ROOF SYSTEMS

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1.0 SCOPE

This document provides support information on roof systems as discussed in Data Sheet 1-29. Information is included on the various generic types of roof components, wind forces, fire resistance, hail resistance, etc. The RoofNav contains additional information on FM Approved systems.

Prefabricated panel roofs (insulated panels, standing seam, etc.) which are attached directly to purlins are not included in this data sheet. Refer to RoofNav and Data Sheet 1-31 for information on these systems.

There are no recommendations in this document.

Refer to Data Sheet 1-49 for additional information on flashing systems.

1.1 Changes

January 2016. Interim revision. Reformatting and editorial changes were made.

2.0 WIND

2.1 Wind Forces on Roofs

The wind uplift forces on roofs vary, depending on many factors, including wind speed, building geometry, surrounding ground terrain, roof deck type, wall opening protection and in some cases, the presence of a parapet. Most of these factors are considered in Data Sheet 1-28.

When the wind strikes a building, the resultant uplift force acting on the roof system is the sum of the negative pressure above the roof and the positive internal building pressure (Fig. 1). For buildings without large openings (defined in Data Sheet 1-28), the internal pressure accounts for approximately 15 percent of the total uplift pressure in the field of the roof (Zone 1). For buildings with large openings, the contribution of this internal pressure is greater. To compensate, Data Sheet 1-28 roof uplift pressures are increased considerably for these buildings. For a given building and wind speed, the **internal** pressure is constant across the entire roof.

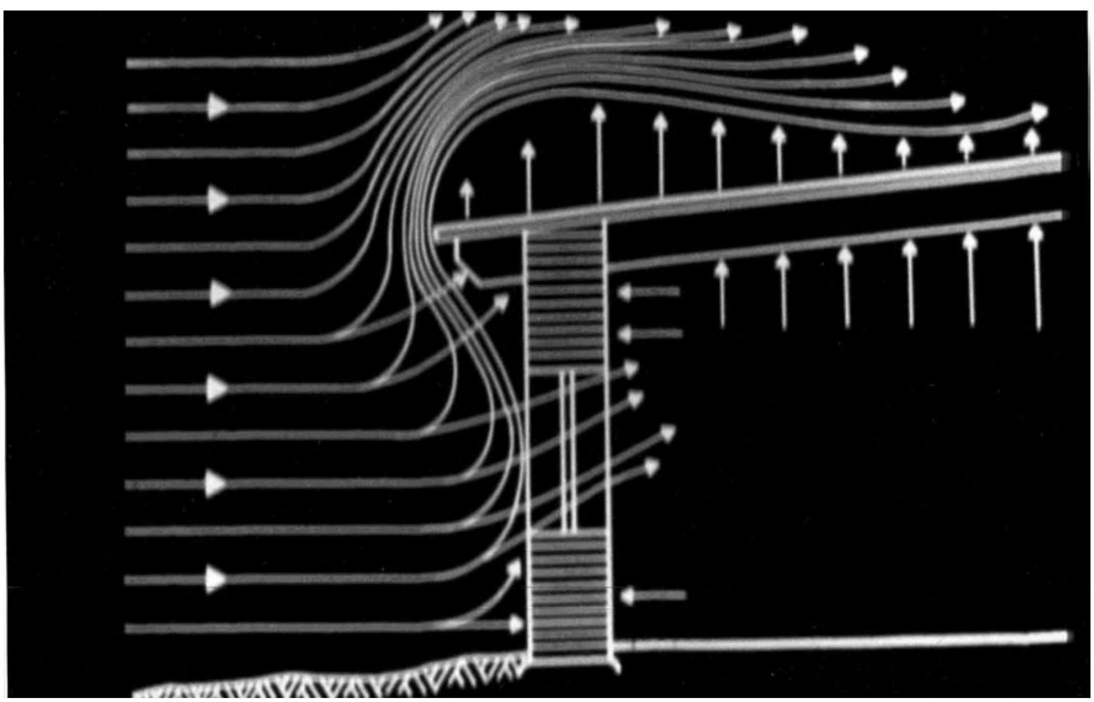


Fig. 1. Section view, wind acting on a roof

The wind exerts varying negative (suction) forces on different areas of the roof (Fig. 2). For simplicity, the roof can be divided into three areas: corners, perimeter, and roof field. The perimeter and corners are exposed to higher uplift forces than the roof field. The maximum uplift force occurs at the corners when the wind blows at an angle of about 45° to the roof. The maximum uplift force at the windward roof perimeter occurs when the wind blows at 90° to the perimeter. Actual pressure coefficients for the corners and perimeter vary depending opening protection and building geometry. The reason for the higher forces in these areas is the wind speed increases at the building edge as the wind flows over the structure.

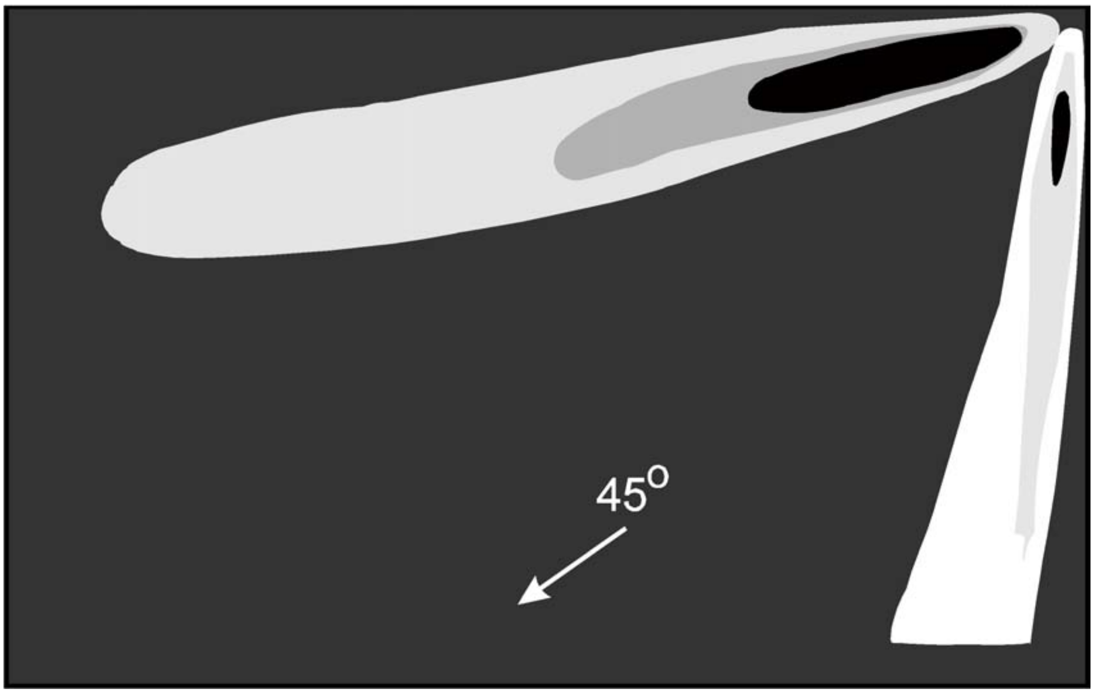


Fig. 2. Plan view, areas of high uplift pressure

To compensate for the increased pressures at the roof corners and perimeter, additional roof component fastening over the FM Approval requirements is recommended in these areas. **In most cases, it is generally not necessary to actually calculate the increased pressure. The increased fastening recommended in these areas is sufficient to resist these forces.**

For most building shapes ≤ 60 ft (18 m) in height, the roof corners are defined as squares with sides equal to the smaller of:

- 10 percent of the lesser building plan dimension
- 40 percent of the eave height
- subject to a minimum dimension of 4 ft (1.2 m), except for ballast coverage only, 8.5 ft (2.6 m).

The perimeter, with a width equal to the above dimensions, is all edge strips inside the corners.

For roofs with slopes >10°, 2 in./ft (167 mm/m) the strip along the peak (width as above) is also considered a perimeter strip. The reason for this is as the wind blows over the peak on higher sloped roofs, the strip along the peak is loaded in a manner similar to the eave.

For buildings with slope ≤10°, 2 in./ft (167 mm/m) and continuous, minimum 3 ft (0.3 m) high parapets, perimeter pressures can be used for the corners. The reason is the parapet has the effect of enlarging the area of higher negative pressure thereby reducing its magnitude.

Where multilevel roofs meet at a common wall, the edge of the upper roof is treated as a perimeter if the height difference is ≥ 10 ft (3 m). The lower roof strip where it meets a higher roof is not considered a perimeter. The reason for this is the taller roof edge reacts much like a perimeter with increased wind speed at the building edge.

All of the above dimensions are the consensus definitions for design purposes.

2.2 FM Approval Wind Uplift Testing

Two pressure vessels are used for testing wind uplift resistance of roof assemblies as shown in Figures 3 and 4. One meaures 9 × 5 ft (2.7 × 1.5 m), the other measures 24.25 × 12.5 ft (7.4 × 3.8 m).

Fig. 3. Uplift pressure test samples and equipment 12.5 × 24.25-ft (3.8 × 7.4 m) test apparatus

To construct a test sample, the appropriate deck is secured to the test frame. Insulation, if used, is then secured to the deck and the appropriate roof cover is installed. The cover seals the top of the vessel. The sample is then clamped to the bottom section of the apparatus.

During testing, compressed air is slowly introduced below the deck in increments of 15 psf (0.7 kPa). If the sample maintains 60 psf (2.9 kPa) for one minute without damage, the assembly is rated Class 1-60. The same procedure is used for Classes 1-75, 1-90, 1-105, etc., but the sample must maintain 75 psf (3.6 kPa), 90 psf (4.3 kPa), 105 psf (5.0 kPa), etc. For monolithic decks like lightweight concrete (LWIC), modifications are made to allow tests of the above-deck components. The above deck components are loaded using a vacuum chamber placed above the sample.

The relationship between FM Approval classifications and Data Sheet 1-28 calculated uplift pressures is as follows. Actual uplift pressures on the roof field are listed in Data Sheet 1-28. The actual field of roof pressure is multiplied by 2.0 to determine the factored pressure. A roof system with an approval rating equal to or greater than the factored pressure is then used for Zone 1. For Zones 2 and 3, either prescriptive enhancements are provided according to Data Sheet 1-29, or higher rated FM Approved systems are used (performance based option).

