

PROCEEDINGS

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CHANGES TO FM APPROVAL STANDARD 4470

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ABSTRACT

Several significant changes have been made to FM Approval Standard 4470. Two of the “new” requirements include checks of deck stress under service wind loads and deck fastener stress. The test sponsor will submit calculations showing these elements are not overstressed.

During wind uplift tests, the assembly must now maintain the service wind load for one minute without visible cracking or visible creasing of the insulation or cover board.

Dynamic Puncture Resistance Rating of Roof Covers per ASTM D5635 and Solar Reflectance of Roof Surfaces rating per ASTM C1549 are now optional ratings.

SPEAKER

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MARK D. TYROL, PE, has over 25 years of experience with the evaluation, testing, and approval of building materials. Tyrol began his career with FM Global in 1987 and joined the Approvals Division in 1993. He is a graduate of the University of Massachusetts College of Engineering at Lowell, with postgraduate studies from Northeastern University. He is a licensed professional engineer in several states. He is also a member of the American Society of Mechanical Engineers (ASME), Steel Door Institute (SDI), International Firestop Committee (IFC), National Academy of Building Inspection Engineers (NABIE), National Society of Professional Engineers (NSPE), American Society for Testing and Materials (ASTM) Committee E.05 Fire Testing, National Council of Examiners for Engineering and Surveying (NCEES), and RCI.

CHANGES TO FM APPROVAL STANDARD 4470

In June 2012, FM Approvals revised Approval Standard Class No. 4470, *Approval Standard for Single-Ply, Polymer-Modified Bitumen Sheet, Built-Up Roof (BUR), and Liquid-Applied Roof Assemblies for Use in Class 1 and Noncombustible Roof Deck Construction*.

FM 4470 is used to evaluate single-ply, polymer-modified bitumen sheet, built-up roof (BUR), and liquid-applied roof assemblies for their performance in regard to fire from above and below the structural deck, simulated wind uplift, corrosion of metal parts, susceptibility to hailstorm damage, foot traffic, water leakage, and optionally, puncture resistance and solar reflectance.

Meeting the requirements of FM 4470 will qualify the roof assembly as FM-Approved. FM-Approved roof assemblies are not a significant fire hazard and can resist rated wind uplift forces, hailstones, etc. when installed in accordance with all approval requirements. FM-Approved roofing products and assemblies, the Ratings Calculator, roofing-related FM Global Property Loss Prevention Data Sheets, FM Approval Standards, etc. are published in RoofNav (www.roofnav.com).

This paper will discuss the latest revisions made to FM 4470 and what these revisions may mean to consultants.

A summary of the revisions to FM 4470 is as follows:

1. Checks of steel deck stress under wind loads and steel deck fastener stress calculations in order to verify that these elements are not overstressed. Note: this is not a change from the previous edition of the standard. This requirement was included in the previous version of FM 4470; however, the effective date for compliance has been extended.
2. Wind uplift resistance tests acceptance criteria: Some visible cracking and creasing of the insulation or cover board is now permitted at load

levels less than the service load.

3. For a reroof over steel deck, rigid cover boards may be used to stiffen existing decks that do not meet wind design pressures. When a rigid cover board is used, the allowable bending stress of the deck shall be permitted to be increased by 40%.
4. Dynamic puncture resistance rating of roof covers per ASTM D5635 has been added to FM 4470 (as an optional rating).
5. Solar reflectance of roof surfaces rating per ASTM C1549 has been added to FM 4470 (as an optional rating).
6. Test requirements regarding combustibility from below the roof deck may now be met with either NFPA 276 or FM 4880.
7. The susceptibility to heat damage test requirement, previously in FM 4450, has been added to FM 4470. This is not a new requirement, as this test has been required for the approval of roof insulations.
8. Corrosion resistance: A second test method is now offered.

The effective date of FM 4470 was December 31, 2012. As of this writing, FM Approvals was working to ensure all RoofNav assemblies complied with all requirements by the effective date. In the interim, FM Approvals addressed currently approved assemblies where the deck and/or deck fasteners were overstressed.

