UL 6703

STANDARD FOR SAFETY

Connectors for Use in Photovoltaic Systems

UL Standard for Safety for Connectors for Use in Photovoltaic Systems, UL 6703

First Edition, Dated August 28, 2014

Summary of Topics

This revision of ANSI/UL 6703 dated June 25, 2024 includes the following changes in requirements:

– Addition of Assembly Procedures for Field Assembled Connector Test Samples; 9.1.2.7– 9.1.2.9, 12.3.1

– Addition of a Cyclic Pull Test; 3.6A, 3.8, 9.2.2.4, 9.4.1 – 9.4.5, 12.2.1

– Revision to Test Condition for Low Temperature Impact test for PV Connectors; 9.1.3.2, 9.1.3.3, 12.2.1

– Harmonize Permitted Cables with NEC 2020 Requirements; 1.2, 1.4

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

The new and revised requirements are substantially in accordance with Proposal(s) on this subject dated July 21, 2023 and May 24, 2024.

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ANSI/UL 6703-2024

UL 6703

Standard for Connectors for Use in Photovoltaic Systems

Prior to the first edition, the requirements for the products covered by this standard were included in the Outline of Investigation for Connectors for Use in Photovoltaic Systems, UL 6703 and the Outline of Investigation for Multi-Pole Connectors for Use in Photovoltaic Systems, UL 6703A.

First Edition

August 28, 2014

This ANSI/UL Standard for Safety consists of the First Edition including revisions through June 25, 2024.

The most recent designation of ANSI/UL 6703 as an American National Standard (ANSI) occurred on June 25, 2024. 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 ULSE at any time. Proposals should be submitted via a Proposal Request in the Collaborative Standards Development System (CSDS) at https://csds.ul.com.

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CONTENTS

INTRODUCTION

1 Scope 5
2 General 5
2.1 Components 5
2.2 Units of measurement 6
2.3 Undated references 6
3 Glossary 6

CONSTRUCTION

4 General 7
5 Current Carrying Parts (Contacts) 7
6 Polymeric Materials 8
6.1 General 8
6.2 Insulating material 8
6.3 Gaskets, Seals and O rings 10
7 Spacings 10
8 Accessibility of Uninsulated Live Parts 11
8A Field Assembled Connectors 12

PERFORMANCE

9 PV Connector Tests 12
9.1 General 12
9.2 Effectiveness of Locking and Strain Relief tests 16
9.3 Gasket tests 17
9.4 Cyclic pull test 18

RATINGS

10 Details 19

MARKINGS

11 General 19

INSTRUCTIONS

12 Assembly Instructions 20
12.1 Dissemination 20
12.2 Required content 21
12.3 Assembly procedure 22
12.4 Verification 22

APPENDIX A

Standards for Components 23

No Text on This Page

INTRODUCTION

1 Scope

1.1 This standard covers latching or locking type PV connectors either as a free connector (separate entity) or as a fixed connector (panel or bulkhead type) and rated 1500 V ac or dc or less. These connectors are intended for use in wiring methods detailed in Part IV of Article 690 – Solar Photovoltaic Systems of the National Electrical Code, NFPA 70.

1.2 This standard is intended for single pole or multi-pole PV connectors suitable for use on insulated, stranded copper wires rated 90°C, 105°C, 125°C, or 150°C dry; 90°C wet; 600, 1000, or 2000 V. This standard covers wire types that are one of the following:

a) PV wire or cable; or

b) Single-conductor cable marked sunlight resistant and Type USE-2 and Type RHW-2.

1.3 This standard also covers latching or locking type multi-pole PV connectors rated 1500 Vac or dc or less. Multi-pole PV connectors consist of connectors, panel mounted connectors, distribution blocks and splitter connectors for the purpose of facilitating connections to and from inverters and like devices in a PV system.

1.4 *Deleted*

1.5 This standard covers PV connectors whose dimensions are not defined in any national or international technical standard. Connectors are identified and tested with compatible mating part (or parts if multiple exist) and are to be of the same brand unless multiple product manufacturers are submitting under the same evaluation for the purpose of proving intermatability.