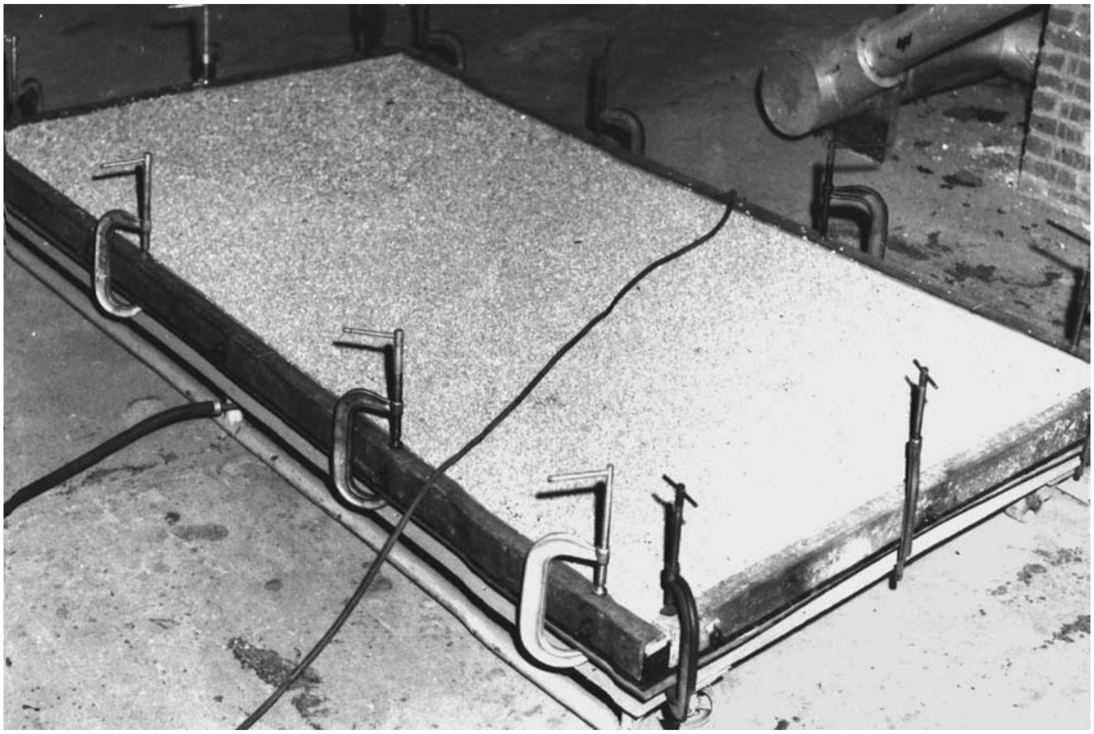


Fig. 4. Uplift pressure test samples and equipment 9 × 5-ft (2.7 × 1.5 m) test apparatus

Table 1. Example of FM Approval Rating Needed

Actual Field of Roof Pressure	*Factored Pressure*	*Minimum Field of Roof Approval Rating Needed*
≤ 30 psf (≤ 1.4 kPa)	≤ 60 psf (2.9 kPa)	1-60
31–37 psf (1.4–1.8 kPa)	61–75 psf (2.9–3.6 kPa)	1-75
38–45 psf (1.8–2.1 kPa)	76–90 psf (3.6–4.3 kPa)	1-90

2.3 Inferior Construction

If the uplift resistance of the roof is less than needed, the roof is vulnerable to wind damage and is termed ‘‘inferior’’. This can occur for several reasons, including:

- Inadequately applied asphalt used to adhere the insulation. For example, asphalt allowed to cool before the insulation was placed or applied perpendicular to the deck ribs
- Poor fastener installation
- Inadequate number or wrong type of fastener was used
- Insulation board thinner than FM Approved
- Roof deck installation deficiencies
- Inadequate roof cover securement

In some cases, inferior construction can be determined from the specifications; in others, wind uplift testing (field or laboratory) may be needed.

3.0 INTERNAL FIRE RESISTANCE

Roof systems are classified with one of three internal fire spread ratings: noncombustible, Class 1 and Class 2.

Noncombustible decks allow no fuel contribution from the roof system under simulated interior fire conditions regardless of the above-deck components. Structural concrete, FM Approved cement-fiber panels and certain FM Approved lightweight insulating concrete (LWIC) assemblies are noncombustible.

An insulated roof deck assembly is Class 1 when it has met FM Approval limitations for heat release rates when tested in the FM Approval's Materials Calorimeter in accordance with NFPA 276. When the heat release rates of a roof assembly exceeds these limitations, the roof is designated Class 2. The Class 1 limits are given below:

Table 2. Maximum Average Rates of Fuel Contribution
Btu/ft^2/min (kg-cal/m^2/min) for Various Time Intervals

3 min.	*5 min.*	*10 min.*	*test avg (30 min.)*
410 (1111)	390 (1057)	360 (975)	285 (772)

When a fire occurs under a Class 2 insulated roof deck, the components of the roof are heated by rising hot gases or flame impingement. Most of the flammable gases liberated from the roof system cannot escape upward through the roof covering. They are forced down through the deck joints into the building and ignited. If the fire continually heats the underside of the deck to approximately 800°F (427°C), there are sufficient combustibles in Class 2 roof decks to produce a self-propagating fire across the underside of the roof. The fire can propagate without additional heat input from the occupancy fire, resulting in complete destruction of the building and contents. Sprinkler protection or an FM Approved roof deck undercoating is needed to prevent fire spread under Class 2 roofs.

Flammable gases are also liberated when Class 1 roofs are heated, but the heat release rate of Class 1 assemblies is limited. These assemblies are expected to burn to a maximum of about 60 ft (18 m) radially from the exposure before propagation ceases. In most cases the fire spread will be less. However, if the occupancy fire exceeds the American Society for Testing and Materials (ASTM) Time Temperature Curve (ASTM E119, Data Sheet 1-21), burning in Class 1 roofs may be greater. Class 1 roofs do not require sprinkler protection in and of themselves.

Simply using fasteners for insulation securement, instead of adhesives or asphalt, does not assure Class 1 construction. Mechanically fastened Class 2 roofs include:

- non-Approved insulation placed directly on the deck
- non-Approved or inadequate thermal barrier installed below certain plastic insulations or asphalt mopped vapor retarders
- non-Approved combustible vapor retarder placed directly on the deck
- insulations thinner or thicker than Approved
- some nail/mop constructions
- greater number of plies than Approved in the BUR cover
- excessive recover insulations applied over an existing Class 1 assembly
- any construction that exceeds the maximum Class 1 heat release rates

When recovering an existing Class 1 assembly only limited additional insulation can be applied (an FM Approved recover system) otherwise a Class 2 deck can result. The reason is the additional insulation can trap more heat and flammable gases liberated by the existing roof. Conversely, if the existing roof is Class 2, application of a Class 1 rated recover system will not upgrade the roof to Class 1. An Approved recover system should still be used, however, to ensure adequate wind uplift and external fire resistance. By definition, Class 1 recover systems allow existing Class 1 roofs (one existing roof) to remain Class 1 after installation.

Reroof systems are a relatively new Approval category. These insulation assemblies have been tested and are FM Approved (Class 1) when installed on steel roof decks which have up to 15 lb/sq (0.73 kg/m^2) of asphalt left on the deck from an existing asphalt-adhered roof system. Prior to these Approvals, all above deck components, including asphalt, had to be removed and a system FM Approved for new construction applied. If a system FM Approved for new construction is applied over a steel deck with asphalt remaining on it, a Class 2 deck can result.

4.0 EXTERNAL FIRE RESISTANCE

FM Approved roof covers are evaluated for external fire resistance via the ASTM E108 test procedure. This test method gives a basis to compare the fire resistance characteristics of roof cover assemblies exposed to **exterior** fires.

The E108 tests evaluate specific combinations of roof covers, insulations and decks. The tests cover five areas: intermittent flame exposure, spread of flame, burning brand, flying brand and the long term effects of rain on fire resistance. Assemblies that are to be used on noncombustible roof decks (steel, concrete, gypsum, etc.) are tested for spread of flame only. (Note: per the E108 procedure, the noncombustible/combustible determination is made on the basis of the **deck material** only. These definitions should not be confused with the FM Approval underside fire exposure classifications for roof deck **assemblies**: noncombustible, Class 1 and Class 2.) The procedure rates roof covers as Class A, B or C. It is important to note that changing any aspect of the assembly such as the substrate, roof slope, roof cover attachment method, etc. can drastically affect performance.

Class A assemblies are applicable to roof coverings that are effective against severe test exposure; Class B assemblies against moderate test exposures and Class C assemblies against light test exposures. These generic descriptions are taken directly from the written E108 procedure.

The test samples are 3.3 ft (1 m) wide using a plywood deck with the insulation (if applicable) and membrane secured to it. Burning brand, flying brand and intermittent flame samples are 4.3 ft (1.3 m) long. Spread of flame samples are up to 13 ft (4 m) long.

For the intermittent flame, spread of flame and flying brand tests, the sample is exposed on the shorter side to a gas flame at 1400°F ± 50° (760°C ± 28°) for the A or B tests or 1300°F ± 50° (704°C ± 28°) for the C test. A 12 mph ± 0.5 (5.4 ± 0.2 m/s) wind blows the flame across the sample. The sample can be inclined from horizontal up to a 5 in./ft (23°, 416 mm/m) slope. The slope is specified by the manufacturer and the classification is valid for slopes up to the tested slope.

4.1 Spread of Flame Test (See Figs. 5 and 6)

The flame exposure for this test is 10 minutes for Class A and B or until the flame front retreats. For Class C the flame exposure is 4 minutes.

- For Class A, maximum flame spread: 6 ft (1.8 m)
- For Class B, maximum flame spread: 8 ft (2.4 m)
- For Class C, maximum flame spread: 13 ft (4.0 m)

4.2 Intermittent Flame Test

The sample is exposed to the flame for on/off cycles. For Class A, 15 cycles of 2 minutes on and 2 minutes off. Class B is the same exposure as A, but only for 8 cycles. For Class C, 3 cycles of 1 minute on and 2 minutes off.

4.3 Burning Brand Test

The exposure for these tests is a wood crib for Class A and B and small blocks of wood for the Class C test (Fig. 7). The crib or block is ignited and placed on the sample where the most damage can be expected. The test lasts until failure or all evidence of flame, smoke, or glowing has ceased.

The pass/fail criteria for the intermittent flame, spread of flame (in addition to flame spread limits) and burning brand tests are similar. Burning/glowing pieces of the cover may not fall from the sample and continue to burn or glow on the floor. There can be no burnthrough of the assembly exposing the deck. (Exception: for noncombustible decks, the deck can be exposed during the spread of flame test.) For the intermittent flame

Fig. 5. ASTM E108 spread of flame test

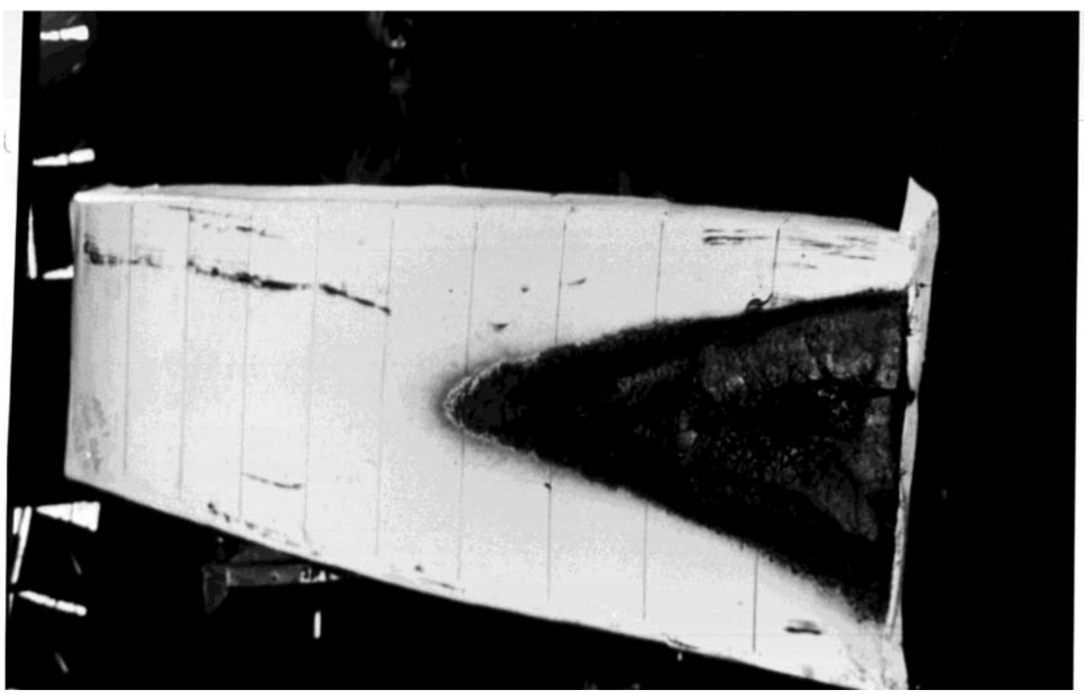


Fig. 6. ASTM E108 spread of flame test. Sample after test

and burning brand tests, sustained flaming of the underside of the deck is not allowed.

