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CONSOLIDATED VERSION

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

**Measurement procedures for materials used in photovoltaic modules –
Part 5-1: Edge seals – Suggested test methods for use with edge seal materials**

**Procédures de mesure des matériaux utilisés dans les modules photovoltaïques –
Partie 5-1: Joints d’étanchéité périphériques – Méthodes d’essai suggérées pour l’utilisation des matériaux de joints d'étanchéité périphériques**

IEC 62788-5-1:2020-03+AMD1:2022-01 CSV(en-fr)

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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IEC 62788-5-1 edition 1.1 contains the first edition (2020-03) [documents 82/1658/FDIS and 82/1689/RVD] and its amendment 1 (2022-01) [documents 82/1973/FDIS and 82/1991/RVD].

In this Redline version, a vertical line in the margin shows where the technical content is modified by amendment 1. Additions are in green text, deletions are in strikethrough red text. A separate Final version with all changes accepted is available in this publication.

International Standard IEC 62788-5-1 has been prepared by IEC technical committee 82: Solar photovoltaic energy systems.

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 the base publication and its amendment will remain unchanged until the stability date indicated on the IEC web site under webstore.iec.ch in the data related to the specific publication. At this date, the publication will be

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- withdrawn,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

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MEASUREMENT PROCEDURES FOR MATERIALS USED IN PHOTOVOLTAIC MODULES –

Part 5-1: Edge seals – Suggested test methods for use with edge seal materials

1 Scope

This part of IEC 62788 provides procedures for standardized test methods for evaluating the properties of materials designed to be used as edge seals. When modules are constructed with impermeable (or extremely low permeability) front- and backsheets designed to protect moisture-sensitive photovoltaic (PV) materials, there is still the possibility for moisture to get in from the sides. This moisture ingress pathway can be restricted by using a low-diffusivity material around the perimeter of a module between the impermeable front- and backsheets. Alternatively, it can be desirable to use a low-diffusivity encapsulant, which may significantly reduce moisture ingress over the lifetime of the module, and to evaluate it in a similar way to an edge seal material.

In addition to restricting moisture ingress, edge seal materials also provide electrical insulation. To perform these functions, edge seal materials are relied upon to adhere well.

The test methods described in this document are intended to be used to standardize the way edge seals are evaluated. The use of tests in this document does not evaluate compatibility with other materials or appropriateness for a given technology. Only some of these tests are applied for IEC 61215 and IEC 61730, and that status depends on the specific design. It is not required that all of these tests be performed, but that if these measurements are made that they be performed as outlined 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 60112, *Method for the determination of the proof and the comparative tracking indices of solid insulating materials*

IEC 60243-1~~:2013~~, *Electrical strength of insulating materials – Test methods – Part 1: Tests at power frequencies*

IEC 60243-2~~:2013~~, *Electrical strength of insulating materials – Test methods – Part 2: Additional requirements for tests using direct voltage*

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

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

IEC 60695-11-10, *Fire hazard testing – Part 11-10: Test flames – 50 W horizontal and vertical flame test methods*

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

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

IEC 62788-1-2, *Measurement procedures for materials used in photovoltaic modules – Part 1-2: Encapsulants – Measurement of volume resistivity of photovoltaic encapsulants and other polymeric materials*

IEC TS 62788-2:2017, *Measurement procedures for materials used in photovoltaic modules – Part 2: Polymeric materials – Frontsheets and backsheets*

IEC 62788-6-2, *Measurement procedures for materials used in photovoltaic modules – Part 6-2: General Tests – Moisture permeation testing with polymeric materials*

ISO 62, *Plastics – Determination of water absorption*

ISO 1133-1, *Determination of the melt mass-flow rate (MFR) and melt volume-flow rate (MVR) of thermoplastics – Part 1: Standard method*

ISO 4587, *Adhesives – Determination of tensile lap-shear strength of rigid-to-rigid bonded assemblies*

ISO 6721-6, *Plastics – Determination of dynamic mechanical properties – Part 6: Shear vibration – Non-resonance method*

ISO 11359-2, *Plastics – Thermomechanical analysis (TMA) – Part 2: Determination of coefficient of linear thermal expansion and glass transition temperature*

