FM Approvals

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Examination Standard for Steep Slope Building Integrated Photovoltaic Roof Covers

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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 steep slope building integrated photovoltaic roof covers that are installed as the roof covering.

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 building integrated steep slope photovoltaic roof covers that are installed as the roof covering.

1.2.2 Steep slope roofing is defined as a roof slope with an incline of > 2 units per 12 units (9.50).

1.2.3 This standard evaluates steep slope building integrated photovoltaic roof covers for their performance in regard to fire from above and below the structural deck, simulated wind uplift, susceptibility from hail damage, electrical safety and electrical performance. The standard is intended to evaluate only those hazards investigated and is not intended to determine suitability for the end use of a product.

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

1.2.5 This standard does not evaluate flexible or rigid photovoltaic modules installed on low slopes roofs.

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 steep slope photovoltaic roof covers for the purpose of obtaining certification. Products having characteristics not anticipated by this standard may be certified if performance is equal, or superior, to that required by this standard is demonstrated.

1.4 BASIS FOR CERTIFICATION

Certification is based upon satisfactory evaluation of the product, when used as part of a certified roof assembly, and the manufacturer in the following major areas:

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 Steep slope photovoltaic roof covers shall be fabricated, tested and certified in accordance with recognized, international standards per current edition of either IEC/EN 61730-2 or ANSI/UL 1703 for electrical safety and IEC/EN 61215-1, IEC/EN 61215-1-1, IEC/EN 61215-1-2, IEC/EN 61215-1-3, IEC/EN 61215-1-4 and IEC/EN 61215-2 for electrical performance.

1.4.3 An examination of the manufacturing facilities and audit of quality control procedures may be conducted 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;
- satisfactory field experience;
- compliance with the terms stipulated by the certification;
- satisfactory re-examination of production samples for continued conformity to earYssrequirements; and
- satisfactory surveillance audits conducted as part of the certification agency's product surveillance program.

1.6 EFFECTIVE DATE

The effective date of this examination 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.

American Iron and Steel Institute (AISI)

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

American National Standard Institute (ANSI)

ANSI/FM 4473*, Impact Resistance Testing of Rigid Roofing Materials by Impacting with Freezer Ice Balls*

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

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

American Society for Testing and Materials (ASTM International)

ASTM E108, *Standard Test Method for Fire Tests of Roof Coverings*

ASTM D3161, *Standard Test Method for Wind-Resistance of Steep Slope Roofing Products*

ASTM G154, *Standard Practice for Operating Fluorescent Light Apparatus for UV Exposure of Nonmetallic Materials*

International Electrotechnical Commission (IEC)

IEC/EN 61215-1, IEC/EN 61215-1-1, IEC/EN 61215-1-2, IEC/EN 61215-1-3, IEC/EN 61215-1-4 and IEC/EN 61215-2, *Crystalline silicon terrestrial photovoltaic (PV) modules – Design qualification and type approval*

IEC/EN 61730-2, *Photovoltaic (PV) module safety qualifications – Part 2: Requirements for Testing*

FM Approvals LLC (FM)

FM 4451, *Examination Standard for Profiled Steel Panels for Use as Decking in Class 1 Insulated Roof Construction*.

National Fire Protection Association (NFPA)

NFPA 276, *Standard Method of Fire Test for Determining the Heat Release Rate of Roofing Assemblies with Combustible Above-Deck Roofing Components*.

1.9 TERMS AND DEFINITIONS

For purposes of this standard, the following terms apply:

