FIELD VERIFICATION OF ROOF WIND UPLIFT RESISTANCE

FM clients must contact the local FM office before beginning uplift testing or any roofing work.

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1.0 SCOPE

This data sheet describes two methods of field testing new installations of above-deck roofing assemblies to determine if there is adequate wind resistance. It also provides alternative visual construction observation guidelines. Confirmation of acceptable wind uplift resistance on completed roof systems is critical in tropical cyclone-prone regions.

Field tests can be used to assess existing roofs for adequate wind resistance. Field tests should not be used to determine the cause of wind uplift damage after a storm event unless comparable field tests were conducted directly before the storm; and roof cover damage or deficiencies can be proven to not exist prior to the storm. Field tests are not applicable to metal panel roofs (standing seam and through fastened), ballasted roofs, or mechanically fastened covers with fasteners spaced more than 2 ft (0.6 m) apart in either direction.

1.1 Changes

October 2024. Interim revision. The following changes have been made:

A. Clarification has been provided on using deflection measurements to determine final results.

B. Additional information has been provided on conducting roof test cuts.

C. Additional details are given regarding the provision of a detailed test report or Visual Construction Observer (VCO) report.

2.0 LOSS PREVENTION RECOMMENDATIONS

2.1 Introduction

2.1.1 At locations that are **both** (a) within a tropical cyclone-prone region as defined in Data Sheet 1-28, and (b) in areas where design wind-speeds are greater than or equal to 100 mph (45 m/s), ensure one of the following is performed for new, recovered, or reroofed above-deck roof assemblies:

A. Satisfactory completion of uplift tests in accordance with both Section 2.2 and Section 2.3, or with Section 2.4.

B. Visual construction observation (VCO) in accordance with Section 2.5.

Exception: New roof covers (single-ply, or multi-ply with a mechanically fastened base sheet) mechanically fastened directly to one of the deck types listed below do not require field uplift testing provided the roof cover fastener spacing is verified to be adequate:

- Steel deck minimum 22 ga (0.295 in. [0.75 mm])
- Wood deck
- Cementitious panel roof deck
- Structural concrete with a minimum ultimate compressive strength (f'c) of 2500 psi (17.4 mPa)
- Lightweight insulating concrete (LWIC) in which roof cover fasteners completely penetrate the LWIC and fully engage minimum 22 ga. (0.0295 in., 0.75 mm) steel form deck

Note: Verification of roof cover fastener spacing may be accomplished by visual identification or nondestructive examination (e.g., metal detection).

2.1.2 If uplift tests are performed, ensure testing requirements are included in the building contract, and roofing contracts/subcontracts when applicable, to determine that the wind uplift performance for the test areas meets the specifications in this data sheet.

2.1.3 Have testing witnessed by the owner's representative.

2.1.4 Record the results of uplift tests or visual construction observation (VCO) and forward to the FM local servicing office. See Appendix C for a copy and suggested contract wording.

2.1.5 Have roof test cuts conducted by a roofing professional in test areas with a failed or suspect test. Have a roofing professional present to repair the test areas and return the roof area to a watertight condition should any of the tests fail.

2.2 General

2.2.1 Prior to any testing, ensure adequate curing of roof adhesives in accordance with the manufacturer's instructions.

2.2.2 Select the appropriate field uplift test based on roof system per Table 2.2.2-1.

Table 2.2.2-1. Recommended Tests for Various Roof Systems

Type of Test or Analysis/ Roof Type	*MF SP, MF BUR[Note 2] or MF Mod Bit[Note 2] to deck other than LWIC*	*MF SP[Note 1],MF BUR[Note 2] or Mod Bit[Note 2] to LWIC*	*FA SP, BUR or Mod Bit w/MF insulation*	*FA BUR or Mod Bit w/FA insulation*	*FA SP w/FA insulation*	*Metal Roofs*	*Ballasted See Data Sheet 1-29*
Negative Pressure Test	DNA	R[1]	R	R	R	DNA	DNA
Bonded Uplift Test	DNA	NR	NR	R	R	DNA	DNA

Note 1. Fastener spacing does not exceed 2 ft (0.6 m)in both directions.
Note 2. Base sheet is mechanically attached and upper plies are adhered.
MF – mechanically fastened R – recommended
FA – fully adhered NR – not recommended
SP – single-ply membrane BUR – built-up roof
Mod Bit – modified bitumen roof cover DNA – does not apply
Metal Roofs – standing seam (concealed clip securement) or lap seam (through fastened)

2.2.3 Determine the design wind pressure (p_i) for roof zones using Roof*Nav* Ratings Calculator or Data Sheet 1-28.

2.2.4 Determine the required passing uplift test pressures (U_i) for roof zones 1, 1', 2, and 3 per Equation 1:

$$U_i = \Omega_{test} \times p_i \qquad \text{(Equation 1)}$$

Where the uplift testing factor, Ω_{test}, is defined as follows:

$$\Omega_{test} = 1.25 \text{ for zones 1', 1, 2, and 3}$$

Equation 1 results in the following required passing uplift test pressures for the respective roof zones:

$$U_{Zone1} = 1.25 \times p_{Zone1}$$

$$U_{Zone1'} = 1.25 \times p_{Zone1'}$$

$$U_{Zone2} = 1.25 \times p_{Zone2}$$

$$U_{Zone3} = 1.25 \times p_{Zone3}$$

2.2.5 As an alternative to Section 2.2.4, U_i can be determined per Table 2.2.5-1. Note that Table 2.2.5-1 was created for ease of application. In some cases, the table is conservative (see Note 1).

Table 2.2.5-1. Required Passing Uplift Test Pressures as a Function of Required Rated Resistance for Enclosed Low-Slope Buildings[Note 1]

Required FM Rated Resistance[Notes 3,4] (Zone 1)	*Required Passing Uplift Test Pressure (U_i)*							
	Zone 1'	Zone 1		Zone 2		Zone 3		
	See Notes 2, 3	lbf/ft^2	kPa	lbf/ft^2	kPa	lbf/ft^2	kPa	
60		38	1.8	49	2.3	67	3.2	
75		47	2.3	62	3.0	84	4.0	
90		56	2.7	74	3.5	101	4.8	
105		66	3.2	87	4.2	118	5.6	
120		75	3.6	99	4.7	135	6.5	
135		84	4	111	5.3	152	7.3	
150		94	4.5	124	5.9	169	8.1	
165		103	4.9	136	6.5	185	8.9	
180		113	5.4	148	7.1	202	9.7	
195		122	5.8	161	7.7	219	10.5	
210		131	6.3	173	8.3	236	11.3	
225		141	6.8	186	8.9	253	12.1	
240		150	7.2	198	9.5	270	12.9	
255		159	7.6	210	10.1	287	13.7	
270		169	8.1	223	10.7	303	14.5	
285		178	8.5	235	11.3	320	15.3	
300		188	9	247	11.8	337	16.1	

Note 1. For design pressures that fall between or above the ratings in the table, the required passing uplift test pressure is equal to 125% of the specific design wind pressure for Zones 1', 1, 2, and 3 as calculated using Data Sheet 1-28. The required passing uplift test pressures for Zone 2 and Zone 3 shown in the table are for enclosed buildings with gable roofs (without overhangs) with low slopes (<7 degrees [1.5 in 12]) and eave roof heights less than or equal to 60 ft (27.4 m).
Note 2. For roofs that include a Zone 1', the required passing uplift test pressure is equal to 125% of the design wind pressure for zone 1' as calculated using Data Sheet 1-28.
Note 3. Treat Zone 1' independently of all other roof zones. Do not determine Zone 2 and Zone 3 passing uplift test pressures based on Zone 1'. The values for Zone 2 and Zone 3 are correlated with Zone 1 values only.
Note 4. The rated resistance is based upon a Safety Factor of 2.0.

Example No. 1: Determination of required passing uplift test pressures for each roof zone.

Note: Negative signs in Table 2.2.5-2 indicate uplift in accordance with typical convention.

Building dimensions: 200 ft x 300 ft x 30 ft
Building type: enclosed building
Roof slope: low-slope roof
Velocity pressure: q_h = 25.8 psf.
Importance factor: I = 1.15

The required passing uplift test pressures, U_i, for each roof zone are calculated as follows:

$$U_i = \Omega_{test} * p_i = \Omega_{test} * q_h (GC_p - GC_{pi}) * I$$

Table 2.2.5-2. Required Passing Uplift Test Pressures [Note 1]

Roof Zone	*Velocity Pressure, q_h [psf]*	*Pressure Coeff Sum (GC_p — GC_{pi})*	*Design Wind Pressure, p [psf]*	*Minimum FM Approved Rating[Note 2] [psf]*	*Uplift Testing Factor, Ω_{test}* (see 2.2.4)	*Required Passing Uplift Test Pressure[Note 2] [psf]*
3	25.8	-3.38	-100.3	1-210	1.25	-125
2		-2.48	-73.6	1-150	1.25	-92
1		-1.88	-55.8	1-120	1.25	-70
1'		-1.08	-32.0	1-75	1.25	-40

Note 1. Due to the lower end limit (1-60) and 15 psf increments for FM Approved roof assembly ratings, in some cases the rating of the installed roof assembly may be significantly higher than both the design wind pressure and required passing uplift test pressure. The likelihood of this scenario is particularly true for zone 1'.
Note 2. The minimum FM Approved roof assembly rating is based upon a factor of safety of 2 over the design wind pressure. The required passing uplift test pressure is lower than the minimum FM Approved rating in all scenarios.

2.2.6 Except where otherwise noted, evaluation of uplift tests resulting in a passing designation is based on withstanding the required passing uplift test pressure (U_i) or equivalent for its respective roof zone for a period of 1 minute without experiencing any defined mode of failure.