CHECKS FOR DECK STRESS UNDER WIND LOADS AND DECK FASTENER STRESS

Checks of deck stress under service wind loads and deck fastener stress calculations are required by FM 4470 in order to verify that these elements are not overstressed. This requirement was included in the previous version of FM 4470; however,

the effective date for compliance has been extended. Further details and guidance are provided below.

Stresses induced to steel roof decking shall be determined by rational analysis using allowable strength design (ASD) principles and shall not exceed the allowable stresses per the *North American Specification for the Design of Cold-Formed Steel Structural Members*, AISI S100-2007; and *Approval Standard for Profiled Steel Panels for Use as Decking in Class 1 Insulated Roof Construction*, FM 4451.

What does all this mean to the consultant? Here are some general guidelines:

- For 1.5-in.-deep, 22-ga., wide-rib steel deck spanning 6 ft. (1.8 m) with mechanically secured covers, mechanically attached covers have varying ratings, based on roof cover securement row spacing. See *Figure 1*. For example, for roof membranes secured in rows 8 ft. (2.4 m) wide:
 - 33-ksi (kips per square inch) (230-MPa [megapascal]) steel deck limited to Class 1-60 maximum
 - 80-ksi (552-MPa) steel deck limited to Class 1-120 maximum
- For 1.5-in.-deep, 22-ga., wide-rib steel deck spanning 6 ft. (1.8 m) with fully adhered covers and mechanically secured covers with row spacings less than or equal to half the deck span. See *Figure 2*.
 - 33-ksi (230-MPa) steel deck limited to Class 1-165 maximum
 - 80-ksi (552-MPa) steel deck limited to Class 1-300 maximum

Ratings for assemblies that currently exceed these limits shall be modified. Modifications may include reduced wind-uplift ratings, shorter deck spans, changes in minimum deck yield strength from 33 to 80 ksi, increases in minimum deck thickness, etc.

membrane Fastener rows (ft)	Deck ((ksi)	max Class
3.5	33	135
3.5	80	255
4	33	135
4	80	255
4.5	33	120
4.5	80	240
5	33	120
5	80	210
5.5	33	105
5.5	80	195
6	33	90
6	80	165
6.5	33	75
6.5	80	150
7	33	75
7	80	150
7.5	33	75
7.5	80	135
8	33	60
8	80	120
8.5	33	60
8.5	80	105
9	33 NA	
9	80	90
9.5	33 NA	
9.5	80	90
10	33 NA	
10	80	75
10.5	33 NA	
10.5	80	75
11	33 NA	
11	80	75
11.5	33 NA	
11.5	80	75
12	33 NA	
12	80	60

Figure 1 – Maximum wind uplift ratings for 1.5-in. deep, 22-ga. wide rib-steel deck spanning 6 ft.