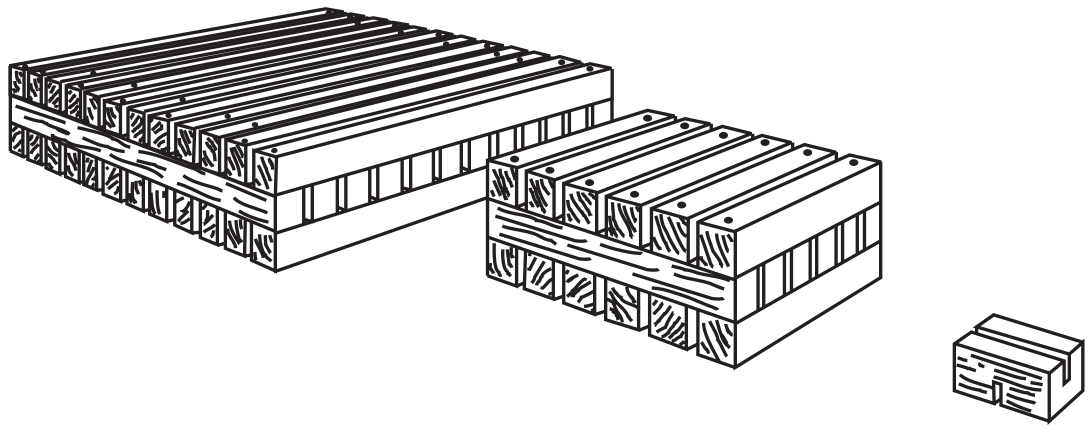


Fig. 7. Brands for Class A, B, & C tests

4.4 Flying Brand Test

The flying brand test is made during the spread of flame test with the observer watching for conditions of failure. The pass/fail criteria are that burning or glowing pieces of the cover and insulation cannot fall to the floor.

4.5 Rain Test

The rain test is used for roof covers in which the fire performance could be affected by the weather, such as fire retardant (FR) treated wood shingles. During the conditioning, the samples are exposed to cycles of wet and dry conditions over a 12 week period. The above tests are then run on the conditioned samples. This conditioning/testing is generally not conducted on single-ply membranes, built-up roofs (BURs), asphalt shingles or modified bitumens.

5.0 HAIL DAMAGE

Hail damage to BUR covers can be greatly reduced by providing slag or gravel surfacing adhered with hot bitumen **in combination with** good maintenance. Most larger hail stones can break blisters on an existing covering, including gravel surfaced ones. Broken blisters destroy the water-tightness of the roof.

5.1 Hail resistance ratings

FM Approved roof covers have one of three hail resistance ratings, very severe hail (VSH), severe hail (SH) or moderate hail (MH). These ratings are noted in the RoofNav. Details of each procedure are outlined in FM Approval Standard 4470.

Some assemblies are tested using an ice ball test in accordance with ANSI/FM 4473. For more information, also see Data Sheet 1-34.

6.0 ROOF COMPONENTS

6.1 Roof Decks

The roof deck provides the structural support for the roof system. It needs sufficient stiffness so that the above-deck layers will not flex excessively and separate due to applied loads. This is achieved by limiting the deck span; adequately fastening panel-type decks to supporting members and fastening panel side laps. Excessive deck deflections can fracture the insulation and delaminate the roof cover.

6.1.1 Steel Deck

FM Approved steel deck (Fig. 8) is currently available in 22 ga. (0.0295 in., 0.749 mm), 20 ga. (0.0358 in., 0.909 mm), 18 ga. (0.0474 in., 1.204 mm), and 16 ga. (0.0595 in., 1.5 mm) thick sheets with 1.5 in. (38 mm) deep ribs. An Approved 2 in. (51 mm) profile, and 3 in. (75 mm) profiles are also available from at least one manufacturer. The corrugations (ribs) are cold rolled in the sheets. The deck has a 6 in. (152 mm) module, that is, the ribs are 6 in. (152 mm) on center. All fastening Approvals and recommendations are based on this profile. (Approved and recommended spacings are such that the fasteners will engage the top flange of the deck). Another common configuration is 3 in. (76 mm) deep deck which usually has an 8 in. (203 mm) module.

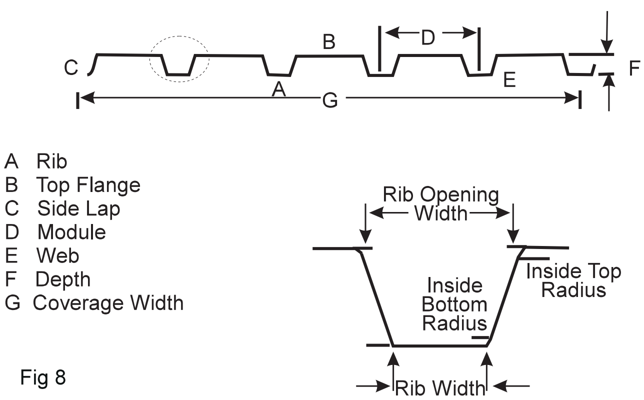


Fig. 8. Explanation of terminology

There are also proprietary FM Approved steel deck systems which utilize thinner decks. These typically rely on composite action to achieve acceptable deflection performance. Refer to the *Approval Guide* for descriptions of these systems.

Decks are classified by rib opening width. Narrow rib deck has a nominal rib opening of 1 in. (25 mm); intermediate rib, 1.75 in. (44 mm); and wide rib, 2.5 in. (64 mm); all measured at the top of the opening.

Deck sections are secured to the roof support members by welding or FM Approved deck fasteners. For a typical weld, a hole is made in the deck by the welding apparatus and the area is filled with liquid weld metal that fuses the deck to the supporting steel. This method is referred to as plug or puddle welding. FM Approved deck fasteners are either the self-drilling type or powder or compressed air actuated. They are Approved for securement of steel deck or form deck to various thicknesses of supporting members.

FM Approval testing of steel deck includes deflection criteria.

6.1.2 Nailable and Nonnailable Decks

Wood and cementitious roof decks have traditionally been categorized as nailable or nonnailable. Nailable decks include wood and new decks of gypsum and lightweight insulating concrete (LWIC) such as perlite concrete, vermiculite concrete and cellular (air-entrained) concrete. These decks are soft enough so that the above-deck components can be secured with fasteners. Cementitious wood fiber and poured or precast structural concrete decks have been referred to as nonnailable. The term nonnailable is misleading. With the variety of FM Approved fasteners available, mechanical securement to most deck types is now possible, if desired.

LWIC has a unit weight of approximately 22–44 lbs/ft^3 (352–704 kg/m^3) and a compressive strength of 100-1000 psi (690-6900 kn/m^2) depending on generic type and manufacturer. LWIC is usually poured over FM Approved galvanized steel form deck. Galvanized deck is needed for two reasons. One is corrosion resistance and the other is wind uplift resistance which is enhanced by the chemical bond which develops between the zinc coating and the concrete slurry. Decks with aluminum alloy coatings cannot be used due to detrimental chemical reactions which would occur between the concrete and aluminum. The form deck is welded or fastened to supports in a manner similar to that for insulated steel deck construction. Weld washers are needed for decks <22 ga (0.0295 in., 0.749 mm). A weld washer is a heavier gage (usually 16 ga. [0.06 in., 1.52 mm]) piece of steel about 1 in. (25 mm) square. It has a hole (usually ⅜ in. [9.5 mm] diameter) in the center. The washer is placed on the deck and secured by burning a hole through the deck and welding the washer to the supporting member. This prevents the weld hole from becoming too large.

Alternatively, LWIC may be poured over a structural concrete deck.

Typically, a slurry of LWIC is poured over the form deck to cover the entire deck. A perforated expanded polystyrene (EPS) board is then placed into the wet concrete with an additional 2 in. (51 mm) of lightweight insulating concrete poured over the EPS. After a cure period, a base sheet is rolled out and fastened to the deck with FM Approved base sheet fasteners (Fig. 9). A BUR or modified bitumen cover is then usually installed. Some systems do not include the EPS. Others can also be applied over structural concrete or existing BUR. Descriptions of various assemblies are outlined in RoofNav.

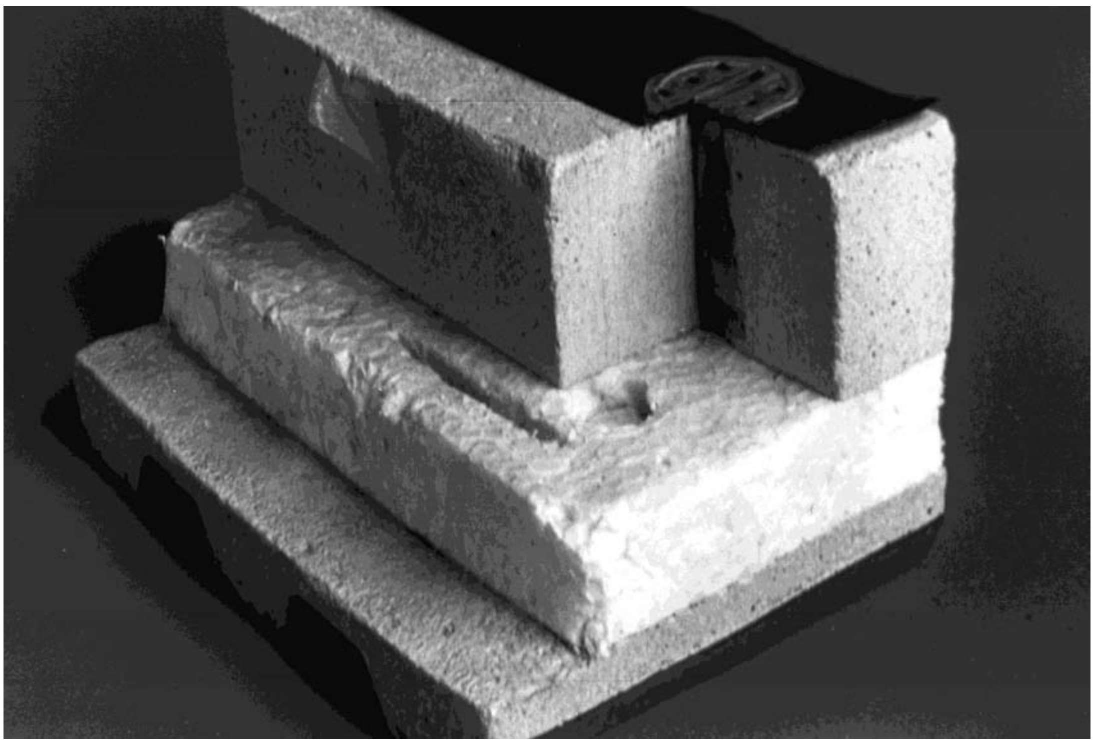


Fig. 9. Lightweight insulating concrete deck assembly

Structural concrete is defined as that which has a minimum compressive strength of 2500 psi (120 kPa). The material may be lightweight structural concrete which has a unit weight of 90-115 lbs/ft^3 (1440-1840 kg/m^3) or conventional structural concrete with a unit weight of approximately 150 lbs/ft^3 (2400 kg/m^3). Lightweight structural concrete should not be confused with lightweight insulating concrete (LWIC).

