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NORME INTERNATIONALE

Measurement procedures for materials used in photovoltaic modules –
Part 7-3: Accelerated stress tests – Methods of abrasion of PV module external surfaces

Procédures de mesure des matériaux utilisés dans les modules photovoltaïques –
Partie 7-3: Essais sous contraintes accélérés – Méthodes d’abrasion des surfaces externes des modules photovoltaïques

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MEASUREMENT PROCEDURES FOR MATERIALS USED IN PHOTOVOLTAIC MODULES –

Part 7-3: Accelerated stress tests – Methods of abrasion of PV module external surfaces

FOREWORD

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IEC 62788-7-3 has been prepared by IEC technical committee 82:Solar photovoltaic energy systems. It is an International Standard.

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

Draft	Report on voting
82/1987/FDIS	82/2009/RVD

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

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

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

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 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- withdrawn,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

There is a need for abrasion test methods in the PV industry, particularly for the front and back surfaces of PV modules. This document defines a set of test methods to be used for evaluating the abrasion of materials and coatings in photovoltaic modules or other solar devices. Linear and rotary machine abrasion methods are specified that can be used to address durability to abrasion with respect to the cleaning of solar devices. Linear abrasion is intended to emulate traditional manual methods of cleaning, where the cleaning equipment typically acts perpendicular to the surface, giving a scratching motion. Rotary abrasion is intended to emulate popular robotic methods of cleaning, where the cleaning element often may act along the surface in a swiping motion. Relative to DIN 53778-2 and ASTM D2486, application specific modifications for the machine abrasion tests include the longer bristle length, use of abrasive (test dust) of the size encountered in PV, the use of dry or wet abrasive as may be encountered during cleaning modules, and the number of test cycles relative to the maintenance of PV systems. A falling sand method is specified that can be used to address durability to abrasion with respect to damage from ordinary use in the application environment, i.e., typically meteorological events. Relative to DIN 52348, modifications include the quantity of test sand, which is intended for examination of PV surfaces and coatings. A forced sand impingement method is specified that can be used to address durability to abrasion from severe weather events and/or the most challenging locations of use. Relative to IEC 60068-2-68, modifications include the composition of test sand that may be compared to the PV application and the falling sand test in this document as well as the specified carrier velocities based on the PV application. The methods in this document can be used to aid performance analysis and/or for the purpose of material design/selection. Comparing the linear brush, rotary brush, falling sand, and forced impingement methods, different rates of abrasion and/or damage morphology can occur between the different test methods – they are not expected to produce the same result.

Formal working reference materials are identified in this document. The purpose of the working reference is to verify the apparatus is installed and working correctly. The characteristic(s) of interest can be verified on a regular basis (monthly, weekly, etc.). The characteristic(s) of interest and their values (with acceptance limits for precision) will be given in a referencing document or future version of this document, based on the results of an interlaboratory precision study.

MEASUREMENT PROCEDURES FOR MATERIALS USED IN PHOTOVOLTAIC MODULES –

Part 7-3: Accelerated stress tests – Methods of abrasion of PV module external surfaces

1 Scope

This part of IEC 62788 defines the test methods that can be used for evaluating the abrasion of materials and coatings in photovoltaic modules or other solar devices. This document may be applied to components on the incident surface (including coatings, frontsheet, and glass) as well as the back surface (including backsheets or back glass). This document is intended to address abrasion of PV module surfaces and any coatings present using representative specimens (e.g. which can be centimetres in size); the methods and apparatus used here can also be used on PV module specimens (e.g. meters in size). A suite of tests and their methods are identified in this document, including falling sand, forced sand impingement, and machine (brush) abrasion. Materials and coatings can have different intended design purposes and design lifetimes and therefore no specific pass/fail criteria are defined in this document. The results of the testing can, however, be used to identify relative durability of coatings for various outdoor environments and cleaning practices. The methods can be used for the purpose of relative comparison, e.g. for the purpose of material or coating selection. The quantitative correlation between artificial abrasion and field erosion (which will depend on factors including climate or location of use as well as application, e.g., use of a tracker, rack-mount, roof-mount, building integrated, or vehicle integrated PV) can be established for each specific material or coating, which is beyond the scope of this document.

