

UL 1703

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Flat-Plate Photovoltaic Modules and Panels

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Underwriters Laboratories Inc. (UL)
 333 Pfingsten Road
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UL Standard for Safety for Flat-Plate Photovoltaic Modules and Panels, UL 1703

Third Edition, Dated March 15, 2002

Revisions: This Standard contains revisions through and including June 30, 2004.

SUMMARY OF TOPICS

The following revision is being issued to incorporate requirements in accordance with Subject 1703 bulletin dated October 15, 2003.

Correction of test references in Table 18.1

UL Standards for Safety are developed and maintained in the Standard Generalized Markup Language (SGML). SGML -- an international standard (ISO 8879-1986) -- is a descriptive markup language that describes a document's structure and purpose, rather than its physical appearance on a page. Due to formatting differences resulting from the use of UL's new electronic publishing system, please note that additional pages (on which no requirements have been changed) may be included in revision pages due to relocation of existing text and reformatting of the Standard.

Text that has been changed in any manner is marked with a vertical line in the margin. Changes in requirements are marked with a vertical line in the margin and are followed by an effective date note indicating the date of publication or the date on which the changed requirement becomes effective.

The new and revised requirements are substantially in accordance with UL's Bulletin(s) on this subject dated October 15, 2003 and June 18, 2004.

As indicated on the title page (page 1), this UL Standard for Safety is an American National Standard. Attention is directed to the note on the title page of this Standard outlining the procedures to be followed to retain the approved text of this ANSI/UL Standard.

The UL Foreword is no longer located within the UL Standard. For information concerning the use and application of the requirements contained in this Standard, the current version of the UL Foreword is located on ULStandardsInfoNet at: <http://ulstandardsinfo.net/ulforeword.html>

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The requirements in this Standard are now in effect, except for those paragraphs, sections, tables, figures, and/or other elements of the Standard having future effective dates as indicated in the note following the affected item. The prior text for requirements that have been revised and that have a future effective date are located after the Standard, and are preceded by a "SUPERSEDED REQUIREMENTS" notice.

New product submittals made prior to a specified future effective date will be judged under all of the requirements in this Standard including those requirements with a specified future effective date, unless the applicant specifically requests that the product be judged under the current requirements. However, if

the applicant elects this option, it should be noted that compliance with all the requirements in this Standard will be required as a condition of continued Listing and Follow-Up Services after the effective date, and understanding of this should be signified in writing.

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This Standard consists of pages dated as shown in the following checklist:

Page	Date
1-3	June 30, 2004
4-5	March 15, 2002
6	June 30, 2004
7	October 1, 2003
8-11	March 15, 2002
12	October 1, 2003
13-14	March 15, 2002
15-16	October 1, 2003
17-19	March 15, 2002
20-23	October 1, 2003
24-26	June 30, 2004
27-28	October 1, 2003
29-35	March 15, 2002
36-38B	October 1, 2003
39-41	March 15, 2002
42-44	October 1, 2003
45-46	March 15, 2002
47	October 1, 2003
48-68	March 15, 2002
SA1-SA2	March 15, 2002
A1-A2	March 15, 2002
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1

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March 15, 2002

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This ANSI/UL Standard for Safety, which consists of the Third Edition with revisions through June 30, 2004, is under continuous maintenance, whereby each revision is ANSI approved upon publication. Comments or proposals for revisions on any part of the Standard may be submitted to UL at any time. Written comments are to be sent to the UL-Northbrook Standards Department, 333 Pfingsten Road, Northbrook, IL 60062.

Revisions of this Standard will be made by issuing revised or additional pages bearing their date of issue. A UL Standard is current only if it incorporates the most recently adopted revisions, all of which are itemized on the transmittal notice that accompanies the latest set of revised requirements.

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CONTENTS

INTRODUCTION

1 Scope 7
 2 Glossary 8
 3 Units of Measurement 9
 4 Components 9
 5 References 10

CONSTRUCTION

6 General 10
 7 Polymeric Materials 11
 8 Current-Carrying Parts and Internal Wiring 13
 9 Wireways 14
 10 Connection Means 14
 11 Bonding and Grounding 15
 12 Spacings 16
 13 Wiring Compartments 17
 13.1 General 17
 13.2 Metallic wiring compartments 18
 13.3 Nonmetallic wiring compartments 19
 14 Corrosion Resistance 20
 15 Accessibility of Uninsulated Live Parts 21
 16 Fire Resistance 23
 17 Superstrate 23

PERFORMANCE

18 General 23
 19 Temperature Test 26
 20 Voltage, Current and Power Measurements Test 31
 21 Leakage Current Test 31
 22 Strain Relief Test 32
 23 Push Test 32
 24 Cut Test 33
 25 Bonding Path Resistance Test 35
 26 Dielectric Voltage-Withstand Test 35
 27 Wet Insulation-Resistance Test 36
 28 Reverse Current Overload Test 37
 29 Terminal Torque Test 37
 30 Impact Test 38
 31 Fire Tests 38
 31.1 Spread-of-flame test 38
 31.2 Burning-brand test 38A
 32 General 39
 33 Water Spray Test 39
 34 Accelerated Aging Test 42
 35 Temperature Cycling Test 43

36 Humidity Test	45
37 Corrosive Atmosphere Test	47
37.1 Salt spray test	47
37.2 Moist carbon dioxide/sulphur dioxide	48
38 Metallic Coating Thickness Test	49
39 Hot-Spot Endurance Test	51
39.1 General	51
39.2 Cell selection and instrumentation	51
39.3 Intrusive method	52
39.4 Nonintrusive method	53
39.5 Theory and method of cell selection	54
39.6 Selection of hot-spot test level	55
39.7 Type A cells (high shunt resistance)	56
39.8 Type B cells (low shunt resistance)	56
39.9 Test execution	56
40 Arcing Test	58
40.1 General	58
40.2 Method A	60
40.3 Method B	60
40.4 Methods A and B	60
40.5 Method C	60
40.6 All methods	61
41 Mechanical Loading Test	61
42 Wiring Compartment Securement Test	63

PRODUCTION LINE TESTS

43 Factory Dielectric Voltage-Withstand Test	63
44 Factory Voltage, Current, and Power Measurements Test	64
45 Grounding Continuity Test	64

RATING

46 Details	64
------------------	----

MARKING

47 Details	65
48 Installation and Assembly Instructions	67

SUPPLEMENT SA - SAMPLE PRODUCTION LINE TESTS

SA1 Scope	SA1
SA2 Sample Size	SA1
SA3 Factory Voltage, Current, and Power Measurements Test	SA1

APPENDIX A

Standards for Components	A1
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CANADIAN REQUIREMENTS COMPARISON GUIDE, CRG 1703

UL AND CANADIAN STANDARDS FOR FLAT-PLATE PHOTOVOLTAIC MODULES AND
PANELSCRG1

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INTRODUCTION

1 Scope

1.1 These requirements cover flat-plate photovoltaic modules and panels intended for installation on or integral with buildings, or to be freestanding (that is, not attached to buildings), in accordance with the National Electrical Code, NFPA 70, and Model Building Codes.

1.2 These requirements cover modules and panels intended for use in systems with a maximum system voltage of 1000 V or less.

1.3 These requirements also cover components intended to provide electrical connection to and mounting facilities for flat-plate photovoltaic modules and panels.

1.4 These requirements do not cover:

- a) Equipment intended to accept the electrical output from the array, such as power conditioning units (inverters) and batteries;
- b) Any tracking mechanism;
- c) Cell assemblies intended to operate under concentrated sunlight;
- d) Optical concentrators; or
- e) Combination photovoltaic-thermal modules or panels.

1.5 Deleted October 1, 2003

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2 Glossary

2.1 For the purpose of this standard, the following definitions apply.

2.2 AIR MASS (AM) – A dimensionless quantity, the ratio of:

- a) The actual path length of radiation through the atmosphere to
- b) The vertical path length of radiation through the atmosphere to sea level. At sea level, for all but very high zenith angles (θ_z) (the angle subtended by the zenith and the line of sight to the sun),

$$AM = \sec \theta_z$$

2.3 ARRAY – A mechanically-integrated assembly of modules or panels with a support structure and foundation, tracking, thermal control, and other components, if used, to form a dc power-producing unit.

2.4 BLOCKING DIODE – A diode used to block reverse current into a photovoltaic-source circuit.

2.5 BYPASS DIODE – A diode connected across one or more cells, modules, or panels in the forward current direction to allow current to bypass such cells, modules, or panels.

2.6 CELL – The basic photovoltaic device that generates electricity when exposed to sunlight.

2.7 ELECTRIC SHOCK – A risk of electric shock is considered to exist at a part if the potential between the part and earth ground or any other accessible part is more than 30 Vdc and the leakage current exceeds the values specified in Table 21.1.

2.8 ENCAPSULANT – Transparent insulating material enclosing the cells and cell interconnects.

2.9 INTERCONNECT – A conductor within a module that provides a mechanism for conducting electricity between cells.

2.10 MAXIMUM POWER (P_{max}) – The point on the current-versus-voltage curve of a module, at STC, where the product of current and voltage is maximum.

2.11 MAXIMUM SYSTEM VOLTAGE – The sum of the maximum open-circuit voltages of the maximum number of modules or panels to be connected in series in a system.

2.12 METALLIZATION – An electrically conductive metal coating on the surface of a cell.

2.13 MODULE (FLAT-PLATE) – The smallest environmentally protected, essentially planar assembly of solar cells and ancillary parts, such as interconnects and terminals, intended to generate dc power under unconcentrated sunlight. The structural (load-carrying) member of a module can either be the top layer (superstrate), or the back layer (substrate), in which:

- a) The superstrate is the transparent material forming the top (light-facing) outer surface of the module. If load-carrying, this constitutes a structural superstrate.
- b) The substrate is the material forming the back outer surface of a module. If load-carrying, this constitutes a structural substrate.

2.14 NOMINAL OPERATING CELL TEMPERATURE (NOCT) – The equilibrium cell junction temperature corresponding to nominal module service operating conditions in a reference environment of 80 mW/cm² irradiance, 20°C (68°F) ambient air temperature, 1 m/s wind across the module from side to side, an electrically open circuit, and a mounting method in accordance with 19.6 and 19.7.

2.15 PANEL (FLAT-PLATE) – A collection of modules mechanically fastened together, wired, and designed to provide a field-installable unit.

2.16 RATED OPERATING VOLTAGE – The voltage, ±10 percent, at which maximum power is available from the module or panel under STC.

2.16.1 REVERSE CURRENT – Current flowing in a reverse direction to the normal direction resulting from a normally illuminated PV module.

2.17 STANDARD TEST CONDITIONS (STC) – Test conditions consisting of:

- a) 100 mW/cm² irradiance,
- b) AM 1.5 spectrum, and
- c) 25°C cell temperature.

2.18 UNCONDITIONED MODULES OR SPECIMENS – Modules or specimens that have not been previously subjected to tests or environmental exposures.

3 Units of Measurement

3.1 Values stated without parentheses are the requirement. Values in parentheses are explanatory or approximate information.

4 Components

4.1 Except as indicated in 4.2, a component of a product covered by this standard shall comply with the requirements for that component. See Appendix A for a list of standards covering components generally used in the products covered by this standard.

4.2 A component need not comply with a specific requirement that:

- a) Involves a feature or characteristic not needed in the application of the component covered by this standard, or
- b) Is superseded by a requirement in this standard.

4.3 A component shall be used in accordance with its rating established for the intended conditions of use.

4.4 Specific components are incomplete in construction features or restricted in performance capabilities. Such components are intended for use only under limited conditions, such as certain temperatures not exceeding specified limits, and shall be used only under those specific conditions.

5 References

5.1 Any undated reference to a code or standard appearing in the requirements of this standard shall be interpreted as referring to the latest edition of that code or standard.

CONSTRUCTION

6 General

6.1 A module shall be completely assembled when shipped from the factory. A panel may be completely assembled when shipped from the factory, or may be provided in subassemblies, provided assembly of the panel does not involve any action that is likely to affect compliance with the requirements of this standard.

Exception: An assembly part need not be affixed to the module at the factory.

6.2 A module or panel assembly bolt, screw, or other part shall not be intended for securing the complete device to the supporting surface or frame.

6.3 Incorporation of a module or panel into the final assembly shall not require any alteration of the module or panel unless specific details describing necessary modification(s) for alternate installation(s) are provided in the installation instructions. If a module or panel must bear a definite relationship to another for the intended installation and operation of the array (for example, to allow connectors to mate), it shall be constructed to permit it to be incorporated into the array in the correct relationship without the need for alteration.

6.4 The construction of a product shall be such that during installation it will not be necessary to alter or remove any cover, baffle, insulation, or shield that is required to reduce the likelihood of:

- a) Excessive temperatures, or
- b) Unintentional contact with a part that may involve a risk of electric shock.

Exception: A cover of a wiring compartment providing access to a connection means that may involve a risk of electric shock may be removable to allow for the making of electrical connections.

6.5 Parts shall be prevented from loosening or turning if such loosening or turning may result in a risk of fire, electric shock, or injury to persons.

6.6 Friction between surfaces is not acceptable as the sole means to inhibit the turning or loosening of a part, but a lock washer properly applied is acceptable for this purpose.

6.7 An adjustable or movable structural part shall be provided with a locking device to reduce the likelihood of unintentional shifting, if any such shifting may result in a risk of fire, electric shock, or injury to persons.

6.8 Metals used in locations that may be wet or moist shall not be employed in combinations that could result in deterioration of either metal such that the product would not comply with the requirements in this standard.

6.9 Edges, projections, and corners of photovoltaic modules and panels shall be such as to reduce the risk of injury to persons.

6.10 Whenever a referee measurement is necessary to determine that a part as mentioned in 6.9 is not sufficiently sharp to constitute a risk of injury to persons, the method described in the requirements in the Standard for Determination of Sharpness of Edges on Equipment, UL 1439, is to be employed.

7 Polymeric Materials

7.1 A polymeric material system serving as the enclosure of a part involving a risk of fire or electric shock shall comply with the applicable requirements in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C, concerning:

- a) Flammability,
- b) Ultraviolet light exposure,
- c) Water exposure and immersion, and
- d) Hot-wire ignition (HWI).

Exception: The flammability tests prescribed in UL 746C do not apply to the superstrate, encapsulation, and substrate. These materials shall comply with 7.4.

7.2 A polymeric material system serving as the support or insulation of a part involving a risk of fire or electric shock shall:

- a) Have a flammability classification of HB, V-2, V-1, or V-0 determined in accordance with the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94;
- b) Have a minimum High-Current Arc Ignition performance level category (PLC) in accordance with the following:

Flammability classification

HB
 V-2
 V-1
 V-0

High-current arc ignition, PLC

1
 2
 2
 3

- c) Have a Comparative Tracking Index performance level category (PLC) of 2 or better, when the system voltage rating is 600 V or less, as determined in accordance with the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A;
- d) Have an Inclined Plane Tracking (ASTM D2303) rating of 1 h using the time to track method at 2.5 kilovolts when the system voltage rating is in the range 601 – 1000 V; and
- e) Comply with the requirements for exposure to ultraviolet light as determined in accordance with the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C, when exposed to light during normal operation of the product. Polymeric materials that are exposed to sunlight and are protected by glass, or other transparent medium, shall be tested with an equivalent layer of that medium attenuating the ultraviolet light exposure during the test.

Exception: Encapsulant materials between the substrate and the superstrate are not required to comply with this requirement.

7.3 A polymeric substrate or superstrate shall have a thermal index, both electrical and mechanical, as determined in accordance with the Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B, not less than 90°C (194°F). In addition, the thermal index shall not be less than 20°C (36°F) above the measured operating temperature of the material. All other polymeric materials shall have a thermal index (electrical and mechanical) 20°C above the measured operating temperature. The measured operating temperature is the temperature measured during the open-circuit mode for Temperature Test, Section 19, or the temperature during the short-circuit mode, whichever is greater.

7.4 A polymeric material that serves as the outer enclosure for a module or panel that:

- a) is intended to be installed in a multi-module or multi-panel system; or
- b) has an exposed surface area greater than 10 ft²(0.93 m²) or a single dimension larger than 6 ft (1.83 m)

shall have a flame spread index of 100 or less as determined under the Standard Method of Test for Surface Flammability of Materials Using a Radiant Heat Energy Source, ASTM E162-2001.

Exception No. 1: A material that serves as the outer enclosure for a small cover or box used for electrical connections is not required to have an index of 100 or less.

Exception No. 2: A material that serves as the outer enclosure for a module or panel complying with 16.1 meets the intent of this requirement.

7.4 revised October 1, 2003

7.5 A barrier or liner of polymeric insulating material providing the sole insulation between a live part and an accessible metal part or between uninsulated live parts not of the same potential shall be of adequate thickness and of a material appropriate for the application. The barrier or liner shall be held in place and shall not be adversely affected to the extent that its necessary properties may fall below the minimum acceptable values for the application.

8 Current-Carrying Parts and Internal Wiring

8.1 A current-carrying part and wiring shall have the mechanical strength and ampacity necessary for the service.

8.2 A current-carrying part shall be of silver, a copper-base alloy, stainless steel, aluminum, or other material appropriate for the application.

8.3 Wiring used in a module or panel shall be insulated and acceptable for the purpose, when considered with respect to temperature, voltage, and the conditions of service to which the wiring is likely to be subjected within the equipment.

8.4 A splice shall be provided with insulation equivalent to that required for the wires involved.

8.5 A joint or connection shall be mechanically secure and shall provide electrical contact without strain on connections and terminals. Soldered connections between interconnects and metallizations are considered mechanically secure when held by encapsulation systems.

8.6 An uninsulated live part, including a terminal, shall be secured to its supporting surface by a method other than friction between surfaces so that it will be prevented from turning or shifting in position if such motion may result in reduction of spacings to less than required in Tables 12.1 and 12.2.

8.7 Strain relief shall be provided so that stress on a lead intended for field connection, or otherwise likely to be handled in the field, including a flexible cord, is not transmitted to the connection inside the module or panel.

8.8 The wiring of a module or panel shall be located so that after installation of the product in the intended manner it will not be exposed to the degrading effects of direct sunlight.

Exception: Wiring rated sunlight resistant need not be so located.

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9 Wireways

9.1 An enclosure for wire shall be smooth and free from sharp edges, burrs, or the like that may damage insulation or conductors.

10 Connection Means

10.1 In 10.2 – 10.10, connection means are considered to be those to which field-installed wiring is connected when the product is installed. Connection means may be within a wiring compartment, may be connectors outside of a wiring compartment, or may be another means acceptable for the application.

10.2 A module or panel shall be capable of accommodating at least one of the acceptable wiring systems described in the National Electrical Code, NFPA 70.

10.3 A module or panel shall be provided with wiring terminals, connectors, or leads to accommodate current-carrying conductors of the load circuit.

10.4 The connection means for a module or panel shall be so located that after installation of the product in the intended manner they will not be exposed to the degrading effects of direct sunlight.

Exception: Connection means rated for use in direct sunlight need not be so located.

10.5 A lead that is intended to be spliced in the field to a circuit conductor shall not be smaller than No. 18 AWG (0.82 mm²) and the insulation shall not be less than 1/32 in (0.8 mm) thick.

