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REDLINE VERSION

INTERNATIONAL STANDARD

Concentrator photovoltaic (CPV) modules and assemblies – Design qualification and type approval

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colour inside

Concentrator photovoltaic (CPV) modules and assemblies – Design qualification and type approval

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

CONCENTRATOR PHOTOVOLTAIC (CPV) MODULES AND ASSEMBLIES – DESIGN QUALIFICATION AND TYPE APPROVAL

FOREWORD

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This redline version of the official IEC Standard allows the user to identify the changes made to the previous edition IEC 62108:2016. A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text.

IEC 62108 has been prepared by IEC technical committee 82: Solar photovoltaic energy systems. It is an International Standard.

This third edition cancels and replaces the second edition published in 2016. This edition constitutes a technical revision.

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

a) Changes in the procedure of the thermal cycling test for the active cooling module.

b) Solar simulator I-V measurement.

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

Draft	Report on voting
82/2024/FDIS	82/2046/RVD

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

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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CONCENTRATOR PHOTOVOLTAIC (CPV) MODULES AND ASSEMBLIES – DESIGN QUALIFICATION AND TYPE APPROVAL

1 Scope ~~and object~~

This document specifies the minimum requirements for the design qualification and type approval of concentrator photovoltaic (CPV) modules and assemblies suitable for long-term operation in general open-air climates as defined in IEC 60721-2-1. The test sequence is partially based on that specified in IEC 61215-1 for the design qualification and type approval of flat-plate terrestrial crystalline silicon PV modules. However, some changes have been made to account for the special features of CPV receivers and modules, particularly with regard to the separation of on-site and in-lab tests, effects of tracking alignment, high current density, and rapid temperature changes, which have resulted in the formulation of some new test procedures or new requirements.

The object of this test document is to determine the electrical, mechanical, and thermal characteristics of the CPV modules and assemblies and to show, as far as possible within reasonable constraints of cost and time, that the CPV modules and assemblies are capable of withstanding prolonged exposure in climates described in the scope. The actual life of CPV modules and assemblies so qualified will depend on their design, production, environment, and the conditions under which they are operated.

This document ~~shall be~~ is used in conjunction with the retest guidelines described in Annex B.

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 60068-2-21:2006, *Environmental testing – Part 2-21: Tests – Test U: Robustness of terminations and integral mounting devices*~~

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

IEC 60664-1:2020, *Insulation coordination for equipment within low-voltage supply systems – Part 1: Principles, requirements and tests*

IEC 60721-2-1, *Classification of environmental conditions – Part 2-1: Environmental conditions appearing in nature – Temperature and humidity*

IEC 60904-1:2020, *Photovoltaic devices – Part 1: Measurement of photovoltaic current-voltage characteristics*

IEC 60904-1-1:2017, *Photovoltaic devices – Part 1-1: Measurement of current-voltage characteristics of multi-junction photovoltaic (PV) devices*

IEC TS 60904-1-2:2019, *Photovoltaic devices – Part 1-2: Measurement of current-voltage characteristics of bifacial photovoltaic (PV) devices*

IEC 60904-2:2015, *Photovoltaic devices – Part 2: Requirements for photovoltaic reference devices*

IEC 60904-3:2019, *Photovoltaic devices – Part 3: Measurement principles for terrestrial photovoltaic (PV) solar devices with reference spectral irradiance data*

IEC 60904-4:2019, *Photovoltaic devices – Part 4: Photovoltaic reference devices – Procedures for establishing calibration traceability*

IEC 60904-5:2011, *Photovoltaic devices – Part 5: Determination of the equivalent cell temperature (ECT) of photovoltaic (PV) devices by the open-circuit voltage method*

IEC 60904-7:2019, *Photovoltaic devices – Part 7: Computation of the spectral mismatch correction for measurements of photovoltaic devices*

IEC 60904-8:2014, *Photovoltaic devices – Part 8: Measurement of spectral responsivity of a photovoltaic (PV) device*

IEC 60904-8-1:2017, *Photovoltaic devices – Part 8-1: Measurement of spectral responsivity of multi-junction photovoltaic (PV) devices*

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

IEC 61210:2010, *Connecting devices – Flat quick-connect terminations for electrical copper conductors – Safety requirements*

IEC 61215-1:2021, *Terrestrial photovoltaic (PV) modules – Design qualification and type approval – Part 1: Test requirements*

IEC 61215-2:~~2016~~2021, *Terrestrial photovoltaic (PV) modules – Design qualification and type approval – Part 2: Test procedures*

IEC TS 61836:2016, *Solar photovoltaic energy systems – Terms, definitions and symbols*

IEC 61853-1:2011, *Photovoltaic (PV) module performance testing and energy rating – Part 1: Irradiance and temperature performance measurements and power rating*

IEC 61853-2:2016, *Photovoltaic (PV) module performance testing and energy rating – Part 2: Spectral responsivity, incidence angle and module operating temperature measurements*

IEC 61853-3:2018, *Photovoltaic (PV) module performance testing and energy rating – Part 3: Energy rating of PV modules*

IEC 62670-1, *Photovoltaic concentrators (CPV) – Performance testing – Part 1: Standard conditions*

IEC 62670-3:2017, *Photovoltaic concentrators (CPV) – Performance testing – Part 3: Performance measurements and power rating*

IEC 62790:2020, *Junction boxes for photovoltaic modules – Safety requirements and tests*

IEC 62852:2014, *Connectors for DC-application in photovoltaic systems – Safety requirements and tests*
IEC 62852:2014/AMD1:2020

~~ANSI/UL 1703:2002, *Standard for Safety: Flat-Plate Photovoltaic Modules and Panels*~~

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60664-1, IEC TS 60904-1-2, IEC 61140, IEC TS 61836 and the following apply, see also Table 1.

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

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

3.1
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. Typically, it is a lens or a mirror

Note 1 to entry: 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 stand-alone, 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 above components are usually prefabricated as one unit, and the focus point is not field adjustable.

Note 2 to entry: A module could be made of several sub-modules. The sub-module is a physically stand-alone, smaller portion of the full-size module.

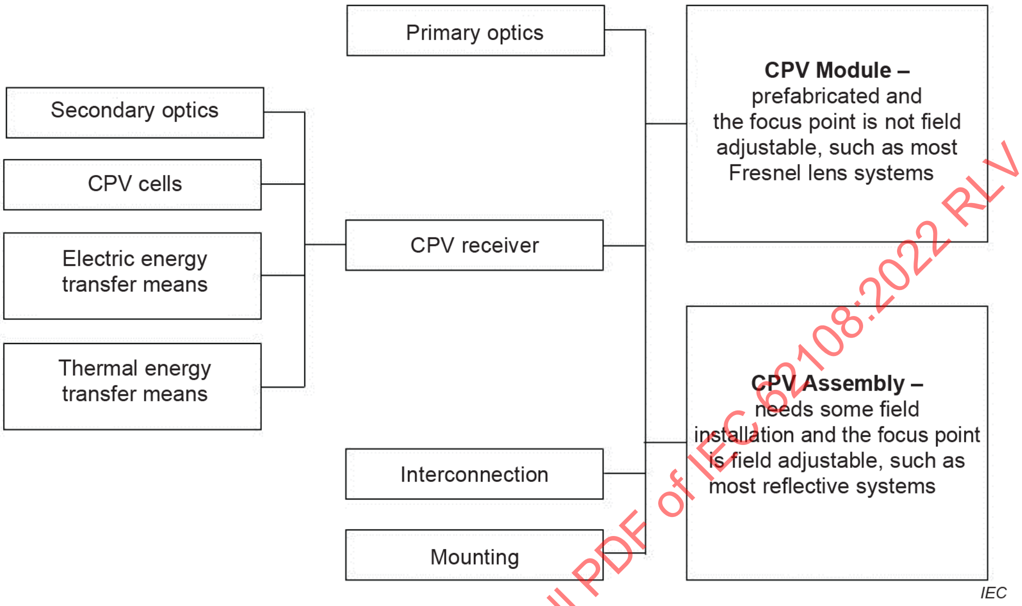
3.6
concentrator assembly
group of receivers, optics, and other related components, such as interconnection and mounting, that accepts unconcentrated sunlight

Note 1 to entry: All above components would usually be shipped separately and need some field installation, and the focus point is field adjustable.

Note 2 to entry: 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
control unit
hardware that is not stressed, but is included in each measurement to enable greater confidence in consistent measurements

Table 1 – Terms used for CPV



4 Sampling

Figure 1 to Figure 5 are schematics of cells, receivers, modules, and assemblies.

For non-field-adjustable focus-point CPV systems or modules, 7 modules and 2 receivers are required to complete all the specified tests, plus one receiver for the bypass/blocking diode thermal test (intrusive or non-intrusive). For details, see Figure 6. For field-adjustable focus-point CPV systems or assemblies, 9 receivers (including secondary optics sections, if applicable) and 7 primary optics sections are required to complete all the specified tests, plus one receiver for the bypass/blocking diode thermal test (intrusive or non-intrusive). For details, see Figure 7.

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 can be used. However, even if representative samples are used for the other test, a full-size module or assembly shall 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 shall use sub-receivers, sub-modules, or sub-assemblies. 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 shall 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 should be noted in the test report (see Clause 8).

The test samples shall have been manufactured from specified materials and components in accordance with the relevant drawings and process instructions and should have been subjected to the manufacturer's normal inspection, quality control, and production acceptance procedures. They shall be complete in every detail and should 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 is required with extra electrical and thermal detector leads so that each individual diode can be accessed separately.

5 Marking

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

– Name, monogram, or symbol of manufacturer.
– Type or model number.
– Serial number.
– Polarity of terminals or leads (color coding is permissible).
– Maximum system voltage for which the module or assembly is suitable.
– Nominal maximum output power and its tolerance at specified condition.
– The date, place of manufacture, and cell materials shall be marked, or be traceable from the serial number.

If representative samples are used, the same markings as on full-size products shall be included for all tests, and the marking should be capable of surviving all test sequences.

6 Testing

If recommended by the manufacturer, before beginning the testing, all testing samples, including the control module and control receiver, shall be exposed to the direct normal irradiation (DNI) of sunlight (either natural or simulated) for a total of 5 kWh/m^2 to 5,5 kWh/m^2 while open circuited. This procedure is designed to reduce the initial photon degradation effects.

In this document all references to short-circuit current I_{sc}, open-circuit voltage V_{oc}, maximum output power P_m, are based on Concentrator Standard Test Condition (CSTC), which is defined in IEC 62670-1. Alternatively, Concentrator Standard Operating Conditions (CSOC), as defined in IEC 62670-1, may be used consistently. Other parameters and testing method unless specified are based on IEC 60904 and IEC 61853.

The test samples shall be randomly divided into groups and subjected to the qualification test sequences in Figure 6 or Figure 7. Test procedures and requirements are detailed in Clause 10, and summarized in Annex A. The allocation of test samples to typical test sequences is given in Table 2.

After initial tests and inspections, one module or one receiver/mirror section shall be removed from the test sequence as a control unit. Preferably, the control unit should be stored in the dark at room temperature to reduce the electrical performance degradation, but it may be kept outdoors with a dark cover. As shown in Figure 6 for modules or in Figure 7 for assemblies, the test sequence is performed both in-lab and on-site. If the CPV receiver uses crystalline silicon, a 1-sun measurement (flash or outdoor) can be used as a diagnostic tool throughout the program. 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 should be performed to evaluate any possible changes on testing samples.

If a particular manufacturer produces only specific components, such as receivers, lenses, or mirrors, the design qualification and type approval testing can be conducted only on applicable test sequences, and a partial certification can be issued independently.

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 document. Any changes and deviations shall be recorded and reported in details, as required in Clause 8 j).

Table 2 – Allocation of test samples to typical test sequences

Test sequence	Module		Assembly	
	receiver	module	receiver	mirror
Control		1	1	1
A	2		2	
B		2	2	2
C		2	2	2
D		1	1	1
E		1 (full-size)	1 (full-size)	1 (full-size)
F	1		1	
Total	3	7	10	7

7 Pass criteria

A concentrator photovoltaic module or assembly design shall be judged to have passed the qualification tests, and therefore to be IEC 62108 type approved, if each test sample meets all the following criteria:

a) The relative power degradation in sequence A to D does not exceed 13 % if the I-V measurement is under outdoor natural sunlight, or 8 % if the I-V measurement is under solar simulator.

b) The relative power degradation in sequence E does not exceed 7 % for natural sunlight I-V measurement, or 5 % for solar simulator I-V measurement, because the 1 000 kWh/m^2 DNI outdoor exposure test is not an accelerated stress test.

c) No sample has exhibited any open circuit during the tests.

d) There is no visual evidence of a major defect, as defined in 10.1.2.

e) The insulation test requirements are met at the beginning and the end of each sequence.

f) The wet leakage current test requirements are met at the beginning and the end of each sequence.

g) Specific requirements of the individual tests are met.

If there are some failures observed during the test, the following judgment and re-test procedure shall apply:

h) If two or more test samples do not meet pass criteria, the design shall be deemed not to have met the qualification requirements.

i) Should one sample fail any test, another two samples meeting the requirements of Clause 4 could be subjected to the whole of the relevant test sequence from the beginning.

j) In case i), if both samples pass the test sequence, the design shall be judged to have met the qualification requirements.

k) In case i), if one or both of these samples also fail, the design shall be deemed not to have met the qualification requirements.

l) In case h) or k), the entire test program illustrated in Figure 6 or Figure 7 shall be re-performed, usually after some design or processing improvement.