The correlation between the rates of degradation from the different test methods (linear brush, rotary brush, falling sand, and forced impingement) is beyond the scope of this document and may be covered in referencing documents. The correlation between the rates of degradation for unaged and aged specimens is also beyond the scope of this document and may be covered in referencing documents.

The methods related to the characterization of abraded specimens (which might include optical transmittance, optical reflectance, surface roughness, and surface energy) are not defined in this document; characterization methods from other standards (including optical transmittance, optical reflectance, electrical performance, surface roughness, and surface energy) can be applied to specimens abraded using the methods defined in this document. Methods for examining the contamination of specimens, including artificial soiling, are not examined in this document. Additional specimen conditioning can be applied prior to the methods in this document. The abrasion tests in this document can be referenced and/or applied in conjunction with an accelerated test or test sequence in other standards.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60068-2-68, *Environmental testing – Part 2-68: Tests – Test L: Dust and sand*

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

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

ISO 12103-1, *Road vehicles – Test contaminants for filter evaluation – Part 1: Arizona test dust*

ASTM D2486, *Standard test methods for scrub resistance of wall paints*

DIN 52348:1985-02, *Testing of glass and plastics; abrasion test; sand trickling method*

DIN 53778-2:1983-08, *Emulsion paints for interior use; evaluation of cleanability and of wash and scrub resistance of coatings*

MIL-STD-810G, *Environmental engineering considerations and laboratory tests*

VDI 3956, *Evaluation of the soiling properties of surfaces – Test method for the dust soiling behaviour of solar energy systems*

3 Terms and definitions

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
artificial abrasion
wear resulting from the cleaning of a PV device, including manual or robotic cleaning

3.2
natural erosion
wear resulting from the ordinary terrestrial use of a PV device

Note 1 to entry: Sources of erosion may include particulate impingement, particulate transport (from wind or water), or autonomous scraping (from snow or ice by gravity).

4 Artificial linear machine abrasion test (SAT01)

4.1 Principle

The machine abrasion methods are specified that can be used to address durability to abrasion with respect to the cleaning of solar devices. Linear abrasion is intended to emulate traditional manual methods of cleaning, where the cleaning equipment typically acts perpendicular to the surface, giving a scratching motion. The test is typically applied to the irradiance incident surface of a PV module. Because either dry or wet cleaning may be used to clean a PV module, both dry and wet (slurry) abrasives may be used in this test. The test may simulate the cleaning of fixed, tracked, or vehicle integrated PV.

4.2 Apparatus

4.2.1 Artificial linear machine abrasion apparatus

A linear abrasion apparatus fulfilling the requirements of ASTM D2486 or DIN 53778-2 shall be used. Essential components of the apparatus include: a linear abrasion mechanism, a brush, an abrasive dispenser (slurry or dry abrasive), and an enclosure (if applicable). An enclosure is recommended for the apparatus to prevent spilling or spraying of abrasive (dry or wet slurry abrasives) or the possibility of silicosis (with ventilation, for dry abrasive). Additional equipment and containers for the management of waste abrasive and its disposal after the test is advised.

The abrasion mechanism shall provide a brush stroke length of at least 14,5 cm. The brush may operate at either a constant or varied velocity through each stroke. The brush velocity of 30 ± 3 cm·s^{-1} shall be used for the through the central 7,5 cm test region on the specimen during machine abrasion testing. Other test rates may be used for the purposes of research and development.

NOTE For example, the brush velocity of 30 cm·s^{-1}, when used with a stroke length of 25,4 cm corresponds to a test rate of 37± 1 cycles per minute.

Specimens shall be rigidly mounted relative to the apparatus using mechanical springs or clamps, tape or other means.

To ensure repeatability of results (i.e., avoid temperature-related effects related to the abrasion process or abrasive) the apparatus shall be maintained, in a laboratory maintained at (23 ± 2) °C, (50 ± 10) % RH, as specified per Class 2 in ISO 291.

The dispenser for dry dust shall be separated from the specimen surface by at least 10 cm to provide clearance for the motion of the brush (in both linear and rotary configurations) and also aid dispensing to the designated test area of the specimen.

The dispenser for wet slurry shall be separated from the specimen surface by at least 5 cm to aid dispensing to the designated test area of the specimen.

