UL 62790

STANDARD FOR SAFETY

Junction Boxes for Photovoltaic Modules – Safety Requirements and Tests

UL Standard for Safety for Junction Boxes for Photovoltaic Modules – Safety Requirements and Tests, UL 62790

First Edition, Dated May 26, 2023

Summary of Topics

First Edition of the UL IEC-Based Standard for Junction Boxes for Photovoltaic Modules – Safety Requirements and Tests, ANSI/UL 62790, dated May 26, 2023. UL 62790 is an adoption of IEC 62790 (Edition 2.0, issued July 2020). Please note that the National Difference document incorporates all of the U.S. national differences for UL 62790.

The new requirements are substantially in accordance with Proposal(s) on this subject dated August 26, 2022 and April 14, 2023.

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MAY 26, 2023

ANSI/UL 62790-2023

UL 62790

Standard for Junction Boxes for Photovoltaic Modules – Safety Requirements and Tests

First Edition

May 26, 2023

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

The most recent designation of ANSI/UL 62790 as an American National Standard (ANSI) occurred on May 26, 2023. 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 ULSE at any time. Proposals should be submitted via a Proposal Request in ULSE's Collaborative Standards Development System (CSDS) at https://csds.ul.com.

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Bibliography

PREFACE

This UL Standard is based on IEC Publication 62790: Edition 2.0, Junction Boxes for Photovoltaic Modules – Safety Requirements and Tests. IEC publication 62790 is copyrighted by the IEC.

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 62790, Standard for Junction boxes for photovoltaic modules – 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

JUNCTION BOXES FOR PHOTOVOLTAIC MODULES – 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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8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.

9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

International Standard IEC 62790 has been prepared by IEC technical committee 82: Solar photovoltaic energy systems.

This second edition cancels and replaces the first edition published in 2014. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) Modifications in normative references and terms and definitions;

b) Improvement of declaration of categories for junction boxes in 4.1;

c) Clarification for ambient temperature in 4.1;

d) Addition of requirement to provide information concerning RTE/RTI or TI in 4.2;

e) Reference to IEC 62930 instead of EN 50618 in 4.6;

f) Addition of "Functional insulation" in Table 1;

g) Addition of "Distance through cemented joints" in Table 3;

h) Correction of procedure of process to categorize material groups (deletion of PTI) in 4.15.2.3;

i) Requirement for approval of RTE/RTI or TI for insulation parts in 4.16.1 and 4.16.2;

j) Change of requirements concerning electrochemical potential in 4.17.2;

k) Clarification for IP-test in 5.3.4.2;

l) Addition of test voltage for cemented joints in 5.3.6 and 5.3.16;

m) Addition of detailed description on how to prepare the test sample for the thermal cycle test in 5.3.9.1;

n) New test procedure for bypass diode thermal test (5.3.18) in accordance with MQT 18.1 of IEC 61215-2:2016;

o) New test procedure for reverse overload current test in 5.3.23;

p) New Figure 1 for thermal cycle test.

The text of this International Standard is based on the following documents:

FDIS	Report on voting
82/1719/FDIS	82/1738/RVD

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

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

The committee has decided that the contents of this document 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 document. At this date, the document will be

• reconfirmed,

• withdrawn,

• replaced by a revised edition, or

• amended.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

JUNCTION BOXES FOR PHOTOVOLTAIC MODULES – SAFETY REQUIREMENTS AND TESTS

1 Scope

This document describes safety requirements, constructional requirements and tests for junction boxes up to 1 500 V DC for use on photovoltaic modules in accordance with class II of IEC 61140:2016.

This document applies also to enclosures mounted on PV-modules containing electronic circuits for converting, controlling, monitoring or similar operations. Additional requirements concerning the relevant operations are applied under consideration of the environmental conditions of the PV-modules. This document does not apply to the electronic circuits of these devices, for which other IEC standards apply.

NOTE For junction boxes in accordance with classes 0 and III of IEC 61140:2016, in photovoltaic-systems, this document can be used as a guideline.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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 60068-2-14:2009, *Environmental testing – Part 2-14: Tests – Test N: Change of temperature*

IEC 60068-2-70, *Environmental testing – Part 2-70: Tests – Test Xb: Abrasion of markings and letterings caused by rubbing of fingers and hands*

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 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 60352-2, *Solderless connections – Part 2: 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 60529, *Degrees of protection provided by enclosures (IP Code)*

IEC 60664-1:2007, *Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests*

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 60695-10-2, *Fire hazard testing – Part 10-2: Abnormal heat – Ball pressure test method*

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

IEC 60695-11-20, *Fire hazard testing – Part 11-20: Test flames – 500 W flame test method*

IEC 60947-7-1, *Low-voltage switchgear and controlgear – Part 7-1: Ancillary equipment – Terminal blocks for copper conductors*

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 60999-1:1999, *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 61140:2016, *Protection against electric shock – Common aspects for installation and equipment*

IEC 61191-1, *Printed board assemblies – Part 1: Generic specification – Requirements for soldered electrical and electronic assemblies using surface mount and related assembly technologies*

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

IEC 61215-1:2016, *Terrestrial photovoltaic (PV) modules – Design qualification and type approval – Part 1: Test requirements*

IEC 61215-2:2016, *Terrestrial photovoltaic (PV) modules – Design qualification and type approval – Part 2: Test procedures*

IEC 61730-1:2016, *Photovoltaic (PV) module safety qualification – Part 1: Requirements for construction*

IEC 62852, *Connectors for DC-application in photovoltaic systems – Safety requirements and tests*

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

ISO 868:2003, *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 lamps*

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

2DV D2 *Modification by replacing the referenced IEC standards with corresponding harmonized UL standards and adding a new reference in accordance with the following:*

Replace IEC 61215-1:2016 with UL 61215-1, Terrestrial photovoltaic (PV) modules – Design qualification and type approval – Part 1: Test requirements;

Replace IEC 61215-2:2016 with UL 61215-2, Terrestrial photovoltaic (PV) modules – Design qualification and type approval – Part 2: Test procedures;

Replace IEC 61730-1:2016 with UL 61730-1, Photovoltaic (PV) Module Safety Qualification – Part 1: Requirements For Construction;

Replace IEC 62852 with UL 62852, Connectors for DC-Application in Photovoltaic Systems – Safety Requirements and Tests;

Add UL 4703, Photovoltaic Wire

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC TS 61836 as well as the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

• IEC Electropedia: available at http://www.electropedia.org/

• ISO Online browsing platform: available at http://www.iso.org/obp

3.1
module junction box
combination of parts, such as boxes, covers, cover-plates, lids, box extensions, accessories, etc., providing after assembly and installation at the photovoltaic-module in normal use, an appropriate protection against external influences, and a defined protection against contact with enclosed live parts from any accessible direction

3.1.1
junction box for re-opening
junction box that can be opened at any time

Note 1 to entry: It may contain rewirable and non-rewirable connections.

3.1.1.1
junction box for factory wiring
junction box which is attached and connected to the PV module under controlled conditions, usually at the manufacturer's location

3.1.1.2
junction box for field wiring
junction box containing wiring connections that are intended to be made in the field

3.1.2
junction box, not intended to be re-opened
junction box that cannot be opened after mounting in the end application

3.2
cable gland
device permitting the introduction of one or more electric cables into the junction box so as to maintain the relevant type of protection

[SOURCE: IEC 60050-426:2008, 426-04-18, modified – "and/or fibre optics" has been deleted and "an electrical apparatus" has been replaced by "the junction box".]

3.3
sealing
method for providing the ability of a component to resist the ingress of contaminants

[SOURCE: IEC 60050-581:2008, 581-23-16]

3.4
cable anchorage
ability to limit the displacement of a fitted flexible cable against pull and push forces and torques

3.5
connector for photovoltaic-systems
PV-connector
component suitable for use in PV systems that terminates conductors for the purpose of providing connection to and disconnection from a suitable mating component

3.6
intended use
use of a junction box in accordance with the information for use provided by the manufacturer

[SOURCE: IEC 60050-903:2013, 903-01-13, modified – "product, process or service" has been replaced by "junction box" and "supplier" has been replaced by "manufacturer".]

3.7
clamping unit
part(s) of the terminal necessary for the mechanical clamping and the electrical connection of the conductor(s), including the parts that are necessary to ensure the correct contact pressure

3.8
clearance
shortest distance in air between two conductive parts

[SOURCE: IEC 60050-426:2008, 426-04-12, modified – The note was deleted.]

3.9
creepage
distance shortest distance along the surface of the insulating material between two conductive parts

[SOURCE: IEC 60050-151:2001, 151-15-50, modified – "a solid insulating material" has been replaced by "the insulating material".]

3.10
overvoltage category
numeral defining a transient overvoltage condition

[SOURCE: IEC 60050-581:2008, 581-21-02]

3.11
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 60050-442:1998, 442-01-28, modified – Definition revised and note deleted.]

3.12
pollution degree
numeral characterising the expected pollution of the micro-environment

[SOURCE: IEC 60050-581:2008, 581-21-07]

3.13
rated voltage
value of voltage assigned by the manufacturer to the junction box 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, 3.9, modified – "a component, device or equipment" has been replaced by "the junction box" and the note has been replaced by Note 1 to entry.]

3.14
rated insulation voltage

RMS withstand voltage value assigned by the manufacturer to the junction box, 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, 3.9.1, modified – "equipment or to a part of it" has been replaced by "junction box".]

3.15
rated impulse voltage
impulse withstand voltage value assigned by the manufacturer to the junction box, characterising the specified withstand capability of its insulation against transient overvoltages

[SOURCE: IEC 60664-1:2007, 3.9.2, modified – "equipment or to a part of it" has been replaced by "junction box".]

3.16
impulse withstand voltage
highest peak value of impulse voltage of specified form and polarity that 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, 3.8.1, modified – "prescribed" replaced with "specifed" and Note 1 to entry has been added.]

3.17
RMS withstand voltage
power-frequency withstand voltage highest RMS value of a voltage that does not cause breakdown of insulation under specified conditions

[SOURCE: IEC 60664-1:2007, 3.8.2]

3.18
current

3.18.1
rated current
current value assigned by the manufacturer, which the junction box can carry continuously (without interruption) and simultaneously through all its contacts and bypass-diodes, if applicable, wired with the largest specified conductor, at the maximum ambient temperature, without the upper limiting temperature being exceeded

3.18.2
reverse current
I_{REV}
current value assigned by the manufacturer, which the junction box can carry at the maximum ambient temperature, without causing a hazardous situation

Note 1 to entry: The reverse current is comparable with the reverse test current of the photovoltaic module (see IEC 61730-2).

