Approval Standard for Rigid Photovoltaic Modules

Class Number 4478

March 2012
The FM Approvals certification mark is intended to verify that the products and services described will meet stated conditions of performance, safety and quality useful to the ends of property conservation. The purpose of Approval Standards is to present the criteria for FM Approval of various types of products and services, as guidance for FM Approvals personnel, manufacturers, users and authorities having jurisdiction.

Products submitted for certification by FM Approvals shall demonstrate that they meet the intent of the Approval Standard, and that quality control in manufacturing shall ensure a consistently uniform and reliable product. Approval Standards strive to be performance-oriented. They are intended to facilitate technological development.

For examining equipment, materials and services, Approval Standards:

a) must be useful to the ends of property conservation by preventing, limiting or not causing damage under the conditions stated by the Approval listing; and

b) must be readily identifiable.

Continuance of Approval and listing depends on compliance with the Approval Agreement, satisfactory performance in the field, on successful re-examinations of equipment, materials, and services as appropriate, and on periodic follow-up audits of the manufacturing facility.

FM Approvals LLC reserves the right in its sole judgment to change or revise its standards, criteria, methods, or procedures.
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1 INTRODUCTION

1.1 Purpose

This standard states Approval requirements for rigid photovoltaic modules that are installed with an FM Approved roof assembly.

1.2 Scope

1.2.1 This standard applies to all rigid photovoltaic modules intended to be 1) mechanically fastened through or adhered to an FM Approved single-ply, polymer-modified bitumen sheet, built-up roof, liquid applied roof cover or steep slope roof, 2) mechanically fastened or adhered to a metal roof cover assembly using clamps or other types of fasteners, adhesive or welding or 3) loose laid and ballasted over an FM Approved fully adhered single-ply, polymer-modified bitumen sheet or built-up roof cover assembly.

1.2.2 This standard also applies to panels secured to racks and/or rack framing which are independently secured to the building structure, roof deck or metal roof cover or ballasted. It also applies to the rack itself and its securement.

1.2.3 The standard is intended to evaluate only those hazards investigated and is not intended to determine suitability for the end use of a product.

1.2.4 This standard evaluates rigid photovoltaic modules for their performance in regard to fire from above the structural deck, simulated wind uplift, susceptibility from hail storm damage and seismic performance requirements.

1.2.5 Single-ply, polymer-modified bitumen sheet, build-up roof and liquid applied roof cover systems used with rigid photovoltaic modules shall be qualified in accordance with FM Approval Standard 4470. Metal panel roofs used with rigid photovoltaic modules shall be qualified in accordance with FM Approval Standard 4471. Steep slope roofs used with rigid photovoltaic modules shall be qualified in accordance with FM Approval Standard 4475.

1.2.6 This standard only addresses the photovoltaic module and does not address any other electrical component utilized to supply the generated electrical power to the facility.

1.2.7 This standard does not qualify flexible photovoltaic modules. Flexible photovoltaic systems are evaluated per FM Approval Standard 4476.

1.3 Basis for Requirements

1.3.1 The requirements of this standard are based on experience, research and testing, and/or the standards of other organizations. The advice of manufacturers, users, trade associations, jurisdictions and/or loss control specialists was also considered.

1.3.2 The requirements of this standard reflect tests and practices used to examine characteristics of rigid photovoltaic modules for the purpose of obtaining FM Approval. Products having characteristics not anticipated by this standard are permitted to be FM Approved if performance is equal, or superior, to that required by this standard, or if the intent of the standard is met. Alternatively, products which meet all of the requirements identified in this standard may not be FM Approved if other conditions which adversely affect performance exist or if the intent of this standard is not met.
1.4 **Basis for Approval**

Approval is based upon satisfactory evaluation of the product when used as part of an FM Approved roof assembly:

1.4.1 Examination and tests on production samples shall be performed to evaluate:
- the suitability of the product for use in a roof assembly;
- the performance of the product as part of a roof assembly as specified by the manufacturer and required by FM Approvals; and as far as practical,
- the durability and reliability of the product.

1.4.2 Rigid photovoltaic modules shall be fabricated, tested and certified in accordance with recognized, international standards per current specification of either IEC/EN 61730 or ANSI/UL 1703 for electrical safety and IEC/EN 61215 for electrical performance.

1.4.3 An examination of the manufacturing facilities and audit of quality control procedures is made to evaluate the manufacturer's ability to consistently produce the product which is examined and tested and the marking procedures used to identify the product. These examinations may be repeated as part of FM Approvals’ Surveillance Audit program.

1.5 **Basis for Continued Approval**

Continued Approval is based upon:
- production or availability of the product as currently FM Approved;
- the continued use of acceptable quality assurance procedures;
- satisfactory field experience;
- compliance with the terms stipulated in the Master Agreement and Approval Report;
- satisfactory re-examination of production samples for continued conformity to requirements; and
- satisfactory Surveillance Audits conducted as part of FM Approvals’ product surveillance program.

Also, as a condition of retaining Approval, manufacturers may not change a product or service without prior written authorization by FM Approvals.

1.6 **Effective Date**

The effective date of an Approval Standard mandates that all products tested for Approval after the effective date shall satisfy the requirements of that Standard.

The standard shall be effective upon publication.

