UL 3730

STANDARD FOR SAFETY

Photovoltaic Junction Boxes

UL Standard for Safety for Photovoltaic Junction Boxes, UL 3730

First Edition, Dated November 11, 2014

Summary of Topics

This revision of ANSI/UL 3730 dated June 11, 2021 is being issued to update the title page to reflect the most recent designation as a Reaffirmed American National Standard (ANS). No technical changes have been made.

Text that has been changed in any manner or impacted by UL's electronic publishing system is marked with a vertical line in the margin.

The requirements are substantially in accordance with Proposal(s) on this subject dated April 2, 2021.

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UL 3730

Standard for Photovoltaic Junction Boxes

First Edition

November 11, 2014

This ANSI/UL Standard for Safety consists of the First Edition including revisions through June 11, 2021.

The most recent designation of ANSI/UL 3730 as a Reaffirmed American National Standard (ANS) occurred on June 4, 2021. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, and Title Page.

Comments or proposals for revisions on any part of the Standard may be submitted to UL at any time. Proposals should be submitted via a Proposal Request in UL's On-Line Collaborative Standards Development System (CSDS) at https://csds.ul.com.

No Text on This Page

CONTENTS

INTRODUCTION

CONSTRUCTION

PERFORMANCE

INTRODUCTION

1 Scope

1.1 These requirements cover photovoltaic junction boxes intended to be attached to photovoltaic modules and panels.

1.2 These requirements cover photovoltaic junction boxes intended for factory and field wiring and may include conduit openings, wiring leads, and/or photovoltaic connectors intended for interconnection of PV modules.

1.3 The products covered by these requirements are intended to be installed in accordance with the National Electrical Code, ANSI/NFPA 70.

2 General

2.1 Components

2.1.1 Except as indicated in 2.1.2, 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.

2.1.2 A component is not required to comply with a specific requirement that:

a) Involves a feature or characteristic not required in the application of the component in the product covered by this standard, or

b) Is superseded by a requirement in this standard.

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

2.1.4 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.

2.2 Units of measurement

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

2.3 References

2.3.1 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.

3 Glossary

3.1 In the text of this standard, the term "unit" refers to any product covered by this standard. For the purpose of this standard, the definitions in 3.2 – 3.18 apply.

3.2 AC MODULE – The smallest complete unit that includes solar cells, optics, inverters, and other components, excluding tracking devices, intended to generate ac power from sunlight.

3.3 BARRIER – A part inside an enclosure that reduces access to a part that involves a risk of fire, electric shock, injury to persons, or electrical energy-high current levels.

3.4 ELECTRIC SHOCK - VOLTAGE – A live part does not involve a risk of electric shock when the maximum voltage of the part to ground does not exceed 30 Vdc.

3.5 ENCLOSURE – A surrounding case constructed to provide a degree of protection against:

a) The accessibility of a part that potentially involves a risk of fire, electric shock or injury to persons, or

b) The risk of propagation of flame, sparks, and molten metal initiated by an electrical disturbance occurring within.

3.6 FIELD-WIRING LEAD – A lead to which a supply, load, or other wire is intended to be connected by an installer.

3.7 FIELD-WIRING TERMINAL – A terminal to which a supply, load, or other wire is intended to be connected by an installer.

3.8 FIXED UNIT – A unit that is intended to be permanently connected mechanically and electrically and only able to be detached by the use of a tool.

3.9 GROUNDED CONDUCTOR – A system or circuit conductor that is intentionally grounded.

3.10 KNOCKOUT – A portion of the wall of an enclosure so fashioned that it is capable of being readily removed by a hammer, screwdriver, and pliers at the time of installation in order to provide an opening or hole for the attachment of an auxiliary device, raceway, cable, or fitting.

3.11 LIVE PART – An electrically conductive part within a unit that during intended use has a potential difference with respect to earth ground.

3.12 MAXIMUM SYSTEM VOLTAGE – The sum of the open-circuit voltage (Voc) of the photovoltaic module or panel multiplied by the temperature correction factor specified in Article 690.7 of the National Electrical Code, ANSI/NFPA 70, for the maximum number of crystalline and multi-crystalline silicon photovoltaic modules and panels in a series string. The maximum system voltage is equal to the sum of the Voc for the maximum number of amorphous silicon and thin film photovoltaic modules and panels in a series string.

3.13 OPEN-CIRCUIT VOLTAGE (Voc) – The maximum no load output voltage of a photovoltaic module or panel at standard test conditions (STC).

3.14 PERMANENTLY CONNECTED UNIT – A unit connected to the electrical supply by means other than a supply cord and an attachment plug.

3.15 PRESSURE TERMINAL CONNECTOR – A terminal that accomplishes the connection of one or more conductors by means of pressure without the use of solder. Examples of pressure terminal connectors are:

a) Barrel and setscrew type,

b) Crimp-type barrel, or

c) Clamping plate and screw type.

3.16 SERVICE PERSONNEL – Trained persons having familiarity with the construction and operation of the equipment and the risks involved.

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

a) 100 mW/cm^2 irradiance,

b) AM 1.5 spectrum, and

c) 25°C (77°F) cell temperature.

3.18 TOOL – A screwdriver, coin, key, or any other object that is usable to operate a screw, latch, or similar fastening means.

CONSTRUCTION

4 Enclosure and Materials

4.1 General

4.1.1 Photovoltaic junction boxes shall be considered an enclosure or be provided with an enclosure that houses all current-carrying parts. The enclosure shall protect the various parts of the unit against mechanical damage from forces external to the unit. The parts of the enclosure that are required to be in place to comply with the requirements to reduce the risk of fire, electric shock, injury to persons shall comply with the applicable enclosure requirements specified in this standard.

