UL 62852

STANDARD FOR SAFETY

Connectors for DC-Application in Photovoltaic Systems – Safety Requirements and Tests

UL Standard for Safety for Connectors for DC-Application in Photovoltaic Systems – Safety Requirements and Tests, UL 62852

First Edition, Dated July 6, 2022

Summary of Topics

First Edition of the UL IEC-Based Standard for Connectors for DC-Application in Photovoltaic Systems – Safety Requirements and Tests, UL 62852, dated July 6, 2022. UL 62852 is an adoption of IEC 62852 (Edition 1.1, issued March 2020). The IEC standard consists of the first edition (2014-11) and its amendment 1 (2020-03). Please note that the National Difference document incorporates all of the U.S. national differences for UL 62852.

The new requirements are substantially in accordance with Proposal(s) on this subject dated November 5, 2021 and May 20, 2022.

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UL 62852

Standard for Connectors for DC-Application in Photovoltaic Systems – Safety Requirements and Tests

First Edition

July 6, 2022

This ANSI/UL Standard for Safety consists of the First Edition.

The most recent designation of ANSI/UL 62852 as an American National Standard (ANSI) occurred on July 6, 2022. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, Title Page, or Preface. The National Difference Page and IEC Foreword are also excluded from the ANSI approval of IEC-based standards.

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.

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PREFACE

This UL Standard is based on IEC Publication 62852: Edition 1.1, Connectors for DC-Application in Photovoltaic Systems – Safety Requirements and Tests. IEC publication IEC 62852 is copyrighted by the IEC.

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Note – Although the intended primary application of this Standard is stated in its Scope, it is important to note that it remains the responsibility of the users of the Standard to judge its suitability for their particular purpose.

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NATIONAL DIFFERENCES

National Differences from the text of International Electrotechnical Commission (IEC) Publication 62852, Connectors for DC-application in photovoltaic systems – Safety requirements and tests, copyright 2020, are indicated by notations (differences) and are presented in bold text.

There are five types of National Differences as noted below. The difference type is noted on the first line of the National Difference in the standard. The standard may not include all types of these National Differences.

DR – These are National Differences based on the **national regulatory requirements**.

D1 – These are National Differences which are based on **basic safety principles and requirements**, elimination of which would compromise safety for consumers and users of products.

D2 – These are National Differences from IEC requirements based on existing **safety practices**. These requirements reflect national safety practices, where empirical substantiation (for the IEC or national requirement) is not available or the text has not been included in the IEC standard.

DC – These are National Differences based on the **component standards** and will not be deleted until a particular component standard is harmonized with the IEC component standard.

DE – These are National Differences based on **editorial comments or corrections**.

Each national difference contains a description of what the national difference entails. Typically one of the following words is used to explain how the text of the national difference is to be applied to the base IEC text:

Addition / Add - An addition entails adding a complete new numbered clause, subclause, table, figure, or annex. Addition is not meant to include adding select words to the base IEC text.

Modification / Modify - A modification is an altering of the existing base IEC text such as the addition, replacement or deletion of certain words or the replacement of an entire clause, subclause, table, figure, or annex of the base IEC text.

Deletion / Delete - A deletion entails complete deletion of an entire numbered clause, subclause, table, figure, or annex without any replacement text.

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FOREWORD

INTERNATIONAL ELECTROTECHNICAL COMMISSION

CONNECTORS FOR DC-APPLICATION IN PHOTOVOLTAIC SYSTEMS – SAFETY REQUIREMENTS AND TESTS

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.

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This Consolidated version of IEC 62852 bears the edition number 1.1. It consists of the first edition (2014-11) [documents 82/878/FDIS and 82/905/RVD] and its amendment 1 (2020-03) [documents 82/1646/FDIS and 82/1667/RVD]. The technical content is identical to the base edition and its amendment.

This Final version does not show where the technical content is modified by amendment 1. A separate Redline version with all changes highlighted is available in this publication.

International Standard IEC 62852 has been prepared by IEC technical committee 82: Solar photovoltaic energy systems.

This International Standard is derived from EN 50521.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of the base publication and its amendment will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

• reconfirmed,

• withdrawn,

• replaced by a revised edition, or

• amended.

CONNECTORS FOR DC-APPLICATION IN PHOTOVOLTAIC SYSTEMS – SAFETY REQUIREMENTS AND TESTS

1 Scope

This International Standard applies to connectors for use in the d.c. circuits of photovoltaic systems according to class II of IEC 61140:2001 with rated voltages up to 1 500 V d.c. and rated currents up to 125 A per contact.

This standard applies to connectors without breaking capacity but which might be engaged and disengaged under voltage.

This standard also applies to connectors which are intended to be built-in or integrated in enclosures of devices for photovoltaic systems. This standard may be used as a guide for connectors in photovoltaic systems of classes 0 and III according to IEC 61140:2001 as well as for protection for Class II equipment intended for use at less than 50 V d.c. This document does not apply to connectors for data collection, tracker controls or similar, but it may be used as a guide for those connectors.

1DV DR *Modification by adding the following:*

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.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60050 (all parts): *International Electrotechnical Vocabulary* (available at http://www.electropedia.org)

IEC 60060-1, *High-voltage test techniques – Part 1: General definitions and test requirements*

IEC 60068-1, *Environmental testing – Part 1: General and guidance*

IEC 60068-2-14, *Environmental testing – Part 2-14: Tests – Test N: Change of temperature*

IEC 60068-2-75, *Environmental testing – Part 2-75: Tests – Test Eh: Hammer tests*

IEC 60068-2-78, *Environmental testing – Part 2-78: Tests – Test Cab: Damp heat, steady state*

IEC 60112, *Method for the determination of the proof and the comparative tracking indices of solid insulating materials*

IEC 60216-1, *Electrical insulating materials – Thermal endurance properties – Part 1: Ageing procedures and evaluation of test results*

IEC 60216-5, *Electrical insulating materials – Thermal endurance properties – Part 5: Determination of relative thermal endurance index (RTE) of an insulating material*

IEC 60228, *Conductors of insulated cables*

IEC 60309-1, *Plugs, socket-outlets and couplers for industrial purposes – Part 1: General requirements*

IEC 60352-2, *Solderless connections – Part 2: Solderless crimped connections – General requirements, test methods and practical guidance*

IEC 60352-3, *Solderless connections – Part 3: Solderless accessible insulation displacement connections – General requirements, test methods and practical guidance*

IEC 60352-4, *Solderless connections – Part 4: Solderless non-accessible insulation displacement connections – General requirements, test methods and practical guidance*

IEC 60352-5, *Solderless connections – Part 5: Press-in connections – General requirements, test methods and practical guidance*

IEC 60352-6, *Solderless connections – Part 6: Insulation piercing connections – General requirements, test methods and practical guidance*

IEC 60352-7, *Solderless connections – Part 7: Spring clamp connections – General requirements, test methods and practical guidance*

IEC 60364-7-712, *Electrical installations of buildings – Part 7-712: Requirements for special installations or locations – Solar photovoltaic (PV) power supply systems*

IEC 60512 (all parts), *Connectors for electronic equipment – Tests and measurements*

IEC 60512-1, *Connectors for electronic equipment – Tests and measurements – Part 1: General*

IEC 60512-11-7, *Electromechanical components for electronic equipment – Basic testing procedures and measuring methods – Part 11-7: Climatic tests – Test 11g: Flowing mixed gas corrosion test*

IEC 60529, *Degrees of protection provided by enclosures (IP Code)*

IEC 60664-1, *Insulation coordination for equipment within low voltage systems – Part 1: Principles, requirements and tests*

IEC TR 60664-2-1, *Insulation coordination for equipment within low-voltage systems – Part 2-1: Application guide – Explanation of the application of the IEC 60664 series, dimensioning examples and dielectric testing*

IEC 60695-2-11, *Fire hazard testing – Part 2-11: Glowing/hot-wire based test methods – Glow-wire flammability test method for end-products (GWEPT)*

IEC 60695-11-10, *Fire hazard testing – Part 11-10: Test flames – 50 W horizontal and vertical flame test methods*

IEC TR 60943, *Guidance concerning the permissible temperature rise for parts of electrical equipment, in particular for terminals*

IEC 60998-2-3, *Connecting devices for low-voltage circuits for household and similar purposes – Part 2-3: Particular requirements for connecting devices as separate entities with insulation-piercing clamping units*

