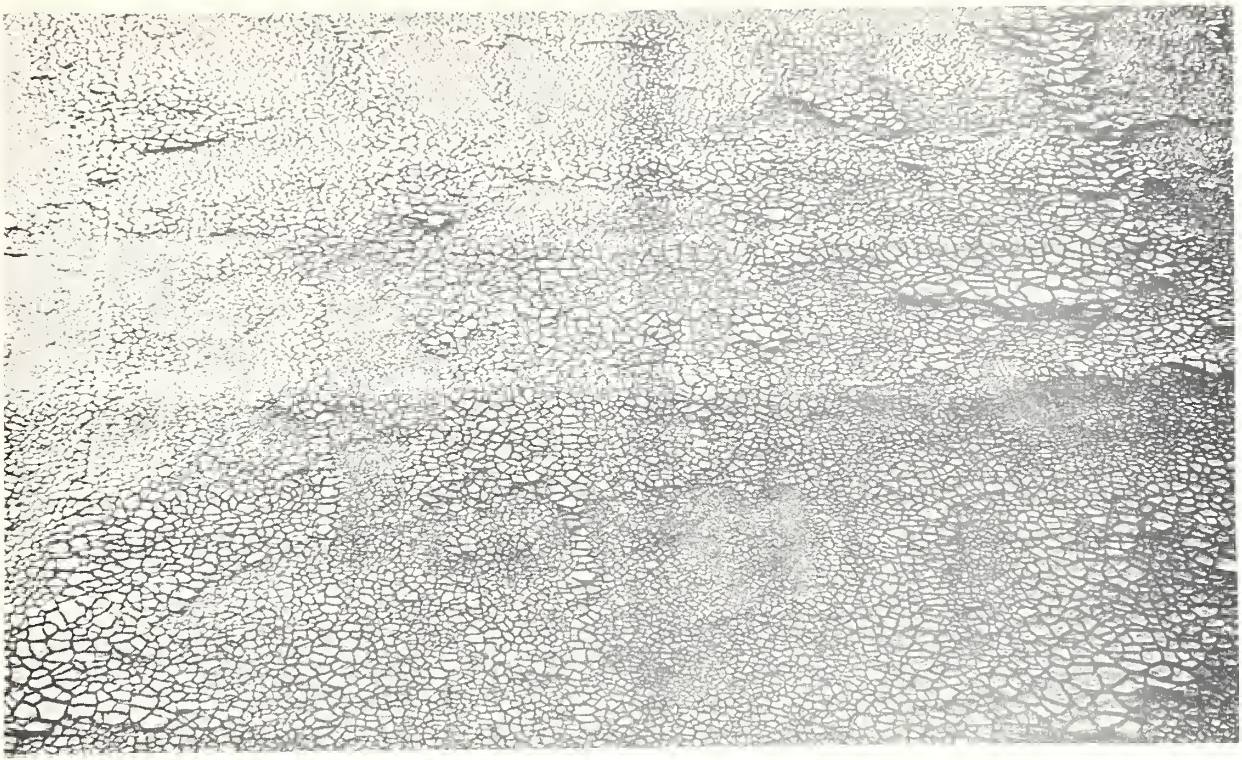

Figure 3. Alligatoring due to a heavy application of asphalt on a smooth-surfaced built-up roof.

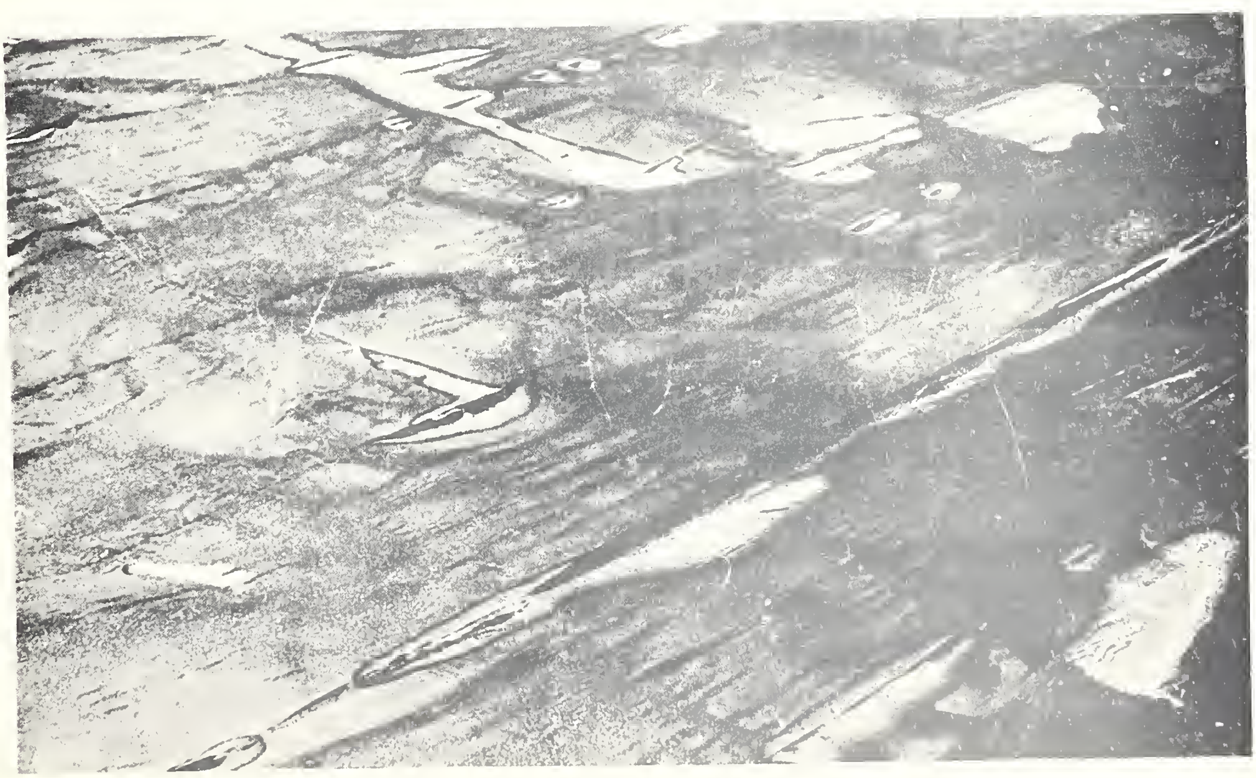

Figure 4. Wrinkles, buckles and lack of adhesion of felts.

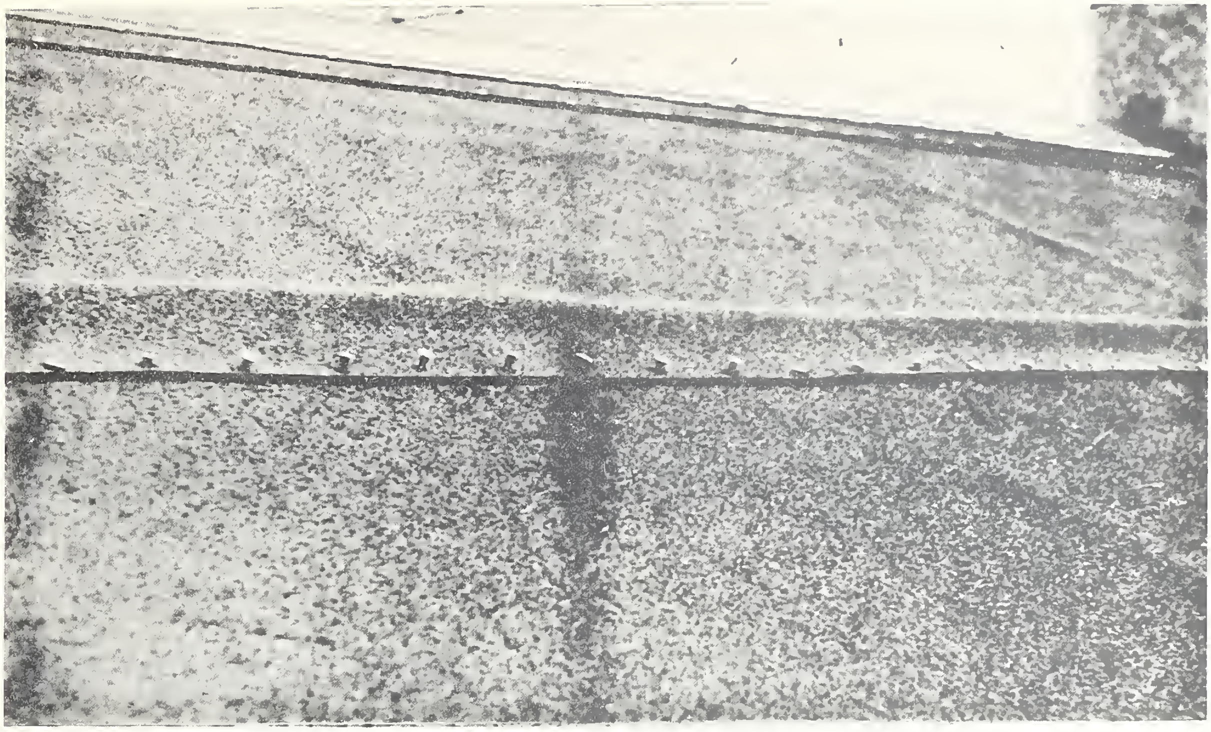

Figure 5. Exposed nails that have worked loose from seams of roll roofing.

