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colour inside

Concentrator photovoltaic (CPV) modules and assemblies – Safety qualification

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Concentrator photovoltaic (CPV) modules and assemblies – Safety qualification

INTERNATIONAL
ELECTROTECHNICAL
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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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CONCENTRATOR PHOTOVOLTAIC (CPV) MODULES AND ASSEMBLIES – SAFETY QUALIFICATION

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FDIS	Report on voting
82/1299/FDIS	82/1323/RVD

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

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CONCENTRATOR PHOTOVOLTAIC (CPV) MODULES AND ASSEMBLIES – SAFETY QUALIFICATION

1 Scope

This document describes the fundamental construction and testing requirements for Concentrator Photovoltaic (CPV) modules and assemblies in order to provide safe electrical and mechanical operation during their expected lifetime. Specific topics are provided to assess the prevention of electrical shock, fire hazards, and personal injury due to mechanical and environmental stresses.

This document attempts to define the basic requirements for various application classes of concentrator photovoltaic modules and assemblies, but it cannot be considered to encompass all national and regional codes.

This document is designed so that its test sequence can coordinate with those of IEC 62108, so that a single set of samples may be used to perform both the safety and performance evaluation of a CPV module and assembly.

CPV modules that are constructed in the flat plate module format and operate at 3X and less geometric concentration ratio are considered for evaluation to IEC 61730-1 and IEC 61730-2.

2 Normative references

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

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

IEC 60065, *Audio, video and similar electronic apparatus – Safety requirements*

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

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

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

IEC 60417, *Graphical symbols for use on equipment – 12-month subscription to regularly updated online database comprising all graphical symbols published in IEC 60417*

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

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

IEC TR 60664-2-1:2011, *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 60664-3:2016, *Insulation coordination for equipment within low-voltage systems – Part 3: Use of coating, potting or moulding for protection against pollution*

IEC 60695-1-10, *Fire hazard testing – Part 1-10: Guidance for assessing the fire hazard of electrotechnical products – General guidelines*

IEC 60695-1-11, *Fire hazard testing – Part 1-11: Guidance for assessing the fire hazard of electrotechnical products – Fire hazard assessment*

IEC 60695-2-10, *Fire hazard testing – Part 2-10: Glowing/hot-wire based test methods – Glow-wire apparatus and common test procedure*

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

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

IEC 60947-1, *Low-voltage switchgear and control gear – Part 1: General rules*

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

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

IEC 61140:2016, *Protection against electric shock – Common aspects for installation and equipment*

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

IEC 61508 (all parts), *Functional safety of electrical/electronic/programmable electronic safety-related systems*

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

IEC 61730-2:2016, *Photovoltaic (PV) module safety qualification – Part 2: Requirements for testing*

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

IEC 62108:2016, *Concentrator photovoltaic (CPV) modules and assemblies – Design qualification and type approval*

IEC 62305-2, *Protection against lightning – Part 2: Risk management*

IEC 62305-3, *Protection against lightning – Part 3: Physical damage to structures and life hazard*

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

IEC 62670-1, *Concentrator photovoltaic (CPV) performance testing – Part 1: Standard conditions*

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

IEC 62852:2014, *Connectors for DC-application in photovoltaic systems – Safety requirements and tests*

ISO 179-1, *Plastics – Determination of Charpy impact properties – Part 1: Non-instrumented impact test*

ISO 261, *ISO general-purpose metric screw threads – General plan*

ISO 262, *ISO general-purpose metric screw threads – Selected sizes for screws, bolts and nuts. Media and price*

ISO 527 (all parts), *Plastics – Determination of tensile properties*

ISO 834-1, *Fire-resistance tests – Elements of building construction – Part 1: General Requirements*

ISO TR 834-3, *Fire-resistance tests – Elements of building construction – Part 3: Commentary on test method and test data application* guide to the application of the outputs from the fire-resistance test

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 coatings – Electroplated coatings of zinc with supplementary treatments on iron or steel*

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

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

ISO 5657, *Reaction to fire tests – Ignitability of building products using a radiant heat source*

ISO 8124-1, *Safety of toys – Part 1: Safety aspects related to mechanical and physical properties*

ENV 1187-1 to -4, *Test methods for roof coverings under the influence of a thermal attack of burning brands and radiant heat*

ANSI/UL 790 (April 2004), *Standard Test Methods for Fire Tests of Roof Coverings*

ANSI/UL 746B, *Standard for Polymeric Materials – Long Term Property Evaluations*

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

UL 1703, *Standard for Flat-Plate Photovoltaic Modules and Panels*

ASTM E162-13, *Standard Test Method for Surface Flammability of Materials Using a Radiant Heat Energy Source*

ASTM D3755-14, *Standard Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials Under Direct-Voltage Stress*

ASTM D257-14, *Standard Test Methods for DC Resistance or Conductance of Insulating Materials*

ASTM D1002-10, *Standard Test Method for Apparent Shear Strength of Single-Lap-Joint Adhesively Bonded Metal Specimens by Tension Loading (Metal-to-Metal)*

EN 13501-1:2007 + A1, *Fire classification of construction products and building elements – Part 1: Classification using data from reaction to fire tests*

3 Terms and definitions

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

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

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

See Figure 1 to Figure 4 as schematics of various types of CPV.

3.1
concentrator
term associated with photovoltaic devices that use concentrated sunlight

3.2
concentrator cell
basic photovoltaic device that is used under the illumination of concentrated sunlight

3.3
concentrator optics
optical device that performs one or more of the following functions from its input to output: increasing the light intensity, filtering the spectrum, modifying light intensity distribution or changing light direction

Note 1 to entry: Typically, it is a lens or a mirror. A primary optics receives unconcentrated sunlight directly from the sun. A secondary optics receives concentrated or modified sunlight from another optical device, such as primary optics or another secondary optics.

3.4
concentrator receiver
group of one or more concentrator cells and secondary optics (if present) that accepts concentrated sunlight and incorporates the means for thermal and electric energy transfer

Note 1 to entry: A receiver could be made of several sub-receivers. The sub-receiver is a physically standalone, smaller portion of the full-size receiver.

3.5
concentrator module
group of receivers, optics, and other related components, such as interconnection and mounting, that accepts unconcentrated sunlight

Note 1 to entry: All of the above components are usually prefabricated as one unit, and the focus point is not field adjustable. A module could be made of several sub-modules. The sub-module is a physically stand-alone, smaller portion of the full-size module.

3.6
concentrator assembly
group of receivers, optics, and other related components, such as interconnection and mounting, that accepts unconcentrated sunlight

Note 1 to entry: All of the above components would usually be shipped separately and need some field installation, and the focus point is field adjustable. An assembly could be made of several sub-assemblies. The sub-assembly is a physically stand-alone, smaller portion of the full-size assembly.

3.7
normal condition
condition in which all means for protection against hazards are intact

3.8
single fault condition
condition in which one means for protection against a hazard is defective or one fault is present which could cause a hazard

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

3.10
clearance
shortest distance in air between two conductive parts

3.11
solid insulation
solid insulating material interposed between two conductive parts

3.12
cemented joint
insulating adhesive material that provides a reliable bond between two materials for which it has been evaluated to adhere

Note 1 to entry: Two separate materials that have been cemented together with an insulating adhesive material can be considered as a solid insulating material.

3.13
comparative tracking index
CTI
numerical value of the maximum voltage in volts which a material can withstand without tracking and without a persistent flame occurring under specified test conditions

3.14
transient overvoltage
short-duration overvoltage of few milliseconds or less, oscillatory or non-oscillatory, usually highly damped

Note 1 to entry: Transient overvoltages may be immediately followed by temporary overvoltages. In such cases the two overvoltages are considered as separate events.

Note 2 to entry: IEC 60071-1 defines three types of transient overvoltages, namely slow-front overvoltages, fast-front overvoltages and very fast-front overvoltages according to their time to peak, tail or total duration, and possible superimposed oscillations.

3.15
partial discharge
electric discharge that only partially bridges the insulation between conductors

Note 1 to entry: A partial discharge may occur inside the insulation or adjacent to a conductor.

Note 2 to entry: Scintillations of low energy on the surface of insulating materials are often described as partial discharges but should rather be considered as disruptive discharges of low energy, since they are the result of local dielectric breakdowns of high ionization density, or small arcs, according to the conventions of physics.

3.16
conformal coating <for printed wiring boards>
electric insulating coating applied to loaded printed wiring boards to produce a thin layer conforming to the surface to provide a protective barrier against deleterious environmental effects

3.17
pollution
any addition of foreign matter, solid, liquid or gaseous that can produce a permanent reduction of dielectric strength or surface resistivity of the insulation

Note 1 to entry: Ionized gases of a temporary nature are not considered to be a pollution.

3.18
electrical hazard
potential source of harm when electric energy is present in an electrical installation

Note 1 to entry: Limited in this document to 75 V DC or greater.

4 Sampling

For non-field-adjustable focus-point CPV systems or modules, at least 6 standard production modules are required to complete a full test protocol including all the specified tests, plus one special module, prepared for the bypass/blocking diode thermal test (intrusive or non-intrusive) and CPV temperature test. For details, see Figures 7 and 8 and. Sample size has been optimized to reduce number of samples in a combined program with IEC 62108.

For field-adjustable focus-point CPV systems or assemblies, at least 7 receivers (including secondary optics sections, if applicable) and at least 9 primary optics – referred to hereinafter as mirrors – are required to complete all the specified tests, plus one special receiver for the bypass/blocking diode thermal test (intrusive or non-intrusive).

For details, see Figures 9 and 10. Sample size has been optimized to reduce number of samples in a combined program with IEC 62108.

In the case that a full-size module or assembly is too large to fit into available testing equipment, such as environmental chambers, or a full-size module or assembly is too expensive (e.g., for a 20 kW reflective dish concentrator system, 9 receiver samples account for 180 kW of PV cells), a smaller representative sample may be used. However, even if representative samples are used for the other test, a full-size module or assembly should be installed and tested for outdoor exposure. This can be conducted either in the testing lab, or through on-site witness.

Representative samples shall include all components, except some repeated parts. If possible, the representative samples should use sub-receivers, sub-modules, or subassemblies. During the design and manufacturing of the representative samples, much attention shall be paid to reach the maximum similarity to the full-size component in all electrical, mechanical, and thermal characteristics related to quality and reliability. Specifically, the cell string in representative samples should be long enough to include at least two bypass diodes, but in no case less than ten cells. The encapsulations, interconnects, terminations, and the clearance distances around all edges shall be the same as on the actual full-size products. Other representative components, including lens/housing joints, receiver/housing joints, and end plate/lens shall also be included and tested.

Test samples should be taken at random from a production batch or batches. When the samples to be tested are prototypes of a new design and not from production, or representative samples are used, these facts shall be noted in the test report (see Clause 6).

The test samples shall have been manufactured from specified materials and components in accordance with the relevant drawings and process instructions and have been subjected to the manufacturer's normal inspection, quality control, and production acceptance procedures. They shall be complete in every detail and be accompanied by the manufacturer's handling, mounting, connection, and operation manuals. Samples shall not be subjected to other special procedures that are not a part of standard production.

If the intrusive bypass/blocking diode thermal test is to be performed, an additional specially manufactured receiver or module is required with extra electrical and thermal detector leads so that each individual diode can be accessed separately.