Adhesive	Adhesive is used in construction to adhere components together. Depending on the use, the adhesive could be in either a liquid form, semi liquid form, reactive liquid form or a solid form as in a tape or as in hot asphalt which is solid until heated.
Building Integrated Photovoltaics	Device that converts solar energy into electricity that are also used to replace conventional building materials such as roofing shingles.
Crack	During testing, when a component is stressed to the point that it separates from itself while continuing to maintain the applied uplift pressure without catastrophic failure of the test assembly.
Crease	During testing, when a component is stressed to the point that it bends at a sharp, defined angle, without breaking. Often a crack will form on the opposite face of the component.
Deck	The structural component of the roof assembly to which the roof system is secured.
Fasteners	A mechanical securement device used alone or in combination with a stress distributor to secure various components of a roof assembly.
Mechanically Fastened	Mechanically fastened describes components of the roof assembly that have been attached to the substrate at defined intervals using fasteners with, or without, stress distributors.
Minor Delamination	During testing, an area approximately 1% of the test sample. For a 12 x 24 ft. (3.7 x 7.3 m) test an area of 3 ft2 (2.8 m2); for a 5 x 9 ft. (1.5 x 2.7 m) test an area of 0.5 ft2 (0.05 m2), whereby two adhered components which are intended to be in contact are not in contact.
Permanent Deformation	Any deformation of a component that remains after the load has been removed. Panel deflection that can be removed by mechanical means not involving special equipment and without additional deformation shall not be considered permanent deformation.
Photovoltaic Roof Cover	A small thin piece of building material that is applied in overlapping row as a covering for the roof that is also a device that converts solar energy into electricity.
Rated Wind Load	The uplift load given to a roof assembly based on ultimate failure load in psf (kPa).
Roof Assembly	A group of interacting roof components (including the roof deck) designed to weatherproof and, normally, to insulate a building's top surface. The roof assembly includes the photovoltaic shingle.
Roof Cover	The exterior surface of a roof assembly designed to protect the building components from the weather. In this standard, the photovoltaic roof cover defined above is also the roof cover.
Roof System	A group of interacting roof components (not including the roof deck) designed to weatherproof and, normally, to insulate a building's top surface. The roof system includes the photovoltaic shingle.
Service Wind Load	The un-factored uplift load resulting from a windstorm that a roof assembly must resist.
Stress Distributor/Plate	A metal or plastic disk or bar designed to distribute a concentrated load over a larger surface area.
Weld	A weld is a type of securement whereby metal or plastic materials are joined together through heat or solvent fusion.

2 GENERAL INFORMATION

2.1 PRODUCT INFORMATION

Steep slope photovoltaic roof covers are supplied in several forms including but not limited to, self-sealing, interlocking and tab fastened. The roof covers have integrated photovoltaic modules.

2.2 CERTIFICATION APPLICATION REQUIREMENTS

2.2.1 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 modules being submitted for certification consideration.
- The components that make up each roof assembly. All components in the finished roof assembly must be identified by manufacturer, product trade name, method of installation and the ratings desired for each combination.
- All ratings which are desired or expected for each assembly:
    - Class and maximum roof slope requested for ASTM E108 Test
    - Wind Uplift Rating, Class 1-60, 1-75, etc.
    - Hail Damage Rating, Class 2, 3, 4 or VSH
- The number and location of manufacturing facilities.
- All documents shall contain the manufacturer's name, document number or other form of reference, title, date of last revision and revision level. All documents shall be provided in English.
- Certification documentation for IEC/EN 61730-2 or ANSI/UL 1703 and IEC/EN 61215-1, IEC/EN 61215 -1-1 and IEC/EN 61215 -2 shall be submitted to the certification agency prior to completion of the certification program. This documentation shall include a copy of the test report as well as the certification of compliance.
- Manufacturer’s specifications and technical bulletins may be needed to confirm certifications requested are in compliance with paragraph 3.3.1.

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 to 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. Any decision to use test data generated using prototypes is at the discretion of the certification agency.

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

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 examination results may further define the limits of the final 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 product trade name, model number, or model 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 permanent.

3.3 MANUFACTURER’S INSTALLATION INSTRUCTIONS

3.3.1 The manufacturer

- shall prepare instructions for the installation, maintenance, and operation of the product;
- shall provide facilities for repair of the product and supply replacement parts, if applicable; and
- shall provide services to ensure proper installation, inspection, or maintenance for products of such nature that it would not be reasonable to expect the average user to be able to provide such installation, inspection, or maintenance;
- may be required to perform at least one inspection of the field installation during and/or after completion. In some cases, a continued program of inspections shall be necessary to assess the application procedures or changes within the application techniques.
- shall not certify any assembly if is in conflict with the manufacturer’s specifications and/or other written documentation such as technical bulletins.

