ROOF DECK SECUREMENT AND ABOVE-DECK ROOF COMPONENTS

Note to Insureds of Factory Mutual Insurance Company: Contact the local FM office before beginning any roofing work.

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1.0 SCOPE

This data sheet provides guidance on the following subjects:

A. Wind resistance, including:

1. The proper span and securement of steel roof decks to supporting members. This is appropriate information for the Structural Engineer of Record (SER).

2. The proper design and installation of above-deck roof components. This is appropriate information for the roofing professional.

B. Fire classification of roofs

Items covered include:

- roof covers
- insulation
- cover boards
- vapor retarders
- air barriers
- fasteners
- re-roof and re-cover assemblies

This data sheet is intended to be used in conjunction with Roof*Nav* and Data Sheet 1-28, *Wind Design.*

See the following data sheets for guidance on subjects that are not covered in this data sheet:

Data Sheet 1-15, *Roof-Mounted Solar Photovoltaic Panels*

Data Sheet 1-42, *Maximum Foreseeable Loss Limiting Factors, for guidance on roofs of buildings divided by MFL fire walls*

Data Sheet 1-31, *Panel Roof Systems,* for guidance on panel roofs, including lap seam, standing seam, and insulated metal panels

Data Sheet 1-33, *Safeguarding Torch-Applied Roof Installations*

Data Sheet 1-34, *Hail Damage*

Data Sheet 1-49, *Perimeter Flashing*

Data Sheet 1-54, *Roof Loads For New Construction*, for guidance on gravity loads (e.g., snow, ponding)

Clients of FM should contact their local FM office before beginning any roofing design or construction.

1.1 Changes

July 2022. Interim Revision. Added guidance for the use of FM Approved roof leakage detection systems. Also made minor editorial corrections.

2.0 LOSS PREVENTION RECOMMENDATIONS

2.1 Introduction

The recommendations provided in this document are not intended to supersede the requirements of any FM Approval (see Appendix A for definition). FM Approval listings in Roof*Nav*, an online resource of FM Approvals, describe the requirements for a specific wind uplift rating, as well as ratings for hail, interior fire exposure, and exterior fire exposure. This data sheet covers other Zone 2/Zone 3 fastening methods. Use the recommendations in this data sheet to supplement the listings in RoofNav.

For re-roofing and re-covers, an analysis of the roof deck span and securement is needed before selecting an appropriate RoofNav assembly because the existing deck may not have been designed based on the

same assumptions. This is particularly true in regard to mechanically fastened roof covers with a larger spacing between rows of roof cover fasteners. Review of the Roof*Nav* glossary definitions of recover and reroof is advised.

FM Approved insulated steel deck assemblies have an internal fire rating of Class 1. Some FM Approved roof insulations have a noncombustible core rating. Structural concrete roof decks are rated noncombustible with regard to internal fire exposure regardless of the above-deck components due to the substantial thermal barrier offered by the deck itself. Form boards used beneath existing gypsum decks may themselves be combustible.

2.2 Construction and Location

2.2.1 General Design Recommendations and Material Selection

2.2.1.1. Use FM Approved roof assemblies as noted in Roof*Nav* for all installations. Ensure the assembly has the appropriate rating for wind and hail resistance and exterior fire exposure.

Using individually FM Approved components that have not been FM Approved for use together does not constitute an FM Approved assembly.

Determine recommended FM Approvals wind uplift ratings for roof assemblies per Roof*Nav* Ratings Calculator and Data Sheet 1-28, *Wind Design.* Do not use any system beyond its FM Approval rating. Select assemblies based on the required wind rating for the specific roof area (Zone 1', 1, 2, or 3). Alternatively, refer to Sections 2.2.10.1 for prescriptive Zone 2 and Zone 3 enhancements. Prescriptive enhancements for Zone 2 and Zone 3 are based on the roof system installed in Zone 1 only.

2.2.1.2 Use FM Approved materials that have the FM Approval mark on the packaging or the material itself. Materials without proper labeling are not FM Approved.

2.2.1.3 Use FM Approved perimeter flashing systems where available. Secure nailers in accordance with Data Sheet 1-49, *Perimeter Flashing.*

2.2.1.4 Provide a minimum roof slope of 1.2° (1/4 per 12) to facilitate drainage and optimize roof longevity. Refer to Data Sheet 1-54, *Roof Loads for New Construction,* for additional guidance regarding roof slope and drainage. Do not exceed the roof slope listed in Roof*Nav* for the assembly because that will compromise the exterior fire rating.

Exception: Coal tar BUR roof covers may be installed at slopes as low as 1/8 in. per ft (0.6°). Due to the low softening temperature of coal tar, the maximum roof slope should not exceed ½ in. per ft (2.4°).

2.2.1.5 Select the type and span of the steel deck in accordance with Roof*Nav* and Section 2.2.3 of this document.

2.2.1.6 If roof electronic leak detection (ELD) systems are to be installed, do all of the following:

A. Use only FM Approved ELD systems.

B. Use FM Approved roof assemblies that specifically include the FM Approved ELD system within the RoofNav listing.

C. Install the system in accordance with both the RoofNav listing and the manufacturer's installation instructions.

D. Install roof assemblies so fasteners do not penetrate leak location grid components of ELD systems, where applicable. This is particularly important for roof assembly prescriptive enhancement that includes mechanically fastened layers.

Use of an FM Approved ELD system within a roof assembly that does not include the system does not constitute an FM Approved assembly.

FM Approval of roof assemblies with ELD systems includes testing the leak detection system and verifying the ELD system does not adversely affect the wind uplift rating of the roof assembly.

2.2.2 General Installation Recommendations

2.2.2.1 Provide thorough supervision by the building owner's qualified representative during all roof construction to ensure quality of workmanship and adherence to FM Approval standards and project specifications.

2.2.2.2 Install "torch-applied" roof covers in accordance with Data Sheet 1-33, *Safeguarding Torch-Applied Roof Installation,* to prevent an accidental fire.

2.2.2.3 Install torch-applied covers to ensure adequate adhesion and wind uplift resistance. Ensure the following where practical and safe:

A. The torch applicator should face the leading edge of the roll and pull the roll toward them. Walking behind the roll and pushing the roll results in an improper angle for torch flame impingement onto the roll and damage to the cover from walking on the heated and softened sheet layer.

B. The torch flame should be passed back and forth across the leading edge of the roll, with most of the flame impinging on the leading edge of the roll, and only slight heating of the substrate below.

C. The roll should not be overheated, such as to cause excessive smoke.

D. The bitumen should be allowed to pool slightly at the leading edge of the roll across its entire width as the sheet is unrolled (see Fig. 1).

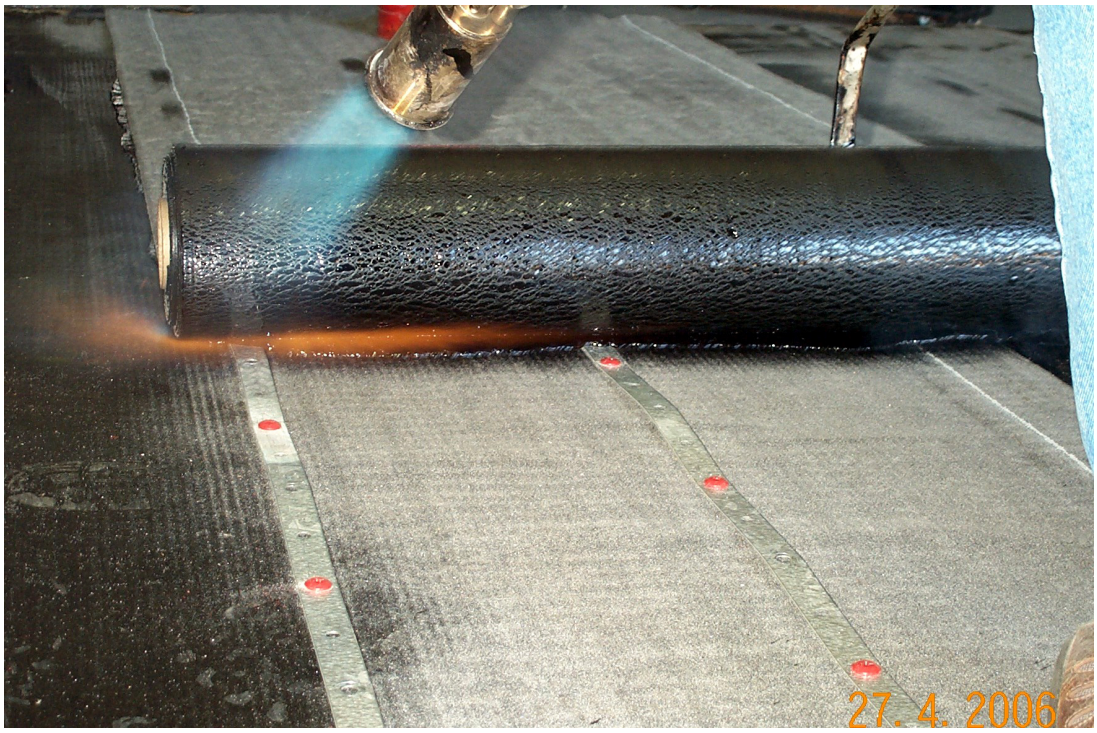

Fig. 1. Torch application of upper ply to a mechanically fastened base sheet — Note adhesive pooling at the leading edge of the roll. Also, screws and stress plates or batten bars are steel as they could come in contact with the torch flame. The screws in this figure are actually coated steel, not plastic.

2.2.2.4 Follow guidance in DS 1-0 regarding the temporary storage of combustible roofing materials and other issues related to safety during construction and alterations.

2.2.2.5 Prevent over-stressing of the roof deck due to possible high concentrated loads during construction. This includes rolls of membrane and gravel carts. When the weight of individual rolls of single-ply membrane exceeds 1100 lb (500 kg), use precautions such as plywood sheets over steel deck to reduce point loads.

2.2.2.6 Protect roof expansion joints by filling the space between nailers with noncombustible, compressible insulation, such as mineral wool. Cover the expansion joint with flashing made of galvanized steel, zinc-aluminum-coated steel, or stainless steel secured in accordance with Data Sheet 1-49. An example is shown in Figure 2. Similar details can be found in the *NRCA Roofing Manual: Membrane Roof Systems.*

2.2.2.7 Provide adequate separation and/or noncombustible insulation between hot exhaust stacks and combustible roof components. See DS 1-13, *Chimneys,* for details.

2.2.2.8 Ensure all above-deck components are dry and surfaces are free of debris or dirt prior to adhering roof covers to them. This will help ensure complete adhesion of the cover to its substrate.

2.2.2.9 In locations that are prone to tropical cyclones, plan roof installations that use cold-process adhesives to ensure adequate curing time prior to potential exposure from a tropical cyclone. Also, see Section 3.1.2.2.

2.2.2.10 Apply adhesives in accordance with the manufacturer's temperature limitations.

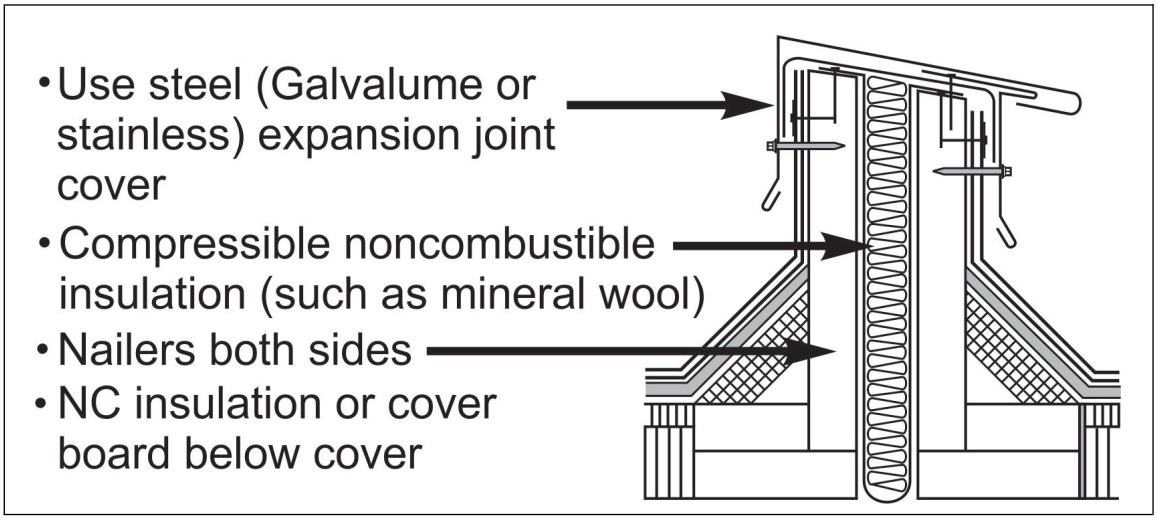

Fig. 2. Protection for roof expansion joints

2.2.3 Steel Roof Deck

2.2.3.1 Select a Roof*Nav* assembly after determining the needed wind, hail, and interior and exterior fire ratings. Use the center-to-center spacing of supports to determine the deck span.

2.2.3.2 When designing the steel deck, give consideration to the needed wind rating, and how the load is applied (concentrated vs. uniformly distributed) from the above-deck components to the deck. Where the distance between rows of roof cover fasteners is greater than half the deck span, treat as a concentrated load.

As an alternative to using Tables 1A or 1B for concentrated loads, a performance-based approach may be used if calculations are conducted by a licensed S.E. or P.E. in structural engineering. This applies to situations where the distance between rows of roof cover fasteners is greater than one-half the deck span. Make the following assumptions:

A. Assume a 3-span structural condition.

B. Assume the first row of roof cover fasteners is located at mid-point of the first deck span.

C. Assume maximum allowable strength is determined using allowable strength design (ASD) in accordance with AISI S100-2016, or comparable standard outside the United States.

Due to the more brittle nature of higher grade steels, the maximum yield stress used in the analysis is 60,000 psi (414 MPa), even for 80,000 psi (552 MPa) yield stress steel. Use Tables 1A through 1E as follows to facilitate deck selection:

Table 1A. Use for roof covers or base plies that are mechanically fastened to the steel deck when the distance between rows of roof cover fasteners is more than half the deck span and the deck is 1-1/2 in. (38 mm) deep, wide rib (Type B) with a minimum yield stress of 33,000 psi (228 MPa).

Table 1B. Use for roof covers or base plies that are mechanically fastened to the steel deck when the distance between rows of roof cover fasteners is more than half the deck span and the deck is 1-1/2 in. (38 mm) deep, wide rib (Type B) with a minimum yield stress of 60,000 psi (414 MPa).

Note: Where the minimum specified yield stress is between 33,000 psi (228 MPa) and 60,000 psi (414 MPa), it is reasonably accurate to interpolate the maximum deck span linearly based on Tables 1A and 1B.

Table 1C. Use for roof covers or base plies that are adhered to insulation or cover board, or mechanically fastened to the steel deck when the distance between rows of roof cover fasteners is one-half the deck span or less and the deck is 1-1/2 in. (38 mm) deep, wide rib (Type B) with minimum yield stresses of 33,000 psi (228 MPa) and ultimate wind ratings of from 60 to 225 psf (2.9 to 10.8 kPa).

Table 1D. Use for roof covers or base plies that are adhered to insulation or cover board, or mechanically fastened to the steel deck when the distance between rows of roof cover fasteners is one-half the deck span or less and the deck is 1-1/2 in. (38 mm) deep, wide rib (Type B) with minimum yield stresses of 33,000 psi (228 MPa) and ultimate wind ratings of from 240 to 405 psf (11.5 to 19.4 kPa).

Table 1E. Use for roof covers or base plies that are adhered to insulation or cover board, or mechanically fastened to the steel deck when the distance between rows of roof cover fasteners is one-half the deck span or less and the deck is 3 in. (75 mm) deep, with an 8 in. (200 mm) rib spacing (Type N) with minimum yield stresses of 33,000 psi (228 MPa) and ultimate wind ratings of from 60 to 225 psf (2.9 to 10.8 kPa).

NOTE for Tables 1A through 1E: Maximum spans may vary slightly depending on the exact section properties for the specific deck.

Table 1A. Maximum Steel Deck Span (ft) for 1½ in. (38 mm) Deep, 33,000 psi (228 MPa) Yield Stress with a Mechanically Fastened Roof Cover
(Note: Use this table when the distance between rows of roof cover fasteners is more than one-half the deck span.)

Max Deck Spans By Wind Rating/Fastener Spacing, Sheet Gauge for 33 ksi, 1½ in. Deep Wide Rib Deck																				
Roof Cover Fastener Row Spacing (ft)	Gauge	Wind Rating [psf]																		
		330	315	300	285	270	255	240	225	210	195	180	165	150	135	120	105	90	75	60
3.5	18	4.5	5.5	5.5	5.5	5.5	5.5	6	6	6	6	6	6	6	6	6	6	6	6	6
	20	-	4	4	4.5	4.5	4.5	5	5.5	5.5	5.5	6	6	6	6	6	6	6	6	6
	22	-	-	-	-	-	4	4	4.5	4.5	4.5	5.5	5.5	5.5	6	6	6	6	6	6
4	18	4.5	4.5	5	5	5	6	6	6	6	6	6	6	6	6	6	6	6	6	6
	20	-	-	-	-	4	4.5	4.5	5	5	5.5	6	6	6	6	6	6	6	6	6
	22	-	-	-	-	-	-	-	-	4	4.5	5	5	6	6	6	6	6	6	6
4.5	18	-	4	4	4.5	5	5	5.5	6	6	6	6	6	6	6	6	6	6	6	6
	20	-	-	-	-	-	-	4	4	5	5	5.5	6	6	6	6	6	6	6	6
	22	-	-	-	-	-	-	-	-	-	-	4	4.5	5	5.5	6	6	6	6	6
5	18	-	-	-	4	4	4.5	5	5	5.5	6	6	6	6	6	6	6	6	6	6
	20									4	4.5	5	5.5	6	6	6	6	6	6	6
	22	-	-	-	-	-	-	-	-	-	-	-	4	4.5	5	6	6	6	6	6
5.5	18	-	-	-	-	-	-	4	4.5	5	5.5	6	6	6	6	6	6	6	6	6
	20	-	-	-	-	-	-	-	-	-	-	4	4.5	5	6	6	6	6	6	6
	22	-	-	-	-	-	-	-	-	-	-	-	-	-	4.5	5	6	6	6	6
6	18	-	-	-	-	-	-	-	-	4	5	5.5	6	6	6	6	6	6	6	6
	20	-	-	-	-	-	-	-	-	-	-	-	-	4.5	5.5	6	6	6	6	6
	22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.5	5.5	6	6	6
6.5	18	-	-	-	-	-	-	-	-	-	4	4.5	5.5	6	6	6	6	6	6	6
	20	-	-	-	-	-	-	-	-	-	-	-	-	-	4.5	5.5	6	6	6	6
	22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.5	5.5	6	6
7	18	-	-	-	-	-	-	-	-	-	-	-	4	5.5	6	6	6	6	6	6
	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.5	6	6	6	6
	22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	6	6
7.5	18	-	-	-	-	-	-	-	-	-	-	-	-	4	5.5	6	6	6	6	6
	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	5	6	6	6
	22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	6	6

Table 1A. Maximum Steel Deck Span (ft) for 1½ in. (38 mm) Deep, 33,000 psi (228 MPa) Yield Stress with a Mechanically Fastened Roof Cover (continued)
(Note: Use this table when the distance between rows of roof cover fasteners is more than one-half the deck span.)

Max Deck Spans By Wind Rating/Fastener Spacing, Sheet Gauge for 33 ksi, 1½ in. Deep Wide Rib Deck																				
Roof Cover Fastener Row Spacing (ft)	Gauge	Wind Rating [psf]																		
		330	315	300	285	270	255	240	225	210	195	180	165	150	135	120	105	90	75	60
8	18	-	-	-	-	-	-	-	-	-	-	-	-	4	4.5	5.5	6	6	6	6
	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	5.5	6	6
	22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.5	6
8.5	18	-	-	-	-	-	-	-	-	-	-	-	-	-	4	4.5	6	6	6	6
	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	4.5	6	6
	22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.5	6
9	18	-	-	-	-	-	-	-	-	-	-	-	-	-	4	4.5	5	6	6	6
	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	4.5	5.5	6
	22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	5
9.5	18	-	-	-	-	-	-	-	-	-	-	-	-	-	4	4	4.5	6	6	6
	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	5	6
	22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	5
10	18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	4.5	5	6	6
	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	4.5	6
	22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	4.5
10.5	18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	4.5	5	6	6
	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	4.5	5.5
	22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.5
11	18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.5	5	6	6
	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.5	5.5
	22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.5
11.5	18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	4.5	5.5	6
	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.5	5
	22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4
12	18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	4.5	5	6
	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		4	5
	22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			4
Roof Cover Fastener Row Spacing	Gauge	330	315	300	285	270	255	240	225	210	195	180	165	150	135	120	105	90	75	60
		Wind Rating [psf]																		

Table 1B. Maximum Steel Deck Span (ft) for 1 ½ in. (38 mm) Deep, Yield Stress ≥ 60,000 psi (414 MPa) with a mechanically fastened Roof Cover
(Note: Use this table when the distance between rows of roof cover fasteners is more than one-half the deck span.)

