भारतीय मानक
Indian Standard

IS 16792 (Part 1/Sec 7) : 2023
IEC 62788-1-7 : 2020

फोटोवोल्टिक मॉड्यूल में प्रयुक्त सामग्री के लिए मापन प्रक्रियाएं

भाग 1-7 इनकैप्सुलेट्स — ऑप्टिकल टिकाऊपन की परीक्षण प्रक्रिया

Measurement Procedures for Materials Used in Photovoltaic Modules

Part 1-7 Encapsulates — Test Procedure of Optical Durability

ICS 27.160

भारतीय मानक ब्यूरो
BUREAU OF INDIAN STANDARDS
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NATIONAL FOREWORD

This Indian Standard which is identical with IEC 62788-1-7 : 2020 'Measurement procedures for materials used in photovoltaic modules — Part 1-7 : Encapsulates — Test procedure of optical durability' issued by the International Electrotechnical Commission (IEC) was adopted by the Bureau of Indian Standards on recommendation of the Solar Photovoltaic Energy Systems Sectional Committee and approval of the Electrotechnica Division Council.

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

a) Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'.
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 certain International Standards for which Indian Standards also exist. The corresponding Indian Standards, which are to be substituted in their respective places, are listed below along with their degree of equivalence for the editions indicated:

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
IEC 61215-2 Terrestrial photovoltaic (PV) modules — Design qualification and type approval — Part 2: Test procedures	IS 14286 (Part 2) : 2019 Terrestrial photovoltaic (PV) modules design qualification and type approval: Part 2 Test procedures (*second revision*)	Identical with IEC 61215-2 : 2016
IEC 61730-1 Photovoltaic (PV) module safety qualification —— Part 1: Requirements for construction	IS/IEC 61730-1 : 2016 Photovoltaic (PV) module safety qualification: Part 1 Requirements for construction (*first revision*)	Identical with IEC 61730-1 : 2016
IEC TS 61836 Solar photovoltaic energy systems — Terms, definitions, and symbols	IS 12834 : 2013 Solar photovoltaic energy systems terms, definitions and symbols (*first revision*)	Identical with IEC TS 61836 : 2007
IEC 62788-1-4 Measurement procedures for materials used in photovoltaic modules — Part 1-4: Encapsulants — Measurement of optical transmittance and calculation of the solar-weighted photon transmittance,yellowness index and UV cut-off wavelength	IS 16792 (Part 1/Sec 4) : 2019 Measurement procedures for materials used in photovoltaic modules: Part 1 Encapsulants, Section 4 Measurement of optical transmittance and calculation of the solar-weighted photon transmittance, yellowness index, and UV cut-off wavelength	Identical with IEC 62788-1-4 : 2016
IEC TS 62788-7-2 Measurement procedures for materials used in photovoltaic modules — Part 7-2: Environmental exposures — Accelerated weathering tests of polymeric materials	IS 16792 (Part 7/Sec 2) : 2020 Measurement procedures for materials used in photovoltaic modules: Part 7 Environmental exposures, Section 2 Accelerated weathering tests of polymeric materials	Identical with IEC TS 62788-7-2:2017

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INTRODUCTION

IEC 61215-2 (covering module design qualification and type approval) specifies a UV preconditioning of 54 $MJ \cdot m^{-2}$ (15 $kWh \cdot m^{-2}$), which would be encountered after ~40 ideal sunny days of exposure to the AM1.5G UV spectrum in IEC 60904-3. IEC 61730-2 presently specifies 4x the same UV exposure, i.e., 5 months UV dose. The International PV Quality Assurance Task Force (PVQAT) leads global efforts to craft quality and reliability standards for solar energy technologies. These standards will allow stakeholders to quickly assess a solar photovoltaic (PV) module's performance and ability to withstand weather stresses, thereby reducing risk and adding confidence for those developing products, designing incentive programs, and determining private investments. As developed in conjunction with PVQAT, this part of IEC 62788-1 is intended to supplement module qualification, which typically covers reliability issues related to infant mortality, i.e., the first months of field use. This part of IEC 62788-1 may also facilitate the pre-qualification of encapsulation materials using coupon specimens, because long term weathering is not practical for larger module specimens. This part of IEC 62788-1 also importantly uses high fidelity UV irradiation (relative to the terrestrial solar spectrum), which is not practical to apply to module specimens (due to the lack of available commercial equipment and the anticipated cost of operation).This part of IEC 62788-1 is not presently specified for pre-qualification purposes in other standards, but may be used for that purpose by module manufacturers.