3.4 CALIBRATION

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 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 production of the test specimens shall be at the discretion of the certification agency.

4 PERFORMANCE REQUIREMENTS

This standard is intended to evaluate a steep slope building integrated photovoltaic roof covers for their performance as it relates to fire from above and below the structural deck, simulated wind uplift, susceptibility from hail storm damage and electrical safety and electrical performance.

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

The use of screening tests is permitted to be used to determine critical components to be used for full scale testing or to evaluate components as alternate to those already tested and found to be satisfactory via the full scale tests described in section 4.3 below. Alternate components must perform to an equal or higher level than the component qualified via large scale testing. Acceptable screening tests shall be at the discretion of the certification agency.

A re-test of an identical assembly following a failure shall be acceptable at the 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. Any test specimen that fails more than three times is no longer considered a candidate for certification.

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

4.1 COMBUSTIBILITY FROM ABOVE THE ROOF DECK

Testing for combustibility from above the steep slope building integrated photovoltaic roof cover shall be in accordance with ASTM E108. The tests shall include spread of flame, intermittent flame and burning brand as applicable. A minimum rating of Class B is required.

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

4.1.1.1 Spread of Flame Test:

- For Class A, the maximum flame spread of the sample materials shall not exceed 72 in. (1830 mm).
- For Class B, the maximum flame spread of the sample materials shall not exceed 96 in. (2440 mm).
- There shall be no excessive lateral flame spread which is defined as flames extending to the two lateral edges of the exposed roof covering or coating beyond 12 in. (305 mm) from the ignition source.
- There shall be no portion of the roof covering material blown or falling off of the test deck in the form of flaming or glowing brands that continue to glow after reaching the floor.
- There shall be no portion of the roof deck that fall in the form of flaming of particles that continue to glow after reaching the floor.

4.1.1.2 Intermittent Spread of Flame and Burning Brand tests for Classes A or B:

- There shall be no portion of the roof covering material blown or falling off of the test deck in the form of flaming or glowing brands that continue to glow after reaching the floor.
- There shall be no exposure of the deck or sustained flaming on the underside of the deck.
- There shall be no portion of the roof deck that fall in the form of flaming of particles that continue to glow after reaching the floor.

4.2 COMBUSTIBILITY FROM BELOW THE ROOF DECK

Testing for combustibility from below the roof deck shall be in accordance with NFPA 276.

4.2.1 Conditions of Acceptance for Combustibility from Below the Roof Deck

4.2.1.1 The roof assembly, when subjected to the NFPA 276 test, shall not exhibit fuel contribution rates in excess of the values shown in the following table.

Time Interval	***Maximum Fuel Contribution Rate***	
Min	***Btu/ft2/min***	***(kW/m2)***
3	410	(77.6)
5	390	(73.8)
10	360	(68.1)
Avg. (30 min)	285	(54.0)

4.2.1.2 There shall be no dropping of flaming particles into the furnace or uncontrolled flaming on the exterior surface of the sample.

4.3 WIND UPLIFT RESISTANCE

For wind uplift resistance, the steep slope building integrated photovoltaic roof covers will be tested using two methods. These two methods are a simulated wind uplift pressure test (section 4.3.1 or 4.3.2) and simulated wind resistance test (section 4.3.3).

4.3.1 12 x 24 ft (3.7 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 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. The rating assigned to the assembly shall be the maximum simulated uplift resistance pressure which the assembly maintains for one (1) minute without failure. In addition, the assembly must maintain the service wind load for one (1) minute without visible cracking or visible creasing of the steep slope photovoltaic shingle, insulation or cover board.