4.2.2 Brush

The brush block shall be (35 ± 1) mm × (85± 1) mm in area and (13 ± 1) mm in thickness.

The brush bristles shall consist of polyamide 612, (0,23 ± 0,03) mm in diameter that extend (38 ± 2) mm from the brush block. Brushes with bristles shorter than 35 mm in length shall be replaced. The bristle profile shall be round, with no taper or other change in geometry along their length. The lateral space of 12 mm shall be used for the bristle tuft columns along the length of the brush, with a offset space of 4 mm between rows and lateral offset space of 6 mm between adjacent bristle columns. The bristle tufts shall be staggered in a 5-4-5-4-... pattern along the brush, with total of 59 tufts. The bristle count shall be (158 ± 6) tips·tuft^{-1}.

A 325 g external weight shall be used with the brush, as in ASTM D2486. The nominal brush weight of 125 g includes the dry weight of brush block and bristles. The nominal brush net weight (including 5 g attachment bolt) shall be 455 ± 10 g, including the dry weight of brush block, bristles, external weight, fasteners, and holder. The nominal contact force of 4,46 N shall result from the self-weight of the components; no spring or other external force shall be used.

4.2.3 Abrasive medium (dry)

The dry abrasive medium shall consist of A3 (medium) AZ test dust, as specified in ISO 12103-1. The nominal abrasive concentration of (0,7) mg·cm^{-2}·cycle^{-1} shall be used during the test. To ensure repeatability, the test dust shall not be reused after testing. Other abrasive materials or quantities of abrasive may be used for the purposes of research and development.

NOTE The abrasive concentration of (20 ± 5) mg·cycle^{-1} when applied to the nominal area of the linear brush (29,75) cm^{-2} provides the nominal abrasive concentration of (0,7) mg·cm^{-2}·cycle^{-1}.

Dry abrasive shall be maintained at (23 ± 2) °C and (50 ± 10) % RH for at least 24 h, as specified per Class 2 in ISO 291, prior to use in the linear abrasion test.

For the dry abrasive test, the brush bristles shall be maintained at (23 ± 2) °C and (50 ± 10) % RH for at least 24 h, as specified per Class 2 in ISO 291, prior to use in the linear abrasion test.

Other dry abrasives may be used for the purposes of research and development. Dry abrasive may be used in conjunction with an artificial soiling method for the purposes of research and development. Alternative abrasives include the “Middle East” (ME) test dust as specified in VDI 3956, and “quartz free” AZ test dust (similar to ISO 12103-1, but using corundum instead of silica to avoid safety issues related to respiration). Both particle size and particle composition can affect the rate of abrasion. The aforementioned alternative abrasives have not been widely studied relative to ISO 12103-1 AZ test dust.

4.2.4 Abrasive medium (wet slurry)

The wet abrasive medium shall consist of A3 (medium) AZ test dust, as specified in ISO 12103-1. The abrasive concentration of (5,0 ± 0,2) $g \cdot l^{-1}$ in deionized water shall be used during the test. The slurry shall be flowed at the rate of (5,0 ± 0,2) $l \cdot h^{-1}$ during the test. To ensure repeatability, the test dust shall not be reused after testing. Other abrasive materials or quantities of abrasive may be used for the purposes of research and development.

NOTE The abrasive concentration of (5,0 ± 0,2) $g \cdot l^{-1}$ when flowed at the rate of (5,0 ± 0,2) $l \cdot h^{-1}$ to the nominal area of the linear brush (29,75) cm^{-2} provides the nominal abrasive concentration of (0,4) $mg \cdot cm^{-2} \cdot cycle^{-1}$ for the nominal brush travel distance (25,4 cm) and operating speed (30 ± 3 $cm \cdot s^{-1}$).

Deionized water at (23 ± 2) °C shall be used during the test to avoid temperature-related effects related to the abrasion process or abrasive.

For the wet slurry abrasive test, the brush bristles shall be conditioned using water for 24 h before the start of the test. Methods of brush conditioning include soaking the bristles in a container of water, completely immersing the brush in a container of water, and/or the use of water flow (where the water or brush may be adjusted to provide regular conditioning). Brushes that are in frequent use may be stored in water.

