UL 61730-1

STANDARD FOR SAFETY

Photovoltaic (PV) Module Safety Qualification – Part 1: Requirements for Construction

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

Second Edition, Dated October 28, 2022

Summary of Topics

This new edition of ANSI/UL 61730-1 dated October 28, 2022 includes updating IEC TS 62915 references to UL 62915.

UL 61730-1 is an adoption of IEC 61730-1, Photovoltaic (PV) Module Safety Qualification – Part 1: Requirements for Construction (Second Edition, issued by the IEC August 2016). Please note that the National Difference document incorporates all of the U.S. national differences for UL 61730-1.

The new and revised requirements are substantially in accordance with Proposal(s) on this subject dated September 16, 2022.

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UL 61730-1

Photovoltaic (PV) Module Safety Qualification – Part 1: Requirements for Construction

First Edition – December, 2017

Second Edition

October 28, 2022

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

The most recent designation of ANSI/UL 61730-1 as an American National Standard (ANSI) occurred on October 28, 2022. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, Title Page, or Preface. The National Difference Page and IEC Foreword are also excluded from the ANSI approval of IEC-based standards.

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

No Text on This Page

CONTENTS

PREFACE

This UL Standard is based on IEC Publication IEC 61730-1: Second edition Photovoltaic (PV) Module Safety Qualification – Part 1: Requirements for Construction. IEC publication IEC 61730-1 is copyrighted by the IEC.

This edition has been issued to satisfy UL Standards policy and to align the UL edition number with the IEC edition number.

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

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NATIONAL DIFFERENCES

National Differences from the text of International Electrotechnical Commission (IEC) Publication 61730-1, Photovoltaic (PV) Module Safety Qualification – Part 1: Requirements for Construction, copyright 2016, are indicated by notations (differences) and are presented in bold text.

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

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

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

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

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

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

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

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

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

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

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FOREWORD

INTERNATIONAL ELECTROTECHNICAL COMMISSION

PHOTOVOLTAIC (PV) MODULE SAFETY QUALIFICATION – Part 1: Requirements for construction

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

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6) All users should ensure that they have the latest edition of this publication.

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8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.

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

International Standard IEC 61730-1 has been prepared by IEC technical committee 82: Solar photovoltaic energy systems.

This second edition cancels and replaces the first edition of IEC 61730-1, issued in 2004, and its amendments 1 (2011) and 2 (2013); it constitutes a technical revision.

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

a) Adaption of horizontal standards and inclusion of IEC 60664 and IEC 61140.

b) Implementation of insulation coordination, overvoltage category, classes, pollution degree (PD), and material groups (MG).

c) Implementation of component qualification.

d) IEC Guide 108 *Guidelines for ensuring the coherency of IEC publications – Application of horizontal standards*.

e) Definition of creepage (cr), clearance (cl) and distance through insulation.

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

FDIS	Report on voting
82/1128/FDIS	82/1146/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.

A list of all parts in the IEC 61730 series, published under the general title *Photovoltaic (PV) module safety qualification*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC website 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.

PHOTOVOLTAIC (PV) MODULE SAFETY QUALIFICATION – Part 1: Requirements for construction

1 Scope

This part of IEC 61730 specifies and describes the fundamental construction requirements for photovoltaic (PV) modules in order to provide safe electrical and mechanical operation. Specific topics are provided to assess the prevention of electrical shock, fire hazards, and personal injury due to mechanical and environmental stresses. This part of IEC 61730 pertains to the particular requirements of construction. IEC 61730-2 defines the requirements for testing.

This International Standard series lays down IEC requirements of terrestrial photovoltaic modules suitable for long-term operation in open-air climates. This standard is intended to apply to all terrestrial flat plate module materials such as crystalline silicon module types as well as thin-film modules.

PV modules covered by this standard are limited to a maximum DC system voltage of 1 500 V.

This International Standard defines the basic requirements for various applications of PV modules, but it cannot be considered to encompass all national or regional codes. Specific requirements, e.g. for building, marine and vehicle applications, are not covered.

This International Standard does not address specific requirements for products that combine a PV module with power conversion equipment, monitoring or control electronics, such as integrated inverters, converters or output disabling functions.

While parts of this standard may be applicable to flat plate PV modules with internally generated low level concentration below 3 times, it was not written specifically to address these concerns.

This International Standard is designed to coordinate with the test sequences in the IEC 61215 series, so that a single set of samples may be used to perform both the safety and qualification of a photovoltaic module design.

The object of this International Standard is to define the requirements for the construction of photovoltaic modules with respect to safety. These requirements are intended to minimize the misapplication and misuse of PV modules or the failure of their components which could result in fire, electric shock and personal injury.

Additional construction requirements outlined in relevant ISO standards, or the national or local codes which govern the installation and use of these PV modules in their intended locations, should be considered in addition to the requirements contained within this standard.

2 Normative references

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

IEC 60050 (all parts), *International Electrotechnical Vocabulary*

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

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

IEC 60216-2, *Electrical insulating materials – Thermal endurance properties – Part 2: Determination of thermal endurance properties of electrical insulating materials – Choice of test criteria*

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

IEC 60243-1:2013, *Electric strength of insulating materials – Test methods – Part 1: Tests at power frequencies*

IEC 60243-2:2013, *Electric strength of insulating materials – Test methods – Part 2: Additional requirements for tests using direct voltage*

IEC 60269-6, *Low-voltage fuses – Part 6: Supplementary requirements for fuse-links for the protection of solar photovoltaic energy systems*

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

IEC 60417-DB, *Graphical symbols for use on equipment*

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 60664-3:2003, *Insulation coordination for equipment within low-voltage systems – Part 3: Use of coating, potting or moulding for protection against pollution*

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

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

IEC 60904-3, *Photovoltaic devices – Part 3: Measurement principles for terrestrial photovoltaic (PV) solar devices with reference spectral irradiance data*

IEC 60950-1:2005, *Information technology equipment – Safety – Part 1: General requirements*

IEC 61032:1997, *Protection of persons and equipment by enclosures – Probes for verification*

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

IEC 61215 (all parts), *Terrestrial photovoltaic (PV) modules – Design qualification and type approval*

IEC 61558-1:2005, *Safety of power transformers, power supplies, reactors and similar products – Part 1: General requirements and tests*

IEC 61701, *Salt mist corrosion testing of photovoltaic (PV) modules*

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

IEC TS 61836, *Solar photovoltaic (PV) energy systems – Terms, definitions and symbols*

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

IEC 62716, *Photovoltaic (PV) modules – Ammonia corrosion testing*

IEC 62788-1-2, *Measurement procedures for materials used in photovoltaic modules – Part 1- 2: Encapsulants – Measurement of volume resistivity of photovoltaic encapsulants and other polymeric materials*

IEC 62790, *Junction boxes for photovoltaic modules – Safety requirements and tests*

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

IEC TS 62915, *Photovoltaic (PV) Modules – Retesting for type approval, design and safety qualification*[1]

ISO 1456, *Metallic and other inorganic coatings – Electrodeposited coatings of nickel, nickel plus chromium, copper plus nickel and of copper plus nickel plus chromium*

ISO 1461, *Hot dip galvanized coatings on fabricated iron and steel articles – Specifications and test methods*

ISO 2081, *Metallic and other inorganic coatings – Electroplated coatings of zinc with supplementary treatments on iron or steel*

ISO 2093, *Electroplated coatings of tin – Specification and test methods*

EN 50618, *Electric cables for Photovoltaic systems*

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

2DV DR *Addition of the following:*

UL 790, *Standard Test Methods for Fire Tests of Roof Coverings*

UL 969, *Marking and Labeling Systems*

UL 2703, *Mounting Systems, Mounting Devices, Clamping/Retention Devices, and Ground Lugs for Use with Flat-Plate Photovoltaic Modules and Panels*

UL 3730, *Photovoltaic Junction Boxes*

UL 6703, *Connectors for Use in Photovoltaic Systems*

UL 62915, *Photovoltaic (PV) Modules – Type Approval, Design and Safety Qualification – Retesting*

ANSI/NFPA 70, *National Electrical Code*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050, IEC 60664-1, IEC 61140, and IEC TS 61836 together with the following, apply.

NOTE Some terms from IEC 60050 were modified to make them more specific and applicable to PV modules.

3.1 General terms and definitions

3.1.1
functional earthing
earthing point or points in a system or in an installation or in equipment, for purposes other than electrical safety

[SOURCE: IEC 60050-195:1998, 195-01-13]

3.1.1DV DE *Modification by adding the following note to 3.3.1:*

NOTE "Functional Earthing" is similar, but not identical to the terms "system grounding" and "function ground" in the National Electrical Code, ANSI/NFPA 70 (2014-2017). Functional earthing, system grounding or function ground may be applicable to PV systems but are not applicable to PV modules.

3.1.2
internal wiring
wiring and electrical connections that are made within the apparatus by its manufacturer

[SOURCE: IEC 60050-426:2008, 426-11-32]

3.1.3
laminate
product made by bonding together two or more layers of the same or different materials. This includes all components prior to attaching the junction box, frame or rail, and name plate

[SOURCE: IEC 60050-212:2010, 212-15-52, modified: Second sentence added]

3.1.4
manufacturer
any legal entity manufacturing a product or has a product designed or manufactured, and markets that product under its name or trademark

3.1.5
module quality test
MQT
PV module quality test in accordance with IEC 61215-2

3.1.6
module safety test
MST
PV module safety test in accordance with IEC 61730-2

3.1.7
polymeric material
natural or synthetic material primarily composed of chained molecules of monomers, combinations of monomers, combined polymers, crosslinking agents, inorganic fillers, colorants, and other materials

3.1.8
tool
screwdriver, coin, key, or any other object that is used to operate a screw, latch, or similar fastening means

3.1.9
wiring <external>
wiring that is not internal wiring, including, but not limited to, output cables

3.1.10
thin layer
cohesive material of uniform thickness which is small in proportion to length and width

3.2 Components

3.2.1
backsheet
(combination of) outer layer(s) of the PV module, located on the back of PV module and providing protection of the inner components of the PV module from external stresses and weather elements, as well as electrical insulation

3.2.2
connector
component which terminates conductors for the purpose of providing connection to and disconnection from a suitable mating component

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

3.2.3
encapsulant
intermediate layer(s) of the PV module, located between the frontsheet and the backsheet that enclose the live parts of the PV module

3.2.4
enclosure
part of an assembly providing a specified degree of protection of equipment against external influences and a specified degree of protection against approach to or contact with live parts

[SOURCE: IEC 60050-441:1984, 441-13-01, modified: “moving parts” deleted]

3.2.5
frontsheet
(combination of) outer layer(s) of the PV module, located on the front of PV module and providing protection of the inner components of the PV module from external stresses and weather elements, as well as electrical insulation

3.2.6
insulation barrier
raised or recessed configuration of an insulator to increase creepage distance between conducting surfaces

[SOURCE: IEC 60050-581:2008, 581-22-15]

3.2.7
junction box
electrical enclosure in which electrical wiring connections are made

3.2.8
potting
sealing of components and associated conductors with a compound to exclude contaminants

[SOURCE: IEC 60050-581:2008, 581-24-20]

3.2.9
terminal
conductive part of a device, electric circuit or electric network, provided for connecting that device, electric circuit or electric network to one or more external conductors

Note 1 to entry: The term "terminal" is also used for a connection point in circuit theory. [IEC 60050-151:2001, 151-12-12]

Note 2 to entry: Terminals can contain one or several contacts and the term therefore includes sockets, connectors, etc.

