Examination Standard for Ground-Mounted or Elevated Photovoltaic Module Systems

Class Number 4480

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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 rigid photovoltaic modules that are installed with a ground-mounted or elevated system.

1.1.2 Testing and certification criteria may include, but are not limited to, 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 rigid photovoltaic module systems that are secured to frames which are independently secured in place. This standard does not apply to the frame itself but does apply to the securement of the photovoltaic modules to the frame. The frame and its securement should be evaluated by a Registered Professional Engineer or Chartered Engineer competent in this area of practice.

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

1.2.3 This standard addresses fire, hail resistance and simulated wind uplift applied perpendicular and shear loading applied to the photovoltaic modules and its connections. It does not evaluate torsional loading on the photovoltaic modules and should be evaluated by a Registered Professional Engineer or Chartered Engineer competent in this area of practice.

1.2.4 This standard does not certify roof mounted or building integrated photovoltaic modules. They are evaluated per FM 4476, *Approval Standard for Flexible Photovoltaic Modules*, FM 4478, *Examination Standard for Rigid Photovoltaic Modules* or FM 4479, *Examination Standard for Building Integrated Steep Slope Photovoltaic Roof Covers*.

1.3 Basis for Requirements

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

1.3.2 The requirements of this standard reflect tests and practices used to examine characteristics of rigid photovoltaic modules for the purpose of obtaining certification.

1.4 Basis for Certification

Certification is based upon satisfactory evaluation of the product in the following major areas:

1.4.1 Examination and tests on production samples shall be performed to evaluate:

- the suitability of the product;
- the performance of the product as specified by the manufacturer and required for certification;
- the durability and reliability of the product.

1.4.2 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 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 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 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 National Standard Institute

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

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

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

America Society of Civil Engineers

- *Minimum Design Loads and Associated Criteria for Buildings and Other Structures.,* ASCE 7-22

American Society for Testing Materials

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

International Electrotechnical Commission

- *Terrestrial Photovoltaic (PV) modules – Design qualification and type approval,* International Standard 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

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

1.9 Terms and Definitions

For purposes of this standard, the following terms apply:

Crack – During wind uplift or hail 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.

Critical Crack – During electroluminescence evaluation following hail testing, a critical crack is a cracking of the cells that affects between 1% and 20% of an individual cell's area.

Crease - During wind uplift 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.

Elevated Photovoltaic System – The system of mounts, frames or racking use to secure photovoltaic modules above the ground or substrate such as a carport.

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

Frame or Racking System – used to fix solar modules on surfaces.

Photovoltaic Module – A device that converts solar energy into electricity.

Rigid Photovoltaic Module –An arrangement of photovoltaic cells or material, mounted on a rigid surface with the cells exposed freely to incoming sunlight.

Service Wind Load – The uplift load resulting from a windstorm that a photovoltaic assembly must resist.

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

Uncritical Crack – During electroluminescence evaluation following hail testing, an uncritical crack is a crack that affects less than 1% of an individual cell's area.

Very Critical Crack – During electroluminescence evaluation following hail testing, a very critical crack is a crack that affects greater than 20% of an individual cell's area.

2 GENERAL INFORMATION

2.1 Product Information

Ground-mounted or elevated photovoltaic module systems are submitted in panels or a panel array. They can be installed using either mechanical fasteners, clips, mounting brackets, or other means used to secure the photovoltaic assembly to the ground or frame.

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 modules being submitted for certification consideration.
- All ratings which are desired or expected for each assembly:
    - Maximum photovoltaic module slope vs. the ground
    - Wind Uplift Rating, Class 1-45,1-50, 1-55, etc.
    - Hail Damage Rating, specific kinetic energy
    - (Optional) Seismic Load Rating, Non-Seismic, or maximum allowable SDS (g) value
    - (Optional) Gravity Load Rating
- 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 or ANSI/UL 1703 and IEC/EN 61215 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.

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 based on the testing in performance requirements section 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.

2.3.4 It is the manufacturer's responsibility to provide any necessary test fixtures, 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 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, size, rating, capacity, etc., as appropriate.

When hazard warnings are needed, the markings should be universally recognizable.

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 durable.

3.3 Manufacturer's Installation and Operation Instructions

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

3.4 Calibration

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 manufacturer of the test specimens shall be at the sole discretion of the certification agency.

