भारतीय मानक

Indian Standard

IS 16228 : 2024
IEC 62108 : 2022

कॉन्सेंट्रेटर फोटोवोल्टिक (सीपीवी) मॉड्यूल और असेंबली — डिजाइन योग्यता और प्रकार की स्वीकृति

(दूसरा पुनरीक्षण)

Concentrator Photovoltaic (CPV) Modules and Assemblies — Design Qualification and Type Approval

(Second Revision)

ICS 27.160

भारतीय मानक ब्यूरो
BUREAU OF INDIAN STANDARDS
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July 2024 **Price Group 14**

Solar Photovoltaic Energy Systems Sectional Committee, ETD 28

NATIONAL FOREWORD

This Indian Standard (Second Revision) which is identical to IEC 62108 : 2022 'Concentrator photovoltaic (CPV) modules and assemblies — Design qualification and type approval' issued by the International Electrotechnical Commission (IEC) was adopted by the Bureau of Indian Standards on the recommendation of the Solar Photovoltaic Energy Systems Sectional Committee and approval of the Electrotechnical Division Council.

This standard was initially published in 2015 and subsequently revised in 2013. The first revision was based on IEC 62108 : 2016. The second revision of this standard has been undertaken to align it with the latest version of IEC 62108 : 2022.

The text of the IEC standard has been approved as suitable for publication as an Indian Standard without deviations. Certain conventions are, however, not identical to those used in Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words 'International Standard' appears referring to this standard, they should be read as 'Indian Standard'; and
b) Comma (,) has been used as a decimal marker, while in Indian Standards the current practice is to use a point (.) as the decimal marker.

In this adopted standard, reference appears to International Standards for which Indian Standards also exists. The corresponding Indian Standards, which are to be substituted, are listed below along with their degree of equivalence for the editions indicated:

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
IEC 60529 Degrees of protection provided by enclosures (IP Code)	IS/IEC 60529 : 2001 Degrees of protection provided by enclosures (IP Code)	Identical
IEC 60664-1 : 2020 Insulation coordination for equipment within low-voltage supply systems — Part 1: Principles, requirements and tests	IS 15382 (Part 1) : 2022/IEC 60664-1 : 2020 Insulation coordination for equipment within low-voltage systems: Part 1 Principles, requirements and tests (*second revision*)	Identical
IEC 60721-2-1 Classification of environmental conditions — Part 2-1: Environmental conditions appearing in nature — Temperature and humidity	IS 13736 (Part 2/Sec 1) : 2020/ IEC 60721-2-1 : 2013 Classification of environmental conditions: Part 2 Environmental conditions appearing in nature, Section 1 Temperature and humidity (*first revision*)	Identical
IEC 60904-1 : 2020 Photovoltaic devices — Part 1: Measurement of photovoltaic current-voltage characteristics	IS 12762 (Part 1) : 2023/IEC 60904-1 : 2020 Photovoltaic devices: Part 1 Measurement of photovoltaic current -voltage characteristics (*second revision*)	Identical
IEC 60904-1-1 : 2017 Photovoltaic devices — Part 1-1: Measurement of current-voltage characteristics of multi-junction photovoltaic (PV) devices	IS 12762 (Part 1/Sec 1) : 2020/ IEC 60904-1-1 : 2017 Photovoltaic devices: Part 1 Measurement of current-voltage characteristics, Section 1 Multi-junction PV devices	Identical

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
IEC TS 60904-1-2 : 2019 Photovoltaic devices — Part 1-2: Measurement of current-voltage characteristics of bifacial photovoltaic (PV) devices	IS 12762 (Part 1/Sec 2) : 2020/ IEC TS 60904-1-2 : 2019 Photovoltaic devices: Part 1 Measurement of current-voltage characteristics, Section 2 Bi-facial photovoltaic (PV) devices	Identical
IEC 60904-2 : 2015 Photovoltaic devices — Part 2: Requirements for photovoltaic reference devices	IS 12762 (Part 2) : 2018 Photovoltaic devices: Part 2 Requirements for photovoltaic reference devices (*second revision*)	Identical
IEC 60904-3 : 2019 Photovoltaic devices — Part 3: Measurement principles for terrestrial photovoltaic (PV) solar devices with reference spectral irradiance data	IS 12762 (Part 3) : 2020/IEC 60904-3 : 2019 Photovoltaic devices: Part 3 Measurement principles for terrestrial photovoltaic pv solar devices with reference spectral irradiance data (*third revision*)	Identical
IEC 60904-4 : 2019 Photovoltaic devices — Part 4: Photovoltaic reference devices — Procedures for establishing calibration traceability	IS 12762 (Part 4) : 2023/IEC 60904-4 : 2019 Photovoltaic devices: Part 4 Reference solar devices — Procedures for establishing calibration traceability	Identical
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	IS 12762 (Part 5) : 2014/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 (*first revision*)	Identical
IEC 60904-7 : 2019 Photovoltaic devices — Part 7: Computation of the spectral mismatch correction for measurements of photovoltaic devices	IS 12762 (Part 7) : 2023/IEC 60904-7 : 2019 Photovoltaic devices: Part 7 Computation of the spectral mismatch correction for measurements of photovoltaic devices (*first revision*)	Identical
IEC 60904-8 : 2014 Photovoltaic devices — Part 8: Measurement of spectral responsivity of a photovoltaic (PV) device	IS 12762 (Part 8) : 2018/IEC 60904-8 : 2014 Photovoltaic devices: Part 8 Measurement of spectral responsivity of a photovoltaic (PV) device (*first revision*)	Identical
IEC 60904-8-1 : 2017 Photovoltaic devices — Part 8-1: Measurement of spectral responsivity of multi-junction photovoltaic (PV) devices	IS 12762 (Part 8/Sec 1) : 2020 Photovoltaic devices: Part 8 Measurement of spectral responsivity of a photovoltaic (PV) device, Section 1 Multi-junction (PV) devices	Identical
IEC 61215-1 : 2021 Terrestrial photovoltaic (PV) modules — Design qualification and type approval — Part 1: Test requirements	IS 14286 (Part 1) : 2023/IEC 61215-1 : 2021 Terrestrial photovoltaic (PV) modules — Design qualification and type approval: Part 1 Test requirements (*third revision*)	Identical
IEC 61215-2 : 2021 Terrestrial photovoltaic (PV) modules — Design qualification and type approval — Part 2: Test procedures	IS 14286 (Part 2) : 2023/IEC 61215-2 : 2021 Terrestrial photovoltaic (PV) modules — Design qualification and type approval: Part 2 Test procedures (*third revision*)	Identical

