



*Member of the FM Global Group*

# **Approval Standard for Flexible Photovoltaic Modules**

**Class Number 4476**

**January 2011**

---

# Foreword

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.

# TABLE OF CONTENTS

<b>1 INTRODUCTION.....</b>	<b>1</b>
1.1 Purpose.....	1
1.2 Scope.....	1
1.3 Basis for Requirements.....	1
1.4 Basis for Approval.....	1
1.5 Basis for Continued Approval.....	2
1.6 Effective Date.....	2
1.7 System of Units.....	2
1.8 Applicable Documents.....	3
1.9 Definitions.....	4
<b>2 GENERAL INFORMATION.....</b>	<b>4</b>
2.1 Product Information.....	4
2.2 Approval Application Requirements.....	5
2.3 Requirements for Samples for Examination.....	5
<b>3 GENERAL REQUIREMENTS.....</b>	<b>6</b>
3.1 Review of Documentation.....	6
3.2 Markings.....	6
3.3 Manufacturer's Installation Instructions.....	6
3.4 Calibration.....	6
3.5 Test Sample Production.....	6
<b>4 PERFORMANCE REQUIREMENTS.....</b>	<b>7</b>
4.1 Combustibility From Above the Roof Deck.....	7
4.2 Wind Uplift Resistance for Roof Assemblies Other than Flexible Photovoltaic Modules Adhered to Metal Panel Roof Coverings.....	7
4.3 Wind Uplift Resistance for Roof Assemblies With Flexible Photovoltaic Modules Adhered to Metal Panel Roof Coverings.....	11
4.4 Hail Damage Resistance Test.....	12
4.5 Electrical Performance.....	12
4.6 Electrical Safety.....	12
4.7 Heat Aging Affects.....	12
<b>5 OPERATIONS REQUIREMENTS.....</b>	<b>13</b>
5.1 Demonstrated Quality Control Program.....	13
5.2 Facilities and Procedures Audit (F&PA).....	14
5.3 Installation Inspections.....	14
5.4 Manufacturer's Responsibilities.....	14
<b>APPENDIX A: UNITS OF MEASUREMENT.....</b>	<b>15</b>
<b>APPENDIX B: FM APPROVALS CERTIFICATION MARKS.....</b>	<b>16</b>
<b>APPENDIX C: SMALL SCALE TESTS.....</b>	<b>18</b>
<b>APPENDIX D: DETERMINATION OF THE APPROPRIATE WIND UPLIFT TESTS.....</b>	<b>19</b>

# 1 INTRODUCTION

## 1.1 Purpose

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

## 1.2 Scope

**1.2.1** This standard applies to all flexible photovoltaic modules when adhered to, or mechanically fastened through, an FM Approved single-ply, polymer-modified bitumen sheet, built-up roof, liquid applied or metal roof cover assembly.

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

**1.2.3** This standard evaluates flexible photovoltaic modules for their performance in regard to fire from above the structural deck, simulated wind uplift, susceptibility from hail storm damage, and heat aging effects on the substrate.

**1.2.4** Single-ply, polymer-modified bitumen sheet, built-up roof, and liquid applied roof cover systems that do not contain flexible photovoltaic modules shall be qualified in accordance with Approval Standard 4470. Standing seam or metal panel roofs that do not contain flexible photovoltaic modules shall be qualified in accordance with Approval Standard 4471.

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

**1.2.6** This standard does not intend to qualify rigid photovoltaic modules that are mechanically fastened using clips or other types of fasteners through single-ply, polymer-modified bitumen sheet, built-up roof, liquid applied roof systems or to standing seam or metal roofs. Rigid photovoltaic systems are evaluated per FM Approvals Standard 4478.

## 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 flexible photovoltaic modules for the purpose of obtaining Approval. Products having characteristics not anticipated by this standard, may 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 Flexible 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 61646 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' product follow-up 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 Facilities and Procedures Audits (F&PAs) conducted as part of FM Approvals' product follow-up program.