1.7 **System of Units**

Units of measurement used in this Standard are United States (U.S.) customary units. These are followed by their arithmetic equivalents in International System (SI) units, enclosed in parentheses. The first value stated shall be regarded as the requirement. The converted equivalent value may be approximate. Appendix A lists the selected units and conversions to SI units for measures appearing in this standard. Conversion of U.S. customary units is in accordance with *Standard for Use of the International System of Units (SI): The Modern Metric System*, BSR/IEEE/ASTM SI 10.
1.8 Applicable Documents

The following standards, test methods and practices are referenced in this standard:

ASTM International

- *Fire Tests of Roof Coverings*, ASTM E108
- *Standard Specification for Concrete Roof Pavers*, ASTM C1491

American National Standard Institute

- *Flat Plate Photovoltaic Modules and Panels*, ANSI/UL 1703

American Iron and Steel Institute

- *North American Specification for the Design of Cold-Formed Steel Structural Members, 2007 Edition*, AISI S100-200

American Society of Civil Engineers


International Electrotechnical Commission


FM Approvals LLC

- *Approval Standard for Class 1 Panel Roofs*, Class Number 4471.
- *Approval Standard for Class 1 Steep Slope Roof Covers*, Class Number 4475.
- *Test Procedure, Test Method for Determining the Susceptibility to Hail Damage of Photovoltaic Modules*.
- *Test Procedure, Pull Out Tests for Fastener/Roof Deck Combination and Pull Through Test for Fastener/Stress Plate or Batten Bar Combinations Using Tensile Loading*.
1.9 Definitions

For purposes of this standard, the following terms apply:

**Ballast** – for the purposes of this document, the only acceptable ballast shall be concrete paver blocks.

**Coefficient of Friction** – The ratio of the force that maintains contact between an object and a surface and the frictional force that resists the motion of the object.

**Crack** – During wind uplift testing, when an insulation 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 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 board.

**Deck** - The structural component of the roof assembly to which the roof system is secured.

**External Seam Clamps** – A securement for attaching photovoltaic modules or racking to the seam of a standing seam roof, the clamps are specific to the seams of the standing seam roof.

**Fasteners** - A mechanical securement device used alone or in combination with a stress distributor to secure various components of a roof assembly.

**Lap Seam Roof Cover** – A lap seam roof cover consists of metal or plastic panels which are through fastened to structural members. A lap seam occurs where overlapping materials are seamed, sealed or otherwise bonded.

**Mechanically Fastened** - Mechanically fastened describes roof covers or base sheets that have been attached to the substrate at defined intervals using fasteners with, or without, stress distributors and also describes a photovoltaic module that has been attached to the substrate at defined intervals using fasteners with, or without, stress distributors.

**Metal Panel** — (1) A single metal sheet formed into a specified profile. (2) A composite assembly formed to a specified profile and consisting of an insulating core or batten material with an exterior metal skin.

**Minor Delamination** – In wind uplift testing, an area approximately 1% of the test sample. For a 12 x 24 ft (3.7 x 7.3 m) test an area of 3 ft² (2.8 m²); for a 5 x 9 ft (1.5 x 2.7 m) test an area of 0.5 ft² (0.05 m²), whereby two adhered components which are intended to be in contact are not in contact.

**Permanent Deformation**—Any displacement of a panel or component that remains after the load has been removed. Panel deflection that can be removed by mechanical means not involving special equipment and without additional displacement shall not be considered permanent deformation.

**Photovoltaic Module** – A device that converts solar energy into electricity using the photovoltaic effect.

**Rigid Photovoltaic Module** – An arrangement of photovoltaic cells or material, mounted on a rigid surface with the cells exposed freely to incoming sunlight.
Roof Assembly - A group of interacting roof components (including the roof deck) designed to weatherproof and, normally, to insulate a building's top surface.

Roof Cover - The exterior surface of a roof assembly designed to protect the building components from the weather.

Roof System - A group of interacting roof components (not including the roof deck) designed to weatherproof and, normally, to insulate a building's top surface. The roof system includes the rigid photovoltaic module if it is fully adhered or mounted directly above the roof cover and no air space is allowed between the roof cover and the photovoltaic module.

Service Wind Load – The uplift load resulting from a windstorm that a roof assembly must resist. The service load is equal to one half of the rated load in psf (kPa).

Standing Seam Roof Cover - The standing seam roof cover generally consists of metal sheets or panels, field seamed to adjacent sheets by a special roll-forming machine to create an upstanding seam (rib) of folded metal along the sheet sidelaps. The panels are secured to the building framing with clips. The clip, which contains metal tabs, is roll-formed into the panel seam.

Stress Distributor/Plate - A metal or plastic disk or bar designed to distribute a concentrated load over a larger surface area.

Wind Deflector – A component of the photovoltaic panel or racking system that is designed to turn the flow of air away from the underside of the photovoltaic panel.

2 GENERAL INFORMATION

2.1 Product Information

Rigid photovoltaic modules are submitted in panels or a panel array. They can be installed using either mechanical fasteners, clips, mounting brackets, adhesives, loose laid or ballasted.

2.2 Approval Application Requirements

2.2.1 To apply for an Approval examination the manufacturer, or its authorized representative, should submit a request to

    Materials Director
    FM Approvals
    1151 Boston-Providence Turnpike
    PO Box 9102
    Norwood, MA  02062
    U.S.A.

2.2.2 The manufacturer shall provide the following preliminary information with any request for Approval consideration:

- A complete list of all models, types, sizes, and options for the modules being submitted for Approval consideration.
• The components that make up each roof assembly. All components in the finished roof assembly must be identified by manufacturer, product trade name, method of installation and the ratings desired for each combination.

• All ratings which are desired or expected for each assembly:
  o ASTM E108 Class A, B, or C with maximum roof slope;
  o Wind Uplift Rating, Class 1-60, 1-75, etc.
  o Hail Damage Rating, Class 2, 3 or 4
  o (Optional) Seismic Load Rating, Non-Seismic, 50 year, 100 year, etc.

• The number and location of manufacturing facilities.

• All documents shall contain the manufacturer's name, document number or other form of reference, title, date of last revision and revision level. All documents shall be provided in English.

• A document from the FM Approved roof cover manufacturer acknowledging that the photovoltaic module will be installed over their roof cover and is compatible with it.

• Certification documentation for IEC/EN 61730 or ANSI/UL 1703 and IEC/EN 61215 shall be submitted to FM Approvals prior to completion of the Approval program. This documentation shall include a copy of the test report as well as the certification of compliance.

2.3 Requirements for Samples for Examination

2.3.1 Following authorization of an Approval examination, the manufacturer shall submit samples for examination and testing based on the requested Approvals. Sample requirements shall be determined by FM Approvals following review of the preliminary information.

2.3.2 Requirements for samples may vary depending on design features, results of prior or similar testing and results of any foregoing tests.

2.3.3 The manufacturer shall submit samples representative of production. Any decision to use test data generated using prototypes is at the sole discretion of FM Approvals.