6.2 Insulated and Uninsulated Roof Decks

Roof decks can further be categorized as insulated or uninsulated. In insulated construction, a board stock insulation is secured to the deck and the roof cover system is then installed. Uninsulated constructions usually consist of a base sheet mechanically secured or adhered to the deck followed by two to four plies of roofing felts in asphalt, coal tar or cold adhesive moppings or a modified bitumen membrane. This construction is common on wood and some concrete decks.

6.3 Above-Deck Fasteners

For many years, adhesives or asphalt were used to secure insulation to steel deck. Due to their loss history in this application, it is now recommended that insulation boards be secured to steel deck only with FM Approved mechanical fasteners. Asphalt or adhesive securement to other deck types is acceptable if the assembly is FM Approved.

When the roof cover is adhered to the insulation, the number of fasteners needed in the roof field varies, depending on the fastener used, the insulation type and thickness and the roof cover type. Generally, fully-adhered, single-ply membranes need more fasteners per unit area than BURs for the same wind uplift resistance.

Poor fastening installation practices result in weak securement. Poor fasteners can be:

- overdriven, which can cause stripping of threads cut into deck, bending of metal plates and fracture of plastic plates or insulation facer (Fig. 10)

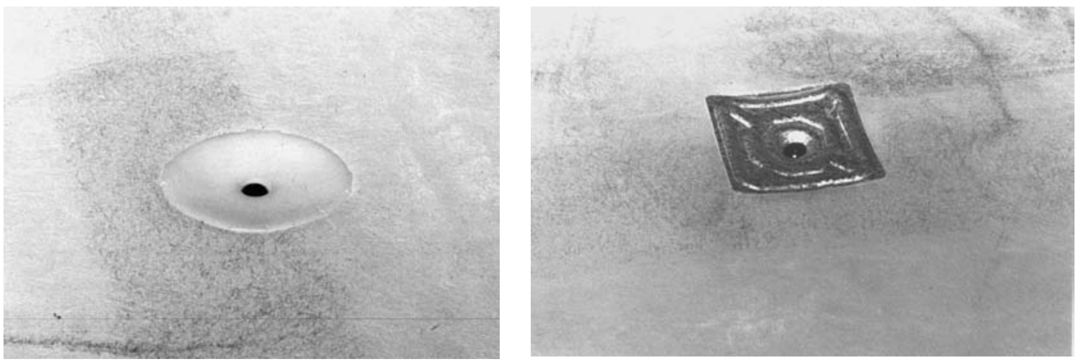


Fig. 10. Overdriven fasteners with plastic and metal plates

- underdriven leaving fastener loose
- driven without a plate or with incorrect plate
- too short (or too long) so that the threads do not engage the deck; if it is too long, the fastener is driven through the deck, possibly enlarging the hole
- not engaging the top flange of steel deck
- not driven perpendicular to the deck
- driven too close to or too far from the edge of the insulation board (Fig. 11) or roof cover.

6.3.1 Fastener Performance

Proper screw length is important to uplift resistance. For example, use of a significantly longer screw than recommended in steel deck construction is not desirable. The reason is longer screws driven into the top flange of the deck tend to enlarge the hole, reducing pull-out strength. If the top flange is missed, it will not be readily apparent, because the screw may be long enough to engage the bottom flange and bend the insulation into the deck rib opening, causing insulation board fracture. With mechanically attached, single-ply membranes, bottom flange engagement is a critical problem. The longer moment arm (1.5 in. [38 mm] longer than top flange engagement) will cause significantly more moment on the fastener, increasing the potential for fastener back-out.

In recent years the phenomenon of fastener loosening or back-out has received considerable attention. Problems appear to be greatest with mechanically-attached, single-ply membranes where wind-induced flutter causes cyclic loading on the fasteners. Based on a limited amount of data available, fasteners in which the threads or head solidly engage the plate might offer improved back-out resistance.

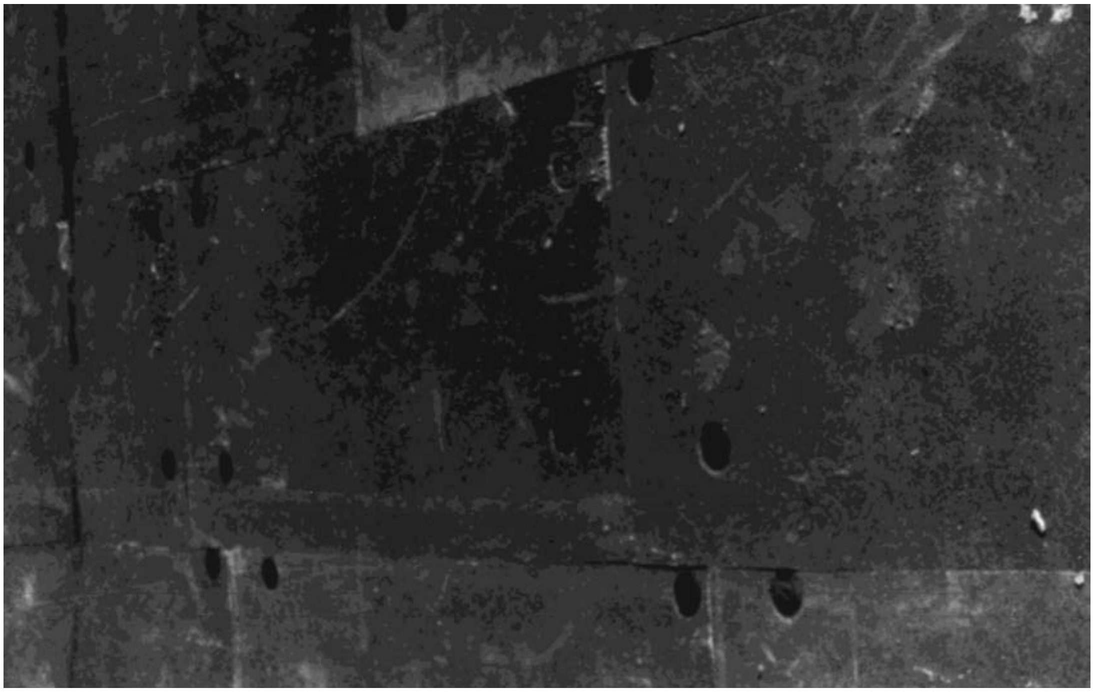


Fig. 11. Fasteners driven too close to insulation board edge

Fastener pull-out performance in gypsum and cement-wood fiber decks is extremely dependent upon deck condition. Fasteners are only effective if driven into sound, dry decks. For structural concrete deck applications, the correct pre-drilled hole diameter and depth are critical.

6.3.2 Corrosion Resistance

FM Approved roof cover, base sheet and insulation fasteners have been evaluated for corrosion resistance per FM Approval Standard 4470 or 4450. The test procedure consists of exposing ten fasteners and ten plates to a mild concentration of sulfur dioxide (100 percent relative humidity at 104°F [40°C]) for 8 hours. The samples are rinsed and then dried at ambient conditions for 16 hours. The procedure is conducted for 15 cycles.

Components cannot exhibit more than 15 percent surface corrosion nor can the protective coating, if any, be cracked or blistered at the completion of the test.

Several base metal/coating systems have been Approved for screw-type fasteners including certain grades of stainless steel or polymer or fluorocarbon coatings over carbon steel. For nail-type fasteners used in structural concrete, the above coatings or hot-dipped galvanizing have been Approved. Metal stress distribution plates and batten bars utilize polymer coatings, zinc-aluminum alloy coatings or selected stainless steels.

6.3.3 Fastener Descriptions

Most insulation fastener assemblies consist of a metal or plastic stress distribution plate, approximately 3 in. (76 mm) square or diameter and a fastener. The plate and fastener may be an integral unit or separate components. The plate creates a wide stress distribution area in the insulation. If the plates are omitted or improperly sized, uplift forces will fracture the insulation board.

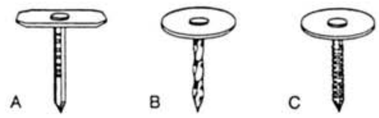
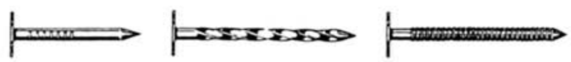
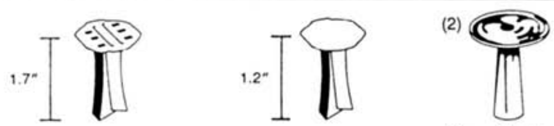
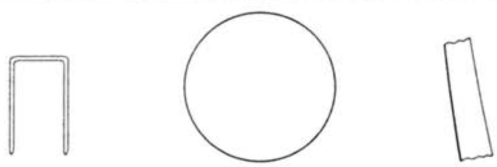
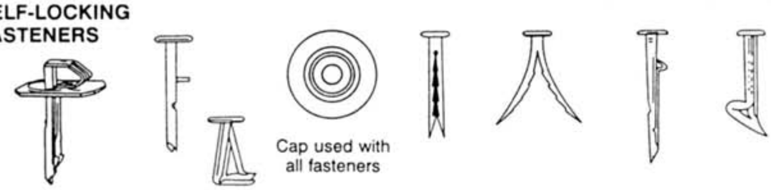
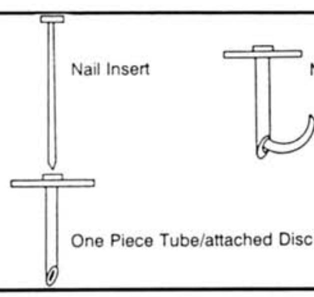
Insulation fasteners for steel deck include self-drilling screws and powder/air actuated hardened steel pins. Fasteners for structural concrete decks include nails, expansion pins or screws (driven into pre-drilled holes) or powder/air actuated hardened steel pins. Wood deck fasteners are usually the self-drilling screw type. Cement-wood fiber and gypsum deck fasteners are usually a plastic auger. Generally, they can be driven directly into cement-wood fiber decks, but require predrilling in gypsum decks. Consult the *Approval Guide* for details. Toggle-bolt type fasteners are placed through pre-drilled holes and utilize a spring-loaded wing as the means of tightening. They are acceptable for use in most decks except cement-wood fiber.

Roof cover fastener assemblies usually use the fastener elements described above with batten bars, smaller, nominal 2 in. (51 mm) plates, or nonpenetrating assemblies. Batten bars are generally 1 in. (25 mm) wide metal or plastic strips, prepunched with holes 6 or 12 in. (152 or 305 mm) on center. The bars or plates are either fastened within the roof cover laps or are independent of the laps and covered with a piece of membrane. Some plates have barbs on the underside to reduce fastener back-out. Nonpenetrating assemblies usually consist of a plastic base plate secured through the insulation to the deck. The membrane is rolled out over the plates and secured by snapping or screwing a top plate over the base plate.

Roof cover fastener plates or bars are not generally recommended for insulation securement. One exception is nonpenetrating base plates described above. These plates are large enough so that they provide adequate preliminary insulation securement. To be effective for insulation securement, the fasteners must be installed so that each insulation board is secured with at least the number of fasteners needed for preliminary securement per RoofNav and Data Sheet 1-29.

Base sheet fasteners are typically a nail and disc. FM Approved nail designs are different for each deck type. Typically, split shank nails are used in lightweight insulating concrete and cone shaped nails are used in gypsum. Not all fasteners in Table 3 are FM Approved.