IEC 60999-1, *Connecting devices – Electrical copper conductors – Safety requirements for screw-type and screwless-type clamping units – Part 1: General requirements and particular requirements for clamping units for conductors from 0,2 mm^2 up to 35 mm^2 (included)*

IEC 60999-2, *Connecting devices – Electrical copper conductors – Safety requirements for screw-type and screwless-type clamping units – Part 2: Particular requirements for clamping units for conductors above 35 mm^2 up to 300 mm^2 (included)*

IEC 61032, *Protection of persons and equipment by enclosures – Probes for verification*

IEC 61140, *Protection against electric shock – Common aspects for installation and equipment*

IEC 61210, *Connecting devices – Flat quick-connect terminations for electrical copper conductors – Safety requirements*

IEC 61215-2, *Terrestrial photovoltaic (PV) modules – Design qualification and type approval – Part 2: Test procedures*

IEC 61984, *Connectors – Safety requirements and tests*

IEC 62444, *Cable glands for electrical installations*

IEC 62548, *Photovoltaic (PV) arrays – Design requirements*

IEC 62930, *Electric cables for photovoltaic systems with a voltage rating of 1,5 kV DC*

ISO 868, *Plastics and ebonite – Determination of indentation hardness by means of a durometer (Shore hardness)*

ISO 4892-2, *Plastics – Methods of exposure to laboratory light sources – Part 2: Xenon-arc sources*

ISO 4892-3, *Plastics – Methods of exposure to laboratory light sources – Part 3: Fluorescent UV-lamps*

ISO 6988, *Metallic and other non organic coatings – Sulfur dioxide test with general condensation of moisture*

2DV DR *Addition of the following:*

ASTM D 3638, *Standard Test Method for Comparative Tracking Index of Electrical Insulating Materials*

NFPA 70, *National Electrical Code*

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

UL 486A-486B, *Wire Connectors*

UL 746B, *Polymeric Materials – Long Term Property Evaluations*

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

UL 4703, *Photovoltaic Wire*

UL 6703, *Connectors for Use in Photovoltaic Systems*

UL 61730-1, *Photovoltaic (PV) Module Safety Qualification – Part 1: Requirements for Construction*

UL 61730-2, *Photovoltaic (PV) Module Safety Qualification – Part 2: Requirements for Testing*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-581, IEC 60050-826, IEC 60309-1, IEC 60664-1, IEC 60999-1 and IEC 61140, as well as the following apply.

3.1
connector
component which terminates conductors for the purpose of providing connection to and disconnection from a suitable mating component

[SOURCE: IEC 60050-581:2008, 581-06-01]

3.2
multi-way connector
connector with more than one contact

Note 1 to entry: Multiple single-way connectors used in a PV-junction box are not to be regarded as a multi-way connector according to this standard.

3.3
connector under voltage
CuV
connector specially designed to be engaged or disengaged in normal use when live but not under load

Note 1 to entry: In this standard, the term "live" is used if contacts are under an applied voltage, but not necessarily carrying current. The term "load" is used if a current is flowing through the contacts.

3.4
connector without breaking capacity
COC
connector which is not allowed to be engaged or disengaged in normal use when live or under load

[SOURCE: IEC 60050-581:2008, 581-27-73]

3.5
type of connector

3.5.1
free connector
connector for attachment to the free end of a wire or cable

[SOURCE: IEC 60050-581:2008, 581-06-12]

3.5.2
built-in connector
a pre-manufactured connector that is subsequently integrated into an enclosure

3.5.3
integrated connector
a connector assembly that is manufactured as an integral component during enclosure fabrication

3.6
non-rewirable connector
connector so constructed that the cable cannot be separated from the connector without making it permanently useless

[SOURCE: IEC 60309-1:1999, 2.5, modified]

3.7
connector for Class II equipment
connector in which the protection against indirect contact is realised by double or reinforced insulation

Note 1 to entry: Class II according to IEC 61140.

3.8
intended use
application conditions of connectors which are included within the permissible rated values and environmental conditions and characteristics assigned by the manufacturer

3.9
interlock
device, either electrical or mechanical, which prevents the contacts of a connector from becoming live before it is in proper engagement with its counterpart, and which either prevents the connector from being withdrawn while its contacts are live or makes the contacts dead before separation

[SOURCE: IEC 60309-1:1999, 2.9, modified]

3.10
cycle of mechanical operation
one insertion and one withdrawal of the connector with his counterpart

3.11
clamping unit
part(s) of the terminal necessary for the mechanical clamping and the electrical connection of the conductor(s), including the parts which are necessary to ensure the correct contact pressure

[SOURCE: IEC 60999-1:1999, 3.1]

3.12
upper limiting temperature
maximum temperature of a connector as defined by the manufacturer, in which the connector is intended to operate

Note 1 to entry: The abbreviation ULT is often used.

3.13
maximum ambient temperature
maximum temperature of the ambient assigned from the manufacturer, in which the connector is able to operate permanently without the upper limiting temperature being exceeded

3.14
lower limiting temperature
minimum temperature of a connector as defined by the manufacturer in which a connector is intended to operate

Note 1 to entry: The abbreviation LLT is often used.

3.15
clearance
the shortest distance in air between two conductive parts

[SOURCE: IEC 60664-1:2007, 1.3.2]

3.16
creepage distance
shortest distance along the surface of the insulating material between two conductive parts

[SOURCE: IEC 60664-1:2007, 1.3.3]

3.17
overvoltage category
numeral defining a transient overvoltage condition

[SOURCE: IEC 60664-1:2007, 1.3.10]

3.18
pollution
any addition of foreign matter, solid, liquid, or gaseous, that can result in a reduction of electric strength or surface resistivity of the insulation

[SOURCE: IEC 60664-1:2007, 1.3.11]

3.19
pollution degree
numeral characterising the expected pollution of the micro-environment

[SOURCE: IEC 60664-1:2007, 1.3.13]

3.20
rated voltage
value of voltage assigned by the manufacturer to the connector and to which operation and performance characteristics are referred

Note 1 to entry: Rated voltage is equivalent to the rated system voltage according to IEC 61730-1.

[SOURCE: IEC 60664-1:2007, 1.3.9, modified]

3.20DV D1 ***Modification in accordance with the following:***

Replace IEC 61730-1 with UL 61730-1.

3.21
rated insulation voltage
r.m.s. withstand voltage value assigned by the manufacturer to the connector, characterising the specified (long term) withstand capability of its insulation

Note 1 to entry: The rated insulation voltage is not necessarily equal to the rated voltage, which is primarily related to functional performance.

[SOURCE: IEC 60664-1:2007, 1.3.9.1, modified]

3.22
rated impulse voltage
impulse withstand voltage value assigned by the manufacturer to the connector, characterising the specified withstand capability of its insulation against transient overvoltages

[SOURCE: IEC 60664-1:2007, 1.3.9.2, modified]

3.23
impulse withstand voltage
highest peak value of impulse voltage, of prescribed form and polarity which does not cause breakdown of the insulation under specified conditions

Note 1 to entry: The impulse withstand voltage is equal to or higher than the rated impulse voltage.

[SOURCE: IEC 60664-1:2007, 1.3.8.1]

3.24
r.m.s. withstand voltage
power-frequency withstand voltage
highest r.m.s. value of a voltage which does not cause breakdown of the insulation under specified conditions

[SOURCE: IEC 60664-1:2007, 1.3.8.2]

3.25
rated current
current value assigned by the manufacturer, which the connector can carry continuously (without interruption) and simultaneously through all its contacts wired with the largest specified conductor, preferably at an ambient temperature of 85 °C, without the upper limiting temperature being exceeded

Note 1 to entry: If other ambient temperature values are used for the definition of the rated current, the manufacturer should state in the technical documentation the ambient temperature on which the rating is based, with reference, if appropriate, to the derating curve defined in IEC 60512-5-2, test 5b.

3.26
functional insulation
insulation between conductive parts which is necessary only for the proper functioning of the equipment

[SOURCE: IEC 60664-1:2007, 1.3.17.1]

3.27
basic insulation
insulation applied to live parts to provide basic protection against electric shock

Note 1 to entry: Basic insulation does not necessarily include insulation used exclusively for functional purposes (see IEC 61140:2001, 3.10.1).

