BS EN 62790:2015

BSI Standards Publication

Junction boxes for photovoltaic modules — Safety requirements and tests

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National foreword

This British Standard is the UK implementation of EN 62790:2015. It is identical to IEC 62790:2014. It supersedes BS IEC 62790:2014, which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee GEL/82, Photovoltaic Energy Systems.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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Compliance with a British Standard cannot confer immunity from legal obligations.

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Amendments/corrigenda issued since publication

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31 May 2015	This corrigendum renumbers BS IEC 62790:2014 as BS EN 62790:2015, Annex ZA also added

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EN 62790

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English Version

Junction boxes for photovoltaic modules - Safety requirements and tests (IEC 62790:2014)

Boîtes de jonction pour modules photovoltaïques - Exigences de sécurité et essais (IEC 62790:2014)

Anschlussdosen für Photovoltaik-Module - Sicherheitsanforderungen und Prüfungen (IEC 62790:2014)

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

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Foreword

The text of document 82/876/FDIS, future edition 1 of IEC 62790, prepared by IEC/TC 82 "Solar photovoltaic energy systems" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 62790:2015.

The following dates are fixed:

- latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 2015-09-13
- latest date by which the national standards conflicting with the document have to be withdrawn (dow) 2017-12-11

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Endorsement notice

The text of the International Standard IEC 62790:2014 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

IEC 60352-3	NOTE	Harmonized as EN 60352-3.
IEC 60352-4	NOTE	Harmonized as EN 60352-4.
IEC 60364-7-712	NOTE	Harmonized as HD 60364-7-712.
IEC 60512-1	NOTE	Harmonized as EN 60512-1.
IEC 60695-10-2	NOTE	Harmonized as EN 60695-10-2.
IEC 61210	NOTE	Harmonized as EN 61210.
IEC 61215	NOTE	Harmonized as EN 61215.
IEC 61646	NOTE	Harmonized as EN 61646.

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

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.

NOTE 1 When an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cenelec.eu.

Publication	Year	Title	EN/HD	Year
-	-	Electric cables for photovoltaic systems	EN 50618	-
IEC 60060-1	-	High-voltage test techniques - Part 1: General definitions and test requirements	EN 60060-1	-
IEC 60068-1	-	Environmental testing - Part 1: General and guidance	EN 60068-1	-
IEC 60068-2-14	2009	Environmental testing - Part 2-14: Tests - Test N: Change of temperature	EN 60068-2-14	2009
IEC 60068-2-70	-	Environmental testing - Part 2: Tests - Test Xb: Abrasion of markings and letterings caused by rubbing of fingers and hands	EN 60068-2-70	-
IEC 60068-2-75	-	Environmental testing - Part 2-75: Tests - Test Eh: Hammer tests	EN 60068-2-75	-
IEC 60068-2-78	-	Environmental testing - Part 2-78: Tests - Test Cab: Damp heat, steady state	EN 60068-2-78	-
IEC 60228	-	Conductors of insulated cables	EN 60228	-
IEC 60352-2	-	Solderless connections - Part 2: Crimped connections - General requirements, test methods and practical guidance	EN 60352-2	-
IEC 60512-12-1	-	Connectors for electronic equipment - Tests and measurements - Part 12-1: Soldering tests - Test 12a: Solderability, wetting, solder bath method	EN 60512-12-1	-

Publication	Year	Title	EN/HD	Year
IEC 60512-12-2	-	Connectors for electronic equipment - Tests and measurements - Part 12-2: Soldering tests - Test 12b: Solderability, wetting, soldering iron method	EN 60512-12-2	-
IEC 60529	-	Degrees of protection provided by enclosures (IP Code)	EN 60529	-
IEC 60664-1	2007	Insulation coordination for equipment within low-voltage systems - Part 1: Principles, requirements and tests	EN 60664-1	2007
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 60664-3	-	Insulation coordination for equipment within low-voltage systems - Part 3: Use of coating, potting or moulding for protection against pollution	EN 60664-3	-
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)	EN 60695-2-11	-
IEC 60695-11-10	-	Fire hazard testing - Part 11-10: Test flames - 50 W horizontal and vertical flame test methods	EN 60695-11-10	-
IEC 60695-11-20	1999	Fire hazard testing - Part 11-20: Test flames - 500 W flame test methods	EN 60695-11-20	1999
IEC/TR 60943	-	Guidance concerning the permissible temperature rise for parts of electrical equipment, in particular for terminals	-	-
IEC 60947-7-1	-	Low-voltage switchgear and controlgear - Part 7-1: Ancillary equipment - Terminal blocks for copper conductors	EN 60947-7-1	-
IEC 60998-2-1	-	Connecting devices for low-voltage circuits for household and similar purposes - Part 2-1: Particular requirements for connecting devices as separate entities with screw-type clamping units	EN 60998-2-1	-
IEC 60998-2-2	-	Connecting devices for low-voltage circuits for household and similar purposes - Part 2-2: Particular requirements for connecting devices as separate entities with screwless-type clamping units	EN 60998-2-2	-

Publication	Year	Title	EN/HD	Year
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 mm² up to 35 mm² (included)	EN 60999-1	2000
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 mm² up to 300 mm² (included)	EN 60999-2	-
IEC 61032	-	Protection of persons and equipment by enclosures - Probes for verification	EN 61032	-
IEC 61140	2001	Protection against electric shock - Common aspects for installation and equipment	EN 61140	2002
IEC 61730-1	-	Photovoltaic (PV) module safety qualification - Part 1: Requirements for construction	EN 61730-1	-
IEC 61730-2 (mod)	2004	Photovoltaic (PV) module safety qualification - Part 2: Requirements for testing	EN 61730-2	2007
IEC 62852	-	Connectors for DC-application in photovoltaic systems - Safety requirements and tests	EN 62852	-
ISO 868	2003	Plastics and ebonite - Determination of indentation hardness by means of a durometer (Shore hardness)	EN ISO 868	2003
ISO 4892-2	2013	Plastics - Methods of exposure to laboratory light sources - Part 2: Xenon-arc lamps	EN ISO 4892-2	2013
ISO 4892-3	2006	Plastics - Methods of exposure to laboratory light sources - Part 3: Fluorescent UV lamps	EN ISO 4892-3	2006

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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JUNCTION BOXES FOR PHOTOVOLTAIC MODULES – SAFETY REQUIREMENTS AND TESTS

FOREWORD

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

The European Standard EN 50548 (first edition, 2011), has served as a basis for the elaboration of this standard.