4.1.2 The frame or chassis of a junction box shall not be relied upon to carry current during normal operation.

4.1.3 A part, such as a nameplate that is a part of the enclosure shall comply with the enclosure requirements.

4.1.4 Sheet-metal screws threading directly into metal shall not be used to attach a cover, door, or other part that is to be removed to install field wiring or for operation of the equipment. Machine screws, self-tapping machine screws, and thread forming screws are able to thread directly into sheet-metal when they allow for at least two full threads of screw engagement.

4.1.5 Sheet-metal screws mounting internal components that are not removed for installation or operation are able to thread directly into metal.

4.2 Nonmetallic enclosures and polymeric materials

4.2.1 A polymeric enclosure or polymeric part of an enclosure shall comply with Sections 7 and 34 in the Standard for Flat-Plate Photovoltaic Modules and Panes, UL 1703, except as noted by the following.

4.2.2 With reference to paragraph 7.2 (c) of the Standard for Flat-Plate Photovoltaic Modules and Panes, UL 1703, a polymeric material serving as the support or insulation of a live part as defined in Table 6.1 of the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C, shall have a Comparative Tracking Index performance level category (PLC) as determined in accordance with the Standard for Polymeric Materials - Short Term Property Evaluations, UL 746A, and as defined in Table 4.1, when the system voltage rating is 600 V or less.

Exception No. 1: The CTI rating is not required for a polymeric material serving as the support or insulation of a live part as defined in UL 746C, Table 6.1, when both the material and live part are completely

encapsulated by the potting material such that there is no surface upon which tracking may occur, and the potting material has been evaluated according to UL 746C, Table 6.1, for Electric Strength, Resistance to Electrical Ignition Sources (HAI and HWI), and Thermal Endurance.

Exception No. 2: The CTI rating is not required for a polymeric material serving as the support or insulation of a live part as defined in UL 746C, Table 6.1, when both the material and live part are completely coated by a conformal coating that has been evaluated to the requirements of UL 746C, Section 43, at the rated thickness such that there is no surface upon which tracking may occur.

Exception No. 3: Silicone based RTV when applied in accordance with Exception No. 2 is considered a suitable conformal coating without further evaluation.

Table 4.1
Determination of comparative tracking index performance level category (PLC)

Voltage	Creepage distance	IPT 1 hr rating required	CTI PLC of 2 or better required
0 – 30	Any	No	No
> 30 – 600	< 12.7 mm	No	Yes
> 30 – 600	≥ 12.7 mm	No	No
> 600 – 1000	< 16.0 mm	Yes	No
> 600 – 1000	≥ 16.0 mm	No	No
> 1000 – 1500	< 24.0 mm	Yes	No
> 1000 – 1500	≥ 24.0 mm	No	No

Note – Voltage is determined as follows:

Between live parts: the maximum potential difference during normal use

Between live parts and dead metal parts that may be grounded in service: maximum system voltage

Between live parts and any surface exposed to contact: maximum system voltage

4.2.3 With reference to paragraph 7.2 (d) of the Standard for Flat-Plate Photovoltaic Modules and Panes, UL 1703, a polymeric material serving as the support or insulation of a live part as defined in Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C, Table 6.1, shall have an Inclined Plane Tracking (ASTM D2303) rating of 1 hour using the time to track method at the higher of system voltage or 1000 V when the system voltage is in the range of 601 – 1000 V as specified in Table 4.1.

Exception No. 1: The 1 hr rating is not required for a polymeric material serving as the support or insulation of a live part as defined in UL 746C, Table 6.1, when both the material and live part are completely encapsulated by a potting material such there is no surface upon which tracking may occur, and the potting material has been evaluated according to UL 746C, Table 6.1, for Electric Strength, Resistance to Electrical Ignition Sources (HAI and HWI), and Thermal Endurance.

Exception No. 2: The 1 hr rating is not required for a polymeric material serving as the support or insulation of a live part as defined in UL 746C, Table 6.1, when both the material and live part are completely coated by a conformal coating that has been evaluated to the requirements of UL 746C, Section 43, at the rated thickness such that there is no surface upon which tracking may occur.

Exception No. 3: Silicone based RTV when applied in accordance with Exception No. 2 is considered a suitable potting material without further evaluation.

4.2.4 A nonmetallic enclosure intended for connection to a rigid conduit system shall comply with the Polymeric Enclosure Rigid Metallic Conduit Connection Tests in the Standard for Enclosures for Electrical Equipment, UL 50.

4.2.5 Relative thermal indexes for polymeric materials are required according to 7.3 of the Standard for Flat-Plate Photovoltaic Modules and Panes, UL 1703, and shall be considered applicable for junction boxes as follows:

a) RTI Electrical – applies to all polymeric materials in contact with live parts as defined in UL 746C, Table 6.1, and to all polymeric materials protecting, insulating, or encapsulating live parts.

b) RTI Mechanical Strength – applies to all polymeric materials that form an enclosure and all polymeric materials that make up a part of a junction box that is relied upon to meet spacing requirements, Section 16, Strain Relief Test compliance, Section 25, Mold Stress-Relief Test compliance, Section 24, Crush Test compliance, Section 26, or polymeric materials that otherwise protect or insulate live parts.

c) RTI Mechanical Impact – applies to all polymeric materials that are subject to impact from hail or other impact sources during normal operation when installed per the manufacturer's instructions.

4.2.6 Gasket materials shall comply with Section 33.1.

4.3 Openings for wiring system connections

4.3.1 Where threads for the connection of conduit are tapped all the way through a hole in an enclosure wall, or where an equivalent construction is employed, there shall not be less than three, or more than five threads in the metal; and the construction of the enclosure shall be such that a conduit bushing is attachable as intended. Where threads for the connection of conduit are not tapped all the way through a hole in an enclosure wall, conduit hub, or a similar component, there shall not be less than 3-1/2 threads in the metal, and there shall be a smooth, rounded inlet hole for the conductors equivalent to that provided by a standard conduit bushing and the hole shall have an internal diameter that corresponds with the applicable trade size of rigid conduit.