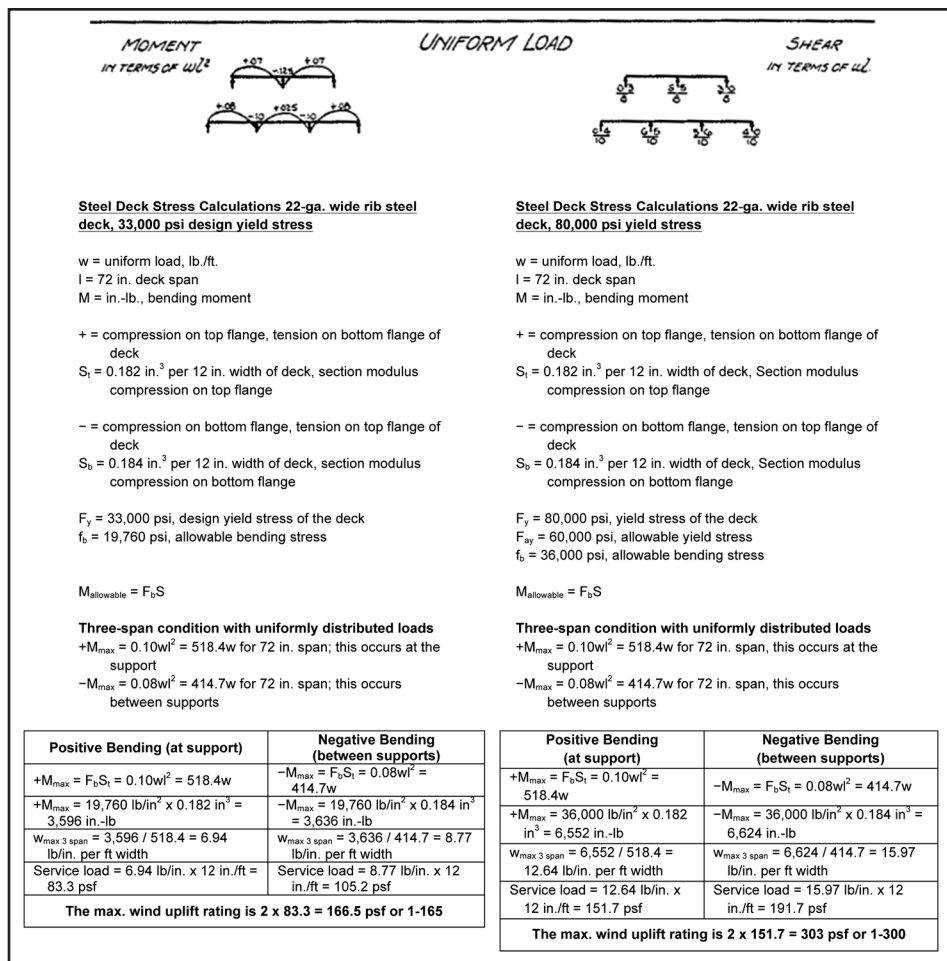


Figure 2 – For all fully adhered covers and mechanically attached covers with row spacing \leq one-half the deck span (generally 3 ft.), 22-ga., 33-ksi is limited to Class 1-165, and 80-ksi is limited to Class 1-300.

Details

1. Stress calculations are completed in accordance with AISI using the following parameters:
 - a. A three-span deck condition exists (this is slightly less conservative than the two-span condition used for deck deflection).
 - b. For row-attached membranes, the first row is assumed to have been placed midspan of the first span. The remaining rows are spaced based on row spacing.
 - c. All fully adhered covers and mechanically attached covers where row spacing does not exceed half the deck span are analyzed as fully distributed loads.
 - d. The standard requires the customer to submit calculations; however, FM Approvals has completed calculations for common mechanically secured membrane

- assemblies and fully adhered membrane assemblies.
- e. Stresses are determined using allowable strength design (ASD) and cannot exceed AISI S100-2007 allowables.
2. Similarly, deck fasteners will be tested for pull-through and pull-over. In addition, allowable stress calculations of the deck/fastener heads are conducted and the lower value used as the basis of approval. Essentially, testing demonstrates fastener performance (i.e., no pullout or head fracture), and calculation shows that the deck is not overstressed. These are conducted per AISI. Note: Generally, deck-bending stress will be the limiting condition. See Figure 3.
3. The steel deck deflection (FM 4451) evaluation now assumes a 200-lb. (0.89-Neston [N]) load vs. the 300-lb. (1.3-N) load previously used.