[SOURCE: IEC 60664-1:2007, 1.3.17.2]

3.28
supplementary insulation
independent insulation applied in addition to basic insulation, in order to provide protection against electric shock in the event of a failure of basic insulation (see IEC 61140:2001, 3.10.2)

[SOURCE: IEC 60664-1:2007, 1.3.17.3]

3.29
double insulation
insulation comprising both basic insulation and supplementary insulation (see IEC 61140:2001, 3.10.3)

[SOURCE: IEC 60664-1:2007, 1.3.17.4]

3.30
reinforced insulation
single insulation system applied to live parts, which provides a degree of protection against electric shock equivalent to double insulation under the conditions specified in the relevant IEC standard (see IEC 61140:2001, 3.10.4)

Note 1 to entry: A single insulation system does not imply that the insulation is a homogeneous piece. It may comprise several layers which cannot be tested separately as basic or supplementary insulation.

[SOURCE: IEC 60664-1:2007, 1.3.17.5]

3.31
internal insulation
part of basic insulation providing the required clearance and creepage distances inside a conductive housing or enclosure

3.32DV D2 *Addition:*

factory assembled connector
A connector that is intended to be assembled and terminated to the cable under controlled conditions at a manufacturer's location.

3.33DV D2 *Addition:*

field assembled connector
A connector that is intended to be assembled and terminated to the cable in the field.

4 Classification

4.1 General

In order to apply the relevant test requirements, connectors shall be classified by the manufacturer's specification, according to their intended use under consideration of class II, according to IEC 61140 and characteristics, as set out below.

4.2 Type of connector

a) Free connector.

b) Built-in connector.

c) Integrated connector.

4.3 Additional characteristics

a) Connector with cable anchorage.

b) IP-code of a connector according to IEC 60529.

c) Connector for Class II equipment.

d) Non-rewirable connector.

e) Rewirable connector.

f) Terminations and connection methods.

5 Constructional requirements and performance

5.1 General

This standard does not define electrical rating values for voltage and current. These values are assigned by the manufacturer.

Connectors shall be suitable for durable outdoor use in an ambient temperature area from –40 °C to +85 °C.

Multi-way connectors shall be designed so that these requirements for earth-faulted and short-circuit-proofed installation complies with IEC 62548 or IEC 60364-7-712.

Compliance with the requirements is verified by the specified tests of this standard.

5.2 Marking and identification

5.2.1 Identification

Connectors shall be identified and characterised by the following:

a) manufacturer's name, trademark or mark of origin;

b) type reference (for example, the catalogue number);

c) rated current in amperes (A);

d) rated voltages or rated insulation voltages between line to earth and line to line in volts (V);

e) rated impulse voltage in kilovolts (kV), if specified;

f) pollution degree;

g) degree of protection by enclosure according to IEC 60529;

h) specified temperatures: ULT, LLT, maximum ambient temperature (minimum +85 °C);

i) type of terminals;

j) connectable conductors;

NOTE For current capacity of cables and wires, see IEC 60364-5-52.

k) reference to this standard or to the Detail Specification (DS), if applicable;

l) symbols "Do not disconnect under load", as given in Annex A; alternatively an adequate warning notice can be found in particular national language;

m) polarity of connector, if applicable;

n) RTE/RTI or TI (mechanical and electrical) of all polymeric insulating materials used in the connector.

5.2.2 Marking

The marking shall be indelible and easily legible.

The minimum marking on the connector shall be that of item a), l) and m) in 5.2.1.

Symbol or warning notice listed in l) of 5.2.1 shall be imprinted or labelled close to connector. A notice to attach the label shall be given in technical documentation.

Markings a) and b) of 5.2.1 shall be applied on the smallest package unit.

5.2.2DV DR *Modification by adding in accordance with the following:*

5.2.2DV.1 Markings (c) and (d) of 5.2.1, rated current and rated voltage, shall be applied on the connector, or on the smallest package unit.

5.2.2DV.2 Marking (m) of 5.2.1, polarity on PV connectors shall be identified with one of the following marking statements:

a) "+" and "-";

b) "POS" and "NEG"; or

c) "POSITIVE" and "NEGATIVE".

5.2.3 Technical documentation

Identification items of 5.2.1 not marked on the connector according to 5.2.2 and the following information shall be given in the technical documentation of the manufacturer:

a) information regarding the type of cable suitable for termination, if applicable;

b) information regarding mounting, if applicable;

c) assembly information such as required tooling (part number) by manufacturer, if applicable.

5.3 Provision against incorrect mating (non-intermateable)

A multi-way connector shall be so designed that contact between live contacts of different polarity is not possible by engagement.

Compliance shall be tested by performing a polarisation test (see A3 of Table 6).

5.4 Protection against electric shock

5.4.1 A connector shall be so designed that, after mounting, its live parts are not accessible by the IEC test finger in accordance with IEC 60529.

5.4.2 Protection against electric shock shall be ensured also during insertion and withdrawal. Compliance shall be tested by the IEC test probe 11 in accordance with IEC 61032.

5.5 Terminations and connection methods

This standard applies to the following terminations and connection methods:

a) crimped connections	according to IEC 60352-2
b) insulation displacement connections	according to IEC 60352-3 (accessible IDC) or IEC 60998-2-3
c) insulation displacement connections	according to IEC 60352-4 (non-accessible IDC) or IEC 60998-2-3
d) press-in connections	according to IEC 60352-5
e) insulation piercing connections	according to IEC 60352-6 or IEC 60998-2-3
f) screwless-type clamping units	according to IEC 60999-1 or IEC 60999-2 or IEC 60352-7
g) screw-type clamping units	according to IEC 60999-1 or IEC 60999-2
h) flat, quick-connect terminations	according to IEC 61210

As a minimum the applicable tests according to 6.3.15 shall be performed for all terminations and connection methods intended to be used.

Other terminations and connection methods shall be tested in accordance with the relevant standards.

Soldering and welding connections are also permitted.

Termination and connection methods shall provide sufficient means for retaining the conductor in position.

Electrical connections shall be so designed that the contact pressure is not transmitted through insulating material other than ceramic, pure mica or other material with characteristics not less suitable, unless there is sufficient resiliency in the metallic parts to compensate for any shrinkage or yielding of the insulating material (see IEC 60309-1:1999, 25.3 or IEC 60999-1:1999, Clause 7 or IEC 60999-2). Insulation piercing terminations and insulation displacement connections are excluded from this requirement because of the tests performed according to IEC 60352-6 or IEC 60998-2-3.

Precautions shall be taken to ensure that adequate contact pressure is maintained during connector lifetime.

To compensate for changes during use, (e.g. loosening at screw-type clamping units caused by thermal cycles) the use of a lock washer, spring washer or similar could be sufficient.

All terminations and connection methods shall be protected from mechanical and excessive thermal stress which could cause increased contact resistance.

5.6 Resistance to deterioration

If deterioration of specific parts might impair safety, the resistance of those parts to expected stresses shall be verified by the execution of the test program in Clause 6.

5.7 General design

5.7.1 Mechanisms which are used for mounting the connector and/or termination of conductors shall not be used to fix live parts in the connector housing, if it may impair the proper function of the mechanism or reduce the clearance and creepage distances below the requirements according to 5.18.

5.7.2 Connectors shall be so designed that connection of conductors of the type and cross-sectional areas as described in 5.7.3 and as specified by the manufacturer is possible. Besides the termination of the conductor, care shall be taken that no damage of the insulation is possible, e.g. by avoiding sharp edges.

5.7.3 Cables connected to the connector shall be suitable for use in photovoltaic systems and shall comply with the requirements of IEC 62930. The values of the rated current and the rated voltage shall have at least the rated values of the connector.

The class of the conductor shall be Class 5 in accordance with IEC 60228, Class 2 conductors are allowed for cables intended for fixed installation.

5.7.3DV DR *Modification by replacing 5.7.3 with the following:*

Cables connected to the connector shall be suitable for use in photovoltaic systems and shall comply with the requirements of the National Electrical Code (NEC), NFPA 70, Section 690.31, Wiring Methods.

The cable in exposed outdoor locations in PV system dc circuits within the PV array shall be 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.

5.7.4 Non-rewirable connectors shall be so designed that:

– the flexible cable cannot be separated from the connector without making it permanently useless,

– the connector cannot be disassembled or parts of it cannot be removed by hand or by using a general purpose tool, for example a screwdriver, as intended,

– means are provided to prevent live parts, e.g. free strands of a conductor, from reducing the minimum insulation distance between such live parts and all accessible external surfaces of the connector, with the exception of the engagement face of the male connector,

– a connector becomes useless for further use when for the re-mounting, other parts than the original ones are necessary,

– connectors with non-rewirable terminations are also considered as rewirable, if they are reconstituted with original parts and with tools of the manufacturer, if applicable.