2.3.4 It is the manufacturer's responsibility to provide any special tools, such as those which may be required to evaluate the products for Approval.

3 GENERAL REQUIREMENTS

3.1 Review of Documentation

During the initial investigation, and prior to physical testing, the manufacturer's specifications and details shall be reviewed to assess the ease and practicality of installation and use. The Approval investigation shall define the limits of the FM Approval.

3.2 Markings

3.2.1 Marking on the product or, if not possible due to size, on its packaging or label accompanying the product, shall include the following information:

- name and address of the manufacturer or marking traceable to the manufacturer;
- date of manufacture or code traceable to date of manufacture or lot identification;
- model number, model type, and/or product name, as appropriate.

When hazard warnings are needed, the markings shall be universally recognizable and permanent.
3.2.2 The product trade name, model number, or model type identification shall correspond with the manufacturer's catalog designation and shall uniquely identify the product as FM Approved. The manufacturer shall not place this trade name or model type identification on any other product unless covered by a separate agreement with FM Approvals.

3.2.3 The Approval Mark (see Appendix B) shall be displayed visibly and permanently on the product and the packaging, as appropriate. The manufacturer shall not use this Mark on any other product unless such product is covered by a separate FM Approvals Approval Report.

3.2.4 All markings shall be legible and permanent.

3.3 Manufacturer’s Installation Instructions

The manufacturer shall provide the user with printed instructions to demonstrate proper installation procedures to be followed by installers. As part of the Approval examination, and at the sole discretion of FM Approvals, at least one inspection of the field installation during and/or after completion may be required. In some cases, a continued program of inspections shall be necessary to assess the application procedures or changes within the application techniques.

3.4 Calibration

All examinations and tests performed in evaluation to this standard shall use calibrated measuring instruments traceable and certified to acceptable national standards.

3.5 Test Sample Production

All products submitted for testing shall be representative of production run material. The need to monitor the manufacturer of the test specimens shall be at the sole discretion of FM Approvals.

3.6 Seismic Loads

Rigid photovoltaic modules, installed at locations within FM-designated Earthquake Zones 50 year, 100 year, 250 year or 500 year as shown in the FM Loss Prevention Data Sheet 1-2, shall be designed in accordance the FM Design Procedure for Seismic Design of Rigid Photovoltaic Modules to withstand the seismic loading experienced in these areas. Rigid photovoltaic modules located in >500 year zones are considered non-seismic and do not require analysis for seismic design. The design shall be certified by a Professional Engineer competent in this area of practice. Calculations shall be submitted to verify compliance with design requirements for the range of rigid photovoltaic modules for which Approval is sought.

The FM Design Procedure for Seismic Design of Rigid Photovoltaic Modules is as follows:

3.6.1 General

The rigid photovoltaic modules and racking systems (if used) shall be rated (Approved) for a base shear coefficient (acceleration). The manufacturer shall demonstrate (through tests or analysis) that the rigid photovoltaic modules and racking systems (if used) shall remain intact and operational when subjected to the rated base shear coefficient. A seismically rated rigid photovoltaic module can be erected in FM Global earthquake zones 50-through 500-year as long as the rated base shear coefficient is greater than the design base shear coefficient calculated according to this standard. The anchorage of the rigid photovoltaic modules and racking systems (if used) to the supporting structure shall be designed for the base shear, overturning moment about the two principal axes and torque about the vertical axis. The supporting structure shall be designed for the loads transmitted from the rigid photovoltaic modules. The seismic loads calculated according to this standard are intended for use in Load and Resistance Factor Design (LRFD) or
Strength Design, also known as Ultimate Limit State Design, and should, therefore, be used in LRFD load combinations with a load factor of 1.0 applied to the seismic loads.

FM Global does not require seismically rated rigid photovoltaic modules in >500-year earthquake zone. However, the applicable building codes may require seismic design of rigid photovoltaic modules in a >500-year zone. The FM Global earthquake zones do not necessarily correspond to the local building code zones.

If the weight of the rigid photovoltaic module and racking systems (if used) exceeds 10% of the weight of the supporting structure, the dynamic interaction between the rigid photovoltaic modules and the supporting structure shall be considered in calculating the base shear coefficient; the simple procedure presented in this standard cannot be used for such rigid photovoltaic modules and an alternative design method satisfactory to FM Approvals must be used.

3.6.2 Nomenclature

\[ A_p \] – base shear coefficient (acceleration in g’s).

\[ S_{DS} \] – 0.2 second (short period) 5% damped design spectral response acceleration (g’s)

\[ a_p \] – dynamic amplification factor. Equal to 1 for rigid photovoltaic modules.

\[ R_p \] – component response modification factor. Equal to 1.5 for rigid photovoltaic modules.

\[ z \] – height of the base of the rigid photovoltaic module above ground, in feet. Equal to zero for a ground supported rigid photovoltaic module.

\[ h \] – total height of the supporting structure measured from the ground, in feet.

\[ \bar{h} \] – height of the center of gravity (C.G.) of the rigid photovoltaic module from the base of the rigid photovoltaic modules, in ft

\[ S_{MS} \] – 0.2 second (short period) 5% damped free surface spectral acceleration adjusted for site soil properties.

\[ F_p \] – design base shear

\[ W_p \] – weight (dead load) of the rigid photovoltaic module, in lbs.

\[ M_p \] – design overturning moment. Calculated using \[ M_p = F_p \cdot \bar{h} \]

3.6.3 Base Shear Coefficient

The seismic base shear coefficient shall be calculated as follows:

\[ A_p = \frac{0.4a_p S_{DS}}{R_p} \left(1 + 2 \frac{z}{\bar{h}}\right) \]  \( \text{(1)} \)

\[ A_p \] shall not be less than 0.3 \( S_{DS} \) and need not be more than 1.6 \( S_{DS} \)

3.6.4 Short-period design spectral response acceleration (\( S_{DS} \))

For sites within the USA, the short-period design spectral response acceleration \( S_{DS} \) shall be calculated according to the ASCE 7 standard, as follows.

