IEC TS 62804-1-1

Edition 1.0 2020-01

TECHNICAL SPECIFICATION

colour inside

Photovoltaic (PV) modules – Test methods for the detection of potential-induced degradation –
Part 1-1: Crystalline silicon – Delamination

IEC TS 62804-1-1:2020-01(en)

IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

About the IEC
The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications
The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

IEC publications search - webstore.iec.ch/advsearchform
The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee,…). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished
Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

IEC Customer Service Centre - webstore.iec.ch/csc
If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: sales@iec.ch.

Electropedia - www.electropedia.org
The world's leading online dictionary on electrotechnology, containing more than 22 000 terminological entries in English and French, with equivalent terms in 16 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC Glossary - std.iec.ch/glossary
67 000 electrotechnical terminology entries in English and French extracted from the Terms and Definitions clause of IEC publications issued since 2002. Some entries have been collected from earlier publications of IEC TC 37, 77, 86 and CISPR.

IEC TS 62804-1-1

Edition 1.0 2020-01

TECHNICAL SPECIFICATION

colour inside

Photovoltaic (PV) modules – Test methods for the detection of potential-induced degradation –
Part 1-1: Crystalline silicon – Delamination

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 27.160

ISBN 978-2-8322-7693-8

Warning! Make sure that you obtained this publication from an authorized distributor.

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

____

PHOTOVOLTAIC (PV) MODULES – TEST METHODS FOR THE DETECTION OF POTENTIAL-INDUCED DEGRADATION –

Part 1-1: Crystalline silicon – Delamination

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as “IEC Publication(s)”). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
6) All users should ensure that they have the latest edition of this publication.
7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

The main task of IEC technical committees is to prepare International Standards. In exceptional circumstances, a technical committee may propose the publication of a Technical Specification when

- the required support cannot be obtained for the publication of an International Standard, despite repeated efforts, or
- the subject is still under technical development or where, for any other reason, there is the future but no immediate possibility of an agreement on an International Standard.

Technical Specification are subject to review within three years of publication to decide whether they can be transformed into International Standards.

IEC TS 62804-1-1, which is a Technical Specification, has been prepared by IEC technical committee 82: Solar photovoltaic energy systems.

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

Draft TS	Report on voting
82/1566/DTS	82/1596A/RVDTS

Full information on the voting for the approval of this Technical Specification 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 62804 series, published under the general title *Photovoltaic (PV) modules – Test methods for the detection of potential-induced degradation*, 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.

A bilingual version of this publication may be issued at a later date.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

Potential-induced degradation (PID) refers to any PV module degradation that is caused by the stress of an electric potential between the active cell circuit and the external surfaces or parts of the PV module. This part of IEC 62804 is for testing and evaluating the durability of crystalline silicon PV modules for PID in the mode of delamination (PID-d), as may be induced by the stress factors of moisture and system voltage.

The applied stresses, with system voltage being the principal factor in IEC 62804-series documents, manifest themselves in different degradation modes that depend in part on the module technology. Therefore, a series of technical specifications is being developed to define PID tests for different PV module technologies and differing PID modes.

IEC TS 62804-1 defines test methods for evaluating power loss by PID in crystalline silicon PV modules.

IEC TS 62804-1-1 defines a test method for evaluating delamination by PID in crystalline silicon PV modules.

IEC TS 62804-2 defines test methods for evaluating power loss by PID in thin-film PV modules and modules with moisture-sensitive components and moisture-barrier packaging.

Additional TSs in the series may be introduced in the future for emerging module technologies, mechanisms, or evaluation methods.

Delamination of PV modules is a failure mode that can lead to electrical shocks, ground faults, rapid moisture ingress or collection of condensed moisture and can be associated with corrosion, some loss in photocurrent and hotspots due to degraded transmission of light to the solar cells, and visual undesirability. Various delamination modes are seen occurring in fielded modules for which standardized methods for accelerated testing do not exist to predict these vulnerabilities.