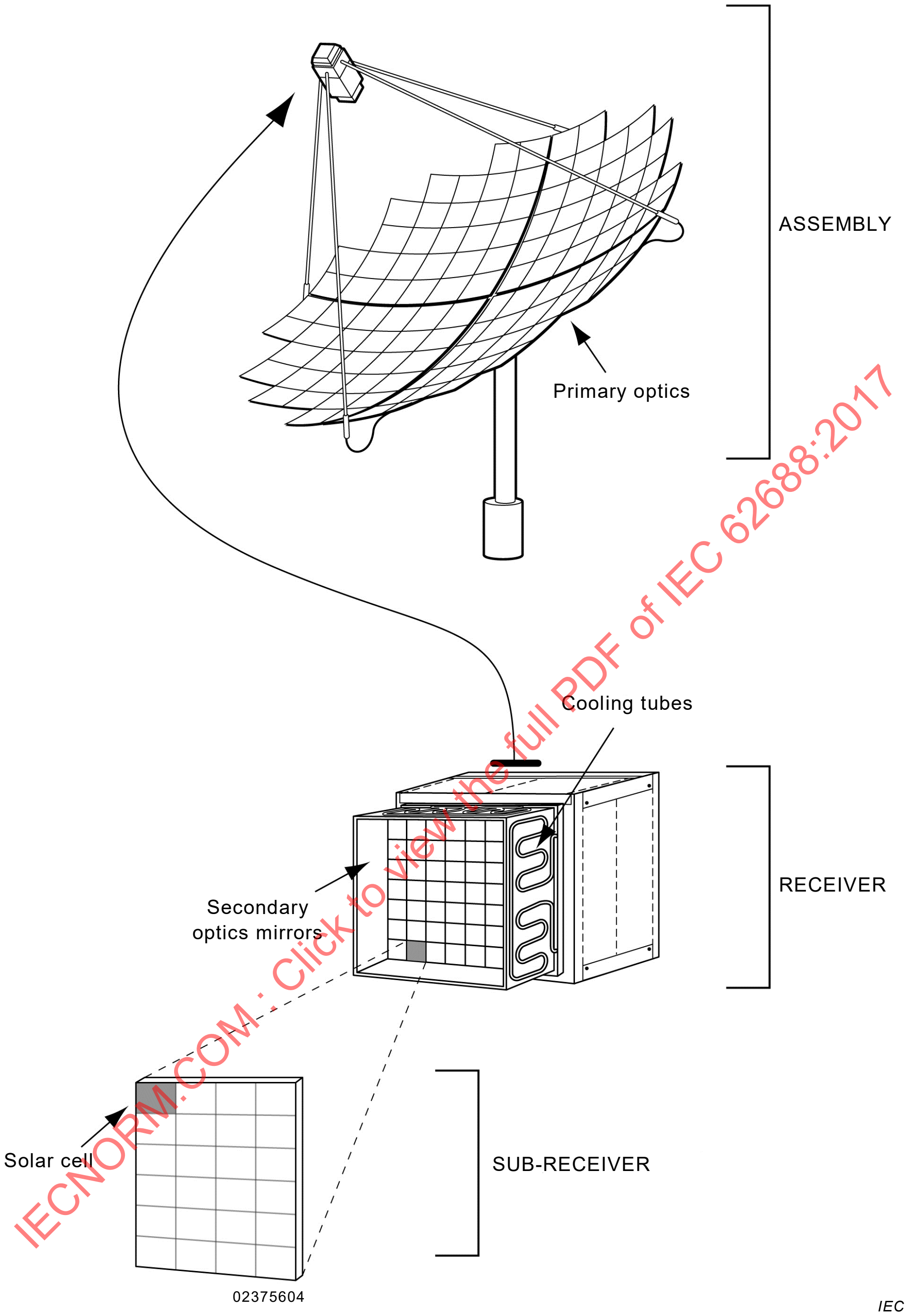


Figure 1 – Schematic of a point focus dish PV concentrator

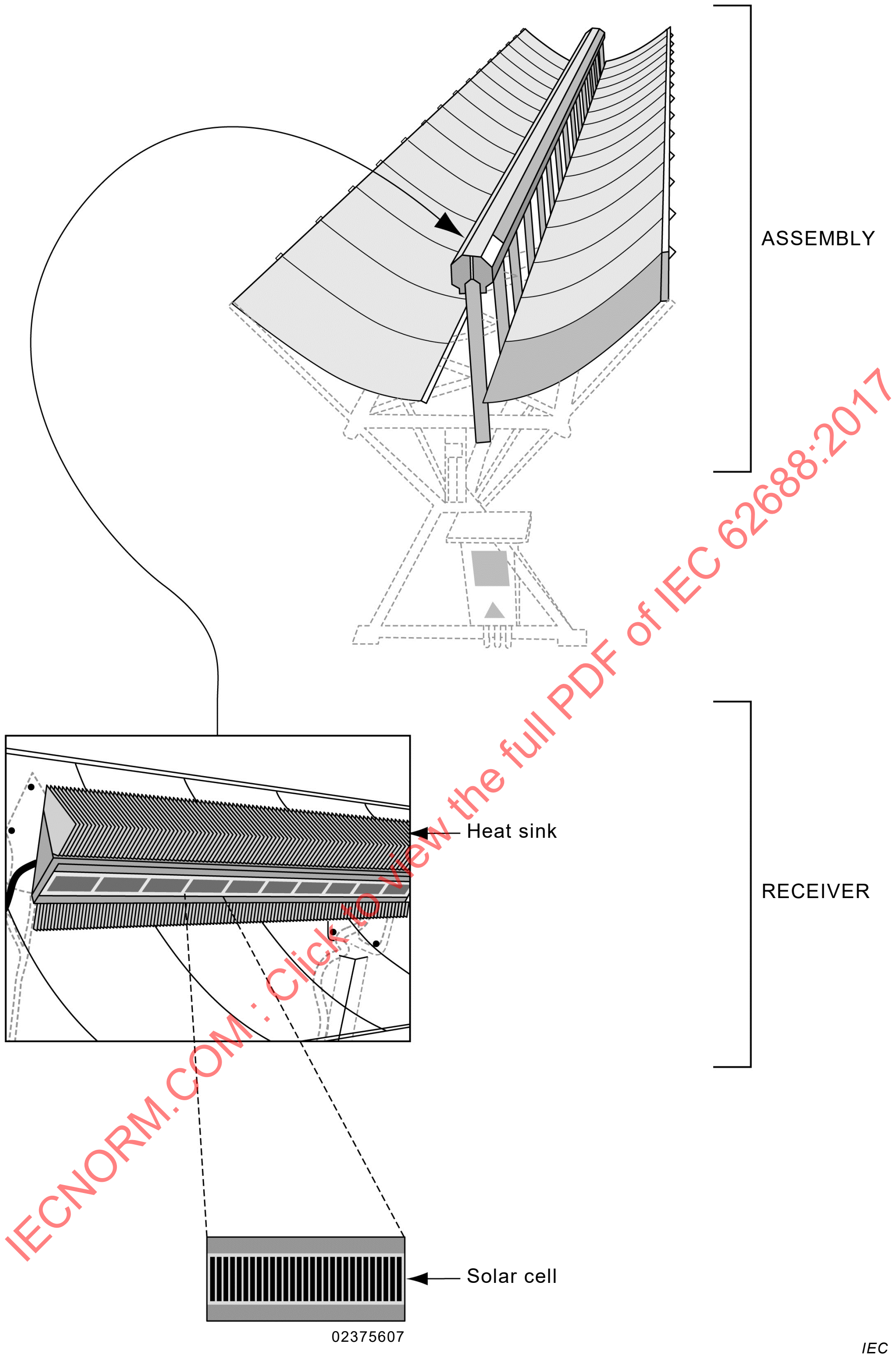


Figure 2 – Schematic of a linear focus trough PV concentrator

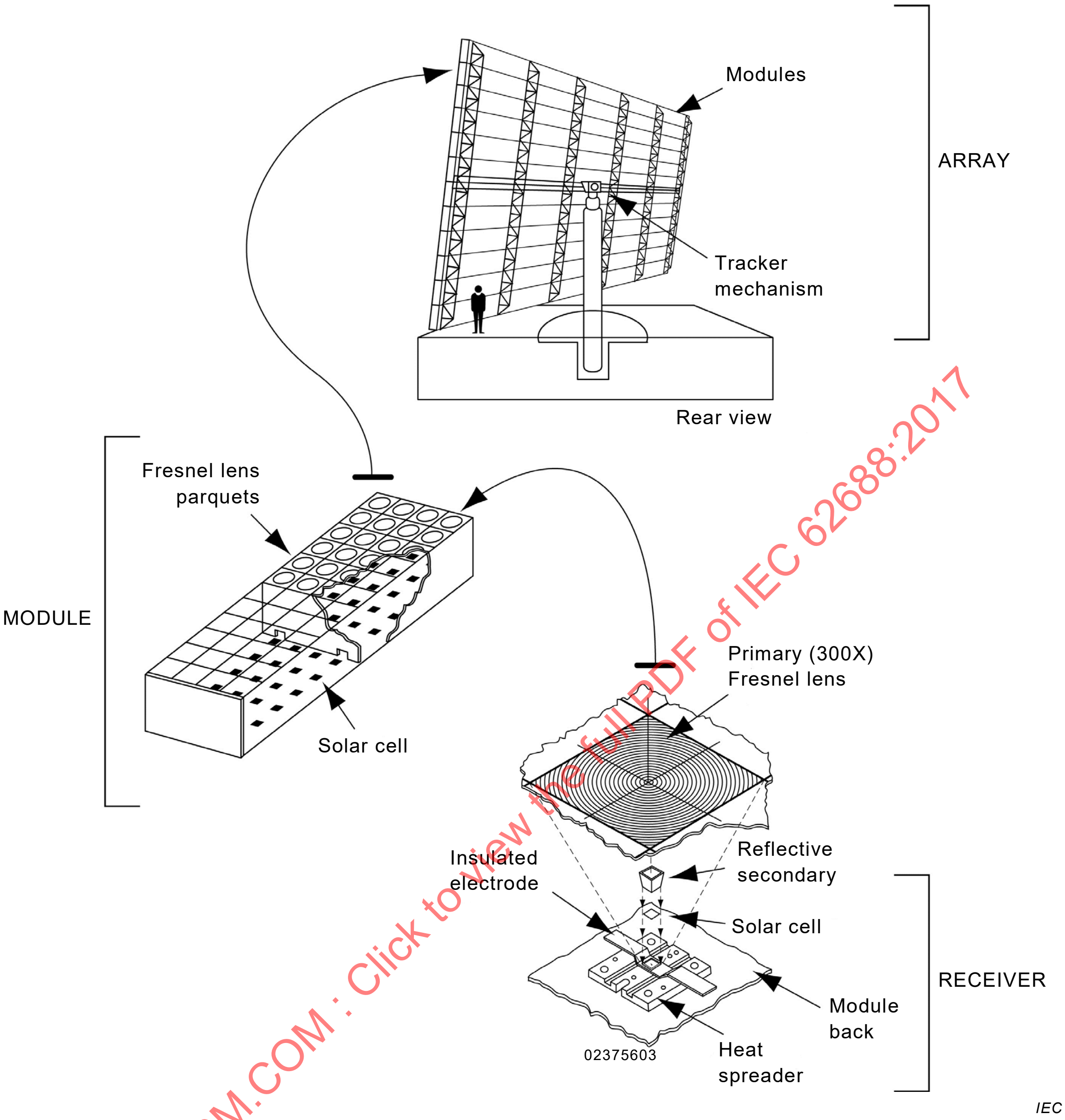


Figure 3 – Schematic of a point focus Fresnel lens PV concentrator

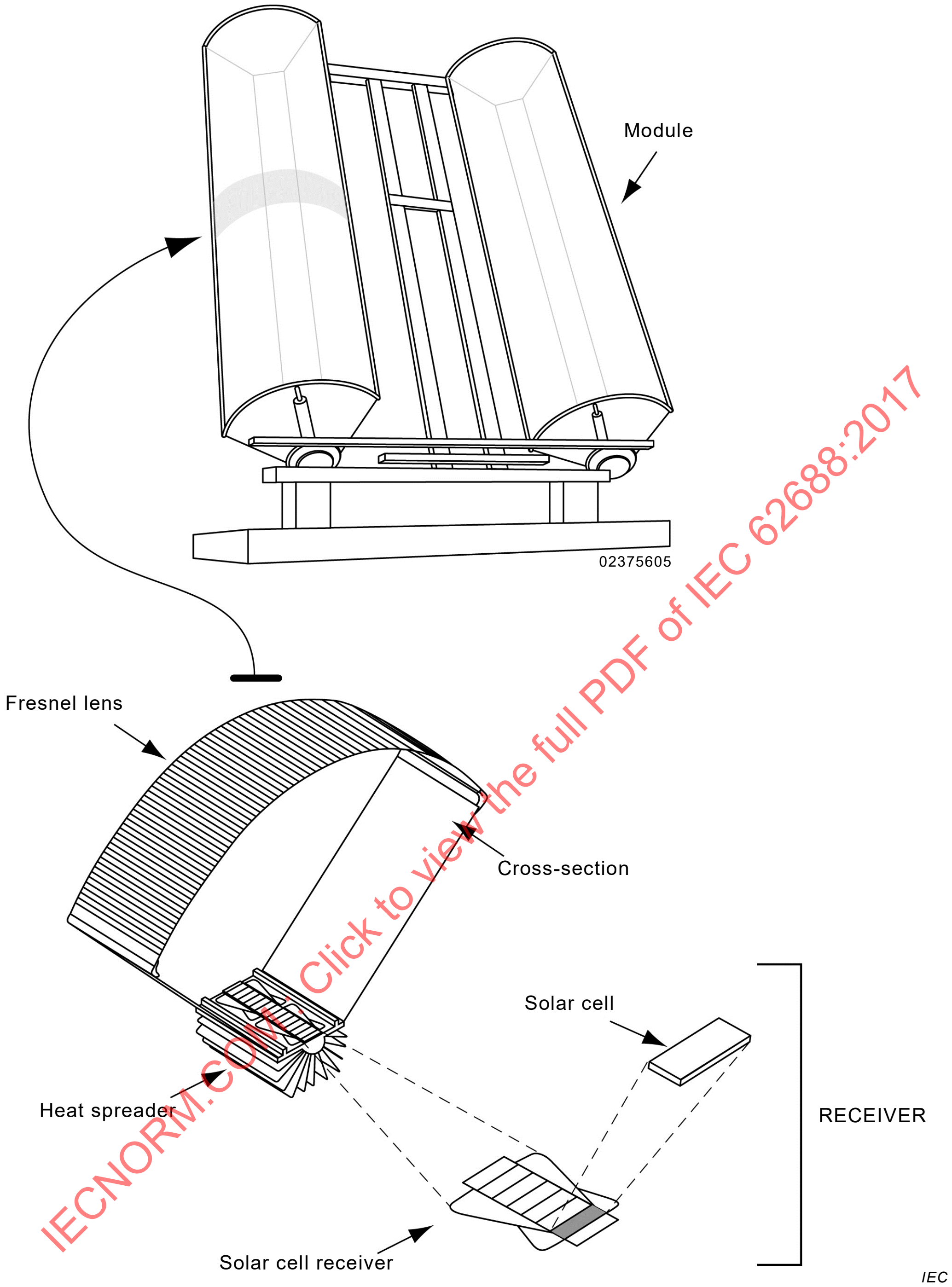


Figure 4 – Schematic of a linear focus Fresnel lens PV concentrator

5 Marking

5.1 Nameplate

Each module or assembly shall carry the following clear and indelible markings:

- name, monogram or symbol of the manufacturer;
- type or model number;
- serial number;
- polarity of terminals or leads (colour coding is permissible);

- maximum system voltage;
- application class of product;
- maximum over-current protection rating, as verified by the reverse current overload test;
- nominal values of maximum output power at concentrator standard operating conditions (CSOC) as defined in IEC 62670-1 specified for the product type after preconditioning;
- rated voltage at open-circuit at CSOC;
- rated current at short-circuit at CSOC;
- β, the temperature coefficient of open circuit voltage.

The date and place of manufacture shall be marked on the module or be traceable from the serial number.

CSOC (Concentrator Standard Operating Conditions)

- Irradiance: 900 W/m^2 direct normal irradiance.
- Temperature: 20 °C local ambient temperature.
- Spectrum: Direct normal AM1.5 spectral irradiance distribution consistent with conditions described in IEC 60904-3.
- Wind speed: 2 m/s

5.2 Hazards

5.2.1 High intensity light

Where there is a possibility of eye hazard from high intensity reflected or direct beam light – based on proximity, a sign shall be located in an area near the system and be legibly marked with the following words, or equivalent:

"CAUTION: HIGH INTENSITY LIGHT – This product reflects or concentrates light at high concentration – Use appropriate eye protection when near"

If a unit allows access to concentrated irradiance above a maximum geometric ratio of 3X, there shall be marking located in the vicinity of the hazard, where readily visible, with the following words, or equivalent:

"CAUTION: HIGH INTENSITY LIGHT – To reduce the risk of burns – Keep away"

5.2.2 Field connections

Connectors not rated for disconnection under load shall be marked (see Figure 5):

"CAUTION: Do not disconnect under load"

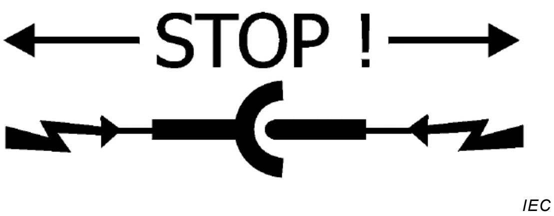


Figure 5 – Field connection warning label

[Image Ref: IEC 62852, Figure A.1]

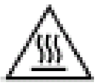
5.2.3 Hot surfaces

A unit that exceeds the temperature limits specified in Table 1 shall be legibly marked, where readily visible after installation, with the words, or equivalent (see Figure 6):

"CAUTION: HOT SURFACES – To reduce the risk of burns – DO NOT TOUCH"

Accessible surfaces shall not exceed the values of Table 1 below in normal condition, or 105 °C in single fault condition, at an ambient temperature of 40 °C, or the maximum rated ambient temperature if higher.

If accessible heated surfaces are necessary for functional reasons, they are permitted to exceed the values of Table 1 below in normal condition and to exceed 105 °C in single fault condition, provided that they are recognizable as such by appearance or function or are marked with symbol below.

	IEC 60417 – 5041	Caution, hot surface

IEC

Figure 6 – Symbol for hot surface can be used

Surfaces protected by guards that prevent them from being touched accidentally are not considered to be easily touched surfaces, provided that the guards cannot be removed without the use of a tool.

Table 1 – Touch temperature limits

Part	Limit °C
1 Outer surface enclosure	
a) Metallic	70
b) Non-metallic	80
c) Small areas that are not likely to be touched in normal use	100

NOTE If a single fault condition results unavoidably in another single fault condition, the two failures are considered as one single fault condition.

6 Report

Following completion of the procedure, a certified report of the tests shall be prepared by the test agency. Each certificate or test report shall include at least the following information.

a) a title;
b) name and address of the test laboratory and location (including latitude and altitude) where the tests were carried out;
c) unique identification of the certification or report and of each page;
d) name and address of client, where appropriate;
e) description and identification of the item tested;
f) characterization and condition of the test item;
g) date of receipt of test item and date(s) of test, where appropriate;
h) identification of test method used;
i) reference to sampling procedure, where relevant;

j) any deviations from, additions to or exclusions from the calibration or test method, and any other information relevant to a specific calibration or test, such as environmental conditions. Details of the test procedure including the bias (e.g. maximum power or open circuit) maintained between test scans and how the data was filtered to meet the specified criteria;

k) a signature and title, or equivalent identification of the person(s) accepting responsibility for the content of the certificate or report, and the date of issue;

l) where relevant, a statement to the effect that the results relate only to the items calibrated or tested;

m) a statement that the certificate or report shall not be reproduced except in full, without the written approval of the laboratory.