Max Deck Spans By Wind Rating/Fastener Spacing, Sheet Gauge for 80 ksi, 1½ in. Deep Wide Rib Deck																				
Roof Cover Fastener Row Spacing (ft)	Gauge	Wind Rating [psf]																		
		330	315	300	285	270	255	240	225	210	195	180	165	150	135	120	105	90	75	60
3.5	18	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
	20	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
	22	5.5	5.5	5.5	5.5	5.5	6	6	6	6	6	6	6	6	6	6	6	6	6	6
4	18	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
	20	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
	22	4.5	5	5	5	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
4.5	18	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
	20	5.5	5.5	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
	22	4	4	4.5	5	5	5.5	5.5	6	6	6	6	6	6	6	6	6	6	6	6
5	18	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
	20	4.5	5	5.5	5.5	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
	22	-	-	4	4	4.5	4.5	5	5.5	6	6	6	6	6	6	6	6	6	6	6
5.5	18	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
	20	4	4.5	4.5	5	5.5	5.5	6	6	6	6	6	6	6	6	6	6	6	6	6
	22	-	-	-	-	-	4	4.5	5	5.5	6	6	6	6	6	6	6	6	6	6
6	18	5	5.5	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
	20	-	-	-	4	4.5	5	5.5	6	6	6	6	6	6	6	6	6	6	6	6
	22	-	-	-	-	-	-	-	4	4.5	5	5.5	6	6	6	6	6	6	6	6
6.5	18	4.5	5	5	5.5	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
	20	-	-	-	-	-	4	4.5	5	5.5	6	6	6	6	6	6	6	6	6	6
	22	-	-	-	-	-	-	-	-	-	4	5	5.5	6	6	6	6	6	6	6
7	18	-	4	4	4.5	5.5	6	6	6	6	6	6	6	6	6	6	6	6	6	6
	20	-	-	-	-	-	-	4	4	5	5.5	6	6	6	6	6	6	6	6	6
	22	-	-	-	-	-	-	-	-	-	-	4	4.5	5.5	6	6	6	6	6	6
7.5	18	-	-	-	4	4.5	4.5	5.5	6	6	6	6	6	6	6	6	6	6	6	6
	20	-	-	-	-	-	-	-	-	4	4.5	5.5	6	6	6	6	6	6	6	6
	22	-	-	-	-	-	-	-	-	-	-	-	4	4.5	6	6	6	6	6	6
8	18	-	-	-	-	4	4	4.5	5	6	6	6	6	6	6	6	6	6	6	6
	20	-	-	-	-	-	-	-	-	-	4	4.5	5.5	6	6	6	6	6	6	6
	22	-	-	-	-	-	-	-	-	-	-	-	-	4	5	6	6	6	6	6

Table 1B. Maximum Steel Deck Span (ft) for 1½ in. (38 mm) Deep, Yield Stress ≥ 60,000 psi (414 MPa) with a mechanically fastened Roof Cover (continued)
(Note: Use this table when the distance between rows of roof cover fasteners is more than one-half the deck span.)

Max Deck Spans By Wind Rating/Fastener Spacing, Sheet Gauge for 80 ksi, 1½ in. Deep Wide Rib Deck																				
Roof Cover Fastener Row Spacing (ft)	Gauge	Wind Rating [psf]																		
		330	315	300	285	270	255	240	225	210	195	180	165	150	135	120	105	90	75	60
8.5	18	-	-	-	-	-	4	4	4.5	5	5.5	6	6	6	6	6	6	6	6	6
	20	-	-	-	-	-	-	-	-	-	4	4	4.5	5.5	6	6	6	6	6	6
	22	-	-	-	-	-	-	-	-	-	-	-	-	4	4.5	5	6	6	6	6
9	18	-	-	-	-	-	-	4	4	4.5	5	5.5	6	6	6	6	6	6	6	6
	20	-	-	-	-	-	-	-	-	-	-	4	4.5	5	5.5	6	6	6	6	6
	22	-	-	-	-	-	-	-	-	-	-	-	-	-	4	4.5	5.5	6	6	6
9.5	18	-	-	-	-	-	-	4	4	4	4.5	5	5.5	6	6	6	6	6	6	6
	20	-	-	-	-	-	-	-	-	-	-	4	4	4.5	5	6	6	6	6	6
	22	-	-	-	-	-	-	-	-	-	-	-	-	-	4	4.5	5	6	6	6
10	18	-	-	-	-	-	-	-	4	4	4.5	4.5	5	6	6	6	6	6	6	6
	20	-	-	-	-	-	-	-	-	-	-	-	4	4.5	4.5	5.5	6	6	6	6
	22	-	-	-	-	-	-	-	-	-	-	-	-	-	4	4	4.5	5.5	6	6
10.5	18	-	-	-	-	-	-	-	4	4	4.5	4.5	5	5.5	6	6	6	6	6	6
	20	-	-	-	-	-	-	-	-	-	-	-	4	4	4.5	5	6	6	6	6
	22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	4.5	5.5	6	6
11	18	-	-	-	-	-	-	-	-	4	4	4.5	5	5	6	6	6	6	6	6
	20	-	-	-	-	-	-	-	-	-	-	-	-	4	4.5	5	5.5	6	6	6
	22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	4.5	5	6	6
11.5	18	-	-	-	-	-	-	-	-	-	4	4	4.5	5	5.5	6	6	6	6	6
	20	-	-	-	-	-	-	-	-	-	-	-	-	4	4.5	5	5.5	6	6	6
	22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	4.5	5	6	6
12	18	-	-	-	-	-	-	-	-	-	4	4	4.5	5	5.5	6	6	6	6	6
	20	-	-	-	-	-	-	-	-	-	-	-	-	-	4	4.5	5	6	6	6
	22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	5	5.5	6
Roof Cover Fastener Row Spacing	Gauge	330	315	300	285	270	255	240	225	210	195	180	165	150	135	120	105	90	75	60
		Wind Rating [psf]																		

Table 1C. Maximum Steel Deck Span (ft) for 1½ in. (38 mm) Deep, Wide Rib (Type B) Steel Deck with an Adhered Roof Cover, for Wind Ratings from 60 to 225 psf (2.9 to 10.8 kPa)
(NOTE: Use this table when the distance between rows of roof cover fasteners is one-half the deck span or less. Green font indicates that deflection governs over bending stress.)

Yield Stress psi	*Deck Gauge*	*Ultimate Wind Rating per RoofNav (psf)*											
		Maximum Span (ft)											
		60	75	90	105	120	135	150	165	180	195	210	225
33,000	22	7.10	7.10	7.10	7.10	7.07	6.67	6.33	6.03	5.78	5.55	5.35	5.17
	20	7.78	7.78	7.78	7.78	7.78	7.43	7.05	6.72	6.44	6.18	5.96	5.76
	18	9.08	9.08	9.08	9.08	9.08	8.66	8.22	7.84	7.50	7.21	6.95	6.71
	16	10.36	10.36	10.36	10.36	10.36	9.89	9.38	8.94	8.56	8.23	7.93	7.66
40,000	22	7.10	7.10	7.10	7.10	7.10	7.10	6.96	6.64	6.35	6.10	5.88	5.68
	20	7.78	7.78	7.78	7.78	7.78	7.78	7.76	7.40	7.08	6.80	6.56	6.33
	18	9.08	9.08	9.08	9.08	9.08	9.08	9.04	8.62	8.25	7.93	7.64	7.38
	16	10.36	10.36	10.36	10.36	10.36	10.36	10.32	9.84	9.42	9.05	8.72	8.43
45,000	22	7.10	7.10	7.10	7.10	7.10	7.10	7.10	7.04	6.74	6.48	6.24	6.03
	20	7.78	7.78	7.78	7.78	7.78	7.78	7.78	7.78	7.51	7.22	6.95	6.72
	18	9.08	9.08	9.08	9.08	9.08	9.08	9.08	9.08	8.76	8.41	8.11	7.83
	16	10.36	10.36	10.36	10.36	10.36	10.36	10.36	10.36	9.99	9.60	9.25	8.94
50,000	22	7.10	7.10	7.10	7.10	7.10	7.10	7.10	7.10	6.93	6.66	6.42	6.20
	20	7.78	7.78	7.78	7.78	7.78	7.78	7.78	7.78	7.72	7.42	7.15	6.91
	18	9.08	9.08	9.08	9.08	9.08	9.08	9.08	9.08	9.00	8.65	8.33	8.05
	16	10.36	10.36	10.36	10.36	10.36	10.36	10.36	10.36	10.28	9.87	9.51	9.19
55,000	22	7.10	7.10	7.10	7.10	7.10	7.10	7.10	7.10	7.10	7.10	6.90	6.67
	20	7.78	7.78	7.78	7.78	7.78	7.78	7.78	7.78	7.78	7.78	7.69	7.43
	18	9.08	9.08	9.08	9.08	9.08	9.08	9.08	9.08	9.08	9.08	8.97	8.66
	16	10.36	10.36	10.36	10.36	10.36	10.36	10.36	10.36	10.36	10.36	10.24	9.89
60,000 +	22	7.10	7.10	7.10	7.10	7.10	7.10	7.10	7.10	7.10	7.10	7.10	6.97
	20	7.78	7.78	7.78	7.78	7.78	7.78	7.78	7.78	7.78	7.78	7.78	7.77
	18	9.08	9.08	9.08	9.08	9.08	9.08	9.08	9.08	9.08	9.08	9.08	9.06
	16	10.36	10.36	10.36	10.36	10.36	10.36	10.36	10.36	10.36	10.36	10.36	10.34
Green font indicates that deflection governs over bending stress.													

Table 1D. Maximum steel Deck span (ft) for 1½ in. (38 mm) Deep, Wide Rib (Type B) Steel Deck with an Adhered Roof Cover, for wind ratings from 240 to 405 psf (11.5 to 19.4 kPa)
(NOTE: Use this table when the distance between rows of roof cover fasteners is one-half the deck span or less.)

Yield Stress psi	*Deck Gauge*	*Ultimate Wind Rating per RoofNav (psf)* Maximum Span (ft)											
		240	255	270	285	300	315	330	345	360	375	390	405
33,000	22	5.00	4.85	4.72	4.59	4.47	4.37	4.27	4.17	4.08	4.00	3.92	3.85
	20	5.57	5.41	5.26	5.12	4.99	4.87	4.75	4.65	4.55	4.46	4.37	4.29
	18	6.50	6.30	6.13	5.96	5.81	5.67	5.54	5.42	5.30	5.20	5.10	5.00
	16	7.42	7.19	6.99	6.81	6.63	6.47	6.32	6.19	6.06	5.93	5.82	5.71
40,000	22	5.50	5.34	5.19	5.05	4.92	4.80	4.69	4.59	4.49	4.40	4.32	4.24
	20	6.13	5.95	5.78	5.63	5.48	5.35	5.23	5.11	5.01	4.91	4.81	4.72
	18	7.15	6.93	6.74	6.56	6.39	6.24	6.09	5.96	5.84	5.72	5.61	5.50
	16	8.16	7.91	7.69	7.49	7.30	7.12	6.96	6.80	6.66	6.53	6.40	6.28
45,000	22	5.84	5.66	5.50	5.36	5.22	5.10	4.98	4.87	4.77	4.67	4.58	4.49
	20	6.51	6.31	6.13	5.97	5.82	5.68	5.55	5.43	5.31	5.20	5.10	5.01
	18	7.58	7.36	7.15	6.96	6.78	6.62	6.47	6.32	6.19	6.07	5.95	5.84
	16	8.65	8.40	8.16	7.94	7.74	7.55	7.38	7.22	7.07	6.92	6.79	6.66
50,000	22	6.00	5.82	5.66	5.51	5.37	5.24	5.12	5.01	4.90	4.80	4.71	4.62
	20	6.47	6.27	6.10	5.93	5.78	5.64	5.51	5.39	5.28	5.17	5.07	4.98
	18	7.54	7.31	7.11	6.92	6.74	6.58	6.43	6.29	6.15	6.03	5.91	5.80
	16	8.60	8.35	8.11	7.89	7.69	7.51	7.34	7.18	7.02	6.88	6.75	6.62
55,000	22	6.46	6.27	6.09	5.93	5.78	5.64	5.51	5.39	5.27	5.17	5.07	4.97
	20	7.20	6.98	6.79	6.60	6.44	6.28	6.14	6.00	5.88	5.76	5.65	5.54
	18	8.39	8.14	7.91	7.70	7.50	7.32	7.15	7.00	6.85	6.71	6.58	6.46
	16	9.57	9.29	9.03	8.79	8.56	8.36	8.17	7.99	7.82	7.66	7.51	7.37
60,000 +	22	6.75	6.55	6.37	6.20	6.04	5.89	5.76	5.63	5.51	5.40	5.30	5.20
	20	7.53	7.30	7.10	6.91	6.73	6.57	6.42	6.28	6.14	6.02	5.90	5.79
	18	8.77	8.51	8.27	8.05	7.85	7.66	7.48	7.32	7.16	7.02	6.88	6.75
	16	10.01	9.71	9.44	9.19	8.95	8.74	8.54	8.35	8.17	8.01	7.85	7.71

Table 1E. 3 in. (75 mm) Deep, Type N Steel Deck with 8 in. (200 mm) Rib Spacing for Wind Ratings from 60 to 225 psf (2.9 to 10.8 kPa)
(NOTE: Use this table when the distance between rows of roof cover fasteners is one-half the deck span or less. Green font indicates that deflection governs over bending stress.)

Yield Stress psi	*Deck Gauge*	*Ultimate Wind Rating per RoofNav (psf)*											
		Maximum Span (ft)											
		60	75	90	105	120	135	150	165	180	195	210	225
33,000	22	13.29	11.88	10.85	10.04	9.40	8.86	8.40	8.01	7.67	7.37	7.10	6.86
	20	14.83	13.27	12.11	11.21	10.49	9.89	9.38	8.94	8.56	8.23	7.93	7.66
	18	17.39	15.56	14.20	13.15	12.30	11.60	11.00	10.49	10.04	9.65	9.30	8.98
	16	20.45	18.29	16.69	15.46	14.46	13.63	12.93	12.33	11.80	11.34	10.93	10.56
40,000	22	14.62	13.07	11.93	11.05	10.34	9.74	9.24	8.81	8.44	8.11	7.81	7.55
	20	16.32	14.59	13.32	12.33	11.54	10.88	10.32	9.84	9.42	9.05	8.72	8.43
	18	19.13	17.11	15.62	14.46	13.53	12.75	12.10	11.54	11.05	10.61	10.23	9.88
	16	22.28	20.12	18.36	17.00	15.90	14.99	14.22	13.56	12.98	12.48	12.02	11.61
45,000	22	14.82	13.87	12.66	11.72	10.96	10.34	9.81	9.35	8.95	8.60	8.29	8.01
	20	16.56	15.48	14.13	13.08	12.24	11.54	10.95	10.44	9.99	9.60	9.25	8.94
	18	19.48	18.15	16.57	15.34	14.35	13.53	12.84	12.24	11.72	11.26	10.85	10.48
	16	22.28	21.34	19.48	18.04	16.87	15.91	15.09	14.39	13.78	13.23	12.75	12.32
50,000	22	14.82	14.26	13.02	12.05	11.27	10.63	10.08	9.62	9.21	8.84	8.52	8.23
	20	16.56	15.92	14.53	13.45	12.59	11.87	11.26	10.73	10.28	9.87	9.51	9.19
	18	19.48	18.67	17.04	15.78	14.76	13.91	13.20	12.59	12.05	11.58	11.16	10.78
	16	22.28	21.94	20.03	18.55	17.35	16.36	15.52	14.79	14.16	13.61	13.11	12.67
55,000	22	14.82	14.82	14.01	12.97	12.13	11.44	10.85	10.34	9.90	9.52	9.17	8.86
	20	16.56	16.56	15.63	14.48	13.54	12.77	12.11	11.55	11.06	10.62	10.24	9.89
	18	19.48	19.48	18.33	16.97	15.88	14.97	14.20	13.54	12.96	12.46	12.00	11.60
	16	22.28	22.28	21.55	19.95	18.66	17.60	16.69	15.92	15.24	14.64	14.11	13.63
60,000 +	22	14.82	14.82	14.65	13.56	12.68	11.96	11.34	10.82	10.36	9.95	9.59	9.26
	20	16.56	16.56	16.35	15.14	14.16	13.35	12.66	12.07	11.56	11.11	10.70	10.34
	18	19.48	19.48	19.17	17.75	16.60	15.65	14.85	14.16	13.56	13.02	12.55	12.13
	16	22.28	22.28	22.54	20.86	19.52	18.40	17.46	16.64	15.94	15.31	14.75	14.25
Green font indicates that deflection governs over bending stress													

2.2.3.3 If the deck type and span have already been installed, do the following, select the Roof*Nav* assembly based on deck type and span used. Consider higher wind loads in Zone 2, Zone 3, and Zone 1, if applicable. In some cases the deck type and span may be designed for the highest wind load (Zone 3) that can occur on any area of the roof. In other cases, the deck type and span may be designed for Zone 1 and a reduced span may be used in Zone 2 and Zone 3.

If the deck design assumes the wind load was uniformly applied from the roof cover to the deck, this may prevent the use of MFSP roof covers, or limit the design to those for which roof cover fastener row spacing is close enough to prevent overstress of the roof deck.

2.2.3.4 Provide deck securement as required by Roof*Nav* for the needed wind rating using one of the following methods:

A. Performance-based approach: Where Roof*Nav* assemblies are selected to account for the higher wind ratings needed in Zone 2 and Zone 3, the entry for the Roof*Nav* assembly will address the specific securement requirements.

B. Prescriptive enhancement approach: Where a single Roof*Nav* assembly is selected based on the needed Zone 1 rating (assuming deck span is adequate for all areas as noted above), enhance deck securement in Zone 2 and Zone 3 as follows:

1. Zone 2: Increase deck securement by a minimum of 50% compared to that required by Roof*Nav* for the Zone 1 rating.

2. Zone 3: Provide deck securement equivalent to at least 2 times that required by the RoofNav listing for Zone 1 and in accordance with Tables 2 or 3, where applicable.

In most cases, due to steel deck module spacing, it will be practical for both Zone 2 and Zone 3 to provide deck securement equivalent to 2 times that required by the RoofNav listing for Zone 1.

Table 2. Steel Roof Deck, Zone 3 Enhancement Options for 6 in. (150 mm) Module (Rib Spacing), Common With 1 ½ in. (38 mm) Deep Deck

Required Zone 1 Securement	*Zone 3 Securement*
5/8 in. welds @ 12 in. (300 mm)	5/8 in. welds or FM Approved deck fasteners @ 6 in. (150 mm)
5/8 in. welds @ 6 in. (150 mm)	Two 5/8 in. welds or two FM Approved deck fasteners @ 6 in. (150 mm)
3/4 in. welds @ 12 in. (300 mm)	¾ in. welds or FM Approved deck fasteners @ 6 in. (150 mm)
3/4 in. welds @ 6 in. (150 mm)	Two ¾ in. welds or two FM Approved deck fasteners @ 6 in. (150 mm)
One FM Approved deck fastener @ 12 in. (300 mm)	One FM Approved deck fastener with minimum ½ in. integral washer diameter or ¾ in. washer @ 6 in. (150 mm)
One FM Approved dek fasteners @ 6 in. (150 mm)	Two FM Approved deck fasteners withminimum ½ in. integral washer diameter or ¾ in. washers @ 6 in. (150 mm)
Two FM Approved deck fasteners @ 6 in. (150 mm)	Two FM Approved deck fastener with ¾ in. washer @ 6 in. (150 mm)

Table 3. Steel Roof Deck, Zone 3 Enhancement Options for 8 in. (200 mm) Module (Rib Spacing), Common with 3 in. (75 mm) Deep Deck

Required Zone 1 Securement	*Zone 3 Securement*
5/8 in. welds @ 8 in. (200 mm)	Two 5/8 in. welds or two FM Approved deck fasteners @ 8 in. (200 mm)
¾ in. welds @ 8 in. (200 mm)	Two ¾ in. welds or two FM Approved deck fasteners @ 8 in. (200 mm)
One FM Approved deck fastener @ 8 in. (200 mm)	Two FM Approved deck fasteners with minimum 1/2 in. integral washer diameter or 3/4 in. washer @ 8 in. (200 mm)
Two 5/8 in. (16 mm) welds @ 8 in. (200 mm)	Two FM Approved deck fasteners with ¾ in. washers @ 8 in. (200 mm)

Note: Where deck welds are used, the weld size listed is the visible outer diameter or nominal diameter as seen from the top surface (see Fig. 3b). The effective diameter is somewhat less, however, than is accounted for within the supporting calculations.

