

INTERNATIONAL STANDARD



Photovoltaic (PV) module safety qualification – Part 2: Requirements for testing



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INTERNATIONAL ELECTROTECHNICAL COMMISSION

PHOTOVOLTAIC (PV) MODULE SAFETY QUALIFICATION –

Part 2: Requirements for testing

FOREWORD

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This redline version of the official IEC Standard allows the user to identify the changes made to the previous edition IEC 61730-2:2016. A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text.

IEC 61730-2 has been prepared by IEC technical committee 82: Solar photovoltaic energy systems. It is an International Standard.

This third edition cancels and replaces the second edition published in 2016. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- a) MST 06: Sharp edge test revised.
- b) MST 14: Impulse voltage test contains technical corrections to Figure 4.
- c) MST 21: Temperature test has been removed from this standard because modules tested individually in unrestricted mounting systems in open-air climates below 40 °C operate at or below a 98th-percentile operating temperature of 70 °C. As a result, the existing IEC 61730-1 requirement for a minimum RTI/RTE/TI of 90 °C is adequate. To address modules operating at higher temperatures, IEC TS 63126 includes an informative annex to describe tests and analysis techniques suitable for estimating the 98th-percentile operating temperature. This covers system effects such as mounting methods that restrict airflow and result in a 98th-percentile module operating temperature in excess of 70 °C.
- d) MST 24: Ignitability test revised.
- e) MST 26: Reverse current overload test revised.
- f) MST 32: Module breakage test is no longer required for Class 0 modules.
- g) MST 54: Instead of sequential test with one module now one module for sequence B shall be irradiated from the front side and another module from the backside during the 60 kWh/m² cycle.
- h) MST 57: Evaluation of insulation coordination added.
- i) All MQT references updated to revised IEC 61215 series Ed.2.0 2021.
- j) Bifacial modules: Requirements updated for MST 02 Performance at STC, MST 07 Bypass diode functionality test, MST 22 Hot-spot endurance test, MST 25 Bypass diode thermal test and MST 51 Thermal cycling (TC200).
- k) Term “Very large module” defined and Annex C (normative) “Usage of representative samples for very large modules” added.

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

Draft	Report on voting
82/2122/FDIS	82/2166/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/publications.

A list of all parts in the IEC 61730 series, published under the general title *Photovoltaic (PV) module safety qualification*, 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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PHOTOVOLTAIC (PV) MODULE SAFETY QUALIFICATION –

Part 2: Requirements for testing

1 Scope

The scope of IEC 61730-1 is also applicable to this part of IEC 61730. While IEC 61730-1 outlines the requirements of construction, this document lists the tests a PV module is required to fulfill for safety qualification. This document applies for safety qualification only in conjunction with IEC 61730-1.

The sequence of tests required in this document may not test for all possible safety aspects associated with the use of PV modules in all possible applications. This document utilizes the best sequence of tests available at the time of its writing. ~~There are some issues – such as the potential danger of electric shock posed by a broken PV module in a high voltage system – that should be addressed by the system design, location, restrictions on access and maintenance procedures.~~

The objective of this document is to provide the testing sequence intended to verify the safety of PV modules whose construction has been assessed by IEC 61730-1. The test sequence and pass criteria are designed to detect the potential breakdown of internal and external components of PV modules that would result in fire, electric shock, and/or personal injury. This document defines the basic safety test requirements and additional tests that are a function of the PV module end-use applications. Test categories include general inspection, electrical shock hazard, fire hazard, mechanical stress, and environmental stress.

The additional testing requirements outlined in relevant ISO documents, or the national or local codes which govern the installation and use of these PV modules in their intended locations, ~~should be~~ **are** considered in addition to the requirements contained within this document.

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 60060-1, *High-voltage test techniques – Part 1: General definitions and test requirements*

IEC 60068-2-1:2007, *Environmental testing – Part 2-1: Tests – Test A: Cold*

IEC 60068-2-2:2007, *Environmental testing – Part 2-2: Tests – Test B: Dry heat*

IEC 60068-3-5, *Environmental testing – Part 3-5: Supporting documentation and guidance – Confirmation of the performance of temperature chambers*

IEC 60598-1:2014/2020, *Luminaires – Part 1: General requirements and tests*

IEC 60664-1:2007/2020, *Insulation co-ordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests*

IEC 60695-2-10, *Fire hazard testing – Part 2-10: Glowing/hot-wire based test methods – Glow-wire apparatus and common test procedure*

~~IEC 60904-2, Photovoltaic devices – Part 2: Requirements for photovoltaic reference devices~~

~~IEC 60904-9, Photovoltaic devices – Part 9: Solar simulator performance requirements~~

IEC 60950-1:2005, *Information technology equipment – Safety – Part 1: General requirements*

IEC 60950-1:2005/AMD1:2009

IEC 60950-1:2005/AMD2:2013

IEC 61010-1, *Safety requirements for electrical equipment for measurement, control and laboratory use – Part 1: General requirements*

IEC 61032:1997, *Protection of persons and equipment by enclosures – Probes for verification*

IEC 61140, *Protection against electric shock – Common aspects for installation and equipment*

IEC 61215 (all parts), *Terrestrial photovoltaic (PV) modules – Design qualification and type approval*

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

IEC 61730-1:2016/2023, *Photovoltaic (PV) module safety qualification – Part 1: Requirements for construction*

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

IEC 62788-2-1:2023, *Measurement procedures for materials used in photovoltaic modules – Part 2-1: Polymeric materials – Frontsheet and backsheet – Safety requirements*

IEC 62790:2020, *Junction boxes for photovoltaic modules – Safety requirements and tests*