7 Requirements for construction – Module application classes

7.1 General

Photovoltaic modules may be installed in many different applications and system configurations. Therefore, it is important to evaluate the potential hazards associated with use of modules in those applications to facilitate the necessary module construction evaluation. Relevant safety requirements and necessary tests shall be performed to verify the conformance to the requirements of that application class.

Classes for sources and circuits are defined within IEC 61140. Module classifications define acceptable module use and applications which are based upon the module's system voltage rating and protection from live parts. The following PV module applications classes are based upon the requirements of IEC 61140.

PV module application classes assume the proper installation and use of the equipment within its ratings and the requirements defined within this standard. Additional information on these Voltage limits and energy limits are included in Annex A.

Field history has shown that failures resulting from improper installation practices, rodent and weather related damage and premature material degradation can lead to isolation faults of live parts to accessible metal on and around all types and classes of PV modules, including Class II modules. To address this hazard, accessible conductive PV module surfaces such as frames, mounting rails and mounting structures are required to be provided with a functional ground connection to allow PV system protection equipment to operate properly and identify and mitigate module and wiring isolation failures that can lead to shock and fire hazards. This grounding practice is consistent with the requirements IEC 62548.

7.2 Class II – general access, hazardous voltage, current and power, double insulated/reinforced insulation

7.2.1 Electrical output

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

7.2.2 Protection

These modules provide two independent protective provisions that shall have no influence on each other such that – a failure of one of the protective provisions cannot impair the other. Class II is based upon the premise that simultaneous failure of the two independent protective provisions is unlikely and need not normally be taken into consideration. Reliance is placed on one of the protective provisions remaining effective.

7.2.3 Application

These modules are intended for installation where general user access and contact to insulated parts is anticipated. Class II modules are evaluated based on the safety requirements of Class II, double or reinforced insulation, as classified according to IEC 61140.

7.3 Class 0 – Restricted access, hazardous voltage, current and power basic insulation only with no protection from faults

7.3.1 Electrical output

Class 0 modules have individual and or system level electrical outputs at hazardous levels of voltage (greater than 75 V DC) and current.

7.3.2 Protection

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

7.3.3 Application

Class 0 modules are intended for use in restricted areas that are protected from public access by fences or other features of the location that prevent general access. They are only to be accessed by persons knowledgeable of the inherent hazards associated with their use and failure modes. Accessible metal on a Class 0 module is intended to be earthed or considered to be at hazardous potential. Class 0 modules are evaluated based on the safety requirements of Class 0, basic insulation, as classified according to IEC 61140.

7.4 Class 0-X – additional fire or concentrated light hazard

The extension "-X" is used for Class 0 modules that class incorporate an unmitigated fire or concentrated light hazard and shall be installed over a non-combustible surface.

7.5 Class III – general access limited voltage, current and power

7.5.1 Electrical output

Class III modules have a limited output voltage, current and power. Class III modules shall not have electrical output greater than 75 V DC, 240 W and 8 A I_{sc} when tested under concentrator standard test conditions.

NOTE The energy hazards and electric shock limits for PV systems equipment are defined in IEC 62109-1. These limits are derived from IEC 60950 and IEC 61010 for wet location, accessible voltage limits and current limits for inherently limited power sources, Table 2B.

7.5.2 Protection

Based upon the Class III module inherently limited electrical output capability 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, isolation or safety testing of Class III modules.

7.5.3 Application

Class III modules are intended for installation where general user access and contact to un-insulated parts is anticipated. Class III modules shall not be combined in series strings operating at more than 75 V DC and shall not have a system voltage rating above 75 V DC. These modules are not intended for use in parallel with other modules or energy sources unless the combination provides protection from back fed current and overvoltage protection.

7.6 Fire safety

It shall be noted that fundamental requirements for fire safety are not internationally harmonised. It is therefore not possible to define general requirements for fire safety for CPV modules as recognition of test results is commonly not practiced.

CPV Modules may be installed with the notice “Not fire rated”. However, these modules shall be evaluated by the local authority and additional restrictions may apply.

Fire tests described for flat-plate PV modules are generally applicable for flat-plate profile receivers of CPV assemblies. However, the tests shall be conducted with the receivers in a configuration that they are used – as agreed between the manufacturer and certifying authority.

Applicable fire testing may be required by local codes but are not covered in this document.

8 Construction

Incorporation of a module or assembly into the final form shall not require any alteration of the module or assembly from its originally evaluated form, unless specific details describing necessary modification(s) are provided in the installation instructions.

9 Modifications

Any changes in design, materials, components, or processing of the modules and assemblies may require a repetition of some or all of the qualification tests to maintain type approval. Manufacturers shall report to and discuss with the certifying body and testing agency every change that has been made to a previously qualified design.

10 Requirements for supplied documents

10.1 General

A module or assembly shall be supplied with installation instructions describing the methods of electrical and mechanical installation and its associated electrical ratings. The instructions shall state the application class under which the module was qualified and any specific limitations required for that application class.

10.2 Fire

When the fire rating is dependent on a specific mounting structure, specific spacing, or specific means of attachment to the roof or structure, details of the specific parameter or parameters shall be included in the instructions.

10.3 Electrical

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

- the grounding method(s) to be used. All provided or specified hardware shall be identified in the instruction manual;
- the size, type, material and temperature rating of the conductors to be used;
- maximum series/parallel module configurations;
- the type of overcurrent protection and diode bypassing to be used (if applicable);
- the minimum cable diameters when the wiring method is cable;

- any limitations on wiring methods that apply to the wiring compartment or box.

10.4 Mechanical

The mechanical installation instructions for roof mounting shall include:

- a statement indicating the minimum mechanical means for securing the module to the tracker (as evaluated during the mechanical load test);
- a statement indicating the fire test, fire rating (s) and installation slope or other applicable installation information as defined by the fire test.

10.5 Temperature

Results of the temperature test indicating the expected maximum temperature the module may reach in a restricted cooling configuration.

10.6 Field assembly

Assembly instructions shall be provided with a product shipped in subassemblies, and shall be detailed and adequate to the degree required to facilitate total assembly of the product.

10.7 Component ratings

To allow for increased output of a module resulting from certain conditions of use, the installation instructions shall include the following statement or equivalent:

"Under normal conditions, a photovoltaic device is likely to experience conditions that produce more current and/or voltage than reported at concentrator standard operating conditions. Accordingly, the values of I_{sc} and V_{oc} marked on this module shall be multiplied by a factor of 1,25 when determining component voltage ratings, conductor current ratings, and size of controls connected to the CPV output."

11 Overcurrent protection

The module overcurrent protection rating shall be greater than 1,56 times the modules rated short-circuit current, I_{sc}, at CSOC (DNI = 900 W/m^2). If the rating does not match a commercially available overcurrent device rating, the overcurrent protection rating shall be rated for the next larger commercially available overcurrent rated device.

The reverse current overload test is performed at 135 % of this overcurrent protection rating.

NOTE 1 1,56 = 1,25 x 1,25 and is derived from 1,25 multiplier for high irradiance conditions and the second 1,25 for fuse derating to prevent overheating of the fuse element and fuse holder and nuisance tripping.

NOTE 2 I_{sc} at CSOC rating was chosen as the base because effects like snow and/or cloud enhancement are not possible for CPV unlike for flat-plate PV.

EXAMPLE

I_{sc} = 8,5 A

x 125 % high irradiance

x 125 % derating of fuse requirement per local code

= 13,26 A fuse

15 A fuse rating.

12 Metal parts

12.1 Combinations of metals

Combinations of metals in direct contact with each other shall not generate a potential greater than 0,6 V. See Annex A for guidance on dissimilar metals.

12.2 Corrosion protection

Iron or mild steel serving as a necessary part of the product shall be plated, painted, or enamelled for protection against corrosion. The corrosion protection shall be equivalent to or greater than a zinc coating of 0,015 mm or cadmium coating of 0,0254 mm thickness. Corrosion protection means shall comply with ISO 1456, ISO 1461, ISO 2081 or ISO 2093.

Simple sheared or cut edges and punched holes are not required to be additionally protected.

Certain applications or installation locations may require other metal coatings to prevent corrosion.

12.3 Edges

Simple sheared or cut edges and punched holes are not required to be additionally protected.

All accessible materials shall be free from sharp edges (IEC 60950-1).

13 Polymeric materials

13.1 General

13.1.1 Overview

Materials used in the construction of the CPV module or assembly shall be selected and arranged so that they remain within their manufacturer’s ratings under normal operating conditions and can be expected to perform in a reliable manner without creating a mechanical, shock and / or fire hazard.

Any requirements regarding fire hazards of polymers shall be compatible or consistent with the fact that modules of module application class 0-X may be installed with the notice “not fire rated”, as described in 7.3 and 7.6.

Polymer samples shall be prepared as required by the test methods listed below, whenever possible from polymer parts built into the CPV module or assembly. If it is not possible to prepare appropriate polymer samples from parts, they may be produced by injection moulding, extrusion or other means of moulding.

13.1.2 Solid insulation and cemented joints

Tests shall be performed on components and subassemblies using solid insulation, in order to ensure that the insulation performance has not been compromised by the design or manufacturing process. Where the path between conductive parts is filled with layers of insulating material, and the adhesion of the insulating composite forms a cemented joint between two different non-conductive parts, the cemented joint shall be verified to show the layered material meets solid insulation in accordance with 17.3.5.

Where the path between conductive parts is filled with layers of insulating material, and the adhesion of the insulating composite forms a cemented joint between two different non-conductive parts, the cemented joint shall be considered as an encapsulant, in which properties of solid insulation may be proven through the test methods of IEC 60664-1.

A solid insulation material that serves more than one operational category shall comply with all applicable requirements and/or the more stringent of common requirements.

Printed circuit board type receivers may be evaluated for type 2 protection as described in IEC 60664-3. Type 2 protection is considered to be similar to solid insulation. Under the protection, the requirements for solid insulation specified in IEC 60664-1 are applicable and the spacings shall be not less than those specified in Table 1 of IEC 60664-3:2016. The requirements for clearances and creepage distances in IEC 60664-1 or IEC TR 60664-2-1:2011 do not apply. Between two conductive parts, it is a requirement that both conductive parts, together with all the spacings between them, are covered by the protection so that no air gap exists between the protective material, the conductive parts and the printed board.

13.1.3 Requirements for polymers

13.1.3.1 Thermal endurance

Solid insulation shall not be impaired by short-term heating stresses which may occur in normal and, where appropriate, abnormal use. Solid 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 ANSI/UL 746B equal to or greater than the maximum measured normalized operating temperature of the material as measured during the temperature test described in IEC 61730-2, MST 21, or a minimum of 90 °C, whichever is higher.

13.1.3.2 UV weathering resistance

Those materials that will be directly exposed to UV irradiation during normal operation shall be tested for UV exposure using a Xenon arc lamp instrument according to ISO 4892-2:2013, using method A, cycle 1 or cycle 4, at spectral irradiance of 0,51 (W/m^{2})/nm (at 340 nm) or at irradiance of 60 W/m^{2} (in the wavelength range from 300 nm to 400 nm), test duration 1 000 h. Those materials that will be exposed via transmission through other components shall be tested to the same level, but may be tested in a test package of similar geometry as exposure in the field so the UV shall penetrate through the same materials as occurs in the field. Those materials that will be exposed to indirect or reflected light shall be tested via the same procedure from ISO 4892-2, but with test duration of 350 h.

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

Compliance is checked by examination of the construction and examination of data regarding the UV resistance characteristics of the insulation material and any associated protective coating as described in this standard and the material tests after the exposure defined in this section.

Polymeric solid insulation material shall maintain 85 % of the tensile strength (per ISO 527) and impact strength (per ISO 179-1) measured as received after UV weathering test if the material will be exposed to direct or indirect sunlight in the module specified installation orientation and maintain at least 50 % of the tensile strength and impact strength measured as received after the water immersion test.

13.1.3.3 Flammability

Polymers involved in functions that are susceptible to combustion shall have flammability ratings. Flammability ratings are determined by methods described in IEC 60695-11-20, either by material test or testing in the end product design. For modules meeting application Class II and installed on or near dwellings, a flammability rating of 5-V is needed. For application Classes 0 and III, a flammability rating of HB is required.

Polymers serving in functions that are susceptible to combustion, but protected by external components that have suitable flammability ratings, are not required to have flammability ratings. Proof of protection can be determined through the burning brand as described in 20.19. For modules intended to be installed on or near dwellings, evaluated to application Class II, a Class II burning brand test is required. For all other scenarios, a Class III test is required.

13.1.3.4 Radiant panel index

Polymeric materials used as accessible surfaces of a receiver or as encapsulants shall have a maximum radiant panel index of 100 in accordance with ASTM E162-13. If possible, the test shall be executed with the test sample mounted about the substrate material of the end-product. Otherwise, the test may be performed using aluminium foil-wrapped hardboard.

If the requirements of spread of flame and flame spread index are not met, the module or assembly shall be appropriately marked as "Not fire rated" as described in 13.1.

13.1.3.5 Hot wire ignition

Polymeric materials in contact with live parts shall have a minimum resistance to hot wire ignition rating of 30 (IEC 60695-1-10, IEC 60695-1-11, IEC TS 60695-2-20).

Exception: Materials used in modules that comply with the reverse current overload test are not required to have a hot wire ignition rating.

13.1.3.6 Comparative tracking index

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

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

13.1.3.7 Dielectric strength

CPV materials relied upon as solid insulation shall have a minimum material dielectric strength rating for a specific use thickness of four (4) times the rated voltage plus 2 000 V after dry as received conditions of 40 h at (23 ± 2) °C, 50 % ± 5 % relative humidity and after wet exposure conditions of 96 h at (35 ± 2) °C, 90 % ± 5 % relative humidity, in accordance with IEC 60243-2.

13.1.4 Operational categories for CPV modules and assemblies

Material requirements are intended to provide evidence of performance appropriate to its application(s) in the module or assembly construction and environment.

Polymers are classified to serve in the following operational categories:

- an enclosure for live parts 13.2;
- direct support of (in contact with) live parts 13.3;
- an outer surface for a receiver 13.4;
- an internal electrical barrier providing the sole insulation between live parts 13.5;
- encapsulants 13.6;
- adhesives for attachment 13.7;

- moisture barriers 13.8;
- gaskets or seals 13.9;
- frames 13.10;
- optics 13.11;
- mechanical support for CPV optics 13.12;
- polymers potentially exposed to direct concentrated light 13.13.

13.2 Polymers serving as an enclosure for live parts (such as a junction box, connector, or plug)

A polymeric material serving as the enclosure of a part involving a risk of fire or electric shock shall comply with the requirements of:

- 13.1.3.1, Thermal endurance
- 13.1.3.2, UV weathering resistance
- 13.1.3.3, Flammability, following water exposure and immersion
- 13.1.3.5, Hot wire ignition
- 13.1.3.7, Dielectric strength, if replied upon as solid insulation

The material shall have a thermal endurance index (TI) or relative thermal endurance index (RTE) as determined in accordance with IEC 60216 of at least 90 °C, and at least the measured polymer temperature in the CPV Temperature test. RTI (relative thermal index, UL 746C) is acceptable in lieu of RTE or TI.

NOTE Enclosures that comply with IEC 62790 (EN 50548) meet the requirements of this subclause, with the exception of 13.13.

13.3 Polymers serving in direct support of live parts (such as integrated terminals and potting compounds)

A polymeric material serving as the support or insulation of a part involving a risk of fire or electric shock shall comply with the requirements of:

- 13.1.3.3, Flammability
- 13.1.3.5, Hot wire ignition
- 13.1.3.6, Comparative tracking index

The above ratings are not required if the polymer is located between and in direct contact with non-combustible components (such as glass), or that have flammability ratings as described in 13.1.3.3.