Also, as a condition of retaining Approval, manufacturers may not change a product or service without prior 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. Products FM Approved under a previous edition shall comply with the new version by the effective date or else forfeit Approval.

This 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:

- *Approval Standard for Single-Ply, Polymer-Modified Bitumen Sheet, Built-Up Roof (BUR) and Liquid Applied Roof Systems for use in Class 1 and Noncombustible Roof Deck Construction, Class Number 4470.* FM Approvals LLC, PO Box 9102, Norwood, MA 02062.
- *Approval Standard for Class 1 Panel Roofs, Class Number 4471.* FM Approvals LLC, PO Box 9102, Norwood, MA 02062.
- *Evaluating the Simulated Wind Uplift Resistance of Roof Assemblies Using Static Positive and/or Negative Differential Pressures,* American National Standard, ANSI/FM Approvals 4474
- *Thin-film terrestrial photovoltaic (PV) modules – Design qualification and type approval,* International Standard IEC/EN 61646, International Electrotechnical Commission / European Norm
- *Photovoltaic (PV) module safety qualifications – Part 2: Requirements for Testing,* International Standard IEC/EN 61730-2, International Electrotechnical Commission / European Norm
- *Flat Plate Photovoltaic Modules and Panels,* American National Standard, ANSI/UL 1703
- *Fire Tests of Roof Coverings,* ASTM E108, ASTM International
- *Standard Test Methods for Sampling and Testing of Modified Bituminous Sheet Material,* ASTM D5147, ASTM International
- *Test Procedure, 12 x 24 ft Wind Uplift Tests for Single Ply and Multi Ply Roof Coverings using Negative Static Pressure,* FM Approvals, LLC
- *Test Procedure, 12 x 24 ft Wind Uplift Tests for Standing Lap Seam and Composite Panel Roof Coverings,* FM Approvals, LLC
- *Test Procedure, 1 x 4 ft Wind Uplift Tests for Flexible Photovoltaic Modules adhered to Standing Lap Seam and Composite Panel Roof Coverings,* FM Approvals, LLC
- *Test Procedure, 5 x 9 ft Wind Uplift Tests for Single Ply and Multi Ply Roof Coverings using Negative Static Pressure,* FM Approvals, LLC
- *Test Procedure, Test Method for Determining the Susceptibility to Hail Damage of Flexible Photovoltaic Modules,* FM Approvals, LLC
- *Test Procedure, Membrane Delamination Tests for Roofing Membranes and Substrates Using Tensile Loading,* FM Approvals, LLC
- *Test Procedure, Pull Through Tests for Roofing Membranes and Substrates Using Tensile Loading,* FM Approvals, LLC
- *Test Procedure, Tests for Measuring Heat Aging Affects of Flexible Photovoltaic Modules on Roof Coverings,* FM Approvals, LLC

## 1.9 Definitions

For purposes of this standard, the following terms apply:

*Adhesive* – Adhesive is used in roof construction to adhere roof coverings to roof coverings as in lap construction. It is also used to bond roof coverings to the substrate below, to adhere insulation to the substrate or to adhere flexible photovoltaic modules to the roof covering. Depending on the use, the adhesive could be in either a liquid form, semi liquid form or a solid form as in a seam tape or as in hot asphalt which is solid until heated

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

*Delamination* - Separation of the plies in a roof membrane or system in any laminated roofing material or component, e.g., laminated layers of rigid insulation or the felt plies in a built-up roof or separation of any membrane from the substrate to which it is adhered. This includes the separation of the photovoltaic modules from the membrane or metal roof panel.

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

*Fully Adhered* - Fully adhered describes roof coverings or photovoltaic modules that have been bonded to the substrate using a compatible adhesive throughout the entire surface of the roof.

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

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

*Roof Assembly* - A system 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.