3.19
functional insulation
insulation between conductive parts that is necessary only for the proper functioning of the equipment

[SOURCE: IEC 60664-1:2007, 3.17.1]

3.20
basic insulation
insulation applied to live parts to provide basic protection against electric shock

Note 1 to entry: This concept does not apply to insulation used exclusively for functional purposes.

[SOURCE: IEC 61140:2016, 3.10.1, modified – "insulation of hazardous-live-parts which provides" has been replaced by "insulation applied to live parts to provide" and "against electric shock" has been added.]

3.21
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

[SOURCE: IEC 60664-1:2007, 3.17.3, modified – "for fault protection" has been replaced by "in order to provide protection against electric shock in the event of a failure of basic insulation".]

3.22
double insulation
insulation comprising both basic insulation and supplementary insulation

[SOURCE: IEC 60664-1:2007, 3.17.4]

3.23
reinforced insulation
single insulation system applied to live parts, which provides a degree of protection against electric shock equivalent to double insulation

Note 1 to entry: Reinforced insulation may comprise several layers which cannot be tested singly as basic insulation or supplementary insulation.

[SOURCE: IEC 60664-1:2007, 3.17.5, modified – "insulation of hazardous-live-parts" has been replaced by "single insulation system applied to live parts".]

3.24
working voltage
highest RMS value of the DC voltage across any particular insulation which can occur inside the junction box when it operates at rated voltage

[SOURCE: IEC 60664-1:2007, 3.5, modified – "a.c. or" has been removed and “when the equipment is supplied at rated voltage" has been replaced by "inside the junction box when it operates at rated voltage".]

3.25
comparitive tracking index
CTI
numerical value of the maximum voltage in volts which a material can withstand without tracking and without a persistent flame occurring under specified test conditions

[SOURCE: IEC 60050-212:2010, 212-11-59]

3.26
accessible part
part which can be touched by means of standard test finger

[SOURCE: IEC 60050-442:1998, 442-01-15]

3.27
photovoltaic cable
electrical cable (cabling) specifically designed for the purpose of carrying electric current from photovoltaic devices and enduring the environmental conditions commonly encountered in photovoltaic arrays

[SOURCE: IEC TS 61836:2016, 3.2.21, modified – Deletion of the notes to entry.]

3.28
maximum ambient temperature
maximum temperature of the ambient assigned by the manufacturer, in which the junction box is able to operate without the limiting temperatures of the materials (TI, RTE/RTI) being exceeded

4 Constructional requirements and performance

4.1 General

Junction boxes in accordance with this document can be categorized as

– junction boxes, for re-opening;

– junction boxes, not intended to be re-opened.

Junction boxes for re-opening can be distinguished as

– junction boxes for factory wiring;

– junction boxes for field wiring.

For junction boxes in accordance with this document, no values have been specified for electric rated voltage and current. These values shall be declared by the manufacturer.

Junction boxes shall be suitable for durable use outside in an ambient temperature area from −40 °C to +85 °C or as declared by the manufacturer if lower than −40 °C or higher than +85 °C.

Junction boxes shall be so designed and dimensioned that they can withstand the electrical, mechanical, thermal and corrosive stresses occurring in their intended use and present no danger to the user or the environment.

Compliance with these requirements is verified by specified tests of this document.

4.2 Marking and identification

4.2.1 Identification

Junction boxes shall be identified and characterized by the following:

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

b) type identification;

c) rated current;

d) rated voltages or rated insulation voltages;

e) rated impulse voltage, if specified;

f) maximum working voltage;

g) pollution degree;

h) degree of protection by enclosure in accordance with IEC 60529;

i) range of temperature; (lowest and upper ambient temperature), if different from −40°C to +85°C ;

j) type of terminals;

k) connectable conductors;

l) reference to this document, if applicable;

m) symbols "Do not disconnect under load", as given in Annex A, or an adequate warning notice in the respective national language;

n) polarity of connector, if applicable;

o) type and number of bypass-diodes, if applicable;

p) reverse current (I_{REV});

q) RTE/RTI or TI (mechanical and electrical) of all insulating materials used in the junction box.

4.2.2 Marking

The marking shall be indelible and easily legible.

The minimum marking on the junction boxes shall be that of items a), b) and n) in 4.2.1.

If connection of the junction box is made by connectors or by a fixed cable that has implemented a connector on its end, the warning notice listed in m) of 4.2.1 shall be on a label or similar on or close to the connector. An instruction where to place the warning notice shall be included in the technical documentation.

Markings a) and b) of 4.2.1 shall be found on the smallest unit of packaging.

4.2.2DV D2 *Addition of the following for using aluminum conductors:*

4.2.2DV.1 If the junction box is rated for use copper wires only, the junction box shall be marked, at or adjacent to the terminals, with the statement "Use copper wire only", "CU only", or the equivalent.

4.2.2DV.2 If the junction box is rated for use both copper and aluminum wires, the junction box shall be marked (independent of any marking of the terminal) with the statement "Use aluminum or copper wire", "AL-CU", or the equivalent.

4.2.3 Technical documentation

Identification items of 4.2.1 not marked on the junction box in accordance with 4.2.2 and the following information shall be given in the technical documentation of the manufacturer:

a) information on termination regarding the cable and cell connection, if applicable;

b) information regarding the connector(-system), if applicable;

c) information regarding mounting (e.g. backsheet material of the module) and mounting material (e.g. sealing material, adhesive), if applicable.

4.3 Protection against electric shock

4.3.1 A junction box shall be so designed that, after mounting, the live parts are not accessible. This requirement shall be fulfilled even if there is any deformation of the housing and/or cover as a result of mechanical and thermal stress, which can occur during normal use; furthermore, the degree of protection of the housing may not be impaired by this possible deformation.

4.3.2 Parts intended to be removed shall only be detachable with the aid of tools. Lids that are attached without screws shall have one or several detectable facilities, for example recesses, which enable tools to be deployed in order to remove them. If the lid is removed correctly, the tool shall not come into contact with the active parts.

4.3.3 Parts of junction boxes for field wiring in accordance with 3.1.2 shall be prevented to be lost or to become loose.

4.4 Terminations, connecting devices and connection methods

4.4.1 Terminations shall be suitable for the type and range of conductor cross-sectional areas in accordance with the specification of the manufacturer.

Terminations shall be held in such a position that a possible displacement does not result in a reduction of clearances and creepage distances.

Measures need to be taken to prevent contact stress resulting in contact degradation and possible movement of contacts.

Terminations shall be so designed that the contact pressure is not transmitted through insulating material other than ceramic, pure mica or other material with suitable characteristics, unless there is sufficient resiliency in the metallic parts to compensate for any shrinkage or yielding of the insulating material.

Measures shall be taken to prevent connections becoming loose, for example by using a washer.

4.4.2 Connecting devices shall meet the following requirements under the conditions specified in 5.1.3:

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

i) terminal blocks	IEC 60947-7-1
j) soldered connections	IEC 61191-1

Connecting devices shall provide sufficient means to be held in position after connection.

Different terminals or connecting technologies may be used if they fulfil a comparable level of safety as the above-mentioned standards.

Terminations by connectors inside the junction box shall meet the relevant requirements specified in IEC 62852.

Soldered connections of cables and cell connectors shall have additional means for retaining the conductor in position.

Welded connections are also permitted.

4.4.3 Compliance is checked by tests according to 5.3.19.

4.5 Connectors

PV-connectors that are part of the junction box and PV-connectors connected via a cable with the junction box shall comply with the requirements of IEC 62852. The values of the rated current and voltage shall be minimum the rated values of the junction box.

4.5DV D2 *Modification in accordance with the following:*

Replace IEC 62852 with UL 62852.

4.6 Cables

Photovoltaic cables connected to the junction box shall comply with the requirements of IEC 62930. The rated values of the cables shall be the rated values of the junction box or greater.

4.6DV D2 *Modification by replacing 4.6 with the following:*

4.6DV.1 Cables connected to the junction box 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.

4.6DV.2 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.

4.7 Resistance to ageing

Parts, whose breakdown will impair safety, shall be resistant to ageing.

4.8 General design

4.8.1 Junction boxes shall be so designed and dimensioned that they provide sufficient protection for cables and terminations against electrical, mechanical and environmental stresses occurring in normal use.

4.8.2 Junction boxes shall be so designed that connection of conductors of the type and cross-sectional areas as specified by the manufacturer shall be possible. Besides the termination of the conductor, precautions shall be taken that no damage of the conductor insulation is possible, for example by avoiding sharp edges.

4.8.3 All openings shall be provided with appropriate coverings (lids, blank plugs, etc.), which shall comply with the requirements of 5.3.15. They shall only be able to be removed by the use of a tool.

These requirements are also applicable for knock-outs.

4.8.4 Barriers of polymeric insulating material providing the sole insulation between a live part and an accessible metal part or between non-insulated live parts not of the same electrical potential shall be of adequate thickness and of a material appropriate for the application. The barrier shall only be able to be removed by the use of a tool.

4.8.5 Junction boxes for re-opening in accordance with 3.1.1 with rewirable connections shall be designed such that

a) precautions are taken that the conductor is protected against shear and tensile stress at the termination and is secured in a manner so as to prevent twisting,

b) the junction box is able to accept suitable cables for use in photovoltaic systems as specified by the manufacturer (see 4.2.3),

c) there is sufficient volume for connecting the conductor.

4.9 Degree of protection (IP)

A junction box shall have at least a degree of protection of IP55, category 1 in accordance with IEC 60529.

4.10 Dielectric strength

A junction box shall withstand the impulse withstand voltage test and the voltage proof test depending on its rated voltage in accordance with 5.3.6.

4.11 Range of ambient temperature

Junction boxes shall withstand the upper and lower values of temperature range as given in 4.1 or as specified by the manufacturer, if lower than the minimum value or higher than the maximum value as defined in 4.1.

4.12 Cable anchorage

The cable anchorage shall be suitable for the cable to be connected. The manufacturer shall specify the range of acceptable cable diameters.

Loose parts inserted to obtain clamping of the cable are permissible if they are fixed in the junction box in the assembled state.