The material shall have a thermal endurance index (TI) or relative thermal endurance index (RTE) as determined in accordance with IEC 60216 of at least 90 °C, and at least the measured polymer temperature in the CPV Temperature test. RTI (relative thermal index, UL 746C) is acceptable in lieu of RTE or TI.

13.4 Polymers serving as an outer surface of a receiver (such as a front sheet or back sheet on a flat-plate profile receiver in a medium-X assembly)

A polymeric material serving as the outer surface of a receiver shall comply with the requirements of:

- 13.1.3.2, UV weathering resistance
- 13.1.3.4, Radiant panel index
- 13.1.3.5, Hot wire ignition

- 13.1.3.7, Dielectric strength, if replied upon as solid insulation

13.5 Polymers serving as an internal electrical barrier providing the sole insulation between live parts

A polymeric material serving as an internal electrical barrier providing the sole insulation between live parts shall comply with the requirements of:

- 13.1.3.1, Thermal endurance
- 13.1.3.3, Flammability, see note
- 13.1.3.5, Hot wire ignition, see note
- 13.1.3.6, Comparative tracking index, see note

NOTE The above ratings are not required if the polymer is located between and in direct contact with non-combustible components (such as glass), or that have flammability ratings as described in 13.1.3.3.

The material shall have a thermal endurance index (TI) or relative thermal endurance index (RTE) as determined in accordance with IEC 60216 of at least 90 °C, and at least the measured polymer temperature in the CPV temperature test. RTI (relative thermal index, UL 746C) is acceptable in lieu of RTE or TI.

13.6 Polymers serving as encapsulants

A polymeric material serving as an encapsulant shall comply with the requirements of:

- 13.1.3.4, Radiant panel index, see note
- 13.1.3.2, UV weathering resistance, if directly exposed to sunlight
- 13.1.3.7, Dielectric strength, if replied upon as solid insulation

NOTE The above ratings are not required if the polymer is located between and in direct contact with non-combustible components (such as glass), or that have flammability ratings as described in 13.1.3.3.

Protection by any kind of encapsulation as coating, potting or moulding including any type of film material or liquid processed systems or equivalent protection of insulating material on one side or both sides of the assemblies may be assessed for solid insulation properties, according to IEC 60664-3. IEC 60664-3 applies for the reduction of the dimensioning of clearance and creepage distances under certain condition to rigid assemblies such as printed boards or terminals of components.

13.7 Polymers serving as adhesives for attachment (such as for a junction box)

A polymeric material serving as adhesives for attachment shall comply with the requirements of:

- 13.1.3.2, UV weathering resistance, if directly exposed to sunlight
- 13.1.3.3, Flammability, see note

NOTE The above ratings are not required if the polymer is located between and in direct contact with non-combustible components (such as glass), or that have flammability ratings as described in 13.1.3.3.

13.8 Polymers serving as moisture barriers (such as edge sealants)

A polymeric material serving as moisture barriers shall comply with the requirements of:

- 13.1.3.1, Thermal endurance
- 13.1.3.2, UV weathering resistance, if directly exposed to sunlight

13.9 Polymers serving as gaskets or seals (such as with front glass)

A polymeric material serving as gaskets or seals shall comply with the requirements of UL 1703 section 34 (or IEC 61730-1).

13.10 Polymers serving as frames (such as with flat-plate profile medium-concentration receivers)

A polymeric material serving as frames shall comply with the requirements of:

- 13.1.3.1, Thermal endurance
- 13.1.3.2, UV weathering resistance, if directly exposed to sunlight
- 13.1.3.3, Flammability

13.11 Polymers serving as CPV optics

Polymers serving as CPV optics shall fulfil the requirements of 10.1 of IEC 62108:2016 following environmental stressing as defined in IEC 62108.

13.12 Polymers exposed to sunlight, serving as a mechanical support, not functioning in categories 13.2 to 13.11

- The polymer shall meet the requirements of IEC 62108:2016, 10.1 after 1 000 h of weathering in accordance with ISO 4892-2.
- If the failure of the mechanical support results in electrical shock, fire hazard, or personal injury, the material shall have a thermal endurance index (TI) or relative thermal endurance index (RTE) for mechanical properties as determined in accordance with IEC 60216 of at least 90 °C, and at least the measured polymer temperature in the CPV temperature test. RTI (relative thermal index, UL 746C) is acceptable in lieu of RTE or TI.

13.13 Polymers exposed to concentrated sunlight

Modules or assemblies with polymers located in the path of the concentrated light path as verified during the off-axis beam test shall have:

- Control to mitigate unsuitable temperature rises (e.g. – active cooling, movement off-axis).
- The polymer shall meet the requirements of IEC 62108:2016, 10.1 after 1 000 h of weathering in accordance with ISO 4892-2.

14 Internal wiring and current-carrying parts

14.1 General

A current-carrying part and wiring shall have the mechanical strength and current-carrying capacity necessary for its application.

14.2 Internal wiring

Wiring used within a module shall have an insulation rated for a minimum of 90 °C, with a gauge and voltage rating acceptable for the application as determined in the electrical parameters test.

The wiring of a module shall be located so that after installation of the product in the intended manner, the insulation will not be exposed to the degrading effects of direct sunlight.

Exception: The requirement does not apply to wiring with insulation rated “sunlight resistant”.

14.3 Splices

A splice shall be considered acceptable with insulation equivalent to that required for the wiring involved.

14.4 Mechanical securement

A joint or connection shall be mechanically secure and shall provide electrical contact without strain on connections and terminals. Soldered connections between module interconnections and cell metallization are considered mechanically secure when held by encapsulation systems.

An uninsulated live part, including a terminal, shall be secured to its supporting surface so that it will be prevented from turning or shifting in position, if such motion may result in reduction of spacing to less than required, as defined in 17.3.3 of this document.

15 Connections

15.1 Field connections – general requirements

A module shall be provided with wiring terminals, connectors, or leads to accommodate current-carrying conductors of the load circuit.

Field connections shall either be rated for exposure to direct sunlight as defined in Clause 13 or so located that after installation they will not be exposed to the degrading effects of direct sunlight.

15.2 Field wiring terminals

If the module contains a field wiring terminal block, it shall be rated for the appropriate voltage and current for the application and constructed in compliance with the requirements of IEC 60947-1.

If the module alternately contains wiring terminals integral to the construction of the terminal enclosure, they shall comply with the following requirements:

a) Screws and nuts which clamp external conductors shall have a thread conforming with ISO 261 or ISO 262, or a thread comparable in pitch and mechanical strength (e.g. standard threads). The screws and nuts used for field wiring shall not serve to fix any other component. These connections are also permitted to clamp internal conductors provided that the internal conductors are so arranged that they will not be displaced when fitting the external conductors.

b) Terminal screws shall have minimum sizes as shown in Table 2. Stud terminals shall be provided with nuts and washers.

c) Terminals shall be so designed that they clamp the conductor between metal surfaces with sufficient contact pressure and without damage to the conductor. Terminals shall be so designed or located that the conductor cannot slip out when the clamping screws or nuts are tightened.

Terminals shall be so fixed that, when the means of clamping the conductor is tightened or loosened:

d) The terminal itself does not work loose.

e) Internal wiring is not subjected to stress.

f) Creepage distances and clearances are not reduced below the values specified in Clause 17.

Table 2 – Sizes of terminals for supply conductors

Rated current of equipment A	Minimum nominal thread diameter mm	
	Pillar terminal or stud terminal	Screw terminal
Up to and including 10	3,0	3,5
Up to and including 16	3,5	4,0
Up to and including 25	4,0	5,0
Up to and including 32	4,0	5,0
Up to and including 40	5,0	5,0

15.3 Connectors

NOTE Connectors meeting the requirements of IEC 62852 are considered to meet the requirements of this subclause.

A connector intended for use in the output circuit of a module shall be rated for the appropriate voltage and current, as per the requirements of IEC 62852. In addition, the connector shall comply with the requirements of Clause 13, with respect to flammability, comparative tracking index and relative thermal index for the support of live parts.

Unless a connector is appropriately evaluated for disconnect overload performance, the connector shall be assumed to be suitable for assembly only and not reliable as a disconnect means as marked per 5.4.2.

A connector intended for exposure to the outdoor environment shall be enclosed by material which complies with the following:

a) the requirements of Clause 13, with respect to UV resistance;
b) resistance to inclusion of water, as per IEC 60529, equivalent to IP55;
c) the steel ball impact test, per IEC 60065, with a vertical drop distance of 1 m;
d) the requirements of the accessibility test.

Separable multi-pole connectors shall be polarised. If two or more separable connectors are provided, they shall be configured or arranged so that the other and vice-versa will not accept the mating connector for one, if it will result in an improper connection.

15.4 Output lead or cables

Leads extending from the module shall be rated for the appropriate system voltage, current capacity, wet locations, temperature and sunlight resistance.

16 Bonding and grounding

16.1 General

A module with accessible conductive parts which forms a perimeter framing or mounting system, or have a conductive surface area of greater than 10 cm^2 accessible after installation shall have provision for grounding.

Modules rated as Class II may be provided with provisions for functional grounding. Such grounding means shall be isolated from live parts by reinforced insulation (IEC 61140).

Each exposed conductive part of the module or receiver that is accessible during normal use shall be bonded together, as verified by 10.3 of IEC 61730-1:2016.

Exception: If conductive materials are used only as fasteners for installation and separated from the conductive components of the module by both appropriate insulation and spacing, they are not required to be bonded.

Routine maintenance of a module shall not involve breaking or disturbing the bonding path. A bolt, screw, or other part used for bonding purposes within a module or panel shall not be intended for securing the complete device to the supporting surface or frame.

Bonding shall be by a positive means, such as clamping, riveting, bolted or screwed connections, or by welding, soldering or brazing. The bonding connection shall penetrate all nonconductive coatings, such as paint, anodised coatings or vitreous enamel, or naturally-developing oxides

All joints in the bonding path shall be mechanically secure, independently of any soldering.

If the bonding connection depends upon screw threads, two or more screws or two full threads of a single screw shall engage the metal.

The diameter of the grounding screw or bolt shall be sized appropriately to the gauge of the bonding conductor, as per Table 2.

A ferrous metal part in the grounding path shall be protected against corrosion by metallic or non-metallic coatings, such as painting, galvanising, or plating. Stainless steel is acceptable without additional coating.

A metal-to-metal multiple-bearing pin-type hinge is considered to be an acceptable means for bonding.

A wiring terminal or bonding location of a module intended to accommodate a field installed equipment-grounding conductor shall be identified with the appropriate symbol (IEC 60417-5019) or shall have a green-colored part. No other terminal or location shall be identified in this manner.

A ground marking shall be located on or adjacent to the terminal or on a wiring diagram affixed to the module or panel near the terminal.

16.2 Lightning protection

If the product is installed locations where lightning protection is required, the lightning protection system shall be assessed in accordance with IEC 62305-2 and, if required, it shall be installed in compliance with IEC 62305-3.

17 Protection against electric shock and energy hazards

17.1 General

This clause defines the minimum requirements for the design and construction of PV modules for protection against shock and energy hazards during installation, operation, and maintenance, under normal and single fault conditions, for the expected lifetime of the PV modules. Consideration is also given to minimizing hazards resulting from reasonably foreseeable misuse. The V-t test that is commonly used to predict the lifetime of the high-voltage cable may be used to predict the lifetime under the voltage stress (see Annex C).

17.2 Fault conditions

Protection against electric shock and energy hazards shall be maintained under normal and abnormal and single fault conditions.

Compliance is checked by inspection, by analysis of normal and abnormal fault scenarios, and by the tests in this standard, such as reverse current overload.

For testing the safety of the CPV receivers, this reverse current overload test may be replaced to the V-t test (see Annex C).

17.3 Protection against electric shock

NOTE Alternatively, testing requirements for protection can be done according to the V-t test (see Annex C).

17.3.1 General

The electrically live metal parts of a module shall be compliant with Clause 12, which presents a summary of possible design solutions with regard to protection against electric shock arising from direct and indirect contact.

The module system voltage class per Clause 17 determines the minimum required level of protection.

17.3.2 Module classification

17.3.2.1 General

Module classifications define acceptable module use and application which are based upon the module’s system voltage rating and protection from live parts.

17.3.2.2 Voltage limits

Protective measures against electric shock depend on the CPV module system voltage. The system voltage rating is as specified in and 17.3.2.3.

The module system voltage indicates the minimum required level of protection for the module classification type. Modules complying with the requirements for Class II are considered safe to touch. Class II and 0 modules and system circuits shall not be accessible unless they comply with the requirements for protection in case of direct contact in 17.3.4 (see IEC 61730).

17.3.2.3 Requirements for protection

Protection shall be provided that ensures that no single fault, including faults to functional, basic, or supplementary insulation, can result in a voltage appearing on an accessible surface or accessible conductive part.

Application Class II modules may be provided with reinforced or double insulation between live parts and accessible surfaces. Accessible un-earthed conductive parts shall be separated from energized circuits by reinforced or double insulation.

NOTE Class II Modules may be provided with a functional earthed frame, but a Class 0 or 0-X module does not rely upon a protective earthed frame for protection from electric shock.

Class 0 or 0-X modules shall be provided with at least basic insulation between live parts and earthed conductive surfaces or by reinforced or double insulation to accessible nonconductive surfaces. It is required that accessible conductive surfaces be reliably bonded together and that the conductive part will be properly connected to an earthed conductor at the time of installation.

17.3.2.4 General

Protection against direct contact is employed to prevent persons from touching live parts or surfaces that exceed 35 V and shall be provided by one or more levels of protection provided by enclosures, barriers and insulation.

17.3.2.5 Protection by means of enclosures and barriers

17.3.2.5.1 General

The following requirements apply where protection against contact with live parts is provided by enclosures or barriers and not by insulation.

Parts of enclosures and barriers that provide protection in accordance with these requirements shall not be removable without the use of a tool.

17.3.2.5.2 Access probe tests

Compliance with class 0 is checked by visual inspection, and by the accessibility test of 20.2.

17.3.2.6 Protection by means of insulation of live parts

Where the requirements of 17.3.2.5 are not met, live parts shall be provided with insulation if the working voltage or system voltage is greater than 35 V.

The insulation shall be rated according to the impulse voltage, temporary overvoltage or working voltage, whichever gives the most severe requirement. It shall not be possible to remove the insulation without the use of a tool. The insulation shall extend as far as necessary to ensure compliance with the access probe test.

Any conductive part, which is not separated from parts that can operate at a potential above 35 V, 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.

17.3.3 Creepage and clearance distances

17.3.3.1 General

The creepage and clearance distances between uninsulated live parts not of the same potential, and between a live part and an accessible conductive part, shall not be less than the values specified in Tables 3, 4, 5, and 6.

These spacing requirements do not apply to the inherent spacing within a component. Such spacing shall comply with the requirements for the component in question. These distances also do not apply to distances through solid insulation materials.

Between any two uncoated conductive parts and over the coating between conductive parts, the clearance and creepage distance requirements of IEC 60664-1 resp. IEC TR 60664-2-1:2011 (for distances smaller than 2 mm) applies.

17.3.3.2 Creepage and clearance distances at field wiring terminals

The spacing at a field wiring terminal is to be measured with wires representative of field wiring in place and connected to the terminals as in actual service.

Clearance distances at field wiring terminals are to be spaced based on the module maximum system voltage. If additional unmarked terminals exist in the terminal block, or if wiring terminals are marked specifically for grounding, the creepage and clearance distances will be judged on the basis of the maximum system operating voltage.