Delamination in crystalline silicon PV modules has been found to occur associated with electrochemical reactions on the silicon PV cell surface and metallization (Mon and Ross, 1985, Matsuda *et al.* 2012). Moisture has been found to sometimes accelerate the adhesion loss at interfaces in PV modules, along with elevated sodium concentration on the cell surface within the module package, which may result from the electric field of system voltage stress (Dhere *et al.,* 2002, Bosco *et al.*, 2017, Wohlgemuth *et al.*, 2017, Li *et al.,* 2018). Modules with encapsulation materials of low bulk resistivity have been found to have greater susceptibility to PID-d under electric fields due to system voltage stress (Hacke *et al.*, 2016). Modules that do not exhibit significant power loss by PID-shunting (PID-s) or PID polarization (PID-p) modes may still be prone to degradation by the delamination mode examined in this document if, for example, the cells are made durable to power loss by these modes, but the encapsulation is of low bulk resistivity.

Elevated dissolved moisture content in encapsulants has been found to increase the bulk conductivity of many encapsulants (Berghold *et al.*, 2014). An accelerated test is therefore provided in this document to evaluate modules for susceptibility to delamination under the stress factors of moisture and system voltage. While mounting and grounding configuration may be optimized to mitigate PID degradation modes, as a test of the laminate, glass surfaces are grounded in this document independent of consideration of the intended mounting and grounding configuration of the module.

The conductivity of glass and resultant charge transfer through it enable electrochemical reactions within the laminate when subjected to a voltage potential. Therefore, this document is intended primarily for modules with one or two glass faces. To date, module package resistivity has been measured to vary by several orders of magnitude. Accordingly, the testing protocol herein has been found to differentiate susceptible modules from durable modules as a function of resistivity for this delamination mode (Hacke *et al.*, 2016). The stress test conditions contained herein are highly accelerated and have been determined to differentiate susceptibility of modules to this degradation mode; but their acceleration factor with respect to the rate of occurrence in various natural environments has not been established. Annex A gives examples of the degradation modes manifested by application of the protocol and visually similar examples from the field.

Delamination may additionally occur by other mechanisms, such as from the reaction products of photocatalysis (Matsuda *et al.*, 2012), and may not manifest under this or other presently existing standardized testing protocols.

It is known that variability in manufacturing processes can affect the susceptibility of modules to system voltage stress. Periodic retesting of module samples by the test protocols contained herein, by internal quality assurance programs such as given in IEC TS 62941, and by external audits will aid in verifying not only the durability of the design of the module to system voltage stress, but also, the effects of any variability of the materials and manufacturing processes.

PHOTOVOLTAIC (PV) MODULES – TEST METHODS FOR THE DETECTION OF POTENTIAL-INDUCED DEGRADATION –

Part 1-1: Crystalline silicon – Delamination

1 Scope

This part of IEC 62804 defines procedures to test and evaluate for potential-induced degradation-delamination (PID-d) mode in the laminate of crystalline silicon PV modules—principally those with one or two glass faces. This document evaluates delamination attributable to current transfer between ground and the module cell circuit. Elements driving the delamination that this test is designed to actuate include reduced adhesion associated with damp heat exposure, sodium accumulation at interfaces, and cathodic gas evolution in the cell circuit, metallization, and other components within the PV module activated by the voltage potential. The change in power of crystalline silicon PV modules associated with the stress factors applied (the purview of IEC TS 62804-1) is not considered in the scope.

Modules are tested in a climactic chamber with damp heat and application of module-rated system voltage to the cell circuit in each polarity that is specified or allowed in the module documentation. This document does not differentiate the effects of some construction methods of mitigating PID—for example, the use of rear rail mounts, edge clips, and insulating frames that may serve to electrically isolate the module faces to varying extents. The actual durability of modules to system voltage stress will depend on the mounting design and the environmental conditions under which the modules are operated. These tests are intended to assess the sensitivity of the PV module laminate to PID-d irrespective of actual stresses under operation in different climates and systems.