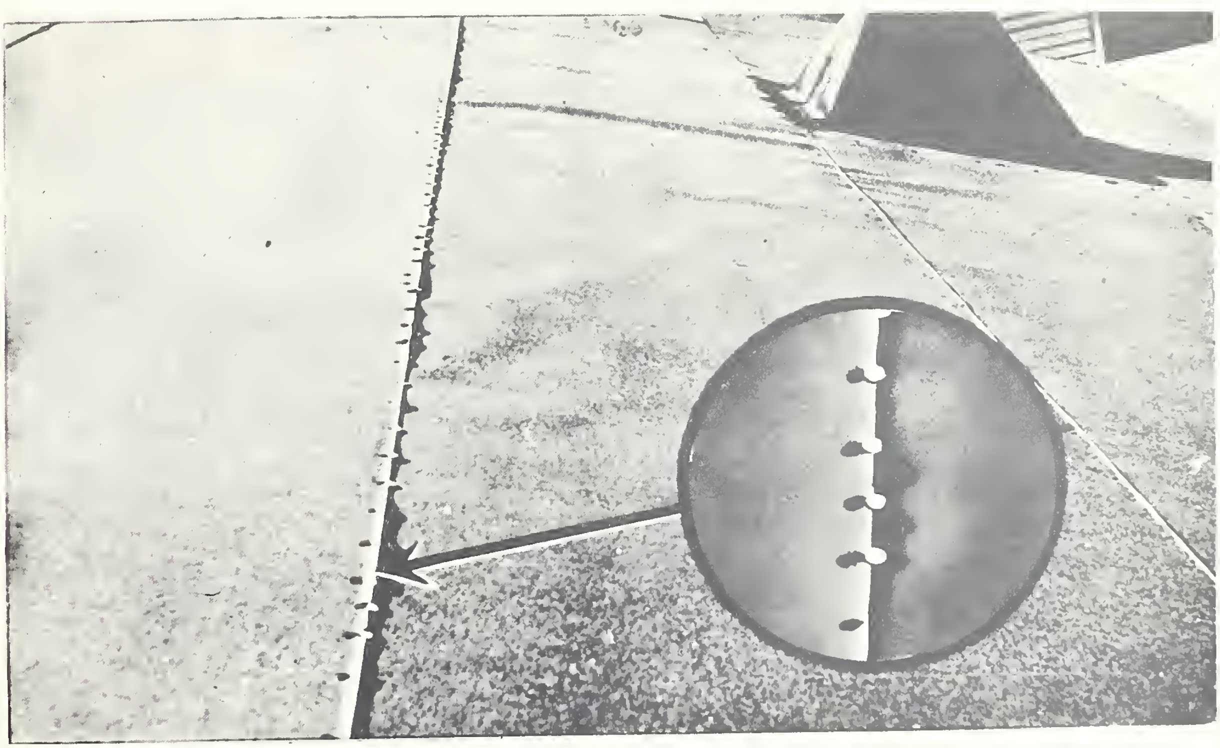

Figure 6. Roll roofing pulling away from nails placed too close to edge of sheet.

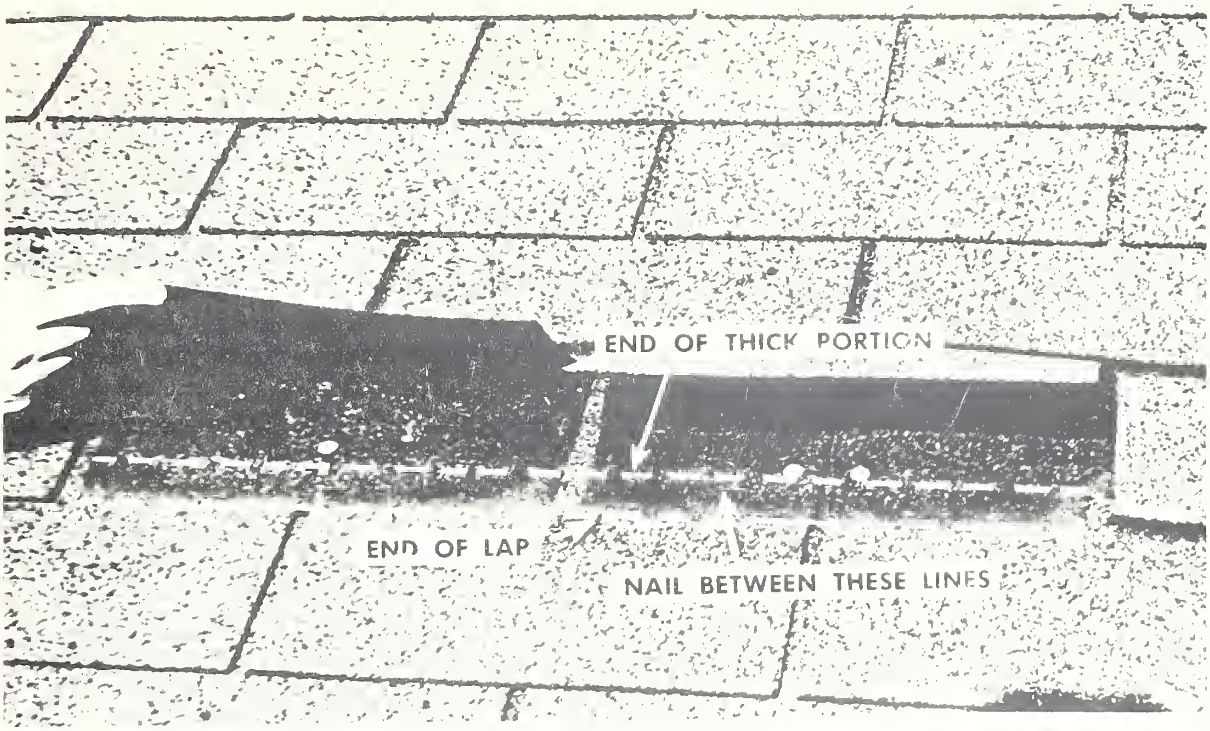

Figure 7. Asphalt shingles nailed too high.

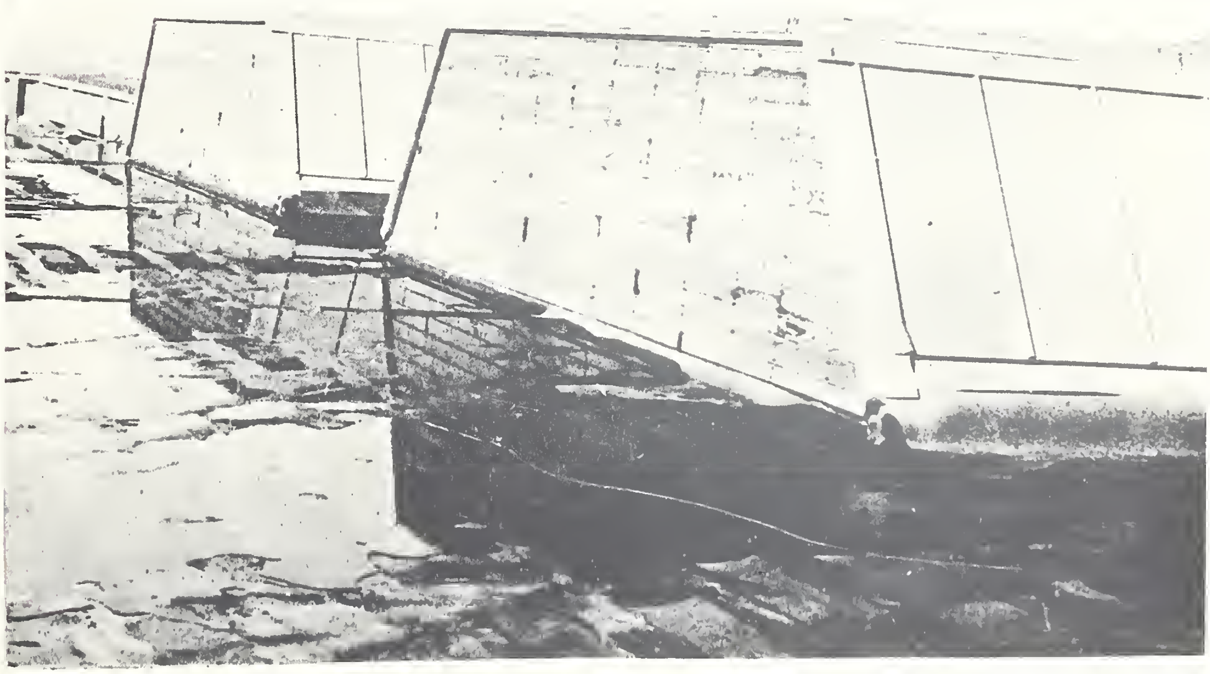

Figure 8. Wide selvage roll roofing on practically flat roof.

Figure 9. Action of strong winds on asphalt shingles nailed too high.

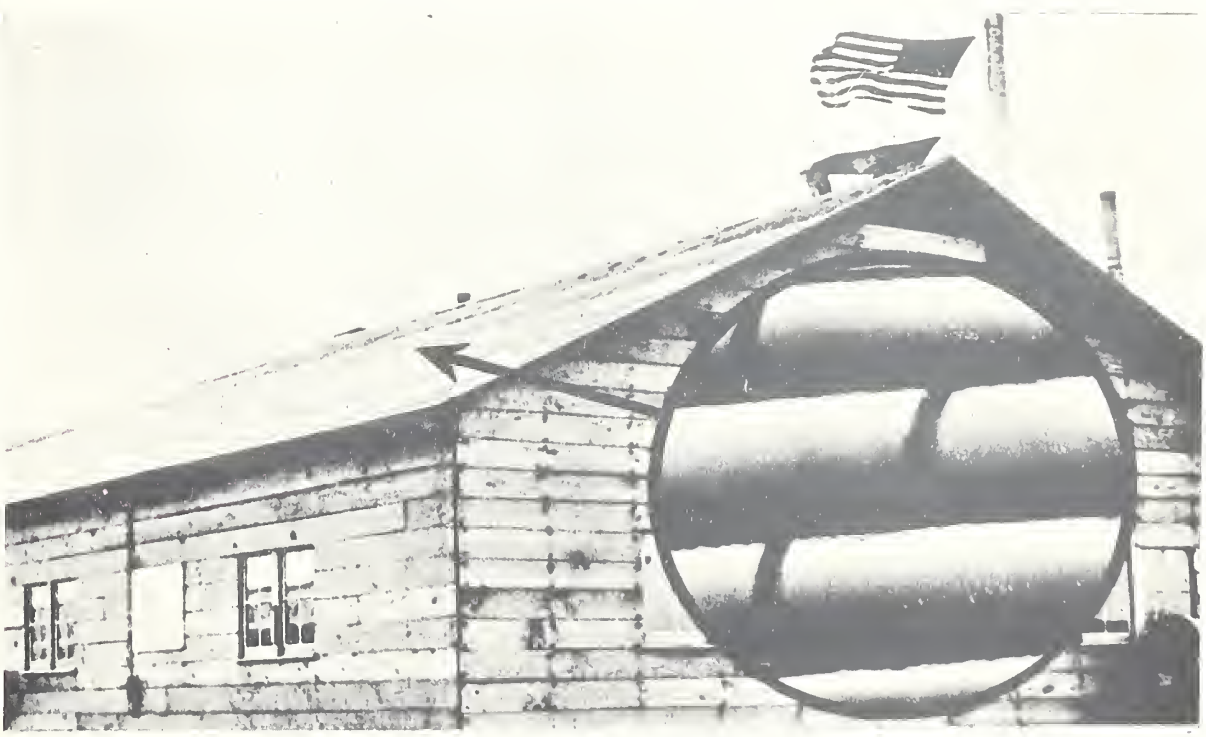

Figure 10. Effect of strong wind blowing perpendicularly to the ridge of a roll roofing roof.