1.6 This standard does not apply to PV wiring harnesses or cable assemblies consisting of connectors (single pole or multi-pole) assembled on to cables, which are covered by the Outline of Investigation for Distributed Generation Wiring Harnesses, UL 9703. PV Wiring Harnesses may use PV connectors covered by this standard in their assembly. Harnesses have PV connectors factory assembled onto each end of the cable.

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 needed 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 recognized rating established for the intended conditions of use.

2.1.4 Specific components are recognized as being 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 for which they have been recognized.

2.2 Units of measurement

2.2.1 The requirements in this standard are stated in metric units that make the requirement conveniently useable in countries employing the various metric systems (practical SI and customary). In addition to being stated in metric units, the inch/pound units, that are customary in the USA, are also provided. The values given in SI (metric) units shall be normative, except for AWG conductor sizes. Any other values given are for information purposes only.

2.2.2 Equivalent – although, not necessarily exactly identical – results are to be expected from applying a requirement in USA or metric terms. Equipment calibrated in metric units is to be used when a requirement is applied in metric terms.

2.3 Undated 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 For the purpose of this standard, the following terms and definitions apply. In addition, see the Glossary section of the Standard for Cable Assemblies and Fittings for Industrial Control and Signal Distribution, UL 2238, for multi-polarity devices.

3.2 ACCESSIBLE PART – a part so located that it can be contacted by a person, either directly or by means of a probe or a tool, or that is not recessed the required distance behind an opening.

3.3 AMBIENT TEMPERATURE – maximum temperature of the ambient as assigned by the manufacturer, in which the connector is able to operate permanently without the maximum operating temperature being exceeded.

3.4 DISTRIBUTION BLOCK – an insulated fitting with or without mounting options that terminates in two or more outlets or that terminates in two or more female cable fittings for the purpose of distributing power to additional outlets/inlets.

3.5 ENCLOSURE – that part of the connector that:

a) renders inaccessible all or any parts of the connector that may otherwise present a risk of electric shock, and/or

b) retards propagation of flame initiated by electrical disturbances occurring within.

3.5.1 FACTORY ASSEMBLED CONNECTOR – A connector that is intended to be assembled and terminated to the cable under controlled conditions at a manufacturer's location.

3.5.2 FIELD ASSEMBLED CONNECTOR – A connector that is intended to be assembled and terminated to the cable in the field.

3.6 MAXIMUM OPERATING TEMPERATURE (MOT) [UPPER LIMITING TEMPERATURE] – maximum temperature of a connector as defined by the manufacturer in which the connector is intended to operate.

3.6A SINGLE-USE CONNECTOR – A connector which cannot be plugged-in to make a connection or be unplugged to make a disconnection. The only way to disconnect is to cut out or disengage and remove the whole connector and install a new one.

3.7 OVERMOLD – additional material applied over the enclosure and cable to provide additional environmental protection and sealing.

3.8 SPIRAL CONNECTOR – A type of connector which uses a helical or spiral shaped conductive tube to make a compression type termination to a wire or wires. A spiral connector is an example of a single-use connector as defined in 3.6A.

CONSTRUCTION

4 General

4.1 Only materials that are acceptable for the particular use shall be employed in a PV connector. PV connectors shall be made and finished with the degree of uniformity and grade of workmanship that are practicable in a well-equipped factory.

4.2 A PV connector shall comply with the requirements in the Standard for Wire Connectors, UL 486A-486B, as appropriate, and with this standard.

4.3 Multi-pole PV connectors shall additionally comply with the following construction requirements, as appropriate, in the Standard for Cable Assemblies and Fittings for Industrial Control and Signal Distribution, UL 2238:

a) Grounding and Dead-Metal Parts (Section 9);

b) Terminals (Section 10);

c) Strain Relief and Cord Entries (Section 11); and

d) Assembly (Section 13).

4.4 There shall be no sharp edges or corners on the outer surface of a PV connector that can result in damage to the PV wire insulation that the connector contacts.

4.5 Latching connectors shall not require the use of a tool to unlatch. Latching connectors shall incorporate a suitable latching mechanism such as ribs, twisting action, or other latching mechanisms between the mated pair.

4.6 Locking connectors shall require the use of a tool to unlock the connectors in a mated position. A tool can be a specialized device provided by the manufacturer or a standard common device, i.e. screwdriver. The tool and its operation shall be identified in the manufacturer's assembly instructions, see 12.2.1(d)(8).