2.2.7 To prevent water damage to insulation, promptly patch and make watertight all damaged/failed test areas.

2.2.8 Perform repairs in accordance with Data Sheets 1-30, *Repair of Wind Damaged Single- and Multi-Ply Roof Systems*; 1-28, *Wind Design*; and 1-29, *Roof Deck Securement and Above-Deck Roof Components*.

2.3 Negative Pressure Test

2.3.1 The negative pressure uplift test is generally preferrable to the bonded uplift test. It is not to be used directly on porous surfaces because the test requires an airtight seal between the test apparatus and the roof covering.

2.3.2 Negative pressure uplift tests may be conducted on totally adhered built-up roofs (BUR), modified bitumen (mod bit), or single-ply membranes. This test can also be performed on mechanically attached base sheets, or mechanically attached/plate-bonded/induction-welded reinforced single-ply membranes if fasteners are spaced no more than 2 ft (0.6 m) on center in both orthogonal directions.

2.3.3 For the fastened base sheets or reinforced single-ply membranes described in Section 2.3.2, the negative pressure apparatus may be used provided a minimum of one fastener is tested at its full fastener-to-fastener span in both orthogonal directions.

2.3.4 Conduct negative pressure uplift tests in accordance with Appendix D, *Negative Pressure Test Procedure*.

2.3.5 Determine the minimum number of individual negative pressure tests per roof area (NOT per building) in accordance with Table 2.3.12-1. Roof areas are defined as areas bordered by roof dividers or expansion joints.

2.3.6 Divide roof areas A > 60,000 ft^2 (5,600 m^2) into sub-areas A_i with 10,000 ft^2 (930 m^2) < A_i ≤ 60,000 ft^2 (5,600 m^2) (see Figure 2.3.6-1).

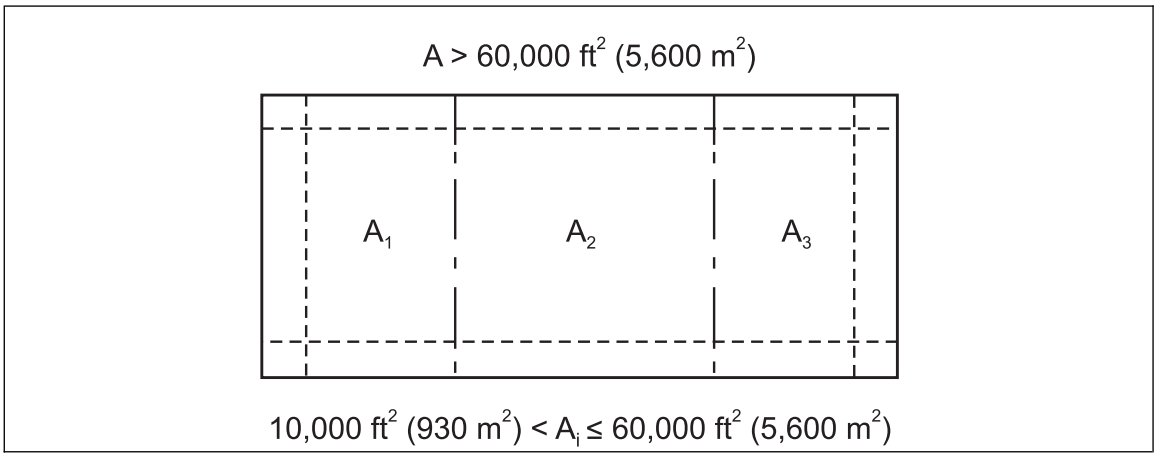

Fig. 2.3.6-1. Roof area divided into sub-areas

2.3.7 Refer to Data Sheet 1-28, *Wind Design*, to determine the roof zone geometric parameters and dimensions.

2.3.8 When determining roof zones for adjacent roof areas (A^i), a height differential of h ≤ 9.8 ft (3 m) at that elevation change would result in Zone 3 becoming a Zone 2 and Zone 2 becoming a Zone 1 at the higher roof elevation (see Figure 2.3.6-2).

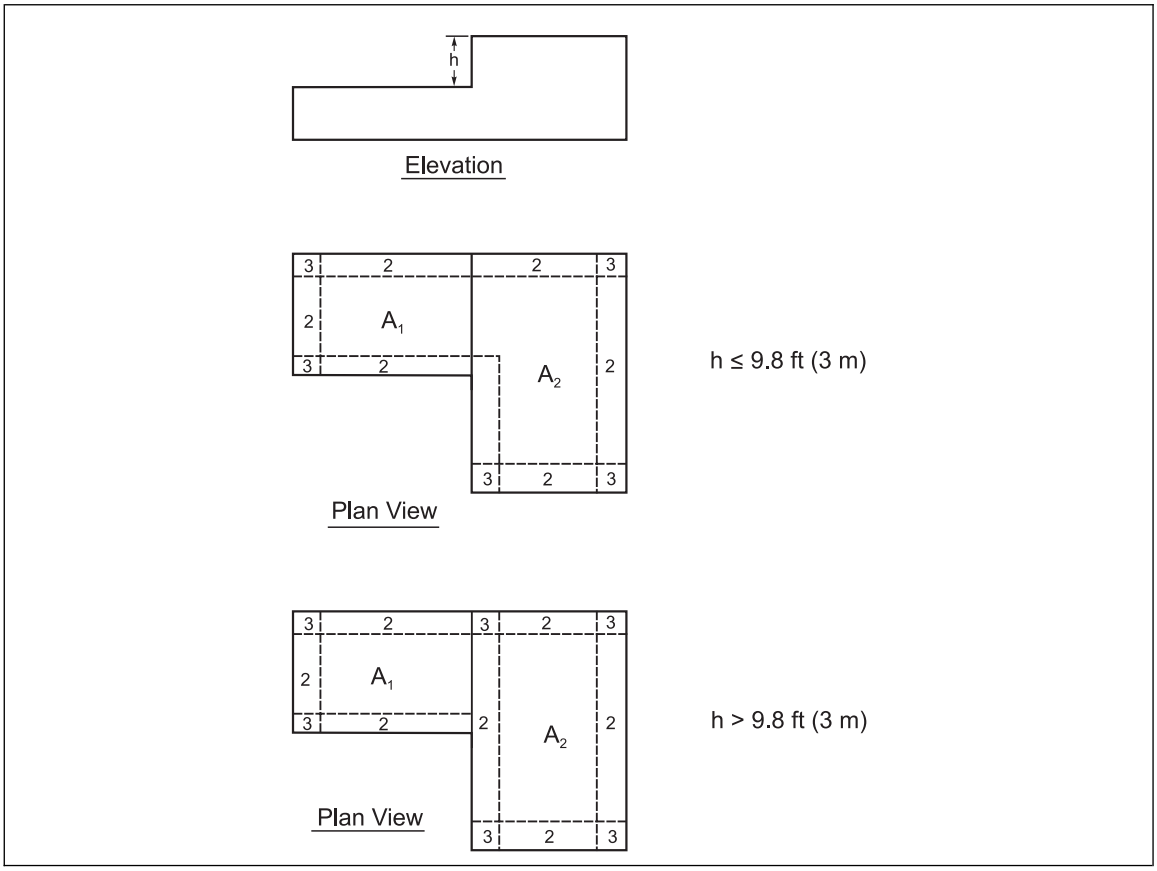

Fig. 2.3.6-2. Roof zone designations for a roof with a height differential

2.3.9 Test perimeters (Zone 2) and corners (Zone 3) only when roof area Ai terminates along an outside edge (see Figure 2.3.12-1).

2.3.10 Only two tests are required for every interior roof area (see Figure 2.3.12-1).

2.3.11 If a roof area includes Zone 1', **and** the construction of the above-deck roofing assembly **does** differ between Zone 1 and Zone 1', test Zone 1' using the appropriate Zone 1' test pressure.

2.3.12 If a roof area includes Zone 1 and Zone 1', **and** the construction of the above-deck roofing assembly **does not** differ between Zone 1 and Zone 1', testing of Zone 1 is sufficient.

2.3.13 Negative Pressure Test contractors should have specialized training from qualified persons or organizations or certification from an industry-recognized organization. Training should be focused on developing competent persons qualified to run these tests.

Table 2.3.12-1. Minimum Number of Negative Pressure Tests

Roof Area (A) [ft² or m²]	*Minimum Number of Individual Tests(per Roof Zone)*			
	Zone 1'	Zone 1	Zone 2	Zone 3
A < 10,000 (930)	See Note 1.	1	1	1
10,000 (930) < A < 60,000 (5,600)		2	2	1
A > 60,000 (5,600) or multiple adjoining roof areas	See Note 1.			

Note 1. See Sections 2.3.6 to 2.3.12 and Figures 2.3.6-1, 2.3.6-2 and 2.3.12-1.