10.6 The free length of a lead for field connection shall be at least 6 in (152 mm).

10.7 A wire-binding screw or stud- and nut-type terminal used to terminate conductors not larger than No. 10 AWG (5.3 mm²) shall comply with the following:

a) A threaded screw or stud shall be of nonferrous metal, stainless steel, or plated steel appropriate for the application, shall not have more than 32 threads/in, and shall not be smaller than No. 8 when used to terminate No. 10 or 12 AWG (5.3 or 3.3 mm²) wire; and not smaller than No. 6 when used to terminate No. 14 AWG (2.1 mm²) and smaller wire. A wire-binding screw or stud- and nut-type terminal shall be provided with upturned lugs, a cupped washer, a barrier, or other equivalent means to retain the wire in position. The head of a wire-binding screw used to terminate No. 12 AWG or smaller wire shall have a minimum diameter of 0.275 in (7.0 mm) and the head of a screw used to terminate No. 10 AWG wire shall have a minimum diameter of 0.327 in (8.3 mm).

b) A tapped terminal plate shall:

1) Be of nonferrous metal,

2) Not have less than two full screw threads, and

3) Be of metal not less than 0.050 in (1.27 mm) thick when used to terminate No. 10 or 12 AWG wire and not less than 0.030 in (0.76 mm) thick when used to terminate a No. 14 AWG or smaller wire. Unextruded metal for screw threads obtained by extruding a hole shall have a thickness not less than the pitch of the screw thread.

10.8 A connector intended for use on the output wiring of a module or panel only shall comply with:

- a) the Standard for Component Connectors for Use in Data, Signal, Control and Power Applications, UL 1977,
- b) Temperature Cycling Test, Section 35, excluding the Wiring Compartment Securement Test and the following Wet Insulation-Resistance Test, and
- c) Humidity Test, Section 36, excluding the Wiring Compartment Securement Test and the following Wet Insulation-Resistance Test.

10.8 revised October 1, 2003

10.9 A separable multipole connector shall be polarized. If two or more separable connectors are provided, they shall be configured or arranged so that the mating connector for one will not be accepted by the other, and vice-versa, if such is an improper connection.

10.10 For a connector incorporating a grounding member, the grounding member shall be the first to make and the last to break contact with the mating connector.

11 Bonding and Grounding

11.1 A module or panel shall have a means for grounding all accessible conductive parts. The grounding means shall comply with the applicable requirements in Connection Means, Section 10. The grounding means shall be bonded to each conductive part of the module or panel that is accessible during normal use. The grounding means shall be described in detail in the installation manual. See Installation and Assembly Instructions, Section 48.

Exception: When the grounding means is a module or panel mounting member intended to contact an array structural member, the module or panel grounding means are not required to comply with the requirements for Connection Means, Section 10.

11.2 Routine maintenance of a module or panel shall not involve breaking or disturbing the bonding path. A bolt, screw, or other part used for bonding purposes within a module or panel shall not be intended for securing the complete device to the supporting surface or frame.

11.3 Bonding shall be by a positive means, such as clamping, riveting, bolted or screwed connections, or welding, soldering (see 11.5) or brazing. The bonding connection shall penetrate nonconductive coatings, such as paint or vitreous enamel.

11.4 A bolted or screwed connection that incorporates a star washer under the screwhead or a serrated screwhead may be acceptable for penetrating nonconductive coatings. If the bonding means depends upon screw threads, two or more screws or two full threads of a single screw shall engage the metal.

11.5 All joints in the bonding path shall be mechanically secure independent of any soldering.

11.6 A separate bonding conductor or strap shall:

- a) Be of copper, copper alloy, or other material acceptable for use as an electrical conductor;
- b) Be protected from mechanical damage; and

c) Not be secured by a removable fastener used for any purpose other than bonding, unless the bonding conductor is unlikely to be omitted after removal and replacement of the fastener.

11.7 A ferrous metal part in the grounding path shall be protected against corrosion by metallic or nonmetallic coatings, such as painting, galvanizing, or plating. Stainless steel is acceptable without additional coating.

11.8 A metal-to-metal multiple-bearing pin-type hinge is considered to be an acceptable means for bonding.

11.9 A terminal of a module or panel (for example, a wire-binding screw, a pressure wire connector, or a nut-on-stud) intended to accommodate an equipment grounding conductor shall be identified by being marked "G," "GR," "GROUND," "GROUNDING," or the like, or shall have a green-colored part. No other terminal shall be so identified.

11.10 If a marking is used to identify an equipment grounding terminal, it shall be located on or adjacent to the terminal, or on a wiring diagram affixed to the module or panel near the terminal.

11.11 If a green-colored part is used to identify the equipment-grounding terminal, it shall be readily visible during and after installation of the equipment-grounding conductor and the portion of the terminal that is green shall not be readily removable from the remainder of the terminal.

11.12 The surface of a lead of a module or panel intended for the connection of an equipment-grounding conductor shall be identified by insulation colored green, or green with yellow stripe(s). No other lead shall be so identified.

12 Spacings

12.1 The spacings between uninsulated live parts not of the same potential and between a live part and an accessible metal part, shall not be less than the values specified in Tables 12.1 and 12.2.

Exception: These spacing requirements do not apply to the inherent spacings of a component; such spacings shall comply with the requirements for the component in question.

Table 12.1
Minimum acceptable spacings at wiring terminals

Potential involved, V	Through air and over surface	
	in	(mm)
0 – 50	1/4	(6.4)
51 – 300	3/8	(9.5)
301 – 600	1/2	(12.7)
601 – 1000	5/8	(15.9)

Table 12.2
Minimum acceptable spacings elsewhere than at wiring terminals

Potential involved, V	Through air		Over surface	
	in	(mm)	in	(mm)
0 – 50	1/16	(1.6)	1/16	(1.6)
51 – 300	1/8	(3.2)	1/4	(6.4)
301 – 600	1/4	(6.4)	3/8	(9.5)
601 – 1000	3/8	(9.5)	1/2	(12.7)

12.2 The spacings at a field-wiring terminal are to be measured with and without wire connected to the terminal. The wire is to be connected as it would be in actual use. If the terminal will properly accommodate it, and if the product is not marked to restrict its use, the wire is to be one size larger than that required; otherwise, the wire is to be the size required.

12.3 Surfaces separated by a gap of 0.013 in (0.33 mm) or less are considered to be in contact with each other for the purpose of judging over surface spacings.

12.4 In Tables 12.1 and 12.2, the potential involved is the maximum voltage that may exist between parts during any anticipated use of the module or panel.

12.5 A barrier or liner of electrical grade fiber providing the sole insulation between a live part and an accessible metal part or between uninsulated live parts not of the same potential shall not be less than 0.028 in (0.71 mm) thick. The barrier or liner shall be held in place and shall not be adversely affected to the extent that its necessary properties may fall below the minimum values required for the application.

13 Wiring Compartments

13.1 General

13.1.1 A wiring compartment shall comply with the requirements specified in 13.1.2 – 13.3.4.

13.1.2 The internal volume of the wiring compartment shall be in accordance with Table 13.1. The volume shall be calculated for each conductor intended to be installed, including integral conductors of the module or panel. In the space being evaluated for the minimum required volume, no enclosure dimension shall be less than 3/4 in (19.1 mm). The internal volume shall be determined using water as prescribed for the Volume Verification Test in the Standard for Metallic Outlet Boxes, UL 514A.

Table 13.1
Volume required per conductor

Size of conductor, AWG	Free space within box for each conductor, in ³
18	1.50
16	1.75
14	2.00
12	2.25
10	2.50
8	3.00
6	5.00

For SI units: 1 cubic in = 16.4 cm³

13.1.3 A wiring compartment shall have provision for accommodating a wiring system employing a raceway or cable.

13.1.4 A wiring compartment shall have no more than one opening when the module or panel is shipped from the factory. Tapped holes with screwed-in plugs and knockouts are not considered openings.

13.1.5 Gaskets and seals shall not deteriorate beyond limits during accelerated aging, and shall not be used where they may be subject to flexing during normal operation. See Accelerated Aging Test, Section 32.

13.1.6 A wiring compartment that is secured to a substrate by means of an adhesive shall comply with Wiring Compartment Securement Test, Section 42.

13.2 Metallic wiring compartments

13.2.1 A wiring compartment of sheet steel shall have a wall thickness of not less than 0.053 in (1.35 mm) if uncoated, or 0.056 in (1.42 mm) if zinc coated.

13.2.2 A wiring compartment of sheet aluminum shall have a wall thickness of not less than 0.0625 in (1.59 mm).

13.2.3 A wiring compartment of cast iron, aluminum, brass, or bronze shall have a wall thickness of not less than 3/32 in (2.4 mm).

13.2.4 A threaded hole in a metal wiring compartment intended for the connection of rigid metal conduit shall be reinforced to provide metal not less than 1/4 in (6.4 mm) thick, and shall be tapered unless a conduit end stop is provided.

13.2.5 If threads for the connection of conduit are tapped all the way through a hole in a compartment wall, or if an equivalent construction is employed, there shall not be less than 3-1/2 nor more than five threads in the metal and the construction shall be such that a conduit bushing can be attached as intended.

13.2.6 If threads for the connection of conduit are not tapped all the way through a hole in a compartment wall, there shall not be less than five full threads in the metal and there shall be a smooth, rounded inlet hole for the conductors which shall afford protection to the conductors equivalent to that provided by a standard conduit bushing. The throat diameter of an inlet hole shall be within the limits specified in the Standard for Metallic Outlet Boxes, UL 514A.

13.2.7 For a nonthreaded opening in a metal wiring compartment intended to accommodate rigid metallic conduit, a flat surface of sufficient area as described in the Standard for Metallic Outlet Boxes, UL 514A, shall be provided around the opening to accept the bearing surfaces of the bushing and lock washer.

13.3 Nonmetallic wiring compartments

13.3.1 The considerations mentioned in 7.1 concerning polymeric materials serving as the enclosure apply to nonmetallic wiring compartments.

13.3.2 A nonmetallic wiring compartment intended to accommodate nonmetallic conduit shall have:

- a) One or more unthreaded conduit-connection sockets integral with the compartment that comply with the requirements in the Standard for Nonmetallic Outlet Boxes, Flush-Device Boxes, and Covers, UL 514C,
- b) One or more threaded or unthreaded openings for a conduit-connection socket, or
- c) One or more knockouts that comply with UL 514C.

13.3.3 With reference to 13.3.2 (b), a module or panel provided with a nonmetallic wiring compartment having a threaded opening shall be marked in accordance with 47.8.

13.3.4 In a nonmetallic compartment, a socket for the connection of nonmetallic conduit shall provide a positive end stop for the conduit; and the socket diameters, the throat diameter at the entrance to the box, the socket depths, and the wall thickness of the socket shall be within the limits specified in the Standard for Nonmetallic Outlet Boxes, Flush-Device Boxes, and Covers, UL 514C.

13.3.5 A knockout or opening in a nonmetallic wiring compartment intended to accommodate rigid nonmetallic conduit shall comply with the requirements in the Standard for Nonmetallic Outlet Boxes, Flush-Device Boxes, and Covers, UL 514C.

14 Corrosion Resistance

14.1 Sheet steel having a thickness of 0.12 in (3.05 mm) or more that may be exposed to the weather shall be made corrosion-resistant by one of the following coatings:

- a) Hot-dipped mill-galvanized sheet steel conforming with the coating designation G60 or A60 in the Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot Dip Process, ASTM A653/A653M-01, with not less than 40 percent of the zinc on any side, based on the minimum single spot-test requirement in this ASTM specification. The weight of zinc coating may be determined by any method; however, in case of question, the weight of coating shall be established in accordance with the Standard Test Method for Weight of Coating on Zinc-Coated (Galvanized) Iron or Steel Articles, ASTM A90-81 (1991).
- b) A zinc coating, other than that provided on hot-dipped mill-galvanized sheet steel, uniformly applied to an average thickness of not less than 0.00041 in (0.010 mm) on each surface with a minimum thickness of 0.00034 in (0.009 mm). The thickness of the coating shall be established by the Metallic Coating Thickness Test, Section 38.
- c) An organic or inorganic protective coating system on both surfaces, applied after forming. The results of an evaluation of the coating system shall demonstrate that it provides protection at least equivalent to that provided by the zinc coating described in 14.1(a). See Polymeric Materials, Section 7 and Corrosive Atmosphere Test, Section 37.
- d) Any one of the means specified in 14.2.

14.1 revised October 1, 2003

14.2 Sheet steel having a thickness of less than 0.12 in (3.05 mm) which may be exposed to the weather shall be made corrosion-resistant by one of the following coatings:

- a) Hot-dipped, mill-galvanized sheet steel conforming with the coating designation G90 in the Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot Dip Process, ASTM A653/A653M-01, with not less than 40 percent of the zinc on any side, based on the minimum single spot-test requirement in this ASTM specification. The weight of zinc coating may be determined by any acceptable method; however, in case of question, the weight of coating shall be established in accordance with the Standard Test Method for Weight of Coating on Zinc-Coated (Galvanized) Iron or Steel Articles, ASTM A90-81 (1991).
- b) A zinc coating, other than that provided on hot-dipped mill-galvanized sheet steel, uniformly applied to an average thickness of not less than 0.00061 in (0.015 mm) on each surface with a minimum thickness of 0.00054 in (0.014 mm). The thickness of the coating shall be established by the Metallic-Coating Thickness Test, Section 38. An annealed coating shall also comply with 14.5 and 14.6.
- c) A cadmium coating not less than 0.0010 in (0.025 mm) thick on both surfaces. The thickness of the coating shall be established by the Metallic Coating Thickness Test, Section 38.
- d) A zinc coating conforming with 14.1(a) or 14.1(b) with one coat of outdoor paint. The coating system shall comply with 14.3.

e) A cadmium coating not less than 0.00075 in (0.019 mm) thick on both surfaces with one coat of outdoor paint on both surfaces, or not less than 0.00051 in (0.013 mm) thick on both surfaces with two coats of outdoor paint on both surfaces. The thickness of the cadmium coating shall be established by the Metallic Coating Thickness Test, Section 38, and the coating system shall comply with 14.3.

14.2 revised October 1, 2003

14.3 With reference to 14.2(d) and 14.2(e), the results of an evaluation of the coating system shall demonstrate that it provides protection at least equivalent to that provided by the zinc coating as described (G90) in 14.2(a). See Polymeric Materials, Section 7 and Corrosive Atmosphere Test, Section 37.

14.4 With reference to 14.1 and 14.2, other finishes, including paints, other metallic finishes, and combinations of the two may be accepted when comparative tests with galvanized sheet steel (without annealing, wiping, or other surface treatment) conforming with 14.1(a) or 14.2 as applicable, indicate they provide equivalent protection. See Corrosive Atmosphere Test, Section 37.

14.5 An annealed coating on sheet steel that is bent or similarly formed or extruded or rolled at edge of holes after annealing shall additionally be painted in the bent or formed area if the bending or forming process damages the zinc coating. If flaking or cracking of a zinc coating at the outside radius of a bent or formed section is visible at 25 power magnification, the zinc coating is considered damaged.

14.6 Simple sheared or cut edges and punched holes are not required to be additionally protected.

14.7 Iron or steel serving as a necessary part of the product but not exposed to the weather shall be plated, painted, or enameled for protection against corrosion.

14.8 Aluminum, stainless steel, and polymeric materials may be used without corrosion-resistant coatings or platings.

14.9 Materials not specifically mentioned in this section shall be evaluated on an individual basis. The tests described in Polymeric Material, Section 7, and Corrosive Atmosphere Test, Section 37, may be used for the evaluation.

15 Accessibility of Uninsulated Live Parts

15.1 An accessible part of a module or panel shall not involve a risk of electric shock.

Exception: A part that is not energized when it is accessible need not comply with this requirement.

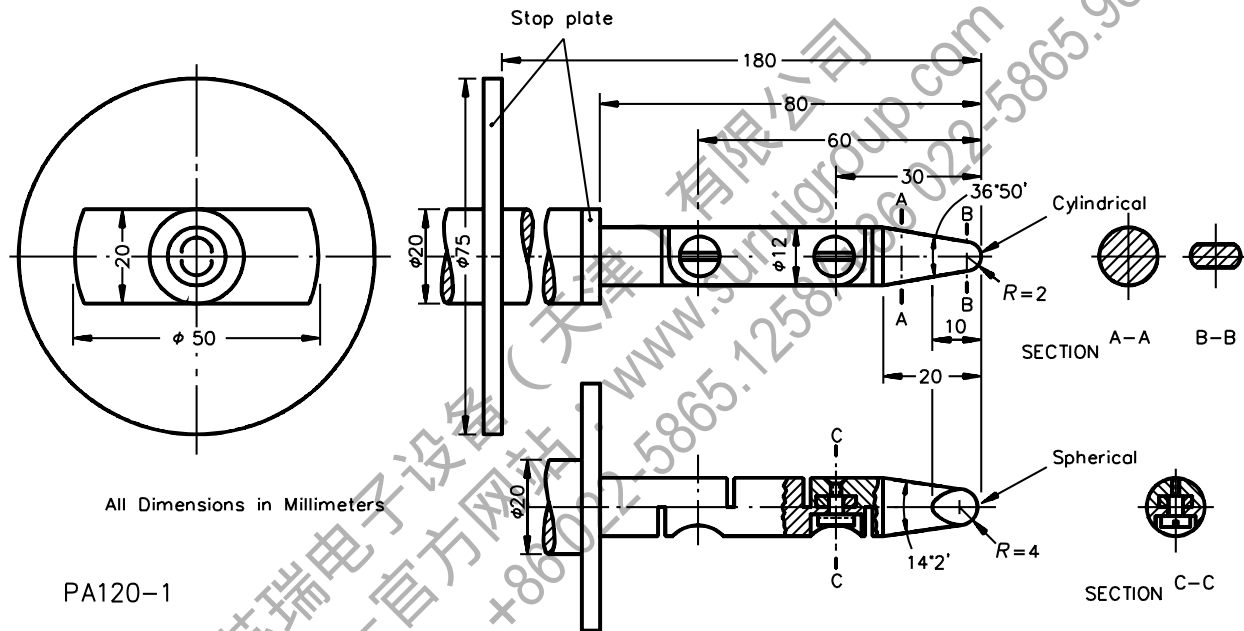
15.2 In determining whether a part is energized, the module or panel is to be evaluated:

- a) Not connected, and
- b) Connected in any implied or described acceptable manner. In both cases, the module or panel is to be in the state described in 15.4 and in the environment described in 20.2.

15.3 For voltages and currents between parts of the individual unconnected product, voltage is to be determined in accordance with 20.2. For voltages and currents between parts of the assembly of products, voltage is to be the maximum system voltage, current is to be the available current.

15.4 A part is considered accessible if, in a fully assembled module or panel (that is, with all covers in place) the part may be touched by the probe illustrated in Figure 15.1. A cover that may be removed without the use of a tool is to be removed for purposes of this requirement. A cover that may be removed (with or without a tool) for routine maintenance such as cleaning, or to gain access to tools, is to be removed for purposes of this requirement.