IEC TS 62915, *Photovoltaic (PV) modules – Type approval, design and safety qualification – Retesting*

~~ISO/IEC 17025, General requirements for the competence of testing and calibration laboratories~~

ISO 813, *Rubber, vulcanized or thermoplastic – Determination of adhesion to a rigid substrate – 90 degree peel method*

~~ISO 4046-4, Paper, board, pulps and related terms – Vocabulary – Part 4: Paper and board grades and converted products~~

ISO 4587:2003, *Adhesives – Determination of tensile lap-shear strength of rigid-to-rigid bonded assemblies*

ISO 5893, *Rubber and plastics test equipment – Tensile, flexural and compression types (constant rate of traverse) – Specification*

~~ISO 8124-1, Safety of toys – Part 1: Safety aspects related to mechanical and physical properties~~

ISO 11925-2:2010/2020, *Reaction to fire tests – Ignitability of products subjected to direct impingement of flame – Part 2: Single-flame source test*

ISO 23529, *Rubber – General procedures for preparing and conditioning test pieces for physical test methods*

ANSI/UL 1703:2015, *Flat-plate photovoltaic modules and panels*

ANSI Z97.1:2009, *Standard – Safety Glazing Materials Used in Buildings – Safety Performance Specifications and Methods of Test*

3 Terms and definitions

~~The Clause of Part 1 applies.~~

For the purposes of this document, the terms and definitions in IEC 61730-1 and IEC TS 61836, as well as 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

representative sample

sample that includes all the components of the module, except some repeated parts

3.2

very large module

module that exceeds 2,2 m in any dimension or exceeds 1,5 m in both dimensions

EXAMPLE: a 2,3 m × 0,3 m module is considered very large, as is a 1,6 m × 1,6 m module.

4 Test categories

4.1 General

The hazards described in the following subclause might influence the safety of PV modules. In accordance with these hazards, test procedures and criteria are described. The specific tests to which a PV module will be subjected will depend on the end-use application for which the minimum tests are specified in Clause 5.

NOTE PV module safety tests are labelled MST.

Table 1 through Table 5 show the origin of the required tests. For some tests the third column lists the origin of the tests for information only; the appropriate test requirements are given in 10.1 through 10.34. The other tests are based on or are identical to the ~~module qualification tests~~ ~~MQT~~ **MQT tests** defined in the IEC 61215 series. References to the relevant tests are given in the last column. Some of the IEC 61215-based tests were modified for IEC 61730-2 and are included in 10.1 through 10.34.

4.2 Environmental stress tests

Table 1 – Environmental stress tests

Test	Title	Referenced standards	Based on
			IEC 61215-2
MST 51	Thermal cycling (TC50 or TC200)	–	MQT 11
MST 52	Humidity freeze (HF10)	–	MQT 12
MST 53	Damp heat (DH200 or DH1000)	–	MQT 13
MST 54	UV preconditioning	–	MQT 10
MST 55	Cold conditioning	IEC 60068-2-1	–
MST 56	Dry heat conditioning	IEC 60068-2-2	–

4.3 General inspection tests

Table 2 – General inspection tests

Test	Title	Referenced standards	Based on
			IEC 61215-2
MST 01	Visual inspection	–	MQT 01
MST 02	Performance at STC	–	MQT 6.1
MST 03	Maximum power determination	–	MQT 02
MST 04	Insulation thickness	–	–
MST 05	Durability of markings	IEC 60950-1	–
MST 06	Sharp edge test	~~ISO 8124-1~~ –	–
MST 07	Bypass diode functionality test	–	–
MST 57	Evaluation of insulation coordination	IEC 60664-1	–

4.4 Electrical shock hazard tests

These tests are designed to assess the risk to persons due to shock or injury from contact with parts of a PV module that are electrically energised as a result of design, construction, or faults caused by environment or operation.

Table 3 – Electrical shock hazard tests

Test	Title	Referenced standards	Based on
			IEC 61215-2
MST 11	Accessibility test	IEC 61032	–
MST 12	Cut susceptibility test	ANSI/UL 1703:2015	–
MST 13	Continuity test for equipotential bonding	ANSI/UL 1703:2015	–
MST 14	Impulse voltage test	~~IEC 60664-1~~ IEC 60060-1	–
MST 16	Insulation test	–	MQT 03
MST 17	Wet leakage current test	–	MQT 15
MST 42	Robustness of terminations test	IEC 62790	MQT 14
MST 57	Evaluation of insulation coordination	IEC 60664-1	–

4.5 Fire hazard tests

These tests assess the potential fire hazard due to the operation of a PV module or failure of its components.

Table 4 – Fire hazard tests

Test	Title	Referenced standards	Based on
			IEC 61215-2
~~MST 21~~	~~Temperature test~~	~~ANSI/UL 1703:2015~~	–
MST 22	Hot-spot endurance test	–	MQT 09
MST 23 ^a	Fire test	–	National/Local code
MST 24	Ignitability test	ISO 11925-2:2020	–
MST 25	Bypass diode thermal test	–	MQT 18
MST 26	Reverse current overload test	~~ANSI/UL 1703:2015~~ –	–
^a Fire tests are locally regulated and typically only required for building integrated or building added products, typically to verify their ability to resist fire from external sources.			

4.6 Mechanical stress tests

These tests are to minimise potential injury due to mechanical failure.

Table 5 – Mechanical stress tests

Test	Title	Referenced standards	Based on
			IEC 61215-2
MST 32	Module breakage test	ANSI Z97.1	–
MST 33	Screw connection test	IEC 60598-1	–
MST 34	Static mechanical load test	–	MQT 16
MST 35	Peel test	ISO 5893	–
MST 36	Lap shear strength test	ISO 4587:2003	–
MST 37	Materials creep test	–	–
MST 42	Robustness of terminations test		MQT 14

Recommendations for testing of PV modules from production are given in Annex A.