3.3 Installation and application

3.3.1
building attached PV
BAPV
photovoltaic modules are considered to be building attached if the PV modules are mounted on a building envelope and do not fulfil the criteria for building integrated PV

3.3.2
building integrated PV
BIPV
photovoltaic modules are considered to be building integrated if the PV modules form a building component providing additional functions as defined in 4.5 b)

3.3.3
installation <fixed>
permanent wiring system such as a raceway or conduit that prevents or reduces wire and cable movement

3.3.4
installation <non-fixed>
unconstrained wiring system that consists of cables or wires able to move freely

3.3.5
non-restricted access area
area where general access by persons who are not skilled, trained or instructed in electrical safety is anticipated

Note 1 to entry: Examples for non-restricted access areas are PV installations which are not protected against public access by any means.

3.3.6
restricted access area
area marked as restricted for access by unauthorized persons as per IEC 60050-826:2004, 826-18-04

Note 1 to entry: Examples for restricted access areas are utility scale PV installations which are protected against public access by fences, location, etc., and where only persons skilled, trained or instructed in electrical safety have access.

3.3.7DV D2 *Addition of the following definition:*

Reduced mechanical load
mechanical load with a minimum test load of 1 200 Pa (MST 34) for use at particular ground-mounted PV power generation plants with restricted access.

NOTE The term PV power generation plant is defined in IEC 60364-7-712 and is conceptually similar to the Large-Scale Photovoltaic (PV) Electric Power Production Facility as defined in the National Electrical Code, ANSI/NFPA 70 (2017), article 691. Such plants require restricted access, are operated under daily supervision and maintained by qualified personnel, have a capacity greater than 5 MW, specifically designed for the site conditions considering equipment and approved by a licensed professional engineer competent in the specific area under supervision.

3.4 Insulation system

3.4.1
accessible part
part which can be touched by means of a standard test finger

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

3.4.2
cemented joint
joint comprised of two insulating materials where the interface has been demonstrated to be cemented, and thus be considered as solid insulation with no interface for creepage

3.4.3
comparative tracking index
CTI
numerical index value related to the maximum voltage which a material can withstand without a permanent electrically conductive carbon path tracking when evaluated under specified test conditions defined in IEC 60112

Note 1 to entry: The mentioned maximum test voltage is not in conjunction with any system or operational voltage, but it is used for evaluation of material groups.

[SOURCE: IEC 60050-212:2010, 212-11-59, modified: clarified that CTI is an index value to evaluate material groups]

3.4.4
clearance
shortest distance through air between two conductive parts, or between a conductive part and an accessible surface. (used abbreviation in this standard: “cl”)

[SOURCE: IEC 60050-581:2008, 581-27-76, modified: added information after “comma” and abbreviation]

3.4.5
creepage distance
shortest distance along the surface of a solid insulating material between two conductive live parts or between conductive live parts and accessible parts. (used abbreviation in this standard: “cr”)

[SOURCE: IEC 60050-581:2008, 581-21-23, modified: added information after “or” and abbreviation]

3.4.6
insulation <electrical>
part of an electrotechnical product which separates conducting parts at different electric potentials during operation or insulates such parts from the surroundings

[SOURCE: IEC 60050-212:2010, 212-11-07]

3.4.7
live part
conductor or conductive part intended to be energized in normal operation

[SOURCE: IEC 60050-195:1998, 195-02-19, modified: second part of definition deleted because not applicable to DC]

3.4.8 Insulation concepts

3.4.8.1
basic insulation
insulation of hazardous live parts which provides basic protection against electric shock

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

[SOURCE: IEC 60050-826:2004, 826-12-14, modified: added: “against electric shock”]

3.4.8.2
double insulation
insulation comprising both basic insulation and supplementary insulation

[SOURCE: IEC 60050-826:2004, 826-12-16]

3.4.8.3
functional insulation
insulation that is necessary for the proper functioning of the equipment

Note 1 to entry: Functional insulation by definition does not protect against electric shock. It may, however, reduce the likelihood of ignition and fire.

[SOURCE: IEC 60050-195:1998, 195-02-41]

3.4.8.4
reinforced insulation
insulation of hazardous live parts which provides a degree of protection against electric shock equivalent to double insulation

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

[SOURCE: IEC 60050-826:2004, 826-12-17]

3.4.8.5
supplementary insulation
independent insulation applied in addition to basic insulation for fault protection, e.g. in order to reduce the risk of electric shock in the event of a failure of the basic insulation

[SOURCE: IEC 60050-826:2004, 826-12-15, modified: added example]

3.4.8.6
solid insulation
insulating material consisting entirely of a solid

Note 1 to entry: Solid insulating material interposed between two conductive parts or between conductive parts and outer accessible parts or surfaces with no interfaces and therefore there is no creepage pathway.

[SOURCE: IEC 60050-212:2010, 212-11-02]

3.4.9
material group
category of insulation materials according to IEC 60664-1

3.4.10
relied upon insulation
insulation system providing the sole protection against electric shock in final application

Note 1 to entry: A polymeric backsheet or frontsheet can consist of relied upon insulation plus additional layers that, e.g., protect the polymeric materials from UV light.

3.5 Ratings

3.5.1
rating
set of rated values and operating conditions

[SOURCE: IEC 60050-151:2001, 151-016-11]

3.5.2
pollution degree
numeric classification characteristic of the expected pollution of the micro-environment

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

3.5.3
rated current of overcurrent protection device
current rating of fuse or circuit breaker according to IEC 60269-6

3.5.4
rated value
value of a quantity used for specification purposes, established for a specified set of operating conditions of a component, device, equipment, or system

[SOURCE: IEC 60050-151:2001, 151-16-08]

3.5.5 Temperatures

3.5.5.1
ambient temperature
average temperature of air or another medium in the vicinity of the equipment

Note 1 to entry: During the measurement of the ambient temperature the measuring instrument/probe should be shielded from draughts and radiant heating.

[SOURCE: IEC 60050-826:2004, 826-10-03]

3.5.5.2
environmental temperature
air temperature defined in degrees Celsius for the geographic installation location as measured and documented by meteorological services for this geographic location

3.5.5.3
relative temperature index
RTI
temperature index of an insulating material or system obtained from the time which corresponds to the known temperature index of a reference material or system when both are subjected to the same ageing and diagnostic procedures in a comparative test

[SOURCE: IEC 60050-212:2010, 212-12-12]

3.5.5.4
relative thermal endurance index
RTE
numerical value of the Celsius temperature expressed in degrees Celsius at which the estimated time to endpoint of an insulating material is the same as the estimated time to endpoint of a control material at a temperature equal to its assessed thermal endurance

[SOURCE: IEC 60050-212:2010, 212-12-14]

3.5.5.5
temperature index
TI
numerical value of the Celsius temperature expressed in degrees Celsius characterizing the thermal capability of an insulating material or an insulation system

[SOURCE: IEC 60050-212:2010, 212-12-11]

3.5.6 Voltages

3.5.6.1
rated system voltage
maximum voltage under operating conditions between any live part and accessible surfaces or ground to which the insulation of the PV module is designed as specified by the manufacturer

3.5.6.2
working voltage
highest DC voltage across any particular insulation which can occur when the equipment is operated at rated voltage

[SOURCE: IEC 60050-581:2008, 581-21-19, modified: limited to DC and replaced “supplied” by “operated”]

4 Classification, applications and intended use

4.1 General

Protection against electric shock will be achieved by combinations of constructional measures used to build the module together with how the module is installed.

The PV modules shall be classified according to IEC 61140. The use of the protections in the different classes for the PV modules is described in 4.2 to 4.4. Class I PV modules are not covered in this standard.

The PV modules shall be marked in accordance with 5.2.2.

Correlation between classes for protection against electric shock and former terms for application classes according to IEC 61730-1:2004 are shown in Table 1.

Table 1
Correlation between classes for protection against electric shock and former terms for application classes

Class (IEC 61140)	Application class (IEC 61730-1:2004)	Description
0	B	Application in restricted access area
I	Special installation measures required	Special installation measures required
II	A	Application in non-restricted access area
III	C	Basic protection by limitation of voltage (ELV)

4.2 PV modules of class 0

4.2.1 General

Class 0 PV modules have individual and/or system level electrical outputs at hazardous levels of voltage, current and power.

4.2.2 Insulation

These PV modules are provided with basic insulation only as provision for basic protection and with no provisions for fault protection. All conductive components that are not separated from hazardous live parts by at least basic insulation shall be treated as if they are hazardous live parts.

4.2.3 Application

Class 0 PV modules are intended for use in restricted access areas that are protected from public access by fences or other measures of the location that prevent general access. Such PV modules are only to be accessed by persons knowledgeable of the inherent hazards associated with their use and failure modes. Accessible conductive parts on a Class 0 PV module are intended to be earthed or considered to be at hazardous potential.

NOTE In IEC 61140 the use of class 0 equipment is not recommended. IEC 61140 is currently under revision with respect to the use of classes.

4.3 PV modules of class II

4.3.1 General

Class II PV modules may have individual and/or system level electrical outputs at hazardous levels of voltage, current and power.

4.3.2 Insulation

These PV modules are provided with

• basic insulation as basic protection, and

• supplementary insulation as precaution for fault protection,

or

reinforced insulation as basic and supplementary insulation.

Accessible conductive parts and accessible surfaces of insulation material shall be

• separated from hazardous live parts by double or reinforced insulation,

or

• designed with constructional measures which provide comparable protection.

All conductive parts which are separated from hazardous live parts only by basic insulation or by constructional design means which provide comparable protection shall be separated from accessible surfaces by supplementary insulation. All conductive parts which are not separated from hazardous live parts at least by basic insulation shall be considered as hazardous live parts.

4.3.3 Application

These PV modules are intended for installation where general user access and contact to insulated live parts is anticipated.

4.4 PV modules of class III

4.4.1 General

Class III PV modules shall not have electrical ratings greater than 240 W where the open-circuit voltage does not exceed 35 V DC and the short-circuit current does not exceed 8 A when tested under standard test conditions.