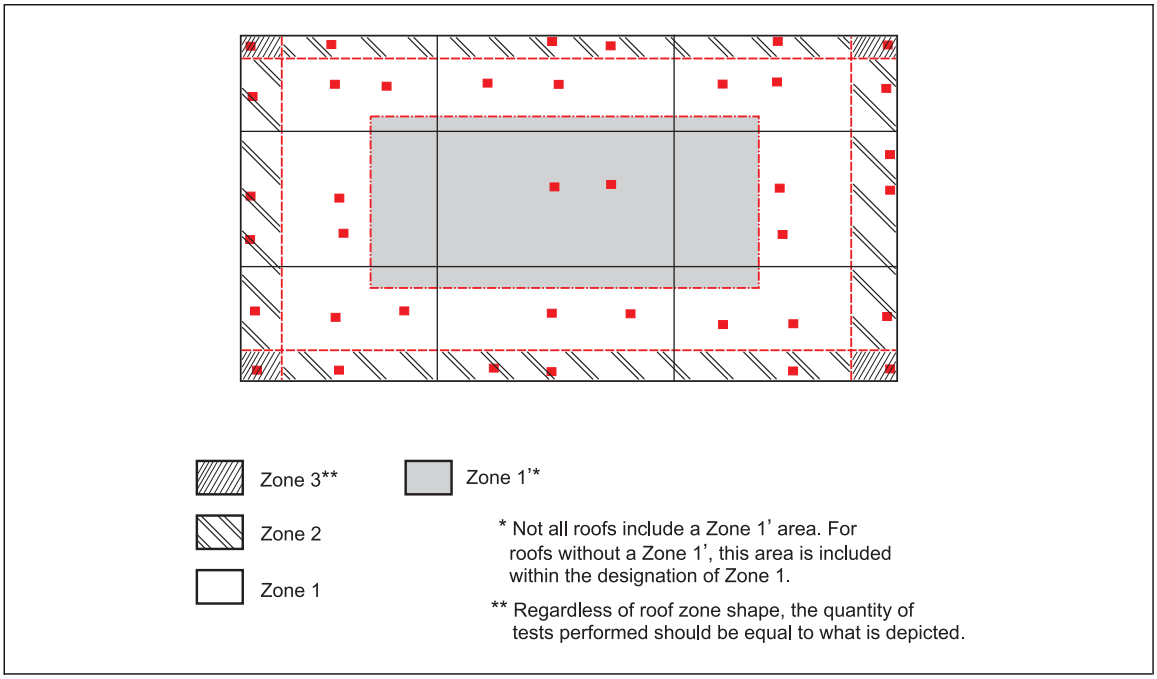

Fig. 2.3.12-1. Uplift test location example: Nine sections Ai with individual roof areas up to 60,000 ft^2 (5,600 m^2) and no change in above-deck roofing assembly for Zones 1 and 1'

2.4 Bonded Uplift Test

2.4.1 Bonded uplift testing is not valid if the insulation, base sheet, or membrane is secured with mechanical fasteners.

2.4.2 Do not perform bonded uplift test when the roof slope exceeds 1.2° (1/4 in 12).

2.4.3 Conduct four times as many bonded uplift tests (BUT) as recommended by Table 2.3.12-1, Figure 2.3.12-1, and Sections 2.3.5 through 2.3.12 than that recommended for the negative pressure test (NPT) to account for the smaller test sample area.

2.4.4 Prepare the four BUT samples in close proximity to each other, taking into consideration that a complete cut needs to be made down to the top of the deck around the entire perimeter of the sample, and the required bearing points for the tripod legs.

2.4.5 Determine the required passing scale reading (Freq) for the required passing uplift test pressure (U_i) per Equation 2.

$$F_{req}\ [lb] = U_i\ [psf] \times A_{Testsample}\ [ft^2] + Weight_{Testpanel}\ [lb]$$

$$F_{req}\ [kN] = U_i\ [kPa] \times A_{Testsample}\ [m^2] + Weight_{Testpanel}\ [kN] \qquad \text{(Eq. 2)}$$

2.4.6 Conduct bonded uplift tests and record data in accordance with Appendix E, *Bonded Uplift Test Procedure.*

2.5 Visual Construction Observation (VCO)

2.5.1 Use full-time visual construction observation (VCO) during roof system installations as an alternative to performing field wind uplift testing for verification of adequate wind resistance.

2.5.2 Ensure the visual construction observer (VCO) has the following minimum qualifications:

A. A thorough knowledge of the roofing system being installed, relevant industry accepted-practices, contract documents, blueprint reading, approved components (as detailed in the FM Approval listing) and relevant FM data sheets.

B. A thorough knowledge of the specified roofing system and the manufacturer's requirements.

C. Is listed as one or more of the following:

1. Registered roof consultant (RRC) by IIEBEC.
2. Registered roof observer (RRO) by IIEBEC.
3. For locations outside the United States where individuals with the above qualifications are not available, completion of specialized training or certification as a rooftop quality assurance observer from an industry-recognized organization.

2.5.3 Follow guidelines and requirements in Appendix F, *Visual Construction Observation (VC0)*.

3.0 SUPPORT FOR RECOMMENDATIONS

3.1 Background Information

Performing these tests can identify inferior roofs that might be damaged by wind, resulting in water damage to building contents and possible interruption to business. Do not substitute uplift testing for built-in quality. Ensure the roof system is designed to be wind-resistant, and the construction work is performed by a professional roofing contractor who employs quality-control measures that guarantee the system is installed as intended.

Whether tests are to be run on new roofs, or simply because the construction is unknown, passing criteria is based on 125% (Zones 1', 1, 2, and 3) of the design wind pressure (e.g., for a design wind pressure of 45 psf in Zone 1, the minimum test pressure, U_i, to pass is 56 lbf/ft^2 [2.7 kPa], with higher pressures for Zone 2 and Zone 3 due to the higher uplift pressures experienced in those areas. Note for this example the minimum required FM Approved roof assembly in Zone 1 would be a 1-90).

The ability of the roof deck and edge conditions to resist wind uplift are also critical but uplift testing does not accurately evaluate the uplift resistance of the roof deck or edge securement, such as flashing, coping, etc. Lifting of metal edge flashing and coping and subsequent lifting and progressive membrane peeling is the most common cause of membrane loss. See Data Sheet 1-29, *Roof Deck Securement and Above-Deck Roof Components*, for proper deck securement, the *Approval Guide*, an online resource of FM Approvals, and Data Sheet 1-49, *Perimeter Flashing*, for proper flashing securement.

3.1.1 Commentary

Table 3.1.1-1 contains explanatory material related to some of the loss prevention recommendations in Section 2.0. The specific section number to which the commentary applies is identified in the table.

Table 3.1.1-1. Commentary for Section 2.0 Loss Prevention Recommendations

Section Number	*Commentary*
2.2.1	Cold adhesives normally require 28 days to cure to the strength obtained during FM Approvals testing, which allows a maximum 28-day cure time. These may acquire additional strength after 28 days and it is acceptable to conduct uplift testing after 28 days. Note: Where time permits (such as prior to the hurricane season), it is preferred to allow a 2-month cure time for cold process, bituminous adhesives.
2.2.2	Neither the negative pressure test nor the bonded uplift test can be used on ballasted roofs or metal-panel roofs. The bonded pull test is not recommended where any type of mechanically fastened cover or insulation is used.
2.2.3	Data Sheet 1-28 is used to determine the roof Zone 1 design wind pressure.
2.2.4	For low roof slopes and a minimum 3 ft (0.9 m) parapet around the entire outside edge of the roof, the required passing uplift test pressure used for Zone 3 is the same as that for Zone 2. Zone 1' is present for certain building configurations only. In addition, the external pressure coefficient difference between Zone 1' and Zone 2 and Zone 3 is high.
2.2.5	Table 2 is based on reference to the Zone 1 FM roof wind rating, in which the Zone 2 and Zone 3 values were calculated using Zone 3:Zone 1 and Zone 2:Zone 1 pressure coefficient ratios. Zone 1' must be treated as a zone independent of Zones 1, 2, and 3. This is intended to avoid confusion and potential errors.
2.3	The bonded uplift test is a destructive test. The negative pressure test is more desirable due to its potential to be nondestructive and closer to true wind uplift conditions.
2.3.2	When the membrane is mechanically attached using fastener spacings greater than 2 ft (0.6 m) on center in either direction, a conventional field test is not possible. See Section 3.3.1, Mechanically Fastened Single-Ply Coverings, for more details.
2.3.3	Full fastener-to-fastener span tests are possible only when spacing in both directions is 2 ft (600 mm) or less due to test apparatus dimensions. This arrangement allows one fastener to be centered beneath the apparatus with the entire membrane span contributing to the uplift in normal fashion.
2.3.11	Interior roof areas, including portions categorized as Zone 1', may include differing construction of the above-deck roofing assembly compared to Zone 1. The differing construction is economical for large Zone 1' areas only. Because the uplift pressure for Zone 1' is considerably lower than Zone 1, testing of Zone 1' is only critical when the construction differs.

3.2 Loss History

An extensive loss history exists on failures of roof systems due to wind forces. Since the majority of roof deficiencies leading to wind uplift failures are not readily visible on completed roofs, uplift testing and visual construction observation (VCO) are offered as tools to aid in ensuring adequate wind resistance.

3.3 Negative Pressure Test

Observers not directly involved in operating the test equipment should not stand immediately adjacent to the test area. Also, it is imperative that there be no walking near the test area between the time the deflection gauge has been zeroed out and completion of the test. For example, if someone stands immediately adjacent to the center of the test area while the gauge is being zeroed out, then moves away from that area before the test is complete, the deflection gauge reading may be unrealistically high. In contrast, if someone is initially standing away from the test area, but later walks immediately adjacent to the center of the test area after the gauge was zeroed out, it can cause the deflection gauge reading to be unrealistically low.

Additives to the manometer water solution may cause changes to the specific gravity. Any change to the specific gravity will alter the manometer readings.

The manometer, when used, acts as a safety device to prevent negative pressure that could cause the dome to collapse.

Loose surfacing material can cause pump damage and will prevent a proper seal between the apparatus and the roof.

Laboratory tests have revealed that some improperly adhered roof assemblies may not show obvious signs of ballooning and failure, but will experience considerable deflection (see Section 3.3.1). Field testing of successful roof samples typically results in negligible deflection.

ASTM E-907, *Standard Test Method for Field Testing Uplift Resistance of Adhered Membrane Roofing Systems*, was frequently referenced by contractors conducting uplift tests. This standard allowed a 1 in. (25.4 mm) deflection.

3.3.1 Mechanically Attached/Plate Bonded/Induction Welded Roof Coverings

Mechanically attached, plate bonded, and induction-welded single-ply membranes normally will balloon between supports when subjected to uplift pressures. Consequently, it is impractical to use a deflection gauge with such assemblies. The only applicable method of examination for such systems is visual observation of the test specimen for failure throughout testing.