Steel Deck Attachment Fastener Capacity

$$P_{nov} = 1.5t_1d'_wF_{u1}$$

P_{nov} = nominal pull-over strength (resistance) of the fastener

t_1 = thickness of member in contact with fastener head or washer

F_{u1} = Tensile strength of member in contact with fastener head or washer

d'_w = Effective pull-over diameter = $d_h + 2t_w + t_1 < d_w$

$d'_w = d_h + 2t_w + t_1 < d_w$ for a round, hex, or hex-washer head fastener and independent solid-steel washer beneath

$d'_w = d_h \leq 0.5$ in. (13 mm) for a round, hex, or hex-washer head fastener without an independent washer

$d'_w = d_h + 2t_w + t_1 \leq 0.625$ in. (16 mm) for a domed (nonsolid) and independent steel washer

d_h = fastener or integral washer head diameter

t_w = steel washer thickness

d_w = washer diameter

Ω_f = Resistance factor = 3.0

$$P_{all} = P_{nov}/\Omega_f$$

$$F_{u1} = 48,000 \text{ psi for 33,000 psi deck}$$

$$F_{u1} = 82,000 \text{ psi for 80,000 psi deck}$$

$$d'_w = d_h = 0.4 \text{ in. for the screws used in the lab}$$

For a 0.75-in. diameter washer that is 0.065-in. thick as described in RoofNav

$$d'_w = d_h + 2t_w + t_1 = 0.4 + 2(0.065) + t_1 = 0.53 + t_1 < 0.75 \text{ in.}$$

Screw Capacity Spaced 12 in. o.c., lb.		
	33,000	80,000
	Rated Load	Rated Load
	595	1016
	722	1233
	956	1632
	1206	2060

Screw & Washer Capacity Spaced 12 in. o.c., lb.		
	33,000	80,000
	Rated Load	Rated Load
	832	1421
	1021	1744
	1379	2356
	1778	3037

		Screw	33,000	80,000	33,000	80,000
Deck	t_1	d'_w	P_{nov}	P_{nov}	P_{all}	P_{all}
22 ga	0.0295	0.4	850	1451	283	484
20 ga	0.0358	0.4	1031	1761	344	587
18 ga	0.0474	0.4	1365	2332	455	777
16 ga	0.0598	0.4	1722	2942	574	981

		Screw & Washer	33,000	80,000	33,000	80,000
Deck	t_1	d'_w	P_{nov}	P_{nov}	P_{all}	P_{all}
22 ga	0.0295	0.560	1188	2030	396	677
20 ga	0.0358	0.566	1458	2491	486	830
18 ga	0.0474	0.577	1971	3366	657	1122
16 ga	0.0598	0.590	2539	4338	846	1446

Figure 3 – Use the capacity numbers vs. rated load and tributary area to determine adequacy for deck fasteners. Above are values for fasteners with integral washers (first group of values, assuming a 0.4-in.- (10-mm-) diameter head and values for separate 3/4-in.- (19-mm-) diameter washers (second group of values). For example, a 0.4-in.- (10-mm-) diameter screw head at 6-ft. x 6-in. spacing with a fully adhered cover or mechanically attached cover with row spacing less than or equal to deck span is 3- sq.-ft. tributary area = 595/3 = 198 = Class 1-195 maximum rating. Compare with limit of deck stress to determine the governing condition for this case. (595 is from spreadsheet for screw with 22-ga., 33-ksi steel deck.)

4. Testing on 33-ksi steel deck can be extended to include 80-ksi steel deck, but testing on 80-ksi steel deck does not allow 33-ksi steel deck, regardless of stress calculations.
5. Steel deck thickness that is tested is the minimum deck thickness that can be granted from that test.
6. Steel deck span that is tested is the maximum deck span that can be granted from that test.
7. Minimum steel deck design of 0.0276-in. (0.7-mm) steel deck (slightly less than 22-ga.) is now allowed. The previous minimum was 0.0295 in. (0.75 mm). This change is intended to allow evaluation of deck typically used outside North America. The uncoated minimum steel thickness delivered to a job site shall not be less than 95% of the steel design