Figure 15.1
Probe for determining accessibility of live parts



15.5 The probe illustrated in Figure 15.1 shall be applied to any depth that the opening will permit and shall be rotated or angled before, during, and after insertion through the opening to any position that is necessary to examine the product. The probe shall be applied in any possible configuration; and, if necessary, the configuration shall be changed after insertion through the opening. The probe is to be used as a measuring instrument to judge the accessibility provided by an opening, and not as an instrument to judge the strength of a material; as such, it is to be applied with the minimum force necessary to accurately determine accessibility.

16 Fire Resistance

16.1 A module or panel intended for stand-off, rack, or direct mounting in combination with a specified roof, or intended for integral mounting shall comply with the fire resistance requirements for a Class A, B, or C roof covering when the module or panel is indicated or implied as being fire rated. For a combination construction, the rating shall be coincident with, or at a lower level than, the rating of the basic roof covering material. The fire resistance shall be determined in accordance with the Standard for Tests for Fire Resistance of Roof Covering Materials, UL 790, as modified by Fire Tests, Section 31.

17 Superstrate

17.1 A module or panel superstrate shall comply with at least one of the following:

- a) The requirements in the Performance Specifications and Methods of Test for Safety Glazing Material Used in Buildings, ANSI Z97.1-1984; or
- b) The requirements in the Code of Federal Regulations, Title 16 CPSC Part 1201 – Safety Standard for Architectural Glazing Materials; or
- c) The Impact Test, Section 30.

Exception No. 1: Thin-film flexible glazing material having a thickness of 0.01 in (0.254 mm) or less need not comply with this requirement.

Exception No. 2: Encapsulant that is protected with wire screen or other similar means having openings that will not pass a 1/2-in (12.7-mm) diameter hemispherically tipped probe applied with a force of 1 lb (4.4 N).

PERFORMANCE

18 General

18.1 The same test procedures shall be used for the electrical performance measurements required by the Temperature Test, Section 19, Voltage, Current, and Power Measurements Test, Section 20, and Hot-Spot Endurance Test, Section 39. The test procedures described in the following standard shall be applied where applicable:

- a) Standard Tables for Terrestrial Solar Spectral Irradiance at Air Mass 1.5 for 37 Degree Tilted Surface, ASTM G159-1998;
- b) Standard Specifications for Solar Simulation for Terrestrial Photovoltaic Testing, ASTM E927-91;
- c) Standard Methods of Testing Electrical Performance of Nonconcentrator Terrestrial Photovoltaic Modules and Arrays Using Reference Cells, ASTM E1036-96;
- d) Procedures for Temperature Irradiance Corrections to Measured I-V Characteristics of Crystalline Silicon Photovoltaic Devices, IEC 891;
- e) Photovoltaic Devices, Part 1: Measurement of Photovoltaic Current-Voltage Characteristics, IEC 904-1; and

f) Photovoltaic Devices, Part 3: Measurement Principles for Terrestrial Photovoltaic (PV) Solar Devices With Reference Spectral Irradiance Data, IEC 904-3.

18.1 revised October 1, 2003

18.2 With reference to the tests mentioned in 18.1, parameters may be measured under conditions other than specified irradiance, air mass, or temperature, and the values at the specified conditions calculated using correction coefficients described in the referenced standards.

18.3 Samples of the module or panel, or partial or representative samples, shall be subjected to the tests indicated in Table 18.1. The order of the tests in Table 18.1 is for convenience only. It is not intended to imply that any one sample be subjected to the complete sequence or a partial sequence of tests unless specifically stated in Figure 18.1. Unless one sample is to be subjected to a specific sequence of tests, separate samples are able to be used for each test.

Exception: Samples of a module or panel with a system open-circuit voltage rating less than 30 V and a short-circuit current rating less than 8 A is only required to be subjected to the Temperature, Voltage and Current Measurement, Strain Relief, Push, Bonding Path Resistance, and Dielectric Voltage-Withstand Tests.

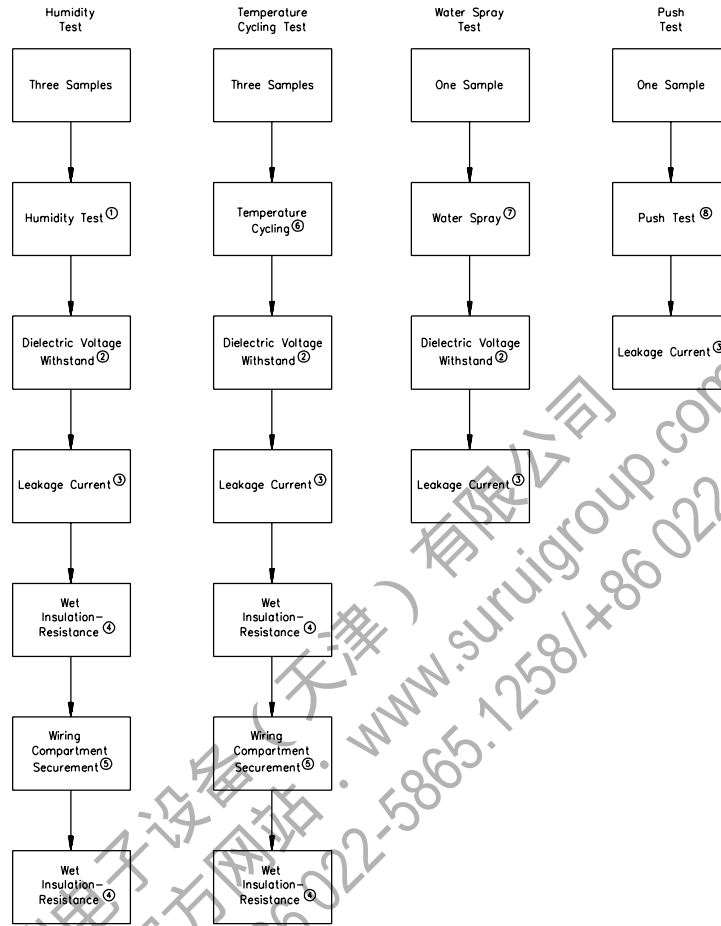
Table 18.1
Module and panel performance

Table 18.1 revised June 30, 2004

Section	Test	Number of samples
19	Temperature test ^d	1
20	Voltage and current measurements test ^d	1
21	Leakage current test	3
22	Strain relief test ^d	1
23	Push test ^d	1
24	Cut test	1
25	Bonding path resistance test	3
26	Dielectric voltage-withstand test ^d	3
27	Wet insulation-resistance test	3
28	Reverse current overload test	1
29	Terminal torque test	1
30	Impact test	1
31	Fire test	a
33	Water spray test	1
34	Accelerated aging test	b
35	Temperature cycling test	3
36	Humidity test	3
37	Corrosive atmosphere test	2
38	Metallic coating thickness test	1
39	Hot-spot endurance test	1
40	Arcing test	c
41	Mechanical loading test	1
42	Wiring compartment securement test	1

^a A function of the physical size of the module.
^b A function of the physical size of the gasket and seal material.
^c One or more, depending upon test procedure elected.
^d With reference to the Exception to 18.3, only these tests are needed for a module or panel with the specified ratings.

Figure 18.1
Test sequences and samples



NOTES –

- 1 = Section 36
- 2 = Section 26
- 3 = Section 21
- 4 = Section 27
- 5 = Section 42
- 6 = Section 35
- 7 = Section 33
- 8 = Section 23

19 Temperature Test

19.1 When a module or panel is at thermal equilibrium in its intended application mounting at electrical open circuit and reverse voltage hot-spot heating associated with operation as short-circuit— see 19.5; no part shall attain a temperature that would:

- a) Ignite materials or components;
- b) Cause the temperature limits of surfaces, materials, or components, as described in Table 19.1, to be exceeded; or
- c) Cause creeping, distortion, sagging, charring or similar damage to any part of the product, if such damage or deterioration may impair the performance of the product under the requirements of this standard.

19.1A With reference to 19.1, thermal equilibrium is attained when three successive readings indicate no change in temperature. These readings shall be taken at the conclusion of three consecutive, equal intervals of time; each interval having a duration of 10 minutes minimum test time. Wind speed and irradiance are to be factored into each measurement.

19.2 Material and component temperatures are to be determined for an ambient temperature of 40°C (104°F), AM 1.5 spectrum, 100 mW/cm² irradiance as measured in the plane of the module or panel, and 1 m/s (2.237 mph) average wind speed. The ambient temperature may be in the range of 10 to 55°C (50 to 131°F), in which case each observed temperature shall be corrected by the addition (if the ambient temperature is below 40°C) or subtraction (if the ambient temperature is above 40°C) of the difference between 40°C and the observed ambient temperature. If the irradiance is other than 100 mW/cm², temperatures for numerous irradiance levels are to be determined, and a linear extrapolation conducted to determine the temperature under 100mW/cm² irradiance.

19.3 If an unacceptable performance is encountered during the temperature test, and the performance is attributed to a test condition that, although within the limits specified, may be considered more severe than necessary; for example an ambient temperature near the limits allowed (10 or 55°C), the test may be reconducted under conditions closer to the norm.

19.4 For the determination of temperatures, a module or panel is to be operated under both open- and short-circuit conditions.

19.5 To cover the hot-spot heating effect caused by reverse voltage operation of a cell, a cell is to be shadowed during the short-circuit condition of the temperature test by covering one-half of one of the cells of the module or panel with black vinyl tape, 0.007 in (0.18 mm) thick in direct contact with the superstrate so that this cell is not fully irradiated. During this test, the modules or panels are to be connected in series without bypass diodes to the extent that is permitted by the marking specified in 47.9. The temperatures of the shaded cell and adjacent area are to be measured.

19.6 A module or panel is to be installed according to the instructions provided with it. If the instructions do not describe the accommodating structure, spacings, and the like, the module or panel is to be mounted as described in 19.8 – 19.10.

19.7 With reference to 19.8 and 19.9, the type of mounting intended, (for example, stand-off, direct, and the like) is to be determined from the construction of the module or panel. If more than one type of mounting is possible, the module or panel is to be tested in each such mounting, unless one mounting can be shown to represent all.

19.8 A module or panel intended for direct mounting on a roof or wall surface is to be mounted on a platform constructed of wood, pressed wood, or plywood, 3/4 in (19 mm) thick (See Figure 19.1). The platform is to be painted flat black on the side facing the test sample. The platform is to extend at least 2 ft (0.6 m) beyond the module or panel on all sides.

19.9 A module or panel intended for stand-off or rack mounting on a roof, wall, or the ground is to be mounted on a frame constructed from 2 in by 4 in (trade size) lumber. Two frame members are to be located at the outside edges of the underside of the module or panel, and are to be oriented longitudinally along the long axis of the module or panel. Additional frame members are to be located at the outside edges of the underside of the module or panel along its short axis. If the distance between the two outer short axis members exceeds 2 ft (0.6 m), an additional frame member is to be located at the center line of the module or panel assembly. The frame is to be secured to a platform as described in 19.8 with a 4-ft (1.22-m) spacing between the back of the module or panel and the platform (See Figure 19.2). The frame is to be painted flat black on the side facing the test sample.

19.10 A module or panel intended for integral mounting within a roof or wall is to be tested while mounted on a platform constructed as described in 19.8 with the module or panel boxed in on all sides by 1-in thick (trade size) wood boards that are wide enough to cover the entire outer edge (See Figure 19.3). The boards are to be painted flat black on the side facing the sample.

Table 19.1
Maximum temperatures

Table 19.1 revised October 1, 2003

Part, material, or component	Temperature	
	°C	(°F)
1. Insulating materials ^d		
Polymeric	a	a
Varnished cloth	85	185
Fiber	90	194
Laminated phenolic composition	125	257
Molded phenolic composition	150	302
2. Sealing compound ^d	b	b
3. Field wiring terminals ^c	60	140
4. Field wiring compartments that wires may contact ^c	60	140
5. Insulated conductors	Rated temperature	
6. Wood and wood products	90	194
7. Surfaces accessible to contact	90	194
8. Mounting surface and adjacent structural members ^d	90	194

^a For the open-circuit mode, the relative thermal index, less 20°C (36°F). For reverse voltage hot-spot heating under short-circuit conditions, the relative thermal index.

^b The maximum sealing compound temperature, when corrected to a 40°C (104°F) ambient temperature, is to be 15°C (27°F) less than the softening point of the compound as determined by the Standard Test Method for Softening Point by Ring and Ball Apparatus, ASTM E28-99.

^c If a marking is provided in accordance with 47.5, the temperatures observed on the terminals and at points within a wiring compartment may exceed the value specified but shall not attain a temperature higher than 90°C (194°F).

Table 19.1 Continued

Part, material, or component	Temperature	
	°C	(°F)
^d Higher temperatures than specified are acceptable if it can be determined that the higher temperatures will not cause a risk of fire or electric shock or conditions not in compliance with 19.1(a) or 19.1(c). ^e Only for reverse voltage hot-spot heating under short-circuit conditions; for nonmetallic surfaces 40°C (72°F) above the temperature achieved during open-circuit conditions; for metallic surfaces, 20°C (36°F) above the temperature achieved during open-circuit conditions.		

Figure 19.1
Fixture for test products for direct mounting

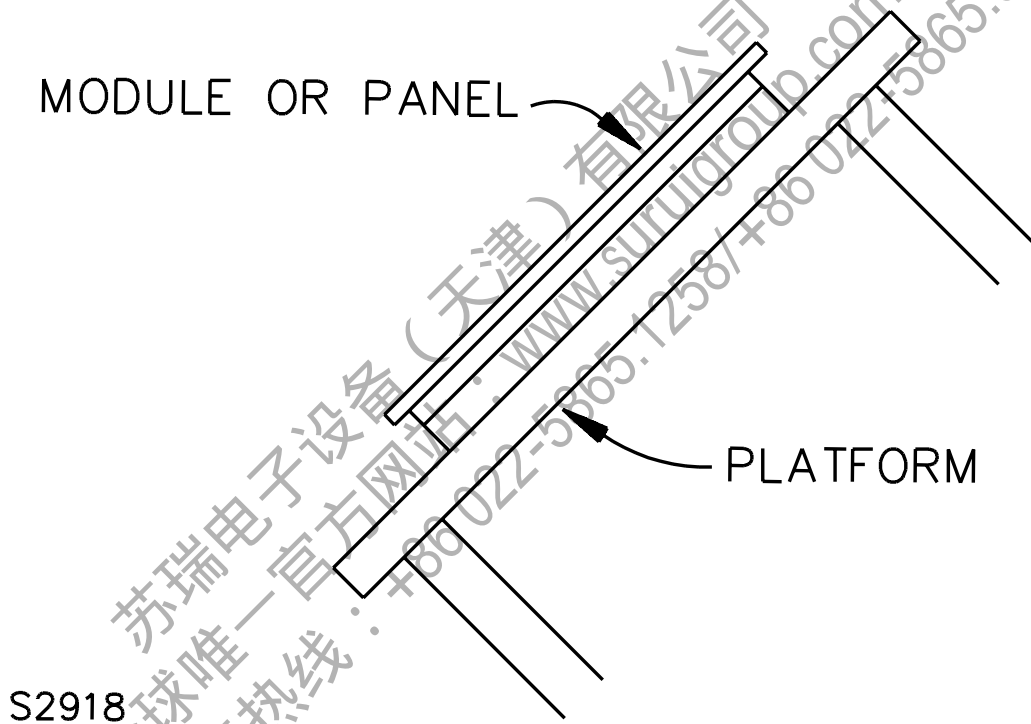
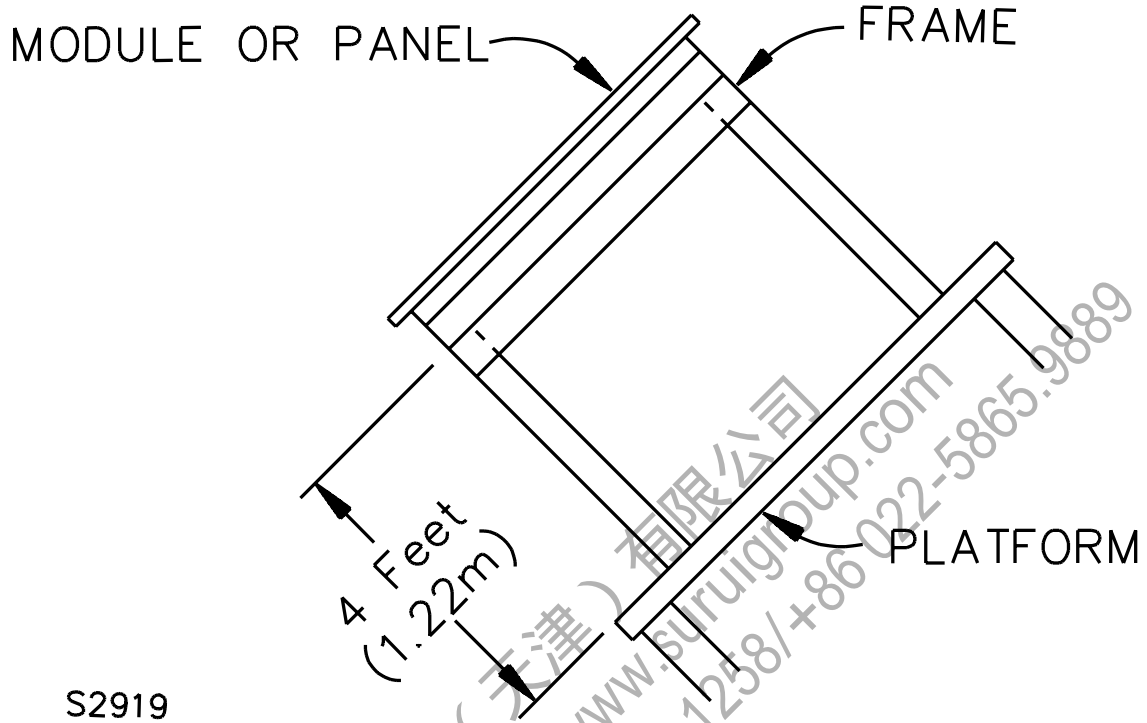


Figure 19.2
Fixture for test products for stand-off or rack mounting

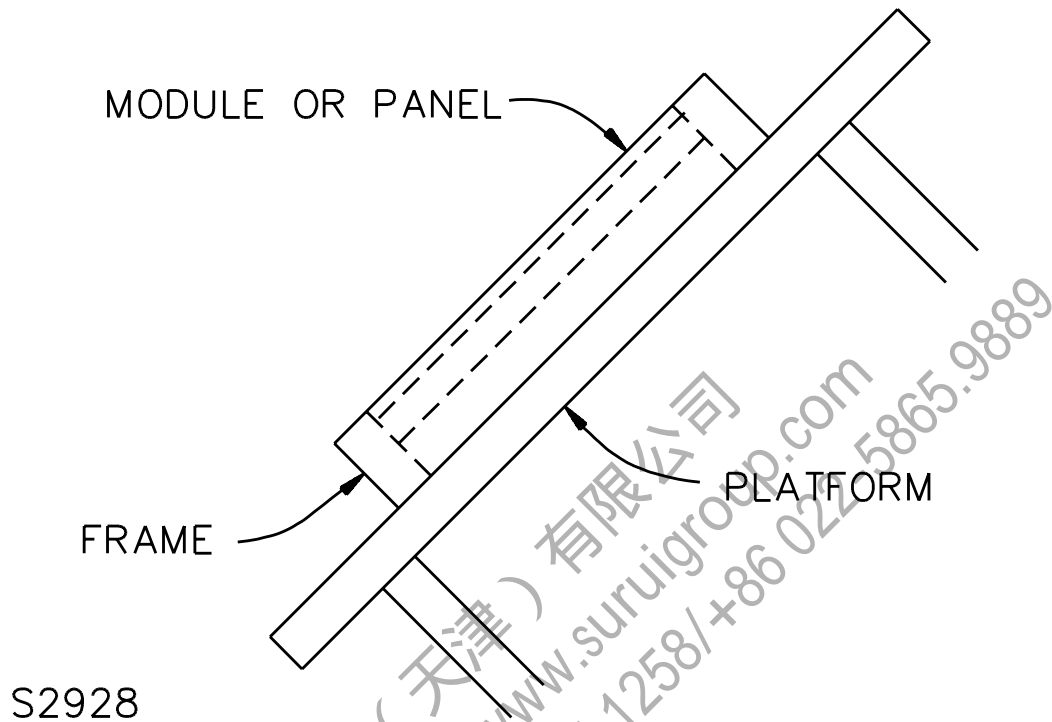


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Figure 19.3
 Fixture for test products for integral mounting



19.11 Temperatures are to be measured by means of thermocouples. Thermocouples exposed to irradiation are to be shielded from the direct effect of such irradiation. A thermocouple junction is to be securely held in positive thermal contact with the surface of the material the temperature of which is being measured. Thermal contact may be achieved by securely cementing the thermocouple in place. For a metal surface, brazing, welding, or soldering the thermocouple to the metal may be used. A thermocouple junction may be secured to wire insulation or wood surfaces by taping.