The optical performance (transmittance) of polymeric frontsheets and backsheets is not covered in this part of IEC 62788-1. These components are addressed in the IEC TS 62788-2.

Indian Standard

MEASUREMENT PROCEDURES FOR MATERIALS USED IN PHOTOVOLTAIC MODULES

PART 1-7 ENCAPSULANTS — TEST PROCEDURE OF OPTICAL DURABILITY

1 Scope

IEC 61215-2 provides a set of qualification tests that indicate that a PV module design is likely to be free of flaws that will result in early failure. However, IEC 61215-2 does not address the long term wear-out of PV modules. This part of IEC 62788-1 is designed as a more rigorous qualification test, using accelerated UV exposure at elevated temperature to determine whether polymeric encapsulants can suffer loss of optical transmittance. IEC 61215-2 already includes a UV preconditioning test (MQT 10), however, the parameters for that test only represent a limited level of exposure (~weeks of UV dose). This test procedure is intended for representative coupon specimens, applying stress at a greater intensity (designed relative to Phoenix, AZ), using a radiation spectrum that is more similar to the terrestrial solar spectrum, and using a duration of exposure that is more relevant to the PV application (i.e., equivalent to several years of outdoor exposure). This test quantifies the degradation rate of encapsulants so that the risk of the materials losing optical transmittance during operation in the terrestrial environments can be managed. The quantitative correlation between climate (or location of use), a specific application (utility-installation, residential-installation, roof-mount, rack-mount, use of a tracker, the system electrical configuration and its operation), and the test can be established for each specific encapsulant material, but is beyond the scope of this document.

The method herein is intended to qualify encapsulants for use in a PV module. This document is intended to apply to encapsulants used in PV modules deployed under temperature conditions of normal use, as defined in IEC TS 63126. The use of this method for encapsulants in modules deployed under conditions of higher temperature is specified elsewhere, for example IEC TS 63126. The method here is intended to be used to examine a particular encapsulant and does not cover incompatibilities between the encapsulant and other packaging materials. This document covers PV technology constructed using a transparent incident surface/encapsulant/photovoltaic device construction, the relevance to other geometries where the encapsulant layer is located behind the photovoltaic device layer, is outside the scope of this document. In the case of bifacial cell technology, the module can accept light from its front and back surfaces – the transmittance of a frontsheet (if used), encapsulant, and transparent backsheet (if used) is relevant for both active surfaces. The optical durability of frontsheets and backsheets, however, is addressed separately in the IEC TS 62788-2. Thin coatings that might be added for antireflection or anti-soiling purposes are outside the scope of this document. The method in this document can be used for other purposes (e.g., research and development); many details of alternate uses of the method (e.g., alternate test durations or measurement increments) are not described here.

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

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

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

IEC 62788-1-4, *Measurement procedures for materials used in photovoltaic modules. Part 1-4: Encapsulants – Measurement of optical transmittance and calculation of the solar-weighted photon transmittance, yellowness index, and UV cut-off wavelength*

IEC TS 62788-7-2, *Measurement procedures for materials used in photovoltaic modules – Part 7-2: Environmental exposures – Accelerated weathering tests of polymeric materials*

IEC TS 62915, *Photovoltaic (PV) modules – Type approval, design and safety qualification – Retesting*

IEC TS 63126[1], *Guidelines for qualifying PV modules, components, and materials for operation at high temperatures*

ISO 291, *Plastics – Standard atmospheres for conditioning and testing*

ASTM G7, *Standard practice for atmospheric environmental exposure testing of nonmetallic materials*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC TS 61836 and IEC 61730-1 apply.

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

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

4 Principle

The total spectral transmittance shall be quantified using a spectrophotometer equipped with an integrating sphere (IEC 62788-1-4). Artificial weathering shall be performed at stable specified irradiance, temperature, and relative humidity conditions using an environmental chamber (IEC TS 62788-7-2). The changes in transmittance resulting from weathering shall be quantified using subsequent spectrophotometer measurement(s). The results of this artificial weathering test may be benchmarked against natural weathering, for example ASTM G7.

5 Apparatus

5.1 Spectrophotometer for transmittance measurements

A double beam or single beam spectrophotometer equipped with an integrating sphere and conforming to the requirements of IEC 62788-1-4 shall be used.

5.2 Environmental chamber for weathering

An artificial weathering apparatus shall be used, as specified in IEC TS 62788-7-2. The weathering apparatus shall meet the requirements of the artificial accelerated weathering method specified, for example IEC TS 62788-7-2, method A3.