3.6 Seismic Loads (Optional)

The design shall be certified by a Registered Professional Engineer or Chartered Engineer competent in this area of practice. Calculations shall be submitted to verify compliance with design requirements for the range of rigid photovoltaic modules for which certification is sought.

The certification design procedure for seismic design of rigid photovoltaic modules is as follows:

3.6.1 General

The rigid photovoltaic modules and racking systems (if used) shall be rated (certified) for a base shear coefficient (acceleration) at the mounting level. The manufacturer shall demonstrate (through tests or analysis) that the rigid photovoltaic modules and racking systems (if used) shall remain intact and operational when subjected to the rated base shear coefficient. The anchorage of the rigid photovoltaic modules and racking systems (if used) to the supporting structure shall be designed for the base shear, overturning moment about the two principal axes and torque about the vertical axis. The supporting structure shall be designed for the loads transmitted from the rigid photovoltaic modules. The seismic loads calculated according to this standard are intended for use in Load and Resistance Factor Design (LRFD) or Strength Design, also known as Ultimate Limit State Design, and shall, therefore, be used in LRFD load combinations with a load factor of 1.0 applied to the seismic loads.

If the weight of the rigid photovoltaic module and racking systems (if used) exceeds 25% of the seismic weight of the supporting structure, the dynamic interaction between the rigid photovoltaic modules and the supporting structure shall be considered in calculating the base shear coefficient; the simple procedure presented in this standard cannot be used for such rigid photovoltaic modules and an alternative design method satisfactory to the certification agency must be used. The procedure presented in this standard cannot be used for unanchored systems. This procedure is also not applicable for these modules installed in soft or liquefiable soils.

3.6.2 Nomenclature

A_p – base shear coefficient (acceleration in g's)

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

C_{AR} – Component resonance ductility factor as per ASCE 7-22

R_μ – Structure ductility reduction factor as per ASCE 7-22

R_{po} – component response modification factor. Equal to 1.5 for rigid photovoltaic modules.

H_f – Factor for force amplification with height = 1.0 for components at grade

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

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

F_p – design base shear (Seismic design force)

W_p – weight (dead load) of the rigid photovoltaic module, in lbs

M_p – design overturning moment

I_p – component importance factor = 1.0 or 1.5 as per ASCE 7-22

3.6.3 Seismic design force

The seismic base shear coefficient shall be calculated as follows as per ASCE 7-22:

$$F_p = A_p W_p = 0.4 S_{DS} I_p W_p \left[\frac{H_f}{R_\mu}\right]\left[\frac{C_{AR}}{R_{po}}\right] \quad (1)$$

where $0.3S_{DS}I_pW_p \leq F_p \leq 1.6S_{DS}I_pW_p$.

$$H_f = 1 + a_1\left(\frac{z}{h}\right) + a_2\left(\frac{z}{h}\right)^{10} \quad (2)$$

where $a_1 = \frac{1}{T_a} \leq 2.5$, and $a_2 = 1 - \left(\frac{0.4}{T_a}\right)^2 > 0$,
and T_a is the approximate fundamental period of the building. ASCE 7-22 Section 12.8.2.1 explains how to calculate T_a. If the building period is unknown, H_f can be simplified to Equation (3).

$$H_f = 1 + 2.5\left(\frac{z}{h}\right) \quad (3)$$

The Structure Ductility Reduction Factor, R_μ, is calculated by:

$$R_\mu = \left(\frac{1.1R}{I_e \Omega_0}\right)^{1/2} \geq 1.3 \quad (4)$$

where I_e is the Importance Factor as prescribed in Section 11.5.1 for the building or nonbuilding structure supporting the component, R is the response modification coefficient and Ω_0 the overstrength factor of the building seismic force-resisting systems from ASCE 7-22 Table 12.2-1.

3.6.4 Short-Period Design Spectral Response Acceleration (S_{DS})

The short-period design spectral response acceleration S_{DS} for which the rigid photovoltaic modules and racking systems (if used) will be rated should equal or exceed the largest value for locations at which they are expected to be installed.