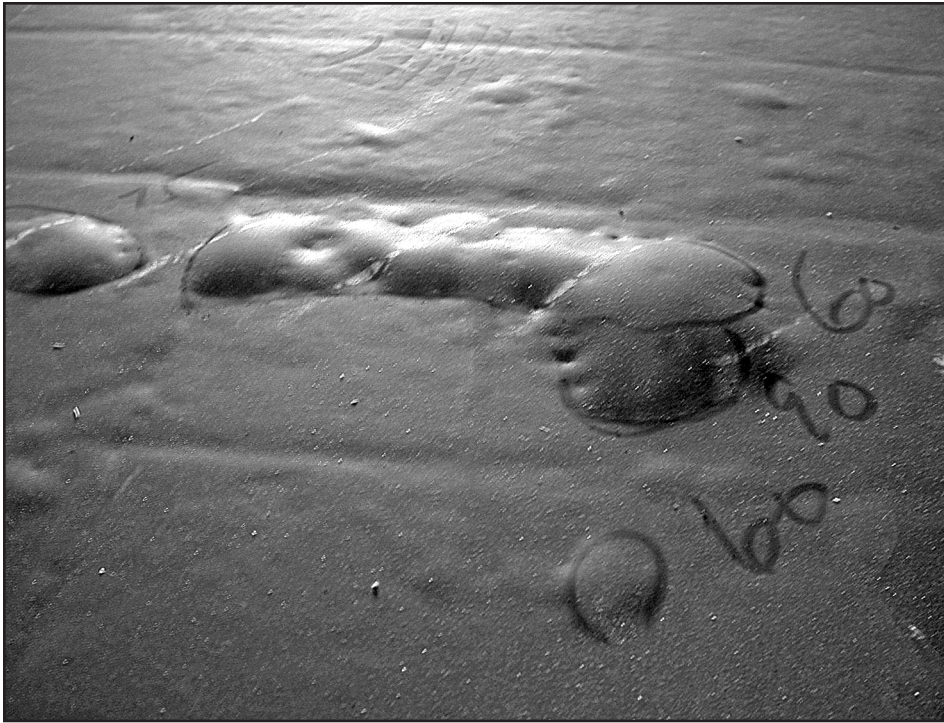


Figure 4 – Minor adhesive delamination of fully adhered single-ply during wind uplift test.

thickness at any location. (Exception: Lesser thickness due to cold forming is permitted at bends.)

8. Steel deck material is now specified as minimum 33 ksi (230 MPa) and minimum 80 ksi (552 MPa), rather than an ASTM specification. Again, this is to allow evaluation of steel deck typically used outside North America.
9. The previous version of FM 4470 included steel deck stress limits. Implementation was extended to the effective date of the revised FM 4470 (December 31, 2012).

WIND UPLIFT RESISTANCE TESTING ACCEPTANCE CRITERIA

The acceptance criteria for 12- x 24- and 5- x 9- simulated wind uplift pressure testing has been relaxed to allow limited cracking and creasing of the insulation or cover board. No changes to the actual test methods and acceptance criteria have been made; the revised test procedures now more accurately reflect actual judgments typically made.

In the previous version of FM 4470, insulation or cover board was not allowed to fracture, crack, or crease; and no delamination of the insulation facer or membrane was allowed.

The revised acceptance criteria allow limited visible cracking or creasing of the insulation or cover board when tested at less than the service load. Limited visible cracking or creasing may not exceed half the minimum board dimension (e.g., maximum 24 in. [1220 mm] for a 48 x 96-in. [1220 x 2440-mm] board). In addition, the assembly must now maintain the service wind load for one minute without visible cracking or visible creasing of the insulation or cover board.

Below are the definitions:

Crack – During wind uplift testing, when an insulation or cover board is stressed to the point that it separates from itself while continuing to maintain the applied uplift pressure without catastrophic failure of the test assembly.

Crease – During wind uplift testing, when insulation or cover board is stressed to the point that it bends at a sharp, defined angle without breaking. Often a crack will form on the opposite face of the insulation or cover board.