The cable anchorage can be made of insulating material or metal. If it consists of metal, it shall meet one of the following requirements:

a) be provided with a covering of insulating material to prevent any accessible metal part becoming live in case of a fault;

b) no contact shall be possible with the test finger in accordance with IEC 60529.

Compliance is checked by the test in 5.3.21.

4.13 Mechanical strength

4.13.1 A junction box shall show no damage likely to impair safety after exposure to mechanical stress specified in the test programme.

4.13.2 In a junction box assembled for final use, the contacts shall be securely retained in the contact insert.

4.13.3 After exposure to the stresses specified in the test schedule, the internal insulation shall show no damage that could impair normal use.

4.14 Insulation

4.14.1 Type of insulation

Depending on the class specified in IEC 61140 and the intended use of the junction box the type of insulation shall be chosen from Table 1.

Table 1
Required type of insulation

Class (IEC 61140)	Protection required against direct contact	Insulation between live parts and accessible surfaces	Insulation between connecting devices for junction boxes in accordance with 3.1.1[a]	Insulation between live parts of different polarity of the same circuit
Class 0	Yes	B	R	B
Class II	Yes	R	R	B
Class III	No	F	R	F

Key

B Basic insulation

R Reinforced insulation or double insulation

F Functional insulation

[a] This column only describes protection against arc flash.

4.14.2 Basic insulation

Basic insulation shall be such that it withstands the voltage tests of 5.3.6 and that it meets the requirements for creepage distances and clearances in accordance with 4.15.

4.14.3 Supplementary insulation

For supplementary insulation, the same requirements shall apply as for basic insulation.

4.14.4 Double insulation

Double insulation shall be so designed that the breakdown of one part (basic or supplementary insulation) does not impair the protective function of the other part. It shall not be possible to remove the supplementary insulation without using a tool.

For double insulation, where basic and supplementary insulation cannot be tested separately, the insulation system shall be considered as reinforced insulation.

4.14.5 Reinforced insulation

Reinforced insulation shall be such that it withstands the voltage tests of 5.3.6, clearances for reinforced insulation shall be selected from Table 2.

The creepage distances shall be twice the value for basic insulation in accordance with Table 3.

4.15 Clearances and creepage distances

4.15.1 Clearances

Clearances between live parts and accessible surfaces shall be dimensioned in accordance with Table 2 depending on the rated voltage.

All other clearances within the junction box shall meet the requirements of basic insulation in accordance with Table 2 depending on the working voltage.

Table 2
Rated impulse voltages and minimum clearances

Basic insulation			Reinforced insulation	
Rated or working 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 and IEC TR 60664-2-1 for overvoltage category III and for altitudes up to 2 000 m.				

4.15.2 Creepage distances

4.15.2.1 General

Creepage distances between live parts and accessible surfaces shall be dimensioned for reinforced or double insulation in accordance with Table 3 related to the rated voltage considering the pollution degree as specified in 4.15.2.2.

Rewirable junction boxes shall meet the requirements of reinforced or double insulation in accordance with Table 3 between clamping units for the termination of the connecting cables in relation to the rated voltage of junction box.

All other creepage distances within the junction box shall meet the requirements of basic insulation in accordance with Table 3 in relation to the maximum working voltage as specified by the manufacturer.

Table 3
Creepage distances for basic insulation

Voltage (V DC)	Pollution degree 1	Pollution degree 2			Pollution degree 3			Distance through cemented joint
	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	mm
≤ 35	0,2	0,6	1,0	1,2	1,5	1,7	1,9	0,1
100	0,3	0,7	1,0	1,4	1,8	2,0	2,2	0,2
150	0,3	0,8	1,1	1,6	2,0	2,2	2,5	0,3
200	0,4	1,0	1,4	2,0	2,5	2,8	3,2	0,3
300	0,7	1,5	2,1	3,0	3,8	4,2	4,7	0,5
600	1,7	3,0	4,3	6,0	7,6	8,6	9,5	0,7
1 000	3,2	5,0	7,1	10	13	14	16	1,0
1 500	5,2	7,5	10	15	19	21	24	1,7
Linear interpolation is allowed. Values for reinforced or double insulation are twice the values for basic insulation.								

The sufficient insulation of the adhesive area between module and junction box is checked by tests of test groups E, F and G of 5.4 under consideration of increased test voltages (see relevant test). In case that the tests have been passed, the distances through cemented joints shall be dimensioned as listed in the last column of Table 3.

NOTE Details for cemented joints can be found in IEC 61730-1.

4.15.2.2 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 dimensioned according to pollution degree 2, pollution degree 1 may be applied if relevant requirements of Annex B are fulfilled.

In case potting material is used, the test of Annex B shall be performed on the junction box together with the associated module.

4.15.2.3 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

The values specified for the groups are reference values and based on the test voltage of IEC 60112.

NOTE The CTI-value is not in relation to a system or working voltage 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.

4.16 Insulation parts

4.16.1 Outer accessible parts

Outer accessible parts consisting of insulating material, whose deterioration could impair the safety of the junction box, shall meet following requirements:

a) Flammability class minimum V-1 in accordance with IEC 60695-11-0. This shall be proved by a data sheet of the material supplier or a test on the end-product or prepared test plates. See 5.3.12.1.

If the wall thickness is less than 3,0 mm then flammability class 5-V in accordance with IEC 60695-11-20 shall be fulfilled on the end product. See 5.3.12.2.

b) Weather resistance, checked by the test specified in 5.3.11 followed by the glow wire test of 5.3.14 a).

c) Temperature resistance in accordance with 5.3.13 a) shall be fulfilled.

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 the technical documentation.

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

4.16.1DV D2 *Modification by replacing the second paragraph of part (d) with following:*

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.

4.16.2 Inner parts keeping active parts in position

Inner parts consisting of insulating material keeping active parts in position shall meet the following requirements:

a) Flammability class minimum HB in accordance with IEC 60695-11-10. This shall be proved by a data sheet of the material supplier or a test on the end-product or prepared test plates. See 5.3.12.1.

b) Test in accordance with 5.3.14 b) shall be fulfilled.

c) Temperature resistance in accordance with 5.3.13 b) shall be fulfilled.

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 the technical documentation.

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

4.16.2DV D2 *Modification by replacing the second paragraph of part (d) with following:*

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.

The requirements of this subclause apply also for potting material which keeps active parts in position.

4.17 Current carrying parts and resistance against corrosion

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

All current carrying parts shall consist of metal, such that under normal operation, a sufficient mechanical strength, electrical conductivity and corrosion resistance are given.

4.17.2 The requirements of 5.5.3.1 of IEC 61730-1:2016 apply.

4.18 Sealing

Gaskets and seals shall not deteriorate after the accelerated ageing test of 5.3.15.

4.19 Bypass-diode

The bypass-diode and heat dissipation applied to limit the detrimental effects of module hot-spot susceptibility shall be sufficient for the module.

Bypass diodes in parallel are permitted in case that one of both diodes is able to carry the rated current of junction box without exceeding the maximum junction temperature. If bypass diodes are operated in parallel they shall be thermally coupled.

4.20 Knock-out inlets (outlets) intended to be removed by mechanical impact

It shall be possible to remove knock-out inlets (outlets) intended to be removed by mechanical impact without damaging the box.

For knock-out inlets (outlets) for cables, chips or burrs are not accepted.

For knock-out inlets (outlets) for conduits and/or for use with a grommet or a membrane, chips and burrs are disregarded.

Approval is given by test according to 5.3.20.

5 Tests

5.1 General

5.1.1 The test programme consists both of safety tests and of qualification tests as specified by standards for components and for PV-modules and -systems.

5.1.2 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.

Table 4
Number of specimens

Test	Description	Number
Group A	Separate specimen, provided with all markings and components.	1
Group B	Separate specimen, provided with all markings and components.	3
B3	Test plates of polymer materials serving as an enclosure and of polymers serving as support for live metal parts, each.	1
B6	Additional test plate of potting material, if applicable.	1
B10	Specimen mounted on back-sheet material, potted (if applicable).	1
Group C	Separate specimen, provided with all markings and components.	1
Group D	Separate specimen, provided with all markings and components.	5
Group E	Specimen mounted on relevant back-sheet material with relevant adhesive, potted (if applicable). Cell connections bent and connected as described in 5.2.5. Intended cable shall be connected.	1[a]
Group F	Specimen mounted on relevant back-sheet material with relevant adhesive, potted (if applicable). Cell connections bent and connected as described in 5.2.5. Intended cable shall be connected.	1[a]
Group G	Specimen mounted on relevant back-sheet material with relevant adhesive, potted (if applicable). Cell connections bent and connected as described in 5.2.5. Intended cable shall be connected.	1[a]
H1	Specimen mounted on relevant back-sheet material with relevant adhesive, potted (if applicable). Cell connections bent and connected as described in 5.2.5. Intended cable shall be connected.	1[a b c]
I1	Specimens prepared in accordance with 5.2.6.	1[a b c]
Group J	Specimen mounted on relevant back-sheet material with relevant adhesive, potted (if applicable). Cell connections bent and connected as described in 5.2.5. Intended cable shall be connected.	1[a]

[a] If the junction box is intended to be mounted on several back-sheet materials and/or fixed with several adhesives and/or potted with several potting materials, the tests shall be performed in all possible combinations with the relevant number of specimens.

[b] If the junction box is intended to be used with several types and/or combinations of bypass-diodes and/or several rated currents of junction box, the tests shall be performed in all possible configurations with the relevant number of specimens.

[c] If the junction box is intended to be potted such that the bypass-diodes are not accessible, the thermocouples shall be fixed before potting upon consultation with the testing body.

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

5.1.4 The tests on the terminations shall be made on all terminations per specimen.

5.1.5 The specimen is deemed not to comply with this document 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 that may have affected the result shall be repeated on a new specimen, which shall then pass all of the repeated tests.

5.1.6 All visual examination tests should be performed with the naked eye, unless otherwise specified.

5.2 Preparation of specimens

5.2.1 Specimens shall be pre-conditioned under standard conditions in accordance with IEC 60068-1 before testing for a period of 24 h at (25 ± 5) °C.

5.2.2 The tests shall be carried out with copper conductors unless otherwise specified by the manufacturer and with the type of conductor specified for the junction box. If terminations are provided for all types of conductors (solid, stranded and flexible), the tests shall be carried out with conductors representing the worst case.