4.4.1DV DR *Modification by replacing 4.4.1 with the following:*

Class III PV modules shall not have electrical ratings greater than 240 W where the open circuit voltage does not exceed 30 V DC and the short-circuit current does not exceed 8 A when tested under standard test conditions.

4.4.2 Insulation

Based upon the inherently limited electrical output capability of Class III PV modules their use, misuse, and failure are unlikely to result in a risk of electric shock or fire. Based upon these electrical output limitations there are no requirements for construction or insulation beyond functional insulation, but for several applications requirements for construction or insulation may be necessary.

4.4.3 Application

These PV modules are intended for installation where general user access and contact to uninsulated live parts is anticipated, e.g. consumer electronics. Class III PV modules shall not be combined in series strings operating at more than 35 V V_{oc} and shall not have a system voltage rating above 35 V. These PV modules are not intended for use in parallel with other PV modules or energy sources unless the combination provides protection from reverse current and overvoltage protection.

4.4.3DV DR *Modification by replacing 4.4.3 with the following:*

These PV modules are intended for installation where general user access and contact to uninsulated live parts is anticipated, e.g. consumer electronics. Class III PV modules shall not be combined in series strings operating at more than 30 V V_{oc} and shall not have a system voltage rating above 30 V. These PV modules are not intended for use in parallel with other PV modules or energy sources unless the combination provides protection from reverse current and overvoltage protection.

4.5 Intended use

PV modules may be installed in many different applications and system configurations. Manufacturers shall assess the intended use of their PV modules.

For special applications such as examples listed below additional requirements may apply:

a) Building attached PV (BAPV);

b) Building integrated PV (BIPV);

The building's functions in the context of BIPV are one or more of the following:

– mechanical rigidity and structural integrity,

– primary weather impact protection: rain, snow, wind, hail,

– energy economy, such as shading, daylighting, thermal insulation,

– fire protection,

– noise protection.

Thus, the BIPV module is a prerequisite for the integrity of the building's functionality. If the integrated PV module is dismounted (in the case of structurally bonded modules, dismounting includes the adjacent building component), the PV module would have to be replaced by an appropriate building component.

Inherent electro-technical properties of PV such as antenna function, power generation and electromagnetic shielding etc. alone do not qualify PV modules as building integrated.

c) Applications in areas where snow and/or wind load exceed loads as tested in IEC 61730-2 are expected;

d) Applications at environmental temperature exceeding the limits listed in 5.1;

e) Marine application (e.g. IEC 61701);

f) Vehicle application;

g) Agricultural application (e.g. IEC 62716);

h) Application in explosive or corrosive atmospheres;

i) Low-concentrating modules;

j) Module-applied electronics.

5 Requirements for design and construction

5.1 General

Where applicable, materials and components shall comply with the safety requirements specified in the relevant IEC standards.

Compliance with the IEC standard for the relevant material and component does not necessarily ensure compliance with the requirements of this standard.

All PV modules shall be suitable for operation in outdoor non-weather protected locations, exposed to direct and indirect (albedo) solar radiation, in an environmental temperature range of at least –40 °C to +40 °C and up to 100 % relative humidity as well as rain. PV modules shall be designed to withstand the electrical, mechanical, thermal and environmental (temperature, mechanical load, humidity, UV/weather, pollution, etc.) stresses occurring in their intended use and present no danger to the user or the environment. Compliance is verified by evaluation of materials, components and PV module construction as well as tests specified in IEC 61730-2.

NOTE 1 The environmental temperature is typically measured 1 m above ground. PV modules deployed closer to the ground may experience higher ambient temperatures than this quoted environmental temperature.

PV module can either be completely assembled when shipped from the factory, or be provided in subassemblies. The provided assemblies of the product shall not involve any action that is likely to affect compliance with the requirements of the IEC 61730 series.

Incorporation of a PV module into the final assembly shall not require any alteration of the PV module from its originally evaluated form.

All PV module mounting and wiring methods specified in the installation instructions shall be evaluated for compliance with the IEC 61730 series. This includes, but is not limited to, wiring methods, physical connection and/or attachment between PV modules and support structures as well as combinations of wiring connections and mounting system where the wiring is integral to the frame. Compliance with the IEC 61730 series assesses the impact of the mounting and wiring methods on the safety of the PV modules, but does not assess the safety or suitability of the mounting or wiring methods for their intended use, see IEC 61215. These may be subject to additional requirements or local code requirements.

IEC 60364-7-712 and IEC 62548 provide guidance for interconnection between PV modules and systems.

The construction of a PV module shall be such that equipotential bonding continuity, if applicable, is not interrupted by installation.

Any adjustable or movable structural part shall be provided with a locking device to reduce the likelihood of unintentional movement, if any such movement may result in a risk of fire, electric shock, or injury to persons.

NOTE 2 Physical properties or constructions that provide an interference or form fit to prevent unintended movement or rotation of the component comply with this requirement.

PV modules shall not have accessible burrs, sharp edges or sharp points that can cause injury to users or service persons. Edges and points that appear to be sharp by inspection, shall comply with the sharp edge test (MST 06).

Parts shall be prevented from loosening or turning if such loosening or turning may result in a risk of fire, electric shock, or injury to persons. Compliance for components is verified by specific tests described in the relevant standards or screw connection test (MST 33).

5.2 Marking and documentation

5.2.1 General

Instructions related to safety shall be in an official language of the country where the equipment is to be installed.

5.2.2 Marking

5.2.2.1 General

Each PV module shall include the following clear and indelible markings:

a) name, registered trade name, or registered trade mark of manufacturer;

b) type or model number designation;

c) serial number;

d) date and place of manufacture; alternatively serial number assuring traceability of date and place of manufacture;

e) polarity of terminals or leads;

f) “Maximum system voltage” or “V_{sys}”;

g) Class of protection against electrical shock, in accordance with Clause 4 of this standard;

h) “voltage at open-circuit” or “V_{oc}” including manufacturing tolerances;

i) “current at short-circuit;” or “I_{sc}” including manufacturing tolerances;

j) “PV module maximum power” or “P_{max}” including manufacturing tolerances; and

k) “Maximum overcurrent protection rating”, compliance is verified by reverse current overload test (MST 26).

All electrical data shall be shown as relative to standard test conditions (STC) (1 000 W/m^2, (25 ± 2) °C, AM 1,5 according to IEC 60904-3).

International symbols shall be used where applicable.

Compliance is to be verified according to visual inspection (MST 01) and durability of markings (MST 05).

PV connectors or wiring shall be marked in accordance to IEC 62852 with a symbol “Do not disconnect under load”, as given in Annex A. Symbol or warning notice shall be imprinted or labelled close to connector. PV connectors shall be clearly marked indicating the terminal polarity.

For Class II and Class 0 PV modules, the  (IEC 60417-6042: Caution, risk of electric shock) symbol shall be applied near the PV module electrical connection means.

PV modules shall be marked to indicate the classes as follows:

PV module classification	Marking	Symbol
Class II	Marking according to IEC 60417-5172: Class II equipment	
Class 0	No marking	No symbol
Class III	Marking according to IEC 60417-5180: Class III equipment	

PV modules provided with a functional earth connection shall be provided with a symbol according to 5.2.2.2.2, Figure 3.

PV modules provided with terminals for field wiring rated only for use with copper wire shall be marked, at or adjacent to the terminals, with the statement "Use copper wire only", "Cu only", or the equivalent.

PV modules provided with terminals for field wiring rated only for use with a different specific wiring material shall be marked with a similar statement referring to the rated material.

PV modules provided with terminals for field wiring rated for use with all types of wiring material do not need to be marked.

5.2.2.1DV DE *Modification:*

5.2.2.1DV.1 Add the following to item (d):

Exception No. 1: The manufacturer's identification may be in a traceable code if the product is identified by the brand or trademark owned by a private labeler.

Exception No. 2: The date of manufacture may be abbreviated; or may be in a nationally accepted conventional code or in a code affirmed by the manufacturer, provided that the code:

a) Does not repeat in less than 10 years; and

b) Does not require reference to the production records of the manufacturer to determine when the product was manufactured.

5.2.2.1DV.2 Add the following to the end of Clause 5.2.2.1:

In the US a PV module may be marked with "Fire Type:___. See Installation Instructions for Installation Requirements to Achieve a Specified System Fire Class Rating with this Product".

A module employing a nonmetallic junction box having a threaded or unthreaded opening shall be marked "For use with nonmetallic conduit systems only" or the equivalent.

NOTE It is recommended that the label meet the requirements of UL 969.

5.2.2.1DV.3 Add the following below item (b):

Type or model number designation for modules with reduced mechanical load shall be identified by a unique model number on nameplate and documentation.

5.2.2.1DV.4 Add the following item (l):

l) Modules for reduced mechanical load shall be marked by "Reduced mechanical design load" on nameplate followed by the range of positive and negative design loads they are designed for. Then the sentence "May only be used in ground-mounted PV power generation plants designed by a licensed professional engineer competent in the specific area under supervision in accordance with requirements in the installation manual." or similar equivalent warning shall be added.

EXAMPLE "Reduced mechanical design load ± 800 Pa. May only be used in ground-mounted PV power generation plants designed by a licensed professional engineer competent in the specific area under supervision in accordance with requirements in the installation manual."

NOTE One module construction may be designed for multiple design loads based on mounting configurations.

5.2.2.2 Symbols

5.2.2.2.1 Equipotential bonding

A wiring terminal or bonding location of a PV module intended to accommodate a field installed bonding conductor for equipotential bonding shall be identified with the appropriate symbol IEC 60417-5021 (DB:2002-10) (Figure 2)). Alternatively IEC 60417-5017 (Figure 1) can be used. No other terminal or location shall be identified in this manner.

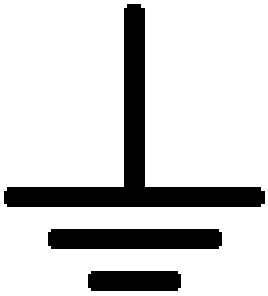


Figure 1
IEC 60417-5017

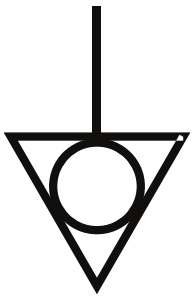


Figure 2
IEC 60417-5021

5.2.2.2.1DV DE *Modification by replacing the text of Clause 5.2.2.2.1 with the following:*

Equipment grounding

A wiring terminal or bonding location of a PV module intended to accommodate a field installed equipment grounding conductor for equipment grounding shall be identified with the appropriate symbol IEC 60417-5017 (Figure 1). No other terminal or location shall be identified in this manner.

5.2.2.2.2 Functional earthing

A wiring terminal or bonding location of a PV module intended to accommodate a field installed functional earthing conductor shall be identified with the appropriate symbol (IEC 60417-5018 (DB: 2002-10) (Figure 3)).