5 Classes and their necessary test procedures

The specific tests to which a PV module will be subjected, depending on the Class defined in IEC 61730-1 referring to IEC 61140, are described in Table 6. The order in which the tests are carried out shall be in accordance with Figure 1. Some tests shall be carried out as preconditioning tests.

Table 6 – Required tests, depending on the Class

Class according to IEC 61140			Tests
II	0	III	
X	X	X	Environmental stress tests:
X	X	X	MST 51 Thermal cycling (T50 or T200)
X	X	X	MST 52 Humidity freeze (HF10)
X	X	X	MST 53 Damp heat (DH200 or DH1 000)
X	X	X	MST 54 UV pre-conditioning (15 kWh/m ² or 60 kWh/m ²)
X ^a	X ^a	X ^a	MST 55 Cold conditioning
X ^a	X ^a	X ^a	MST 56 Dry heat conditioning
X	X	X	General inspection test:
X	X	X	MST 01 Visual Inspection
X	X	X	MST 02 Performance at STC
X	X	X	MST 03 Maximum power determination
X ^c	X ^c	-	MST 04 Insulation thickness
X	X	X	MST 05 Durability of markings
X	X	X	MST 06 Sharp edge test
X	X	X	MST 57 Evaluation of insulation coordination
X	X	-	Electrical shock hazard tests:
X ^c	X ^c	-	MST 11 Accessibility test
X	X	-	MST 12 Cut susceptibility test
X	X	-	MST 13 Continuity test for equipotential bonding
X	X	-	MST 14 Impulse voltage test
X	X	X	MST 16 Insulation test
X	X	-	MST 17 Wet leakage current test
X	X	X	MST 42 Robustness of terminations test
X	X	X	MST 57 Evaluation of insulation coordination
~~X~~	~~X~~	~~X~~	Fire hazard tests:
X	X	X	~~MST 21 Temperature test~~
X ^b	X ^b	X ^b	MST 22 Hot-spot endurance test
X	X	X	MST 23 Fire test
X	X	X	MST 24 Ignitability test
X	X	X	MST 25 Bypass diode thermal test
X	X	-	MST 26 Reverse current overload test
X	~~X~~ -	X	Mechanical stress tests:
X	X	X	MST 32 Module breakage test
X	X	X	MST 33 Screw connection test
X	X	X	MST 34 Static mechanical load test
X ^{c,e}	X ^{c,e}	X ^{c,e}	MST 35 Peel test
X ^{d,e}	X ^{d,e}	X ^{d,e}	MST 36 Lap shear strength test
X	X	X	MST 37 Materials creep test
X Test required. - Test does not need to be carried out. ^a Only required to prove reduction of Pollution Degree PD=2 to PD=1. ^b Fire tests are nationally regulated and typically only required for building integrated or building added products. Hence, the applicability of a fire test does not depend on the Class, but on the mounting location. ^c This test is not applicable to rigid-to-rigid bonded assemblies (e.g. glass/glass PV modules). ^d This test is not applicable to rigid-to-flexible or flexible-to-flexible bonded assemblies. ^e Only required for proof of cemented joints around the PV module edges.			

6 Sampling

~~Nine~~ A minimum of 10 PV modules and ~~one~~ two unframed PV modules are used for safety testing (plus spares as desired). In order to prove reduction of Pollution Degree to PD 1, one additional PV module is required. If tests of Sequence F are performed in parallel, ~~between one and three additional modules are required.~~

If cemented joints according to MST 35 or MST 36 are to be qualified, one of the following is required:

- ~~An unframed PV module is tested in sequence B (One additional unframed PV module is required) for glass/flexible or flexible/flexible.~~
- Two unframed PV modules are tested in sequence B, one with the front-side facing the light and one with the backside facing the light. The front-side exposed specimen shall be used in the evaluation. One additional unframed PV module is required to test initial adhesion strength if a peel test (MST 35) is used for evaluation.
- For Glass/Glass constructions 20 additional samples according to 10.25.2 are required for the lap shear strength test (MST 36) to prove cemented joints.

All specimens shall be technically identical (same components). For MST 24, and MST 32 ~~and MST 37~~ PV modules which are complete in every detail, but not functioning or of low power, etc., are acceptable.

All test specimens except for ~~MST 24, MST 32, MST 35, MST 36, and MST 37 shall~~ MST 35 and MST 36, should be taken at random from a production batch or batches.

Additional PV modules for MST 23 might be necessary (PV modules which are complete in every detail, but not functioning or of low power, etc., are acceptable).

The PV 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 ~~module~~ manufacturer's normal inspection, quality control and production acceptance procedures. The PV modules shall be complete in every detail and shall be accompanied by the manufacturer's handling, mounting, and connection instructions. When the PV modules to be tested are prototypes of a new design and not from production, this fact shall be noted in the test report (see Clause 7). For sampling in the context of retesting, e.g. multiple bill of material (BOM), please see Clause 8 as well as IEC TS 62915.

The use of representative samples as substitutes for very large modules is described in Annex C.