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
IEC TS 61836 : 2016 Solar photovoltaic energy systems — Terms, definitions and symbols	IS 12834 : 2023/IEC TS 61836 : 2016 Solar photovoltaic energy systems — Terms, definitions and symbols (*second revision*)	Identical
IEC 61853-1 : 2011 Photovoltaic (PV) module performance testing and energy rating — Part 1: Irradiance and temperature performance measurements and power rating	IS 16170 (Part 1) : 2014/IEC 61853-1 : 2011 Photovoltaic (PV) module performance testing and energy rating: Part 1 Irradiance and temperature performance measurements and power rating	Identical
IEC 61853-2 : 2016 Photovoltaic (PV) module performance testing and energy rating — Part 2: Spectral responsivity, incidence angle and module operating temperature measurements	IS 16170 (Part 2) : 2018/IEC 61853-2 : 2016 Photovoltaic (PV) module performance testing and energy rating: Part 2 Spectral responsivity, incidence angle and module operating temperature measurements	Identical
IEC 61853-3 : 2018 Photovoltaic (PV) module performance testing and energy rating — Part 3 Energy rating of PV modules	IS 16170 (Part 3) : 2022/IEC 61853-3 : 2018 Photovoltaic (PV) module performance testing and energy rating: Part 3 Energy rating of PV modules (*first revision*)	Identical
IEC 62670-1 Photovoltaic concentrators (CPV) — Performance testing — Part 1: Standard conditions	IS 16662 (Part 1) : 2017/IEC 62670-1 : 2013 Photovoltaic concentrators (CPV) — Performance testing: Part 1 Standard conditions	Identical
IEC 62670-3 : 2017 Photovoltaic concentrators (CPV) — Performance testing — Part 3: Performance measurements and power rating	IS 16662 (Part 3) : 2018/IEC 62670-3 : 2017 Photovoltaic concentrators (CPV) — Performance testing: Part 3 Performance measurements and power rating	Identical
IEC 62790 : 2020 Junction boxes for photovoltaic modules — Safety requirements and tests	IS 16911 : 2023/IEC 62790 : 2020 Junction boxes for photovoltaic modules — Safety requirements and tests (*first revision)*	Identical
IEC 62852 : 2014 Connectors for dc-application in photovoltaic systems — Safety requirements and tests IEC 62852 : 2014/ AMD1 : 2020	IS 16781 : 2018/IEC 62852 : 2014 Connectors for d.c. application in photovoltaic systems safety requirements and tests	Identical

The Committee has reviewed the provisions of the following international standards referred in this adopted standard and decided that they are acceptable for use in conjunction with this standard.

International Standard	*Title*
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

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated expressing the result of a test, shall be rounded off in accordance with IS 2 : 2022 'Rules for rounding off numerical values (*second revision*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

CONTENTS

Indian Standard

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

(Second Revision)

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.

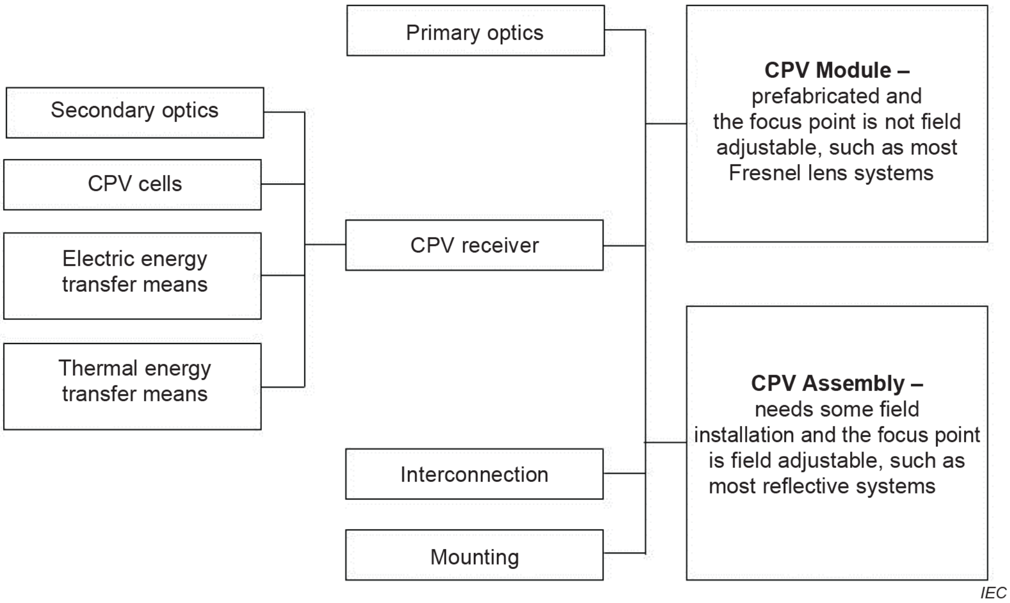
3.6
concentrator assembly
group of receivers, optics, and other related components, such as interconnection and mounting, that accepts unconcentrated sunlight

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.