If fasteners are located in rows and only at laps in the membrane, with or without a batten-type strip, neither type of conventional uplift test will yield satisfactory results. Proper uplift can be simulated only by testing the full membrane freespan on both sides of the fastener row. Row spacing is normally too wide to accommodate this criterion.

3.4 Bonded Uplift Test

Arrangement of the BPT test samples in close proximity allows testing of the same approximate sample area as in the NPT, and minimizes the area requiring post-test repair.

Determination of the required passing scale reading (lb [kN]) for the respective required passing uplift test pressure (U_i) are calculated as the following:

$$U_i \text{ (psf[kPa])* AREA (ft}^2 \text{ [m}^2\text{])} + \text{Weight of test panel (lb[kN])}$$

An example is depicted in Table 3.4-1 based on a 4 ft^2 (0.37 m^2) panel that weighs 15 lb (6.8 kg; 66.7 N).

Conversely, determination of the pressure achieved (psf [kPa]) is calculated as follows:

$$\frac{\text{[Scale Reading (lb [kN]) - Weight of test panel (lb [kN])]}}{\text{AREA (ft}^2 \text{ [m}^2\text{])}}$$

For example, if the highest scale reading was 375 lb (170 kg) and the panel weighed 15 lb (6.8 kg) and was 4 ft^2 (0.37 m^2) in area, the pressure held was (375-15) lb/4 ft^2 = 90 psf. In SI units, (170-6.8) kg/0.37 m^2 x (9.81/1000) = 4.3 kPa.

Table 3.4-1. Typical Scale Readings for 4 ft^2 (1.2 m^2) Test Panel That Weighs 15 lbs (6.8 kg)

Uplift Test Pressure		*Scale Reading*	
lbf/ft^2	(kPa)	lb	(kg)
15.0	(0.7)	75	(34)
22.5	(1.1)	105	(48)
30.0	(1.4)	135	(61)
37.5	(1.8)	165	(75)
45.0	(2.2)	195	(88)
52.5	2.5	225	102
60.0	2.9	255	116
67.5	3.2	285	129
75.0	3.6	315	143
82.5	4.0	345	156
90.0	4.3	375	170
97.5	4.7	405	184
105.0	5.0	435	197
112.5	5.4	465	211
120.0	5.7	495	225
127.5	6.1	525	238
135.0	6.5	555	252
142.5.	6.8	585	265
150.0	7.2	615	279
157.5	7.5	645	293
165.0	7.9	675	306
172.5	8.3	705	320
180.0	8.6	735	333
187.5	9.0	765	347
195.0	9.3	795	361
202.5	9.7	825	374
210.0	10.1	855	388
217.5	10.4	885	401
225.0	10.8	915	415
232.5	11.1	945	429
240.0	11.5	975	442
247.5	11.9	1005	456
255.0	12.2	1035	469
262.5	12.6	1065	483
270.0	12.9	1095	497
277.5	13.3	1125	510
285.0	13.6	1155	524
292.5	14.0	1185	538
300.0	14.4	1215	551
307.5	14.7	1245	565
315.0	15.1	1275	578
322.5	15.4	1305	592
330.0	15.8	1335	606
337.5	16.2	1365	619
345.0	16.5	1395	633
352.5	16.9	1425	646
360.0	17.2	1455	660
367.5	17.6	1485	674
375.0	18.0	1515	687
382.5	18.3	1545	701
390.0	18.7	1575	714
397.5	19.0	1605	728
405.0	19.4	1635	742

3.5 Visual Construction Observation (VCO)

3.5.1 Visual construction observation (VCO) is an alternative to performing field wind uplift testing for verification of adequate wind resistance.

4.0 REFERENCES

4.1 FM

Data Sheet 1-28, *Wind Design*

Data Sheet 1-29, *Roof Deck Securement and Above-Deck Roof Components*

Data Sheet 1-30, *Repair of Wind-Damaged Single- and Multi-Ply Roof Systems*

Roof*Nav*, an online resource of FM Approvals for roofing professionals

4.2 Other

American Society for Testing and Materials (ASTM) International. ASTM E-907, *Standard Test Method for Field Testing Uplift Resistance of Adhered Membrane Roofing Systems*.

APPENDIX A GLOSSARY OF TERMS

Construction observer (CO): A properly qualified, unbiased consultant who conducts a visual construction observation (VCO).

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

Hurricane-prone region: See the definition of “tropical cyclone-prone region” in Data Sheet 1-28.

Negative pressure: Pressure less than that of atmosphere.

Roof area: A single roof area for uplift testing is a section of roof (single composition including the same substrate that was installed at the same time) up to its termination point, which is the roof outside edge, an expansion joint, or a roof area divider.

Roof divider: A terminating point intended to break large flat roof areas into smaller sections and to relieve thermal stresses over large areas. A roof dividers is a structural element that only provides a break in the roof construction, whereas an expansion joint is a gap that separates two areas of roof covering.

Tropical cyclone-prone region: See Data Sheet 1-28 for definition.

Visual construction observation (VCO): The practice of using a properly qualified consultant to continuously observe the installation of roofing components.

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).

October 2024. Interim revision. The following changes have been made:

A. Clarification has been provided on using deflection measurements to determine final results.

B. Additional information has been provided on conducting roof test cuts.

C. Additional details are given regarding the provision of a detailed test report or Visual Construction Observer (VCO) report.

July 2021. Interim revision. Updated the scope of this data sheet to clarify the intent of the document for existing situations. Also removed references to an incorrect FM Global form.

October 2020. Interim revision. Scope of this data sheet was updated to clarify the intent of the document and clarification was made to recommendation D.4.1.8.

February 2020. This data sheet has been completely revised. The following significant changes were made:

A. Reformatted the document to simplify implementation of testing. Moved procedures for field testing and visual construction observation (VCO) to appendices to facilitate their use.

B. Renamed the “safety factor” for testing to “uplift testing” factor (Ω_{test}).

C. Updated the roof zone nomenclature.

D. Added testing parameters to accommodate a new interior roof zone (Zone 1’).

E. Moved supporting information from Section 2.0 to Section 3.0 (Table 3.1 Commentary).

July 2012. The following changes were made:

A. The option to provide visual construction observation (VCO) in lieu of conducting field uplift tests was added. The title of this document was revised to reflect this change.

B. The number of tests recommended when using the bonded pull test was increased to account for the smaller sample area.

C. The recommended field test safety factor was reduced from 1.5 to 1.25.

D. The deflection limit for thin, mechanically fastened cover boards was increased.

E. Additional pass/fail criteria were provided.

April 2009. The following was done for this revision:

- Changed wind uplift testing recommendations to exempt new roof covers that are mechanically fastened to minimum 22 ga (0.295 in.; 0.75 mm) steel, wood, or cementitious wood fiber deck or structural concrete.
- Added guidance for evaluating tests in which deflection seems excessive, but failure of the assembly is not obvious.

February 2007. This revision of the document changes the test pressure (to include perimeter and corner pressure coefficients and a safety factor = 1.5), the number of uplift tests required, and requires uplift tests for new above-deck roofing assemblies in regions that are prone to hurricanes, typhoons and tropical cyclones and where design wind speeds are at least 100 mph (45 m/s).

May 2000. The document was reorganized to provide a consistent format.

September 1999. A conversion table was added to convert psf to in. of water. Discussion on roof cuts was added for situation s where testing is not practical.

February 1986. Information was added regarded the maximum fastener spacing for mechanically fastened covers for which the negative pressure test is applicable. Also, research test data was added regarding negative pressure tests with unadhered rigid insulation boards that showed excessive deflection.

August 1980. Information was added regarding the negative pressure test apparatus.

January 1978. Details for fastening existing deficient roofs were moved from this document to another data sheet.

March 1975. Examples were added.

August 1970. Document first published.

APPENDIX C CONTRACTOR’S MATERIALS

C.1 Proposed Contract Wording for Uplift Testing

“ABC Roofing Company agrees to satisfy an uplift test of the completed roofing installation in accordance with FM Property Loss Prevention Data Sheet 1-52, Field Verification of Roof Wind Uplift Resistance. ABC Roofing Company is responsible for obtaining the most recent edition of Data Sheet 1-52 from FM and for supplying all labor, materials, and test equipment. Results of the tests shall be recorded and made available to FM. Acceptance and final payment shall be contingent upon favorable interpretation of the test results (as measured by the specifications) by FM.”

APPENDIX D NEGATIVE PRESSURE TEST PROCEDURE

D.1 General Information

D.1.1 Scope

D.1.1.1 The Negative Pressure Test is used as a method of field testing above-deck roofing assemblies to evaluate for the following conditions:

- Wind resistance
- Suspected inferior construction
- Partial blow-off

D.1.1.2 The Negative Pressure Test is not applicable to metal panel roofs (standing seam and through-fastened), ballasted roofs, or mechanically fastened covers with fasteners spaced more than 2 ft (0.6 m) apart in either direction.

D.1.2 Test Equipment

D.1.2.1 Test Apparatus: General

The test apparatus (see Figures D.1.2.1-1 and D.1.2.1-2) includes a chamber 5 ft by 5 ft (1.5 m by 1.5 m) sufficiently strong to withstand the necessary negative pressure without collapsing. The chamber is dome-shaped and of rigid acrylic plastic, fiberglass-reinforced plastic (FRP), or aluminum construction with polycarbonate view windows. The type of material and thickness will vary depending on the intended capacity of the apparatus. It is generally manufactured in two or four equal segments for ease in transporting it to and from the roof. The segments are provided with flanges so the units can be secured together. The flanges also act as structural ribs. A rubber gasket is provided to seal between the segments. One segment of the dome has a hole, usually 1.6 in. (41 mm) in diameter, to accommodate the vacuum pump, and another hole to accommodate a water or electric manometer. The dome has a bottom flange to set on the roof surface, and this flange is equipped with a flexible foam strip to seal the dome to the roof surface. Maximum pressure of the test apparatus varies depending on the exact make, but may vary from 340 lbf/ft^2 (16.28 kPa) to 410 lbf/ft^2 (19.63 kPa).