4.3.2 Clamps and fasteners for the attachment of conduit, electrical metallic tubing, armored cable, nonmetallic flexible tubing, nonmetallic-sheathed cable, service cable, or equivalent, that are supplied as a part of an enclosure shall comply with the Standard for Conduit, Tubing, and Cable Fittings, UL 514B.

4.3.3 A knockout in a sheet-metal enclosure shall be secured and shall be removable without undue deformation of the enclosure.

4.3.4 A knockout shall be provided with a flat surrounding surface so a conduit bushing of the corresponding size seats as intended. A knockout intended to be used for installation purposes, shall be located so that installation of a bushing does not result in spacings between uninsulated live parts and the bushing of less than required in Spacings, Section 16.

4.3.5 In measuring a spacing between an uninsulated live part and a bushing installed in a knockout as specified in 4.3.4, it is to be assumed that a bushing having the dimensions specified in Table 4.2 is in place, in conjunction with a single locknut installed on the outside of the enclosure.

Table 4.2
Knockout or hole sizes and dimensions of bushings

Trade size of conduit,	Knockout or hole diameter		Bushing dimensions			
			Overall diameter		Height	
Inch	mm	(inch)	mm	(inch)	mm	(inch)
1/2	22.2	(7/8)	25.4	(1)	9.5	(3/8)
3/4	27.8	(1-3/32)	31.4	(1-15/64)	10.7	(27/64)
1	34.5	(1-23/64)	40.5	(1-19/32)	13.1	(33/64)
1-1/4	43.7	(1-23/32)	49.2	(1-15/16)	14.3	(9/16)
1-1/2	50.0	(1-31/32)	56.0	(2-13/64)	15.1	(19/32)
2	62.7	(2-15/32)	68.7	(2-45/64)	15.9	(5/8)
2-1/2	76.2	(3)	81.8	(3-7/32)	19.1	(3/4)
3	92.1	(3-5/8)	98.4	(3-7/8)	20.6	(13/16)
3-1/2	104.8	(4-1/8)	112.7	(4-7/16)	23.8	(15/16)
4	117.5	(4-5/8)	126.2	(4-31/32)	25.4	(1)
4-1/2	130.2	(5-1/8)	140.9	(5-35/64)	27.0	(1-1/16)
5	142.9	(5-5/8)	158.0	(6-7/32)	30.2	(1-3/16)
6	171.5	(6-3/4)	183.4	(7-7/32)	31.8	(1-1/4)

4.3.6 A plate or plug for an unused conduit opening or other hole in the enclosure shall have a thickness not less than:

a) 0.36 mm (0.014 inch) for steel or 0.48 mm (0.019 inch) for nonferrous metal for a hole having a 6.4-mm (1/4-inch) maximum dimension, and

b) 0.69-mm (0.027-inch) steel or 0.81-mm (0.032-inch) nonferrous metal for a hole having a 34.9-mm (1-3/8-inch) maximum dimension.

A closure for a larger hole shall have a thickness equal to that required for the enclosure of the unit or a standard knockout seal shall be used. Such plates or plugs shall be securely mounted.

5 Protection Against Corrosion

5.1 Junction boxes shall comply with the Corrosion Resistance requirements of Sections 35 – 36, and Section 14 in the Standard for Flat-Plate Photovoltaic Modules and Panels, UL 1703.

6 Protection of Users - Accessibility of Uninsulated Live Parts

6.1 Junction boxes shall comply with the Accessibility requirements of Section 15 in the Standard for Flat-Plate Photovoltaic Modules and Panels, UL 1703.

7 Wiring Terminals

7.1 A wiring terminal shall comply with the requirement in 7.3 for a wire of each metal for which it is marked.

7.2 A wiring terminal shall be provided with a factory-installed pressure terminal connector that is securely fastened in place - for example, firmly bolted or held by a screw.

Exception No. 1: A field-installed pressure terminal connector in accordance with 7.4 meets the intent of this requirement.

Exception No. 2: A wire-binding screw employed at a wiring terminal intended for connection of a 10 AWG (5.3 mm^2) or smaller conductor and having upturned lugs, a cupped washer, or the equivalent to hold the wire in position meets the intent of this requirement.

7.3 A wiring terminal shall be secured in position, by a means other than friction between surfaces, so that it does not turn or shift. This is able to be accomplished by two screws or rivets; by square shoulders or mortises; by a dowel pin, lug, or offset; by a connecting strap or clip fitted into an adjacent part; or by an equivalent method.

Exception: A pressure terminal connector used in accordance with 7.4 is able to turn when the spacing complies with Spacings, Section 16, when the connector is oriented in the position resulting in the least spacing between adjacent terminals and also between terminals and dead metal parts.

7.4 With reference to Exception No. 1 to 7.2, a pressure terminal connector is not required to be factory installed when the conditions in (a) – (e) are met:

a) One or more component terminal assemblies shall be available from the unit manufacturer or others and specified in the instruction manual.

b) The fastening hardware such as a stud, nut, bolt, spring, or flat washer, and similar hardware, as required for an effective installation, shall be:

1) Provided as part of the terminal assembly,

2) Mounted on or separately packaged with the unit, or

3) Specified in the instruction manual.

c) The installation of the terminal assembly shall not involve the loosening or disassembly of parts other than a cover or other part giving access to the terminal location. The means for securing the terminal connector shall be readily accessible for tightening before and after installation of conductors.

d) When the pressure terminal connector provided in a terminal assembly requires the use of other than a common tool for securing the conductor, identification of the tool and any additional instructions shall be included in the assembly package or with the unit.

e) Installation of the pressure terminal connector in the intended manner shall result in a unit complying with the requirements of this standard.

7.5 A terminal block or insulating base for support of a pressure terminal connector shall comply with the Standard for Terminal Blocks, UL 1059.