Figure 11. Leaks caused by entrance of water at defective flashings are sometimes attributed to failure of roof membrane.

Figure 12. Results of poor workmanship in applying a built-up roof.

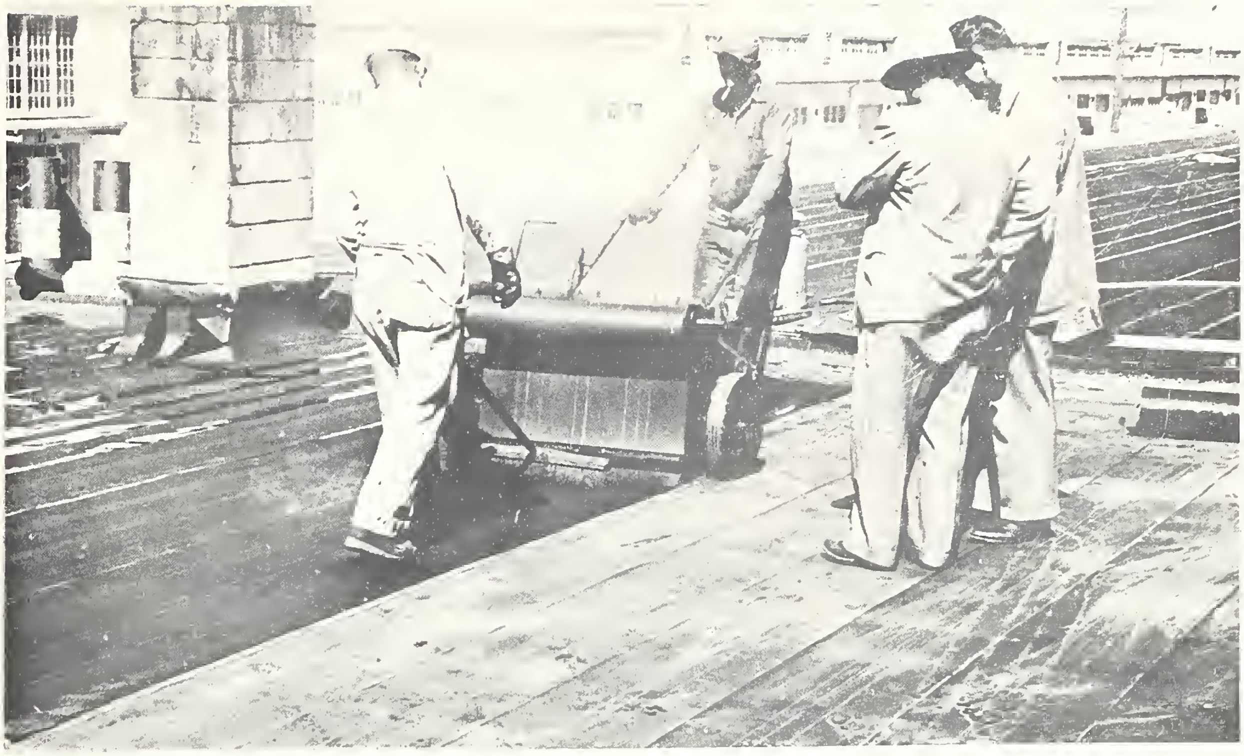

Figure 13. Laying felts mechanically and brooming in after felt is rolled into hot bitumen.

Figure 14. Surface coating of hot bitumen should

Figure 15. Insufficient bitumen to embed mineral surfacing.

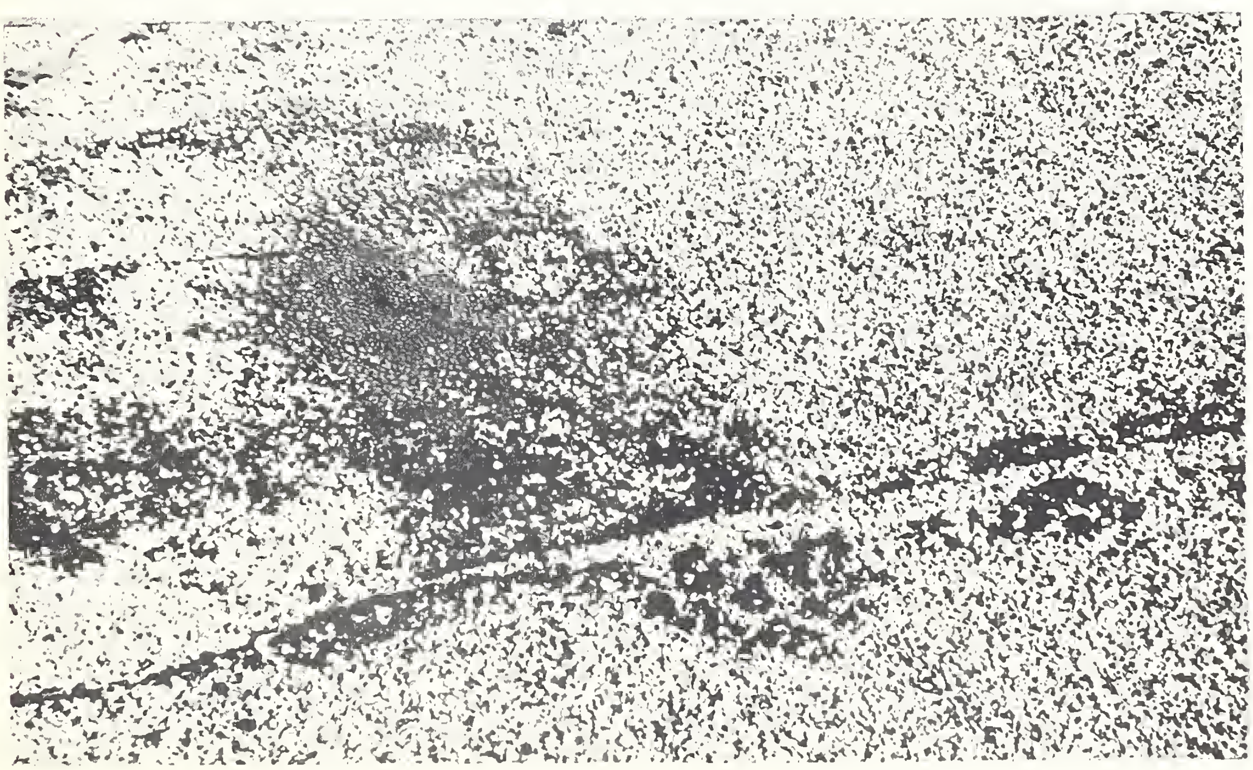

Figure 16. Bituminous coating exposed.

Figure 17. Hot bitumen poured on an unprepared surface. Note the lack of adhesion.

Figure 18. Felts exposed and weathered.

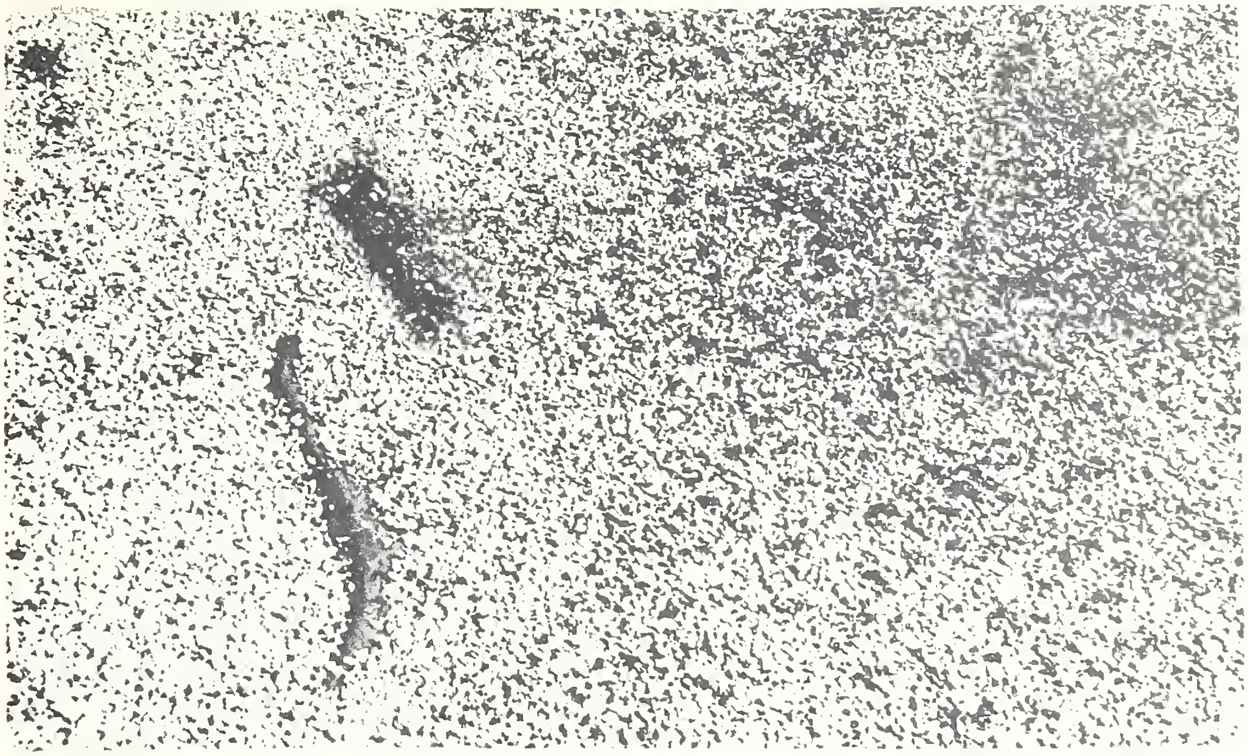

Figure 19. Small blisters or buckles. If bare, should be treated as bare areas.