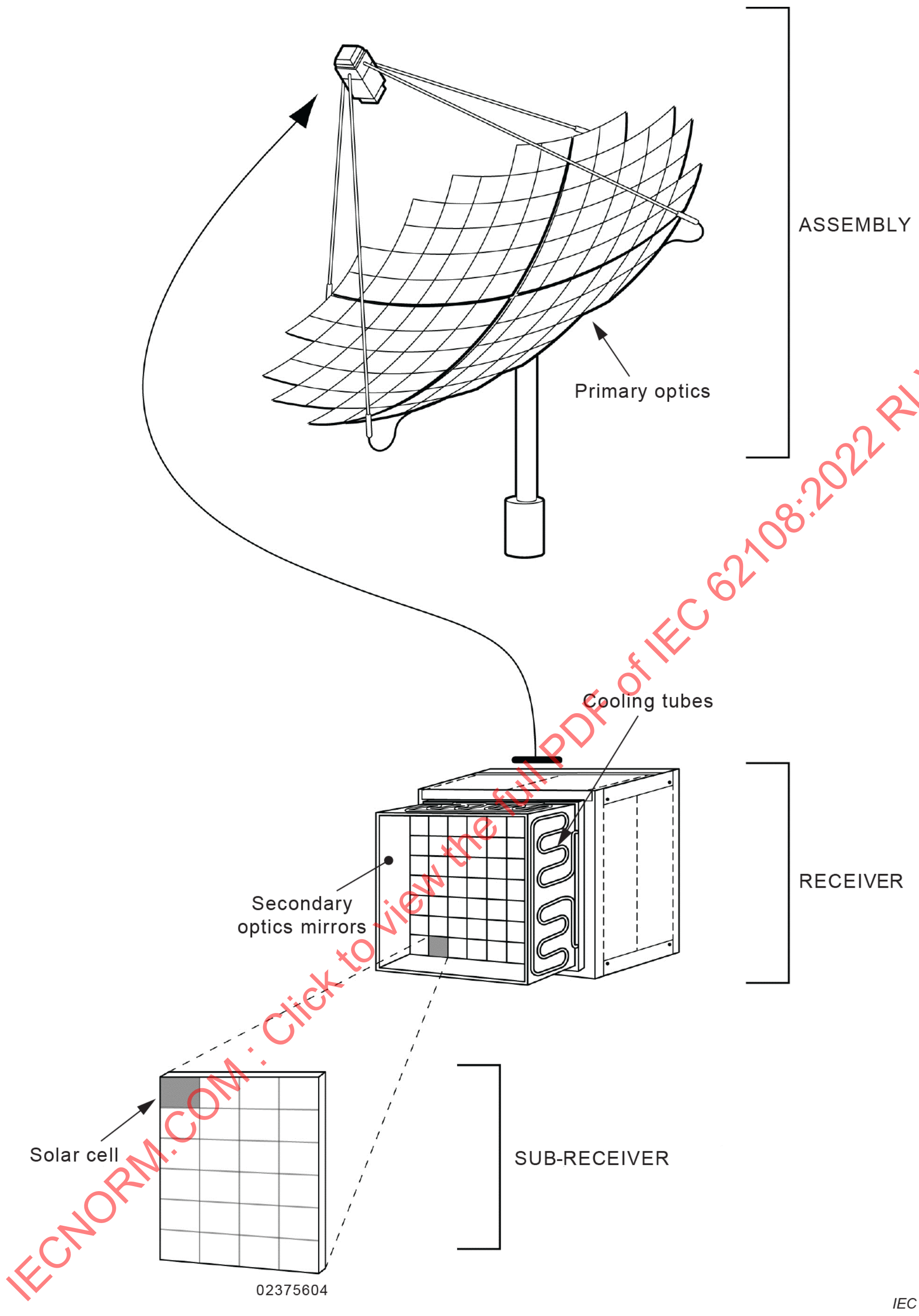


Figure 1 – Schematic of point-focus dish PV concentrator

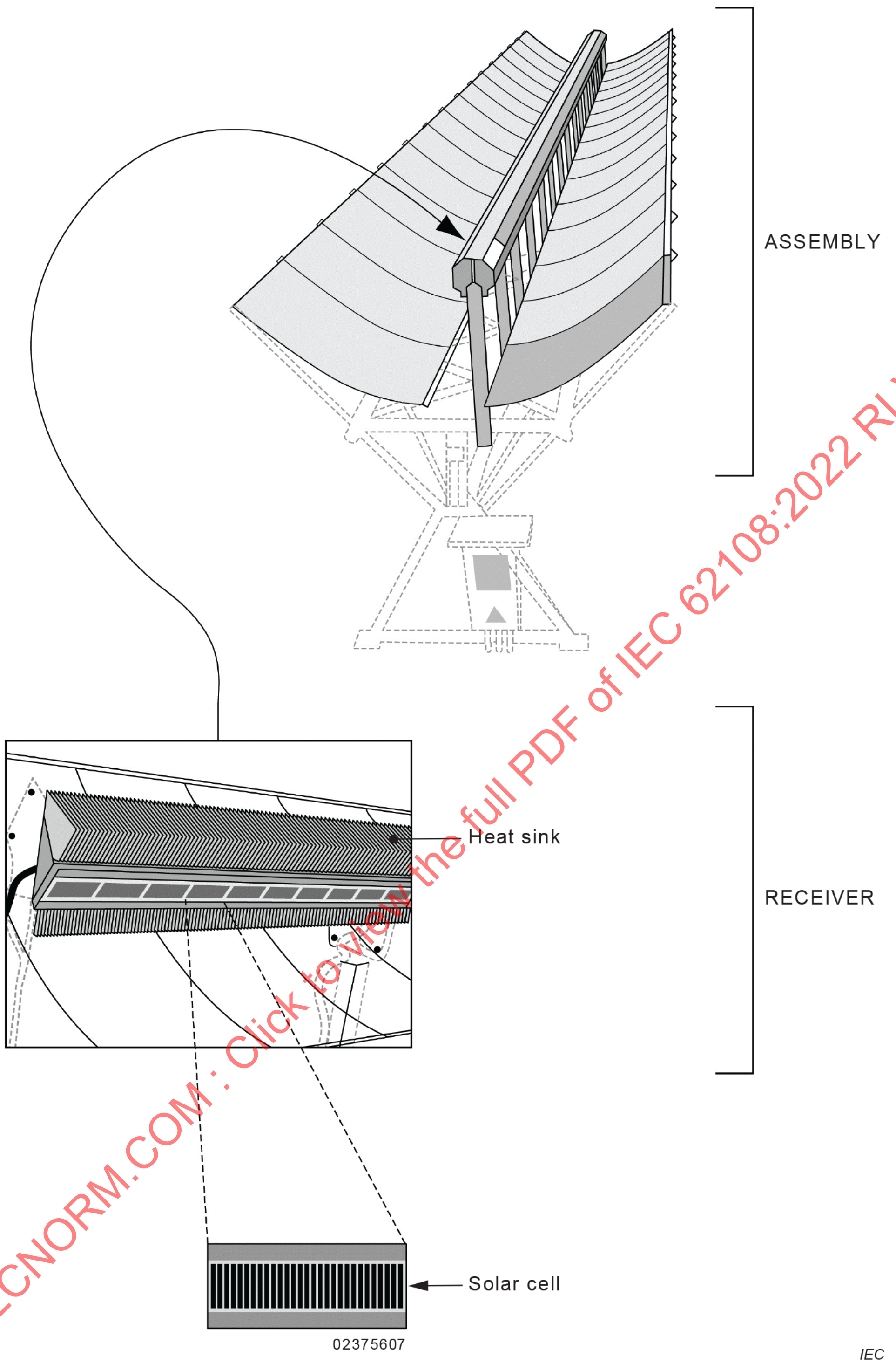


Figure 2 – Schematic of linear-focus trough PV concentrator

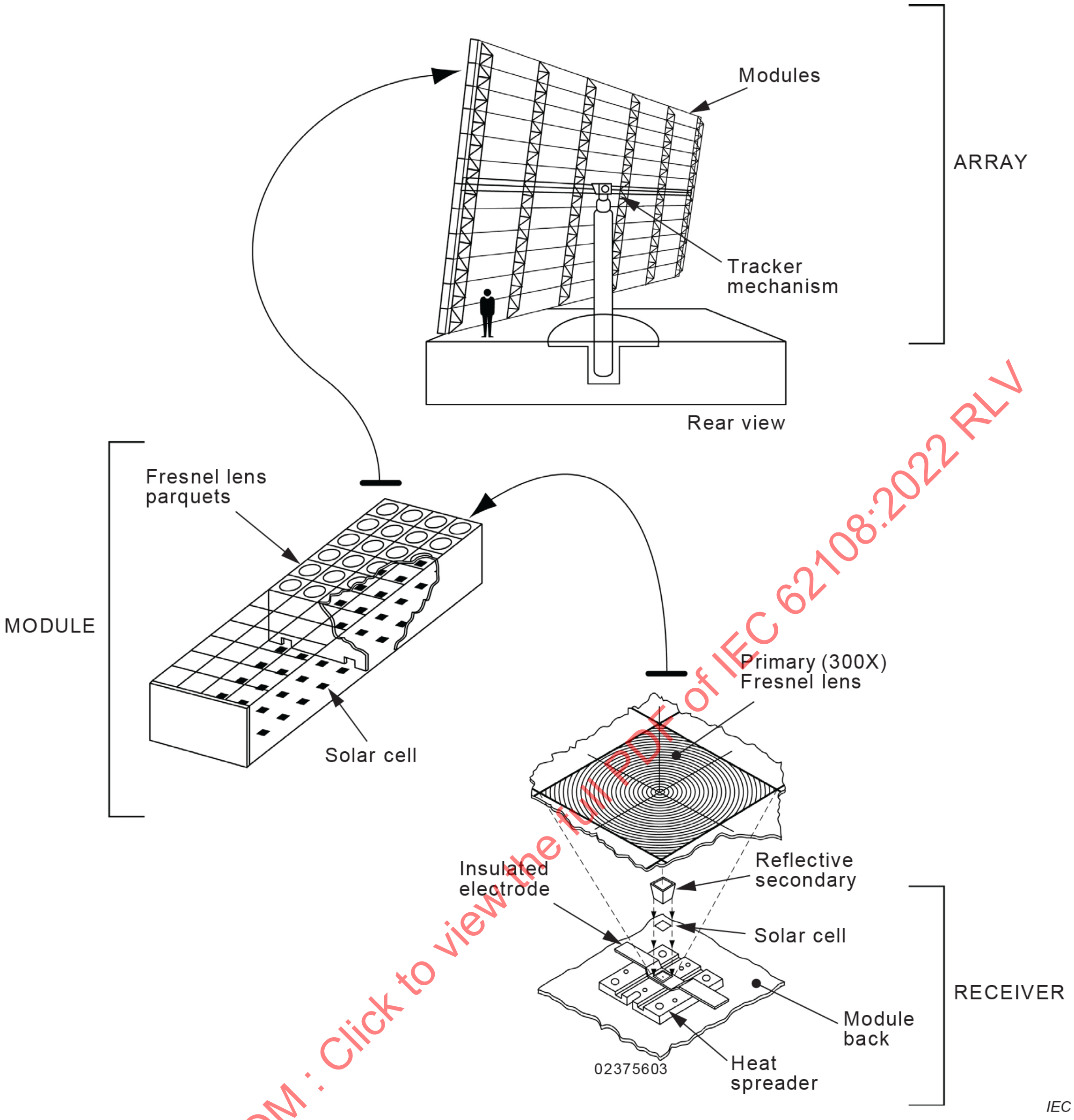


Figure 3 – Schematic of point-focus Fresnel lens PV concentrator

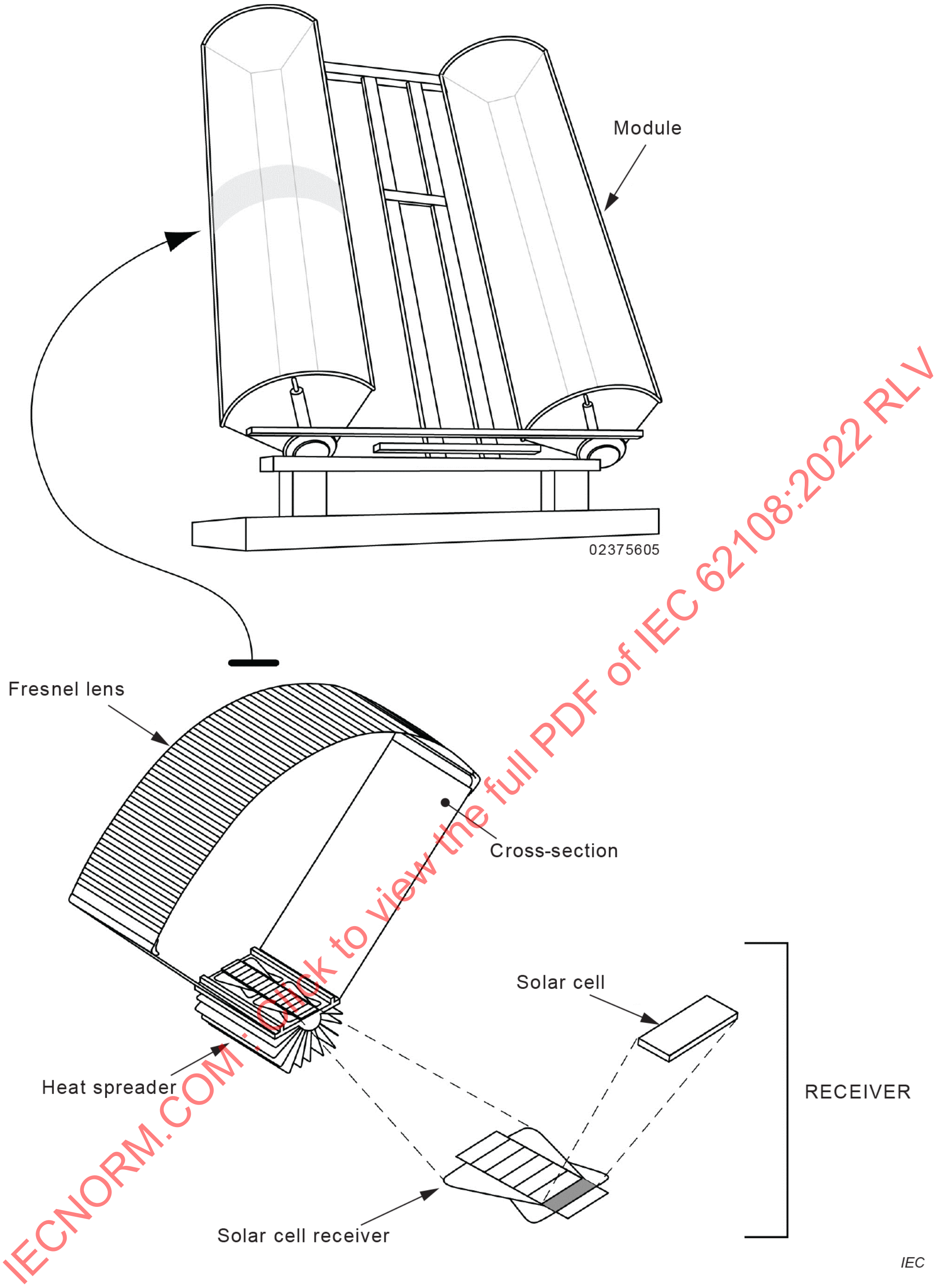


Figure 4 – Schematic of linear-focus Fresnel lens PV concentrator

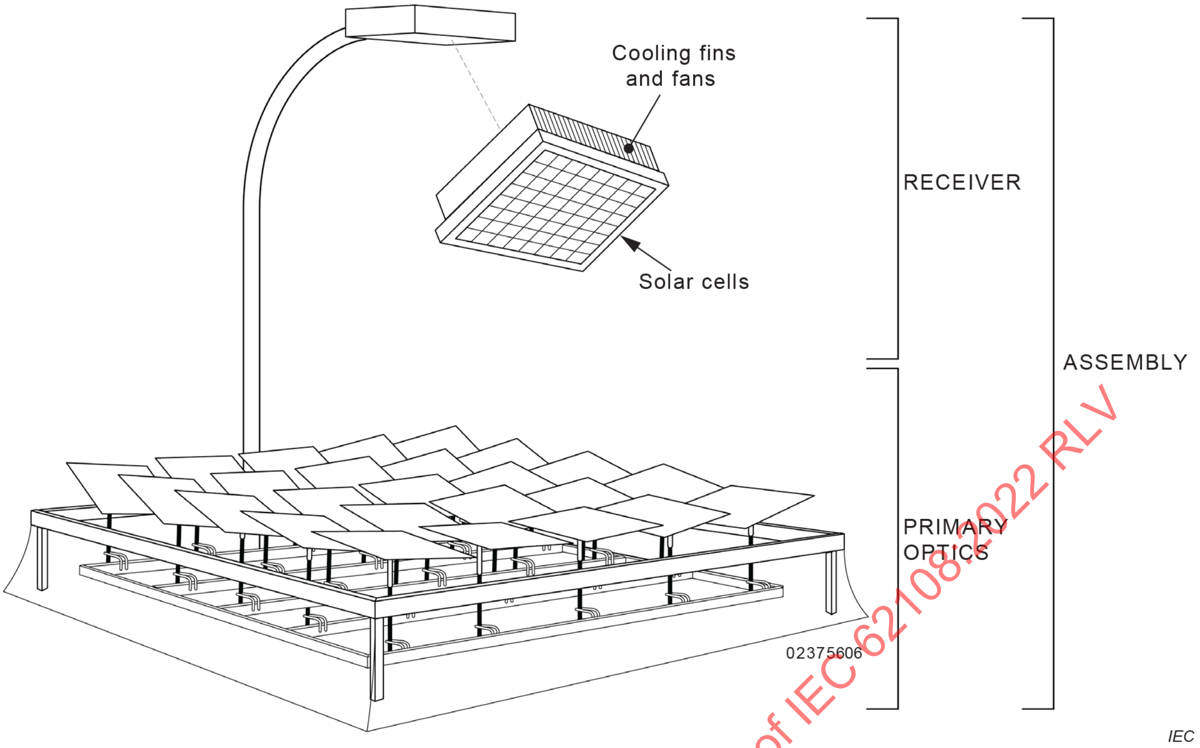


Figure 5 – Schematic of a heliostat CPV

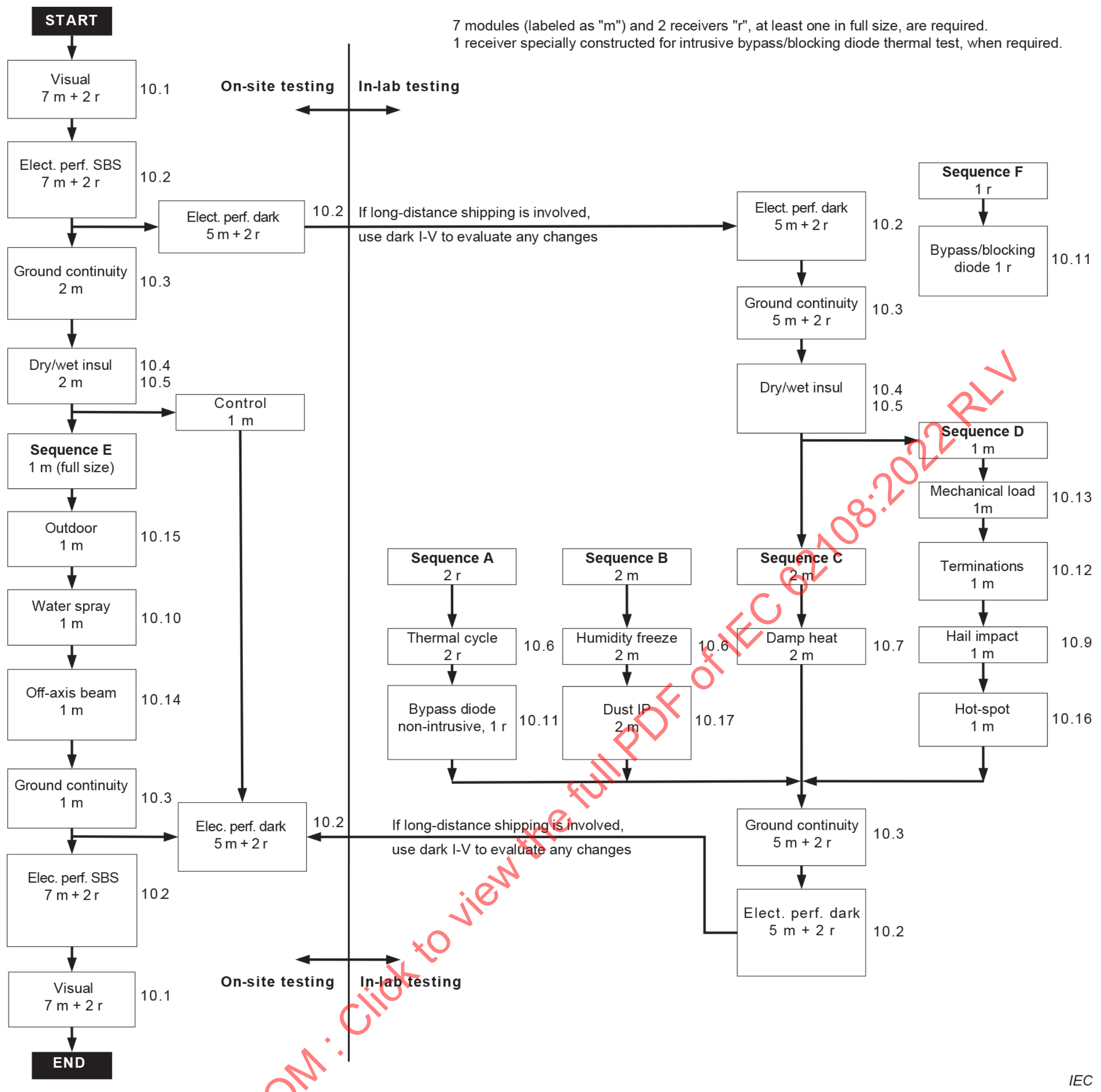


Figure 6 – Qualification test sequence for CPV modules

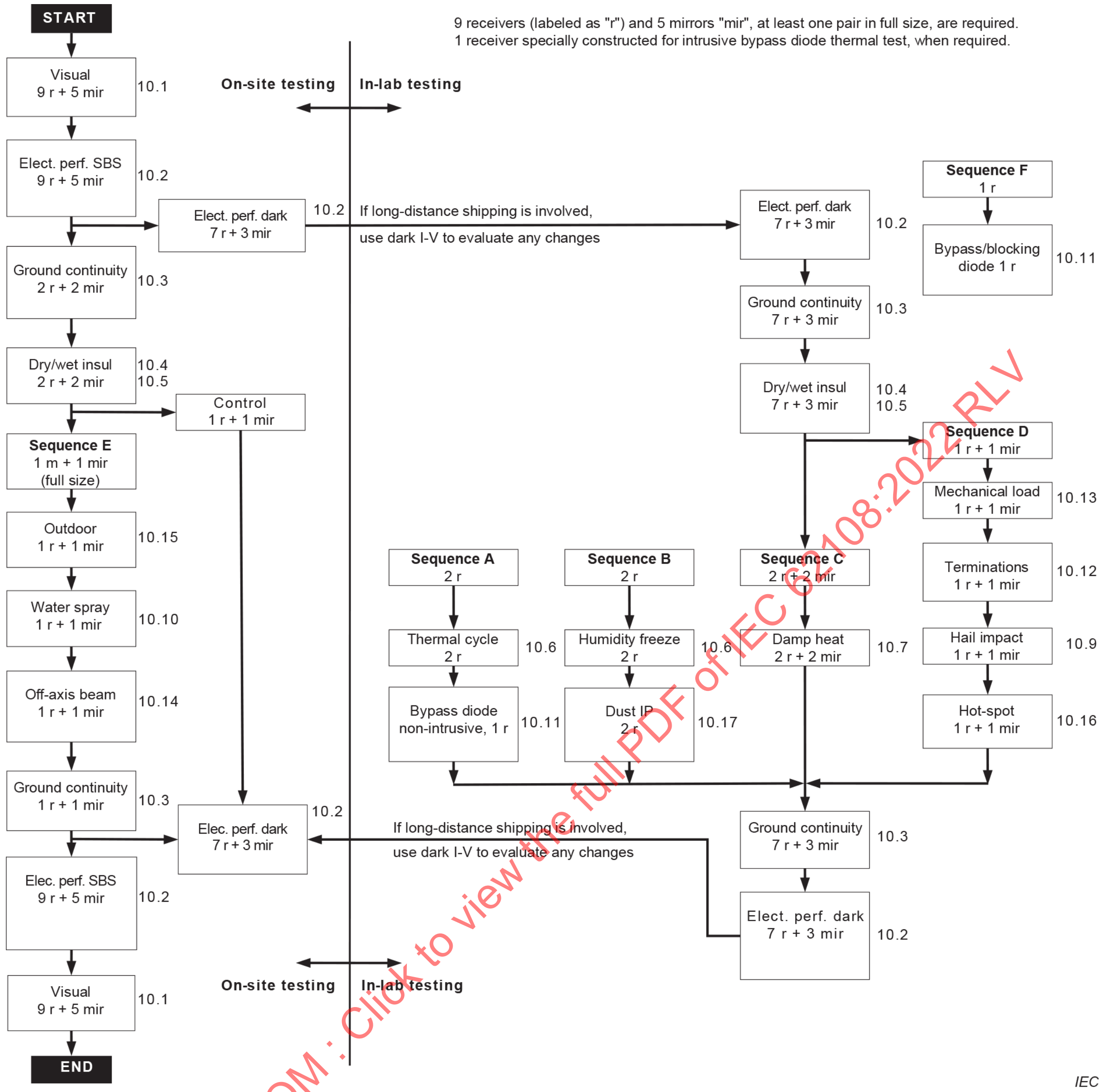


Figure 7 – Qualification test sequence for CPV assemblies

8 Report

Following type approval, a certified report of the qualification tests, with measured performance characteristics and details of any failures and re-tests, shall be prepared by the test agency. Each test report shall include at least the following information: Components test unless specified is based on IEC 62790 and IEC 62852.

a) A title.

b) The name and address of the laboratory, and the location where the tests were carried out, if different from the address of the laboratory (such as on-site location).

c) Unique identification of the test report (such as the serial number), and on each page an identification to ensure that the page is recognized as a part of the test report, and a clear identification of the end of the test report.

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 test method, and any other information relevant to a specific test, such as environmental conditions.

k) Measurements, examinations, and derived results supported by tables, graphs, sketches, and photographs as appropriate, including short-circuit current, open-circuit voltage, maximum output power, maximum power loss observed after all of the tests, and any failures observed.

l) A statement of the estimated uncertainty of the test results, where relevant.

m) A signature and title, or equivalent identification, of the person(s) accepting responsibility for the content of the report, and the date of issue.

n) Where relevant, a statement to the effect that the results relate only to the items tested.

o) A statement that to maintain the qualification and type approval, the manufacturer shall report to and discuss with the certifying body and testing agency every change they made, guided by the retest guidelines provided in Annex B.

p) A statement that the report shall not be reproduced except in full, without the written approval of the laboratory.

A copy of this report should be kept by the manufacturer for reference purposes.

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, as described in Annex B. Manufacturers shall report to and discuss with the certifying body and testing agency every change they made.

10 Test procedures

10.1 Visual inspection

10.1.1 General

This procedure provides the requirements for obtaining baseline, intermediate, and final visual inspections to identify and determine any physical changes or defects in module or assembly construction at the beginning and after the completion of each required test.

Any hardware showing initial damage not due to the manufacturing process should be rejected if it may worsen and lead to failure during the subsequent environmental tests. A new module or assembly may then be substituted before beginning the test sequence.

10.1.2 Procedure

All test samples shall be thoroughly inspected and photographed when necessary. All defects or abnormalities (including initial defects related to the quality of solder joints such as inadequate or excessive solder, solder balls, bent interconnects, or misalignment of parts) shall be documented with appropriate sketches or photographs to show the locations of the defects. Components, such as the lens, mirror, secondary optical elements, heat spreaders, and encapsulants, shall also be inspected for defects. Specifically, inspect for:

a) Bubbles, delamination, or any kind of similar defect on the cell and around its edges.

b) Damage incurred during shipping and handling, such as cracked lenses, cracked or bent housings, and bent terminals or mounting brackets.

c) Integrity of the seal around the lens and housing joints. Any crack or gap in sealant materials shall be noted.
d) Any ventilation hole or breather shall not be clogged.
e) Provision for grounding all accessible conductive parts.
f) Broken, cracked, bent, misaligned, or torn external surfaces.
g) Faulty interconnections or joints.
h) Visible corrosion of output connections, interconnections, and bus bars.
i) Failure of adhesive bonds.
j) Tacky surfaces of plastic materials.
k) Faulty terminations, or exposed live electrical parts.
l) Any other conditions that may affect reliability or performance.

10.1.3 Major visual defects

For the purpose of design qualification and type approval, the following are considered to be major visual defects:

a) Broken, cracked, bent, misaligned, or torn external surfaces, including lens, mirror, receiver body, frame, and junction box.
b) Broken or cracked cells.
c) Bubbles or delamination forming a continuous path between any part of the electrical circuit and the edge of the receiver.
d) Visible corrosion of any of the active circuitry of the sample.
e) Adhesive or sealant failures.
f) Loss of mechanical integrity, to the extent that the installation and/or operation of the modules or assemblies would be impaired.

10.1.4 Requirements

No major visual defects.

10.2 Electrical performance measurement

10.2.1 Purpose

The purpose of the electrical performance test is to identify electrical performance degradation of test samples caused by required tests. The focus of this test is on the power degradation, not on the absolute power output, which will be covered by a separate power and energy rating standard.

Repeatability of the measurement is the most important factor for this test.

10.2.2 Outdoor side-by-side I-V measurement

10.2.2.1 General

The side-by-side I-V measurement identifies power degradation of a test sample by comparing its post-stress test relative power to its pre-stress test relative power. The relative power is defined as the maximum power output of the sample under test divided by the maximum power output of the control sample, measured under similar test conditions. This method is based on the assumption that the changes of the control sample's electrical performance are negligible during the whole qualification test period. By using this method, test condition variables are self-correcting, and the complex translation procedures are eliminated.

The side-by-side I-V measurement is required for each test sample on the beginning and final I-V measurements. It is optional for all intermediate I-V measurements.

When applying this method to receivers, the control receiver and the receiver under test shall be installed with a proper optical and mechanical system so that during the test, the concentrated light and thermal conditions of these two receivers are similar to the real operating conditions.

10.2.2.2 Procedure

Measure the relative power of a test sample according to following procedures:

a) Conduct the test on a favorable day and during a period of time that meets the following conditions:
   - sky is clear, DNI is greater than 700 W/m^2, and its variation is less than 2 % in any 5 min interval;
   - for systems with acceptance half-angle larger than 2,5°, no visible clouds or hazy conditions in 45° view angle around the sun;
   - wind speed is less than 6 m/s, and no gust of greater than 10 m/s in 10 min before any measurement.

   Pay attention to the tracking system's rigidity and make sure it is stable under the windy condition.
b) Mount the test sample and the control sample side-by-side on a two-axis tracker. The alignment of the samples to sunlight could be done by either of following two sequences:
   - adjust the test and control samples to co-plane, then align both of them together to the direction of sun beam; or
   - separately align the test and control samples to the sun beam before each I-V measurement.

   NOTE Test sample and control sample can also be tested on two adjacent two-axis trackers, or two receivers can be tested in sequence on one tracker and optical system, if all conditions in a) are met.
c) Alignment shall meet the manufacturer's specifications. If specifications are not available, use the maximum I_{sc} of the module as an indicator of alignment. Misalignment shall not cause I_{sc} to decrease more than 2 % from its maximum value.
d) Monitor sample's temperature to make sure the sample temperature changes are less than 2 °C in any 1 min period.
e) If coolant is employed, monitor coolant flow rate and inlet/outlet temperatures. The coolant flow rate shall not change by more than 2 %, and the temperature shall not change by more than 1 °C in any 5 min period.
f) Take I-V measurements on both samples to obtain their maximum power output. This procedure shall be completed quickly so that the change of power output caused by solar irradiance, ambient temperature, and wind speed changes is less than 2 % during this step.
g) Calculate the sample's relative power P_r:

$$P_r = \frac{P_m}{P_{mc}} \times 100\ \%$$

   where:

   P_r is the sample's relative power, in %;

   P_m is the test sample's maximum power, in W;

   P_{mc} is the control sample's maximum power measured at the similar condition as P_m, in W.

10.2.2.3 Requirements

a) The sample's maximum power (P_m), I_{sc}, and V_{oc} shall be measured accurately and repeatably.

b) The relative power degradation, P_{rd}, is defined as follows:

$$P_{rd} = \frac{P_{ri} - P_{rf}}{P_{ri}} \times 100\ \%$$

where:

P_{rf} is the relative power measured after the given test;

P_{ri} is the relative power measured before the given test.

For outdoor measurement, P_{rd} shall be less than 13 %, and for indoor simulator measurement, P_{rd} shall be less than 8 %. The 5 % difference takes into account the larger uncertainty from outdoor measurements.

10.2.3 Solar simulator I-V measurement

CPV I-V measurement could also be performed under indoor solar simulator according to IEC 62670-3:2017, 9.5 and 9.6. The testing lab should create its own testing procedure, as long as similar conditions are achieved.

10.2.4 Dark I-V measurement

10.2.4.1 General

The dark I-V measurement compares the sample's series resistances measured before and after the tests. It is performed before and after the test sample's shipping to evaluate any possible changes.

The dark I-V measurement is also a cost-effective method to monitor and diagnose power degradation of test modules or assemblies following intermediate stress tests, or to monitor the electric performance stability of the control samples.

10.2.4.2 Procedure

If the dark I-V is used for diagnostic purpose, it should be measured during initial measurements to establish a reference for later dark I-Vs, in addition to the side-by-side baseline I-V measurement, which serves as a reference for later side-by-side I-Vs. The method is applicable to both receivers and modules.

a) Choose a suitable power source, which could be a conventional DC power supply or a charged-up capacitor, whatever is most convenient, as long as it will generate current up to 1,6 times rated I_{sc}. The current should be adjustable so that there are at least 10 separate points in the range of 0,9 to 1,6 times rated I_{sc}, and the interval of the points should be nearly equal-spaced.

b) Short the blocking diode by placing a jumper lead across the leads of the blocking diode, if there is one installed.

c) Connect the power source's positive lead to sample's positive lead, and the negative lead to negative lead.

d) Block the light source to the cells, e.g. turn the samples upside down, so that the measured open-circuit voltage of the sample is less than 5% of its rated V_{oc}.

e) Apply at least 10 different currents to the module and record each set of current, voltage, and cell temperature.

Complete this procedure as quickly as possible to avoid significant heating of the cells during the test. If the temperature drift is too fast to give a repeatable reading, allow the current to flow while the module heats to its equilibrium temperature, then record the steady-state values.

f) Plot the current and voltage data on a chart with the voltage on the vertical axis and current on the horizontal axis, and perform a linear regression in the region of the linear part of the curve (usually, it is at the higher end of current):

   $V = R \times I + V_0$

   where

   R is the module's series resistance, and

   V_0 is the linear-regression constant.

10.2.4.3 Requirements

The dark I-V test is not intended to be used as the pass/fail criterion for the qualification test, but as a cost-effective method for identifying degradations of the sample following each test.

Side-by-side I-V measurement shall be conducted for pass/fail decision.

10.3 Ground path continuity test

10.3.1 General

In some countries or regions, system grounding is not required. If the product installation is restricted to these areas, this test may be omitted.

10.3.2 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.

10.3.3 Procedure

a) A continuity tester (ohmmeter) shall be used to test electrical continuity between any parts on the test sample and its grounding point.
b) To minimize danger to testing personnel, a current- and voltage-limited power supply that is not capable of producing more than 10 V DC between its output terminals should be used for this test.
c) The resistance between the grounding point and any accessible conductive part shall be measured with a current passing through these two points. If the module manufacturer has not provided contact points for this test on the modules, a small area on the module shall be scraped clear of any anodization or coating to make good contact.
d) Apply a current of two times I_{sc} between the grounding terminal and a point, and measure the voltage within 1,3 cm of each point of current injection.
e) Record the current and voltage until the values are stable.
f) If more than one test is needed to evaluate all paths of conduction, allow enough cooling time between tests if the temperature of the sample increased significantly.
g) At the end of this test, the test sample shall be subjected to an insulation test of 10.4.

10.3.4 Requirements

a) Resistance shall be less than 0,1 Ω.
b) Damage shall not be produced at joints between different exposed conducting parts.

10.4 Electrical insulation test

10.4.1 Purpose

The purpose of the electrical insulation (also called dry insulation) 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.

10.4.2 Procedure

a) Obtain an insulation tester, which has the following functions, to:
   - Supply DC current limiting to 10 mA.
   - Apply DC voltage of 1 000 V plus twice the maximum system voltage of the test sample.
   - Measure the current in μA resolution.

   These functions could be combined in one single unit or with a few separate units:

b) The test shall be conducted on samples at ambient temperature of 25 °C ± 10 °C and relative humidity not exceeding 75 %.

c) Designs that use a cooling medium shall have the cooling medium present during the test, but the cooling medium circulation is not required.

d) The sample cell faces shall be darkened and the sample shall not be connected to any active electrical source.

e) Connect the shorted positive and negative output terminals of the sample to the positive terminal of the tester.

f) Connect the exposed metal parts of the sample to the negative terminal of the tester. If the sample has no conductive frame or if the frame is a poor electrical conductor, wrap the sample with a metallic plate or foil, then connect the plate or foil to the negative terminal of the tester.

g) Increase the voltage applied by the tester at a rate not exceeding 500 V/s to 1 000 V plus twice the maximum system voltage (i.e., the maximum system voltage rated by the manufacturer). If the maximum system voltage does not exceed 50 V, the applied voltage shall be 500 V.

h) Maintain the voltage at this level, and wait for 2 min after a stable leakage current is reached.

i) Observe any sign for dielectric breakdown or surface tracking (steps g) to i) are also called the dry hi-pot test).

j) Reduce the voltage to 500 V, and maintain for 2 min after a stable leakage current is reached.

k) Record the applied voltage and the current.

l) Calculate the insulation resistance based on recorded data.

m) Reduce the applied voltage to zero and short-circuit the terminals of the tester to discharge the electrical charges built up in the sample.

n) Disconnect the tester from the sample.

10.4.3 Requirements

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

b) For samples with an overall receiver aperture area less than or equal to 0,1 m^2, the measured insulation resistance shall not be less than 50 MΩ.

c) For samples with an overall receiver aperture area larger than 0,1 m^2, the measured insulation resistance times cell area shall not be less than 5 $M\Omega m^2$.

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.

10.5 Wet insulation test

10.5.1 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.

10.5.2 Procedure

a) Obtain an insulation tester as described in 10.4.2 a).

b) Prepare a non-corrosive liquid agent (surfactant) solution in a testing tank that is large enough to hold the test samples. The resistivity of the test solution shall be between 1 500 Ω cm to 3 500 Ω cm when measured at a temperature of 22 °C ± 3 °C.

c) Designs that use a cooling medium shall have the cooling medium present during the test, but the cooling medium circulation is not required.

d) The sample cell faces shall be darkened and the sample shall not be connected to any active electrical source.

e) Connect the shorted positive and negative output terminals of the sample to the positive terminal of the tester.

f) Make a good connection between the negative terminal of the tester and the liquid solution.

g) Immerse the sample in the solution, or spray the solution over the sample, for at least 5 min. The terminal boxes, pigtail leads, uninsulated terminations, or other connectors that are not suitable for immersion could be maintained above the solution level, but be thoroughly wetted by spraying the solution over these areas from all possible directions that rain or melt snow could enter.

h) Increase the voltage applied by the tester at a rate not exceeding 500 V/s to 500 V.

i) Maintain the voltage at this level, and wait for 2 min after a stable leakage current is reached, then observe any sign of dielectric breakdown, surface tracking, or bubble generation.

j) Record the applied voltage and the current.

k) Calculate the insulation resistance based on recorded data.

l) Reduce the applied voltage to zero and short-circuit the terminals of the test equipment to discharge the electrical charges built up in the test sample.

m) Disconnect the test equipment from the sample.

n) Clean the surface of the module from residues of the solution.

10.5.3 Requirements

a) No dielectric breakdown or surface tracking.

b) For samples with an overall receiver aperture area less than or equal to 0,1 m^2, the measured insulation resistance shall not be less than 50 MΩ.

c) For samples with an overall receiver aperture area larger than 0,1 m^2, the measured insulation resistance times cell area shall not be less than 5 MΩm^2.

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.

10.6 Thermal cycling test

10.6.1 Purpose

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

10.6.2 Test sample

Two receiver samples are required for the sequence A thermal cycling test, which is a full length of the thermal cycle. If a full-size sample is too large to fit into the environmental chamber, or it is too expensive to use, a smaller representative sample may be specially designed and manufactured for this test. The representative sample shall be carefully designed so that it can reveal similar failure mechanisms as the full-size one, and the fabrication process of the representative sample shall be as identical as possible to the process of the full-size ones.

NOTE Possible failure mechanisms for temperature cycling test could include weak mechanical strength of cells, poor bus bar and soldering (loose, wrong flux, tension) materials, incorrect interconnection design (for example, too large differences of thermal expansion coefficients among bonded layers and not enough buffering layer in between), wrong adhesives, and poor workmanship.

When designing or fabricating the representative samples, special considerations shall include, but not be limited to, the following aspects:

– Repeated parts or sections (sub-receivers) used by the full-size sample can be reduced, but if possible, try to use at least two of these parts or sections in their full dimensions.
– All non-repeated parts or sections, such as cell string's end-connections and corners, electrical and mechanical joints, sensors, and bypass/blocking diodes, should be included in the representative samples.

10.6.3 Procedure

Three options are given in Table 3 to fit the different materials used. The thermal cycle test shall be carried out in air without adding humidity. It could be in a single-chamber system or in a dual-chamber system. A dwell time of at least 10 min within ±3 °C of the high and low temperatures is required. The cycling frequency can range from 5 to 48 cycles per day. During each cycles current I_{test} equal to 1,25 times rated I_{SC} at CSTC shall be applied to the test sample when temperature is above 25 °C as shown in Figure 8.

To apply current during ~~a~~ each thermal cycle, one of the following options could be adopted to:

a) Use an external DC power supply to provide a desired current in the negative direction (the positive direction is the sample's normal generating current direction) while the sample is in the dark (blocking diodes, if present, shall be shorted).
b) Provide a full intensity of illumination so that the sample can generate the desired current in the positive direction.
c) Provide a partial intensity of illumination in combination with an external DC power supply to generate the desired current in the positive direction (bypass diodes, if present, shall be opened).

In the case where the active cooling circuit is used, the manufacturer and test lab may agree to use the maximum fluid temperature to represent the heatsink temperature. The ~~heat-sink~~ temperature shall be monitored at a location as close to the cell as possible during temperature cycling – and the chamber temperature adjusted to ensure that this ~~heat-sink~~ temperature does not exceed the test ~~chamber~~ target temperature. The temperature of the heat-sink or some other representative component close to the cell may be measured if the cell is inaccessible. The exact location of the heat sink temperature ~~measurement location~~ shall be noted on the measurement report.

When the sample has parallel strings, make sure that the required current is supplied to each single string. Sometimes this will require separating the parallel strings, and to use separate power supplies for each string.

Based on the knowledge as this document is written, some large-area III-V cells may not be able to hold up under option a) or c), and some testing facilities may have an equipment limitation to perform option b). In these cases, the thermal cycle test sequence A could be conducted without applying the current, but the manufacturer should prepare three additional receiver samples with similar, but “dead,” cells, i.e., electrically inactive III-V cells. A minimum of 1,25 I_{sc} should be provided in either positive or negative direction. The current should be controlled to maintain a temperature difference between the cell and heat sink comparable to, or greater than, operating conditions so that the localized heating can take place, and the ability of the receivers to withstand thermal mismatch, fatigue, and other stresses can be evaluated. The thermal gradients during operating conditions can be determined from commercially available modeling programs or from direct measurements when DNI is greater than 700 W/m^2 and wind speed is less than 2 m/s. The pass criteria for these receiver samples will be changed to: after the thermal cycle test, the change of the receiver resistance shall be less than 2 % (excluding the cell). This alternative procedure will be re-evaluated, and if necessary, an amendment to this standard will be issued, as soon as further knowledge on this topic becomes available.

~~NOTE~~ Actively cooled systems are typically designed to handle a very large heat load. If coolant is present, it may not be possible to heat the system to the target temperatures, but if the coolant is removed and (I_{sc}) bias current is applied, the temperature can reach arbitrarily high temperatures. Thermal cycling because of bias current applies stress differently than thermal cycling the chamber and may be especially effective if a series resistance develops that enhances local heating from the flow of current. Cooling may need to be reduced below the system operational specification to allow the chamber or electrical biasing to achieve target temperatures.

There will be one current cycle for each temperature cycle. Current flow shall commence during the upward temperature ramp when the ~~heat-sink~~ cell temperature reaches 25 °C and stop at the end of the maximum temperature dwell. (see illustration in Figure 8). The sample’s circuit continuity shall be monitored and recorded. In the case where the active cooling circuit is used, the manufacturer and test lab may agree to use the maximum fluid temperature to represent the heatsink temperature. The temperature shall be monitored at a location as close to the cell as possible during temperature cycling – and the chamber temperature adjusted to ensure that this this heat sink temperature does not exceed the test target temperature. The temperature of the heat-sink or some other representative component close to the cell may be measured if the cell is inaccessible. The exact location of the heat sink temperature measurement location shall be noted on the measurement report.

Table 3 – Thermal cycle test options for sequence A

Option	Target ~~heat sink~~ cell temperature °C	Total cycles	Applied current during heating and high-temperature dwell
TCA-1	85	1 000	Apply ~~1,25 · I_{sc}~~ I_{test} when T > 25 °C
TCA-2	110	500	Apply ~~1,25 · I_{sc}~~ I_{test} when T > 25 °C
TCA-3	65	2 000	Apply ~~1,25 · I_{sc}~~ I_{test} when T > 25 °C

The samples shall be subjected to visual inspection 10.1 and the insulation test 10.4 following the thermal cycling test.

10.6.4 Procedure for active cooling system

Actively cooled systems alternate methods:

a) Phase 1 – A standard temperature cycle profile to be followed without electrical bias being applied. The system can be run "dry" with no cooling fluid present during the duration of this test. The test shall be run at one of the standard temperature profiles listed in Table 3 for the full duration.

Phase 2 – The temperature cycle profile shall be run with bias under the following conditions: a 25 °C test chamber temperature with electrical bias being applied to the receiver(s) under test to raise the cell(s) temperature(s) to one of the accepted temperature profiles listed in Table 3 (instead of using the chamber temperature to cycle the temperature). The current shall then be cycled to duplicate the standard test profile listed in Table 3. The system can be run "dry" with no cooling fluid present during the duration of this test. The current injection will raise the cell(s) temperature(s) to one of the values in Table 3 (see Note).

b) A standard temperature cycle profile to be followed with chamber temperature being controlled to achieve the part of the cycle below 25 °C without electrical bias, and electrical bias being applied to the receiver(s) under test to raise the temperature to one of the accepted temperature profiles listed in Table 3. The testing lab will decide which testing sequence is most adequate, considering the opinions from manufacturers. The system can be run "dry" with no cooling fluid present during the duration of this test, or with an active cooling circuit provided to the specification as agreed between the manufacturer and the test laboratory (on/off conditions, flow rate, coolant temperature, coolant composition) to meet the temperature profile for the part of the cycle above 25 °C.

c) A standard temperature cycle profile to be followed as per b) except that the temperature of receiver(s) under test is controlled below 25 °C by the utilization of the active cooling circuit. The active cooling will operate as per the specification agreed between the manufacturer and test laboratory.

10.6.5 Requirements

a) No evidence of major visual defects, as defined in 10.1.2.

b) No interruption of current flow during the test.

c) Insulation resistance shall meet the same requirements as defined in 10.4.

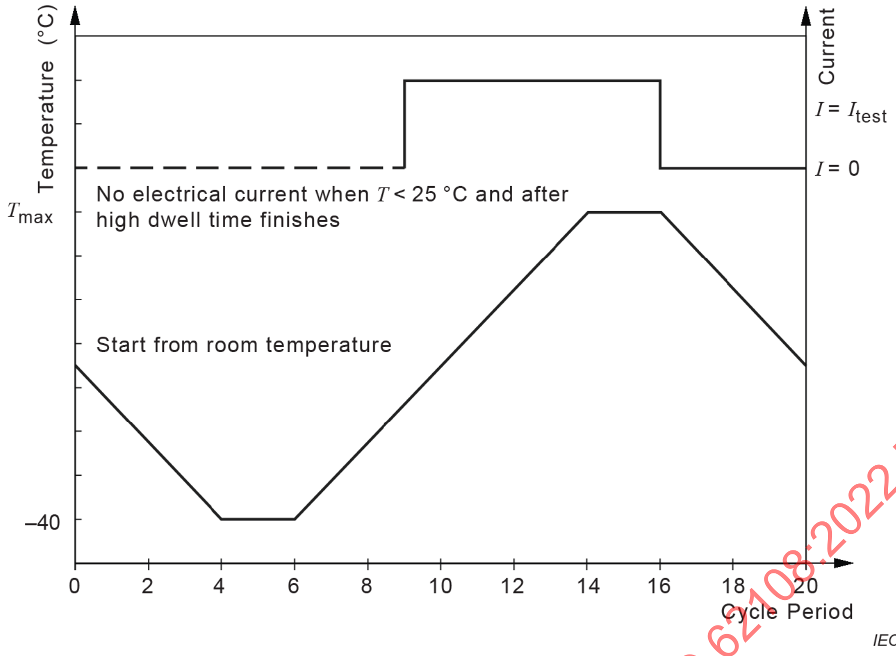


Figure 8 – Temperature and current profile of thermal cycle test (not to scale)

10.7 Damp heat test

10.7.1 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.

10.7.2 Test sample

Total of two modules, or two receivers and mirrors, are required for damp heat test in sequence C. If a full-size sample is too large to fit into the environmental chamber, or it is too expensive to use, a smaller representative sample may be specially designed and manufactured for this test. The representative sample shall be carefully designed so that it can reveal similar failure mechanisms as the full-size one, and the fabrication process of the representative sample shall be as identical as possible to the process of the full-size ones.

NOTE Possible failure mechanisms for damp heat test could include low-quality metal materials (rust), thin or low-quality lamination materials, not enough clearance distance around edges so that the moisture penetrates to active electric circuits, poor workmanship, or wrong or inadequate adhesives.

When designing or fabricating the representative samples, special considerations shall include, but not be limited to, the following aspects:

– Repeated parts or sections used by the full-size sample can be reduced, but if possible, try to use at least two of these parts or sections in their full dimensions.

– Keep the same clearance distance around edges as it is on the full-size products.

10.7.3 Procedure

a) The test samples shall be subjected to a test in an environmental chamber in which the relative humidity shall be controlled to 85 % ± 5 % and the temperature to 85 °C ± 2 °C, for 1 000 h. The test may be continued for up to an additional 60 h to permit the insulation test in step c) to be performed.

b) 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.

c) At the end of the test, within 2 h to 4 h of removal from the environmental chamber, test samples shall be subjected to the dry insulation test 10.4 and wet insulation test 10.5. This period shall be used to reduce temperature in the climatic chamber. The temperature shall be reduced from 85 °C to 25 °C in 1,5 h. This should be held for half an hour. Directly after the removal from the environmental chamber, test samples shall be subjected to the dry insulation test 10.4 and wet insulation test 10.5.

d) Visual inspection 10.1 shall also be performed.

10.7.4 Requirements

a) No evidence of major visual defects, as defined in 10.1.2.

b) Insulation resistance shall meet the same requirements as defined in 10.4.

c) Wet insulation resistance shall meet the same requirements as defined in 10.5.

10.8 Humidity freeze test

10.8.1 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.

10.8.2 Test sample

A total of two modules, or two receivers and two mirrors are required for humidity freeze test in accordance with the temperature/humidity profile shown in Figure 9.

If a full-size sample is too large to fit into the environmental chamber, or it is too expensive to use, a smaller representative sample may be specially designed and manufactured for this test. The representative sample shall be carefully designed so that it can reveal similar failure mechanisms as the full-size one, and the fabrication process of the representative sample shall be as identical as possible to the process of the full-size ones.

NOTE The possible failure mechanisms for humidity freeze test and special considerations for design and fabrication of representative samples are the combination of those for temperature cycling test 10.6 and damp heat test 10.7.