2.2.3.5 Provide additional securement and side lap fastening for the deck as needed for complete re-roofs (stripped down to the deck) where the existing installation details do not meet current criteria.

The use of mechanical deck fasteners is preferred over welding for fire prevention reasons on occupied buildings. Where welding must be used, see Data Sheet 1-0 and Data Sheet 10-3.

2.2.3.6 Secure the deck to supporting members at each deck side lap, regardless of the resultant securement spacing.

2.2.3.7 Secure deck side laps to each other between supports as follows:

A. For interlocking side laps (Fig. 3c), secure both sides of the lap (upper and lower) to each other. The installer must stand on the upper side of the lap.

B. For overlapping side laps (Fig. 3d), ensure securement penetrates all deck panels at the laps. The installer must stand on the upper side of the lap.

2.2.3.8 When Steel Deck Institute (SDI) deck-weld patterns are specified for use with 1-1/2 in. (38 mm) deep deck, 24/3 or 36/4 patterns are acceptable where a maximum 12 in. (300 mm) securement spacing is recommended or FM Approved. Where a maximum 6 in. (150 mm) securement spacing is recommended or FM Approved, 24/5, 24/7, 30/6, 30/8, 36/7, or 36/9 patterns are acceptable. See Figure 3e.

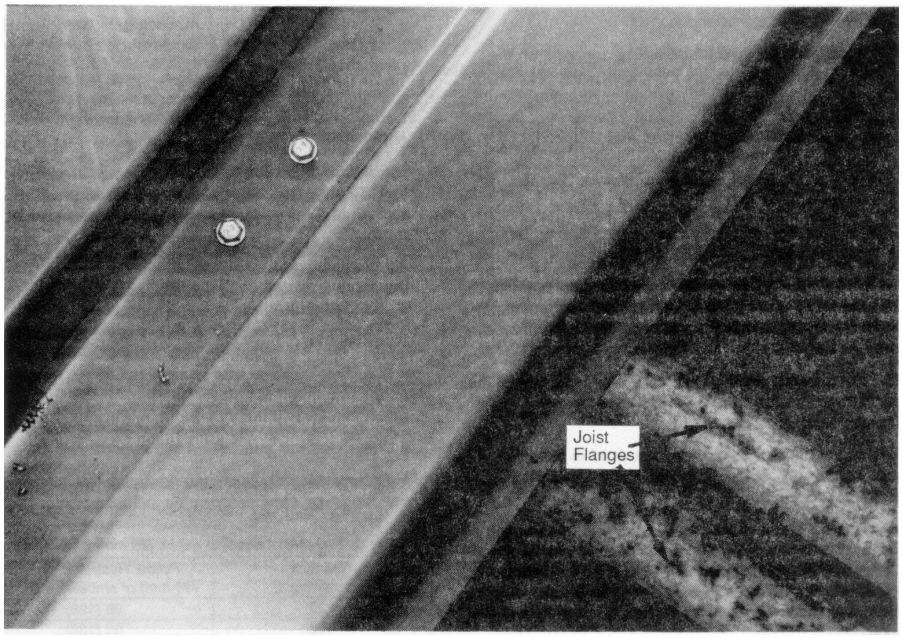

Fig. 3a. Use of multiple deck fasteners in one steel deck rib

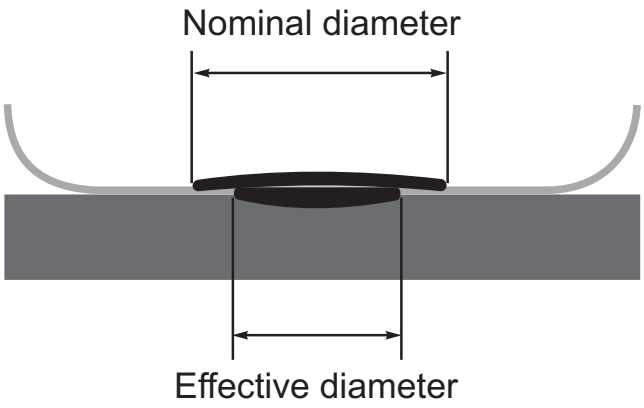

Fig. 3b. Nominal weld diameter

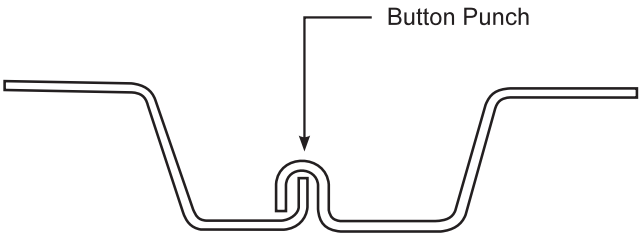

Fig. 3c. Side lap fastening: interlocking seam.

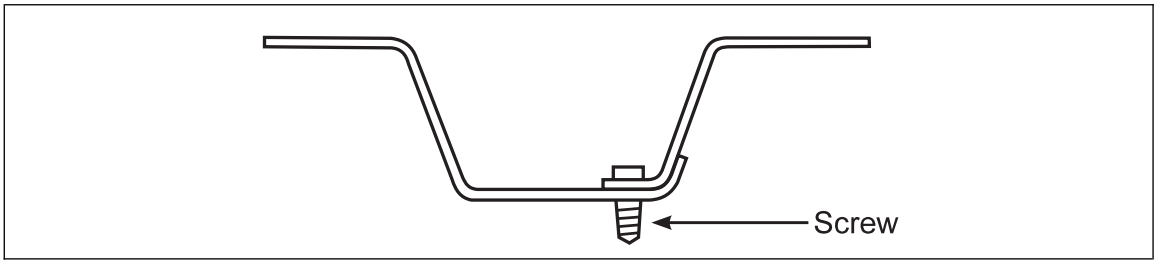

Fig. 3d. Side lap fastening: overlap seam.

Securement Patterns	Deck Width (ft)	*S* (in)
24/3	2	12
36/4	3	12
24/5[1]	2	6
30/6[1]	2.5	6
36/7[1]	3	6

S = Equivalent Weld Spacing (in.) per Roof*Nav.*

1 = For 24/7,30/8 and 36/9 two welds are used at the outer ribs.

Fig. 3e. Selected SDI weld patterns

2.2.3.9 Provide mechanical fastening at all deck side laps as noted in Table 4 unless the FM Approval listing specifically requires a closer spacing, or a closer spacing is required by the Structural Engineer of Record (SER) for diaphragm resistance.

A. Fasten overlapping side laps with FM Approved side lap fasteners.

B. Interlocking laps can be fastened by button punching in Class 1-90 and lower.

C. Do not weld side laps.

D. Stand on the higher side when installing side lap securement

Table 4. Maximum Side Lap Securement Spacing

Zone 1 RoofNav Rating (psf)	*Zone 1, in. (mm)*	*Zone 2, in. (mm)*	*Zone 3, in. (mm)*
< = 90	36 (914)	30 (762)	30 (762)
105 - 120	30 (762)	15 (381)	15 (381)
> = 135	24 (610)	15 (381)	15 (381)

2.2.3.10 Install individual steel deck sections so they terminate over structural supports, and ensure the deck sections are installed so they overlap each other a minimum of 2 in. (50 mm). Where the design requires two deck fasteners or welds per connection, increase the length of the end lap to 4 in. (100 mm) and ensure that both fasteners or welds penetrate both overlapping deck sections.

2.2.3.11 For new construction, the structural engineer of record (SER) is responsible for determining if more stringent design criteria is needed with regard to the deck type and securement, such as providing design diaphragm resistance in conjunction with wind uplift resistance.

2.2.3.12 Acoustical Steel Deck

Acoustical roof deck is used for sound absorption, and FM Approved versions of this deck are available. It is similar to non-acoustical deck except it is perforated with small holes. Glass or mineral fiber insulation is usually field-applied within the ribs to increase the sound absorption performance. This insulation may also enhances the internal fire performance. Some FM Approved acoustical decks consist of a perforated steel sheet added to the bottom of non-acoustic steel deck.

2.2.3.12.1 Avoid the use of acoustical steel deck in oily or dusty occupancies because oil or dust may collect within the deck rib openings and increase the fire hazard.

2.2.3.12.2 For acoustical decks without the added perforated bottom sheet noted above, apply a 10% reduction to the allowable deck spans noted in Tables 1a through 1f. Those tables are for solid decks. The deck strength for acoustical deck is reduced by 5% compared to solid deck that is identical in all other aspects. The allowable spans for FM Approved acoustical deck were calculated considering the reduced strength.

2.2.4 Structural Concrete Roof Deck

2.2.4.1 Where concrete is to be used, use normal-weight structural concrete (approximately 145 pcf, 2300 kg/m^3) with a minimum ultimate compressive strength (f'_C) of 2500 psi (17.2 MPa).

2.2.4.2 Lightweight Structural Concrete (LWSC) Roof Deck

2.2.4.2.1 Where the structure will not safely support normal-weight concrete and therefore lightweight structural concrete (90-115 pcf [1440-1840 kg/m^3]) must be used (e.g., to provide required fire-resistance ratings), design the concrete and its reinforcement as a noncomposite type and pour the LWSC over removable forms.

Lightweight aggregate retains a great deal of moisture that will be released for several months after the concrete has hardened and will be absorbed by abovedeck components. This will damage and weaken those components, resulting in damage from winds below design speeds, or premature deterioration requiring replacement.

2.2.4.2.2 Where the use of removable forms is not practical, take the following precautions to prevent moisture damage to above-deck roof components:

A. Use the lowest reasonable water-to-cement (w/c) ratio in the concrete mix. “Water reducers” may be used in the concrete mix; however, do not use water-reducing admixtures that contain calcium chloride or other chloride salts that are corrosive to the steel form deck.

In addition, do **one** of the following (B or C):

B. Use an FM Approved assembly consisting of a mechanically fastened modified bitumen base sheet directly over a concrete deck followed by adhered components above, or

C. Ensure the concrete roof deck is dry before installing the above-deck components. In some cases, this could take months. Perform a test to ensure the moisture migration has been reduced to a level where damage to above-deck components is unlikely based on the product manufacturer’s recommendations (note: neither the Plastic Sheet Method Test [ASTM D4263] nor the Calcium Chloride Test [ASTM F1869] are recommended for this purpose). The test procedures and acceptance criteria must first be agreed upon by all stakeholders.

Note: The following are NOT considered substitutes for the above recommendations:

- The use of a vented steel form deck alone (without one of the above alternatives) because it will have limited impact on moisture reduction.
- The use of above-deck components that are resistant to moisture.

2.2.4.3 Ensure wind uplift securement of precast concrete planks (approximately 2 by 8 ft [0.6 by 2.4 m] long) is designed by a professional civil or structural engineer (PE).

Ensure clips used to secure the planks to roof framing are provided on both sides of each plank at their junction with the secondary roof framing. Design the clips for the design wind load using a minimum safety factor of 2.0. When used in corrosive occupancies, use stainless steel clips.

2.2.5 Fiberglass Reinforced Plastic (FRP) Insulated Roof Deck Assemblies

2.2.5.1 FRP Deck

2.2.5.1.1 Ensure the deck is secured in accordance with the Roof*Nav* listing to meet the needed wind pressures for Zones 1', 1, 2, and 3.

2.2.5.1.2 Where the deck design is based on Zone 1 wind pressure, ensure the Zone 2 and 3 details for the deck span and fastening are adequate to resist the higher wind pressures in these areas.

Use prescriptive deck enhancement that meets one of the following criteria:

A. The deck span may be reduced to 2/3 and 1/2 of that required for Zone 1 for Zone 2 and Zone 3, respectively.

B. For decks whose span is adequate for higher wind pressures in Zone 2 and/or Zone 3 based on bending stress, increase the number of deck fasteners or fastener securement strength in Zone 2 and Zone 3 by a minimum of 50% and 80%, respectively.

2.2.6 Cementitious Panel Roof Deck

Cementitious panel roof decks are reinforced with wood fiber or glass fiber.

2.2.6.1 Ensure the deck span and its securement is in accordance with the Roof*Nav* listing for the wind ratings in each Zone of the roof.

Exception: Prescriptive deck enhancement meeting **one** of the following criteria (A or B) may be acceptable:

A. The deck span may be reduced to 67% and 50% of that required for Zone 1 for Zone 2 and Zone 3, respectively.

B. For decks whose span is adequate for higher wind pressures needed in Zone 2 and/or Zone 3 based on bending stress, deck securement may be increased as follows:

1. For decks that are through-fastened to supports, increase the number of fasteners or fastener securement strength in Zone 2 and Zone 3 by a minimum of 50% and 80% respectively.

2. For decks that are secured with clips at their side-laps, increase the number of clips or clip securement strength in Zone 2 and Zone 3 by a minimum of 50% and 80% in Zone 2 and Zone 3 respectively.

2.2.7 Lumber and Plywood Deck

2.2.7.1 Where ordinary (non-fire-retardant treated) plywood is used, base the plywood type, span, and securement on the guidelines in ″Designing Commercial Roofs to Withstand Wind Uplift Forces″, which can be found at apawood.org

2.2.7.2 Provide sprinklers directly below the wood roof.

2.2.7.3 Where nominal 2 in. (51 mm) lumber is to be used for the roof deck, provide sprinklers directly below the roof and fasten it as follows:

A. Determine the design wind load and multiply by the tributary area of the nail, to determine the required resistance of the nail.

B. Determine the nail penetration into the support.

C. Determine the nail pullout strength by multiplying penetration length by the appropriate Pullout *Resistance per in of Penetration* value in Table 5.

D. Ensure the nail pullout strength is at leasttwice the design load of the nail.

E. Increase the fastening strength at Zone 2 and Zone 3 by a minimum of 50% and 80% respectively.

Table 5. Nail Pullout Strength per in. (25 mm) of Penetration

Nail Size (pennyweight)	*Diameter, in. (mm)*	*Pullout Resistance per in. (25 mm) of Penetration, lb (N)*
8d	0.131 (3.33)	26 (116)
10d or 12d	0.148 (3.76)	30 (133)
16d	0.162 (4.11)	32 (142)
20d	0.192 (4.88)	38 (169)
30d	0.207 (5.26)	41 (182)

2.2.8 Fire Retardant-Treated Lumber and Plywood

2.2.8.1 This section does not apply to ordinary wood protected with surface coatings. For more information related to fire retardant-treated lumber and plywood (FRTW), see Data Sheet, 1-61. Multiply a strength reduction factor equal to 0.9 times the values given in Section 2.2.7 for the design of fastening when using FRTW.

2.2.9 Lightweight Insulating Concrete (LWIC) and Form Deck

Lightweight insulating concrete (LWIC) is an above-deck component. It is always poured in place and as such is listed in Roof*Nav* as an insulation. It is installed over concrete decks or steel form decks.

2.2.9.1 LWIC Design Recommendations

2.2.9.1.1 Ensure all steel form decks are FM Approved and made of galvanized steel. Do not use aluminum alloy coatings.

2.2.9.1.2 When the roof cover or base sheet used over LWIC is fastened directly into the steel form deck (similar to typical insulated steel deck assemblies), refer to Section 2.2.3 regarding deck span and securement.

When re-roofing is conducted over existing LWIC, this may be a more practical alternative if the steel deck span and securement is adequate. Some base sheet fasteners for use in LWIC are designed to be driven within a few days after the LWIC is poured and they may not properly penetrate the LWIC after it has completely hardened.

2.2.9.1.3 In regions not prone to tropical cyclones, do one of the following:

A. Ensure the assembly meets all Roof*Nav* requirements for the specific wind rating for Zones 1', 1, 2, and 3, including the form deck type, span, and securement.

B. Ensure the LWIC assembly is FM Approved for the specific wind pressure recommended in Zone 1 and Zone 1', if present, with prescriptive enhancements based on Zone 1 provided for the securement of base sheets in Zone 2 and Zone 3 in accordance with Recommendation 2.2.10.14.

In addition, for form deck that consists of minimum 1.5 in. (38 mm) deep, minimum 22 ga. (0.0295 in., 0.75 mm) steel deck, use the guidelines in Section 2.2.3 for prescriptive deck securement enhancement options.

For installations using different form-deck profiles, ensure the securement spacing of the form deck to the supports in the perimeter and corner does not exceed 4 in. (100 mm).

2.2.9.1.4 In regions prone to tropical cyclones, ensure the assembly meets all Roof*Nav* requirements for the specific wind rating needed for Zones 1', 1, 2, and 3, and corner areas, including the form deck type, span, and securement.

2.2.9.1.5 Ensure all welding on deck less than 22 ga. (0.0295 in.; 0.749 mm) incorporates weld washers. Weld washers should be minimum 1 by 1 in. (25 by 25 mm), 16 ga. (0.060 in.; 1.5 mm) thick and have a minimum 3/8 in. (9.5 mm) hole.

Note: If curved weld washers are used with steel deck with flat bottom flanges, and the weld washers are flattened with a hammer, this must be done while the steel is still bright red. If done after the weld and steel cools, it could cause cracking of the weld.

2.2.9.1.6 Provide mechanical fastening at all form deck side laps. Ensure side lap fastener spacing is in accordance with Table 4.

2.2.9.2 LWIC Installation Recommendations

2.2.9.2.1 When installing LWIC on the form deck, the thickness and consistency of the initial slurry, prior to placing the expanded polystyrene (EPS) insulation, is critical. There must be sufficient LWIC to ensure an adequate bond. Refer to Roof*Nav*.

2.2.9.2.2 Ensure the following is done:

A. Have an adequately sized waste container at the job site. Initial flow of LWIC should be into the waste container until it is flowing properly and is free of excess water.

B. Pour samples for wet density, dry density, and compression tests just prior to pouring the actual LWIC deck. Compare wet density results to manufacturer's data immediately, and adjust the mix as needed until the proper density has been achieved. Compare other test results later when they become available.

C. For regions prone to tropical cyclones, if mechanically fastened (MF) base sheets are used, conduct pull-out tests on base sheet fasteners after the deck has set (2 to 3 days) and just before the base sheet is secured.

2.2.9.2.3 Ensure base sheet fasteners driven into LWIC are not closer than 4 in. (100 mm) on center, to avoid cracking the LWIC. If a spacing closer than 4 in. (100 mm) on center is required to meet wind uplift criteria, a stronger fastener and/or base sheet should be used.

2.2.10 Above-Deck Roof Components (Other Than LWIC)

2.2.10.1 Wind Uplift Resistance

2.2.10.1.1 Provide one of the following options to secure Zones 2 and 3:

A. Use a roof system with an FM Approval wind uplift rating that is acceptable for Zones 1', 1, 2, and 3 per the Ratings Calculator of Roof*Nav* or DS 1-28. That could entail using a system throughout the entire roof that had a wind rating adequate for Zone 3, or using a system that has a varied fastener spacing and multiple wind ratings that are adequate for the respective roof zone.

B. Use the appropriate prescriptive recommendation noted in Section 2.2.10.1.2.

In either case, ensure any whole or partial insulation board or roof cover/base sheet width (when the roll is parallel to the building edge) that falls within the calculated Zone 1, Zone 2, or Zone 3 area has the increased securement applied over the entire board or roof cover/base sheet width.

2.2.10.1.2 Use prescriptive enhancements for Zone 2 and Zone 3 (for all deck types) where roof covers are adhered to some combination of insulation or cover board as long as **one** of the following conditions applies:

A. The recommended Zone 1 rating needed per DS 1-28 in any location does not exceed Class 1-90 (3.6 kPa), or

B. The building is in a non-tropical cyclone-prone region (see Appendix A) and the recommended Zone 1 rating per DS 1-28 does not exceed Class 1-105 (4.3 kPa).

2.2.10.1.2.1 For either of the above conditions, increase the securement over the FM Approved Zone 1 rating as follows:

A. For assemblies using insulation fasteners, enhance the fastening as follows:

1. Increase the number of fasteners per board by 50% minimum in Zone 2, but at least one fastener per 2 ft^2 (1 per 0.19 m^2). It is not necessary to install fasteners closer than one per 1 ft^2 (1 per 0.09 m^2).

2. Install one fastener per 1 ft^2 (1 per 0.09 m^2) in Zone 3.

3. Round up to the next whole number of fasteners, if necessary

B. For components adhered with adhesives applied in ribbons, spots, etc., reduce the spacing between ribbons or spots over the FM Approved spacing for the given wind rating as noted below (round down to a dimension that is practical with respect to board sizes, applicators, etc.):

1. In Zone 2, not more than 67% of the Zone 1 spacing between rows, or area

2. In Zone 3, not more than 50% of the Zone 1 spacing between rows, or area.

Note: If the FM Approval wind rating already meets the higher criteria for Zone 2 or Zone 3, no further reduction is needed in those areas.