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1 Under preparation. Stage at the time of publication: IEC/DTS 63126:2019.

6 Test specimens

6.1 Specimen components and general considerations for all material types

Specimens shall be constructed according to the geometry, methodology, and number of replicates for weathering test specimens as specified in IEC 62788-1-4.

Silica glass shall be used for the encapsulant specimens to standardize the results for the purpose of datasheet reporting of the durability. Silica glass may be used to achieve the worst-case weathering results, i.e., the most accelerated, because it is fully UV transmitting. The silica shall fulfill the requirements of IEC 62788-1-4.

To limit the propagation of localized weathering damage through the specimens, the indicated specimens should be marked (with a serial number or other identifier) on the side that is not facing the incident radiation. Because of the aggressive nature of the combined stress factors applied during artificial weathering, it is recommended to mark by physically scribing the substrate.

All specimens shall be laminated or processed in a manner similar to that used to fabricate PV modules.

6.2 Test specimens for datasheet reporting

Encapsulant specimens shall consist of glass/encapsulant/glass coupons as specified in IEC 62788-1-4.

Some module geometries are constructed using separate front encapsulant (that is UV transparent) and back encapsulant (that is not UV transparent). The durability of each encapsulant material shall be examined separately using separate coupons containing each specific material.

6.3 Use of alternate superstrate and substrate materials

For the purpose of research and development, other materials including photovoltaic glass and UV attenuating encapsulant may be used in coupon specimens. The test may reveal material specific degradation, particularly when product glass and/or encapsulants are used.

Photovoltaic glass may be used to achieve weathering that is more representative of that encountered in a PV module. Photovoltaic glass, however, shall not be used for the purpose of datasheet reporting. If a superstrate glass other than silica is used, its transmittance should be similar to the manufactured superstrate. In the case of module representative specimens, the glass used in weathering shall have a solar weighted transmittance that is equal to or greater than that of the glass used in PV modules between the UV cut-off wavelength and 400 nm. The representative glass used in weathering shall also have an initial UV cut-off wavelength within ±2,5 nm that of the glass in used in PV modules, for example the same glass from the same manufacturer. If the manufacturer’s tolerances for UV cut-off wavelength and solar weighted transmittance are available for fabricated lots of photovoltaic glass used for test specimens, then those should be used in place of the aforementioned limits.

In the case of modules using a polymeric frontsheet or superstrate that is not composed of glass, that superstrate material may be used in the encapsulant coupons for weathering in the place of glass. It is recommended to verify that the solar weighted transmittance of the superstrate is equal to or greater than that of the superstrate used in PV modules between the UV cut-off wavelength and 400 nm. The superstrate used in weathering shall also have an initial UV cut-off wavelength within ±2,5 nm the superstrate used in PV modules, for example the same superstrate material from the same manufacturer. If the manufacturer’s tolerances for UV cut-off wavelength and solar weighted transmittance are available for fabricated lots of superstrate material used for specimens, then those should be used in place of the aforementioned limits.

Because the optical characteristics of a glass or a polymeric superstrate can be affected by weathering (e.g., solarization of glass [1] [2] or discoloration of polymeric materials), it is suggested to include reference specimens of the glass or superstrate material for weathering, if the stability of the superstrate material is unknown. For superstrate or substrate materials that are known to solarize, it is suggested to artificially solarize those materials before constructing test specimens.

6.4 Witness specimens and experimental control

Measurement of witness specimens, as described in IEC 62788-1-4, shall be used to verify the measurements within each measurement session. Control measurements shall be performed at the start and end of each measurement session. Control measurements may also be performed intermediately, during the measurement session. The control measurements should be compared to quantify and correct for drift of the spectrophotometer through the weathering.

7 Measurement procedure

Transmittance measurements shall be performed as specified in IEC 62788-1-4, including the equilibration of the spectrophotometer lamp(s), baselining of the instrument, and use of witness specimen(s). Specimens with an impermeable superstrate (e.g., glass) shall be conditioned prior to optical measurements as specified in ISO 291 class 2, for example (23 ± 2) °C, (50 ± 10) % RH for at least 15 min to allow thermal equilibration. Specimens with a permeable superstrate (e.g., polymeric frontsheet) shall be conditioned prior to optical measurements as specified in ISO 291 class 2, for example (23 ± 2) °C, (50 ± 10) % RH for at least 24 h to facilitate moisture equilibration. Because the transmittance at short wavelengths may be used to diagnose the effects of weathering, it is recommended to measure the transmittance from 200 nm to 2 500 nm.