5 Current Carrying Parts (Contacts)

5.1 Connectors shall be rated either for use with aluminum conductors, or rated for use with copper conductors, or dual-rated for use with either aluminum or copper conductors. The current-carrying parts of a connector shall use material that complies with the Standard for Wire Connectors, UL 486A-486B at the points of electrical contact with the conductor.

5.2 Connectors rated for use with aluminum conductors shall only be used with AA-8000 series aluminum alloy conductors that comply with the Standard for Photovoltaic Wire, UL 4703.

5.3 Connectors rated for use with copper conductors with current carrying parts that contain more than 15% zinc shall comply with 7.12.3 of the Standard for Wire Connectors, UL 486A-486B.

5.4 Mated connectors shall both be aluminum-rated, both be copper rated, or at least one connector shall be dual-rated for use with aluminum or copper conductors. Alternatively, mated connectors that are listed for use with each other shall be permitted, irrespective of their individual conductor rating.

6 Polymeric Materials

6.1 General

6.1.1 Polymeric materials may be used as an enclosure or as insulating materials that are in direct contact with or in close proximity, less than 0.8 mm (1/32 in), to live parts. When the same material is used for both purposes, the more stringent requirements shall be applied.

6.1.2 Polymeric materials employed as a part of the connector shall be suitable for its rated temperature. The relative thermal index (RTI), electrical, mechanical impact (IMP) and mechanical strength (STR), as determined in accordance with the Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B, shall not be less than 20°C (36°F) above the maximum operating temperature rating for the connector as specified by the manufacturer. For soft materials, such as elastomers, where the RTI Mechanical IMP cannot be determined, or for those connectors protected from impact under use, the RTI mechanical IMP is not required.

6.1.3 A polymeric material 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) Ultraviolet light exposure, and

Note: An f1 rating signifies compliance, an f2 rating requires further investigation into its suitability.

b) Water exposure and immersion.

6.1.4 A polymeric material serving as the enclosure shall have a minimum flammability classification of V-0 or 5VA as determined by tests described in the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94. The material thickness for determining the flammability shall be measured at the thinnest points of the enclosure.

6.1.5 With reference to 6.1.4, a material other than V-0 or 5VA may be used when the enclosure of the PV wire connector complies with the requirements for the equivalent flame test as specified in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

6.1.6 A polymeric material serving as the enclosure of a part involving a risk of fire or electric shock shall have a relative thermal index (RTI), electrical, mechanical IMP and mechanical STR, as determined in accordance with the Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B, not less than 90°C (194°F).

6.2 Insulating material

6.2.1 A polymeric material that is in direct contact with or in close proximity, less than 0.8 mm (1/32 in) to live parts shall:

a) Have a flammability classification of HB, V-2, V-1, or V-0 as determined in accordance with the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94.

b) Have a High-Current Arc Ignition (HAI) performance level category (PLC) in accordance with Table 6.1;

c) Have a Hot Wire Ignition (HWI) performance level category (PLC) in accordance with Table 6.1;

d) Have a Comparative Tracking Index (CTI) performance level category (PLC) as defined in Table 6.2;

Exception: A material not having a CTI rating may be used when the material complies with the requirements for the Performance Tracking Index test (PTI) test as specified in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

e) Have an Inclined Plane Tracking (IPT) as defined in Table 6.2; and

f) 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 direct sunlight but are protected by glass, or other transparent medium, may be tested with an equivalent layer of that medium attenuating the ultraviolet light exposure during the test.

Table 6.1
Maximum HAI and HWI PLC values

Flammability classification	High-current arc ignition (HAI)	Hot Wire Ignition (HWI)
HB	1	2
V-2	2	2
V-1	2	3
V-0	3	4

Table 6.2
Determination of CTI or IPT

Voltage [a]	Creepage distance	IPT [b] required	CTI [c] 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
1001 – 1500[d]	< 24.0 mm	Yes	No
1001 – 1500[d]	≥ 24.0 mm	No	No

[a] Voltage is the maximum potential difference between:

live parts of different polarity, and

live parts and dead metal parts that may be grounded in service or exposed to contact.

[b] Rating of 1 h using the time to track method at the higher of the rated voltage or 1000 V when the voltage rating is in the range of 601 – 1000 V or 1500 V when the voltage rating is in the range of 1001 – 1500 V.