The text of this standard is based on the following documents:

FDIS	Report on voting
82/876/FDIS	82/902/RVD

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

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

The committee has decided that the contents of this publication 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.

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 International Standard describes safety requirements, constructional requirements and tests for junction boxes up to 1 500 V dc for use on photovoltaic modules according to class II of IEC 61140:2001.

This standard 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 standard does not apply to the electronic circuits of these devices, for which other IEC-standards apply.

NOTE For junction boxes according to classes 0 and III of IEC 61140:2001, in photovoltaic-systems, this standard can be used as a guideline.

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 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: 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 60228, *Conductors of insulated cables*

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

IEC 60512-12-1, *Connectors for electronic equipment – Tests and measurements – Part 12-1: Soldering tests – Test 12a: Solderability, wetting, solder bath method*

IEC 60512-12-2, *Connectors for electronic equipment – Tests and measurements – Part 12-2: Soldering tests – Test 12b: Solderability, wetting, soldering iron method*

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/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 60664-3, *Insulation coordination for equipment within low-voltage systems – Part 3: Use of coating, potting or moulding for protection against pollution*

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

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

IEC 60695-11-20:1999, *Fire hazard testing – Part 11-20: Test flames – 500 W flame test methods*

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

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

IEC 60998-2-1, *Connecting devices for low-voltage circuits for household and similar purposes – Part 2-1: Particular requirements for connecting devices as separate entities with screw-type clamping units*

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

IEC 60999-1:2000, *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 61140:2001, *Protection against electric shock – Common aspects for installation and equipment*

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

IEC 61730-2:2004, *Photovoltaic (PV) module safety qualification – Part 2: Requirements for testing*

IEC 62852, *Connectors for photovoltaic systems – Safety requirements and tests*

ISO 868:2003, *Plastics and ebonite – Determination of indentation hardness by means of a durometer (Shore hardness)*

ISO 4892-2:2013, *Plastics – Methods of exposure to laboratory light sources – Part 2: Xenon-arc lamps*

ISO 4892-3:2006, *Plastics – Methods of exposure to laboratory light sources – Part 3: Fluorescent UV lamps*

EN 50618, *Electric cables for photovoltaic systems*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

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 manufacturer’s location

3.1.1.2
junction box for field wiring
junction box containing wiring connections that are intended to 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

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

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
spout hub
open entry of a box permitting the insertion and containment of a conduit

3.5
cable anchorage
ability to limit the displacement of a fitted flexible cable against pull and push forces and torques

3.6
connector for photovoltaic-systems
component suitable for use in PV-systems that terminates conductors for the purpose of providing connection to and disconnection from a suitable mating component

3.7
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".]

3.8
terminal
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

3.9
clearance
shortest distance in air between two conductive parts

[SOURCE: IEC 60050-426:2008, 426-04-12]

3.10
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" has been replaced by "the".]

3.11
overvoltage category
numeral defining a transient overvoltage condition

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

3.12
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]

3.13
pollution degree
numeral characterising the expected pollution of the micro-environment

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

3.14
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.]

3.15
rated insulation voltage
r.m.s. 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".]

3.16
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".]

3.17
impulse withstand voltage
highest peak value of impulse voltage of prescribed 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 – Note 1 to entry has been added.]

3.18
r.m.s. withstand voltage
power-frequency withstand voltage

highest r.m.s. value of a voltage that does not cause breakdown of insulation under specified conditions

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

3.19
Current

3.19.1
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 highest specified ambient temperature, without the upper limiting temperature being exceeded

3.19.2
reverse current
I_{REV}
current value assigned by the manufacturer, which the junction box can carry at the highest specified 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).

3.20
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]

3.21
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, 3.17.2, modified – " against electric shock " and Note 1 to entry have been added.]

3.22
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”.]

3.23
double insulation
insulation comprising both basic insulation and supplementary insulation

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

3.24
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 (IEC 61140:2001, 3.10.4)

Note 1 to entry: A single insulation system does not imply that the insulation must be a homogeneous piece. It may comprise several layers that cannot be tested singly as basic 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" and "under the conditions specified in the relevant IEC standard" and Note 1 to entry have been added.]

3.25
working voltage
highest r.m.s. value of the dc voltage across any particular insulation which can occur inside the junction box when the 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 "which can occur inside the junction box when it operates at rated voltage".]

3.26
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]

3.27
accessible part
part which can be touched by means of standard test finger

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

4 Constructional requirements and performance

4.1 General

For junction boxes according to this standard, 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.

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 International Standard.

4.2 Marking and identification

4.2.1 Identification

Junction boxes shall be identified and characterised 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 according to IEC 60529;

i) range of temperature; (lowest and upper ambient temperature), if different from this standard;

j) type of terminals;

k) connectable conductors;

l) reference to this standard, if applicable;

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

n) polarity of connector, if applicable;

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

p) reverse current (I_{REV}).

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 junction box is performed by connectors, the warning notice listed in m) of 4.2.1 shall be on a label or similar on or close to the connector.

If connection of the junction box is performed 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.

4.2.3 Technical documentation

Identification items of 4.2.1 not marked on the junction box according to 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, e.g. 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 according to 3.1.1.2 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 according to 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 needs 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, e.g. by using a washer.

4.4.2 Connecting devices shall meet the following requirements under the conditions according to 5.1.3:

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 and 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 according to 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.

4.6 Cable

Cables connected to the junction box shall comply with the requirements of EN 50618. The values of the rated current and the voltage shall be minimum the rated values of the junction box.

4.7 Resistance to aging

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

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, e.g. 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 according to 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 according to 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 according to 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 according to 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 according to the test program.