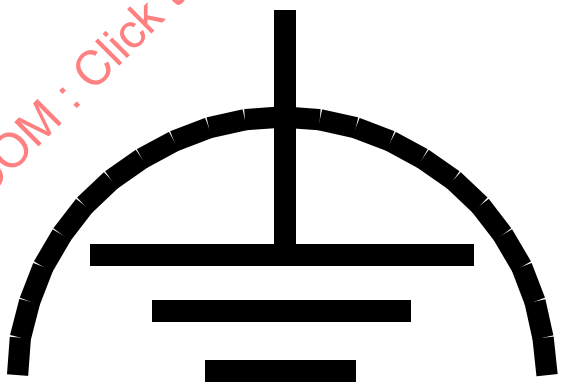


Figure 3
IEC 60417-5018

5.2.2.2.2DV DR *Deletion:*

Delete Clause 5.2.2.2.2

5.2.3 Documentation

PV modules shall be supplied with documentation describing the methods of electrical and mechanical installation as well as the electrical ratings of the PV module. The documentation shall state the Class under which the PV module was qualified and any specific limitations required for that Class. The documentation shall state the environmental conditions to which the module has been qualified, which by default includes a temperature range of –40 °C to +40 °C and wind/snow load including safety factor. It shall be ensured that appropriate documentation for safe installation, use, and maintenance is available to installers and operators.

For identical PV modules it is considered to be sufficient that one set of documentation is supplied with the PV module shipping unit.

Environmental conditions to which a PV module has been qualified may include IEC 61701 or IEC 62716.

The documentation shall contain the following information:

• all information required by 5.2.2.1 with exception of c), d) and e);

• recommended maximum series/parallel PV module configurations;

• the current rating of overcurrent protection, as determined in MST 26. Guidance to determine current rating may be given in to IEC 60269-6;

• manufacturer's stated tolerance for V_{oc}, I_{sc} and maximum power output P_{max} under standard test conditions;

• temperature coefficient for voltage at open-circuit;

• temperature coefficient for maximum power; and

• temperature coefficient for short-circuit current.

All electrical data shall be shown as relative to standard test conditions (1 000 W/m^2, (25 ± 2) °C, AM 1,5 according to IEC 60904-3).

International symbols shall be used where applicable.

The electrical documentation shall include a detailed description of the electrical installation wiring method to be used. This description shall include:

• the minimum cable diameters for PV modules intended for field wiring;

• any limitations on wiring methods and wire management that apply to the junction box for the PV module;

• the size, type, material, and temperature rating of the conductors to be used;

• type of terminals for field wiring;

• specific PV connector model/types and manufacturer to which the PV module connectors can be mated;

• the bonding method(s) to be used (if applicable) shall be specified. All provided or specified hardware shall be identified in the documentation;

• the type and ratings of bypass diode to be used (if applicable);

• limitations to the mounting situation (e.g. slope, mounting means, cooling);

• a statement indicating the fire rating(s) and the applied standard, or a statement that resistance to external fire sources was not evaluated, as well as the limitations to that rating (e.g. installation slope, sub structure or other applicable installation information);

• a statement indicating the minimum mechanical means for securing the PV module (as evaluated during the mechanical load test (MST 34)); and

• a statement indicating the maximum altitude the PV module is designed for. De-ratings can be applied.

The documentation for roof mounting shall include:

• a statement indicating the minimum mechanical means for securing the PV module to the roof (as evaluated during the mechanical load test according (MST 34);

• details of the specific parameter(s) when the fire rating is dependent on a specific mounting structure, specific spacing, or specific means of attachment to the roof or structure.

The documentation shall include a statement advising that external or otherwise artificially concentrated sunlight shall not be directed onto the front or back face of the PV module (if not qualified for).

Assembly instructions shall be provided with a product shipped in subassemblies, and shall be detailed and adequate to the degree required to facilitate complete and safe assembly of the product to specifications set forth in the IEC 61730 standard series.

To facilitate proper system sizing the manufacturer shall include relevant parameters in the installation instructions that allow system layout based not only on STC values given in the documentation. For example a safety factor for V_{oc} and I_{sc} of 1,25 is recommended since irradiance is often higher then 1 000 W/m^2 and temperature below 25 °C may raise V_{oc}.

The following or equivalent statement shall be included:

"Under normal conditions, a photovoltaic module is likely to experience conditions that produce higher current and/or voltage than reported at standard test conditions. Accordingly, the values of I_{sc} and V_{oc}. marked on this PV module should be multiplied by a factor of 1,25 when determining component voltage ratings, conductor current ratings, and size of controls (e.g. inverter) connected to the PV output."

The safety factor of 1,25 for the minimum voltage rating of the components can be modified during the design of a system according to the minimum temperature of the location of the installation and the temperature coefficient for V_{oc}. I_{sc} can be adjusted based on maximal temperature, irradiance and orientation of the module. To this end a full simulation for the specific location is required using long term weather data.

5.2.3DV D2 *Modification of 5.2.3 in accordance with the following:*

– Add the following new paragraph at the end of the first paragraph: "The module is considered to be in compliance with this standard only when the module is either mounted in the manner specified by the mounting instructions, or when the mounting means has been evaluated with this PV module to UL 2703. A module with exposed conductive parts is considered to be in compliance with this standard only when it is either electrically grounded in accordance with the manufacturer's instructions and the requirements of the National Electrical Code, ANSI/NFPA 70 (2014-2017), or when the bonding means has been evaluated with this PV module to UL 2703."

– Add the following note after the phrase "The electrical documentation shall include a detailed description of the electrical insulation wiring method to be used. This description shall include:"

NOTE – The first, third and fourth items in this list refer to modules with a wiring compartment intended for use with field-installed wiring.

– Replace the sixth bullet about bonding with the following: "the bonding and grounding method(s) to be used (if applicable) shall be specified. All provided or specified hardware shall be identified in the documentation;"

– Replace the seventh bullet about the documentation for by-pass diodes with the following: "the type and rating of bypass-diodes to be used as well as the installation instructions for those diodes (if applicable)."

– Add the following bullets after the seventeenth bullet:

- **a statement indicating the minimum mechanical means for securing the PV module (as evaluated during the mechanical load test (MST 34));**
- **the documentation of modules with reduced mechanical load shall contain:**

  "When PV modules are intended to be installed in an engineered scenario by qualified personnel such as in a ground-mounted PV power generation plant, they may be designed to meet a lower minimum test load of 1 200 Pa with a safety factor of 1,5: i.e. an 800 Pa minimum design load for the down pressures (positive) and uplift pressures (negative). These modules are marked by "Reduced mechanical design load" on the nameplate followed by the range of positive and negative design loads they are designed for.

  As an example, these modules may be used in interior or exterior rows where the module mounting and structure in combination are designed to meet a specific design load lower than 1 600 Pa and a licensed professional engineer has taken into consideration all factors below for the combined site specific wind and snow loads.

  1) Pressure coefficients should be derived based on an effective wind area equal to one PV module, from boundary layer wind tunnel tests on the specific mounting system used to support the PV module.

  2) Boundary layer wind tunnel tests should be conducted in accordance with ASCE 7 and ASCE 49, or other recognized industry guidance;

3) Mounting system vibrations with natural frequencies less than 10 Hz may result in loads higher than predicted from static load calculations, depending on wind speed and damping ratio of the vibration mode, and should be considered to assess dynamic amplification factors;

4) Some mounting systems may be susceptible to instabilities due to vortex shedding which may not be addressed in building codes; guidance from qualified experts in boundary layer wind tunnel testing of ground-mounted PV systems may be required to address this risk;

5) Modules when mounted on trackers that rely on being operational or stowing at a specified angle in extreme wind or snow conditions should be verified to limit loads below the design load threshold considering the design controls implemented in such trackers.

Alternatively, modules having a higher minimum design load compatible to the required site-specific loads may be used. Reduced mechanical load modules cannot be used on a rooftop system."

• Reduced mechanical load modules shall not be used on a rooftop system.

NOTE Per the prevailing local codes many large photovoltaic installations of today are designed, engineered and installed by qualified experts in their structural, mechanical and electrical field. To target specific zones in the array to handle higher loading than in interior areas structure designers utilize boundary layer wind tunnel studies of that specific structure per allowances in building codes to utilize such studies. In the overall system design approach the boundary later studies, manufacturer's mounting configurations, stated design loads and test safety factors are utilized.

5.3 Electrical components and insulation

5.3.1 General

PV modules may consist of the following electrical components and insulation:

• the internal wiring, e.g. solar cell and cell interconnects (see 5.3.2);

• external wiring and output cables (see 5.3.3);

• connectors (see 5.3.4);

• junction boxes for PV modules (see 5.3.5);

• frontsheet and backsheet (see 5.3.6);

• insulation barriers (see 5.3.7);

• electrical connections (see 5.3.8);

• encapsulant (see 5.3.9);

• bypass diodes (see 5.3.10).

5.3.1DV DC *Modification by adding the following item to the end of 5.3.1:*

• fuseholders – any fuseholders built into the module shall comply with the relevant UL fuseholder standard.

5.3.2 Internal wiring

Internal wiring shall have sufficient current carrying capacity for the relevant application. Depending on the pollution degree at the place where the internal wiring is located precautions against corrosion have to be taken. Examples for protection against corrosion are given in 5.5.3.1. In case that insulation for the internal wiring is necessary it shall fulfil the relevant requirements for the relevant application according to 5.5.2.3.

Compliance is checked by inspection and by reverse current overload test (MST 26).

5.3.3 External wiring and cables

External wires and cables shall fulfil the requirements of EN 50618.

NOTE Currently an IEC standard (IEC 62930) is under development. IEC 62930 will replace EN 50618.

5.3.4 Connectors

External DC connectors shall fulfil the requirements of IEC 62852. Connectors shall be marked in accordance with 5.2.2.

5.3.4DV DR *Modification by replacing the Clause with the following:*

Connectors shall be marked in accordance with 5.2.2. External DC connectors shall fulfil the requirements of:

a) UL 6703, or

b) IEC 62852 where non-locking connectors are not authorized for use in readily accessible PV systems with voltages above 30 volts.

5.3.5 Junction boxes for PV modules

Junction boxes for PV modules shall fulfil the requirements of IEC 62790.

5.3.5DV D2 *Modification by replacing the Clause with the following:*

Junction boxes for PV modules shall fulfil the requirements of:

a) UL 3730, or

b) IEC 62790 with the following exceptions:

1) The pull force used in the cord anchorage test (Sections 5.3.21.1 and 5.3.21.2 in IEC 62790) shall be either the value given in Table 6 (of IEC 62790) or 89 N, whichever is higher.

2) The pull force used in the retention on mounting surface test (Section 5.3.22.2 and 5.3.22.3 in IEC 62790) shall be 156 N.

5.3.6 Frontsheets and backsheets

Front- and backsheets are typically compositions of layered materials, such as films, adhesives or coatings, in which at least one material layer delivers the relied upon electrical insulation and other layers may provide extended protection of the relied upon insulation against the environmental factors.