[c] CTI PLC of 0, 1, or 2.

[d] Single-pole devices only.

6.3 Gaskets, Seals and O rings

6.3.1 Gaskets, seals and O rings shall not be used where they may be subject to flexing during normal operation and shall not deteriorate beyond limits permitted in the Gasket tests, Section 9.3.

7 Spacings

7.1 Connectors in the mated (male – female pair) condition shall comply with 7.2 – 7.5.

7.2 Spacings between uninsulated live parts of different potentials, and between a live part and an accessible metal part (or the probe detailed in Accessibility of Uninsulated Live Parts, Section 8), shall not be less than the values specified in Table 7.1 and Table 7.2.

Table 7.1
Minimum acceptable spacings for field wiring terminals other than tool applied crimp type terminals

Potential involved, V	Through air and over surface	
	mm	(in)
0 – 50	6.4	(1/4)
51 – 300	9.5	(3/8)
301 – 600	12.7	(1/2)
601 – 1000	15.9	(5/8)
>1000 up to 1500[a]	24	(15/16)

[a] Single-pole devices only.

Table 7.2
Minimum acceptable spacings for tool applied crimp type field wiring terminals and Minimum acceptable spacings for locations elsewhere than at wiring terminals

Potential involved, V	Through air		Over surface	
	mm	(in)	mm	(in)
0 – 50	1.6	(1/16)	1.6	(1/16)
51 – 300	3.2	(1/8)	6.4	(1/4)
301 – 600	6.4	(1/4)	9.5	(3/8)
601 – 1000	9.5	(3/8)	12.7	(1/2)
>1000 up to 1500[a]	14	(9/16)	15	(19/32)

[a] Single-pole devices only.

7.3 The spacings at a field-wiring terminal shall be measured with and without wire connected to the terminal. The wire shall 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 shall be one size larger than that required; otherwise, the wire is to be the size required.

7.4 Surfaces separated by a gap of 0.8 mm (0.031 in) or less are considered to be in contact with each other for the purpose of judging over surface spacings.

7.5 In Table 7.1 and Table 7.2, the potential involved is the maximum voltage that may exist between parts during any anticipated use of the connector.

8 Accessibility of Uninsulated Live Parts

8.1 An accessible part of a connector 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.

8.2 In determining whether a part is energized, the connector is to be evaluated:

a) Not mated, and

b) Mated in any implied or described acceptable manner.

In both cases, the connector is to be in the state described in 8.4.

8.3 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.

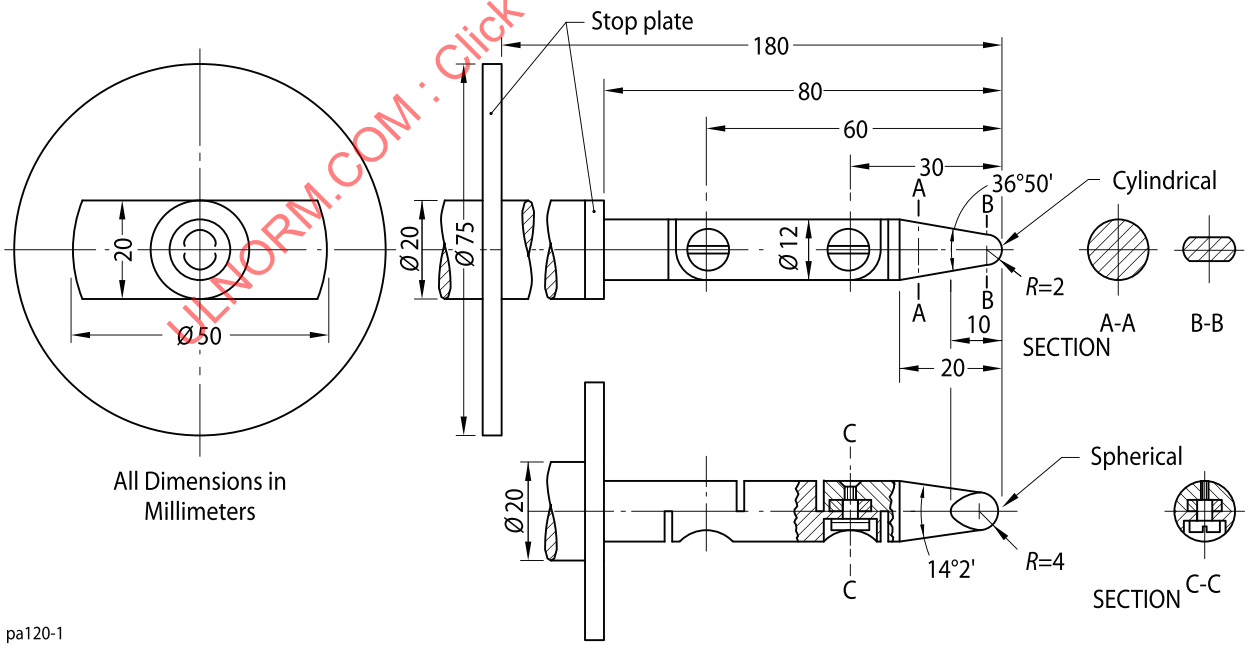
8.4 A part is considered accessible if:

a) In a fully assembled connector or connector pair (that is, with all mated pairs and covers in place) the part may be touched by the probe illustrated in Figure 8.1 or the test probe in IEC 61032, Figure 2. A cover that may be removed without the use of a tool is to be removed for purposes of this requirement.

b) In the unmated condition the part may by touched by the probe illustrated in Figure 8.1.

Figure 8.1

Probe for determining accessibility of live parts



8.5 The probe illustrated in Figure 8.1 or the test probe in IEC 61032, Figure 2 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.

8A Field Assembled Connectors

8A.1 For field assembled connectors, the manufacturer shall provide all connector components, and assembly instructions in accordance with Assembly Instructions, Section 12. If any special or nonstandard tools are required for installation of the connector to the cable in the field, the connector manufacturer shall ensure the availability of these tools for installers, by either providing the required tools with the components shipment, or providing reliable supplier's information in the assembly instructions.

PERFORMANCE

9 PV Connector Tests

9.1 General

9.1.1 All PV connectors shall comply with the tests in Table 9.1 and the Effectiveness of Locking and Strain Relief tests, Section 9.2, and Gasket tests, Section 9.3, as applicable. Multi-pole PV connectors shall additionally comply with the tests in Table 9.2, as applicable. All test sequences are performed using the same assemblies/samples throughout a sequence.

Table 9.1
Required tests

Test	Reference (Standard, Section)	Sample Requirements
Water Spray Sequence		
Dielectric Voltage Withstand - as received	UL 1703, 26	3 assemblies, mated
Leakage Current	UL 1703, 21	
Water Spray	UL 1703, 33	
Dielectric Voltage Withstand following Water Spray	UL 1703, 26	
Leakage Current following Water Spray	UL 1703, 21	
Temperature Cycling Sequence		
Dielectric Voltage Withstand – as received	UL 1703, 26	3 assemblies, mated
Leakage Current – as received	UL 1703, 21	
Temperature Cycling	UL 1703, 35	
Dielectric Voltage Withstand following Temperature Cycling	UL 1703, 26	
Leakage Current following Temperature Cycling	UL 1703, 21	
Wet Insulation Resistance following Temperature Cycling	UL 1703, 27	
Humidity Cycling Sequence		
Dielectric Voltage Withstand – as received	UL 1703, 26	3 assemblies, mated