If this cannot be granted by the design or manufacturing process itself, the in-process test schedule according to 6.4 or another test of the same safety level shall be carried out.

5.8 Design of a free connector

In a free connector, the wires shall be protected against shear and tensile stress at the termination and be secured to prevent twisting.

This requirement does not apply to

a) free connectors for termination to cables in fixed mountings (plug connection in the sense of a detachable connection),

b) free connectors in which the termination is protected against pull and twisting mounting provisions in the end-use product.

5.9 Degree of protection (IP Code)

A connector shall have a degree of protection at least of IP55, according to IEC 60529.

Depending on the installation a higher degree of protection may be required.

5.10 Dielectric strength

A connector shall withstand the specified test voltage. Compliance is determined by the tests according to 6.3.8.

5.11 Mechanical and electrical durability

5.11.1 A connector shall meet the mechanical operations without load of 50 operating cycles.

5.11.2 A non-rewirable connector shall withstand number of bends as described in 6.3.6.

Compliance shall checked by the execution of tests in 6.3.5 and 6.3.6.

5.12 Range of ambient temperature

A connector shall withstand the upper and lower values of temperature range as given in 5.2.1 or as specified by the manufacturer, if lower than the minimum value or higher than the maximum value as defined in 5.2.1.

Compliance is determined by the tests according to test program in Clause 6.

5.13 Temperature rise

The sum of the ambient temperature and the temperature rise of a connector shall not exceed the upper limiting temperature (ULT).

Compliance shall be checked by the execution of test 6.3.4.

5.14 Cable anchorage

5.14.1 Connectors intended to be used with cables specified by the manufacturer

For connectors intended to be used with cables specified by the manufacturer, the tests shall be performed with cables as stated by the manufacturer.

The unloaded cable shall be marked so that any displacement relative to the gland can be easily detected.

The cable is pulled for a duration of 1 s, 50 times, without jerks in the direction of the axis with the relevant force as specified in Table 13.

At the end of this period, the displacement shall not exceed 2 mm. This measurement shall be carried out after unloading the force from the cable.

Afterwards the specimen shall be mounted in the test apparatus for torque test. The unloaded cable shall be marked so that any torsion relative to the gland can be easily detected, and then a torque as specified in Table 14 shall be applied for 1 min.

During test, the torsion shall not exceed 45°.

5.14.2 Connectors intended to be used with generic cables

A test mandrel equivalent to the minimum value of the anchorage range of the cable gland as specified by the manufacturer or supplier, with a sheath thickness as specified in Table 13 shall be fixed to the sample.

The unloaded test mandrel shall be marked so that any displacement relative to the gland can be easily detected.

The test mandrel shall be pulled for a duration of 1 s, 50 times, without jerks in the direction of the axis with the relevant force as specified in Table 13.

At the end of this period, the displacement shall not exceed 2 mm. This measurement is to be carried out after unloading the force from the test mandrel.

Unless otherwise specified, test mandrels shall consist of a metallic rod with an elastomeric sheath having a hardness of 70 Shore D ± 10 points in accordance with ISO 868 and a sheath thickness as specified in Table 13 or Table 14. The complete test mandrel shall have a tolerance of ± 0,2 mm for mandrels up to and

including 16 mm diameter and ± 0,3 mm for mandrels larger than 16 mm diameter. The shape shall be circular or a profile simulating the outer dimension of the cable as specified by the manufacturer or supplier.

Table 13
Pull forces for cord anchorage

Cable diameter mm	Pull force N	Minimum sheath thickness of test mandrel mm
Up to 4	–	1[a]
>4 to 8	30	1
>8 to 11	42	2
>11 to 16	55	2
>16 to 23	70	2
>23 to 31	80	2
>31 to 43	90	2
>43 to 55	100	2
>55	115	2
[a] For cable diameters up to 4 mm, a suitable non-metallic mandrel may be used.		

Afterwards the specimen shall be mounted in the test apparatus for torque test.

The unloaded mandrel shall be marked so that any torsion relative to the gland can be easily detected, and then a torque specified in Table 14 is applied for 1 min.

During test, the torsion shall not exceed 45°.

The torsion test shall be performed by using a test mandrel equivalent to the maximum value of the anchorage range of the cable gland as specified by the manufacturer or supplier, with a torque for the appropriate maximum cable diameter as specified in Table 14.

Table 14
Values for torsion test

Cable diameter mm	Torque Nm	Minimum sheath thickness of test mandrel mm
>4 to 8	0,10	1
>8 to 11	0,15	2
>11 to 16	0,35	2
>16 to 23	0,60	2
>23 to 31	0,80	2
>31 to 43	0,90	2
>43 to 55	1,00	2
>55	1,20	2

For metric cable glands meeting the requirements of IEC 62444 the tests described in this subclause are not required.

5.15 Mechanical strength

5.15.1 A connector including its internal insulation shall show no damage likely to impair safety after exposure to mechanical stress according to Table 6.

5.15.2 In a connector assembled for final use, the contacts shall be securely retained in the contact insert.

5.16 Connector without locking device

Connectors without locking device or without snap-in device shall withstand a withdrawal force of at least 50 N.

Compliance shall be tested according to 6.3.13.

NOTE In some countries locking devices are required. Some countries also require locking devices which can be opened only by use of a tool.

5.16DV DR *Modification by adding the following:*

The mating connectors shall be of the latching or locking type. Mating connectors that are readily accessible and that are used in circuits operating at over 30 volts dc or 15 volts ac shall require a tool for opening.

5.17 Connector with locking device

Connectors with locking device or with snap-in device shall withstand a load of at least 80 N.

Compliance shall be tested according to 6.3.14.

5.18 Clearances and creepage distances

5.18DV D2 *Addition of the following to include an option from UL 6703:*

For Clauses 5.18.1 to 5.18.3, the following options apply:

a) Comply with the requirements in this standard, or

b) Comply with Section 6.2, Insulating Material, and Section 7, Spacings, of UL 6703.

5.18.1 General

Clearances and creepage distances shall be dimensioned according to the following specifications.

For connectors the requirements for double insulation shall be met between energized and accessible parts in the engaged position.

For multi-way connectors the requirements for double or reinforced insulation shall be met between energized and accessible parts with different electrical potential in engaged and unengaged positions.

5.18.2 Clearances

Clearances through slots and openings in enclosures of insulating material shall be dimensioned according to Table 2.

Table 2
Rated impulse voltages and minimum clearances

	Basic insulation		Reinforced insulation	
Rated DC voltage V	Rated impulse voltage kV (1,2/50 µs)	Clearance mm	Rated impulse voltage kV (1,2/50 µs)	Clearance mm
100	1,5	0,5	2,5	1,5
150	2,5	1,5	4,0	3,0
300	4,0	3,0	6,0	5,5
600	6,0	5,5	8,0	8,0
1 000	8,0	8,0	12	14
1 500	10	11	16	19
Minimum values for pollution degree 2 is 0,2 mm and for pollution degree 3 is 0,8 mm. NOTE Values are derived from IEC 60664-1:2007 for overvoltage category III and IEC TR 60664-2-1.				

5.18.3 Creepage distances

5.18.3.1 General

Creepage distances between live parts and accessible surfaces shall be dimensioned for reinforced or double insulation according to Table 3 related to the rated voltage considering the pollution degree as specified in 5.18.3.2.

For relation between creepage distance and clearances see 5.2.2.6 of IEC 60664-1:2007.

Table 3
Creepage distances for basic insulation

Voltage (DC) V	Pollution degree 1	Pollution degree 2			Pollution degree 3		
	All material groups mm	Material group I mm	Material group II mm	Material group III mm	Material group I mm	Material group II mm	Material group III mm
25	0,125	0,5	0,5	0,5	1,3	1,3	1,3
50	0,18	0,6	0,9	1,2	1,5	1,7	1,9
100	0,25	0,71	1,0	1,4	1,8	2,0	2,2
150	0,31	0,8	1,1	1,6	2,0	2,2	2,5
200	0,42	1,0	1,4	2,0	2,5	2,8	3,2
300	0,70	1,5	2,1	3,0	3,8	4,2	4,7
600	1,7	3,0	4,3	6,0	7,6	8,6	9,5
1 000	3,2	5,0	7,1	10,0	12,5	14,0	16,0

Table 3 Continued on Next Page

Table 3 Continued

Voltage (DC) V	Pollution degree 1	Pollution degree 2			Pollution degree 3		
	All material groups	Material group I	Material group II	Material group III	Material group I	Material group II	Material group III
	mm	mm	mm	mm	mm	mm	mm
1 500	5,2	7,5	10,4	15	18,9	20,9	23,6
Linear interpolation is allowed. Values for reinforced or double insulation are twice the values for basic insulation. NOTE Values are derived from IEC 60664 for overvoltage category III, some values are rounded.							