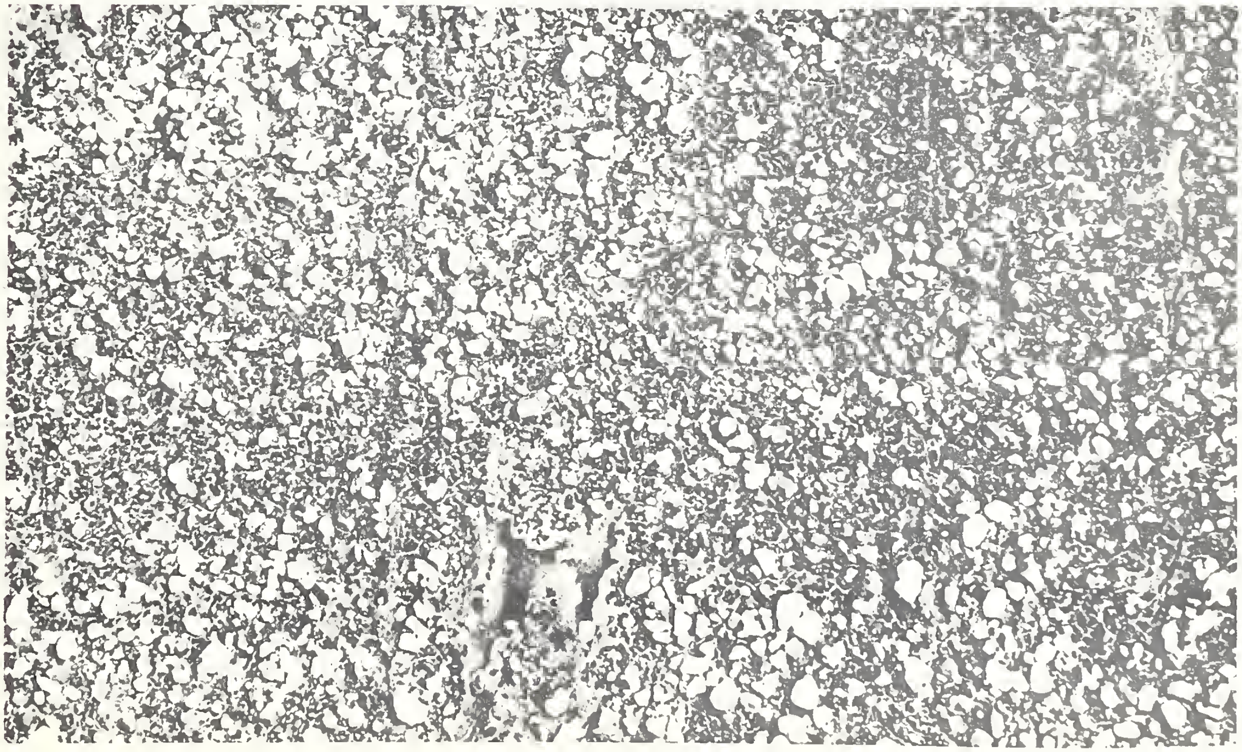

Figure 20. Severely weathered bitumen coating.

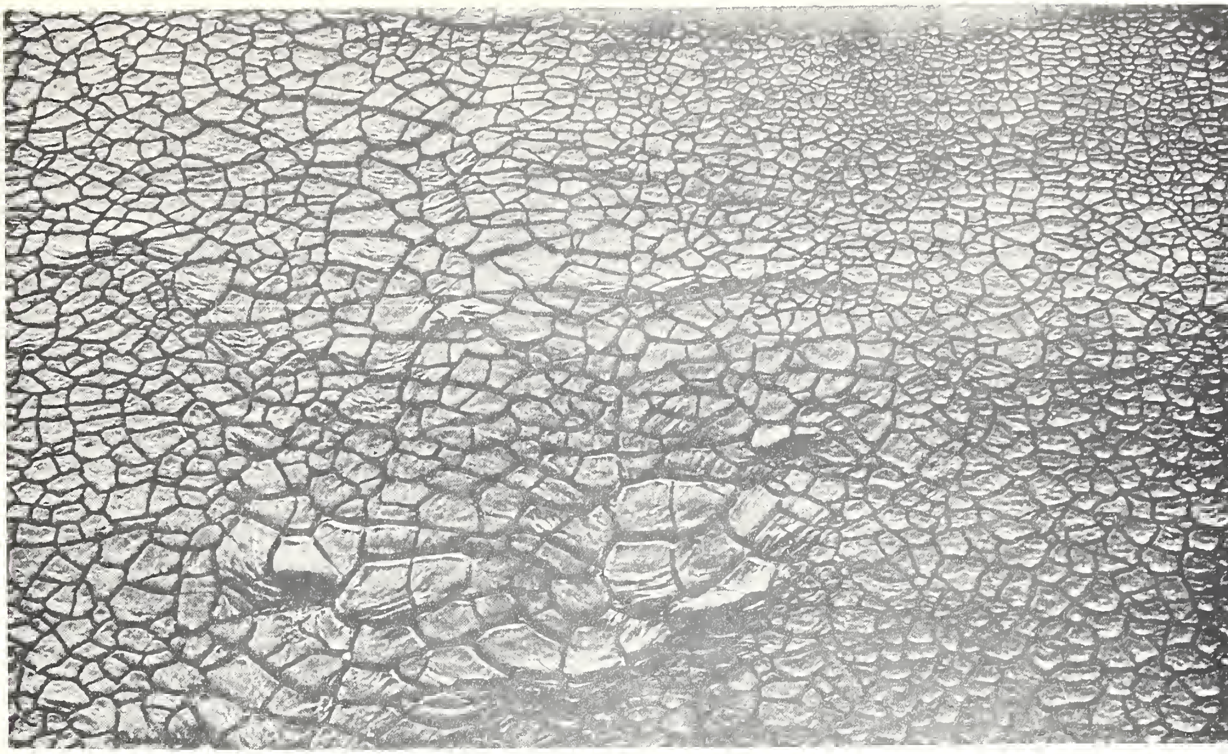

Figure 21. Severe alligatoring on thick coating of asphalt.

Figure 22. Alligatoring and cracking of a cold coating over alligatored asphalt surface after one year exposure.

Figure 23. Comparison of cold coating (asphalt emulsion) with and without the glass membrane.

Figure 24. Typical appearance of asbestos felts after protective coating has weathered off.

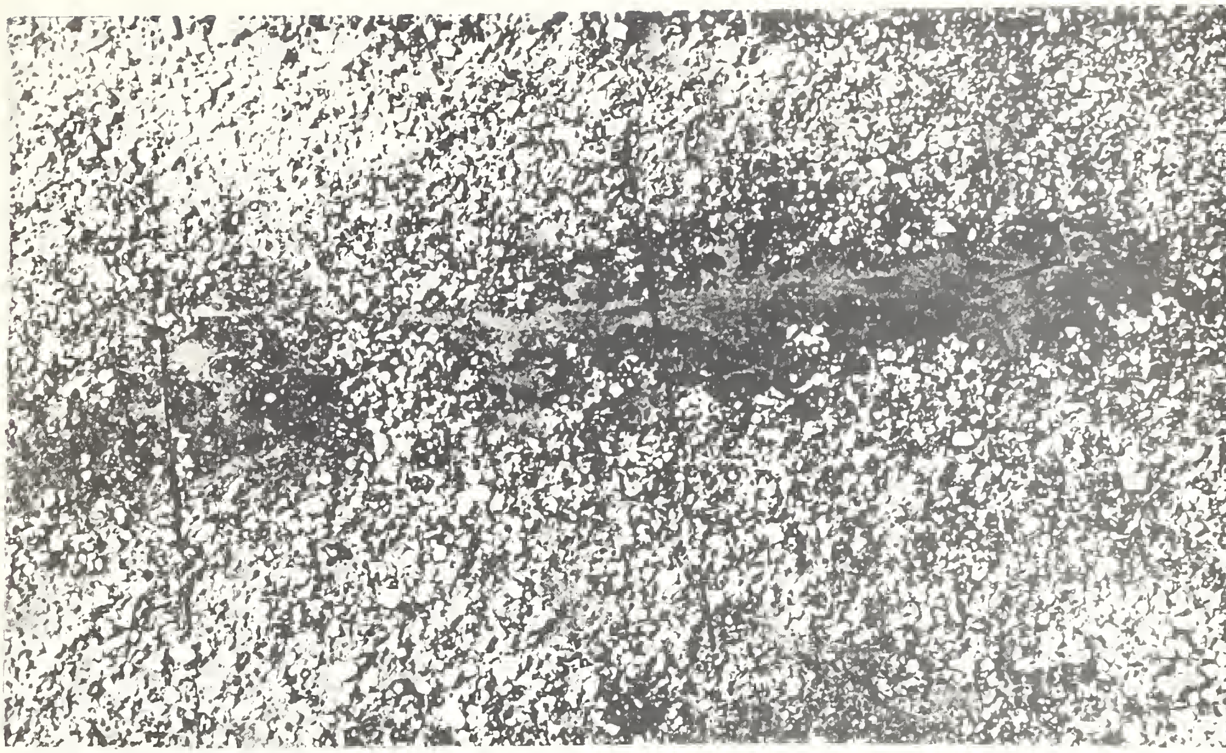

Figure 25. Exposed and partially disintegrated felts.

Figure 26. Large blister on smooth-surfaced roof.

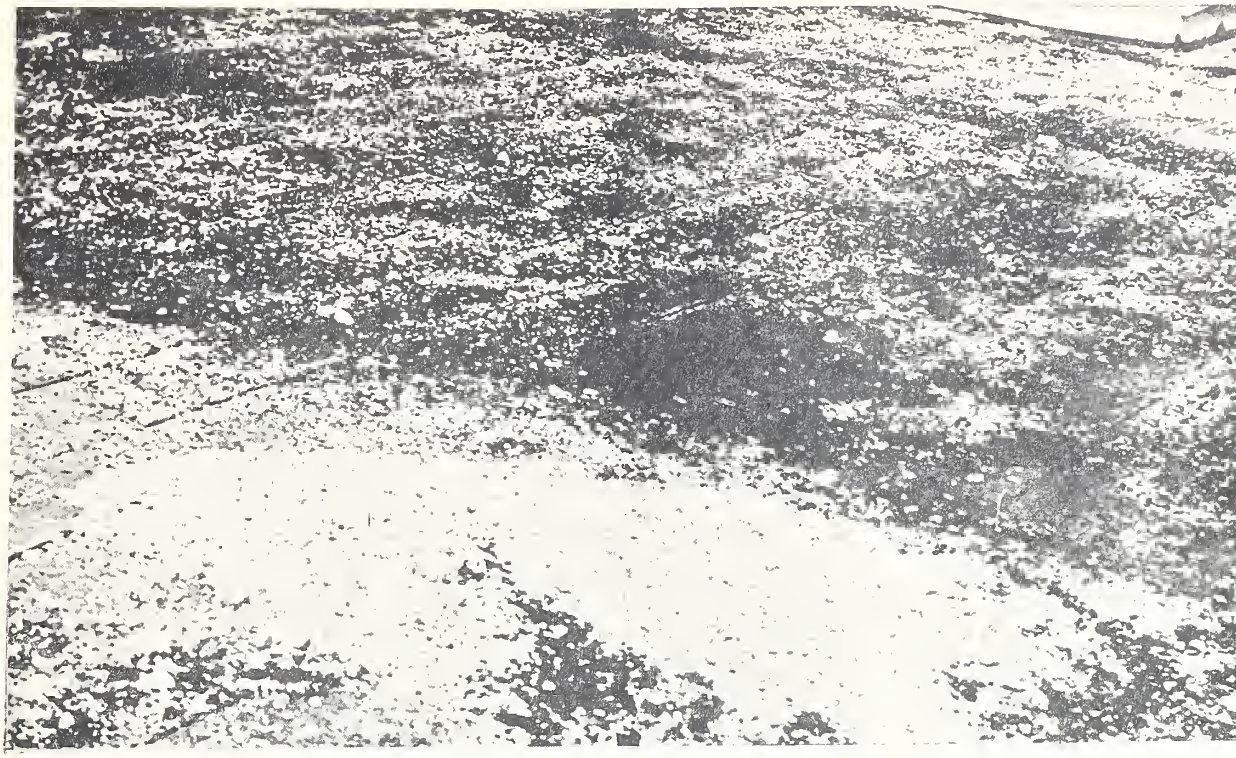

Figure 27. Felts exposed and disintegrated in numerous areas.