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 according to 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 according to 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)	Insulation between live parts and accessible surfaces	Insulation between connecting devices for junction boxes acc. to 3.1.1[a]	Insulation between live parts of different polarity of the same circuit
Class 0	B	R	B
Class II	R	R	B
Class III	–	R	B

B basic insulation

R reinforced insulation or double 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 according to 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 according to Table 3.

4.15 Clearances and creepage distances

4.15.1 Clearances

Clearances between live parts and accessible surfaces shall be dimensioned according to table 2 depending on the rated voltage.

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

Table 2 – Rated impulse voltages and minimum clearances

	Basic insulation		Reinforced insulation	
Rated or working DC voltage	**Rated impulse voltage**	**Clearance**	**Rated impulse voltage**	**Clearance**
V	kV (1,2/50 μs)	mm	kV (1,2/50 μs)	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 for overvoltage category III and for altitude up to 2000 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 according to Table 3 related to the rated voltage considering the pollution degree as specified in 4.14.3.2.

Rewirable junction boxes shall meet the requirements of reinforced or double insulation according to 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 according to Table 3 in relation to the maximum working voltage as specified by the manufacturer.

Table 3 – Creepage distances for basic insulation

Voltage (DC) V2	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
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	0,7	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	13	14	16
1 500	5,2	7,5	10	15	19	21	24
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.

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 for 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 $CTI \geq 600$

Material Group II $400 \leq CTI < 600$

Material Group IIIa $175 \leq CTI < 400$

Material Group IIIb $100 \leq CTI < 175$

A material is 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.

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 according to 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;

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

b) weather resistance, checked by test according to 5.3.11 followed by glow wire test of 5.3.14 a);

c) temperature resistance according to 5.3.13 a) shall be fulfilled.

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 according to 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 according to 5.3.14 b) shall be fulfilled;

c) temperature resistance according to 5.3.13 b) shall be fulfilled.

The requirements of this section 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 Under wet ambient conditions, no metal parts having a difference of their electrochemical potentials more than 350 mV according to IEC/TR 60943 shall be in contact with each other.

4.18 Sealing

Gaskets and seals shall not deteriorate after accelerated ageing 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.

5 Tests

5.1 General

5.1.1 The test program 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 of specimen	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 [d]
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 according to 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 at 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 at all possible configurations with relevant number of specimens.

[c] Is the junction box 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.

[d] Is the junction box intended to be potted such that the bypass-diodes are not accessible, the thermocouples shall be fixed before

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 three terminations per specimen, if available.

5.1.5 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 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 according to 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.

5.2.3 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 electrically connected.

5.2.4 Screw-type clamping units shall be tightened with the value of the torque stipulated in Table 5 according to 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
> 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 according to 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 mounting surface. For some tests, it is necessary to have cell connections electrically connected.

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 Tables 8 to 15 shall be applied.

5.3.2 Durability of marking

The test of the durability of marking shall be done as a wet test according to 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 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 according to 5.3.3.2 and 5.3.3.3 shall be performed on 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 according to 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 according to 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 according to IEC 60529 shall be performed on the specimen according to 5.2.5 with attached cables and/or mated plugs and attached cell-connections. Gaskets shall be aged according to 5.3.15.

5.3.5 Measurement of clearances and creepage distances

Clearances and creepage distances shall be measured according to IEC 60664-1.

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 according to 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) r.m.s. withstand voltage test:

   the voltage proof test shall be performed by applying an r.m.s. withstand voltage (50/60 Hz) with an r.m.s.-value of 1 000 V plus 2 times 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) has to be applied between the short circuited output terminals and a metal foil which is wrapped around the specimen after relevant conditioning

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 according to the following procedure.

Four impacts on the specimen having an energy of 1 J per impact 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 that may impair the function of the junction box is evident. Creepage distances and clearances as well as solid insulation shall not be impaired.

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

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

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

The test shall be carried out in climatic chamber. A thermal cycle according to 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 temperature shall not exceed 100 °C/h. The upper and lower temperature shall be held for a minimum of 10 min after thermal equilibrium of the specimen is reached.

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

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 according to 5.2.5 with attached and short-circuited cell-connections.

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

The test shall be carried out according to 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 at relevant specimens and at the sticker according to 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 according to the 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 adequate sample of material.

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

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

The result is assessed according to flammability class 5VB.

5.3.13 Ball pressure test

The test shall be performed in a heating cabinet according to 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 according to 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.

After restoring the gasket to the lid or junction box the lid must be closed and opened 10 times

Compliance shall be checked by verifying the IP-code according to IEC 60529.

5.3.16 Wet leakage current test

5.3.16.1 General

The specimens shall be prepared according to 5.2.5 with attached and short-circuited cell-connections.

5.3.16.2 Test equipment

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 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 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.

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 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. 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 according to 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 according to 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 % of the specified value for all temperatures above room temperature.

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 r.m.s. withstand voltage test according to 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

The specimens shall be prepared according to 5.2.5.

5.3.18.2 Apparatus

a) Means for heating the ambient temperature in the specimen to (75 ± 5) °C.

b) Means for measuring and recording the temperature of the specimen(s) to an accuracy of ± 1 °C.

c) Means for measuring the temperature of any bypass diodes provided with the junction box and for measuring the temperature of the insulating material. Care should be taken to minimize any alteration of the properties of the diode or its heat transfer path.

d) Means for applying a current equal to 1,25 times the rated current of the junction box under test and means for monitoring the flow of current through the specimen throughout the test.

5.3.18.3 Procedure

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

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

NOTE 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.

c) Heat the specimen such that the ambient temperature inside the enclosure is (75 ± 5) °C. Apply a current to the specimen equal to the rated current ± 2 % of the junction box. After 1 h, measure the temperature of each bypass diode and of the insulating material, where the highest temperature is expected. By using the information provided by the diode manufacturer, calculate the junction temperature from the measured case or lead temperature and the power dissipated in the diode. Use the following relevant formula:

$$T_j = T_{case} + R_{THjc} \times U_D \times I_{D,} \text{ or}$$

$$T_j = T_{lead} + R_{THjl} \times U_D \times I_D$$

where

T_j is the diode junction temperature;

T_{case} is the measured diode case temperature;

T_{lead} is the measured diode lead temperature;

R_{THjc} is the manufacturer's value relating junction temperature to case temperature;

R_{THjl} is the manufacturer's value relating junction temperature to lead temperature;

U_D is the diode voltage;

I_D is the diode current.