7 Test report

The results of the assessment against IEC 61730-1 and IEC 61730-2 shall be laid down in one combined or two separate test reports ~~according to ISO/IEC 17025~~. The results shall be reported, normally in a test report and shall include all the information requested by the client and necessary for the interpretation of the test and all information required by the method used:

- 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;
- d) name and address of client, where appropriate;
- e) description and identification of the item tested;
- f) characterization and condition of the test item;
- g) date of receipt of test item and date(s) of test, where appropriate;

- h) identification of test method used;
- i) reference to sampling procedure, where relevant;
- j) any deviations from, additions to or exclusions from the test method, and any other information relevant to specific tests, such as environmental conditions or test method or procedure;
- k) measurements, examinations and derived results supported by tables, graphs, sketches and photographs as appropriate including maximum systems voltage, Class according to IEC 61140, mounting technique and any failures observed;
- l) a statement indicating whether the impulse voltage test was performed on PV module or laminate (PV module without a frame);
- m) a statement of the estimated uncertainty of the test results (where relevant);
- n) a signature and title, or equivalent identification of the person(s) accepting responsibility for the content of the report, and the date of issue;
- o) where relevant, a statement to the effect that the results relate only to the items tested;
- p) a statement that the report shall not be reproduced except in full, without the written approval of the laboratory.

A copy of this report shall be kept by the manufacturer for reference purposes.

8 Testing

The PV modules shall be divided into groups and subjected to the safety tests shown in Figure 1, carried out in the order specified. The PV modules shall be selected such that the environmental stress tests of 4.2 are met. Each box in Figure 1 refers to the corresponding subclause as described in Clause 4.

Spare PV modules may be included in the safety test program provided that they have been appropriately environmentally tested to meet the necessary prerequisites.

Test procedures and criteria, including initial and final measurements where necessary, are detailed in 10.2 through 10.34. Some tests are identical to tests in IEC 61215-2 and are referenced in Clause 4. In carrying out these tests, the manufacturer's handling, mounting, and connection instructions shall be strictly observed.

~~The PV module for sequence B shall be irradiated during the first 60 kWh/m² cycle from the front side of the specimen and from the backside during the second 60 kWh/m² cycle (MST 54). By doing so, the front side and back side of the PV module will be exposed to the same UV dose.~~

One PV module for sequence B shall be irradiated from the front side of the specimen and another from the backside during the 60 kWh/m² cycle (MST 54).

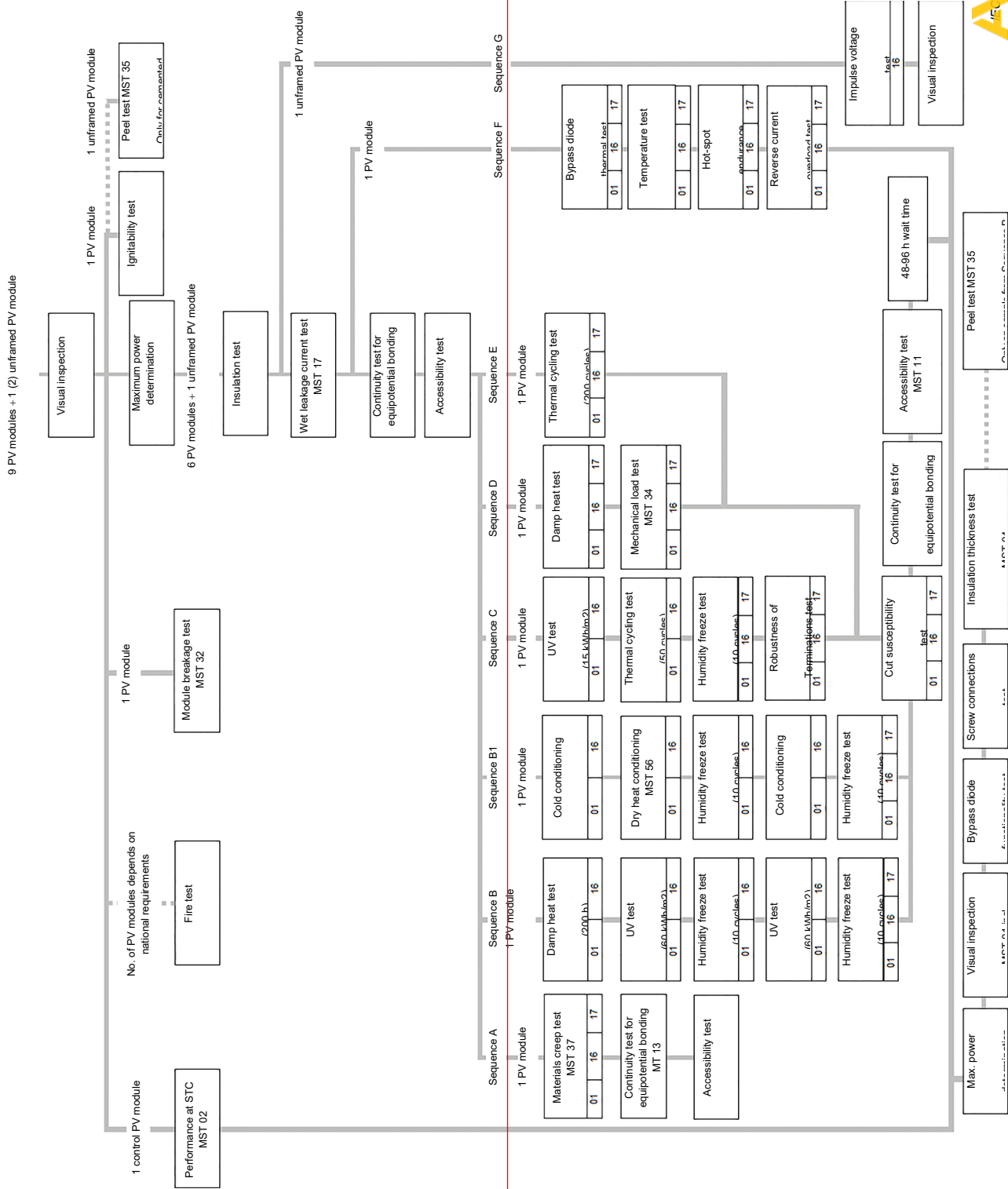
The intermediate control measurements (MST 01, MST 16, MST 17) after each stress test in Figure 1 are informative and may be skipped. Final measurements are required.