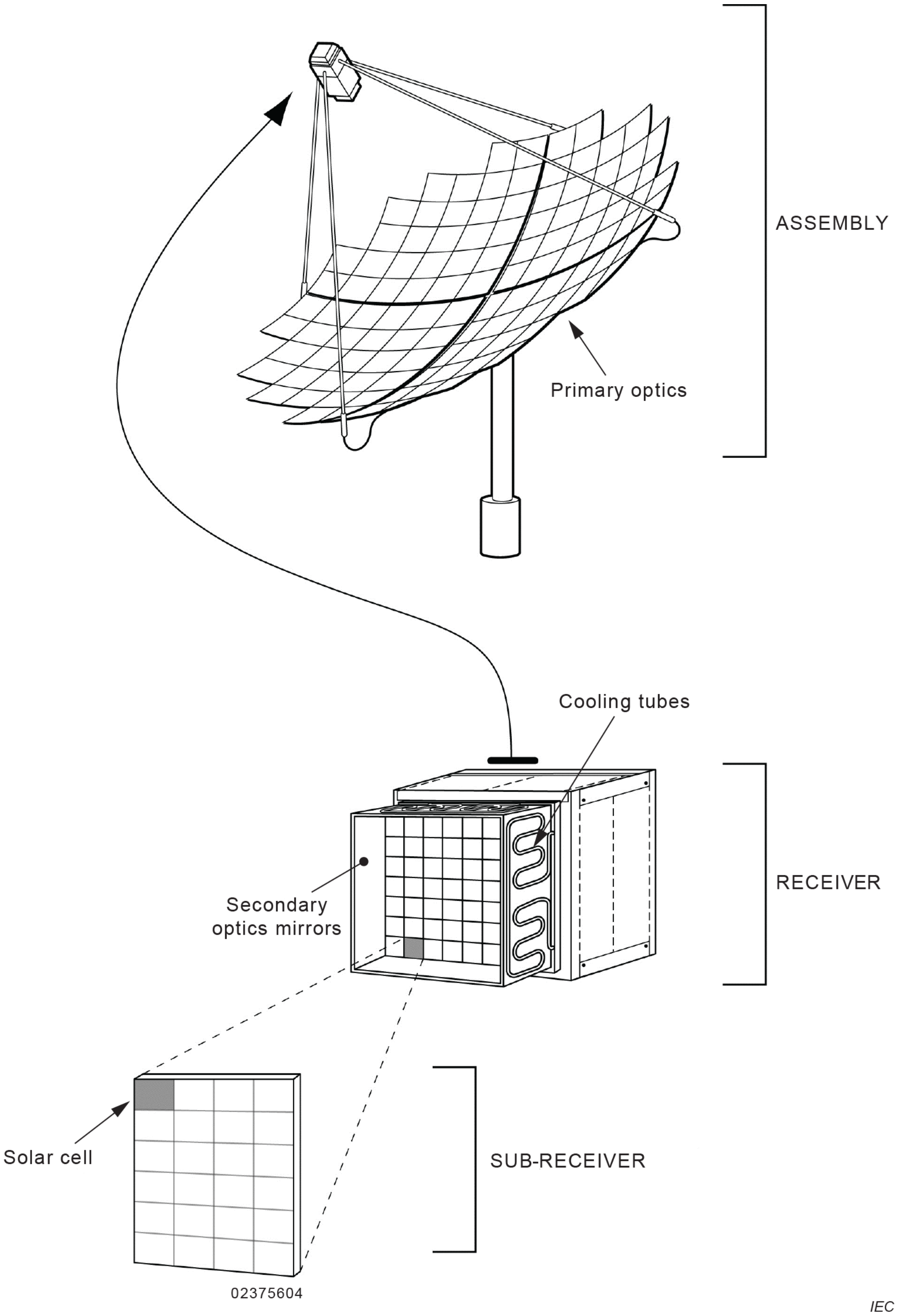


Figure 1 – Schematic of point-focus dish PV concentrator

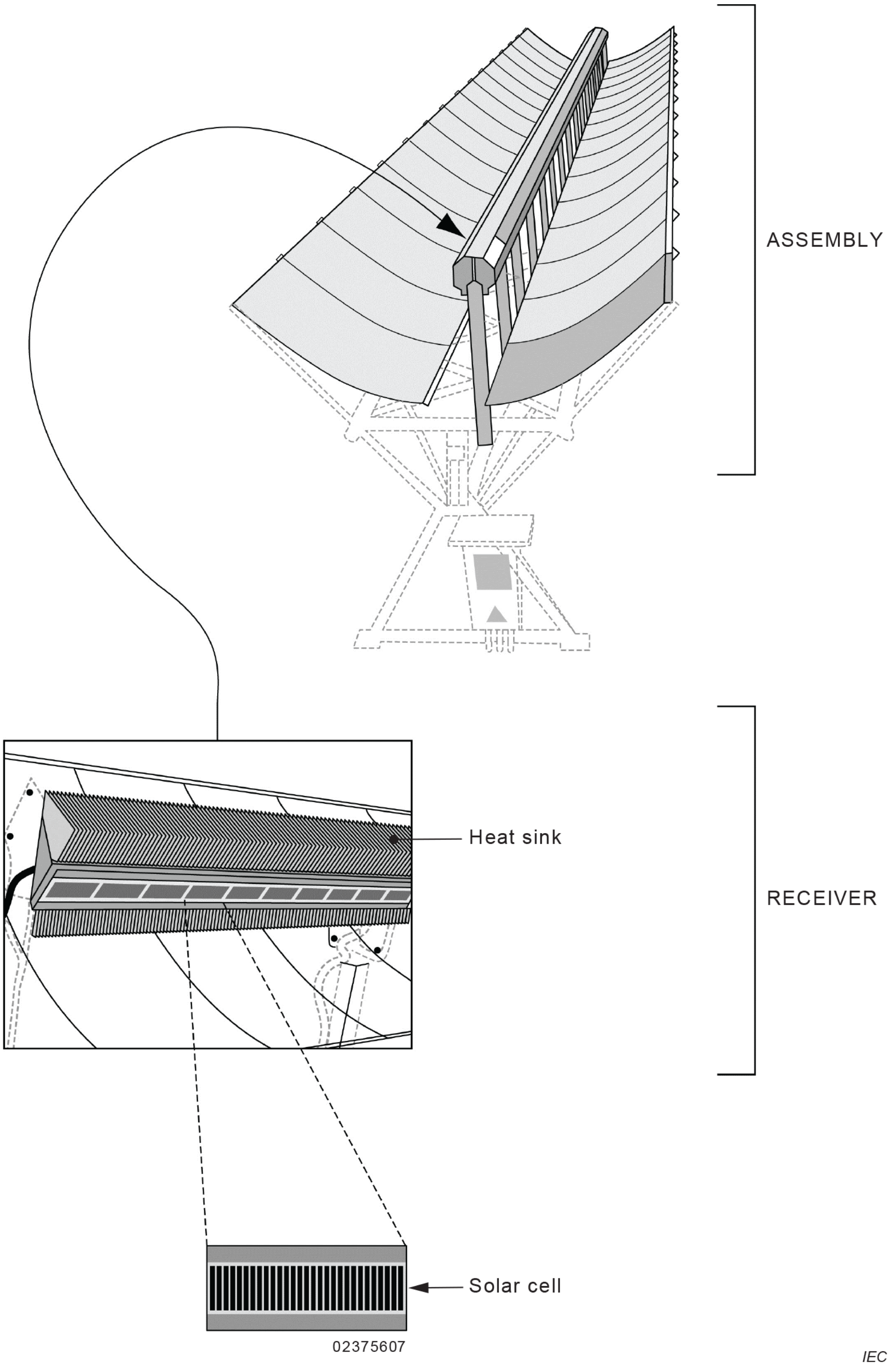


Figure 2 – Schematic of linear-focus