IEC 62788-1-7

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INTERNATIONAL STANDARD

NORME INTERNATIONALE

**Measurement procedures for materials used in photovoltaic modules –
Part 1-7: Encapsulants – Test procedure of optical durability**

**Procédures de mesure des matériaux utilisés dans les modules photovoltaïques –
Partie 1-7: Encapsulants – Procédure d'essai de la durabilité optique**

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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MEASUREMENT PROCEDURES FOR MATERIALS USED IN PHOTOVOLTAIC MODULES –

Part 1-7: Encapsulants – Test procedure of optical durability

FOREWORD

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International Standard IEC 62788-1-7 has been prepared by IEC technical committee 82: Solar photovoltaic energy systems.

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

FDIS	Report on voting
82/1669/FDIS	82/1704/RVD

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

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 62788 series, published under the general title *Measurement procedures for materials used in photovoltaic modules*, can be found on the IEC website.

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

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- withdrawn,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

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.

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

[2] Numbers in square brackets refer to the Bibliography.

for the characteristics and the change in their performance following UV weathering shall be reported.

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.