5.18.3.2 Pollution degree

Creepage distances and clearances between hazardous live parts and accessible surfaces outside the enclosure shall be dimensioned according to pollution degree 3. Distances inside the enclosure shall be at least dimensioned for pollution degree 2.

5.18.3.3 Comparative tracking index (CTI)

Insulation materials are classified into four groups corresponding to their comparative tracking index (CTI), when tested in accordance with IEC 60112:

Material Group I	CTI ≥600
Material Group II	400 ≤ CTI < 600
Material Group IIIa	175 ≤ CTI < 400
Material Group IIIb	100 ≤ CTI < 175

A material may be included in one of these four groups on the basis that the PTI, verified by the method of IEC 60112 using solution A, is not less than the lower value specified for the group.

The values specified for the groups are reference values and based on the test voltage of IEC 60112. The test voltage is not in relation to any voltage (system voltage, working voltage, etc.) of a PV module or system.

The test for comparative tracking index (CTI) in accordance with IEC 60112 is designed to compare the performance of various insulating materials under test conditions. It gives a qualitative comparison and in the case of insulating materials having a tendency to form tracks, it also gives a quantitative comparison.

5.19 Insulation parts

5.19.1 General

Insulating parts shall be so designed that they withstand the expected thermal requirements.

5.19.2 Outer accessible parts

Outer accessible parts consisting of isolating material whose deterioration could impair the safety of the connector shall meet following requirements:

a) Flammability Class minimum HB, or V-2 according to IEC 60695-11-10. This shall be proved by a data sheet of the material supplier or by a test of the end product.

Flammability V-1 or V-0 according to IEC 60695-11-10 are also acceptable.

b) Weather resistance according to ISO 4892-2, method A or ISO 4892-3 with a total duration of 500 h. Dielectric strength according to 6.3.8 b) shall be fulfilled after the test.

c) Glow wire test with 650 °C according to IEC 60695-2-11.

d) Approval of relative thermal endurance, relative thermal index or temperature index (RTE/RTI or TI) in accordance with IEC 60216-5 or IEC 60216-1. Values shall be listed in technical information.

NOTE Relevant RTI values evaluated in accordance to UL 746B are accepted as an alternative to RTE.

5.19.2DV D2 *Modification in accordance with the following:*

5.19.2DV.1 Add the following to part (a):

The material thickness for determining the flammability shall be measured at the thinnest points of the isolating material.

Flammability V-0 or 5VA according to UL 94 are also acceptable.

A material other than V-0 or 5VA may be acceptable when the isolating material complies with the requirements for the equivalent flame test as specified in UL 746C.

5.19.2DV.2 Add the following to part (b):

The material which can comply with the applicable requirements in UL 746C, concerning:

1) Ultraviolet light exposure, and

2) Water exposure and immersion.

NOTE An f1 rating complies. An f2 rating requires further evaluation of its suitability.

5.19.2DV.3 Delete the note and replace it with the following:

NOTE Relevant RTI, electrical, mechanical IMP, and mechanical STR values in accordance with UL 746B, no less than 90 °C, are accepted as an alternative to RTE.

5.19.3 Inner parts

Inner parts consisting of isolating material retaining current carrying parts in position shall meet following requirements:

a) Flammability Class minimum HB, or V-2 according to IEC 60695-11-10. This shall be proved by a data sheet of the material supplier or a test of the end product.

Flammability V-1 or V-0 according to IEC 60695-11-10 are also acceptable.

b) Isolating material shall have a CTI-value complying with the rated values of this standard according to IEC 60664-1.

c) Glow wire test with 750 °C according to IEC 60695-2-11.

d) Approval of relative thermal endurance, relative thermal index or temperature index (RTE/RTI or TI) in accordance with IEC 60216-5 or IEC 60216-1. Values shall be listed in technical information.

NOTE Relevant RTI values evaluated in accordance to UL 746B are accepted as an alternative to RTE.

5.19.3DV D2 *Modification in accordance with the following:*

5.19.3DV.1 Add the following to part (a):

The material thickness for determining the flammability shall be measured at the thinnest points of the isolating material.

Flammability HB, V-2, V-1, or V-0 determined in accordance with UL 94 are also acceptable.

5.19.3DV.2 Replace part (b) with the following:

b) Isolating material shall have a CTI-value complying with the rated values of this standard according to IEC 60664-1, IEC 60112, or ASTM D3638.

5.19.3DV.3 Add the following new part (e):

e) Have a minimum High-Current Arc Ignition performance level category (PLC) in accordance with the following:

Flammability classification	High-current arc ignition, PLC
HB	1
V-2	2
V-1	2
V-0	3

5.19.3DV.4 Delete the note and replace it with the following:

NOTE Relevant RTI for electrical, mechanical IMP, and mechanical STR values in accordance to UL 746B, no less than 90 °C, are accepted as an alternative to RTE.

5.20 Current carrying parts and resistance against corrosion

5.20.1 Metal parts shall be so designed that corrosion shall not impair safety with regard to electrical and mechanical characteristics.

Compliance is checked by 6.3.9.

All current carrying parts shall consist of base metal and plating, such that under normal operation a sufficient mechanical strength, electrical conductivity and corrosion resistance as described in this standard are given.

5.20.2 Under wet ambient conditions all metal parts which have a difference of their electrochemical potentials more than 350 mV according to IEC/TR 60943 shall not be in contact with each other.

6 Tests

6.1 General

6.1.1 The tests shall be carried out in the sequence specified for each test group using the number of specimens as given in Table 4. For each test group a separate set of new specimens shall be used.

If designs of connectors require special tests or preparations which are not explicitly indicated in this standard they are chosen or carried out according to the manufacturers specification, e.g. mechanical locking during IP code testing.

Table 4
Plan of specimens required for tests

Reference table	Test group	Number of specimens
Table 6	Group A: mechanical	One per test
Table 7	Group B: service life	3
8	Group C: service life	3
9	Group D: thermal	3
10	Group E: climatic	3
11	Group F: degree of protection	2
12	Group G: isolating material	3
NOTE For a connector family of the same design and comparable size, tests may be only for that member of a family which represents the worst case for that test.		

6.1.2 A pair of connectors (male and female) or free contacts are defined as a specimen. Unless otherwise specified in the test program the unmated pair of connectors shall be tested.

6.1.3 The tests shall be made under the standard atmospheric conditions of IEC 60068-1, unless otherwise specified in the test schedule.

6.1.4 The specimen is deemed not to comply with this standard if the specimen fails in more than one of the tests of any test group. If the specimen fails in one of the tests, this test and the preceding tests which may have affected its results shall be repeated on a new set of specimen. This new specimen shall pass the repeated tests, otherwise the product is deemed not to comply.

6.1.5 All visual examination tests shall be performed with the naked eye, unless otherwise specified.

6.2 Preparation of specimens

6.2.1 Specimens shall be pre-conditioned under standard conditions for testing, for a period of 24 h, in accordance with IEC 60512-1.

6.2.2 The tests shall be carried out with copper conductors unless otherwise specified by the manufacturer and with the type of conductor specified for the connector. If terminations are provided for all types of conductors, solid, stranded and flexible, the tests shall be carried out only with flexible conductors according to IEC 60228, Class 5.

6.2.2DV D2 *Modification by adding the following:*

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, and in the size ranges as:

a) 12 AWG (3.3 mm^2) and 10 AWG (5.3 mm^2) solid;

b) 12 AWG (3.3 mm^2) to 2 000 kcmil (1 010 mm^2) stranded, Class B concentric, compressed, and compact; and

c) 12 AWG (3.3 mm^2) to 1 000 kcmil (508 mm^2) stranded single input wire (SIW).