Layers of frontsheets and backsheets which are relied upon for insulation shall withstand all relevant mechanical, electrical, thermal, and environmental stresses, with compliance demonstrated at the material or component level. Layers which may represent a part of a tracking path (creepage) shall be classified into a material group (see 5.6.3.3). In general polymeric frontsheets and backsheets shall meet the relevant requirements of section 5.5.2, with compliance demonstrated by the tests in IEC 61730-2.

NOTE A characterization standard for front- and backsheets (IEC 62788-2) is under development.

If these sheets are used as relied upon insulation they shall at a minimum fulfil the requirements of 5.6.4.3 for insulation in thin layers.

In addition, polymeric front- and backsheets used as relied upon insulation shall meet the requirements of 5.5.2.3. The values for TI or RTE (RTI) according to 5.5.2.3.3 shall be evaluated under consideration of particular requirements for flexible multilayer sheets given in IEC 60216-2.

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

Adhesion of the front- and backsheet, e.g. to the encapsulant or glass, shall be appropriate. Compliance is checked by passing the IEC 61730-2 test sequence.

5.3.7 Insulation barriers

An insulation barrier shall withstand all relevant mechanical, electrical, thermal, and environmental stresses. In general a polymeric insulation barrier shall meet the relevant requirements of 5.5.2. It shall be held in place and shall not be adversely affected to the extent that its required electrical and mechanical properties fall below the minimum acceptable values for the application. The removal of the insulation barrier shall only be possible by using a tool. Compliance is checked by passing the IEC 61730-2 test sequence.

5.3.8 Electrical connections

5.3.8.1 General

Electrical connections shall be so designed that 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.

Prevention shall be taken that connections do not become loose, e.g. by using a washer.

Compliance is checked by visual inspection (MST 01), continuity test of equipotential bonding (MST 13) and screw connection test (MST 33), if applicable.

The end of a stranded conductor shall not be consolidated by soft soldering in places where the conductor is subject to contact pressure unless the method of clamping is designed so as to reduce the likelihood of a bad contact or if the soldered portion is maintained outside the contact area of the connection.

Precautions shall be taken that under operation clamping units or other terminations are prevented from thermal and mechanical stress which might impair electrical conductivity.

5.3.8.2 Terminals for external cables and PV connector ribbons

Terminals for electrical connections shall be suitable for the type and range of conductor cross-sectional areas according to specification of the manufacturer. They shall meet the requirements of IEC 62790.

Insulated terminals shall be designed in a manner where a possible displacement that may result in a reduction of clearances and creepage distances is prevented.

5.3.8.2DV DR *Modification by replacing the first paragraph of the Clause with the following:*

Terminals for electrical connections shall be suitable for the type and range of conductor cross-sectional areas according to specification of the manufacturer. They shall meet the requirements of UL 3730 or IEC 62790.

5.3.8.3 Splices and connections inside a PV module

Splices and connections inside a PV module other than those for terminals of external cables and PV connector ribbons shall be mechanically secured and shall provide electrical continuity. Electrical connections shall be soldered, welded, conductively adhered, crimped, or otherwise securely connected. A soldered or conductively adhered joint shall be additionally mechanically secured.

Encapsulation is considered as a means of mechanical securement for soldered and conductively adhered electrical connections in a PV module.

5.3.9 Encapsulants

Encapsulants are considered as a part of the laminate. However, they are not tested separately but shall be considered in the application.

NOTE A standard for encapsulants is currently under consideration (IEC 62788-1).

The technical properties of encapsulant 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 material group, the insulation resistance and the dielectric strength shall be suitable for the intended application.

Compliance is checked by passing the IEC 61730-2 test sequence.

5.3.10 Bypass diodes

Bypass diodes shall be rated to withstand the current and voltage for their intended use. Compliance is checked by bypass diode thermal test (MST 25), hot-spot endurance test (MST 22), bypass diode functionality test (MST 07) and visual inspection (MST 01).

NOTE Currently further characterization standards for bypass diodes are under development.

5.4 Mechanical and electromechanical connections

5.4.1 General

This subclause defines the minimum requirements for mechanical connections providing the mechanical stability of the PV modules (e.g. frame) as well as for connections providing mechanical and electrical function (e.g. equipotential bonding).

Typically found in a PV module are the following mechanical connections:

• connections within a frame;

• PV module mounting interfaces such as frame or backrail to glass or backsheet via adhesive (silicone, rubber, etc.);

• frame to clamp of a mounting system;

• means for equipotential bonding;

• means for the attachment of junction box to the PV modules (silicone, tape, etc.); and

• mechanical connections within the laminate.

Mechanical connections shall be able to durably withstand the thermal, mechanical, and environmental stresses occurring in the application without decreasing the integrity of the connection below safe levels.

Compliance is checked by inspection and during the mechanical load test (MST 34), module breakage test (MST 32), materials creep test (MST 37) and, if applicable, continuity of equipotential bonding tests (MST 13).

Individual material requirements are given in 5.5. 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.

For mechanical connections friction between surfaces, such as simple spring pressure, is not acceptable as the sole means to inhibit the turning or loosening of a part.

Physical properties or constructions that provide an interference or form fit to prevent unintended movement or rotation of the component comply with this requirement.

5.4.2 Screw connections

Screws and mechanical connections, the failure of which might cause the PV module to become unsafe, shall withstand the mechanical stresses occurring in normal use. Screws shall not be made of a material which is soft or liable to creep.

NOTE 1 Examples of soft materials are zinc and some grades of aluminium.

Screws which are operated for maintenance purposes shall not be of insulating material if their replacement by a metal screw could impair supplementary or reinforced insulation.

Screws used to provide mechanical stability and continuity for equipotential bonding, e.g. fixing screws in frames and other components, shall comply with the requirement in the first paragraph of this subclause. At least one screw per electrical mechanical connection shall ensure the electrically connection between the metallic components.

Compliance is checked by inspection and by test for general screw connection (MST 33a).

Screws used for mechanical and electrical connections with a nominal diameter of less than 3 mm shall screw into metal.

For screws used for mechanical and electrical connections two full threads shall engage into the metal.

Screwed and other fixed connections between different parts of the PV module shall be made in such a way that they do not come loose through torsion, bending stresses, vibration, etc., as may occur in normal use.

NOTE 2 Examples of means of preventing the loosening of connections are soldering, welding, lock nuts and setscrews.

Compliance is checked by inspection and by test for locking screws (MST 33b).

5.4.3 Rivets

Rivets which serve as electrical as well as mechanical connections shall be locked against loosening. A noncircular shank or an appropriate notch may be sufficient.

5.4.4 Thread-cutting screws

Thread-cutting screws and self-tapping screws shall not be used for the interconnection of current-carrying parts made of metal which is soft or liable to creep, such as zinc or aluminium.

Thread-forming screws (sheet metal screws) shall not be used for the connection of currentcarrying parts, unless they clamp these parts directly in contact with each other, and are provided with suitable locking means.

Thread-cutting (self-tapping) screws shall not be used for the connection of current-carrying parts unless they generate a full form standard machine screw thread. However, screws of the latter type shall not be used if they are likely to be operated by the user or installer.

Thread-cutting and thread-forming screws, used to provide continuity for equipotential bonding, shall be such that it is not necessary to disturb the connection in normal use.

For equipotential bonding one screw is permitted if two full threads engaged the metal.

5.4.5 Form/press/tight fit

Form/press/tight fits of metallic components not separately equipotentially bonded need to be electrically connected.

NOTE Typical examples for such connections are corner joints in metallic frames.

Compliance is checked by inspection and module breakage test (MST 32) and static mechanical load test (MST 34) and test of continuity of equipotential bonding (MST 13) pre and post the MST 32 and MST 34 tests.

5.4.6 Connections by adhesives

Connections (made during module production) by adhesives handled in this subclause might be:

• mounting of junction box;

• mounting of backrails or frames;

• fixing of backsheet and/or frontsheet to edge seals;

• fixing of backsheet and/or frontsheet to the encapsulant;

• etc.

Compliance is checked with mechanical load test (MST 34), test of continuity of equipotential bonding (MST 13) and module breakage test (MST 32) for mounting means adhesives and with robustness of termination test (MST 42 and MST 17) for junction-box adhesives.

Adhesion of a polymer relied upon for insulation to another insulating layer shall be appropriate for the application.

If the connection by adhesive should be considered as cemented joint the requirements according to 5.6.4.2 shall be applied.

A peel test (MST 35) and a lap shear test (MST 36) are applied in 5.6.4.2 for verification of cemented joints.

5.4.7 Other connections

Other connections such as, for example, welded or soldered, shall be investigated by visual inspection (MST 01). Other connections which are relied upon for equipotential bonding are checked with test of continuity of equipotential bonding (MST 13). Materials and processes for creating the connections shall be appropriate for the intended use.

NOTE An example for a standard for soldered connections is IEC 61191-1.

5.5 Materials

5.5.1 General

This subclause defines requirements for materials used in a PV module. General compliance is checked with tests in accordance to IEC 61730-2.

The choice of materials is not limited to the materials listed in this subclause. Non-conductive materials like glass or ceramic materials can be used as insulating materials. For dimensioning purposes, any non-conductive material may be considered as an insulator whereas compliance to requirements of 5.6 shall be followed.

5.5.2 Polymeric materials

5.5.2.1 General

Polymeric materials shall be able to durably and safely withstand the electrical, mechanical, thermal, environmental, and corrosive stresses occurring in the application, and shall be resistant to electrical and mechanical property degradation.

Polymeric parts which ensure either the electrical or mechanical safety of the PV module, or both, shall be resistant to electrical and mechanical property degradation and shall comply with the requirements of the materials creep test (MST 37) depending on their constructive function in the PV module.

Polymeric materials used in PV modules as part of a cemented joint shall additionally comply with 5.6.4.2.

5.5.2.2 Endurance to weathering stress

Polymeric materials shall be durable to weathering stress occurring in the application.

Components have to be evaluated to the relevant requirement in the applicable component standard.

NOTE Weathering exposure tests for polymeric frontsheets and backsheets are currently under development in IEC TS 62788-7-2.

5.5.2.3 Polymeric materials used as electrical insulation

5.5.2.3.1 General

Polymeric materials may serve multiple insulation functions, e.g. as to external parts and insulation between:

• live parts and accessible conductive parts;

• live parts and accessible surfaces;

• live parts of different polarity of the same circuit;

• live parts not of the same potential;

An insulation material that serves more than one function shall comply with all applicable requirements. In case of multiple similar requirements (e.g. thickness or test duration) the most stringent requirements applies. It shall be evaluated in the thinnest significant thickness used for the specific application. Material relied upon for insulation shall be of adequate thickness, as described in Table 3 and Table 4, and of a material appropriate for the application, as described in the following subclauses.