The MCE (maximum considered earthquake) value of the 5% damped ‘firm’ rock spectral acceleration at 0.2 second (\( S_a \)) is read from the maps in ASCE 7. This is multiplied by the NEHRP (National Earthquake Hazard Reduction Program) soil amplification factor \( F_a \) (2) to obtain the free-surface spectral accelerations \( S_{MS} \):

\[ S_{MS} = S_a \times F_a \]  \( \text{(2)} \)
S\textsubscript{DS} shall be taken as two-thirds of S\textsubscript{MS}:

For locations outside the USA, S\textsubscript{DS} shall be the 475-year return period value of 0.2 second period 5% damped “firm” rock spectral acceleration adjusted for local soil conditions, or two-thirds of the 2,475 return period value of 0.2 second period, 5% damped “firm” rock spectral acceleration adjusted for local soil conditions. Alternatively, S\textsubscript{DS} can be obtained from Table 1 for the FM Global earthquake zone in which the rigid photovoltaic module is located.

Table 1. Suggested values of the 0.2 second short-period 5% damped spectral acceleration for various FM Zones

<table>
<thead>
<tr>
<th>FM Zone</th>
<th>S\textsubscript{DS}</th>
</tr>
</thead>
<tbody>
<tr>
<td>50-year</td>
<td>1.3 g</td>
</tr>
<tr>
<td>100-year</td>
<td>0.9 g</td>
</tr>
<tr>
<td>250-year/500-year</td>
<td>0.55 g</td>
</tr>
</tbody>
</table>

3.6.5 Design Loads for Supporting Structure

The design base shear is calculated as follows:

\[
F_p = A_p \cdot W_p
\]  
(3)

The design overturning moment is calculated as follows:

\[
M_p = F_p \cdot \bar{h}
\]  
(4)

Where applicable, the torque produced by mass eccentricity shall be considered in the design of the support structure.

3.6.6 Design Loads for Base Anchors

The design loads (shear, overturning moment and torque) applied to the base anchors shall be based on R\textsubscript{p} equal to 1.5.

3.6.7 LRFD Load Combinations

Examine load combinations below to determine the design loads:

3.6.7.1 Operational condition dead load.

\[(1.2 \times \text{Dead Load}) + [1.0 \times \text{Seismic Load (F}_p\text{)]} + (0.2 \times \text{Roof Snow Load})\]

Note that the roof snow load should be based on a mean recurrence interval of 50-years.
4 PERFORMANCE REQUIREMENTS

This standard is intended to evaluate a rigid photovoltaic module as part of a finished roof assembly for its performance as it relates to fire from above the structural deck simulated wind uplift, susceptibility from hail storm damage and seismic performance requirements.

Tests of alternate constructions are permitted to be waived if considered less hazardous than those previously tested.

The use of screening tests is permitted to be used to determine critical components to be used for full scale testing or to evaluate components as alternate to those already tested and found to be satisfactory via the full scale tests described in sections 4.1 through 4.7 below. Alternate components must perform to an equal or higher level than the component qualified via large scale testing. Acceptable screening tests shall be at the sole discretion of FM Approvals.

Additional tests may be required, at the sole discretion of FM Approvals, depending on design features and results of any foregoing tests. A re-test of an identical assembly following a failure shall be acceptable at the sole discretion of FM Approvals and with a technical justification of the conditions or reasons for failure. When a test specimen fails to meet the Approval acceptance criteria for a given classification or rating, two successful test specimens of the same or similar construction must meet the Approval acceptance criteria to qualify for the given classification or rating. Any test specimen that fails more than three times is no longer considered a candidate for FM Approval.

Prior to testing, assemblies shall be permitted to cure for a maximum period of 28 days under laboratory conditions.

4.1 Combustibility From Above the Roof Deck

Testing for combustibility from above the roof deck and/or rigid photovoltaic module shall be in accordance with ASTM E108, Fire Test of Roof Coverings.

4.1.1 Conditions of Acceptance for Combustibility from Above the Roof Deck/Photovoltaic Module

4.1.1.1 For Class A, the maximum flame spread of the sample materials shall not exceed 72 in. (1830 mm).

4.1.1.2 For Class B, the maximum flame spread of the sample materials shall not exceed 96 in. (2440 mm).

4.1.1.3 For Class C, the maximum flame spread of the sample materials shall not exceed 156 in. (3960 mm).

4.1.1.4 There shall be no excessive lateral flame spread which is defined as flames extending to the two lateral edges of the exposed module, roof covering or coating beyond 12 in. (305 mm) from the ignition source.

4.1.1.5 There shall be no portion of the module or roof cover blown, or falling, off of the test deck in the form of flaming or glowing brands or particles that continue to glow after reaching the floor.

4.2 Wind Uplift Resistance for Rigid Photovoltaic Module with the Panel Attached at the Same Slope as the Roof Cover.

For wind uplift resistance, the rigid photovoltaic module will be tested using two methods. These two methods are simulated wind uplift pressure test with the photovoltaic module attached to a test frame using a pleated air bag and tensile loading of the fasteners/ clips. The rating assigned to the assembly shall be the lowest rating obtained during all testing.
4.2.1 Rigid Photovoltaic Simulated Wind Uplift Pressure Test

Testing for simulated wind uplift resistance shall be in accordance with Test Procedure, Wind Uplift Tests for Rigid Mechanically Fastened Photovoltaic Modules, FM Approvals, LLC. The minimum rating in psf required for FM Approval is 60 psf (2.9 kPa) for Class 1-60. The maximum rating in psf available is 990 psf (47.3 kPa) for Class 1-990. Ratings between 1-60 and 1-990 are available in 15 psf (0.72 kPa) increments. The rating assigned to the assembly shall be the maximum simulated uplift resistance pressure which the assembly maintained for one (1) minute without ultimate failure.

**In addition, the assembly must maintain one-half the service wind load for one (1) minute without visible cracking or visible creasing.**

- Multiple cracks in the same insulation board, which would impair performance is indicative of catastrophic failure, shall not be permitted.
- Crack length in excess of one half the minimum board dimension; e.g., 24 in. (1220 mm) for a 48 x 96 in. (1220 x 2440 mm) board shall not be permitted.