- Multiple cracks or creases in the same photovoltaic shingle, insulation or cover board, which would impair performance, is indicative of ultimate failure and shall not be permitted.
- Crack or crease length in the same insulation or cover board, in excess of one half the minimum board dimension, e.g., 24 in. (1220 mm) for a 48 x 96 in. (1220 x 2440 mm) board, shall not be permitted. This statement does not apply to the photovoltaic shingle.

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

1. Assemblies other than those evaluated via the 5 x 9 ft (1.5 x 2.7 m) uplift pressure test.
2. Assemblies that utilize mechanical fasteners, adhesives, hot asphalt, heat welding, self-adhesive components or combination thereof, to secure insulations, coverings and other components, in single or multi-layered constructions, to one another and to the roof deck.

   Note: Adhesive and hot asphalt securement to steel roof deck is not permitted.
3. Assemblies that utilize steel, FR treated wood, structural concrete, cementitious panel, plastic or gypsum roof decks having a minimum thickness of 2 in. (51 mm).
4. Assemblies that utilize an air retarder. For wind ratings of Class 1-90 and below, the assembly must also meet the service load (half of the rated load) without the air barrier in place. For wind ratings above Class 1-90, the assembly must perform to the rated level with and without the air barrier in place.
5. For new construction on steel deck, assemblies that do not overstress the structural deck when subjected to service wind loads. Stresses induced to steel roof decking shall be determined by rational analysis using Allowable Strength Design (ASD) principles and shall not exceed the allowable stresses per AISI S100 and FM 4451.
6. The test sponsor shall supply calculations used to determine the stresses.

4.3.1.1 Conditions of Acceptance for the 12 x 24 ft (3.7 x 7.3 m) Simulated Wind Uplift Pressure Test

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

4.3.1.1.2 All components 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 components do not fracture, crack or break.

EXCEPTION for all components other than the photovoltaic shingle: visible cracking or visible creasing, when less than or equal to one half the minimum component dimension, shall be permitted provided ultimate failure does not occur as noted in 4.3.1.

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

EXCEPTIONS: 1) Mechanically fastened photovoltaic roof covers shall be permitted to separate and deflect from adjacent components at locations where they are not fastened, 2) partially adhered roof covers shall be permitted to separate and deflect from adjacent components at locations where adhesive placement was not intended, 3) tearing of roof covers at fastener/stress distributors is allowed up to ultimate failure, 4) minor areas of delamination are allowed provided they do not continue to grow in size by more than 50% from the end of one pressure level through the end of the following pressure level.

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

EXCEPTION: Minor delamination is allowed provided it does not continue to grow in size by more than 50% from the end of one pressure level through the end of the following pressure level.

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

4.3.1.1.6 Stresses induced to steel roof decking shall be determined by rational analysis, supplied by the test sponsor and shall not exceed the allowable stresses per AISI S100.

4.3.1.1.7 All other components, shall not tear, puncture, fracture, disengage, dislodge, disconnect, delaminate or develop any through openings.

4.3.2 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 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 using this method is Class 1-90. Ratings between 1-60 and 1-90 are available in increments of 15. The rating assigned to the assembly shall be the maximum simulated uplift resistance pressure which the assembly maintains for one (1) minute without failure. In addition, the assembly must maintain the service wind load for one (1) minute without visible cracking or visible creasing of the steep slope photovoltaic shingle, insulation or cover board.

- Multiple cracks or creases in the same photovoltaic shingle insulation or cover board, which would impair performance, is indicative of ultimate failure and shall not be permitted.
- Crack or crease length in the same insulation or cover board, in excess of one half the minimum board dimension, e.g., 24 in. (1220 mm) for a 48 x 48 in. (1220 x 1220 mm) board, shall not be permitted. This statement does not apply to the photovoltaic shingle.