8 Artificial accelerated weathering

For encapsulants used in PV modules deployed under temperature conditions of normal use, artificial accelerated weathering shall be performed in conformance with IEC TS 62788-7-2, method A3. For encapsulants in modules deployed under conditions of higher temperature, weathering shall be performed according to IEC TS 63126.

NOTE The details of the test conditions in IEC TS 62788-7-2, including: irradiance; chamber air temperature; black panel temperature; and chamber relative humidity, are specified for reference here as IEC 62788-1-7 is developed. Details including the intent of the test conditions are also provided here to facilitate the development of IEC 62788-1-7. All of these details, however, will be removed in the final version of IEC 62788-1-7 because having them solely located in IEC TS 62788-7-2 will prevent confusion as both documents are revised in the future.

IEC TS 62788-7-2, method A3: irradiance of 0,8 $W \cdot m^{-2} \cdot nm^{-1}$, controlled at 340 nm; 65 °C chamber air temperature with a 90 °C black panel temperature; and chamber relative humidity of 20 %.

Specimens shall be conditioned prior to weathering as specified in IEC TS 62788-7-2.

9 Calculation and expression of results

Results and their corresponding uncertainty shall be calculated from the transmittance measurements, including the solar-weighted transmittance, representative solar-weighted transmittance (solar-weighted transmittance of photon irradiance transmitted throughout the range of the spectrum utilized by a representative PV device, as defined in IEC 62788-1-4), yellowness index, and UV cut-off wavelength, as specified in IEC 62788-1-4. The initial values for the characteristics and the change in their performance fallowing UV weathering shall be reported.

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2 Numbers in square brackets refer to the Bibliography.

10 Test procedure

The following test sequence shall be applied:

a) Specimen fabrication and preparation (as in IEC 62788-1-4).

b) Visual inspection (IEC 61215-2, MQT 01).

c) Specimen conditioning for measurement (as in IEC 62788-1-4 or ISO 291 class 2).

d) Initial transmittance measurement of the specimens (as in IEC 62788-1-4).

e) Transmittance measurement of the superstrate material coupon (as in IEC 62788-1-4).

At least one measurement shall be made on one coupon to verify the optical performance of the superstrate material. The requirements of silica used for datasheet reporting are specified in IEC 62788-1-4. For alternate materials used for alternate purposes, the performance of the superstrate material may also be measured after weathering is complete.

f) Specimen conditioning for weathering (as in IEC TS 62788-7-2, if applicable).

g) Weathering (as in IEC TS 62788-7-2) including up to 2 000 cumulative hours.

h) Specimen conditioning for measurement (as in IEC 62788-1-4 or ISO 291 class 2).

i) Transmittance measurement of weathered specimens (as in IEC 62788-1-4).

j) Visual inspection (IEC 61215-2, MQT 01).

k) Weathering (as in IEC TS 62788-7-2) including up to 4 000 cumulative hours.

l) Specimen conditioning for measurement (as in IEC 62788-1-4 or ISO 291 class 2).

m) Transmittance measurement of weathered specimens (as in IEC 62788-1-4).

n) Visual inspection (IEC 61215-2, MQT 01).

o) Analysis and reporting of results (as in IEC 62788-1-4).

For datasheet reporting or qualification, weathering shall be performed for 2 000 and 4 000 cumulative hours. This weathering may be performed continuously or in multiple intermittent weathering intervals up to the cumulative duration of 4 000 h.

11 Pass/fail criteria

The encapsulant fulfills the requirements of this document when each test sample meets all the following criteria:

a) the change in the representative solar photon weighted transmittance does not exceed 5 %;

b) no evidence of major defects are observed after visual inspection in accordance with MQT 01 in IEC 61215-2. Major defects include, but are not limited to, delamination or other applicable defects, as defined in the visual inspection test. The size of major defects may not exceed 5,2 mm.

If any of the test specimens do not meet these test criteria, the material shall be deemed not to have met the requirements of this document.

A test report shall be issued by the test lab to the material manufacturer. The test report shall document the results of the test, including the qualification (pass/fail) of the test material. The material manufacturer shall include the result of the qualification test in datasheet reporting and should make the qualification test result available to module manufacturers.

The test report shall apply to an encapsulant product, where no retesting is required, according to IEC TS 62915.

NOTE Specimens that do not fulfil the pass/failure criteria prior to 4 000 cumulative h of weathering can be discontinued from the test upon the agreement of the test lab and the material manufacturer. In the event of failure prior to 4 000 cumulative h, the material does not qualify for use in a PV module (fail). The measured results will be included in the test report, along with the cumulative duration used for examination.