Example: A particular roof cover proposed in a non-tropical cyclone-prone region and requiring a 90 psf (4.3 kPa) wind rating has an FM Approval wind rating adequate for Zone 1 and is adhered to the substrate immediately below (cover board or insulation) with an adhesive in ribbons at 1 ft (0.3 m) on center in Zone 1. Zone 2 would need a ribbon spacing of maximum 8 in. (200 mm) and Zone 3 would need a ribbon spacing of maximum 6 in. (150 mm) on-center. Note: the spacing was rounded down for practicality.

2.2.10.1.3 For mechanically fastened single-ply membranes (MFSP), pre-secure the insulation or cover boards below the roof cover throughout the entire roof on all non-monolithic decks (any decks other than cast-in-place concrete) in accordance with Table 6. For cast-in-place concrete, use two preliminary fasteners per insulation boards up to 4 x 4 ft (1.2 x 1.2 m) and four preliminary fasteners per insulation board up to 4 x 8 ft (1.2 x 2.4 m).

Exception: In installations such as grid-attached or point-attached systems (including but not limited to plate-bonded systems), the same fasteners are used for both preliminary board securement and roof cover securement and no additional preliminary securement is needed.

Preliminary securement for insulation or cover boards prevents board breakage from wind uplift. The preliminary securement is based on interior wind pressure, which is constant throughout the entire building Zones 1', 1, 2, and 3).

Table 6 does not apply to roof assemblies with air barriers. Where air barriers are used, more stringent guidelines may be required in Roof*Nav* and those must be followed.

Table 6. Preliminary Insulation Securement for Fastened in the Seam MFSPs

Vapor Retarder	*Building Enclosure Classification*	*Maximum Required Zone 1 Pressure Rating (P), psf (kPa)*	*Fastener Requirements for Insulation or Cover Boards up to 4 x 4 ft (1.2 x 1.2 m) board*	*Fastener Requirements for Insulation or Cover Boards up to 4 x 8 ft (1.2 x 2.4 m) board*
No	Enclosed or Partially-Enclosed	No limit	Minimum 2 per board	Minimum 4 per board
Yes	Enclosed	P = 60 (2.9)	Minimum 2 per board	Minimum 4 per board
Yes	Partially enclosed	P = 60 (2.9)	Minimum 4 per board	Minimum 5 per board
Yes	Enclosed or Partially-Enclosed	60 < P < = 90 (2.9 < P < = 4.3)	Minimum 4 per board	Minimum 5 per board
Yes	Enclosed	90 < P < = 300 (4.3 < P < = 14.4	Minimum 4 per board	Minimum 8 per board
Yes	Partially Enclosed	90 < P < = 300 (4.3 < P < = 14.4)	Minimum 6 per board	Minimum 12 per board
Yes	Enclosed	P > 300 (14.4)	Minimum 6 per board	Minimum 12 per board
Yes	Partially Enclosed	P > 300 (14.4)	Minimum 8 per board	Minimum 16 per board

2.2.10.1.4 Provide enhancements for mechanically fastened single-ply (MFSP) roof covers in accordance with Recommendations 2.2.10.11 and 2.2.10.12, and for mechanically attached base sheets in accordance with Recommendation 2.2.10.14. Install all rows of roof cover fasteners perpendicular to the ribs of the roof deck to better distribute the wind load and prevent deck failure.

2.2.10.1.5 For mechanically attached base sheets, refer to Section 2.2.2.8 or 2.2.2.9 if the base sheet is fastened directly to a wood deck.

2.2.10.2 External Fire Resistance

2.2.10.2.1 Use assemblies having an FM Approval rating of Class A for exterior fire exposure. The FM Approval test is per the American Society for Testing and Materials (ASTM) E108.

2.2.10.2.2 Do not use any aggregate surfacing, such as pea gravel or slag surfacing or crushed stone, in (a) tropical cyclone Region A, B, or C per DS 1-28 and where the wind speed per DS 1-28 is ≥ 100 mph

(≥ 45 m/s), or (b) in other regions on buildings taller than that defined in Table 7. Where added protection for the roof cover is needed, such as near major fire walls, concrete paver blocks can be used.

For large stone ballast for loose-laid single ply roof covers, also see Section 2.2.10.17.

Note: In all cases in Table 7, the rooftop speed is ≤ 100 mph (≤ 45 m/s) Zone 3.

Table 7. Maximum Mean Height for Roofs with Aggregate Surfacing in Areas Not Prone to Tropical Cyclones

Design Wind Speed, V_{ASD}, mph (m/s)	*Maximum Mean Roof Height, ft (m)*		
	Exposure Category		
	B	C	D
85 (38)	170 (52)	60 (18)	30 (9)
90 (40)	110 (34)	35 (11)	15 (5)
95 (42)	75 (23)	20 (6)	NP
100 (45)	55 (17)	15 (5)	NP
105 (47)	40 (12)	NP	NP
110 (49)	30 (9)	NP	NP
115 (51)	20 (6)	NP	NP
120 (53)	15 (5)	NP	NP
120 (53)	NP	NP	NP

NP = not permitted

2.2.10.3 Hail Resistance

2.2.10.3.1 Use FM Approved roof assemblies with a hail rating as recommended in Data Sheet 1-34, *Hail Damage*.

Note: Do not use assemblies that require the use of any type of aggregate surfacing such as pea gravel or slag surfacing, crushed stone, or large stone ballast for loose-laid single-ply roof covers in regions prone to tropical cyclones or as otherwise prohibited by Table 7.

2.2.10.4 Internal Fire Resistance for Noncombustible, Class 1, and Class 2 Steel Deck Assemblies

2.2.10.4.1 Use FM Approved roof assemblies that have an underside fire exposure rating of noncombustible or Class 1.

2.2.10.4.2 Where needed to limit the continuity of combustible construction, or where sprinkler protection is lacking, convert existing Class 2 steel deck roof assemblies to Class 1 by doing **one** of the following (A or B):

A. When re-roofing, strip all above deck roof components down to the bare steel deck (including adhesives).

B. Apply an FM Approved undercoating as found in the Approval Guide, Building Materials Section. If this alternative is chosen, do the following:

1. Clean the underside of the deck before coatings are applied.

2. Ensure FM Approved coatings are applied by applicators qualified to do so by the coating manufacturer.

3. Use under-coatings that contain water-soluble fire retardants only where occupancies have environmental controls and do not have high humidity (i.e., relative humidity less than 80%) because the fire retardant chemicals can leach out of the coating. Examples of high-humidity occupancies include, but are not limited to, paper machine buildings and swimming pools.

4. Do not use steel deck under-coatings where combustible residue can accumulate on the surface.

2.2.10.5 Vapor Retarders (Barriers)

The following recommendations cover vapor retarder applications that maintain Class 1 and appropriate wind uplift ratings (for an example see Figure 4.)

2.2.10.5.1 Do not use a vapor retarder directly on steel deck unless specifically included in Roof*Nav* assemblies for steel decks. Some vapor retarders are FM Approved only for use directly over concrete deck or over thermal barriers on steel deck; use directly over steel deck will cause the roof assembly to be Class 2.

2.2.10.5.2 Seal side and end laps where vapor retarders are used. Some systems are FM Approved with the retarder installed above a base layer of insulation.

2.2.10.5.3 Fastener penetration of the vapor retarder can be avoided by using an FM Approved assembly that has the vapor retarder and all components above it adhered to a mechanically fastened thermal barrier.

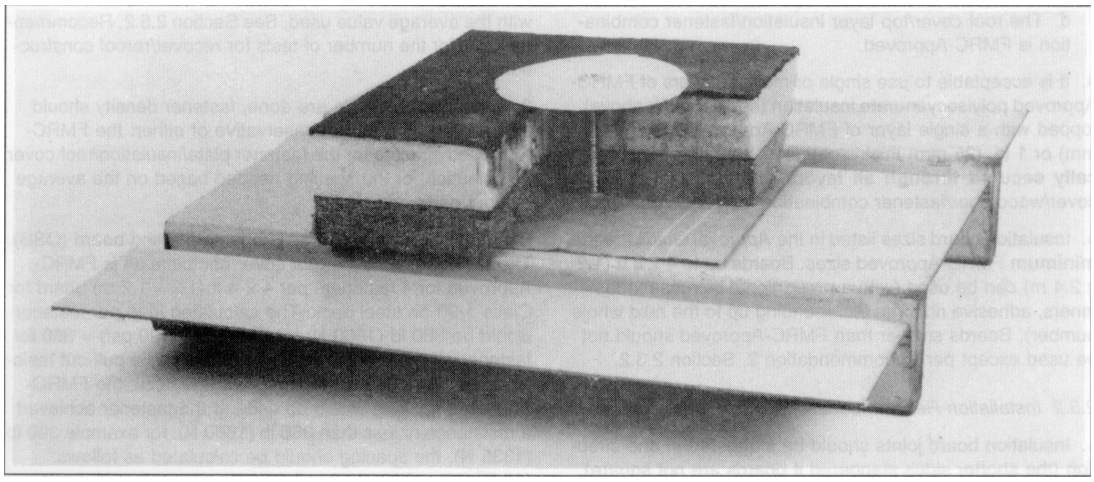

Fig. 4. One example of insulation and vapor retarder mechanically fastened to steel deck

2.2.10.6 Roof Insulation: Design Recommendations

2.2.10.6.1 Use insulation board sizes that are within required upper and lower limits as defined in Roof*Nav* assembly. Boards up to 4 × 8 ft (1.2 × 2.4 m) in plan dimension can be used except as noted in Section 2.2.10.6.2 (with a proportional increase in fasteners, adhesive ribbons, etc., rounding up to the next whole number). Do not use boards smaller than FM Approved except in accordance with Section 2.2.10.7.

2.2.10.6.2 Use a maximum insulation board size of 4 × 4 ft (1.2 × 1.2 m) if the board is adhered.

Exception: The following FM Approved boards may be adhered (to substrates other than steel deck) for board sizes up to 4 × 8 ft (1.2 × 2.4 m) in plan dimension:

- Any mineral wool
- Maximum ½ in. (13 mm) thick wood fiber or perlite
- Any gypsum-based board
- Maximum ¼ in. (6 mm) thick asphalt/glass cover board

2.2.10.7 Roof Insulation: Installation Recommendations

2.2.10.7.1 For all installations, support the two opposite sides of each board on steel deck flanges, as close as practical to the center of the flange, with a minimum bearing width of 1 in. (25 mm). Trim board edges if they veer off the flange center.

Prior to installing adhered roof covers. Stagger insulation board joints in one direction (with the shorter sides staggered if boards are not square). Staggering is not required if the roof cover or base sheet is mechanically fastened.

2.2.10.7.2 If insulation boards are cut (as is common at the roof edge to produce staggered joints), secure each piece with the proportionate number of fasteners and adhesive ribbons. Use the same contributory area, rounding up to the next whole number for fasteners, and rounding down the adhesive spacing.

2.2.10.7.3 Install only as many above-deck components as can be covered each working day. Seal loose roof cover edges at the end of each day to minimize moisture damage. Do not allow water to run in steel deck ribs under completed roof sections.

2.2.10.7.4 Set insulation on pallets or dunnage and use a breathable material to protect it from the weather and sunlight prior to installation.

2.2.10.8 Fasteners for Insulation and Roof Cover Securement: Design Recommendations

2.2.10.8.1 When tests are done to determine fastener pull-out strength, base the fastener density on the more conservative of (a) the FM Approved spacing for the fastener plate/insulation/roof cover combination, or (b) the spacing needed based on the average pull-out performance.

Example: An existing deck is oriented strand board (OSB). The fastener-insulation-roof cover combination is FM Approved for four fasteners per 4 × 4 ft (1.2 × 1.2 m) board for Class 1-90 (90 psf wind rating) on steel deck. The calculated load per fastener would be:

([4 ft^2/fastener][90 psf]= 360 lb (1600 N)/fastener)

If the proposed fastener achieved a pull-out resistance of 360 lb (1600 N) or more in the deck, use the FM Approved spacing. If the fastener achieved a resistance of less than 360 lb (1600 N), calculate the spacing as follows (using a pull-out resistance of 300 lb (1335 N) as an example):

(16 ft^2/board)(90 psf)/(300 lb/fastener) = 4.8 fasteners per board, so use five fasteners per board in the roof field.

Additional fasteners would be needed in Zone 2 and Zone 3.

2.2.10.8.2 Do not secure the base insulation or board layer directly to steel deck with adhesives in lieu of fasteners.

2.2.10.9 Fasteners for Insulation and Roof Cover Securement: Installation Recommendations

2.2.10.9.1 Install fasteners only through dry substrates. Wet constructions can cause deterioration of fasteners, including FM Approved corrosion-resistant fasteners.

Exception: Fasteners that are FM Approved for use in new LWIC, which are designed to be tolerant of the moisture present at the time of installation, are required to be driven from 2 to 5 days after casting the LWIC.

2.2.10.9.2 Fasteners must be driven perpendicular to the deck surface to be effective. Particular caution is needed with tapered insulations to enable the stress plate to rest flush on the insulation surface.

NOTE: If any portion of an insulation or cover board falls within Zone 2 or Zone 3, use the fastener spacing for Zone 2 or Zone 3 throughout the entire board. Likewise, for buildings that include a Zone 1', if a different fastener spacing is used for Zone 1' than for Zone 1 ensure any portion of an insulation or cover board that falls within Zone 1' uses the fastener spacing for Zone 1.

2.2.10.9.3 Use the manufacturer's proprietary installation tool to avoid over-driving or under-driving fasteners. A less desirable option for self-tapping or self-drilling screws is a properly adjusted screw gun that has a depth-sensing clutch.

2.2.10.9.4 Use the following minimum fastener embedment lengths:

A. Structural concrete: 1 in. (25 mm), with minimum 1-1/2 in. deep pilot hole (38 mm) for self-tapping screws

B. Wood deck: 1 in. (25 mm). Note: For 3/4 in. (19 mm) thick plywood deck, approximately 1/4 in. (6 mm) of the screw will protrude through the deck underside.

C. Steel deck: For screw-type fasteners in new construction, use the shortest screw that is at least 3/4 in. (19 mm) longer than the assembly being secured. Ensure fasteners engage the deck top flange. For re-covers with steel deck construction, the fastener must be long enough to be driven through the existing roof system and into the deck at least 3/4 in. (19 mm). While top flange engagement is recommended

in all cases, for re-cover construction, it is acceptable for insulation fasteners to engage the bottom flange of the deck. In that case it is critical that the fastener not be over-tightened as it may cause cracking of above-deck components at the deck rib opening. Ensure fasteners securing mechanically attached roof covers engage the top flange of the deck in all constructions.

For other deck types: Follow the FM Approval requirements and manufacturers' specifications.

2.2.10.9.5 Ensure insulation fastener placement is in accordance with Appendix C, Figures C.1.1, C.1.2, C.1.3, or C.1.4 for steel decks with a 6 in. (150 mm) module or rib spacing. If a particular insulation has a different FM Approved fastener pattern, use that. Each fastener must engage the intended deck flange. This results in a spacing tolerance of approximately ±1.5 in. (±38 mm) for wide-rib deck if the edge of the board is at the centerline of the deck top flange. For smooth-surfaced decks, such as plywood or concrete, or for steel deck in the direction of deck ribs, a maximum tolerance of ±1.5 in. (±38 mm) is acceptable.

For fastening densities not shown, the following guidelines apply:

A. Ensure edge fasteners are 6 in. (152 mm) from the board edges, with tolerance as above.

B. Ensure fasteners are evenly distributed over the board area.

C. Ensure all fasteners engage the top flange of steel deck. See Section 2.2.10.16 for re-cover and re-roof construction.2.2.10.9.6 For the installation of above-deck components over steel decks with an 8 in. (200 mm) module or rib spacing (such as 3 in. [75 mm] deep, Type N deck), use an FM Approved assembly that uses an 8 in. (200 mm) above-deck component spacing.

2.2.10.9.6 For the installation of above-deck components over steel decks with an 8 in. (200 mm) module or rib spacing (such as 3 in. [75 mm] deep, Type N deck), use an FM Approved assembly that uses an 8 in. (200 mm) above-deck component spacing.

Alternatively, ensure the maximum fastener spacing and/or contributory areas are not exceeded. For insulation or cover boards used with adhered roof covers where a maximum fastener spacing of 12 in. (300 mm) is required, reduce the spacing to 8 in. (200 mm) **and** do **one** of the following:

A. Where fasteners are used to secure above-deck components, such as insulation or cover boards that the roof cover is adhered to, do not reduce the fastener spacing in the opposite direction.

B. Where fasteners are used to secure plate-bonded roof covers, the spacing between fastener rows may be increased to provide an equivalent area if an analysis proves the deck span and securement is still adequate for the concentrated wind load as applied. Also, for plate-bonded, mechanically attached single-ply roof covers that use the same fasteners to secure the insulation and roof cover, see Section 2.2.10.11.

2.2.10.10 Single-Ply Membrane Covers

2.2.10.10.1 In areas prone to tropical cyclones (see DS 1-28) and where the design wind speed is 100 mph (45 m/s) or faster, if there is a roof-level exposure from windborne debris (such as glass in atriums or higher walls or sheet metal enclosures for mechanical equipment that extend above the exposed roof), and the occupancy is highly susceptible to water damage, use a roof cover and insulation or cover board immediately below it that provides a minimum puncture resistance rating of 10 Joules per the dynamic puncture resistance rating of roof covers test in FM Approval Standard 4470 (tested per ASTM D5635).

Where such rated materials are unavailable, increased resistance to puncture may be provided by using one or more of the following:

A. A multi-ply cover

B. A reinforced single-ply cover, preferably the thickest version within the range of the specific FM Approval

C. A dense cover board (such as moisture-resistant gypsum board) immediately below the roof cover

Loss experience has shown that even properly secured single-ply roof covers can be punctured or torn by windborne debris such as metal panels and broken glass, resulting in water damage to the building interior and contents.

2.2.10.10.2 Single-ply membranes can deteriorate when exposed to certain materials commonly discharged onto the roof. Also, separate these membranes from incompatible substrate materials. In particular, ensure single-ply membranes do not come into contact with asphalt or coal tar-based materials. Ensure EPDM

membranes are not directly exposed to gasoline, oil, solvents, or animal fats. Ensure PVC membranes are not in direct contact with EPS. Follow the manufacturer's recommendations for protection or separation.

2.2.10.10.3 Some FM Approved single-ply membranes are formulated with fire retardants on the top side only. Install these systems with that surface up. Membranes with this requirement are labeled on the underside "THIS SIDE DOWN/IN."

2.2.10.11 Mechanically Fastened Single-Ply (MFSP) Membrane Covers: Design Recommendations

This section is applicable to both in-seam and point-attached single-ply roof membranes.

2.2.10.11.1 Install a roof system in Zone 2 and Zone 3 using one of the following options:

A. Enhance FM Approved MFSP roof covers in Zone 2 and Zone 3 in a performance-based manner as follows:

1. Reduce the distance between rows of roof cover fasteners and stress plates or batten bars in Zone 2 and Zone 3 by dividing by the ratio of the required rating for the respective zone to Zone 1.

Example 1: A new mechanically fastened roof is proposed with the following parameters:

Table 2.2.10.11-1. Variables for Example

Variable/Factor	*Symbol*	*Value*
Height	H	30 ft (9.1 m)
Internal Pressure Coefficient	GC_{pi}	=/-0.18, Enclosed Building
Exposure C	Affects K_z	Affects K_z
Velocity Pressure Coefficient	K_z	0.98, Exposure C at 30 ft (0.91 m) high
Elevation Factor	K_E	1.0, near sea level
Topographic Factor	K_{zt}	1.0, for Flat Ground Slope (≤6°, 10%)
Directionality Factor	K_d	0.85, for square or rectangular building
Wind Speed	V	110 mph (49 m/s)
Region	DNA	Tropical Cyclone Prone
External Pressure Coefficient	GC_p	-3.2 (Zone 3), -2.3 (Zone 2), -1.7 (Zone 1), -0.9 (Zone 1'),
Safety Factor (SF)	Ω	2.0
Minimum Required FM Approved Roof Wind Uplift Rating	R_{NA}	(p * Ω) rounded up to the next highest 15 psf for roofs, for comparison to wind rated assemblies in RoofNav for roofs

Solution:

Step 1: First determine the velocity pressure q_h.