trough PV concentrator

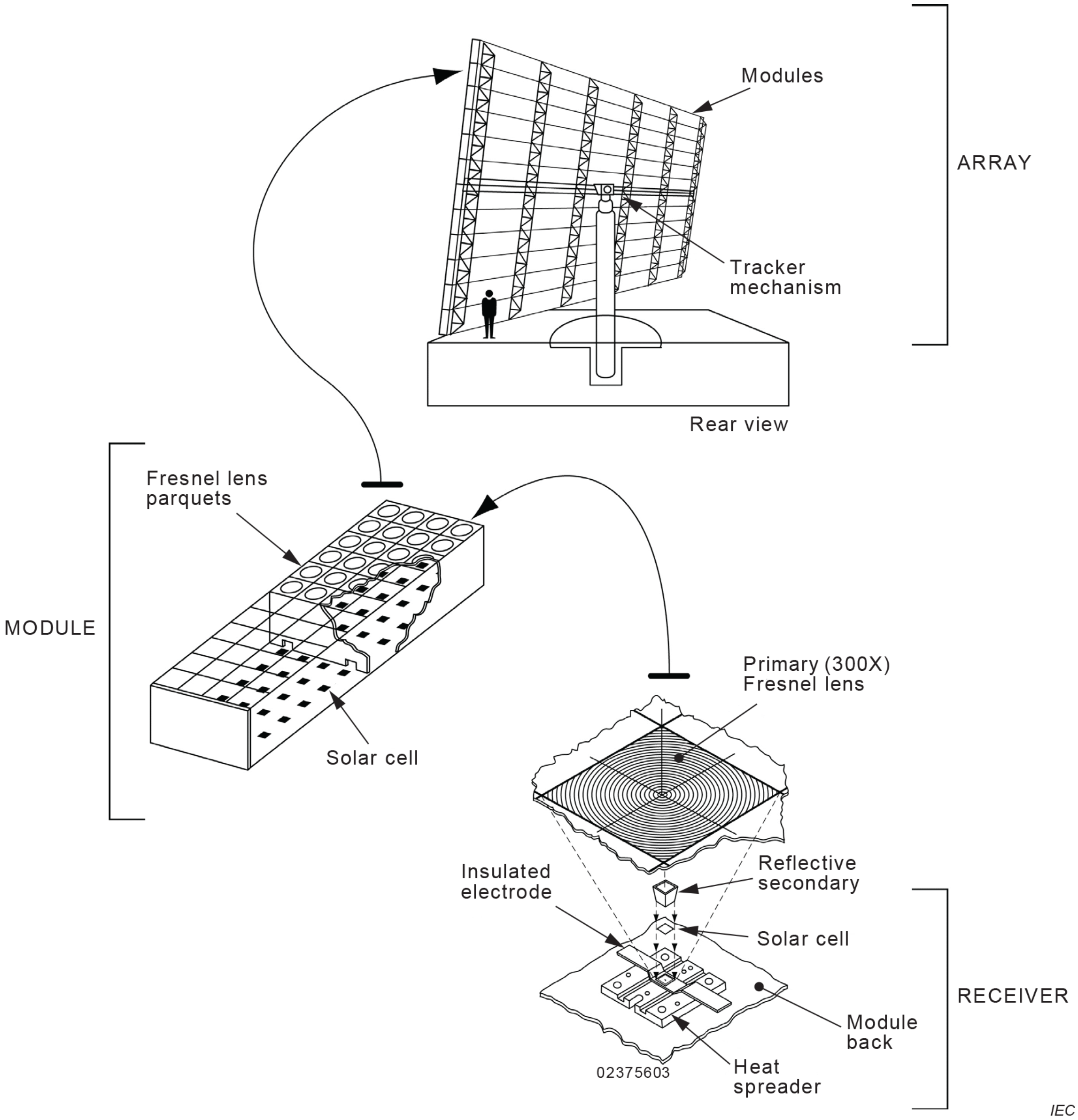


Figure 3 – Schematic of point-focus Fresnel lens PV concentrator

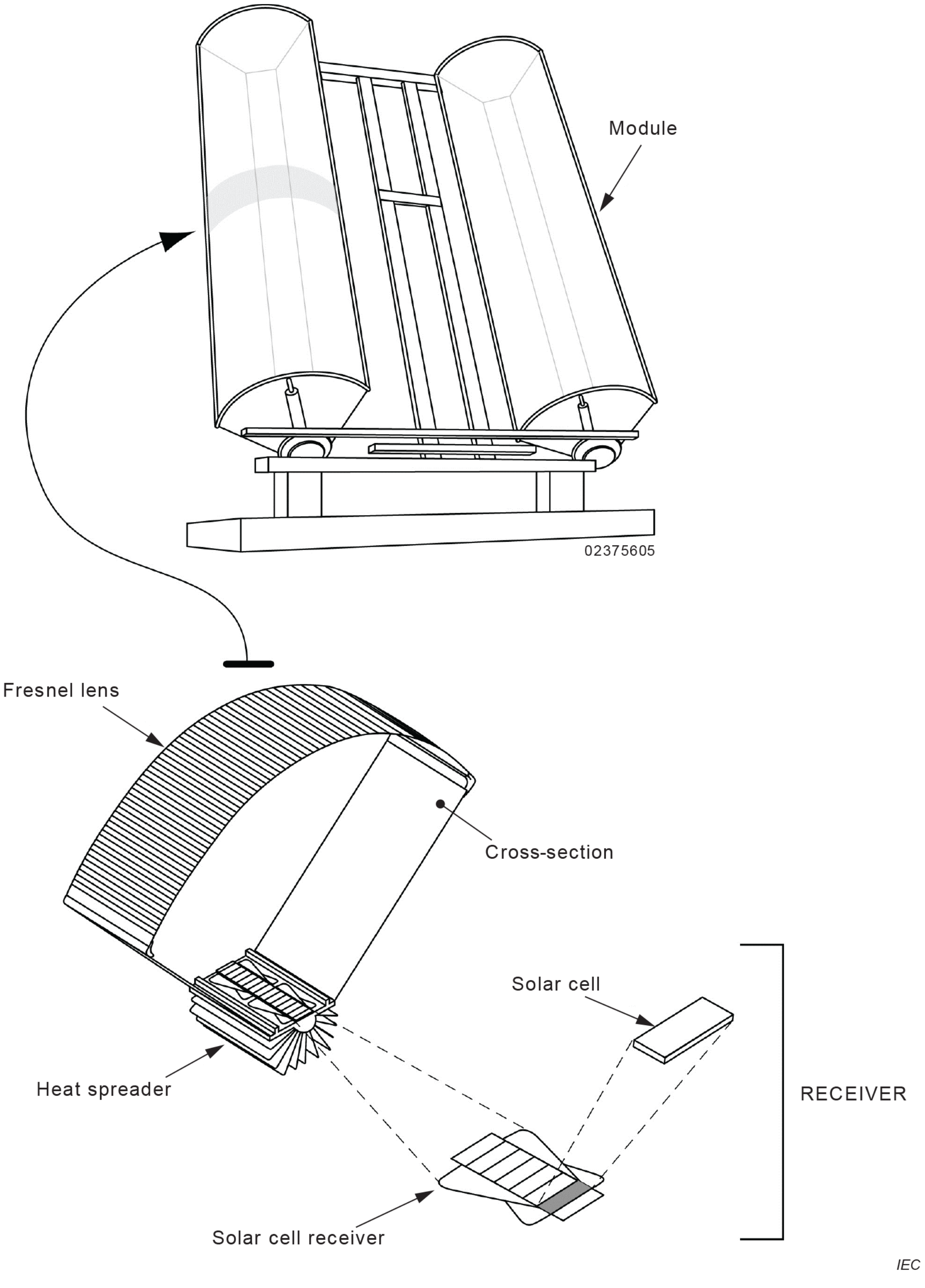