Table 3. General Guide to Base Ply Fasteners

FASTENER TYPE		DECK TYPE	PLYWOOD DECK	NON-VENEER DECK	WOOD PLANK DECK	CEMENT/WOOD FIBER	LT. WT. INSUL. CONC	POURED GYPSUM
LARGE HEAD ROOFING NAIL NOTE: Hardened nails available for installation into mortar joints/CMU	 A B C	A	●	●	●			
		B	●	●	●			
		C	●	●	●			
STANDARD ROOFING NAILS	 Barbed, Screw Shank, Annular Shank	A	●		●			
		B			●			
		C	●	●	●			
BASE PLY FASTENER	 1.7" 1.2" Split-Shank Fasteners; (2) Cone Shank Fasteners (gypsum)						●	●
PNEUMATICALLY DRIVEN STAPLE, CAP OR TAPE NOTE: 1" Crown Width (Min.)	 Staple, Cap, Tape		●	●	●			
SELF-LOCKING FASTENERS	 Cap used with all fasteners					●		
TWO-PIECE TUBE NAIL	 Nail Insert, Nail Locked in Deck, One Piece Tube/attached Disc					●	●	●

NOTES: 1. All fasteners should have heads or metal discs having dimensions in accordance with Data Sheet 1-29
2. New contruction only
3. Table 1 courtesy of the National Roofing Contractors Association

6.3.4 Field Pull-Out Tests

There are a variety of apparatuses available to conduct field pull-out resistance tests of fasteners. Most equipment consists of upper and lower frames connected through a load cell with a dial for reading the force applied. The lower frame is placed on the roof with the fastener clamped into the upper frame. Force is then applied until the fastener is removed from the deck.

6.4 Built-up Roof (BUR) Covers

6.4.1 Felts

BUR covers consist of three to five plies of roofing felts adhered to the insulation and to each other with a full mop of hot asphalt, coal tar or cold adhesive. Approved felts include organic, glass and polyester-based materials. The use of fewer plies than Approved can reduce hail and wind uplift resistance. Using a greater number of plies than Approved can create a Class 2 roof assembly.

6.4.2 BUR Surfacing

Gravel or slag surfacing on BURs is much preferred over smooth surface coverings. There is no appreciable danger of a gravel or slag surfaced roof becoming ignited on the exterior and spreading fire. Properly maintained, these coverings are also not as likely to be damaged by hail. Gravel or slag covering is a cooler surface that reduces slippage of the felt due to thermal effects. It helps retard UV oxidation effects on the asphalt, increasing the roof's life expectancy.

Smooth surface BURs are often damaged by hail. The damage potential regardless of surfacing is much greater if the covering is blistered. Mineral surfaced cap sheets are often used in place of gravel surfacing; several are FM Approved.

6.4.3 Deficiencies in BUR Coverings

Blisters during roof installation, wet felts, entrapped moisture, solid contaminants or voids under the plies may result in blisters. As the roof surface temperature increases during the day, moisture in voids turns into water vapor which increases the pressure within the void. This pressure forces the plies apart. The result is a blister which can be seen on the surface of the covering. As the surface temperature falls at night, the felts become rigid and do not return to their original position. A vacuum is formed due to cooling and additional moisture may be drawn into the blister and increase its size. Blisters are susceptible to hail or foot traffic damage.

Buckles are ripples in the BUR often formed above insulation board joints; moisture from below is one cause. Buckles are often found where insulation has been applied in one layer. They can also be caused by movement in the roof insulation or deck.

Fishmouths are formed during felt application. They can be caused by a roll of felt running out of alignment in which workers force the sheet back into a line. They can also be caused by felts poorly wound at the factory. Fishmouths can lead to leaks.

Alligatored surface is a condition of small, local checks or cracks caused by shrinking and solar degradation of the bitumen. Smooth roofing membranes in which the asphalt coating has alligatored can be covered with cold applied coatings which fill the voids and provide a more pliable surface material. Additional felts or asphalt should not be mopped to an alligatored surface.

Bare spots on gravel-surfaced roofs may be caused by dead level asphalt flowing to the low areas. This frequently happens on the sloping sides of blisters. These bare areas then degrade.

Inadequate bonding between plies occurs when improper methods are used to lay the felts. The result can be lifted edges, voids between plies and leakage.

6.4.4 Felt Application

The felt is rolled out immediately after asphalt application. A small amount of asphalt is forced out along the full width of the roll as it is rolled out. If the felt starts to go off line while being rolled out, it should be cut and started again. Otherwise, fishmouths will result. Felts are broomed in during application.

6.4.5 Asphalt

There are four types of roofing asphalt. The type used depends on the roof slope. See Table 4.

Table 4. Characteristics of Asphalt

Type ASTM D312	*Softening Point*		*Max. Heating Temp.*	*Recommended Slope in./ft (mm/m)*	
	°F	*(°C)*		*in./ft*	*(mm/m)*
Dead Level (I)	135-151	(57-66)	Not to exceed blowing temperature for >4 hours	up to ½	up to 42
Flat (II)	158-176	(70-80)		½ to 1½	42 to 125
Steep (III)	185-205	(85-96)		1 to 3	83 to 250
Special Steep (IV)	210-225	(99-107)		2 to 6	67 to 500

Equiviscous temperature (EVT) is defined as the temperature at which the asphalt has optimum free-flowing and adhering qualities. Blowing temperature is defined as the temperature at which constituents vital to proper asphalt hardening begin to vaporize (blow off). These temperatures are provided by the manufacturer. In order to have the EVT at the application point, the asphalt has to be heated above EVT in the kettle. However, asphalt should not be heated at or above the blowing temperature for more than four hours, nor should it ever be heated to its flash point. Overheating of asphalt vaporizes components necessary for water tightness. Underheating is also undesirable, as full adhesion will not be developed.

6.5 Single-ply Membrane Covers

6.5.1 Materials

Thermoplastics

There are several thermoplastics.

- Polyvinyl chloride (PVC). PVC-based membranes are typically reinforced with polyester or glass fiber fabric. PVC resists most acids but is incompatible with coal tar or asphalt roofing materials. It can also be affected by EPS, oils and animal fats. The polymer is inherently rigid. Membrane flexibility is achieved through the use of additives called plasticizers.

- Polymer alloy membranes. Some thermoplastic membranes consist of a blend of two or more polymers. They are generally reinforced with polyester mats.

- Chlorosulfonated polyethylene (CSPE). These membranes resist many chemicals, bitumens and acids but may be sensitive to coal tar pitch, gasoline and jet fuel. They are usually reinforced with polyester fiber. CSPE membranes behave like thermoplastics when manufactured but cure when exposed to sunlight, heat and moisture. Welding of seams becomes difficult and seam strength reduced if the membrane is exposed for a short time prior to welding.

Thermoplastic polyolefins (TPO), these membranes are also referred to as flexible polyolefins (FPO). They are either polypropylene or polyethelene based membranes typically reinforced with polyester or glass fabric.

- Polyisobutylene (PIB). These membranes consist of a PIB sheet laminated to a felt backing (all Approved PIB membranes have a felt backing). The backing is needed due to the relatively low creep resistance of the PIB polymer. The membranes have good UV resistance but may be susceptible to attack by light oils, gasoline, petroleum distillates and solvents.

Thermosets

Thermoset membranes have very high elastic qualities and are termed synthetic rubbers. Ethylene, propylene, diene, monomer (EPDM) is the most commonly used thermoset. It resists ozone, acids, alkalis, oxygenated solvents and most atmospheric pollutants. It is available from most manufactures in at least two grades, commonly referred to as ‘‘standard’’ and ‘‘fire retardant.’’ (Particular trade names or designations are used by each manufacturer.) EPDM membranes may be reinforced or unreinforced. Previously, some systems included a surface coating of liquid applied CSPE and sand. These coatings were applied to reduce surface combustibility. However, the ‘‘fire retardant’’ formulations accomplish similar fire spread performance without the need for a coating. Hence, coated systems are now becoming less common. In addition, coatings are not considered effective on mechanically fastened membranes, because the flexing of the membrane causes the coating to flake off. CSPE/sand coatings are not considered effective for protection of EPDM membranes from contaminants.

EPDM is not compatible with aromatic or aliphatic solvents or lighter petroleum products such as, gasoline, oils, grease or fats.

Because most generic, single-ply membrane types are available (some are FM Approved) with a felt backing, separate descriptions of felt-backed membranes are not included in each description above. The backing material is usually nonwoven polyester.

Modified Bitumen Membranes

These membranes consist of a modified bitumen (usually asphalt) with glass and/or polyester reinforcements. The modifiers (additives) improve elasticity, waterproofing qualities and durability of the bitumen. Common modifiers are atactic polypropylene (APP) or styrene-butidiene-styrene (SBS). Surfacing treatments include metal foil, granules, coatings or the certain membranes may be left unsurfaced.

Liquid Applied Roof Covers

Liquid applied membranes include polyurethane, silicone and acrylic based materials. They are spray, roller or brush applied in several coats to polyurethane foam, existing BUR or metal roof panels. Some coatings are used with reinforcing mats. Some have mineral or ceramic granules spread into the wet coating.

The polyurethane foam is usually applied to an existing BUR or, for new construction on steel deck, a mechanically fastened thermal barrier of Type X or C core gypsum board or perlite. Systems are listed in the *Approval Guide* by coating and/or foam manufacturer.

6.5.2 Installation Methods

There are four basic installation methods for single-ply membranes. Manufacturers have their own variations of these basic methods.

Fully Adhered

Unbacked EPDM membranes are often fully adhered to the insulation substrate with contact adhesives. The adhesive is applied to the insulation and membrane underside. After a curing (open) time, the membrane is rolled out and the surfaces are broomed together. The insulation itself can be mechanically attached or adhered to the deck depending on deck type.

Some membranes are adhered with water-based adhesives applied to the substrate only. The membrane is rolled out into the adhesive while it is still wet. At least one PVC manufacturer also uses a contact type adhesive applied in a manner similar to EPDM systems.

Felt backed membranes are usually adhered with a water-based adhesive or hot asphalt, both of which are applied to the substrate only.

Modified bitumens are adhered in one of two ways:

1. Torch application melts asphalt in the membrane by torching the underside of the roll as it is rolled out.

2. Full mop of hot asphalt or cold applied adhesives.

The top ‘‘cap’’ sheet is usually adhered to a base sheet. If the base sheet is adhered to the substrate, these assemblies are considered fully adhered systems. If the base sheet is mechanically fastened, these systems are considered mechanically fastened. APP modified sheets are usually torch applied; SBS modified sheets are usually asphalt adhered. Composite systems are becoming popular as well. These consist of several asphalt plies covered with a modified bitumen cap sheet.

Partially Adhered

PIB and modified bitumen systems can be partially adhered. PIB membranes are commonly adhered to the insulation substrate with ribbons of adhesive or asphalt at a rate of 50 percent coverage in the field of roof with a greater percentage at the perimeter and corners. The base sheets of some modified bitumen systems can be applied with a spot or ribbon application of asphalt.

Some PVC, TPO, and EPDM systems are secured to mechanically fastened discs or plates. These systems are considered mechanically fastened and are described below.

Mechanically Fastened

Most systems can be mechanically fastened. These systems are divided into two basic categories, penetrating and nonpenetrating fastening. In penetrating systems, the membrane is fastened through either tabs at the membrane underside with disc fasteners, through batten strips or discs at the membrane side laps, or through batten strips or discs through the field of the membrane and covered with a piece of membrane or self-adhesive tape.