If the creepage distance is ribbed, then the creepage distance of insulating material of group I may be applied when using insulating material of group II and the creepage distance of insulating material of group II may be applied when using insulating material of group III.

Except at pollution degree 1 the ribs shall be 2 mm high at least. For inorganic insulating materials, for example glass or ceramic, which do not track, the creepage distance may equal the associated clearance distance.

The spacings at a field-wiring terminal are to be measured with and without wire connected to the terminal. The wire shall be connected as it would be in actual use. If the terminal will properly accommodate it, and if the product is not marked to restrict its use, the wire is to be one size larger than that required, otherwise, the wire is to be the size required.

Surfaces separated by a gap of 0,4 mm or less are considered to be in contact with each other for the purpose of judging creepage distances.

Creepage and clearance distances from module live parts to accessible components and accessible metal are to be judged upon a module's rated maximum system voltage.

Table 3 – Minimum acceptable clearance distances

Required impulse voltage kV (1,2/50 µs)	**Minimum clearances for inhomogeneous field** mm Pollution degree		
	1	2	3
1,5	0,5	0,5	0,8
2,5	1,5	1,5	1,5
4,0	3,0	3,0	3,0
6,0	5,5	5,5	5,5
8,0	8,0	8,0	8,0
12,0	14,0	14,0	14,0
16,0*	19,4	19,4	19,4

* Values for 16,0 kV are evaluated by interpolation.

Table 4 – Multiplication factors for clearances of equipment rated for operation at altitudes up to 5 000 m

Rated operating altitude m	**Multiplication factor**
Up to 2 000	1,00
2 001 to 3 000	1,14
3 001 to 4 000	1,29
4 001 to 5 000	1,48

Table 5 – Minimum creepage distances for basic insulation

Rated voltage V DC	Minimum creepage distances for basic insulation mm Pollution degree						
	1	2			3		
	All material groups	Material group I	Material group II	Material group III	Material group I	Material group II	Material group III
100	0,25	0,71	1,00	1,40	1,80	2,00	2,20
150	0,31	0,79	1,09	1,57	1,97	2,17	2,47
300	0,7	1,5	2,09	3,0	3,77	4,24	4,71
600	1,6	3,04	4,29	6,0	7,6	8,56	9,54
1 000	3,2	5,0	7,1	10,0	12,5	14,0	16,0
1 500	5,2	7,51	10,43	15,0	18,86	20,86	23,57

Table 6 – Minimum creepage distances for reinforced insulation

Rated voltage V DC	Minimum creepage distances for reinforced insulation mm Pollution degree						
	1	2			3		
	All material groups	Material group I	Material group II	Material group III	Material group I	Material group II	Material group III
100	0,5	1,42	2	2,8	3,6	4	4,4
150	0,62	1,56	2,16	3,14	3,94	4,34	4,94
300	1,4	3	4,16	6	7,54	8,48	9,42
600	3,6	6,06	8,58	12	15,2	17,12	19,06
1 000	6,4	10	14,2	20	25	28	32
1 500	10,4	15,02	20,84	30	37,72	41,72	47,14

NOTE 1 Material group IIIb is not recommended for application in pollution degree 3 above 630 V.

NOTE 2 Generic encapsulant materials without electrical and environmental ratings used in PV construction cannot be considered totally non-hygroscopic and the lamination process does not provide a truly sealed system. Therefore, creepage and clearance distances shall be considered for pollution degree 3, material grade IIIa or IIIb according to IEC 60664-1.

NOTE 3 Pollution degrees based on the presence of contaminants and possibility of condensation or moisture at the creepage distance is as follows: pollution degree 1 – No pollution or only dry, nonconductive pollution. The pollution has no influence. pollution degree 2 – Normally, only nonconductive pollution. However, a temporary conductivity caused by condensation may be expected. Pollution degree 3 – conductive pollution or dry, nonconductive pollution that becomes conductive due to condensation that is expected. Pollution degree 4 – Pollution that generates persistent conductivity through conductive dust or rain and snow.

17.3.3.3 Overvoltage category

This standard assesses the DC side of the system, and as such all evaluations will consider overvoltage category III (see Table 7).

Table 7 – Rated impulse voltage

Rated voltage V	Values for the rated impulse voltage for basic insulation	Values for the rated impulse voltage for reinforced insulation
DC	kV (1,2/50 µs)	kV (1,2/50 µs)
50	0,8	1,5
100	1,5	2,5
150	2,5	4,0
300	4,0	6,0
600	6,0	8,0
1 000	8,0	12,0
NOTE Values are derived from IEC 60664-1 and IEC TR 60664-2-1 for overvoltage category III.		

17.3.4 Degrees of pollution in the micro-environment

For the purpose of evaluating creepage distances and clearances, the following four degrees of pollution in the micro-environment are established:

a) Pollution degree 1

No pollution or only dry, non-conductive pollution occurs. The pollution has no influence.

b) Pollution degree 2

Only non-conductive pollution occurs except that occasionally a temporary conductivity caused by condensation is to be expected.

c) Pollution degree 3

Conductive pollution occurs or dry non-conductive pollution occurs which becomes conductive due to condensation that is to be expected.

d) Pollution degree 4

Continuous conductivity occurs due to conductive dust, rain or other wet conditions.

17.3.5 Cemented joints

17.3.5.1 General

Insulating adhesive material that provides a reliable bond between two materials for which it has been evaluated to adhere. Two separate materials that have been cemented together with an insulating adhesive material can be considered as a solid insulating material.

An insulating adhesive compound shall be rated for adhesion to the specific material type, rated for temperature of use, and rated for weathering exposure including water and UV depending on the exposure in the end application.

Pollution degree 1 creepage and clearances may be used where the interlayer adhesion has been proven to be a cemented joint by end product testing and the insulating adhesive compound is rated for adhesion to the specific material type, rated for use temperature and rated for weathering exposure including water immersion and UV exposure if it is exposure to UV in the end application.

NOTE Pollution degrees 1, 2, and 3 are described in detail in IEC 60664-1.

Exception: Pollution degree 2 shall be used if the encapsulant is not rated for water immersion.

If an insulating compound is applied between conductive parts and the insulating compound forms a cemented joint between two non-conductive parts, or between a non-conductive part and itself one of the following, a), b) or c) applies.

a) The distance along the cemented joint between the two conductive parts shall not be less than the minimum clearances and creepage distances for pollution degree 2. The requirements for distance through insulation do not apply along the joint.
b) The distance along the path between the two conductive parts shall not be less than the minimum clearances and creepage distances for pollution degree 1. The requirements for distance through insulation do not apply along the joint.
c) The requirements for distance through insulation apply between the conductive parts along the joint.

17.3.5.2 Minimum mechanical performance for cemented joints

The material adhesion characteristics shall be evaluated during TI or RTI or RTE in a manner that simulates the joint design in an as-deployed state.

For cemented joints, the mechanical TI or RTI or RTE thermal rating for the electrically insulating adhesive/sealant shall be the higher of:

- 90 °C; or
- the module maximum measured normalized operating temperature as measured during the CPV temperature test.

17.3.5.3 Minimum electrical performance for cemented joints

The DC dielectric strength of the material shall be evaluated on a component level during TI or RTI or RTE, with DC dielectric strength as measured via ASTM D3755.

The electrically insulating adhesive/sealant shall have a volume resistivity of greater than 50 x 10^6 Ω·cm (dry) and greater than 10 x 10^6 Ω·cm (wet), with volume resistivity as measured via ASTM D257 and wet/dry conditioning defined as per section 14 of UL 746C.

For cemented joints, the electrical TI or RTI or RTE rating for the electrically insulating adhesive/sealant shall be the higher of:

- 90 °C;
- the module maximum measured normalized operating temperature as measured during the CPV temperature test.

17.3.5.4 UV weathering resistance for cemented joints

Cemented joints shall be tested for UV exposure using ISO 4892-2 (xenon arc), cycle 1 at 0,35 (W/m^2)/nm or 41 W/m^2 (in the wavelength range from 300 nm to 400 nm), test duration 1 000 h.

The lap shear samples are to be constructed in a manner that is representative of the joint design in an as-deployed state and tested in accordance with the lap shear separation method outlined in ASTM D1002. Data shall be normalized based on the geometry of the overlap region. A strain rate of 1,5 mm/min is recommended.

Compliance is checked by completing pre/post UV exposure lap shear testing and comparing the average force measured before and after exposure. Greater than 50 % retention of average bond strength as measured before exposure is required after exposure.

18 Field wiring compartments with covers

NOTE Polymeric field wiring compartments meeting the requirements of IEC 62790 (EN 50548) are considered to meet the requirements of this document.

18.1 General

Modules designed for the application of a permanently attached wiring system by an installer in the field shall be provided with an enclosed wiring compartment, which provides protection of the conductors and connections from environmental stress, protection from accessibility to live un-insulated parts and strain relief for the attached wiring system.

18.2 Strain relief

Strain relief shall be provided so that stress on a lead intended for field connection, or otherwise likely to be handled in the field, including a flexible cord, is not transmitted to the electrical connection inside the module. Mechanical securement means which comply with 10.12 of IEC 62108:2016 meet this requirement.

18.3 Sharp edges

All accessible parts of the module or assembly shall be smooth and free from sharp edges, burrs, or the like that may damage insulation or conductors. All accessible parts shall meet the sharp edge requirements of ISO 8124-1 or IEC 60950-1:2005, 3.2.7.

This requirement also applies to the inner edges of conduit openings and knockouts.

18.4 Conduit applications – Metallic

A threaded hole in a metal wiring compartment intended for the connection of rigid metal conduit shall be reinforced to provide metal not less than 6,4 mm thick, and shall be tapered unless a conduit end stop is provided.

If threads for the connection of conduit are tapped all the way through a hole in a compartment wall, or if an equivalent construction is employed, there shall not be less than 3,5 nor more than 5 threads in the metal and the construction shall be such that a conduit bushing can be attached as intended.

If threads for the connection of conduit are not tapped all the way through a hole in a compartment wall, there shall not be less than 5 full threads in the metal and there shall be a smooth, rounded inlet hole for the conductors which shall afford protection to the conductors equivalent to that provided by a standard conduit bushing.

For a non-threaded opening in a metal wiring compartment intended to accommodate rigid metallic conduit, a flat surface of sufficient area shall be provided around the opening to accept the bearing surfaces of the bushing and lock washer.

Conduit connections shall comply with the Conduit bending test described in Clause 11 of IEC 61730-2:2016, MST 33.

18.5 Conduit applications – Non-metallic

The sides, end walls, and bottom of a non-metallic wiring enclosure specified for conduit applications shall not have a thickness less than the values specified in in Table 8.

Table 8 – Wall thickness of polymeric boxes intended for conduit

Trade size of conduit mm	Minimum wall thickness mm
13 to 25	3
26 to 50	4
51 to 100	5

A non-metallic wiring compartment intended to accommodate non-metallic conduit shall have one of the following:

a) one or more unthreaded conduit-connection sockets integral with the compartment that comply with the requirements of the conduit system intended;

b) one or more threaded or unthreaded openings for a conduit-connection socket, or one or more knockouts that comply with the requirements of IEC 61730-2, MST 44;

c) compliance with IEC 61730-2, MST 33, if intended for rigid non-metallic conduit. A module which does not comply with MST 33 shall be marked "For use with non-rigid non-metallic conduit only." Modules which comply with MST 33 may be marked "For use with rigid non-metallic conduit".

A socket for the connection of non-metallic conduit shall provide a positive end stop for the conduit. The socket diameters, the throat diameter at the entrance to the box, the socket depths, and the wall thickness of the socket shall be within the limits specified in the applicable conduit system.

A knockout or opening in a non-metallic wiring compartment intended to accommodate rigid non-metallic conduit shall comply with the dimensional requirements of the applicable conduit system.

19 Requirements for testing – Test categories

19.1 General

Electrical, mechanical, and fire hazards might influence the lifetime and the safety of PV modules. In accordance with these hazards, test procedures and criteria are described. The specific tests to which a module will be subjected will depend on the end use application for which the minimum tests are specified in Clause 7.

Tables 9 to 13 show the origin of the required tests. For some tests, a reference test standard is not available, and so no information is given.

19.2 Preconditioning tests

Table 9 – Preconditioning tests

Per IEC 62108:2016 – Subclause	Test	Required per application class		
		II	0	III
10.6	Thermal cycling	X	X	X
10.7	Damp heat	X	X	X
10.8	Humidity freeze	X	X	X
10.15	Ultraviolet conditioning	X	X	X
10.16	Outdoor exposure	X	X	X

19.3 General inspection

Table 10 – General inspection tests

Per Standard – Subclause	Test	Required per application class		
		II	0	III
IEC 62108:2016,10.1	Visual inspection	X	X	X
20.20	CPV electrical parameters	X	X	-
IEC 60950-1:2005, 3.2.7	Sharp edges	X	X	X

19.4 Electrical shock hazard

These tests are designed to assess the risk to personnel due to shock or injury because of contact with parts of a module that are electrically hazardous as a result of design, construction, or faults caused by environment or operation.

Table 11 – Electrical shock hazard tests

Per Standard – Subclause	Test	Required per application class		
		II	0	III
IEC 62108:2016,10.4	Electrical insulation	X	X	-
20.5	Dielectric voltage withstand	X	X	-
IEC 62108:2016,10.5	Wet insulation	X	X	-
20.3	Accessibility	X	X	-
IEC 62108:2016,10.3	Ground path continuity	X	X	X
20.17	Impulse voltage	X	X	-
IEC 62108:2016,10.12	Robustness of terminations	X	X	-
IEC 62108:2016,10.10	Water spray	X	X	-
NOTE 1 The impulse voltage test is only required if module or receiver superstrate or substrate is polymeric. NOTE 2 Electrical insulation, wet insulation, and impulse voltage test levels are dependent on application class.				

19.5 Fire hazard

These tests assess the potential fire hazard due to the operation of a module or failure of its components.

Table 12 – Fire hazard tests

Per Standard – Subclause	Test	Required per application class		
		A	B	C
20.18	CPV Temperature	X	X	X
IEC 62108:2016,10.17	Hot spot endurance	X	X	X
20.7	Reverse current overload	X	X	-
IEC 62108:2016,10.11	Bypass diode thermal	X	X	-
IEC 62108:2016,10.14	Off-axis beam damage	X	X	X
NOTE 1 Class III modules have limited electrical output and are exempted from fire hazard tests. See 7.5.2. NOTE 2 National deviations determine inclusion of an end product test to determine resistance against external fire and radiant heat in a test program.				

Table 13 – Fire hazard test applicability

Module application class	Application class explanation	Class (IEC 61140:2016, Clause 7)	Flammability requirements (= polymer material level)	Internal burning brand test		External burning brand test	
				Test required	Brand class	Test required	Brand class
A	General access	II	5 V (or internal burning brand test module level)	if flammability tests were skipped	B	If rooftop application or if required by local code authorities	According to roof code requirements
B	Restricted access	0	HB (or internal burning brand test module level)	if flammability tests were skipped	C	If rooftop application or if required by local code authorities	According to roof code requirements
B-X	Restricted access plus: unmitigated fire or concentrated light hazard and shall be installed over a non-combustible surface	I	HB (or internal burning brand test module level)	if flammability tests were skipped	C	If rooftop application or if required by local code authorities	According to roof code requirements
C	General access, limited voltage	III	HB (or internal burning brand test module level)	if flammability tests were skipped	C	If rooftop application or if required by local code authorities	According to roof code requirements
Not fire rated	Not on rooftops	Not fire rated	Not fire rated	Not fire rated	Not fire rated	Not fire rated	Not fire rated

19.6 Mechanical stress

These tests are to minimize potential injury due to mechanical failure (see Table 14).