Figure 4 – Schematic of linear-focus Fresnel lens PV concentrator

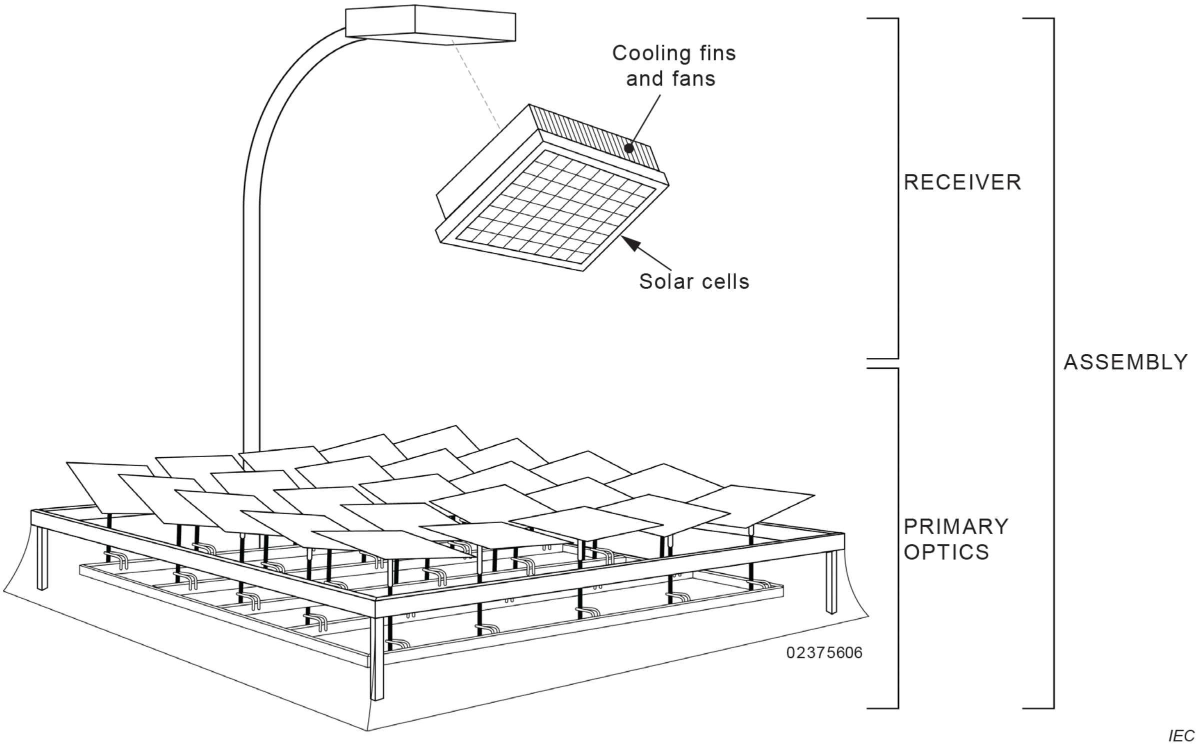


Figure 5 – Schematic of a heliostat CPV

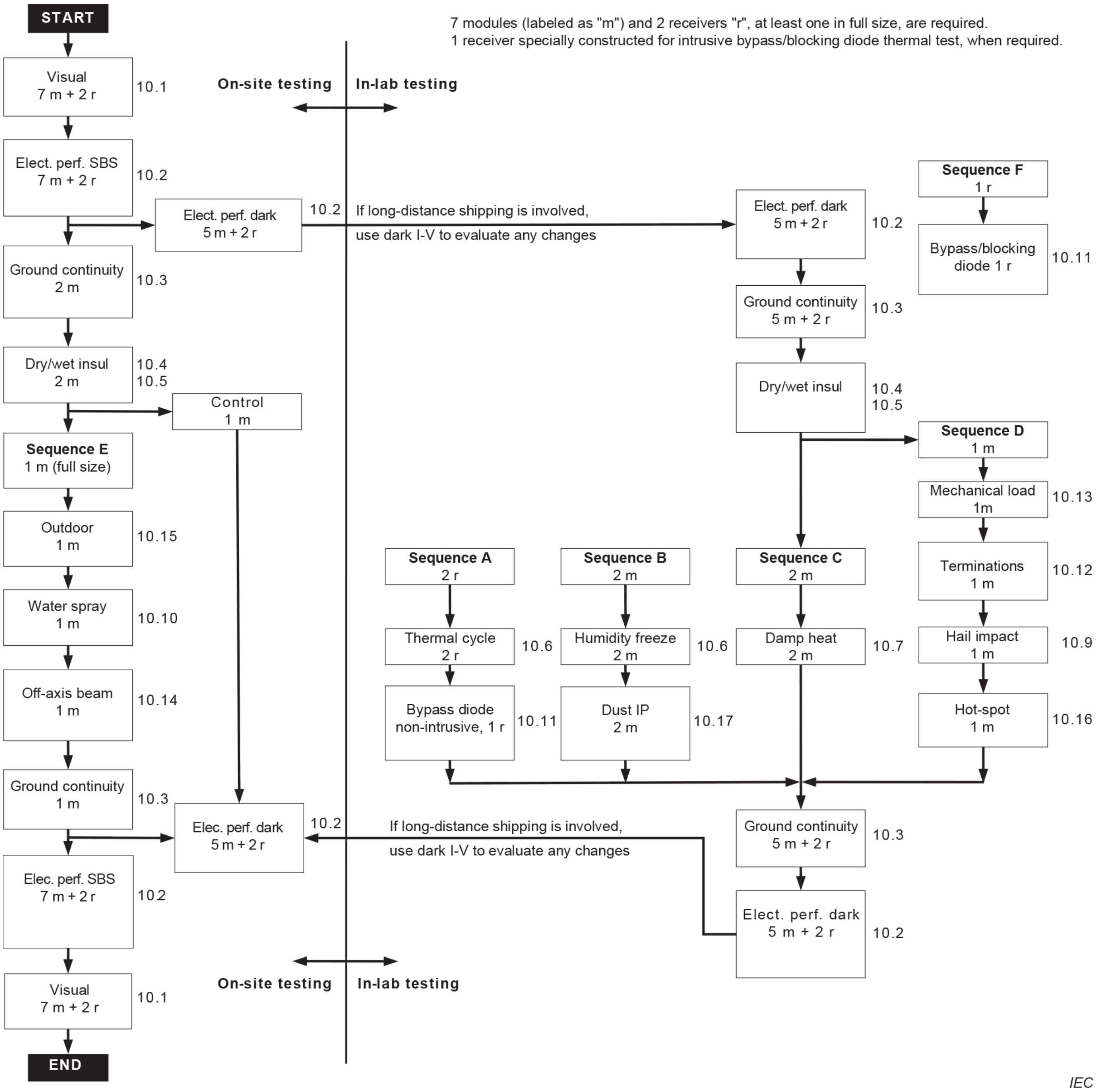