ISO 11443, *Plastics – Determination of the fluidity of plastics using capillary and slit-die rheometers*

ISO 15512, *Plastics – Determination of water content*

UL 746B, *Polymeric materials – Long term property evaluations*

UL 746C, *Polymeric materials – Use in electrical equipment evaluations*

ASTM D3835–08, *Standard test methods determination of properties of polymeric materials by means of a capillary rheometer*

ASTM D6869–03, *Standard test method for coulometric and volumetric determination of moisture in plastics using the Karl Fischer reaction (the reaction of iodine with water)*

ASTM D7191–10, *Standard test method for determination of moisture in plastics by relative humidity sensor*

3 Terms, definitions and symbols

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

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

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

3.1 Terms and definitions

3.1.1
edge seal
polymeric material designed to be placed between two impermeable (or with extremely low permeability) frontsheet and backsheet materials to restrict moisture ingress from the sides

3.1.2
Fickian
material for which the diffusivity is constant, independent of the concentration of the permeant within the experimental uncertainty

3.2 Symbols

$t_{10\,\%}$	time required for an edge seal to reach 10 % of its equilibrium water vapour transmission rate [h]
$K_{10\,\%}$	10 % moisture ingress breakthrough proportionality constant [cm·h$^{-0,5}$]
$K_{o10\,\%}$	Arrhenius prefactor for $K_{10\,\%}$ [cm·h$^{-0,5}$]
$Ea_{K10\,\%}$	Arrhenius activation energy for $K_{10\,\%}$ [cm·h$^{-0,5}$]
X	edge seal film thickness [mm]
D	Fickian diffusivity at a given temperature [cm^2/s]
D_o	Arrhenius prefactor for diffusivity [cm^2/s]
Ea_D	Arrhenius activation energy for diffusivity [kJ/mol]
S	maximum absorption of moisture in a material in equilibrium with liquid water [g/cm^3]
S_{IR}	irreversible absorption capacity of moisture in a material [g/cm^3]
S_o	Arrhenius prefactor for solubility [g/cm^3]
Ea_S	Arrhenius activation energy for solubility [kJ/mol]
P	permeability [g·mm·m^{-2}·day^{-1}]
P_o	Arrhenius prefactor for permeability [g·mm·m^{-2}·day^{-1}]
Ea_p	Arrhenius activation energy for permeability [kJ/mol]

4 Recommended tests

4.1 General

This document is intended to be used as a guideline for presenting edge seal data. When the properties outlined in this document are reported, they shall be reported as measured using the outlined methods. A datasheet may include more data, or less data, than the list of tests outlined. The tests outlined are recommendations only.

4.2 Moisture permeation properties

4.2.1 Moisture breakthrough time

10 % moisture ingress breakthrough proportionality constant [$K_{10\,\%}$, ($X = K_{10\,\%} \cdot t_{10\,\%}{}^{1/2}$)] at (85 ± 2) °C as determined in IEC 62788-6-2. Include activation energy if available. For a Fickian material, $K_{10\,\%} = 3{,}89 \cdot D^{1/2}$.

4.2.2 Fickian materials

Permeability (P) at (85 ± 2) °C steady state. Include activation energy (Ea_p) if available.

If the material is Fickian, report the diffusivity (D) at (85 ± 2) °C and activation energy for diffusivity (Ea_D) as determined from IEC 62788-6-2. Also indicate the temperature range over which the diffusivity was measured.

If the material is Fickian, report the solubility (S) at (85 ± 2) °C and activation energy for solubility as determined from IEC 62788-6-2. Also indicate the temperature range over which the solubility was measured.

4.2.3 Non-Fickian materials

For non-Fickian materials, report the solubility (S) at (85 ± 2) °C using ISO 62, ASTM D7191-10, ASTM D6869-03, or ISO 15512. Samples should be equilibrated at temperature while placed in a sealed container with water, but not in contact with the water. The use of sufficient sample equilibration time shall be verified by testing multiple samples at progressively longer times. Samples should be tested immediately after removal from the container because of the potential for the evaporation of moisture.

