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Examination Standard for Flexible Photovoltaic Modules

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Foreword

This standard 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 this standard is to present the criteria for examination of various types of products and services.

Examination in accordance with this standard shall demonstrate compliance and verify that quality control in manufacturing shall ensure a consistent and reliable product.

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1 INTRODUCTION

1.1 PURPOSE

1.1.1 This standard states testing and certification requirements for flexible photovoltaic modules that are used with a certified roof assembly.

1.1.2 Testing and certification criteria may include performance requirements, marking requirements, examination of manufacturing facility(ies), audit of quality assurance procedures, and a surveillance program.

1.2 SCOPE

1.2.1 This standard applies to all flexible photovoltaic modules when adhered to, or mechanically fastened through, a certified 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 FM Examination Standard 4470. *Single-Ply, Polymer-Modified Bitumen Sheet, Built-Up Roof (BUR) and Liquid Applied Roof Assemblies for use in Class 1 and Noncombustible Roof Deck Construction*. Standing seam or metal panel roofs that do not contain flexible photovoltaic modules shall be qualified in accordance with FM Examination Standard 4471, *Class 1 Panel Roofs*.

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 Examination Standard 4478, *Roof-Mounted Rigid Photovoltaic Module Systems*.

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 certification.

1.4 BASIS FOR CERTIFICATION

Certification is based upon satisfactory evaluation of the product when used as part of a certified 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 for certification;
- 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 may be 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. Subsequent surveillance may be required by the certification agency in accordance with the certification scheme to ensure ongoing compliance.

1.5 BASIS FOR CONTINUED CERTIFICATION

The basis for continual certification may include the following based upon the certification scheme and requirements of the certification agency:

- production or availability of the product as currently certified;
- the continued use of acceptable quality assurance procedures;
- compliance with the terms stipulated by the certification;
- satisfactory re-examination of production samples for continued conformity to requirements; and
- satisfactory surveillance audits conducted as part of the certification agency’s product surveillance program.

1.6 EFFECTIVE DATE

The effective date of this certification standard mandates that all products tested for certification after the effective date shall satisfy the requirements of this standard.

The effective date of this standard is eighteen (18) months after the publication date of the standard for compliance with all requirements.

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. Conversion of U.S. customary units is in accordance with ANSI/IEEE/ASTM SI 10.

1.8 NORMATIVE REFERENCES

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the cited edition applies.:

ANSI/FM Approvals

ANSI/FM Approvals 4474, *Evaluating the Simulated Wind Uplift Resistance of Roof Assemblies Using Static Positive and/or Negative Differential Pressures*

ANSI / Underwriters Laboratories

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

ASTM International

ASTM E108, *Fire Tests of Roof Coverings*, ASTM International

ASTM D5147, *Standard Test Methods for Sampling and Testing of Modified Bituminous Sheet Material*, ASTM International

International Electrotechnical Commission (IEC)

International Standard IEC/EN 61646, *Thin-film terrestrial photovoltaic (PV) modules – Design qualification and type approval*, International Electrotechnical Commission / European Norm

International Standard IEC/EN 61730-2, *Photovoltaic (PV) module safety qualifications – Part 2:Requirements for Testing*, International Electrotechnical Commission / European Norm

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FM 4470, *Examination 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*

FM 4471, *Examination Standard for Class 1 Panel Roofs*

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 CERTIFICATION APPLICATION REQUIREMENTS

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

- a complete list of all models, types, sizes, and options for the products or services being submitted for certification 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;
- a document from the certified roof cover manufacturer acknowledging that the photovoltaic module will be installed over their roof cover and is compatible with it;
- the number and location of manufacturing facilities.

All documents shall identify 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.

2.3 REQUIREMENTS FOR SAMPLES FOR EXAMINATION

2.3.1 Following authorization of a certification examination, the manufacturer shall submit samples for examination and testing based on the following:

- Sample requirements shall be determined by the certification agency.