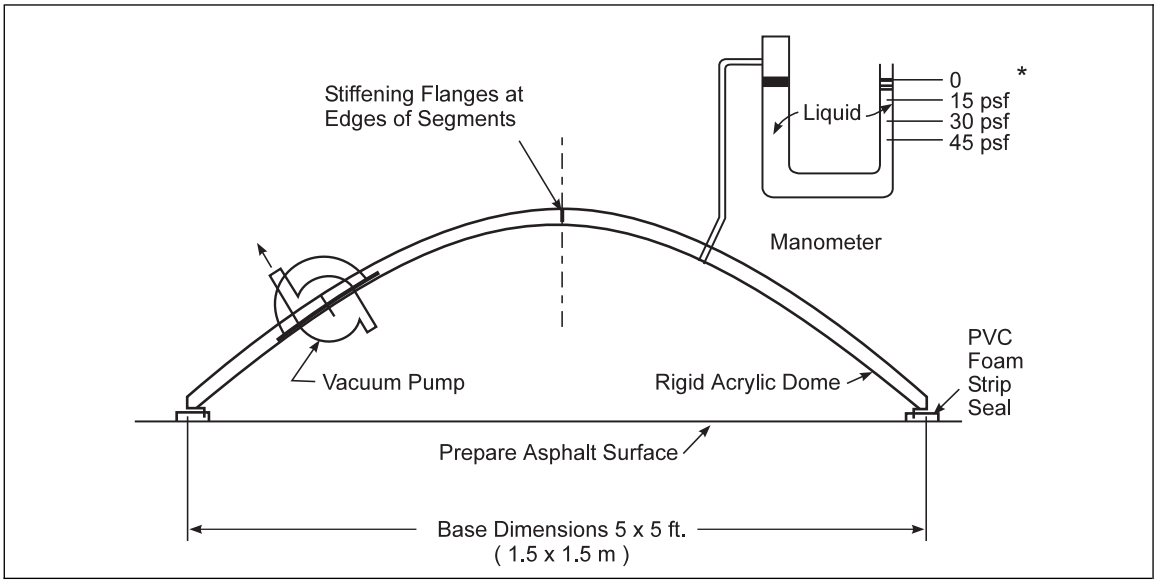

Fig. D.1.2.1-1. Schematic of negative pressure test apparatus with water manometer

D.1.2.2 Test Apparatus: A manometer is a liquid-filled instrument used to measure differential pressure between two fluids (i.e., the inside of the test apparatus versus atmosphere).

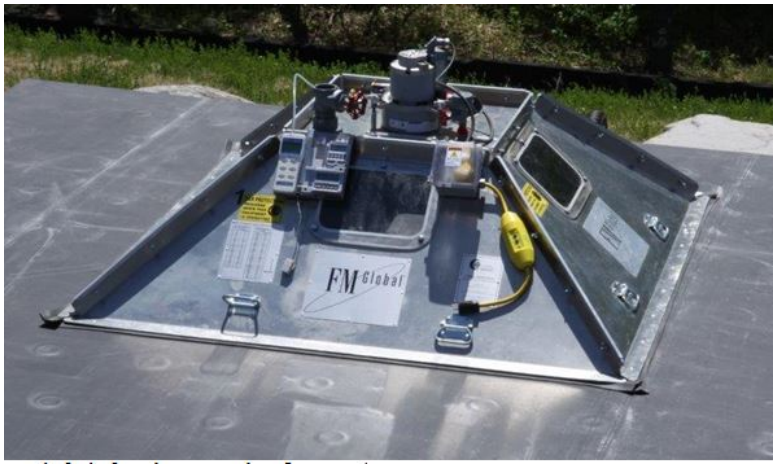

Fig. D.1.2.1-2. Photograph of negative pressure test apparatus

Note: Various manometer arrangements and calibrations are available. When provided, water manometers are made of clear plastic and generally calibrated to indicate negative pressures of 15 lbf/ft^2 (0.72 kPa), 22.5 lbf/ft^2 (1.08 kPa), 30 lbf/ft^2 (1.44 kPa), 45 lbf/ft^2 (2.16 kPa), etc. The manometer is equipped with a flexible tube to connect to the plastic dome. When the liquid is water, each 30 lbf/ft^2 (1.44 kPa) of negative pressure is equivalent to a vertical distance on the manometer water column of 5.77 in. (147 mm). (Inches of water required to pass equals lbf/ft^2 required to pass multiplied by 0.1924)

The vertical distance of the water column is the difference between the elevation of the two water columns and not the distance of one column from the original 0 set point. To convert other levels of water in a manometer, refer to Table D.1.2.2-1.

Table D.1.2.2-1. Conversion From Pressure to Depth of Water

WIND UPLIFT CALCULATIONS			
1 lbf/in.^{2} = 144 lbf/ft^2			
1 in. water = 25.4 mm water = 5.2 lbf/ft^2 = 0.25 kPa			
0.1924 in. of water = 1 lbs/ft^2			
lbf/ft^2	**kPa**	**in. H_2O**	**mm H_2O**
15.0	0.7	2.9	73.7
22.5	1.1	4.3	109.2
30.0	1.4	5.8	147.3
37.5	1.8	7.2	182.9
45.0	2.2	8.7	221.0
52.5	2.5	10.1	256.5
60.0	2.9	11.5	292.1
67.5	3.2	13.0	330.2
75.0	3.6	14.4	365.8
82.5	4.0	15.9	403.9
90.0	4.3	17.3	439.4
97.5	4.7	18.8	477.5
105.0	5.0	20.2	513.1
112.5	5.4	21.6	548.6
120.0	5.7	23.1	586.7
127.5	6.1	24.5	622.3
135.0	6.5	26.0	660.4
142.5	6.8	27.4	696.0
150.0	7.2	28.9	734.1
157.5	7.5	30.3	769.6

Table D.1.2.2-1. Conversion From Pressure to Depth of Water (continued)

WIND UPLIFT CALCULATIONS			
1 lbf/in.^{2} = 144 lbf/ft^2			
1 in. water = 25.4 mm water = 5.2 lbf/ft^2 = 0.25 kPa			
0.1924 in. of water = 1 lbs/ft^2			
lbf/ft^2	**kPa**	**in. H_2O**	**mm H_2O**
165.0	7.9	31.7	805.2
172.5	8.3	33.2	843.3
180.0	8.6	34.6	878.8
187.5	9.0	36.1	916.9
195.0	9.3	37.5	952.5
202.5	9.7	39.0	990.6
210.0	10.1	40.4	1026.2
217.5	10.4	41.8	1061.7
225.0	10.8	43.3	1099.8
232.5	11.1	44.7	1135.4
240.0	11.5	46.2	1173.5
247.5	11.9	47.6	1209.0
255.0	12.2	49.1	1247.1
262.5	12.6	50.5	1282.7
270.0	12.9	51.9	1318.3
277.5	13.3	53.4	1356.4
285.0	13.6	54.8	1391.9
292.5	14.0	56.3	1430.0
300.0	14.4	57.7	1465.6
307.5	14.7	59.2	1503.7
315.0	15.1	60.6	1539.2
322.5	15.4	62.0	1574.8
330.0	15.8	63.5	1612.9
337.5	16.2	64.9	1648.5
345.0	16.5	66.4	1686.6
352.5	16.9	67.8	1722.1
360.0	17.2	69.3	1760.2
367.5	17.6	70.7	1795.8
375.0	18.0	72.2	1833.9
382.5	18.3	73.6	1869.4
390.0	18.7	75.0	1905.0
397.5	19.0	76.5	1943.1
405.0	19.4	77.9	1978.7

D.1.2.3 Test Apparatus: Deflection Bar and Deflection Gauge

A deflection bar and gauge are placed on the roof surface prior to assembly of the dome to measure deflection of the roof assembly during the entirety of the uplift pressure test.

The deflection bar should be placed such that it is centered within the chamber in both directions and perpendicular to both side walls of the chamber. Once the bar and test chamber is set, movement of the bar during testing could affect the deflection readings. To limit movement, the ends of the bar should be positioned against the sides of the chamber, or the feet of the bar (if provided) should be positioned under the test chamber walls, such that movement of the bar is restricted. The bar should not be placed diagonally within the test chamber. Suggest that the bar be fabricated to be 55 in. (1.4 m) long; as this will accommodate the length of the sides of the chamber (the higher up the dome the shorter the perpendicular distance), as well as any inward deflection of the chamber walls as the negative pressure within the chamber is increased.

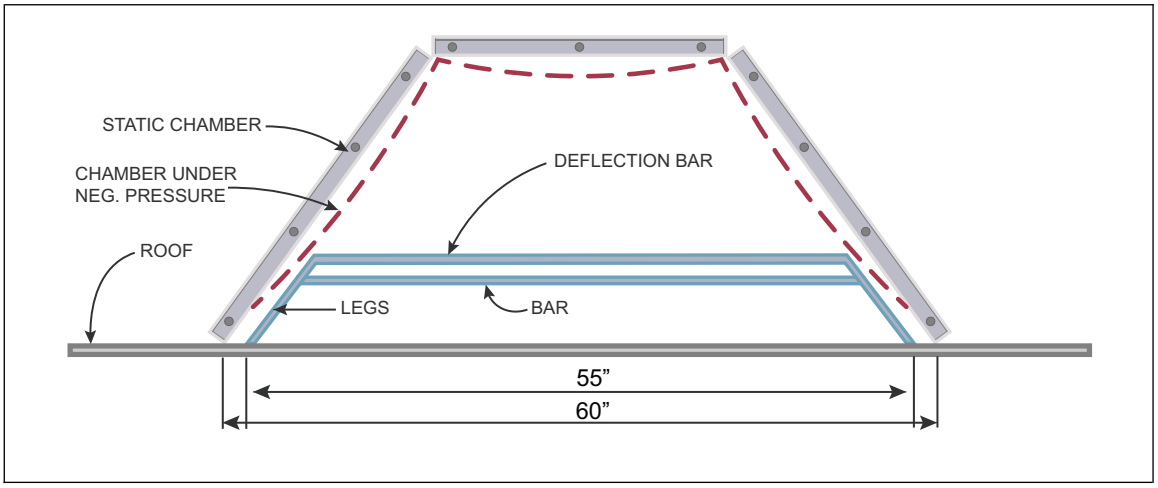

Fig. D.1.2.3-1. Diagram of deflection bar placement

Note 1. Bar is placed perpendicular to two opposing sides.