$q_h = 0.00256K_ZK_{ZT}K_DK_EV^2$

$qh = 0.00256(0.98)(1.0)(0.85)(1.0)(110)^2 = 25.8$ psf

$p = q_h * [GC_p - GC_{pi}] * I$

Table 2.2.10.11-2 Summary for Example

Zone	*q_h, psf*	*GC_{Pi}*	*GC_p*	*(GC_p - GC_{Pi})*	*IF*	Ω	*p * Ω*, psf	*R_{NA}, psf*	*Zone Dimensions from edge, ft (m)*
3	25.8	+0.18	-3.2	-3.38	1.15	2.0	201	**210**	18 x 18 x 6 ft (5.5 x 5.5 x 1.8)
2	25.8	+0.18	-2.3	-2.48	1.15	2.0	147	**150**	0 - 18 (0 - 5.5)
1	25.8	+0.18	-1.7	-1.88	1.15	2.0	112	**120**	18 - 36 (5.5 - 11)
1'	25.8	+0.18	-0.9	-1.08	1.15	2.0	64	**75**	> 36 (> 11)

The designer may select 2 different variations of FM Approved assemblies (the same components with reduced fastener spacing for higher wind ratings) - 75 psf for Zone 1' and 120 psf for Zone 1. For Zones 2

and 3, the roof cover fastener spacing may be reduced as a function of the roof cover fastener spacing FM Approved for the Zone 1 (not Zone 1') requirement as follows:

S_{r1} = roof cover fastener spacing as FM Approved for Zone 1 required rating, for this example the roof cover fasteners are 12 in. (0.3 m) OC within rows and rows are 3 ft 4 in. (1.02 m) OC., or 1 ft x 3.33 ft = 3.33 ft^2. Note in this case the deck is 1.5 in. (38 mm) deep and ribs are 6 in. (152 mm) OC.

S_{r2} = roof cover fastener spacing for Zone 2 as enhanced based on that FM Approved for the Zone 1 required rating

S_{r3} = roof cover fastener spacing for Zone 3 as enhanced based on that FM Approved for the Zone 1 required rating

R_{NA1} = FM Approved roof rating required for Zone 1

R_{NA2} = FM Approved roof rating required for Zone 2

R_{NA3} = FM Approved roof rating required for Zone 3

$S_{r2} = [(R_{NA1})\ (S_{r1})]/\ (R_{NA2}) = [(120)\ (3.33\ ft^2)]/\ (150) = 2.67\ ft^2$ or 1 ft OC within rows that are ≤ 2 ft 8 in. OC
$S_{r3} = [(R_{NA1})\ (S_{r1})]/(R_{NA3}) = [(120)\ (3.33\ ft^2)]/\ (210) = 1.90\ ft^2$ or 1 ft OC within rows ≤ 1 ft 10 in. OC

NOTES:

1. In all cases the rows of roof cover fasteners should run perpendicular to the deck ribs, and the deck should be designed to resist the design wind pressure applied at the roof cover fastener row spacing.
2. This solution does NOT apply to adhered roof assemblies as the increase in wind resistance is not always linear with respect to a decrease in fastener spacing. With adhered assemblies, insulation, cover boards, facers or roof coverings could delaminate before failure associated with a fastener does. With a mechanically fastened roof cover, failure is either due to pullout of the cover screw from the deck or tearing of the cover around the stress plate.

B. Prescriptively enhance FM Approved MFSP roof covers in Zone 2 and Zone 3 by reducing the distance between rows of roof cover fasteners and stress plates or batten bars using one of the following options, as applicable:

1. Zone 2: For single-plies fastened in rows, ensure the distance between rows is no more than 67% of the FM Approved spacing for the needed wind uplift resistance rating, or one row of intermediate fasteners is provided in between (See Example 2.)

2. Zone 3: For single-plies fastened in rows, the distance between rows is no more than 50% of the FM Approved spacing for the needed wind uplift resistance rating, or one row of intermediate fasteners is provided in between.

NOTE: Intermediate securement for single-plies fastened in rows may be provided by installing intermediate fastener rows over the roof cover and providing a seal strip over it, or by pre-fastening an FM Approved intermediate bonding strip in its center and adhering the underside of the roof cover to the top of both sides of the bonding strip.

3. Zone 2: For point-attached single-plies, decrease the spacing between fastener points in one or both directions. Ensure total tributary area to each fastener is no more than 67% of the FM Approved spacing. (See Example 3.)

4. Zone 3: For point-attached single-plies, decrease the spacing between fastener points in one or both directions. Ensure total tributary area to each fastener is no more than 50% of the FM Approved spacing. (See Example 3.)

Increased fastening density for single-ply membranes is obtained by using narrower sheets, underside securement methods, or through-fastening covered by seal strips. Fastening increase is not obtained by increasing the number of fasteners along each row, unless substantiated by FM Approval. Increased securement by reducing the distance between rows is recommended as it also reduces deck bending stress and provides better load distribution to the deck securement.

Example 2: A proposed row-attached MFSP assembly with FM Approved fastener spacing in rows 6 ft (1.8 m) on center and screws 6 in. (152 mm) on center in rows would use the following:

A. Zone 2: maximum 4 ft (1.2 m) on center row spacing, with 6 in. (152 mm) on-center screw spacing in rows. Using one intermediate row of fasteners may be a more practical alternative in some cases.

B. Zone 3: maximum 3 ft (0.9 m) on center row spacing, with 6 in. (152 mm) on-center screw spacing in rows.

In this case, rows of roof cover fasteners should extend perpendicular to the deck ribs in all areas to properly distribute the load to the deck and points of deck securement.

Example 3: A point-attached MFSP assembly with FM Approved fastener spacing of 24 x 24 in. (610 mm x 610 mm) could use the following:

A. Zone 2: A maximum spacing of 16 x 24 in (406 x 610 mm) is calculated. However, a 12 x 24 in. (305 x 610 mm) may be needed for steel deck applications, depending on deck rib direction.

B. Zone 3: A maximum spacing of 12 x 24 in (305 x 610 mm) is calculated.

2.2.10.11.2 When adhered single-ply roof covers are to be used, a peel stop is sometimes proposed. A peel stop typically consists of a batten bar mechanically fastened over the adhered cover (and sealed) to the roof deck around the entire roof perimeter within a few feet from the roof's edge. The purpose is to limit peeling of the roof cover from its substrate during a wind event. If peel stops are installed, no reduction in other wind-related recommendations should be made because of it.

2.2.10.12 Mechanically Fastened Single-Ply (MFSP) Membrane Covers: Installation Recommendations

2.2.10.12.1 Ensure all roof cover fasteners engage the top flanges of steel deck.

2.2.10.12.2 Install fasteners and batten bars or stress plates in rows perpendicular to steel deck ribs in all areas of the roof.

2.2.10.13 Multi-Ply Roof Covers: Installation Recommendations for Adhered Layers

2.2.10.13.1 Locate heating kettles so buildings and combustibles will not be exposed. Refer to DS 1-0 for additional guidance.

2.2.10.13.2 Apply asphalt at the equiviscous temperature (EVT) ±25°F (±14°C). Ensure asphalt is not continuously heated to or above the blowing temperature. These temperature limits are usually supplied by the manufacturer.2.2.10.13.3 Immediately roll felt into the asphalt. If the roll veers off line, cut it and start again. Broom organic felts in place.2.2.10.13.4 Keep rolls of felts dry and store them on end.

2.2.10.13.3 Immediately roll felt into the asphalt. If the roll veers off line, cut it and start again. Broom organic felts in place.

2.2.10.13.4 Keep rolls of felts dry and store them on end.

2.2.10.14 Multi-Ply Roof Covers with Mechanically Attached Base Sheets: Fastener Installation Recommendations

2.2.10.14.1 Enhance the securement for FM Approved base sheets using **one** of the following methods:

A. Use an assembly that has a wind rating that is FM Approved for the required Zone 3 rating, or FM Approved systems that have adequate wind ratings for the respective Zones.

B. Reduce the spacing between rows of fasteners by using one intermediate row in Zone 2 and Zone 3.

C. Reduce the area per fastener to no more than 67% of the FM Approved spacing in Zone 2, and no more than 50% of the FM Approved spacing in Zone 3 .

2.2.10.14.2 Install fasteners that engage lightweight insulating concrete (LWIC) no closer than 4 in. (100 mm) on center to avoid cracking the LWIC.

2.2.10.14.3 When ribbed deck, such as steel deck is used, the fastener spacing within fastener rows must be in even multiples of the deck rib spacing (6 in. [150 mm] for 1-1/2 in. [38 mm] deep deck) to ensure the fastener engages the top deck flange.

To adequately distribute the wind load to the roof deck and its securement and prevent deck buckling and deck securement failure, install fastener rows perpendicular to the deck ribs.

2.2.10.14.4 The above-deck portion of FM Approved roof assemblies may be used for the securement of mechanically fastened base sheets over non-FM Approved roof decks, such as wood, if the deck span and securement is adequate and the fastener pullout resistance from the deck is adequate for the rated pressure and area proposed (see Table 10). In cases where such assemblies are not available, use Tables 8, 9, and 10 and Fig. 5 for the design of base sheet fastening. Note that it will likely be more cost-effective to use FM Approved above-deck components, which may provide more resistance per fastener.

Perform field pull-out tests (see Section 2.2.10.16.4.3) of the proposed base sheet fastener to determine pull-out performance. Base sheet fastener spacing and head or disk size is then determined per Tables 8, 9, and 10.

Table 8. Base Sheet Fastener Coverage for Non-FM Approved Combinations, ft^2 per Fastener

Zone 1 Uplift Pressure (Data Sheet 1-28)	*< 21 psf (< 1.0 kPa)*			*21 - 30 psf (1.0 - 1.4 kPa)*			*31 - 45 psf (1.48 - 2.15 kPa)*		
Roof Area	*Zone 1*	*Zone 2*	*Zone 3*	*Zone 1*	*Zone 2*	*Zone 3*	*Zone 1*	*Zone 2*	*Zone 3*
Fastener Strength, lb(N)									
30 (135)	0.75	0.48	0.36	-	-	-	-	-	-
40 (180)	1.00	0.64	0.48	-	-	-	-	-	-
50 (220)	1.25	0.80	0.60	-	-	-	-	-	-
60 (265)	1.50	0.96	0.71	1.00	0.67	0.50	-	-	-
70 (310)	1.75	1.12	0.83	1.17	0.78	0.58	-	-	-
80 (355)	2.00	1.28	0.95	1.33	0.89	0.67	-	-	-
90 (400)	2.00	1.44	1.07	1.50	1.01	0.75	1.00	0.67	0.50
100 (445)	2.00	1.60	1.19	1.67	1.12	0.83	1.11	0.74	0.56
110 (490)	2.00	1.75	1.31	1.83	1.23	0.92	1.22	0.82	0.61
120 (535)	2.00	1.91	1.43	2.00	1.34	1.00	1.33	0.89	0.67
140 (625)	2.00	2.00	1.67	2.00	1.56	1.17	1.56	1.04	0.78
160 (710)	2.00	2.00	1.90	2.00	1.79	1.33	1.78	1.19	0.89

1. To convert to m^2 per fastener, multiply by 0.0929.
2. When coverage is less than 0.50, a stronger fastener is suggested. Ensure coverage does not exceed 2.00 unless FM Approved.
3. Less than 40 lb (180 N) pull-out per fastener may indicate unsound deck or improper fastener. Consult manufacturer's specifications.
4. If the building has a minimum 3 ft (0.9 m) high continuous parapet and the roof slope is ≤ 10° (167 mm/m), the corner areas may be fastened in the same manner as the perimeter.
5. For Zone 1' roof area analysis, substitute Zone 1' pressure where Zone 1 is noted in the table, then follow fastener coverage as stated in Zone 1 column entries. NOTE: DO NOT base Zone 2 and Zone 3 fastener coverages relative to Zone 1' pressures.

Table 9. Standard 36 in. (0.9 m) Base Sheet Fastening (Non-FM Approved Components). (See Fig. 5.)

Fastener Coverage, ft^2/fastener (Table 8)	*Maximum Fastener Spacing, in. (mm) On Center*			
	One Intermediate Row		*Two Intermediate Rows*	
	At Laps	*Between Laps*	*At Laps*	*Between Laps*
0.30-0.50	—	—	4 (102)	6 (179)
0.51-0.70	4 (102)	7 (179)	5 (127)	11 (279)
0.71-0.90	5 (127)	12 (305)	7 (179)	13 (330)
0.91-1.10	6 (152)	14 (356)	8 (203)	16 (406)
1.11-1.30	8 (203)	14 (356)	10 (254)	20 (508)
1.31-1.50	10 (254)	14 (356)	12 (305)	22 (559)
1.51-1.75	12 (305)	16 (406)	12 (305)	22 (609)
1.76-2.00	12 (305)	20 (508)	—	—
2.01-2.50	12 (305)	24 (609)	—	—
2.51-3.00	12 (305)	24 (609)	—	—
3.01-4.00	12 (305)	24 (609)	—	—

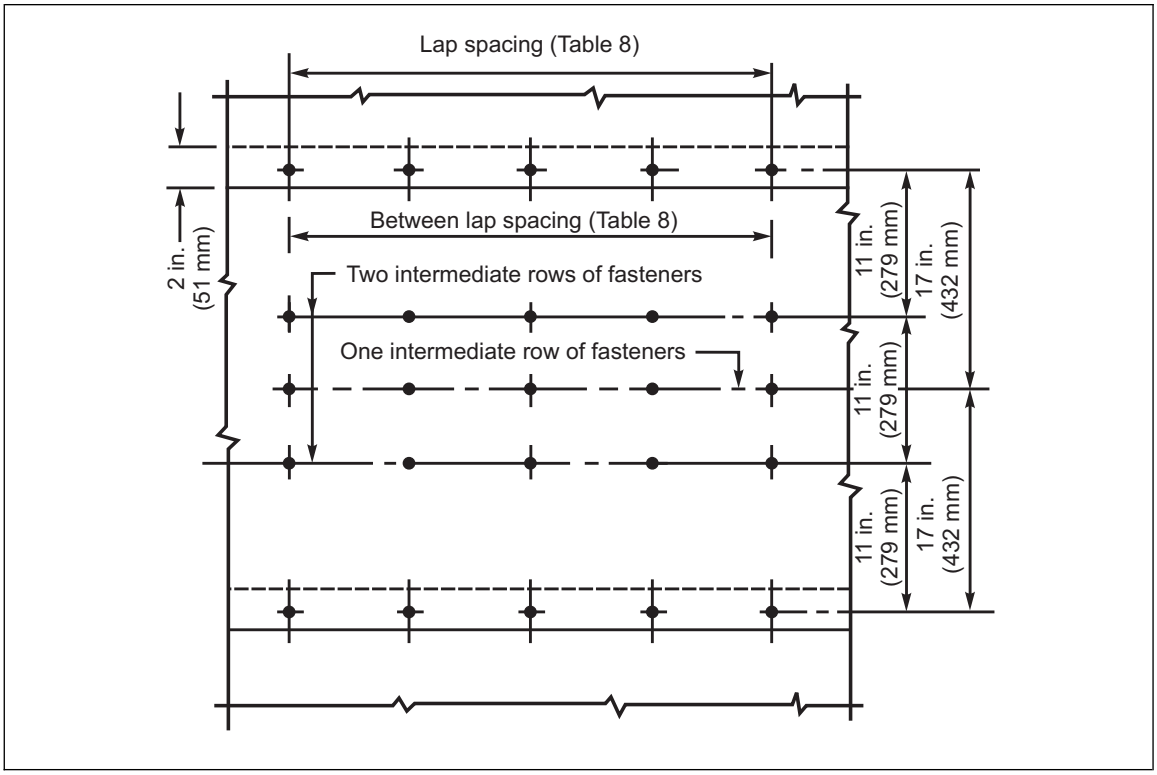

Fig. 5. Fastener layout for 36 in. (914 mm) wide base sheet

Table 10. Minimum Metal Disk or Fastener Head Size (Base Sheet Fasteners)

Fastener Pull-Out Strength, lb (N)	*Minimum Disk/Head Diameter, in. (mm)*
< 45 (200)	1.00 (25)
45-60 (200-265)	1.25 (32)
61-70 (270-310)	1.50 (38)
71-80 (315-355)	1.75 (44)
81-100 (360-445)	2.00 (51)
101-120 (450-535)	2.50 (64)
> 120 (535)	3.00 (76)

2.2.10.14.4.5 Where FM Approved base sheet fasteners are not available, ensure base sheet fasteners have metal heads or disks.

Example Problem: Wood Deck, Nailed Base Sheet

Given: The Zone 1 uplift pressure (see Data Sheet 1-28, Wind Design) is 28 psf (1.35 kPa) and the fastener pull-out strength is 120 lb (535 N). From Table 8, 10th line (120 lb [535 N]), select maximum coverage area per fastener as follows:

Zone 1 = 2.00 ft^2 (0.2 m^2)
Zone 2 = 1.34 ft^2 (0.1 m^2)
Zone 3 = 1.00 ft^2 (0.09 m^2)

From Table 9, select base sheet fastener spacing:

Area	*At Laps*	*Between Laps*
Zone 1	12 in. (305 mm)	20 in. (508 mm)
Zone 2	10 in. (254 mm)	14 in. (356 mm)
Zone 3	6 in.(152 mm)	14 in. (356 mm)

Per Table 10, the fastener head or disk size needs to be at least 2.5 in. (64 mm) in diameter.

2.2.10.15 Liquid- or Spray-Applied Roof Systems

2.2.10.15.1 Ensure the roof surface is clean and dry prior to applying polyurethane foam or a roof coating.

2.2.10.15.2 Test polyurethane foam before applying to the deck or other substrate to ensure its density is in accordance with FM Approval criteria. Apply a thickness of foam that is within the thickness range it is FM Approved for.

2.2.10.16 Re-Cover and Re-Roof Construction

2.2.10.16.1 Re-roof construction is always preferred to re-cover construction due to the potential for moisture damage with re-cover construction from existing wet insulation inadvertently left in place. Also, re-covering adds additional dead weight to the structure and adds fuel to the roof assembly. Re-roofing as opposed to re-covering also provides a more practical opportunity to improve deck securement, if needed. If significant additional weight is added, see DS 1-54.

2.2.10.16.2 When re-roofing, inspect the existing deck securement and, if necessary, fasten the deck from the top surface in accordance with Section 2.2.3 prior to installation of the above-deck components. Analyze the existing deck to ensure the span is adequate for the needed wind load and the proposed above-deck components.

2.2.10.16.3 When reroofing over a steel deck where the original base layer had been adhered to the deck, do one of the following:

A. Use an assembly specifically FM Approved for re-roofing that allows up to 15 lb per square (72 kg/100 m^2) of asphalt to remain on the deck.

B. Remove all asphalt from the deck and install an assembly that is FM Approved for new construction.

2.2.10.16.4 Re-Cover Construction: Existing Components Remain

2.2.10.16.4.1 Limit roof re-covers so there is only one existing roof system. If more than one roof system is in place (i.e., building has already been re-covered), the existing above-deck components should be stripped before adding additional roofing material.

2.2.10.16.4.2 If re-cover construction is considered, do the following:

A. Have a moisture scan conducted by a qualified roof consultant to detect any high-moisture content. Roof cover blistering or rusting deck may be an indication that the existing insulation is wet.

B. Where moisture problems are encountered, consider re-roofing as opposed to re-covering.

C. A less-desirable alternative is to replace all wet materials and cut out blisters prior to application of the re-cover roof system.

2.2.10.16.4.3 Perform fastener pull-out tests in accordance with ANSI/SPRI FX-1, *Standard Field Test Procedure for Determining the Withdrawal Resistance of Roofing Fasteners,* prior to re-cover or re-roofing projects if the fasteners are to engage the following existing substrates:

A. Gypsum, cementitious wood fiber, wood, or existing LWIC not meeting criteria in Section 2.2.9

B. Other deck types if the integrity of the deck or pullout performance of the fastener is in question.

2.2.10.16.4.4 Use an FM Approved re-cover or re-roofing system, as needed. Refer to the Roof*Nav* glossary for a definition of re-roof and re-cover systems and the limits of their Approval.

2.2.10.16.4.5 Ensure the thickness of the insulation used in the re-cover assembly is within the FM Approval limits. Most assemblies are limited to a maximum 1 in. (25 mm) thick roof insulation over steel deck. A greater thickness may affect the Class 1 fire rating of the completed assembly. Installation of an FM Approved Class 1 re-cover assembly over an existing Class 2 roof system will not upgrade the assembly to Class 1. However, it would be possible to upgrade the external fire resistance rating to Class A with the addition of an FM Approved roof cover system.

2.2.10.16.4.6 Do not pile broomed gravel from the roof in one area. This can overload structural members, causing collapse.

2.2.10.16.4.7 Do not use re-cover constructions using additional plies adhered directly to an existing roof cover unless the entire assembly is specifically FM Approved in that manner. This could result in the assembly having a Class 2 underside fire exposure rating, or in an increase in the exterior fire hazard of roof assembly.

2.2.10.16.4.8 Use a re-cover that is adhered to the existing cover only when the following conditions are satisfied:

A. Remove all gravel (if any) from the roof surface.

B. Conduct uplift tests on the existing roof per Data Sheet 1-52. (Tests can be waived if resistance is known.) If the uplift resistance of the existing assembly is inadequate or unknown and uplift tests will not be done (or are done and fail), mechanically fasten the existing roof or new components above.

2.2.10.17 Ballasted Single-Ply Membranes: Design Recommendations

2.2.10.17.1 FM Approvals does not Approve ballasted systems. If a ballasted system is to be used, select components that are FM Approved for use together as shown in a specific Roof*Nav* assembly. In lieu of fasteners or adhesives used to secure above-deck components, use ballast in accordance with this data sheet to provide wind resistance.