12 Test report

A test report shall be prepared by the test agency; it shall contain the detail specification of the test specimens and shall include at least the following minimum information:

a) a title;

b) name and address of the test laboratory and location where the tests were carried out;

c) unique identification of the report and of each page;

d) name and address of client, where appropriate;

e) description and identification of the item tested, including: specimen type; specimen thickness (and its range of variation); specimen size (length and width); the type of superstrate, encapsulant, and substrate material(s) used and their characteristics, including UV cutoff wavelength;

f) characterization and condition of the test item, including the method and details of specimen preparation (including curing, lamination, or similar processing if applicable), conditioning used, and weathering;

g) date of receipt of test item and date(s) of test, where appropriate;

h) identification of test method used; including the make and model of the spectrophotometer and the integrating sphere, and the make and model of the environmental chamber;

i) reference to sampling procedure, where relevant, including the batch number, position within the roll, processing conditions, and equipment used to make the specimens;

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; and the procedure(s) and condition(s) used for weathering and any conditioning conducted prior to measurements;

k) measurements, examinations and derived results supported by tables, graphs, sketches and photographs as appropriate including the complete set of the tabulated average transmittance values and the corresponding range of the averaged values; the estimated uncertainty of the transmittance measurement (instrument); the averaged solar-weighted transmittance of photon irradiance and the corresponding range of the averaged values; the averaged representative solar-weighted transmittance of photon irradiance and the corresponding range of the averaged values (as well as the wavelength range considered); the UV cut-off wavelength and its uncertainty; and any failures observed;

l) the change in transmittance, yellowness index, and UV cut-off wavelength resulting from weathering as well as an assessment of the change relative to the pass/failure criteria; the results of visual inspection, relative to the pass/fail criteria;

m) the yellowness index and its uncertainty (which should be determined after weathering in addition to its original value);

n) the tabulated average transmittance values and corresponding characteristics and its uncertainty (averaged solar-weighted transmittance of photon irradiance, yellowness index, and UV cut-off wavelength) of the superstrate, in its unaged and weathered condition;

o) a statement of the estimated uncertainty of the test results (where relevant); the measurement of the witness specimen (if utilized) and its deviation from its witness values. When applicable, the details of the witness specimen (such as its preparation, composition, and thickness) shall be specified;

p) a statement describing the results of the visual inspection;

q) a statement describing any additional visual observations, including the color, size, location, and uniformity of discoloration of weathered specimens;

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

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

t) a statement that the report shall not be reproduced except in full, without the written approval of the laboratory;

u) other information as agreed to between the test laboratory and the customer.

Bibliography

[1] W. Thiemsorn, K. Keowkamnerd, S. Phanichphant, P. Suwannathada, H. Hessenkemper, Influence of glass basicity on redox interactions of iron-manganese-copper ion pairs in soda-lime-silica glass, Glass Phys. Chem., 34 (2008), 19-29

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

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

IEC 62788-2 (all parts), *Measurement procedures for materials used in photovoltaic modules*

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(*Continued from second cover*)

International Standard	*Corresponding Indian Standard*	Degree of Equivalence
IEC TS 62915 Photovoltaic (PV) modules — Type approval, design and safety qualification — Retesting	IS/IEC TS 62915 : 2018 Photovoltaic (PV) modules type approval, design and safety qualification retesting	Identical with IEC TS 62915 : 2018

The technical committee has reviewed the provisions of the following International Standards referred to in this adopted standard and has decided that they are acceptable for use in conjunction with this standard.

International Standard	*Title*
IEC TS 63126	Guidelines for qualifying PV modules, components, and materials for operation at high temperatures
ISO 291	Plastics — Standard atmospheres for conditioning and testing
ASTM G7	Standard practice for atmospheric environmental exposure testing of nonmetallic materials

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 or analysis shall be rounded off in accordance with IS 2 : 2022 ‘Rules for rounding of 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.

Bureau of Indian Standards

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Review of Indian Standards

Amendments are issued to standards as the need arises on the basis of comments. Standards are also reviewed periodically; a standard along with amendments is reaffirmed when such review indicates that no changes are needed; if the review indicates that changes are needed, it is taken up for revision. Users of Indian Standards should ascertain that they are in possession of the latest amendments or edition by referring to the website-www.bis.gov.in or www.standardsbis.in.

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Amendments Issued Since Publication

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