IEC TS 62788-6-3

Edition 1.0 2022-08

TECHNICAL SPECIFICATION

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Measurement procedures for materials used in photovoltaic modules – Part 6-3: Adhesion testing for PV module laminates using the single cantilevered beam (SCB) method

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Part 6-3: Adhesion testing for PV module laminates using the single cantilevered beam (SCB) method

FOREWORD

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IEC TS 62788-6-3 has been prepared by IEC technical committee 82: Solar photovoltaic energy systems. It is a Technical Specification.

The text of this Technical Specification is based on the following documents:

Draft	Report on voting
82/2012/DTS	82/2057A/RVDTS

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 Technical Specification 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 http://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- withdrawn,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.

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INTRODUCTION

This document describes the single cantilevered beam (SCB) test, useful for characterizing adhesion in photovoltaic (PV) modules. This method is grounded in fundamental concepts of beam and fracture mechanics [1][1], [4], and allows for a quantitative measurement of adhesion strength. A method for calculating the debond length, a_f, has been developed as an option to physical measurement.

PV modules are multi-layer structures that depend on adequate adhesion between each layer to ensure their reliable operation. Adhesion testing is described in current IEC PV standards for module safety qualification (IEC 61730-2) and component characterization (IEC 62788 series). The most commonly used tests are peel tests at either 180° for components (IEC TS 62788-2 test and IEC 62788-1-1), or at 90° for modules (IEC 61730-2 MST 35).

Peel tests are in practice simple to carry out, and provide a peel strength value, different from adhesion strength. Viscoelastic properties of the polymeric material and the mechanics of the pull tab have a strong influence on the result, making these tests of limited value in comparing either different materials, or the same material after stress exposures.

In the SCB method, an elastic width-tapered cantilever beam is adhered to the sample. When the beam is loaded at its apex, delamination will initiate at the weakest interface and advance upon continued loading. This measurement allows for calculation of the critical value of the energy release rate, G_c, which is the adhesion property for a given material interface. The value defined by this method is less dependent of the viscoelastic properties of the polymeric material, and so more useful for measuring differences or changes in adhesive strength.

The SCB method can be conducted at either the coupon or module level. Because it does not require using the backsheet as a pull tab, it is more likely to able to test the adhesion of a thin outer layer of the backsheet. These considerations give this test method good flexibility to use in applications related to PV modules. Examples for several specific use cases are provided.

This document offers a generalized method for performing the test, with the expectation that best practices for utilizing this test method will be developed for specific applications.

Examples of this method being employed to quantify and define the threshold values of encapsulant and backsheet adhesion for PV module reliability may be found in the literature [1] through [5].

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1 Numbers in square brackets refer to the Bibliography.

MEASUREMENT PROCEDURES FOR MATERIALS USED IN PHOTOVOLTAIC MODULES –

Part 6-3: Adhesion testing for PV module laminates using the single cantilevered beam (SCB) method

1 Scope

This part of IEC TS 62788 provides a method for measuring the adhesion energy of most interfaces within the photovoltaic (PV) module laminate.

In contrast to other adhesion tests in general use, this method provides a measure of adhesive energy, via the critical energy release rate, and so is more useful for comparing adhesion of different specimen types; e.g. different materials, module or coupon samples, or materials before and after stress exposure.

This is a "weakest link" test, meaning that the weakest interface is the one most likely to fail in a given test. Adhesion of a specific layer may be difficult to intentionally measure if there is a weaker interface in the system.

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

ISO 7500-1, *Metallic materials – Calibration and verification of static uniaxial testing machines – Part 1: Tension/compression testing machines – Calibration and verification of the force-measuring system*

3 Terms and definitions

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

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
cantilevered beam
beam supported at only one end such that the slope and deflection of that end is ideally zero

3.2
mechanical compliance
measure of the extent of deformation due to the action of external forces (reciprocal of stiffness)

Note 1 to entry: Unit (preferred): m/N.