Table 14 – Mechanical stress tests

Per IEC 62108:2016 – Subclause	Test	Required per application class		
		A	B	C
10.13	Mechanical load	X	X	X
10.9	Hail impact	X	X	X

20 Testing

20.1 General

The test samples shall be randomly divided into groups and subjected to the test sequences in Figure 7, Figure 8, Figure 9 or Figure 10 – depending on the test subject and coordination with IEC 62108. Test procedures and requirements are detailed in each subsequent subclause or referenced standard subclause.

As shown in Figure 7 and Figure 8 for modules or in Figure 9 and Figure 10 for assemblies, the test sequence is performed both in-lab and on-site. If the distance between these two locations is considerable or public shipping companies are involved, a dark current/voltage (I-V) curve measurement before and after the shipping can be performed to evaluate any possible changes on testing samples. Consideration of potential damages induced by the dark I-V test should be given.

The accessibility, reverse current overload, impulse voltage, hail impact, and hot spot endurance tests can be completed on separate samples. The test sequence that contains these tests are only suggested as a way to reduce the number of samples – the pass/fail requirements for each test are independent of one another. All samples shall be subjected to the initial and final tests of the overall sequence.

If some test procedures in this document are not applicable to a specific design configuration, the manufacturer should discuss this with the certifying body and testing agency to develop a comparable test program, based on the principles described in this standard. Any changes and deviations shall be recorded and reported in details, as required in Clause 6.

The robustness of terminations test may be run in the same manner/sequence as that of flat plate: TC/HF/robustness of terminations. Refer to IEC 61215-2 MQT14 for the test procedure.

NOTE 1 Final requirements of each individual test are defined within the test standard subclause, but are not shown in this diagram.

NOTE 2 Outdoor UV Exposure sequence may be tested on-site at manufacturer's facility, or at test lab.

NOTE 3 Standard production module may be replaced by representative sample where justified.

NOTE 4 Bypass diode thermal test can be performed on a receiver.

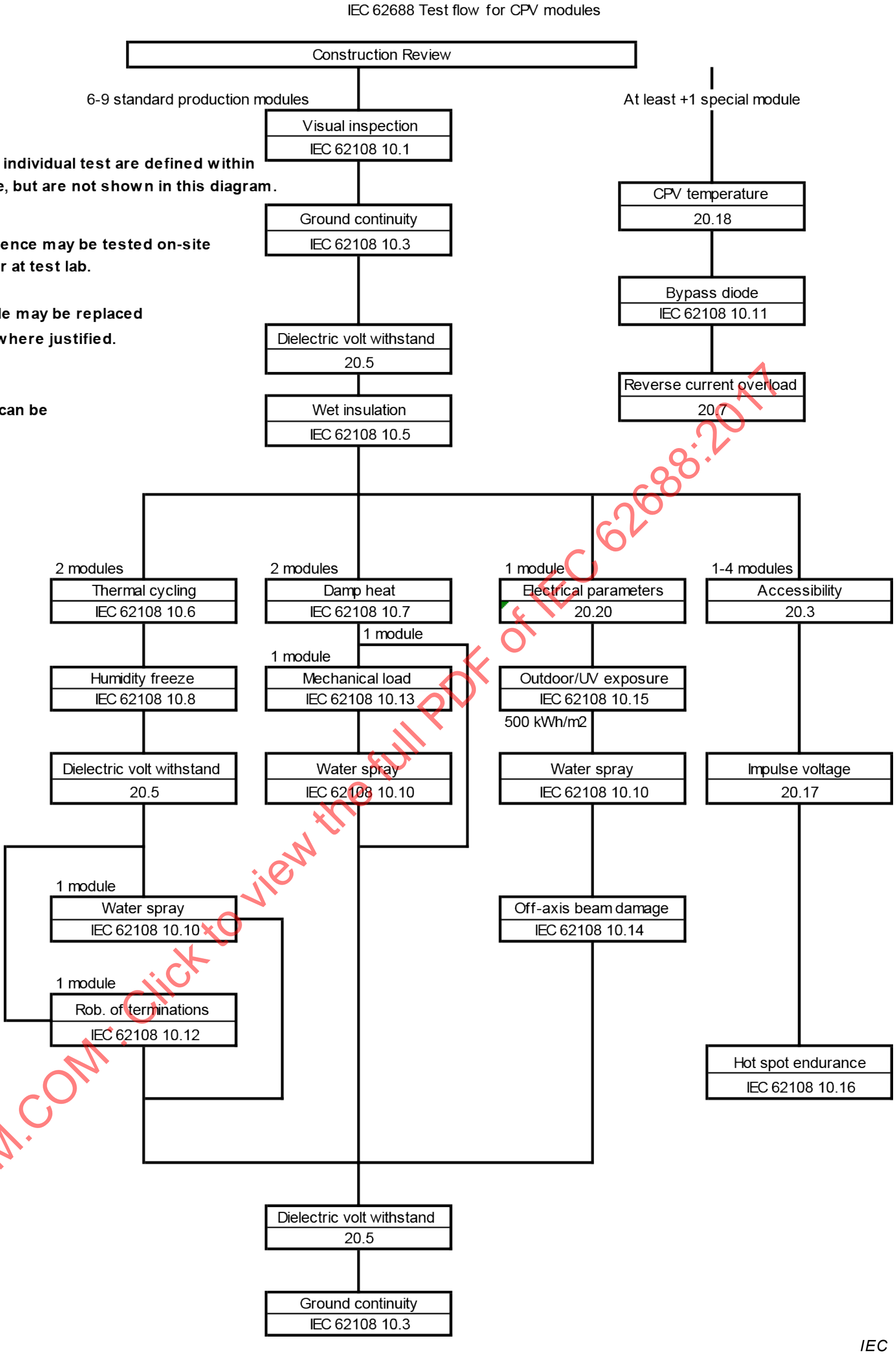


Figure 7 – IEC 62688 safety test plan for CPV modules (IEC 62108:2016)

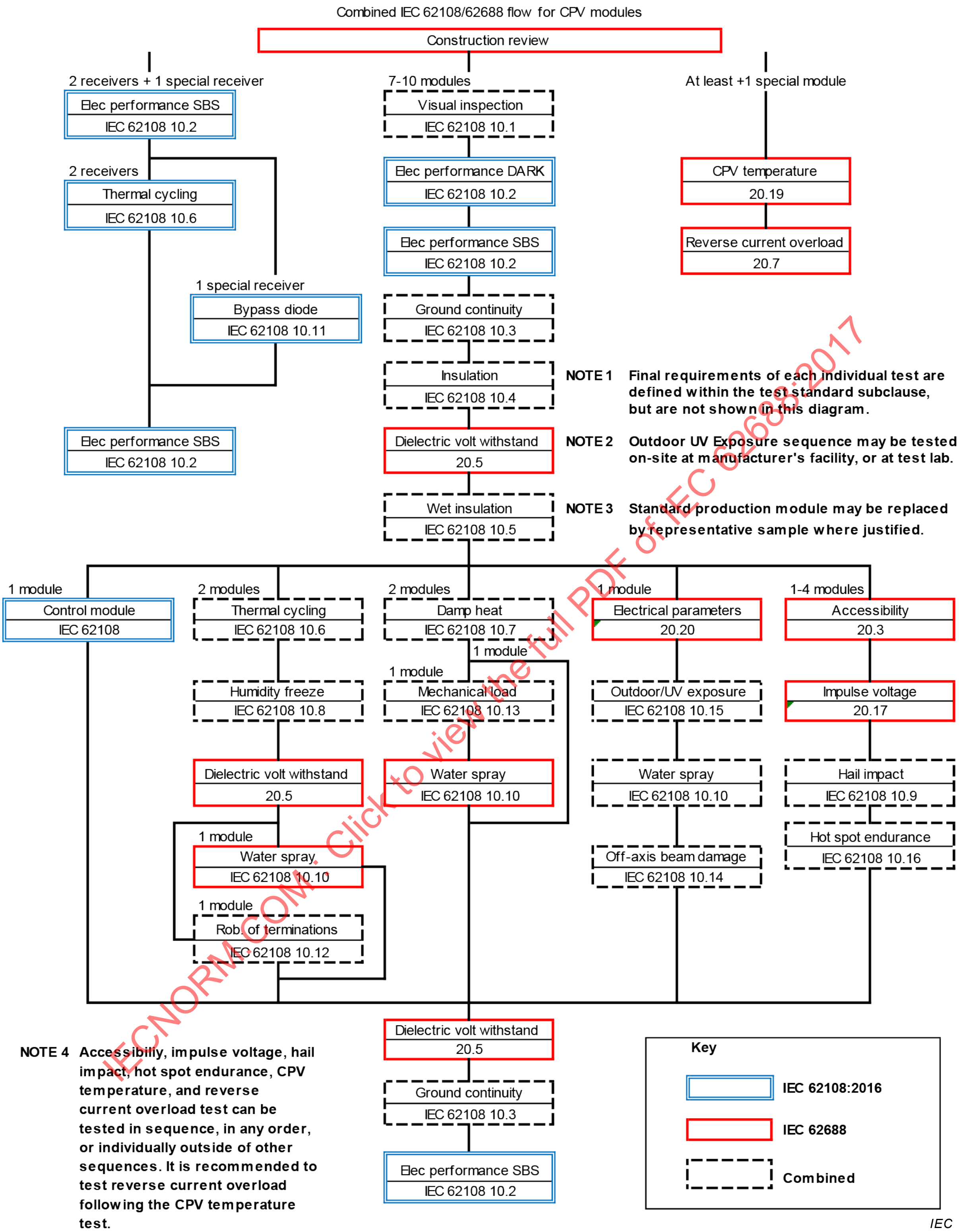


Figure 8 – Combined IEC 62108:2016 and IEC 62688 test plan for CPV modules

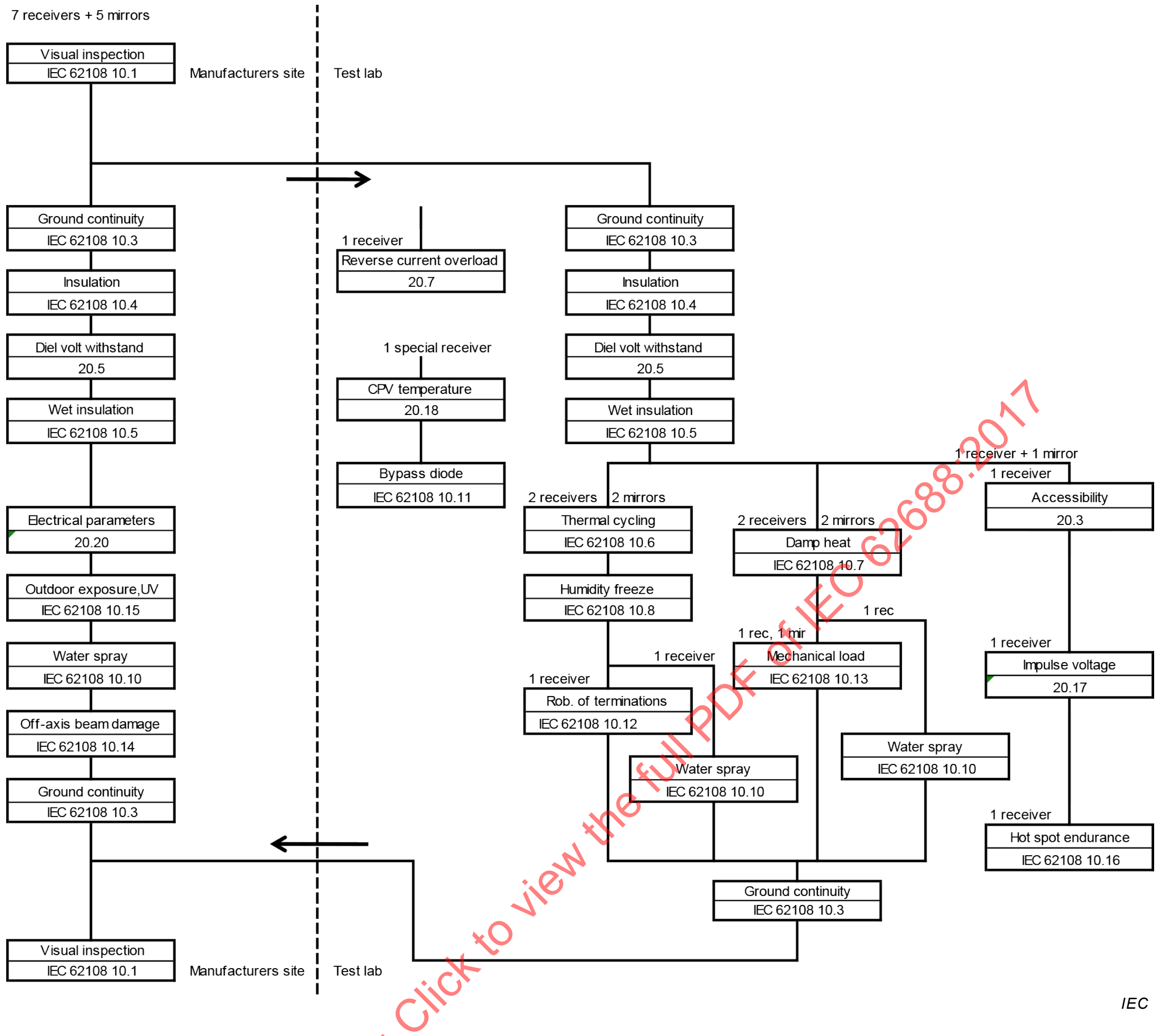


Figure 9 – IEC 62688 safety test plan for CPV assemblies (IEC 62108:2016)

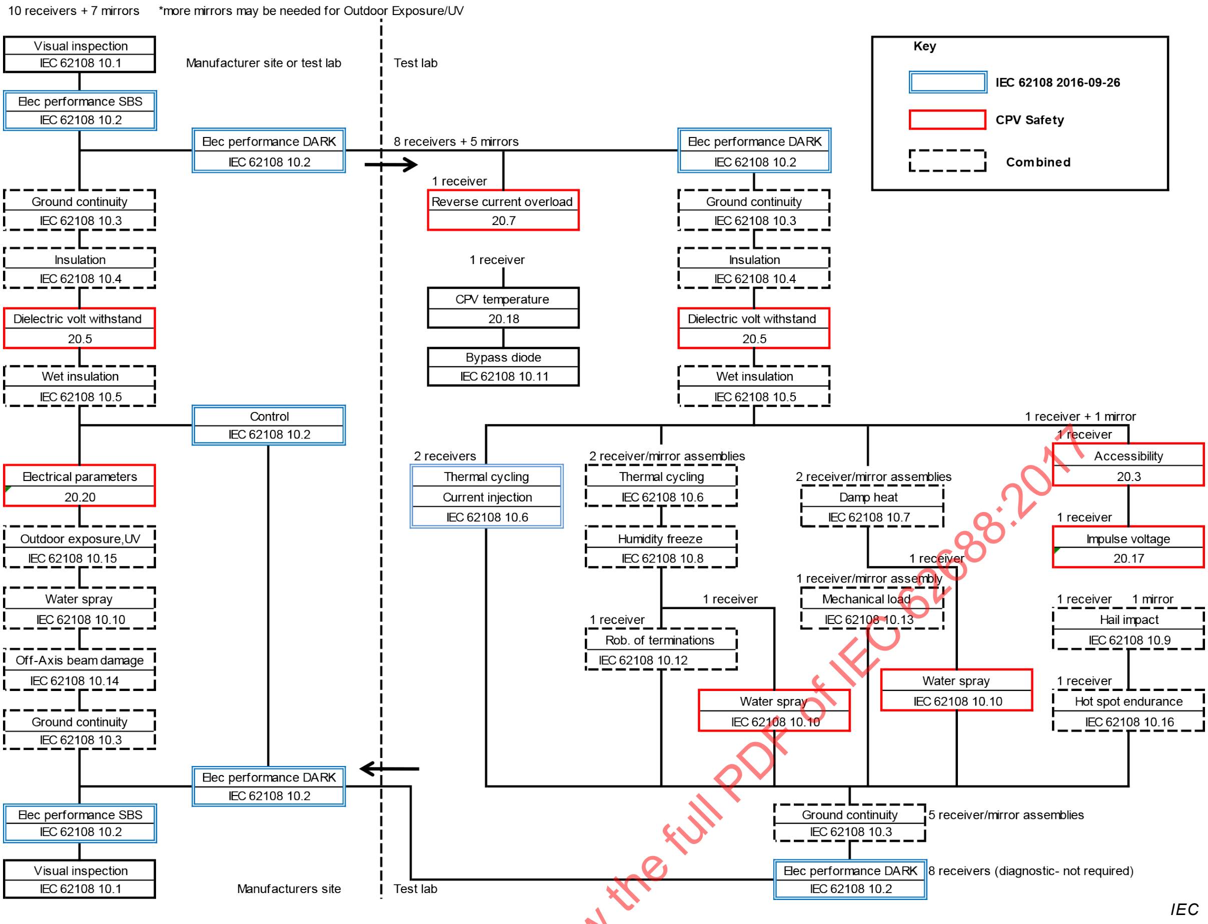


Figure 10 – Combined IEC 62108:2016 and IEC 62688 test plan for CPV assemblies

20.2 Visual inspection

20.2.1 General

Conducted per IEC 62108:2016,10.1.