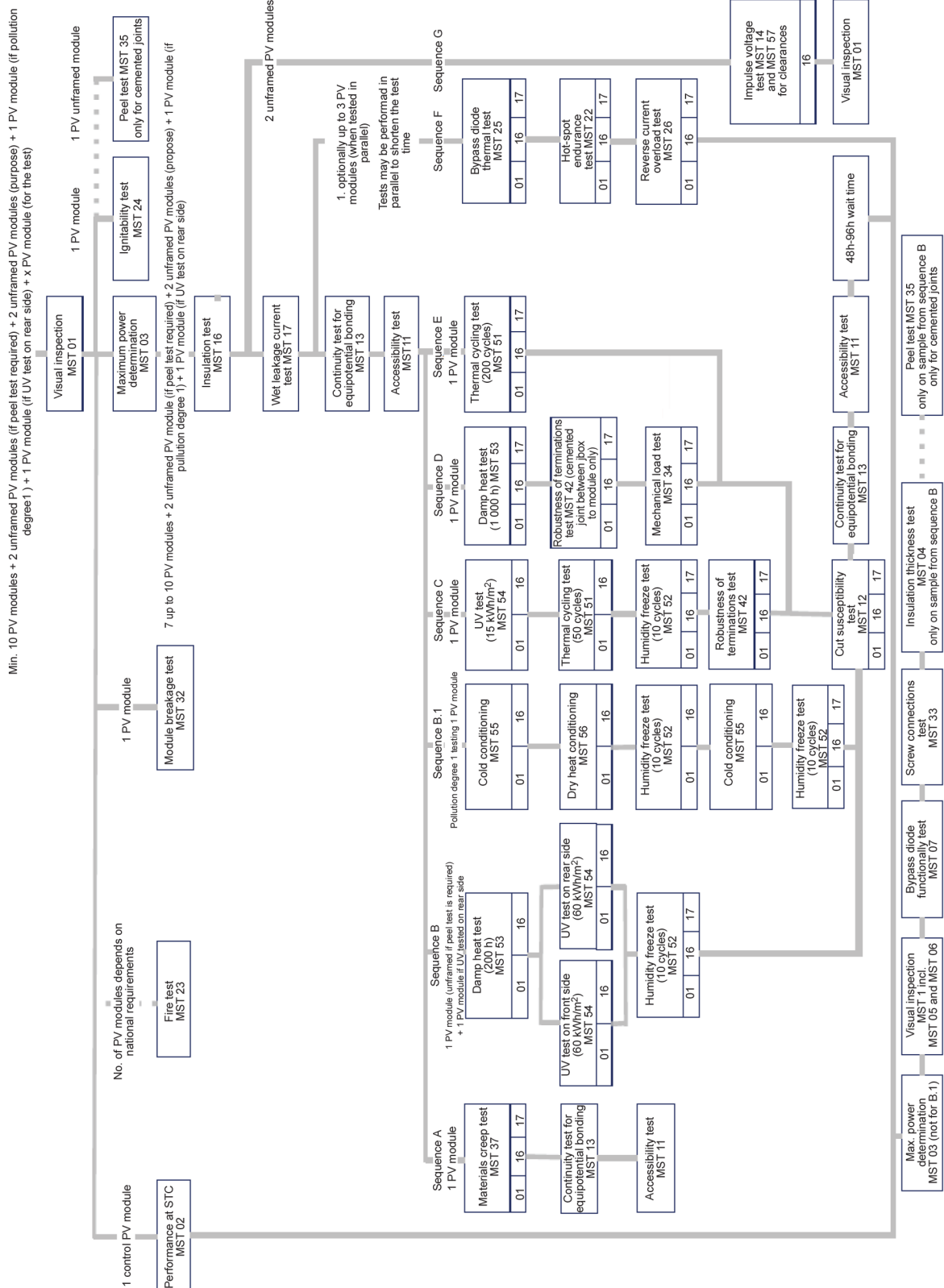
The wait time (48 h to 96 h) at the end of the sequence shall ensure that a minimum time between the immediate control inspection after completion of each environmental test (time counter starts after completion of MST 51, MST 52 and MST 53) and a second visual inspection is maintained. This is due to possible variation in visual defects apparent a few hours versus several days after an environmental stress test. The wait time does not apply to any other control check other than the visual inspection.

The tests in sequence F may be performed on separate modules. The test for ~~MST 21 and MST 25~~ may be performed on specially prepared samples (e.g. thermocouples within the laminate or junction box). If any of the individual tests of the sequence impact the outcome of

one of the subsequent tests, a separate sample shall be used. Potential impact on module output can be verified by MST 02.

The number of PV modules required for the fire test MST 23 will depend on the relevant test procedure. Retesting, e.g. multiple BOM, shall be performed according to IEC TS 62915. The recommended test sequences have been selected to identify adverse changes to the modified product.





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Intermediate tests for MST 01, MST 16 and MST 17 are optional.

For MST 16 after MST 12, preparation-requirements of 10.10.4 apply.

Maximum power determination shall not be performed for Sequence B.1.

Figure 1 – Test sequences – Pass criteria

9 Pass criteria

The product under evaluation shall be judged to have passed the safety qualification test, if the test samples meet all of the criteria of each individual test and no loss of electrical continuity occurs during testing in sequences A through F. The product is deemed not to comply with this document if any sample fails in one or more of the tests.