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 60068-2-78:2012, *Environmental testing – Part 2-78: Tests – Test Cab: Damp heat, steady state*

IEC 61215-1:2016, *Terrestrial photovoltaic (PV) modules – Design qualification and type approval – Part 1: Test requirements*

IEC 61215-2:2016, *Terrestrial photovoltaic (PV) modules – Design qualification and type approval – Part 2: Test procedures*

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

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

IEC TS 62804-1*, Photovoltaic (PV) modules – Test methods for the detection of potential-induced degradation – Part 1: Crystalline silicon*

IEC TS 62941, *Terrestrial photovoltaic (PV) modules – Guidelines for increased confidence in PV module design qualification and type approval*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC TS 61836 and IEC TS 62804-1 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 Samples

Representative and identical samples shall be procured, two for each polarity of the system voltage that is specified or allowed in the module documentation. An additional control module that shall remain unstressed for use as a visual comparison with the stressed modules shall be procured. Optionally, an additional module for testing alongside these may be procured for evaluation with the damp heat component of the stress but without system voltage stress applied to differentiate the effect of the applied system voltage. Modules not explicitly requiring string connections with one terminal grounded shall be tested in both polarities. The laminates for test shall be constructed with the same process and design as the model type to be evaluated—it shall contain components including cells, encapsulant, backsheet, and glass, made with the same manufacturing process, inclusive of process tools, materials, design, and process conditions. As a test of the laminate, inclusion of the module frame or mounting hardware is not required.

The modules shall have been manufactured from specified materials and components in accordance with the relevant drawings and process sheets and have been subjected to the manufacturer's normal inspection, quality control, and production acceptance procedures.

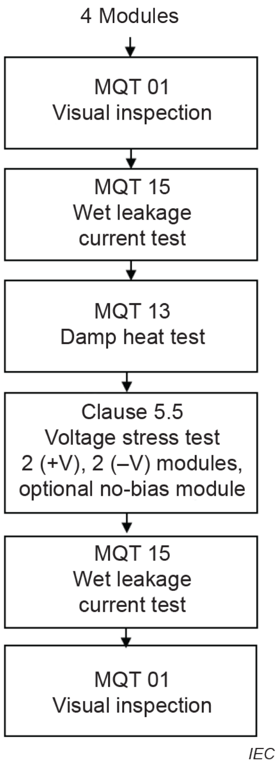
If modules are submitted to another party for testing, they shall be accompanied by the manufacturer's handling, mounting, and connection instructions, including the maximum permissible system voltage. Markings on the module shall conform to the requirements of IEC 61215-1 and IEC 61730-2. If the modules tested are prototypes of a new design and not from production, this fact shall be noted in the test report (see Clause 6).

The test results relate only to the module construction tested. If a module manufacturer uses several sources for PV module components, module designs, cell designs, process designs, or differing process set points and tolerances for a given PV module model designation, then additional modules for each permutation are required for evaluation with this document. However, changes of the junction boxes, cables, frames, mounting hardware, and connectors do not indicate retest.

5 Test procedures

5.1 General

In the following stress tests, an extended damp heat exposure is first performed to allow moisture to diffuse into the module, which can reduce interface adhesion in regions of the module laminate and increase conductivity in some polymeric materials. This exposure is followed by application of voltage bias stress to the cell circuit with use of a grounded conductive electrode (foil) on the module glass surface. The resultant electric field creates and drives mobile ions, depending on the polarity applied, to or from the module glass and the silicon cells and connected conductive parts. Delamination may occur by, for example, cathodic gas evolution. The overview of the test procedure is given in Figure 1.



Module quality tests (MQT) refer to procedures in IEC 61215-2.

Figure 1 – Test flow

5.2 Initial visual inspection

Perform IEC 61215-2 Visual inspection (MQT 01) for each module. Especially note and photograph any pre-existing areas of delamination or bubbles in the laminate. If there is evidence of major visual defects as defined in IEC 61215-1, then this test procedure shall be terminated or restarted at Clause 4 with different samples.

5.3 Wet leakage current test

Perform IEC 61215-2 Wet leakage current test (MQT 15) for each module. If the insulation resistance does not meet the requirements of MQT 15, then the module shall be replaced and documented (see Clause 6) and this test restarted at Clause 4 with different samples, or the test procedure terminated.