20.2.2 Requirements

No evidence of major visual defects.

For the purpose of the safety test approval, the following are considered to be major visual defects:

a) broken, cracked, or torn external surfaces;

b) bent or misaligned external surfaces, including superstrates, substrates, cables, frames and junction boxes to the extent that the safety of the module would be impaired;

c) bubbles or delaminations forming a continuous path between any part of the electrical circuit and the edge of the module, or which exhibited significant growth during the testing and would, if testing were continued, reach such a condition;

d) evidence of any molten or burned encapsulant, back sheet, diode or active PV component;

e) loss of mechanical integrity to the extent that the safety of the installation and operation of the module would be impaired;

f) markings not complying with Clause 12 of IEC 61730-1:2016.

20.3 Accessibility test

20.3.1 Purpose

To determine if uninsulated electrical live parts represent a shock hazard to personnel.

20.3.2 Apparatus

The apparatus is as follows:

- A cylindrical test probe Type 11 according to IEC 61032.
- An ohmmeter or continuity tester.

20.3.3 Procedure

The procedure is as follows:

- Mount and wire the test module as recommended by the manufacturer.
- Attach the ohmmeter or continuity tester to the module short circuited terminals and to the test fixture.
- Remove all covers, plugs and connections from the module that can be removed without using a tool.
- Probe with the test fixture in and around all electrical connectors, junction boxes and any other areas where live parts of the module may be accessible.
- The test fixture shall be used with an applied force of (10 ± 1) N.
- Monitor the ohmmeter or continuity tester during the probing to determine if the test fixture makes electrical contact to the module live parts.

20.3.4 Requirements

At no time during the test shall the probe contact any live electrical part. This test is performed at the beginning and the end of the sequence, but also can be used at any time during the test sequence if there is any reason to believe that active electric circuitry has been exposed by one of the other tests.

20.4 Grounding/Bonding path continuity test

20.4.1 Purpose

The purpose of the ground path continuity test is to verify adequate electrical continuity between all exposed conductive parts and the grounding point under high-current conditions.

20.4.2 Procedure

Conducted per method of IEC 62108:2016, 10.3.

20.4.3 Requirements

Resistance shall be less than 0,1 Ω.

The joints between different exposed conducting parts shall not be damaged.

20.5 Dielectric voltage withstand test

20.5.1 Purpose

The purpose of the dielectric voltage withstand test (also called dry hi-pot) test is to determine whether or not the concentrator system is sufficiently well-insulated between all active parts in the power-generating circuit and the frame or the outside world.

20.5.2 Procedure

Conducted per method of IEC 62108:2016, 10.4, except as indicated.

The maximum test voltage shall be equal to 2 000 V plus four times the maximum system voltage for application-class II and equal to 1 000 V plus two times the maximum system voltage for application-class 0 or 0-X. For application class III the test voltage is 500 V.

20.5.3 Requirements

a) No dielectric breakdown, surface tracking, or bubble generation.

b) For samples with a total electrically active surfaces less than or equal to 0,1 m^2, the measured insulation resistance shall not be less than 50 MΩ as measured/calculated during the insulation test of IEC 62108. The total electrically active surface is the cell area plus surface area of all current carrying parts within the module including cell to cell interconnection means.

c) For samples with a total electrically active surfaces larger than 0,1 m^2, the measured insulation resistance times cell area shall not be less than 5 MΩ·m^2 as measured/calculated during the Insulation test of IEC 62108.

d) In addition to the previous requirements, receivers, modules, or assemblies shall always have a total insulation resistance more than 1 MΩ, or more than 10 MΩ if double-insulated.

e) If cell to cell interconnection is achieved via a wire or cable that has rated insulation for both temperature and voltage, then that area needs not be considered for the purposes of calculating total allowed resistance for insulation testing purposes.

20.6 Wet insulation test

20.6.1 Purpose

The purpose of the wet insulation test is to evaluate the insulation of the concentrator system under wet operating conditions and verify that moisture from rain, fog, dew, or melted snow does not enter the active parts of the sample circuitry, where it might cause corrosion, a ground fault, or a safety hazard.

20.6.2 Procedure

Conduct per method of IEC 62108:2016, 10.5, except test at U_{SYS}.

20.6.3 Requirements

a) No dielectric breakdown, surface tracking, or bubble generation.

b) For samples with a total electrically active surfaces less than or equal to 0,1 m^2, the measured insulation resistance shall not be less than 50 MΩ as measured/calculated during the Insulation test of IEC 62108.

c) For samples with a total electrically active surfaces larger than 0,1 m^2, the measured insulation resistance times cell area shall not be less than 5 MΩ·m^2 as measured/calculated during the insulation test of IEC 62108. The total electrically active surface is the cell area plus surface area of all current carrying parts within the module including cell to cell interconnection means.

d) In addition to the previous requirements, receivers, modules, or assemblies shall always have a total insulation resistance more than 1 MΩ, or more than 10 MΩ if double-insulated.

e) If cell to cell interconnection is achieved via a wire or cable that has rated insulation for both temperature and voltage, then that area needs not be considered for the purposes of calculating total allowed resistance for insulation testing purposes.

20.7 Reverse current overload

20.7.1 Purpose

Receivers contain electrically conductive material, contained in an insulating system. Under reverse current fault conditions, the tabbing and cells of the receiver are forced to dissipate energy as heat, prior to circuit interruption by an over-current protector installed in the system. This test is intended to determine the acceptability of the risk of ignition or fire from this condition.

20.7.2 Procedure

The module or receiver under test is to be placed so that the irradiance on the cell area of the module is less than 50 W/m^2. The back surface of the module or receiver, and the exposed wiring compartment, shall be covered with a single layer of tissue paper conforming to 12 g/m^2 to 30 g/m^2 (IEC 60695-2-10).

Any blocking diode provided shall be defeated (short-circuited). The test shall be conducted in an area free of drafts.

A laboratory DC power supply shall be connected to the module with positive output connected to the positive terminal of the module. The applied reverse current (I_{TEST}) shall be equal to 135 % of the module's overcurrent protection rating, as provided by the manufacturer. The test supply current shall be limited to the value of I_{TEST}, and the test supply voltage shall be increased to cause the reverse current to flow through the module. The test shall be continued for 2 h, or until ultimate results are known (i.e. glass breakage), whichever occurs first.

Throughout the test the current flow shall be kept stable within ± 2 %.

The maximum over-current protection rating of a module can be interpreted as the module series fuse rating. A series fuse may be required in the installation of CPV systems and arrays. The maximum over-current rating has to be provided by the manufacturer.

Concerning the maximum overcurrent protection rating, see Clause 11.

NOTE A method to determine the limiting reverse current of a module can be found in EN 50380:2003, 3.6.2.

20.7.3 Requirements

The pass criteria are as follows:

a) There shall not be flaming of the receiver, nor flaming or charring of the tissue paper.
b) No evidence of major visual defects, as defined per 20.1.
c) Insulation resistance shall meet the same requirements as per 20.4.
d) Wet insulation resistance shall meet the same requirements as per 20.5.

20.8 Thermal cycling

20.8.1 General

Two samples are required for the thermal cycling test (see Figures 7 to 10). Representative samples meeting all requirements of the Clause 4 of this document can be used where laboratory constraints prohibit conducting the tests on full size samples.

20.8.2 Purpose

The purpose of the thermal cycling test is to determine the ability of the modules to withstand thermal mismatch, fatigue, and other stresses caused by rapid, non-uniform or repeated changes of temperature.

20.8.3 Procedure

Conducted per IEC 62108:2016, 10.6, without current injection, per module profile. Cycling rate shall be at least 4 cycles per day.

20.8.4 Requirements

The pass criteria are as follows:

a) No evidence of major visual defects, as defined in 20.1.
b) Insulation resistance shall meet the same requirements as per 20.4.
c) Wet insulation resistance shall meet the same requirements as per 20.5.

20.9 Humidity freeze

20.9.1 General

Two samples are required for the humidity freeze test (see Figures 7 to 10). Representative samples meeting all requirements of Clause 4 of this document can be used where laboratory constraints prohibit conducting the tests on full size samples.

20.9.2 Purpose

The purpose of the humidity freeze test is to determine the ability of the modules or assemblies to withstand the effects of high temperature and humidity followed by below freezing temperatures. This is not a thermal shock test.

20.9.3 Procedure

Conducted per method of IEC 62108:2016, 10.8.

20.9.4 Requirements

The pass criteria are as follows:

a) No evidence of major visual defects, as defined in 20.1.
b) Insulation resistance shall meet the same requirements as per 20.4, within 2 h to 4 h of removal from chamber.
c) Wet insulation resistance shall meet the same requirements as per 20.5, within 2 h to 4 h of removal from chamber.

20.10 Damp heat

20.10.1 General

Two modules are required for the damp heat test. Representative samples may be used due to laboratory constraints. If some components are not suitable for 85 °C, the other option is to test under 65 °C and 85 % RH for 2 000 h.

20.10.2 Purpose

The purpose of the damp heat test is to determine the ability of the modules or assemblies to withstand the effects of long-term penetration of humidity.

20.10.3 Procedure

Conducted per method of IEC 62108:2016, 10.7.

20.10.4 Requirements

The pass criteria are as follows:

a) No evidence of major visual defects, as defined in 20.1.

b) Insulation resistance shall meet the same requirements as per 20.4, within 2 h to 4 h of removal from chamber.

c) Wet insulation resistance shall meet the same requirements as per 20.5, within 2 h to 4 h of removal from chamber.

20.11 Bypass diode thermal

20.11.1 Purpose

The purpose of the bypass/blocking diode thermal test is to assess the adequacy of the thermal design and relative long-term reliability of bypass/blocking diodes used to limit the detrimental effects of system hot-spot susceptibility.

20.11.2 Special test sample

One receiver or module sample is required for this test. A specially manufactured test sample may be needed if the bypass/blocking diodes are part of the module construction and the access to measure the temperature of bypass/blocking diode case or hottest diode contacting surface is not possible without compromising the integrity of the module. This test sample shall be manufactured with accessible temperature sensor attached to the case of the bypass/blocking diode. The temperature sensor wires shall be low thermal mass, attached in a way to ensure a minimum of disturbance to the diode and its thermal environment. In all other respects, this test sample shall be manufactured as close as possible to the standard receiver product.

The test using the specially manufactured receiver as described above is called the intrusive bypass/blocking diode thermal test; otherwise, it is called the non-intrusive test.

20.11.3 Procedure

Conducted per method of IEC 62108:2016, 10.11.

Exception: This test shall not be subjected to insulation tests.

20.11.4 Requirements

The pass criteria are as follows:

a) The diode junction temperature as determined in IEC 62108:2016, 10.11 shall not exceed the diode manufacturer's maximum junction temperature rating.

b) No evidence of major visual defects, as defined in 20.2.

c) The diode shall still function after the conclusion of the test.

20.12 Hot spot endurance

20.12.1 General

A module or assembly could be exempt from this test if it has one bypass diode for each cell. The purpose of this test is to evaluate the ability of a module or assembly to endure the long-term effects of periodic hot-spot heating associated with common fault conditions such as severely cracked or mismatched cells, single-point open-circuit failures, or non-uniform illumination such as partial shadowing.

20.12.2 Procedure

Conducted per method of IEC 62108:2016, 10.16.

20.12.3 Requirements

The pass criteria are as follows:

a) No evidence of major visual defects, as defined in 20.1. In particular, there shall be no evidence of melting, smoking, charring, deformation, or burning of any material.

b) Insulation resistance shall meet the same requirements as defined in 20.5.

20.13 Off-axis beam damage

20.13.1 General

One full-size module or assembly is required for the off-axis beam damage test. This test shall be conducted by installing it in the lab, or through on-site witness.

20.13.2 Purpose

The purpose of the off-axis beam damage test is to evaluate that no part of the module or assembly could be damaged by concentrated solar radiation during conditions of misalignment or malfunctioning.

20.13.3 Special case

Concentrator systems that use a functional safety system to manage misalignment issues may be exempt from the requirements of this test. The manufacturer shall state in the system manual how this level of protection is achieved, what levels of maintenance are required, what locations are suitable for installation, and how to commission and operate such a system correctly.

The testing agency should agree with the manufacturer on a procedure to conduct verifications on the functional safety system that meets the requirements of IEC 61508. Under all possible vulnerable conditions, the protection system should respond to the misalignment or malfunction according to the manufacturer's design; otherwise, a regular off-axis beam damage test shall be conducted.

20.13.4 Procedure

Conducted per method of IEC 62108:2016, 10.14.

20.13.5 Requirements

The pass criteria are as follows:

a) No evidence of major visual defects, as defined in 20.2. In particular, there shall be no evidence of melting, smoking, charring, deformation, or burning of any material.

b) Insulation resistance shall meet the same requirements as defined in 20.5.

20.14 Water spray

20.14.1 General

Three samples are required for the water spray test. One full-size sample is required for the outdoor exposure sequence. One sample each is required for the humidity freeze and damp heat sequences.

20.14.2 Purpose

The purpose of the water spray test is to determine whether rain water can enter the module or assembly under field conditions, and if the entered water can cause a ground fault or a safety hazard.

20.14.3 Procedure

Conducted per method of IEC 62108:2016, 10.10.

20.14.4 Requirements

The pass criteria are as follows:

a) No evidence of major visual defects, as defined in 20.2.
b) Insulation resistance shall meet the same requirements as defined in 20.5.
c) No significant amount of water shall remain inside the module after the test (the depth of the remaining water shall not reach any electrically active parts in any possible position).

Test insulation within 30 min following end of water spray, with irradiance level < 50 W.