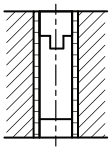
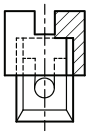
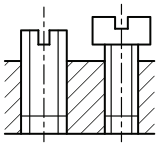
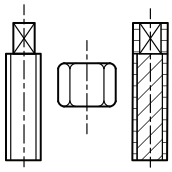
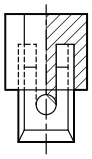
Test specimens for aluminum alloy conductors shall be selected according to UL 486A-486B Table 6.

6.2.3 Screw-type clamping units shall be tightened with the value of the torque stipulated in Table 5 according to IEC 60999-1 and IEC 60999-2 unless otherwise specified by the manufacturer.

6.2.4 Unless otherwise specified in the test schedule, all tests shall be made on the specimen completely assembled according to the manufacturer's instructions.

Table 5

Values of torque for screw-type clamping units

Nominal diameter of thread mm	 I Nm	 II Nm	 III Nm	 IV Nm	 V Nm
≤1,6			0,1	0,1	
> 1.6 up to 2,0			0,2	0,2	
> 2,0 up to 2,8	0,2		0,4	0,4	
> 2,8 up to 3,0	0,25		0,5	0,5	
> 3,0 up to 3,2	0,3		0,6	0,6	
> 3,2 up to 3,6	0,4		0,8	0,8	
> 3,6 up to 4,1	0,7	1,2	1,2	1,2	1,2
> 4,1 up to 4,7	0,8	1,2	1,8	1,8	1,8
> 4,7 up to 5,3	0,8	1,4	2,0	2,0	2,0
> 5,3 up to 6,0	1,2	1,8	2,5	3,0	3,0
> 6,0 up to 8,0	2,5	2,5	3,5	6,0	4,0
> 8,0 up to 10,0		3,5	4,0	10,0	6,0
> 10,0 up to 12,0		4,0		14,0	8,0
> 12,0 up to 15		5,0		19,0	10,0

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Column I	applies to screws without heads if the screw, when tightened, does not protrude from the screw hole and to other screws which cannot be tightened by means of a screwdriver with a blade wider than the diameter of the screw.
Column II	applies to nuts of mantle clamping units which are tightened by means of a screwdriver.
Column III	applies to other screws which are tightened by means of a screwdriver.
Column IV	applies to screws and nuts, other than nuts of mantle clamping units, which are tightened by means other than a screwdriver.
Column V	applies to nuts of mantle clamping units which can be tightened by means other than that of a screwdriver.

Where a screw has a hexagonal head with a slot and the values in columns III and IV are different, the test is made twice, first on a set of three specimens, applying to the hexagonal head the torque specified in column IV, and then to another set of three specimens, applying the torque specified in column III by means of a screwdriver. If the values in columns III and IV are the same, only the test with the screwdriver shall be made.

6.2.5DV DR *Addition of the following requirements for field assembled connectors:*

6.2.5DV.1 For field assembled connectors, the manufacturer shall provide all connector components, and assembly instructions in accordance with 6.2.5DV.3. 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.

6.2.5DV.2 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 6.2.5DV.1.

6.2.5DV.3 If the PV connector is intended to be field assembled and terminated to the cable in the field, additional procedures and requirements shall be provided in the assembly instructions, as follows:

a) For electrical connections between connector parts and conductor cables, detailed cable end preparation shall be provided.

NOTE: Dedicated tools are recommended.

b) For polymer material sealing and strain relief, if a specific torque value is required for proper assembly, proper tightening torque values shall be provided through one of following:

1) If special tools are used, especially plastics tools, the proper temperature range or temperature limitations for the use of the tool shall be provided; or

2) If a generic torque tool is permitted, the tool calibration requirement shall be specified, and the torque adjustment for different temperatures shall be provided by equations, tables, or charts;

3) Application means of adhesive or sealant, if it is provided as part of the connector;

4) A statement outlining additional assembly instructions or procedures if assembly occurs in adverse environmental conditions. Examples of adverse environmental conditions include, but are not limited to, extreme rain or snowfall, extremely hot or cold ambient temperatures, or in an area where there is excessive dust; and

5) A statement requiring special precautions if assembly occurs at a time without the other mating connector, such that a connector's contacts are left unmated and exposed. The statement should specify necessary precautions to prevent occurrences including, but not limited to, corrosion, contamination, icing, etc. that may compromise the integrity of the connector in its final use.

6.2.5DV.4 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.

6.2.5DV.5 The metal connection (such as crimping) between conductor and connector pin/socket is to be fully assembled (tightened to the specification) at room temperature. Polymeric material sealing and strain relief (such as a gland), is to be assembled and finger tight at room temperature, then the steps in 6.2.5DV.6 shall be applied.

NOTE This purpose of this requirement is that the temperature effect is mainly on polymeric material sealing and strain relief, such as a gland.

6.2.5DV.6 One set of samples, as defined in 6.2.5DV.4 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 6.2.5DV.3.

6.2.5DV.7 A detailed procedure that must be followed for proper assembly of a PV connector to a conductor shall include the following:

a) Instructions for preparation of the conductors, such as twisting strands together before assembly;

b) Location and number of crimping points;

c) Use of crimping tool or reference to tool manufacturer's instructions for the tool;

d) Tightening of any strain relief;

e) Inspection of completed assembly; and

f) Any additional steps or precautions required for field assembly of connectors, for those connectors which comply with the test requirements in this Clause, 6.2, Preparation of Specimens.

6.3 Performance of tests

6.3.1 General

In accordance with the test schedule given in 6.5, the general test methods specified in Table 6 to Table 12, columns 3 and 7, shall be applied according to IEC 60512. Other tests are indicated in column 4.

6.3.2 Durability of marking

The test is made by rubbing the marking by hand for 15 s with a piece of cotton cloth soaked with water and again for 15 s with a piece of cotton cloth soaked in petroleum spirit.

Petroleum spirit is defined as the aliphatic solvent hexane with a content of aromatics of maximum 0,1 % volume, a kauri-butanol value of 29, initial boiling point of 65 °C, a dry point of 69 °C and a specific gravity of approximately 0,68 kg/l.

After this test, the marking shall be legible to normal or corrected vision without additional magnification.

This test shall be also carried out on an additional label with specified warning indication listed under l) from 5.2.1, if applicable.

Markings made by impression, moulding, pressing, or engraving or the like are not subjected to this test.

6.3.3 Protection against electric shock

6.3.3.1 Connectors shall be tested by the test probe 11 according to IEC 61032 using a test force of 10 N.

For the test all covers and housing parts which are detachable without a tool shall be removed.

6.3.3.2 The tests for the given IP code according to IEC 60529 shall be applied in the mated position.

Subsequently the dielectric strength test according to 6.3.8 shall be performed within 1 h of second IP numeral (water) test.

6.3.4 Temperature rise

The object of this test is to assess the ability of a connector to continuously carry the rated current without exceeding the upper limiting temperature.

The test shall be carried out according to test 5a of IEC 60512, under the following test conditions.

Test conditions:

– maximum permissible conductor cross-section according to manufacturer's specification. In case of a declared cross-section area with same rated current, the test will be applied to the most unfavourable cross-section;

– length of test cables = 500 mm ± 50 mm for cross-section ≤ 10 mm^2;

– length of test cables = 1 000 mm ± 100 mm for cross-section > 10 mm^2;

– the test shall be carried out with rated current as specified by the manufacturer at an ambient temperature of 85 °C or the maximum ambient temperature specified by manufacturer, if higher;

– the test shall be continued until a constant temperature is obtained.

6.3.5 Mechanical operation

The object of this test is to assess the mechanical operational endurance of a connector in the normal operational mode without electrical load. The test shall be carried out according to test 9a of IEC 60512, under the following conditions.

Test conditions:

– the specimens shall be engaged and disengaged by means of a device simulating normal operating conditions for a number of cycles specified by the manufacturer. The preparation and mounting of the specimen shall be as in normal use;

– the type and cross-section of the cable/wire bundle to be used shall be specified by the manufacturer;

– the speed of insertion and withdrawal shall be approximately 0,01 m/s with a rest in the unmated position of approximately 30 s.

6.3.6 Bending (flexing) test (see IEC 60309-1:1999, 24.4)

Non-rewirable connectors shall be subjected to a bending test in an apparatus similar to that shown in Figure 1.

The specimen is fixed to the oscillating member of the apparatus so that, when this is at the midpoint of its travel, the axis of the flexible cable, where it enters the specimen, is vertical and passes through the axis of oscillation.