Insulation shall not be impaired by short-term or long-term thermal stresses which may occur in normal operation (5.5.2.3.3). Insulation shall not be impaired by electrical stress (5.5.2.3.2) or weathering (5.5.2.2).

Variations in polymer additives such as anti-oxidants, UV stabilizers, colorants, and change of chemical formulation of polymeric component shall be evaluated to determine if the material property changes with respect to electrical, mechanical, thermal, and physical properties. Compliance is checked by inspection and by the relevant PV module and material tests.

The temperature limits of materials used as insulation shall not be less than the maximum measured operating temperature of the specific material in application, as measured during the temperature test (MST 21).

5.5.2.3.2 Endurance to electrical stress

Materials used as electrical insulation shall withstand electrical stresses which occur in the application both in the unconditioned and preconditioned cases.

If relevant for clearance and creepage distance evaluation insulating materials shall be assigned a materials group designation based on a CTI rating.

Minimum spacing requirements can be reduced by using materials with a lower materials group rating.

Insulating materials between conductive parts of different polarity or between conductive parts and accessible surfaces shall be assessed according to their material group designation based on their CTI rating (see B.2.2.4.2), if those materials are a part of a creepage distance. CTI rating is required from each surface, on which tracking could occur, e.g. at inner frontand/ or backsheet layer surface to encapsulant, if applicable. See Clause B.9. Figure B.2, Figure B.3 and Figure B.4.

Whenever electrical stress is present through a material layer (not along an interface or surface) the concept of distance through insulation is applicable and CTI is not required.

Additionally the following PV module tests apply:

– Insulation test (MST 16) before and after preconditioning, and

– Impulse voltage test (MST 14).

5.5.2.3.3 Endurance to thermal stress – RTE (RTI) or TI (mechanical/electrical)

Materials used as relied upon insulation shall have a minimum relative thermal endurance, relative thermal index or temperature index (RTE/RTI or TI) in accordance with IEC 60216-5 or IEC 60216-1 equal to or greater than the maximum normalized operating temperature of the material as measured in the particular mounting situation (e.g. roof mounted) during the temperature test (MST 21), or 90 °C, whichever is higher.

For open rack mounted PV modules, the normalized measured maximum PV module operating temperature can be assumed to be 90 °C, so the insulation RTE/RTI or TI rating shall be at least 90 °C.

To ensure that the electrical and mechanical properties are provided through the expected lifetime the TI and RTE (RTI) values have to be evaluated as mechanical and electrical ones according to IEC 60216-2.

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

For multilayer constructions with separately tested RTE, RTI or TI values, the thermal rating can be derived from the film components, the lowest value of the film components defines the RTE, RTI or TI value of the multilayer system.

NOTE Relationship between RTE, RTI and TI can be found in IEC 60216-1, IEC 60216-2 and IEC 60216-5.

5.5.2.3.4 Polymeric insulating materials used as external parts

Any accessible part (edge seal, front- and backsheet) that is used as insulation shall meet the criteria of this subclause.

The requirements for external parts do not apply to parts meeting requirements of applicable component standards, e.g. material for enclosure of a junction box for PV modules.

External polymeric parts of the PV module whose deterioration could impair the safety shall meet the following additional requirements:

a) flammability class minimum V-1 according to IEC 60695-11-10 (not applicable to insulation in thin layers; those are covered only by MST 24);

b) ball pressure test according to IEC 60695-10-2 with a temperature of 75 °C (not applicable to insulation in thin layers); and

c) ignitability test (MST 24) in final application (laminated or the PV module); and

d) peel test for proof of cemented joints according to IEC 61730-2 (MST 35), where applicable;

e) lap shear strength test (MST 36), where applicable.

5.5.2.3.4DV DR *Modification:*

Delete item (c), Ignitability Test (MST 24).

5.5.2.3.5 Polymeric insulating parts supporting live parts

External parts of non-metallic material, parts of insulating material supporting live parts including connections, and parts of polymeric material providing supplementary insulation or reinforced insulation, shall be sufficiently resistant to heat if their deterioration could cause the PV module to fail to comply with this standard.

Polymeric parts which are not components of the laminate whose deterioration could impair the safety of the PV module are evaluated with the module level ignitability test MST 24.

Other than elastomeric polymeric materials (e.g. duroplastic) shall meet the following additional requirements:

a) Flammability class minimum HB according to IEC 60695-11-10.

b) Ball pressure test according to IEC 60695-10-2 with a temperature of 125 °C.

NOTE IEC 60695-10-2 specifies the ball pressure test as a method for testing parts of non-metallic materials for resistance to heat.

c) Materials creep test (MST 37).

The requirements in this subclause do not apply to parts which have met the requirements of their applicable component standards, e.g. junction boxes.

5.5.2.4 Polymeric materials used for mechanical functions

Materials used shall be durable against weathering stress in their application.

Materials used for mechanical functions shall have a minimum mechanical relative thermal endurance, relative thermal index or temperature index (RTE/RTI or TI) in accordance with IEC 60216-5 or IEC 60216-1 equal to or greater than the maximum normalized operating temperature of the material as measured in the particular mounting situation (e.g. roof mounted) during the temperature test (MST 21), or 90 °C, whichever is higher.

Test requirements are currently under development.

5.5.3 Metallic materials

5.5.3.1 General

In accordance with IEC 60950-1 metal parts designed for applications in climates with wet or humid ambient conditions shall not be in contact to metal parts that have a difference of their electrochemical potentials of more than 600 mV. Larger electrochemical potential differences are permissible if the contact points of these materials are designed to remain dry. The material combinations listed in Table J.1 of IEC 60950-1:2005 serve as guideline to determine generic electrochemical potentials between two materials. Electrochemical potentials for specific material combinations have to be taken into consideration.

Iron or mild steel as a part of the product shall be plated, painted, or enamelled for protection against corrosion. The corrosion protection at a minimum shall be at least equivalent to a zinc coating of 0,015 mm thickness. Simple sheared or cut edges and punched holes are not required to be additionally protected, provided these features do not affect the mechanical bonding, mounting or structural performance of the PV module.

Compliance is checked by inspection.

5.5.3.1DV DE *Modification by adding the following sentence at the end of the second paragraph:*

The manufacturer shall specify how they demonstrate that the corrosion protection is at least equivalent to a zinc coating of 0,015 mm thickness.

5.5.3.2 Current carrying parts

Under normal operation current-carrying parts shall have a sufficient mechanical strength and electrical conductivity. If environmental conditions may cause corrosion current-carrying materials (metal, polymeric based, etc.) shall be protected against corrosion, e.g. by coating.

In case of current-carrying parts consisting of corrosion protective coated metal the coating shall be capable of preventing corrosion according to either one of ISO 1456, ISO 1461, ISO 2081 or ISO 2093. If the current-carrying parts may be stressed by abrasion, coated metal parts are not allowed.

Other materials shall be protected accordingly.

5.5.4 Adhesives

Adhesives shall be appropriate for the application. Compliance is checked by relevant tests of IEC 61730-2, including lap shear strength test (MST 36), peel test (MST 35), robustness of terminations test (MST 42), mechanical load test (MST 34), and visual inspection (MST 01), accessibility test (MST 11), wet leakage current test (MST 17) pre- and post-test sequences, where applicable.

Additionally, if an adhesive is part of the relied upon electrical insulation it has to meet the requirements of 5.5.2.3.3.

NOTE Specific requirements for adhesives are under consideration.

5.6 Protection against electric shock

5.6.1 General

PV modules shall be provided with adequate protection against contact with hazardous live parts and shall pose no risk of electric shock.

Annex B contains additional information and is to be used in conjunction with this subclause.

5.6.2 Protection against accessibility to hazardous live parts

5.6.2.1 General

PV modules shall be constructed to provide adequate protection against accessibility to hazardous live parts (> 35 V DC).

For Class 0 PV modules, accessible parts shall be separated from hazardous live parts by at least basic insulation.

Class II PV modules shall be so constructed and enclosed that only parts separated from hazardous live parts by double or reinforced insulation are accessible.

In Class III PV modules live parts are not considered as hazardous, so a separation from accessible parts is not needed. To ensure sufficient functionality and protection against hazardous lighting arc, live parts of different polarity shall be separated by at least functional insulation.

Compliance is checked by visual inspection (MST 01) and by accessibility test (MST 11).

Materials used for realizing protection against accessibility of hazardous live parts by means of enclosure, insulation barrier or relied upon insulation shall comply with the requirements of 5.5.2 due to their application.

5.6.2.1DV DR *Modification by replacing the first sentence with the following:*

PV modules shall be constructed to provide adequate protection against accessibility to hazardous live parts (> 30 V DC).

5.6.2.2 Protection by means of enclosures and insulation barriers

Enclosures or insulation barriers 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.

Parts of enclosures and insulation barriers that provide protection in accordance with these requirements shall not be removable without the use of a tool. Lids which are attached without screws shall have one or several detectable features, e.g. recesses, which enable tools to be deployed in order to remove them. If the lid is removed correctly the tool may not come into contact with the live parts.

An insulation barrier shall be held in place and shall not be adversely affected by influences expected during normal operation to the extent that its necessary electrical and mechanical properties fall below the minimum acceptable values for the application.

Parts shall be prevented from loosening or turning if such loosening or turning may result in a risk of fire, electric shock, or injury to persons.

5.6.2.3 Protection by means of insulation of live parts

An insulation material providing the sole insulation between a live part and an accessible metal part, or between uninsulated live parts not of the same potential, shall be of adequate thickness and of a material appropriate for the application.

Any conductive part, which is not separated from parts that can operate at a potential above 35 V DC by at least basic insulation, is considered to be a live part. A metallic accessible part is considered to be conductive if its surface is bare or is covered by an insulating layer which does not comply with the requirements of basic insulation.

An overview of the required insulation is given in Table 2.

Table 2
Required type of insulation as defined in IEC 61140

Protection class (IEC 61140)	Protection required against direct contact	Insulation between live parts and accessible metal parts	Insulation between live parts and accessible surfaces	Insulation between live parts of different potential of the same circuit
Class 0	Yes	B	B	B
Class II	Yes	R	R	B
Class III	No	F	F	F
F: functional insulation. B: basic insulation. R: reinforced insulation or double insulation.				

Neighbouring solar cells connected in series have no special insulation requirements if the maximum power dissipation between two neighbouring cells is less than 15 W (based on solar cell rating).

NOTE For a typical c-Si cell with an open circuit voltage of ~0,7 V and short circuit current ~9,0 A the above criterion is met (6,3 W).

5.6.2.3DV DR *Modification by replacing the second paragraph with the following:*

Any conductive part, which is not separated from parts that can operate at a potential above 30 V DC by at least basic insulation, is considered to be a live part. A metallic accessible part is considered to be conductive if its surface is bare or is covered by an insulating layer which does not comply with the requirements of basic insulation.