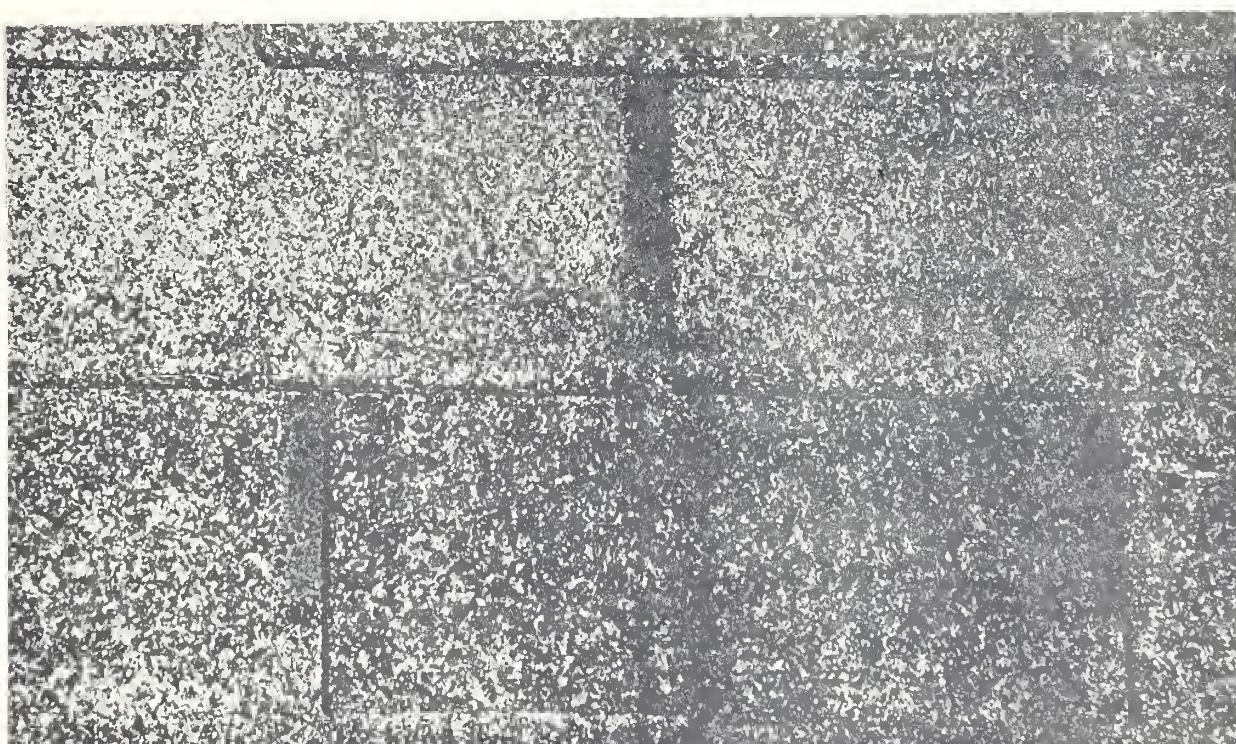

Figure 28. Loss of mineral surfacing granules due to normal weathering.

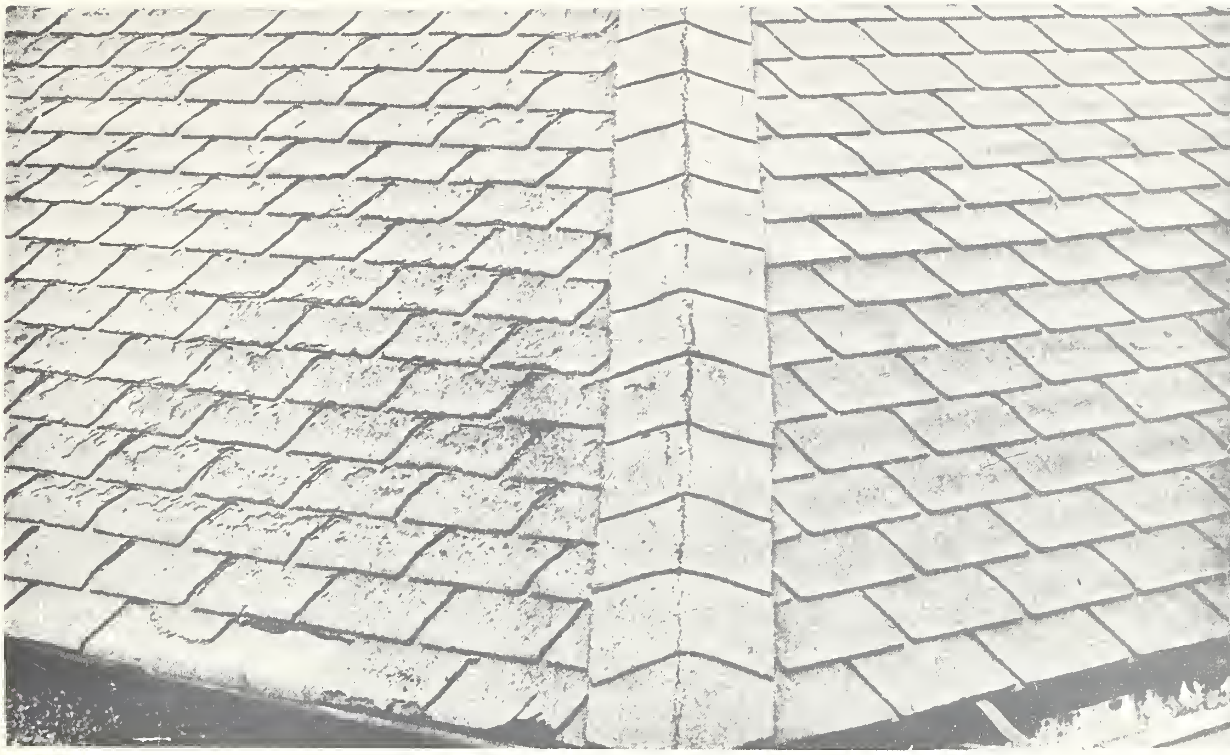

Figure 29. Differential weathering of asphalt shingles on Southern and Eastern exposures.

Figure 30. Severe loss of mineral granules and coating asphalt due to weathering.

Figure 31. Recoated asphalt shingles. Note damage due to brittleness.

Figure 32. Proper nailing of asphalt shingles.

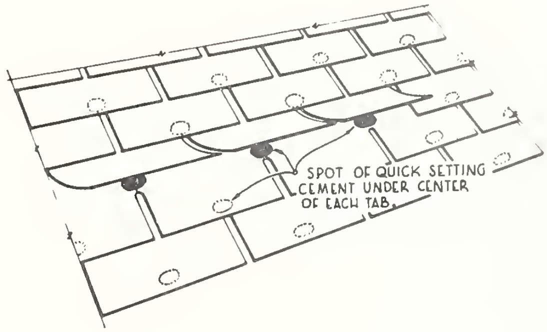

Figure 33. Location of cement under tabs.

Figure 34. Hail damage where reroofing is mandatory.

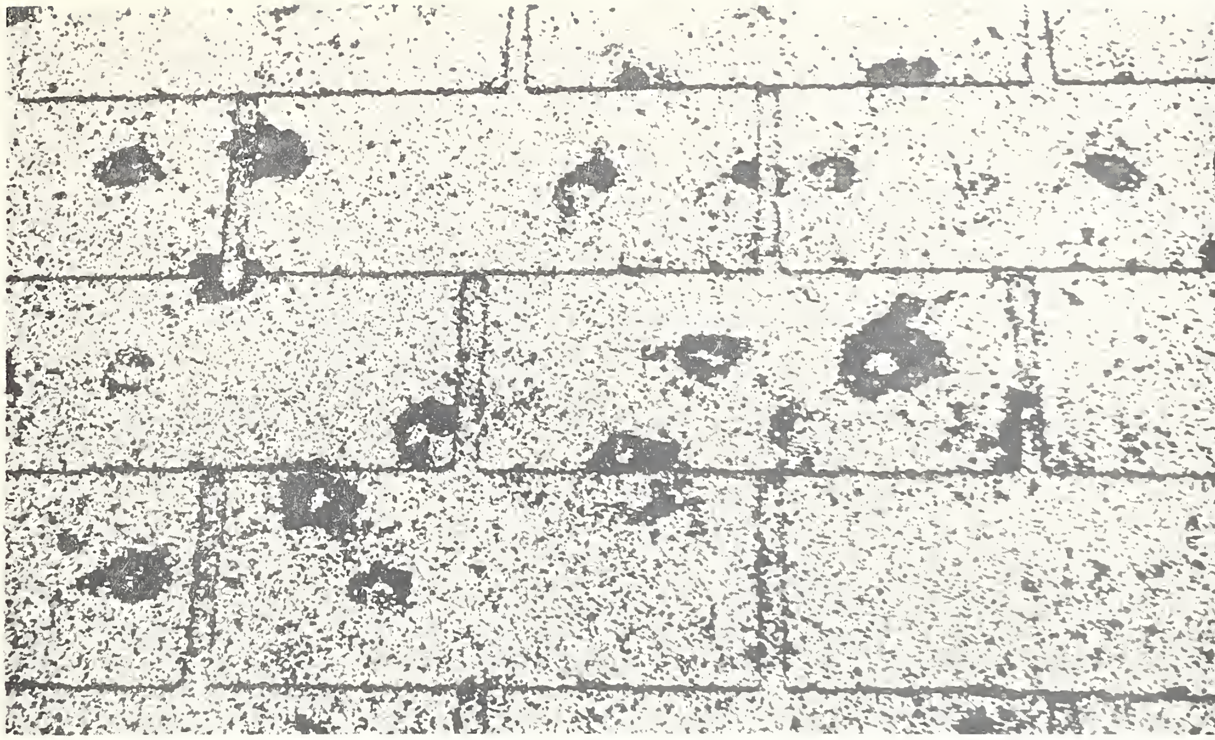

Figure 35. Hail damage (shingles not broken).