If the manufacturer of diode has specified another R_{TH} as R_{THjc} this value is to be inserted in the formula and the thermal sensor shall be fixed at specified position. The diode junction temperature shall not exceed the diode manufacturer's maximum junction temperature rating.

d) Increase the applied current to 1,25 times of the rated current of the junction box while maintaining the ambient temperature inside the specimen at (75 ± 5) °C. Maintain the current flow for 1 h. After that the diode shall be still operational and there shall be no evidence of major visual defects like:

- current carrying parts are not kept in 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 according to their relevant IEC-standards as listed in 4.4.

Contact resistance has to 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 has to be measured and the contact resistance has to be calculated. These determined values have to 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 is to 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 is to 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 by 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 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 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 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 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 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 $\pm$ 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 $\pm$ 0,2 mm for mandrels up to and including 16 mm diameter and $\pm$ 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 pull test is shown in Figure 3.

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 specified in Table 7 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 7.

NOTE 2 A typical arrangement for 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 according to 5.3.22.2 and 5.3.22.3 shall be performed on a specimen that has passed the test sequences of test groups E and F. 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.

5.3.23 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) Cheesecloth according to IEC 60695 series.

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, covered by a single layer of cheesecloth. A single layer of cheesecloth is laid on the surface of the junction box so that the outer surface of the junction box is completely covered.

d) Heat the specimen to the upper rated ambient temperature. Apply a current to the specimen equal to the reverse current ± 2 % of the junction box for 2 h.

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 according to 4.2.2
A2	Technical documentation	4.2.3	Mounting instruction, warning notice, manual or similar	Visual examination	Information according to 4.2.3 and additional information
A3	Approval of attached components		Approval by data sheets or certificates for cable, connectors, cable glands, etc.	Visual examination	4.4, 4.5, 4.6 Components shall comply with the relevant standards.

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 according to V-1 of IEC 60695-11-10
B4	Weather resistance test	5.3.11	Polymers serving as an enclosure	Weather resistance test according to ISO 4892 standards	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 E1	No change of sealing characteristic Passing the requirements of IP-test according to J1 and J2
B10	Flammability class	5.3.12.2	Specimen from C7	Flammability test	Requirements according to 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
C2		5.3.4.1		Test with test finger 20 N	No live parts are accessible.
C3	General construction	4.8.6	Complete specimen	Visual examination and measurement	Sufficient wall thickness according to IEC 61140 and fixing
C4		4.8.4	Complete specimen	Visual examination	No sharp edges
C5	Terminations and connection methods	4.4.1 and 4.4.4	Complete specimen	Visual examination	Fix position of terminals Additional means for soldered connections
C6	Clearances and creepage distances	5.3.5	Complete specimen, terminated	Measurement	Requirements of 4.14 shall be fulfilled.
C7	Wall thickness	4.8.3	Complete specimen	Measurement	Wall thickness min. 3,0 mm, otherwise test according to B10
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 clauses 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 according to 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		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		Test cycles: 200 Application of rated current	No visible damage, which could impair function or safety
E4	Dielectric strength	5.3.6 b)		r.m.s 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		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 according to 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 shearing	5.3.10		Visual test	No shearing occurred
F4	Retention on the mounting surface	5.3.22		Mechanical test	No loosening or displacement of specimen
				Wet leakage current test according to 5.3.16	Insulation resistance not less than 400 MΩ
F5	Dielectric strength	5.3.6 b)		r.m.s 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
F7	Coating test	Annex B		Visual inspection	See Annex B

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 according to 5.2.5 with attached and short-circuited cell-connections	Test cycle: 50	No visible damage, which could impair function or safety
G2	Humidity-freeze test	5.3.17			Requirements according to 5.3.17.5
G3	Retention on the mounting surface	5.3.22		Mechanical test	No loosening or displacement of specimen
				Wet leakage current test according to 5.3.16	Insulation resistance not less than 400 MΩ
G4	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 described in 5.2.5		Requirements according to 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 described in 5.2.6		No flaming of the junction box, nor flaming or charring of the cheesecloth in contact with the junction box

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 according to 5.2.5 with attached and short-circuited cell-connections	IP-code	IP55 according to IEC 60529
J2	Dielectric strength	5.3.6 b)		r.m.s withstand voltage test 2 000 V + (4 × rated voltage)	No flashover or breakdown of voltage