5.6.3 Insulation coordination

5.6.3.1 General

The construction of the insulation system of a PV module depends on several influencing factors, including overvoltage category (see Annex B.2.2), pollution degree (B.2.2.3), materials, system- and working voltage.

For evaluation of the minimum values and measurement of existing clearances and creepage distances the general requirements of insulation coordination according to relevant clauses of IEC 60664-1 shall be considered. The relevant requirements for insulation coordination and for measuring of clearances and creepage distances within PV modules have been extracted and listed in Annex B. Examples for determination of clearances and creepage distances are also shown in Annex B.

The requirements for clearances and creepage distances do not apply to the inherent dimensions within a component. Such dimensions shall comply with the requirements for the component in question according to their relevant standards (e.g. IEC 62790 for PV module junction boxes).

For the purpose of determining a clearance or a creepage distance from conductive parts to accessible parts, the accessible surface of an insulating enclosure is to be considered as conductive as if it were covered by a metal foil wherever it can be touched by the standard test finger according to Figure 2, test probe B of IEC 61032:1997. These distances shall be dimensioned for the relevant system voltage.

5.6.3.2 Pollution degree

In general the macro-environment according to IEC 60664-1 for an entire PV module is considered pollution degree 3. In case of enclosures having a degree of protection IP 55 or higher according to IEC 60529 the consideration for the micro-environment can be reduced to pollution degree 2.

For parts enclosed or encapsulated to provide protection against ingress of dust and moisture the minimum required creepage distance of pollution degree 2 apply if test criteria of IEC 61730-2 (except B.1 test sequence) are met.

Any change of spacing will require re-evaluation in accordance to IEC 61730 series and IEC TS 62915.

For parts enclosed or encapsulated to provide protection against ingress of dust and moisture, pollution degree 1 might be applicable, if additional requirements according to IEC 61730-2, Test sequence B.1, are met.

5.6.3.2DV D1 *Modification in accordance with the following:*

Replace the reference to IEC TS 62915 with UL 62915 in the third paragraph.

5.6.3.3 Material groups

With regard to tracking insulating material between accessible and current carrying parts or between current carrying parts of different polarity which have a surface where tracking can occur and are of polymeric materials tend to get conductive on their surface caused by discharge. Those shall be categorized into material groups (minimum material group IIIb) for evaluation of minimum creepage distances (see Annex B).

For this standard materials classified as material groups IIIa and IIIb are combined to material group III.

Material group IIIb is not recommended for application in pollution degree 3 above 600 V.

Materials, for instance inner layers of a multilayer back-sheets, that are not part of a tracking path (creepage) do not need characterization of a material group.

5.6.3.4 Clearances (cl) and creepage distances (cr)

Clearances (cl) and creepage distances (cr) shall be dimensioned according to Table 3, and Table 4. For evaluation of the minimum clearances and creepage distances the general requirements of insulation coordination according of IEC 60664-1 shall be considered. The relevant requirements for insulation coordination and for measuring of clearances and creepage distances within PV modules have been extracted and listed in Annex B.

For a creepage pathway along an interface composed of materials of different materials groups, the higher number will apply.

The values for clearances in Table 3 and Table 4 are valid for operation at an altitude up to 2 000 m. If the equipment is rated to operate at an altitude greater than 2 000 m, all clearances shall be multiplied by the applicable factor of Table B.3.

NOTE System voltages could also be de-rated based on altitude.

The requirements for creepage distances do not apply to distance through insulation (e.g. cemented joints).

5.6.4 Distance through insulation (dti)

5.6.4.1 General

Solid insulation in the sense of this standard can be comprised of single or multiple layers, and typically appear as thin layers (5.6.4.3) and cemented joints (5.6.4.2).

The solid insulation properties of polymeric materials are defined in 5.5.2 and are verified through the tests outlined in IEC 61730-2.

The distances through insulation (dti) are required for supplementary, double or reinforced insulation only as shown in lines 4 of Table 3 and Table 4 (see Annex B).

Polymeric materials for cemented insulation parts and insulation in thin layers shall withstand environmental, thermal, electrical and mechanical stresses as far as they occur. They shall comply with requirements according to 5.5.2. The insulation shall fulfil the material classification as given in IEC 60216-1, IEC 60216-2 and IEC 60216-5 (RTI/RTE/TI).

NOTE Other, non-polymeric materials like glass can also be used as parts of a cemented joint.

5.6.4.1DV D2 *Modification:*

Delete the paragraph that says "The distances through insulation (dti) are required for supplementary, double or reinforced insulation only as shown in lines 4 of Table 3 and Table 4 (see Annex B)."

5.6.4.2 Cemented joints

Distances through cemented joints as listed in lines 4 of Tables Table 3 and Table 4 (values for distance through cemented joints are extracted from Table 13 of IEC 61558-1:2005) shall be used if the following requirements according to IEC 61730-2 are fulfilled:

a) Joint between rigid part and rigid part

1) Visual inspection (applicable parts of MST 01) to verify that there are neither cracks nor voids in the insulating compounds which either by themselves or in combination reduce the distances through the cemented joint below the required values.

2) Insulation test (MST 16) using a 1,35 times higher test voltage.

3) Wet leakage current test (MST 17) using a 1,35 times higher test voltage.

4) The electrically insulating adhesive/sealant, if applicable, shall have a volume resistivity of greater than 50×10^6 Ω cm (dry) and greater than 10×10^6 Ω cm (wet), with volume resistivity as measured according to IEC 62788-1-2, method A.

NOTE Wet/dry conditioning based on Clause 14 of UL 746C.

5) Lap shear test (MST 36).

b) Joint between rigid part and flexible part, also between flexible part and flexible part

1) Visual inspection (applicable parts of MST 01) to verify that there are neither cracks nor voids in the insulating compounds which either by themselves or in combination reduce the distances through the cemented joint below the required values.

2) Insulation test (MST 16) using a 1,35 times higher test voltage.

3) Wet leakage current test (MST 17) using a 1,35 times higher test voltage.

4) The electrically insulating adhesive/sealant, if applicable, shall have a volume resistivity of greater than 50×10^6 Ω cm (dry) and greater than 10×10^6 Ω cm (wet), with volume resistivity as measured according to IEC 62788-1-2, method A.

NOTE Wet/dry conditioning based on Clause 14 of UL 746C.

5) Peel test (MST 35).

5.6.4.2DV D2 *Modification by replacing the first paragraph with the following:*

Distances through cemented joints as listed in line 4 of Table 3 (values for distance through cemented joints are extracted from Table 13 of IEC 61558-1:2005) shall be used if the following requirements according to IEC 61730-2 are fulfilled. Class 0 modules with cemented joints are acceptable if they meet the requirements for cemented joints for Class II modules as specified in line 4 of Table 3:

5.6.4.3 Insulation in thin layers

Thickness of relied upon insulation is checked by insulation thickness test (MST 04) in final application. To ensure that the protection against electric shock is still provided after failure of either the double or reinforced insulation the insulation test (MST 16) after cut susceptibility test (MST 12) shall be performed as for basic insulation.

In case of insulation constructed of thin layers of insulated material, the relied upon insulation shall be such that the following requirements are fulfilled at every location.

a) Single-layer sheet (see also Figure 4, example a))

– Minimum thickness according to lines 1b) of Table 3 and Table 4, as applicable depending on class (see Table 1).

Exception: The minimum thickness for a single layer is 30 µm, even for system voltages < 600 V, since pinholes may be present. For thicknesses < 30 µm a multilayer concept shall be adopted to mitigate risk.

– RTI / RTE / TI as defined in 5.5.2.3.3.

– Dielectric strength for reinforced insulation.

b) Multi-layer sheets (see also Figure 4, examples for double layers b1), b2) and generic n-layers c))

– The sum of thickness of all layers providing relied upon insulation shall be in compliance with values according to lines 1b) of Table 3 and Table 4, as applicable depending on class (see Table 1).

Each layer of a multi-layer (e.g. 2 layers, see Figure 4, example b1) and b2)) sheet providing relied upon insulation shall meet the following requirements:

– RTI / RTE / TI as defined in 5.5.2.3.3.

– Dielectric strength for basic insulation.

If single layers are not characterized individually the following applies:

The combined thickness of all layers (more and including 2 layers, see Figure 4, example b1), b2) and c)) providing relied upon insulation shall be in compliance with values according to Table 3 and Table 4 as applicable depending on class (see Table 1).

• RTI / RTE / TI shall be determined in the full layer stack or each layer providing relied upon insulation shall meet RTI / RTE / TI as defined in 5.5.2.3.3. Any changes in the stack or application require a new RTI / RTE / TI evaluation.

• Dielectric strength of entire multi-layer sheet providing relied upon insulation shall fulfill requirements for reinforced insulation.

A test procedure for dielectric strength test at the relied upon insulation can be found in 10.6 of IEC 60243-1:2013 and IEC 60243-2:2013. The DC test voltages are as follows:

• 1 000 V + 2 times system voltage for basic insulation;

• 2 000 V + 4 times system voltage for double or reinforced insulation.

5.6.4.3DV D2 *Modification by replacing the text of Clause 5.6.4.3 with the following:*

To ensure that the protection against electric shock is still provided after failure of either the double or reinforced insulation the insulation test (MST 16) after cut susceptibility test (MST 12) shall be performed as for basic insulation.

In the case of insulation constructed of thin layers of insulated material, the relied upon insulation shall be such that the following requirements are fulfilled:

a) Single-layer sheet [see also Figure 4, example (a)]

– RTI / RTE / TI as defined in 5.5.2.3.3.

– Dielectric strength for reinforced insulation.

b) Multi-layer sheets [see also Figure 4, examples for double layers b1), b2) and generic n-layers c))

Each layer of a multi-layer (e.g. 2 layers, see Figure 4, example (b1) and (b2)] sheet providing relied upon insulation shall meet the following requirements:

– RTI / RTE / TI as defined in 5.5.2.3.3.

– Dielectric strength for basic insulation.

If single layers are not characterized individually the following applies:

• RTI / RTE / TI shall be determined in the full layer stack or each layer providing relied upon insulation shall meet RTI / RTE / TI as defined in 5.5.2.3.3. Any changes in the stack or application require a new RTI / RTE / TI evaluation.

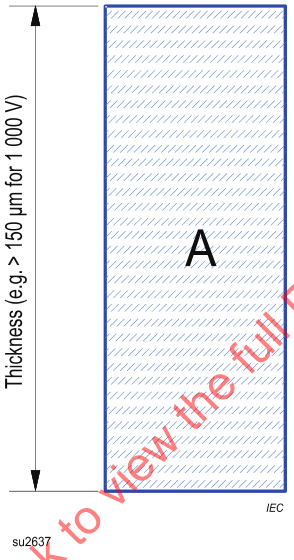
• Dielectric strength of entire multi-layer sheet providing relied upon insulation shall fulfill requirements for reinforced insulation.