Table 9.1 Continued on Next Page

Table 9.1 Continued

Test	Reference (Standard, Section)	Sample Requirements
Leakage Current – as received	UL 1703, 21	
Humidity Cycling	UL 1703, 36	
Leakage Current following Humidity Cycling	UL 1703, 21	
Wet Insulation Resistance following Humidity Cycling	UL 1703, 27	
Additional tests to UL 1703		
Wet Insulation Resistance – as received	UL 1703, 27	3 assemblies, mated
Impact[a]	UL 1703, 30	3 assemblies, mated
Low Temperature Impact[a]	UL 1703, 30	3 assemblies, mated
Additional tests to UL 746C		
Crush Resistance	UL 746C, 21	3 assemblies, mated
Mold Stress-Relief Distortion followed by Strain Relief	UL 746C, 29 and UL 1703, 22	6 assemblies, mated
Additional tests to UL 486A-486B		
Current Cycling[b,e]	UL 486A-486B, 9.2	4 assemblies, max wire size/amp rating, mated
Static Heating Sequence[e]	UL 486A-486B, 9.3	4 assemblies, max wire size/amp rating, mated
Mechanical Sequence[e]	UL 486A-486B, 9.4	4 assemblies, min wire size not mated
Dielectric Voltage Withstand[f]	UL 486A-486B, 9.5	24 assemblies, max and min
	Test A, 9.5.2	– 6 assemblies and mated as received
	Test A, 9.5.2	– 6 assemblies aged then assembled and mated
	Test A, 9.5.2	– 6 assemblies mated, conditioned, then tested
	Test B, 9.5.3	– 6 assemblies mated[c]
Stress Corrosion (for current-carrying parts containing more than 15% zinc)	UL 486A-486B, 9.12	3 assemblies, max wire size, not mated
Additional tests to UL 486C		
Spring-action clamp sequence[d]	UL 486C, 9.12	6 of each combination of connector and test conductor(s)
– Conditioning		
– Temperature		
– Dielectric withstand		

[a] See 9.1.3.

[b] A PV connector that is dependent upon insulation piercing, insulation displacement or spring action shall be subjected to the current cycling test. A PV connector that is a compression type (tool applied crimp) and is rated for copper wire only, need not be subjected to the Current Cycling Test.

[c] With the concurrence of those concerned, the unconditioned specimens used for Test A, insulation puncture, may be used for Test B, flashover.

[d] A PV connector that is dependent upon spring action shall be subjected to the spring action sequence.

[e] Applicable to single pole connectors. For multi-pole connectors, see Table 9.2.

[f] Table 28 in UL 486A-486B covers voltage rating up to 600 V. Above 600 V, the following requirements apply:

a) For voltage rating of 1 000 V, the test voltage (Vac) for puncture (1 min) is 5 000, and for flashover (maximum) is 11 000.

Table 9.1 Continued on Next Page

Table 9.1 Continued

Test	Reference (Standard, Section)	Sample Requirements
b) For voltage rating of 1 500 V, the test voltage (Vac) for puncture (1 min) is 7 000, and for flashover (maximum) is 16 000.		
c) For other voltage ratings between 600 V and 1 500 V, the following formula applies:		
1) Test voltage (Vac) for puncture (1 min) equal to 4 times voltage rating plus 1 000;		
2) Test voltage (Vac) for flashover (maximum) equal to 10 times voltage rating plus 1 000.		
Note 1 – The sample requirements assume only one construction (male and female) and one size and type conductor unless otherwise noted. Additional tests and samples may be required based on construction.		
Note 2 – 1 assembly consists of 1 male and 1 female connector with 0.7 m of intended conductor for each connector.		
Note 3 – If connectors may be assembled in the field, unassembled connectors and 2 sets of all necessary tools are required.		

Table 9.2
Additional required tests for multi-pole PV connectors

Test	Reference (Standard, Section)	Sample Requirements
Current Interruption Sequence (ac ratings only), see 10.2.		
Overload[a]	UL 1977, 15	6 assemblies, mated
Temperature	UL 2238, 25	
Dielectric Voltage Withstand	UL 2238, 21[a]	
Resistance to Arcing[a]	UL 1977, 18	
Temperature sequence[c]		
Temperature	UL 2238, 25	6 assemblies, mated
Dielectric Voltage Withstand	UL 2238, 21[b]	
Additional tests to UL 2238		
Insulation resistance	UL 2238, 22	1 assembly, mated
Conductor secureness	UL 1703, 23	6 samples
Polarization	UL 2238, 28	1 assembly
Grounding impedance	UL 2238, 31	6 assemblies
Strength of insulation base	UL 2238, 37.7	6 assemblies
Grounding (bonding) path current	UL 2238, 37.8	6 assemblies
Assembly	UL 2238, 37.9	6 assemblies
Accelerated aging	UL 2238, 37.10	6 assemblies
PVC compounds and copolymers	UL 2238, 37.11	6 assemblies
Current Cycling[d]	UL 2238, 10.7 and UL 486E, 9.2	4 assemblies, max wire size/amp rating, mated
Static Heating Sequence[d]	UL 2238, 10.7 and UL 486E, 9.3	4 assemblies, max wire size/amp rating, mated
Mechanical Sequence[d]	UL 2238, 10.7 and UL 486E, 9.4	4 assemblies, min wire size not mated
Strain Relief[e]	UL 2238, 11 and 24	6 assemblies
[a] The overload and resistance to arcing tests need not be performed on devices rated and marked in accordance with 11.1(d).		
[b] For devices rated over 600 V, use the Standard for Terminal Blocks, UL 1059, Section 24.		
[c] The temperature sequence need not be performed if the temperature and dielectric voltage withstand tests are conducted as part of the Current Interruption sequence.		