7.6 A wire-binding screw at a field-wiring terminal shall not be smaller than No. 10 (4.8 mm diameter).

Exception No. 1: A No. 8 (4.2 mm diameter) screw is usable at a terminal intended only for the connection of:

a) 14 AWG (2.1 mm^2) conductor, or

b) 16 or 18 AWG (1.3 or 0.82 mm^2) control-circuit conductor.

Exception No. 2: A No. 6 (3.5 mm diameter) screw is usable for the connection of a 16 or 18 AWG (1.3 or 0.82 mm^2) control-circuit conductor.

7.7 A wire-binding screw shall thread into metal.

7.8 A terminal plate tapped for a wire-binding screw shall be of metal not less than 1.27 mm (0.050 inch) thick.

Exception: A terminal plate of metal less than 1.27 mm (0.050 inch) thick complies where used with a maximum system open-circuit voltage rating less than 30 V and a maximum short-circuit current rating less than 8 A, and the tapped threads are capable of withstanding the tightening torque specified in Table 7.1 without stripping when subjected to the test method described in Section 29.

Table 7.1
Tightening torque for wire-binding screws

Size of terminal screw,		Wire sizes to be tested,	Tightening torque	
No.	(diameter, mm)	AWG (mm^2)	Newton meters	(Pound-inch)
6	(3.5)	Stranded 16 – 18 (1.3 – 0.82)	1.4	(12)
8	(4.2)	Solid 14 (2.1) and Stranded 16 – 18	1.8	(16)
10	(4.8)	Solid 10 – 14 (4.8 – 2.1) and Stranded 16 – 18	2.3	(20)

7.9 There shall be two or more full threads in the metal of a terminal plate. The metal may be extruded at the tapped hole to provide at least two full threads.

Exception: Two full threads are not required for a terminal in used with a maximum system open-circuit voltage rating less than 30 V and a maximum short-circuit current rating less than 8 A, when a lesser number of threads results in a secure connection in which the threads do not strip when subjected to the tightening torque specified in Table 7.1.

8 Wiring Leads

8.1 A field-wiring lead shall not be less than 152.4 mm (6 inches) long.

Exception: Leads exiting the junction box terminating with a PV Connector may be less than 152.4 mm (6 inches) long.

8.2 A field-wiring lead shall consist of PV Wire or USE-2 Wire.

8.3 All wiring leads exiting the junction box shall comply with Strain Relief Test, Section 25, both in as-received condition and following the Mold Stress-Relief Test, Section 24.

9 Field Wiring Compartments

9.1 A field wiring compartment shall not have a volume less than specified in Table 9.1. The volume is to be determined in accordance with the Standard for Metallic Outlet Boxes, UL 514A, or the Standard for Nonmetallic Outlet Boxes, Flush-Device Boxes and Covers, UL 514C, as applicable. No compartment enclosure dimension shall be less than 19.1 mm (3/4 inch).

Table 9.1
Wiring compartment volume

Size of conductor,		Free space for each conductor	
AWG	(mm^2)	Cubic centimeter	(Cubic inches)
18	(0.82)	24.60	(1.50)
16	(1.3)	28.70	(1.75)
14	(2.1)	32.80	(2.00)
12	(3.3)	36.90	(2.25)
10	(5.3)	40.00	(2.50)
8	(8.4)	49.20	(3.00)
6	(13.3)	82.00	(5.00)

10 Grounding

10.1 A photovoltaic junction box shall have a means for grounding all accessible conductive parts. The grounding means shall comply with the applicable Connection Means requirements in Section 10 of the Standard for Flat-Plate Photovoltaic Modules and Panels, UL 1703. The grounding means shall be bonded to each conductive part of the junction box that is accessible during normal use. The grounding means shall be described in detail in the installation manual. See Installation and Assembly Instructions, Section 42.

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

10.3 Bonding shall be by a positive means, such as clamping, riveting, bolted or screwed connections, or welding, soldering (see 10.5) or brazing. The bonding connection shall penetrate nonconductive coatings, such as paint or vitreous enamel.

10.4 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.

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

10.6 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.

10.7 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.

10.8 A terminal of a photovoltaic junction box (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.

10.9 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 junction box near the terminal.

10.10 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.

10.11 The surface of an insulated lead of a junction box 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.

11 Internal Bonding for Grounding

11.1 All exposed dead metal parts, which in the event of an electrical malfunction, involve a risk of electric shock or electrical energy-high current levels, shall be conductively connected to the equipment-grounding means specified in Grounding, Section 10.

11.2 In a unit having means for grounding, all uninsulated metal parts of the enclosure, mounting brackets, component mounting brackets, capacitors, and other electrical components that involve a risk of electric shock shall be bonded for grounding where they are accessible for contact by the user or inadvertent contact by a serviceman.

Exception: A metal part as described in (a) - (e) is not required to be bonded for grounding:

a) An adhesive-attached metal foil marking, a screw, a handle, or similar metal part, that is located on the outside of an enclosure or cabinet and isolated from electrical components or wiring by grounded metal parts so that they do not become energized.

b) An isolated metal part, such as a small assembly screw, or similar part, that is positively separated from wiring and uninsulated live parts.

c) A panel or cover that does not enclose uninsulated live parts; and wiring is positively separated from the panel or cover so that it is unable to become energized.

d) A panel or cover that is secured in place and that is insulated from electrical components and wiring by an insulating barrier of vulcanized fiber, varnished cloth, phenolic composition, or similar material not less than 0.8 mm (1/32 inch) thick.

e) An isolated metal part that is mounted on a printed wiring board - such as heat sinks.

11.3 A conductor or strap used for bonding shall be of copper, a copper alloy, or an equivalent material. A conductor or strap:

a) Shall be protected from mechanical damage or be located within the outer enclosure or frame,

b) Shall not be secured by a removable fastener used for any purpose other than bonding for grounding, unless there is a low risk of the bonding conductor being omitted after removal and replacement of the fastener, and

c) Shall not be spliced.