5.2.2DV D2 *Addition of the following for wires with aluminum conductors:*

5.2.2DV.1 Aluminum conductors, insulated or uninsulated, used as internal wiring, such as for interconnection between current-carrying parts or in a component winding, shall be terminated at each end by a terminal that is rated for the combination of metals involved at the connection points. A wire-binding screw or a pressure wire connector used as a terminating device shall be rated for use with aluminum under the conditions involved – for example, temperature, heat cycling, vibration, and other similar conditions.

5.2.2DV.2 Junction boxes rated for use with aluminum conductors shall only be used with AA-8000 series aluminum alloy conductors that comply with UL 4703. Test specimens for aluminum alloy conductors shall be selected in accordance with UL 486A-486B, Table 6, Conductor Materials to be used in Test Sequences.

5.2.3 For the cell-connections, conductors as specified from the manufacturer shall be connected so as to represent the worst case. For some tests, it is necessary to have cell connections short-circuited.

5.2.4 Screw-type clamping units shall be tightened with the value of the torque stipulated in Table 5, in accordance with IEC 60999-1, unless otherwise specified by the manufacturer.

Table 5
Values of torque for screw-type clamping units

Nominal diameter of thread	Values of torque for metallic and non-metallic screws			
	I	II	III	IV
mm	Nm	Nm	Nm	Nm
≤ 2,8	0,2	0,4	0,4	0,7
> 2,8 up to 3,0	0,25	0,5	0,5	0,9
> 3,0 up to 3,2	0,3	0,6	0,6	1,1
> 3,2 up to 3,6	0,4	0,8	0,8	1,4
> 3,6 up to 4,1	0,7	1,2	1,2	1,8

Table 5 Continued on Next Page

Table 5 Continued

Nominal diameter of thread mm	Values of torque for metallic and non-metallic screws			
	I Nm	II Nm	III Nm	IV Nm
> 4,1 up to 4,7	0,8	1,8	1,8	2,3
> 4,7 up to 5,3	0,8	2,0	2,0	4,0
> 5,3 up to 6,0	1,2	2,5	3,0	4,4
> 6,0 up to 8,0	2,5	3,5	6,0	4,7
> 8,0	3,0 [a]	4,0	10,0	5,0
[a] Or to be specified by the manufacturer.				
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 tightened by means of a screwdriver. **Column III** applies to screws and nuts, other than nuts of mantle clamping units, tightened by means other than a screwdriver. **Column IV** applies to screws tightened by means of a cross-slotted screwdriver.				

5.2.5 Unless otherwise specified in the test schedule, all tests shall be made on the specimen completely assembled in accordance with the instructions of the manufacturer.

A sufficient number of specimens shall be glued on a mounting surface as in normal use. The mounting surface shall consist of the same material as the back-sheet material of the module on which the box is intended to be fixed. If the box is intended to be fixed with several adhesives on several back-sheet materials, a sufficient number of specimens for each material shall be tested. The tests shall be carried out with the maximum specified number of bypass diodes in arrangement covering the worst-case condition.

The cell connections shall be bent down and fixed such that they have a conductive connection to the mounting surface. For some tests, it is necessary to have cell connections short-circuited.

5.2.6 For the reverse current test, the specimens shall be mounted on relevant back-sheet material with relevant adhesive, potted (if applicable). The terminals of the cell connections shall be short-circuited with conductors of the maximum cross-section as specified by the manufacturer. The intended cable shall be connected; blocking diodes shall be short-circuited.

5.3 Performance of tests

5.3.1 General

In accordance with the test schedule given in 5.4, the general test methods specified in Table 8 to Table 17 shall be applied.

5.3.2 Durability of marking

The test of the durability of marking shall be done as a wet test in accordance with test Xb (abrasion of marking) of IEC 60068-2-70. For the test piston, size 1 shall be used and the test liquid shall be water. A force of 5 N shall be applied for a duration of 10 cycles.

After the test, the marking shall still be legible.

This test shall also be carried out at an additional sticker (if applicable) with the warning notice listed under m) of 4.2.1, if applicable.

The test shall not be carried out on imprinted markings.

5.3.3 Fixing of lid on rewirable junction box

5.3.3.1 General

Tests in accordance with 5.3.3.2 and 5.3.3.3 shall be performed on a specimen that has already passed test sequences of test groups E and F.

5.3.3.2 Screw-fixed lid

Screws intended to fix the lid shall be tightened and loosened:

– 10 times for a metal-screw entering threaded insulating material;

– 5 times for other screws.

Screws and nuts entering threaded insulating material and screws made of insulating material are to be removed and reinserted completely each time. The test shall be performed using a suitable screwdriver or an appropriate tool applying a torque as indicated in Table 5. Greater values of torque may be used if specified by the manufacturer.

During the test, there shall be no damage, such as breakage of screw, damage of the slot of the head (which makes further use of the appropriate screwdriver impossible) or damage of the threads or to the enclosure impairing the further use of the fixing means. The screws shall be tightened in a smooth manner.

5.3.3.3 Screwless fixing of lid

Enclosures shall be tested with the test probe 11 in accordance with IEC 61032 applied with a force of 75 N for one minute to all areas where this could cause a loosening of the lid. During the test, the lid shall not come off.

However, the lid shall detach without any damage when using a suitable tool as described in the specification of the manufacturer.

5.3.4 Protection against electric shock

5.3.4.1 The junction box shall be tested by the test probe 11 in accordance with IEC 61032 using a test force of 20 N. For the test, all covers and housing parts that are detachable without a tool shall be removed. It shall not be possible to access live parts.

5.3.4.2 The relevant tests to verify the specified IP-Code in accordance with IEC 60529 shall be performed on the specimen in accordance with 5.2.5 with attached cables and/or mated plugs and attached cell-connections. Gaskets shall be aged in accordance with 5.3.15.

If the second numeral of the IP-Code for protection against ingress of water is IPx7 or higher, a supplement test for IPx5 shall be performed since IPx7 or higher do not cover the lower IP-Codes.

5.3.5 Measurement of clearances and creepage distances

Clearances and creepage distances shall be measured in accordance with IEC 60664-1 taking into consideration the requirements listed in Annex C.

5.3.6 Dielectric strength

For verification of the insulation, the following tests are applicable:

a) impulse withstand test:

the impulse withstand test shall be carried out with a voltage having a 1,2/50 µs waveform in accordance with IEC 60060-1 with three impulses of each polarity and an interval of at least 1 s between pulses. The output impedance of the impulse generator shall not be higher than 500 Ω. The test voltage shall comply with the rated impulse voltage taking into account the requirements of IEC 60664-1.

b) RMS withstand voltage test:

the voltage proof test shall be performed by applying an RMS withstand voltage (50/60 Hz) with an RMS value of 1 000 V plus 2 times the rated voltage for basic insulation, and twice this value for double or reinforced insulation. The test duration shall be 1 min.

The test voltage for both a) and b) shall be applied between the short-circuited output terminals and a metal foil which is wrapped around the specimen after relevant conditioning.

The test voltage for b) shall be applied additionally via the path of a cemented joint. The value of the voltage shall be multiplied by the factor 1,35.

5.3.7 Resistance to corrosion

Metal parts of boxes and enclosures shall be adequately protected against corrosion.

Compliance is checked by the following test.

All grease shall be removed from the parts to be tested, by immersion in a degreasing agent for (10 ± 1) min. The parts are then immersed for (10 ± 1) min in a 10 % solution of ammonium chloride in water at a temperature of (20 ± 5) °C.

Without drying, but after shaking off any drops, the parts are then placed for (10 ± 1) min in a box containing air with a relative humidity of 91 % to 95 % at a temperature of (20 ± 5) °C.

After the parts have been dried for (10 ± 1) min in a heating cabinet at a temperature of (100 ± 5) °C, their surface shall show no sign of corrosion.

NOTE Traces of corrosion on sharp edges and any yellowish film removable by rubbing are ignored.

5.3.8 Mechanical strength at lower temperatures

Before the tests, the specimens are stored for 5 h at a temperature of −40 °C on a 20 mm thick steel plate. The tests are carried out immediately after the end of the storage duration in the cold chamber.

The test shall be carried out in accordance with the following procedure.

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

The test is passed successfully if no damage that may impair the function of the junction box is evident. Creepage distances and clearances as well as solid insulation shall not be impaired.

5.3.8DV D2 *Modification by adding another required test condition and procedure in accordance with the following:*

5.3.8DV.1 Addition of required test condition by adding the following second paragraph: "Before the test, the specimens are to be stored for 5 h at a temperature of –35 °C on a 20 mm thick steel plate. The test is to be carried out immediately after the end of the storage duration in the cold chamber."

5.3.8DV.2 Addition of required test procedure by adding the following after the third paragraph: "For the –35 °C test condition, one impact on the specimen having an energy of 5 J, at any point considered most vulnerable, with an appropriate impact test apparatus in accordance with IEC 60068-2-75 shall be carried out."

5.3.8DV.3 Add the following: 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.

5.3.9 Thermal cycle test (IEC 60068-2-14:2009, Test Nb)

5.3.9.1 The specimens shall be prepared in accordance with 5.2.5 with attached and short-circuited cell-connections.

Before performance of the thermal cycle, the initial contact resistance shall be measured as described in 5.3.19. After the environmental and subsequent dielectric strength tests of test sequence E the measurement shall be repeated.

The test shall be carried out in a climatic chamber. A thermal cycle in accordance with Figure 1 shall be applied. For the number of cycles refer to 5.3.9.2 and 5.3.9.3.

The transfer time between upper and lower temperatures shall not exceed 100 °C/h. The upper and lower temperatures shall be held for a minimum of 10 min after thermal equilibrium of the specimen is reached.

During the thermal cycle test the rated current shall be applied such that it is conducted via each termination as described in 5.3.19.