Figure 6 – Qualification test sequence for CPV modules

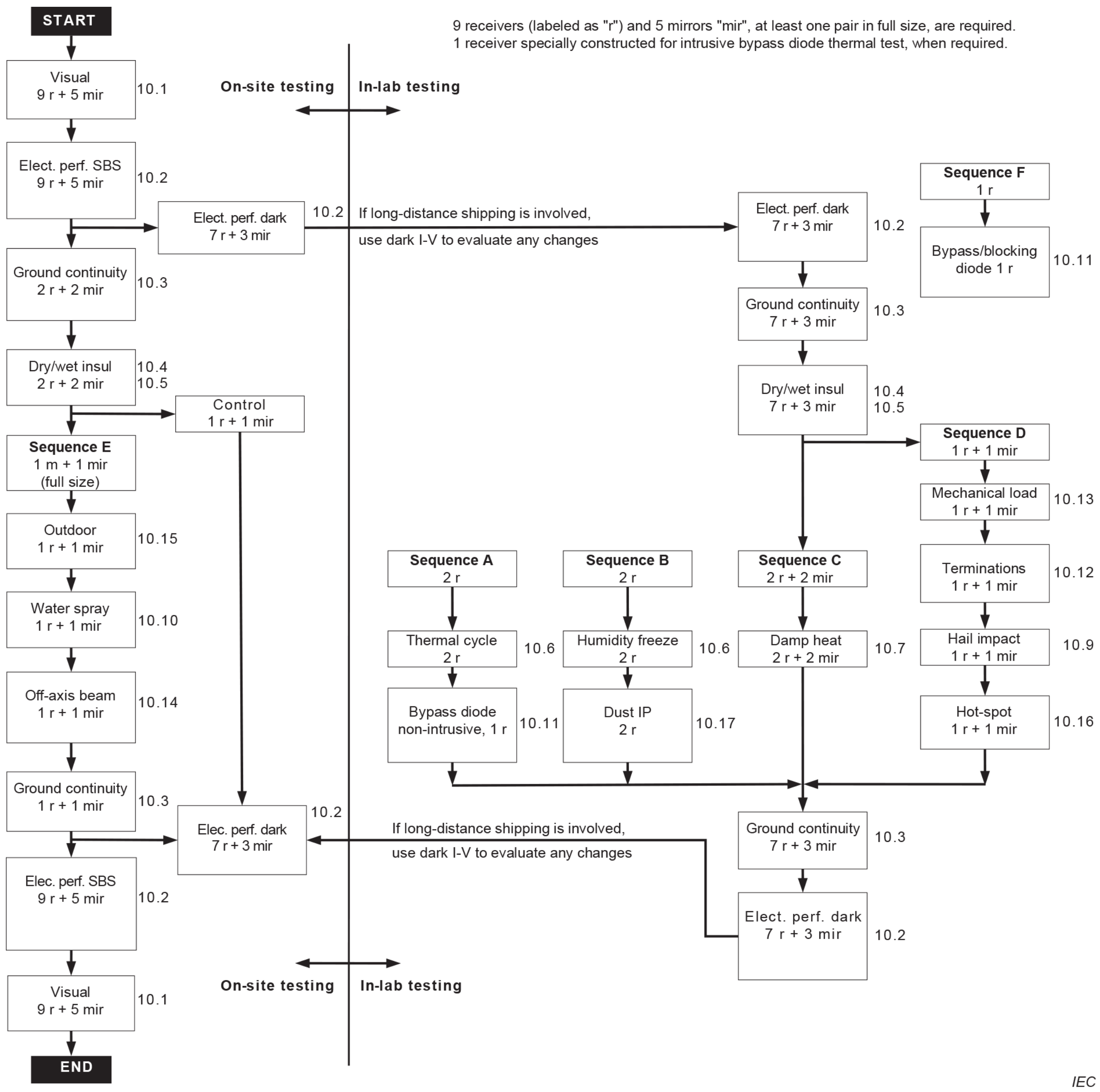


Figure 7 – Qualification test sequence for CPV assemblies

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 $M\Omega m^2$.

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 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.