Table 9.2 Continued on Next Page

Table 9.2 Continued

Test	Reference (Standard, Section)	Sample Requirements
[d] Applicable to a direct bearing, setscrew pressure wire connector intended for field wiring; see 10.7 and 10.8 in UL 2238.		
[e] Applicable to a multi-pole connector intended for connection to a flexible cord.		
Note 1 – The sample requirements assume only one construction (male and female) and one size and type conductor unless otherwise noted. Additional tests and samples may be required based on construction.		
Note 2 – 1 assembly consists of 1 male and 1 female connector with 0.7 m of intended conductor for each connector.		
Note 3 – If connectors may be assembled in the field, unassembled connectors and 2 sets of all necessary tools are required.		

9.1.2 Preparation of specimens

9.1.2.1 Representative specimens of the PV connector shall be assembled to conductors of the proper type, length, and size and in the manner used in service. PV connectors shall be tested using the maximum and minimum outside diameters (OD) for each conductor type, PV or USE-2, while considering the number of strands and the wire size or range, if applicable.

Exception No. 1: A dual rated and labeled PV and USE-2 conductor need only be tested once.

Exception No. 2: For a family of similar designed connectors, the intermediate size need not be tested.

9.1.2.2 If a connector is intended for assembly by means of a specific tool, this tool shall be used in the intended manner.

9.1.2.3 If a connector is intended to be assembled to a conductor by means of more than one type of specific tool, the connector shall meet the requirements when any of the specific tools are employed in the assembly operation.

9.1.2.4 With reference to 9.1.2.3, in selecting tools for assembly of a connector to a conductor, the following features shall be considered:

a) profile, width, and depth of the connector;

b) material of connector body;

c) crimping die geometry;

d) the number of crimps; and

e) similarity of crimp forces.

9.1.2.5 If specific instructions for assembling the connector to the conductor are furnished with the connector, such instructions shall be followed in the preparation of the specimens, except that the conductor shall not be brushed or abraded and an antioxidant shall be used only if the connector is prefilled with the antioxidant. See 12.3.

9.1.2.6 For field assembled connectors, all test samples required by this standard shall be assembled from the connector components provided by the manufacturer. The sample assembly process shall be performed precisely according to the manufacturer's assembly instructions, including using manufacturer specified special or nonstandard tools, as described in 8A.1.

9.1.2.7 For field assembled connectors, the test samples shall include at least four sets representing the maximum and minimum sizes of intended wires, assembled at the upper and lower temperature ratings.

9.1.2.8 The metal connection (such as crimping) between conductor and connector pin/socket is to be fully assembled (tightened to the specification) at a temperature of 23 ±5°C (73.4 ±9°F). Polymeric material sealing and strain relief (such as a gland) is to be assembled and tightened by hand at a temperature of 23 ±5°C (73.4 ±9°F), then the steps in 9.1.2.9 shall be applied.

NOTE: This purpose of this requirement is to evaluate the assembly temperature effect on polymeric materials used in connectors for sealing and strain relief, such as a gland.

9.1.2.9 One set of samples, as defined in 9.1.2.7, with maximum wire size and one set with minimum wire size shall be placed into an environmental chamber at the upper rated temperature, and the other two sets shall be placed into an environmental chamber at the lower rated temperature. Samples shall be conditioned for a minimum of 3 hours. In less than 2 minutes following removal from the chamber, polymer material sealing and strain relief shall be tightened to the required torque in accordance with Assembly Instructions, Section 12.

9.1.3 Impact Test

9.1.3.1 As a result of the test, there shall be no reduction in spacings below the minimum allowable as defined in Spacings, Section 7, no exposed live parts as defined in Accessibility of Live parts, Section 8, and no other conditions that would increase the shock or fire hazard. Small cracks are acceptable if the assembly is additionally subjected to the Leakage Current Test, Dielectric Withstand Test, and Wet Insulation Resistance Test in UL 1703, Sections 26, 21, and 27, respectively.