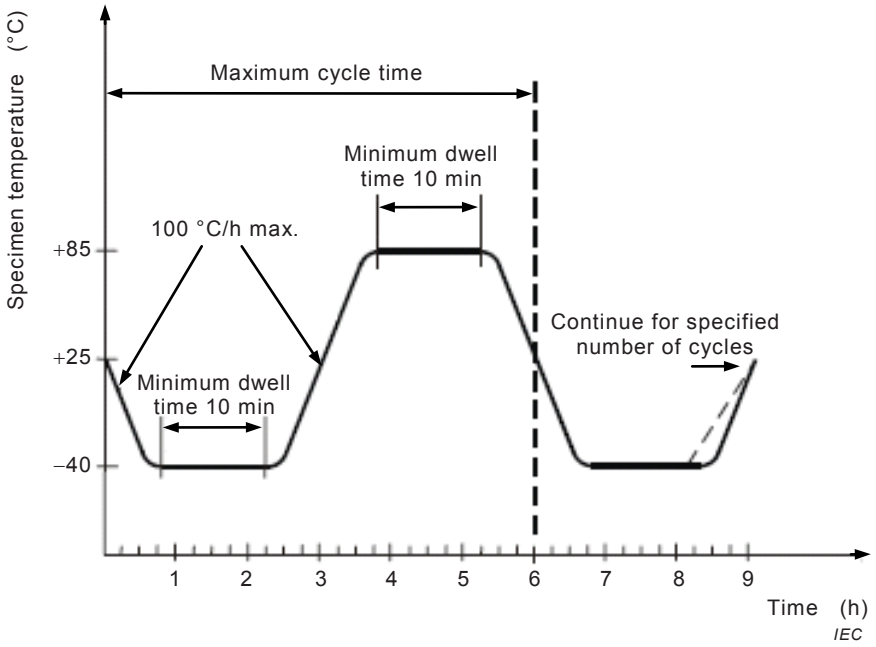


Figure 1 – Thermal cycling test

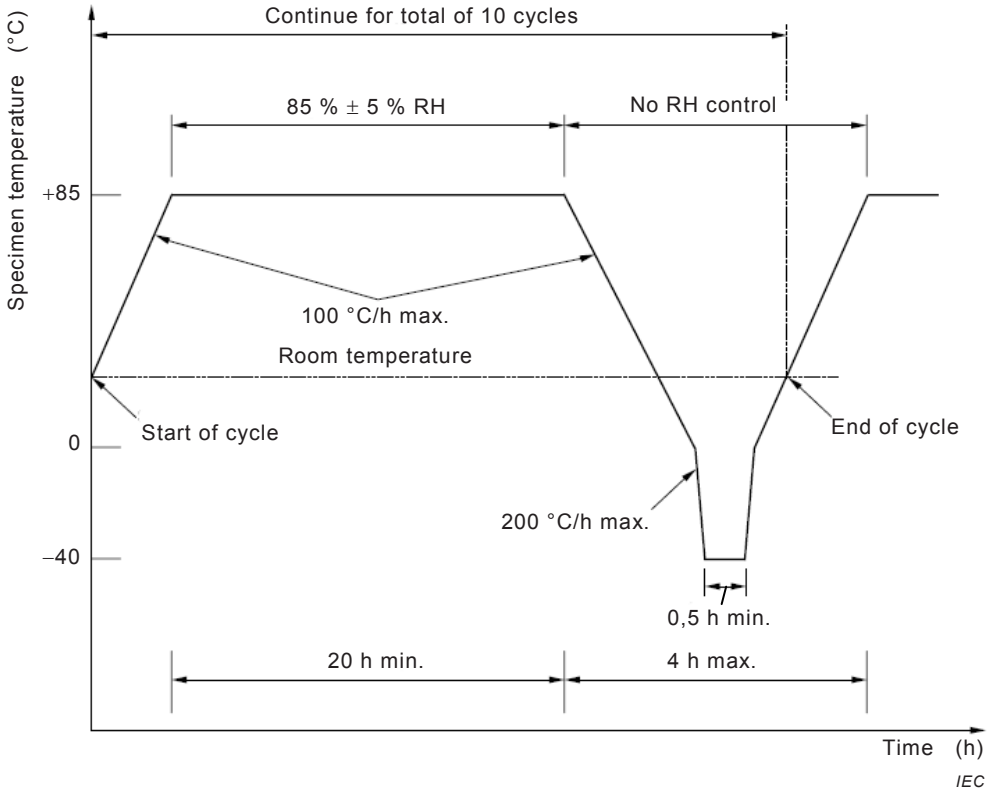


Figure 2 – Humidity-freeze cycle

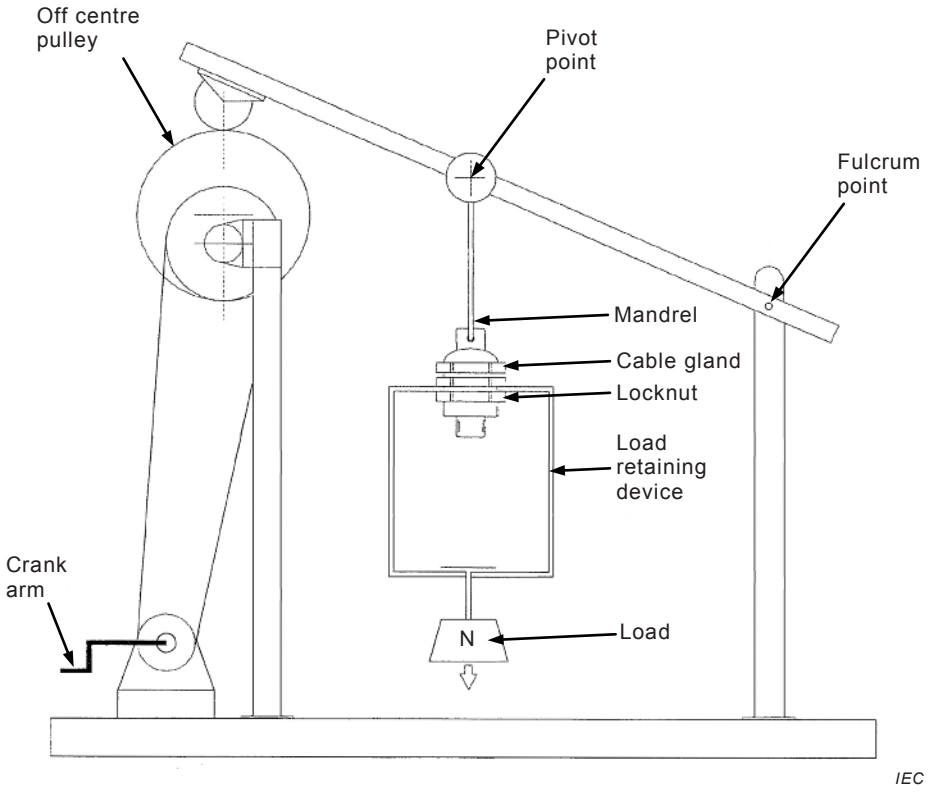


Figure 3 – Typical arrangement for the cable anchorage pull test

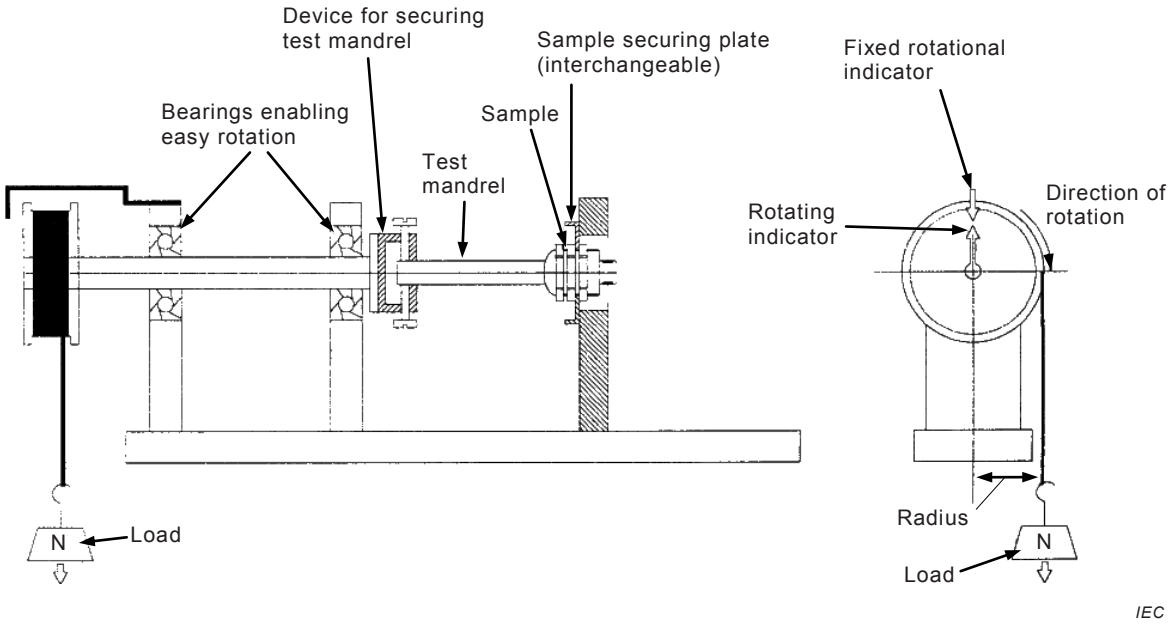


Figure 4 – Typical arrangement for torsion test

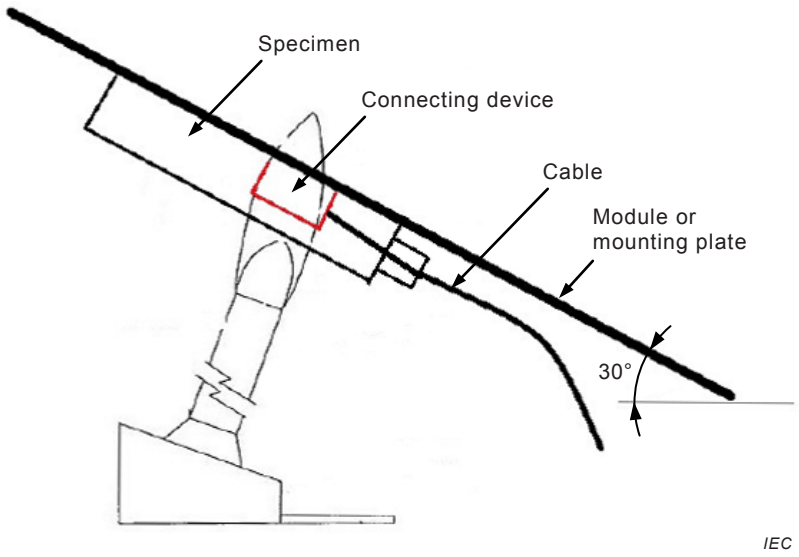


Figure 5 – Typical arrangement for flammability test according to 5.3.12.2

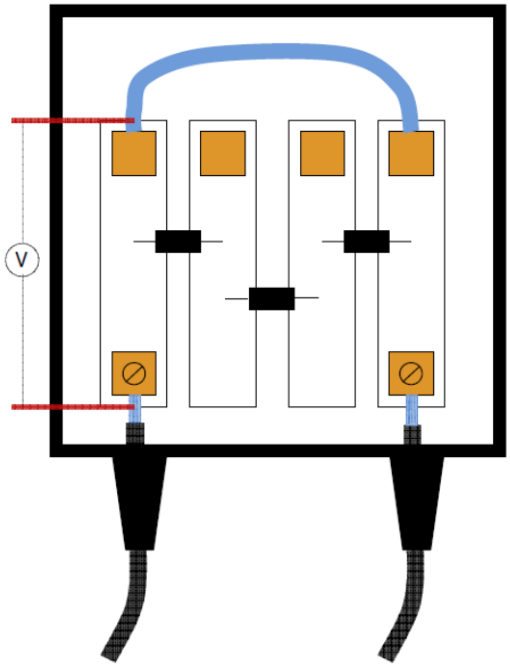


Figure 6 – Measurement of voltage drop

Annex A
(informative)