The oscillating member is so positioned that the flexible cable makes a minimum lateral movement when the oscillating member of the test apparatus is moved over its full travel.

The cable is loaded with a weight such that the force applied is

• 20 N for non-rewirable connectors with a conductor cross-section > 0,75 mm^2,

• 10 N for non-rewirable connectors with a conductor cross-section ≤ 0,75 mm^2.

A current equal to the rated current of the connector is passed through the conductors.

The oscillating member is moved backwards and forwards through an angle of 90° (45° on either side of the vertical). The rate of bends shall be 60 per minute. One bending is one movement, either backwards or forwards. The number of bends is 100.

Specimens with cables of circular cross-section shall be rotated approximately 90° around the vertical axis within the oscillating part after 50 % of flexings; specimens with flat flexible cables are only bent in a direction perpendicular to the plane containing the axis of the conductor.

During this test, there shall be no interruption of the test current.

After the test there shall be no damage; the cable support sleeve shall not be loosened from the body and the insulation shall show no signs of abrasion or of wear and tear. Broken strands shall not pierce the insulation, during the high voltage test according to 6.3.8 b) there shall be no breakdown of the test voltage.

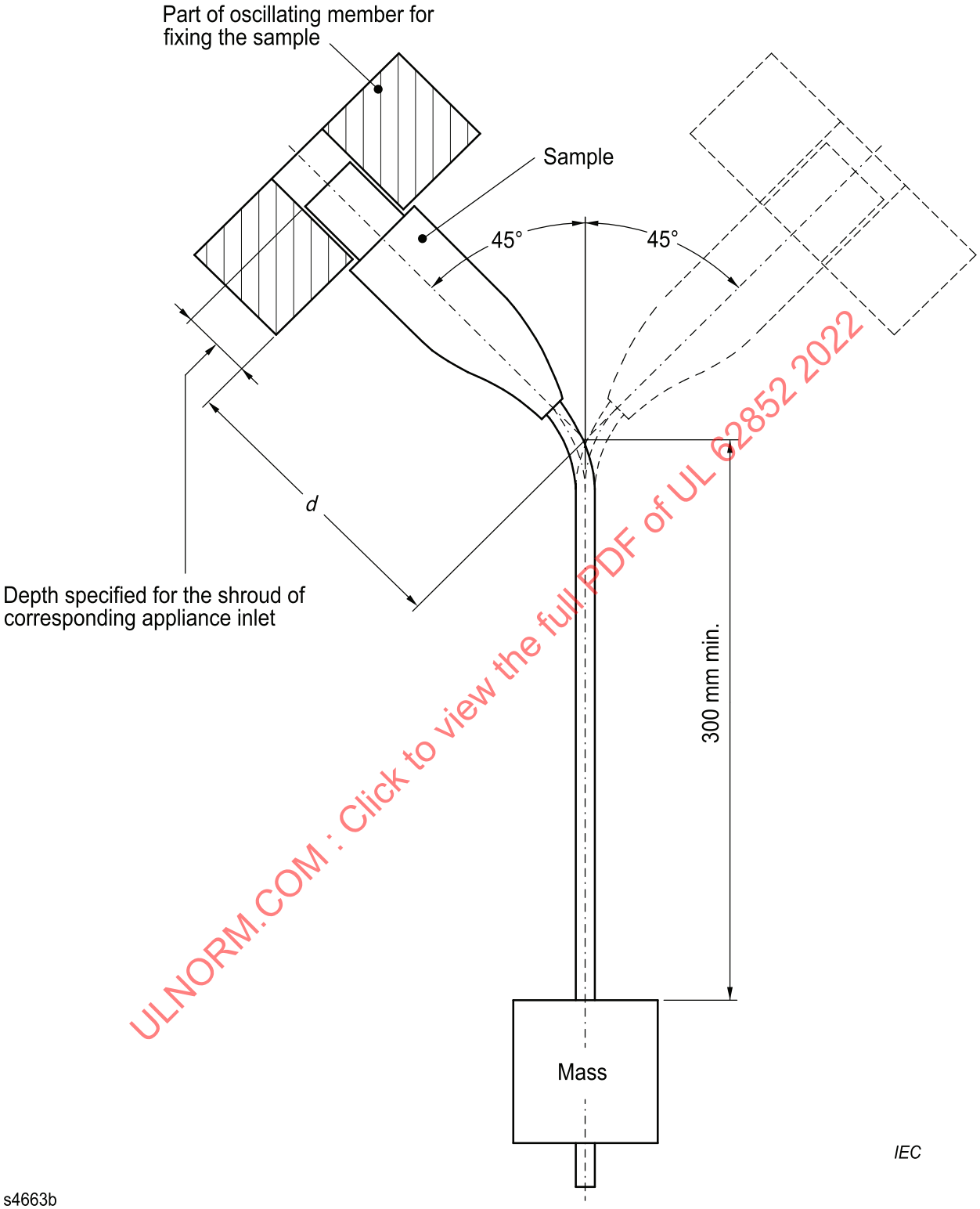

Figure 1

Device for the bending test

6.3.7 Measurement of clearances and creepage distances

Clearances and creepage distances shall be measured according to Annex B with the following additional requirements.

For connectors without breaking capacity, clearances and creepage distances to the accessible surface shall be measured only in the mated position.

For multi-way connectors the requirements for double or reinforced isolation between active parts with different potential shall be determined in mated and unmated condition.

The surface of an unenclosed connector to be incorporated into an equipment or a device shall not be regarded as accessible, unless otherwise claimed by the manufacturer.

6.3.8 Dielectric strength

The test voltage has to be applied between the short circuited output terminals and a metal foil which is wrapped around the specimen after relevant conditioning. During dielectric strength test no breakdown of test voltage shall occur. The insulation shall be tested according to the following tests:

a) Impulse withstand test

The impulse withstand test shall be carried out with a voltage having a 1,2/50 µs waveform according to IEC 60060-1 with three impulses of each polarity and an interval of at least 1 s between impulses. The output impedance of the impulse generator should not be higher than 500 Ω. The test voltage shall comply with the rated impulse voltage according to Table 2.

b) Voltage proof (IEC 60512-4-1, test 4a)

The voltage proof shall be performed by applying a r.m.s. withstand voltage (50 Hz/60 Hz) with a r.m.s. value of 2 000 V + 4 times rated voltage. The test duration shall be 1 min.

Voltage proof can also be performed with DC voltage. For this the value of test voltage shall be equal to the amplitude value of AC voltage.

6.3.9 Corrosion test

For testing the protection of contacts against the influence of a corrosive atmosphere, one of the two alternative tests shall be selected. In both cases, the specimens shall be mated.

Test 1:	Flowing mixed gas corrosion according to test 11g of IEC 60512, with a choice of method 1 or method 4 (see IEC 60512-11-7:2003, Table 1)
	The test duration shall be four days.
Test 2:	Sulphur dioxide test with general condensation of moisture according to ISO 6988. The test duration shall be 24 h (1 test cycle).

6.3.10 Mechanical strength at lower temperatures

The specimens and the test apparatus shall be stored for 5 h at a temperature of –40 °C or the minimum ambient temperature specified by the manufacturer, if lower, on a steel plate of 20 mm thickness. The test shall be carried out immediately after the storage duration in the cold chamber.

Test shall be carried according to the following procedure:

Four impacts on the specimen, an energy of 1 J with an appropriate impact test apparatus according to IEC 60068-2-75 shall be carried out at four uniformly distributed positions on the circumference.

The test is passed successfully if no damage appeared which may impair the function of the connector and the dielectric strength test of 6.3.8 b) has been passed.

6.3.10DV D2 *Modification in accordance with the following:*

6.3.10DV.1 In the first paragraph, change the storage temperature from – 40 °C to – 35 °C.

6.3.10DV.2 In the third paragraph, change the impact energy from 1 J to 5 J.

6.3.10DV.3 Add the following:

Exception: If the manufacturer specifies temperature ranges or temperature limitation either for PV system installation (not for PV system operation), or for connector field assembly, the test shall be conducted at the specified lowest temperature, or 0 °C, whichever is lower. If the manufacturer does not specify temperature ranges or temperature limitation, the test shall be conducted at – 35 °C.