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.

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 certification.

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 certification investigation shall define the limits of the certification.

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 model or type identification shall correspond with the manufacturer's catalog designation and shall uniquely identify the certification agency’s mark of conformity.

3.2.3 The certification agency’s mark of conformity shall be displayed visibly and permanently on the product and/or packaging as appropriate and in accordance with the requirements of the certification agency. The manufacturer shall exercise control of this mark as specified by the certification agency and the certification scheme.

3.2.4 All markings shall be legible and durable.

3.3 MANUFACTURER’S INSTALLATION INSTRUCTIONS

3.3.1 The manufacturer shall:

- prepare instructions for the installation, maintenance, and operation of the product;
- provide facilities for repair of the product and supply replacement parts, if applicable;
- provide services to ensure proper installation, inspection, or maintenance for the product where it is not reasonable to expect the average user to be able to provide the installation, inspection, or maintenance.

3.4 CALIBRATION

3.4.1 3.4.1 Each piece of equipment used to verify the test parameters shall be calibrated within an interval determined on the basis of stability, purpose, and usage. A copy of the calibration certificate for each piece of test equipment is required. The certificate shall indicate that the calibration was performed against working standards whose calibration is certified and traceable to an acceptable reference standard and certified by an ISO/IEC 17025 accredited calibration laboratory. The test equipment shall be clearly identified by label or sticker showing the last date of the calibration and the next due date. A copy of the service provider’s accreditation certificate as an ISO/IEC 17025 accredited calibration laboratory should be available.

3.4.2 3.4.2 When the inspection equipment and/or environment is not suitable for labels or stickers, other methods such as etching of control numbers on the measuring device are allowed, provided documentation is maintained on the calibration status of thus equipment.

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 the certification agency.

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 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 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 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 the certification agency.

Additional tests may be required, at the sole discretion of the certification agency, 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 the certification agency and with a technical justification of the conditions or reasons for failure. When a test specimen fails to meet the certification acceptance criteria for a given classification or rating, two successful test specimens of the same or similar construction must meet the certification 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.

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 4474. The minimum rating required for certification 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 described in ANSI/FM 4474-Appendix D 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 described in ANSI/FM 4474 Appendix C 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^2 (0.50 m^2) 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 4470.

4.2.3 Simulated Wind Uplift Pull Test

The simulated wind uplift pull test described in ANSI/FM 4474 Appendix B 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 described below in section 4.3.1 and 4.3.2 The minimum rating required for certification 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 tested per ANSI/FM 4474 Appendix D.

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 as follows: 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.

1. Prepare the test sample by applying a foam gasket around the 1x4 ft (0.3 x 1.2 m) perimeter of the test area.
2. Place the vacuum chamber of the test area and connect the manometer and the blower.
3. Air is exhausted by opening the air exhaust valve on the blower until the pressure level in the vacuum chamber reaches 15 lbs/ft^2 (0.7 kPa) with a tolerance of +2 lbs/ft^2, -0 lbs/ft^2 (+0.1 kPa, -0 kPa). The air shall be exhausted at a rate that will increase the resulting pressure 1.5 lbs/ft^2/sec ± 1 lbs/ft^2/sec (0.07 kPa/sec ± 0.05 kPa/sec). Upon reaching 15 lbs/ft^2 (0.7 kPa), the pressure level shall be maintained while the perimeter of the sample is checked to ensure that there are minimal air leaks into the vacuum chamber. Adjustments shall be permitted as necessary to maintain a constant reading. While the sample is being maintained at this pressure level, the sample shall be visually examined to ensure that it continues to meet the conditions of acceptance.
4. After 60 seconds, the pressure level shall be increased in 15 lbs/ft^2 (0.7 kPa) increments by exhausting additional air at the rate and within the tolerance described above. Upon reaching the next 15 lbs/ft^2 (0.7 kPa) level, the pressure shall be maintained for a period of 60 seconds. The exhaust air shall be adjusted as necessary in order to maintain a constant reading. While the sample is being maintained at this pressure level, the sample shall be visually examined to ensure that it continues to meet the conditions of acceptance.
5. The sequence described in step 4 above shall be repeated until the sample fails, additional pressure levels are unable to be attained or maintained, or at the discretion of the test sponsor. Failure is considered to occur when the conditions of acceptance are no longer being met or until the pressure level is no longer able to be maintained.