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

## 2 GENERAL INFORMATION

### 2.1 Product Information

Flexible photovoltaic modules are submitted in either sheet or roll form. They can be installed using either mechanical fasteners and plates or adhesives. Modules that are mechanically fastened are installed on site during or after the installation of the roof system. Modules that are installed using adhesives can be adhered to the roof cover during the manufacturing process or installed on site during or after the installation of the roof system.

## 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 should 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:
  - ASTM E108 Class A, B, or C with maximum roof slope;
  - Wind Uplift Rating, Class 1-60, 1-75, etc.
  - Hail Damage Rating, MH or SH;
- 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 with English translation.
- A document from the Approved roof cover manufacturer acknowledging that the photovoltaic module will be installed over their roof cover and is compatible with it.

## 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 necessary test fixtures or 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 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/or 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 durable.

#### **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 shall 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 manufacture of the test specimens shall be at the sole discretion of FM Approvals.

## 4 PERFORMANCE REQUIREMENTS

This standard is intended to evaluate a flexible 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 heat aging effects on the substrate.

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

The use of screening tests are 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 the 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. Refer to the Appendix C of this Standard for acceptable screening tests. If the nature of a product requires the use of a test not shown in Appendix C, the test may be used 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.

Prior to testing, flexible photovoltaic modules as part of finished roof assemblies, shall be permitted to cure for a maximum period of 28 days.

See Appendix D to determine the methods of wind uplift testing to be used for the various roof cover systems and photovoltaic module combinations.

### 4.1 Combustibility From Above the Roof Deck

Testing for combustibility from above the roof deck 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

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 Roof Assemblies Other than Flexible Photovoltaic Modules Adhered to Metal Panel Roof Coverings

Testing for wind uplift resistance shall be in accordance with ANSI/FM Approvals 4474, *Evaluating the Simulated Wind Uplift Resistance of Roof Assemblies Using Static Positive and/or Negative Differential Pressures*. The minimum rating required for FM Approval is Class 1-60. The maximum rating available is

Class 1-990. Ratings between 1-60 and 1-990 are available in increments of 15 psf (0.72 kPa). The rating assigned to the assembly shall be the maximum simulated uplift resistance pressure which the assembly maintained for one (1) minute without failure.

#### 4.2.1 12 x 24 ft (3.7 m x 7.3 m) Simulated Wind Uplift Pressure Test

The 12 x 24 ft (3.7 x 7.3 m) simulated wind uplift pressure test procedure is to be used to determine the simulated wind uplift resistance of the following types of roof assemblies:

- 1) assemblies other than those evaluated via the uplift pull test or 5 x 9 ft uplift pressure test.
- 2) assemblies that utilize mechanical fasteners, adhesives, hot asphalt, heat welding or combination thereof, to secure the flexible photovoltaic module to the roof cover or to the roof deck.
- 3) assemblies that utilize battens bars or rows of fasteners spaced less than, or equal to, 144 in. (3660 mm) on center with maximum in-row spacing of 48 in. (1220 mm).

##### 4.2.1.1 Conditions of Acceptance for 12 x 24 ft Simulated Wind Uplift Pressure Test

- 4.2.1.1.1 All fasteners and stress plates 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.  
  
EXCEPTIONS: cracking at fastener plates shall be permitted provided ultimate pull through does not occur.
- 4.2.1.1.3 All membranes or photovoltaic modules shall: a) not tear, puncture, fracture or develop any through openings; b) not delaminate or separate from adjacent components (exception: 1) mechanically fastened modules or membranes shall be permitted to separate and deflect from adjacent components at locations where they are not fastened, 2) partially adhered membranes or modules shall be permitted to separate and deflect from adjacent components at locations where adhesive placement was not intended).  
  
EXCEPTIONS: a) tearing of membrane or module at fastener plates and batten bars is allowed up to ultimate failure provided water-tightness is maintained; b) minor areas of delamination are allowed provided they do not continue to grow in size by more than 50% during a given 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 areas of delamination shall be permitted provided they do not continue to grow in size by more than 50% during a given 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, (this is covered by 4.2.1.1.3 and eliminated the issue of minor deformation at deck fasteners etc.) or allow for fastener withdrawal.