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

For locations outside the USA, S_{MS} shall be estimated as the 475-year return period value of 0.2 second period 5% damped "firm" rock spectral acceleration adjusted for local soil conditions multiplied by a factor of 1.8, or the 2475 year return period value of 0.2 second period, 5% damped "firm" rock spectral acceleration adjusted for local soil conditions. The 0.2 second period, 5% damped "firm" rock spectral acceleration at 475- or 2475-year return periods can be estimated as the corresponding peak ground acceleration multiplied by a factor of 2.5. S_{DS} shall be taken as two-thirds of this estimated S_{MS}. If the 475-year or 2475-year accelerations are not available, S_{DS} can be estimated from other sources acceptable to the certification agency.

3.6.5 Design Loads for Supporting Structure

The design overturning moment is calculated as follows:

$$M_p = F_p \cdot \bar{h} \tag{5}$$

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

3.6.6 Design Loads for Base Anchors

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

3.6.7 LRFD Load Combinations

Examine load combinations below to determine the design loads:

3.6.7.1 Operational condition dead load.

(1.2 × Dead Load) + [1.0 × Seismic Load (F_p)] + (0.15 × Snow Load)

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

3.6.7.2 Operational condition minimum dead load

(0.9 × Dead Load) + [1.0 × Seismic Load (F_p)]

4 PERFORMANCE REQUIREMENTS

This standard is intended to evaluate a ground-mounted or elevated rigid photovoltaic module system for its performance as it relates to fire, simulated wind uplift, susceptibility from hailstorm damage, seismic performance requirements (optional), and gravity loads (optional).

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

The use of screening tests is permitted to be used to determine critical components to be used for full scale testing or to evaluate components as alternate to those already tested and found to be satisfactory via the full-scale tests described in sections 4.1 through 4.8 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.

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 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.

4.1 Combustibility of Ground-Mounted or Elevated Rigid Photovoltaic Module System

Testing for combustibility of the ground-mounted or elevated rigid photovoltaic module shall be in accordance with a modified version of the ASTM E108 Class A Spread of Flame Test without a roof deck.

The modifications are as follows:

If the photovoltaic module is more than 10 inches (25.4 cm) above the ground or substrate, then no simulated ground or substrate will be included in the testing. The length of the test sample for the spread of flame test shall be 8 ft (2.4 m) minimum to a maximum of 16 ft (4.9 m). The sample shall be long enough to accommodate 2 modules if the combined length of 2 modules is greater than 13 ft. (4.0 m) or long enough to accommodate 3 modules if the combined length of 2 modules is less than 13 ft. (4.0 m). If the combined length of 2 modules is less than 13 ft. (4.0 m) and the combined length of 3 modules is longer than 16 ft. (4.9 m) then the test shall be run with 2 modules. The test sample shall be minimum 3 ft – 4 in. (1 m) wide up to a maximum of 6 ft -8 in. (2 m) wide.

4.1.1 Conditions of Acceptance for Combustibility of Ground-Mounted or Elevated Rigid Photovoltaic Module System

There shall be no fire damage to the PV module system within 6 in (152 mm) of the end of the last PV module.

4.2 Wind Uplift Resistance for Rigid Photovoltaic Module

For wind uplift resistance, the rigid photovoltaic module system will be evaluated using a simulated wind uplift pressure test with the photovoltaic module attached to a test frame using a pleated air bag with the load applied to the photovoltaic module.

4.2.1 Rigid Photovoltaic Simulated Wind Uplift Pressure Test

Testing for simulated wind uplift resistance shall be in accordance with the *12 × 24 Simulated Wind Uplift Pressure Test Procedure* per *ANSI/FM Approvals 4474*. The reduced wind pressure loading shall be applied to the PV system using a pleated airbag. The minimum rating in psf required for certification is 45 psf (1.4 kPa). The maximum rating in psf available is 990 psf (47.3 kPa). Ratings between 45 psf (2.2 kPa) and 990 psf (47.3 kPa) are available in 5 psf (0.24 kPa) increments. The rating assigned to the PV module system shall be the maximum simulated uplift resistance pressure which the assembly maintained for one (1) minute without ultimate failure as defined in 4.2.1.1. Adjustments to the pressure applied over the test area are made to account for the tributary area of only the PV modules and mounting system.

In addition, the assembly must maintain 63% of the ultimate failure pressure for one (1) minute without any permanent deformation of any component of the photovoltaic panel or the attachment method.

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

4.2.1.1.1 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: 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 4.2.1.

4.2.1.1.2 All photovoltaic modules shall: a) not puncture, fracture, crack or develop any through openings; b) not delaminate or separate from the frame.