19.12 Thermocouples consisting of No. 30 AWG (0.05 mm²) iron and constantan wires are to be employed. However, when it is not practical to use iron and constantan thermocouples some other type described in Initial Calibration Tolerances for Thermocouples table in Temperature Measurement Thermocouples, ANSI/ISA, MC96.1, is to be used.

20 Voltage, Current and Power Measurements Test

20.1 The short-circuit current (I_{SC}), rated current (I_r), maximum power (P_{max}), and open-circuit voltage (V_{OC}) shall be within ± 10 percent of the rated value – See 43.1 and 44.1(c) – under conditions of:

- a) Standard test conditions (STC) and
- b) For I_r and P_{max} , also at normal operating cell temperature (NOCT).

20.2 For purposes of accessibility to individual module or panel live parts as specified in 15.3, the voltage is to be determined under conditions of open circuit, an irradiance of 100 mW/cm², AM1.5 and a cell temperature of minus 20°C (minus 4°F).

21 Leakage Current Test

21.1 The leakage current of a module having a marked maximum system voltage of more than 30 V shall not be greater than the values specified in Table 21.1 when tested as described in 21.2 – 21.7.

21.2 The test is to be conducted on three unconditioned modules, and the modules that have been subjected to the Water Spray Test, Section 31; the Temperature Cycling Test, Section 33; and the Humidity Test, Section 34. The leakage current of the unconditioned modules is to be measured with the module cell temperature at $25 \pm 3^\circ\text{C}$ ($77 \pm 5^\circ\text{F}$), and then with the cells at NOCT $\pm 2^\circ\text{C}$ ($\pm 3.6^\circ\text{F}$). If panels are used for the Water Spray Test, a module of a panel is to be used for the Leakage Current Test.

Table 21.1
Allowable leakage current

Surface or part from which measurement is made	Maximum current (dc)
Accessible conductive frame, pan, or the like	10 μA
Accessible circuit parts	1 mA
Conductive foil over accessible insulating surfaces	1 mA

21.3 Leakage current refers to all currents that may be conveyed between accessible parts of a module when the module is connected to the source described in 21.4 and 21.5.

21.4 The dc test voltage is to be at a level equal to the rated maximum system voltage.

21.5 All accessible parts and surfaces are to be tested for leakage current. The positive and negative terminals of an unilluminated module are to be connected together and to one terminal of a dc power supply. Both polarities of the source connection are to be used, unless it can be shown that one polarity will represent both. Leakage currents are to be measured between the part or surface and the other terminal of the power supply. Leakage current is to be measured with the meter described in 21.7.

21.6 When leakage current is measured at an insulating surface, a 40 cm by 20 cm conductive foil is to be in contact with the surface, and the measurement is to be made from the foil. If the surface is less than 40 cm by 20 cm, the foil is to be the same size as the surface.

21.7 With reference to 21.5, the meter for the measurement is to be responsive to dc only, and is to have an input impedance of 500 ohms.

22 Strain Relief Test

22.1 A lead or cable for connection to external wiring, or a lead or cable terminated at both ends on the product but which may be subjected to handling during installation or routine servicing of a module or panel shall withstand for 1 min a force of 20 lb (89 N) applied in any direction permitted by the construction, without damage to the lead or cable, its connecting means, and the module or panel.

22.2 A separable connector not enclosed by a wiring compartment, and such connector's joining to its mating connector, shall withstand for 1 min a force of 20 lb (89 N) applied in any direction permitted by the construction, either directly or through any wire or cable attached to the mating connector, without damage to the connector, the module or panel, or the mounting of the connector to the module or panel, or separation of the two mating connectors.

23 Push Test

23.1 A module or panel shall be capable of withstanding for 1 min the application to any point of:

- a) A 20 lb (89 N) force applied by a 1/2-in (12.7-mm) diameter steel rod, the end of which is rounded to a 1/2-in diameter hemisphere, and
- b) A 4 lb (17.8 N) force applied by a 1/16-in (1.6-mm) diameter steel rod, the end of which is rounded to a 1/16-in diameter hemisphere,

without creating a risk of fire, electric shock, or injury to persons.

23.2 A risk of fire is considered to exist, if, as a result of the application of either probe, parts of the module are displaced to the extent that arcing between parts of available current and voltage in the "ARC TEST" zone, Figure 40.1, is likely.

23.3 A risk of electric shock is considered to exist if:

- a) A part involving a risk of electric shock is contacted by the applied probe;
- b) A part involving a risk of electric shock is rendered accessible (transitory or permanent) as a result of the application of either probe; or
- c) There is a reduction in resistance between a part involving a risk of electric shock and an accessible part such that the module or panel would not comply with the Leakage Current Test, Section 21.

23.4 A risk of injury to persons is considered to exist, if, as a result of the application of either probe, parts are displaced or broken so as to expose edges which would not comply with the requirements for sharp edges in 6.9.

24 Cut Test

24.1 A module or panel shall withstand the application of a sharp object drawn across its superstrate and substrate surfaces without creating a condition described in 2.7.

Exception: Glass surfaces are not required to be tested.

24.2 The module or panel is to be positioned in a horizontal plane with the surface to be tested facing upward. The tool illustrated in Figure 24.1 is to be placed on the surface for 1 min, and then drawn across the test surface of the module or panel at a speed of 6 ± 1.2 in/s (152.4 ± 30.5 mm/s).

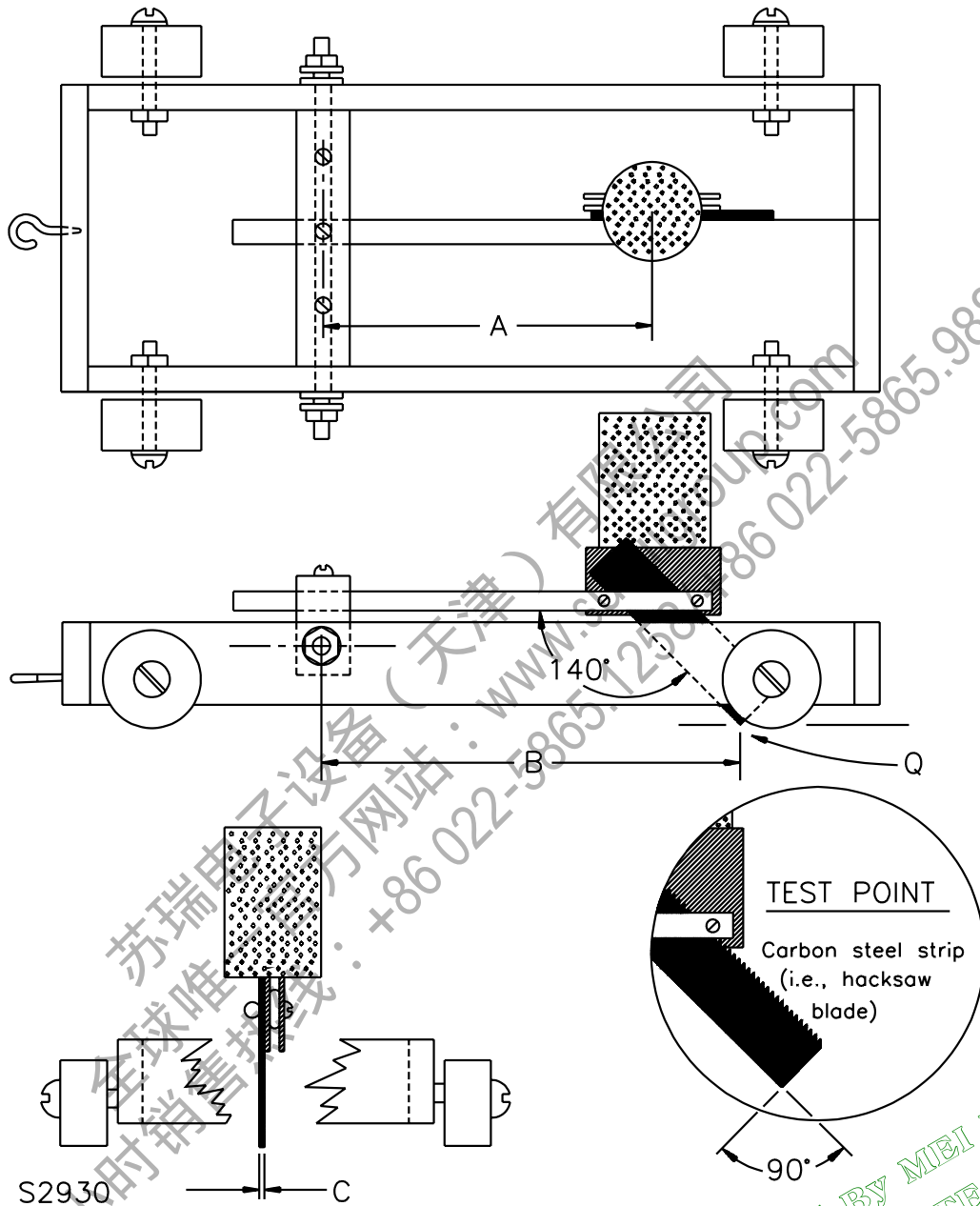
24.3 A condition as described in 2.7 exists when the blade of the tool illustrated in Figure 24.1, contacts a part described in 2.7, or such a part is rendered accessible (transitory or permanent) as a result of the placement of the blade on, or the drawing of the blade across, the surface.

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Figure 24.1
Cut test tool



A – 5-7/8 in (149 mm) from axis to center of weight.

B – 6-5/8 in (168 mm) from axis to test point.

C – Test point – 0.025 in (0.64 mm) thick carbon steel strip.

Q – Total force exerted at test point Q; 2 lb (907 g).

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25 Bonding Path Resistance Test

25.1 The resistance between the grounding terminal or lead and any accessible conductive part shall not be more than 0.1 ohm when measured in accordance with 25.2.

25.2 A current equal to twice the fuse ampere rating specified in accordance with 47.10 is to be passed between the grounding terminal or lead and the conductive part. The resistance is to be calculated using the voltage drop measured between the grounding terminal or lead and a point within 1/2 in (12.7 mm) of the point of current injection.

25.3 If more than one test is needed to evaluate all the paths of conduction between accessible metal parts, there is to be a cooling time of at least 15 min between tests.

25.4 The test is to be conducted on three unconditioned samples.

26 Dielectric Voltage-Withstand Test

26.1 The insulation and spacings between live parts and accessible conductive parts and between live parts and exposed nonconductive surfaces shall withstand the application of a dc test voltage equal to two times the system voltage plus 1000 V without the leakage current between these two points exceeding 50 μ A dc. The voltage is to be applied in both polarities.

Exception: For a module or panel with a system voltage rating of 30 V or less, the applied voltage is to be 500 V.

26.2 The test voltage is to be applied between all current-carrying parts and all accessible parts.

26.3 The voltage is to be increased from zero at a substantially uniform rate as described in 26.4, so as to reach the specified test potential in approximately 5 s, and then is to be held at the required test voltage until the leakage current is stabilized for at least 1 min. The module or panel is to be observed during the test and there are to be no signs of arcing or flash-over.

26.4 With reference to 26.3, the test voltage is to be gradually and smoothly increased to the specified value so that:

- a) There are no transients that may cause the instantaneous voltage to exceed the peak value specified, and
- b) The flow of capacitive current, due to charging, does not cause the test device to indicate breakdown.

26.5 The test is to be conducted on three unconditioned samples, and the samples that have been subjected to the Water Spray Test, Section 33; the Temperature Cycling Test, Section 35; the Humidity Test, Section 36; and the Corrosive Atmosphere Test, Section 37. The unconditioned samples are to be at both room temperature and also as heated from the short-circuit operation portion of the temperature test in Section 19.

26.6 For tests on exposed surfaces of insulating parts, the part is to be covered with conductive foil or the equivalent.

26.7 The equipment for conducting the dielectric voltage-withstand test is to have the following characteristics:

- a) A means for indicating the test voltage that is being applied to the product under test;
- b) A sensitivity such that a current in excess of 50 μA across the output indicates unacceptable performance; and
- c) A capacity of at least 500 VA.

Exception: The capacity may be lower if the means for indicating the test voltage is located in the output circuit – to maintain the potential indicated in 26.1 except in the case of breakdown. The voltage of the source is to be continuously adjustable.

27 Wet Insulation-Resistance Test

27.1 As a result of the test described in 27.2 and 27.3:

- a) There shall not be dielectric breakdown or surface tracking as a result of the applied dc voltage;
- b) For a module with an area 0.1 m^2 or less, the insulation resistance shall not be less than 400 $\text{M}\Omega$; and
- c) For a module with an area larger than 0.1 m^2 , the measured insulation resistance times the area of the module shall not be less than 40 $\text{M}\Omega\cdot\text{m}^2$.

27.1 revised October 1, 2003

27.2 The laminate portion of the module or panel is to be immersed in a non-corrosive liquid agent (surfactant) solution. The liquid agent is to have 35 ohm-meter maximum resistance, 0.03 N/m maximum surface tension, and a temperature of $22 \pm 3^\circ\text{C}$ ($72 \pm 5^\circ\text{F}$). Terminal boxes and pigtail-leads or other connectors are to be maintained above the solution level and are to be thoroughly wetted by pouring the solution over these areas. Uninsulated terminations are not to be wetted.

27.3 After two min of immersion in the solution, the insulation resistance between the shorted output terminals of the module or panel and the solution is to be measured, in both polarities, with an instrument having a voltage of 500 Vdc.

28 Reverse Current Overload Test

28.1 There shall not be flaming or charring of the cheesecloth or tissue paper in contact with a module or panel, or flaming of the module or panel itself for 15 s or more, when a reverse current equal to 135 percent of the module or panel series fuse rating current (See 47.10) is caused to flow through the module or panel.

28.2 To determine whether a module or panel complies with the requirements in 28.1, a module or panel is to be placed on a single layer of white tissue paper over a 3/4 in (19.1 mm) thick pine board and covered with a single layer of cheesecloth. The cheesecloth is to be untreated cotton cloth running 14 – 15 square yards/lb (26 – 28 m²/kg) and having what is known to the trade as a count of 32 by 28.

28.3 For the test required by 28.1, any blocking diode provided as a part of the module or panel is to be defeated (short-circuited).

28.4 The test required by 28.1 is to be conducted in an area free of drafts, and the irradiance on the module or panel is to be less than 5 mW/cm².

28.5 The test required by 28.1 is to be continued for 2 h or until ultimate results are known, whichever occurs first.

29 Terminal Torque Test

29.1 A wire-binding screw or nut on a wiring terminal shall be capable of withstanding 10 cycles of tightening to and releasing from the applicable value of torque specified in Table 29.1 without:

- a) Damage to the terminal supporting member,
- b) Loss of continuity, or
- c) Short circuiting of the electrical circuit to accessible metal.

Table 29.1
Torque requirements

Screw size	Torque	
	Lbf-in	(N·m)
No. 6	12	(1.4)
No. 8	16	(1.8)
No. 10	20	(2.3)

30 Impact Test

30.1 A polymeric material serving as the enclosure of a part involving a risk of fire or electric shock and a superstrate material evaluated in accordance with 17.1(c) are to be subjected to the tests described in 30.2 and 30.3.

30.2 When a module or panel is impacted as described in 30.3, there shall be no accessible live parts as defined in Accessibility of Uninsulated Live Parts, Section 15. Breakage of the superstrate material is acceptable provided there are no particles larger than 1 square in (6.5 cm²) released from their normal mounting position.

30.3 A module or panel is to be mounted in a manner representative of its intended use, and is to be subjected to a 5 ft-lb (6.78 J) impact normal to the surface resulting from a 2-in (51-mm) diameter smooth steel sphere weighing 1.18 lb (535 g) falling through a distance of 51 in (1.295 m). The module or panel is to be struck at any point considered most vulnerable. If the construction of a module or panel does not permit it to be struck free from above by the free falling sphere, the sphere is to be suspended by a cord and allowed to fall as a pendulum through the vertical distance of 51 in with the direction of impact normal to the surface. For a polymeric wiring enclosure, the test is to be performed on the enclosure at 25°C (77°F) and also after being cooled and maintained for 3 h at a temperature of minus 35.0 ±2.0°C (minus 31.0 ±3.6°F).

30.3 revised October 1, 2003

31 Fire Tests

31.1 Spread-of-flame test

31.1.1 A module or panel intended for roof mounting, and designated for installation above, upon, or integral with a building roof structure having a surface consisting of a Class A, Class B, or Class C type roof covering material, shall be subjected to a spread-of-flame test as described in Tests for Fire Resistance of Roof Covering Materials, UL 790. At no time during or after the tests shall:

- a) Any portion of the module or panel be blown off or fall off the test deck in the form of flaming or glowing brands;
- b) Portions of the roof deck, or portions of a module or panel intended for installation integral with or forming a part of the building roof structure, fall away in the form of glowing particles;
- c) The flame spread beyond 6 ft (1.82 m) for Class A, 8 ft (2.4 m) for Class B, or 13 ft (3.9 m) for Class C rating. The flame spread is to be measured from the leading edge of the sample; or
- d) There be significant lateral spread-of-flame from the path directly exposed to the test flame. Spread-of-flame includes flaming on both the top surface (the surface to which the external flame is applied) and in any intermediate channel, such as the space between stand-off or integral modules and a shingle roof.

31.1.2 For a module or panel intended for installation above a building roof structure, the Spread-Of-Flame Test is to be conducted with the module or panel oriented with respect to the test flame such that the flame impinges only on the top surface of the module or panel.