- 4.2.1.1.6 Stresses induced to steel roof decking shall be determined by rational analysis and shall not exceed the allowable stresses per the latest edition of the *North American Specification for the Design of Cold-Formed Steel Structural Members*, AISI S100-200.
- 4.2.1.1.7 All other components, including photovoltaic modules, seams, base sheets, base plies, plies and cap plies, shall not tear, puncture, fracture, disengage, dislodge, disconnect, delaminate or develop any through openings. See allowable exception given above in 4.2.1.1.3.
- 4.2.1.1.8 The theoretical load per fastener (pressure x contributory area) does not exceed the pullout resistance of the fastener per C.6.1, FM Approval Standard 4470.

#### **4.2.2 5 x 9 ft (1.5 x 2.7 m) Simulated Wind Uplift Pressure Test**

The 5 x 9 ft (1.5 x 2.7 m) simulated wind uplift pressure test procedure is used to determine the simulated wind uplift resistance of the following types of roof assemblies with a maximum wind uplift rating of Class 1-90:

- 1) Assemblies that utilize mechanical fasteners, adhesives, hot asphalt, heat welding, self adhesive components or combination thereof, to secure insulations, a base ply, plies or a cap ply sheet, exterior coverings and other components, in single or multi-layered constructions, to one another and to the roof deck. Note: Adhesive securement to steel roof deck is not permitted.
- 2) Assemblies that utilize air pervious decks to include cementitious wood fiber, steel, wood or fiber reinforced plastic roof decks.
- 3) Assemblies with mechanically secured roof covers with securement row spacing less than, or equal to, 48 in. (1220 mm) on center with maximum in-row spacing of 24 in. (610 mm).
- 4) Assemblies with mechanically secured roof covers with securements (spot or grid affixed) spacing less than, or equal to, 24 x 48 in. (610 x 1220 mm) on center.
- 5) Assemblies with mechanically secured insulation (maximum 48 x 96 in. (1220 x 2440 mm) board) with a maximum contributory securement area of 5.33 ft<sup>2</sup> (0.50 m<sup>2</sup>) per fastener, e.g. 6 fasteners on a 48 x 96 in. (1220 x 2440 mm) board size.

##### **4.2.2.1 Conditions of Acceptance for 5 x 9 Simulated Wind Uplift Pressure Test**

- 4.2.2.1.1 All fasteners and stress plates 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.
- 4.2.2.1.2 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.

EXCEPTIONS: cracking at fastener plates shall be permitted provided ultimate pull through does not occur.

- 4.2.2.1.3 All membranes or photovoltaic modules shall: a) not tear, puncture, fracture or develop any through openings; b) not delaminate or separate from adjacent components (exception: 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 or modules shall be permitted to separate and deflect from adjacent components at locations where adhesive placement was not intended).

EXCEPTIONS: a) tearing of membrane or module at fastener plates and batten bars is allowed up to ultimate failure provided water-tightness is maintained; b) minor areas of delamination are allowed provided they do not continue to grow in size by more than 50% during a given pressure level.

- 4.2.2.1.4 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 areas of delamination shall be permitted provided they do not continue to grow in size by more than 50% during a given pressure level.

- 4.2.2.1.5 All roof decks shall: a) maintain their structural integrity during the entire classification period; b) not fracture, split, crack, (this is covered by 4.2.2.1.3 and eliminated the issue of minor deformation at deck fasteners etc.) or allow for fastener withdrawal.
- 4.2.2.1.6 Stresses induced to steel roof decking shall be determined by rational analysis and shall not exceed the allowable stresses per the latest edition of the *North American Specification for the Design of Cold-Formed Steel Structural Members*, AISI S100-200.
- 4.2.2.1.7 All other components, including photovoltaic modules, seams, base sheets, base plies, plies and cap plies, shall not tear, puncture, fracture, disengage, dislodge, disconnect, delaminate or develop any through openings. See allowable exception given above in 4.2.2.1.3.
- 4.2.2.1.8 The theoretical load per fastener (pressure x contributory area) does not exceed the pullout resistance of the fastener per C.6.1, FM Approval Standard 4470.