10.8.3 Procedure

At the end of the test, within 2 h to 4 h of removal from the environmental chamber, test samples shall be subjected to the dry insulation test 10.4 and wet insulation test 10.5. Visual inspection 10.1 shall also be performed, see Table 4.

Table 4 – Humidity freeze test options for sequence B

Option	Target sample temperature °C	Humidity %	Total cycles	Applied current
HFC-1	85	85	20	None
HFC-2	65	85	40	None

10.8.4 Requirements

a) No evidence of major visual defects, as defined in 10.1.2.

b) Insulation resistance shall meet the same requirements as defined in 10.4.

c) Wet insulation resistance shall meet the same requirements as defined in 10.5.

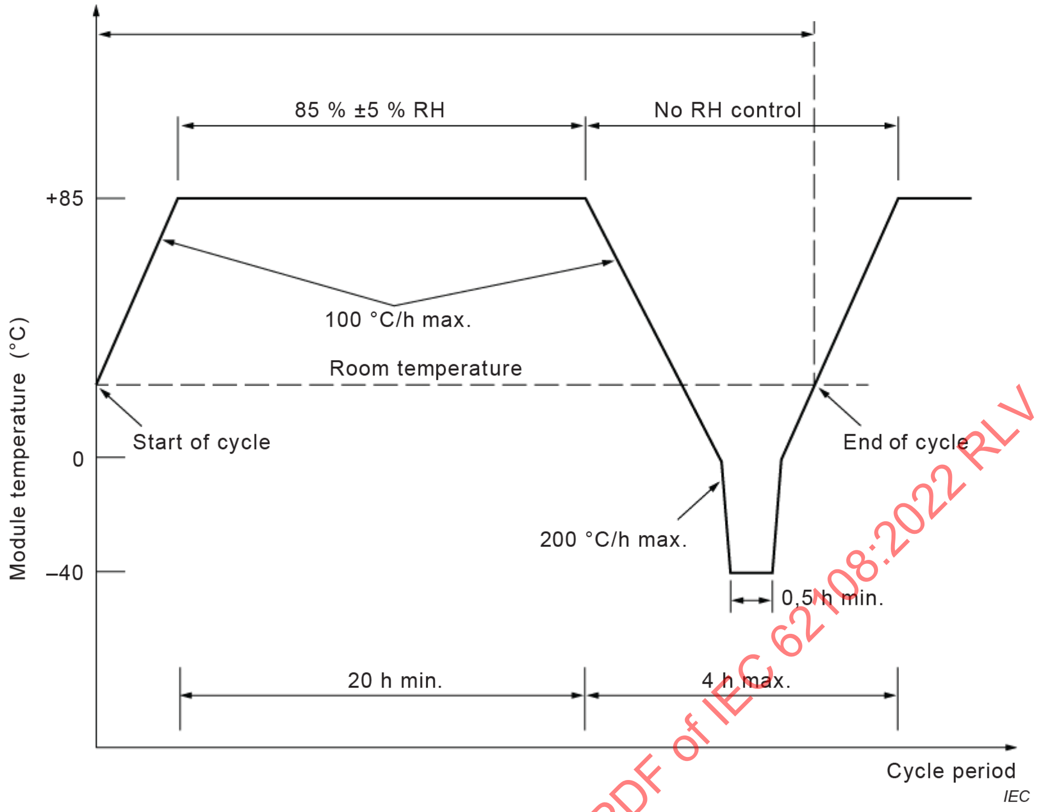


Figure 9 – Profile of humidity-freeze test conditions

10.9 Hail impact test

10.9.1 Purpose

The purpose of the hail impact test is to determine whether the module or assembly, particularly the concentrator lens and mirrors, or any other parts exposed to possible hail impact, can survive a hailstorm.

If the system is designed for a specific area where a hailstorm is very unlikely, this test could be omitted. This fact shall be emphasized on the test report and the product certificate.

10.9.2 Apparatus

a) Moulds of suitable material for casting spherical ice balls of the required diameter. The standard diameter is 25,4 mm with a tolerance of ± 5 %.

b) A freezer, controlled at –10 °C ± 5 °C.

c) A storage container for storing the ice balls at a temperature of –4 °C ± 2 °C.

d) A launcher capable of propelling an ice ball at a speed of 22,4 m/s with a tolerance of ± 5 %, so as to hit the sample within the specified impact location. The path of the ice ball from the launcher to the sample may be horizontal, vertical, or at any other angle, as long as the test requirements are met.

e) A rigid mount for supporting the test sample by the method prescribed by the manufacturer.

f) A balance for determining the mass of an ice ball. The required mass of the ball is 7,9 g with a tolerance of ± 5 %.

g) An instrument for measuring the speed of the ice ball to an accuracy of ± 2 %. The speed sensor shall be no more than 1 m from the impact point.

10.9.3 Procedure

a) Use the mould and the freezer to make sufficient ice balls of the required size for the test, including some extra balls for preliminary adjustment of the launcher.

b) Install the sample according to manufacturer's instruction, with the impact surface normal to the path of the ice ball.

c) Mark at least ten different target impact locations on receiver, module, or optics by using the following selection guidelines:

   – Areas that may possibly be hit by a hailstone falling from 45° around the vertical line when the system is under normal operation positions or on the stow position.

   – Corners that are no more than 25 mm from edges.

   – Edges that are no more than 12 mm from the side.

   – Points that are no more than 12 mm from the fixing point to supporting structures.

   – Points that are farthest from the fixing point to supporting structures.

   – Any points that may be vulnerable to hail impact.

d) Examine size and mass of ice balls to make sure the requirements in 10.9.2 are met, and the ice balls shall have no cracks visible to the unaided eye.

e) Place the ice balls in the storage container and leave them there for at least 1 h before use.

f) Ensure that all surfaces of the launcher likely to be in contact with the ice balls are near room temperature.

g) The time between the removal of the ice ball from the container and impact on the sample shall be less than 60 s.

h) Fire a number of trial shots at a simulated target and adjust the launcher until the hitting position and speed of the ice ball meet the requirement.

i) Fire the first actual testing shots on the sample at the locations marked in step c).

j) Inspect the module in the impact area for signs of damage and make a note of any visual effects of the shot.

k) Repeat steps i) and j) for all other desired locations.

10.9.4 Requirements

The requirement for hail impact is very site dependent, therefore, there is no specific pass/fail criteria for it. The results, however, shall be recorded and reported in details, such as:

a) The sample shall be inspected after each impact to determine if any obvious damage has occurred. All damages and major visual defects shall be documented.

b) Any cracks or holes on the sample that are visible to the unaided eye, or any pieces larger than 2 mm^2 that have broken off and flown out, shall be recorded and included in the report.

~~10.10 Water spray test~~

~~10.10.1 General~~

~~One full-size module or assembly is required for water spray test. It can be conducted by installing it in the lab, or through on-site witness.~~

~~10.10.2 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.~~

~~10.10.3 Procedure~~

~~a) Install the module or assembly on a test fixture that can reach the following four orientations:~~

   ~~– With its front surface 45° to the horizontal.~~

– In its stow position.

– At the normal limit of its allowed tracking.

– Upside down (if appropriate for the module's operation).

NOTE For some designs, these orientations may be redundant.

b) Make field wiring connections in accordance with the wiring method specified in the installation instructions. When more than one wiring method is specified, the method least likely to restrict the entrance of water into the field wiring compartment is to be used.

c) Put the rain-test fixture that meets the requirements of ANSI/UL1703:2002, the Standard for Flat-Plate Photovoltaic Modules and Panels, section 33.5 above the module's most vulnerable location.

d) The module or assembly shall be exposed to the water spray for 1 h in each orientation specified in a), with at least 15 min between tests in different orientations. After each 1 h spray, the module or assembly shall be examined for evidence of water penetration or collection of water in any area containing electrically active parts. If water is present in such an area, there shall be adequate means, such as drain holes, to keep the water level from reaching uninsulated electrically active parts.

e) The insulation test of 10.4 shall be conducted within 1 h to 2 h after the last spray. No manual dry-up shall be performed during this time period. If the insulation resistance is found to be below that specified, the insulation test shall be repeated after the module has dried to determine if the condition was caused by moisture inside the module.

10.10.4 Requirements

a) No evidence of major visual defects, as defined in 10.1.2.

b) Insulation resistance shall meet the same requirements as defined in 10.4.

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).

10.10 Dust and water ingress protection test

10.10.1 Purpose

The degree of protection (IP-code) defines the extent to which an enclosure provides protection against the entry of dust, as proved by standard testing methods. This testing only applies to modules which have package design that is deemed an enclosure. To be considered an enclosure the module shall contain an interior space that contains gas or liquid.

This requirement is for modules only; assemblies are exempt from this requirement.

One full-size module is required for dust and water ingress protection test.

10.10.2 Procedure

The module or a representative sample shall be subjected to IP testing after the humidity freeze sequence with provisions provided by the manufacturer to close ports or openings into the enclosure that are included in the existing module design for attaching the module to other systems (air drying for example).

10.10.3 Requirements

The module shall meet a minimum of IP6X. See 10.10 for water ingress requirements. The IP6X test is for dust ingress only and is conducted in conformance with IEC 60529.

a) The module shall meet a minimum of IP65. The IP65 test is conducted in conformance with IEC 60529 test. It can be conducted by installing it in the lab, or through on-site witness.

b) No evidence of major visual defects, as defined in 10.1.2.

c) Insulation resistance shall meet the same requirements as defined in 10.4.

d) 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).

10.11 Bypass/blocking diode thermal test

10.11.1 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 within the receiver being tested. This procedure verifies that the bypass diode can safely operate at elevated temperatures and throughput current levels. The non-intrusive method requires that the bypass diode's case be accessible for thermocouple attachment by the test personnel. The intrusive method is required for modules that have bypass diodes that are inaccessible without special invasive procedures. The intrusive method requires that the manufacturer provide a specially built module that has the thermocouple already installed. If invasive measures by the lab are required, the test personnel will consult with the manufacturer about the method and risks associated prior to acting.

If the bypass diodes are not accessible in the module type under test, a special sample can be prepared for this test. This sample shall be fabricated to provide as close to the same thermal environment for the diode as a standard production module under test and does not have to be an active CPV module, but shall have access to measure the temperature of the diode(s) during the test. The test shall then proceed as normal. This special test sample shall be used only for the bypass diode thermal test not for the other tests in the sequence nor the final measurement.

10.11.2 Test sample

Three bypass diodes are to be selected for testing. These bypass diodes are to be selected by the test laboratory and should be representative bypass diodes which are subject to the most stress in the design. The test lab shall indicate in the test report which three bypass diodes were selected and why they were selected.

a) Select diode locations representative of the thermal profile of the receiver, in the order below:
   1) Center.
   2) High temperature location (if applicable) – such as a junction box or terminal block.
   3) Corner.

10.11.3 Apparatus

Environmental chamber capable of heating the test sample to 75 °C ± 5 °C, digital thermometer, type K thermocouple wire, thermal adhesive, a power supply capable of producing 1,25 times I_{sc} of the receiver, and a DMM or current shunt capable of measuring up to 125 % of the receiver's short circuit current at standard reporting conditions, digital timer.

10.11.4 Procedure

a) Electrically short any blocking diodes incorporated in the sample.
b) Lab-prepared receivers: Mount a functionally checked type K thermocouple to each diode's case using thermally conductive electrically isolating adhesive. Feed the thermocouple wire(s) through the electrical leads junction box penetration and reseal the junction box per manufacturer's instructions, if applicable.
c) Manufacturer-prepared receivers: Functionally check the thermocouple(s) previously attached to the diode(s) by the manufacturer.
d) Mount the receiver inside the environmental chamber. Feed the electrical leads through one of the chamber's access ports. Feed the thermocouple wire through the same access port.
e) Attach a thermocouple to the front face of the receiver. This temperature sensor will be used to monitor the receiver's temperature of 75 °C ± 5 °C during the duration of the tests.

f) Connect the electrical leads to a power supply with the power supply's positive lead connected to the receiver's negative terminal and power supply's negative lead to the positive terminal of the receiver.

g) Connect the thermocouple(s) to a digital thermometer.

h) Heat the receiver to 75 °C ± 5 °C. Apply a current to the receiver equal to I_{sc} with a tolerance of ± 2 %. After 1 h, measure the temperature of each bypass/blocking diode.

i) Calculate the junction temperature using information provided by the diode manufacturer, along with the measured case temperature or temperature of the hottest surface contacting the diode.

j) Increase the applied current to 1,25 times I_{sc} while maintaining the receiver temperature at 75 °C ± 5 °C. Maintain the current flow for 1 additional hour.

k) Verify that the diode is still operational.

10.11.5 Requirements

a) The calculated diode junction temperature shall not exceed the diode manufacturer's maximum temperature rating.

b) No evidence of major visual defects, as defined in 10.1.3.

c) Insulation resistance shall meet the same requirements as defined in 10.4.

d) The diodes shall still function as diodes after the diode thermal test. The test report shall include a description of the test used to make this determination and the results of that test.

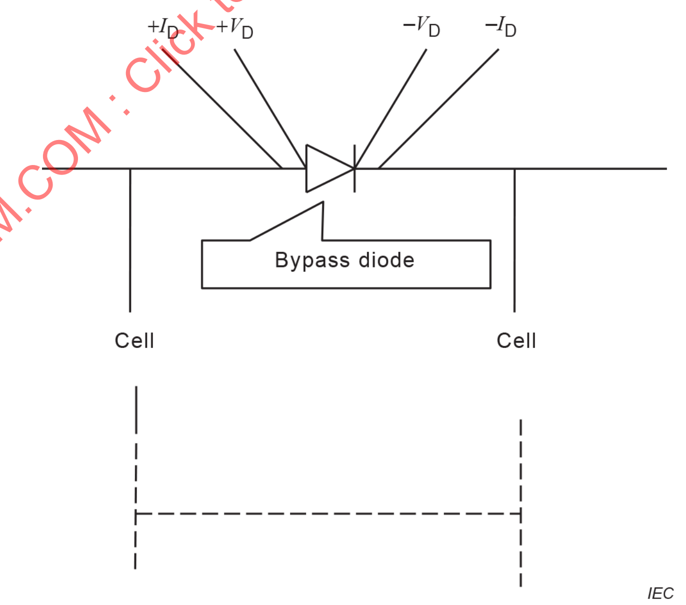
10.11.6 Procedure 2 – Alternate method

a) Electrically short any blocking diodes incorporated in the module.

b) Determine the rated STC short circuit current of the module from its label or instruction sheet.

c) Connect the lead wires for V_D and I_D on both diode terminals as shown in Figure 10.

d) It is recommended that the connections be made by the module manufacturer.



NOTE The lead wire should not cause heat dissipation from the terminal box.

Figure 10 – Bypass diode thermal test

e) Put the module into the chamber set up to 30 °C ± 2 °C until the module temperature reaches the saturation.

f) Apply the pulsed current (pulse width 1 ms) equal to the STC short circuit current of the module, measure the forward voltage V_{D1} of diode.

g) Using the same procedure, measure V_{D2} at 50 °C ± 2 °C.

h) Using the same procedure, measure V_{D3} at 70 °C ± 2 °C.

i) Using the same procedure, measure V_{D4} at 90 °C ± 2 °C.

j) Then, obtain the V_D versus T_j characteristic by a least-squares-fit curve from V_{D1}, V_{D2}, V_{D3} and V_{D4}.

This V_D versus T_j characteristic may be provided by the diode manufacturer with a manufacturer's certification.

k) Heat the module to 75 °C ± 5 °C. Apply a current to the module equal to the short circuit current of the module as measured at STC ± 2 %. After 1 h measure the forward voltage of the each diodes.

l) Using the V_D versus T_j characteristic obtained in item j), obtain T_j of the diode.

m) Increase the applied current to 1,25 times the short-circuit current of the module as measured at STC while maintaining the module temperature at 75 °C ± 5 °C.

n) Maintain the current flow for 1 h.

o) Verify that the diode is still operational after completing this test.

10.12 Robustness of terminations test

10.12.1 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.

~~10.12.2 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.~~

~~10.12.3 Procedure~~

~~10.12.3.1 General~~

~~Preconditioning: 1 h at standard atmospheric conditions for measurement and test.~~

~~10.12.3.2 Type A terminations~~

~~Tensile test: As described in IEC 60068-2-21, test Ua, with the following provisions:~~

- ~~All terminations shall be tested.~~
- ~~Tensile force shall never exceed the module weight.~~

~~Bending test: As described in IEC 60068-2-21, test Ub, with the following provisions:~~

- ~~All terminations shall be tested.~~
- ~~Method 1 with 10 cycles (1 cycle is 1 bend in each opposite direction).~~

~~10.12.3.3 Type B terminations~~

~~Tensile and bending tests:~~

a) ~~For modules with exposed terminals, each termination shall be tested as for type A terminations.~~

b) ~~If the terminations are enclosed in a protective box, the following procedure shall be applied:~~

   – ~~A cable of the size and type recommended by the module manufacturer, cut to a convenient length, shall be connected to the terminations inside the box using the manufacturer's recommended procedures. The cable shall be taken through the hole of the cable gland, taking care to use any cable clamp arrangement provided. The lid of the box shall be securely replaced. The module shall then be tested as for type A terminations.~~

~~Torque test: As described in IEC 60068-2-21, test Ud, with the following provisions:~~

– ~~All terminations shall be tested.~~

– ~~Severity 1.~~

~~The nuts or screws shall be capable of being loosened afterwards, unless they are specifically designed for permanent attachment.~~

~~10.12.3.4 Type C terminations~~

~~A cable of the size and type recommended by the module manufacturer, cut to a convenient length, shall be connected to the output end of the connector, and the tests for type A terminations shall be carried out.~~

10.12.2 Procedure

Connectors have to comply with IEC 62852. If other connectors than above mentioned connectors are meant than refer to relevant IEC standard, e.g. IEC 61210. The test procedure is according to IEC 61215.

10.12.3 Requirements

a) No evidence of major visual defects, as defined in 10.1.2.

b) Insulation resistance shall meet the same requirements as defined in 10.4.

c) Wet insulation resistance shall meet the same requirements as defined in 10.5.

10.13 Mechanical load test

10.13.1 Purpose

The purpose of 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 aligned to match the maximum specification of the manufacturer. If the design is entirely unsuitable for snow areas, the snow load test needs not be carried out and minimum testing shall correspond to wind loading. 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, receivers, mirrors, 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, shall be analyzed by suitable qualified engineers to verify that the design meets the local code requirements of the installation site.

Wind load minimums shall apply (see Table 5).

Table 5 – Minimum wind loads

Test load Pa	Wind load capacity m/s	Snow/ice load capacity	Tracker requirement/restriction
800	40 in a wind stow position only	None	Restricted to use on trackers with automatic and failsafe wind stow of 24 m/s or less
1 600	40	None	None
2 400	40	Light to medium	None
5 400	40	Heavy	None

If the module under test is restricted in application to trackers which shall horizontally stow at wind speeds of 24 m/s or less, the module shall be tested to a minimum of 800 Pa. 800 Pa corresponds to potential forces generated on the modules by 40 m/s winds when the tracker is in the horizontal position. Trackers which stow at lower wind speeds will not lessen this requirement as the worst case force occurs in the stow position due to the higher wind speeds.

If the module under test can be mounted on any tracker (no stow function possible), the module shall be tested to a minimum of 1 600 Pa, corresponding to potential forces generated one the module by 40 m/s winds in any tracking position.

If the module is indicated for regions where snow and ice occur it is recommended that minimum test requirement should be 2 400 Pa.

10.13.2 Procedure

a) Make a rigid test base structure. If the load is provided by weight, the sample shall be mounted horizontally. The test base shall be capable of withstanding loads applied to both the front and back of the test sample and shall enable the test sample to deflect freely during the test.

b) Mount the test sample on the rigid structure using the method prescribed by the manufacturer. If there are different possibilities, use the worst case, such as the largest distance between the fixing points. The mounting method and photos shall be included in the report.

c) Connect the test sample to the monitoring instrument so that the electrical continuity of the internal circuit can be monitored continuously during the test.

d) Obtain suitable weights or pressure means that enable the load to be applied in a gradual, uniform manner.

e) On the front surface, gradually apply a uniform load up to the maximum indicated by the test. This load may be applied pneumatically or by means of weights covering the entire surface. In the later case, the test sample shall be mounted horizontally. Maintain this load for 1 h.

f) Repeat step e) on the back surface of the test sample.

g) Repeat steps e) and f) for a total of three cycles.

10.13.3 Requirements

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

b) No evidence of major visual defects, as defined in 10.1.3.

c) Insulation resistance shall meet the same requirements as defined in 10.4.

10.14 Off-axis beam damage test

10.14.1 General

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

10.14.2 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.

10.14.3 Special case

Concentrator systems that use a fully redundant and failsafe protection system to manage misalignment issues may be exempt from the requirements of this clause. 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 shall agree with the manufacturer on a procedure to conduct verifications on these redundant and failsafe protection systems. Under all possible vulnerable conditions, the protection system shall respond to the misalignment or malfunction according to the manufacturer's design; otherwise, a regular off-axis beam damage test shall be conducted.

10.14.4 Procedure

a) The module or assembly design and the receiver itself shall be examined first to determine whether any materials might be damaged by high temperatures or intense solar radiation, and whether these materials are sufficiently protected from exposure.

b) If such insufficiently protected materials are identified, the module or assembly alignment will be offset so that light is focused on such a suspect location.

c) The module or assembly will then track the sun in this position for at least 3 h, with DNI greater than 800 W/m^2.

d) Repeat for step c) for any other suspect locations.

e) Observe the test sample during each exposure and inspect for evidence of damage after each exposure.

f) If no specific locations are identified, a simple "walk-off" test shall be performed:

   – The module shall be aligned toward the sun.

   – Tracking will be stopped.

   – Allow the sun to "walk off" to an angle of 45° relative to the module or assembly (about 3 h).

   – Throughout this test, DNI shall be at least 800 W/m^2.

10.14.5 Requirements

a) No evidence of major visual defects, as defined in 10.1.3. 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 10.4.

10.15 Outdoor exposure test

10.15.1 Purpose

The purpose of the outdoor exposure test is to make a preliminary assessment of the ability of the module or assembly to withstand exposure to outdoor conditions and to reveal any synergistic degradation effects that may not be detected by laboratory tests. If the manufacturer specifies a stabilization period after which the system reaches the steady state performance, the system shall be operated for the specified amount of time prior to the initial electrical performance test as defined in 10.2.This test requires one full-size module or assembly. It can be conducted either by installing it in an exterior area of the test lab, or through on-site witness.

10.15.2 Procedure

a) A full-size module or assembly shall be installed outdoor as recommended by the manufacturer.

b) A direct-normal irradiation monitor and a global total irradiation monitor shall be installed co-planar with the module or assembly.

c) Any hot-spot protective devices recommended by the manufacturer shall be installed before the module or assembly is mounted.

d) If the system requires active cooling, the cooling system shall be operated during the test.

e) The module or assembly shall be exposed outdoors with tracking and meet the following requirements:

   – Cumulative DNI of at least 450 kWh/m^2 while the module or assembly is connected to a maximum power point tracking load.

   – Followed by cumulative DNI of at least 50 kWh/m^2 while the module or assembly is operating in open circuit condition; during or after that time of exposure at least 1 h of continuous DNI greater than 900 W/m^2 is required while in open circuit condition.

   – When the DNI is less than 600 W/m^2, the DNI radiation shall not be counted towards the total exposure.

   – UV dosage is recommended to be recorded and included in the report;.

10.15.3 Requirements

a) No evidence of major visual defects, as defined in 10.1.2.

b) Power degradation shall not exceed 5 % for solar simulator I-V measurement, and 7 % for natural sunlight I-V measurement.

c) Insulation resistance shall meet the same requirements as defined in 10.4.

10.16 Hot-spot endurance test

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.

Currently, a major revision for the hot-spot endurance test on flat-plate PV modules is under consideration. For CPVs, perform this test according to IEC 61215-2:~~2016~~2021, 10.9 Hot-spot endurance test, and its amendments, with one exception: add an extra 3 % for the solar simulator I-V measurement, and 5 % for the natural sunlight I-V measurement, to the maximum power degradation requirement, to count for an extra uncertainty on the CPV I-V measurement.

Annex A
(informative)

Summary of test conditions and requirements

~~NOTE~~ This annex is for reference only. Requirements and values in the main body of this document supersede requirements and values included in this summary, see Table A.1.

Table A.1 – Summary of test conditions and requirements

Seq. No.	Test title	Sample m – module r – receiver mir – mirror	Test condition	Requirement
10.1	Visual inspection	All	Visual inspection	No major visual defects (MVD) defined in 10.1.2.
10.2	Electrical performance	All	Outdoor side-by-side I-V with DNI > 700 W/m^2, wind speed < 6 m/s, clear sky. Dark I-V as a diagnostic means to measure resistance, at least 10 points from 0,9 to 1,6 I_{sc}	Power degradation < 8 % for solar simulator measurement, and < 13 % for natural sunlight measurement, (except for 10.15 and 10.16). If dark I-V shows 10 % resistance increase, side-by-side I-V shall be performed.
10.3	Ground path continuity	All	Measure resistance between grounding point and other conductive parts with 2 × I_{sc} current passing through.	Resistance < 0,1 Ω No damage at grounding path bonds
10.4	Electrical insulation test	All	At ambient temperature, 25 °C ± 10 °C and RH < 75 %, apply 2 × V_{sys} + 1 000 V for 2 min (hi-pot); Measure R at 500 V.	No dielectric breakdown or surface tracking during high voltage; R > 50 MΩm^2, if area ≤ 0,1 m^2, R > 5 MΩm^2, if area > 0,1 m^2, total overall R > 1 MΩ if encapsulated in earthed metal, total overall R > 10 MΩ if double insulated
10.5	Wet insulation test	All	Measure R at 500 V when the sample is wetted by surfactant solution with resistivity 1 500 Ωcm to 3 500 Ωcm.	Same as 10.4

Seq. No.	Test title	Sample m – module r – receiver mir – mirror	Test condition	Requirement
10.6	Thermal cycling test	2r	All TC test options are from –40 °C to T_{max}. **Options for T_{max} on receivers in sequence A:** 1 000 cycles if T_{max} = 85 °C, 500 cycles if T_{max} = 110 °C, 2 000 cycles if T_{max} = 65 °C, Apply 1,25 × I_{sc} when T > 25 °C until the end of the high dwell time **Options for T_{max} as pre-conditioning for HF on modules or assemblies in sequence B:**	No MVD. Meet insulation test 10.4 and 10.5.
		2r as pre-conditioning for HF	200 cycles if T_{max} = 85 °C, 100 cycles if T_{max} = 110 °C, 400 cycles if T_{max} = 65 °C,	
10.7	Damp-heat test	2 m or 2r/2mir	1 000 h at 85 °C and 85 % RH; Or 2 000 h at 65 °C and 85 % RH.	No MVD. Meet insulation test 10.4 and wet insulation test 10.5 in 2 h to 4 h after removal from the chamber.
10.8	Humidity freeze test	2 m or 2r/2mir	T_{max} and 85 % RH for 20 h followed by 4 h cool down to –40 °C; 20 cycles if T_{max} is 85 °C; 40 cycles if T_{max} is 65 °C.	No MVD. Meet insulation test 10.4 and wet insulation test 10.5 in 2 h to 4 h after removal from the chamber.
10.9	Hail impact test	1 m or 1r/1mir	At least 10 shots of 25,4 mm diameter ice ball at 22,4 m/s on areas where an impact by hailstone falling from 45° around the vertical line is possible.	Report all results, no pass/fail criteria.
~~10.10~~	~~Water spray test~~	~~1m or 1r/1mir~~	~~1 h water spray on each of four orientations.~~	~~No MVD.~~ ~~Meet insulation test 10.4.~~ ~~No significant water remains inside (the depth of the remaining water shall not reach any electrically active parts in any possible orientation).~~
10.10	Dust and water ingress protection test	2 m	Modules which have package design that is deemed an enclosure shall be subjected to IP testing according to IEC 60529	~~The module shall meet a minimum of IP6X~~ No MVD. Meet insulation test 10.4. No significant water remains inside (the depth of the remaining water shall not reach any electrically active parts in any possible orientation). The module shall meet a minimum of IP65.

Seq. No.	Test title	Sample m – module r – receiver mir – mirror	Test condition	Requirement
10.11	Bypass/blocking diode thermal test	1 m or 1r	At 75 °C chamber temperature, apply I_{sc} through the receiver for 1 h, then measure bypass/blocking diode temperature. Apply 1,25 × I_{sc} for additional 1 h. Verify diode is functional.	When I_{sc} applied: Diode junction temperature not to exceed rated maximum temperature, No MVD. Meet insulation test 10.4. After 1,25 × I_{sc} applied: Diode is still functioning.
10.12	Robustness of terminations test	1 m or 1r/1mir	20 N tensile and 10 cycles bending	No MVD. Meet insulation test 10.4 and wet insulation test 10.5.
10.13	Mechanical load test	1 m or 1r/1mir	2 400 Pa on front and back, 1 h each, total of 3 cycles. Other loads may be used.	No MVD. Meet insulation test 10.4. No intermittent open-circuit.
10.14	Off-axis beam damage test	1 m or 1r/1mir	Aim the light on suspect locations for at least 3 h when DNI > 800 W/m²; or walk-off for 3 h.	No MVD, especially, no melting, smoking, charring, deformation, or burning. Meet insulation test 10.4.
10.15	Outdoor exposure test	1m or 1r/1mir Full size	Expose to DNI accumulation of: – 450 kWh/m² at Pm – followed by 50 kWh/m² at V_{oc} with at least 1 h of DNI > 800 W/m². DNI < 600 W/m² should not be counted	No MVD. Power degradation shall be less than 5 %. Meet insulation test 10.4.
10.16	Hot-spot endurance test	1m or 1r	Refer to IEC 61215-2:~~2016~~2021, 10.9.	Add 3 % (simulator) or 5 % (sunlight) to flat-plate module requirement for maximum power degradation to count for measurement uncertainty.

Annex B
(normative)

Retesting guideline

B.1 Product or process modifications requiring limited retesting to maintain certification

This annex sets forth a uniform approach to maintain the certification of products that have, or will, undergo modification from the articles originally certified. It shall not be used as a guideline to certify new product submittals.

Changes in design, materials, components and manufacturing process can impact the performance of the modified CPV module or assembly. The recommended test sequences given below have been selected to identify adverse changes to modified cell packages within CPV modules or assemblies.

Those CPV modules or assemblies meeting the requirements of IEC 62108 after retesting are considered to be compliant and will be issued as an amended Conformity Assessment Certificate and an Amended Technical Report Form.

The annex is organized by component modification headings. Following this are the recommended retesting requirements with parenthetical reference to the specific relevant clauses of this document. The changes shall be assessed relative to the design that was previously certified.

For the modifications listed below the testing lab shall use the tests in IEC 62108 as a guideline.