11.4 A connection in the bonding path shall be by a positive means, such as by a clamp, a rivet, a bolted or screwed connection, or by welding, soldering, or brazing with materials having a softening or melting

point greater than 455°C (850°F). The bonding connection shall penetrate nonconductive coatings, such as paint or vitreous enamel. Ferrous metal parts in the grounding path shall be protected against corrosion by painting, galvanizing, plating, or equivalent means. Bonding around a resilient mount shall not depend on the clamping action of rubber or similar material.

11.5 A bolted or screwed connection that incorporates a star washer under the screwhead shall penetrate nonconductive coatings and shall comply with Grounding Impedance Test, Section 30.

11.6 Where the bonding connection depends on screw threads in metal, two or more screws or two full threads of a single screw engaging two full threads in the metal shall be used.

11.7 A connection that depends on the clamping action exerted by rubber or similar material shall comply with Bonding Conductor Test, Section 31, when installed as intended. The material shall be rated for the condition of use, such as oil, grease, moisture, and thermal degradation that potentially occur in service. Before testing, the clamping device is to be disassembled as it is for maintenance purposes and then reassembled.

11.8 A bonding conductor or strap:

a) Shall not be smaller than the conductor supplying the component, or

b) Shall comply with Bonding Path Resistance Test in Section 13 of the Standard for Mounting Systems, Mounting Devices, Clamping/Retention Devices, and Ground Lugs for Use with Flat-Plate Photovoltaic Modules and Panels, UL 2703.

Exception: A smaller conductor or strap is usable when it complies with Bonding Conductor Test, Section 31.

11.9 The bonding connection, the enclosure, the frame, or a component mounting panel shall not carry current other than current resulting from an electrical malfunction.

12 Internal Wiring

12.1 The internal wiring of a unit shall consist of general-use building wire or appliance wiring material rated for the temperature, voltage, and conditions of service to which the wiring is subjected.

12.2 Insulating tubing or sleeving shall not be used as insulation other than for a short length of insulated conductor, for example, a short coil lead, or similar component. Where so used:

a) The tubing or sleeving shall not be subjected to compression, repeated flexure, or sharp bends,

b) The conductor covered with the tubing or sleeving shall be well rounded and free from sharp edges,

c) A shrinkable tubing shall be used in accordance with the tubing manufacturer's instructions, and

d) The tubing or sleeving shall not be subjected to a temperature or voltage higher than that for which the tubing or sleeving is rated.

13 Protection of Wiring

13.1 Internal wiring shall not be accessible from outside the enclosure in accordance with Protection of Users - Accessibility of Uninsulated Live Parts, Section 6.

13.2 Wires within an enclosure, compartment, raceway, or similar housing, shall be located or protected against contact with any sharp edge, burr, fin, moving part, or similar part, that is able to damage the conductor insulation.

13.3 Mounting screws and nuts shall be constructed or located so that sharp edges do not damage wiring. A screw shall have a flat or blunt end. The end of the screw shall not have burrs, fins, or sharp edges that are able to abrade wire insulation, and the end shall not project more than 4.8 mm (3/16 inch) into a wireway.

13.4 A hole through which insulated wires pass in a sheet metal wall internal to the overall enclosure of a unit shall be provided with smooth, rounded surfaces upon which the wires bear, to protect against abrasion of the insulation.

14 Electrical Connections

14.1 A splice or connection shall be mechanically secure and shall make reliable electrical contact.

14.2 A soldered connection shall be made mechanically secure before being soldered.

Exception: A connection is not required to be mechanically secured before soldering when:

a) A soldering or brazing material having a softening or melting point greater than 454°C (849°F) is used,

b) A hand-soldered lead is passed through a hole in a printed wiring board or other mounting surface and bent 90 degrees to the board to make contact with the conductor before soldering,

c) Soldering on a printed wiring board or other surface is done by a machine process in which the soldering time and solder temperature are automatically controlled - bending over of leads is not required, or

d) The lead wire is strapped in place, or the equivalent, adjacent to the soldered connection to hold the lead end in place.

14.3 A stranded internal wiring connection shall be such that it reduces the potential for loose strands of wire contacting dead metal parts or other live parts not always of the same potential. This is able to be accomplished by the use of a pressure terminal connector, a soldering lug, a crimped eyelet, soldering of all strands together, or an equivalent means.

14.4 An open-end spade lug secured by a screw or nut shall be secured by additional means, such as upturned ends on the lug, or bosses or shoulders on the terminal, to hold the lug in place in the event the screw or nut loosens.

14.5 A nominal 0.110-, 0.125-, 0.187-, 0.205-, or 0.250-inch wide quick-connect terminal shall comply with the Standard for Electrical Quick-Connect Terminals, UL 310. Other sizes of quick-connect terminals shall be investigated with respect to crimp pull-out, engagement-disengagement forces of the connector and tab, and temperature rises in accordance with UL 310.

14.6 Aluminum conductors, insulated or uninsulated, used as internal wiring, such as for interconnection between current-carrying parts or in a component winding, shall be terminated at each end by a terminal that is rated for the combination of metals involved at the connection points. A wire-binding screw or a pressure wire connector used as a terminating device shall be rated for use with aluminum under the conditions involved - for example, temperature, heat cycling, vibration, and other similar conditions.

14.7 A splice shall be provided with insulation equivalent to that of the wires involved unless permanent spacings are maintained between the splice and other metal parts.

a) Splicing devices such as pressure wire connectors insulated for the voltage and temperature to which they are subjected are in compliance with this requirement.

b) Insulating tubing or sleeving used to cover a splice shall comply with 12.2.

c) Two layers of thermoplastic tape, or two layers of friction tape, or one layer of friction tape and one layer of rubber tape, are able to be used on a splice when the voltage involved is less than 250 volts. The use of thermoplastic tape wrapped over a sharp edge is not in compliance with the requirement.