### 4.2.3 Simulated Wind Uplift Pull Test

The simulated wind uplift pull test shall be used to evaluate fully adhered photovoltaic modules used with: fully adhered roof coverings having substrates (cover board layer, insulation layer(s) vapor retarder layer) either partially, or fully, adhered to monolithic structural concrete roof decks or gypsum or lightweight concrete cast over monolithic structural concrete. When substrates are partially adhered, the maximum row spacing to be evaluated is 12 in. (305 mm).

- 1) Assemblies with components (cover board, insulation, vapor retarder) either partially or fully adhered to monolithic structural concrete roof decks or gypsum or lightweight concrete cast over monolithic structural concrete. When substrates are partially adhered in ribbons, the adhesive is applied in rows spaced less than, or equal to, 12 in. (305 mm) on center.
- 2) Assemblies where the single ply roof cover is fully adhered to a cover board, insulation or deck.
- 3) Assemblies where the multi ply roof cover is partially adhered to a cover board, insulation or deck.
- 4) Assemblies with a perforated base sheet partially adhered to an insulation or deck and with a rigid insulation adhered above the perforated base sheet.
- 5) Assemblies with a maximum rigid insulation board size of 48 x 48 in. (1220 x 1220 mm).

#### 4.2.4 Conditions of Acceptance for Simulated Wind Uplift Pull Test

- 4.2.4.1 All insulations and photovoltaic modules shall 1) not fracture or break; 2) not delaminate or separate from their facers or adjacent components to which they have been adhered.
- 4.2.4.2 All photovoltaic modules and/or membranes shall not delaminate or separate from adjacent components.
- 4.2.4.3 All adhesive 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.
- 4.2.4.4 All other components, including seams, vapor retarders, base or ply sheets, shall not tear, puncture, fracture, disengage, dislodge, disconnect, delaminate or develop any through openings.

#### 4.3 Wind Uplift Resistance for Roof Assemblies With Flexible Photovoltaic Modules Adhered to Metal Panel Roof Coverings

Testing for wind uplift resistance for flexible photovoltaic modules adhered to metal panel roof covers shall be in accordance with the Test Procedure *12 x 24 ft Wind Uplift Tests for Standing Lap Seam and Composite Panel Roof Coverings*, FM Approvals, LLC and the Test Procedure *1 x 4 ft Wind Uplift Test for Flexible Photovoltaic Modules adhered to Standing Lap Seam and Composite Panel Roof Covers*, FM Approvals, LLC. The minimum rating required for FM Approval is Class 1-60. The maximum rating available is Class 1-990. Ratings between 1-60 and 1-990 are available in increments of 15 psf (0.72 kPa). The rating assigned to the assembly shall be the maximum simulated uplift resistance pressure which the assembly maintained for one (1) minute without failure. The maximum simulated uplift resistance pressure will be the minimum value from either of the required tests. Both of the tests are required.

##### 4.3.1 12 x 24 ft (3.7 m x 7.3 m) Simulated Wind Uplift Pressure Test

The 12x24 ft simulated wind uplift pressure tests shall be used to evaluate adhered photovoltaic modules used with metal panel roof covering. Testing for wind uplift resistance for flexible photovoltaic modules adhered to metal panel roof covers shall be in accordance with the Test Procedure *12 x 24 ft Wind Uplift Tests for Standing Lap Seam and Composite Panel Roof Coverings*, FM Approvals, LLC.