Symbol "Do not disconnect under load"

The following symbols in Figures A.1 and A.2 may be used to show that a PV-connector shall not be disconnected under load.

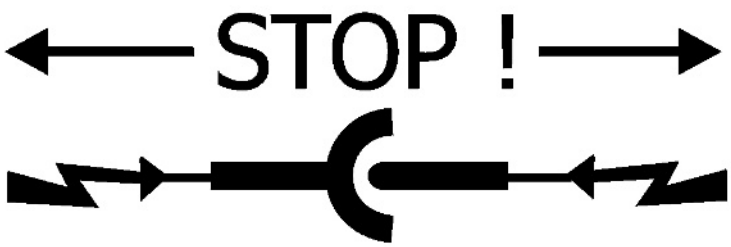


Figure A.1 – Symbol "DO NOT DISCONNECT UNDER LOAD"

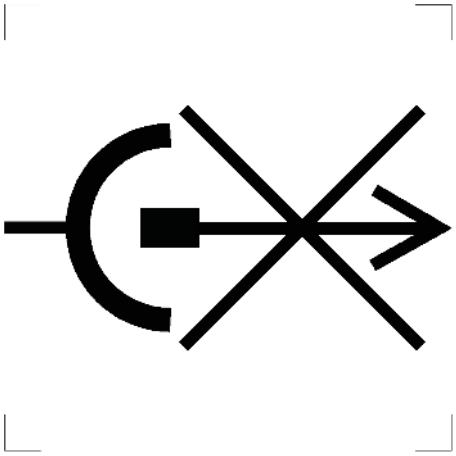


Figure A.2 – Symbol "DO NOT DISCONNECT UNDER LOAD" (IEC 60417-6070)

Annex B
(normative)

Qualification of conformal coatings for protection against pollution

B.1 General

This annex covers requirements for conformal coatings used to reduce the pollution degree.