In case of failure the manufacturer ~~is recommended to~~ shall prepare a failure analysis and propose corrective actions. Depending on the proposed modification(s), a re-evaluation program can be defined before testing (IEC TS 62915), including design review to IEC 61730-1.

10 Test procedures

10.1 General

If not otherwise specified, all applied forces in N shall have an accuracy of 5 %.

If not otherwise specified, all torques (Nm) shall have an accuracy of 5 %.

10.2 Visual inspection MST 01

10.2.1 Purpose

To detect and document any visual defects and changes in the PV module.

10.2.2 Procedure

This test is identical with MQT 01 of IEC 61215-2 with the additional inspection criteria of

- any other conditions which may affect safety.
- during final inspection check compliance of markings with 5.2 of IEC 61730-1:20162022 subsequent to the Durability of markings test (MST 05) as described in 10.6.
- during final inspection check for sharp edges as described in 10.7 (MST 06).
- during final inspection check of minimum distances as defined in Tables 3 and 4 of IEC 61730-1:20162022 according to MST 57. See Figure 2a and Figure 2b for examples of creepage distance measurement when bubbles occur. Bubbles are assumed to be conductive for this evaluation. For clearance and creepage assessment check Annex C of IEC 61730-1:20162022.

It is advisable to check distances during the initial inspection to validate that the PV module meets the insulation requirements.

- During final inspection check the joint between junction boxes and modules for signs of creeping.

Make note of and/or photograph the nature and position of any cracks, bubbles or delaminations, etc., which may worsen and adversely affect the PV module safety in subsequent tests. Visual conditions other than the major defects listed below are acceptable for the purpose of safety test approval.

10.2.3 Pass criteria

For the purpose of this safety test, the following are considered to be major visual defects:

- a) broken, cracked, or torn external surfaces;
- b) bent or misaligned external surfaces, including frontsheet, backsheet, frames and junction boxes to the extent that the safety of the PV module would be impaired;

- c) in cemented joints bubbles, **foreign material** or delaminations with closest distances to each other ≤ 2 times the minimum required distance through cemented joint (see Tables 3 and 4 of IEC 61730-1:20162022) shall be evaluated as conductive and electrically connected. The shortest distance from and to such bubbles or delaminations through insulation material shall in sum not be shorter than the required minimum distance through cemented joint. See Figure 2b for example;
- d) for adhesive bonds other than in c) bubbles or delaminations with closest distances to each other ≤ 2 times the minimum required creepage distance (see Tables 3 and 4 of IEC 61730-1:20162022) shall be evaluated as conductive and electrically connected. The shortest distance from and to such bubbles or delaminations through insulation material shall in sum not be shorter than the required minimum creepage distance. See Figure 2b for example;
- e) loss of mechanical integrity to the extent that the safety of the installation and safe operation of the PV module would be impaired;
- f) if the mechanical integrity depends on lamination or other means of adhesion, the sum of the area of all bubbles shall not exceed 1 % of the total PV module area;
- g) evidence of any molten or burned component;
- h) markings not complying with 5.2 of IEC 61730-1:20162022 and the durability of markings test (MST 05) at final inspection;
- i) edges not complying with MST 06 sharp edge test at final inspection;
- j) **The final inspection of a joint between junction box and module shall show no sign of creeping.**