4.2.1.1 Conditions of Acceptance for Rigid Photovoltaic Simulated Wind Uplift Pressure Test

4.2.1.1.1 All fasteners, clamps and stress distributors shall: a) remain securely embedded into, or through, the roof deck and other structural substrates to which they are being fastened to or through; b) not pull through, become dislodged, disconnected or disengaged from plates, battens, seams or substrates; c) not fracture, separate or break.

4.2.1.1.2 All insulations shall: a) not fracture, break or pull through, or over, fastener heads, plates or battens; b) not delaminate or separate from their facers or adjacent components to which they have been adhered; c) be permitted to deflect between points of mechanical securement provided that the insulation boards do not fracture, crack or break.

**EXCEPTION:** Visible cracking or visible creasing, when less than or equal to one half the minimum board dimension, shall be permitted provided ultimate failure does not occur as noted in 4.2

4.2.1.1.3 All membranes shall: a) not tear, puncture, fracture or develop any through openings; b) not delaminate or separate from adjacent components.

**EXCEPTIONS:** 1) Mechanically fastened membranes shall be permitted to separate and deflect from adjacent components at locations where they are not fastened, 2) partially adhered membranes shall be permitted to separate and deflect from adjacent components at locations where adhesive placement was not intended, 3) tearing of membrane at fastener/stress distributors is allowed up to ultimate failure, 4) minor areas of delamination are allowed provided they do 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.

4.2.1.1.4 All adhesives shall maintain full contact between all the surfaces of all components to which it has been applied to, or comes in contact with, without any separation, delamination, fracture, cracking or peeling of the adhesive or its bond.

**EXCEPTION:** Minor delamination is allowed 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.

4.2.1.1.5 All roof decks shall: a) maintain their structural integrity during the entire classification period; b) not fracture, split, crack, permanently deform or allow for fastener withdrawal.

4.2.1.1.6 Stresses induced to steel roof decking shall be determined by rational analysis, supplied by the test sponsor and shall not exceed the allowable stresses per the North American Specification for the Design of Cold-Formed Steel Structural Members, AISI S100-2007.
4.2.1.7 All photovoltaic modules shall: a) not puncture, fracture, crack or develop any through openings; b) not delaminate or separate from the frame.

EXCEPTION: Mechanically fastened modules shall be permitted to separate and deflect from adjacent components at locations where they are not fastened.

4.2.1.8 All other components, including seams, base sheets, base plies, plies and cap plies, shall not tear, puncture, fracture, disengage, dislodge, disconnect, delaminate or develop any through openings.

4.2.1.9 The theoretical load per fastener (pressure x contributory area) shall not exceed the pullout resistance of the fastener per Section C.6.1, FM Approval Standard 4470.

4.2.2 Pull Out Tests for Rigid Photovoltaic Module/ Photovoltaic Clamp Combination, Photovoltaic Clamp/Metal Panel Combinations, Photovoltaic Clamp/Frame Combinations, Photovoltaic Frame/Roof Deck Combinations using Pull Tests

Pull out tests for fastener/roof deck combinations and pull through tests for fastener/stress plate or batten bar combinations using pull testing shall be in accordance with Test Procedure, Wind Uplift Tests for Rigid Mechanically Fastened Photovoltaic Modules, FM Approvals, LLC. The minimum rating required for FM Approval is 60 psf (2.9 kPa) for Class 1-60. The maximum rating available is 990 psf (47.4 kPa) Class 1-990. Ratings between 1-60 and 1-990 are available in 15 psf (0.72 kPa) increments. The rating assigned to the assembly shall be the ultimate failure load. The results values shall be rounded down to the next multiple of 15 psf (0.72 kPa).

4.2.2.1 Conditions of Acceptance for Rigid Photovoltaic Module/ Photovoltaic Clamp Combination, Photovoltaic Clamp/Metal Panel Combinations, Photovoltaic Clamp/Frame Combinations, Photovoltaic Frame/Roof Deck Combinations using Tensile Loading are as follows:

4.2.2.1.1 The result reported shall be the highest force attained by the sample during the test.

4.2.2.1.2 The overall sample results shall be determined based on the average of three (3) tests. If the standard deviation of the three values divided by the mean is greater than 20%, two additional tests shall be required. The results of all tests shall be used to determine the final average.

4.2.2.1.3 The sample result from the above tensile testing will be the load determined in lbf (N). The total area of the rigid photovoltaic module will be divided by the total number fasteners/clamps used to secure the module, the result will be the contributory area for each fastener/clamp in ft² (m²). The Approval rating shall be the load determined from the tensile testing divided by the contributory area rounded down to the next multiple of 15 psf (0.72 kPa).

4.3 Wind Uplift Resistance for Rigid Photovoltaic Module with the Panel Attached at a Different Slope than the Roof Cover.

For wind uplift resistance, the rigid photovoltaic module will be tested using two methods. These two methods are a simulated wind uplift pressure test with the photovoltaic module attached to a test frame using a pleated bag and tensile loading of the fasteners/clips. The rating assigned to the assembly shall be the lowest rating obtained during all testing.

4.3.1 Rigid Photovoltaic Simulated Wind Uplift Pressure Test

Testing for simulated wind uplift resistance shall be in accordance with Test Procedure, Wind Uplift Tests for Rigid Mechanically Fastened Photovoltaic Modules, FM Approvals, LLC. The minimum rating required for FM Approval is 60 psf (2.9 kPa) for Class 1-60. The maximum rating available is 990 psf (47.4 kPa) for Class 1-990. Ratings between 1-60 and 1-990 are available in 15 psf (0.72 kPa) increments.

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The rating assigned to the assembly shall be 80% of the maximum simulated uplift resistance pressure which the assembly maintained for one (1) minute without ultimate failure rounded down to the next multiple of 15 psf (0.72 kPa). The sample will be tested with pressure loads beginning at 40 psf (1.92 kPa) increasing the tested sample in 20 psf (0.96 kPa) increments.

In addition, the assembly must maintain the service load for one (1) minute without visible cracking or visible creasing.