Conformal coatings shall meet the requirements of Clause B.2 and B.3.

NOTE The requirements of Clause B.2 assure that the conformal coating has been suitably rated for the purpose of coating. The requirements of B.3 assure that the coating will continue to adhere to the surfaces after environmental and physical stresses.

Conformity is checked as specified in Clauses B.2 and B.3.

B.2 Technical properties

The technical properties of conformal coatings shall be suitable for the intended application. In particular:

a) the rated operating temperature range shall include the temperature range of the intended application;

b) the comparative tracking index (CTI), the insulation resistance and the dielectric strength shall be suitable for the intended application;

c) the flammability properties of the coating shall be in compliance with 5.3.14 b).

Conformity is checked by inspection of the manufacturer’s data, in case of doubt by glow wire test.

B.3 Qualification of coatings

The coating shall meet the conformity requirements of Figure B.1 after the tests of Table B.1.

Conformity is checked as specified in Table B.1 and Figure B.1, on 6 specimens.

Table B.1 – Test parameters, test conditions and test procedures

	Test, conditioning	Test parameter, conditions	Test procedure
1	Cold conditioning	Conditioning temperature: T_{min}. T_{min} is the minimum rated ambient temperature or the minimum rated storage temperature, whichever is lower, of the specimen. Any humidity is acceptable. Conditioning time: 24 h	The specimens are placed in a temperature chamber and held at T_{min} for the specified conditioning time.
2	Dry heat	Conditioning temperature: T_{max}. T_{max} is the maximum rated surface temperature, maximum rated ambient temperature, or maximum rated storage temperature, whichever is higher, of the specimen. Any humidity is acceptable. Conditioning time: 48 h	The specimen is placed in a temperature chamber and held at T_{max} for the specified conditioning time.
3	Rapid change of temperature	Maximum temperature: T_{max} T_{max} is the maximum rated surface temperature, maximum rated ambient temperature, or maximum rated storage temperature, whichever is highest, of the specimen. Minimum temperature: T_{min}. T_{min} is the minimum rated ambient temperature or the minimum rated storage temperature, whichever is lower, of the specimen. Rate of change of temperature: within 30 s Cycle time (duration of one cycle): T_{max} and T_{min} are each held until steady state conditions of the specimens are achieved and then maintained for 10 min. The cycle starts when the specimen has reached the target within 2 °C. Number of cycles: 5 cycles	The conditioning procedure follows test Na of IEC 60068-2-14.
4	Insulation resistance of conductors	Temperature: 40 °C ± 2 °C Humidity: 90 %…95 % RH Insulation resistance: ≥100 MΩ	Insulation resistance is measured between the two outer conductors with the smallest creepage distance for at least 1 min. The test voltage shall be as close to the working voltage as possible. Diodes have to be removed before coating of the specimen

Preparation	
Preparation of the test specimens	Each specimen is to be assembled in the normal manner, using the normal soldering procedure, including any cleaning and protection steps that are normally applied. Diodes have to be removed before coating of the specimen
Conditioning of the test specimens	
Table B.1, item 1	Cold conditioning
Table B.1, item 2	Dry heat
Table B.1, item 3	Rapid change of temperature
Table 11, item F.2	Damp heat test
	
Mechanical and electrical tests after conditioning	
Table H.1, item 4	Insulation resistance Conformity is checked by measuring of the insulation resistance of Table H.1, item 8. All specimens shall meet the required value.
	
Visual inspection	Conformity is checked by inspection. All specimens shall show no • blistering, • swelling, • separation from base material, • cracks, • voids.

Figure B.1 – Test sequence and conformity check

Annex C
(normative)

Measurement of clearances and creepage distances

The methods of measuring clearances and creepage distances are indicated in the following Examples 1 to 11 (see Figure C.1). These cases do not differentiate between gaps and grooves or between types of insulation.

The following assumptions are made:

a) where the distance across a groove is equal to or larger than *X* (see Table C.1), the creepage distance is measured along the contours of the groove (see example 2);

b) any recess is assumed to be bridged with an insulating link having a length equal to *X* and being placed in the least favourable position (see example 3);

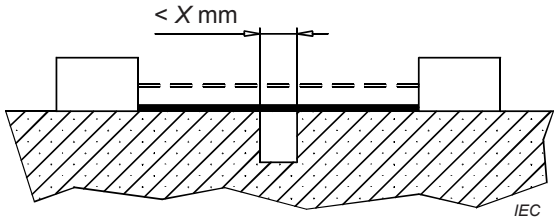
c) clearances and creepage distances measured between parts which can assume different positions in relation to each other are measured when these parts are in their least favourable position.

In the following Examples 1 to 11 in Figure C.1 dimension *X* has the value given in Table C.1 depending on the pollution degree.

Table C.1 – Dimensions of *X*

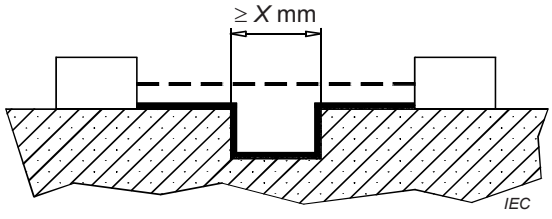
Pollution degree	Dimension *X* mm
1	0,25
2	1,0
3	1,5

If the associated clearance is less than 3 mm, the dimension *X* in Table C.1 may be reduced to one-third of this clearance.



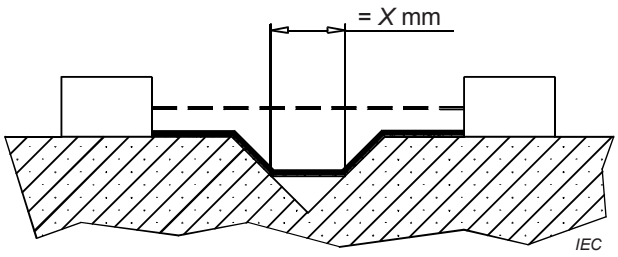
EXAMPLE 1 The path includes a parallel- or converging-sided groove of any depth with a width less than *X*.