20.15 Mechanical load

20.15.1 Purpose

The purpose of the mechanical load test is to determine the ability of the module or assembly to withstand wind, snow, static, or ice loads. If the concentrator systems are specified by the manufacturer not to be suitable for installation in areas of extreme conditions, the manufacturer shall specify the limits of wind, snow, static, and ice loads that apply to the product. Pressure values used in the following test can then be calculated to match the maximum specification of the manufacturer. If the design is entirely unsuitable for snow areas, the snow load test need not be carried out. The test report shall state the manufacturer’s recommended limits and whether the equipment survived testing at those limits.

This test is only performed on modules, assemblies, or their representative samples. It is not an evaluation for trackers and other mounting means. A full-size concentrator system, including all structures and foundations, should be analyzed by suitably qualified engineers to verify that the design meets the local code requirements of the installation site.

If there is no specific location specified, structures and foundations should meet the following minimum requirements:

a) survival of a 27 m/s wind in the worst-case position;
b) survival of a 45 m/s wind in a stowed position;
c) survival of 5 400 Pa snow load, if desired.

2 400 Pa corresponds to a wind pressure of 130 km/h (approximately 800 Pa) with a safety factor of 3 for gusty winds. If the module is to be qualified to withstand heavy accumulations of snow and ice, the load applied to the front of the module during the last cycle of this test shall be increased from 2 400 Pa to 5 400 Pa.

20.15.2 Procedure

Conducted per method of IEC 62108:2016, 10.13.

20.15.3 Requirements

The pass criteria are as follows:

a) No intermittent open-circuit fault detected during the test.

b) No evidence of major visual defects, as defined in 20.2.

c) Insulation resistance shall meet the same requirements per 20.5.

The mechanical load test may be substituted by an independent wind load test, as long as the minimal static loads are met for the time required.

20.16 Robustness of terminations

20.16.1 Purpose

The purpose of the robustness of terminations test is to determine that the terminations and the attachment of the terminations to the body of the module or assembly will withstand such stresses as are likely to be applied during normal installation or handling operations.

20.16.2 Types of terminations

Three types of module terminations are considered:

- Type A: wire or flying lead;
- Type B: tags, threaded studs, screws, etc.;
- Type C: connector.

20.16.3 Procedure

Conducted per method of IEC 62108:2016, 10.12.

20.16.4 Requirements

a) No evidence of major visual defects, as defined in 20.2;

b) Insulation resistance shall meet the same requirements per 20.5;

c) Wet insulation resistance shall meet the same requirements per 20.6.

20.17 Impulse voltage

20.17.1 Purpose

To verify the capability of the solid insulation of the module to withstand over-voltages of atmospheric origin (e.g, lightning). It also covers over-voltages due to switching of low-voltage equipment.

For the purposes of test reproducibility, this test is conducted under the conditions of room temperature and relative humidity of less than 75 %. The procedure is as follows:

a) Disable any voltage limiting device installed on the module, if applicable.

b) For receivers constructed in the flat-plate format, go to step c). For all others, go to step d).

c) Cover the whole receiver with a conductive metal foil. Connect the foil to the negative terminal of the impulse voltage generator. The adhesive (conducting glue) shall have an electrical resistance < 1 Ω related to an area of 625 mm^2. Care shall be taken to avoid particle or air enclosure between the foil and the module as much as possible. Go to step e).

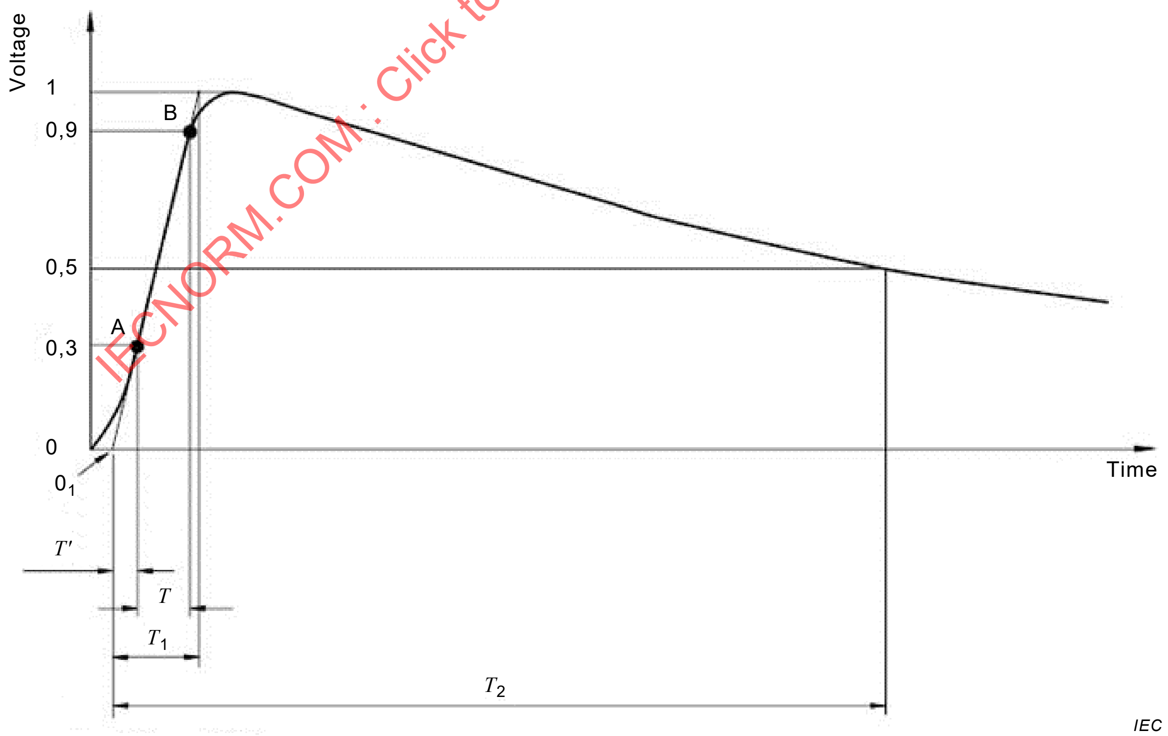
d) Connect the negative terminal of the impulse voltage generator to the accessible metallic part of the module housing. Connect the shorted output terminals of the module to the positive terminal of the impulse voltage generator. Apply the surge impulse voltage given in Table 15 with a waveform as shown in Figure 11 by the impulse voltage generator. According to IEC 60060-1 the surge impulse voltage shall be within ± 3 % of the value given in Table 15. No pressure correction is applicable during the MST14 tests lowering the impulse voltages applied.

e) The waveform of the pulse shall be observed by an oscilloscope connected as close to the short circuited module terminals as possible or with sufficient terminating impedance on the measurement cable connections, and the rise time and the pulse duration shall be checked for each test. Care should be taken that probes are appropriate to guarantee a reproducible measurement.

NOTE In IEC 60060-1 a test voltage function is defined, representing the response of insulations applicable for signal filtering.

Table 15 – Impulse voltage versus maximum system voltage

Maximum system voltage V	Impulse voltage Class II V	 Class 0 V
100	1 500	800
150	2 500	1 500
300	4 000	2 500
600	6 000	4 000
1 000	8 000	6 000
1 500	10 000	8 000



T_1 = 1,2 µs −10 % + 50 %

T_2 = 50 µs ± 20 %

Figure 11 – Waveform of the impulse voltage test

According to 4.3.3.2.2 of IEC 60664-1:2007, modules belong to the over-voltage category III. The test level has been reduced by one step because systems are normally equipped with over-voltage protection devices. On the other hand, to verify reinforced insulation (as required for application class II and Class II), the level for application class II has been increased by one step.

Linear interpolation is allowed for intermediate values of maximum system voltage.

f) Three successive pulses shall be applied.

g) Change the polarity of the terminals of the pulse generator and apply three successive pulses.

20.17.2 Requirements

a) No evidence of dielectric breakdown or surface tracking of the module is observed during the test.

b) No evidence of major visual defects as defined in 20.2.

c) Subclause 20.5 shall meet the same requirements as for the initial measurements.

20.18 CPV temperature test

20.18.1 Purpose

The CPV temperature test is designed to determine the maximum reference temperatures for various components and materials used to construct the module, in order to establish the suitability of their use.

20.18.2 Test apparatus

- The module shall be mounted in its position of maximum concentration onto the receiver. Some concentrators may achieve maximum concentration on off-normal solar incidence.
- A normal incidence pyrheliometer (NIP) mounted on a plane parallel to the input aperture of the test sample. – or verified as co-planar for assemblies and 1-axis systems. The location of the NIP shall be indicated in the test report.
- Instruments to measure wind speed down to 0,25 m/s installed at a location suitable to measure wind incident on the system.
- An ambient temperature sensor, with a time constant equal to, or less than, that of the module(s), installed in a shaded enclosure with good ventilation. The sensor shall be placed left or right of the platform so that no thermal interference can occur.
- A temperature monitoring system capable to measure module component temperatures with accuracy of ± 2 °C.
- A data acquisition system capable to record the parameters within an interval of no more than 5 s.
- A resistive load sized to operate the module near maximum power point for CSOC or maximum power tracking.

20.18.3 Procedure

CPV modules or representative modules shall be tested in their normal tracking condition during the test.

CPV assemblies shall be tested in their normal operation. A separate 2-axis tracker shall be used to take direct normal measurements incident on the total assembly.

CPV modules and assemblies utilizing active cooling shall be tested in their normal operation, with active cooling engaged.

Whenever possible, trough-type CPV assemblies should also be tested on a 2-axis tracker continually tracking the sun during the test. If logistical constraints prevent the mounting of the trough-type assembly a 2-axis tracker, then the trough-type assembly may be tested in 1-axis, but the direct normal irradiance shall be measured on a separate 2-axis tracker. In this case, the total diffuse radiation during the test shall be less than 10 % of the total global irradiance during the measurement. This alternate method should be discussed, as measured values changes with angular variations in the season.

The module under test shall be conducted in two operating conditions:

a) open-circuit;
b) connected to a resistive load or maximum power-tracking device.

Throughout the test the following parameters shall be monitored:

- Temperatures of module components and materials, as listed below;
- ambient temperature;
- irradiance;
- wind speed.

The ambient temperature during the test may be in the range of 20 °C to 55 °C. The irradiance during the test shall be no less than 700 W/m² *DNI*. All data shall be taken at wind-speeds of less than 2 m/s.

Stabilised temperature data for each test location shall be collected. Thermal stability has been attained when three successive readings, taken at least 5 min apart, indicate a change in temperatures of less than ±2 °C.

The temperatures of the measured components shall be normalized through standard regression techniques. The criteria and calculations listed below shall be used to normalize the temperatures measured during the test.

- Reference *DNI* = 900 W/m^2
- Reference global total irradiance = 1 000 W/m^2
- Wind speed < 1 m/s
- Ambient temperature = 40 °C

Normalization to each reference irradiance condition shall be made. The higher of the two values shall be used as the final measurement value.

Typical component measurement points shall include:

- Terminal enclosure interior surface.
- Field wiring terminals.
- Insulation of the field wiring leads.
- External connector bodies (if applicable).
- Bypass diode bodies (if applicable).
- Housing seals or adhesives.
- Secondary optics – if polymeric.

20.18.4 Requirements

The requirements are as follows:

a) No measured temperatures exceed any of the temperature limits of surfaces as given in Table 1; or materials or components as given in independently verified product specifications.

b) Temperature of polymer materials that require a TI, RTE or RTI rating are found to be at least 10 ºC less than their respective TI, RTE or RTI ratings.

c) No visual defects as defined in 20.1.

20.19 Fire test recommendation for CPV modules

20.19.1 General

Modules mounted in or on buildings, in general, shall fulfil national building and construction regulations and requirements. If such requirements are not available, the following international and national standards give information for tests, which could be used: ISO 834-1, ISO 834-3, ISO 5657, ENV 1187-1 to-4, ANSI/UL 790, EN 13501-1.

20.19.2 Burning brand fire tests

20.19.2.1 Purpose

20.19.2.2 Internal burning brand test

The internal burning brand test ensures that the creation of flame within the module itself is contained and does not propagate.

In this case, the components inside the enclosure, if applicable, are exposed to the burning brands, typically the receivers. See Table 16 for applicability of this test.

20.19.2.3 External burning brand test

The external burning brand test ensures there is no propagation of fire in the event of a burning ember landing on a module.

In this case, the outer surface of the module facing the sun during operation is exposed to the burning brands, typically the primary optic. See Table 16 for applicability of this test.

20.19.2.4 Test apparatus and set-up

Test apparatus and test environment shall be consistent with all applicable aspects of UL 790:2004, section 5. Size and construction of brands.

The brands to be used in these tests are described in Figure 8.2 of UL 790:2004 (see Table 16).

Table 16 – Brand size and its number

	Class B	Class C	
Brand size (mm)	150 x 150 x 57	38,1 x 38,1 x 19,8	
Number of brands	2	20	

20.19.2.5 Ignition of brands

Before application to the test deck, the brands are to be ignited so as to burn freely in still air. The flame of the gas burner used to ignite the brands is to essentially envelop the brands during the process of ignition. The temperature of the igniting flame is to be 888 28 °C measured 58,7 mm above the top of the burner. The burner is to be shielded from drafts.

Class 0 brands are to be exposed to the flame for 4 min during which time they are to be rotated to present each surface to the flame as follows:

a) Each 152 by 152 mm face for 30 s,

b) Each 57,2 by 152 mm face for 30 s,

c) Each 152 by 152 mm face again for 30 s.

Class III brands are to be exposed to the flame for 2 min, during which time they are to be rotated so as to present each of the 38,1 mm by 38,1 mm faces to the flame for 1 min.

20.19.2.6 Test conditions

20.19.2.6.1 General

In the case of a test using the Class B brand, two brands are to be used. The brands are to be placed so that the strips in both the upper and lower layers are parallel to the direction of air flow from the blower.

In the case of a test using the Class C brand, twenty ignited brands are to be placed, at 1 min or 2 min intervals so that the saw kerf on the deck side of the brand is to be parallel to the direction of the air flow from the blower, No brand is to be placed closer than 102 mm to the point where the previous brand was located, except in cases where the module size is too small to accommodate all 20 brands. In that situation, the 20 brands are to be equally spaced on the test surface at a distance smaller than 102 mm. Test samples are to be handled consistent with 4.5 of UL 790:2004.

20.19.2.6.2 Internal burning brand test

The internal burning test is applicable in cases where the material flammability rating of 13.1.3.3 has not been met and the module manufacturer wishes to use this test as an alternate method of evaluation in order to obtain a fire rating.

The brand(s) are to be placed directly on surfaces inside the enclosure. A test sample shall be provided such that the cover can be easily removed in order to execute the test. Brands are to be placed such that all flammable materials are evaluated, including on the surface of receivers and in the spaces between. In the case of a test using Class III brands, attempt should be made to equally space the brands. However, the requirement for equal spacing is superseded by the requirement to evaluate vulnerable materials and locations within the module.

If the module shall be altered in any way, such as removal of the primary optic, the modules shall be re-assembled as close to its original configuration as practicable. In the case where a primary optic is installed over a box enclosure, a sample shall be provided which allows the primary optic to be easily removed, brands to be placed inside the enclosure, and primary optic to be returned to position during the test.

20.19.2.6.3 External burning brand test

For the external burning brand test, the brands are placed directly on the outer surface of the module which faces the sun during operation. Typically, this will be the primary optic.

20.19.2.7 Duration of test

The test is to be continued until all brands are consumed and until all evidence of flame, glow, and smoke has disappeared from the exposed surface of the material being tested or until unacceptable results occur, but not for more than 1,5 h. The results of tests in which the brands do not show progressive and substantially complete consumption after application to the module test surface are to be disregarded and the test is to be repeated on a new test sample.