##### 4.3.1.1 Conditions of Acceptance for 12 x 24 ft Simulated Wind Uplift Pressure Test

- 4.3.1.1.1 The candidate panel roof assembly comprised of a specific combination of components shall possess adequate physical properties to resist 1) a specified minimum uplift pressure without disengagement or fracture of any component and 2) half the specified minimum uplift pressure without any permanent deformation of any component. Any separation, permanent deformation, withdrawal, or fracture within the panel roof assembly is considered a failure.

##### 4.3.2 1 x 4 ft (0.3 m x 1.2 m) Wind Uplift Test

The 1x4 ft simulated wind uplift reduced pressure tests shall be used to evaluate adhered photovoltaic modules used with metal panel roof covering. Testing for wind uplift resistance for flexible photovoltaic modules adhered to metal panel roof covers shall be in accordance with the Test Procedure *1 x 4 ft Wind Uplift Test for Flexible Photovoltaic Modules adhered to Standing Lap Seam and Composite Panel Roof Covers*, FM Approvals, LLC. The photovoltaic module will be subjected to the 1x4 ft wind uplift test on the same roof system as the 12x24 ft Simulated Wind Uplift Pressure Test after the 12x24 ft test is completed.

#### 4.3.2.1 Conditions of Acceptance for 1 x 4 ft Wind Uplift Test

- 4.3.2.1.1 All photovoltaic modules and/or membranes shall not delaminate or separate from adjacent components.
- 4.3.2.1.2 All adhesive 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.

#### 4.4 Hail Damage Resistance Test

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 Approval is Class 1-MH.

##### 4.4.1 Conditions of Acceptance for Hail Damage Resistance

- 4.4.1.1 The photovoltaic module shall show no signs of cracking or splitting. Under adhered conditions, minor separation of the module from the roof cover or roof cover from the substrate (directly under the impact area) is acceptable for monolithic decks only (i.e. structural concrete, lightweight insulating concrete, or gypsum). The photovoltaic module shall show no signs of cracking, splitting, separation, or rupture when examined closely under 10X magnification.

#### 4.5 Electrical Performance

Testing for electrical performance shall be in accordance with *Thin-film terrestrial photovoltaic (PV) modules – Design qualification and type approval*, International Standard IEC/EN 61646, International Electrotechnical Commission / European Norm.

##### 4.5.1 Conditions of Acceptance for Electrical Performance

- 4.5.1.1 A test sample must meet all tests requirements in IEC/EN 61646.

#### 4.6 Electrical Safety

Testing for electrical safety shall be in accordance with *Photovoltaic (PV) module safety qualification – Part 2: Requirements for testing*, International Standard IEC/EN 61730-2, International Electrotechnical Commission / European Norm or *Flat Plate Photovoltaic Modules and Panels*, American National Standard, ANSI/UL 1703.

##### 4.6.1 Conditions of Acceptance for Electrical Safety

- 4.6.1.1 A test sample must meet all tests requirements in IEC/EN 61730-2 or a test sample must meet all test requirements in ANSI/UL 1703.

#### 4.7 Heat Aging Affects

Testing for affects of heat aging from a photovoltaic modules applied to a roof cover shall be in accordance with *Test Procedure, Tests for Measuring Heat Aging Affects of Flexible Photovoltaic Modules on Roof Coverings*, FM Approvals, LLC if the roof covering is not made from asphalt or modified bitumen. Roof covers made from asphalt or modified bitumen are requirement to meet the compound stability test per ASTM D5147, *Standard Test Methods for Sampling and Testing of Modified Bituminous Sheet Material*. No heat aging testing is required for Approval over metal panel roof covers due to the type of material.

#### 4.7.1 Conditions of Acceptance for Heat Aging Affects

##### 4.7.1.1 For non-asphaltic roof covers:

4.7.1.1.1 After 60 days of exposure, the roof cover bent over a 3 in. (76 mm) diameter mandrel shall not show any signs of cracking or splitting when examined closely under 10X magnification.