The test plate with the mounted junction box shall be carried into the climatic chamber and a force of 5 N shall be applied vertically during the test.

a) Install the test plate at room temperature in the chamber. Attach a single 5 N weight to the junction box using one of two options. The weight may be attached utilizing the electrical termination leads of each junction box so that it hangs down vertically from the junction box, as shown in Figure 8 a). The weight may also be attached to the junction box using a wire introduced by the tester, as shown in Figure 8 b). In either case, the weight shall not touch the test plate back surface, and shall be at least 5 cm above the floor at the start of the test, as indicated in Figure 8 b). For that the wire may be fixed by drilling one or more holes to the junction box or by wrapping it around. The weight shall not be attached to the lid.

b) Attach a suitable temperature sensor to the front surface of the junction box near the middle.

c) Close the chamber and subject the test plates to cycling between measured junction box temperatures of (−40 ± 2) °C and (+85 ± 2) °C, in accordance with the profile in Figure 1. The rate of change of temperature between the low and high extremes shall not exceed 100 °C/h and the junction box temperature shall remain stable at each extreme for a period of at least 10 min. The cycle time shall not exceed 6 h unless the junction box has such a high heat capacity that a longer cycle is required. The number of cycles shall be as listed in 5.3.9.2 and 5.3.9.3. Air circulation around the junction box shall ensure compliance with each junction box under test meeting the temperature cycling profile.

d) Throughout the test, record the junction box temperature.

The temperature shall be measured with a suitable temperature sensor that is attached on the outer surface of the enclosure and connected to the temperature-monitoring equipment.

During the thermal cycling test set the continuous current flow as shown in Figure 1 during the heat up cycle to the rated current at temperature from −40 °C to +80 °C. During cool down, the −40 °C dwell phase and temperatures above +80 °C, the continuous current shall be switched off.

5.3.9.2 The number of cycles for test sequence E is 200.

5.3.9.3 The number of cycles for test sequence G is 50.

5.3.10 Damp heat test

The specimens shall be prepared in accordance with 5.2.5 with attached and short-circuited cell-connections.

The test plate with the mounted junction box shall be carried out into the climatic chamber and a weight of 5 N shall be applied vertically during the test.

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

– test temperature: maximum working temperature, minimum (+85 ± 2) °C;

– relative humidity: (+85 ± 5) %;

– test duration: 1 000 h.

5.3.11 Weather resistance test

The weather resistance test shall be performed on relevant specimens and on the sticker in accordance with the requirements of ISO 4892-2 or ISO 4892-3 under the following conditions:

– spectral irradiance:	minimum 60 W/m^2;
– bandpass:	300 nm to 400 nm;
– Black Standard Temperature (BST):	65 °C;
– relative humidity:	65 %;
– cycles:	18 min spraying, 102 min drying with Xenon lamp or equivalent lamp;
– duration:	500 h.

5.3.12 Flammability class

5.3.12.1 The test shall be performed in accordance with flammability class V-1 of IEC 60695-11-10 for outer accessible parts and flammability class HB of IEC 60695-11-10 for inner parts on an adequate sample of material.

5.3.12.2 The test shall be performed in accordance with flammability class 5V of IEC 60695-11-20 on the end-product.

The mounted and closed junction box shall be installed in a position as shown in Figure 5. The flame shall be applied at all outer locations where, in some areas (e.g. where a terminal is mounted inside the box) an arcing might cause an ignition.

The result is assessed in accordance with flammability class 5VB.

5.3.12DV D2 *Modification by adding the following:*

5.3.12DV.3 The material thickness for determining the flammability shall be measured at the thinnest points of the isolating material.

5.3.12DV.4 Flammability V-0 or 5VA according to UL 94 is also acceptable.

5.3.12DV.5 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.

5.3.13 Ball pressure test

The test shall be performed in a heating cabinet in accordance with IEC 60695-10-2 at one of the following temperatures

a) (90 ± 2) °C for outer materials providing protection against electric shock,

b) (125 ± 2) °C for materials serving as a support for live metal parts.

5.3.14 Glow wire test

The glow wire test shall be performed in accordance with IEC 60695-2-11. The test temperature is

a) 650 °C for outer materials providing protection against electric shock,

b) 750 °C for materials necessary to retain current carrying parts in position and for potting material, if applicable.

5.3.15 Resistance against ageing

Gaskets (e.g. separate polymer seals) shall be separated from the junction box or lid and shall be stored in a heating cabinet for 240 h at (100 ± 5) °C and subsequently cooled for 16 h at ambient temperature.

Gaskets that are not intended to be separated from the junction box or the lid shall be tested with the junction box or the lid.

For junction boxes designed to be re-opened the lid shall be closed and opened 10 times (e.g. for rewirable junction boxes). For other junction boxes the lid shall be closed once.

Compliance shall be checked by verifying the IP-code in accordance with 5.3.4.2.

5.3.16 Wet leakage current test

5.3.16.1 General

The specimens shall be prepared in accordance with 5.2.5 with attached and short-circuited cell-connections.

5.3.16.2 Apparatus

a) A basin or tank of sufficient size to accept the specimen, which shall be placed in the water/wetting agent solution in a flat, horizontal position.

b) The basin or tank shall contain a water/wetting agent solution meeting the following requirements:

– resistivity: 3 500 Ω cm or less;

– temperature: (22 ± 2) °C.

The depth of the solution shall be sufficient to cover all surfaces between the mounting surface and box.

c) Spray equipment containing the same solution.

d) DC voltage source, with current limitation, capable of applying 500 V or the maximum rated voltage as specified by the manufacturer, whichever is greater. In case of cemented joints the DC voltage source shall be capable of applying the test voltage multiplied by the factor 1,35.

e) Measurement device to measure insulation resistance.

5.3.16.3 Procedure

All connections shall be representative of the recommended wiring installation and precautions shall be taken to ensure that leakage currents do not originate from wiring of the measurement device.

a) Immerse the specimen in the tank of the required solution to a depth sufficient to cover all surfaces between the mounting surface and box. The cable entries and connectors shall be thoroughly sprayed with solution, if applicable.

b) Connect the short-circuited output terminals of the test specimen to the positive terminal of the test equipment. Connect the liquid test solution to the negative terminal of the test equipment using a suitable metallic conductor.

c) Increase the voltage applied by the test equipment at a rate not to exceed 500 V s^{-1} to 500 V or to the maximum rated voltage as specified by the manufacturer, whichever is greater. This value of the test voltage shall be multiplied by the factor 1,35 when checking cemented joints. Then determine the insulation resistance.

d) Reduce the applied voltage to zero and short-circuit the terminals of the test equipment to discharge the voltage build-up in the test setup.

5.3.17 Humidity freeze test

5.3.17.1 General

The specimens shall be prepared in accordance with 5.2.5 with attached and short-circuited cell-connections.

5.3.17.2 Apparatus

a) A climatic chamber with automatic temperature and humidity control, capable of subjecting one or more specimens to the humidity-freeze cycle specified in Figure 2.

b) Means for mounting or supporting the specimen in the chamber, so as to allow free circulation of the surrounding air. The thermal conduction of the mount or support shall be low, so that, for practical purposes, the specimen is thermally isolated.

5.3.17.3 Procedure

a) Attach a suitable temperature sensor to the front or back surface of the specimen(s) near the middle.

b) Install the specimen(s) in the climatic chamber at room temperature.

c) After closing the chamber, subject the specimen(s) to 10 complete cycles in accordance with the profile of Figure 2. The maximum and minimum temperatures shall be within ±2 °C of the specified levels and the relative humidity shall be maintained within ±5 % when the temperature is at the maximum value of +85 °C.

d) Throughout the test, record the specimen temperature.

e) Then the specimen(s) are stored for a recovery time between 2 h and 4 h at room temperature.

5.3.17.4 Final measurements

A visual check and the RMS withstand voltage test in accordance with 5.3.6 b) shall be performed. For performing the withstand voltage test, wrap a conductive foil around the edges of specimen(s).

5.3.18 Bypass diode thermal test

5.3.18.1 General

This test is equivalent to MQT 18.1 of IEC 61215-2:2016 with the following differences:

MQT 18.1 of IEC 61215-2:2016 applies with the exception that "module" shall be replaced by "test specimen", and that the applied test current shall refer to the "rated current of the junction box" instead of "short circuit current of the module".

5.3.18.2 Test sample

The specimens shall be prepared in accordance with 5.2.5 and Table 4, item H1. Thermocouples shall be fixed at the relevant insulating materials to determine if the values of TI, RTE/RTI are not exceeded. Wires for the measurement of voltage drop and current at the bypass diode shall be fixed as shown in Figure 7.

5.3.18.3 Procedure

MQT 18.1 of IEC 61215-2:2016 applies with the exception that a) and b) within "Procedure" (4.18.1.3 of IEC 61215-2:2016) shall be replaced by the following:

a) Operation of diodes in the direction of current flow.

b) Connect wires of the manufacturer's minimum recommended cross section to the output terminals of the junction box.

Some boxes have overlapping bypass diode circuits. In this case, it may be necessary to install a jumper cable to ensure that all of the current is flowing through one bypass diode.

Additionally the following modification shall be made:

5.3.18.4 Requirements

After the test of MQT 18.1 the diode shall be still operational and there shall be no evidence of major visual defects according to Clause 8 of IEC 61215-1:2016 and additional defects such as:

• current carrying parts not retained in the original position,

• deformation of insulation parts serving as protection against electric shock,

• other deformation of insulation parts which could impair safety or function of the junction box.

5.3.19 Test of terminations and connection methods

All terminations and connection methods shall be tested in accordance with their relevant IEC-standards as listed in 4.4.

Contact resistance shall be measured for all terminations and connection methods for external cables and ribbons before and after environmental and subsequent dielectric strength tests of test sequence E.

The contact resistance shall be measured between external cable and connected ribbon as shown in Figure 6 by application of a DC current of 1 A. The voltage drop shall be measured and the contact resistance shall be calculated. These determined values shall be listed as reference resistance and shall not exceed 5 mΩ. After accomplishment of thermal cycles and subsequent dielectric strength tests the measurement of contact resistance shall be repeated as described above. The determined values shall not exceed 150 % of the reference resistance.

Internal connectors shall meet the relevant tests of IEC 62852. The number of cycles in the thermal cycle (shock) test of IEC 62852 shall be 800.

5.3.20 Knock-out inlets (outlets) intended to be removed by mechanical impact

5.3.20.1 Knock-out retention

5.3.20.1.1 Procedure

For boxes and enclosures having knock-outs accessible after installation, a force of (45 ± 1) N shall be applied to a knock-out for (15 ± 1) s by means of a 6 mm diameter mandrel with a flat end. The force shall

be applied without a blow in a direction perpendicular to the plane of the knock-out and at a point most likely to cause movement.