5.4 Damp heat test

For samples that will eventually undergo stress by system voltage bias and for the optional module evaluated with the damp heat component of the stress only, perform IEC 61215-2 Damp heat test, MQT 13, inclusive of the post-test requirements of IEC 61215-2:2016, 4.13.4, MQT 01, Visual inspection and MQT 15, Wet leakage current test. If a module does not meet the requirements of MQT 01 or MQT 15, then this test procedure shall be terminated or restarted at Clause 4 replacing all samples.

5.5 Voltage stress test

5.5.1 General

This procedure shall be performed (Voltage stress test commenced) between 2 days and 7 days after completion of 5.4 (MQT 15, Damp heat test). The modules shall be stored in the laboratory or workroom environment out of direct sunlight.

5.5.2 Apparatus

a) An environmental chamber suitable for accommodating the modules under test and capable of controlling temperature and humidity independently to achieve the severities indicated in 5.5.4, with non-porous, electrically insulating module mounts (e.g., polytetrafluoroethylene, glazed porcelain), with minimal contact area to the module. Electrical insulation of the individual modules from the chamber and each other is required. Using such insulating mounts, multiple modules may be placed horizontally in a chamber with horizontal support beams that permit air circulation around the modules. The test shall be carried out in an environmental chamber for damp heat, with requirements for the test chamber and its usage given in IEC 60068-2-78:2012, 4.1 and 4.4, respectively; however, this document shall supersede where conditions and specifications differ.

NOTE 1 Insulator mounts are used to prevent alternative paths for leakage current between the biased active cell circuit and the intended ground point(s) and for the safety of personnel and equipment.

b) Sensors and data logger for recording the environmental conditions (chamber air temperature, relative humidity). Temperatures and relative humidity shall be measured and recorded in 5 min or lesser intervals.

c) DC voltage power source capable of applying the module-rated maximum system voltage in the designated polarity of the modules under test with sufficient current to maintain the set-point voltage with tolerance of 0,5 % and an appropriate device for resolving and recording the leakage current from each module to ground in 5 min or lesser intervals (optional: measure and record applied bias voltage). For testing a wide variety of modules, capability of sourcing and measuring current supplied by the DC voltage power source in the 1×10^{-3} A to 1×10^{-8} A range transferred through each module under bias is required.

NOTE 2 Current and voltage measurements and their recording are primarily intended as indicators of stability, uniformity, and continuity of the stress test conditions and not intended as performance criteria for the module under test. These may also be analyzed for trends in behaviour (e.g., the effects of moisture penetration).

d) Insulated wire rated for application of the intended test voltage, temperature, and humidity; module manufacturer-specified or stainless-steel hardware for electrical connections to the modules at the grounding points. If the module laminate is provided without grounding points, then an electrically conductive adhesive (including, for example, electrically conductive adhesive tape) is required.

e) Temperature sensors applied to each module recorded in 5 min or lesser intervals providing accuracy of ±1,0 °C in a manner that demonstrates temperature uniformity of the modules. Temperature sensors and their wires mounted to the module shall be electrically insulating at all applied temperatures and humidity levels so that they do not impact the voltage bias and leakage current between the module and the intended grounding points.

f) An electrically conductive foil (e.g., aluminium or copper, 8 µm to 150 µm in thickness) and a flexible polymeric mat to distribute a load of 30 Pa minimum on the foil to follow the surface morphology of the module glass to achieve a uniform electrical conducting electrode.

5.5.3 Voltage stress test procedure

a) For each module, connect the positive and negative electrical terminal wires (leads, tags, studs, screws, connectors) to each other and to the high voltage DC terminal of the power supply with the insulated wire rated for the intended test voltage. Two modules are connected for application of the positive system voltage to the modules' cell circuit and two modules are connected for application of the negative system voltage to the modules' cell circuits, or as is specified or allowed in the module documentation. Cover the PV module primary light-facing glass surface with the electrically conductive foil to achieve contact to the surfaces. The foil shall be compressed onto a module grounding point of the module frame with a stainless-steel annulus washer and bolt and/or nut (if applicable) and connected to the ground terminal of the DC voltage supply. Any coatings on a metallic module frame shall be abraded off under the area of the annulus washer. If there are no grounding points on the module laminate, then electrically conductive adhesive (including electrically conductive adhesive tapes) may be used to connect the grounding wire to the foil and complete the electrical circuit to the ground terminal of the DC voltage supply. Place modules horizontally on non-porous electrically insulating mounts described in 5.5.2a). To achieve more consistent adherence of the conductive electrode to the module, apply a homogeneous load of 30 Pa minimum to the electrically conductive foil on the light-facing surfaces of the module using a flexible polymeric mat.