2.2.10.17.2 Do not use stone-ballasted roofs on the following:

A. Buildings taller than 150 ft (46 m)

B. In areas prone to tropical cyclones

C. In areas with design wind speeds ≥ 100 mph (45 m/s) (see Data Sheet 1-28, *Wind Design*)

D. Beyond the acceptable limits shown in Tables 12 and 13

These limitations do not apply to paver ballasted systems.

2.2.10.17.3 Ensure stone ballast in loose-laid systems is clean, smooth, well-rounded gravel meeting the gradation requirements of Standard Size No. 3 for Coarse Aggregate per ASTM D448 (nominal 1 to 2 in. [25 to 50 mm] diameter). Refer to Table 11.

Table 11. Stone Gradations: Percentage Passing Each Sieve By Weight (ASTM D448)

	Nominal	*Sieve Opening, in. (mm)*							
Size No.	*Size, in. (mm)*	3 (76)	2-1/2 (63)	2 (50)	1-1/2 (38)	1 (25)	¾ (19)	½ (13)	3/8 (10)
2	2-1/2 to 1-1/2 (63-38)	100	90-100	35-70	0-15	-	0-5	-	-
3	2 to 1 (50 to 25)	-	100	90-100	35-70	0-15	-	0-5	-
4	1-1/2 to ¾ (38 to 19)	-	-	100	90-100	20-55	0-15	-	0-5

2.2.10.17.4 Ensure the density of stone ballast is approximately 165 pcf (2650 kg/m^3). Do not use lightweight stone such as limestone.

2.2.10.17.5 Apply stone ballast per Table 12 or 13. Install paver blocks per Tables 14 through 17. Ensure square edge pavers are a minimum of 1 ft^2 (0.1 m^2). Ensure beveled/strapped pavers are a minimum of 0.89 ft^2 (0.08 m^2) (8 × 16 in. [203 × 404 mm]). All weights are the minimum recommended.

2.2.10.17.6 For ballast application only, Zone 2 and Zone 3 dimensions should be equal to at least 60% of the mean roof height, but not less than 8.5 ft (2.6 m) or 4% of the lesser plan dimension.

2.2.10.17.7 Have the load capacity of the roof verified by a registered civil or structural engineer. The structure must be capable of supporting the dead weight of the roof system and ballast considering other gravity loads, without creating or aggravating a ponding problem.

2.2.10.17.8 Ensure the roof slope is no more than 10°, 2 in./ft (167 mm/m).

2.2.10.17.9 Stone ballast can be used in Zone 1' and Zone 1 with pavers used at Zone 2 and Zone 3 if the appropriate weights of stones and pavers are used in each area.

2.2.10.17.10 Ensure flashing systems used with pavers secure the pavers at the building edge.

2.2.10.18 Ballasted Single-Ply Membrane: Installation Recommendations

2.2.10.18.1 Extreme care is needed when transporting ballast to the roof. Stop the conveying machine if ballast begins to pile up. Distribute ballast to the specified weight before restarting the conveying machine.

2.2.10.18.2 Inspect ballasted roofs semi-annually and after storms. Redistribute scoured ballast. Gravel scour greater than 50 ft^2 (5 m^2) is considered excessive. See Data Sheet 1-30, *Repair of Wind Damaged Single- and Multi-Ply Roof Systems,* if this type of damage occurs.

Table 12. Weight Needed of No. 3 Round Stone Ballast, Parapet ≤ 36 in. (914 mm)

Uplift Pressure (psf) Data Sheet 1-28	*Ballast Weight, (psf)*					
	Steel or Pre-Cast Panel Deck			*Cementitious Wet Fill Deck*		
	Zone 1	*Zone 2*	*Zone 3*	*Zone 1*	*Zone 2*	*Zone 3*
≤ 20	10	12	15	10	10	10
21 to 25	12	15	15	10	12	12
26 to 30	12	15	18	12	12	15
31 to 35	Use FM Approved 1-90 System			12	15	18
36 to 45	Use FM Approved 1-90 System			Use FM Approved 1-90 System		

Table 13. Weight Needed of No. 3 Round Stone Ballast, Parapet > 36 in. (914 mm)

Uplift Pressure (psf) Data Sheet 1-28	*Ballast Weight, psf*					
	Steel or Pre-Cast Panel Deck			*Cementitious Wet Fill Deck*		
	Zone 1	*Zone 2*	*Zone 3*	*Zone 1*	*Zone 2*	*Zone 3*
≤ 20	10	10	12	10	10	10
21 to 25	12	12	12	10	10	12
26 to 30	12	12	15	12	12	12
31 to 35	12	15	18	12	12	15
36 to 45	Use FM Approved 1-90 System			15	15	18

Table 14. Weight Needed of Paver Blocks: Not T&G, Beveled or Strapped to Each Other, Parapet ≤ 36 in. (914 mm)

Uplift Pressure (psf) Data Sheet 1-28	*Paver Weight, psf*					
	Steel or Pre-Cast Panel Deck			*Cementitious Wet Fill Deck*		
	Zone 1	*Zone 2*	*Zone 3*	*Zone 1*	*Zone 2*	*Zone 3*
≤ 15	12	12	15	12	12	12
16 to 20	12	15	20	12	12	15
21 to 25	12	18	23	12	15	18
26 to 30	15	23	30	12	18	21
31 to 35	Use FM Approved 1-90 System			15	21	23
36 to 45	Use FM Approved 1-90 System			Use FM Approved 1-90 System		

Table 15. Weight Needed of Paver Blocks: Not T&G, Beveled or Strapped to Each Other, Parapet > 36 in. (914 mm).

Uplift Pressure (psf) Data Sheet 1-28	*Paver Weight, psf*					
	Steel or Pre-Cast Panel Deck			*Cementitious Wet Fill Deck*		
	Zone 1	*Zone 2*	*Zone 3*	*Zone 1*	*Zone 2*	*Zone 3*
≤ 15	12	12	12	12	12	12
16 to 20	12	12	15	12	12	12
21 to 25	12	15	18	12	12	15
26 to 30	15	18	21	12	15	18
31 to 35	Use FM Approved 1-90 System			15	18	21
36 to 45	Use FM Approved 1-90 System			Use FM Approved 1-90 System		

Table 16. Weight Needed of Paver Blocks: T&G, Beveled or Strapped to Each Other, Parapet ≤ 36 in. (914 mm)

Uplift Pressure (psf) Data Sheet 1-28	*Paver Weight, psf*					
	Steel or Pre-Cast Panel Deck			*Cementitious Wet Fill Deck*		
	Zone 1	*Zone 2*	*Zone 3*	*Zone 1*	*Zone 2*	*Zone 3*
≤ 15	12	12	12	12	12	12
16 to 20	12	12	15	12	12	12
21 to 25	12	15	15	12	12	12
26 to 30	12	15	18	12	12	15
31 to 35	15	18	18	12	15	18
36 to 40	Use FM Approved 1-90 System			12	18	18

Table 17. Weight Needed of Paver Blocks: T&G Beveled or Strapped to Each Other, Parapet > 36 in. (914 mm)

Uplift Pressure (psf) Data Sheet 1-28	*Paver Weight (psf)*					
	Steel or Pre-Cast Panel Deck			*Cementitious Wet Fill Deck*		
	Zone 1	*Zone 2*	*Zone 3*	*Zone 1*	*Zone 2*	*Zone 3*
≤ 15	12	12	12	12	12	12
16 to 20	12	12	12	12	12	12
21 to 25	12	12	12	12	12	12
26 to 30	12	12	12	12	12	12
31 to 35	15	15	18	12	12	12
36 to 45	15	18	18	12	12	12

Note 1. For all tables, to convert to kg/m^2, multiply by 4.88.
Note 2. Uplift pressure is that determined from Data Sheet 1-28, *Wind Design*, and is not factored.

2.3 Inspection, Testing, and Maintenance

2.3.1 At FM client locations in tropical cyclone-prone regions where the basic wind speed is 100 mph (45 m/s) or faster, conduct field uplift tests or provide full-time supervision in accordance with DS 1-52 for all new, re-roof, or re-cover installations.

2.3.2 Inspect roof systems and flashing semi-annually and after storms. During inspection, note and repair any holes or deterioration of the covering, opened seams, backed-out fasteners, loose anchorages, loose flashing, membrane shrinkage, etc. Replace any wet insulation when making roof repairs. Inspect and clean drains as needed. Maintain written records.

3.0 SUPPORT FOR RECOMMENDATIONS

3.1 Supplemental Information

3.1.1 Class 1 and Class 2 Roof Decks

In 1953, a serious fire occurred in which fire spread along the underside of the insulated steel roof deck of a large industrial facility. There were few combustibles in the building. The fire started at floor level and heated the underside of the deck. Hot gases (from combustible above-deck components) were forced down through the deck joints and became ignited. The fire continued to feed on the hot gases and spread along the underside of the roof throughout the building. The entire building and contents were lost.

Such losses led to the development of the FM Approved Class 1 insulated steel deck roof, in which only insulations of relatively low combustibility, used with restricted quantities of adhesive, were recommended. As a result, fire losses from the burning of insulated steel deck roofs have decreased significantly.

The use of mechanical fasteners, as opposed to adhesives, to secure materials to the deck, further decreases the fire hazard of newly constructed roofs. It should be noted that many Class 2 roofs are still in existence. Loss experience involving Class 2 insulated steel deck in recent years has been favorable because most are protected with sprinklers.

While flammable gases are liberated from both Class 1 and 2 roof decks, there are sufficient combustibles only in Class 2 roof decks to produce a self-propagating fire across the roof underside. The fire propagates without additional heat input from the occupancy fire. This can result in complete destruction of the building contents. Sprinkler protection or an FM Approved roof deck undercoating is needed to prevent fire spread under Class 2 roofs.

Class 2 steel deck roofs can be upgraded to Class 1 using one of the following methods:

A. Remove all above-deck components, including asphalt, down to the deck and mechanically fasten a roof system that is FM Approved for new construction on the deck.

B. Apply an FM Approved roof deck undercoating to the entire steel deck underside. These coatings enable Class 2 roof decks to meet the heat release rate limits of Class 1 roofs. Under-coatings are only FM Approved and recommended for use on steel decks.

3.1.2 Wind Uplift Resistance, Non-Ballasted Roof Covers

3.1.2.1 Zone 2 and Zone 3 Enhancements for Mechanically Fastened, Multi-Ply Roof Covers

For a mechanically attached roof, the spacing between rows of fasteners should not exceed 67% of the FM Approved spacing for Zone 1 in Zone 2 and 50% of the FM Approved spacing for Zone 1 in Zone 3. This accounts for the higher external pressure coefficients in those areas. From a practical standpoint, using a multi-ply cover that is FM Approved when fastened in or through the seams only equates to adding one intermediate row of roof cover fasteners in both Zone 2 and Zone 3. Rows of fasteners should run perpendicular to deck ribs to evenly distribute the wind load to points of deck securement. Spacing within rows can be the same throughout.

When the Zone 1 FM Approved system already has one intermediate row and the spacing is 12 in. (300 mm) in the seams and 12 in. (300 mm) in one staggered intermediate row, the average fastener spacing is about 1.5 ft^2 (0.14 m^2) for Zone 1, and should be no more than 1.0 ft^2 (0.09 m^2) in Zone 2 and 0.75 ft^2 (0.07 m^2) in Zone 3. The spacing between fasteners in rows should be in multiples of 6 in. in order to hit the top flanges of 1-1/2 in. (38 mm) deep steel deck. For Zone 2, the fasteners could be placed 6 in. (150 mm) on center in the seams and 12 in (300 mm) on center in the intermediate row (1.0 ft^2 [0.09 m^2] per fastener). For Zone 3, the fasteners could be place 6 in on center (150 mm) in the seams and 6 in (150 mm) on center in the intermediate row (0.75 ft^2 [0.07 m^2] per fastener).

When the FM Approved system to be used in Zone 1 of the roof already requires one or more intermediate rows of roof cover fasteners, this becomes a little more complicated. If the Zone 1 FM Approved system already has two intermediate rows and the FM Approved spacing is 12 in. (300 mm) in the seams and 18 in. (450 mm) in two staggered intermediate rows, the average fastener spacing is about 1.25 ft^2 (0.12 m^2) for Zone 1, and should not exceed 0.84 ft^2 (0.08 m^2) in Zone 2 and 0.63 ft^2 (0.06 m^2) in Zone 3. The spacing between fasteners should be in multiples of 6 in. (150 mm) in order to hit the top flanges of 1-1/2 in. (38 mm) deep steel deck.

For Zone 2, the fasteners could be placed 6 in. on center (150 mm) in the seams and 12 in. (300 mm) on center in two staggered intermediate rows, or 12 in. (300 mm) on center in the seams and in three staggered intermediate rows (0.75 ft^2 [0.07 m^2] per fastener). If fasteners go through both layers at the seam, then the latter alternative is recommended.

For Zone 3, the fasteners should be placed 6 in. (150 mm) on center in the seams and 6 in (150 mm) on center in two intermediate rows (0.50 ft^2 [0.05 m^2] per fastener).

An adhered roof covering obtains its uplift resistance from the tensile strength of the adhesive bond between the roof cover and insulation. When failure occurs, the result is separation from the material below, or fractured insulation boards. Further uplift forces lead to peeling of the cover, which can result in the rapid delamination of large areas of the roof covering.

FM testing has shown that fastener placement on the insulation board has a significant effect on the ultimate strength of the assembly. For example, research conducted with 4 × ft 4 ft × 1.5 in. (1.2 m × 1.2 m × 38 mm) polyisocyanurate insulation covered with a BUR showed a dramatic change in performance simply by rearranging the fasteners on the boards. For both tests, the fastening density was 1 fastener per 1.78 ft^2 (0.17 m^2). Figures 6a and 6b show the fastener placement for each test.

The test of pattern 6a failed at 105 psf (5.0 kPa) by fracture of the insulation board. The test of pattern 6b failed at 160 psf (7.6 kPa) by screws pulling out of the deck.

Mechanically attached single-ply membranes are secured by fasteners that directly engage the deck. This results in a concentration of forces that are transmitted into the fastener. There are also high stresses in the membrane at the fastener. If one fastener fails, the load will be transferred to adjacent fasteners, usually causing those fasteners to be overstressed.

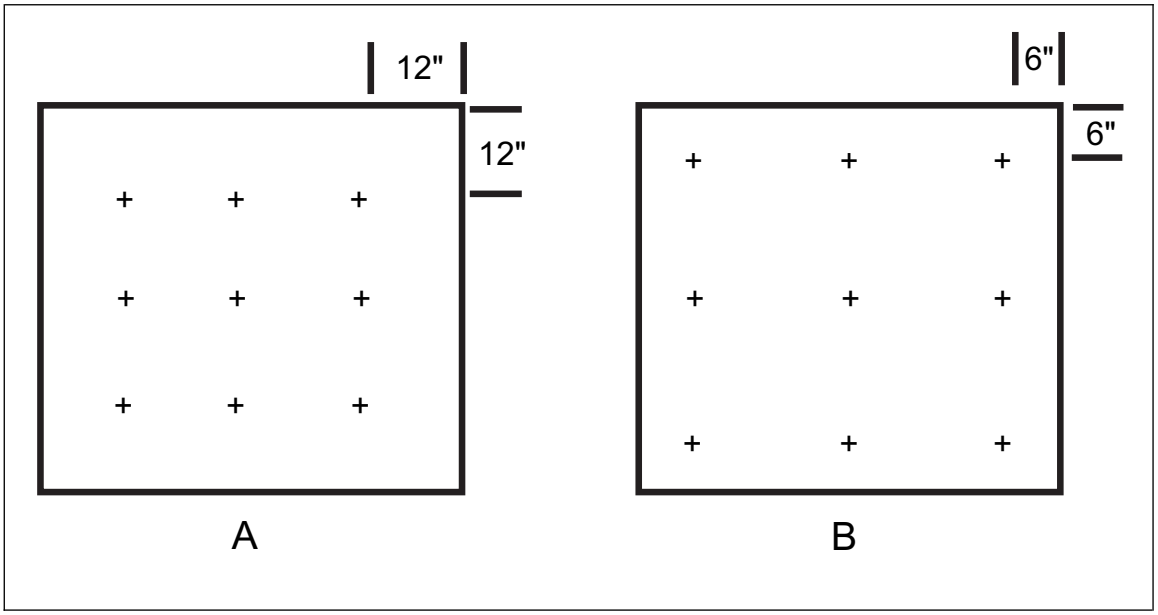

Fig. 6a/6b. 4 × 4 ft (1.2 × 1.2 m) insulation boards secured with nine fasteners per board.

If fasteners are driven into the bottom flange of steel deck, the moment arm is at least 1.5 in. (38 mm) longer (the depth of the steel deck) than with top flange engagement. This longer moment arm can result in increased fastener back-out and failure.

3.1.2.1.1.Vapor Retarders

For adhered above-roof covers, when insulation is adhered to the top surface of a vapor retarder, the vapor retarder is part of the wind load path and, as such, its strength and securement are critical. When roof covers are adhered to insulation or cover boards that are fastened through the vapor retarder into the deck, the wind load applied to the roof cover by-passes the vapor retarder.

3.1.2.2 Cold Process Adhesives in Tropical Cyclone-Exposed Areas

The installation of roof systems in regions prone to hurricanes, typhoons, and tropical cyclones needs to be completed in sufficient time for the adhesive to cure prior to exposure by these storms. While it is sometimes difficult to control installation schedules, every effort should be made to minimize the exposure.

The start of hurricane season is June 1 north of the equator, and November 1 south of the equator. Hurricane seasons last six months and the worst storms typically occur during the middle of the season. For some adhesive types used with multi-layer roof systems, a minimum of 28 days is required for curing. That is the maximum cure time allowed prior to lab testing.

While local weather conditions can vary exact cure times, allowing 28 days helps to ensure the strength is comparable to that of the sample that was lab tested. Single-ply covers adhered with contact adhesive may be near full strength in about 7 days. Depending on local conditions, types of materials, and even the number of roof cover layers, some cold-process, multi-ply assemblies may continue to increase in strength for 60 days or more after the installation. Scheduling to avoid hurricane season also allows more time for curing prior to conducting field uplift tests, increasing the probability of success.

Consult the roof material manufacturer regarding information relating to the percentage of ultimate strength for the assembly in question vs. cure time. In no case should an assembly be used where it may be exposed by a tropical storm before reaching at least 50% of its ultimate strength.

3.1.3 Wind Uplift Resistance, Ballasted Systems

It is not possible to evaluate the uplift resistance of ballasted systems in the same manner as adhered coverings. The criterion for failure for the latter system is separation of the covering from the insulation, or the insulation from the deck. Ballasted systems fail these criteria by definition.

Uplift forces are not uniform over the entire roof. Properly designed ballasted systems take advantage of the average uplift force in a given roof area. The membrane distributes the uplift force, allowing the ballast to be effectively used. Extreme winds, however, may cause gravel scour, paver dislodgement, and minor ballooning of the covering. The gravel will pile up around the edges of the ballooned area. The ridges of stone usually limit the scouring to a small area. Larger ballooned areas can be expected if the roof deck has joints (steel, wood, precast panel, etc.).

If the deck is monolithic, very little air can flow up through the deck and act on the underside of the covering. In addition, a parapet at least 3 ft (0.9 m) high will help to reduce ballast scour.

3.1.4 External Combustibility

FM Approved roof covers are required to pass the ASTM E108 external fire test.

During installation, unique fire hazards can occur with some single-ply membranes. Low flash point cleaning solvents and solvent-based adhesives can be ignited and are particularly hazardous when vapor is confined, such as at expansion joints. The installation of torch-applied membranes is an inherent fire hazard; see DS 1-33 for additional information.

3.1.5 Re-Cover Construction

As recommended, all existing wet material should be removed from an existing roof system prior to reroofing. If only a small amount of existing material is wet, it is acceptable to remove only the wet areas to the deck, replace the material with a properly secured insulation FM Approved for reroof or new construction on that deck, and then apply an FM Approved re-cover system over the entire roof. There is no preference for either removing all existing materials or only the wet materials, provided no wet materials remain. Roof vents are not considered effective in removing existing moisture.

A maximum of one re-cover roof system is recommended, for the following reasons:

A. For other than noncombustible decks, if more than one re-cover system is installed, the roof would be considered Class 2.

B. Additional re-cover systems increase the possibility of trapped moisture.

C. Most building codes allow only one re-cover system.

3.1.6 Wind Uplift

See Data Sheet 1-28 for guidance on determining uplift pressure.

DS 1-28 offers various **optional** design levels for winds that meet or exceed the basic design wind speed. The intent is to provide an increase in building performance for various incremental construction cost increases, and the guidance takes into consideration the likelihood of various failure modes occurring based on past experience.