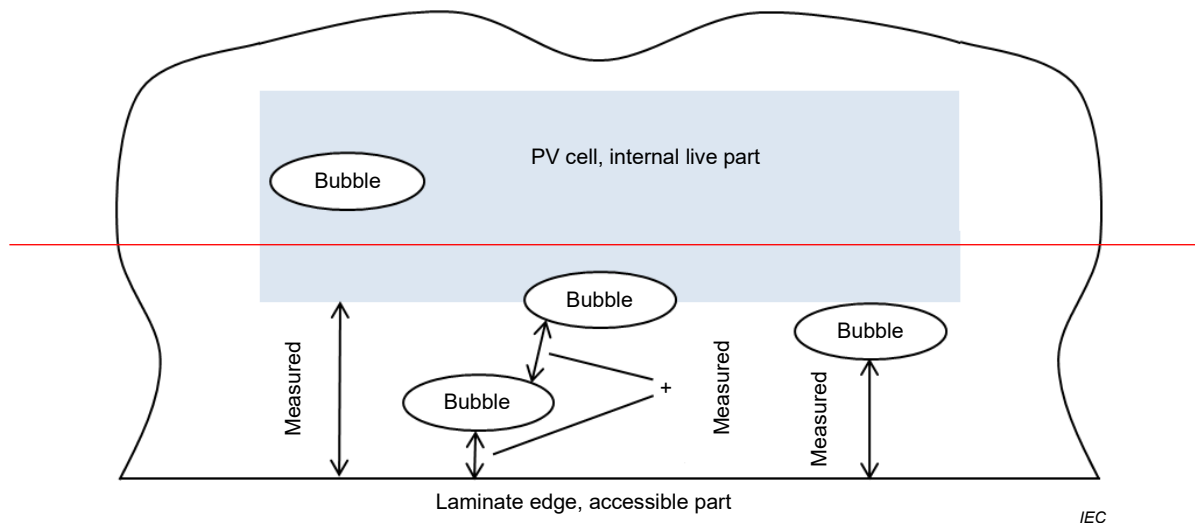


**Figure 2a – Example for delamination assessment
when measuring creepage or distance through insulation**

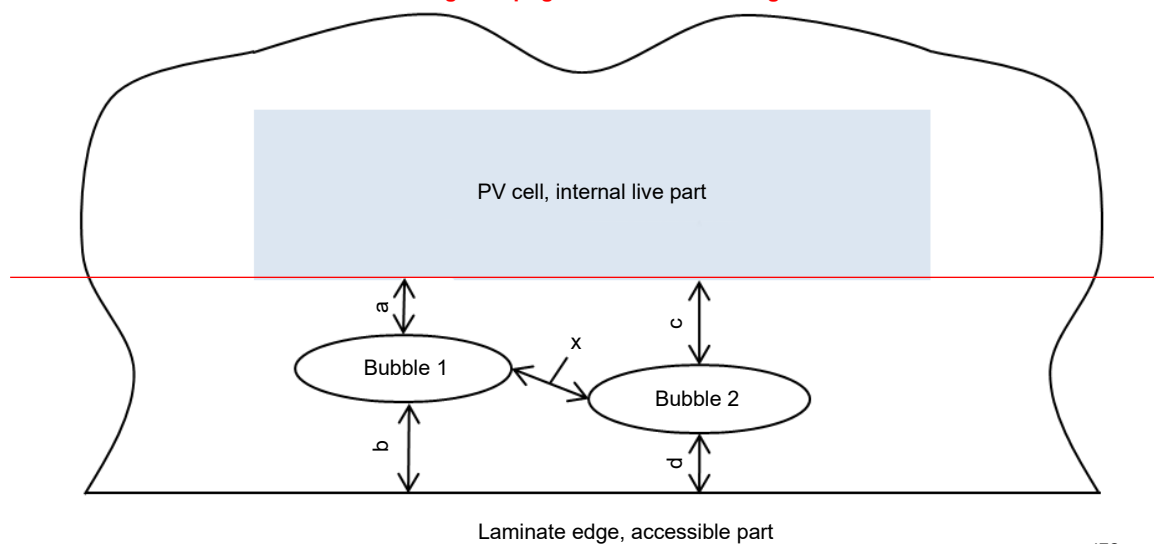
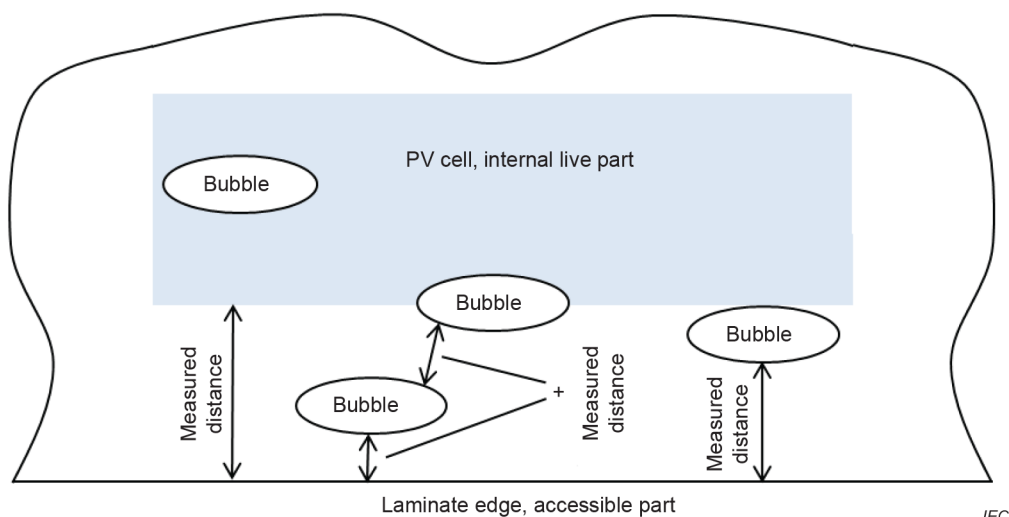
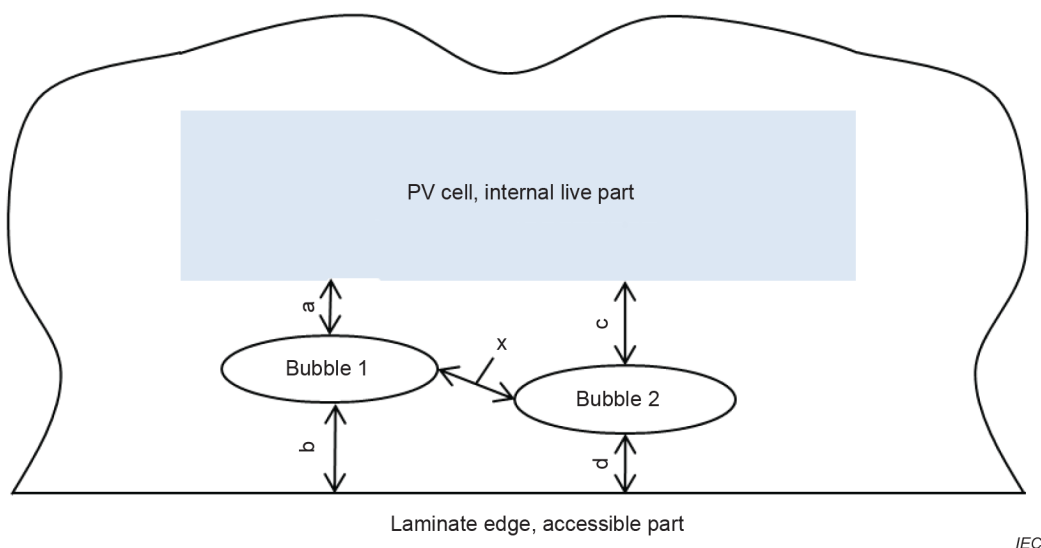


**Figure 2b – Example for delamination distance (x) assessment
when measuring creepage or distance through insulation**

Figure 2 – Assessment of bubbles in edge seals for cemented joints



a) Example for delamination assessment when measuring creepage distances and clearances, or distance through insulation



b) Example for delamination distance (x) assessment when measuring creepage distances and clearances, or distance through insulation

Figure 2 – Assessment of bubbles for evaluation of clearances and creepage distances, or distance through insulation

EXAMPLE 1 Cemented joint:

If distance x between bubbles is ≤ 2 times the minimum distance through cemented joint then the shortest path through insulation would be measured by adding distances a and d . If distance x between bubbles is > 2 times the minimum distance through cemented joint then the shortest path through insulation would be measured by adding distances a and b and respectively by adding distances c and d . The shorter of the two sums needs to comply with the requirements set forth in IEC 61730-1.