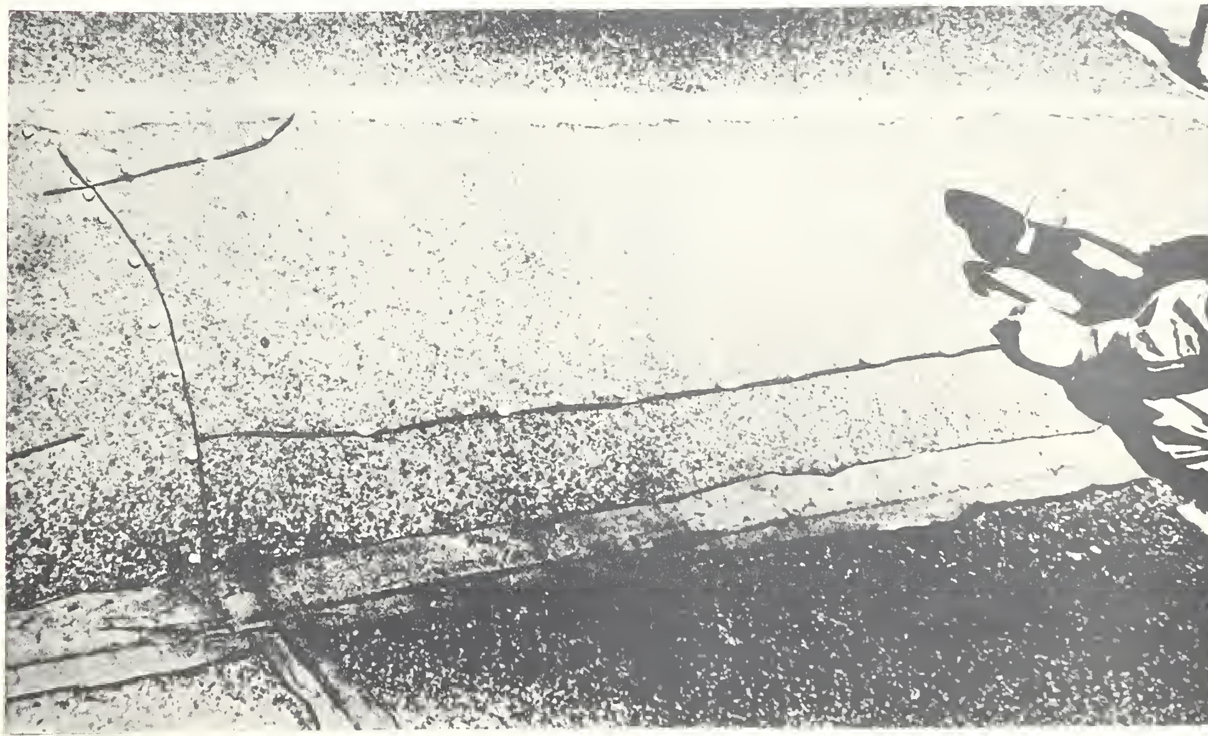

Figure 36. Buckles and wrinkles in existing roofing must be cut and edges nailed down to obtain a flat surface for application of a new roof.

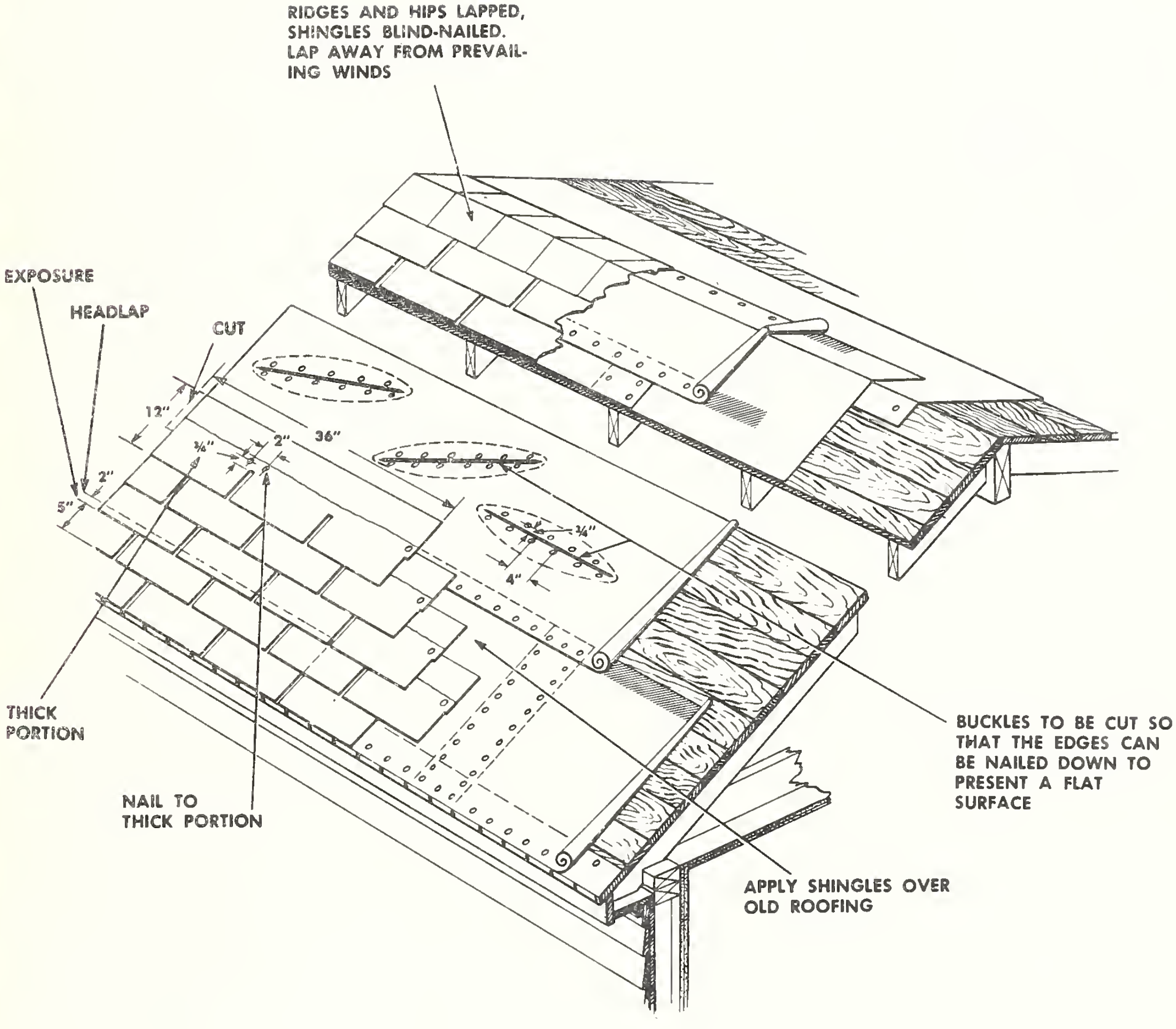

Figure 37. Application of asphalt shingles over asphalt roll roofing.

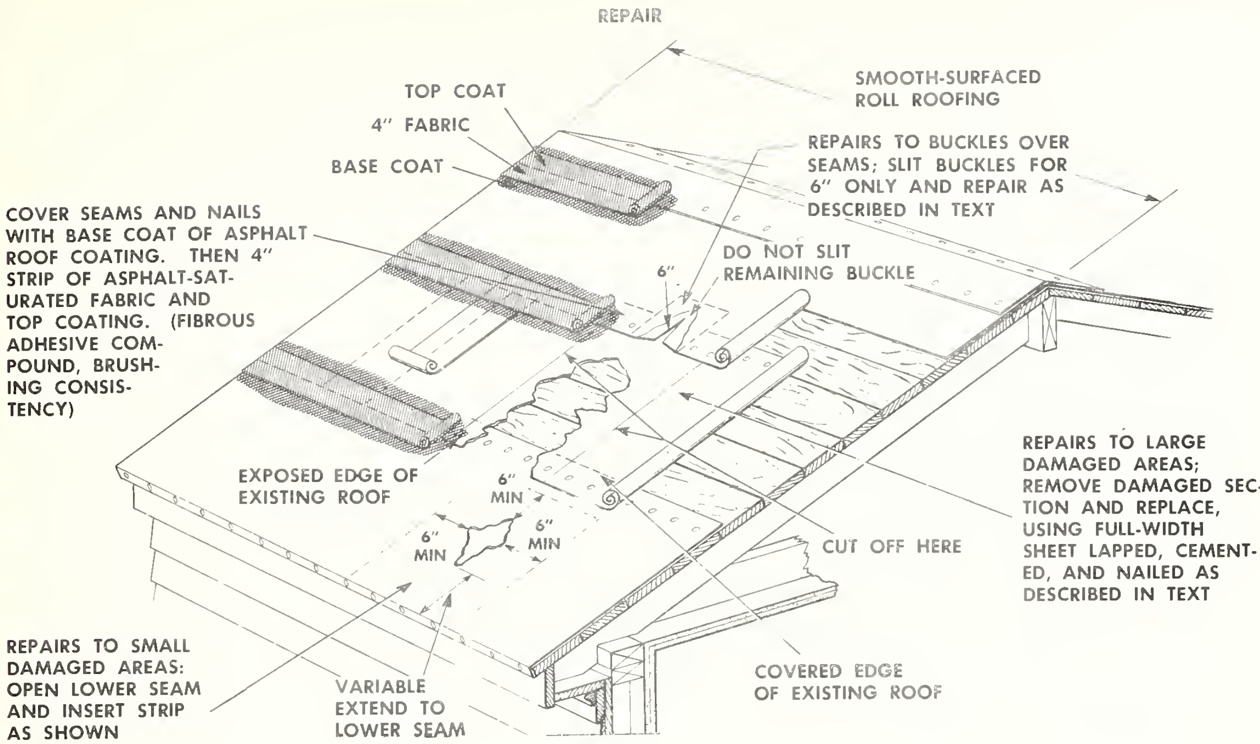

Figure 38. Repairing asphalt roll roofing.