15 Live Parts

15.1 A current-carrying part shall be of silver, copper, copper alloy, aluminum, or the equivalent.

15.2 Uninsulated live parts and components that have uninsulated live parts shall be secured so they do not turn or shift in position where such displacement results in a reduction of spacings below the minimum values specified in Section 15, Spacings.

16 Spacings

16.1 Spacings for junction boxes shall comply with the requirements in Section 12, Spacings, of the Standard for Flat-Plate Photovoltaic Modules and Panels, UL 1703.

17 Barriers

17.1 An insulating barrier of vulcanized fiber, thermoplastic, or other material used in lieu of required spacings shall not be less than 0.71 mm (0.028 inch) thick and shall be so located or of such material that it is not adversely affected by arcing.

Exception: Vulcanized fiber not less than 0.33 mm (0.013 inch) thick is usable:

a) In conjunction with an air spacing of not less than 50 percent of the minimum through-air spacing as specified in Table 12.1 of the Standard for Flat-Plate Photovoltaic Modules and Panels, UL 1703, and

b) Between a heat sink and a metal mounting surface, including the enclosure, or an isolated secondary circuit rated 30 volts or less.

18 Connectors

18.1 A connector provided external to the photovoltaic junction box shall comply with the Standard for Connectors for Use in Photovoltaic Systems, UL 6703.

18.2 Connectors integral to a photovoltaic junction box shall comply with the material requirements of the Standard for Connectors for Use in Photovoltaic Systems, UL 6703, regarding flammability.

19 Printed-Wiring Boards

19.1 A printed-wiring board in a unit shall comply with the Standard for Printed-Wiring Boards, UL 796. For a unit with miscellaneous or ventilation openings in the enclosure, the board shall be classed V-0 or V-1 in accordance with the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and

Appliances, UL 94. The use of a material Classed V-2 requires the use of an enclosure without openings. Drain holes are not prohibited regardless of the material Class.

Exception: This requirement does not apply to a printed wiring board connected only in a junction box with a system open-circuit voltage rating less than 30 V and a short-circuit current rating less than 8 A and where deterioration or breakage of the bond between a conductor and the base material does not result in a risk of fire or electric shock.

PERFORMANCE

20 General

20.1 Photovoltaic junction boxes shall be subjected to the tests described in Sections 20 – 35.

Table 20.1
Required tests

Required test	Section Reference
Temperature	21
Dielectric Voltage-Withstand	22
Leakage Current	23
Mold Stress-Relief Distortion	24
Strain Relief	25
Crush	26
Push	27
Impact	28
Terminal Torque	29
Grounding Impedance	30
Bonding Conductor	31
Compression	32
Gasket	33
Corrosive Atmosphere	34
Metallic Coating Thickness	35

20.2 Photovoltaic junction boxes may optionally be subjected to the tests described in Sections 36 – 39 with the agreement of the junction box manufacturer. For these tests, the junction boxes are to be mounted to a representative substrate material using a representative adhesive.

Table 20.2
Optional tests

Optional test	Section Reference
Water Spray	36
Wet Insulation-Resistance	37
Temperature Cycling	38
Humidity Cycling	39

21 Temperature Test

21.1 When a junction box is at equilibrium while conducting rated current in the forward direction (minus to plus) through the tabbing (diodes shall be replaced in the circuit with representative tabbing); 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 21.1, to be exceeded;

c) Cause the Relative Thermal Index – 20 degrees C of polymeric materials to be exceeded; or

d) 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.

21.2 The temperature of a surface that is subject to contact shall not be more than specified in Table 21.1.

Exception: The temperature maximums specified for casual contact in Table 21.1 items 6 and 7 do not apply when:

a) The unit is a fixed unit that is typically not subject to contact by persons; and

b) The unit is marked as required by 41.5.

Table 21.1
Maximum surface temperatures

	Part, material, or component	Temperature	
		°C	(°F)
1	Metal surfaces subject to casual contact	70	158
2	Nonmetallic surfaces subject to casual contact (other than wood)	95 or rated temperature, whichever is less	203 or rated temperature, whichever is less
3	Wood and wood product surfaces subject to casual contact	90	194
4	Metal adjacent structural members	70	158
5	Nonmetallic adjacent structural members (other than wood)	95 or rated temperature, whichever is less	203 or rated temperature, whichever is less
6	Field wiring terminals[a]	60	140
7	Field wiring compartments that wires may contact[a]	60	140
8	Insulated conductors	Rated temperature	Rated temperature

[a] If a marking is provided in accordance with 41.5, 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).

21.3 With reference to 21.1, thermal equilibrium is attained when four successive readings indicate no change in temperature. No change in temperature is determined when the maximum difference between any two readings is at most 1° C. These readings shall be taken at the start and conclusion of three consecutive, equal intervals of time; each interval having a duration of 10 minutes minimum test time.

21.4 Material and component temperatures are to be determined for an ambient temperature of 40° C (104° F). 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.

21.5 A junction box is to be installed in a manner consistent with the intended end product application and according to the instructions provided with it.

21.6 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.

21.7 Thermocouples consisting of 30 AWG (0.05 mm^2) 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 the Initial Calibration Tolerances for Thermocouples table in Temperature Measurement Thermocouples, ANSI/ISA, is to be used.

21.8 A thermocouple junction is to be held securely in intimate thermal contact with the surface of the material being tested. Thermocouples are to be secured to surfaces by welding, brazing, soldering, fuller's earth and sodium silicate (waterglass), adhesive rated for the surface and temperatures involved, or an equivalent method. Tape is not to be used as a means of securing the thermocouple junction. The thermocouple lead is to be secured so that strain on the lead does not affect the adhered thermocouple junction. Tape is usable as a means of strain relief for the thermocouple junction.