In the case that the substrates or rear surfaces are made of glass, additionally apply ground-connected conductive foil to it and place the module on a conforming, soft polymeric surface so that the foil is pressed to the glass by the module's weight on at least 95% of the exposed rear-surface glass area. Support the modules and the conforming, soft polymeric material on which they rest using a rigid supporting platform isolated from the chamber with non-porous electrically insulating mounting material.

Orientations other than horizontal are permissible if they meet the requirement of module to module isolation and applied pressure of 30 Pa minimum normal to the module face to compress the foil onto all glass surfaces of the module.

If procured, place the optional module for testing with the above for evaluation with the damp heat component of the stress, without application of the voltage and electrically conductive foil, electrically isolated from the other modules that are tested with voltage bias in the climactic chamber.

b) Recording of sensor data shall be commenced, and prescribed stresses shall be applied to the modules according to the severities listed in 5.5.4. The ramps to and from the stress conditions and the stress test itself shall be performed in a continuous and uninterrupted manner. The chamber temperature shall be ramped from ambient to the specified stress temperature. When both the chamber air temperature and the module temperature reach the set point within the tolerance, increase the chamber relative humidity to arrive at the specified relative humidity. When the temperature and relative humidity set points are reached within the prescribed tolerances, start a 12 h to 24 h stabilization period for the environmental conditions. At the end of this period, switch on the voltage to the prescribed stress level (rated maximum system voltage and polarity). The prescribed dwell period begins when the voltage has arrived at the prescribed severity. For the cooling phase to ambient temperature at the end of the damp heat dwell, turn off the humidity generation and simultaneously begin to cool the chamber so that the modules reach 23 °C ± 5 °C within 1 h. The specified applied voltage shall be switched off when the module temperature reaches 23 °C ± 5 °C. The voltage stress test duration shall correspond to the time that the prescribed voltage severity at the prescribed dwell temperature and relative humidity was applied, not including periods of ramps in temperature. Reference the profile in Figure 2, to be used in conjunction with one of the severities listed in 5.5.4 and the actual nameplate-rated system voltage bias of the modules under test.

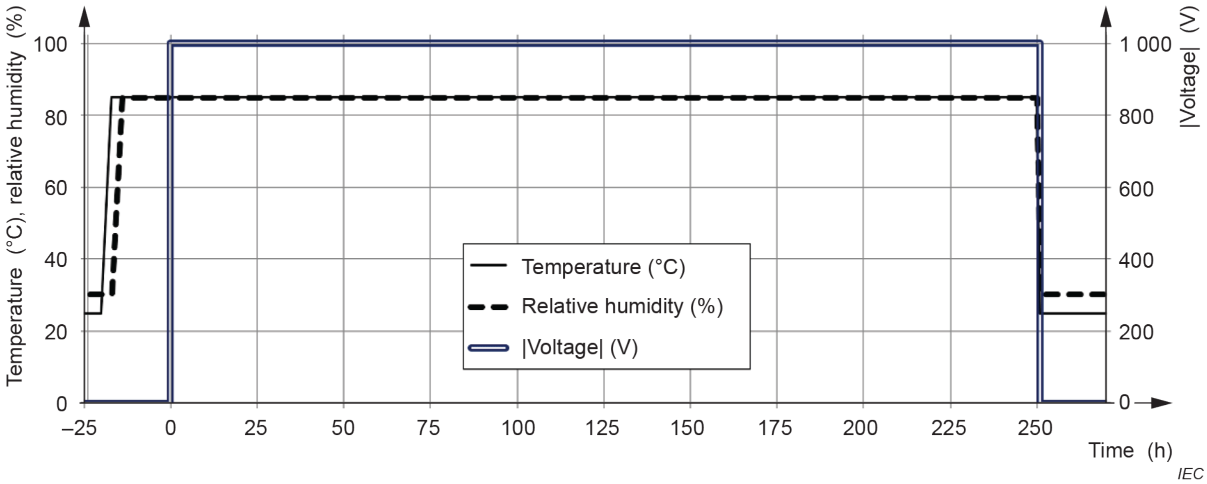


Figure 2 – Example test time-temperature-humidity-voltage profile for application of stress in an environmental chamber