Figure 39. Seams of roll roofing repaired with asphalt saturated fabric and asphalt roof coating (Method I).

Figure 40. Close-up of Figure 39.

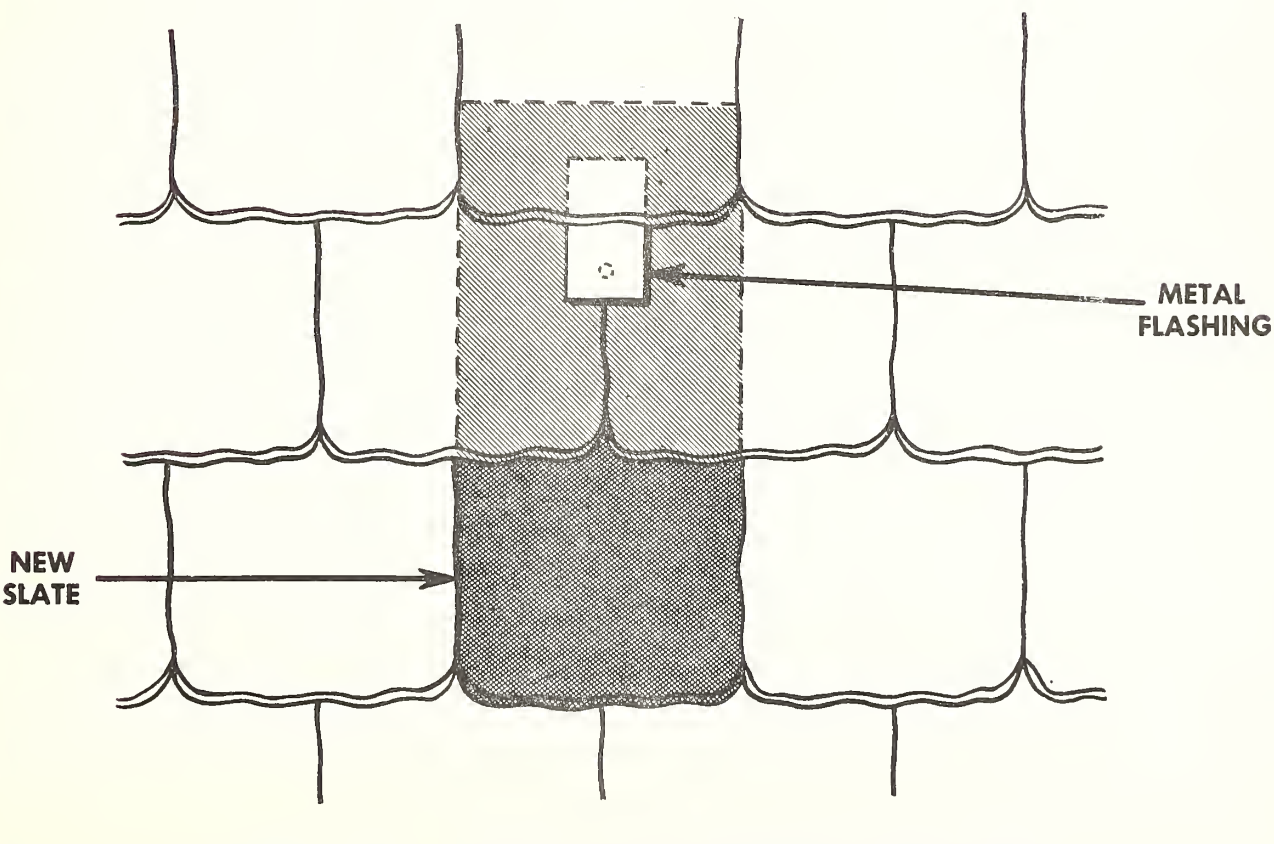

Figure 41. Method for inserting new slate.

Figure 42. Puncture resulting from lack of a cant strip.

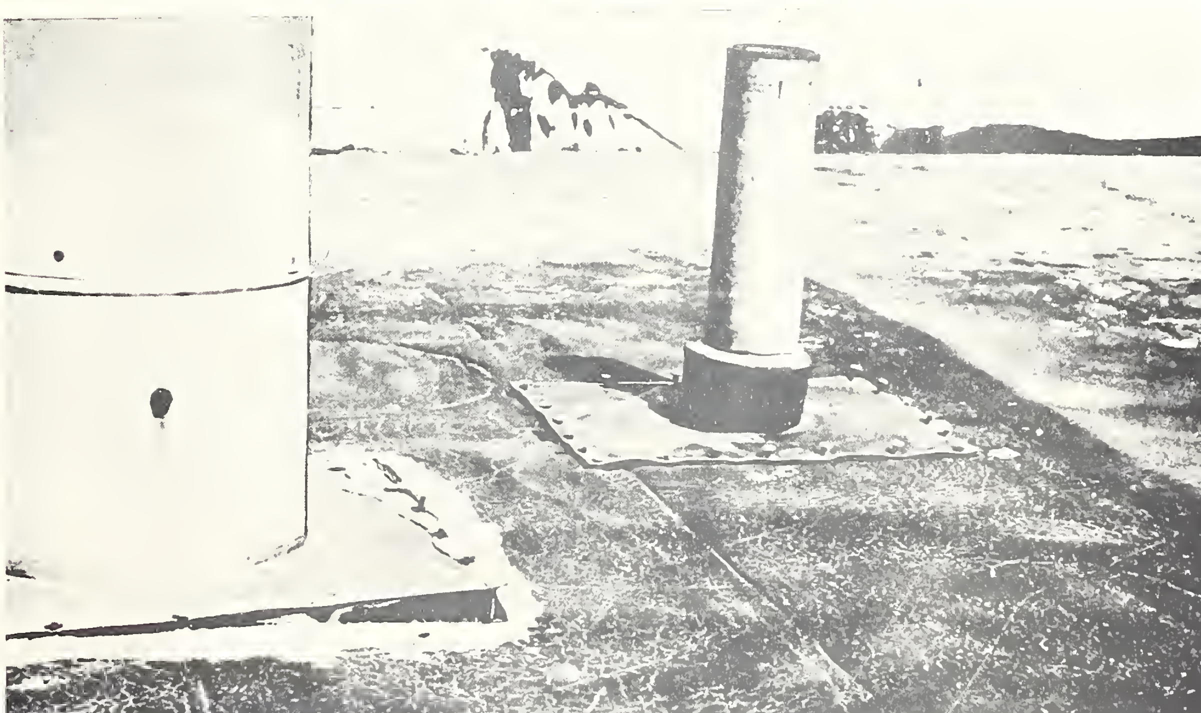

Figure 43. Separation of metal flashing flange from roof caused by exposed nails working loose.

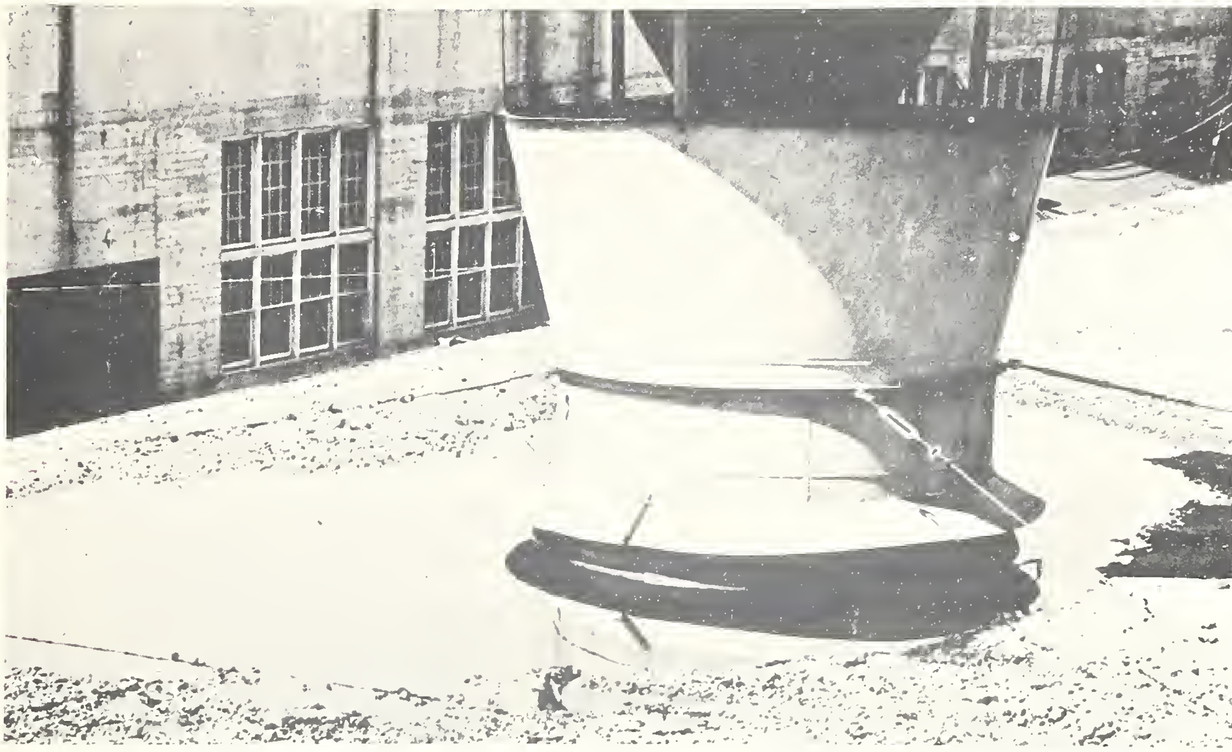

Figure 44. Standing water around vent.

Figure 45. Debris left on roof results in poor drainage.