22 Dielectric Voltage-Withstand Test

22.1 The photovoltaic junction box shall be subjected to the Dielectric Voltage test according to Section 26 in the Standard for Flat-Plate Photovoltaic Modules and Panels, UL 1703.

23 Leakage Current Test

23.1 The leakage current of a junction box having a marked maximum system voltage of more than 30 V shall not be greater than the values specified in Table 23.1 when tested as described in 23.2 – 23.7.

23.2 The test is to be conducted on three unconditioned junction boxes mounted to a representative substrate, and the junction boxes that have been subjected to the Water Spray Test, Section 36, the Temperature Cycling Test, Section 38, and the Humidity Cycling Test, Section 39. The leakage current of the unconditioned junction boxes is to be measured at 25 ±3°C (77 ±5°F).

Table 23.1
Allowable leakage current

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

23.3 Leakage current refers to all currents that may be conveyed between accessible parts of a junction box when the junction box is connected to the source described in 23.4 and 23.5.

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

23.5 All accessible parts and surfaces are to be tested for leakage current. The input and outputs of the junction box 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 23.7.

23.6 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.

23.7 With reference to 23.5, the meter for the measurement is to be responsive to dc only, and is to have an input impedance of 500 ohms.

24 Mold Stress-Relief Distortion Test

24.1 Conditioning of the junction box as described 24.2, shall not cause softening of the material as determined by handling immediately after the conditioning, nor shall there be shrinkage, warpage, or other distortion as judged after cooling to room temperature, that results in any of the following:

a) Reduction of spacings between uninsulated live parts of opposite polarity, uninsulated live parts and accessible dead or grounded metal, uninsulated live parts and the enclosure below the minimum acceptable values.

b) Making uninsulated live parts or internal wiring accessible to contact, or defeating the integrity of the enclosure so that acceptable mechanical or environmental protection is not afforded to internal parts of the junction box.

c) Causing a condition that results in the equipment not complying with the strain-relief requirements, if applicable.

d) Causing interference with the intended operation or servicing of the equipment.

24.2 One sample of the complete equipment (in the case of an enclosure) or the part under consideration, is to be placed in a full draft circulating air oven maintained at a uniform temperature at least 10°C (18°F) higher than the maximum temperature of the material measured under the Temperature Test, Section 21, but not less than 70°C (158°F) in any case. The sample is to remain in the oven for 7 hours. After its careful removal from the oven and return to room temperature, the sample is to be investigated for compliance with 24.1 and Section 25.

25 Strain Relief Test

25.1 A wiring lead exiting the junction box shall be subjected to the Strain Relief Test as described in 25.2 and 25.3, both in an as-received condition and following the Mold-Stress Relief Distortion Test, Section 24.

25.2 A lead or cable for connection to external wiring, or a lead or cable terminated at both ends shall withstand for 1 min a force of 20 lb (89 N) applied in any direction permitted by the construction, without transfer of the force to the electrical connection, or damage to the lead or cable, and its connecting means.

25.3 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 junction box, or the mounting of the connector to the junction box, or separation of the two mating connectors.

26 Crush Test

26.1 Junction boxes shall withstand a 1 minute application of the crushing force described in 26.2 without resulting in any of the following:

a) Reduction of spacings below the minimum acceptable values.

b) Making bare live parts or internal wiring accessible to contact.

c) Such breakage, cracking, rupture, and the like as to produce an adverse effect on the insulation.

d) Producing any other condition that would increase the likelihood of electric shock or fire, or both, during use of the equipment.

26.2 Three samples of the junction box are to be supported on the mounting side by a fixed rigid supporting surface, in the position that is recommended by the manufacturer. Crushing force is to be applied to the exposed surfaces of the junction boxes. The compression force is to be applied by flat surfaces each 102 by 254 mm (4 by 10 in). Each force applicator is to exert 45.4 kg (100 lb) on the sample.

27 Push Test

27.1 Any part of a junction box 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.

27.2 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 junction box would not comply with the Leakage Current Test, Section 23.

27.3 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 the Standard for Flat-Plate Photovoltaic Modules and Panels, UL 1703, paragraph 6.9.

28 Impact Test

28.1 The equipment shall withstand the impact described in 28.4 without occurrence of any of the following:

a) Making uninsulated live parts accessible to contact (use the accessibility probe of the product standard for this evaluation); and

b) Producing cracking or denting of the enclosure or displacement of water seals.

28.2 The equipment is to comply with the dielectric voltage-withstand requirements applicable to the equipment after being subjected to the impact.

28.3 A polymeric junction box serving as the enclosure of a part involving a risk of fire or electric shock is to be subjected to the tests described in 28.4. If the junction box includes an integral connector, it shall be tested in a mated condition.

28.4 The junction box 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 junction box is to be struck at any point considered most vulnerable. If the construction of junction box 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. The test is to be performed on the junction box 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).

Exception: Junction boxes intended to be used on systems that will only be installed at temperatures above 0°C shall be marked accordingly, and shall be tested after being cooled and maintained for 3 h at a temperature of 0 ±2.0°C (32.0 ±3.6°F).

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 Grounding Impedance Test

30.1 The photovoltaic junction box with accessible conductive surfaces shall be subjected to the Bonding Path Resistance Test in accordance with Section 13 of the Standard for Mounting Systems, Mounting Devices, Clamping/Retention Devices, and Ground Lugs for Use with Flat-Plate Photovoltaic Modules and Panels, UL 2703.

31 Bonding Conductor Test

31.1 With reference to the Exception to 11.8, a bonding circuit, including the conductor, terminations and portions of the unit intended to be bonded, shall be subjected to the following tests using a separate bonding circuit for each test:

a) The conductor is to carry currents equal to 135 and 200 percent of the rating or setting of the intended branch-circuit overcurrent-protective device for the times specified in Table 31.1, and

b) Three specimens are to be subjected to a limited-short-circuit test using a test current as specified in Table 31.2 while connected in series with a nonrenewable fuse having a rating equal to the intended branch-circuit overcurrent-protective device.