9.1.3.2 If the Assembly Instructions, Section 12, specifies temperature ranges or temperature limitations for which the connector product is to be assembled and used in, the Low Temperature Impact Test required by Table 9.1 shall be conducted at the specified lowest temperature ±2.0°C (±3.6°F), or 0 ±2.0°C (32.0 ±3.6°F), whichever is lower.

9.1.3.3 If the temperature range or limitations are not specified in the Assembly Instructions, Section 12, the Low Temperature Impact Test required by Table 9.1 shall be conducted at the minus 35.0 ±2.0°C (minus 31.0 ±3.6°F).

9.2 Effectiveness of Locking and Strain Relief tests

9.2.1 General

9.2.1.1 Three samples of each mating pair of connectors (both male and female) shall be subjected to the Strain Relief test.

9.2.1.2 Six mated pair assemblies of a locking type connector shall be subjected to the Effectiveness of Locking test.

9.2.2 Strain Relief Test (single pole connector)

Note: For multi-pole connectors, see Table 9.2.

9.2.2.1 Each cable exiting a PV connector (both male and female halves) shall be individually subjected to the Strain Relief Test as described in 9.2.2.2 and 9.2.2.3.

9.2.2.2 The cable shall withstand for 1 min a force of 89 N (20 lb) applied in any direction permitted by the construction, without transfer of the force to the internal electrical connection, or damage to the conductor.

9.2.2.3 The internal connections within the PV connector shall be disconnected or otherwise made ineffective prior to the test. The strain relief is not acceptable if, at the point of exit of the conductors, there is such movement of the conductor as to indicate that stress on the internal connections would have resulted.

9.2.2.4 After the test described in 9.2.2.1 – 9.2.2.3 is complete, then the Cyclic Pull Test, 9.4, shall be conducted.

9.2.3 Effectiveness of Locking Test (locking type connector)

Note: Latching type connectors are not subjected to this test.

9.2.3.1 Connectors with a locking device or with a snap-on device for locking purposes shall withstand for 1 minute, a minimum tensile force of 89 N (20 lb) without separation.

9.2.3.2 The test shall be conducted on the PV connector with its mating part. The specified force shall be applied in the direction of the separation of the mated pair at the rate of 10 N/sec (4.4 lb/sec). The force shall be applied directly to the mated parts or using the assembled conductors for ease of applying the force.

9.3 Gasket tests

9.3.1 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 9.3, and shall comply with the physical property requirements of Table 9.4. The material shall not deform, melt, or harden to a degree which would affect its sealing properties.

Table 9.3
Physical property requirements

Material	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 (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 9.4
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 (a material such as foam rubber).

9.4 Cyclic pull test

9.4.1 This is a test performed after the Strain Relief Test in 9.2.2, to ensure the strain relief test force does not transfer to the internal electrical connection. See 9.2.2.4.

9.4.2 The test apparatus is to be a device which is capable of providing a cyclic pull force on two wire ends of a mated connector with a specified force and time described in 9.4.4.

9.4.3 Four mated connector samples shall be subjected to the Strain Relief Test, 9.2.2, then to the cyclic pull test. The four connector samples shall include two connectors with the maximum strand count and two connectors with the minimum strand count. In the case of a connector accepting a range of wire sizes, the sample count shall be increased to eight mated connector samples. The eight samples include two of each: connectors with the maximum and minimum conductor sizes and corresponding maximum and minimum numbers of wire strands.

9.4.4 The test procedure includes the following:

a) Fix two wire ends of the mated connector to the test device, so that the force is applied between the wire conductors and the internal connection interface.

b) Loosen the cable glands on each end of the connector.

c) Apply an AC or DC current equal to the Standard for Wire Connectors, UL 486A-486B, Table 7 Test current for connectors intended for a single conductor, Column 3 Assigned maximum ampere rating.

d) Apply pulling force with following parameters:

1) Cycling rate shall not be quicker than 2 cycles per minute, where a cycle consists of “zero tension – pull – full tension – release – zero tension”;

2) There are no changing rate requirements during pull force increase or decrease periods;