31.2 Burning-brand test

31.2.1 A module or panel intended for roof mounting, and designated for installation above, upon, or integral with a building roof structure having a surface consisting of a Class A, Class B, or Class C type roof covering material, shall be subjected to a burning-brand test as described in Tests for fire Resistance of Roof Covering Materials, UL 790. At no time during or after the tests shall:

- a) Any portion of the module or panel or be blown off or fall off the test deck in the form of flaming or glowing brands;
- b) The brand burn a hole through the roof covering or through any part of the module or panel;
- c) Portions of a module or panel intended for installation integral with, or forming a part of, the building roof structure fall away in the form of glowing particles; or
- d) There be sustained flaming of the module or panel.

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32 General

32.1 For both the Spread-Of-Flame and Burning-Brand Tests, the test severity (Class A, B, or C) shall be commensurate with the intended designated Class of roof covering material.

32.2 For both the Spread-Of-Flame and Burning-Brand Tests, the module or panel is to be installed in accordance with the instructions supplied with it. The mounting hardware furnished with the module or panel, or the mounting means recommended in the instructions, is to be used to mount the module or panel for the test. The slope of the module or panel with respect to the horizontal is to be the minimum slope specified in the installation instructions. The slope of the simulated roof deck shall not exceed 5 in/ft (416 mm/m).

32.3 A module or panel is not required to be usable after any of the tests of this section.

32.4 For each fire classification requested, only one of each Burning-Brand and Spread-Of-Flame Tests are required to be conducted.

33 Water Spray Test

33.1 A module or panel shall be subjected to a water spray test as described in 33.2 – 33.8. The test shall not result in water on uninsulated live parts or the collection of water in a compartment containing live parts. Immediately following the test, the module or panel shall comply with:

- a) Dielectric Voltage-Withstand Test, Section 26; and
- b) Leakage Current Test, Section 21.

Both the Dielectric Voltage-Withstand Test and the Leakage Current Test are to be conducted without any drying of the samples.

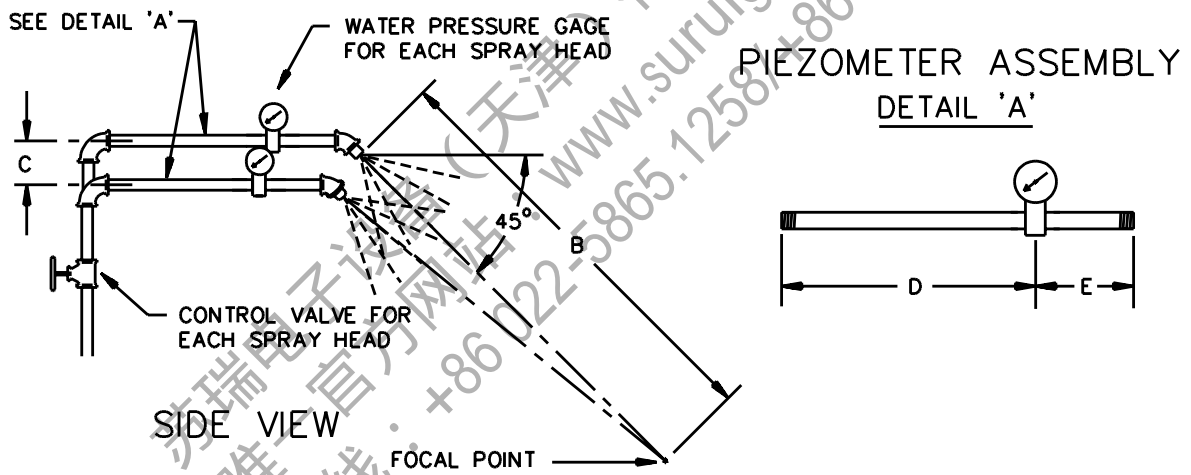
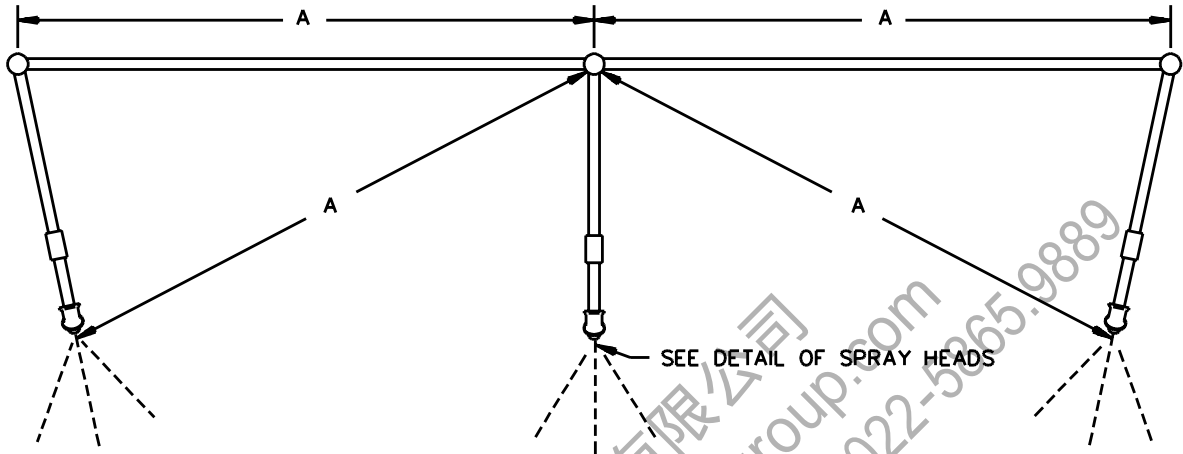
33.2 A module or panel is to be mounted and oriented in a manner representative of its intended use in the focal area of the apparatus described in 33.5. If the mounting or orientation of the module or panel under the water spray may affect the results, the test is to be conducted with the module or panel in those mountings and orientations deemed necessary to represent any application of the product, considering also that the mounting may be on a tracking frame which alters the module orientation.

33.3 If a module or panel is intended to be mounted as an integral part of the roof with an adjacent module or panel in an array using factory-designed joining sections, the test is to be conducted using the joining hardware in accordance with the installation instructions.

33.4 Field wiring connections are to be made in accordance with the wiring method specified in the installation instructions. When more than one wiring method is specified, the method least likely to restrict the entrance of water into the field wiring compartment is to be used.

33.5 The rain test apparatus is to consist of three spray heads mounted in a water supply rack as illustrated in Figure 33.1. Spray heads are to be constructed in accordance with Figure 33.2. The water pressure for all tests is to be maintained at 5 psig (34.5 kPa) at each head. The distance between the center nozzle and the product is to be approximately 3 ft (0.9 m). The product is to be brought into the focal area of the three spray heads in such position and under such conditions so as to present the greatest quantity of water to entrances to the product. The spray is to be directed toward the module or panel at an angle of 45 degrees to the vertical.

Figure 33.1
Rain-test spray-head piping
PLAN VIEW



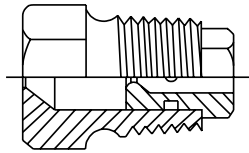
RT101C

Item	in	mm
A	28	710
B	55	1400
C	2-1/4	55
D	9	230
E	3	75

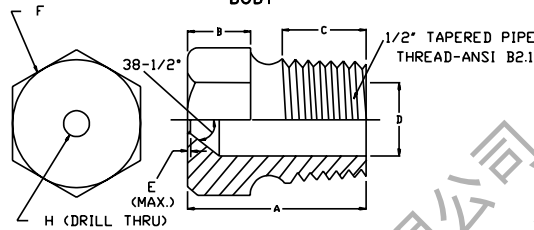
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Figure 33.2
Rain-test spray head

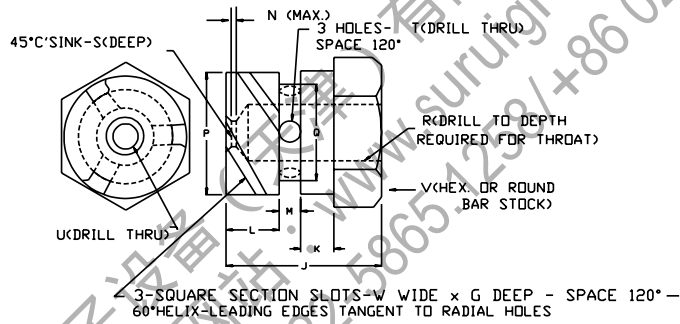
ASSEMBLY^a



BODY



INSERT



SA0820B

Item	in	mm	Item	in	mm
A	1-7/32	31.0	N	1/32	0.80
B	7/16	11.0	P	.575	14.61
C	9/16	14.0	Q	.576	14.63
D	.578	14.68	R	.453	11.51
E	.580	14.73	S	.454	11.53
F	1/64	0.40	T	1/4	6.35
G	c	c	U	1/32	0.80
H	(No. 9) ^b	5.0	V	(No. 35) ^b	2.79
J	23/32	18.3	W	(No. 40) ^b	2.49
K	5/32	3.97	V	5/8	16.0
L	1/4	6.35	W	0.06	1.52
M	3/32	2.38			

^a Molded nylon Rain-Test Spray Heads are available from Underwriters Laboratories, Inc.

^b ANSI B94.11 Drill Size.

^c Optional M To serve as wrench grip.

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33.6 The water for the test is to have a resistivity before the test of 3500 ± 175 ohm-cm at 25°C (77°F). At the conclusion of the test, the resistivity of the water is not to be less than 3200 ohm-cm nor more than 3800 ohm-cm at 25°C .

33.7 The exposure time is to be 1 h.

33.8 After exposure, the module or panel is to be examined for evidence of water penetration to and above uninsulated live parts and for evidence of the collection of water in any compartment containing live parts. If drain holes are provided, consideration is to be given to their preventing the water level from reaching uninsulated live parts.

34 Accelerated Aging Test

34.1 Materials used for gaskets, seals, and the like (other than cork, fibrous material, and similar products) shall have the physical properties as specified in Table 34.1, and shall comply with the physical property requirements of Table 34.2. The material shall not deform, melt, or harden to a degree which would affect its sealing properties.

Table 34.1
Physical property requirements

Table 34.1 revised October 1, 2003

Minimum tensile strength ^a	Minimum ultimate elongation ^a	Compressive set ^c , maximum set
Silicone rubber – 500 psi (3.45 MPa)	100 percent	15 percent
Flexible cellular materials (that is such as foam rubber) – 65 psi (0.448 MPa)	100 percent	d
Other Elastomers – 1500 psi (10.3 MPa) ^b	300 percent ^b	15 percent
Nonelastomers (excluding cork, fiber and similar materials)– 1500 psi (10.3 MPa) ^b	200 percent	15 percent

^a Tensile strength and ultimate elongation are to be determined using Die C specimens described in the Standard Test Methods for Rubber Properties in Tension, ASTM D 412-98 or Type I specimens described in the Standard Test Method for Tensile Properties of Plastics, ASTM D 638-01.

^b As an alternate, an ultimate elongation of 200 percent is acceptable providing that the tensile strength is at least 2200 psi (15.1 MPa).

^c Compressive set is to be determined 30 min after specimen release using the Standard Test for Rubber Property-Compression Set, ASTM D395-01, Method B.

^d Compressive set is not applicable to flexible cellular materials.

Table 34.2
Physical requirements after conditioning

Table 34.2 revised October 1, 2003

Temperature on material in temperature test		Conditioning Procedure	Minimum percent of the result with unaged specimens		Maximum change (Duro) from unconditioned value ^{a,b}
°C	(°F)		Tensile strength	Ultimate elongation	
60 or less	(140 or less)	Air oven aging for 70 h at 100 ±2°C (212 ±3.6°F)	60	60	5
61 – 75	(142 – 167)	Air oven aging for 168 h at 100 ±2°C (212 ±3.6°F)	50	50	5
76 – 90	(169 – 194)	Aged in full-draft, air-circulating oven for 168 h at 121 ±2°C (250 ±2°F)	50	50	10
91 – 105	(196 – 221)	Aged in full-draft, air-circulating oven for 168 h at 136 ±2°C (277 ±2°F)	50	50	10
Above 105	(Above 221)	20 ±1°C (36 ±2°F) greater than use temperature in circulating convection oven, 168 h exposure	50	50	10

^a Determined in accordance with the Standard Method for Rubber Property-Durometer Hardness, ASTM D2240-02.
^b Not applicable to flexible cellular materials (that is, a material such as foam rubber).

35 Temperature Cycling Test

35.1 A module or panel shall be subjected to 200 cycles of temperature change as described in 35.2 – 35.4; and:

- a) The test shall not result in:
- 1) Loss of circuit continuity;
 - 2) Accessibility of parts that involves a risk of electric shock, such as by delamination or separation of materials;
 - 3) A reduction in the resistance between parts involving a risk of electric shock and an accessible part such that the module or panel is not in compliance with Leakage Current Test, Section 21;
 - 4) Reduction in the thickness of the wall of a nonmetallic wiring compartment below required values;
 - 5) Reduction in the volume of a nonmetallic wiring compartment below required values; or
 - 6) A gap greater than 1/16 in (1.6 mm) or an increase of 1/16 in or more in an existing opening between nonmetallic wiring compartment walls and the cover;
- b) The module or panel shall comply with Dielectric Voltage Withstand Test, Section 26, at 50°C (122°F) or higher and also at room temperature;

- c) Immediately following the Dielectric Voltage-Withstand Test, the module or panel shall comply with Leakage Current Test, Section 21;
- d) Following the Leakage Current Test, the module or panel shall comply with Wet Insulation-Resistance Test, Section 27;
- e) A module or panel with a wiring compartment as described in 13.1.6 shall comply with Wiring Compartment Securement Test, Section 42, following the Wet Insulation-Resistance Test; and
- f) A module or panel with a wiring compartment as described in 13.1.6 shall comply with Wet Insulation-Resistance Test, Section 27, following the Wiring Compartment Securement Test.

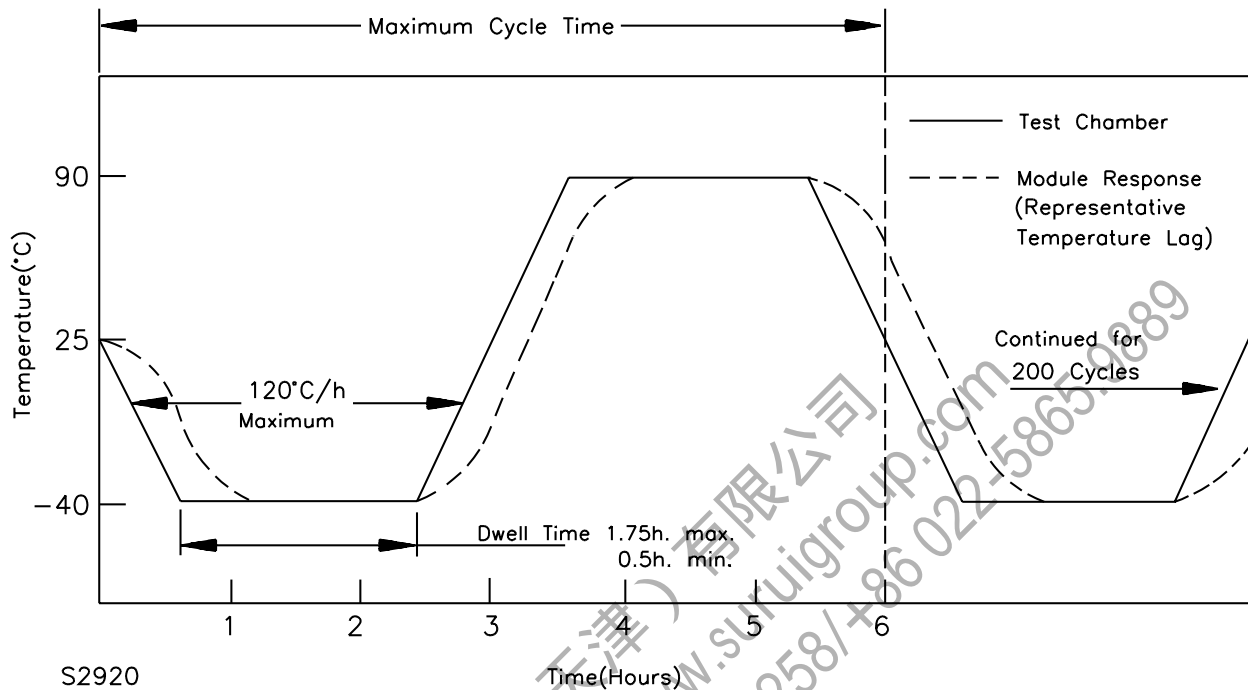
35.2 Three samples of a module or panel are to be placed in an air circulating chamber, the temperature and humidity of which can be varied and controlled. The humidity is to be regulated only as required to prevent the accumulation of humidity on the samples. Leads are to be connected to the terminals and the frame of the samples to provide for continuous individual detection of loss of circuit continuity and loss of resistance between the electrical circuit and accessible metal.

35.3 The samples are to be mounted or supported in the chamber, so as to provide for free circulation of the surrounding air. The thermal conduction of the mount or support means is to be low, so that the samples are thermally isolated.

35.4 Each test is to consist of:

- a) A transition in test chamber temperature from 25°C to minus 40°C (77°F to minus 40°F);
- b) A dwell at minus 40°C for 30 min or until the module or panel attains a temperature within 2°C (4°F) of the chamber temperature, whichever is longer, but in no case longer than 1 h, 45 min;
- c) A transition in test chamber temperature from minus 40°C to 90°C (194°F);
- d) A dwell at 90°C for 30 min or until the module or panel attains a temperature within 2°C of the chamber temperature, whichever is longer, but in no case longer than 1 h, 45 min; and
- e) A transition in test chamber temperature from 90°C to 25°C. The total cycle time is not to exceed 6 h. If the 25°C temperature is the start or end of the 200 cycles, any nominal room temperature in the range of 15°C – 35°C (59°F – 95°F) may be used. For all transitions, the instantaneous rate of temperature change of the test chamber with respect to time is not to be greater than 120°C/h (216°F/h). See Figure 35.1.

Figure 35.1
Thermal cycle test



36 Humidity Test

36.1 A module or panel shall be subjected to 10 cycles of humidity-freezing as described in 36.2 – 36.6; and:

a) The test shall not result in:

- 1) Loss of circuit continuity;
- 2) Accessibility of parts that involves a risk of electric shock, such as by delamination or separation of materials;
- 3) A reduction in the resistance between a part involving a risk of electric shock and an accessible part such that the module or panel is not in compliance with the Leakage Current Test, Section 21;
- 4) Corrosion of metal parts;
- 5) Reduction in the thickness of the wall of a nonmetallic wiring compartment below required values;
- 6) Reduction in volume of a nonmetallic wiring compartment below required values; or
- 7) A gap greater than 1/16 in. (1.6 mm) or an increase of 1/16 in or more in an existing opening between nonmetallic wiring compartment walls and the cover.