Service Wind Load – The uplift load resulting from a windstorm that a roof assembly must resist. The service load is equal to half of the rated load in psf (or kilopascals [kPa]). FM-Approved roofs are rated for wind uplift—for example, “1-90.” The “1” refers to FM Class 1, which means the roof

assembly is not a fire hazard; and the “90” means the roof meets a wind uplift resistance of 90 psf (the rated load). The service load is equal to half of the rated load—in this case, 45 psf.

The revised acceptance criteria also allow minor adhesive delamination, provided it does not continue to grow in size by more than 50% from the end of one pressure level through the end of the following pressure level. During wind uplift testing, pressure is slowly increased to 60 psf (2.9 kPa) and held for one minute. The pressure is then increased by 15 psf (0.7 kPa) and held for one minute at each pressure level and repeated until failure is observed. An example of minor adhesive delamination is shown in *Figure 4*.

CREDIT FOR RIGID COVERBOARDS FOR REROOF OVER STEEL DECK

For reroof over steel deck, rigid cover boards may be used to stiffen existing decks that do not meet wind design pressures. When a rigid cover board is used and performance is demonstrated via a test, the allowable bending stress of the deck shall be permitted to be increased by 40% over the above calculations.

A rigid cover board is defined as a hard, dense board that, in the sole judgment of FM Approvals and through testing, has demonstrated the ability to act in a composite manner with the steel deck to increase the moment of inertia and the section modulus and, thus, the wind uplift capacity of the roof assembly. Rigid cover boards must be used over minimum 1.5-in.- (38-mm-) thick insulation and secured to the deck, either alone or in combination with the roof cover, using fasteners placed within a contributory area of less than or equal to 1 sq. ft. (0.09 m²) per fastener.

A rigid cover board differs from a cover board, which is defined as a board stock product used over insulation, applied as the top layer of some multilayer insulation assemblies. This application is only for rigid cover boards used in a reroof assembly over steel deck.

DYNAMIC PUNCTURE RESISTANCE RATING

Dynamic puncture resistance rating of roof covers has been added to FM 4470. Testing is performed in accordance with ASTM D5635, *Standard Test Method for Dynamic Puncture Resistance of Roofing*

Membrane Specimens. This test is optional and is not a requirement of FM 4470.

SOLAR REFLECTANCE RATING

Solar reflectance of roof surfaces has been added to FM 4470. Testing is performed in accordance with ASTM C1549, *Standard Test Method for Determination of Solar Reflectance Near Ambient Temperature Using a Portable Solar Reflectometer*. This test is optional and is not a requirement of FM 4470.

ALTERNATIVE TEST FOR COMBUSTIBILITY FROM BELOW THE ROOF DECK

Combustibility from below the roof deck test requirements may now be met with either NFPA 276 or FM 4880. NFPA 276, *Standard Method of Fire Tests for Determining the Heat Release Rate of Roofing Assemblies with Combustible Above-Deck Roofing Components*, was formerly known as the FM Approvals Construction Materials Calorimeter Test. This 30-minute fire test measures the fuel contribution rate of a roof assembly to determine if the roof assembly meets Class 1, which means the roof assembly will burn in a slow, controlled manner; is not considered a hazard; and may be installed in accordance with the Approval without requiring automatic sprinklers (when permitted by FM Global Property Loss Prevention Data Sheets). NFPA 276 is recognized by building codes throughout North America and overseas.

TEST FOR SUSCEPTIBILITY TO HEAT DAMAGE

The susceptibility to heat damage test has been added to FM 4470. This test is used to assess the damage to roof insulation applied to decks (other than concrete) from exposure to radiant heat as a result of an interior building fire.

After the test exposure, the insulation shall not be decomposed, discolored, or otherwise damaged beyond a depth of 1/8 in. (3 mm), and there shall be no curling or bowing of the sample. There are no new requirements due to this change, as insulations previously had to pass this test based on a separate approval standard.