If applicable, also report the irreversible solubility (S_{IR}) by measuring the reversible absorption of a sample saturated at (85 ± 2) °C using ISO 15512, ASTM D7191-10 or ASTM D6869-03 and subtracting that from S.

NOTE If the sample contains desiccant, ASTM D7191-10 and ASTM D6869-03 may not work because the water may be irreversibly adsorbed. Furthermore, for molecular sieve-type desiccants, the time required to remove trace amounts of water fully from the desiccant can severely limit the accuracy of these methods and the temperature required to dry the samples can cause other volatile molecules to evaporate.

4.3 Electrical properties

4.3.1 Dielectric strength of the film

Perform a measurement of dielectric strength in accordance with IEC 60243-2 for a DC test. This shall conform to IEC TS 62788-2:2017, 4.5.1 and IEC TS 62788-2:2017, Annex C. Use a material thickness that is useable at a practical voltage, which is rarely greater than 100 kV DC, for the testing equipment. The surfaces of the samples shall be free of volumetric defects (e.g. bubbles, voids or foreign particles) and be made smooth, which may require curing according to the manufacturer's specifications.

~~Measure and report values before and after saturation with water to duplicate conditions after the desiccant is spent. For the saturated samples, precondition at (85 ± 2) °C and (85 ± 5) % relative humidity (RH) prior to testing. Allow materials to equilibrate at room temperature prior to testing. Ensure that saturated samples do not dry out before testing, but one may remove any water droplets from the surface. The amount of time needed for equilibration will be determined by the manufacturer such that the mass of the sample does not increase over the course of 24 h.~~

Materials shall be tested in a surrounding medium selected to prevent flashover as indicated in IEC 60243-1 and IEC 60243-2. The short-time (rapid-rise) method (see IEC 60243-1~~:2013~~, 10.1) shall be used with a voltage rise of 2 000 V·s^{-1} unless breakdown occurs in less than 10 s. Equal diameter electrodes measuring (25 ± 1) mm shall be used as indicated in IEC 60243-1~~:2013~~, 5.2.1.2.

NOTE In IEC 61730-1:2016, 5.6.4.3, requirements for the dielectric test~~ing~~ are described for that document. This test method only applies if the edge seal material is part of "relied upon insulation". Because of the potential of polyisobutylene (PIB) based desiccants to absorb or to dissolve in mineral oil, this test is performed as quickly as is reasonable.

4.3.2 Volume resistivity

Volume resistivity in accordance with IEC 62788-1-2. Test before and after saturation with water to evaluate the properties of the material with the spent desiccant. Condition at room temperature in a sealed package to prevent moisture exposure for the "before exposure" condition. Precondition at (85 ± 2) °C and (85 ± 5) % RH prior to testing. The manufacturer shall determine the amount of time needed to fully saturate the desiccant (if applicable) and fill the material with moisture such that the weight no longer increases over time.

NOTE In IEC 61730-1:2016, 5.6.4.2, if the edge seal functions as a cemented joint, then in the context of IEC 61730-1 it has a volume resistivity greater than 50 × 10^6 Ω·cm when dry and greater than 10 × 10^6 Ω·cm when wet. For most polymeric materials, these values would be expected to be exceeded by many orders of magnitude.

4.3.3 Comparative tracking index

Comparative tracking index (CTI) in accordance with IEC 60112 or UL 746C.

NOTE If the material is used as the relied upon insulation, then in the context of IEC 61730-1 the CTI determines the material group that is then used to define the creepage distance. If the edge seal is considered a cemented joint in the PV module, then IEC 61730-1 does not use creepage and clearance distances, but distances through cemented joints.