The 5 x9 (1.5 x 2.7) simulated wind uplift pressure test procedure is used to determine the simulated wind uplift resistance of the following types of roof assemblies:

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 and hot asphalt securement to steel roof deck is not permitted.
2. Assemblies that utilize air pervious decks to include cementitious panel, 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 securement spacing of 24 in. (610 mm).
4. Assemblies with roof covers adhered to mechanically secured insulation [maximum 48 x 48 in. (1220 x 1220 mm) board] with a maximum contributory securement area of 4 ft^2 (0.37 m^2) per fastener, e.g. 4 fasteners on a 48 x 48 in. (1220 x 1220 mm) board size.

4.3.2.1 Conditions of Acceptance for the 5 x 9 ft (1.5 x 2.7 m) Simulated Wind Uplift Pressure Test

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

4.3.2.1.2 All components 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 components do not fracture, crack or break.

EXCEPTION for all components other than the photovoltaic shingle: Visible cracking or visible creasing, when less than or equal to one half the minimum component dimension, shall be permitted provided ultimate failure does not occur as noted in 4.3.2.

4.3.2.1.3 All steep slope building integrated photovoltaic roof covers shall: a) not tear, puncture, fracture or develop any through openings; b) not delaminate or separate from adjacent components.

EXCEPTIONS: 1) Mechanically fastened photovoltaic roof covers shall be permitted to separate and deflect from adjacent components at locations where they are not fastened, 2) partially adhered roof covers shall be permitted to separate and deflect from adjacent components at locations where adhesive placement was not intended, 3) tearing of roof covers at fastener/stress distributors is allowed up to ultimate failure, 4) minor areas of delamination are allowed provided they do not continue to grow in size by more than 50% from the end of one pressure level through the end of the following pressure level.

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

EXCEPTION: Minor delamination is allowed provided it does not continue to grow in size by more than 50% from the end of one pressure level through the end of the following pressure level.

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

4.3.2.1.6 Stresses induced to steel roof decking shall be determined by rational analysis, supplied by the test sponsor and shall not exceed the allowable stresses per AISI S100.

4.3.2.1.7 All other components shall not tear, puncture, fracture, disengage, dislodge, disconnect, delaminate or develop any through openings.

4.3.3 Simulated Wind Resistance Test

In order to qualify as certified, steep slope building integrated photovoltaic shingles shall possess adequate physical properties to assure that the attachment of all the roof covers resist the minimum wind speed for testing of 110 mph (177 km/h) under ASTM D3161 Class F.

OPTIONAL: Following completion of the 110 mph (177 km/h) Class F testing, the velocity may be increased to achieve a higher rating as follows. The velocity will be increased in 10 mph (16 km/h) increments, each for a duration of 10 minutes, until the 150 mph (241 km/h) test has been completed or the test panel fails as indicated above.

1. The Simulated Wind Resistance test apparatus shall provide a consistent wind speed not less than 110 mph (177 km/h).
2. A minimum of two test panels shall be tested.
3. For products that utilize sealants, prior to testing, the sample to be tested shall be conditioned at a slope of 2 in 12 for a period of 16 hours at a temperature of 135-140 °F (57-60 °C). The samples are allowed to cool to room temperature while maintaining the 2 in 12 slope prior to the test.
4. For products that do not utilize sealants, prior to testing, the sample to be tested shall be conditioned at a slope of 2 in 12 for a period of 16 hours at a temperature of 80 °F (+/- 15 °C). The samples are allowed to cool to room temperature while maintaining the 2 in 12 slope prior to the test.

4.3.3.1 Conditions of Acceptance for the Simulated Wind Resistance Test

4.3.3.1.1 At the end of the test period, all photovoltaic roof covers shall be intact and no photovoltaic roof covers shall be broken, bent back or have edges standing in the air. All other components shall not tear, puncture, fracture, disengage, dislodge, disconnect, delaminate or develop any through openings.

4.4 HAIL DAMAGE RESISTANCE TEST

Testing for hail damage resistance shall be in accordance with ANSI/FM 4473, *Impact Resistance Testing of Rigid Roofing Materials by Impacting with Freezer Ice Balls for Class 2, 3 and 4*. Testing for hail damage resistance for Class VSH shall be in accordance with ANSI/FM 4473 with the following changes: Testing is performed with Class 4 nominal 2.0 in (50.8 mm) diameter ice balls and the samples are conditioned prior to testing. The minimum rating required for certification is Class 2.