A test procedure for dielectric strength test at the relied upon insulation can be found in 10.6 of IEC 60243-1:2013 and IEC 60243-2:2013. The DC test voltages are as follows:

• 1 000 V + 2 times system voltage for basic insulation;

• 2 000 V + 4 times system voltage for double or reinforced insulation.

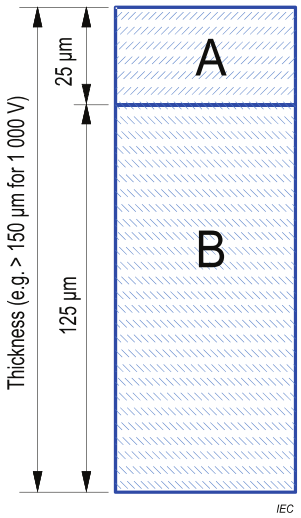
a) Single layer



Pass, if A fulfills the requirements of:

- 5.5.2.3.3
- MST 04
- reinforced insulation

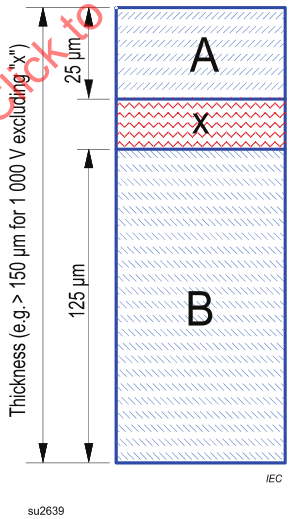
Multi layer
b1) Double layer



Pass, if each layer A and B (of single layers) fulfill the requirements of:

- 5.5.2.3.3
- MST 04
- basic insulation or reinforced insulation for full stack

b2) Double layer



Pass, if full stack fulfill the requirements of:

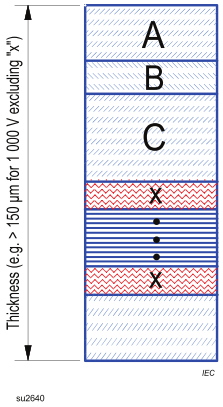
- 5.5.2.3.3
- MST 04
- reinforced insulation

or

if each layer A and B (of single layers) fulfill the requirements of:

- 5.5.2.3.3
- MST 04
- basic insulation
- "X"-layer which lies between insulation layers not considered as insulating layer

c) Generic multi layer



Pass, if full stack fulfill the requirements of:	or	if at least 2 layers each fulfill the requirements of:
• 5.5.2.3.3 • MST 04 • reinforced insulation		• 5.5.2.3.3 • MST 04 • basic insulation • "X"-layer which lies between insulation layers not considered as insulating layer

Figure 4

Examples for individual layer assessment for relied upon insulation

Figure 4DV D2 *Modification:*

Delete all references to MST 04.

Table 3

Distances through insulation, creepage distances (cr) and clearances (cl) for Class II PV modules

Between	pollution degree	≤35 V DC [a,d] cl	≤35 V DC cr Material group I	II	III	100 V DC [a] cl	100 V DC cr Material group I	II	III	150 V DC [a] cl	150 V DC cr Material group I	II	III	300 V DC [a] cl	300 V DC cr Material group I	II	III	600 V DC [a] cl	600 V DC cr Material group I	II	III	1 000 V DC [a] cl	1 000 V DC cr Material group I	II	III	1 500 V DC [a] cl	1 500 V DC cr Material group I	II	III
1a) Internal live parts and outer accessible surfaces	1		0,4				0,5				0,6				1,4				3,4				6,4				10,4		
	2	0,5 [b, c]	1,2	1,7	2,4	1,5 [b]	1,4	2,0	2,8	3,0 [b]	1,6	2,2	3,1	5,5 [b]	3,0	4,2	6,0	8,0 [b]	6,1	8,6	12,0	14,0 [b]	10,0	14,2	20,0	19,4 [b]	15,0	20,8	30,0
	3		3,0	3,4	3,8		3,6	4,0	4,4		3,9	4,3	4,9		7,5	8,5	9,4		15,2	17,1	19,1		25,0	28,0	32,0		37,7	41,7	47,1
1b) Thickness of thin layers (see 5.6.4.3)	-	0,01				0,01				0,01				0,01				0,06				0,15				0,3			
2) Live parts of different potential inside a PV module	1	0,1	0,2				0,3				0,3				0,7				1,7				3,2				5,2		
	2	0,2	0,6	1,0	1,2	0,5 [b, c]	0,7	1,0	1,4	1,5 [b]	0,8	1,1	1,6	3,0 [b]	1,5	2,1	3,0	5,5 [b]	3,0	4,3	6,0	8,0 [b]	5,0	7,1	10,0	11,0 [b]	7,5	10,4	15,0
	3	0,8	1,5	1,7	1,9		1,8	2,0	2,2		2,0	2,2	2,5		3,8	4,2	4,7		7,6	8,6	9,5		12,5	14,0	16,0		18,9	20,9	23,6
3) Terminals of different polarity of rewireable junction boxes	1		0,4				0,5				0,6				1,4				3,4				6,4				10,4		
	2	0,5 [b, c]	1,2	1,7	2,4	1,5 [b]	1,4	2,0	2,8	3,0 [b]	1,6	2,2	3,1	5,5 [b]	3,0	4,2	6,0	8,0 [b]	6,1	8,6	12,0	14,0 [b]	10,0	14,2	20,0	19,4 [b]	15,0	20,8	30,0
	3		3,0	3,4	3,8		3,6	4,0	4,4		3,9	4,3	4,9		7,5	8,5	9,4		15,2	17,1	19,1		25,0	28,0	32,0		37,7	41,7	47,1
4) Distance through cemented joints	-	0,2				0,3				0,5				1,0				1,5				2,0				3,5			

Distances in mm.

[a] For lines 1a), 1b), 3) and 4) the relevant voltage which is applicable shall be the system voltage. For line 2) the working voltage between parts of different potential at STC is relevant. All values given in this table are rounded to one digit from IEC 60664-1.

[b] If a measured clearance is smaller than the minimum required clearance an impulsive voltage test as specified in IEC 60664-1 shall show that the distance is adequate. To assess clearances between internal live parts and outer accessible surfaces IEC 61730-2, MST 14 may be applied.

[c] This value is increased to 0,8 mm for pollution degree 3.

[d] For designs where working voltage is below 20 V values directly from IEC 60664-1 can be applied.

su2635

Table 3DV D2 ***Modification of Table 3 in accordance with the following:***

– Delete the row labeled “1b) thickness of thin layers (see 5.6.4.3)”.

– Replace the voltage level given in the first column from "≤ 35 V DC" to "≤30 V DC".

Table 4

Distances through insulation, creepage distances (cr) and clearances (cl) for Class 0 and class III PV modules

		Distances mm																												
	pollution degree	≤35 V DC [a, d, e]				100 V DC [a]				150 V DC [a]				300 V DC [a]				600 V DC [a]				1 000 V DC [a]				1 500 V DC [a]			
		cl	cr			cl	cr			cl	cr			cl	cr			cl	cr			cl	cr			cl	cr		
			Material group				Material group				Material group				Material group				Material group				Material group				Material group		
Between			I	II	III		I	II	III		I	II	III		I	II	III		I	II	III		I	II	III		I	II	III
1a) Internal live parts and outer accessible surfaces	1	0,1	0,2			0,5 [b, c]	0,3			1,5 [b]	0,3			3,0 [b]	0,7			5,5 [b]	1,7			8,0 [b]	3,2			11,0 [b]	5,2		
	2	0,2	0,6	1,0	1,2		0,7	1,0	1,4		0,8	1,1	1,6		1,5	2,1	3,0		3,0	4,3	6,0		5,0	7,1	10,0		7,5	10,4	15,0
	3	0,8	1,5	1,7	1,9		1,8	2,0	2,2		2,0	2,2	2,5		3,8	4,2	4,7		7,6	8,6	9,5		12,5	14,0	16,0		18,9	20,9	23,6
1b) Thickness of thin laters (see 5.6.4.3)	-	0,01				0,01				0,01				0,01				0,06				0,15				0,3			
2) Live parts of different potential inside a PV module	1	0,1	0,2			0,5 [b, c]	0,3			1,5 [b]	0,3			3,0 [b]	0,7			5,5 [b]	1,7			8,0 [b]	3,2			11,0 [b]	5,2		
	2	0,2	0,6	1,0	1,2		0,7	1,0	1,4		0,8	1,1	1,6		1,5	2,1	3,0		3,0	4,3	6,0		5,0	7,1	10,0		7,5	10,4	15,0
	3	0,8	1,5	1,7	1,9		1,8	2,0	2,2		2,0	2,2	2,5		3,8	4,2	4,7		7,6	8,6	9,5		12,5	14,0	16,0		18,9	20,9	23,6
3) Terminals of different polarity of rewireable junction boxes	1		0,4			1,5 [b]	0,5			3,0 [b]	0,6			5,5 [b]	1,4			8,0	3,4			14,0 [b]	6,4			19,4 [b]	10,4		
	2	0,5 [b, c]	1,2	1,7	2,4		1,4	2,0	2,8		1,6	2,2	3,1		3,0	4,2	6,0		6,1	8,6	12,0		10,0	14,2	20,0		15,0	20,8	30,0
	3		3,0	3,4	3,8		3,6	4,0	4,4		3,9	4,3	4,9		7,5	8,5	9,4		15,2	17,1	19,1		25,0	28,0	32,0		37,7	41,7	47,1
4) Distance through cemented joints	-	0,1				0,2				0,25				0,5				0,7				1,0				1,7			

[a] For lines 1a), 1b), 3) and 4) the relevant voltage which is applicable shall be the system voltage. For line 2) the working voltage between parts of different potential at STC is relevant. All values given in this table are rounded to one digit from IEC 60664-1.

[b] If a measured clearance is smaller than the minimum required clearance an impulsive voltage test as specified in IEC 60664-1 shall show that the distance is adequate. To assess clearances between internal live parts and outer accessible surfaces IEC 61730-2, MST 14 may be applied.

[c] This value is increased to 0,8 mm for pollution degree 3.

[d] For class III PV modules only this column (≤ 35 V) and lines 2) and 3) apply.

[e] For designs where working voltage is below 20 V values directly from IEC 60664-1 can be applied.

su2636

Table 4DV D2 *Modification of Table 4 in accordance with the following:*

– Delete the row labeled “1b) thickness of thin layers” (see 5.6.4.3)”.

– Replace the voltage level given in the first column from "≤ 35 V DC" to "≤ 30 V DC".

– Delete the row labeled “4) Distance through cemented joints”.

– Replace Note (d) with “ For Class III PV modules only this column (≤ 30 V) and lines 2) and 3) apply.”