3.3
adhesive failure
de-bonding occurring between the adhesive and the adherent, to be differentiated from cohesive failure within the adhesive material

3.4
cohesive failure
crack propagating within the adhesive during adhesion test, e.g. peel test

3.5
adhesive energy
G
specific energy (in J/m^2) released during separation of two material layers

3.6
critical adhesive energy
G_c
critical strain energy release rate necessary to promote crack growth

3.7
debond length
a
measured length of specimen from the apex of the tapered beam to the end of the debonded area

3.8
load-line displacement
Δ
displacement measured along the loading axis of a load frame

3.9

unfixed beam length

L_b
length of the beam between the clamp and the tip, used to determine the compliance calibration of the beam

3.10
compliance calibration method
method used to calculate the debond length based on the measured compliance at various crack lengths for a specific beam

3.11
plastic deformation
permanent, non-recoverable deformation

3.12
cohesive zone
trailing area adjacent to the debond edge that may consist of cavitation, voids and ligaments within the adhesive

4 Apparatus

4.1 Load frame

A properly calibrated load frame shall be used that can be operated in a displacement control mode with a constant rate of 10,0 μm/s. A load cell with a capacity of 200 N is recommended. The load frame shall conform to the requirements of ISO 7500-1.

The load frame shall be equipped with the following:

- a clevis grip link that couples the load train to the loading tab attached to the specimen, Figure 1. The link should be ≥ 30 mm between the centres of the connection points, and each end of the link shall be able to rotate freely about the clevis pin orthogonal to the specimen plane. The clevis pin should be 1,0 mm steel or material of equal or greater elastic modulus.
- a platen opposite the loading grip to which the test specimen is secured, Figure 2a); or, the load frame may be modified to sit on the specimen (e.g., PV module) Figure 2b).
- a displacement indicator capable of monitoring and recording load-line displacement. The displacement indicator shall indicate the load-line displacement within an accuracy of 10 μm.
- a load-sensing device capable of monitoring and recording the total load carried by the specimen. This device shall indicate the load with an accuracy over the load range(s) of interest within 0,1 N.