6.3.11 Change of temperature (IEC 60068-2-14 test Na)

The test shall be carried in climatic chamber without any pre-treatment of the specimens as follows:

– 30 min at upper specified ambient temperature, minimum +85 °C ± 2 °C;

– 30 min at lower specified ambient temperature, maximum –40 °C ± 2 °C;

– transfer duration t2 ≤ 3 min;

– number of test cycles: 200.

During thermal cycle test the rated current shall be applied such that it is conducted through the current-carrying contacts.

6.3.12 Damp heat test

The test shall be carried out according to IEC 60068-2-78 with the following test conditions:

Severity according to IEC 61215-2:2016, 4.13:

– test temperature: upper specified ambient temperature, minimum +85 °C ± 2 °C

– relative humidity: +85 % ± 5 %

– test duration: 1 000 h

6.3.13 Insertion and withdrawal force

The test shall be carried out with the relevant counterpart according to IEC 60512, test 13b.

The actuation speed shall be 50 mm/min.

The measured withdrawal force shall not be less than 50 N.

6.3.14 Effectiveness of connector coupling device

The test shall be carried out according to IEC 60512, test 15f.

The specified force of 80 N shall be applied in the direction of the separation of the mated pair with the rate of 10 N/s.

It shall not be possible to disengage the connector.

6.3.14DV D2 ***Modification of the test force and duration in accordance with the following:***

Replace "The specified force of 80 N shall be applied in the direction of the separation of the mated pair with the rate of 10 N/s" with following:

The specified force of 89 N shall be applied in the direction of the separation of the mated pair with the rate of 10 N/s, for 1 minute.

6.3.15 Terminations and connecting methods

The following applicable tests shall be conducted:

a) for crimped connections,

visual tests on the crimp barrel and tensile strength test of the crimp connection as specified in IEC 60352-2. If deviations to IEC 60352-2 exist, the tensile strength according to IEC 60352-2 and the dimensions according to the manufactures specifications are tested to fulfil IEC 61984;

b) and c) for insulation displacement connections,

visual examination is carried out on new parts for insulation displacement terminals according to IEC 60352-3:1993, 12.1 and for solderless non-accessible displacement terminals according to IEC 60352-4:1994, 12.2.4.

The electrical and thermal tests are carried out according to IEC 61984;

d) for press-in connections,

visual and dimensional tests on the press-in post and test of the push-out force as specified in IEC 60352-5;

e) insulation piercing connections according to IEC 60352-6 or IEC 60998-2-3;

f) for the screwless-type clamping unit,

mechanical tests on the conductor connection as specified in IEC 60999-1 or IEC 60999-2 or IEC 60352-7;

g) for the screw-type clamping unit,

mechanical tests on the conductor connection as specified in IEC 60999-1 or IEC 60999-2.

For prepared conductors the manufacturers instructions for the preparation applies;

h) for flat, quick-connect terminations,

dimensional tests and safety tests as specified in IEC 61210 as far as applicable.

The dimensional test is carried out according to IEC 61210. The compliance check of dimensions is the verification of the safety of the connection according to IEC 61984. If the dimensions do not comply with the specification the test requirements are not met.

Flat, quick-connect terminations, which are definitely not designed according to IEC 61210 can be used if the test program according to IEC 61984 is met.

Electrical and thermal tests on terminations shall be carried out in conjunction with the test on the connector.

6.4 Test schedule (routine test) for non-rewirable free connectors

For non-rewirable free connectors, it shall be ensured that live parts, e.g. loose strands, cannot become accessible. If this cannot be ensured by design or by the manufacturing process, each manufactured connector shall be subjected to the following test.

The accessible outer surface of the connector, with the exception of the engagement face of the male connector, shall be scanned by plane electrodes with a force of 20 N and each time the specified impulse withstand voltage of the connector shall be applied between all live parts and these electrodes according to 6.3.8.

Alternatively, the specified r.m.s. withstand voltage according to 6.3.8 shall be applied for a minimum of three full cycles (60 ms).

No breakdown or flashover shall occur.

6.5 Test schedule

Table 6
Mechanical test group A (test group A are separate tests)

1	2	3	4	5	6	7	8
Test phase	Designation	IEC 60512 test no.	Test according to	Severity or conditions	Measurements to be performed		Requirements
					Designation or title	IEC 60512 test no.	
A1.1				Any existing cover shall be removed, if required	Visual and dimensional examination	1a, 1b	5.2.3 Dimensions shall comply with the manufacturer's specification
A1.2	Clearances and creepage distances		6.3.7	Measuring of creepage distances and clearances according to annex B	Dimensional examination		5.18 Dimensions shall comply with 5.18
A2	Durability of marking		6.3.2	With the naked eye	Visual examination	1a	Markings according to 5.2
A3	Polarisation	13e		Test force: 20 N or 1,5 times the insertion force, whichever is higher, but not higher than 80 N			5.3
					Visual examination	1a	No damage likely to impair safety and function
A4	Terminations		6.3.15	Verification by test report or minimum test			5.5
A5	Contact retention in insert	15a		Test load shall be three times the specified insertion force (mating) of one contact or the specified insertion force of one contact plus 50 N, whichever is less. The minimum test load shall not be less than 20 N.			5.15.2
					Visual examination	1a	No axial displacement likely to impair normal operation
A6.1	Cable clamp (pull)	17 c			Visual examination	1a	5.14, Table 13
A6.2	Cable clamp (torsion)	17 d			Visual examination	1a	5.14, Table 14
A7	Mechanical strength impact	7b		Only free connectors. Dropping height: – 750 mm for specimens of mass ≤ 250 g, – 500 mm for specimens of mass > 250 g. Dropping cycles: 8 Positions in 45° steps, one cycle per position	Visual examination	1a	Parts used for protection against electric shock shall not be damaged. A reduction of clearances and creepage distances is not allowed.

Table 6 Continued on Next Page

Table 6 Continued

1	2	3	4	5	6	7	8
Test phase	**Designation**	**IEC 60512 test no.**	**Test according to**	**Severity or conditions**	**Measurements to be performed**		**Requirements**
					Designation or title	**IEC 60512 test no.**	
A8	Mechanical strength at lower temperature		6.3.10	Test temperature: lower limiting temperature specified for the specimen Test duration: 5 h			5.15
					Visual examination	1a	
					Dielectric strength		6.3.8 b)
A9	Insertion and withdrawal force	13 b	6.3.13	Only for connectors without coupling device or locking means			measured withdrawal force not less than 50 N
A10	Effectiveness of connector coupling device	15 f	6.3.14	Only for connectors with coupling device or locking means	Visual examination		5.17 No damage likely to impair function
NOTE Test group A consists of separate tests. There is no required test sequence.							

Table 7
Service life test group B

1	2	3	4	5	6	7	8
Test phase	**Designation**	**IEC 60512 test no.**	**Test according to**	**Severity or conditions**	**Measurements to be performed**		**Requirements**
					Designation or title	**IEC 60512 test no.**	
B1	Initial measurement			Test current: 1 A Measuring points: At the end of the termination. Maximum three contacts per specimen	Contact resistance	2b	Reference value for subsequent measurement
B2	Mechanical operation	9a	6.3.5	Number of cycles as specified by the manufacturer			5.11
					Visual examination	1a	No damage likely to impair safety and function
B3	Final measurement			Same conditions as for test phase B1	Contact resistance	2b	Deviation of the contact resistance shall be no more than 50 % of the reference value or ≤ 5 mΩ. The higher value is permissible.
			6.3.8	Measuring points[b]: contact/contact contact/earth[a]	Voltage proof	4a	5.10 There shall be no breakdown or flashover

[a] Earth in the sense of non-live metal parts (e.g. fixing devices/housings/accessible surfaces).

[b] Measuring points: At the conductors as close as possible to the termination. If this is not possible, the conductor resistance shall be recalculated.

Table 8
Service life test group C

1	2	3	4	5	6	7	8
Test phase	**Designation**	**IEC 60512 test no.**	**Test according to**	**Severity or conditions**	**Measurements to be performed**		**Requirements**
					Designation or title	**IEC 60512 test no.**	
C1	Bending test		6.3.6	Only non-rewirable connectors			6.3.6
					Visual examination	1a	No damage likely to impair function
C2	Final measurement		6.3.8 b)	Measuring points: End of cable/metal foil	Voltage proof	4a	There shall be no breakdown or flashover
					Visual examination	1a	No loosening of the cable support sleeve from the body, no signs of abrasion or of wear and tear of insulation, broken strands shall not pierce the insulation