For a description of nonpenetrating disc systems refer to Section 6.3.3. For plate bonded systems, flexible plates are secured in a grid pattern and the membrane is adhered with adhesive to the plate. It is very important the plate be flexible enough to move with the membrane (keep the adhesive in shear), because the adhesives used have very little peel strength. Use of rigid plates would allow the membrane to delaminate from the plate.

For some PVC or TPO systems, a rigid PVC or TPO covered disc is secured through the insulation to the deck in a grid pattern. The PVC membrane is then adhered to the disc by solvent or heat welding. The rigid plate is effective for PVC because of the nature of the welding of PVC.

Air Barrier Systems (Mechanically Attached)

Air-barrier systems are used on panel-type decks to reduce the effect of internal building pressure on the roof cover. They are essentially a mechanically attached membrane with the addition of a air retarding layer under the insulation.

Most systems use a polyethylene sheet placed under the insulation. The laps are sealed. The insulation is then attached with mechanical fasteners. The insulation fastening density is greater than the ordinary preliminary securement for mechanically attached systems, because the insulation resists part of the uplift force. The membrane is then attached over the insulation. Generally, the membrane fastening is less than that required for the system without the air barrier.

The principal of the system is the internal pressure of the building is resisted by the insulation/air barrier and the remaining pressure is resisted by the membrane. By limiting the air infiltration under the membrane, ballooning and stress in the membrane are reduced. Some systems also include vents in the membrane to further reduce the forces acting on the membrane. Building edge and roof penetration details are critical in the performance of these systems. They must be properly sealed to eliminate air pressure under the membrane.

Similar increased insulation fastening for systems which use vapor retarders with mechanically attached membranes has been recommended. The vapor retarder can act similarly to an air barrier. However, a corresponding reduction in roof cover fastening has not been applied to these systems due to the potential for variation in performance.

Ballasted

Ballasted membrane systems do not have the insulation or membrane secured to the deck. The membrane is only secured at the building perimeter and at roof penetrations. The roof system is held in place by the weight the ballast.

Ballast consists of smooth round stones or concrete paver blocks. Paver blocks are laid as individual units; however, interlocking, beveling or strapping the blocks together will improve performance. The recommended unit weights for beveled blocks is generally less than square edge blocks.

Beveled blocks are usually beveled on two opposite sides and installed in a staggered manner. At least one proprietary block manufacturer uses a silicone adhesive between blocks to increase the wind uplift resistance of the system.

6.5.3 Single-ply Membrane Laps

EPDM membrane laps are sealed with contact adhesives or self-sticking tapes. The adhesive method usually requires caulking the laps after sealing. Some manufacturers incorporate a second sealant bead within the lap. The laps may have to be primed before applying adhesive. Ethylene-Propylene (EP) membrane laps are sealed by heat welding.

Thermoplastic membrane laps are usually heat welded. In some systems, seam edges are then caulked with the manufacturer’s sealant.

Torch-applied modified bitumen laps are made by heat application. Asphalt-adhered modified bitumen laps are sealed with asphalt. Those adhered with cold adhesive may use an adhesive or heat welding for sealing laps.

6.6 Vapor Retarders

A vapor retarder is not always a component of an insulated roof deck assembly, but one may be used to prevent condensation. FM Approval of vapor retarders is based on testing the product in combination with other components. FM Approvals does not evaluate retarders for permeability.

Some currently FM Approved vapor retarders were originally Approved for adherence to steel deck with an adhesive, followed by an adhered insulation. As such, the assembly was evaluated for fire and wind uplift performance. The recommendations and Approval requirements for complete mechanical fastening of insulation to steel decks no longer allow this construction method.

The FM Approved vapor retarder is placed on the steel deck with only the side and end laps sealed with adhesive, followed by the insulation. Fasteners are then driven through the insulation and vapor retarder into the deck (Fig. 12). Currently, vapor retarders are evaluated for fire hazard only if they are placed directly on the deck. If they are used in nail/mop construction or other deck types in an adhered application, they are evaluated for wind uplift resistance and fire hazard. Approved vapor retarders can be placed on the deck under any FM Approved assembly.

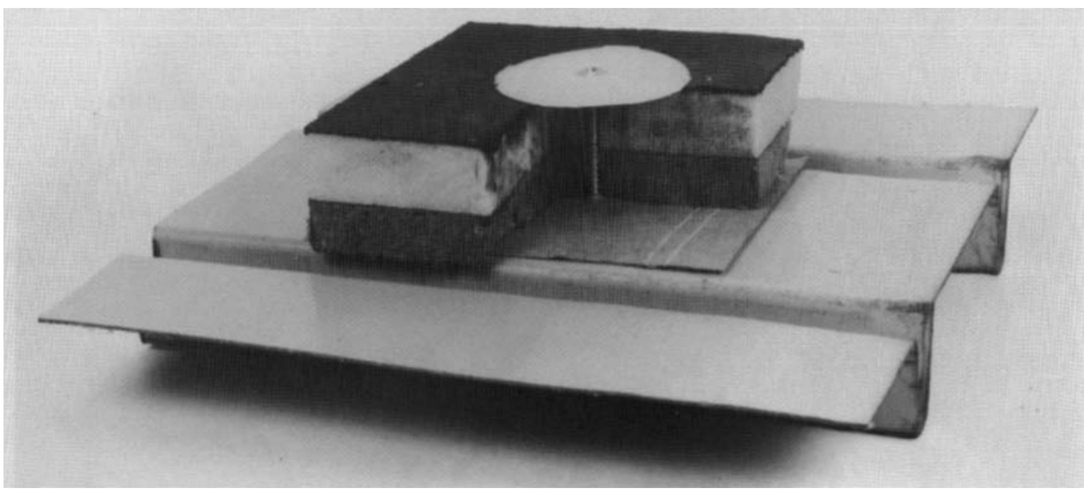


Fig. 12. Insulation and vapor barrier mechanically fastened to steel deck

6.7 Insulation Materials

6.7.1 Material Descriptions

FM Approved insulation boards include wood fiber, perlite, glass fiber, mineral wool, composite, cellular glass and polyisocyanurate foam. Certain EPS and XPS boards are also Approved in combination with a thermal barrier below and a cover board above. Generic types are discussed below.

Approved wood fiber roof insulations contain a limited amount of asphalt so that Class 1 assemblies are achieved. Other wood fiber products such as sheathing boards have different asphalt contents and strength characteristics and should not be used in roofing applications.

Expanded perlite-based insulation is Approved at ¾ in. (19 mm) minimum thickness when used directly over the deck for new construction and ½ in. (13 mm) minimum thickness for re-cover construction or when used as a cover or topping board over other FM Approved insulation. Manufacturers specify using thicker boards for intermediate or wide rib deck in new construction to avoid board fracture from foot traffic.

Glass fiber insulation is Approved at ¾ in. (19 mm) minimum thickness. The manufacturers recommend using thicker boards in new construction on steel deck if rib openings exceed 1.75 in. (44 mm).

Composite insulation consists of a polyurethane or polyisocyanurate foam layer bonded to a thermal barrier of perlite or gypsum board. Other Approved composite boards consist of a polyisocyanurate foam bottom layer laminated to a wood fiber, oriented strand board (OSB), or mineral wool top layer. These are generally used in BUR construction to avoid damage to the foam layer from hot asphalt. Approved sandwich boards consist of foam plastic insulation bonded between two layers of perlite or mineral board.

Polyisocyanurate foam board is usually minimum 1.2 to 1.5 in. (30 to 38 mm) for new construction, depending on the manufacturer. Some are Factory Mutual Research-Approved at a 1 in. (25 mm) thickness for recover construction only with mechanically secured single-ply membranes. Some are Approved in multilayer applications at greater thicknesses. The boards are faced on both sides with various facers depending on the application. Some are Approved with a reduced fastener density for greater thicknesses, usually 2.0 in. (51 mm) and above.

Approved site-mixed insulation consists of asphalt and expanded perlite mineral fiber. The deck is first primed, then the Approved mixture is spread on the deck and rolled in a manner similar to a bituminous paving operation. A BUR covering is then installed above.

Some spray-applied polyurethanes are Approved for recover construction or new construction on concrete or steel deck (when used in combination with a thermal barrier for steel decks). They are typically used with liquid applied roof covers.

6.7.2 Multilayer Applications

Two or more layers of insulation with offset joints is a common assembly. Usually, the bottom board is mechanically attached and the upper board is adhered with hot asphalt or adhesive. This is commonly referred to as ‘‘nail/mop’’ construction. A vapor retarder may also be installed between the layers. If a non-Approved combination is used, inferior construction and/or a Class 2 deck can result.

6.7.3 Recover of an Existing BUR

The existing roof system must be carefully prepared before applying recover materials. Refer to Section 3.0 for information on internal fire ratings of recovered roofs.

If the recover materials are to be adhered to a BUR, any dried-out and bare areas on the top ply should be primed with bitumen prior to recovering. Blisters should be cut out and patched. If the covering has already ruptured due to insufficient expansion joints, the installation of roof area dividers should be considered.

7.0 SUPPLEMENTAL INFORMATION FROM EXTERNAL SERVICES

Listed below are brief descriptions of various applicable standards.

7.1 Steel Deck Surface Treatments

ASTM A525 has been replaced by A653. G60 — zinc coating at a minimum of 0.60 oz/ft^2 (183 gm/m^2) total both sides. G90 — minimum of 0.90 oz/ft^2 (275 gm/m^2) total both sides.

ASTM A792 AZ50 — 55 percent aluminum-zinc alloy coating at a minimum of 0.50 oz/ft^2 (153 gm/m^2) total both sides. AZ55 — minimum of 0.55 oz/ft^2 (168 gm/m^2) total both sides.

ASTM A876 GF60 — 5 percent aluminum-zinc alloy coating at a minimum of 0.60 oz/ft^2 (183 gm/m^2) total both sides.

7.2 Steel Deck Strength

Table 5. Mechanical Properties of Steel Deck

ASTM Designation	Grade	Yield Strength, F_y (ksi)	Tensile Strength, F_u (ksi)	F_u/F_y	Elongation for 2 in. Length (%)[a]	Surface Treatment
A 611	C	33	48	1.45	22	Plain/painted
(Former, now obsolete)	D	40	52	1.30	20	Plain/painted
	E	80[b]	82[b]	1.03		Plain/painted
A 1008 (SS)[c]	33	33	48	1.48	22	Plain/painted
	40	40	52	1.30	20	Plain/painted
	80	80[b]	82[b]	1.03		Plain/painted
A 1008 (HSLAS-F)[d]	50	50	60	1.20	22	Plain/painted
	80	80[b]	90[b]	1.13	14	Plain/painted
A 446	A	33	45	1.36	30	Galvanized
Former, now obsolete	C	40	55	1.38	16	Galvanized
	E	80[b]	82[b]	1.03		Galvanized
A 653 (SS)[c]	33	33	45	1.36	20	Galvanized
	40	40	55	1.38	16	Galvanized
	80	80[b]	82[b]	1.03		Galvanized
A 653 (HSLAS-A)[d]	40	40	50	1.25	22	Galvanized
	80	80[b]	90[b]	1.13	10	Galvanized
A 653 (HSLAS-A)[d]	40	40	50	1.25	24	Galvanized
	80	80[b]	90[b]	1.13	10	Galvanized
Note that all values are specified minimums, except F_u/F_y						

[a]Elongation is not provided for SS in the ASTM standard.

[b]Per AISI, a maximum value of 60 ksi (415 mPa) is used in design due to the low ductility of this material. This lower value has been used in this operating standard and should be used for analysis.

[c](SS) indicates structural steel, not stainless steel.