5.3.20.1.2 Requirement

The knock-out shall remain in place and the degree of protection of the enclosure shall be unchanged when measured 1 h after the force has been removed.

5.3.20.2 Knock-out removal

5.3.20.2.1 Procedure

The knock-outs shall be removed by means of a tool, as stated by the manufacturer. The side edge of a screwdriver may be run along the edge of the knock-out opening once to remove any fragile tabs remaining along the edge.

The test is repeated with one box or enclosure that has been conditioned for 5 h ± 10 min in air maintained at the temperature (−20 ± 2) °C. Immediately following this conditioning, the knock-out shall be removed as above. For a box and an enclosure employing multi-stage knock-outs, there shall be no displacement of a larger stage when a smaller stage is removed.

5.3.20.2.2 Requirement

After the test, there shall be no sharp edges except for knock-out inlets (outlets) for conduits and/or for use with a grommet or a membrane. The box and enclosure shall not be damaged.

5.3.21 Test of cord anchorage

5.3.21.1 Junction boxes intended to be used with cables specified by the manufacturer

For junction boxes intended to be used with the manufacturer specified cables, 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 6.

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 the 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 7 shall be applied for 1 min.

During the test, the torsion shall not exceed 45°.

5.3.21.2 Junction boxes 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 6 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 6.

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 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 6 or Table 7. 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 6
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.		

NOTE 1 A typical arrangement for the pull test is shown in Figure 3.

Table 6DV D2 *Modification by adding the following at the end of the table:*

The test pull force shall be either the value given in Table 6 or 89 N, whichever is higher.

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

The unloaded cable shall be marked so that any torsion relative to the gland can be easily detected, and then a torque specified in Table 7 is applied for 1 min.

During the 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 7.

NOTE 2 A typical arrangement for the torsion test is shown in Figure 4.

Table 7
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

5.3.22 Retention on the mounting surface

5.3.22.1 Tests specified in 5.3.22.2 and 5.3.22.3 shall be performed on a specimen that has passed the test sequences of test groups F and G. During the test, there shall be no displacement of the junction box at the mounting surface that would impair the isolating characteristics.

The test shall be performed under consideration of the requirements of 5.2.5.

5.3.22.2 A force of 40 N shall be gradually increased and applied for 30 min in each direction in steps of 90° parallel to the mounting surface.

5.3.22.3 A force of 40 N shall be gradually increased and applied for 30 min without jerks, in a direction perpendicular to the mounting surface.

The pull force should be applied at the centre point of the box.

5.3.22DV D2 *Modification of 5.3.22.2 and 5.3.22.3 in accordance with the following:*

Replace the retention force of 40 N with 156 N.

5.3.23 Reverse current test at junction box

5.3.23.1 Apparatus

a) Means for heating the specimen to the upper rated ambient temperature.

b) Means for applying a current equal to the reverse current of the junction box under test.

c) Means for detection of the point at the outer surface having the highest temperature during the test, for example an infrared sensor.

d) Means for measurement and record of temperature, for example a thermocouple.

5.3.23.2 Procedure

a) All blocking diodes shall be short-circuited.

b) Connect cables of the manufacturer's minimum recommended cross section to the output terminals of the junction box.

c) The specimen shall be placed with its back on a pineboard in a horizontal position.

d) Heat the specimen to the maximum ambient temperature. Apply a current to the specimen equal to the reverse current ±2 % of the junction box. After 1 h determine the hottest point, for example by using an infrared camera, switch off current, cool down to room temperature and attach a thermocouple to this point. Reheat the specimen to the upper rated ambient temperature and reapply a current equal to the reverse current ±2 % of the junction box for 1 h.

e) At the end of the test, record the temperature measured by the thermocouple.

5.4 Test schedule

Table 8
Marking, information, documentation, test group A

1	2	3	4	5	6
Test phase	**Designation**	**Test according to**	**Specimen**	**Measurements, designation**	**Requirements**
A1	Marking	4.2.2	Label, sticker (or similar) with warning notice	Visual examination	Marking in accordance with 4.2.2
A2	Technical documentation	4.2.3	Mounting instruction, warning notice, manual or similar	Document inspection	Information in accordance with 4.2.3 and additional information
A3	Approval of attached components		Approval by data sheets or certificates for cable, connectors, cable glands, etc.	Document inspection	4.4, 4.5, 4.6, 4.16.1, 4.16.2 Components shall comply with the relevant standards. Upper limit temperature shall not exceed the RTE/RTI/TI values

Table 9
Material test, test group B (single tests)

1	2	3	4	5	6
Test phase	**Designation**	**Test according to**	**Specimen**	**Measurements, designation**	**Requirements**
B1	Durability of marking	5.3.2	Label, sticker (or similar) with warning notice	Wet test	Marking easily legible
B2	Resistance to corrosion	5.3.7	Metal parts	Chemical test	No sign of corrosion on surface
B3	Flammability class	5.3.12.1	Sample of polymers serving as an enclosure and for polymers serving as a support for live metal parts	Flammability test or approval of manufacturer of material	Requirements in accordance with V-1 of IEC 60695-11-10 for outer parts and in accordance with HB of IEC 60695-11-10 for inner parts.
B4	Weather resistance test	5.3.11	Polymers serving as an enclosure	Weather resistance test in accordance with ISO 4892-2 and ISO 4892-3	No cracks, proceed with test of B5 Marking still legible
B5	Glow wire test	5.3.14 a)	Specimen from B4	Glow wire test with 650 °C	No ignition of material or support, or self extinguishing within 30 s
B6	Glow wire test	5.3.14 b)	Polymers serving as a support for live metal parts and potting material (test sample)	Glow wire test with 750 °C	No ignition of material or support, or self extinguishing within 30 s
B7	Ball pressure test	5.3.13 a)	Polymers serving as an enclosure	Ball pressure test at 90 °C	Diameter of impression ≤ 2,0 mm
B8	Ball pressure test	5.3.13 b)	Polymers serving as a support for live metal parts	Ball pressure test at 125 °C	Diameter of impression ≤ 2,0 mm
B9	Resistance against ageing	5.3.15	Gaskets	Accelerated ageing in oven, 10 times opening and closing of lid with integrated gasket. Continue with J1 of Table 17	No change of sealing characteristic Passing the requirements of IP-test in accordance with J1 and J2 of Table 17
B10	Flammability class	5.3.12.2	Specimen in accordance with Table 4	Flammability test	Requirements in accordance with 5-VB of IEC 60695-11-20

Table 10
Constructional requirements, test group C (single tests)

1	2	3	4	5	6
Test phase	**Designation**	**Test according to**	**Specimen**	**Measurements, designation**	**Requirements**
C1	Protection against electric shock	4.3.3	Complete specimen as described in 5.2.5	Visual examination	No loosening or displacement

Table 10 Continued on Next Page

Table 10 Continued

1	2	3	4	5	6
Test phase	**Designation**	**Test according to**	**Specimen**	**Measurements, designation**	**Requirements**
C2		5.3.4.1		Test with test finger 20 N	No live parts are accessible
C3	General construction	4.8.4	Complete specimen	Visual examination and measurement	Sufficient wall thickness in accordance with IEC 61140 and fixing
C4		4.8.2	Complete specimen	Visual examination	No sharp edges
C5	Terminations and connection methods	4.4.2	Complete specimen	Visual examination	Fix position of terminals Additional means for soldered connections
C6	Clearances and creepage distances	5.3.5, 4.14 and 4.15	Complete specimen, terminated	Measurement	Requirements of 4.14 shall be fulfilled
C7	Wall thickness	4.16.1 a)	Complete specimen	Measurement	Wall thickness min. 3,0 mm, otherwise test in accordance with B10 of Table 9
C8	Lids	4.3.2	Complete specimen	Visual examination	Requirements of 4.3.2 shall be fulfilled

Table 11
Mechanical tests, test group D (single tests)

1	2	3	4	5	6
Test phase	**Designation**	**Test according to**	**Specimen**	**Measurements, designation**	**Requirements**
D1	Terminations and connection methods	5.3.19	Complete specimen	Mechanical test of suitability of terminals and connections	Requirements of relevant items listed in 4.4.2 shall be fulfilled.
D2	Knock-out inlets (outlets)	5.3.20	4 complete specimen	Mechanical test	Requirements of 5.3.20 shall be fulfilled.
D3	Cord anchorage	5.3.21	Cord anchorage	Pull- and torsion test	Requirements of 5.3.21 shall be fulfilled.
D4	Mechanical strength at lower temperatures	5.3.8	Complete specimen	Impact test	No damage, which may impair function
D5	Fixing of lid	5.3.3	2 pre-aged specimen from Groups E and F	Mechanical test	No damage in accordance with the relevant subclause of 5.3.3

Table 12
Test sequence I, test group E
(tests to be performed consecutively in this order)

1	2	3	4	5	6
Test phase	**Designation**	**Test according to**	**Specimen**	**Measurements, designation**	**Requirements**
E1	Initial measurement	5.3.19	Complete specimen in accordance with 5.2.5 and Table 4 item Group E.	Contact resistance measurement Test current: 1 A Measuring points: see Figure 6	Contact resistance ≤ 5 mΩ
E2	Wet leakage current test	5.3.16		Insulation resistance	Insulation resistance not less than 400 MΩ
E3	Thermal cycle test	5.3.9		Thermal cycle test Test cycles: 200 Attachment of rated current, application of a force of 5 N	No visible damage, which could impair function or safety
E4	Dielectric strength	5.3.6 b)		RMS withstand voltage test 2 000 V + (4 × rated voltage)	No flashover or breakdown of voltage
E5	Dielectric strength	5.3.6 a)		Impulse withstand test	No flashover or breakdown of voltage
E6	Final measurement	5.3.19		Contact resistance measurement Test current: 1 A Measuring points: see Figure 6	Contact resistance ≤ 150 % of initial value
E7	Wet leakage current test	5.3.16		Insulation resistance	Insulation resistance not less than 400 MΩ

Table 13
Test sequence II, test group F
(tests to be performed consecutively in this order)