The clearance and the creepage distance are measured directly across the groove as shown.



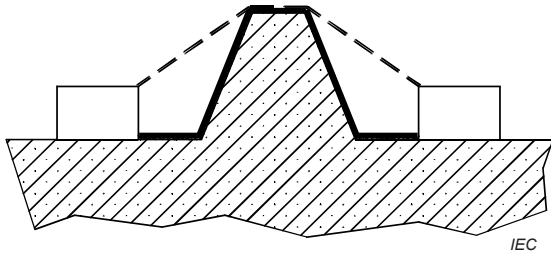
EXAMPLE 2 The path includes a parallel-sided groove of any depth and equal to or more than *X*.

The clearance is the “line-of-sight” distance. The creepage distance follows the contour of the groove.



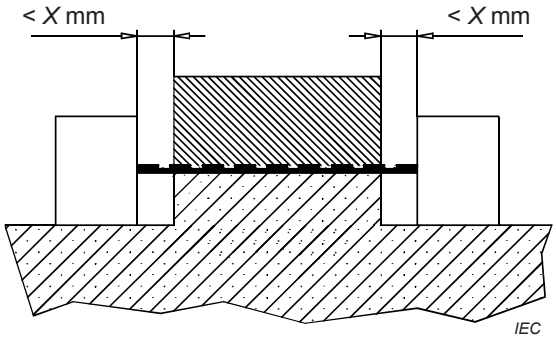
EXAMPLE 3 The path includes a V-shaped groove with a width greater than *X*.

The clearance is the “line-of-sight” distance. The creepage distance follows the contour of the groove but “short-circuits” the bottom of the groove by *X* link.



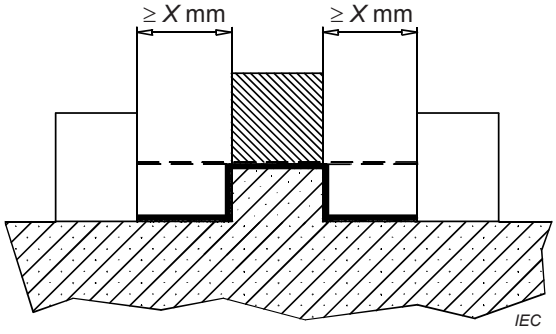
EXAMPLE 4 The path includes a rib.

The clearance is the shortest direct air path over the top of the rib. The creepage distance follows the contour of the rib.



EXAMPLE 5 The path includes an uncemented joint with grooves less than *X* wide on each side.

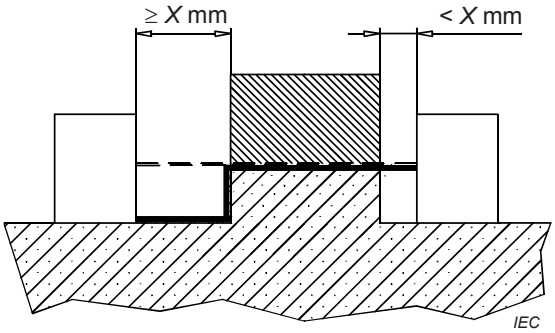
The clearance and the creepage distance path is the “line-of-sight” distance shown.



EXAMPLE 6 The path includes an uncemented joint with grooves equal to, or more than, *X*.

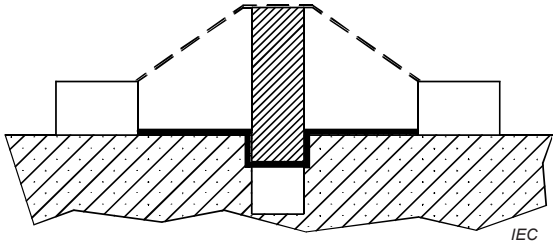
The clearance is the “line-of-sight” distance.

The creepage distance follows the contour of the grooves.



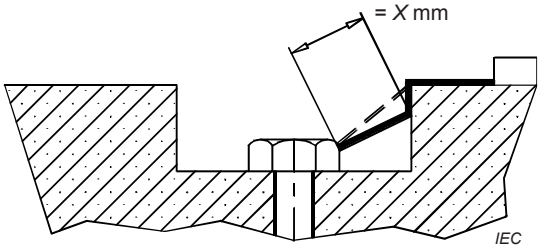
EXAMPLE 7 The path includes an uncemented joint with a groove on one side less than *X* wide and the groove on the other side equal to, or more than, *X* wide.

The clearance and the creepage distance are as shown.

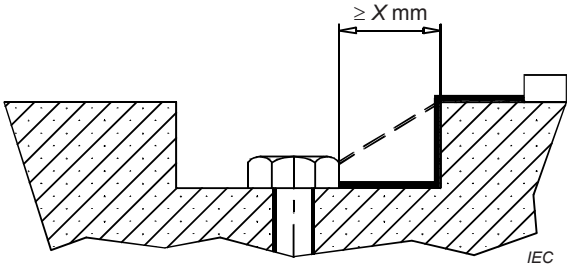


EXAMPLE 8 The creepage distance through the uncemented joint is less than the creepage distance over the barrier.

The clearance is the shortest direct air path over the top of the barrier.

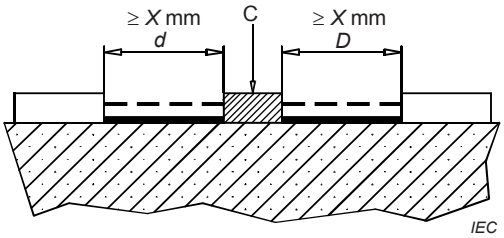


EXAMPLE 9 The gap between the head of the screw and the wall of the recess too narrow to be taken into account.



EXAMPLE 10 The gap between the head of the screw and the wall of the recess wide enough to be taken into account.

Measurement of the creepage distance is from screw to wall when the distance is equal to *X*.



EXAMPLE 11 C = floating part

The clearance is the distance $d + D$. The creepage distance is also $d + D$.

creepage distance

clearance

Figure C.1 – Examples of methods of measuring clearances and creepage distances

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