B.2 Modifications of CPV cell technology

For modifications such as:

- Metallization materials and/or process
- Type of diffusion process
- Anti-reflective coating material
- Semiconductor layer materials and/or process
- Order of cell processing if the change involves the metallization system
- Change of manufacturing site of the solar cells not under the same quality assurance system
- Use of cells from a different manufacturer
- Major change in cell thickness greater than 25 % change in total cell thickness
- Major increase in cell area (greater than 25 %), and
- Reduction in output power per cell (greater than 10 %)

Repeat**:**

- Thermal cycling test (10.6, sequence A)
- Damp heat test (10.7)
- Hot-spot endurance test (10.16), if applicable
- Outdoor exposure test 10.15); change ~~1 000~~ 900 kWh/m² in 10.15.2.e) to 500 kWh/m²

B.3 Modifications in optical encapsulation on the cell (Includes optical coupling between the cell and a glass secondary optical element bonded to the cell)

For modifications such as:

- Different encapsulation or optical coupling material
- Different additives or formulation of an encapsulation or optical coupling material, and
- Different encapsulation or optical coupling application process (e.g. curing temperature, rate, or time)

Repeat:

- Thermal cycling test (10.6, sequence A)
- Humidity freeze test (10.8)
- Damp heat test (10.7)
- Hot-spot endurance test (10.16) if applicable and if material composition changes
- Outdoor exposure test (10.15)

B.4 Modification in cell encapsulation outside of intended light path

For modifications such as:

- Different encapsulation material
- Different additives in encapsulation material, and
- Different encapsulation process (e.g. curing rate)

Repeat:

- Thermal cycling test (10.6, sequence A)
- Humidity freeze test (10.8)
- Damp heat test (10.7)
- Hot-spot endurance test (10.16) if applicable and material composition changes
- Outdoor exposure test (10.15)
- Bypass diode thermal test (10.11) if diode is located in encapsulant
- Off-axis beam damage test (10.14)

B.5 Modification of cell package substrate used for heat transfer

For modifications such as:

- Different polymeric materials used in bond to heat sink
- Change in substrate heat spreader material
- Reduction in heat spreader area, and
- Different method of substrate attachment

Repeat:

- Thermal cycling (10.6, sequence A)
- Humidity freeze (10.8)
- Damp heat (10.7) for any change, addition, or removal of a polymeric material
- Hot-spot endurance test (10.16) if applicable and material composition changes
- Outdoor exposure test (10.15)

B.6 Accessible optics (primary or secondary)

For modifications such as:

- optic material or design
- thickness, and
- surface treatment

Repeat:

- Thermal cycling/Humidity freeze (10.8)
- Damp heat (10.7)
- Hail impact (10.9)
- Mechanical load (10.13)
- Off-axis test (10.14), if susceptibility to beam damage is increased
- ~~Water spray (10.10), if the optic serves as part of the weather seal~~
- Dust and water ingress protection test (10.10), if the optic serves as part of the weather seal
- Thermal cycling (10.6), if the optics are part of the receiver assembly
- Outdoor exposure (10.16), if the optical material thickness is increased by more than 20 %

B.7 Inaccessible optics (secondary)

For modifications such as:

- optic material or design
- thickness, and
- surface treatment

Repeat:

- Damp heat (10.7)
- Outdoor exposure (10.15)
- Off-axis beam damage test (10.14), if increased beam damage
- Thermal cycling (10.6), if the optics are part of the receiver assembly
- Thermal cycling/humidity freeze (10.8), if an optical element or structural adhesive changes

B.8 Frame and/or mounting structure

For modifications such as:

- cross-section of frame
- different framing material, and

- different mounting technique

Repeat:

- Mechanical load test (10.13)
- Ground continuity (10.3), for change in material or grounding means of metallic designs
- Outdoor exposure (10.15), for polymeric materials
- Off-axis beam damage test (10.14), for polymeric materials

B.9 Enclosure

For modifications such as:

- different enclosure material, and
- different enclosure geometries, including > 5 % change in any dimension

Repeat:

- Damp heat (10.7)
- Mechanical load test (10.13)
- Humidity freeze (10.8)
- Hail impact test
- Ground continuity (10.3), for change in material or grounding means of metallic designs
- Outdoor exposure (10.15), for polymeric materials
- Off-axis beam damage test (10.14), for polymeric materials

B.10 Wiring compartment/junction box

For modifications such as:

- different compartment material, and
- different compartment design

Repeat:

- Damp heat (10.7)
- Thermal cycling/humidity freeze (10.8)
- ~~Water spray test (10.10)~~
- Dust and water ingress protection test (10.10)
- Robustness of terminations (10.12)
- Bypass diode thermal test (10.11), if bypass diode is located in wiring compartment
- Outdoor exposure test (10.15), if exposed to direct UV
- Off-axis beam damage test (10.14), if exposed to concentrated sunlight

B.11 Interconnection terminals

For modifications such as:

- different material
- different design

- different potting material, and
- different method of attachment

Repeat:

- Thermal cycling test (receiver) (10.6)
- Humidity freeze (10.8)
- Off-axis beam damage test (10.14)
- Bypass diode thermal test
- Damp heat (10.7) – For changes in materials
- Hot-spot endurance test (10.16) – For changes in bonding technique or bonding material. (Not required if a bypass diode is employed for each cell)

B.12 Interconnection materials or technique (to cells and between receivers)

For modifications such as:

- different manufacturer
- different interconnect material
- different thickness/diameter of interconnect material, more than 10 % change
- different bonding technique
- different number of solder bonds, and
- different solder material or flux

Repeat:

- Thermal cycling (10.6)
- Humidity freeze (10.8)
- Off-axis beam damage test (10.14)
- Damp heat (10.7) for changes in materials
- Hot-spot endurance (10.16) for changes in bonding technique or solder material

B.13 Change in electrical circuit design in an identical package

For modifications such as:

- Modifications to the interconnection circuitry (for example more cells per bypass diode or re-routing of output leads), and
- Reconfiguration of voltage (i.e., 12 to 24)

Repeat:

- Hot-spot endurance test (10.16)
- Bypass diode thermal test (10.11), if current in any diode increases by 5 %
- Thermal cycling test (10.6) if the current in any cell increases by 5 %

B.14 Output power

For modifications such as:

- more than 10 % increase in current or power

Repeat:

- Hot-spot endurance (10.16)
- Thermal cycling (receiver) (10.6)
- Bypass diode thermal (10.11)

B.15 Thermal energy transfer means

For modifications such as:

- different heat sink gel
- different heat spreader material
- reduction in heat spreader area by > 10 %
- removal or addition of thermally or electrically insulating layers
- different thermally or electrically insulating layer material, and
- different method of attachment

Repeat:

- Outdoor exposure test (10.15)
- Off-axis beam damage test
- Thermal cycling (receiver) (10.6), for any change, addition, or removal of a polymeric material
- Damp heat (10.7) and humidity freeze (10.8) for any change, addition, or removal of a polymeric material
- Hot-spot endurance (10.16), except if the only change is a mechanical method of attachment

B.16 Adhesives

For modifications such as:

- usage of new or different adhesive which is not covered by another category

Repeat:

- Damp heat (10.7)
- Humidity freeze (10.8, including pre-thermal cycling)
- Outdoor exposure (10.15)
- Mechanical load sequence D (10.13), if structural adhesive
- ~~Water spray sequence E (10.10), if the adhesive provides a moisture seal~~
- Dust and water ingress protection test (10.10), if the adhesive provides a moisture seal

NOTE The default position is that a different supplier means different material, for any material. The burden of proof of equivalency is up to the manufacturer and supplier of material, through acceptable results of test and evaluation.

~~The retesting guideline for CPV cell technology and encapsulation were published in Provisional Decision Sheet 0778 (2010).~~

IEC 62108

Edition 3.0 2022-06

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Concentrator photovoltaic (CPV) modules and assemblies – Design qualification and type approval

Modules et ensembles photovoltaïques à concentration – Qualification de la conception et homologation

IEC 62108:2022-06(en-fr)

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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CONCENTRATOR PHOTOVOLTAIC (CPV) MODULES AND ASSEMBLIES – DESIGN QUALIFICATION AND TYPE APPROVAL

FOREWORD

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

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IEC 62108 has been prepared by IEC technical committee 82: Solar photovoltaic energy systems. It is an International Standard.

This third edition cancels and replaces the second edition published in 2016. This edition constitutes a technical revision.

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

a) Changes in the procedure of the thermal cycling test for the active cooling module.

b) Solar simulator I-V measurement.

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

Draft	Report on voting
82/2024/FDIS	82/2046/RVD

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

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

CONCENTRATOR PHOTOVOLTAIC (CPV) MODULES AND ASSEMBLIES – DESIGN QUALIFICATION AND TYPE APPROVAL

1 Scope

This document specifies the minimum requirements for the design qualification and type approval of concentrator photovoltaic (CPV) modules and assemblies suitable for long-term operation in general open-air climates as defined in IEC 60721-2-1. The test sequence is partially based on that specified in IEC 61215-1 for the design qualification and type approval of flat-plate terrestrial crystalline silicon PV modules. However, some changes have been made to account for the special features of CPV receivers and modules, particularly with regard to the separation of on-site and in-lab tests, effects of tracking alignment, high current density, and rapid temperature changes, which have resulted in the formulation of some new test procedures or new requirements.

The object of this test document is to determine the electrical, mechanical, and thermal characteristics of the CPV modules and assemblies and to show, as far as possible within reasonable constraints of cost and time, that the CPV modules and assemblies are capable of withstanding prolonged exposure in climates described in the scope. The actual life of CPV modules and assemblies so qualified will depend on their design, production, environment, and the conditions under which they are operated.

This document is used in conjunction with the retest guidelines described in Annex B.

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

IEC 60664-1:2020, *Insulation coordination for equipment within low-voltage supply systems – Part 1: Principles, requirements and tests*

IEC 60721-2-1, *Classification of environmental conditions – Part 2-1: Environmental conditions appearing in nature – Temperature and humidity*

IEC 60904-1:2020, *Photovoltaic devices – Part 1: Measurement of photovoltaic current-voltage characteristics*

IEC 60904-1-1:2017, *Photovoltaic devices – Part 1-1: Measurement of current-voltage characteristics of multi-junction photovoltaic (PV) devices*

IEC TS 60904-1-2:2019, *Photovoltaic devices – Part 1-2: Measurement of current-voltage characteristics of bifacial photovoltaic (PV) devices*

IEC 60904-2:2015, *Photovoltaic devices – Part 2: Requirements for photovoltaic reference devices*

IEC 60904-3:2019, *Photovoltaic devices – Part 3: Measurement principles for terrestrial photovoltaic (PV) solar devices with reference spectral irradiance data*

IEC 60904-4:2019, *Photovoltaic devices – Part 4: Photovoltaic reference devices – Procedures for establishing calibration traceability*

IEC 60904-5:2011, *Photovoltaic devices – Part 5: Determination of the equivalent cell temperature (ECT) of photovoltaic (PV) devices by the open-circuit voltage method*

IEC 60904-7:2019, *Photovoltaic devices – Part 7: Computation of the spectral mismatch correction for measurements of photovoltaic devices*

IEC 60904-8:2014, *Photovoltaic devices – Part 8: Measurement of spectral responsivity of a photovoltaic (PV) device*

IEC 60904-8-1:2017, *Photovoltaic devices – Part 8-1: Measurement of spectral responsivity of multi-junction photovoltaic (PV) devices*

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

IEC 61210:2010, *Connecting devices – Flat quick-connect terminations for electrical copper conductors – Safety requirements*

IEC 61215-1:2021, *Terrestrial photovoltaic (PV) modules – Design qualification and type approval – Part 1: Test requirements*

IEC 61215-2:2021, *Terrestrial photovoltaic (PV) modules – Design qualification and type approval – Part 2: Test procedures*

IEC TS 61836:2016, *Solar photovoltaic energy systems – Terms, definitions and symbols*

IEC 61853-1:2011, *Photovoltaic (PV) module performance testing and energy rating – Part 1: Irradiance and temperature performance measurements and power rating*

IEC 61853-2:2016, *Photovoltaic (PV) module performance testing and energy rating – Part 2: Spectral responsivity, incidence angle and module operating temperature measurements*

IEC 61853-3:2018, *Photovoltaic (PV) module performance testing and energy rating – Part 3: Energy rating of PV modules*

IEC 62670-1, *Photovoltaic concentrators (CPV) – Performance testing – Part 1: Standard conditions*

IEC 62670-3:2017, *Photovoltaic concentrators (CPV) – Performance testing – Part 3: Performance measurements and power rating*

IEC 62790:2020, *Junction boxes for photovoltaic modules – Safety requirements and tests*

IEC 62852:2014, *Connectors for DC-application in photovoltaic systems – Safety requirements and tests*
IEC 62852:2014/AMD1:2020

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60664-1, IEC TS 60904-1-2, IEC 61140, IEC TS 61836 and the following apply, see also Table 1.

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

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

3.1
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. Typically, it is a lens or a mirror

Note 1 to entry: 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 stand-alone, 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 above components are usually prefabricated as one unit, and the focus point is not field adjustable.

Note 2 to entry: A module could be made of several sub-modules. The sub-module is a physically stand-alone, smaller portion of the full-size module.

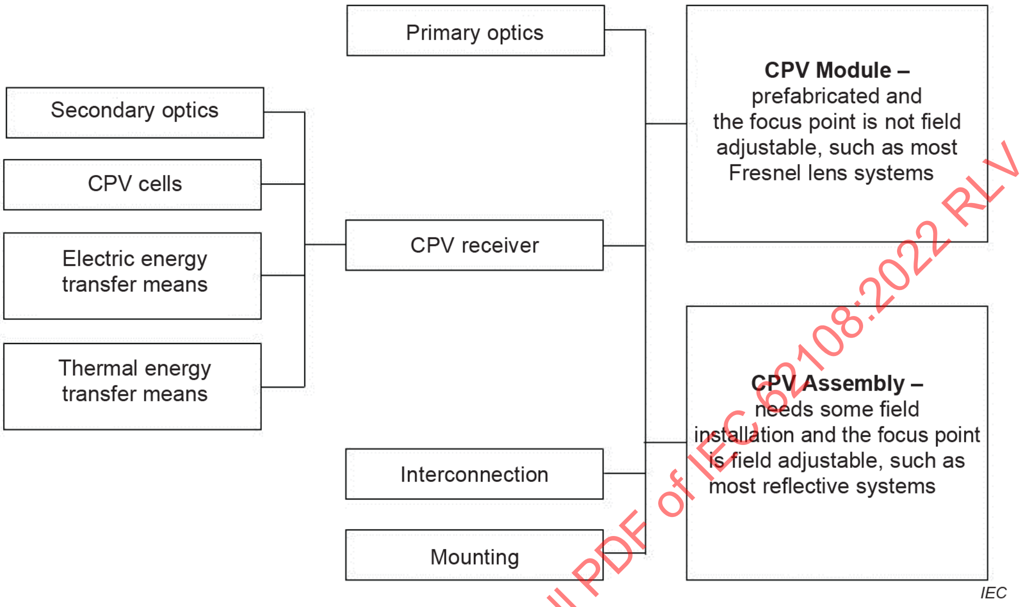
3.6
concentrator assembly
group of receivers, optics, and other related components, such as interconnection and mounting, that accepts unconcentrated sunlight

Note 1 to entry: All above components would usually be shipped separately and need some field installation, and the focus point is field adjustable.

Note 2 to entry: 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
control unit
hardware that is not stressed, but is included in each measurement to enable greater confidence in consistent measurements

Table 1 – Terms used for CPV



4 Sampling

Figure 1 to Figure 5 are schematics of cells, receivers, modules, and assemblies.

For non-field-adjustable focus-point CPV systems or modules, 7 modules and 2 receivers are required to complete all the specified tests, plus one receiver for the bypass/blocking diode thermal test (intrusive or non-intrusive). For details, see Figure 6. For field-adjustable focus-point CPV systems or assemblies, 9 receivers (including secondary optics sections, if applicable) and 7 primary optics sections are required to complete all the specified tests, plus one receiver for the bypass/blocking diode thermal test (intrusive or non-intrusive). For details, see Figure 7.

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 can be used. However, even if representative samples are used for the other test, a full-size module or assembly shall 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 shall use sub-receivers, sub-modules, or sub-assemblies. 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 shall 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 should be noted in the test report (see Clause 8).

The test samples shall have been manufactured from specified materials and components in accordance with the relevant drawings and process instructions and should have been subjected to the manufacturer's normal inspection, quality control, and production acceptance procedures. They shall be complete in every detail and should 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 is required with extra electrical and thermal detector leads so that each individual diode can be accessed separately.

5 Marking

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

– Name, monogram, or symbol of manufacturer.
– Type or model number.
– Serial number.
– Polarity of terminals or leads (color coding is permissible).
– Maximum system voltage for which the module or assembly is suitable.
– Nominal maximum output power and its tolerance at specified condition.
– The date, place of manufacture, and cell materials shall be marked, or be traceable from the serial number.

If representative samples are used, the same markings as on full-size products shall be included for all tests, and the marking should be capable of surviving all test sequences.

6 Testing

If recommended by the manufacturer, before beginning the testing, all testing samples, including the control module and control receiver, shall be exposed to the direct normal irradiation (DNI) of sunlight (either natural or simulated) for a total of 5 kWh/m^2 to 5,5 kWh/m^2 while open circuited. This procedure is designed to reduce the initial photon degradation effects.

In this document all references to short-circuit current I_{sc}, open-circuit voltage V_{oc}, maximum output power P_m, are based on Concentrator Standard Test Condition (CSTC), which is defined in IEC 62670-1. Alternatively, Concentrator Standard Operating Conditions (CSOC), as defined in IEC 62670-1, may be used consistently. Other parameters and testing method unless specified are based on IEC 60904 and IEC 61853.

The test samples shall be randomly divided into groups and subjected to the qualification test sequences in Figure 6 or Figure 7. Test procedures and requirements are detailed in Clause 10, and summarized in Annex A. The allocation of test samples to typical test sequences is given in Table 2.

After initial tests and inspections, one module or one receiver/mirror section shall be removed from the test sequence as a control unit. Preferably, the control unit should be stored in the dark at room temperature to reduce the electrical performance degradation, but it may be kept outdoors with a dark cover. As shown in Figure 6 for modules or in Figure 7 for assemblies, the test sequence is performed both in-lab and on-site. If the CPV receiver uses crystalline silicon, a 1-sun measurement (flash or outdoor) can be used as a diagnostic tool throughout the program. 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 should be performed to evaluate any possible changes on testing samples.

If a particular manufacturer produces only specific components, such as receivers, lenses, or mirrors, the design qualification and type approval testing can be conducted only on applicable test sequences, and a partial certification can be issued independently.

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 document. Any changes and deviations shall be recorded and reported in details, as required in Clause 8 j).

Table 2 – Allocation of test samples to typical test sequences

Test sequence	Module		Assembly	
	receiver	module	receiver	mirror
Control		1	1	1
A	2		2	
B		2	2	2
C		2	2	2
D		1	1	1
E		1 (full-size)	1 (full-size)	1 (full-size)
F	1		1	
Total	3	7	10	7

7 Pass criteria

A concentrator photovoltaic module or assembly design shall be judged to have passed the qualification tests, and therefore to be IEC 62108 type approved, if each test sample meets all the following criteria:

a) The relative power degradation in sequence A to D does not exceed 13 % if the I-V measurement is under outdoor natural sunlight, or 8 % if the I-V measurement is under solar simulator.

b) The relative power degradation in sequence E does not exceed 7 % for natural sunlight I-V measurement, or 5 % for solar simulator I-V measurement, because the 1 000 kWh/m^2 DNI outdoor exposure test is not an accelerated stress test.

c) No sample has exhibited any open circuit during the tests.

d) There is no visual evidence of a major defect, as defined in 10.1.2.

e) The insulation test requirements are met at the beginning and the end of each sequence.

f) The wet leakage current test requirements are met at the beginning and the end of each sequence.

g) Specific requirements of the individual tests are met.

If there are some failures observed during the test, the following judgment and re-test procedure shall apply:

h) If two or more test samples do not meet pass criteria, the design shall be deemed not to have met the qualification requirements.

i) Should one sample fail any test, another two samples meeting the requirements of Clause 4 could be subjected to the whole of the relevant test sequence from the beginning.

j) In case i), if both samples pass the test sequence, the design shall be judged to have met the qualification requirements.

k) In case i), if one or both of these samples also fail, the design shall be deemed not to have met the qualification requirements.

l) In case h) or k), the entire test program illustrated in Figure 6 or Figure 7 shall be re-performed, usually after some design or processing improvement.