1	2	3	4	5	6
Test phase	**Designation**	**Test according to**	**Specimen**	**Measurements, designation**	**Requirements**
F1	Wet leakage current test	5.3.16	Specimen in accordance with 5.2.5 with attached and short-circuited cell-connections	Insulation resistance	Insulation resistance not less than 400 MΩ
F2	Damp heat	5.3.10		Ageing test	No visible damage, which could impair function or safety
F3	Resistance against creeping	5.3.10		Visual test	No creeping occurred
F4	Retention on the mounting surface	5.3.22		Mechanical test	No loosening or displacement of specimen
F5	Dielectric strength	5.3.6 b)		RMS withstand voltage test 2 000 V + (4 × rated voltage)	No flashover or breakdown of voltage
F6	Wet leakage current test	5.3.16		Insulation resistance	Insulation resistance not less than 400 MΩ

Table 14
Test sequence III, test group G
(tests to be performed consecutively in this order)

1	2	3	4	5	6
Test phase	**Designation**	**Test according to**	**Specimen**	**Measurements, designation**	**Requirements**
G1	Thermal cycle test	5.3.9.3	Specimen in accordance with 5.2.5 and Table 4, item Group G	Test cycles: 50 Application of rated current Attachment of a force of 5 N	No visible damage, which could impair function or safety
G2	Humidity-freeze test	5.3.17			No visible damage, which could impair function or safety
G3	Dielectric strength	5.3.6 b)		RMS withstand voltage test 2 000 V + (4 × rated voltage)	No flashover or breakdown of voltage
G4	Retention on mounting surface	5.3.22		Mechanical test	No loosening or displacement of specimen
G5	Wet leakage current test	5.3.16		Insulation resistance	Insulation resistance not less than 400 MΩ

Table 15
Test sequence IV, test group H
(tests to be performed consecutively in this order)

1	2	3	4	5	6
Test phase	**Designation**	**Test according to**	**Specimen**	**Measurements, designation**	**Requirements**
H1	Bypass diode thermal test	5.3.18	Specimen in accordance with 5.2.5 and Table 4, item Group H1		Specified diode maximum junction temperature is not exceeded after test of 5.3.18.3
					No evidence of visible damages as described in 5.3.18.4
H2	Wet leakage current test	5.3.16		Insulation resistance	Insulation resistance not less than 400 MΩ

Table 16
Reverse current test, test group I

1	2	3	4	5	6
Test phase	**Designation**	**Test according to**	**Specimen**	**Measurements, designation**	**Requirements**
I1	Reverse current test at junction box	5.3.23	Specimen in accordance with 5.2.6 and Table 4, item Group I1		No flaming nor charring of the junction box. The maximum measured surface temperature during the test shall not exceed 150 °C

Table 17
Test sequence V, test group J
(tests to be performed consecutively in this order)

1	2	3	4	5	6
Test phase	**Designation**	**Test according to**	**Specimen**	**Measurements, designation**	**Requirements**
J1	Degree of protection	5.3.4.2	Specimen in accordance with 5.2.5 with attached and short-circuited cell-connections	IP-code	Specified IP-degree, minimum IP55 in accordance with IEC 60529. If IP-degree for protection against ingress of water is IPx7 or higher, IPx5 shall be tested additionally.
J2	Dielectric strength	5.3.6 b)		RMS withstand voltage test 2 000 V + (4 × rated voltage)	No flashover or breakdown of voltage