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- b) Immediately following the test, the module or panel shall comply with Dielectric Voltage-Withstand Test, Section 26.
- c) The module or panel shall comply with Leakage Current Test, Section 21, immediately following the Dielectric Voltage-Withstand Test;
- d) Following the Leakage Current Test, the module or panel shall comply with Wet Insulation-Resistance Test, Section 27;
- e) A module or panel with a wiring compartment as described in 13.1.6 shall comply with Wiring Compartment Securement Test, Section 42, following the Wet Insulation-Resistance Test; and
- f) A module or panel with a wiring compartment as described in 13.1.6 shall comply with Wet Insulation-Resistance Test, Section 27, following the Wiring Compartment Securement Test.

36.2 Three samples of a module or panel are to be placed in a chamber, the humidity and temperature of which can be varied and controlled. Leads are to be connected to the terminals and the frame if necessary, of the samples, to allow for continuous individual detection of loss of circuit continuity and loss of resistance between the electrical circuit and accessible metal.

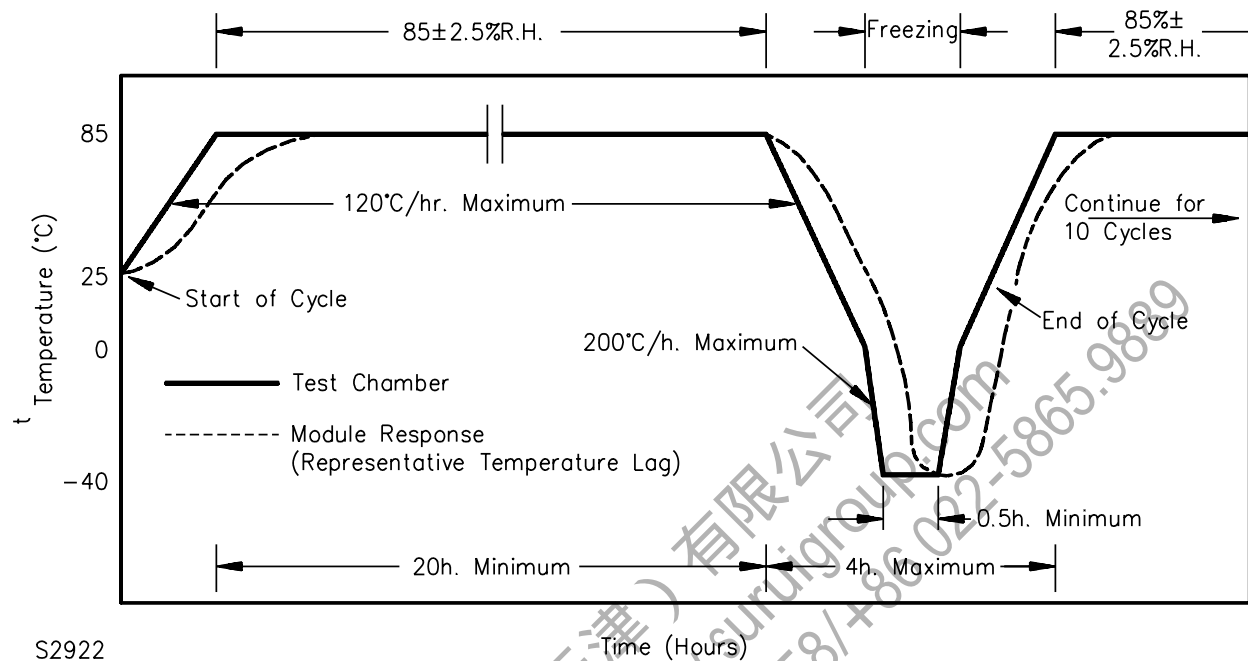
36.3 The samples are to be mounted or supported in the chamber, so as to provide for free circulation of the surrounding air. The thermal conduction of the mount or support means is to be low, so that the samples are thermally isolated.

36.4 The test apparatus and arrangement of samples is to be such that dripping of condensate on a sample is prevented. Terminations are to be afforded the least degree of protection against condensation of water as they would be in any intended installation of the product.

36.5 Each cycle is to consist of:

- a) A transition in the test chamber temperature from 25°C to 85°C (77°F to 185°F);
- b) A dwell at 85°C for 20 h minimum;
- c) A transition from 85°C to minus 40°C (minus 40°F);
- d) A dwell at minus 40°C for 30 minutes minimum; and
- e) A transition from minus 40°C to 25°C. When the temperature is 0°C (32°F) or above, the temperature transitions of the test chamber with respect to time are not to be greater than 120°C/h (216°F/h). When the temperature is less than 0°C, the temperature transitions of the test chamber with respect to time are not to be greater than 200°C/h (360°F/h). The total time for the transitions and the minus 40°C dwell together is not to exceed 4 h. If the 25°C temperature is the start or end of the 10 cycles, any nominal room temperature in the range 15°C – 30°C (59°F – 86°F) may be used. The total cycle time is not to exceed 24 h. See Figure 36.1.

Figure 36.1
Humidity-freezing cycle test



36.6 The humidity of the chamber air when the chamber air temperature is 85°C (185°F) is to be 85 ±2.5 percent relative humidity. During all temperature transitions the chamber air is to be isolated from the outside air (no make-up air) to avoid condensing water vapor to freeze in the module or panel.

37 Corrosive Atmosphere Test

37.1 Salt spray test

37.1.1 One complete sample of the module or specimen samples of materials representative of that used in the module shall be subjected to the salt spray test as described in 37.1.3 – 37.1.11.

Exception: A module constructed of materials such as plastic, stainless steel, or aluminum that are inherently resistant to atmospheric corrosion need not be tested.

37.1.2 With reference to 37.1.1, after the test, the corrosion products formed on the test sample shall not be more than that formed on the reference sample as determined by visual observation. Corrosion in the scribed line area is judged by the spread of corrosion from the scribed line.

37.1.3 The apparatus for salt spray testing is to consist of a chamber with inside measurements of 48 in by 30 in by 36 in (1.22 m by 0.76 m by 0.91 m) or larger if required; a salt solution reservoir; a supply of conditioned compressed air; one dispersion tower constructed in accordance with ASTM designation B117-97, for producing a salt spray; specimen supports; provision for heating the chamber; and necessary means of control.

37.1.3 revised October 1, 2003

37.1.4 The dispersion tower for producing the salt spray is to be located in the center of the chamber and is to be supplied with humidified air at a gauge pressure of 17 to 19 lb/in² (117 to 131 kPa) so that the solution is aspirated as a fine mist or fog into the interior of the chamber.

37.1.5 The salt solution is to consist of 5 percent by weight of common salt (sodium chloride) in distilled water. The pH value of the collected solution is to be between 6.5 and 7.2 and have a specific gravity between 1.026 and 1.040 at 95°F (35°C). The temperature of the chamber is to be maintained within the range of 92°F to 97°F (33°C to 36°C) throughout the test.

37.1.6 The test sample is to be supported on plastic racks at an angle of 15 degrees from the vertical.

37.1.7 Drops of solution which accumulate on the ceiling or cover of the chamber are to be diverted from dropping on the specimen. Drops of solution which fall from the specimens are not to be recirculated, but are to be removed by a drain located in the bottom of the apparatus.

37.1.8 Reference specimens, 4 in by 12 in (102 mm by 305 mm) of commercial zinc coated sheet steel are to be used for comparison. The selected specimens are to be representative of the minimum acceptable amount of zinc coating under requirements for G90 or G60 coating designation (as applicable, see Accessibility of Uninsulated Parts, Section 15) as determined in accordance with the Standard Test Method for Weight of Coating on Zinc-Coated (Galvanized) Iron or Steel Articles, ASTM A90-81(1991) Such zinc coatings are considered as providing acceptable protection against corrosion.

37.1.9 The zinc coated reference specimens are to be cleaned with soap and water, rinsed with ethyl alcohol and ethyl ether, dried, and the cut edges protected with paint, wax, or other effective medium before being placed in the salt spray chamber.

37.1.10 Both the reference specimen and the samples under test are to be scribed with a single groove approximately 6 in (152 mm) long, to expose the underlying steel.

37.1.11 The test is to continue until the coating on the test samples or reference samples are broken down and corrosion products are formed on the underlying steel.

37.2 Moist carbon dioxide/sulphur dioxide

37.2.1 One complete sample of the module or specimen samples of materials representative of that used in the module shall be subjected to the Moist Carbon Dioxide/Sulphur Dioxide Test as described in 37.2.3 – 37.2.9.

Exception: A module constructed of materials such as plastic, stainless steel or aluminum that are inherently resistant to atmospheric corrosion need not be tested.

37.2.2 The corrosion products formed on the test sample shall be no more than that formed on the reference sample as determined by visual observation. Corrosion in the scribed line area is to be judged by the spread of corrosion from the scribed lines.

37.2.3 A chamber measuring 48 in by 30 in by 36 in (1.22 m by 0.76 m by 0.91 m) or larger if required, having a water jacket and a thermostatically controlled heater in order to maintain a temperature of 95 ±3°F (35 ±2°C) is to be used.

37.2.4 Sulphur dioxide and carbon dioxide are to be supplied to the test chamber from commercial cylinders containing these gases under pressure. An amount of sulphur dioxide equivalent to 1 percent of the volume of the test chamber and an equal volume of carbon dioxide are to be introduced into the chamber each day. Prior to introducing the new charge of gas each day, the remaining gas from the previous day is to be purged from the chamber. A small amount of water is to be maintained at the bottom of the chamber for humidity.

37.2.5 The samples are to be supported on plastic racks at an angle of 15 degrees from the vertical.

37.2.6 Reference specimens, 4 in by 12 in (102 mm by 305 mm) of commercial zinc coated sheet steel are to be used for comparison. The selected specimens are to be representative of the minimum acceptable amount of zinc coating under requirements for G90 or G60 coating designation (as applicable, see Corrosion Resistance, Section 15) as determined in accordance with the Standard Test Method for Weight of Coating on Zinc-Coated (Galvanized) Iron or Steel Articles, ASTM A90-81(1991). Such zinc coatings are considered as providing acceptable corrosion protection.

37.2.7 The zinc coated specimens are to be cleaned with soap and water, rinsed with ethyl alcohol and ethyl ether, dried, and the cut edges protected with paint, wax, or other effective media before being placed in the chamber.

37.2.8 Both the reference specimen and sections of the module being tested are to be scribed with a single groove approximately 6 in (152 mm) long, to expose the underlying steel.

37.2.9 The test is to continue until the coating on the module or reference specimen is broken down and corrosion products are formed on the underlying steel.

38 Metallic Coating Thickness Test

38.1 The method for determining the thickness of a zinc or cadmium coating mentioned in 14.1 and 14.2 is described in 38.2 – 38.9.

38.2 The solution to be used for the metallic coating thickness test is to be made from distilled water and is to contain 200 g/L of reagent (or better) grade chromium trioxide (CrO_3) and 50 g/l of reagent (or better) grade concentrated sulfuric acid (H_2SO_4). The latter is equivalent to 27 ml/l of reagent grade concentrated sulphuric acid, specific gravity 1.84, containing 96 percent of H_2SO_4 .

38.3 The test solution is to be contained in a glass vessel such as a separatory funnel with the outlet equipped with a stopcock and a capillary tube of approximately 0.025 in (0.64 mm) inside bore and 5.5 in (150 mm) long. The lower end of the capillary tube is to be tapered to form a tip, the drops from which are about 0.05 milliliter each. To preserve an effectively constant level, a small glass tube is to be inserted in the top of the funnel through a rubber stopper and its position is to be adjusted so that when the stopcock is open, the rate of dropping is 100 ± 5 drops/min. If desired, an additional stopcock may be used in place of the glass tube to control the rate of dropping.

38.4 The sample and the test solution are to be kept in the test room long enough to acquire the temperature of the room, which should be noted and recorded. The test is to be conducted at a room temperature of $70.0^\circ\text{F} - 90.0^\circ\text{F}$ ($21.2^\circ\text{C} - 32.0^\circ\text{C}$).

38.5 The sample is to be thoroughly cleaned before testing. All grease, lacquer, paint, or other nonmetallic coatings, including skin oils, are to be removed completely by means of solvents. The sample is then to be thoroughly rinsed in water and dried with clean cheesecloth.

38.6 The sample to be tested is to be supported from 0.7 in to 1 in (17 mm to 25 mm) below the orifice. The surface to be tested shall be inclined at approximately 45 degrees from the horizontal so that the drops of solution strike the point to be tested and run off quickly.

38.7 The stopcock is to be opened and the time in seconds is to be measured until the dropping solution dissolves the protective metal coating, exposing the base metal. The end point is the first appearance of the base metal recognizable by the change in color at that point.

38.8 The sample of a test lot is to be subjected to the test at three or more points, excluding cut, stenciled, and threaded surfaces, on the inside surface and at an equal number of points on the outside surface, at places where the metal coating may be expected to be the thinnest. (On enclosures made from precoated sheets, the external corners that are subjected to the greatest deformation are likely to have thin coatings.)

38.9 To calculate the thickness of the coating being tested, select from Table 38.1 the thickness factor appropriate for the temperature at which the test was conducted and multiply by the time in seconds required to expose base metal as noted in 38.7.

Table 38.1
Metallic coating thickness factors

Temperature		Thickness factors, 0.00001 in/s (0.00025 mm/s)	
°F	(C)	Cadmium platings	Zinc platings
70	(21.1)	1.331	0.980
71	(21.7)	1.340	0.990
72	(22.2)	1.352	1.000
73	(22.8)	1.362	1.010
74	(23.3)	1.372	1.015
75	(23.9)	1.383	1.025
76	(24.4)	1.395	1.033
77	(25.0)	1.405	1.042
78	(25.6)	1.416	1.050
79	(26.1)	1.427	1.060
80	(26.7)	1.438	1.070
81	(27.2)	1.450	1.080
82	(27.8)	1.460	1.085
83	(28.3)	1.470	1.095
84	(28.9)	1.480	1.100
85	(29.4)	1.490	1.110
86	(30.0)	1.501	1.120
87	(30.6)	1.513	1.130
88	(31.1)	1.524	1.141
89	(31.7)	1.534	1.150
90	(32.2)	1.546	1.160

39 Hot-Spot Endurance Test

39.1 General

39.1.1 Each representative cell of a module or panel shall be subjected to simulated reverse voltage hot-spot heating conditions for 100 h, intermittently, as described in 39.1.2 – 39.9.8. The test shall not result in:

- a) The accessibility of parts involving a risk of electric shock;
- b) Melting of solder; or
- c) Any other indication of a risk of fire or electric shock.

39.1.2 The reverse voltage hot-spot heating condition specified in 39.1.1 occurs when a module is operating at current levels that exceed the reduced short-circuit current capability of an individual cell or group of cells in an array circuit. This reduced short-circuit current capability can be the result of a variety of causes including nonuniform illumination of the module (local shadowing), individual cell degradation due to cracking, or loss of a portion of a series-parallel circuit due to individual interconnect open circuits. A module can operate at current levels exceeding its reduced short-circuit current capability during uncontrolled or deliberate fault conditions such as a short circuit deliberately placed on the module for servicing or to otherwise disable the array. During a reverse voltage hot-spot heating condition, power is dissipated in the overcurrented cell or cells at a level equal to the product of the current and the reverse voltage that develops across the cell or cells. This can heat the cell or cells to elevated temperatures.

39.1.3 The procedure for conducting this test is as follows:

- a) Selection and connection of power sources and instruments to appropriate cells for testing,
- b) Determination of the hot-spot test levels, and
- c) Conduction of the hot-spot endurance test.

39.2 Cell selection and instrumentation

39.2.1 The degree of hot-spot heating within an affected cell is dependent upon, in part, the reverse-voltage current-voltage (I-V) characteristics of the affected cell. The reverse-voltage I-V characteristics may vary considerably from cell-to-cell within a given module. Accordingly, the range of the dark reverse-voltage I-V curves for a representative sample of cells (at least ten) within the test module are to be determined in accordance with 39.2.2 – 39.5.5. This can be done by directly accessing individual cells (intrusive method), or by shadowing technique (nonintrusive method) if the module is a simple series string of cells. The intrusive-nonintrusive option relates to cell selection only. All cells subjected to hot-spot endurance shall be individually accessed.

39.2.2 The dark, reverse-voltage current-to-voltage (I-V) curves for not less than ten cells within the module, modules, or panel, are to be determined using one of the following equations for reverse voltages from 0 (zero) to the maximum voltage limit (V_L) or currents from 0 (zero) to the maximum current limit (I_L), whichever limit is reached first:

$$I_L = I_{SC}, \text{ or}$$

$$V_L = N \times V_{mp}$$

In which:

I_{SC} is the short-circuit current of an average cell at 100 mW/cm², NOCT.

N is the number of series cells per bypass diode:

- a) As an integral part of the module or panel, or
- b) As is described for use with the module or panel in a marking affixed to the module or panel whichever is less. See 47.9.

V_{mp} is the average maximum power voltage of an average cell at 100 mW/cm², NOCT.

When no bypass diode information is provided, N shall be equal to the number of series cells.

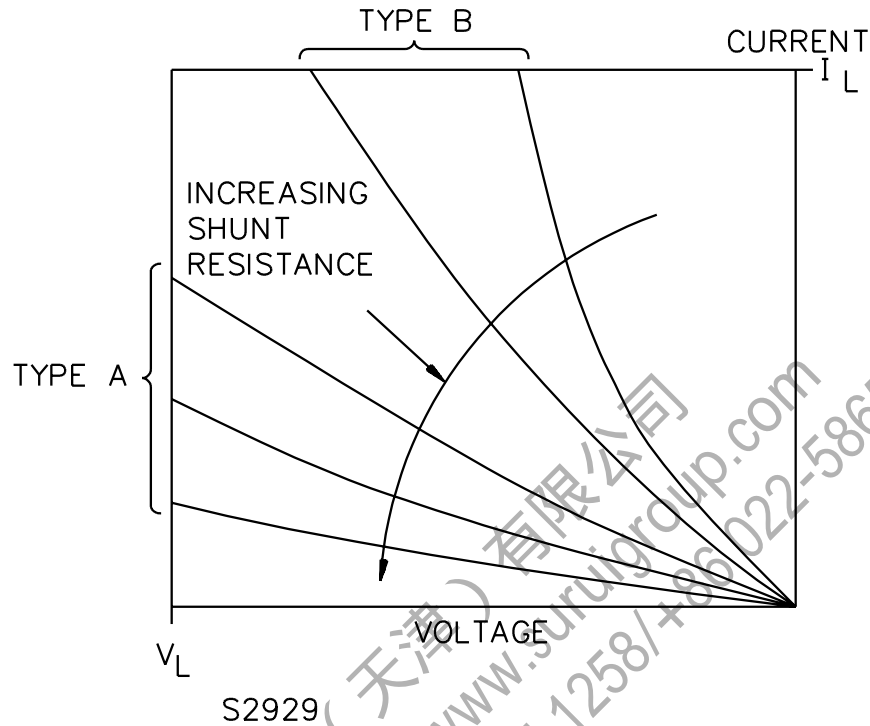
39.3 Intrusive method

39.3.1 With reference to 39.2.2, for the determination of cell I-V characteristics by the intrusive method, each cell tested is to be provided with individual positive and negative electrical leads to allow it to be accessed independently of other cells.

39.3.2 The reverse voltage I-V curves of the tested cells are to be plotted. See 39.3.3. The cells are to be identified as Type A (voltage limited) or Type B (current limited). A graph similar to Figure 39.1 should be obtained.