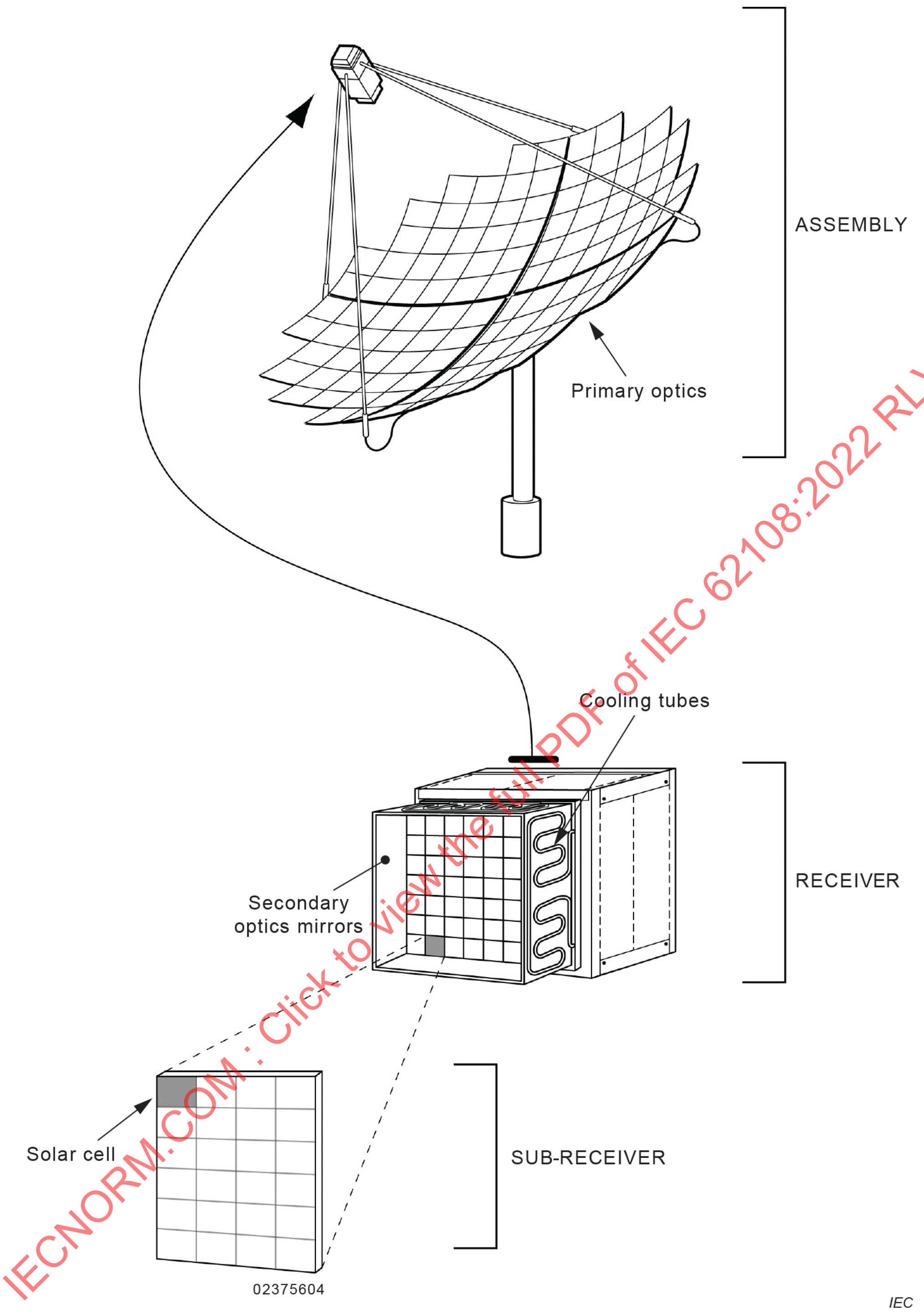


Figure 1 – Schematic of point-focus dish PV concentrator

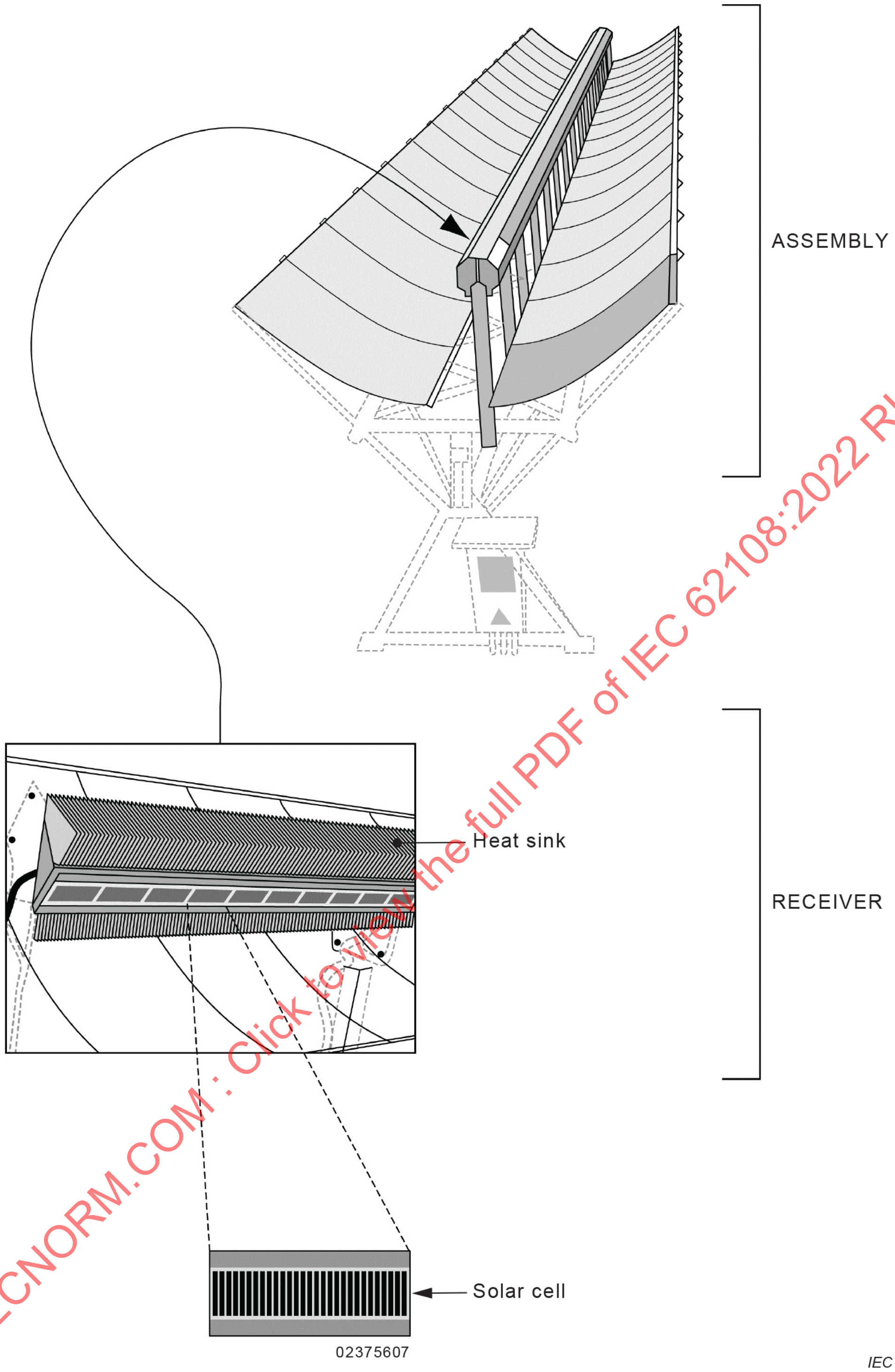


Figure 2 – Schematic of linear-focus trough PV concentrator

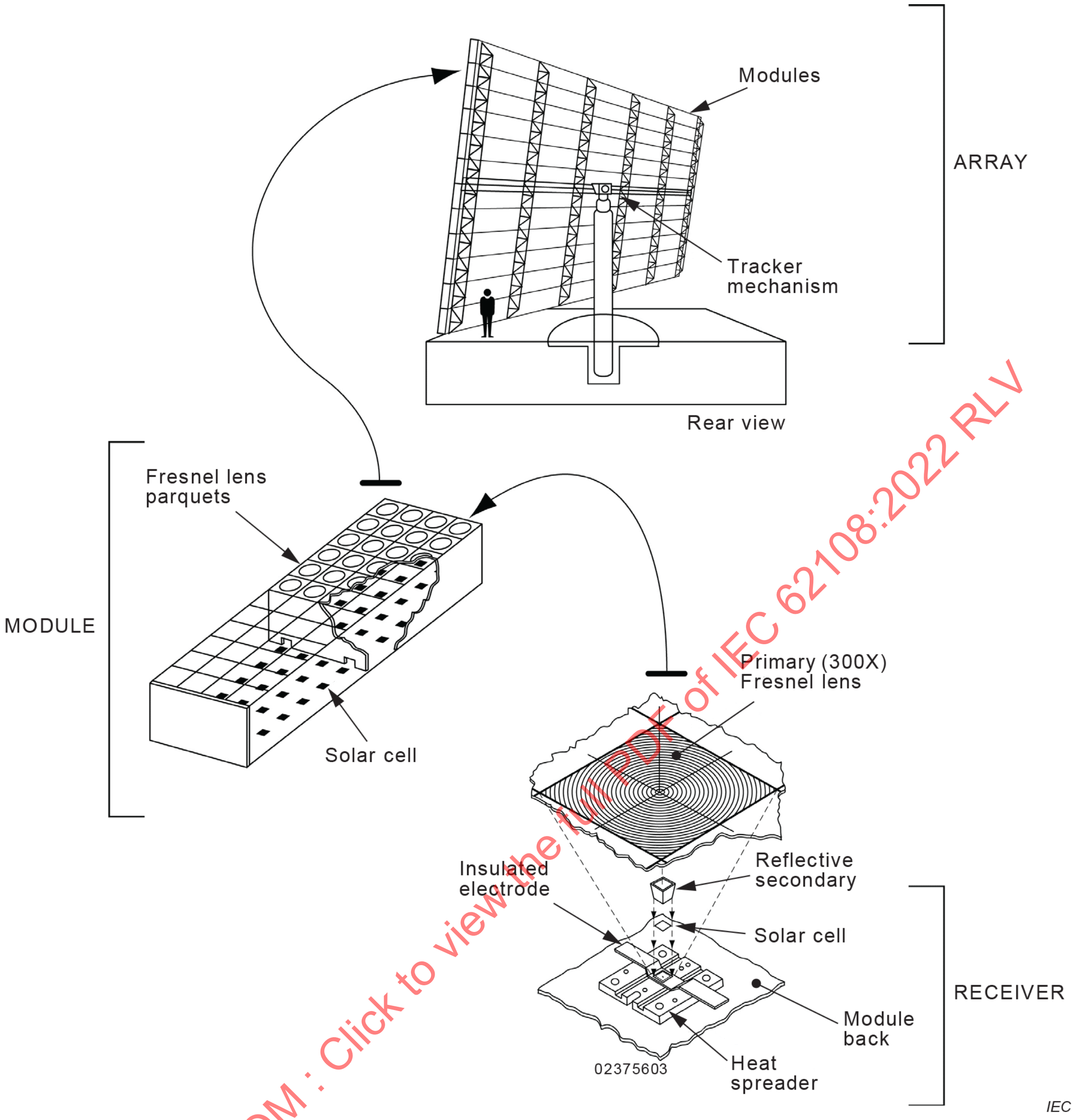


Figure 3 – Schematic of point-focus Fresnel lens PV concentrator

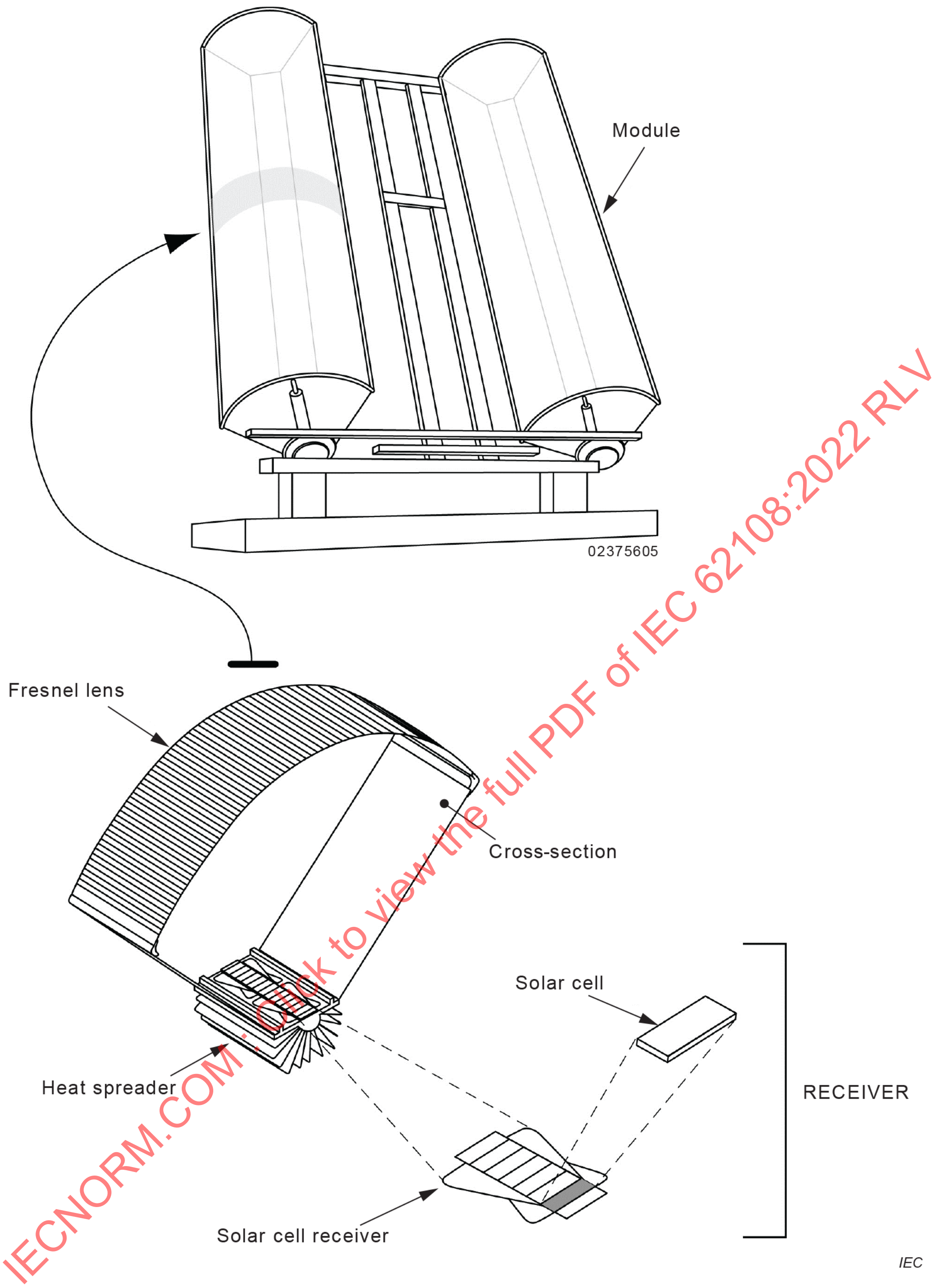


Figure 4 – Schematic of linear-focus Fresnel lens PV concentrator

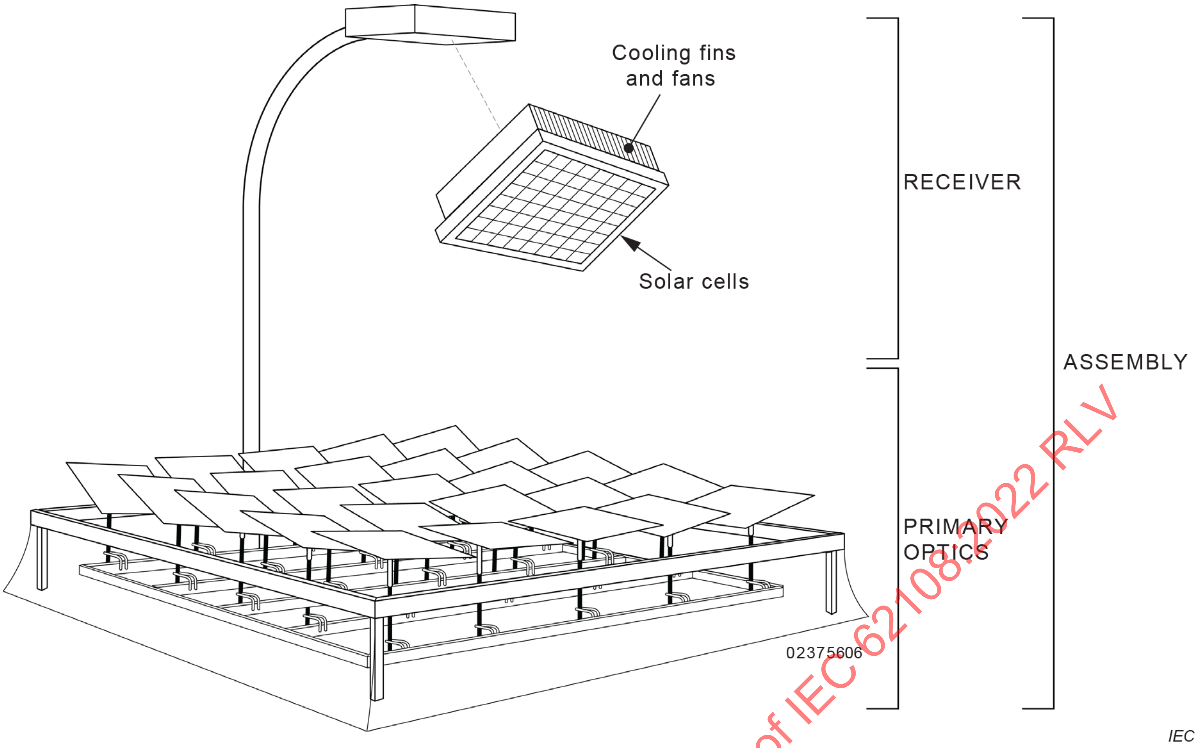


Figure 5 – Schematic of a heliostat CPV

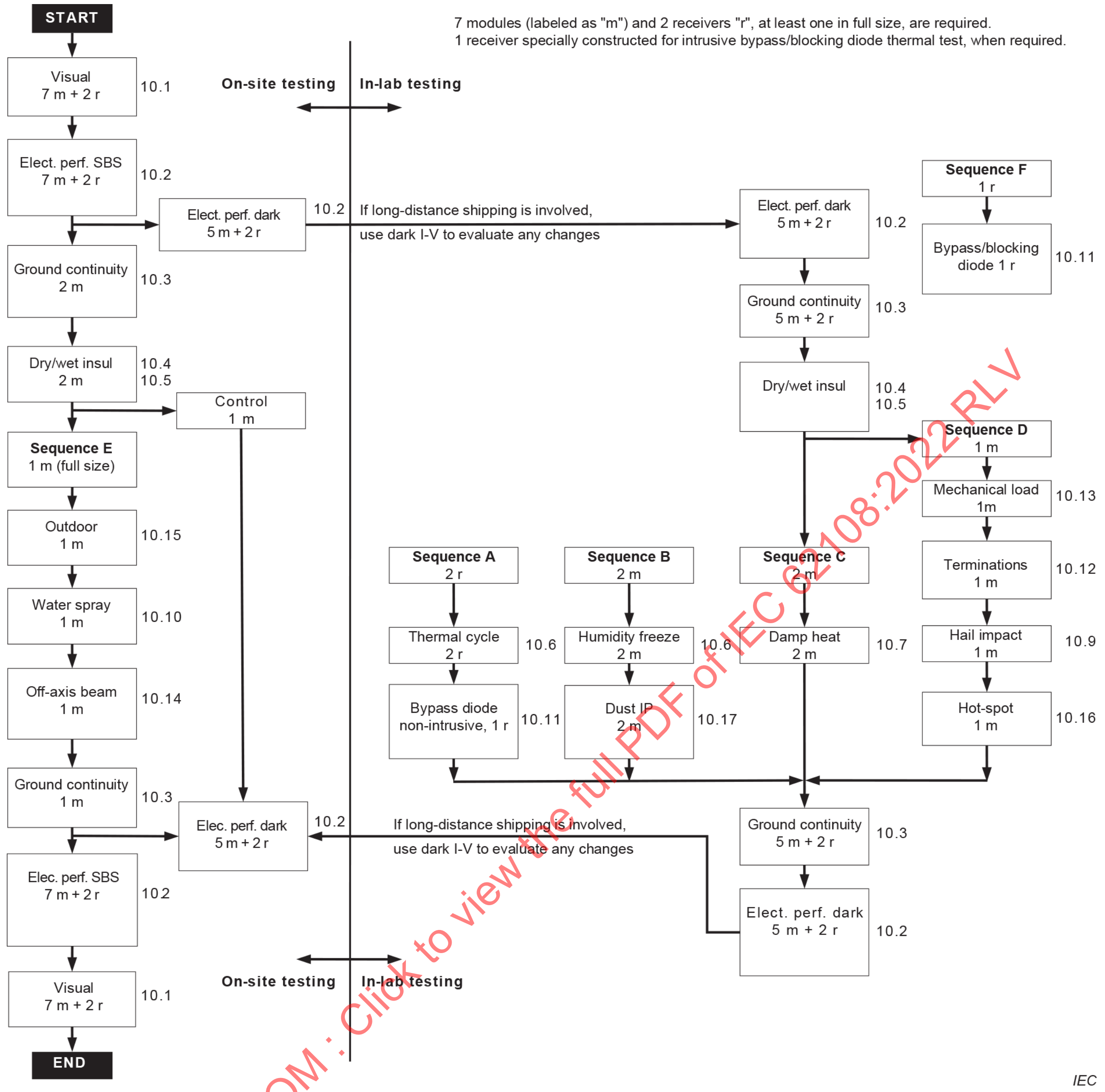


Figure 6 – Qualification test sequence for CPV modules

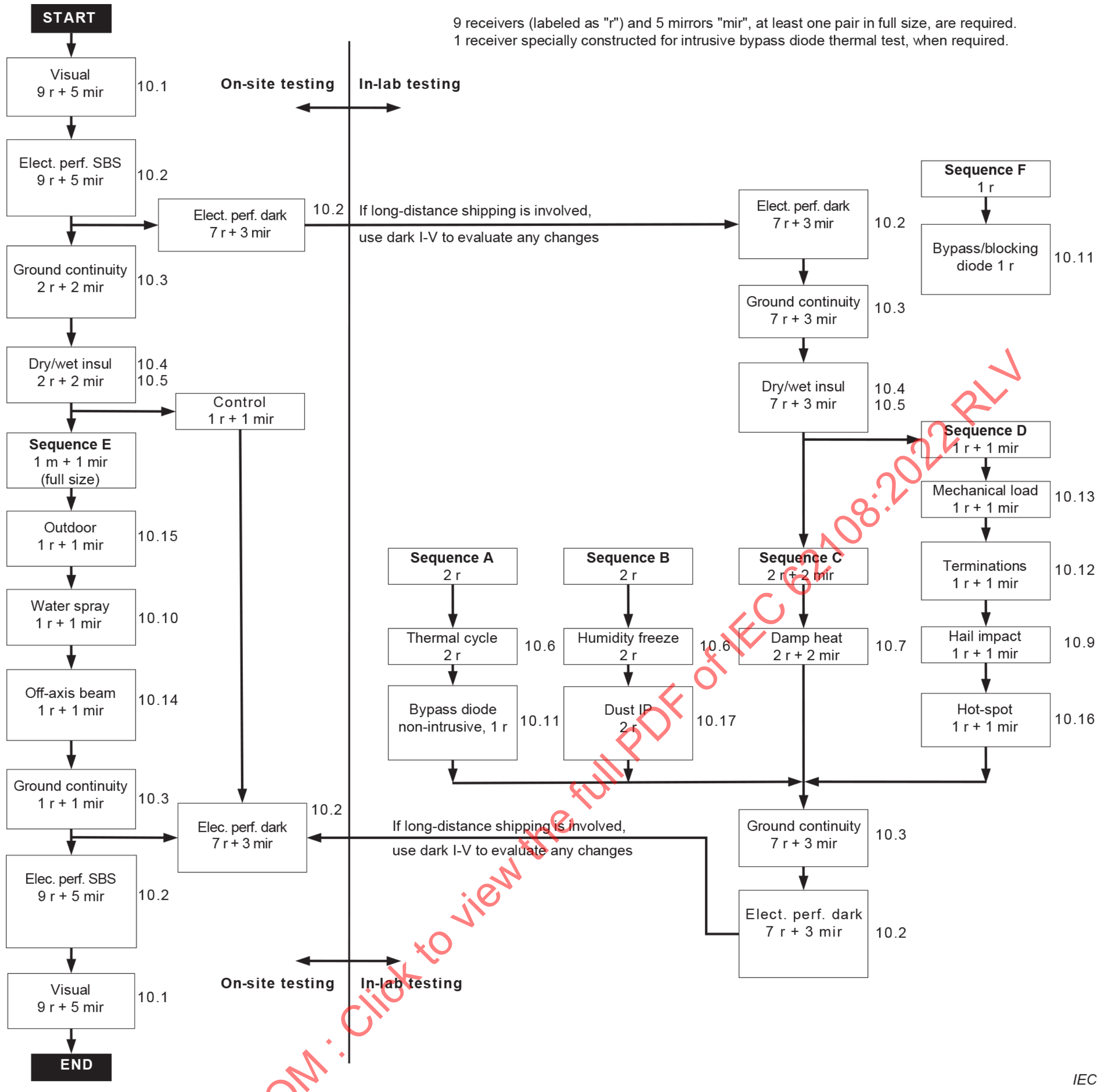


Figure 7 – Qualification test sequence for CPV assemblies

8 Report

Following type approval, a certified report of the qualification tests, with measured performance characteristics and details of any failures and re-tests, shall be prepared by the test agency. Each test report shall include at least the following information: Components test unless specified is based on IEC 62790 and IEC 62852.

a) A title.

b) The name and address of the laboratory, and the location where the tests were carried out, if different from the address of the laboratory (such as on-site location).

c) Unique identification of the test report (such as the serial number), and on each page an identification to ensure that the page is recognized as a part of the test report, and a clear identification of the end of the test report.

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 test method, and any other information relevant to a specific test, such as environmental conditions.

k) Measurements, examinations, and derived results supported by tables, graphs, sketches, and photographs as appropriate, including short-circuit current, open-circuit voltage, maximum output power, maximum power loss observed after all of the tests, and any failures observed.

l) A statement of the estimated uncertainty of the test results, where relevant.

m) A signature and title, or equivalent identification, of the person(s) accepting responsibility for the content of the report, and the date of issue.

n) Where relevant, a statement to the effect that the results relate only to the items tested.

o) A statement that to maintain the qualification and type approval, the manufacturer shall report to and discuss with the certifying body and testing agency every change they made, guided by the retest guidelines provided in Annex B.

p) A statement that the report shall not be reproduced except in full, without the written approval of the laboratory.

A copy of this report should be kept by the manufacturer for reference purposes.

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, as described in Annex B. Manufacturers shall report to and discuss with the certifying body and testing agency every change they made.

10 Test procedures

10.1 Visual inspection

10.1.1 General

This procedure provides the requirements for obtaining baseline, intermediate, and final visual inspections to identify and determine any physical changes or defects in module or assembly construction at the beginning and after the completion of each required test.

Any hardware showing initial damage not due to the manufacturing process should be rejected if it may worsen and lead to failure during the subsequent environmental tests. A new module or assembly may then be substituted before beginning the test sequence.

10.1.2 Procedure

All test samples shall be thoroughly inspected and photographed when necessary. All defects or abnormalities (including initial defects related to the quality of solder joints such as inadequate or excessive solder, solder balls, bent interconnects, or misalignment of parts) shall be documented with appropriate sketches or photographs to show the locations of the defects. Components, such as the lens, mirror, secondary optical elements, heat spreaders, and encapsulants, shall also be inspected for defects. Specifically, inspect for:

a) Bubbles, delamination, or any kind of similar defect on the cell and around its edges.

b) Damage incurred during shipping and handling, such as cracked lenses, cracked or bent housings, and bent terminals or mounting brackets.

c) Integrity of the seal around the lens and housing joints. Any crack or gap in sealant materials shall be noted.
d) Any ventilation hole or breather shall not be clogged.
e) Provision for grounding all accessible conductive parts.
f) Broken, cracked, bent, misaligned, or torn external surfaces.
g) Faulty interconnections or joints.
h) Visible corrosion of output connections, interconnections, and bus bars.
i) Failure of adhesive bonds.
j) Tacky surfaces of plastic materials.
k) Faulty terminations, or exposed live electrical parts.
l) Any other conditions that may affect reliability or performance.

10.1.3 Major visual defects

For the purpose of design qualification and type approval, the following are considered to be major visual defects:

a) Broken, cracked, bent, misaligned, or torn external surfaces, including lens, mirror, receiver body, frame, and junction box.
b) Broken or cracked cells.
c) Bubbles or delamination forming a continuous path between any part of the electrical circuit and the edge of the receiver.
d) Visible corrosion of any of the active circuitry of the sample.
e) Adhesive or sealant failures.
f) Loss of mechanical integrity, to the extent that the installation and/or operation of the modules or assemblies would be impaired.

10.1.4 Requirements

No major visual defects.

10.2 Electrical performance measurement

10.2.1 Purpose

The purpose of the electrical performance test is to identify electrical performance degradation of test samples caused by required tests. The focus of this test is on the power degradation, not on the absolute power output, which will be covered by a separate power and energy rating standard.

Repeatability of the measurement is the most important factor for this test.

10.2.2 Outdoor side-by-side I-V measurement

10.2.2.1 General

The side-by-side I-V measurement identifies power degradation of a test sample by comparing its post-stress test relative power to its pre-stress test relative power. The relative power is defined as the maximum power output of the sample under test divided by the maximum power output of the control sample, measured under similar test conditions. This method is based on the assumption that the changes of the control sample's electrical performance are negligible during the whole qualification test period. By using this method, test condition variables are self-correcting, and the complex translation procedures are eliminated.

The side-by-side I-V measurement is required for each test sample on the beginning and final I-V measurements. It is optional for all intermediate I-V measurements.

When applying this method to receivers, the control receiver and the receiver under test shall be installed with a proper optical and mechanical system so that during the test, the concentrated light and thermal conditions of these two receivers are similar to the real operating conditions.

10.2.2.2 Procedure

Measure the relative power of a test sample according to following procedures:

a) Conduct the test on a favorable day and during a period of time that meets the following conditions:
   - sky is clear, DNI is greater than 700 W/m^2, and its variation is less than 2 % in any 5 min interval;
   - for systems with acceptance half-angle larger than 2,5°, no visible clouds or hazy conditions in 45° view angle around the sun;
   - wind speed is less than 6 m/s, and no gust of greater than 10 m/s in 10 min before any measurement.

   Pay attention to the tracking system's rigidity and make sure it is stable under the windy condition.
b) Mount the test sample and the control sample side-by-side on a two-axis tracker. The alignment of the samples to sunlight could be done by either of following two sequences:
   - adjust the test and control samples to co-plane, then align both of them together to the direction of sun beam; or
   - separately align the test and control samples to the sun beam before each I-V measurement.

   NOTE Test sample and control sample can also be tested on two adjacent two-axis trackers, or two receivers can be tested in sequence on one tracker and optical system, if all conditions in a) are met.
c) Alignment shall meet the manufacturer's specifications. If specifications are not available, use the maximum I_{sc} of the module as an indicator of alignment. Misalignment shall not cause I_{sc} to decrease more than 2 % from its maximum value.
d) Monitor sample's temperature to make sure the sample temperature changes are less than 2 °C in any 1 min period.
e) If coolant is employed, monitor coolant flow rate and inlet/outlet temperatures. The coolant flow rate shall not change by more than 2 %, and the temperature shall not change by more than 1 °C in any 5 min period.
f) Take I-V measurements on both samples to obtain their maximum power output. This procedure shall be completed quickly so that the change of power output caused by solar irradiance, ambient temperature, and wind speed changes is less than 2 % during this step.
g) Calculate the sample's relative power P_r:

$$P_r = \frac{P_m}{P_{mc}} \times 100\,\%$$

where:

P_r is the sample's relative power, in %;

P_m is the test sample's maximum power, in W;

P_{mc} is the control sample's maximum power measured at the similar condition as P_m, in W.

10.2.2.3 Requirements

a) The sample's maximum power (P_m), I_{sc}, and V_{oc} shall be measured accurately and repeatably.

b) The relative power degradation, P_{rd}, is defined as follows:

$$P_{rd} = \frac{P_{ri} - P_{rf}}{P_{ri}} \times 100\ \%$$

where:

P_{rf} is the relative power measured after the given test;

P_{ri} is the relative power measured before the given test.

For outdoor measurement, P_{rd} shall be less than 13 %, and for indoor simulator measurement, P_{rd} shall be less than 8 %. The 5 % difference takes into account the larger uncertainty from outdoor measurements.

10.2.3 Solar simulator I-V measurement

CPV I-V measurement could also be performed under indoor solar simulator according to IEC 62670-3:2017, 9.5 and 9.6. The testing lab should create its own testing procedure, as long as similar conditions are achieved.

10.2.4 Dark I-V measurement

10.2.4.1 General

The dark I-V measurement compares the sample's series resistances measured before and after the tests. It is performed before and after the test sample's shipping to evaluate any possible changes.

The dark I-V measurement is also a cost-effective method to monitor and diagnose power degradation of test modules or assemblies following intermediate stress tests, or to monitor the electric performance stability of the control samples.

10.2.4.2 Procedure

If the dark I-V is used for diagnostic purpose, it should be measured during initial measurements to establish a reference for later dark I-Vs, in addition to the side-by-side baseline I-V measurement, which serves as a reference for later side-by-side I-Vs. The method is applicable to both receivers and modules.

a) Choose a suitable power source, which could be a conventional DC power supply or a charged-up capacitor, whatever is most convenient, as long as it will generate current up to 1,6 times rated I_{sc}. The current should be adjustable so that there are at least 10 separate points in the range of 0,9 to 1,6 times rated I_{sc}, and the interval of the points should be nearly equal-spaced.

b) Short the blocking diode by placing a jumper lead across the leads of the blocking diode, if there is one installed.

c) Connect the power source's positive lead to sample's positive lead, and the negative lead to negative lead.

d) Block the light source to the cells, e.g. turn the samples upside down, so that the measured open-circuit voltage of the sample is less than 5% of its rated V_{oc}.

e) Apply at least 10 different currents to the module and record each set of current, voltage, and cell temperature.

Complete this procedure as quickly as possible to avoid significant heating of the cells during the test. If the temperature drift is too fast to give a repeatable reading, allow the current to flow while the module heats to its equilibrium temperature, then record the steady-state values.

f) Plot the current and voltage data on a chart with the voltage on the vertical axis and current on the horizontal axis, and perform a linear regression in the region of the linear part of the curve (usually, it is at the higher end of current):

$V = R \times I + V_0$

where

R is the module's series resistance, and

V_0 is the linear-regression constant.

10.2.4.3 Requirements

The dark I-V test is not intended to be used as the pass/fail criterion for the qualification test, but as a cost-effective method for identifying degradations of the sample following each test.

Side-by-side I-V measurement shall be conducted for pass/fail decision.

10.3 Ground path continuity test

10.3.1 General

In some countries or regions, system grounding is not required. If the product installation is restricted to these areas, this test may be omitted.

10.3.2 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.

10.3.3 Procedure

a) A continuity tester (ohmmeter) shall be used to test electrical continuity between any parts on the test sample and its grounding point.

b) To minimize danger to testing personnel, a current- and voltage-limited power supply that is not capable of producing more than 10 V DC between its output terminals should be used for this test.

c) The resistance between the grounding point and any accessible conductive part shall be measured with a current passing through these two points. If the module manufacturer has not provided contact points for this test on the modules, a small area on the module shall be scraped clear of any anodization or coating to make good contact.

d) Apply a current of two times I_{sc} between the grounding terminal and a point, and measure the voltage within 1,3 cm of each point of current injection.

e) Record the current and voltage until the values are stable.

f) If more than one test is needed to evaluate all paths of conduction, allow enough cooling time between tests if the temperature of the sample increased significantly.

g) At the end of this test, the test sample shall be subjected to an insulation test of 10.4.

10.3.4 Requirements

a) Resistance shall be less than 0,1 Ω.

b) Damage shall not be produced at joints between different exposed conducting parts.

10.4 Electrical insulation test

10.4.1 Purpose

The purpose of the electrical insulation (also called dry insulation) 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.

10.4.2 Procedure

a) Obtain an insulation tester, which has the following functions, to:
   - Supply DC current limiting to 10 mA.
   - Apply DC voltage of 1 000 V plus twice the maximum system voltage of the test sample.
   - Measure the current in µA resolution.

   These functions could be combined in one single unit or with a few separate units:

b) The test shall be conducted on samples at ambient temperature of 25 °C ± 10 °C and relative humidity not exceeding 75 %.

c) Designs that use a cooling medium shall have the cooling medium present during the test, but the cooling medium circulation is not required.

d) The sample cell faces shall be darkened and the sample shall not be connected to any active electrical source.

e) Connect the shorted positive and negative output terminals of the sample to the positive terminal of the tester.

f) Connect the exposed metal parts of the sample to the negative terminal of the tester. If the sample has no conductive frame or if the frame is a poor electrical conductor, wrap the sample with a metallic plate or foil, then connect the plate or foil to the negative terminal of the tester.

g) Increase the voltage applied by the tester at a rate not exceeding 500 V/s to 1 000 V plus twice the maximum system voltage (i.e., the maximum system voltage rated by the manufacturer). If the maximum system voltage does not exceed 50 V, the applied voltage shall be 500 V.

h) Maintain the voltage at this level, and wait for 2 min after a stable leakage current is reached.

i) Observe any sign for dielectric breakdown or surface tracking (steps g) to i) are also called the dry hi-pot test).

j) Reduce the voltage to 500 V, and maintain for 2 min after a stable leakage current is reached.

k) Record the applied voltage and the current.

l) Calculate the insulation resistance based on recorded data.

m) Reduce the applied voltage to zero and short-circuit the terminals of the tester to discharge the electrical charges built up in the sample.

n) Disconnect the tester from the sample.

10.4.3 Requirements

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

b) For samples with an overall receiver aperture area less than or equal to 0,1 m^2, the measured insulation resistance shall not be less than 50 MΩ.

c) For samples with an overall receiver aperture area larger than 0,1 m^2, the measured insulation resistance times cell area shall not be less than 5 $MΩm^2$.

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.

10.5 Wet insulation test

10.5.1 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.

10.5.2 Procedure

a) Obtain an insulation tester as described in 10.4.2 a).

b) Prepare a non-corrosive liquid agent (surfactant) solution in a testing tank that is large enough to hold the test samples. The resistivity of the test solution shall be between 1 500 Ω cm to 3 500 Ω cm when measured at a temperature of 22 °C ± 3 °C.

c) Designs that use a cooling medium shall have the cooling medium present during the test, but the cooling medium circulation is not required.

d) The sample cell faces shall be darkened and the sample shall not be connected to any active electrical source.

e) Connect the shorted positive and negative output terminals of the sample to the positive terminal of the tester.

f) Make a good connection between the negative terminal of the tester and the liquid solution.

g) Immerse the sample in the solution, or spray the solution over the sample, for at least 5 min. The terminal boxes, pigtail leads, uninsulated terminations, or other connectors that are not suitable for immersion could be maintained above the solution level, but be thoroughly wetted by spraying the solution over these areas from all possible directions that rain or melt snow could enter.

h) Increase the voltage applied by the tester at a rate not exceeding 500 V/s to 500 V.

i) Maintain the voltage at this level, and wait for 2 min after a stable leakage current is reached, then observe any sign of dielectric breakdown, surface tracking, or bubble generation.

j) Record the applied voltage and the current.

k) Calculate the insulation resistance based on recorded data.

l) Reduce the applied voltage to zero and short-circuit the terminals of the test equipment to discharge the electrical charges built up in the test sample.

m) Disconnect the test equipment from the sample.

n) Clean the surface of the module from residues of the solution.

10.5.3 Requirements

a) No dielectric breakdown or surface tracking.

b) For samples with an overall receiver aperture area less than or equal to 0,1 m^2, the measured insulation resistance shall not be less than 50 MΩ.

c) For samples with an overall receiver aperture area larger than 0,1 m^2, the measured insulation resistance times cell area shall not be less than 5 $MΩm^2$.

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.

10.6 Thermal cycling test

10.6.1 Purpose

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

10.6.2 Test sample

Two receiver samples are required for the sequence A thermal cycling test, which is a full length of the thermal cycle. If a full-size sample is too large to fit into the environmental chamber, or it is too expensive to use, a smaller representative sample may be specially designed and manufactured for this test. The representative sample shall be carefully designed so that it can reveal similar failure mechanisms as the full-size one, and the fabrication process of the representative sample shall be as identical as possible to the process of the full-size ones.

NOTE Possible failure mechanisms for temperature cycling test could include weak mechanical strength of cells, poor bus bar and soldering (loose, wrong flux, tension) materials, incorrect interconnection design (for example, too large differences of thermal expansion coefficients among bonded layers and not enough buffering layer in between), wrong adhesives, and poor workmanship.

When designing or fabricating the representative samples, special considerations shall include, but not be limited to, the following aspects:

– Repeated parts or sections (sub-receivers) used by the full-size sample can be reduced, but if possible, try to use at least two of these parts or sections in their full dimensions.
– All non-repeated parts or sections, such as cell string's end-connections and corners, electrical and mechanical joints, sensors, and bypass/blocking diodes, should be included in the representative samples.

10.6.3 Procedure

Three options are given in Table 3 to fit the different materials used. The thermal cycle test shall be carried out in air without adding humidity. It could be in a single-chamber system or in a dual-chamber system. A dwell time of at least 10 min within ±3 °C of the high and low temperatures is required. The cycling frequency can range from 5 to 48 cycles per day. During each cycles current I_{test} equal to 1,25 times rated I_{SC} at CSTC shall be applied to the test sample when temperature is above 25 °C as shown in Figure 8.

To apply current during each thermal cycle, one of the following options could be adopted to:

a) Use an external DC power supply to provide a desired current in the negative direction (the positive direction is the sample's normal generating current direction) while the sample is in the dark (blocking diodes, if present, shall be shorted).
b) Provide a full intensity of illumination so that the sample can generate the desired current in the positive direction.
c) Provide a partial intensity of illumination in combination with an external DC power supply to generate the desired current in the positive direction (bypass diodes, if present, shall be opened).

In the case where the active cooling circuit is used, the manufacturer and test lab may agree to use the maximum fluid temperature to represent the heatsink temperature. The temperature shall be monitored at a location as close to the cell as possible during temperature cycling – and the chamber temperature adjusted to ensure that this temperature does not exceed the test target temperature. The temperature of the heat-sink or some other representative component close to the cell may be measured if the cell is inaccessible. The exact location of the heat sink temperature shall be noted on the measurement report.

When the sample has parallel strings, make sure that the required current is supplied to each single string. Sometimes this will require separating the parallel strings, and to use separate power supplies for each string.

Based on the knowledge as this document is written, some large-area III-V cells may not be able to hold up under option a) or c), and some testing facilities may have an equipment limitation to perform option b). In these cases, the thermal cycle test sequence A could be conducted without applying the current, but the manufacturer should prepare three additional receiver samples with similar, but “dead,” cells, i.e., electrically inactive III-V cells. A minimum of 1,25 I_{sc} should be provided in either positive or negative direction. The current should be controlled to maintain a temperature difference between the cell and heat sink comparable to, or greater than, operating conditions so that the localized heating can take place, and the ability of the receivers to withstand thermal mismatch, fatigue, and other stresses can be evaluated. The thermal gradients during operating conditions can be determined from commercially available modeling programs or from direct measurements when DNI is greater than 700 W/m^2 and wind speed is less than 2 m/s. The pass criteria for these receiver samples will be changed to: after the thermal cycle test, the change of the receiver resistance shall be less than 2 % (excluding the cell). This alternative procedure will be re-evaluated, and if necessary, an amendment to this standard will be issued, as soon as further knowledge on this topic becomes available.

Actively cooled systems are typically designed to handle a very large heat load. If coolant is present, it may not be possible to heat the system to the target temperatures, but if the coolant is removed and (I_{sc}) bias current is applied, the temperature can reach arbitrarily high temperatures. Thermal cycling because of bias current applies stress differently than thermal cycling the chamber and may be especially effective if a series resistance develops that enhances local heating from the flow of current. Cooling may need to be reduced below the system operational specification to allow the chamber or electrical biasing to achieve target temperatures.

There will be one current cycle for each temperature cycle. Current flow shall commence during the upward temperature ramp when the cell temperature reaches 25 °C and stop at the end of the maximum temperature dwell. (see illustration in Figure 8). The sample’s circuit continuity shall be monitored and recorded. In the case where the active cooling circuit is used, the manufacturer and test lab may agree to use the maximum fluid temperature to represent the heatsink temperature. The temperature shall be monitored at a location as close to the cell as possible during temperature cycling – and the chamber temperature adjusted to ensure that this this heat sink temperature does not exceed the test target temperature. The temperature of the heat-sink or some other representative component close to the cell may be measured if the cell is inaccessible. The exact location of the heat sink temperature measurement location shall be noted on the measurement report.

Table 3 – Thermal cycle test options for sequence A

Option	Target cell temperature °C	Total cycles	Applied current during heating and high-temperature dwell
TCA-1	85	1 000	Apply I_{test} when T > 25 °C
TCA-2	110	500	Apply I_{test} when T > 25 °C
TCA-3	65	2 000	Apply I_{test} when T > 25 °C

The samples shall be subjected to visual inspection 10.1 and the insulation test 10.4 following the thermal cycling test.

10.6.4 Procedure for active cooling system

Active cooled systems alternate methods:

a) Phase 1 – A standard temperature cycle profile to be followed without electrical bias being applied. The system can be run "dry" with no cooling fluid present during the duration of this test. The test shall be run at one of the standard temperature profiles listed in Table 3 for the full duration.

   Phase 2 – The temperature cycle profile shall be run with bias under the following conditions: a 25 °C chamber temperature with electrical bias being applied to the receiver(s) under test to raise the cell(s) temperature(s) to one of the accepted temperature profiles listed in Table 3 (instead of using the chamber temperature to cycle the temperature). The current shall then be cycled to duplicate the standard test profile listed in Table 3. The system can be run "dry" with no cooling fluid present during the duration of this test. The current injection will raise the cell(s) temperature(s) to one of the values in Table 3.

b) A standard temperature cycle profile to be followed with chamber temperature being controlled to achieve the part of the cycle below 25 °C without electrical bias, and electrical bias being applied to the receiver(s) under test to raise the temperature to one of the accepted temperature profiles listed in Table 3. The testing lab will decide which testing sequence is most adequate, considering the opinions from manufacturers. The system can be run "dry" with no cooling fluid present during the duration of this test, or with an active cooling circuit provided to the specification as agreed between the manufacturer and the test laboratory (on/off conditions, flow rate, coolant temperature, coolant composition) to meet the temperature profile for the part of the cycle above 25 °C.

c) A standard temperature cycle profile to be followed as per b) except that the temperature of receiver(s) under test is controlled below 25 °C by the utilization of the active cooling circuit. The active cooling will operate as per the specification agreed between the manufacturer and test laboratory.

10.6.5 Requirements

a) No evidence of major visual defects, as defined in 10.1.2.

b) No interruption of current flow during the test.

c) Insulation resistance shall meet the same requirements as defined in 10.4.