4.4.1 Hail damage test apparatus consists of a launcher device capable of propelling frozen ice balls at speeds necessary to develop the intended kinetic energy and a speed meter capable of measuring ice ball speeds within 1 mph (1.6 km/h).

Class	***Nominal Ice Ball Diameter (in. [mm])***	***Kinetic Energy (ft-lb [J]) Target***	***Kinetic Energy (ft-lb [J]) + 10%***
2	1 ½ (38.1)	7.77 (10)	8.55 (11)
3	1 ¾ (44.5)	14.95 (20)	16.5 (22)
4	2.0 (50.8)	26.81 (36)	29.5 (40)
VSH	2.0 (50.8)	53 (72)	58 (79)

A minimum of two test panels for Class 2, 3 or 4 shall be tested. A minimum of three test panels for VSH shall be tested. The first VSH panel is tested with no conditioning, the second after 1000 hours Ultraviolet (UV) conditioning and the third following 1000 hours UV and 1000 hours Heat conditioning. UV conditioning shall be conducted in accordance with *ASTM G154 Standard Practice for Operating Fluorescent Light Apparatus for UV Exposure of Nonmetallic Material*. For heat aging, non-asphaltic shingles are conditioned at 240 ± 5°F (116 ± 3°C) and asphaltic shingles are conditioned at 160 ± 5°F (71 ± 3°C).

4.4.2 Condition of Acceptance for Hail Damage Resistance

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

4.5 ELECTRICAL PERFORMANCE

Testing for electrical performance shall be in accordance with IEC/EN 61215-1, IEC/EN 61215-1-1, IEC/EN 61215-1-2, IEC/EN 61215-1-3, IEC/EN 61215-1-4 and IEC/EN 61215-2.

4.5.1 Condition of Acceptance for Electrical Performance

All test samples must meet all test requirements in IEC/EN 61215-1, IEC/EN 61215-1-1, IEC/EN 61215-1-2, IEC/EN 61215-1-3, IEC/EN 61215-1-4 and IEC/EN 61215-2.

4.6 ELECTRICAL SAFETY

Testing for electrical safety shall be in accordance with IEC/EN 61730-2 or ANSI/UL 1703.

4.6.1 Condition of Acceptance for Electrical Safety

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

4.7 IDENTIFICATION TESTS - STANDARD PRACTICE FOR GENERAL TECHNIQUES FOR OBTAINING INFRARED SPECTRA FOR QUALITATIVE ANALYSIS, ASTM E1252

4.7.1 For polymer roof covers and adhesives and other components as applicable, FTIR spectra shall be determined and reported at the discretion of the certification agency[1].

4.7.2 Test/Verification: Standard Practice for General Techniques for Obtaining Infrared Spectra for Qualitative Analysis, ASTM E1252

NOTE 1: These tests are conducted for identification purposes. There are no limits on the values obtained.

4.8 IDENTIFICATION TEST – FM APPROVALS THERMAL DESORPTION GAS CHROMATOGRAPHY MASS SPECTROMETRY (TD/GC/MS)

4.8.1 For foam plastic and other applicable materials, TD/GC/MS Spectrograms shall be determined and reported at the discretion of the certification agency[1].

4.8.2 Test/Verification: Standard Practice for General Techniques of Gas Chromatography Infrared (GC/IR) Analysis, ASTM E1642

NOTE 1: These tests are conducted for identification purposes. There are no limits on the values obtained.

5 OPERATIONS REQUIREMENTS

5.1 DEMONSTRATED QUALITY CONTROL PROGRAM

5.1.1 A quality assurance program is required to assure that subsequent components produced by the manufacturer shall present the same quality and reliability as the specific components 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 shall 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 agency's 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, the 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 discretion of the certification agency.

5.4 MANUFACTURER'S RESPONSIBILITIES

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