4.4 Adhesion test~~ing~~

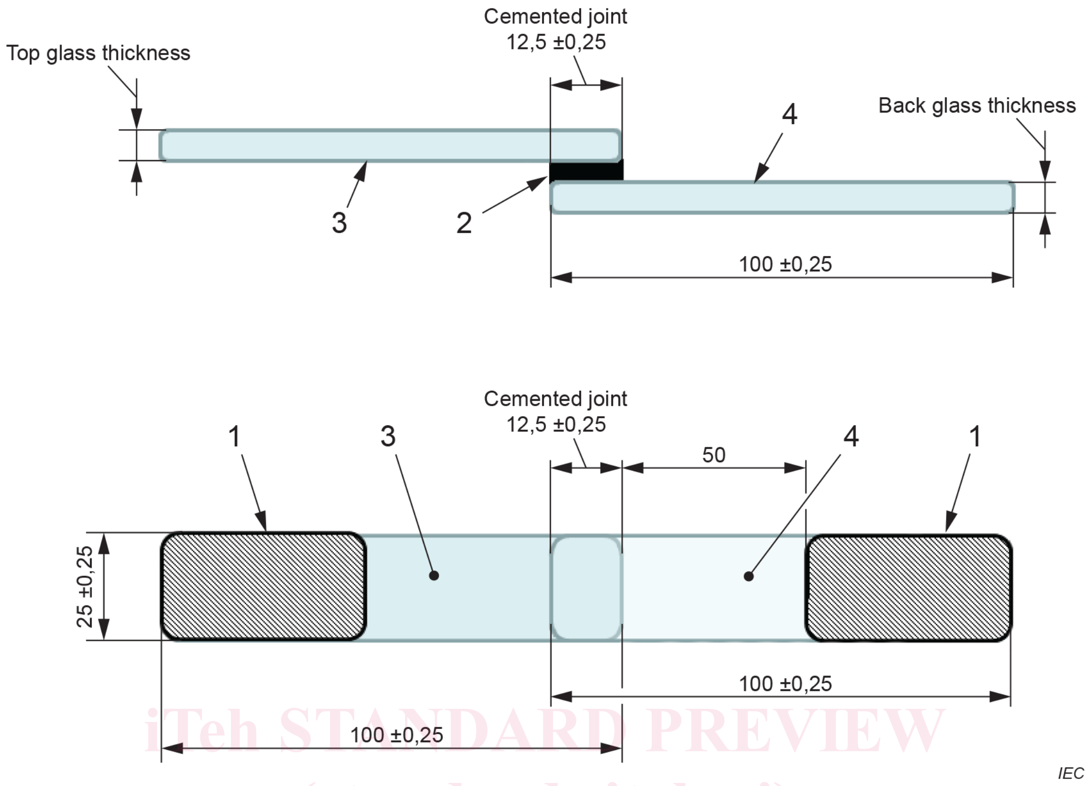
4.4.1 General

Adhesion testing is designed to conform to the data necessary to consider the edge seal being listed as a cemented joint in accordance with IEC 61730-2. As such, the strength is reported as the average and standard deviation of 10 replicate measurements.

4.4.2 Lap shear strength

Lap shear strength at (23 ± 2) °C in accordance with ISO 4587 using a sample thickness of (0,5 ± 0,1) mm, an overlap area of (25 ± 0,25) mm × (12,5 ± 0,25) mm, and a ~~strain~~ pull rate of (0,8 ± 0,01) mm·min^{-1} (see Figure 1, taken from Figure 11 in IEC 61730-2:2016.) Typically, at least one substrate in a PV module will be glass; therefore, testing is accomplished with photovoltaic soda lime glass. If one of the substrate surfaces in the module application is not glass and is a rigid substrate, then that substrate shall be tested.

Dimensions in millimetres



Key:

1 area held in grips

2 cemented joint

3 PV module front glass

4 PV module back glass

NOTE Schematic taken from IEC 61730-2:2016, Figure 11.

Figure 1 – Lap shear test sample for proving cemented joint

NOTE ISO 4587 specifies that the test should take (65 ± 20) s or use a shear load rate of 8,3 MPa·min^{-1} to 9,8 MPa·min^{-1}. Edge seals typically fail at between 200 % and 600 % strain at around 0,5 MPa. For a sample 0,5 mm thick, the pull rate is between ~~1 mm·min^{-1} and 3 mm·min^{-1}~~ 0,76 mm min^{-1} and 4 mm min^{-1}, but IEC 61730 specifies 0,8 mm·min^{-1}. If the shear load rate is used, edge seals would be expected to fail in around 3 s to 3,6 s.