##### 4.7.1.2 For asphaltic or modified bitumen roof covers:

4.7.1.2.1 No flowing, dripping or drop formation on the lower edge of the specimen shall be observed at 215 °F (102 °C).

## 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 Facilities and Procedures Audit (F&PA).
- 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 should be an authoritative collection of procedures/policies. It should provide an accurate description of the quality management system while serving as a permanent reference for implementation and maintenance of that system. The system should 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 Facilities and Procedures Audit (F&PA)

- 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 Approval Report. Manufacture of products bearing the 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 = in. x 25.4  ft - "feet"; (m - "meters") m = ft x 0.3048
PRESSURE:	psi - "pounds per square foot"; (kPa - "kilopascals") kPa = psf x 0.04788
TEMPERATURE:	°F "degrees Fahrenheit"; (°C "degrees Celsius") °C = (°F - 32) x 0.556

## APPENDIX B: FM APPROVALS CERTIFICATION MARKS

FM Approvals certifications 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: SMALL SCALE TESTS

The following scale tests are used to screen and/or compare the properties of individual roof components or roof components used in combination with other components that make up complete roof assemblies. The purpose of these tests is 1) to identify via small scale test procedures critical combinations of components to include in large scale tests and 2) to determine if FM Approval may be extended to alternate components after full scale tests have been completed and 3) to assess physical characteristics necessary for the continued performance of a component when installed within a roof assembly. The decision to extend FM Approval to any components via small scale testing shall be at the sole discretion of FM Approvals. Alternate components must perform to an equal or higher level than the component qualified via large scale testing in order for testing to be waived.

### C.1 Pull Through Tests for Roofing Membranes Using Tensile Loading

Pull through tests for flexible photovoltaic modules using tensile loading shall be in accordance with *Test Procedure, Pull Through Tests for Roofing Membranes and Substrates Using Tensile Loading*, FM Approvals, LLC.

#### C.1.1 Results

- 1) The result shall be the highest force attained by the sample during the test.
- 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%, then up to two additional tests will be required. The results of all tests shall be used to determine the final average.

### C.2 Membrane Delamination Tests for Roofing Membranes and Substrates Using Tensile Loading

Membrane delamination tests for photovoltaic modules and substrates using tensile loading shall be in accordance with *Test Procedure, Membrane Delamination Tests for Roofing Membranes and Substrates Using Tensile Loading*, FM Approvals, LLC.

#### C.2.1 Results

- 1) The result shall be the highest force attained by the sample during the test.
- 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% then up to two additional tests will be required. The results of all tests shall be used to determine the final average.

## APPENDIX D: DETERMINATION OF THE APPROPRIATE WIND UPLIFT TESTS

The following table is used to determine the wind uplift testing that should be used for the various roof cover and photovoltaic designs.

	<b>Fully Adhered PV</b>	<b>Partially Adhered PV</b>	<b>Mechanically Fastened PV</b>
<b>Fully Adhered Roof Cover</b>	Small scale (See Appendix C), then full scale reduced pressure test or pull test (See 4.2.1, 4.2.2, 4.2.3)	Reduced pressure test or pull test (See 4.2.1, 4.2.2, 4.2.3)	Reduced pressure test (See 4.2.1, 4.2.2)
<b>Mechanically Attached Roof Cover</b>	Reduced pressure test (See 4.2.1, 4.2.2)	Reduced pressure test (See 4.2.1, 4.2.2)	Reduced pressure test (See 4.2.1, 4.2.2)
<b>Metal Roof</b>	12x24 Uplift per 4471 to service load (1/2 rating) then test PV with a 1x4 ft reduced pressure test (See 4.3.1, 4.3.2)	12x24 Uplift per 4471 to service load (1/2 rating) then test PV with a 1x4 ft reduced pressure test (See 4.3.1, 4.3.2)	12x24 Uplift per 4471 to service load (1/2 rating) then test PV with a 1x4 ft reduced pressure test (See 4.3.1, 4.3.2)