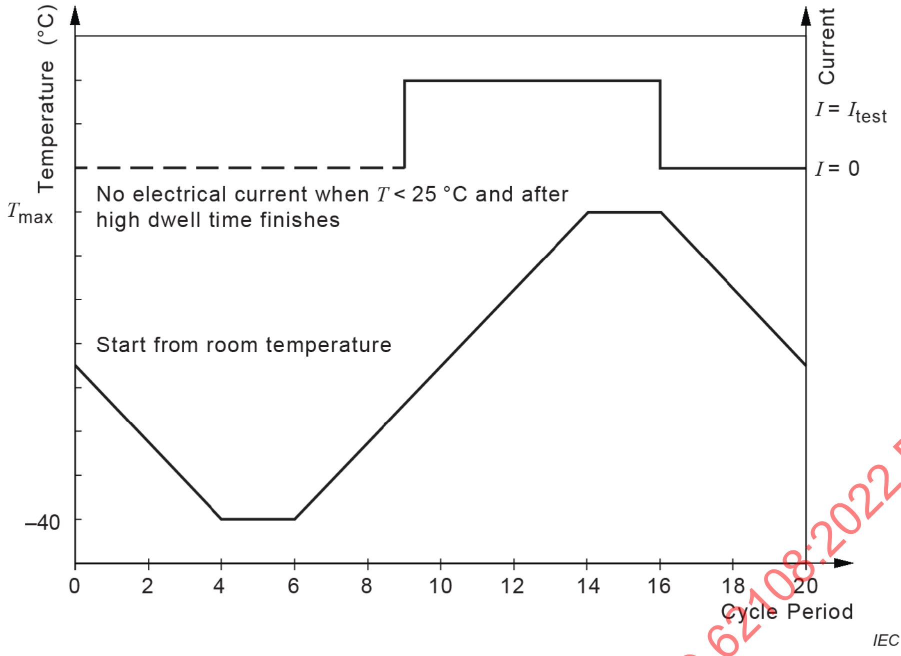


Figure 8 – Temperature and current profile of thermal cycle test (not to scale)

10.7 Damp heat test

10.7.1 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.

10.7.2 Test sample

Total of two modules, or two receivers and mirrors, are required for damp heat test in sequence C. If a full-size sample is too large to fit into the environmental chamber, or it is too expensive to use, a smaller representative sample may be specially designed and manufactured for this test. The representative sample shall be carefully designed so that it can reveal similar failure mechanisms as the full-size one, and the fabrication process of the representative sample shall be as identical as possible to the process of the full-size ones.

NOTE Possible failure mechanisms for damp heat test could include low-quality metal materials (rust), thin or low-quality lamination materials, not enough clearance distance around edges so that the moisture penetrates to active electric circuits, poor workmanship, or wrong or inadequate adhesives.

When designing or fabricating the representative samples, special considerations shall include, but not be limited to, the following aspects:

– Repeated parts or sections used by the full-size sample can be reduced, but if possible, try to use at least two of these parts or sections in their full dimensions.
– Keep the same clearance distance around edges as it is on the full-size products.

10.7.3 Procedure

a) The test samples shall be subjected to a test in an environmental chamber in which the relative humidity shall be controlled to 85 % ± 5 % and the temperature to 85 °C ± 2 °C, for 1 000 h. The test may be continued for up to an additional 60 h to permit the insulation test in step c) to be performed.

b) 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.

c) At the end of the test, within 2 h to 4 h of removal from the environmental chamber, test samples shall be subjected to the dry insulation test 10.4 and wet insulation test 10.5. This period shall be used to reduce temperature in the climatic chamber. The temperature shall be reduced from 85 °C to 25 °C in 1,5 h. This should be held for half an hour. Directly after the removal from the environmental chamber, test samples shall be subjected to the dry insulation test 10.4 and wet insulation test 10.5.

d) Visual inspection 10.1 shall also be performed.

10.7.4 Requirements

a) No evidence of major visual defects, as defined in 10.1.2.

b) Insulation resistance shall meet the same requirements as defined in 10.4.

c) Wet insulation resistance shall meet the same requirements as defined in 10.5.

10.8 Humidity freeze test

10.8.1 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.

10.8.2 Test sample

A total of two modules, or two receivers and two mirrors are required for humidity freeze test in accordance with the temperature/humidity profile shown in Figure 9.

If a full-size sample is too large to fit into the environmental chamber, or it is too expensive to use, a smaller representative sample may be specially designed and manufactured for this test. The representative sample shall be carefully designed so that it can reveal similar failure mechanisms as the full-size one, and the fabrication process of the representative sample shall be as identical as possible to the process of the full-size ones.

NOTE The possible failure mechanisms for humidity freeze test and special considerations for design and fabrication of representative samples are the combination of those for temperature cycling test 10.6 and damp heat test 10.7.

10.8.3 Procedure

At the end of the test, within 2 h to 4 h of removal from the environmental chamber, test samples shall be subjected to the dry insulation test 10.4 and wet insulation test 10.5. Visual inspection 10.1 shall also be performed, see Table 4.

Table 4 – Humidity freeze test options for sequence B

Option	Target sample temperature °C	Humidity %	Total cycles	Applied current
HFC-1	85	85	20	None
HFC-2	65	85	40	None

10.8.4 Requirements

a) No evidence of major visual defects, as defined in 10.1.2.

b) Insulation resistance shall meet the same requirements as defined in 10.4.

c) Wet insulation resistance shall meet the same requirements as defined in 10.5.

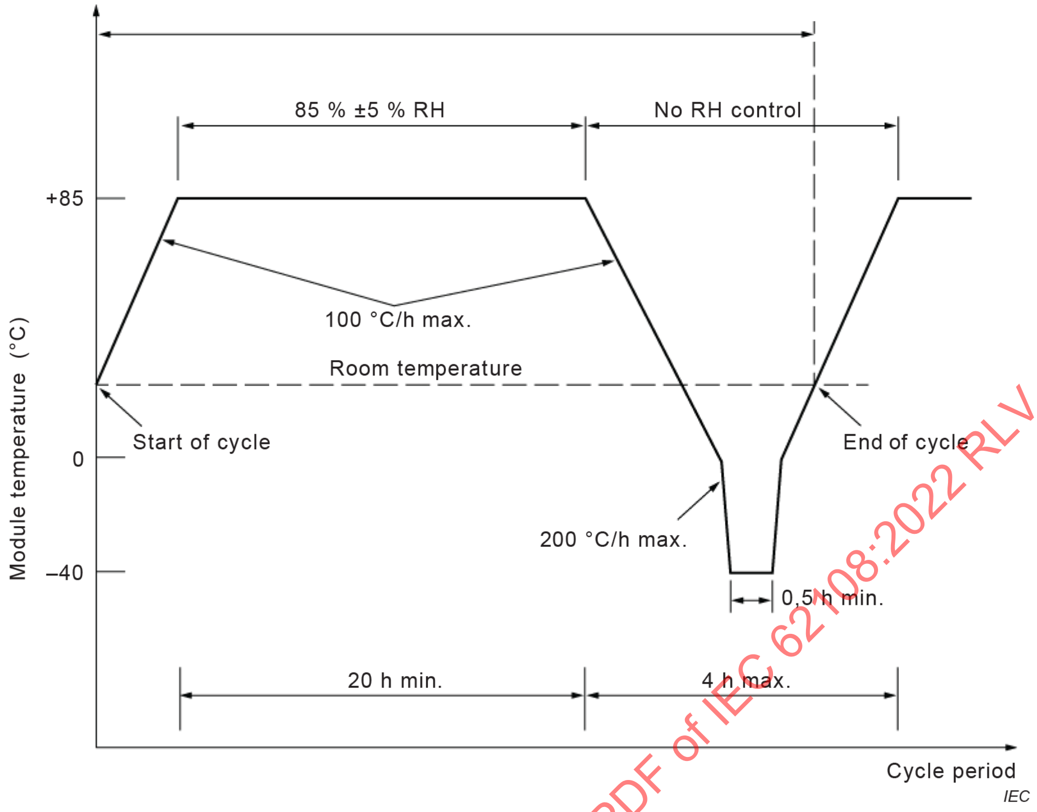


Figure 9 – Profile of humidity-freeze test conditions

10.9 Hail impact test

10.9.1 Purpose

The purpose of the hail impact test is to determine whether the module or assembly, particularly the concentrator lens and mirrors, or any other parts exposed to possible hail impact, can survive a hailstorm.

If the system is designed for a specific area where a hailstorm is very unlikely, this test could be omitted. This fact shall be emphasized on the test report and the product certificate.

10.9.2 Apparatus

a) Moulds of suitable material for casting spherical ice balls of the required diameter. The standard diameter is 25,4 mm with a tolerance of ± 5 %.

b) A freezer, controlled at –10 °C ± 5 °C.

c) A storage container for storing the ice balls at a temperature of –4 °C ± 2 °C.

d) A launcher capable of propelling an ice ball at a speed of 22,4 m/s with a tolerance of ± 5 %, so as to hit the sample within the specified impact location. The path of the ice ball from the launcher to the sample may be horizontal, vertical, or at any other angle, as long as the test requirements are met.

e) A rigid mount for supporting the test sample by the method prescribed by the manufacturer.

f) A balance for determining the mass of an ice ball. The required mass of the ball is 7,9 g with a tolerance of ± 5 %.

g) An instrument for measuring the speed of the ice ball to an accuracy of ± 2 %. The speed sensor shall be no more than 1 m from the impact point.

10.9.3 Procedure

a) Use the mould and the freezer to make sufficient ice balls of the required size for the test, including some extra balls for preliminary adjustment of the launcher.

b) Install the sample according to manufacturer's instruction, with the impact surface normal to the path of the ice ball.

c) Mark at least ten different target impact locations on receiver, module, or optics by using the following selection guidelines:

   – Areas that may possibly be hit by a hailstone falling from 45° around the vertical line when the system is under normal operation positions or on the stow position.

   – Corners that are no more than 25 mm from edges.

   – Edges that are no more than 12 mm from the side.

   – Points that are no more than 12 mm from the fixing point to supporting structures.

   – Points that are farthest from the fixing point to supporting structures.

   – Any points that may be vulnerable to hail impact.

d) Examine size and mass of ice balls to make sure the requirements in 10.9.2 are met, and the ice balls shall have no cracks visible to the unaided eye.

e) Place the ice balls in the storage container and leave them there for at least 1 h before use.

f) Ensure that all surfaces of the launcher likely to be in contact with the ice balls are near room temperature.

g) The time between the removal of the ice ball from the container and impact on the sample shall be less than 60 s.

h) Fire a number of trial shots at a simulated target and adjust the launcher until the hitting position and speed of the ice ball meet the requirement.

i) Fire the first actual testing shots on the sample at the locations marked in step c).

j) Inspect the module in the impact area for signs of damage and make a note of any visual effects of the shot.

k) Repeat steps i) and j) for all other desired locations.

10.9.4 Requirements

The requirement for hail impact is very site dependent, therefore, there is no specific pass/fail criteria for it. The results, however, shall be recorded and reported in details, such as:

a) The sample shall be inspected after each impact to determine if any obvious damage has occurred. All damages and major visual defects shall be documented.

b) Any cracks or holes on the sample that are visible to the unaided eye, or any pieces larger than 2 mm^2 that have broken off and flown out, shall be recorded and included in the report.

10.10 Dust and water ingress protection test

10.10.1 Purpose

The degree of protection (IP-code) defines the extent to which an enclosure provides protection against the entry of dust, as proved by standard testing methods. This testing only applies to modules which have package design that is deemed an enclosure. To be considered an enclosure the module shall contain an interior space that contains gas or liquid.

This requirement is for modules only; assemblies are exempt from this requirement.

One full-size module is required for dust and water ingress protection test.

10.10.2 Procedure

The module shall be subjected to IP testing after the humidity freeze sequence with provisions provided by the manufacturer to close ports or openings into the enclosure that are included in the existing module design for attaching the module to other systems (air drying for example).

10.10.3 Requirements

a) The module shall meet a minimum of IP65. The IP65 test is conducted in conformance with IEC 60529 test. It can be conducted by installing it in the lab, or through on-site witness.

b) No evidence of major visual defects, as defined in 10.1.2.

c) Insulation resistance shall meet the same requirements as defined in 10.4.

d) 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).

10.11 Bypass/blocking diode thermal test

10.11.1 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 within the receiver being tested. This procedure verifies that the bypass diode can safely operate at elevated temperatures and throughput current levels. The non-intrusive method requires that the bypass diode's case be accessible for thermocouple attachment by the test personnel. The intrusive method is required for modules that have bypass diodes that are inaccessible without special invasive procedures. The intrusive method requires that the manufacturer provide a specially built module that has the thermocouple already installed. If invasive measures by the lab are required, the test personnel will consult with the manufacturer about the method and risks associated prior to acting.

If the bypass diodes are not accessible in the module type under test, a special sample can be prepared for this test. This sample shall be fabricated to provide as close to the same thermal environment for the diode as a standard production module under test and does not have to be an active CPV module, but shall have access to measure the temperature of the diode(s) during the test. The test shall then proceed as normal. This special test sample shall be used only for the bypass diode thermal test not for the other tests in the sequence nor the final measurement.

10.11.2 Test sample

Three bypass diodes are to be selected for testing. These bypass diodes are to be selected by the test laboratory and should be representative bypass diodes which are subject to the most stress in the design. The test lab shall indicate in the test report which three bypass diodes were selected and why they were selected.

a) Select diode locations representative of the thermal profile of the receiver, in the order below:

   1) Center.

   2) High temperature location (if applicable) – such as a junction box or terminal block.

   3) Corner.

10.11.3 Apparatus

Environmental chamber capable of heating the test sample to 75 °C ± 5 °C, digital thermometer, type K thermocouple wire, thermal adhesive, a power supply capable of producing 1,25 times I_{sc} of the receiver, and a DMM or current shunt capable of measuring up to 125 % of the receiver's short circuit current at standard reporting conditions, digital timer.

10.11.4 Procedure

a) Electrically short any blocking diodes incorporated in the sample.

b) Lab-prepared receivers: Mount a functionally checked type K thermocouple to each diode's case using thermally conductive electrically isolating adhesive. Feed the thermocouple wire(s) through the electrical leads junction box penetration and reseal the junction box per manufacturer's instructions, if applicable.

c) Manufacturer-prepared receivers: Functionally check the thermocouple(s) previously attached to the diode(s) by the manufacturer.

d) Mount the receiver inside the environmental chamber. Feed the electrical leads through one of the chamber's access ports. Feed the thermocouple wire through the same access port.

e) Attach a thermocouple to the front face of the receiver. This temperature sensor will be used to monitor the receiver's temperature of 75 °C ± 5 °C during the duration of the tests.

f) Connect the electrical leads to a power supply with the power supply's positive lead connected to the receiver's negative terminal and power supply's negative lead to the positive terminal of the receiver.

g) Connect the thermocouple(s) to a digital thermometer.

h) Heat the receiver to 75 °C ± 5 °C. Apply a current to the receiver equal to I_{sc} with a tolerance of ± 2 %. After 1 h, measure the temperature of each bypass/blocking diode.

i) Calculate the junction temperature using information provided by the diode manufacturer, along with the measured case temperature or temperature of the hottest surface contacting the diode.

j) Increase the applied current to 1,25 times I_{sc} while maintaining the receiver temperature at 75 °C ± 5 °C. Maintain the current flow for 1 additional hour.

k) Verify that the diode is still operational.

10.11.5 Requirements

a) The calculated diode junction temperature shall not exceed the diode manufacturer's maximum temperature rating.

b) No evidence of major visual defects, as defined in 10.1.3.

c) Insulation resistance shall meet the same requirements as defined in 10.4.

d) The diodes shall still function as diodes after the diode thermal test. The test report shall include a description of the test used to make this determination and the results of that test.

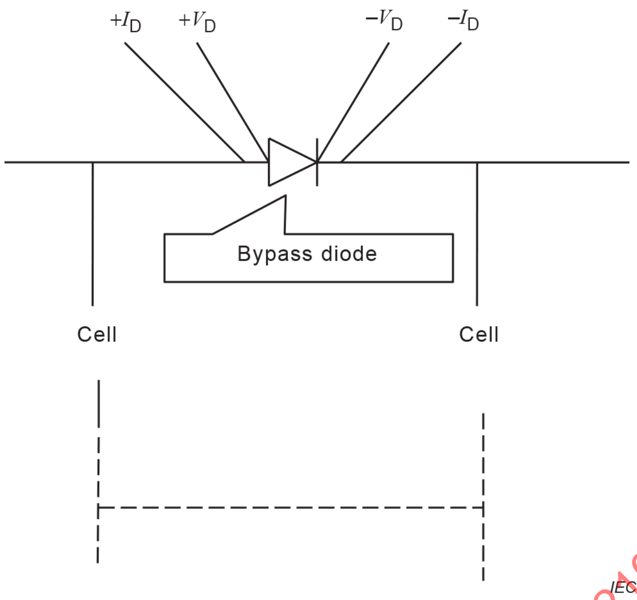
10.11.6 Procedure 2 – Alternate method

a) Electrically short any blocking diodes incorporated in the module.

b) Determine the rated STC short circuit current of the module from its label or instruction sheet.

c) Connect the lead wires for V_D and I_D on both diode terminals as shown in Figure 10.

d) It is recommended that the connections be made by the module manufacturer.



The lead wire should not cause heat dissipation from the terminal box.

Figure 10 – Bypass diode thermal test

e) Put the module into the chamber set up to 30 °C ± 2 °C until the module temperature reaches the saturation.

f) Apply the pulsed current (pulse width 1 ms) equal to the STC short circuit current of the module, measure the forward voltage V_{D1} of diode.

g) Using the same procedure, measure V_{D2} at 50 °C ± 2 °C.

h) Using the same procedure, measure V_{D3} at 70 °C ± 2 °C.

i) Using the same procedure, measure V_{D4} at 90 °C ± 2 °C.

j) Then, obtain the V_D versus T_j characteristic by a least-squares-fit curve from V_{D1}, V_{D2}, V_{D3} and V_{D4}.

   This V_D versus T_j characteristic may be provided by the diode manufacturer with a manufacturer's certification.

k) Heat the module to 75 °C ± 5 °C. Apply a current to the module equal to the short circuit current of the module as measured at STC ± 2 %. After 1 h measure the forward voltage of the each diodes.

l) Using the V_D versus T_j characteristic obtained in item j), obtain T_j of the diode.

m) Increase the applied current to 1,25 times the short-circuit current of the module as measured at STC while maintaining the module temperature at 75 °C ± 5 °C.

n) Maintain the current flow for 1 h.

o) Verify that the diode is still operational after completing this test.

10.12 Robustness of terminations test

10.12.1 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.

10.12.2 Procedure

Connectors have to comply with IEC 62852. If other connectors than above mentioned connectors are meant than refer to relevant IEC standard, e.g. IEC 61210. The test procedure is according to IEC 61215.

10.12.3 Requirements

a) No evidence of major visual defects, as defined in 10.1.2.

b) Insulation resistance shall meet the same requirements as defined in 10.4.

c) Wet insulation resistance shall meet the same requirements as defined in 10.5.

10.13 Mechanical load test

10.13.1 Purpose

The purpose of 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 aligned to match the maximum specification of the manufacturer. If the design is entirely unsuitable for snow areas, the snow load test needs not be carried out and minimum testing shall correspond to wind loading. 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, receivers, mirrors, 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, shall be analyzed by suitable qualified engineers to verify that the design meets the local code requirements of the installation site.

Wind load minimums shall apply (see Table 5).

Table 5 – Minimum wind loads

Test load Pa	Wind load capacity m/s	Snow/ice load capacity	Tracker requirement/restriction
800	40 in a wind stow position only	None	Restricted to use on trackers with automatic and failsafe wind stow of 24 m/s or less
1 600	40	None	None
2 400	40	Light to medium	None
5 400	40	Heavy	None

If the module under test is restricted in application to trackers which shall horizontally stow at wind speeds of 24 m/s or less, the module shall be tested to a minimum of 800 Pa. 800 Pa corresponds to potential forces generated on the modules by 40 m/s winds when the tracker is in the horizontal position. Trackers which stow at lower wind speeds will not lessen this requirement as the worst case force occurs in the stow position due to the higher wind speeds.

If the module under test can be mounted on any tracker (no stow function possible), the module shall be tested to a minimum of 1 600 Pa, corresponding to potential forces generated one the module by 40 m/s winds in any tracking position.

If the module is indicated for regions where snow and ice occur it is recommended that minimum test requirement should be 2 400 Pa.

10.13.2 Procedure

a) Make a rigid test base structure. If the load is provided by weight, the sample shall be mounted horizontally. The test base shall be capable of withstanding loads applied to both the front and back of the test sample and shall enable the test sample to deflect freely during the test.

b) Mount the test sample on the rigid structure using the method prescribed by the manufacturer. If there are different possibilities, use the worst case, such as the largest distance between the fixing points. The mounting method and photos shall be included in the report.

c) Connect the test sample to the monitoring instrument so that the electrical continuity of the internal circuit can be monitored continuously during the test.

d) Obtain suitable weights or pressure means that enable the load to be applied in a gradual, uniform manner.

e) On the front surface, gradually apply a uniform load up to the maximum indicated by the test. This load may be applied pneumatically or by means of weights covering the entire surface. In the later case, the test sample shall be mounted horizontally. Maintain this load for 1 h.

f) Repeat step e) on the back surface of the test sample.

g) Repeat steps e) and f) for a total of three cycles.

10.13.3 Requirements

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

b) No evidence of major visual defects, as defined in 10.1.3.

c) Insulation resistance shall meet the same requirements as defined in 10.4.

10.14 Off-axis beam damage test

10.14.1 General

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

10.14.2 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.

10.14.3 Special case

Concentrator systems that use a fully redundant and failsafe protection system to manage misalignment issues may be exempt from the requirements of this clause. 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 shall agree with the manufacturer on a procedure to conduct verifications on these redundant and failsafe protection systems. Under all possible vulnerable conditions, the protection system shall respond to the misalignment or malfunction according to the manufacturer’s design; otherwise, a regular off-axis beam damage test shall be conducted.

10.14.4 Procedure

a) The module or assembly design and the receiver itself shall be examined first to determine whether any materials might be damaged by high temperatures or intense solar radiation, and whether these materials are sufficiently protected from exposure.

b) If such insufficiently protected materials are identified, the module or assembly alignment will be offset so that light is focused on such a suspect location.

c) The module or assembly will then track the sun in this position for at least 3 h, with DNI greater than 800 W/m^2.

d) Repeat for step c) for any other suspect locations.

e) Observe the test sample during each exposure and inspect for evidence of damage after each exposure.

f) If no specific locations are identified, a simple “walk-off” test shall be performed:

   – The module shall be aligned toward the sun.

   – Tracking will be stopped.

   – Allow the sun to “walk off” to an angle of 45° relative to the module or assembly (about 3 h).

   – Throughout this test, DNI shall be at least 800 W/m^2.

10.14.5 Requirements

a) No evidence of major visual defects, as defined in 10.1.3. 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 10.4.

10.15 Outdoor exposure test

10.15.1 Purpose

The purpose of the outdoor exposure test is to make a preliminary assessment of the ability of the module or assembly to withstand exposure to outdoor conditions and to reveal any synergistic degradation effects that may not be detected by laboratory tests. If the manufacturer specifies a stabilization period after which the system reaches the steady state performance, the system shall be operated for the specified amount of time prior to the initial electrical performance test as defined in 10.2.This test requires one full-size module or assembly. It can be conducted either by installing it in an exterior area of the test lab, or through on-site witness.

10.15.2 Procedure

a) A full-size module or assembly shall be installed outdoor as recommended by the manufacturer.

b) A direct-normal irradiation monitor and a global total irradiation monitor shall be installed co-planar with the module or assembly.

c) Any hot-spot protective devices recommended by the manufacturer shall be installed before the module or assembly is mounted.

d) If the system requires active cooling, the cooling system shall be operated during the test.

e) The module or assembly shall be exposed outdoors with tracking and meet the following requirements:
   – Cumulative DNI of at least 450 kWh/m^2 while the module or assembly is connected to a maximum power point tracking load.
   – Followed by cumulative DNI of at least 50 kWh/m^2 while the module or assembly is operating in open circuit condition; during or after that time of exposure at least 1 h of continuous DNI greater than 900 W/m^2 is required while in open circuit condition.
   – When the DNI is less than 600 W/m^2, the DNI radiation shall not be counted towards the total exposure.
   – UV dosage is recommended to be recorded and included in the report;.

10.15.3 Requirements

a) No evidence of major visual defects, as defined in 10.1.2.
b) Power degradation shall not exceed 5 % for solar simulator I-V measurement, and 7 % for natural sunlight I-V measurement.
c) Insulation resistance shall meet the same requirements as defined in 10.4.

10.16 Hot-spot endurance test

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.

Currently, a major revision for the hot-spot endurance test on flat-plate PV modules is under consideration. For CPVs, perform this test according to IEC 61215-2:2021, 10.9 Hot-spot endurance test, and its amendments, with one exception: add an extra 3 % for the solar simulator I-V measurement, and 5 % for the natural sunlight I-V measurement, to the maximum power degradation requirement, to count for an extra uncertainty on the CPV I-V measurement.

Annex A
(informative)

Summary of test conditions and requirements

This annex is for reference only. Requirements and values in the main body of this document supersede requirements and values included in this summary, see Table A.1.

Table A.1 – Summary of test conditions and requirements

Seq. No.	Test title	Sample m – module r – receiver mir – mirror	Test condition	Requirement
10.1	Visual inspection	All	Visual inspection	No major visual defects (MVD) defined in 10.1.2.
10.2	Electrical performance	All	Outdoor side-by-side I-V with DNI > 700 W/m^2, wind speed < 6 m/s, clear sky. Dark I-V as a diagnostic means to measure resistance, at least 10 points from 0,9 to 1,6 I_{sc}	Power degradation < 8 % for solar simulator measurement, and < 13 % for natural sunlight measurement, (except for 10.15 and 10.16). If dark I-V shows 10 % resistance increase, side-by-side I-V shall be performed.
10.3	Ground path continuity	All	Measure resistance between grounding point and other conductive parts with 2 × I_{sc} current passing through.	Resistance < 0,1 Ω No damage at grounding path bonds
10.4	Electrical insulation test	All	At ambient temperature, 25 °C ± 10 °C and RH < 75 %, apply 2 × V_{sys} + 1 000 V for 2 min (hi-pot); Measure R at 500 V.	No dielectric breakdown or surface tracking during high voltage; R > 50 MΩm^2, if area ≤ 0,1 m^2, R > 5 MΩm^2, if area > 0,1 m^2, total overall R > 1 MΩ if encapsulated in earthed metal, total overall R > 10 MΩ if double insulated
10.5	Wet insulation test	All	Measure R at 500 V when the sample is wetted by surfactant solution with resistivity 1 500 Ωcm to 3 500 Ωcm.	Same as 10.4

Seq. No.	Test title	Sample m – module r – receiver mir – mirror	Test condition	Requirement
10.6	Thermal cycling test	2r	All TC test options are from –40 °C to T_{max}. **Options for T_{max} on receivers in sequence A:** 1 000 cycles if T_{max} = 85 °C, 500 cycles if T_{max} = 110 °C, 2 000 cycles if T_{max} = 65 °C, Apply 1,25 × I_{sc} when T > 25 °C until the end of the high dwell time **Options for T_{max} as pre-conditioning for HF on modules or assemblies in sequence B:**	No MVD. Meet insulation test 10.4 and 10.5.
		2r as pre-conditioning for HF	200 cycles if T_{max} = 85 °C, 100 cycles if T_{max} = 110 °C, 400 cycles if T_{max} = 65 °C,	
10.7	Damp-heat test	2 m or 2r/2mir	1 000 h at 85 °C and 85 % RH; Or 2 000 h at 65 °C and 85 % RH.	No MVD. Meet insulation test 10.4 and wet insulation test 10.5 in 2 h to 4 h after removal from the chamber.
10.8	Humidity freeze test	2 m or 2r/2mir	T_{max} and 85 % RH for 20 h followed by 4 h cool down to –40 °C; 20 cycles if T_{max} is 85 °C; 40 cycles if T_{max} is 65 °C.	No MVD. Meet insulation test 10.4 and wet insulation test 10.5 in 2 h to 4 h after removal from the chamber.
10.9	Hail impact test	1 m or 1r/1mir	At least 10 shots of 25,4 mm diameter ice ball at 22,4 m/s on areas where an impact by hailstone falling from 45° around the vertical line is possible.	Report all results, no pass/fail criteria.
10.10	Dust and water ingress protection test	2 m	Modules which have package design that is deemed an enclosure shall be subjected to IP testing according to IEC 60529	No MVD. Meet insulation test 10.4. No significant water remains inside (the depth of the remaining water shall not reach any electrically active parts in any possible orientation). The module shall meet a minimum of IP65.
10.11	Bypass/blocking diode thermal test	1 m or 1r	At 75 °C chamber temperature, apply I_{sc} through the receiver for 1 h, then measure bypass/blocking diode temperature. Apply 1,25 × I_{sc} for additional 1 h. Verify diode is functional.	When I_{sc} applied: Diode junction temperature not to exceed rated maximum temperature, No MVD. Meet insulation test 10.4. After 1,25 × I_{sc} applied: Diode is still functioning.

Seq. No.	Test title	Sample m – module r – receiver mir – mirror	Test condition	Requirement
10.12	Robustness of terminations test	1 m or 1r/1mir	20 N tensile and 10 cycles bending	No MVD. Meet insulation test 10.4 and wet insulation test 10.5.
10.13	Mechanical load test	1 m or 1r/1mir	2 400 Pa on front and back, 1 h each, total of 3 cycles. Other loads may be used.	No MVD. Meet insulation test 10.4. No intermittent open-circuit.
10.14	Off-axis beam damage test	1 m or 1r/1mir	Aim the light on suspect locations for at least 3 h when DNI > 800 W/m²; or walk-off for 3 h.	No MVD, especially, no melting, smoking, charring, deformation, or burning. Meet insulation test 10.4.
10.15	Outdoor exposure test	1m or 1r/1mir Full size	Expose to DNI accumulation of: – 450 kWh/m² at Pm – followed by 50 kWh/m² at V_{oc} with at least 1 h of DNI > 800 W/m². DNI < 600 W/m² should not be counted	No MVD. Power degradation shall be less than 5 %. Meet insulation test 10.4.
10.16	Hot-spot endurance test	1m or 1r	Refer to IEC 61215-2:2021, 10.9.	Add 3 % (simulator) or 5 % (sunlight) to flat-plate module requirement for maximum power degradation to count for measurement uncertainty.

Annex B
(normative)

Retesting guideline

B.1 Product or process modifications requiring limited retesting to maintain certification

This annex sets forth a uniform approach to maintain the certification of products that have, or will, undergo modification from the articles originally certified. It shall not be used as a guideline to certify new product submittals.

Changes in design, materials, components and manufacturing process can impact the performance of the modified CPV module or assembly. The recommended test sequences given below have been selected to identify adverse changes to modified cell packages within CPV modules or assemblies.

Those CPV modules or assemblies meeting the requirements of IEC 62108 after retesting are considered to be compliant and will be issued as an amended Conformity Assessment Certificate and an Amended Technical Report Form.

The annex is organized by component modification headings. Following this are the recommended retesting requirements with parenthetical reference to the specific relevant clauses of this document. The changes shall be assessed relative to the design that was previously certified.

For the modifications listed below the testing lab shall use the tests in IEC 62108 as a guideline.