Note 2. Bar is shortened to allow for deflection of chamber panels as negative pressure increases (shown in red).

Deflection gauges should preferably be capable of measuring up to 2 in. (50 mm) of deflection. Some deflection gauges show a maximum of 1 in. (25.4 mm) deflection, and in those cases, when the gauge indicates a 1 in. (25.4 mm) deflection, the potential deflection may be greater.

Notes: Do not use the deflection bar and deflection gauge on mechanically fastened, plate-bonded or induction-welded roof assemblies. In addition, the results of deflection measurements are not meant to be the sole indication of a failed negative pressure uplift test. Instead, these measurements are used to supplement other failure observations to determine the cause of a test failure.

D.2 Test Preparation

D.2.1 Test Sample

D.2.1.1 Ensure the vacuum pump and dome have sufficient capacity to create the negative pressures required for the test. It must be equipped with controls to maintain a constant negative pressure at each test increment.

D.2.1.2 Locate test sites as follows:

A. Between supporting beams or joists where practical.

B. For pre-cast concrete roof decks, locate the test site over the joints in the pre-cast concrete deck.

C. Wholly within the roof zone under analysis.

D. Include at least one lap joint in the test site.

D.2.1.3 For **mechanically fastened, plate-bonded, or induction-welded systems** determined suitable for testing, do the following:

A. Locate the test site such that a minimum of one (1) fastener is tested at full fastener-to-fastener span in both primary orthogonal directions.

B. Sweep and clean away material (including dust, dirt, and loose granules) from the entire test area.

C. Ensure the removal of any sand or small granules adhered to the top surface in the area of the seal.

D. The test apparatus will cross over lap joints or splice edges, creating void areas at the edge of the lap that must be sealed by the foam strip.

D.2.1.4 For adhered single-ply membranes, do the following:

A. Sweep and clean away material (including dust, dirt, and loose granules) from the entire test area.

B. Ensure the removal of any sand or small granules adhered to the top surface in the area of the seal.

C. The test apparatus will cross over lap joints or splice edges, creating void areas at the edge of the lap that must be sealed by the foam strip.

D.2.1.5 For **built-up roof coverings**, when tests are to be made on a granule, gravel, or slag-covered roof, do the following:

A. The first step is to sweep away any loose surfacing material from the test area and from a 1 ft (0.3 m) wide area around the perimeter of the test area.

B. Pour a compatible sealant such as asphalt or coal tar pitch (whichever is on the existing roof), not to exceed 0.5 in. (13 mm) in thickness, over the perimeter of the test area to make a smooth surface that will allow contact between the apparatus and roof. When the roof is smooth, the existing surface usually is tight enough to draw a vacuum without the pouring. However, if the surface is alligatored, blistered, or otherwise rough, the bitumen layer will be necessary.

D.2.1.6 Prevent observers not directly involved in operating the test equipment from standing immediately adjacent to the test area.

D.2.1.7 Prevent anyone from walking near the test area between the time the deflection gauge has been zeroed out and test completion.

D.3 Test Operation

D.3.1 Test Conditions

Conduct tests only when the roof surface temperature is between 40°F and 100°F (5°C and 38°C).

D.3.2 Test Procedure

D.3.2.1 Place the deflection bar in the center of the dome (not applicable for mechanically fastened or spot-attached roof covers, deflection need not be monitored).

D.3.2.2 Place the assembled dome on top of the prepared roof surface located between supporting beams or joists, when practical. Ensure the apparatus encompasses at least one lap joint.

D.3.2.3 Ensure the dome is in complete contact with the surface to allow the necessary negative pressure to be drawn. Application of water under the foam strip will facilitate sealing.

D.3.2.4 When using a water manometer, attach the flexible hose to the dome and fill the manometer with water to the zero calibration level or to a plus or minus calibration level.

Note: Do not add anti-freeze to the manometer water solution on cold weather days nor food coloring to facilitate level reading.

D.3.2.5 Place the vacuum pump over the hole provided in the dome. Check that the bypass valve on the pump is open, then start the pump.

Note: When a vacuum is drawn on the covering, most roof decks will exhibit a very small upward deflection that will increase with each load increment.

D.3.2.6 Raise the initial pressure level to 15 lbf/ft^2 (0.72 kPa) and hold for one minute.

Note: For very high test pressures, starting the test at 30 lbf/ft^2 (0.144 kPa) is acceptable (subsequent increments should be as described in Section D.3.2.7).

D.3.2.7 Raise the pressure level in increments of 7.5 lbf/ft^2 (0.36 kPa) and hold for 1 minute (see D.3.2.14 for specific criteria) at the end of each increment.

Note: While 7.5 lbf/ft^2 (0.36kPa) provides for more accuracy when determining pressures at which failures occur, increments of 15 lbf/ft^2 (0.72 kPa) are acceptable up to the design pressure (1.0 safety factor) where very high test pressures would result in an excessive number of tests.

D.3.2.8 In the event of failure, record the previous pressure that was successfully held for 1 minute (this represents the actual uplift strength of the roof covering).

D.3.2.9 If localized deflection is excessive (see D.4.1.8 for specific criteria), continue the test until the needed test pressures are held for one minute or obvious failure has occurred.

D.3.2.10 When the passing uplift test pressure (U_i) is reached, do the following:

A. Hold the test pressure for 1 minute (see D.3.2.14 for specific criteria).

B. Carefully observe the deflection test gauge, then slowly release the pressure until the pressure returns to zero.

D.3.2.11 Test is completed. Refer to D.4 for evaluation procedure.

D.3.2.12 Upon completion of Post Test Evaluation, ensure proper repair if applicable, see D.4.2, Roof Repair.

D.3.2.13 Record the results of tests and forward to the FM local servicing office.

D.3.2.14 The roof passes a test pressure if held for 1 entire minute with no separation within the roof covering, or separation of the roof covering from the roof deck or insulation, and deflection is within the required parameters. Separation within the roof covering may include fasteners pulling through insulation boards or base sheets, fasteners pulling out of the roof deck or the adhesives within adhered layers separating. See Section D.4.2.1 for additional information.

D.4 Acceptance Criteria, Test Interpretation, and Reporting

D.4.1 Post-Test Evaluation and Results

D.4.1.1 Deflection measurements are one component of the negative pressure uplift test and can help give an indication of possible failure. However, excessive deflection by itself is not cause for considering the test a failure.

If all test results indicate that all measured deflections are within the maximum recommended in this data sheet, and no indications of other failure modes occurred or were observed during the test, the roof is acceptable from a wind uplift performance perspective.

D.4.1.2 During testing, if the cover suddenly balloons or a crease forms on the roof cover surface (see Figures D.4.2.2-1 and D.4.2.2-2):

A. The roof area tested does not pass the test.

B. Carefully cut out the above-deck assembly down to the deck to identify the mode of failure (see D.4.1.9 for specific criteria).

D.4.1.3 If measured deflections exceed the maximum recommended per D.4.1.8 (**Note:** these areas are sometimes accompanied by a noise at the time of failure):

A. Deflection is considered suspect.

B. Carefully cut out the above-deck assembly down to the deck to determine if failure did occur (see D.4.1.9 for specific criteria).

C. If no failure is evident, the roof is acceptable from a wind uplift performance perspective.

D.4.1.4 If failure is verified from a roof cut visual inspection per D.4.1.2 or D.4.1.3:

A. The roof area tested does not pass the test.

B. Identify the mode of failure including any construction details that are not in accordance with FM Approvals or FM data sheets, and other obvious defects.

D.4.1.5 For mechanically fastened/plate bonded/induction welded, failure modes are the following:

A. Fastener pull-out

B. Plate pull over fastener

C. Membrane tear from around plates/batten bars

D. Membrane seam tear

D.4.1.6 If some tests passed and others failed, additional tests may be conducted to limit the areas needing added securement.

D.4.1.7 For single-ply membranes adhered to mechanically fastened insulation in which Zone 1/Zone 1' areas exhibit both pass and failure of some areas: If test results vary within the same test pressure requirement, do the following:

A. Attempt to visually identify different insulation fastener densities and/or patterns between the two areas which exhibit different uplift performance.

B. Areas that are clearly similar to the areas that passed are acceptable from a wind uplift performance perspective.

C. Areas that are clearly similar to the areas that failed are not acceptable from a wind uplift performance perspective.

Example: The north and south sections of a new roof were installed on two different days by two different crews. All tests conducted on the north section passed, while all those conducted on the south section failed. Close inspection reveals that the area per insulation fastener was adequate for the north side, but was 50% greater on the south side.

Conclusion: The north section is acceptable and the south section must be repaired.

D.4.1.8 Determination of Allowable Deflection

D.4.1.8.1 Maximum allowable deflection is limited to 0.25 in. (6.5 mm), except as otherwise noted in this section.

A. For roofs comprised of wide rib steel deck (see Data Sheet 1-29), the maximum allowable deflection is determined in accordance with Table D.4.1.8.1-1.

B. For roofs comprised of intermediate or narrow rib steel deck, the allowable deflection shown in Table D.4.1.8.1-1 may be doubled, up to a maximum of 2 in. (50 mm).