5.5.4 Severities

Two test conditions that are not necessarily equivalent are given:

Method (A) is given for use when it is desired to perform the testing in the common chamber condition of IEC 61215-1 MQT 13 and if there is no chamber capable of applying the preferred conditions of Method (B) available. The conditions are:

- Module temperature: 85 °C ± 2 °C.
- Chamber relative humidity: 85 % ± 3 % relative humidity.
- Dwell: 240 h ± 2,4 h at the above-stated temperature and relative humidity (not including stabilization).
- Voltage: module-rated system voltage, in the prescribed polarities, applied for the above-given dwell duration and during ramp down of temperature to ambient conditions.

Method (B) is performed at a reduced temperature and higher humidity level. These conditions provide sufficient acceleration, are closer to field-representative conditions, and are thus preferred. The conditions are:

- Module temperature: 72 °C ± 2 °C.
- Chamber relative humidity: 95 % ± 3 % relative humidity.
- Dwell: 240 h ± 2,4 h at the above-stated temperature and relative humidity (not including stabilization).
- Voltage: module-rated system voltage, in the prescribed polarities, applied for the above-given dwell duration and during ramp down of temperature to ambient conditions.

5.6 Wet leakage current test

Perform Wet leakage current test (IEC 61215-2 MQT 15) after storage at (23 ± 5) °C with a relative humidity less than 75 % under open-circuit conditions for a period of between 2 h and 4 h after completion of the Voltage stress test, 5.5.

5.7 Final visual inspection

Within 96 h of completion of 5.6, perform IEC 61215-2 Visual inspection (MQT 01) for each module with the following modifications:

NOTE Delamination can manifest or significantly continue to propagate after termination of the stress test.

Reference Annex A, which gives photographs of examples of delamination that may be produced by application of the test protocol in this document. Consider also that delamination may occur at any interface in the module. Classify any delamination occurring as a result of this test procedure, e.g., not seen in the control module or in 5.2, Initial visual inspection, as follows. Tally the number of cells and other module parts seen to be affected, including:

a) over-cell areas on the primary light-facing side of module,

b) under-cell areas; and

c) non-cell areas (e.g., bussing ribbons) for each module tested using the delamination categories (A), (B), and (C), defined as follows:

(A) Delamination occurring of in-plane dimension (width) of less than 2 mm. A long, narrow delaminated area of width less than 2 mm would be considered category (A).

(B) Delamination occurring of minimum in-plane dimension greater than 2 mm. If there are areas of delamination of both less than 2 mm width and greater than 2 mm width on a given cell or component, then consider the delamination over the cell or component as category (B).

(C) Out-of-plane bubble formation visible in polymeric sheets. Tally affected cells in category (C) independent of (*i.e.*, in addition to) categories (A) and (B).

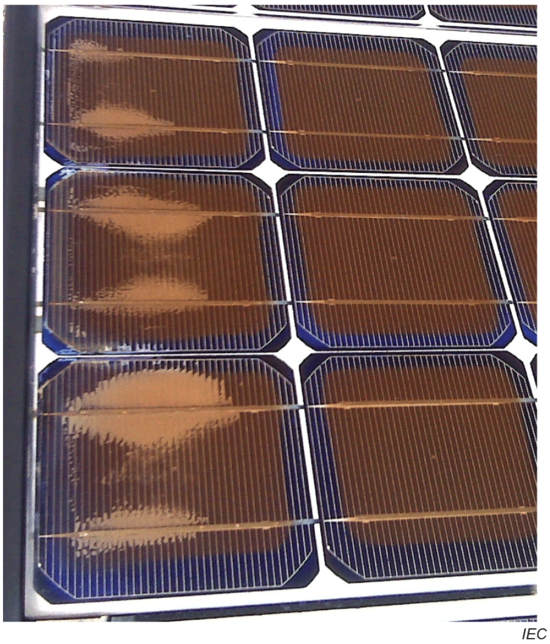
6 Test report

The test report shall contain the following data and information:

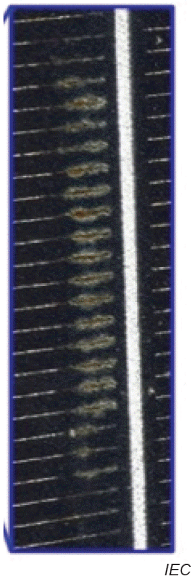
a) a title;
b) name and address of the test laboratory and location where the tests were carried out;
c) unique identification of the report and of each page, and a clear identification of the purpose of the test report;
d) name and address of client, where appropriate;
e) a serial number and production date such that the bill of materials can be traced; reference to sampling procedure; for prototype modules, modules made on alternate or pilot production tools, or not randomly selected, such details of the deviation from the standard test method shall be noted;
f) date of receipt of test items and date(s) of test, where appropriate;
g) description, photographs (inclusive of any observed delamination), and identification of the items tested including test procedure, nominal biases and polarities of voltage stress applied, grounding and mounting methods used during the test, referencing (document, model, date, page) the specifications in the module manufacturer’s documentation (where relevant);
h) characterizations, conditions, and the results obtained of the test items; this includes:
   - wet leakage current test results of each module;
   - visual inspection and photographs obtained before and after stress testing for each module, including tallies of the delamination types determined in 5.7;
   - data files that include test voltage (if recorded), module leakage current, module temperature, chamber temperature, and chamber relative humidity;
   - statement of the measured average, minimum, and maximum of module temperatures, relative humidities, and leakage currents during the test;
   - a time-parameter diagram showing the sequencing of these characterizations and conditions;
i) a description, including photographs, of any deviations from, additions to, or exclusions from the testing or test method, and any other information relevant to a specific test, such as special test conditions, with reference to the specifications in the module’s documentation (where relevant);
j) measurements, examinations, and derived results supported by tables, graphs, sketches, and photographs, as appropriate;
k) a statement of the estimated uncertainty of the test results (where relevant);
l) a signature and title, or equivalent identification, of the person(s) accepting responsibility for the content of the report, and the date of issue;
m) a statement about the domain of products (modules) to which the test result applies;
n) a statement whether the module tested is certified to IEC 61215 and IEC 61730-2 and whether testing is performed for control of design and development changes in accordance with IEC TS 62941 or other change or quality management program;
o) a statement that the report shall not be reproduced except in full, without the written approval of the laboratory.

Annex A
(informative)

Examples of delamination

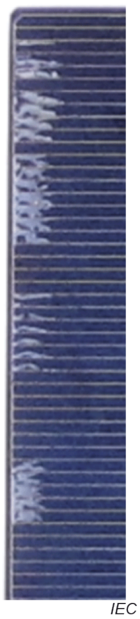


(a)



(b)

(c)

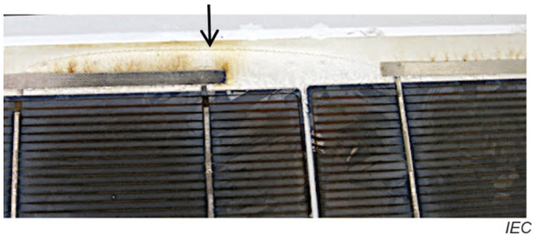


(d)

Figure A.1 – Examples of delamination occurring over cell

Figure A.1: Examples of delamination occurring in the field, (a,b); examples of similar delamination reproduced by application of damp heat and module-rated system voltage bias to the cell circuit in negative (−) voltage polarity, (c,d).