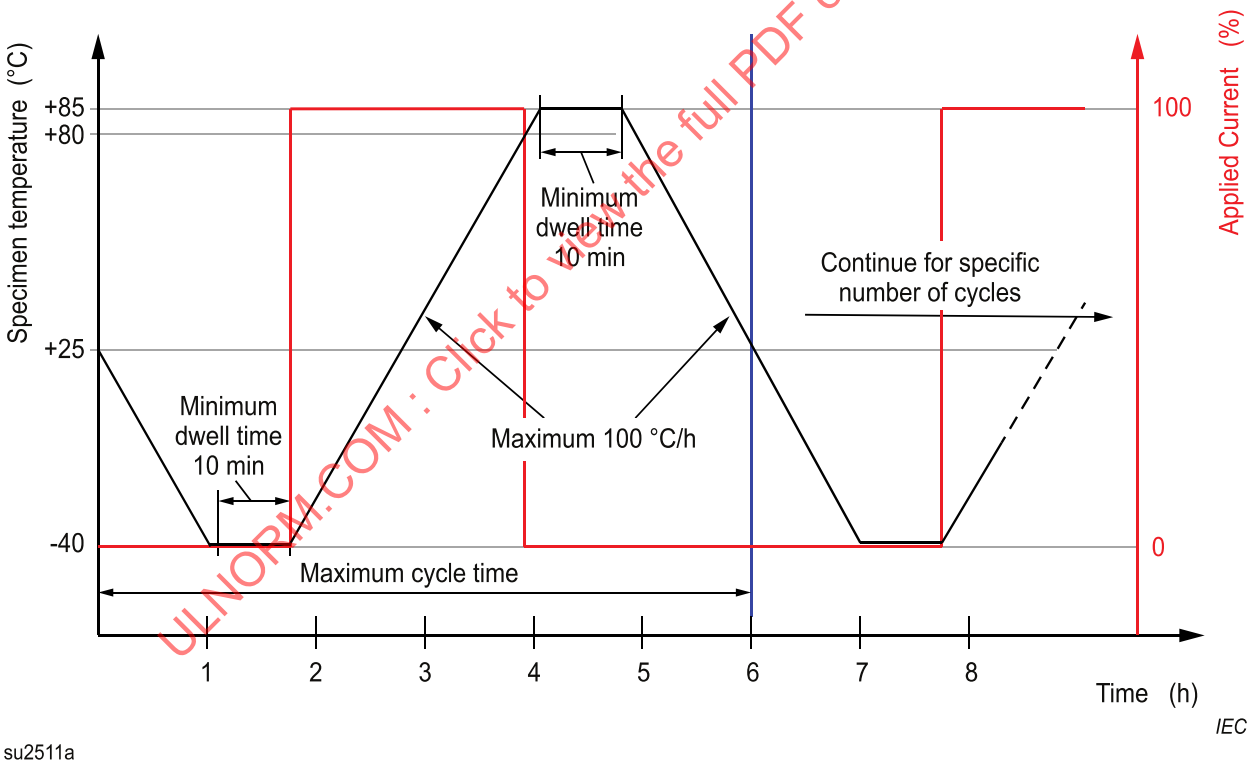

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Figure 1

Thermal cycling test – Temperature and applied current profile

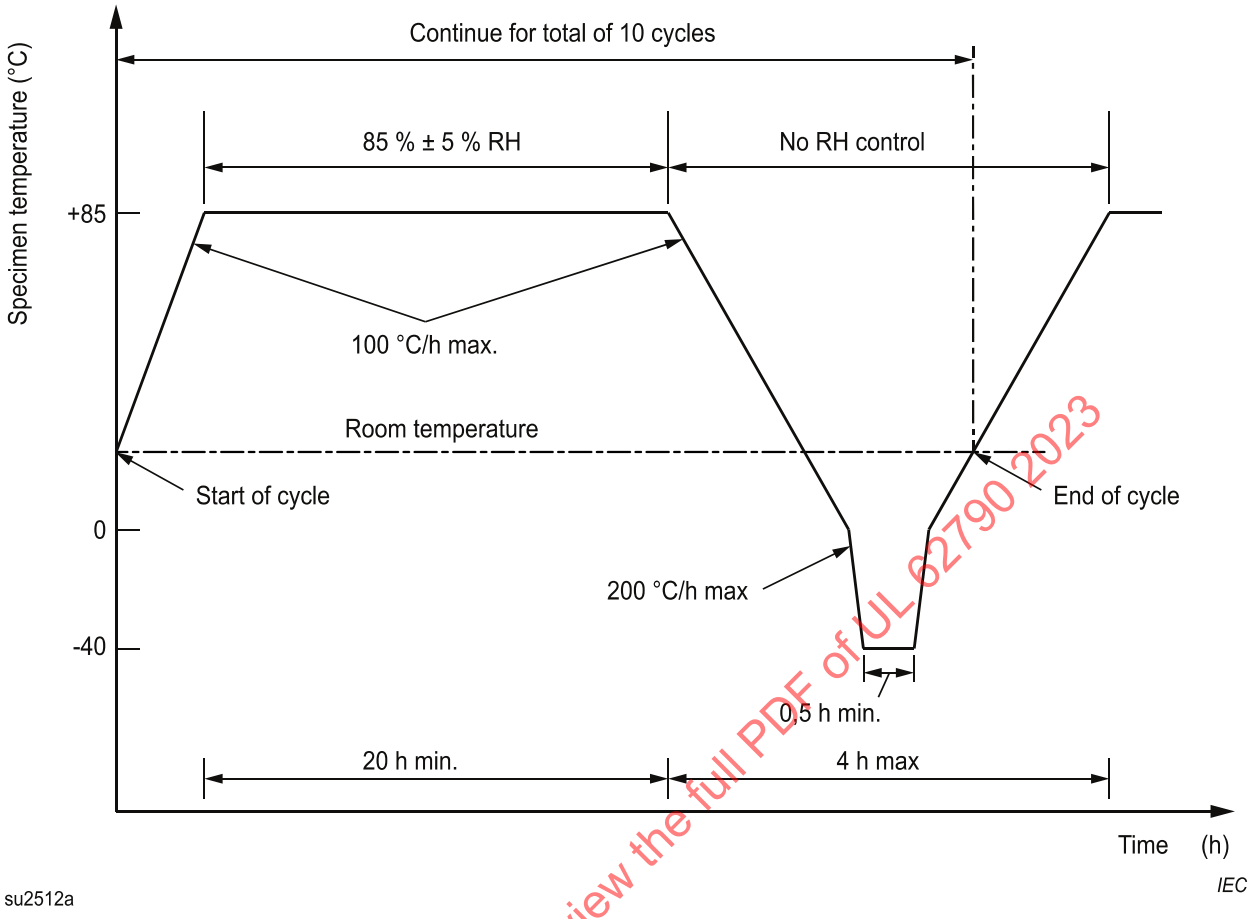

Figure 2

Humidity-freeze cycle

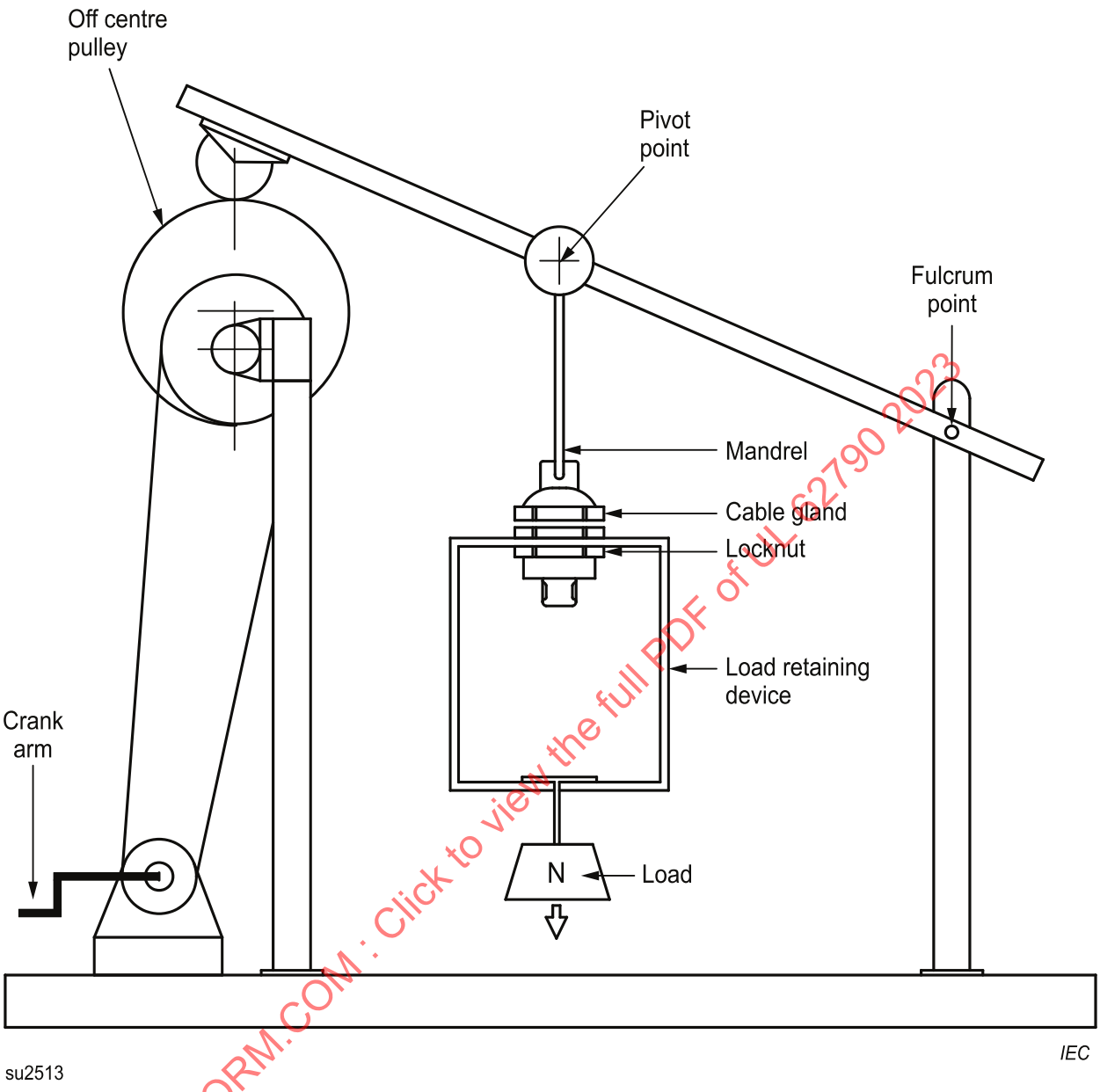

Figure 3

Typical arrangement for the cable anchorage pull test

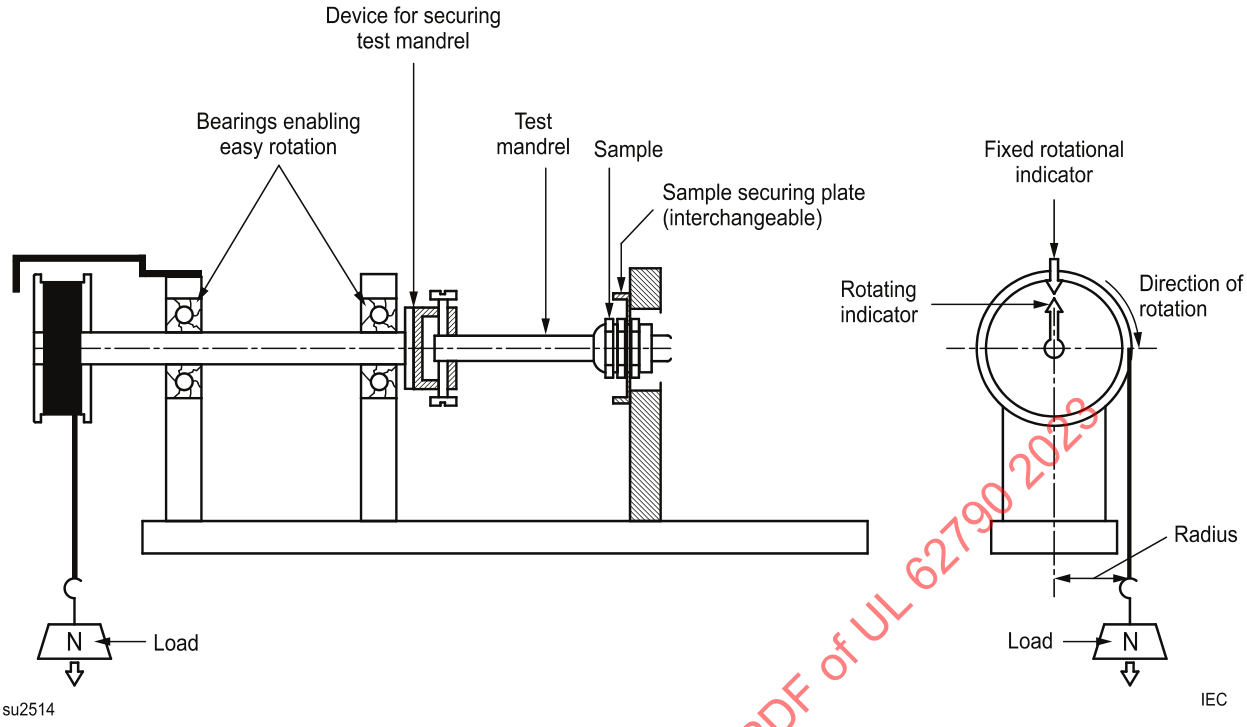

Figure 4

Typical arrangement for torsion test

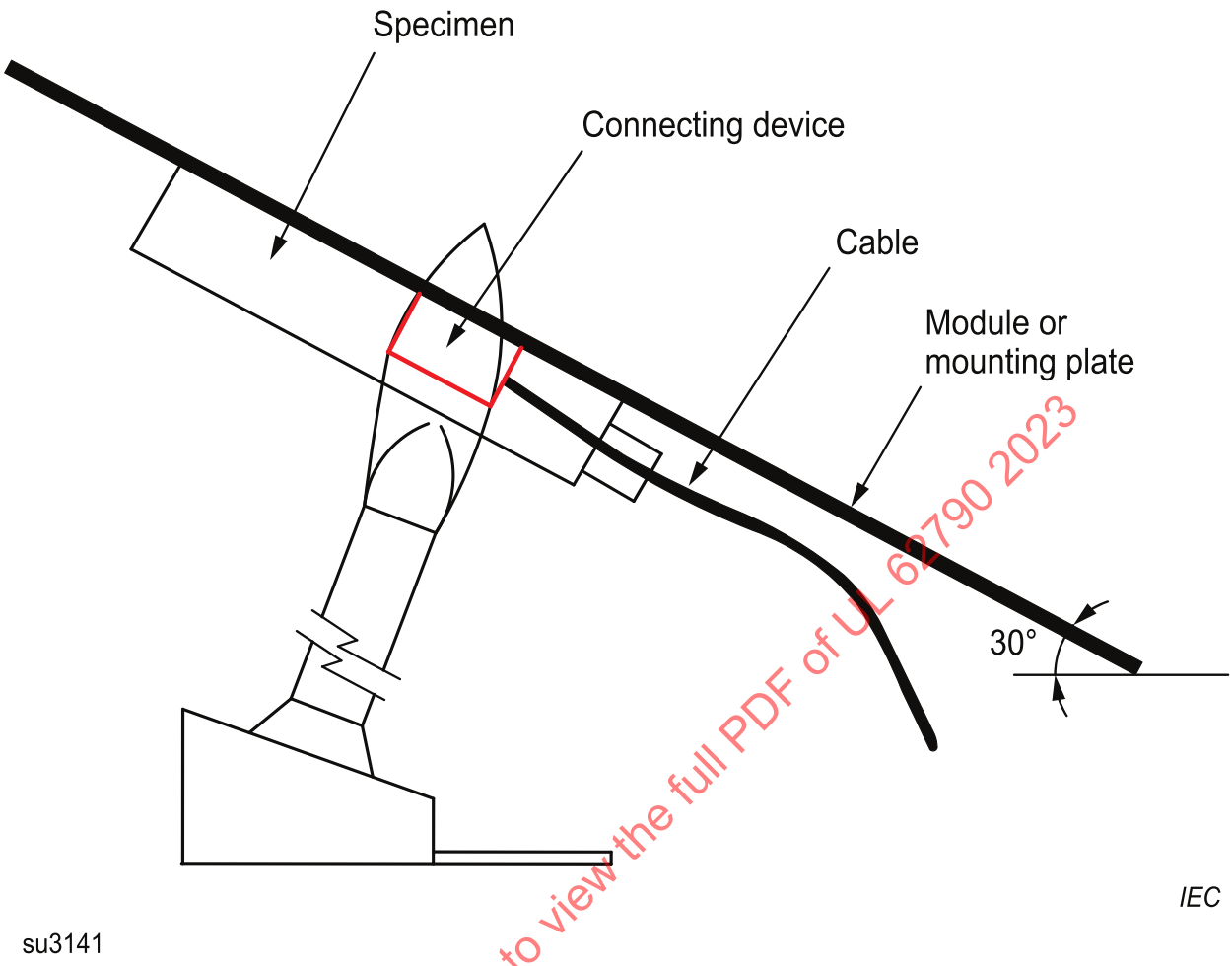

Figure 5

Typical arrangement for flammability test in accordance with 5.3.12.2