CORROSION RESISTANCE ALTERNATIVE TEST METHOD

A second corrosion resistance test method has been added to FM 4470. As

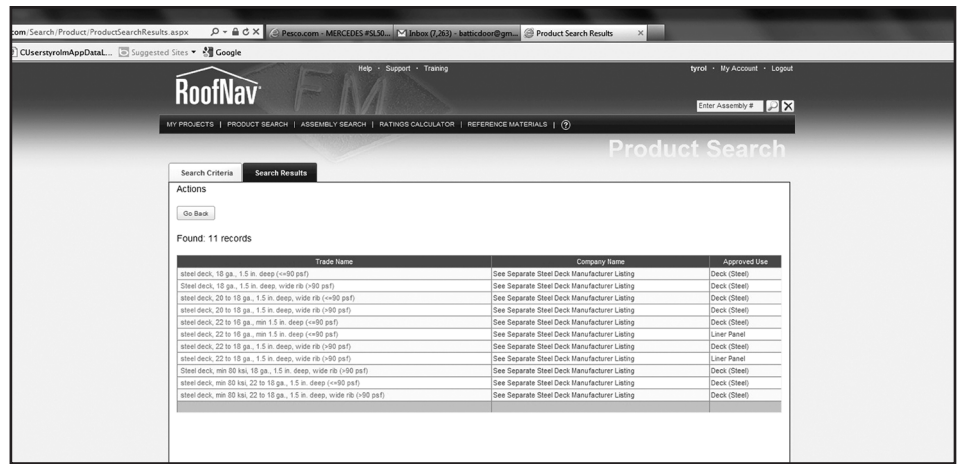


Figure 5 – Generic steel deck listings in RoofNav under “Products.”

an alternative to ASTM D6294, *Standard Test Method for Corrosion Resistance of Ferrous Metal Fastener Assemblies Used in Roofing and Waterproofing*, the following test method may also be used: *Guideline for European Technical Approval of Systems of Mechanically Fastened Flexible Roof Waterproofing Membranes*, ETAG 006, European Organisation for Technical Approvals (EOTA).

WHEN AND HOW WILL ROOFNAV BE UPDATED?

The current edition of FM 4470 has an effective date of December 31, 2012. As such, all assemblies approved after that date must meet all requirements. FM Approvals is working to ensure all existing RoofNav assemblies comply with all requirements by the effective date. During this period, any currently approved assemblies where the deck and/or deck fasteners are overstressed shall be addressed.

One plan is to update the “generic” decks in RoofNav to include maximum wind ratings for various membrane spacings. By updating these products, all approvals will be updated simultaneously. This allows manufacturers to then evaluate their own proprietary systems individually (Figure 5).

WHAT HAS NOT CHANGED

Roof assemblies have to meet all of the performance requirements and tests described in FM 4470 in order to be considered FM-Approved. Virtually all other third-party certification organizations rate a roof assembly vs. one-performance criteria and grant a listing based on that (for example, an external fire test only or wind uplift test only).

MORE ABOUT FM FM Global

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In 1835, a group of mill owners formed their own mutual fire insurance company, known today as Factory Mutual Insurance Company, which conducts business as FM Global. Today, FM Global has over \$5.1 billion in gross premiums in force, 5,300 employees—including 1,500 loss prevention engineers—and serves clients in more than 130 countries from 65 office locations worldwide.

FM Global is one of the world’s largest business property insurers, whose clients include more than one out of every three Fortune 1000-size companies. FM Global believes the majority of all property loss is preventable. The use of FM-Approved products and roof assemblies is recognized around the world as one of the keys to property loss prevention.

FM Approvals

FM Approvals is a member of the FM Global Group and offers product testing and certification. FM Approvals certifies products and services with a unique focus on objectively testing property loss prevention products and services and certifying those that meet rigorous loss prevention standards and encouraging the development and use of FM-Approved products and services that improve and advance property loss prevention practices.

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FM Approvals is also a Notified Body in the European Union (EU), which allows FM Approvals to offer the CE mark for prod-

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To download a copy of FM 4470, visit RoofNav at www.roofnav.com.

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