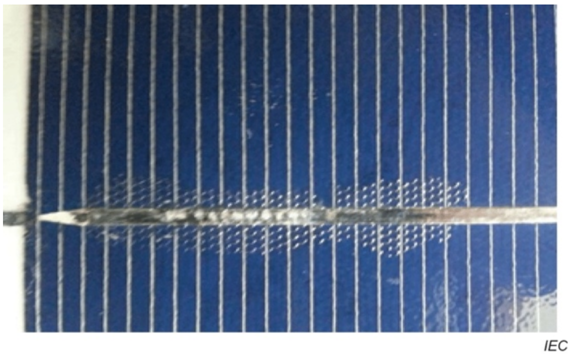
(a)



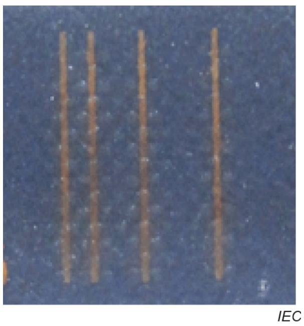
(b)

Figure A.2 – Examples of delamination occurring over bus ribbon

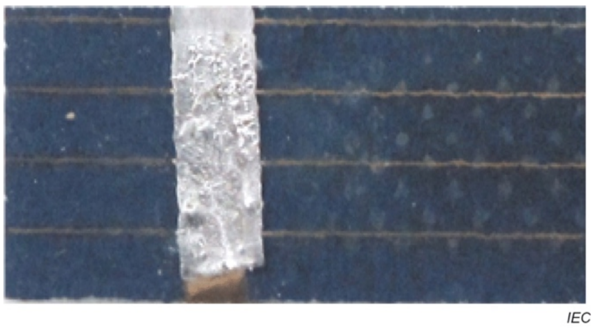
Figure A.2: Example of delamination occurring in the field, (a); example of similar delamination reproduced by application of damp heat with application of module-rated system voltage bias to the cell circuit in positive (+) voltage polarity, (b). The module shown in (b) was stressed for longer duration than that specified in this document. The arrows point to the edge of delaminated region.



(a)



(b)



(c)

Figure A.3 – Examples of precipitation between the glass and the encapsulant

Figure A.3: Example of precipitation between the glass and the encapsulant seen in the field, (a); and features attributable to precipitation and localized delamination between the glass and the encapsulant showing contrast as light spots at the textured glass occurring in accelerated stress testing in damp heat with positive (+) system voltage bias applied to the cell and the glass surface grounded (b,c). Variations may occur associated with factors including the cell metallization width.

Bibliography

BERGHOLD, J., *et al., Properties of encapsulation materials and their relevance for recent field failures*. IEEE 40th Photovoltaic Specialist Conference, 2014

BOSCO, N., *et al.*, *Adhesion degradation of the metallization-encapsulant interface. 33rd European Photovoltaic Solar Energy Conference and Exhibition*, Amsterdam, NL, 2017, pp 1336–1339

DHERE, N.G., *et al., Effect of glass Na content on adhesional strength of PV modules*. Conference Record of the 29th IEEE Photovoltaic Specialists Conference, 2002

HACKE, P., *et al., Potential-induced degradation-delamination mode in crystalline silicon modules*, NREL Workshop on Crystalline Silicon Solar Cells and Modules: Materials and Processes, Vail, CO, 2016

LI, J., *et al.*, *Electrochemical mechanisms of leakage-current-enhanced delamination and corrosion in Si photovoltaic modules*. Solar Energy Materials and Solar Cells 188, 2018, p 273

MATSUDA, K., *et al.*, *Microscopic degradation mechanisms in silicon photovoltaic module under long-term environmental exposure*. Japanese Journal of Applied Physics 51(10S), 2012, p 10NF07

MON, G.R. and ROSS, R.G., *Electrochemical degradation of amorphous-silicon photovoltaic modules*. 8th IEEE Photovoltaic Specialist Conference, Las Vegas, NV, 1985

WOHLGEMUTH, J.H., *et al.*, *Assessing the causes of encapsulant delamination in PV modules.* 44th IEEE Photovoltaic Specialist Conference, 2017

____

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

3, rue de Varembé
PO Box 131
CH-1211 Geneva 20
Switzerland

Tel: + 41 22 919 02 11
Fax: + 41 22 919 03 00
info@iec.ch
www.iec.ch