B.2 Modifications of CPV cell technology

For modifications such as:

- Metallization materials and/or process
- Type of diffusion process
- Anti-reflective coating material
- Semiconductor layer materials and/or process
- Order of cell processing if the change involves the metallization system
- Change of manufacturing site of the solar cells not under the same quality assurance system
- Use of cells from a different manufacturer
- Major change in cell thickness greater than 25 % change in total cell thickness
- Major increase in cell area (greater than 25 %), and
- Reduction in output power per cell (greater than 10 %)

Repeat**:**

- Thermal cycling test (10.6, sequence A)
- Damp heat test (10.7)
- Hot-spot endurance test (10.16), if applicable
- Outdoor exposure test 10.15); change 900 kWh/m^2 in 10.15.2.e) to 500 kWh/m^2

B.3 Modifications in optical encapsulation on the cell (Includes optical coupling between the cell and a glass secondary optical element bonded to the cell)

For modifications such as:

- Different encapsulation or optical coupling material
- Different additives or formulation of an encapsulation or optical coupling material, and
- Different encapsulation or optical coupling application process (e.g. curing temperature, rate, or time)

Repeat:

- Thermal cycling test (10.6, sequence A)
- Humidity freeze test (10.8)
- Damp heat test (10.7)
- Hot-spot endurance test (10.16) if applicable and if material composition changes
- Outdoor exposure test (10.15)

B.4 Modification in cell encapsulation outside of intended light path

For modifications such as:

- Different encapsulation material
- Different additives in encapsulation material, and
- Different encapsulation process (e.g. curing rate)

Repeat:

- Thermal cycling test (10.6, sequence A)
- Humidity freeze test (10.8)
- Damp heat test (10.7)
- Hot-spot endurance test (10.16) if applicable and material composition changes
- Outdoor exposure test (10.15)
- Bypass diode thermal test (10.11) if diode is located in encapsulant
- Off-axis beam damage test (10.14)

B.5 Modification of cell package substrate used for heat transfer

For modifications such as:

- Different polymeric materials used in bond to heat sink
- Change in substrate heat spreader material
- Reduction in heat spreader area, and
- Different method of substrate attachment

Repeat:

- Thermal cycling (10.6, sequence A)
- Humidity freeze (10.8)
- Damp heat (10.7) for any change, addition, or removal of a polymeric material
- Hot-spot endurance test (10.16) if applicable and material composition changes
- Outdoor exposure test (10.15)

B.6 Accessible optics (primary or secondary)

For modifications such as:

- optic material or design
- thickness, and
- surface treatment

Repeat:

- Thermal cycling/Humidity freeze (10.8)
- Damp heat (10.7)
- Hail impact (10.9)
- Mechanical load (10.13)
- Off-axis test (10.14), if susceptibility to beam damage is increased
- Dust and water ingress protection test (10.10), if the optic serves as part of the weather seal
- Thermal cycling (10.6), if the optics are part of the receiver assembly
- Outdoor exposure (10.16), if the optical material thickness is increased by more than 20 %

B.7 Inaccessible optics (secondary)

For modifications such as:

- optic material or design
- thickness, and
- surface treatment

Repeat:

- Damp heat (10.7)
- Outdoor exposure (10.15)
- Off-axis beam damage test (10.14), if increased beam damage
- Thermal cycling (10.6), if the optics are part of the receiver assembly
- Thermal cycling/humidity freeze (10.8), if an optical element or structural adhesive changes

B.8 Frame and/or mounting structure

For modifications such as:

- cross-section of frame
- different framing material, and
- different mounting technique

Repeat:

- Mechanical load test (10.13)
- Ground continuity (10.3), for change in material or grounding means of metallic designs
- Outdoor exposure (10.15), for polymeric materials
- Off-axis beam damage test (10.14), for polymeric materials

B.9 Enclosure

For modifications such as:

- different enclosure material, and
- different enclosure geometries, including > 5 % change in any dimension

Repeat:

- Damp heat (10.7)
- Mechanical load test (10.13)
- Humidity freeze (10.8)
- Hail impact test
- Ground continuity (10.3), for change in material or grounding means of metallic designs
- Outdoor exposure (10.15), for polymeric materials
- Off-axis beam damage test (10.14), for polymeric materials

B.10 Wiring compartment/junction box

For modifications such as:

- different compartment material, and
- different compartment design

Repeat:

- Damp heat (10.7)
- Thermal cycling/humidity freeze (10.8)
- Dust and water ingress protection test (10.10)
- Robustness of terminations (10.12)
- Bypass diode thermal test (10.11), if bypass diode is located in wiring compartment
- Outdoor exposure test (10.15), if exposed to direct UV
- Off-axis beam damage test (10.14), if exposed to concentrated sunlight

B.11 Interconnection terminals

For modifications such as:

- different material
- different design
- different potting material, and
- different method of attachment

Repeat:

- Thermal cycling test (receiver) (10.6)
- Humidity freeze (10.8)
- Off-axis beam damage test (10.14)
- Bypass diode thermal test
- Damp heat (10.7) – For changes in materials
- Hot-spot endurance test (10.16) – For changes in bonding technique or bonding material. (Not required if a bypass diode is employed for each cell)

B.12 Interconnection materials or technique (to cells and between receivers)

For modifications such as:

- different manufacturer
- different interconnect material
- different thickness/diameter of interconnect material, more than 10 % change
- different bonding technique
- different number of solder bonds, and
- different solder material or flux

Repeat:

- Thermal cycling (10.6)
- Humidity freeze (10.8)
- Off-axis beam damage test (10.14)
- Damp heat (10.7) for changes in materials
- Hot-spot endurance (10.16) for changes in bonding technique or solder material

B.13 Change in electrical circuit design in an identical package

For modifications such as:

- Modifications to the interconnection circuitry (for example more cells per bypass diode or re-routing of output leads), and
- Reconfiguration of voltage (i.e., 12 to 24)

Repeat:

- Hot-spot endurance test (10.16)
- Bypass diode thermal test (10.11), if current in any diode increases by 5 %
- Thermal cycling test (10.6) if the current in any cell increases by 5 %

B.14 Output power

For modifications such as:

- more than 10 % increase in current or power

Repeat:

- Hot-spot endurance (10.16)
- Thermal cycling (receiver) (10.6)
- Bypass diode thermal (10.11)

B.15 Thermal energy transfer means

For modifications such as:

- different heat sink gel
- different heat spreader material
- reduction in heat spreader area by > 10 %
- removal or addition of thermally or electrically insulating layers
- different thermally or electrically insulating layer material, and
- different method of attachment

Repeat:

- Outdoor exposure test (10.15)
- Off-axis beam damage test
- Thermal cycling (receiver) (10.6), for any change, addition, or removal of a polymeric material
- Damp heat (10.7) and humidity freeze (10.8) for any change, addition, or removal of a polymeric material
- Hot-spot endurance (10.16), except if the only change is a mechanical method of attachment

B.16 Adhesives

For modifications such as:

- usage of new or different adhesive which is not covered by another category

Repeat:

- Damp heat (10.7)
- Humidity freeze (10.8, including pre-thermal cycling)
- Outdoor exposure (10.15)
- Mechanical load sequence D (10.13), if structural adhesive
- Dust and water ingress protection test (10.10), if the adhesive provides a moisture seal

NOTE The default position is that a different supplier means different material, for any material. The burden of proof of equivalency is up to the manufacturer and supplier of material, through acceptable results of test and evaluation.

SOMMAIRE

COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

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MODULES ET ENSEMBLES PHOTOVOLTAÏQUES À CONCENTRATION – QUALIFICATION DE LA CONCEPTION ET HOMOLOGATION

AVANT-PROPOS

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L'IEC 62108 a été établie par le comité d'études 82 de l'IEC: Systèmes de conversion photovoltaïque de l'énergie solaire. Il s'agit d'une Norme internationale.

Cette troisième édition annule et remplace la deuxième édition parue en 2016. Cette édition constitue une révision technique.

Cette édition inclut les modifications techniques majeures suivantes par rapport à l'édition précédente:

a) Modifications de la procédure de l'essai de cyclage thermique pour le module de refroidissement actif.
b) Mesurage I-V sous simulateur solaire.

Le texte de cette Norme internationale est issu des documents suivants:

Projet	Rapport de vote
82/2024/FDIS	82/2046/RVD

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à son approbation.

La langue employée pour l'élaboration de cette Norme internationale est l'anglais.

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- amendé.

MODULES ET ENSEMBLES PHOTOVOLTAÏQUES À CONCENTRATION – QUALIFICATION DE LA CONCEPTION ET HOMOLOGATION

1 Domaine d'application

Le présent document spécifie les exigences minimales relatives à la qualification de la conception et l'homologation des modules et ensembles photovoltaïques à concentration (CPV - *concentrator photovoltaic*) pour une utilisation de longue durée dans les climats généraux d'air libre, comme cela est défini dans l'IEC 60721-2-1. La séquence d'essais est partiellement issue de celle spécifiée dans l'IEC 61215-1 pour la qualification de la conception et l'homologation des modules PV au silicium cristallin pour application terrestre à plaque plane. Certaines modifications ont cependant été effectuées pour tenir compte des particularités des récepteurs et modules CPV, en particulier en ce qui concerne la séparation des essais sur site et en laboratoire, les effets de la répartition, de la densité de courant élevée et des variations rapides de température, qui ont entraîné la formulation de certaines nouvelles procédures d'essai ou exigences.

Le présent document d'essai a pour objet de déterminer les caractéristiques électriques, mécaniques et thermiques des modules et ensembles CPV et de montrer, autant que possible avec des contraintes de coût et de temps raisonnables, que les modules et ensembles CPV peuvent supporter une exposition prolongée aux climats définis dans le domaine d'application. La durée de vie réelle des modules et ensembles CPV ainsi qualifiés dépend de leur conception, de leur production ainsi que de l'environnement et des conditions dans lesquelles ils fonctionnent.

Le présent document doit être utilisé conjointement avec les lignes directrices de contre-essai décrites à l'Annexe B.

2 Références normatives

Les documents suivants sont cités dans le texte de sorte qu'ils constituent, pour tout ou partie de leur contenu, des exigences du présent document. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

IEC 60529, *Degrés de protection procurés par les enveloppes (Code IP)*

IEC 60664-1:2020, *Coordination de l'isolement des matériels dans les réseaux d'énergie électrique à basse tension – Partie 1: Principes, exigences et essais*

IEC 60721-2-1, *Classification des conditions d'environnement – Partie 2-1: Conditions d'environnement présentes dans la nature – Température et humidité*

IEC 60904-1:2020, *Dispositifs photovoltaïques – Partie 1: Mesurage des caractéristiques courant-tension des dispositifs photovoltaïques*

IEC 60904-1-1:2017, *Dispositifs photovoltaïques – Partie 1-1: Mesurage des caractéristiques courant-tension des dispositifs photovoltaïques (PV) multijonctions*

IEC TS 60904-1-2:2019, *Photovoltaic devices – Part 1-2: Measurement of current-voltage characteristics of bifacial photovoltaic (PV) devices* (disponible en anglais seulement)

IEC 60904-2:2015, *Dispositifs photovoltaïques – Partie 2: Exigences applicables aux dispositifs photovoltaïques de référence*

IEC 60904-3:2019, *Dispositifs photovoltaïques – Partie 3: Principes de mesure des dispositifs solaires photovoltaïques (PV) à usage terrestre incluant les données de l'éclairement énergétique spectral de référence*

IEC 60904-4:2019, *Dispositifs photovoltaïques – Partie 4: Dispositifs photovoltaïques de référence – Procédures pour établir la traçabilité de l'étalonnage*

IEC 60904-5:2011, *Dispositifs photovoltaïques – Partie 5: Détermination de la température de cellule équivalente (ECT) des dispositifs photovoltaïques (PV) par la méthode de la tension en circuit ouvert*

IEC 60904-7:2019, *Dispositifs photovoltaïques – Partie 7: Calcul de la correction de désadaptation des réponses spectrales dans les mesures de dispositifs photovoltaïques*

IEC 60904-8:2014, *Dispositifs photovoltaïques – Partie 8: Mesure de la sensibilité spectrale d'un dispositif photovoltaïque (PV)*

IEC 60904-8-1:2017, *Dispositifs photovoltaïques – Partie 8-1: Mesurage de la sensibilité spectrale des dispositifs photovoltaïques (PV) multijonctions*

IEC 61140:2016, *Protection contre les chocs électriques – Aspects communs aux installations et aux matériels*

IEC 61210:2010, *Dispositifs de connexion – Bornes plates à connexion rapide pour conducteurs électriques en cuivre – Exigences de sécurité*

IEC 61215-1:2021, *Modules photovoltaïques (PV) pour applications terrestres – Qualification de la conception et homologation – Partie 1: Exigences d'essai*

IEC 61215-2:2021, *Modules photovoltaïques (PV) pour applications terrestres – Qualification de la conception et homologation – Partie 2: Procédures d'essai*

IEC TS 61836:2016, *Solar photovoltaic energy systems – Terms, definitions and symbols* (disponible en anglais seulement)

IEC 61853-1:2011, *Essais de performance et caractéristiques assignées d'énergie des modules photovoltaïques (PV) – Partie 1: Mesures de performance en fonction de l'éclairement et de la température, et caractéristiques de puissance*

IEC 61853-2:2016, *Essais de performance et caractéristiques assignées d'énergie des modules photovoltaïques (PV) – Partie 2: Mesurages de réponse spectrale, d'angle d'incidence et de température de fonctionnement des modules*

IEC 61853-3:2018, *Essais de performance et caractéristiques assignées d'énergie des modules photovoltaïques (PV) – Partie 3: Caractéristiques assignées d'énergie des modules PV*

IEC 62670-1, *Concentrateurs photovoltaïques (CPV) – Essai de performances – Partie 1: Conditions normales*

IEC 62670-3:2017 *Concentrateurs photovoltaïques (CPV) – Essai de performances – Partie 3: Mesurages de performances et rapport de puissance*

IEC 62790:2020, *Boîtes de jonction pour modules photovoltaïques – Exigences de sécurité et essais*

IEC 62852:2014, *Connecteurs pour applications en courant continu pour systèmes photovoltaïques – Exigences de sécurité et essais*
IEC 62852:2014/AMD1:2020

3 Termes et définitions

Pour les besoins du présent document, les termes et définitions de l'IEC 60664-1, l'IEC TS 60904-1-2, l'IEC 61140, l'IEC TS 61836, ainsi que les suivants s'appliquent. Voir également le Tableau 1.

L'ISO et l'IEC tiennent à jour des bases de données terminologiques destinées à être utilisées en normalisation, consultables aux adresses suivantes:

- IEC Electropedia: disponible à l'adresse http://www.electropedia.org/
- ISO Online browsing platform: disponible à l'adresse http://www.iso.org/obp

3.1
à concentration
terme associé aux appareils photovoltaïques qui utilisent un ensoleillement intense

3.2
cellule à concentration
appareil photovoltaïque élémentaire qui est utilisé avec un éclairement d'ensoleillement intense

3.3
optique à concentration
appareil optique qui réalise une ou plusieurs des fonctions suivantes à partir de son entrée jusqu'à sa sortie: augmentation de l'intensité lumineuse, filtrage du spectre, modification de la distribution de l'intensité lumineuse, ou changement de direction de la lumière. Il s'agit généralement d'une lentille ou d'un miroir

Note 1 à l'article: Une optique primaire reçoit un ensoleillement non intense directement du soleil. Une optique secondaire reçoit un ensoleillement intense ou modifié provenant d'un autre appareil optique, tel qu'une optique primaire ou une autre optique secondaire.

3.4
récepteur à concentration
groupe constitué d'une ou de plusieurs cellules à concentration et d'optiques secondaires (si elles sont présentes), qui reçoit un ensoleillement intense et comporte des dispositifs pour le transfert d'énergie thermique et électrique

Note 1 à l'article: Un récepteur peut être constitué de plusieurs sous-récepteurs. Le sous-récepteur est une partie physiquement autonome plus petite du récepteur en grandeur réelle.

3.5
module à concentration
groupe constitué de récepteurs, d'optiques et d'autres composants associés, tels que des dispositifs d'interconnexion et de montage, qui reçoit un ensoleillement non intense

Note 1 à l'article: Tous les composants ci-dessus sont généralement préfabriqués en une unité, et le point de focalisation n'est pas ajustable à tout le champ.

Note 2 à l'article: Un module peut être constitué de plusieurs sous-modules. Le sous-module est une partie physiquement autonome plus petite du module en grandeur réelle.

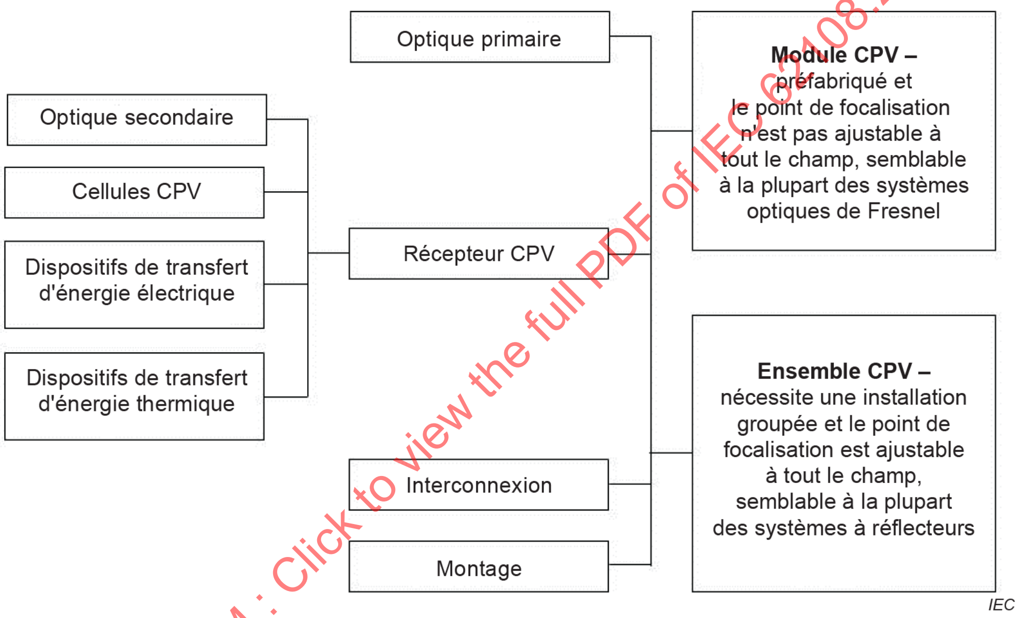
3.6
ensemble à concentration
groupe constitué de récepteurs, d'optiques et d'autres composants associés, tels que des dispositifs d'interconnexion et de montage, qui reçoit un ensoleillement non intense

Note 1 à l'article: Tous les composants ci-dessus sont généralement transportés séparément et nécessitent une installation groupée, et le point de focalisation est ajustable à tout le champ.

Note 2 à l'article: Un ensemble peut être constitué de plusieurs sous-ensembles. Le sous-ensemble est une partie physiquement autonome plus petite de l'ensemble en grandeur réelle.

3.7
unité de commande
matériel non soumis à une contrainte, mais qui est compris dans chaque mesurage afin de favoriser une plus grande confiance dans des mesurages cohérents

Tableau 1 – Termes utilisés pour les CPV



4 Échantillonnage

Les Figure 1 à Figure 5 sont des schémas de cellules, récepteurs, modules et ensembles.

Pour les systèmes ou modules CPV à point de focalisation non ajustable à tout le champ, 7 modules et 2 récepteurs doivent être soumis à tous les essais spécifiés, plus un récepteur pour l'essai thermique de la diode de dérivation/diode antiretour (intrusif ou non intrusif). Pour plus de précisions, se référer à la Figure 6. Pour les systèmes ou ensembles CPV à point de focalisation ajustable à tout le champ, 9 récepteurs (dont des sections de l'optique secondaire, le cas échéant) et 7 sections de l'optique primaire doivent être soumis à tous les essais spécifiés, plus un récepteur pour l'essai thermique de la diode de dérivation/antiretour (intrusif ou non intrusif). Pour plus de précisions, se référer à la Figure 7.

Dans le cas où un module ou ensemble en grandeur réelle est trop volumineux pour être inséré dans un équipement d'essai disponible, par exemple, des chambres climatiques, ou si un module ou ensemble en grandeur réelle est trop coûteux (par exemple, pour un système à concentration parabolique à réflecteurs de 20 kW, 9 échantillons de récepteurs prennent en compte des cellules PV de 180 kW), un échantillon représentatif plus petit peut être utilisé. Cependant, même si des échantillons représentatifs sont utilisés pour l'autre essai, un module ou ensemble en grandeur réelle doit être installé et soumis aux essais pour une exposition en site naturel. Ceci peut être effectué soit dans le laboratoire d'essai, soit par des personnes présentes sur le site.

Les échantillons représentatifs doivent comprendre tous les composants, à l'exception de certaines parties répétées. Si possible, les échantillons représentatifs doivent utiliser des sous-récepteurs, des sous-modules ou des sous-ensembles. Au cours de la conception et de la fabrication des échantillons représentatifs, une attention particulière doit être accordée pour veiller à atteindre la similarité maximale avec le composant en grandeur réelle, concernant toutes les caractéristiques électriques, mécaniques et thermiques liées à la qualité et à la fiabilité.

En particulier, la chaîne de cellules dans les échantillons représentatifs doit être suffisamment longue pour comprendre au moins deux diodes de dérivation, mais en aucun cas moins de dix cellules. Les enrobages, les interconnexions, les sorties et les distances d'isolement autour de tous les bords doivent être les mêmes que sur les produits en grandeur réelle. Les autres composants représentatifs, y compris les joints de la lentille/du boîtier, les joints du récepteur/du boîtier et le fond de capot/la lentille doivent aussi être inclus et soumis aux essais.

Il convient de prélever les échantillons d'essai au hasard parmi un ou plusieurs lots de production. Lorsque les échantillons à soumettre aux essais sont des prototypes d'une nouvelle conception, mais non issus d'une production, ou que les échantillons représentatifs sont utilisés, il convient de mentionner ces faits dans le rapport d'essai (voir l'Article 8).

Les échantillons d'essai doivent avoir été fabriqués à partir de matériaux et composants spécifiés conformément aux schémas et procédures de fabrication correspondants, et il convient qu'ils aient été soumis aux procédures normales d'examen, de contrôle qualité et d'acceptation de la production du fabricant. Ils doivent être dans leur intégrité jusqu'au moindre détail, et il convient qu'ils soient accompagnés des manuels de manipulation, de montage, de raccordement et de fonctionnement fournis par le fabricant. Les échantillons ne doivent pas être soumis à d'autres procédures spéciales qui ne font pas partie de la production normalisée.

Dans le cas où l'essai d'intrusion thermique de la diode de dérivation/antiretour doit être réalisé, un récepteur supplémentaire fabriqué spécialement est exigé avec des conducteurs électriques et des fils de détecteur thermique sortant de telle sorte que chaque diode individuelle puisse être accessible séparément.

5 Marquage

Chaque section du récepteur ou du module doit porter clairement et de manière indélébile les indications suivantes:

– le nom, le monogramme ou le symbole du fabricant;
– le type ou le numéro du modèle;
– le numéro de série;
– la polarité des bornes de sortie ou des conducteurs (un code de couleur est admis);
– la tension maximale de système pour laquelle le module ou l'ensemble est adéquat;
– la valeur nominale de la puissance de sortie maximale et de sa tolérance à la condition spécifiée;
– la date, le lieu de fabrication et les matériaux de cellule doivent être marqués ou être traçables à partir du numéro de série.

Dans le cas où des échantillons représentatifs sont utilisés, les mêmes marquages que sur les produits en grandeur réelle doivent être inclus pour tous les essais, et il convient que le marquage puisse résister à toutes les séquences d'essais.

6 Essais

Lorsque cela est recommandé par le fabricant, avant de commencer les essais, tous les échantillons d'essai, y compris le module de commande et le récepteur de commande, doivent être exposés à l’irradiation normale directe (DNI - *direct normal irradiation*) du soleil (naturel ou simulé) de 5 kWh/m^2 à 5,5 kWh/m^2 au total, tout en étant en circuit ouvert. Cette procédure est conçue pour réduire les effets initiaux de dégradation des photons.

Dans le présent document, toutes les références au courant de court-circuit I_{sc}, à la tension en circuit ouvert V_{oc} et à la puissance de sortie maximale P_m sont fondées sur une condition d'essai normalisée du concentrateur (CSTC - *concentrator standard test condition*) qui est définie dans l'IEC 62670-1. Sinon, de façon logique, les conditions d'exploitation normalisées du concentrateur (CSOC - *concentrator standard operating condition*) telles qu’elles sont définies dans l'IEC 62670-1 peuvent être utilisées. D’autres paramètres et méthodes d’essai sont fondés sur l’IEC 60904 et l’IEC 61853, sauf s’ils ont fait l’objet de spécification.

Les échantillons d'essai doivent être répartis de manière aléatoire en groupes et soumis aux séquences d'essais de qualification de la Figure 6 ou de la Figure 7. Les procédures et exigences d'essai sont détaillées à l'Article 10, et résumées à l’Annexe A. L'attribution des échantillons d'essai à des séquences d'essais types est donnée dans le Tableau 2.

Après les essais et examens initiaux, un module ou une section du récepteur/miroir doit être retiré(e) de la séquence d'essais en tant qu'unité de commande. De préférence, il convient de stocker l'unité de commande dans l'obscurité à température ambiante afin de réduire la dégradation des performances électriques, mais elle peut être maintenue à l'extérieur avec un dispositif de masquage sombre. Comme le représente la Figure 6 pour les modules ou la Figure 7 pour les ensembles, la séquence d'essais est réalisée à la fois en laboratoire et sur site. Lorsque le récepteur CPV utilise du silicium cristallin, un mesurage au soleil (avec flash ou à l'extérieur) peut servir d'outil de diagnostic tout au long du programme. Lorsque la distance entre ces deux emplacements est considérable ou que des sociétés de transport publiques sont impliquées, il convient d'effectuer le mesurage de la courbe courant-tension (I-V) d'obscurité avant et après le transport afin d'évaluer toutes les modifications éventuelles sur les échantillons d'essai.

Dans le cas où un fabricant particulier ne produit que des composants spécifiques (par exemple, des récepteurs, des lentilles ou des miroirs), les essais de qualification de la conception et d'homologation peuvent être soumis seulement aux séquences d'essais applicables et une certification partielle peut être prononcée indépendamment.

Dans le cas où certaines procédures d'essai du présent document ne sont pas applicables à une configuration de conception spécifique, il convient que le fabricant le mentionne auprès de l'organisme de certification et de l'organisme d'essai afin de mettre au point un programme d'essais comparable, fondé sur les principes décrits dans le présent document. Tous les écarts et modifications doivent être enregistrés et consignés en détail, conformément aux exigences de l'Article 8 j).

Tableau 2 – Attribution des échantillons d'essai à des séquences d'essais types

Séquence d'essai	Module		Ensemble	
	Récepteur	module	récepteur	miroir
Contrôle		1	1	1
A	2		2	
B		2	2	2
C		2	2	2
D		1	1	1
E		1 (grandeur réelle)	1 (grandeur réelle)	1 (grandeur réelle)
F	1		1	
Total	3	7	10	7

7 Critères d'acceptation

Une conception de module ou d'ensemble photovoltaïque à concentration doit être jugée comme satisfaisant aux essais de qualification et, par conséquent, comme étant un type approuvé par l'IEC 62108, lorsque chaque échantillon d'essai satisfait à l'ensemble des critères suivants:

a) la dégradation de puissance relative dans la séquence A à D ne dépasse pas 13 % lorsque le mesurage I-V est effectué sous éclairement solaire naturel en extérieur, ou 8 % lorsque le mesurage I-V est effectué sous simulateur solaire;

b) la dégradation de puissance relative dans la séquence E ne dépasse pas 7 % pour le mesurage I-V sous éclairement solaire naturel ou 5 % pour le mesurage I-V sous simulateur solaire, dans la mesure où l'essai d'exposition en site naturel de 1 000 kWh/m^2 DNI n'est pas un essai de contraintes accélérées;

c) aucun échantillon n'a présenté de circuit ouvert pendant les essais;

d) il n'y a pas de défaut visuel majeur apparent, comme ceux définis en 10.1.2;

e) les exigences d'essai d'isolement sont satisfaites au début et à la fin de chaque séquence;

f) les exigences d'essai de courant de fuite en milieu humide sont satisfaites au début et à la fin de chaque séquence;

g) les exigences spécifiques des essais individuels sont satisfaites.

Dans le cas où des défaillances sont observées au cours de l'essai, le jugement et la procédure de contre-essai ci-dessous doivent être appliqués:

h) lorsque deux échantillons d'essai ou plus ne satisfont pas aux critères d'acceptation, la conception doit être considérée comme ne satisfaisant pas aux exigences de qualification;

i) lorsqu'un échantillon échoue à l'un des essais, deux autres échantillons satisfaisant aux exigences de l'Article 4 peuvent être soumis à l'intégralité de la séquence d'essais correspondante depuis le début;

j) dans le cas i), lorsque les deux échantillons satisfont à la séquence d'essais, la conception doit être jugée comme satisfaisant aux exigences de qualification;

k) dans le cas i), lorsque l'un des deux ou les deux échantillons échouent également, la conception doit être considérée comme ne satisfaisant pas aux exigences de qualification;

l) dans le cas h) ou k), l'ensemble du programme d'essai représenté à la Figure 6 ou à la Figure 7 doit être réalisé une nouvelle fois, généralement après avoir apporté une amélioration au niveau de la conception ou du traitement.

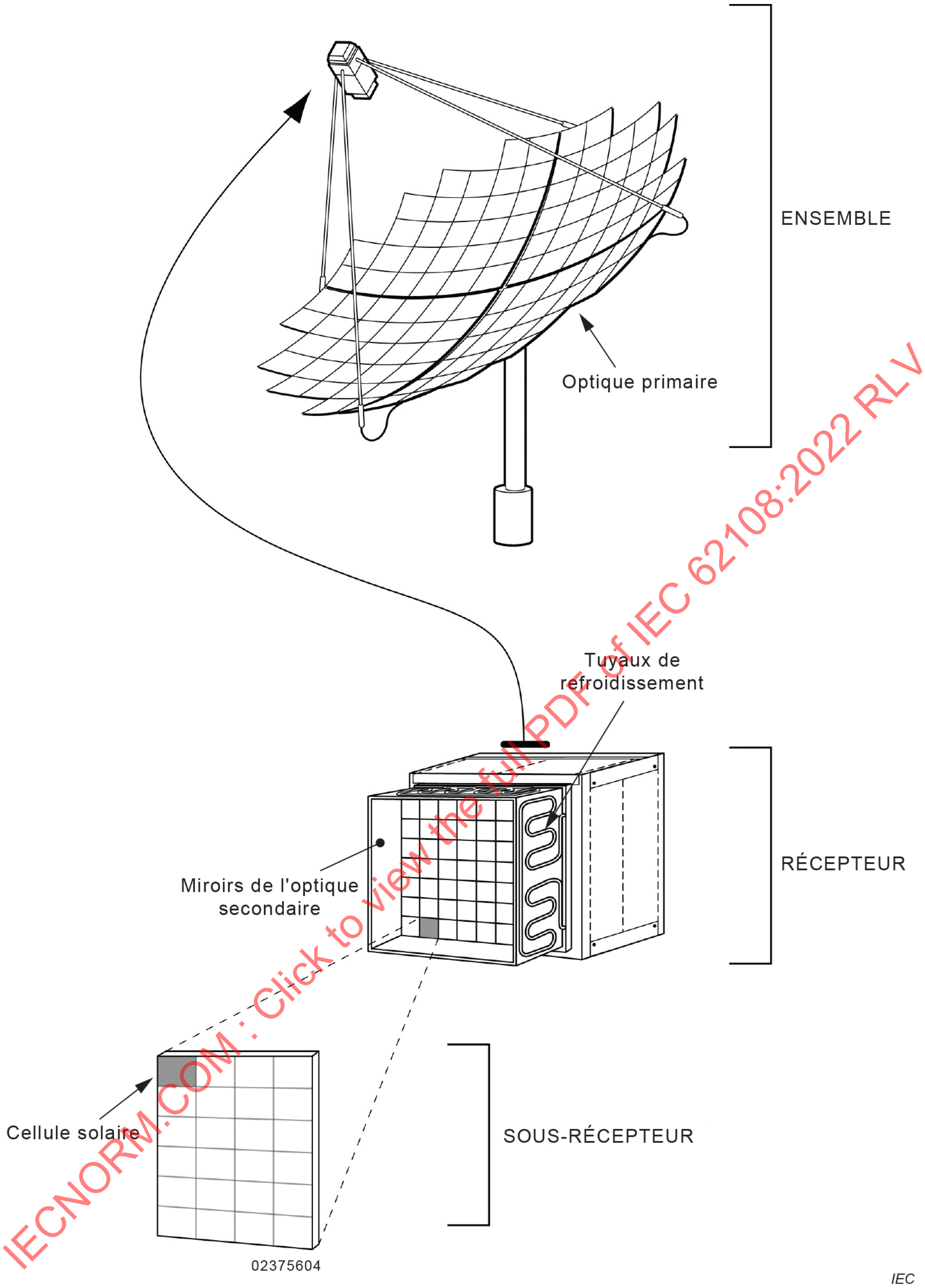


Figure 1 – Schéma d'un système PV à concentration parabolique avec point de focalisation