[d]HSLAS indicates high-strength, low-alloy steel.

7.3 Asphalt Primer

ASTM D-41 asphalt cut-back primer specification is for the viscosity of the finished product.

7.4 Stone Ballast

ASTM D448 — Standard Size No. 3 for Coarse Aggregate (nominal 1 to 2 in. [25 to 50 mm] diameter). This standard permits amounts (by weight percent) to pass through the square sieve openings as shown in Table 6.

Table 6. Gradation for No. 3 Stone

Size Number	Nominal Size in. (mm)	Sieve Opening in. (mm)					
		2 ½ (63)	2 (50)	1 ½ (38)	1 (25)	¾ (19)	½ (13)
3	1 to 2 (25-50)	100	90 to 100	35 to 70	0 to 15	—-	0 to 5

7.5 Aggregate Surfacing for BUR

ASTM D1863 — *Mineral Aggregate Used on Built-Up Roofs* gives gradation and moisture content for aggregate surfacing as noted in Table 7.

Table 7. Gradation for Gravel for BURs

	Amounts finer than sieve specified (mass %)		
Sieve	*Size 6*	*Size 67*	*Size 7*
25 mm	100	100	...
19 mm	90 to 100	90 to 100	100
12.5 mm	20 to 55	...	90 to 100
9.5 mm	0 to 15	20 to 55	40 to 70
4.75 mm	0 to 5	0 to 10	0 to 15
2.36 mm	...	0 to 5	0 t 5

The moisture content limit for stone is ≤2 percent and ≤5 percent for slag. The dust content limit for stone and slag is ≤2 percent.

8.0 REFERENCES

8.1 FM Global

Data Sheet 1-21, *Fire Resistance of Building Assemblies*
Data Sheet 1-28, *Wind Design*
Data Sheet 1-29, *Roof Deck Securement and Above-Deck Roof Components*
Data Sheet 1-31, *Metal Roof Systems*
Data Sheet 1-34, *Hail Damage*
Data Sheet 1-49, *Perimeter Flashing*

FM 4450, Approval Standard for Class I Insulated Steel Roof-Decks
FM 4470, Approval Standard for Single-ply, Polymer-modified Bituman Sheet, Built-Up Roof (BUR) and Liquid-Applied Roof Assemblies for use in Class 1 and Noncombustible Roof Deck Construction
RoofNav, an on-line resource of FM Approvals for roofing professionals.

8.2 Other

American National Standards Institute, ANSI/FM 4473, *Test Standard for Impact Resistance Testing of Rigid Roofing Materials by Impacting with Freezer Ice Balls*

American Society of Testing and Materials International, ASTM A653/A653M-13, *Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process*

American Society of Testing and Materials International, ASTM A792/A792M-10, *Standard Specification for Steel Sheet, 55% Aluminum-Zinc Alloy-Coated by the Hot-Dip Process*

American Society of Testing and Materials International, ASTM A876-12, *Standard Specification for Flat-Rolled, Grain-Oriented, Silicon-Iron, Electrical Steel, Fully Processed Types*

American Society of Testing and Materials International, ASTM A1008/A1008M-13, *Standard Specification for Steel, Sheet, Cold-Rolled, Carbon, Structural, High-Strength Low-Alloy, High-Strength Low-Alloy with Improved Formability, Solution Hardened, and Bake Hardenable*

American Society of Testing and Materials International, ASTM D41/D41M-11, *Standard Specification for Asphalt Primer Used in Roofing, Dampproofing, and Waterproofing*

American Society of Testing and Materials International, ASTM D312/D312M-15, *Standard Specification for Asphalt Used in Roofing*

American Society of Testing and Materials International, ASTM D448-12, *Standard Classification for Sizes or Aggregate for Road and Bridge Construction*

American Society of Testing and Materials International, ASTM D1863/D1863M-05(2011)e1, *Standard Specification for Mineral Aggregate Used on Build-Up Roofs*

American Society of Testing Materials International, ASTM E108-11, *Standard Test Methods for Fire Tests of Roof Coverings*

National Fire Protection Association, NFPA 276, *Standard Method of Fire Test for Determining the Heat Release Rate of Roofing Assemblies with Combustible Above-Deck Roofing Components.*

APPENDIX A GLOSSARY OF TERMS

Adhered Single Ply Membrane: a single-ply membrane adhered to the substrate with an adhesive or asphalt. The insulation itself, if used, may be mechanically attached.

Aggregate: (1) crushed stone, crushed slag or water worn gravel used for surfacing a built-up roof (BUR); (2) any granular mineral material.

Alligatoring: see Section 6.4.3 — BUR deficiencies.

Area Dividers (Roof): (Control Joints, Fig. 13). a raised double wood member attached to a properly flashed base plate anchored to the roof deck. It is used to relieve thermal stresses in the above-deck components where expansion joints have not been provided or to provide discontinuity between two different roof systems. If expansion joints are missing from large structural steel or concrete supported roofs, cracking or rupture of the BUR can occur. Where structural systems are not mechanically tied together, expansion joints (Fig. 14) should be installed over the gap.

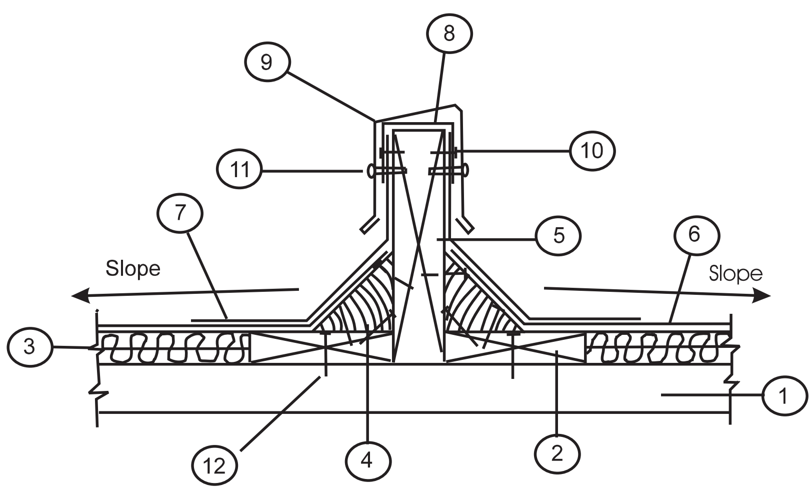


Fig. 13. Raised roof area divider/control joint (with wood curb and cants). This detail can be used on existing roofs where covering has ruptured. It may also be used on new roofs where expansion joints are missing. This detial is not recommended where it will obstruct roof drainage. See Fig. 14 for metal gauge and wood-to-wood nailing.

Asphalt: a dark brown to black hydrocarbon obtained from petroleum processing.

Asphalt Emulsion: a suspension of asphalt in an aqueous solution.

Asphalt Felt: an asphalt-saturated or coated felt. Felts usually have glass fiber or organic reinforcing mats.

Backnailing: the practice of blind-nailing roofing felts to a substrate in addition to hot-mopping to prevent slippage.

Ballasted Single-ply Membrane: single-ply membranes which are only attached at the roof perimeter and penetrations and are held in place with ballast. Ballasted membranes are not FM Approved but may be acceptable if installed per Data Sheet 1-29.

Base Flashing: the lower portion of the flashing system which is sealed or embedded into the roof cover. The upper edge of the base flashing is covered with counter of cap flashing, see Data Sheet 1-49.

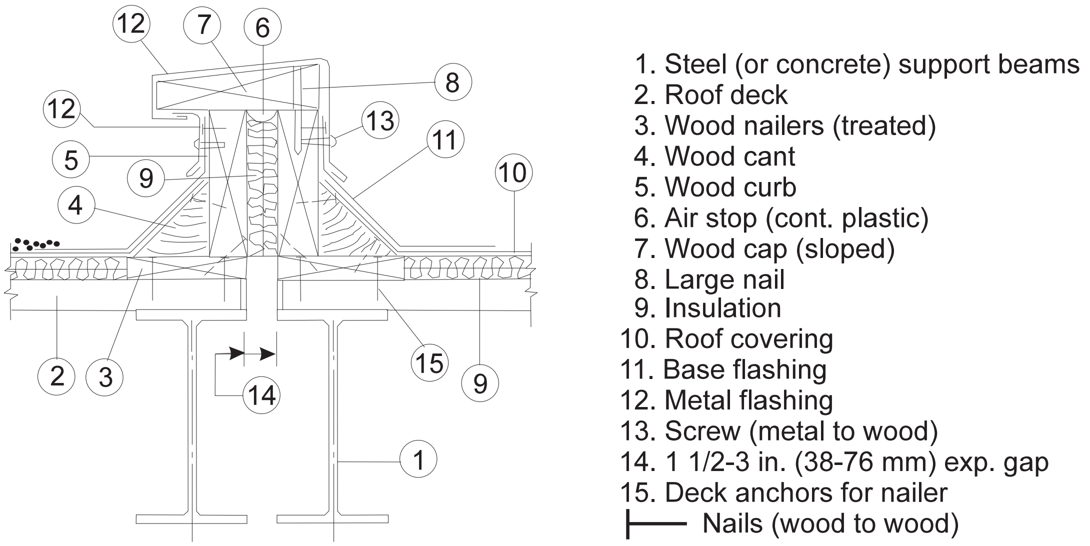


Fig. 14. Expansion joint details (with wood curb, cants and cap). Metal thickness to be 24 ga (0.0234 in., 0.61 mm) galvanized steel, 16 oz/ft^2 (4.88 cu/m^2) copper, or 0.048 in. (1.22 mm) aluminum. Wood to wood nails should have at least 1½ in. (38 mm) penetration into the secured piece, spaced 12 to 18 in. (305-457 mm). Vertical insulation (#9) over expansion gap or at wall juncture to be noncombustible and compressible such as glass, mineral or ceramic fiber.

Base Sheet: the first ply in a BUR or modified bitumen construction if it is not applied in a shingled fashion. The base sheet may be adhered or mechanically fastened. Not all BURs incorporate base sheets. See Figure 15.

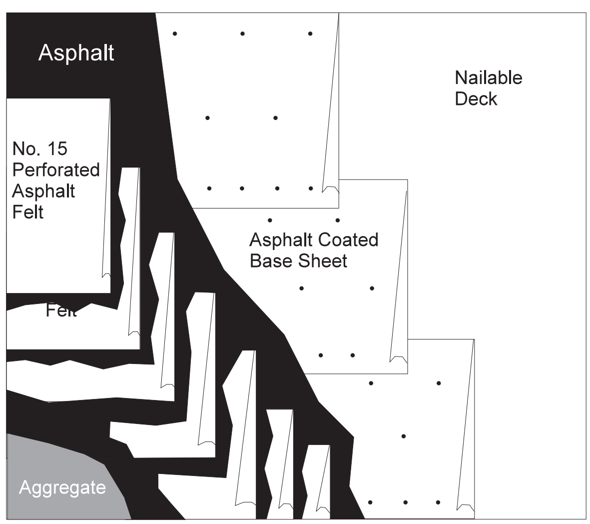


Fig. 15. Built-up roof with a base sheet. Courtesy of National Roofing Contractors Association.

Batten: a metal or plastic band, usually 1 in. (25 mm) wide, used with fasteners to secure single-ply membranes.

Bitumen: a generic term used to describe asphalt, tars and pitches.

Blind Nailing: the practice of nailing the back portion of a roofing ply so that the fasteners are not exposed to the weather in the finished roof cover.

Blister: see Section 6.4.3 — BUR deficiencies.