It is extremely important to recognize that wind blowing over a roof exerts varying uplift forces on different areas of the roof. The maximum uplift force occurs at Zone 3 when the wind blows at an angle of about 45° to the roof (roughly along the diagonal). The maximum uplift force along the windward Zone 2 region occurs when the wind blows at 90° to Zone 2. Actual pressure coefficients for Zone 2 and Zone 3 vary, depending on the building height, parapet height, roof slope, etc.

The 2019 revision of Data Sheet 1-28 and 1-29 introduced a new interior roof zone, Zone 1', and altered the shape of the former perimeter and corner, now referred to as Zone 2 and Zone 3. Refer to Data Sheet 1-28, Section 3.2.2 for a visual representations of roof zones.

Zone 1':

Roof Zone 1' is not present on all buildings. It is located on buildings within stated parameters of roof slope, building size, and orientation as specified within Data Sheet 1-28. For buildings that do not include Zone 1', the entire roof area inboard of Zone 2 and Zone 3 is Zone 1. For buildings that include Zone 1', Zone 1' is the inboard roof area of a narrow, rectangular, perimeter strip-shaped Zone 1, where Zone 1 is located immediately inboard of Zone 2 and Zone 3. Due to significant differences in the required wind uplift pressures resistance between Zone 1' and other roof zones, there are limited options with regard to roof deck securement and above-deck roof components in Zone 1' relative to other Zones. It is acceptable to use the

same construction in Zone 1' as used in Zone 1. This is a conservative approach regarding wind uplift resistance. The other option for Zone 1' is to treat it completely separately from the other roof zones. In this scenario, the wind uplift pressure for Zone 1' is determined from Data Sheet 1-28 and guidance is followed for Zone 1 from Data Sheet 1-29 using the wind uplift pressure for Zone 1' within the location of Zone 1' on the roof only. (For example, if a wind rating of 60 psf is required for Zone 1', follow all guidance in the data sheets stated for Zone 1 at a rating of 60 psf for roof deck securement and above-deck roof components in the Zone 1' area of the roof. Then, for Zones 1, 2 and 3 of the roof, follow guidance as stated at the appropriate pressures for the respective zone.) NOTE: There is no relationship between Zone 1' and other zones for prescriptive enhancement recommendations. Subsequently, for roof deck securement and above-deck roof components in Zones 1, 2 and 3, guidance should be followed as stated in those areas.

Zone 2 and Zone 3:

To compensate for increased pressures in Zone 2 and Zone 3, special roof deck and above-deck component fastening is recommended. To provide adequate resistance for these higher wind pressure areas, one of the following can be done:

A. A roof system that is wind rated for Zones 1', 1, 2, and 3 may be used. This could consist of the same system throughout, or a higher-rated system requiring more fasteners could be provided for Zone 2 and Zone 3. There are many FM Approved assemblies for use on concrete deck, and some assemblies for use on steel deck (with mechanically fastened covers or roofs adhered to dense cover boards), that are rated for several hundred psf.

B. A mechanically fastened cover may be used, with a reduced fastener row spacing in Zone 2 and Zone 3.

C. For relatively low wind-pressure designs, prescriptive enhancements may be used, consisting of providing additional insulation fasteners in Zone 2 and Zone 3 for adhered roof covers. This approach has limitations (described below), but is acceptable where one of the following conditions is met:

1. The NEEDED wind rating in Zone 1 is 90 psf (4.3 kPa) or less.

2. The roof is in a non-tropical cyclone-prone region where the design wind speed does not exceed 90 mph (40 m/s) and the roof height does not exceed 75 ft (23 m) in Surface Roughness Exposure (SRE) B or C. For partially enclosed buildings in SRE D, roof height is limited to 30 ft (9.1 m).

Except where otherwise noted, it is not necessary to actually calculate the increased pressure. The increased fastening recommended for these areas is sufficient to resist these forces.

Prescriptive enhancements, such as providing additional insulation fasteners for adhered roof covers, will usually increase wind resistance. However, there is a practical limit to the additional wind resistance that can be achieved, as well as the reduction in area per fastener. Insulation fastener spacing less than 1 ft^2 (1 per 0.1 m^2) becomes impractical and yields diminishing returns on wind uplift resistance because ultimately the roof cover may peel off the insulation, the roof insulation facer may delaminate, or the insulation or cover board itself may delaminate.

Even with a fastener spacing equal to or slightly greater than 1 ft^2 (1 per 0.1 m^2), the maximum wind resistance rating may be between 150 and 195 psf (7.2 and 9.3 kPa), depending on the type of roof cover and insulation or topping board it is adhered to. Where higher wind ratings are needed for steel deck roofs in Zone 2 and Zone 3, higher wind uplift resistance can be achieved by using mechanically attached base plies or mechanically attached single-ply membranes because they are dependent on the resistance of the interaction of the fastener stress plate and the membrane, or the pullout of the screw from the deck, not the insulation board.

Rows of fasteners for mechanically fastened roof covers should run perpendicular to the deck ribs. If rows of fasteners for roof covers run parallel to the deck ribs, the load is not uniformly distributed to the deck or its points of securement. In such cases, the wind uplift load is shared by the equivalent of only two or three deck fasteners or welds, which may cause failure of the deck at its point of securement.

Recommendations in this document are intented to provide a safety factor of 2.0 between the rated or ultimate wind resistance of above-deck components and deck securement and design wind pressure. This safety factor is intended to compensate for defects in workmanship and materials, and adverse effects due to aging.

Insulation that is pre-secured below a mechanically fastened roof cover is subject to internal pressure, which is constant throughout the internal plan area. Increases in total uplift pressure at Zone 2 and Zone 3 are due to large increases in external pressures there.

3.1.7 Wind Damage

Wind can damage roofs in a number of ways. Types of damage include the following:

A. Perimeter flashing components removed or loosened

B. Roof covering and/or insulation removed

C. Roof covering and/or insulation lifted and dropped back into place

D. Structural roof deck panels dislodged or lifted

E. Roof covering damaged by impact from wind blown objects

F. Dislodged roof protrusions such as vents, skylights, and pipes

G. Roof deck delamination within itself, such as can occur with improperly installed or designed lightweight insulating concrete

Any or all of the various kinds of damage can occur in one windstorm.

Uplift damage to the roof deck usually results in significant additional damage to above-deck components. This damage can spread a considerable distance beyond the damaged deck even if the above-deck components are properly secured. After a small area of deck becomes dislodged, the wind can act on the loose edges of the roof cover and insulation. The wind can then peel the cover from the deck.

3.1.8 Inferior Construction

If the uplift resistance of the roof is less than that needed for the wind loading, the roof is vulnerable to wind damage and is termed inferior. This can occur for several reasons, one being deficiencies in the installation of the roof deck.

If materials that are not FM Approved are used, the construction also may be inferior. In some cases, inferior construction can be determined from the specifications. The inferior designation is an indication of poor wind resistance, not fire classification.

3.1.9 Steel Deck and Eurocode Examples

The roof deck provides the structural support for the roof assembly. It should have sufficient strength and stiffness to prevent the above-deck layers from flexing excessively and separating due to live loads (snow, construction, wind) or dead loads. Some decks, such as structural concrete, are inherently stiff. For others, such as steel, particular attention must be paid to the design to ensure limited deflection and stress within the deck. This is achieved by: (1) limiting the deck span, (2) fastening the panels adequately to the supporting members, and (3) fastening the panel side laps.

Other methods of limiting deflection and stress within the deck to acceptable limits, particularly at higher wind pressures, include using higher strength steel, using thicker or stiffer deck (depth, rib configuration), or using spans that are further reduced. Excessive deflections can cause fracturing of the above-deck insulation and delamination of the roof cover, and excessive stress within the deck can cause the deck to buckle. The combination of a relatively high needed wind rating and relatively long deck spans can result in buckling of steel deck.

If plug welding is used to secure steel deck to supporting members, care is needed to prevent the hole from becoming too large. For decks thinner than 22 ga. (0.0295 in., 0.749 mm), this can be prevented by using weld washers. A typical weld washer is a 16 ga. (0.06 in., 1.52 mm) piece of steel about 1 in. (25 mm) square, having a hole 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. Most experts do not recommend weld washers on decks that are 22 ga. (0.0295 in., 0.749 mm) or thicker. Research at FM Global has shown no detrimental effects on tensile (pull-over) weld strength for 22 ga. (0.0295 in., 0.749 mm) deck when weld washers are used.

Deck side laps also need to be secured. If a worker stands on the bottom panel while fastening the lap, the worker's weight can deflect that panel downward so that adequate fastening may not be possible. If the mating parts are then fastened, the deflected panel will remain in that position. The result is an uneven deck surface, voids under parts of the insulation, and a lack of load distribution (Figs. 3c and 3d). Welding of side laps of decks thinner than 18 ga. (0.0474 in., 1.204 mm) is not recommended due to the difficulty of obtaining consistent weld quality.

3.1.9.1 Examples of Design Considerations for Proposed Steel Deck

Example 1

A proposed building is to use a low slope, steel deck roof and is to be designed as an "enclosed" building. The roof cover is to be fully adhered to mechanically fastened insulation. The required wind uplift pressure resistance for Zone 1 is 44 psf (unfactored). The respective wind uplift pressures for Zone 2 and Zone 3 are 58 psf (2.8 kPa) and 79 psf (3.8 kPa). The building designer would like to use the same deck type and same center-to-center joist spacing throughout the entire building. Deck lengths will meet a three span condition. If a 1-1/2 in. deep, 22 gauge, wide rib deck with a yield stress of 33,000 psi (grade 33) is proposed, what is the maximum span that can be used?

Solution to Example 1

The highest design pressure needed is 79 psf (38 kPa). Multiplying that by a safety factor of 2.0 yields a minimum ultimate rating of 158 psf (7.6 kPa). Rounding that up slightly to 165 psf (7.9 kPa) yields the recommended FM Approval rating. Table 1C is the appropriate table to use for this type of deck and roof assembly, as the adhered roof cover represents a uniformly applied wind load. For the deck thickness and yield stress proposed, the maximum span is 6.03 ft or 6 ft 0 in (1.83 m).

Example 2

The required Zone 1 rating for example 1 is 90 psf (4.3 kPa) and requires one FM Approved mechanical fastener every 12 in. (0.3 m) in Zone 1. The proposal is to use an FM Approved fasteners with a minimum ½ in. (13 mm) diameter integral washer. To prescriptively enhance the deck securement in Zone 2 and Zone 3, what can be specified?

Solution to Example 2

Per Section 2.2.3.4 B.1, the deck fastening for Zone 2 of the roof should be doubled, or in other words one fastener should be provided in the bottom flange of each deck rib or 6 in. (150 mm) on center. Per Table 2, for the Zone 3 securement, a 6 in. (150 mm) spacing may also be used as the diameter of the integral washer for the fastener is at least ½ in. (13 mm).

3.1.9.2 Example for the Use of the EuroCode

A wind design per the EuroCode yields four roof zones. The corresponding design pressures in these roof zones, including a load safety factor of 1.5, are shown in Figure 7.

The next step in the EuroCode (EC) design is to determine the required number of fasteners per m^2. The strength of a fastener is determined based on testing in line with ETAG006 including an additional resistance safety factor of 1.5.

In order to ensure an adequate redistribution of fasteners to meet the EC and FM Approval criteria, the following is recommended for this example:

- Select an assembly with a wind rating of 60 psf or 2.9 kN/m^2.
- Per Roof*Nav*, the required maximum roof cover fastener spacing is 1.4 m (4.6 ft) by 0.3 m (1 ft). The area per fastener is 0.42 m^2 and the fastener density is 2.38 fasteners per m^2.
- The theoretical ultimate strength per fastener is (2.9 kN/m^2)/(2.38 fasteners per m^2) = 1.22 kN (270 lb) per fastener.
- Next, the fastener spacing based on the wind loads required per the EC, including an additional safety factor of 1.5, can be determined using the ultimate strength per fastener of 1.22 kN (270 lb).
- Based on the above example, this would result in:

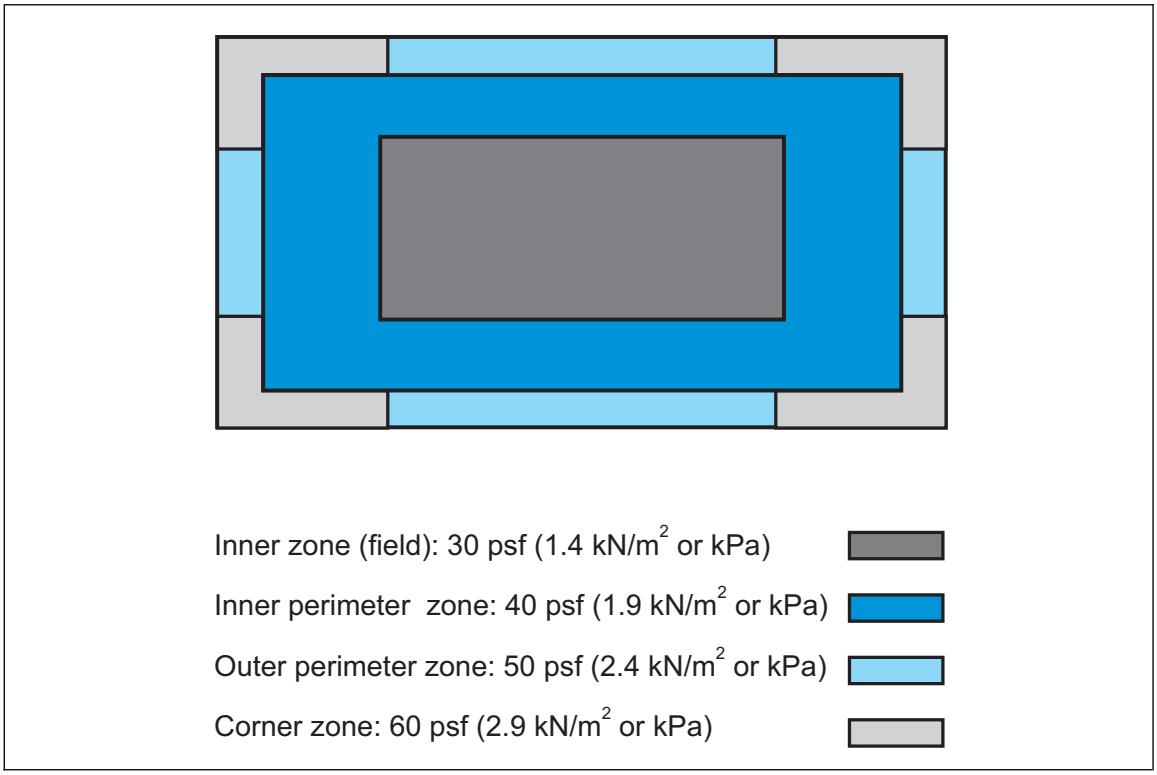

Fig. 7. Example problem based on the EuroCode

EuroCode Roof Zone	*EC Design Wind Load, kN/m²*	*EC Factored Load on Fastener, kN/m²*	*Maximum Fastener Spacing per EC, m²*	*Maximum Recommended Fastener Spacing (lesser of RoofNav or EC), m²*
1	1.4	2.1	0.58	0.42
2	1.9	2.9	0.42	0.42
3	2.4	3.6	0.33	0.33
4	2.9	4.4	0.28	0.28

- For example, for Zone 4, (1.22 kN/fastener)/(4.4 kN/m^2) = 0.28 m^2/fastener.
- The overall safety factor in the design would be well in excess of 2.0.

4.0 REFERENCES

4.1 FM

Data Sheet 1-0, *Safeguards During Construction and Demolition*
Data Sheet 1-5, *Removal and Shipping of Roof Deck Samples for Calorimeter Testing*
Data Sheet 1-12, *Ceilings and Concealed Spaces*
Data Sheet 1-13, *Chimneys*
Data Sheet 1-22, *Maximum Foreseeable Loss*
Data Sheet 1-28, *Wind Design*
Data Sheet 1-30, *Repair of Wind Damaged Single- and Multi-ply Roof Systems*
Data Sheet 1-31, *Metal Roof Systems*
Data Sheet 1-32, *Inspection and Maintenance of Roof Assemblies*
Data Sheet 1-34, *Hail Damage*
Data Sheet 1-33, *Safeguarding Torch-Applied Roof Installations*

Data Sheet 1-42, *MFL Limiting Factors*
Data Sheet 1-49, *Perimeter Flashing*
Data Sheet 1-51, *Fire Retardant Coatings and Paints for Interior Finish Materials*
Data Sheet 1-52, *Field Verification of Roof Wind Uplift Resistance*
Data Sheet 1-54, *Roof Loads for New Construction*
Data Sheet 10-3, *Hot Work Management*

Approval Guide, an online publication of FM Approvals
RoofNav, an online resource for roofing professionals

4.2 Others

American Iron and Steel Institute (AISI). AISI S100, *North American Specification for the Design of Cold Formed Steel Structural Members,* 2016.

American National Standards Institute (ANSI)/Single-Ply Roofing Institute (SPRI). ANSI/SPRI FX-1, *Standard Field Test Procedure for Determining the Withdrawal Resistance of Roofing Fasteners,* 2011.

American Society for Testing and Materials (ASTM). ASTM D448, *Standard Classification for Sizes of Aggregate for Road and Bridge Construction,* 2012.

American Society of Civil Engineers (ASCE). ASCE Standard 7-16, *Minimum Design Loads for Buildings and Other Structures.*

APA-The Engineered Wood Association. *Designing Commercial Roofs to Withstand Wind Uplift Forces,* 2009.

National Roofing Contractors' Association (NRCA). *NRCA Roofing Manual: Membrane Roof Systems,* 2015.

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.

Air barrier: Used with a mechanically fastened roof cover and located directly above the roof deck. The air barrier is sealed to the underside of the roof cover, but not necessarily to the exterior walls of the building. In theory, an air barrier improves wind uplift resistance of the roof assembly by preventing air flow into the space below the roof cover and transferring a portion of the uplift load to the insulation. It should be noted that even for properly installed air barrier systems, roof penetrations made after the installation of an air barrier system can hamper the wind performance of an air barrier system if the air barrier is not sealed to the underside of the roof cover after the penetration cut is made. Consequently, there are special FM Approval restrictions on air barrier systems.

Area dividers (roof) (control joints): 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 should be installed over the gap.

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.

Ballasted single-ply membrane: Single-ply membranes that are only attached at the roof perimeter and penetrations and are held in place with ballast consisting of large stone or concrete paver blocks. Ballasted membranes are not FM Approved, but may be acceptable if installed in accordance with this document.

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.

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.

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.

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.

Coal tar: A dark brown to black, semi-solid hydrocarbon obtained from heating and refining bituminous coal.

Coal-tar pitch: A coal tar used as the waterproofing agent in dead-level or low-slope BURs, conforming to ASTM D450, Type I. Coal-tar waterproofing pitch: a coal tar used as the damp-proofing 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 dead-level 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.

Effective wind area: The span length times the effective width. For roof cover, roof deck, or wall panel fastening, the effective wind area should not exceed that supported by the fastener or clip (generally reflected in the tables in DS 1-28, which use a minimum 10 ft^2 (1 m^2) EWA.

FM Approved: Products and services that have satisfied the criteria for FM Approval. Refer to the Approval Guide, an online resource of FM Approvals, and Roof*Nav* for a complete listing of products and services that are FM Approved.

Hurricane-prone regions: See tropical cyclone-prone region.

Lightweight insulating concrete (LWIC): 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 orhybrids 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 membrane: The single-ply roof cover is secured to the roof deck with mechanical fasteners. This does not include single-ply membranes that are fully or partially adhered to an insulation or cover board below it.

Mechanically fastened base sheet: A bituminous base sheet that is mechanically fastened to the roof deck, with one or more layers of bituminous sheet adhered above it.

Modified bitumen membranes: Polymer-modified asphalt and a reinforcing mat, usually glass and/or polyester fiber. These membranes are adhered by torch application, hot asphalt, or are self-adhering.

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

Re-cover construction: The existing roof system is left in place and new components are installed over it. Compare to re-roof construction.

Re-roof construction: The existing roof system is removed down to the structural deck. New components are then installed. For FM Approval purposes, either a new construction or reroof assembly would be needed. Re-roof Approvals allow up to 15 lb per square (0.73 kg/m^2) of asphalt to remain on steel deck. In order to use an FM Approved new construction system, no asphalt can remain. Compare to re-cover construction.

Self-adhering membrane: A membrane that 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” that is removed during installation.

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

Square: A roofing term meaning 100 ft^2 (9.28 m^2) of roofing area.

Thermoplastic: Materials that 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: Materials that harden or set irreversibly when heated. This usually occurs during the manufacturing process.