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Figure 39.1
 Typical reverse-voltage I-V plot for sample cells



39.3.3 With reference to 39.3.2, the I-V plot will require a power supply to be connected to the cell under test, with the polarity arranged to drive the cell with reverse voltage. The cells are not to be illuminated during this determination.

39.4 Nonintrusive method

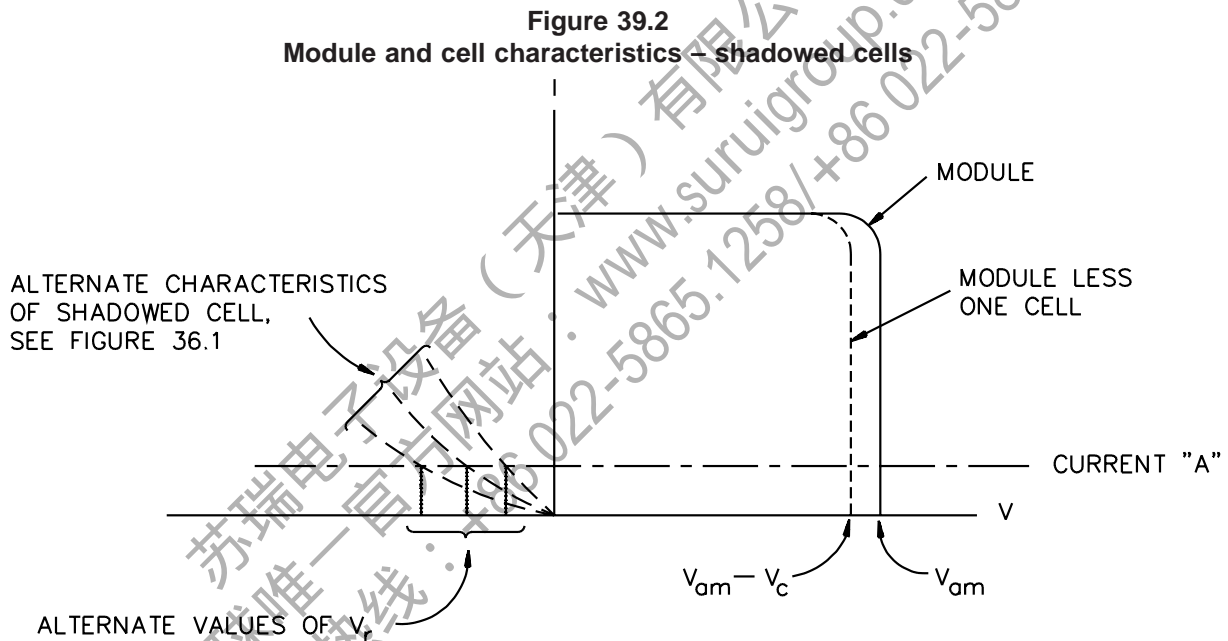
39.4.1 The nonintrusive method may be used to determine cell I-V characteristics only if the module consists of a single series string of cells without bypass diodes. This method consists of uniformly illuminating all but one of the cells, while passing a known current (less than the illuminated short-circuit current) through the module. This results in reverse biasing the shadowed cell, while the remaining illuminated cells are in their normal forward-biased condition.

39.5 Theory and method of cell selection

39.5.1 For example, at the particular known current level, A in Figure 39.2, the output voltage at the module terminals (V_o) under the condition of one cell shadowed will be the normal output voltage of the module with all cells illuminated (V_{am}), less the voltage of one cell (V_c), less the reverse voltage of the shadowed cell (V_r), that is:

$$V_o = V_{am} - V_c - V_r$$

The module's normal output voltage and voltage of one cell, both at a particular current level are fixed. The reverse voltage of a cell at a particular current level is variable, cell-to-cell, being higher for higher shunt resistances. Thus, shadowing of the highest shunt resistance cell will result in lowest module output voltage, and shadowing of the lowest shunt resistance cell will result in the highest module voltage.



S2925A

39.5.2 To determine the relative cell I-V characteristics by the nonintrusive method, the module is to be connected to a variable resistor so that the output current may be maintained at a fixed level under conditions of shadowing any one cell (same current regardless of which cell is shadowed). The module is to be illuminated under a source which can illuminate all cells at a repeatable and uniform intensity. The module temperature is to be monitored and is to remain constant. Normally, these conditions can be achieved by outdoor testing under sunlight.

39.5.3 With the module connected and illuminated as described in 39.5.2, each cell in turn is to be shadowed, the resistor is to be adjusted to maintain the current at the preselected fixed value, and the output voltage of the module measured. The cell that is shadowed when the output voltage is maximum is the cell with minimum shunt resistance, and the cell that is shadowed when the output voltage is minimum is the cell with maximum shunt resistance. Intermediate shunt resistance cells will have intermediate module voltage outputs.

39.5.4 The nonintrusive method is relative only, and in the manner presented does not provide a numerical value of any of the resistances. The cells of a module may be all voltage limited (high shunt resistance, Type A), all current limited (low shunt resistance, Type B), or a combination of both – see 39.3.2. In general, the cells associated with the highest hot-spot heating levels are those with the highest shunt resistance, although low shunt resistance may be associated with highly localized heating.

39.5.5 Three nonadjacent individual cells within the test module or panel are to be selected: one representative of the highest shunt resistance obtained, one representative of the average, and one representative of the lowest. Each cell to be tested is to be provided with individual positive and negative electrical leads to allow the cells to be connected individually and directly to separate power supplies. Parallel current paths around the cells to be tested are to be eliminated by disrupting cell-to-cell connections as necessary. The lead attachment should minimize disruption of the heat transfer characteristics of the cell or the hot-spot endurance of the encapsulant system.

39.6 Selection of hot-spot test level

39.6.1 The objective of this portion of the test procedure is to select the level of heating and the corresponding test condition that will stress the module or panel in a manner similar to a severe hot-spot field condition. The severity of the field condition will depend on the array circuit configuration, the array I-V operating point, the ambient thermal conditions, the overall irradiance level, and the previously described characteristics of the affected cells. When a module is incorporated into a photovoltaic source circuit, the maximum reverse voltage imposed on an individual cell can approach the system voltage unless bypass diodes are properly used. V_L is set to yield the maximum reverse voltage that can be applied across a single cell when the module is applied in a circuit with the minimum number of bypass diodes as specified by its marking.

39.6.2 Thermocouples are to be affixed to the cell insulation system. See 19.11 and 19.12.

39.6.3 In 39.7.1 – 39.8.1, the detailed levels are separately specified for Type A and Type B cells.

39.6.4 The test is to be conducted in an ambient air temperature of $20 \pm 5^\circ\text{C}$ ($68 \pm 9^\circ\text{F}$) and with a radiant heating source that will result in a uniform background module cell temperature equal to $\text{NOCT} \pm 2^\circ\text{C}$ ($\pm 4^\circ\text{F}$).

39.7 Type A cells (high shunt resistance)

39.7.1 The governing parameters concerning reverse voltage heating are:

- a) The maximum cell reverse voltage (V_L),
- b) The cell irradiance level, and
- c) The ambient thermal environment.

39.7.2 V_L is to be set equal to N times the V_{mp} of an individual cell, where N is the number of series cells per specified or integral bypass diode.

39.7.3 The irradiance level directly controls the hot-spot current level, and therefore the power level. As illustrated in Figure 39.3, there is a unique irradiance level that corresponds to worst-case power dissipation for any particular Type A photovoltaic cell. The irradiance level on the test cell is to be adjusted to achieve this worst case power dissipation with the current adjusted to I_{TEST} , where I_{TEST} = the maximum power current of the cell at 100 mW/cm², NOCT.

39.8 Type B cells (low shunt resistance)

39.8.1 The cell shunt resistance of a Type B cell is so low that the maximum reverse voltage is set by the I-R drop across the cell. Worst-case heating occurs when the test cell is totally shadowed, and the current level is at a maximum. Accordingly, the irradiance is not to be more than 5 mW/cm². This irradiance level allows for room lighting and an IR heating source. The current (I_L) is to be equal to the short-circuit current of an average cell at 100 mW/cm², NOCT.

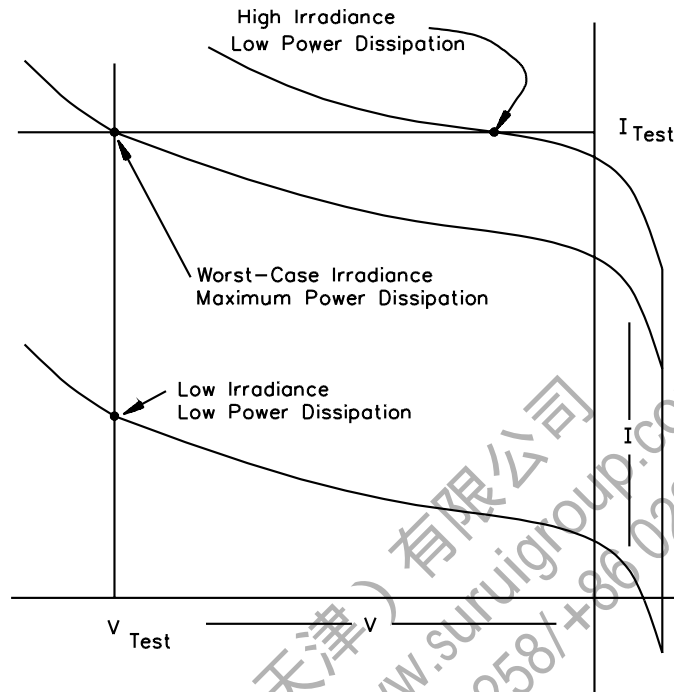
39.9 Test execution

39.9.1 The three selected test cells are to be subjected to cyclic hot-spot heating at the level determined in accordance with 39.7.3 or 39.8.1 for a period of 100 h total on-time as specified in 39.9.2 – 39.9.6.

39.9.2 A constant voltage power supply (for Type A cells) and a constant current power supply (for Type B cells) is to be connected to the cell under test, with the polarity arranged to drive the cells with reverse voltage. The voltage is to be adjusted to V_L , and then the current is to be adjusted to I_{TEST} (for Type A cells) or I_L (for Type B cells). See 39.7.2 – 39.8.1.

39.9.3 An infrared radiant heating source with a visible light contribution below 5 mW/cm² is to be applied to the module or panel and adjusted to result in a uniform module cell temperature equal to NOCT $\pm 2^\circ\text{C}$ ($\pm 4^\circ\text{F}$). The ambient air is to be still and at a temperature of $20 \pm 5^\circ\text{C}$ ($68 \pm 9^\circ\text{F}$).

Figure 39.3
Effect of test-cell illumination level on hot-spot power dissipation



S2921

39.9.4 For a Type A cell, an additional light source is to be used to illuminate each test cell to the level determined in 39.7.3 (Figure 39.3). The illumination is most easily accomplished after the power supply and IR source are turned on by adjusting the irradiance level to achieve the I_{TEST} current after equilibrium test conditions stabilize.

39.9.5 The power supply, IR source, and irradiance source are to be energized for 1 h followed by an off-period sufficient to allow the cells under test to cool to within 10°C (18°F) of the ambient temperature.

39.9.6 The operation is to be repeated until a total of 100 h of on-time have been accumulated.

39.9.7 the test cells and the adjacent areas of the encapsulation system are to be visually inspected at 24-h intervals during the test while the cells are under impressed voltage conditions and also upon completion of the 100 h of on-time operation.

39.9.8 At the conclusion of the test, the module is to be inspected for visible signs of melted solder, openings in the enclosure, delamination, and burn spots on the substrate.



40 Arcing Test

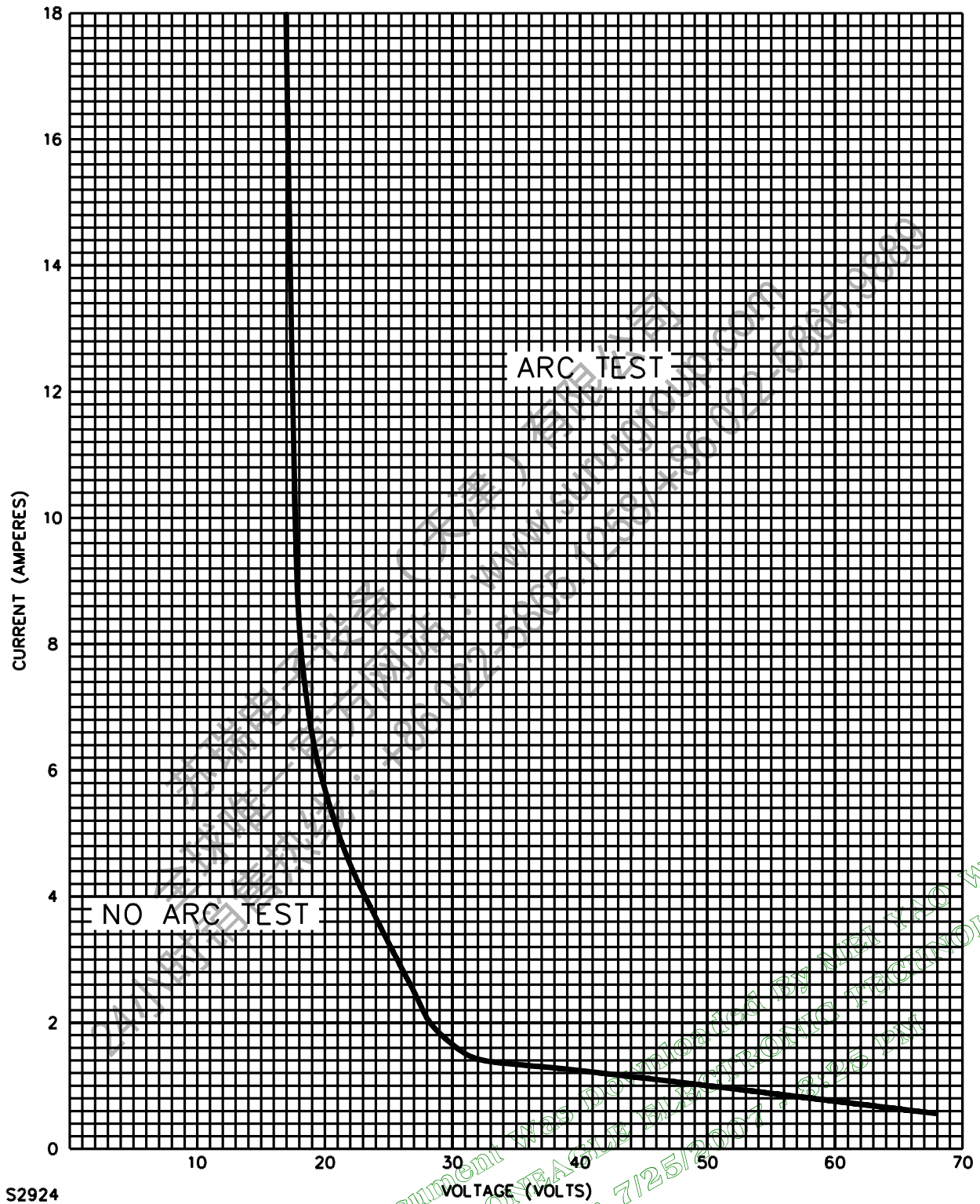
40.1 General

40.1.1 If the point of current (at rated operating voltage) and voltage (V_L as determined from the relationship given in 39.2.2) that can appear across a cell or interconnect fracture is in the "ARC TEST" zone in Figure 40.1, the module or panel shall comply with the provisions of 40.1.2 – 40.6.3. See also 47.9.

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Figure 40.1
Currents and voltages for arc test



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40.1.2 With reference to 40.1.1, during conditions of simulated cell or interconnect fracture, there shall be no ignition of the module or panel.

40.2 Method A

40.2.1 Similar modules or panels to be tested are to be connected in series to achieve an open-circuit voltage across the fracture equal to that which is present during normal use of the modules or panels with the specified bypass diodes. The modules and panels are to be irradiated at 80 mW/cm^2 or more at $20 - 30^\circ\text{C}$ ($68 - 86^\circ\text{F}$).

40.3 Method B

40.3.1 A single module or panel is to be used with a separate power supply as described in 40.5.2 connected in series to provide the remainder of the source. The module or panel under test is to be irradiated at 80 mW/cm^2 or more at $20^\circ\text{C} - 30^\circ\text{C}$ ($68^\circ\text{F} - 86^\circ\text{F}$).

40.4 Methods A and B

40.4.1 All bypass diodes, either included with the module or panel or described in the markings shall be included in the test circuit.

40.5 Method C

40.5.1 A single module or panel is to be used to provide the material for the ignition attempt. However, all power in the arc is to be provided by an external power supply as described in 40.5.2 connected in series with only passive portions of the module's circuit. Cells are to be jumpered if necessary to involve specific portions of the module or panel insulation system.

40.5.2 With reference to 40.3.1 and 40.5.1 the power supply is to be a constant voltage supply with a series connected current-limiting resistor. The parameters of the total system are to be as follows:

- a) Open-Circuit Voltage – The voltage that is across the fracture during normal use of the modules or panels with the specified bypass diodes.
- b) Short-Circuit Current – Not less than 80 percent nor more than the rated module or panel short-circuit current, when the current-limiting resistor is adjusted so that the voltage across the module or panel being tested is zero.

40.6 All methods

40.6.1 The system load is to be a short circuit.

40.6.2 Any connection(s) within the module or panel may be broken (fractured). The breaks are to be chosen to achieve a worst case condition of maximum open-circuit voltage and/or maximum short-circuit current at one of the chosen break points.

Exception: Any electrical connection made with wire of circular cross section or flexible braided construction that is mechanically secured to its connection points is not to be broken. Braided or stranded wire shall not have any process performed on it that reduces its flexibility. Solder coating of a portion of the wire at the connection points is acceptable.

40.6.3 An arc is to be drawn across the breaks, with the arc across the material of the module or panel that it might contact during use of the module or panel. The arcing is to be continued for 15 min at each location tested.