Blocking: wood built into a roof system above the deck and below the cover and flashing to stiffen the deck around an opening, act as a stop for insulation and to serve as a nailer for attaching the membrane or flashing.

Built-Up Roof (BUR) Cover: a continuous, semi-flexible roof cover assembly, consisting of plies of felts, fabrics or mats between which alternate layers of asphalt, coal tar or cold adhesive are applied. BURs are generally surfaced with aggregate or a cap sheet.

Cant Strip: a beveled strip used under flashing at the point where the roof cover meets vertical elements.

Cap Sheet: a mineral or ceramic granule surfaced sheet used as the top ply of some BUR covers or as base flashing.

Chlorosulfonated polyethylene (CSPE): a polymer used as the basis of some single-ply membranes. CSPE membranes are thermoplastic when manufactured and remain so for a limited time after which they cure. CSPE membranes are commonly referred to by the Du Pont trade name for the CSPE polymer: Hypalon. Du Pont does not manufacture single-ply membranes, only the CSPE material.

Coal Tar: a dark brown to black, semi-solid hydrocarbon obtained from heating and refining bitumenous coal.

Coal-Tar Pitch: a coal tar used as the waterproofing agent in deadlevel or low slope BURs, conforming to ASTM D450, Type I. Coal-tar waterproofing pitch: a coal tar used as the dampproofing or waterproofing agent in below-grade structures, conforming to ASTM D450, Type II.

Coal-Tar Bitumen: a coal tar used as the waterproofing agent in deadlevel or low slope BURs, conforming to ASTM D450, Type III.

Coal-Tar Felts: a felt that has been saturated with coal tar.

Cold-Processing Roofing: similar to asphalt BUR except a cold-applied adhesives is used in place of hot asphalt.

Coping (Cap Flashing): the covering piece on top of a wall exposed to the weather, usually sloped to shed water.

Counterflashing: formed metal or elastomeric sheeting secured on or into a wall, curb, pipe, rooftop unit or other surface, to cover the upper edge of a base flashing.

Creep: the permanent deformation of a roofing material or system caused by the movement of the membrane which results from continuous stress.

Cricket: a relatively small, elevated area of a roof constructed to divert water.

Cutback: solvent-thinned bitumen. Cutbacks are used as adhesives, flashing cements, primers and roof coatings.

Cutoff: a detail used at the end of a day’s work which is designed to prevent lateral water movement into the insulation at points where the membrane terminates. It is removed before continuing installation.

Deck: the structural surface to which the roof insulation and cover are applied.

Dew Point: the temperature at which water vapor condenses in cooling air at the existing atmospheric pressure and vapor content.

Disc Fastener: one of several types of fasteners which incorporates a metal or plastic plate (disc) and fastener to secure the single-ply membrane to the substrate. Disc fasteners can be installed at the membrane laps, through the membrane sheet or through tabs along the membrane underside. The discs are typically 2 in. (51 mm) in diameter or square. Insulation fasteners typically utilize the same fastening element with a larger plate (about 3 in. [76 mm] in diameter or square). Compare to batten.

Elastomeric: a rubber-like polymer that will stretch when pulled and will return quickly to its original shape when released.

EPDM: ethylene, propylene, diene, monomer. A type of synthetic rubber used as the basis for some single-ply membranes.

Equiviscous Temperature (EVT): the temperature at which the asphalt or coal tar has maximum, adhering qualities.

Expansion Joint: a structural separation between two building elements that allows free movement between the elements without damage to the structural, roofing or waterproofing system. It separates the deck as well as the above-deck components. A ″roof expansion joint‟ is used over these areas (Fig. 14) so the membrane will not be ruptured by movement of the supporting members below. Compare to roof area divider.

Felt: a flexible sheet used as the reinforcement in BURs. Felts are either organic, glass or polyester fiber based. In the past asbestos fiber felts were also used.

Felt-Backed Membrane: single-ply membranes which incorporate a felt backing, usually a nonwoven polyester mat. They are usually installed in a fully adhered application. Felt-backed membranes may or may not be reinforced (compare to reinforced membranes).

Field of Roof: the portion of the roof inside the defined perimeter to determine wind uplift pressure.

Field Seam: a splice made between membrane sheets during installation.

Fishmouth: See Section 6.4.3 — BUR deficiencies

Flashing: the system used to seal roof cover edges at walls, expansion joints, drains, gravel stops, and other places where the cover is interrupted or terminated. Base flashing covers the edge of the membrane. Cap flashing or counterflashing covers the upper edges of the base flashing.

Flood Coat: the top layer of bitumen into which the aggregate is embedded.

Fully Adhered Single-ply Membrane: are 100 percent adhered to the substrate (insulation or deck) by either an adhesive, asphalt, self-adhering membrane or by torch application. Compare to mechanically attached and partially adhered.

Glass Felt: a BUR ply sheet which incorporates a glass fiber mat as the reinforcing.

Glaze Coat: (1) the top layer of asphalt in a smooth surfaced BUR; (2) a thin protective coating of bitumen applied to the lower plies or top ply of a BUR when application of additional felts or the flood coat and aggregate surfacing are delayed.

Gravel Stop: a flanged device, frequently metal, designed to provide a continuous finished edge for roofing material and to prevent loose aggregate from washing off of the roof.

Heat Welding: a method of fusing field seams of thermoplastic membranes using heat and pressure.

Ice Dam: a mass of ice formed at the transition from a warm to a cold roof surface, frequently formed by refreezing meltwater at the overhang of a steep roof. Ice dams can cause water to back up under roofing materials.

Inorganic: being or composed of matter other than hydrocarbons and their derivatives, or matter that is not of plant or animal origin.

Lightweight Insulating Concrete: a type of roof deck applied over steel form deck or structural concrete. The cementitious deck is composed of either a lightweight aggregate and cement or air entrained cement or hybrids of these. The construction results in a monolithic deck which is usually covered with a nailed base sheet and asphaltic roof cover. These decks may contain perforated EPS board placed within the concrete slurry.

Liquid Applied Membrane: an elastomeric material, fluid at ambient temperature, that dries or cures after application to form a continuous membrane. They are often used to coat spray-applied polyurethane insulation.

Mechanically Attached Single-ply Membranes: are secured to the roof deck with mechanical fasteners. Compare to fully and partially adhered single-ply membrane.

Mineral Granules: natural or synthetically colored aggregate commonly used to surface cap sheets and roofing shingles.

Mineral-Surfaced Roofing: BUR materials whose top ply consists of a mineral/granule-surfaced sheet.

Modified Bitumen Membranes: consist of a polymer modified asphalt and a reinforcing mat, usually glass and/or polyester fiber. These membranes are adhered by torch application, hot asphalt or self-adhering.

Mop-and-Flop: an application procedure in which insulation boards are initially placed upside down adjacent to their ultimate locations, coated with hot asphalt, and are then turned over and applied to the substrate. Often used when a cover board is secured above EPS.

Mopping: the application of hot bitumen with a mop or mechanical applicator.

Solid Mopping: a continuous mopping of a surface, leaving no bare areas.

Spot Mopping: a mopping pattern in which hot bitumen is applied in roughly circular areas, leaving a certain percentage of bare areas.

Strip Mopping: a mopping pattern in which hot bitumen is applied in parallel bands.

Sprinkle Mopping: a random mopping pattern in which heated bitumen beads are strewn onto the substrate with a brush or mop. Not a recommended application procedure.

Organic: being or composed of hydrocarbons or their derivatives, or matter of plant or animal origin.

Partially Adhered Single-ply Membrane: similar to fully adhered except the adhesive is applied over less than 100 percent of the surface.

Perlite: an aggregate used in some lightweight insulating concrete roof decks and in perlite-based insulation boards.

Pitch Pocket: a flange, open-bottomed, metal container filled with a sealant compound. It is placed around columns or other irregular shaped roof penetrations.

Ply Sheet: a shingled layer of felt in a BUR. Compare to Base Sheet, see Figure 15.

Polyvinyl Chloride (PVC): a thermoplastic polymer used as the basis of some single-ply membranes.

Positive Drainage: consideration has been made for all loading deflections of the deck, and roof slope has been provided to ensure drainage of the roof within 48 hours of rainfall.

Rake: the sloped edge of a roof at the first or last rafter, the perimeter strip that extends between the peak and the eaves.

Recover Construction: the existing roof system is left in place and new components are installed over it. Compare to Reroof Construction.

Reroof Construction: the existing roof system is removed down to the structural deck. New components are then installed. For Approval purposes, either a new construction or reroof assembly would be needed. Reroof Approvals allow up to 15 lb/sq (72 kg/m^2) of asphalt to remain on steel deck. In order to use an Approved new construction system, no asphalt can remain. Compare to Recover Construction.

Reglet: a groove in a wall or other surface adjoining a roof surface for use in the attachment of counterflashing.

Reinforced Single-ply Membranes: incorporate a reinforcing mat (usually glass or polyester) **within** the sheet. Reinforced membranes may or may not have felt backings. Compare to felt-backed membrane.

Ridging (Buckles): see Section 6.4.3 — BUR deficiencies

Roof Assembly: the roof deck, its securement and all above-deck components.

Saddle (Cricket): a small structure that helps channel surface water to drains, frequently located in a valley, and often constructed like a small hip roof or a pyramid with a diamond shape base.

Self-Adhering Membrane: adhere to the substrate and to itself at overlaps without the use of adhesives. The underside of the membrane is protected with a ''release paper'' which is removed during installation.

Shingling: the procedure of laying parallel felts so that one longitudinal edge of each felt overlaps and the previous felt. (See Fig. 15). Felts are shingled so that the water flows over rather than against each lap.

Single Ply Membrane: roofing membranes applied using just one layer of membrane material.

Slag: a hard, air-cooled aggregate left as a residue from blast furnaces, used as a surfacing aggregate.

Slippage: relative lateral movement of adjacent components of a BUR. It occurs mainly in roofing membranes on a slope, sometimes exposing the lower plies or base sheet to the weather.

Smooth-Surfaced Roof: a BUR surfaced with a layer of hot-mopped asphalt, cold-applied, asphalt cutback, or a bare inorganic felt.

Softening Point: the temperature at which bitumen becomes soft enough to flow, as determined by an arbitrary, closely defined method.

Spudding: the process of removing roofing aggregate and most of the bituminous top coating by scraping and chipping.

Square: 100 ft^2 (9.3 m^2) of roof area, abbreviated: sq.

Sump: an intentional depression around a roof drain.

Thermal Shock: the stress-producing phenomenon resulting from sudden temperature changes in a roof membrane when, for example, a rain shower follows brilliant sunshine.

Thermoplastic: materials which soften when heated and harden when cooled. This process can be repeated provided that the material is not heated above the point at which decomposition occurs.

Thermoset: a material which hardens or ”sets“ irreversibly when heated. This usually occurs during the manufacturing process.

Vapor Migration: the movement of water vapor from a region of high vapor pressure to a region of lower vapor pressure.

Vapor Retarder: a material designed to restrict the passage of water vapor through a roof or wall.

Vent: an opening designed to convey water vapor or other gas from inside a building or a building component to the atmosphere, thereby relieving vapor pressure.

Vermiculite: a lightweight aggregate used in some lightweight insulating concrete.

APPENDIX B DOCUMENT REVISION HISTORY

July 2015. Reformatting and editorial changes were made.

April 2012. Terminology related to ignitable liqluids has been revised to provide clarity and consistency with regard to FM Global’s loss prevention recommendations for ignitable liqluid hazards.

August 1996. This was the first edition. Some of the information was relocated from Data Sheet 1-28 and 1-29, and the remaining information was added to supplement recommendations in Data Sheet 1-29.