4.4.3 "T" peel test

For applications with flexible substrates or superstrates test the adhesion strength as a peel test. Samples shall be tested in a "T" peel configuration in accordance with IEC 61730-2:2016, 10.24 (MST 35). Always use the complete superstrate and substrate laminates in the test sample because the mechanics of the adherend will affect the loading properties and the final values. Use two sets of samples, one comprising only superstrates, and another comprising only substrates. This serves to test adhesion to both surfaces and may make it easier to maintain angles of (90 ± 10)° as specified in MST 35. The pull rate shall be (50 ± 5) mm·min^{-1}. The sample width shall be (10 ± 1) mm. Condition the samples for at least 16 h at (23 ± 2) °C, or according to the edge seal manufacturer's recommendation, prior to testing.

4.4.4 90° peel test

For applications with flexible to rigid substrates, IEC 61730-2:2016, 10.24 (MST 35) specifies a 90° peel test. Because the substrate choice can dramatically affect the adhesion strength, results from the "T" peel test may not be sufficient to give confidence that the set of materials will pass the cement joint evaluation in a 90° configuration. Use the same combination of rigid and flexible substrates as is intended for the application. Pull at (50 ± 5) mm·min^{-1}. Use a long enough shaft or use a sliding sample holder such that the angle is always (90 ± 5) °. For these samples, the test area width shall be (10 ± 1) mm wide for the flexible substrate, but the rigid substrate can be of any dimension practical (e.g. laminate the flexible substrate to the rigid one and cut test strips to the correct width).

4.4.6 180° peel test

The peel test may also be performed with a 180° pull test as recommended by the backsheet standard IEC TS 62788-2:2017, Clause B.1.

4.4.5 Butt joint test

This test is conducted by preferably sampling from a production PV module, but can also be accomplished using a module mock-up or mini-module. ~~Rectangular~~ Test specimens are cut from the edge seal-covered perimeter. The total sample area shall be between 0,5 cm^2 and 1,5 cm^2, and the maximum aspect ratio of the largest and smallest dimension shall be less than 1,5. This means that rectangular or even circular samples may be used. But in coring a sample, caution shall be used to ensure the samples are not damaged by torque. If cut from a production module, it is recommended that one side of the test specimen shall have a length equal to the width of the edge seal (typically 1 cm to 1,5 cm) and the other should be of a similar length within ±25 %. Test specimens may be cut out using any method that is convenient so long as it produces a clean cut and does not significantly deform the samples. For glass test specimens, it is recommended that cutting be accomplished using a wet saw or a water jet saw. Flexible substrates may be cut out using shears, a saw, or any other appropriate means. One may also use engineered coupons with pre-cut superstrate and substrate material. If this is done the thermal treatment and material thickness shall be taken.

To test the specimens, they shall be mounted to a handle. This is accomplished by adhering bolts to each side of the test specimen, creating a mounted test sample for pulling the joint apart. Elevator bolts have a large flat surface suitable for adhesion. However, any bolt type may be used so long as it is large enough to cover the entire surface of the test specimens. Epoxy-based adhesives have been demonstrated to work well enough to carry out the adhesion test, but it may require some trial and error effort to find the best one for each material. The bolts shall be adhered such that the bolt axis goes through the center of the samples and such that the two bolts are parallel. Mounted test samples may be assembled by securing the bottom bolt's flat side upright and adhering the test specimen making sure it is centered and that the surfaces are parallel. Once the adhesive is sufficiently cured, the top bolt is adhered to the test specimen and positioned to be parallel and centered with respect to the other bolt.

For tempered glass samples, all glass fragments shall remain adhered to the bolt's surface after testing. Similarly, for flexible substrates, all the surface test area shall remain adhered to the bolt surfaces. For flexible substrates, there can be concerns with the adhesive used to attach to the bolt, squeezing out of the sides of the samples and directly adhering the bolts together. Because of this, thin substrates may be glued to the bolts before being cut out of the module and then subsequently cut out along the perimeter of the bolt. Another method would be to cut the test specimen to the exact size of the bolt, then, upon assembly, excess adhesive would be scraped off from the sides.

Using a load frame with grips attached to the specimen bolts (Figure 2a)), pull the samples apart using a load frame displacement rate of 1 mm·min^{-1} while recording the applied force. The stress at failure, σ_{max}, is the ratio of the maximum applied force, F_{max}, to the sample area A,