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 as follows. The minimum rating required for certification is Class 1-MH.

For MH and SH, two identical samples are prepared with the roof cover applied to the selected substrate.

The first sample is unconditioned and tested as follows:

1. The sample is subjected to a minimum of ten impacts from the 1.19 lb 1 kg) steel ball.
2. For SH, the ball is dropped from a height of 141.5 (3595 mm), generating an impact energy of approximately 14 ft-lb (19 J).
3. For MH, the ball is dropped from a height of 81 in (2057 mm), generating an impact energy of approximately 8 ft-lb (10.8 J).
4. The second sample is conditioned (weathered) for 1000 hours in an ultraviolet weathering cabinet. The sample is then subjected to impact testing as described above.

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 IEC/EN 61646.

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 IEC/EN 61730-2 or 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 EFFECTS

Testing for effects of heat aging from photovoltaic modules applied to a roof cover shall be as described below if the roof covering is not made from asphalt or modified bitumen. Roof covers made from asphalt or modified bitumen are required to meet the compound stability test per ASTM D5147. No heat aging testing is required for certification over metal panel roof covers due to the type of material.

For roof covering that is not made from asphalt or modified bitumen or metal:

1. Place the roof cover sample into the forced hot air oven at 280±3.6°F (137±2°C) for 60 days.
2. After removing from the oven allow the sample to cool to room temperature (approximately 1 hour).
3. The test sample is then bent over the 3 in (76 mm) diameter mandrel with the top surface of the roof cover facing outward and held in that position during the sample inspection. The sample shall be monitored during the test and the effect of the test on the sample shall be recorded. The sample shall be viewed under 10X magnification during the post-test evaluation.

4.7.1 Conditions of Acceptance for Heat Aging Effects

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 MANUFACTURER'S REQUIREMENTS

5.1 DEMONSTRATED QUALITY CONTROL PROGRAM

5.1.1 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 certification report.
- Continued conformance to this standard is verified by the certifier's surveillance program.
- Quality of performance is determined by field performance and by periodic re examination and testing.

5.1.2 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.

5.1.3 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.

5.1.4 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.

5.1.5 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 certification report, may be required to be reported to, and authorized by the certification agency prior to implementation for production.
- Records of all revisions to all certified products shall be maintained.

5.2 SURVEILLANCE AUDIT

5.2.1 An audit of the manufacturing facility may be part of the certification agencies surveillance requirements 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 ensure a uniform product consistent with that which was tested and certified.

5.2.2 Certified products or services shall be produced or provided at, or provided from, location(s) disclosed as part of the certification examination. Manufacture of products bearing a certification mark is not permitted at any other location prior to disclosure to the certification agency.

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 the certification agency.

5.4 PRODUCT MODIFICATIONS

The manufacturer shall notify the certification agency of changes in product construction, components, raw materials, physical characteristics, coatings, component formulation or quality assurance procedures prior to implementation.

6 BIBLIOGRAPHY

ISO/IEC 17025, *General Requirements for the Competence of Testing and Calibration Laboratories*.

APPENDIX A:

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APPENDIX B:

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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 certification 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 certification to any components via small scale testing shall be at the sole discretion of the certification agency. 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.

	Fully Adhered PV	Partially Adhered PV	Mechanically Fastened PV
Fully Adhered Roof Cover	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)
Mechanically Attached Roof Cover	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)
Metal Roof	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)