Exception: When a fuse smaller than that indicated in (a) and (b) is employed in the unit for protection of the circuit to which the bonding conductor is connected, the magnitude of the test current and size of fuse used during the test is to be based on the rating of the smaller fuse.

Table 31.1
Duration of overcurrent test

Rating or setting of branch-circuit overcurrent protective device, amperes	Test time, minutes	
	135 percent of current	200 percent of current
0 – 30	60	2
31 – 60	60	4
61 – 100	120	6
101 – 200	120	8

Table 31.2
Circuit capacity for bonding conductor short-circuit test

Rating of unit, volt-ampere		Volts	Capacity of test circuit, amperes
Single phase	3-Phase		
0 – 1176	0 – 832	0 – 250	200
0 – 1176	0 – 832	251 – 600	1000
1177 – 1920	833 – 1496	0 – 600	1000
1921 – 4080	1497 – 3990	0 – 250	2000
4081 – 9600	3991 – 9145	0 – 250	3500
9601 or more	9146 or more	0 – 250	5000
1921 or more	1497 or more	251 – 600	5000

31.2 After the bonding circuits are subjected to the tests in 31.1, the circuits shall comply with Grounding Impedance Test, Section 30.

32 Compression Test

32.1 An enclosure shall be constructed so that during the test described in 32.2, the resulting deflection does not result in spacings less than specified in Spacings, Section 16.

32.2 A force of 445 N (100 pounds) is to be applied to the end, side, and walls of the enclosure. The enclosure is to rest on a smooth solid, horizontal surface. A vertical force is to be applied at any point through a rod having a 12.7 mm (1/2 inch) square flat steel face.

33 Gasket Tests

33.1 General

33.1.1 Materials used for gaskets, seals, and the like (other than cork, fibrous material, and similar products) shall comply with 33.1.2 or Alternate Gasket Tests, Section 33.2.

33.1.2 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 33.1, and shall comply with the physical property requirements of Table 33.2. The material shall not deform, melt, or harden to a degree which would affect its sealing properties.

Table 33.1
Physical property requirements

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
Thermoplastic Elastomer (TPE) – 500 psi (3.45 MPa)	290 percent	55 percent
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 in accordance with Section 7.4 of the Standard for Gaskets and Seals, UL 157.

[d] Compressive set is not applicable to flexible cellular materials.

Table 33.2
Physical requirements after conditioning

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).

33.2 Alternate gasket tests

33.2.1 General

33.2.1.1 Materials used for gaskets, seals, and the like (other than cork, fibrous material, and similar products) shall comply with Sections 33.2.2 and 33.2.3. The material shall not deform, melt, or harden to a degree which would affect its sealing properties.

33.2.2 Tensile strength and elongation tests

33.2.2.1 Gasket material shall be of such quality that samples subjected to conditioning as defined in Table 33.2 have a tensile strength of not less than 75 percent and an elongation of not less than 60 percent of values determined for unaged samples. At the conclusion of the tests, there shall be no visible deterioration, deformation, melting, or cracking of the material, and the material shall not harden as determined by normal hand flexing.

33.2.3 Compression test

33.2.3.1 A set of three specimens of gasket material shall be tested in accordance with 33.2.3.2 – 33.2.3.4. On completion of each test the specimen shall not show signs of deterioration or cracks that can be seen with normal or corrected vision.

33.2.3.2 A circular weight to apply 69 kPa (10 pounds per square inch) shall be placed on the middle portion of each specimen for a period of 2 hours. At the end of that time the weight shall be removed and the specimen allowed to rest at room temperature for 30 minutes. The thickness of the gasket shall then be determined and compared with a measurement obtained before the application of the weight. The compression set shall not exceed 50 percent of the initial thickness of the specimen.

33.2.3.3 Following the test specified in 33.2.3.2, the specimens shall be suspended in an air oven at a temperature of 70°C (158°F) for a period of 5 days. The specimens shall then be tested for compliance with 33.2.3.2, approximately 24 hours after removal from the oven.

33.2.3.4 Following the test specified in 33.2.3.3, the specimens shall be cooled to a temperature of minus 30°C (minus 22°F) for a period of 24 hours and then subjected to an impact from a hammer of 1.35 kg mass (2.98 pounds) falling from a height of 150 mm (6 inches). The hammer head shall be steel, 28.6 mm (1-1/8 inches) in diameter, and have a flat striking surface, 25.4 mm (1 inch) in diameter, with slightly rounded edges. The specimens being tested shall be placed on short lengths of 50 by 100 mm (2 by 4 inch) minimum wooden pieces (clear spruce) when being impacted. Following the impact the specimens shall be examined for evidence of cracking or other adverse effects. The test shall be continued and the specimens impacted every 24 hours for two more days. The specimens shall then be removed from the cold chamber, allowed to rest at room temperature for approximately 24 hours, and then tested for compliance with 33.2.3.2.

34 Corrosive Atmosphere Test

34.1 Salt spray test

34.1.1 One complete sample of the junction box, junction box component or specimen samples of materials representative of that used in the junction box shall be subjected to the salt spray test as described in 34.1.3 – 34.1.11.

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

34.1.2 With reference to 34.1.1, 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.

34.1.3 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.

34.1.4 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/in^2 (117 to 131 kPa) so that the solution is aspirated as a fine mist or fog into the interior of the chamber.

34.1.5 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.

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

34.1.7 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.

34.1.8 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 Live 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.

34.1.9 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.

34.1.10 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.

34.1.11 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.

34.2 Moist carbon dioxide/sulphur dioxide test

34.2.1 One complete sample of junction box, junction box component or specimen samples of materials representative of that used in the junction box shall be subjected to the test as described in 34.2.3 – 34.2.9.

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

34.2.2 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.