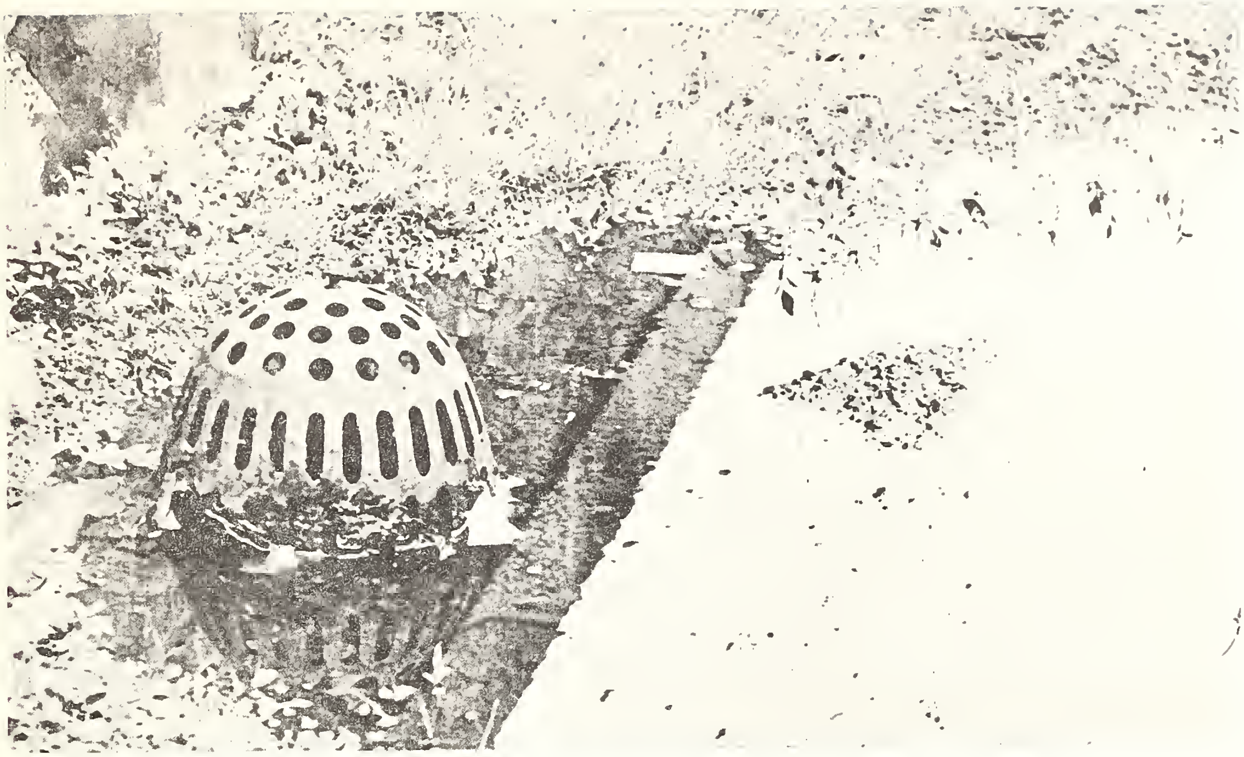

Figure 46. Drains must be kept clean to function properly.

Figure 47. Standing water resulting from structural defect.

Figure 48. Before. Deterioration of roofing material where metal gravel stop was omitted.

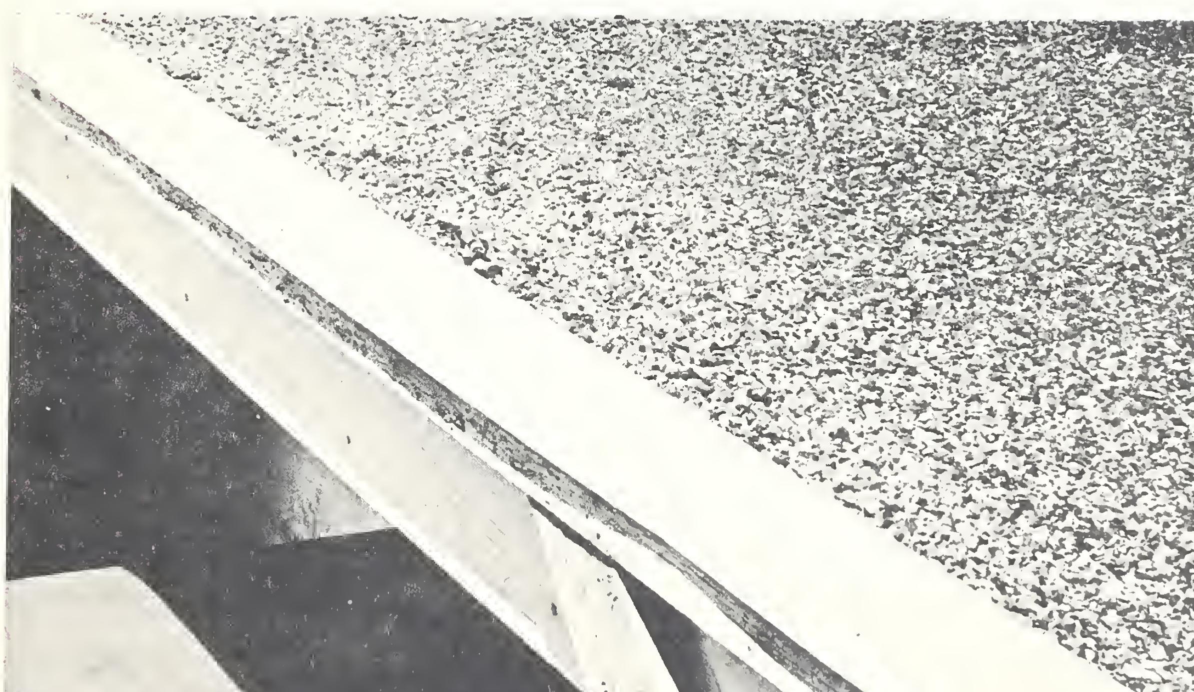

Figure 49. After. Section of roof shown in Figure 48 after repair and installation of metal gravel stop.

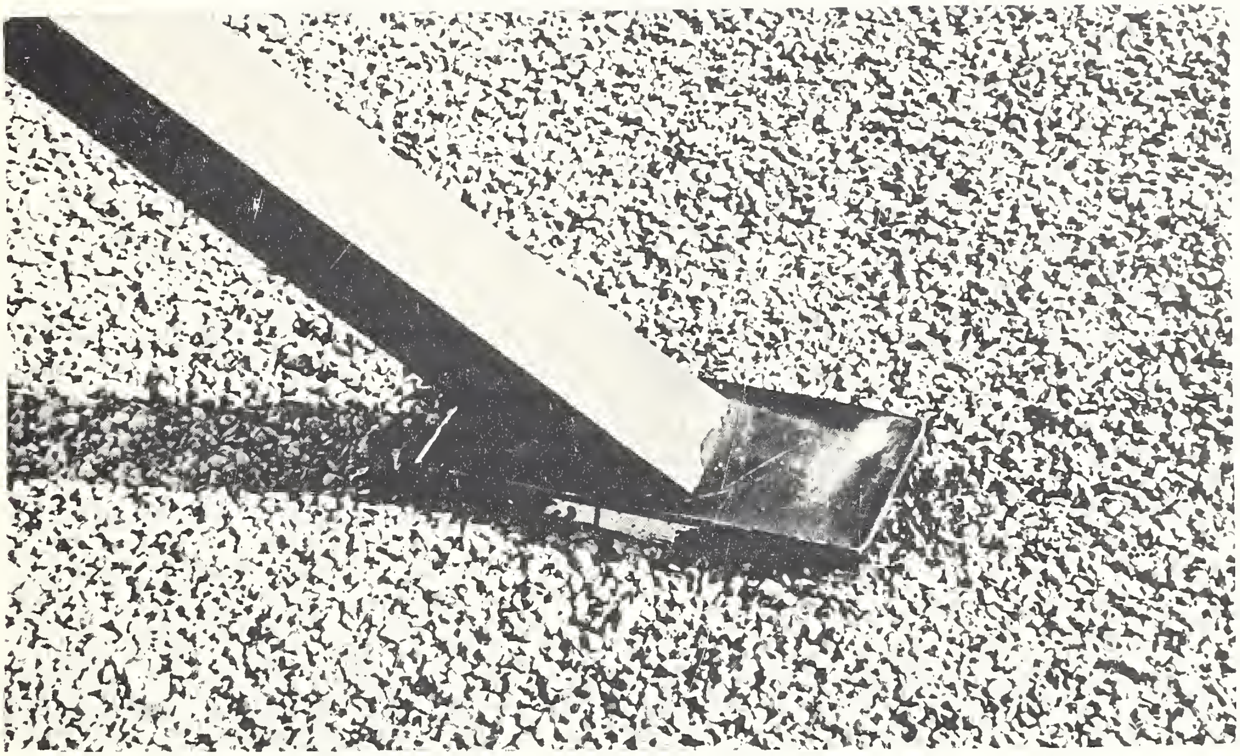

Figure 50. Pitch pocket.

THE NATIONAL BUREAU OF STANDARDS

Functions and Activities

The functions of the National Bureau of Standards are set forth in the Act of Congress, March 3, 1901, as amended by Congress in Public Law 619, 1950. These include the development and maintenance of the national standards of measurement and the provision of means and methods for making measurements consistent with these standards; the determination of physical constants and properties of materials; the development of methods and instruments for testing materials, devices, and structures; advisory services to Government Agencies on scientific and technical problems; invention and development of devices to serve special needs of the Government; and the development of standard practices, codes, and specifications. The work includes basic and applied research, development, engineering, instrumentation, testing, evaluation, calibration services, and various consultation and information services. A major portion of the Bureau's work is performed for other Government Agencies, particularly the Department of Defense and the Atomic Energy Commission. The scope of activities is suggested by the listing of divisions and sections on the inside of the front cover.

Reports and Publications

The results of the Bureau's work take the form of either actual equipment and devices or published papers and reports. Reports are issued to the sponsoring agency of a particular project or program. Published papers appear either in the Bureau's own series of publications or in the journals of professional and scientific societies. The Bureau itself publishes three monthly periodicals, available from the Government Printing Office: The Journal of Research, which presents complete papers reporting technical investigations; the Technical News Bulletin, which presents summary and preliminary reports on work in progress; and Basic Radio Propagation Predictions, which provides data for determining the best frequencies to use for radio communications throughout the world. There are also five series of nonperiodical publications: The Applied Mathematics Series, Circulars, Handbooks, Building Materials and Structures Reports, and Miscellaneous Publications.

Information on the Bureau's publications can be found in NBS Circular 460, Publications of the National Bureau of Standards ($1.25) and its Supplement ($0.75), available from the Superintendent of Documents, Government Printing Office. Inquiries regarding the Bureau's reports and publications should be addressed to the Office of Scientific Publications, National Bureau of Standards, Washington 25, D. C.

NBS