- Multiple cracks in the same insulation board, which would impair performance is indicative of catastrophic failure, shall not be permitted.
- Crack length in excess of one half the minimum board dimension; e.g., 24 in. (1220 mm) for a 48 x 96 in. (1220 x 2440 mm) board shall not be permitted.

4.3.1.1 Conditions of Acceptance for Rigid Photovoltaic Simulated Wind Uplift Pressure Test are as follows:

4.3.1.1.1 All fasteners, clamps and stress distributors shall: a) remain securely embedded into, or through, the roof deck and other structural substrates to which they are being fastened to or through; b) not pull through, become dislodged, disconnected or disengaged from plates, battens, seams or substrates; c) not fracture, separate or break.

4.3.1.1.2 All insulations shall: a) not fracture, break or pull through, or over, fastener heads, plates or battens; b) not delaminate or separate from their facers or adjacent components to which they have been adhered; c) be permitted to deflect between points of mechanical securement provided that the insulation boards do not fracture, crack or break.

EXCEPTION: Visible cracking or visible creasing, when less than or equal to one half the minimum board dimensions, shall be permitted provided ultimate failure does not occur as noted in 4.3.

4.3.1.1.3 All membranes shall: a) not tear, puncture, fracture or develop any through openings; b) not delaminate or separate from adjacent components.

EXCEPTIONS: 1) Mechanically fastened membranes shall be permitted to separate and deflect from adjacent components at locations where they are not fastened, 2) partially adhered membranes shall be permitted to separate and deflect from adjacent components at locations where adhesive placement was not intended, 3) tearing of membrane at fastener/stress distributors is allowed up to ultimate failure, 4) minor areas of delamination are allowed provided they do 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.

4.3.1.1.4 All adhesives shall maintain full contact between all the surfaces of all components to which it has been applied to, or comes in contact with, without any separation, delamination, fracture, cracking or peeling of the adhesive or its bond.

EXCEPTION: Minor delamination is allowed 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.

4.3.1.1.5 All roof decks shall: a) maintain their structural integrity during the entire classification period; b) not fracture, split, crack, permanently deform or allow for fastener withdrawal.

4.3.1.1.6 Stresses induced to steel roof decking shall be determined by rational analysis, supplied by the test sponsor, and shall not exceed the allowable stresses per the North American Specification for the Design of Cold-Formed Steel Structural Members, AISI S100-2007.

4.3.1.1.7 All photovoltaic modules shall: a) not puncture, fracture, crack or develop any through openings; b) not delaminate or separate from the frame.
EXCEPTION: Mechanically fastened modules shall be permitted to separate and deflect from adjacent components at locations where they are not fastened.

4.3.1.1.8 All other components, including seams, base sheets, base plies, plies and cap plies, shall not tear, puncture, fracture, disengage, dislodge, disconnect, delaminate or develop any through openings.

4.3.1.1.9 The theoretical load per fastener (pressure x contributory area) shall not exceed the pullout resistance of the fastener per Section C.6.1, FM Approval Standard 4470.

4.3.2 Pull Out Tests for Rigid Photovoltaic Module/Photovoltaic Clamp Combination, Photovoltaic Clamp/Metal Panel Combinations, Photovoltaic Clamp/Frame Combinations, Photovoltaic Frame/Roof Deck Combinations using Tensile Loading

Pull out tests for fastener/roof deck combinations and pull through tests for fastener/stress plate or batten bar combinations using tensile loading shall be in accordance with Test Procedure, Wind Uplift Tests for Rigid Mechanically Fastened Photovoltaic Modules, FM Approvals, LLC. The minimum rating required for FM Approval is 60 psf (2.9 kPa) for Class 1-60. The maximum rating available is 990 psf (47.4 kPa) for Class 1-990. Ratings between 1-60 and 1-990 are available in 15 psf (0.72 kPa) increments. The rating assigned to the assembly shall be the average load obtained during the tests divided by the contributory area for that fastener/clip. The rating assigned to the assembly shall be 80% of the ultimate failure load rounded down to the next multiple of 15 psf (0.72 kPa).

4.3.2.1 Conditions of Acceptance for Rigid Photovoltaic Module/Photovoltaic Clamp Combination, Photovoltaic Clamp/Metal Panel Combinations, Photovoltaic Clamp/Frame Combinations, Photovoltaic Frame/Roof Deck Combinations using Tensile Loading

4.3.2.1.1 The result reported shall be the highest force attained by the sample during the test.

4.3.2.1.2 The overall sample results shall be determined based on the average of three (3) tests. If the standard deviation of the three values divided by the mean is greater than 20%, two additional tests shall be required. The results of all tests shall be used to determine the final average.

4.3.2.1.3 The sample result from the above tensile testing will be the load determined in lbf (N). The total area of the rigid photovoltaic module will be divided by the total number fasteners/clamps used to secure the module, the result will be the contributory area for each fastener/clip in ft² (m²). The Approval rating shall be the load determined from the tensile testing divided by the contributory area rounded down to the next multiple of 15 psf (0.72 kPa).

4.4 Wind Uplift Resistance for Rigid Photovoltaic Module Loose Laid and Ballasted.

For wind uplift resistance, the rigid photovoltaic module will be Approved using the methods described in Appendix C. Loose laid and ballasted assemblies are only Approved for use in the field of the roof area (as defined in FM Global Data Sheet 1-29) regardless of the uplift load in the roof perimeter and corners.

4.4.1 Rigid Photovoltaic Simulated Wind Uplift Evaluation

Three ratings are available for FM Approval: 60 psf (2.9 kPa) for Class 1-60; 75 psf (3.6 kPa) for Class 1-75 and 90 psf (4.3 kPa) for Class 1-90. These systems shall only be Approved as loose laid and ballasted over FM Approved fully adhered single ply, BUR, Liquid Applied or Modified bitumen roof covers.

4.4.1.1 Conditions of Acceptance for Rigid Photovoltaic Loose Laid and Ballasted - Prescriptive Method

4.4.1.1.1 The combined average uniform weight of the photovoltaic module, racking, concrete paver blocks and all components shall be equal to, or greater than, the loads outlined in the table in Appendix C.
4.5 **Hail Damage Resistance Test**

4.5.1 Testing for hail damage resistance shall be in accordance with *Test Procedure, Test Method for Determining the Susceptibility to Hail Damage of Photovoltaic Modules*, FM Approvals, LLC. The minimum rating required for FM Approval is Class 2.