Tropical cyclone-prone region: An area prone to tropical storms in which winds rotate about a center of low atmospheric pressure, clockwise in the southern hemisphere and counter-clockwise in the northern hemisphere. This includes locations prone to hurricanes, typhoons and cyclones and includes the following regions:

1. The U.S. Atlantic Coast and Gulf of Mexico Coast, including parts of Mexico (Eastern Mexico, the southern end of the Baja Peninsula and the southwest coast of Mexico) and Central America, where the basic wind speed per DS 1-28 is greater than 90 mph, and

2. Hawaii, Puerto Rico, Guam, U.S. Virgin Islands, St. Croix, St. John, St. Thomas and American Samoa.

For locations outside the United States, any areas that are in a “tropical cyclone” region or “typhoon-prone” region. This includes, but is not limited to, Eastern Mexico and the southern coastal areas of Western Mexico, parts of Australia (green, blue, and red banded areas) and northern part of the north island of New Zealand, Bermuda, all the countries and territories of the Caribbean, Bangladesh, India, the Philippines, Japan, South Korea, Hong Kong, Macau, Vietnam, Burma (Miramar), China, Sri Lanka, Hong Kong, Macau, Cambodia, Taiwan, Madagascar, and the southeast coast of Brazil, where the basic design wind speed per DS 1-28 is faster than 90 mph (40 m/s).

Typhoon-prone region: See tropical cyclone-prone region.

Vapor retarder: A material designed to restrict passage of water vapor located on the “warm side” of the roof or sandwiched between insulation layers. The vapor retarder is sealed to the exterior walls of the building, but not necessarily to the underside of the roof cover.

APPENDIX B DOCUMENT REVISION HISTORY

The purpose of this appendix is to capture the changes that were made to this document each time it was published. Please note that section numbers refer specifically to those in the version published on the date shown (i.e., the section numbers are not always the same from version to version).

July 2022. Interim Revision. Added guidance for the use of FM Approved roof leakage detection systems. Also made minor editorial corrections.

February 2020. Interim Revision. The following changes were made:

A. Updated tables and examples throughout to reflect changes made to Data Sheet 1-28.

B. Changed the terms used for roof areas from field, perimeter, and corner to Zone 1, Zone 2, and Zone 3, respectively.

C. Added new interior roof Zone 1’.

April 2016. Interim Revision. The following changes were made:

A. Clarification was added to recommendation 2.2.3.5 to refer those using welding to strengthen existing roofs to follow proper hot worrk procedures.

B. Information on insulation fasterner placement is available in Appendix C.

January 2016. The following significant changes were made:

A. Revised guidance for preliminary securement of insulation or cover boards below in-seam mechanically fastened single-plies (MFSP) and above vapor retarders.

B. Revised guidance for steel deck span and securement.

C. Reformatting of the document.

September 2010. Minor editorial changes were made for this revision.

September 2009. Hailstorm hazard map was reformatted. No technical changes were made.

June 2009. Clarification was made to recommendation 2.2.7.4.2.

January 2009. The following changes were made for this revision:

- Clarification was added to Section 2.2.7.2.1.
- Footnote of Table 1 was revised to clarify its intent.
- Minor revision to Figure 6 was made.

August 2007. Changes were made as follows:

- Recommendation 2.2.2.2 was revised to clarify its intent.
- Recommendation 2.2.1.5.1 was revised to allow prescriptive enhancements for non-hurricane-prone regions where Class 1-90 systems are needed. In addition, other acceptable enhancements were added where Class 1-90 systems are needed in hurricane-prone regions.
- Recommendation 2.2.20.1 was simplified and related portions of section 3 expanded.
- Table 1A was deleted.
- Footnote 2 of Table 1 was relocated to make it clearer that it applied to the entire table.

February 2007. Changes were made as follows:

- Guidance was added and modified for steel deck span and securement to implement optional designs for wind speeds higher than the basic wind speed shown in DS 1-28.
- Allowable wind pressure vs. deck span tables were added for common steel deck types, along with multipliers to determine wind pressures for higher grades of steel.
- Example problems for deck design were added.
- Recommendations were added to help improve the installation quality of lightweight insulating concrete (LWIC).
- Recommendation 2.2.1.2.6 was relocated from DS 1-29R.
- Recommendation 2.2.1.5.1, related to prescriptive enhancements for mechanically fastened insulation with adhered roof covers, was modified to prevent misinterpretation of intent.

May 2006. Editorial changes were made to the Table 1.

January 2006. Recommendations 2.2.1.5.1, 2.2.1.5.2, 2.2.1.5.3, 2.2.7.2.1, 2.2.7.3.2, 2.2.9.1, 2.2.13.1.1 and 2.2.13.1.2 were revised, and 2.2.7.3.3, 2.2.7.3.4, 2.2.13.1.3 and 2.2.14.1.1 were added. They focus on using mechanically attached roof covers with steel deck roofs in high wind areas, and orientation of roof cover fasteners to properly distribute the wind load to steel deck securement points. In addition, Table 1 was modified to provide a full safety factor of 2.0 in the perimeter and corner areas in all cases.

May 2005. Minor editorial changes were made.

January 2005. Editorial changes were made.

September 2003. Minor editorial changes were made for this revision.

January 2002. Deck securement for wind uplift has been relocated here, and was formerly found in Data Sheet 1-28.

September 2000. This revision of the document has been reorganized to provide a consistent format.

APPENDIX C SUPPLEMENTAL INFORMATION FOR PROPRIETARY PROTECTED MEMBRANE ROOF SYSTEMS

C.1 Insulation Fastener Placement

Determine the maximum unit area per fasteners using Roof*Nav* and use Figures C.1.1, C.1.2, C.1.3, or C.1.4 to determine the exact fastener location, depending on the plan dimensions of the insulation or cover board used.

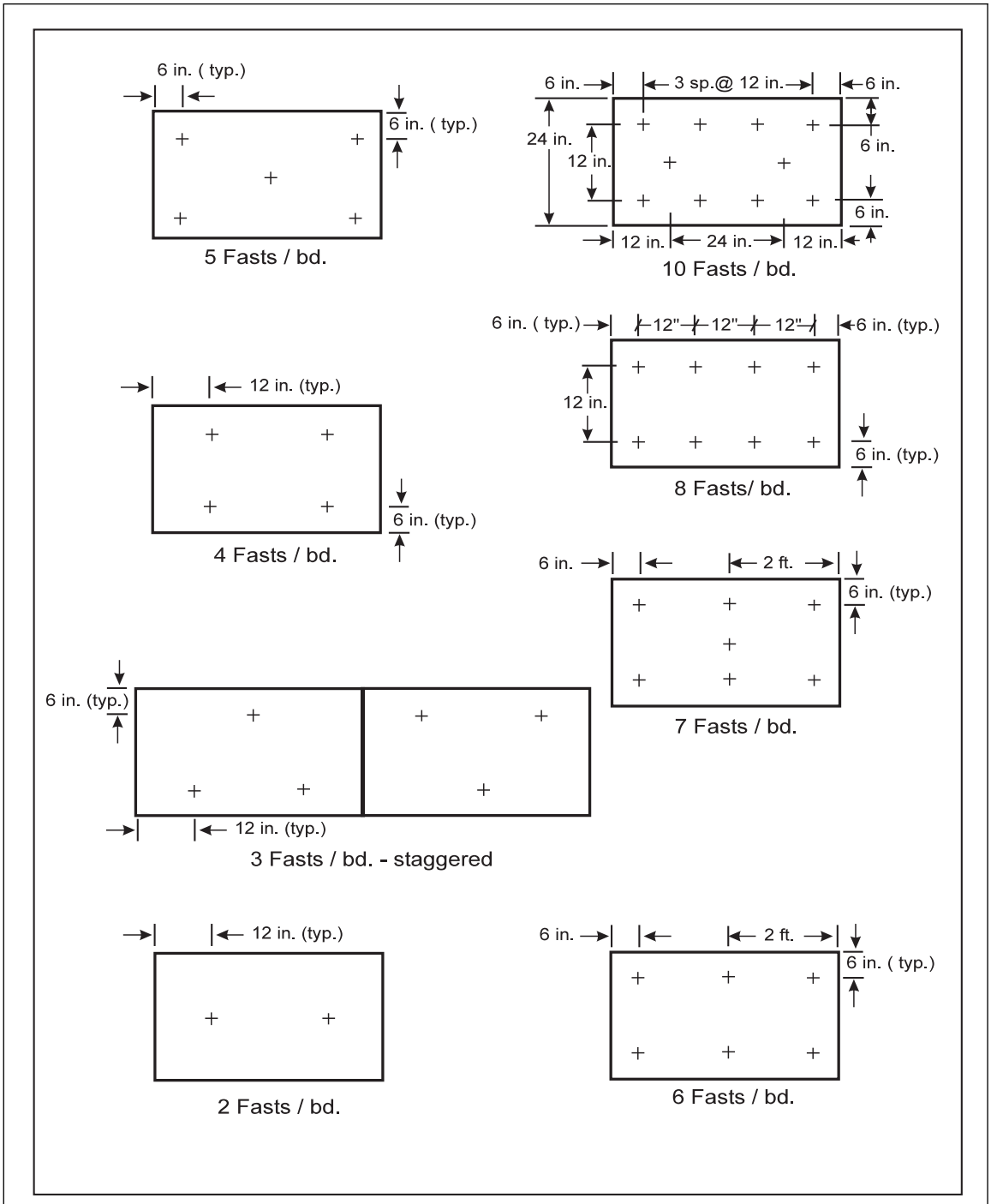

Fig. C.1.1. Fastener placement 2 × 4 ft (0.6 × 1.2 m) boards used on steel decks with a 6 in. (150) module or rib spacing

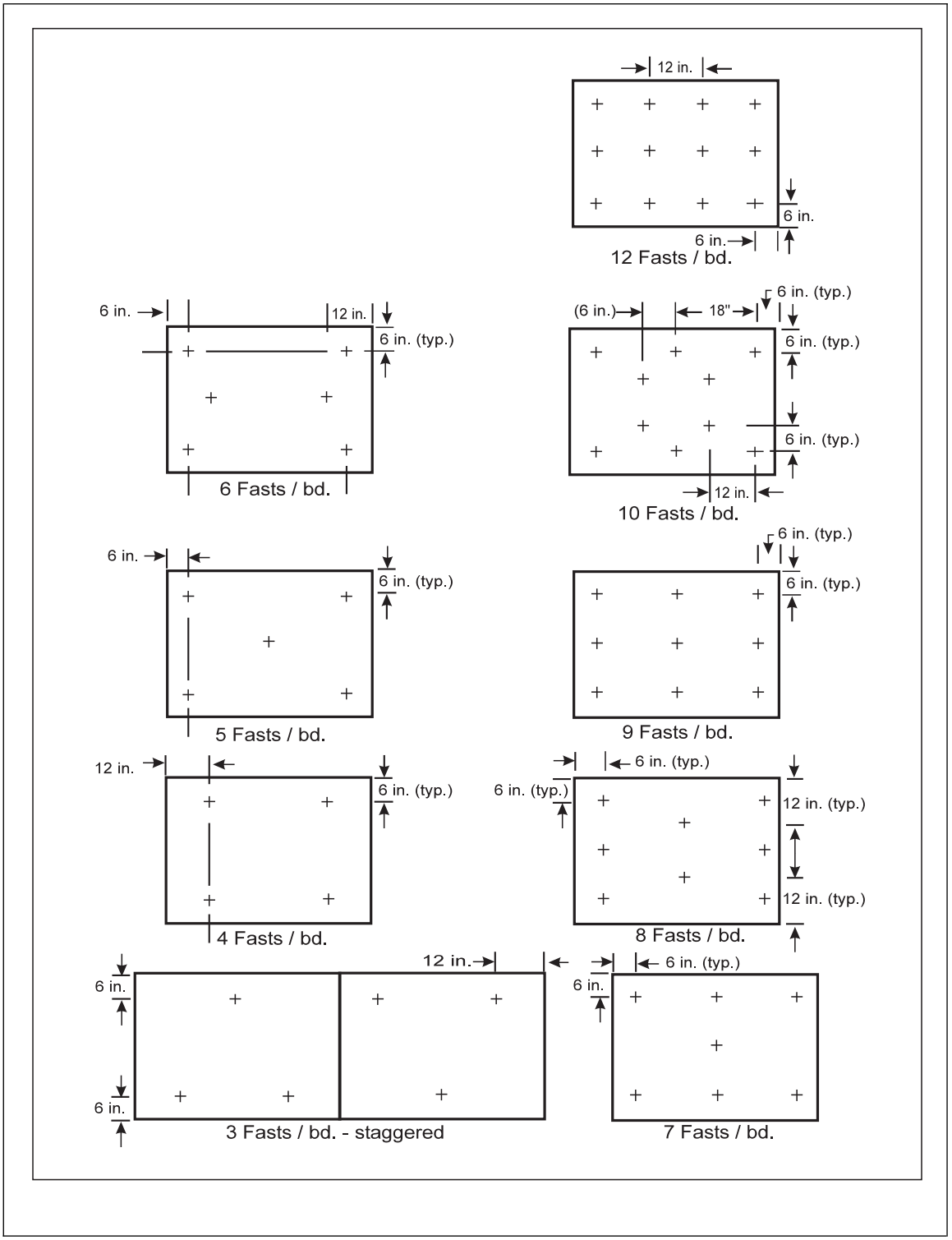

Fig. C.1.2. Fastener placement 3 × 4 ft (0.9 × 1.2 m) boards used on steel decks with a 6 in. (150 mm) module or rib spacing

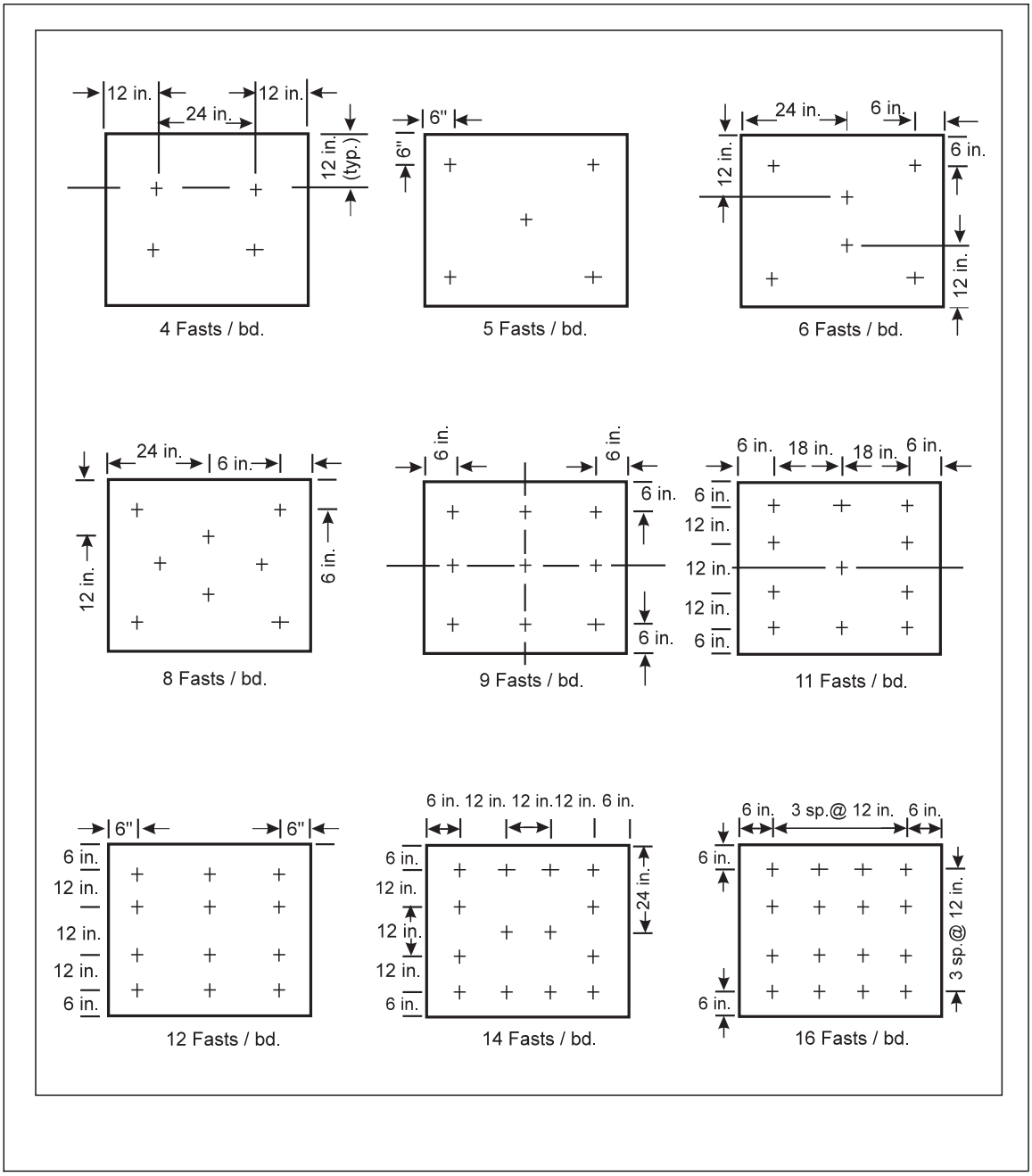

Fig. C.1.3. Fastener placement 4 × 4 ft (1.2 × 1.2 m) boards used on steel decks with a 6 in. (150) module or rib spacing

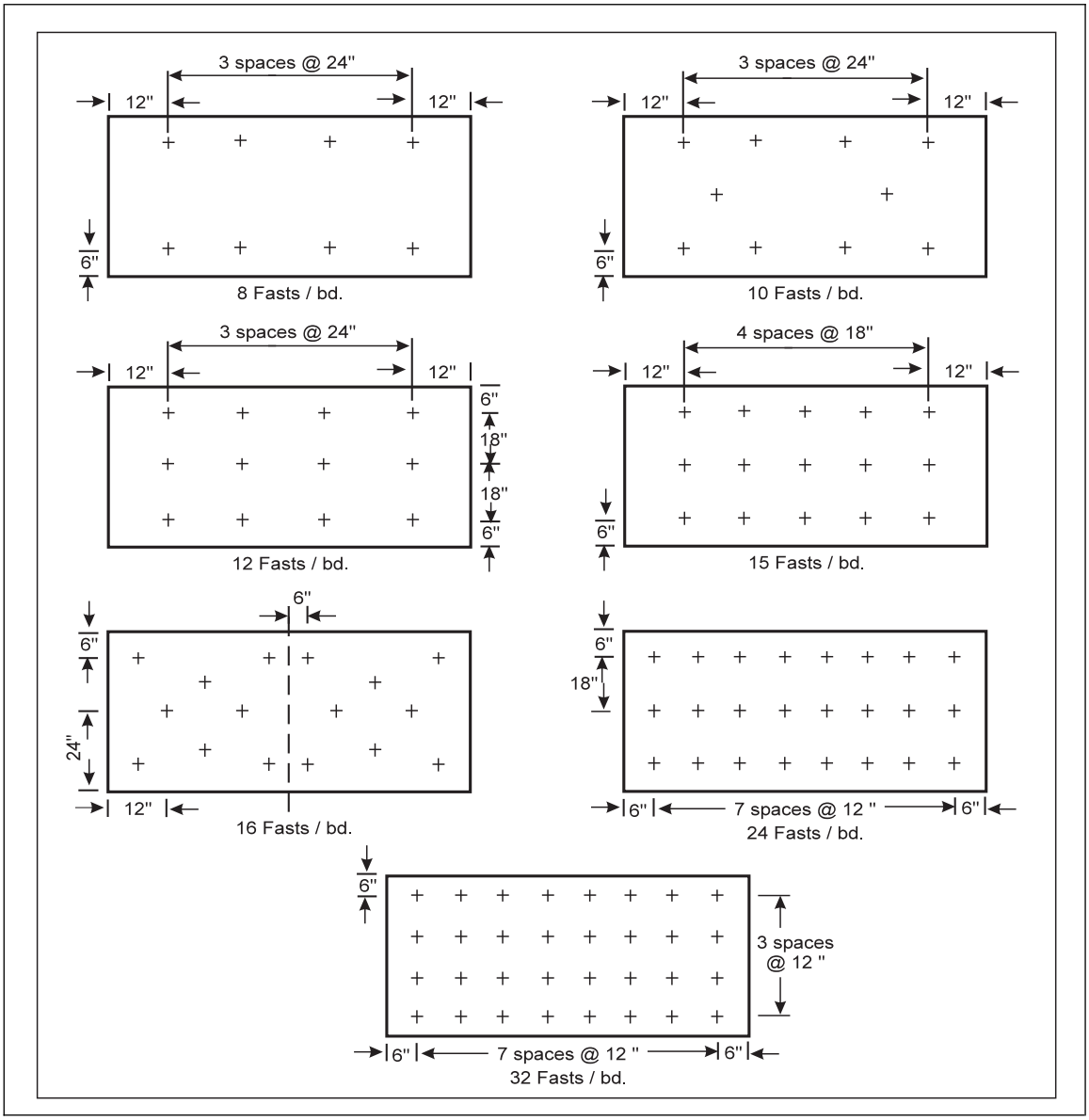

Fig. C.1.4. Fastener placement 4 × 8 ft (1.2 × 2.4 m) boards used on steel decks with a 6 in. (150 mm) module or rib spacing