Table D.4.1.8.1-1. Maximum Recommended Deflection for Adhered Covers on Wide Rib Steel Deck Roofs Before the Sample is Considered Suspect

Test Pressure, psf (kPa)	*Maximum Deflection, in. (mm)*
P ≤ 60 (2.88)	1/4 or 0.25 (6.5)
60 < P ≤ 120 (5.76)	1/2 or 0.50 (13)
120 < P ≤ 180 (8.64)	3/4 or 0.75 (19)
180 < P ≤ 225 (10.8)	15/16 or 0.94 (24)

C. For roof assemblies in which thin (e.g., 1/2 in. (12.7 mm) cover boards or flexible (e.g., glass fiber), mechanically attached insulations are used, use a maximum deflection of 2 in. (50 mm) to determine suspect test samples.

D. For roof assemblies in which thin topping boards are adhered to a substrate immediately below using ribbons of adhesive, use a maximum deflection of 1 in. (25 mm) to determine suspect test samples.

D.4.1.9 Careful Removal of Roof Assembly Components

For negative pressure tests that are believed to have failed, test cuts should be conducted on the failed test area.

Care must be taken during this process to ensure the roof assembly is not damaged in a manner that makes identification of failure modes during the field uplift test impossible. The test cuts should be conducted by carefully cutting each layer of the roof system from the top down, one layer at a time. The cut layer should be carefully lifted to see whether that layer's securement was the layer with the failure mode. Compromised or inadequate application of adhesives or asphalt may result in separation of two layers, facers delamination from insulation boards, plies or insulation boards pulling over fastener plates, or fastener pullout from a deck. Continue with each layer individually down to the roof deck until the failure mode is determined. Other layers can be investigated if another failed layer is believed to exist.

In addition, the following should be incorporated into the test cut procedure:

A. Take steps to minimize damage to surrounding areas when using reciprocating tools (e.g., applying a ballasting load on either side of the tool).

B. Use of prying tools should include a block under the pry bar or other means to distribute applied loads and minimize unintended damage to the roof area.

D.4.2 Test Interpretation

D.4.2.1 Possible Reasons for Failure

A. The inadequately adhered roof covering separated from lower cover layers (if applicable) or from the insulation, or any other subsequent adhered intersection.

B. The top facing of the insulation or cover board delaminated, or the core of the board separated.

C. The insulation board separated from the deck (possibly breaking the insulation).

D. One or more fasteners pulled out of the deck, or the insulation board fracture around the stress plate.

D.4.2.2 Visual Aids: Failures

Fig. D.4.2.2-1. Crease in single-ply roof cover while subjected to uplift pressure

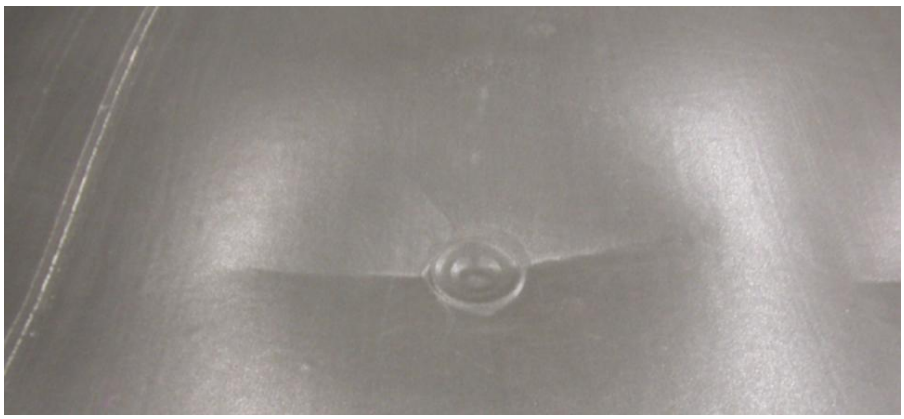

Fig. D.4.2.2-2. Crease in single-ply roof cover while subjected to uplift pressure

Fig. D.4.2.2-3. Crack in underside of cover board at fasterner and beneath where crease was visible in the single-ply roof cover

D.4.3 Roof Repair

D.4.3.1 Ensure repair procedures are in accordance with the following:

- Data Sheet 1-28, *Wind Design*
- Data Sheet 1-29, *Roof Deck Securement and Above-Deck Roof Components*
- Data Sheet 1-30, *Repair of Wind Damaged Single- and Multi-Ply Roof Systems*

D.4.3.2 To prevent water damage to insulation, promptly patch and make watertight all failed test areas. The roof contractor should be present during the test to ensure these repairs are immediately addressed.

D.4.3.3 Provide retrofit securement enhancements for areas that failed the test.

D.4.4 Reporting

D.4.4.1 A full test report should be prepared by the uplift test contractor upon the completion of testing. Describe all details about testing and results in a report that includes the items listed below. Copies of the report should be provided to the building owner or owner's representative, roof contractor, representative of the local FM office, and others as required within contract documents or local jurisdiction, if applicable.

Recommend the following items be included in the final report:

A. Scope of the test to be conducted.

B. Site information, roof test area information (dimensions, deck and roof cover materials and layers, diagram of roof test location, etc.).

C. Details of test pressures and number of tests in Zones 1', 1, 2 and 3.

D. Results of individual test intervals detailing inches of water/uplift pressures at each interval, starting and ending deflection measurements (if applicable), observations, indications of pass/fail and time to fail at a given interval.

E. Details of test cuts conducted for failed tests. The report should include pictures of the test cut at each layer, as well as details of the findings at each layer, including the adequacy or inadequacy of the securement found.

F. Certificates of calibration for equipment, gauges, etc.

APPENDIX E BONDED UPLIFT TEST PROCEDURE

E.1 General Information

E.1.1 Scope

E.1.1.1 The Bonded Uplift Test is used as a method of field testing above-deck roofing assemblies to evaluate for the following conditions:

- Wind resistance
- Suspected inferior construction
- Partial blow-off

E.1.1.2 The Bonded Uplift Test is not applicable to metal panel roofs (standing seam and through fastened), ballasted roofs, or mechanically fastened insulations, base sheets, or roof membranes. This test should not be performed on roof slopes exceeding 1.2° (1/4 in 12).

E.1.2 Test Equipment (Sufficient for Four Tests)

E.1.2.1 Test Equipment and Tools (General)

- Calibrated spring scale or other measurement device with suitable force capacity
- Block and tackle, hand chain hoist or hydraulic lift device
- Tripod (or equivalent support system)
- Patching kettle with heating torch (for bituminous roofs)
- Class B fire extinguisher
- Electric drill with 5/8 and 1/8 in. (16 and 3 mm) bits
- Electric sabre saw with blades
- Crosscut hand saw
- Screwdriver
- Adjustable open-end wrench, 8 or 10 in. (200 or 250 mm)
- Ruler and linoleum knife
- Broom, shovel (square-end, preferably for gravel-surfaced covers), and asphalt mop (if applicable)

E.1.2.2 Additional Materials

- One sheet of plywood, 4 ft x 8 ft x 3/4 in. (1.2 m x 2.4 m x 18 mm), 5 ply, APA Rated Exposure 1, Grade A-D
- 48 wood screws, 1-1/4 in. (32 mm) long, No. 12 round head
- 4 eyebolts, 1/2 in. (13 mm), 3 in. (75 mm) of thread, with nuts and washers
- Adhesive: 1 keg (100 lb [45 kg]) of steep asphalt, or coal tar pitch, or appropriate adhesive
- Insulation and roofing covering for repairs

E.2 Test Preparation

E.2.1 Test Sample

E.2.1.1 Cut the piece of plywood into 2 x 2 ft (0.6 x 0.6 m) squares.

E.2.1.2 Fasten two squares together to form one 2 ft x 2 ft x 1 1/2 in. (0.6 m x 0.6 m x 38 mm) panel by drilling twelve 1/8 in. (3 mm) holes and using wood screws. Figure E.2.1.2-1 shows suggested screw locations.

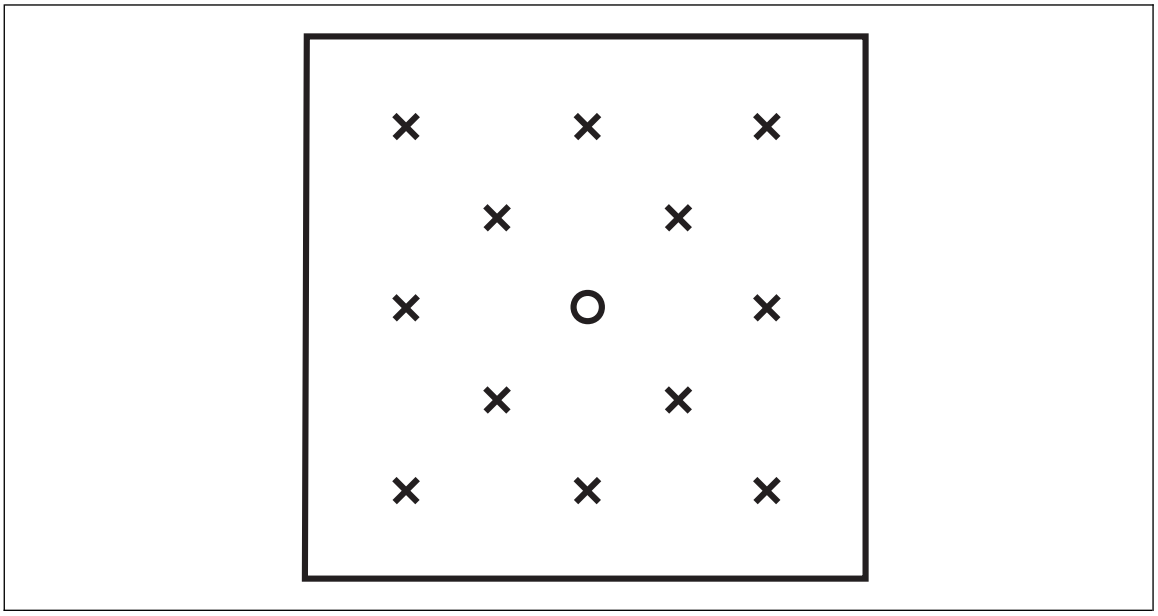

Fig. E.2.1.2-1. Suggested screw locations

E.2.1.3 Drill a 5/8 in. (16 mm) hole in the center of the test panel through both pieces of plywood

E.2.1.4 Connect one of the eyebolts to the test panel with a nut and washer.