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

4.3 Hail Damage Resistance Test

4.3.1 Testing for hail damage resistance shall be in accordance with *ANSI/FM 4473 but with targeting a specific kinetic energy, tested using a comparable ice ball diameter.* The minimum rating required for certification is a kinetic energy of 6 ft-lbs (+10% allowable). Kinetic energies not noted in the tables in ANSI/FM 4473 may be used for testing. The number of hail impact shall be 15% of the number cells in the photovoltaic modules (for example if the photovoltaic module is 72 cells then this sample be impacted with a minimum of 11 hail impacts). Impact locations shall include near the corner (within 2 in (50 mm)), near the perimeter (within 2 in (50 mm)), within the photovoltaic cell and along critical connections. Testing will be conducted on three (3) photovoltaic modules and all modules must meet the same requirements tested at the same kinetic energies.

Prior to performing hail damage resistance testing, electroluminescence (EL) testing and a baseline power output measurement using light IV-testing at 1-Sun condition shall be performed on the photovoltaic module. The average of 3 power output measurements shall be recorded and used for the baseline. The EL profile shall be documented with a photograph or image capture.

4.3.1.1 Condition of Acceptance for Hail Damage Resistance

4.3.1.1.1 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.

4.3.1.1.2 After completion of the impact testing, the photovoltaic module shall again be examined with EL testing. The EL profiles before and after impact shall be compared and evaluated as follows:

- No more than 20% of the cells of the photovoltaic module may show uncritical cracking.
- No more than 10% of the cells of the photovoltaic module may show critical cracking.
- No cells of the photovoltaic module shall be permitted to show very critical cracking.

4.3.1.1.3 After completion of the impact testing, the photovoltaic module shall again be examined with light-IV testing for power output at 1-Sun condition. The average of three measurement shall be taken and the average power output after impact shall be at least 95% of the power output before impact.

4.4 Electrical Performance

Testing for electrical performance shall be in accordance with *Terrestrial Photovoltaic (PV) modules – Design qualification and type approval,* International Standard 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, International Electrotechnical Commission.

4.4.1 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.

4.5 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 or *Flat Plate Photovoltaic Modules and Panels*, American National Standard, or ANSI/UL 1703.

4.5.1 Condition of Acceptance for Electrical Safety

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

4.6 Gravity Load Resistance Test (Optional)

For gravity load resistance, the rigid photovoltaic module will be evaluated using a simulated gravity load pressure test with the photovoltaic module attached to a test frame using a pleated air bag with the load applied to the photovoltaic module.

4.6.1 Rigid Photovoltaic Simulated Gravity Load Pressure Test

Testing for simulated gravity load resistance shall be in accordance with the *5 × 9 Simulated Wind Uplift Pressure Test Procedure* outlined in *ANSI/FM Approvals* 4474 with the following modifications. The pressure load shall be applied to a PV module mounted upside down using a pleated airbag. Air is introduced by opening the air supply valve on the blower until the pressure level reaches one half of the pressure load requested by the test sponsor. For example, if the test sponsor wants a rating of 32 psf (1.5 kPa) then introduce air to a pressure level of 16 psf (0.75 kPa) with a tolerance of +2 psf, -0 psf (+0.1 kPa, -0 kPa). Upon reaching ½ of the requested rating

pressure, the pressure level shall be maintained while the perimeter clamps are checked and that there are minimal air leaks from the pressure vessel. Adjustments shall be permitted 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.

After 60 minutes, the pressure level shall be increased to the full pressure rating requested with a tolerance of +2 psf, -0 psf (+0.1 kPa, -0 kPa). Upon reaching the next pressure level, the pressure shall be maintained for a period of 60 minutes. The supply air and clamps shall be permitted to 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.

The rating assigned to the assembly shall be the maximum simulated gravity load which the assembly maintained for one (1) hour without ultimate failure.

4.6.1.1 Conditions of Acceptance for Rigid Photovoltaic Simulated Gravity Load Pressure Test

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

4.6.1.1.2 All components shall: a) not fracture, break or pull/push 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.

4.6.1.1.3 All photovoltaic modules shall: a) not puncture, fracture, crack or develop any through openings; b) not delaminate or separate from the frame.

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

5 OPERATIONS REQUIREMENTS

5.1 Demonstrated Quality Control Program

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

- Design quality is determined during the examination and tests and may be 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 Manufacturer's Responsibilities

5.3.1 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*.