A stirring apparatus shall be used with the slurry to improve the uniformity of concentration of dust in the slurry as well as to facilitate uniform concentration through the duration of testing. In addition to the stirring/mixing of the slurry, the apparatus and its plumbing should produce good uniformity of deposition slurry on the sample.

Other wet slurry abrasives may be used for the purposes of research and development.

4.3 Test specimens

4.3.1 Materials and geometry

Specimens may consist of representative coupons. The specimens shall be composed of a base material (or substrate), where a coating (if applicable) may be present on the test surface. Representative coupons shall be at least (7,5 ± 0,2) cm × (7,5 ± 0,2) cm in size. Module specimens or glass specimens (for tempered glass, where cutting is impossible) may also be used, if they may be accommodated in the apparatus. In the case of modules, the specimens shall contain at least three test regions 7,5 cm × 7,5 cm in length and width, separated at least 37,5 cm. In the case of unaged specimens, or specimens with no previous test-history, the test region(s) shall be representative of that used in the PV application, being free from visible damage, delamination, or other defects. In the case of weathered specimens or specimens with a previous test-history, the specimen shall be used in its received condition. In the case of polymeric material specimens such as backsheets or frontsheets, both principal directions should be tested, including the machine extrusion direction and the traverse direction.

Some coatings can have limitations regarding the specimen size that can be used to fabricate a representative sample. For example the glass might need to be tempered as part of the manufacturing process, where a 50 cm × 50 cm minimum glass size is required. In such cases, a larger coupon size or a module specimen can be used.

Commercial abrasion test equipment fulfilling the requirements of the test apparatus may be used to test region(s) within a module, if the test apparatus is located and fixtured relative to the test surface of the module. A custom apparatus with equivalent characteristics to a commercial tester may be used for large coupon or module specimens.

4.3.2 Number of replicate specimens

In the case of representative coupons, at least three replicates shall be used. If the apparatus has adequate space or number of brushes, the replicates may be tested together, simultaneously. The use of glass blanks (where the size may be smaller than 7,5 cm) at the sides of the test specimens is recommended to avoid a discontinuous loading of the brush along its path during testing, i.e., the surfaces in PV modules are typically longer than 7,5 cm.

In the case of a PV module at least three replicate modules or three separate regions on the same module shall be used. Test regions on the same PV module shall be separated at least 37,5 cm. The test areas may be marked prior to testing to aid subsequent examination.

In the case of unaged specimens, or specimens with no previous test-history, the specimen may be cleaned prior to testing. A mild detergent (e.g., a non-perfumed liquid soap as recommended by the manufacturer) may be used with deionized water as a cleaning solvent. A fresh cloth wipe may be used to facilitate cleaning. After cleaning, specimens may be dried in the ambient or dried using a jet of clean dry air.

There are no specimen conditioning requirements for this test. Specimens subject to the slurry test do not need to be soaked in water prior to testing.

4.3.3 Reference material

B 270 “Superwite” crown glass (Schott AG) should be used as a default reference material in other abrasion-related standards. “Borofloat” glass (Schott AG) may be used as a reference material, as in the case of a silica thin film or monolithic silica substrate or superstrate. “Acrylite 0Z023” poly(methyl methacrylate) (Evonik Industries AG) may be used as a reference material, as in the case of a polymer substrate or superstrate. Addition coupons of a reference material should be tested alongside the test specimens in the abrasion test.

NOTE The reference materials are given for the convenience of users of this document and do not constitute an endorsement by IEC of these products.

An informal working reference specimen may be used for the purposes of process- and manufacturing-control or research and development. In the case of coupon specimens, a substrate with no coating may be used as an informal working reference specimen. In the case of module specimens, a module or mini-module with no coating may be used as an informal working reference. The details of use of an informal working reference, including: the frequency of use; the characteristic(s) of interest; and acceptance limits may be specified by the user.

4.4 Test procedure

4.4.1 Setting up the apparatus and specimen

The apparatus shall be cleaned of residual abrasive, remaining from previous testing (if applicable).

The abrasive and apparatus (brush) shall be conditioned as designated prior to testing.

- Attach the specimen to the apparatus.
- Activate the abrasive dispenser.
- Activate the abrasion mechanism.