E.2.1.5 Suspend the test panel with an eyebolt from the calibrated spring scale and record the weight (W). The weight may vary from about 15 lb (6.8 kg) to 18 lb (8.2 kg).

E.2.1.6 For built-up roof coverings, when tests are to be made on a granule, gravel, or slag-covered roof, do the following:

A. Sweep away any loose surfacing material from the entire test area.

B. Pour a compatible sealant such as asphalt or coal tar pitch (whichever is on the existing roof), not to exceed 0.5 in. (13 mm) in thickness, over the test panel area to make a smooth surface that will ensure contact between the test panel locations and roof.

E.2.1.7 For single-ply membranes, do the following:

A. Remove any sand or small granules adhered to the top surface in the area of the test panel locations.

B. Sweep away loose material from the entire test area.

Fig. E.2.1.2-2. Bonded uplift test

E.3 Test Operation

E.3.1 Test Conditions

Conduct tests only when the roof surface temperature is between 40 and 100°F (5 and 38°C).

E.3.2 Test Procedure

E.3.2.1 Cut an indentation in the center of the roof covering of the test area to accommodate the nut and washer of the eyebolt.

E.3.2.2 Place adhesive on top of the test surface. Apply a flood coat of hot steep asphalt to the test surface when roofing bitumen is asphalt (coal tar pitch when that material is used), or other compatible adhesive for single-ply covers.

E.3.2.3 Place the test panel in the hot bitumen to ensure complete contact.

E.3.2.4 Allow a curing period for the test panel, dependent on the type of adhesive used. (Two hours for hot asphalt; 48 hours for coal tar pitch.)

E.3.2.5 Cut a 2 to 3 in. (51 to 76 mm) wide strip through the roof covering and insulation (if applicable) around the test panel, all the way down to the top of the roof deck. Do not stand on the panel while cutting, and avoid walking on it.

E.3.2.6 Set up the tripod with attached block and tackle over the test panel. The lift must be perpendicular to the plane of the roof deck.

E.3.2.7 Connect one end of the scale to the test panel, the other to the block and tackle. The scale also may be connected to the top of the tripod.

E.3.2.8 Apply uplift force to the test panel equivalent to 15 lbf/ft^2 (0.72 kPa) and hold for 1 minute.

E.3.2.9 Increase the load in increments equivalent to a pressure of 7.5 lbf/ft^2 (0.36 kPa) and hold for 1 minute at the end of each increment (see E.3.2.15 for specific criteria).

E.3.2.10 In the event of failure, record the previous scale reading that was successfully held for 1 minute (this represents the actual uplift strength of the roof covering).

E.3.2.11 If the plywood test panel separates from the roof covering, re-adhere the panel and increase the curing period of the adhesive.

E.3.2.12 When the passing scale reading is reached,

A. Hold the test load for 1 minute. (see E.3.2.15 for specific criteria)

B. Release the uplift force.

C. Test is completed.

E.3.2.13 Ensure proper repair if applicable, see E4.2 Roof Repair.

E.3.2.14 Record the results of tests and forward to the FM local servicing office.

E.3.2.15 The roof passes a test increment if held for 1 entire minute with no separation within the roof covering, or separation of the roof covering from the roof deck or insulation.

E.4 Acceptance Criteria and Test Interpretation

E.4.1 Post-Test Evaluation and Results

E.4.1.1 Calculate the equivalent uplift pressure:

A. Uplift pressure = (scale reading - W)/test panel area). For example, scale reading minus 15 lb ([6.8kg] divided by 4 (for a 4 ft^2 panel weighing 15 lb [6.8kg]).

B. This value is the uplift strength of the roof and should be recorded on the Contractor's Material & Uplift Test Certificate for Roof Systems Form.

E.4.2 Roof Repair

E.4.2.1 Ensure repair procedures are in accordance with the following:

- Data Sheet 1-28, *Wind Design*
- Data Sheet 1-29, *Roof Deck Securement and Above-Deck Roof Components*
- Data Sheet 1-30, *Repair of Wind-Damaged Single- and Multi-Ply Roof Systems*

F.4.2.2 After the test is complete, remove all insulation and adhesive in the test area. Cut a new insulation square of the same material and thickness as that removed and secure it to the deck with compatible adhesive. Replace the covering with a similar type, providing appropriate laps.

APPENDIX F VISUAL CONSTRUCTION OBSERVATION (VCO)

F.1 General Guidelines

The Visual Construction Observer (VCO) should be given the authority by the building owner to halt the project and installation immediately if the use of non-compliant materials or improper/non-compliant workmanship practices are identified. The local FM office should be contacted to discuss the non-compliance issues. Terminate the use of all noncompliant material or workmanship practices immediately, and replace or repair all noncompliant installation areas as needed. Document all noncompliance issues as well as related corrective measures in the daily construction report.

F.1.1 The following are the minimum guidelines for visual construction observation (VCO) when used as an alternative to field uplift testing.

A. The presence of, or opinions expressed by, the visual construction observer (VCO) in no way relieve the design professional, roofing contractor, manufacturer, owner, or any other responsible party of their contractual obligations.

B. The information provided by the VCO is for the benefit of the owner, roofing contractor, and FM, and no warranty of roof performance (including wind uplift resistance), expressed or implied, is offered.

C. The design professional, roofing contractor, manufacturer, or owner provides the VCO with the approved Roof*Nav* assembly number, contract documents, shop drawings, and other submittals or documentation as required to delineate the proposed roofing system and application parameters.

D. The contract documents become the basis of design and are to be used by the VCO as the standard for construction.

E. The VCO provides full-time onsite visual construction observation during roof system installation and will report on the roof construction process in an accurate and objective manner.

F. The VCO is not a direct employee of the owner, design professional, or installing roof contractor of record, to avoid any conflict of interest.

G. The VCO verifies the following:

1. All materials used on the project conform to those listed in the FM Approved/accepted assembly, contain the appropriate FM Approvals labeling and meet installation guidelines of relevant FM Data Sheets (see Section 4.0).
2. All materials used on the project are installed in new and undamaged condition.

H. The VCO observes and records the following (observations should be made each day any of the following work is accomplished):

1. Condition of the substrate; substrate preparation, repair, replacement, or supplemental attachment
2. Installation and attachment of any base sheet, thermal barrier or vapor barrier, including the type of fasteners or adhesive used and patterns and spacing
3. Installation and attachment of any insulation and/or cover board, including the type of fasteners or adhesive used and fastening patterns and spacing
4. Installation and attachment of any roof covering or materials that comprise the finished roof membrane, including the type of fasteners or adhesive used, fastening patterns and spacing, as well as specified material quantities, temperatures and any other measurement relative to the type of roof membrane being installed
5. Installation and detailing of roof system perimeter and penetration flashings
6. Installation, detailing, and attachment of roof-related sheet metal components
7. Installation of roof-surfacing materials

I. A report will be provided by the VCO that includes both a written and photographic record of the construction project. The report will be made available to the owner, FM, the manufacturer, and the roofing contractor within 24 hours after each day's site visit. Documentation will include a plan that clearly identifies the location of the activities covered by the particular daily report. Documents will accurately describe the sequence of work, materials used, installation methods, condition of existing components, workmanship and noncompliance issues as well as related corrective measures.

J. The VCO will provide non-biased visual construction observation services.

K. The VCO will identify and disclose all relationships with any of the project entities that may create a conflict of interest.

L. The VCO will have the following minimum qualifications:

1. The VCO will have a thorough knowledge of the roofing system being installed, relevant industry accepted-practices, contract documents, blueprint reading, and FM Approval requirements and relevant FM data sheets.
2. The VCO will have a thorough knowledge of the roofing system specified and the manufacturer's requirements.
3. The VCO will have completed one or more of the following:
    a. Certification as a registered roof consultant (RRC) by IIEBEC.
    b. Certification as a registered roof observer (RRO) by IIEBEC.
    c. For locations outside the United States where individuals with the above qualifications are not available, completion of specialized training or certification as a rooftop quality assurance observer from an industry-recognized organization.

In addition, the local FM office representative should review the reports that are generated each day and confirm that all materials and installation requirements are in accordance with the contract documents and the FM Approval listing. Any noncompliance issues identified in the daily reports should be promptly addressed with the building owner.

APPENDIX G USE OF TEMPORARY MEMBRANES IN CONSTRUCTION

G.1 General Information

Wind-borne debris during a tropical cyclone or tornado can penetrate most roof coverings. Hail can also damage roof coverings. To avoid water leaking into a building after a roof is penetrated by wind-borne debris, a secondary membrane is sometimes used. The secondary membrane offers additional protection for the interior occupancy when the primary roof cover is damaged.

The secondary membrane is sometimes included in FM Approved Roof*Nav* assembly as a vapor retarder directly on a concrete deck or over thermal barriers on steel decks. For occupancies that are highly concerned about internal wetting, the use of a temporary membrane may be considered good practice. If a temporary membrane is to be installed within the roof system, it should be done without disrupting the wind load path and should be included in the FM Approved Roof*Nav* assembly. For further information on installing FM Approved Roof*Nav* wind-rated systems, reference FM Property Loss Prevention Data Sheet 1-29, *Roof Deck Securement and Above-Deck Roof Components*.