Dimensions in millimetres

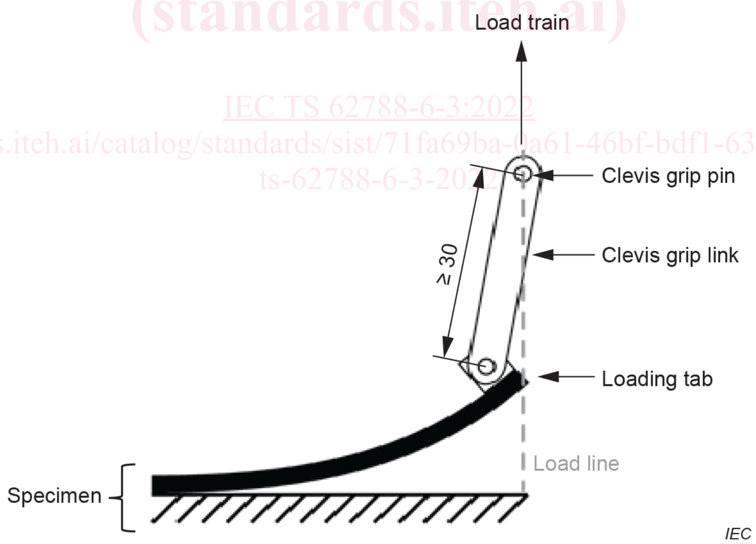

Figure 1 – Diagram of the loading connection using a clevis grip

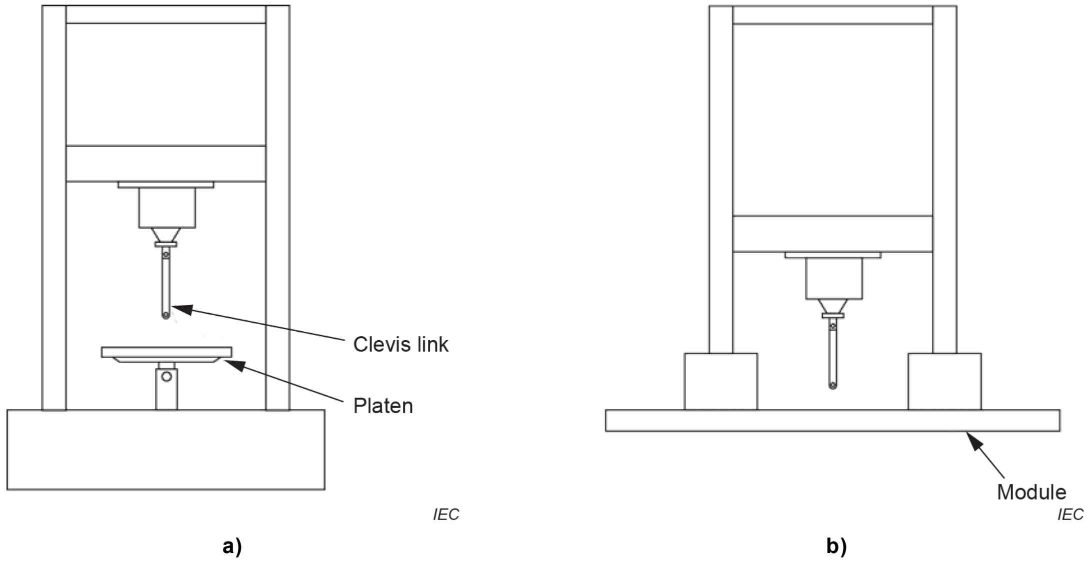

Figure 2 – Schematic of load frame with a) a platen for securing test coupon, and b) modified to sit on top of a PV module

4.2 Loading tab

The loading tab connects to the beam and to the loading pin of the Clevis joint. The preferred material for the loading tab is stainless steel, although aluminium may also be used. To provide a low friction surface, a sapphire jewel bearing is recommended for the contact with the loading pin. This should be inspected for damage prior to each test, and cracked bearings shall be replaced. Photos of a loading tab are shown in Figure 3. A reference engineering design is provided in Annex C.

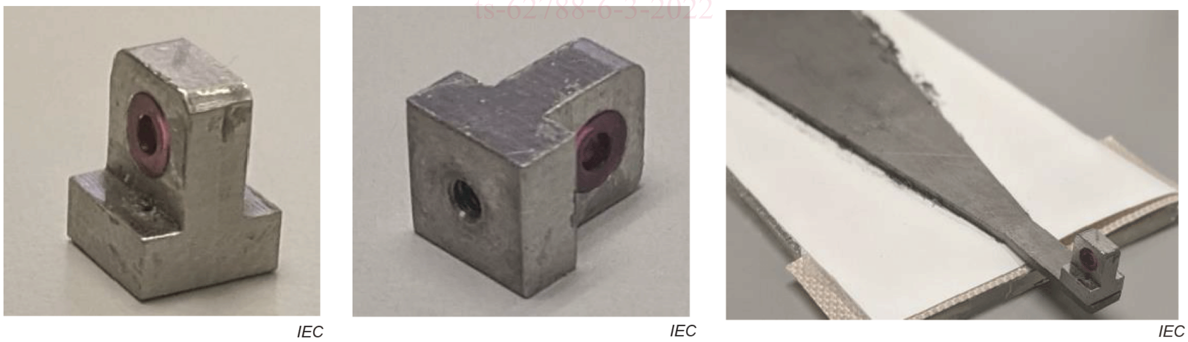

Figure 3 – Photos of the loading tab alone, and attached to the beam

5 Width-tapered cantilever beam

5.1 General

The beam is usually considered disposable and used only once. After cleaning, it may be reused if evaluated to ensure no permanent deformation has occurred. Recovering a deformed beam is not recommended.

Design parameters for the beam include both physical dimensions and material properties. Annex A describes a range of beams which may be used in the context of this document. Two specific designs are included in this specification, with the selection to be made based on the maximum expected adhesion energy, G_{max}, of the system to be measured.