4.5.1.1 **Condition of Acceptance for Hail Damage Resistance**

4.5.1.2 After completion of the impact testing, the photovoltaic module shall show no signs of cracking or splitting or misaligned external surfaces, or rupture when examined closely under 10X magnification.

4.6 **Electrical Performance**


4.6.1 **Condition of Acceptance for Electrical Performance**

4.6.1.1 All test samples must meet all test requirements in IEC/EN 61215.

4.7 **Electrical Safety**


4.7.1 **Condition of Acceptance for Electrical Safety**

4.7.1.1 All test samples must meet all tests requirements in IEC/EN 61730-2 or ANSI/UL 1703.
5 OPERATIONS REQUIREMENTS

A quality assurance program is required to assure that subsequent module(s) produced by the manufacturer shall present the same quality and reliability as the specific module(s) examined. Design quality, conformance to design, and performance are the areas of primary concern.

- Design quality is determined during the examination and tests, and is documented in the Approval Report.
- Continued conformance to this Standard is verified by the Surveillance Audit.
- Quality of performance is determined by field performance and by periodic re-examination and testing.

5.1 Demonstrated Quality Control Program

5.1.1 The manufacturer shall demonstrate a quality assurance program which specifies controls for at least the following areas:
- existence of corporate quality assurance guidelines;
- incoming quality assurance, including testing;
- in-process quality assurance, including testing;
- final inspection and tests;
- equipment calibration;
- drawing and change control;
- packaging and shipping; and
- handling and disposition of non-conforming materials.

5.1.2 Documentation/Manual

There shall be an authoritative collection of procedures/policies. It shall provide an accurate description of the quality management system while serving as a permanent reference for implementation and maintenance of that system. The system shall require that sufficient records are maintained to demonstrate achievement of the required quality and verify operation of the quality system.

5.1.3 Records

To assure adequate traceability of materials and products, the manufacturer shall maintain a record of all quality assurance tests performed, for a minimum period of two years from the date of manufacture.

5.1.4 Drawing and Change Control

- The manufacturer shall establish a system of product configuration control that shall allow no unauthorized changes to the product. Changes to critical documents, identified in the Approval Report, must be reported to, and authorized by, FM Approvals prior to implementation for production.
- The manufacturer shall assign an appropriate person or group to be responsible for, and require that, proposed changes to FM Approved or Listed products be reported to FM Approvals before implementation. The manufacturer shall notify FM Approvals of changes in the product or of persons responsible for keeping FM Approvals advised by means of FM Approvals’ Form 797, FM Approved Product/Specification-Tested Revision Report or Address/Main Contact Change Report.
- Records of all revisions to all FM Approved products shall be maintained.
5.2 Surveillance Audit

5.2.1 An audit of the manufacturing facility is part of the Approval investigation to verify implementation of the quality assurance program. Its purpose is to determine that the manufacturer's equipment, procedures, and quality program are maintained to insure a uniform product consistent with that which was tested and FM Approved.

5.2.2 These audits shall be conducted periodically, but at least annually, by FM Approvals or its representatives.

5.2.3 FM Approved products or services shall be produced at, or provided from, the location(s) audited by FM Approvals and as specified in the FM Approval Report. Manufacture of products bearing the FM Approval Mark is not permitted at any other location without prior written authorization by FM Approvals.

5.3 Installation Inspections

Field inspections may be conducted to review an installation. The inspections are conducted to assess ease of application, and conformance to written specifications. When more than one application technique is used, one or all may be inspected at the sole discretion of FM Approvals.

5.4 Manufacturer's Responsibilities

The manufacturer shall notify FM Approvals of changes in product construction, components, raw materials, physical characteristics, coatings, component formulation or quality assurance procedures prior to implementation.
APPENDIX A: UNITS OF MEASUREMENT

LENGTH: in. - "inches"; (mm - "millimeters")

\[ mm = \text{in.} \times 25.4 \]

ft - "feet"; (m - "meters")

\[ m = \text{ft} \times 0.3048 \]

PRESSURE: psi - "pounds per square foot"; (kPa - "kilopascals")

\[ \text{kPa} = \text{psf} \times 0.04788 \]

AREA: in\(^2\) - "square inches"; (mm\(^2\) - "square millimeters")

\[ \text{mm}^2 = \text{in}^2 \times 6.4516 \times 10^2 \]

ft\(^2\) - "square feet"; (m\(^2\) - "square meters")

\[ \text{m}^2 = \text{ft}^2 \times 0.0929 \]
APPENDIX B: FM APPROVALS CERTIFICATION MARKS

FM Approvals certification marks are to be used only in conjunction with products or services that have been Approved by FM Approvals and in adherence with usage guidelines.

**FM APPROVED mark:**
Authorized by FM Approvals as a certification mark for any product that has been FM Approved. There is no minimum size requirement for the mark, but it must be large enough to be readily identifiable. The mark should be produced in black on a light background, or in reverse on a dark background.

**Cast-On FM Approvals marks:**
Where reproduction of the FM Approved mark described above is impossible because of production restrictions, use these modified versions of the FM Approved mark. There is no minimum size requirement for the mark, but it must be large enough to be readily identifiable.

**FM Approved Mark with “C” only:**
Authorized by FM Approvals as a certification mark for any product that has been evaluated by FM Approvals in accordance with Canadian codes and standards. There is no minimum size requirement for the mark, but it must be large enough to be readily identifiable. The mark should be produced in black on a light background, or in reverse on a dark background.

**FM Approved mark with “C” and “US”:**
Authorized by FM Approvals as a certification mark for any product that has been evaluated by FM Approvals in accordance with US and Canadian codes and standards. There is no minimum size requirement for the mark, but it must be large enough to be readily identifiable. The mark should be produced in black on a light background, or in reverse on a dark background.
FM Approvals Certification Marks Usage Guidelines

All FM Approvals certification marks are the sole property of FM Approvals LLC (“FM Approvals”) and are registered or the subject of applications for registration in the United States and many other countries. They are for use only according to these guidelines.