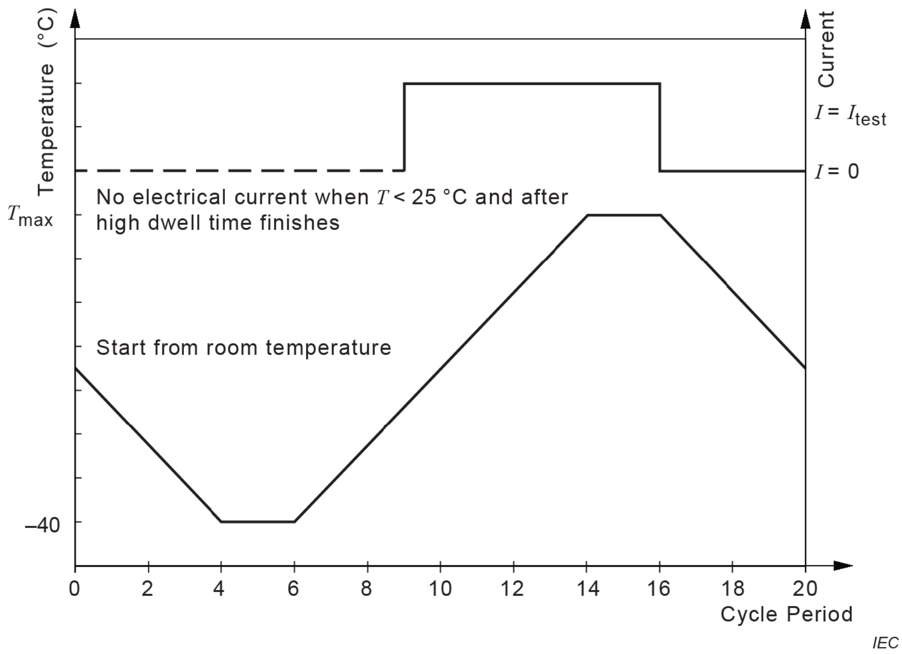


Figure 8 – Temperature and current profile of thermal cycle test (not to scale)

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.

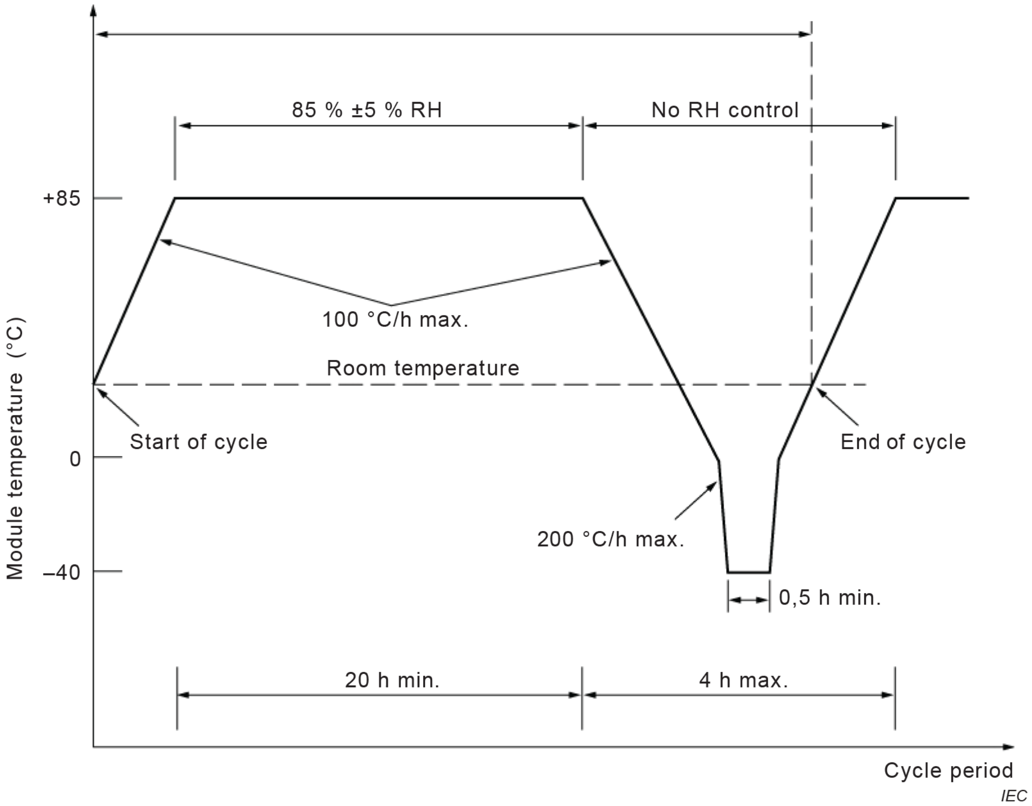


Figure 9 – Profile of humidity-freeze test conditions

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.

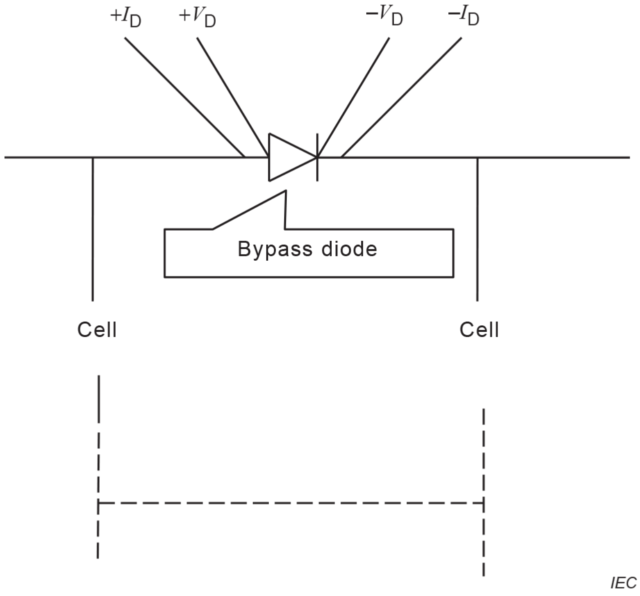
10.11.6 Procedure 2 – Alternate method

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/m^2; 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/m^2 at Pm – followed by 50 kWh/m^2 at V_{oc} with at least 1 h of DNI > 800 W/m^2. DNI < 600 W/m^2 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.

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This Indian Standard has been developed from Doc No.: ETD 28 (21239).

Amendments Issued Since Publication

Amend No.	Date of Issue	Text Affected

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Published by BIS, New Delhi