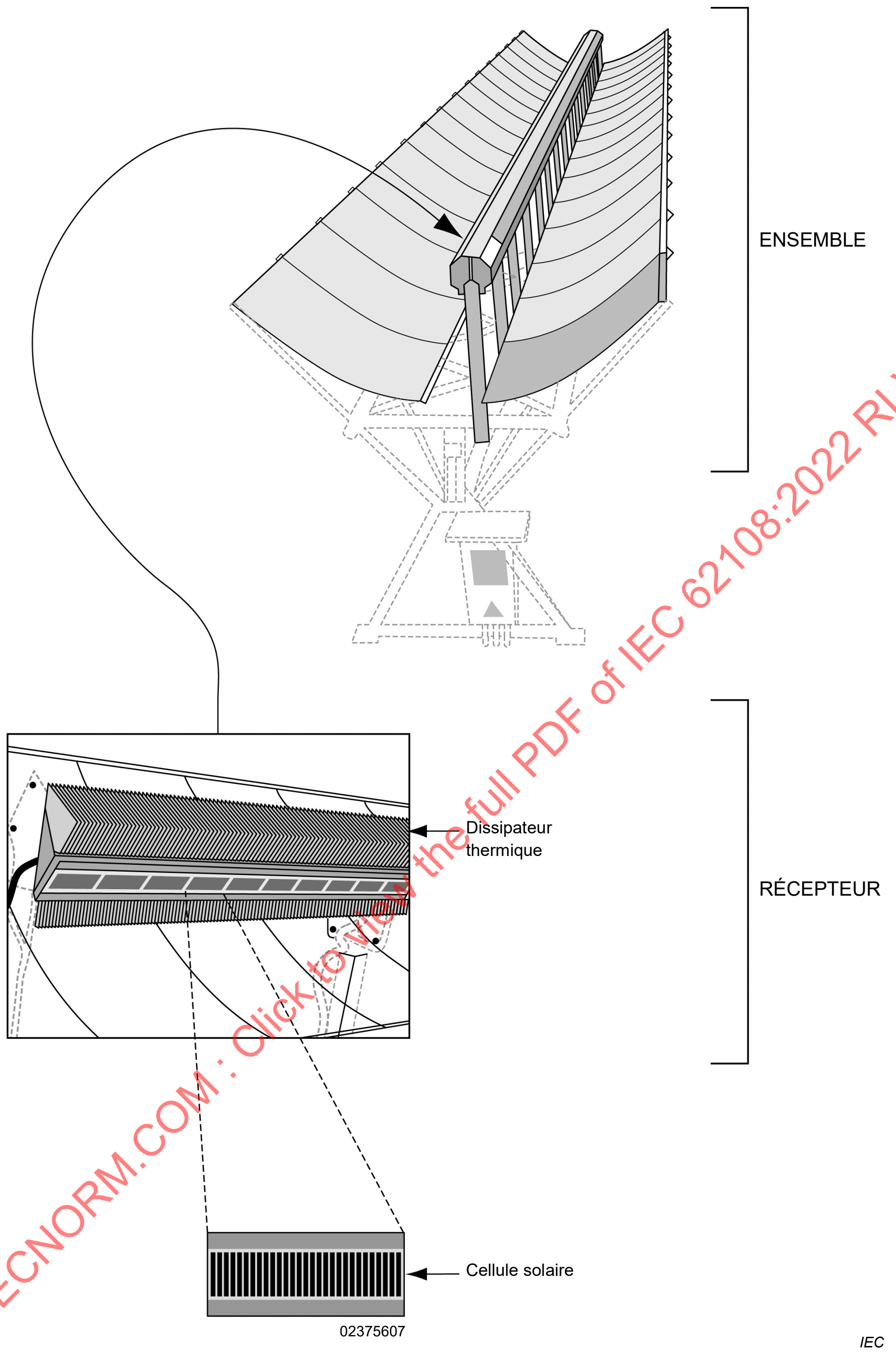


Figure 2 – Schéma d'un système PV à concentration à réceptacle avec focalisation linéaire

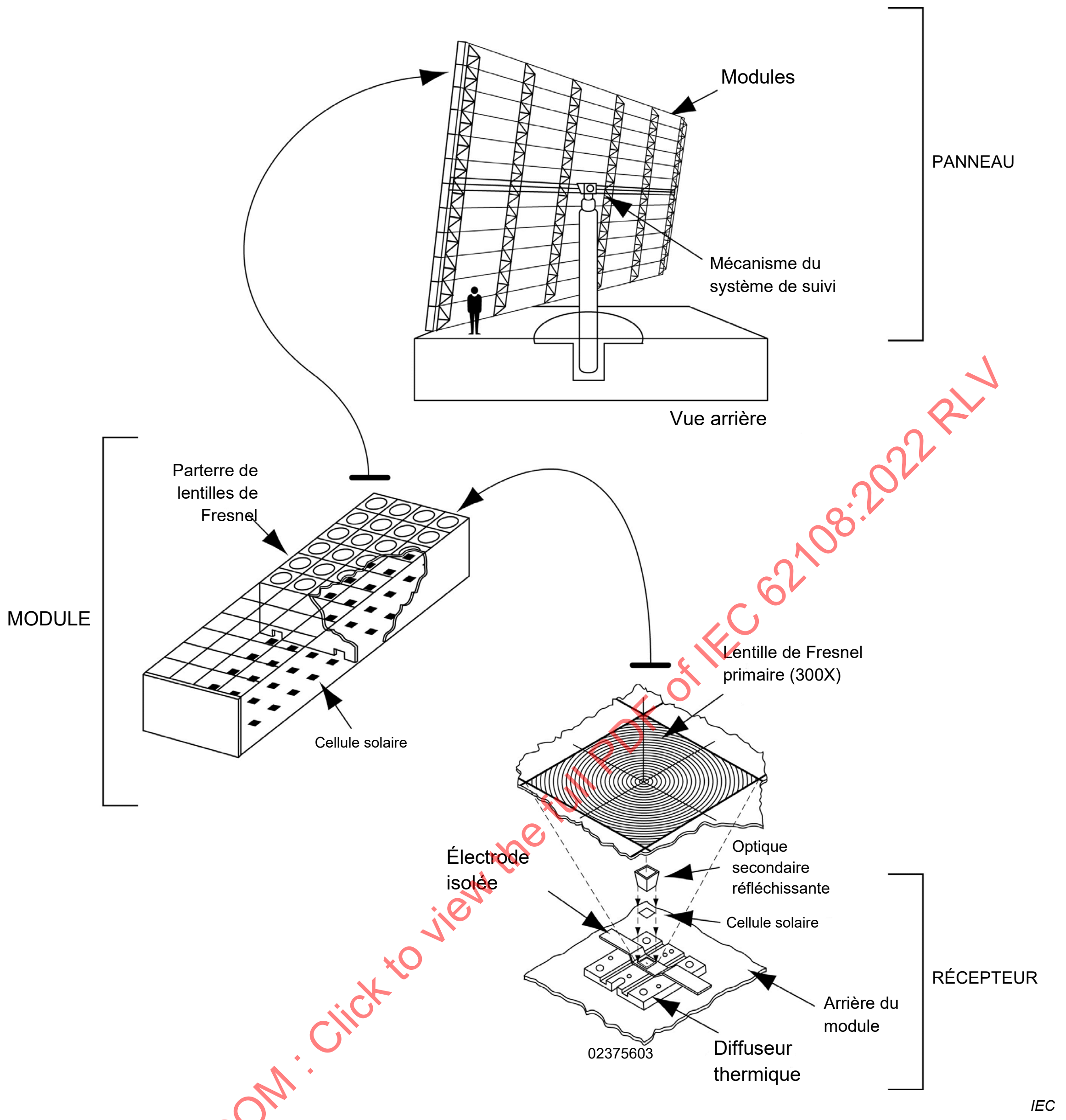


Figure 3 – Schéma d'un système PV à concentration à lentille de Fresnel avec point de focalisation

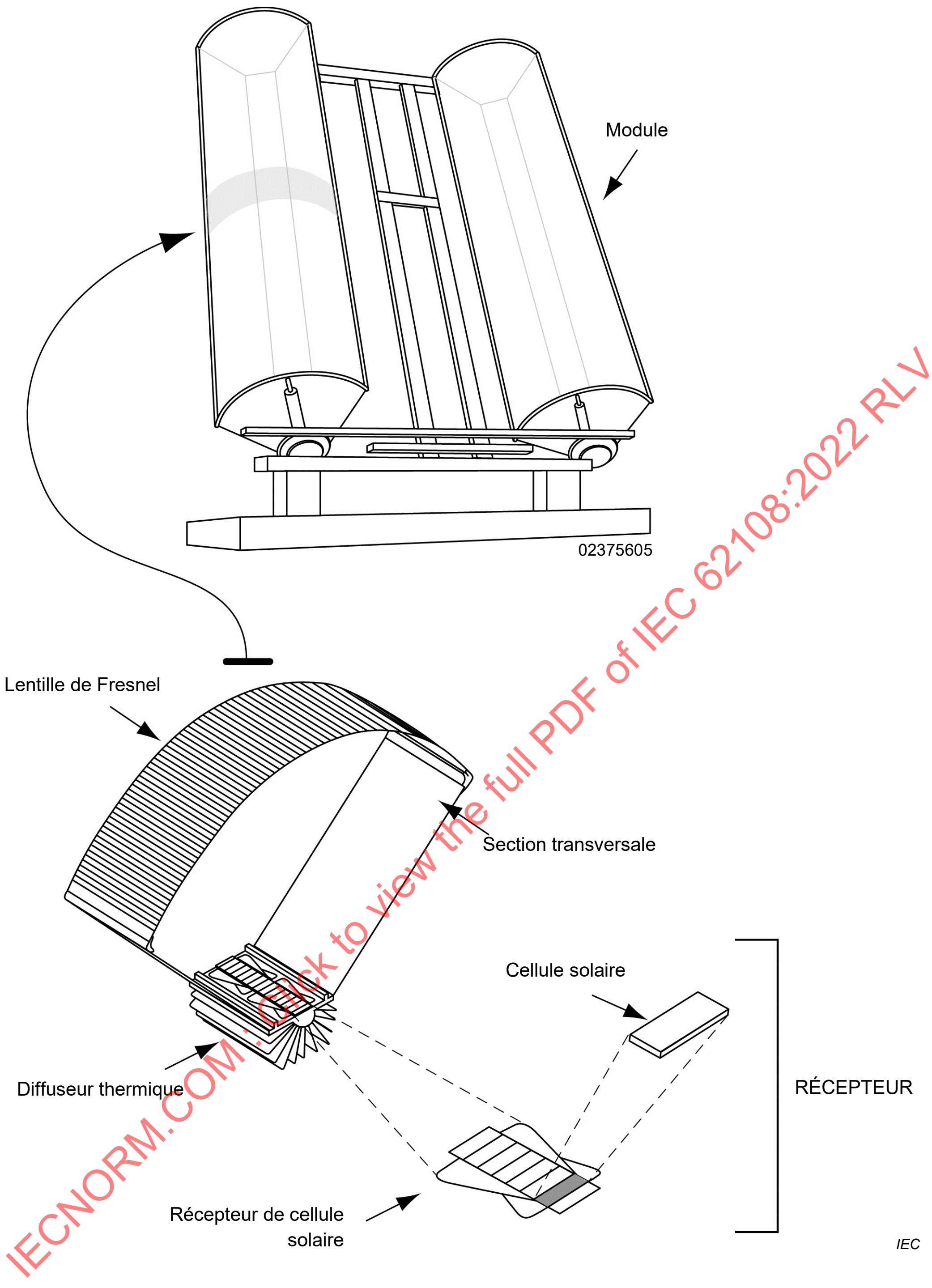


Figure 4 – Schéma d'un système PV à concentration à lentille de Fresnel avec focalisation linéaire

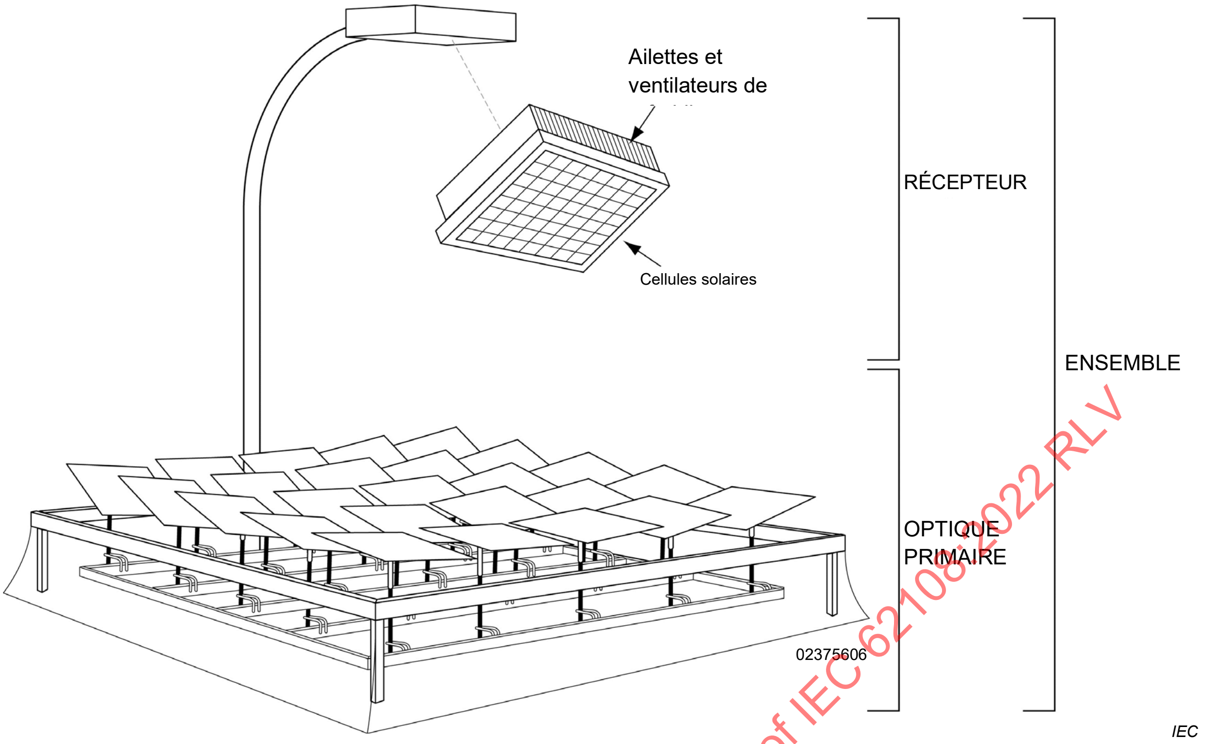


Figure 5 – Schéma d'un CPV à héliostat

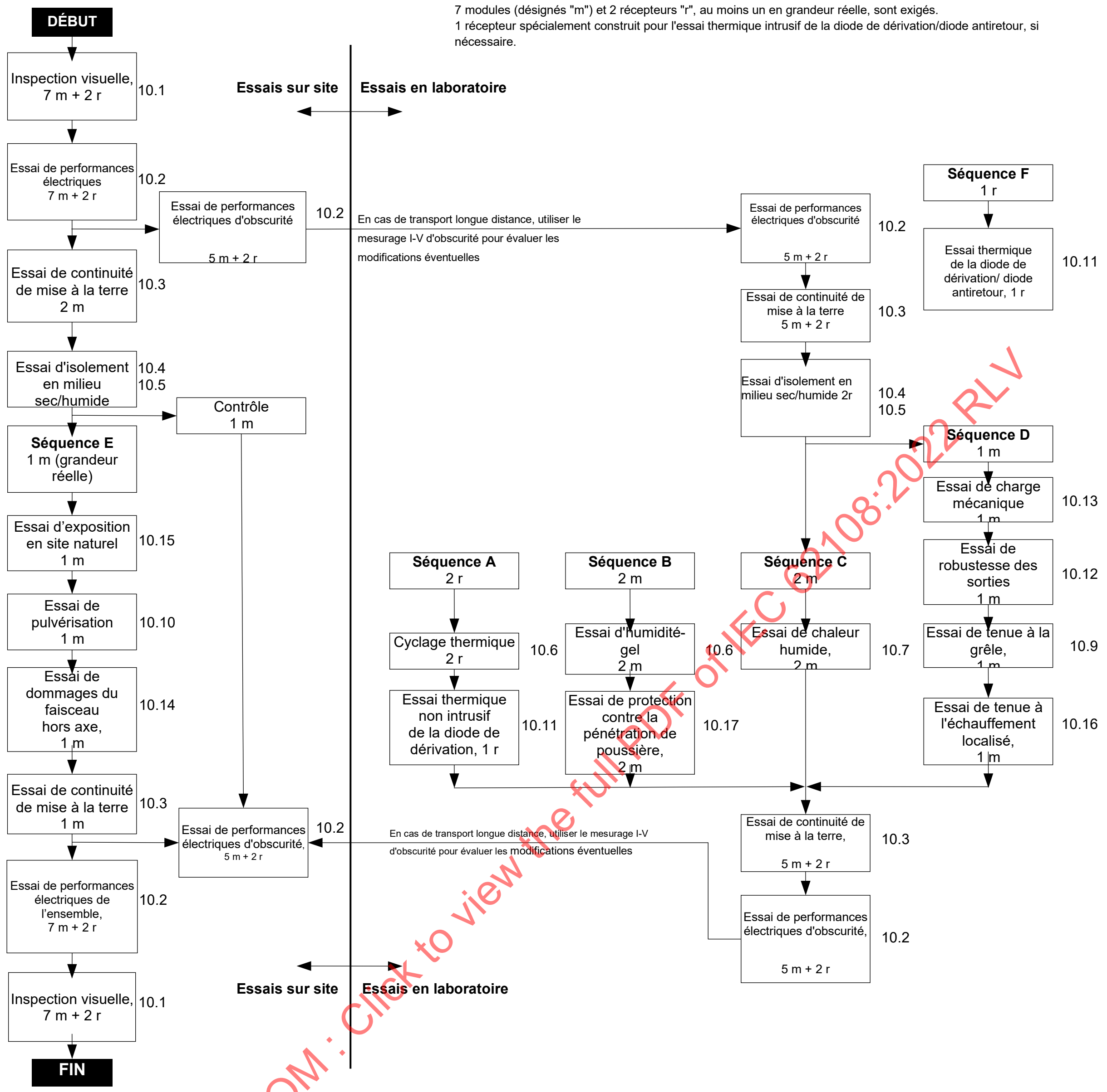


Figure 6 – Séquence d'essais de qualification pour modules CPV

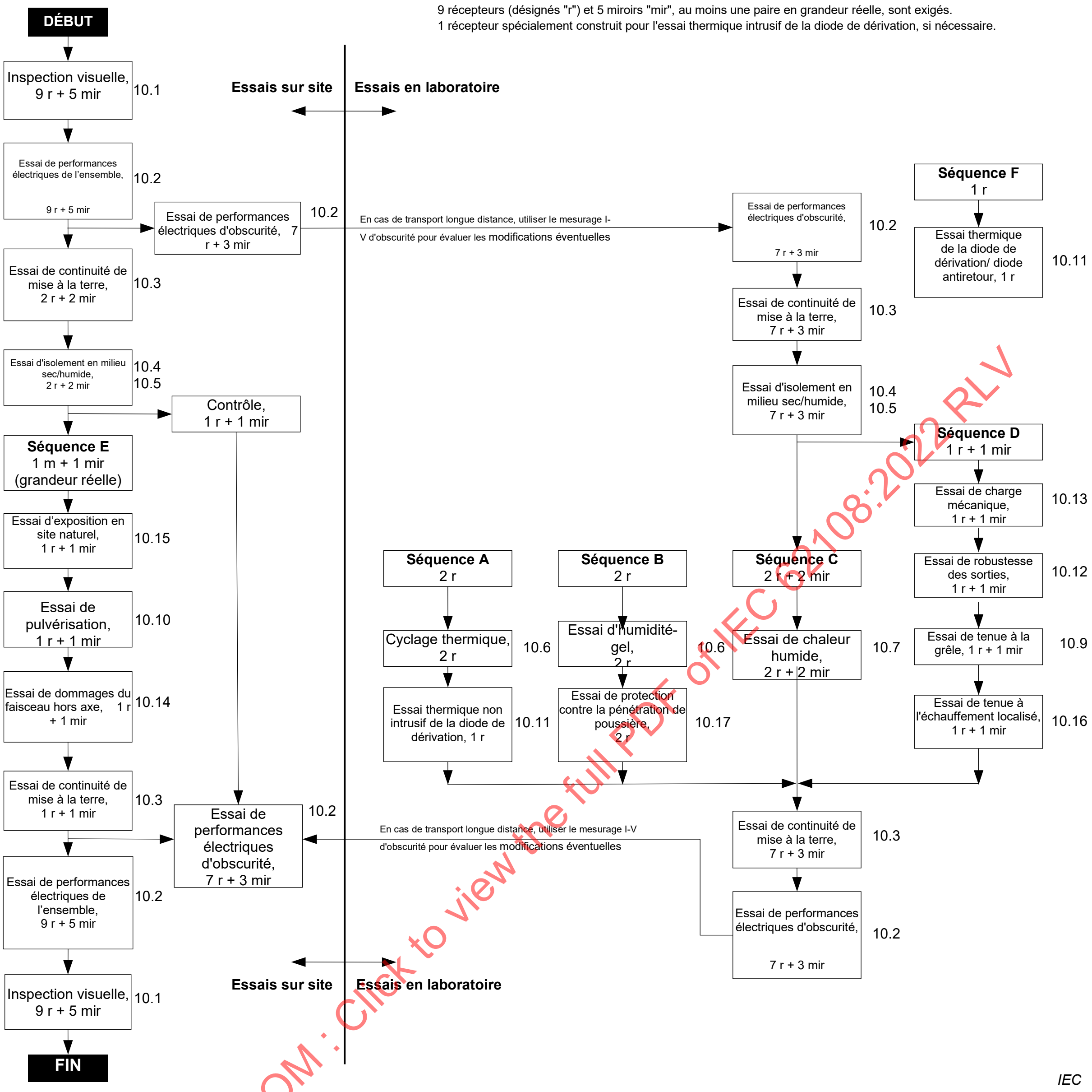


Figure 7 – Séquence d'essais de qualification pour ensembles CPV

8 Rapport

Pour l'homologation, un rapport certifié des essais de qualification incluant les caractéristiques de performance mesurées ainsi que le détail de chaque défaut et contre-essai doit être élaboré par l'organisme d'essai. Chaque rapport d'essai doit comprendre au minimum les informations suivantes (l'essai des composants repose sur l'IEC 62790 et l'IEC 62852, sauf s'il fait l'objet de spécification):

a) un titre;

b) le nom et l'adresse du laboratoire, ainsi que le lieu où les essais ont été réalisés s'il est différent de l'adresse du laboratoire (par exemple, sur site);

c) l'identification unique du rapport d'essai (par exemple, le numéro de série) et, sur chaque page, une identification, permettant d'assurer que la page est reconnue comme faisant partie du rapport d'essai, ainsi qu'une identification claire de la fin du rapport d'essai;

d) le nom et l'adresse du client, s'il y a lieu;

e) la description et l'identification de l'élément soumis aux essais;
f) la caractérisation et la condition de l'élément d'essai;
g) la date de réception de l'élément d'essai, ainsi que la ou les dates de l'essai, s'il y a lieu;
h) l'identification de la méthode d'essai utilisée;
i) une référence à la procédure d'échantillonnage, s'il y a lieu;
j) tout écart par rapport à, tout complément à ou toute exclusion de la méthode d'essai, ainsi que toute autre information se rapportant à un essai spécifique, par exemple les conditions d'environnement;
k) les mesurages, les examens et les résultats dérivés appuyés par des tableaux, graphiques, croquis et photographies selon le cas, y compris le courant de court-circuit, la tension en circuit ouvert et la puissance de sortie maximale, la perte de puissance maximale observée après l'ensemble des essais, ainsi que toute autre défaillance observée;
l) une indication de l'incertitude estimée des résultats d'essai, s'il y a lieu;
m) une signature et un titre, ou une identification équivalente de la ou des personnes acceptant d'être responsables du contenu du rapport, ainsi que la date d'édition;
n) s'il y a lieu, une indication selon laquelle les résultats ne se rapportent qu'aux éléments soumis aux essais;
o) une indication selon laquelle, pour conserver la qualification et l'homologation, le fabricant doit se référer à l'organisme de certification et à l'organisme d'essai et discuter avec ces derniers de toutes les modifications qu'ils ont apportées, conformément aux lignes directrices de contre-essai décrites à l'Annexe B;
p) une spécification indiquant que le rapport ne doit pas être reproduit sauf dans sa totalité, sans l'approbation écrite du laboratoire.

Il convient que le fabricant conserve une copie de ce rapport à titre de référence.

9 Modifications

Toute modification dans la conception, les matériaux, les composants ou le traitement des modules et ensembles peut exiger la répétition de tout ou partie des essais de qualification pour conserver l'homologation, comme cela est décrit à l'Annexe B. Les fabricants doivent se référer à l'organisme de certification et à l'organisme d'essai et discuter avec ces derniers de toutes les modifications qu'ils ont apportées.

10 Procédures d'essai

10.1 Examen visuel

10.1.1 Généralités

Cette procédure fournit les exigences relatives aux examens visuels élémentaires, intermédiaires et finaux dans le but d'identifier et de déterminer les modifications ou défauts physiques dans la construction du module ou de l'ensemble au début et après chacun des essais exigés.

Il convient de rejeter tout matériel présentant des dommages initiaux qui ne sont pas dus au processus de fabrication si ces dommages peuvent s'aggraver et entraîner une défaillance au cours des essais d'environnement ultérieurs. Un nouveau module ou ensemble peut alors être substitué avant le début de la séquence d'essais.

10.1.2 Mode opératoire

Tous les échantillons d'essai doivent être inspectés entièrement et photographiés si cela est nécessaire. Tous les défauts ou anomalies (y compris les défauts initiaux liés à la qualité des joints à souder, tels qu'une soudure inadaptée ou excessive, des billes de soudure, des interconnexions cintrées ou un désalignement des pièces) doivent être documentés avec des croquis ou photographies appropriés pour indiquer l'emplacement des défauts. Les composants tels que la lentille, le miroir, les éléments de l'optique secondaire, les diffuseurs thermiques et les enrobages doivent également être inspectés pour contrôler la présence éventuelle de défauts. Contrôler en particulier les éléments suivants:

a) les bulles, la délamination ou tout type de défaut similaire sur la cellule et autour de ses bords;
b) les dommages survenant au cours du transport et de la manipulation, tels que la fêlure des lentilles, la fêlure/courbure des boîtiers et la courbure des bornes ou équerres de montage;
c) l'intégrité du joint d'étanchéité autour de la lentille et des joints de boîtier. Tout trou ou fissure dans les matériaux d'étanchéité doit être indiqué;
d) les orifices d'aération ou prises d'air ne doivent pas être bouchés;
e) la mise à la terre de toutes les parties conductrices accessibles;
f) les surfaces externes cassées, fêlées, vrillées, désalignées ou déchirées;
g) les interconnexions ou jonctions défectueuses;
h) la corrosion visible des connexions de sortie, interconnexions et barres de raccordement;
i) les défauts de collage;
j) les surfaces collantes au toucher des matériaux plastiques;
k) les sorties défectueuses ou les parties électriques actives exposées;
l) toute autre condition pouvant affecter la fiabilité ou les performances.

10.1.3 Défauts visuels majeurs

Pour les besoins de la qualification de la conception et de l'homologation, chacun des défauts suivants est considéré comme un défaut visuel majeur:

a) les surfaces externes cassées, fêlées, pliées, désalignées ou déchirées, y compris la lentille, le miroir, la carcasse du récepteur, le châssis et la boîte de jonction;
b) les cellules cassées ou fêlées;
c) les bulles ou la délamination formant un chemin continu entre une partie du circuit électrique et le bord du récepteur;
d) la corrosion visible de l'un des circuits actifs de l'échantillon;
e) les défauts du matériau adhésif ou du matériau d'étanchéité;
f) la perte de l'intégrité mécanique entraînant une détérioration de l'installation et/ou du fonctionnement des modules ou ensembles.

10.1.4 Exigences

Aucun défaut visuel majeur.

10.2 Mesurage des performances électriques

10.2.1 Objet

L'objectif de l'essai des performances électriques est d'identifier la dégradation des performances électriques des échantillons d'essai provoquée par les essais exigés. Cet essai s'intéresse à la dégradation de la puissance, et non à la sortie de puissance absolue, qui est traitée par une norme distincte sur les caractéristiques assignées de puissance et d'énergie.

La répétabilité du mesurage constitue le facteur le plus important pour cet essai.

10.2.2 Mesurage I-V de l'ensemble en site naturel

10.2.2.1 Généralités

Le mesurage I-V de l'ensemble identifie la dégradation de puissance d'un échantillon d'essai en comparant sa puissance relative d'essai de post-contrainte à sa puissance relative d'essai de précontrainte. La puissance relative est définie comme la sortie de puissance maximale de l'échantillon en essai, divisée par la sortie de puissance maximale de l'échantillon de contrôle, mesurée dans des conditions d'essai similaires. Cette méthode est fondée sur l'hypothèse selon laquelle les modifications des performances électriques de l'échantillon de contrôle sont négligeables sur toute la période d'essais de qualification. En utilisant cette méthode, les variables des conditions d'essai sont autocorrectives, et les procédures de translation complexes sont éliminées.

Le mesurage I-V de l'ensemble est exigé pour chaque échantillon d'essai lors des mesurages I-V initiaux et finaux. Il est facultatif pour tous les mesurages I-V intermédiaires.

Lors de l'application de cette méthode aux récepteurs, le récepteur de contrôle et le récepteur d'essai doivent être installés avec un système optique et mécanique adéquat de telle sorte que, pendant l'essai, la concentration de lumière et les conditions thermiques de ces deux récepteurs soient semblables aux conditions de fonctionnement réelles.

10.2.2.2 Mode opératoire

Mesurer la puissance relative d'un échantillon d'essai, conformément aux procédures suivantes:

a) Effectuer l'essai lors d'une journée favorable et pendant une période qui satisfait aux conditions suivantes:
   - le ciel est clair, le DNI est supérieur à 700 W/m^2 et sa variation est inférieure à 2 % dans chaque intervalle de 5 min;
   - pour les systèmes avec un demi-angle d'admission supérieur à 2,5°, il n'y a pas de nuages visibles ni de ciel voilé dans un angle d'observation de 45° autour du soleil;
   - la vitesse du vent est inférieure à 6 m/s, et il n'y a pas de rafale supérieure à 10 m/s en 10 min avant tout mesurage.

   Porter une attention particulière à la rigidité du système de suivi et veiller à ce qu'il soit stable lorsqu'il y a du vent.

b) Monter l'échantillon d'essai et l'échantillon de contrôle côte à côte, sur un système de suivi à deux axes. L'alignement des échantillons à l'éclairement solaire peut être réalisé par l'une des deux séquences suivantes:
   - ajuster les échantillons d'essai et de contrôle de façon plane, puis les aligner ensemble par rapport à la direction du faisceau solaire; ou
   - aligner séparément les échantillons d'essai et de contrôle par rapport au faisceau solaire avant chaque mesurage I-V.

   NOTE L'échantillon d'essai et l'échantillon de contrôle peuvent également être soumis aux essais sur deux systèmes de suivi à deux axes adjacents, ou deux récepteurs peuvent être soumis aux essais l'un après l'autre sur un système de suivi et un système optique, si toutes les conditions du point a) sont satisfaites.

c) L'alignement doit satisfaire aux spécifications du fabricant. Lorsque les spécifications ne sont pas disponibles, utiliser la valeur maximale de I_{sc} du module comme indicateur de l'alignement. Le désalignement ne doit pas entraîner une diminution de la valeur de I_{sc} de plus de 2 % de sa valeur maximale.

d) Contrôler la température de l'échantillon afin d'assurer que les variations de température de l'échantillon sont inférieures à 2 °C dans chaque période de 1 min.

e) Dans le cas où un fluide de refroidissement est utilisé, contrôler le débit du fluide de refroidissement et les températures en entrée et en sortie. Le débit du fluide de refroidissement ne doit pas varier de plus de 2 %, et la température ne doit pas varier de plus de 1 °C dans chaque période de 5 min.

f) Prendre les mesurages I-V sur les deux échantillons pour obtenir leur sortie de puissance maximale. Cette procédure doit être effectuée rapidement de sorte que les variations de sortie de puissance provoquées par l'éclairement solaire, les variations de température ambiante et de vitesse du vent soient inférieures à 2 % au cours de cette étape.

g) Calculer la puissance relative P_r de l'échantillon:

$$P_r = \frac{P_m}{P_{mc}} \times 100\,\%$$

où:

P_r est la puissance relative de l'échantillon, en %;

P_m est la puissance maximale de l'échantillon d'essai, en W;

P_{mc} est la puissance maximale de l'échantillon de contrôle, mesurée dans les mêmes conditions que P_m, en W.

10.2.2.3 Exigences

a) La puissance maximale de l'échantillon (P_m), le courant de court-circuit I_{sc} et la tension en circuit ouvert V_{oc} doivent être mesurés avec exactitude et à plusieurs reprises.

b) La dégradation de puissance relative P_{rd} est définie comme suit:

$$P_{rd} = \frac{P_{ri} - P_{rf}}{P_{ri}} \times 100\,\%$$

où:

P_{rf} est la puissance relative mesurée après l'essai donné;

P_{ri} est la puissance relative mesurée avant l'essai donné.

Pour les mesurages en extérieur, la valeur P_{rd} doit être inférieure à 13 %; pour les mesurages avec le simulateur en intérieur, la valeur P_{rd} doit être inférieure à 8 %. La différence de 5 % tient compte de l'incertitude plus importante liée aux mesurages en extérieur.

10.2.3 Mesurage I-V sous simulateur solaire

Le mesurage I-V du CPV peut aussi être réalisé sous simulateur solaire en intérieur, conformément aux paragraphes 9.5 et 9.6 de l'IEC 62670-3:2017. Il convient que le laboratoire d'essai crée sa propre procédure d'essai, à condition que les mêmes conditions soient obtenues.

10.2.4 Mesurage I-V d'obscurité

10.2.4.1 Généralités

Le mesurage I-V d'obscurité compare les résistances en série de l'échantillon mesurées avant et après les essais. Il est effectué avant et après le transport de l'échantillon d'essai afin d'évaluer toutes les modifications éventuelles.

Le mesurage I-V d'obscurité est également une méthode rentable pour contrôler et diagnostiquer la dégradation de la puissance des modules ou ensembles d'essai par suite d'essais de contraintes intermédiaires, ou pour contrôler la stabilité des performances électriques des échantillons de contrôle.