FM Approvals certification marks may be used only on FM Approved products and related product packaging, in advertising material, catalogs and news releases. Use of FM Approvals certification marks on such material is not a substitute for use of the complete FM Approvals certification mark on FM Approved products and/or product packaging.

No FM Approvals certification mark or aspect thereof may be incorporated as part of a business name, Internet domain name, or brand name/trademark for products/product lines. This includes both design aspects (the FM Approvals “diamond,” etc.) and word aspects (“FM,” “Approved,” etc.). The use of any FM Approvals certification mark as a trademark is strictly prohibited.

The Approval Standard number or class number may not be incorporated as part of a business name, Internet domain name, or brand name/trademark for products/product lines. For example, a company may not say “ABC Company’s 4100 Fire Door is FM Approved”; the proper terminology is, “ABC Company’s Fire Door is FM Approved per Approval Standard 4100.”

FM Approvals certification marks, except for the FM Approvals Quality System Registration mark, may not be used on business stationery/cards/signage because this could mischaracterize the relationship with FM Approvals. Additionally, these items should not reference any FM Approvals certification mark.

Products or services may not be marketed under any mark or name similar to “FM Global,” “FM Approvals” or any of the FM Approvals certification marks. Further, products or services may not be marketed to imply a relationship beyond the scope of any Approval made by FM Approvals.

When an FM Approvals certification mark is used in advertising material or on product packaging, all material must reflect the specific circumstances under which the product was FM Approved. The material must clearly differentiate between products that are FM Approved and those that are not, and may not, in any way, imply a more substantial relationship with FM Approvals.

A company may not reference the intent to submit a product for Approval or the expectation that a company will have a certain product FM Approved in the future. For example, a company may not state, “Approval by FM Approvals pending” or “Approval by FM Approvals applied for.”

FM Approvals certification marks should not be preceded or followed by a qualifier that indicates a degree of certification or acceptability. For example, “exceeds,” “first” or “only” may not be used to qualify any FM Approvals certification mark.

Only original artwork issued by FM Approvals should be used. The FM Approvals certification marks should not be altered in any way other than to resize the artwork proportionately. Unacceptable uses of the marks include, but are not limited to, adding/deleting wording or artwork, reducing the artwork to an illegible size, animation or distortion.

The text of the FM Approvals certification marks may not be translated into any language other than English.

FM Approvals certification marks must appear in a size and location that is readily identifiable, but less prominent than the name of the owner of the certification or the manufacturer/seller/distributor of the certified products.
APPENDIX C: TABLE FOR PRESCRIPTIVE WIND UPLIFT RATINGS

C.1 Ballast Requirements:

Table C.1 Combined Needed Equivalent Average Weight of Panels, Racking & Pavers

<table>
<thead>
<tr>
<th>Field of Roof Uplift Rating</th>
<th>Combined Average Uniform Weight psf (kg/m²)</th>
<th>Minimum Array Area (ft²)</th>
<th>Minimum Coefficient of Friction (μ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 1-60</td>
<td>8 (39)</td>
<td>1000</td>
<td>0.75</td>
</tr>
<tr>
<td>Class 1-60</td>
<td>8 (39)</td>
<td>1650</td>
<td>0.65</td>
</tr>
<tr>
<td>Class 1-60</td>
<td>8 (39)</td>
<td>2500</td>
<td>0.50</td>
</tr>
<tr>
<td>Class 1-75</td>
<td>10 (49)</td>
<td>1000</td>
<td>0.75</td>
</tr>
<tr>
<td>Class 1-75</td>
<td>10 (49)</td>
<td>1650</td>
<td>0.65</td>
</tr>
<tr>
<td>Class 1-75</td>
<td>10 (49)</td>
<td>2500</td>
<td>0.50</td>
</tr>
<tr>
<td>Class 1-90</td>
<td>12 (59)</td>
<td>1000</td>
<td>0.75</td>
</tr>
<tr>
<td>Class 1-90</td>
<td>12 (59)</td>
<td>1650</td>
<td>0.65</td>
</tr>
<tr>
<td>Class 1-90</td>
<td>12 (59)</td>
<td>2500</td>
<td>0.50</td>
</tr>
</tbody>
</table>

The above Approval criteria shall only be for rigid photovoltaic module systems and racking system that are constructed in an interlocking array to distribute the combined average uniform weight from the Table C.1. The minimum affected wind area of the array shall be 1000 ft² (92.9 m²). The ballasted photovoltaic modules shall be limited to a maximum slope of 15%. Ballasted photovoltaic modules may only be Approved over fully adhered single ply, BUR, Liquid Applied or Modified bitumen roof covers with a roof slope equal to 0.25 in 12.

C.2 Ballast tray or pedestals shall be designed to prevent sliding of concrete paver blocks in all directions. This shall be accomplished using either of the following methods:

C.2.1 By extending the vertical edges of ballast trays above the lower edge of the highest paver.
C.2.2 Installing concrete pavers that interlock to the pedestals.

C.3 Concrete paver block requirements:

C.3.1 Concrete paver blocks must have a minimum plan area of 128 in² (0.093 m²).
C.3.2 Concrete paver blocks must be a minimum of 9 lbs (4.1 kg).
C.3.3 Concrete paver blocks must have a minimum unit weight of 10 lbs/ft² (48.8 kg/m²).
C.3.4 Concrete paver blocks must meet ASTM C1491.

C.4 Sliding resistance requirements:

C.4.1 Coefficient of friction between the roof cover and the photovoltaic modules or racking system shall be measured per ASTM D1894
C.4.2 Coefficient of friction described above as measured per ASTM D1894 shall be per Table C.1. If the coefficient of friction is less than that per Table C.1 then boundary layer wind tunnel data may be used to determine the sliding resistance. The boundary layer wind tunnel data must be conducted at an ISO 17025 lab and must report maximum C_L and C_D. Use of this data shall be at the sole discretion of FM Approvals.

C.5 Wind deflector requirement:

C.5.1 Wind deflectors shall be provided on the high edge of each row of photovoltaic panels.