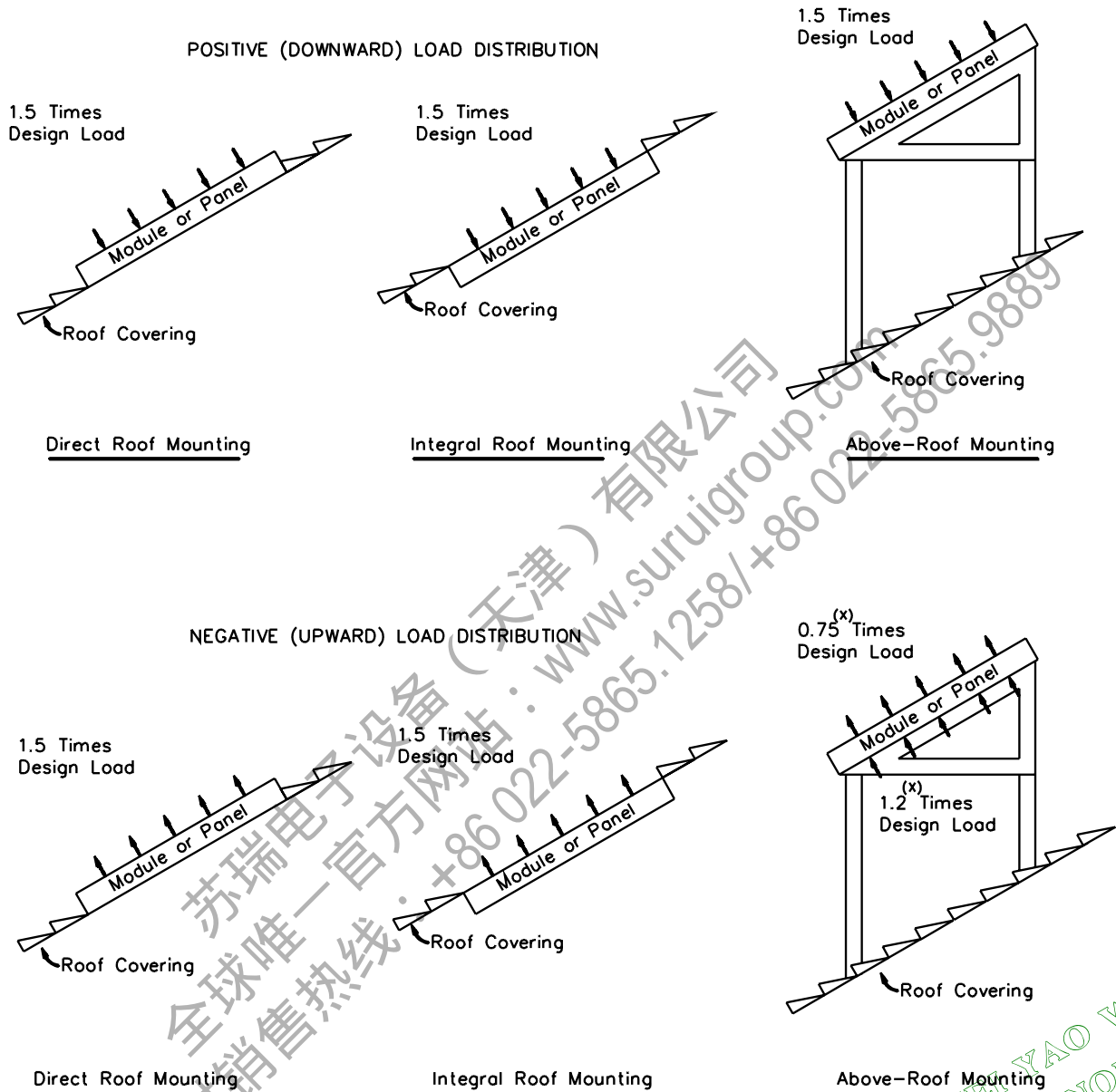
41 Mechanical Loading Test

41.1 A module or panel and any mounting hardware supplied with the module or panel shall withstand a load as shown in Figure 41.1 and specified in 41.2 for a period of 30 min, without evidence of structural or mechanical failure. Modules that are intended to be installed as part of a building wall or roof structure, and serve as primary members of that structure, shall not have a deflection of more than $L/240$; where "L" is equal to the clear span length in feet of the deflected member. All glazing materials shall be of such strength as to withstand the loads specified in 41.2.

41.2 The design load is to be 30 lb/ft² (146.5 kg/m²) positive (downward) or negative (upward); or a design load designated by the manufacturer, whichever is greater. A load of 1.5 times the design load shall be applied for all tests other than the negative (upward) load on the above-roof mounting configuration, as noted in Figure 41.1. The downward and upward loads shall not be applied simultaneously.

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Figure 41.1
Load application



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NOTE: ^(x) The basic load distribution factors for this mounting configuration are 0.5 for the suction load and 0.8 for the uplift load. These factors multiplied by 1.5 result in the indicated factors of 0.75 and 1.2.

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42 Wiring Compartment Securement Test

42.1 The tensile force required to separate a wiring compartment or box from a module shall not be less than 35 lbf (155.7 N) or 4 times the wiring compartment or box weight, whichever is greater, when tested as specified in 42.2 and 42.3. For a test in which the superstrate or substrate fails prior to the adhesive, the force required to cause the superstrate or substrate to fail shall be used to determine compliance, and shall not be less than the specified minimum separation force.

42.2 Seven assemblies consisting of a wiring compartment or box secured to a module with adhesive as intended are to be tested. One assembly is to be tested in the as-received condition, three after being conditioned in accordance with Temperature Cycling Test, Section 35, and three after conditioning in accordance with Humidity Test, Section 36.

42.3 The force is to be applied to each assembly so as to separate the wiring compartment or box from the module. The force is to be applied until the wiring compartment or box and the module separates; or the superstrate or substrate fails.

PRODUCTION LINE TESTS

43 Factory Dielectric Voltage-Withstand Test

43.1 Each module or panel shall withstand for 1 min without electrical breakdown as a routine production line test, the application of a dc test potential as specified in 43.2, between parts involving a risk of electric shock and accessible metal parts.

Exception No. 1: The test period may be reduced to 1 s if the test potential is increased to 120 percent of the value specified in 43.2.

Exception No. 2: A module or panel with a system voltage rating of 30 V or less need not be tested.

43.2 The dc test potential shall be $2V + 1000$ V, where "V" is the rated maximum acceptable system voltage.

43.3 The test equipment is to include a means of indicating the test voltage that is being applied to the product under test. This may be accomplished by sensing the voltage at the test leads or by an equivalent means. The test equipment is also to include a means of effectively indicating unacceptable performance. The indication is to be:

- a) Audible, if it can be readily heard above the background noise level;
- b) Visual, if it commands the attention of the operator; or
- c) A device that automatically rejects an unacceptable product. If the indication of unacceptable performance is audible or visual, the indication is to remain active and conspicuous until the test equipment is manually reset.

43.4 The test potential specified in 43.2 may be obtained from any convenient source having a capacity of at least 500 VA.

Exception: The capacity may be lower if the means of indicating the test voltage is located in the output circuit – to maintain the potential indicated in 43.2 except in case of breakdown. The voltage of the source is to be continuously adjustable.

43.5 The test equipment is to indicate unacceptable performance within 0.5 s if the leakage current at the test voltage exceeds 50 μ A.

43.6 The test is to be conducted when the module is complete and ready for packing, or when it is complete except for covers or other parts that may interfere with the performance of the test.

44 Factory Voltage, Current, and Power Measurements Test

44.1 The short-circuit current (I_{SC}), maximum power (P_{max}), and open-circuit voltage (V_{OC}) of each production module are to be measured in accordance with the appropriate test procedure (Standard Methods of Testing Electrical Performance of Nonconcentrator Terrestrial Photovoltaic Modules and Arrays Using Reference Cells, ASTM E1036-85, or Photovoltaic Devices, Part 1: Measurement of Photovoltaic Current-Voltage Characteristics, IEC 904-1) and the results recorded at STC using the appropriate correction procedure. The recorded values of I_{SC} , P_{max} , and V_{OC} shall be within the marked tolerance. See 48.2. The test procedures mentioned in 18.1 and 18.2 shall be applied.

Exception: See Supplement SA.

45 Grounding Continuity Test

45.1 Each module or panel provided with a connection for grounding accessible conductive parts shall be subjected to a routine production line test to demonstrate electrical continuity between the grounding connection and all accessible conductive parts.

45.2 Any appropriate indicating device, such as an ohmmeter, a low-voltage battery and buzzer combination, or the like may be employed for the test described in 45.1.

RATING

46 Details

46.1 The electrical rating of a module or panel shall include the voltage, current and power ratings specified in Table 46.1.

Table 46.1
Electrical ratings

Voltage	Current	Power
Open-circuit voltage	Short-circuit current	Maximum power
Operating voltage	Current at rated operating voltage	
Maximum system voltage		

MARKING

47 Details

47.1 A module or panel shall have a plain, legible, permanent marking that includes:

- The manufacturer's name, trademark, or other descriptive marking by which the organization responsible for the product can be identified;
- The model number or the equivalent;
- The electrical rating – see 46.1; and
- The date or other dating period of manufacture not exceeding any three consecutive months.

Exception No. 1: The manufacturer's identification may be in a traceable code if the product is identified by the brand or trademark owned by a private labeler.

Exception No. 2: The date of manufacture may be abbreviated; or may be in a nationally accepted conventional code or in a code affirmed by the manufacturer, provided that the code:

- Does not repeat in less than 10 years; and*
- Does not require reference to the production records of the manufacturer to determine when the product was manufactured.*

47.2 A permanent marking shall be molded, die-stamped, paint-stenciled, stamped, or etched metal that is permanently secured, or indelibly stamped on a pressure-sensitive label secured by adhesive that complies with the Standard for Marking and Labeling Systems, UL 969. Ordinary usage, handling, storage, and the like of the unit shall be considered in determining whether a marking is permanent.

47.3 If a module or panel is manufactured at more than one factory, it shall have a marking indicating its place of manufacture.

47.4 The output power wiring terminals, leads, connector, or other connection means of a module or panel shall be identified with one of the following marking statements:

"+"	and	"-" or
"POS"	and	"NEG" or
"POSITIVE"	and	"NEGATIVE"

47.5 During the temperature test, if the temperature on a field-installed lead or on any part of the wiring compartment that the lead might contact is more than 60°C (140°F), the module or panel shall be marked with one of the statements indicated in 47.5(a) or (b) or the equivalent. The marking shall be located at or near the points where field connections will be made, and located so that it will be readily visible during installation.

- a) "For field connections, use No. ___ AWG wires insulated for a minimum of 75°C ", or
- b) "For field connections, use No. ___ AWG wires insulated for a minimum of 90°C "

47.6 If the pressure wire connectors of a module or panel are not acceptable for use with aluminum wire, or if the module or panel manufacturer intends the use of only copper wire, the module or panel shall be marked, at or adjacent to the terminals, with the statement "Use copper wire only," "CU only," or the equivalent. This marking may be combined with the marking required by 47.5.

47.7 If the pressure wire connectors of a module or panel are acceptable for accommodating both copper and aluminum wire and if the manufacturer intends such use, the module or panel shall be marked (independent of any marking of the terminal) with the statement "Use aluminum or copper wire," "AL-CU," or the equivalent. This marking may be combined with the marking required by 47.5.

47.8 In accordance with 13.3.3, a module or panel employing a nonmetallic wiring compartment having a threaded opening shall be marked "For use with nonmetallic wiring systems only" or the equivalent.

47.9 A module or panel shall be marked:

- a) To indicate the minimum acceptable diode ratings and to indicate the configuration for bypassing, or
- b) To make reference to a manufacturer's literature where information on diode bypassing can be found. The module or panel manufacturer shall supply this literature with the module or panel.

Exception No. 1: Marking or literature is not required when the system DC voltage rating is equal to the limit voltage (V_L) used for the Hot-Spot Endurance Test and the Arcing Test. See 39.2.2 and 40.1.1, respectively.

Exception No. 2: A module or panel supplied with a bypass diode is not required to be marked when the type, voltage rating, current rating, and configuration of the diode are identified in the installation instructions.

47.10 A module or panel shall be marked relative to the maximum electrical rating of an acceptable series fuse (for protection against backfeed).

47.11 A module or panel shall be marked relative to its fire resistance rating as a roof covering. A module or panel shall be marked "Not Fire Rated," unless it complies with the requirements for fire rating. If a module or panel is fire rated and if its use is so intended by the manufacturer, it shall be marked accordingly, for example, "Modules mounted freestanding 6 in above a Class B roof constitute a Class C roof."

47.12 A module provided as a part of a panel shall be provided with all of the markings that would be required for its existence as a separate entity.

47.13 A module or panel intended for structural loads greater than 30 lb/ft² (146.5 kg/m²) shall be marked with the intended load in lb/ft².

48 Installation and Assembly Instructions

48.1 A module or panel shall be supplied with installation instructions describing the methods of electrical and mechanical installation and the electrical ratings of the module or panel. When the fire rating is dependent on a specific mounting structure, specific spacings, or specific means of attachment to the roof or structure, details of the specific parameter or parameters shall be included in the instructions.

48.1.1 The electrical installation instructions shall include a detailed description of the wiring method to be used in accordance with the National Electrical Code. This description shall include:

- a) The grounding method to be used,
- b) The size, type, and temperature rating of the conductors to be used,
- c) The type of overcurrent protection to be used,
- d) The minimum and maximum cable diameters when the wiring method is cable, and
- e) Any limitations on wiring methods that apply to the wiring compartment or box.

48.1.2 The mechanical installation instructions for roof mounting shall include:

- a) A statement indicating the minimum mechanical means to be used for securement of the module or panel to the roof,
- b) For a non-integral module or panel (See Figure 41.1), a statement that the assembly is to be mounted over a fire resistant roof covering rated for the application, and
- c) Indication of any slope less than 5 in/ft (127 mm/305 mm) required to maintain a fire Class rating.

48.2 The electrical ratings mentioned in 48.1 shall include information indicated in 48.1 and the following statement or the equivalent: "The electrical characteristics are within ± 10 percent of the indicated values of I_{SC} , V_{OC} , and P_{max} under standard test conditions (irradiance of 100 mW/cm², AM 1.5 spectrum, and a cell temperature of 25°C (77°F))."

Exception: The tolerance may be either smaller than ± 10 percent or omitted, provided the values measured during the production line tests— see 44.1 — are:

- a) *Within a tolerance indicated in the instructions when a smaller tolerance is indicated, or*

b) The same as the values indicated in the instructions when the tolerance is omitted.

48.3 The installation instructions shall include a statement advising that artificially concentrated sunlight shall not be directed on the module or panel.

48.4 Assembly instructions shall be provided with a product shipped in subassemblies, and shall be detailed and adequate to the degree required to facilitate total assembly of the product.

48.5 To allow for increased output of a module or panel resulting from certain conditions of use, the installation instructions for a module or panel containing crystalline-silicon cells shall include the following statement or the equivalent: "Under normal conditions, a photovoltaic module is likely to experience conditions that produce more current and/or voltage than reported at standard test conditions. Accordingly, the values of I_{SC} and V_{OC} marked on this module should be multiplied by a factor of 1.25 when determining component voltage ratings, conductor ampacities, fuse sizes, and size of controls connected to the PV output." For a module or panel containing other than crystalline-silicon cells, the multiplying factor at conditions of an irradiance of 125 mW/cm², AM 1.5 spectrum, and a cell temperature of minus 10°C (plus 14°F) for V_{OC} and plus 75°C (167°F) for I_{SC} is to be determined and this factor is to be indicated in the instructions.

48.6 To inform the installer that a multiplying factor in addition to that mentioned in 48.5 may be applicable, the installation instructions shall include the following statement or the equivalent: "Refer to Section 690-8 of the National Electrical Code for an additional multiplying factor of 125 percent (80 percent derating) which may be applicable."

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SUPPLEMENT SA - SAMPLE PRODUCTION LINE TESTS

SA1 Scope

SA1.1 This supplement describes the tests that are to be conducted on samples of production modules or panels.

SA2 Sample Size

SA2.1 An appropriate number of samples to be tested is to be determined by reviewing previously recorded information on the production process capability.

SA2.2 If previously recorded information on the production process capability is not available, 100 percent production line tests shall be conducted until a sufficient number of samples have demonstrated compliance with specifications.

SA3 Factory Voltage, Current, and Power Measurements Test

SA3.1 The samples as specified in paragraph SA2.1 are to be subjected to the test specified in 41.1. The recorded values of I_{SC} , P_{max} , and V_{oc} shall be within the marked tolerance.

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APPENDIX A**Standards for Components**

Standards under which components of the products covered by this standard are evaluated include the following:

Title of Standard – UL Standard Designation

Fuseholders – UL 512

Insulating Materials – General, Systems of – UL 1446

Marking and Labeling Systems – UL 969

Outlet Boxes, Flush-Device Boxes and Covers, Nonmetallic – UL 514C

Outlet Boxes, Metallic – UL 514A

Plastic Materials for Parts in Devices and Appliances, Tests for Flammability of – UL 94

Polymeric Materials – Fabricated Parts – UL 746D

Polymeric Materials – Long Term Property Evaluations – UL 746B

Polymeric Materials – Short Term Property Evaluations – UL 746A

Polymeric Materials – Use in Electrical Equipment Evaluations – UL 746C

Printed-Wiring Boards – UL 796

Roof Covering Materials, Tests for Fire Resistance of – UL 790

Sharpness of Edges on Equipment, Test for – UL 1439

Terminals, Electrical Quick-Connect – UL 310

Tubing, Extruded Insulating – UL 224

Wire Connectors and Soldering Lugs for Use with Copper Conductors – UL 486A

Wire Connectors for Use with Aluminum Conductors – UL 486B

Wires and Cables, Thermoset-Insulated – UL 44

Wires and Cables, Thermoplastic-Insulated – UL 83

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CANADIAN REQUIREMENTS COMPARISON GUIDE, CRG 1703

UL AND CANADIAN STANDARDS FOR FLAT-PLATE PHOTOVOLTAIC MODULES AND PANELS

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Product Category: Flat-Plate Photovoltaic Modules and Panels
UL Category Control Numbers: QIGU7, QIGU8

UL Standard:

Flat-Plate Photovoltaic Modules and Panels
UL 1703
Third Edition

Canadian Standard:

Flat-Plate Photovoltaic Modules and Panels
ULC/ORD-C1703-01
Second Edition

This Canadian Requirement Comparison Guide is only intended to identify Canadian requirements that must be applied in addition to the requirements in the UL Standard to obtain a C-UL Mark. The guide is not intended to replace a thorough review and comparison of the requirements applicable to the product category as contained in the applicable UL and Canadian Standards. Where requirements are not specifically addressed, compliance with the requirements in the UL Standard satisfy the requirements in the Canadian Standard.

The actual requirements applied for a C-UL product investigation may differ from those identified in this guide based on the specific features, characteristics, components, materials, or systems used in the product.

CRG: 1703
Issue No.: 2
Issue Date: March 15, 2002

Revisions of this guide will be made by issuing revised or additional pages bearing their date of issue. A Canadian Requirement Comparison Guide is current only if it incorporates the most recently adopted revisions, all of which are itemized on the transmittal notice that accompanies the latest set of revision pages for the Guide.

The following outlines the requirements contained in Flat-Plate Photovoltaic Modules and Modules, ULC/ORD-C1703-01, that are in addition to the requirements in UL 1703 that must be met in order for a product to bear the appropriate UL Marking. UL provides a certification program for products that meet the Canadian requirements. The C-UL Mark is the manufacturer's assurance that products, as evaluated by UL, continue to comply with the appropriate Canadian requirements.

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<u>Requirements Topics</u>	<u>ULC Clause</u>	<u>Comparison</u>
Marking	4.6.9	A terminal intended to accommodate an equipment-grounding conductor shall be identified by being marked "G" or "Ⓞ" or shall have a green-coloured part.
Marking	7.1.4	The output power wiring terminals, leads, connector, or other connection means of a module or panel shall be identified with the following marking statements: "+" and "-."
Installation instructions	7.2.3	The electrical installation instructions shall include a statement that installation shall be in accordance with CSA C22.1, Safety Standard for Electrical Installations, Canadian Electrical Code, Part 1.

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