EXAMPLE 2 Creepage distance:

If distance x between bubbles is ≤ 2 times the minimum creepage distance then the shortest path along an interface (creepage distance) through the insulation system would be measured by adding distances a and d . If distance x between bubbles is > 2 times the minimum creepage distance then the shortest path along an interface (creepage distance) through the insulation system would be measured by adding distances a and b and respectively by adding distances

c and d. The shorter of the two sums needs to comply with the requirements set forth in IEC 61730-1.

10.3 Performance at STC MST 02

10.3.1 Purpose

This test shall verify the rated short-circuit current (I_{sc}) and open-circuit voltage (V_{oc}) for monofacial modules, and additional I-V characterizations of bifacial modules as described in 10.3.2.

10.3.2 Procedure

The module shall be stabilized according to MQT 19.1 of IEC 61215-2. The test procedure is equivalent to MQT 06.1 in IEC 61215-2.

10.3.3 Pass criteria

Measured I_{sc} and V_{oc} shall be within the tolerances given by the manufacturer.

10.4 Maximum power determination MST 03

10.4.1 Purpose

This test shall verify that the PV module shows the electrical characteristics of a fully functional photovoltaic device.

10.4.2 Procedure

This test is equivalent to MQT 02 in IEC 61215-2.

10.4.3 Pass criteria

The IV curve shall not show any additional kinks or other unusual characteristics as compared to the initial IV curve taken according to MST 02 (e.g. caused by diodes “turning on”).

NOTE Especially inhomogeneous degradations within PV modules are causes for safety risks and failures. Degradations of single cells or substrings can lead to hot-spots, high module temperatures or diodes conducting permanently. MST 03 aims at detecting such cases.

10.5 Insulation thickness test MST 04

10.5.1 Purpose

~~This test shall verify compliance to the minimum insulation thickness for thin layers as specified in either Table 3 or Table 4 of IEC 61730-1:2016 depending on the PV module's Class according to IEC 61140.~~

This test shall verify compliance to results of DTI-test of IEC 62788-2-1 which determines the minimum insulation thickness for thin layers. The measured values may be lower than specified in IEC 62788-2-1, but shall not be lower than specified in Table 3 or Table 4 of IEC 61730-1:2022 depending on the PV module's Class according to IEC 61140.

The test is to be performed on polymeric insulation sheets front side and/or back side.

This test is not applicable to glass layers.

10.5.2 Procedure

The procedure is as follows:

- a) Select three locations per side on the PV module representing minimum thickness of the polymeric insulation material.

NOTE 1 Typically minimum thickness can be found at solder connections, edges of frameless PV modules, or laminator membrane indents.

- b) Applying a suitable method, measure the thickness of the individual layers separating the electric circuitry from the outer surface. The used method shall have a measurement uncertainty not greater than $\pm 10\%$ including reproducibility. Then determine the thickness of the part of the layers representing the relied upon insulation (see ~~Figure 4 of IEC 61730-1:2016~~ IEC 62788-2-1:2022).

NOTE 2 Suitable methods can be destructive or non-destructive, e.g. cross-sectional cut and optical measurement; ultra-sonic measurements, etc. ~~Solder wire method is under consideration for the measurement of dtt in IEC 62788 series.~~

10.5.3 Pass criteria

The measured insulation thickness shall be greater than the requirements listed in either Table 3 or Table 4 of IEC 61730-1:20162022 depending on the PV module's Class according to IEC 61140 and considering the measurement uncertainty of the test and the set-up.

The layer thicknesses in Table 3 and Table 4 of IEC 61730-1:20162022 are minimum requirements, therefore the uncertainty of the measurement shall be deducted from the measured value.

EXAMPLE For a system voltage of 1 000 V and a PV module design according to Class II the remaining thickness of the relied upon insulation shall be 150 μm . If the measurement uncertainty of the test and of the set-up is $\pm 10\%$, the measured value shall be equal to or greater than 165 μm .

10.6 Durability of markings MST 05

Any marking required by this standard shall be durable and legible. In considering the durability of the marking, the effect of normal use shall be taken into account.

Compliance is checked by inspection, by measurement and by rubbing the marking by hand using medium pressure for 15 s with a piece of cloth soaked with water and again for 15 s with a piece of cloth soaked with petroleum spirits. After this test, the marking shall be legible; it shall not be possible to remove marking plates easily and they shall show no curling.

The petroleum spirits to be used for the test is aliphatic solvent hexane having a maximum aromatics content of 0,1 % by volume, a kauri-butenol value of 29, an initial boiling point of approximately 65 °C, a dry point of approximately 69 °C and a mass per unit volume of approximately 0,7 kg/l.

NOTE Test is identical to IEC 60335-1:20132020, 7.14 and IEC 60950-1:2013, 1.7.11.

10.7 Sharp edge test MST 06

~~The accessible PV module surfaces shall be smooth and free from sharp edges, burrs, etc., which may damage the insulation of conductors or pose a risk of injury. Compliance is checked by inspection.~~

~~Alternatively a sharp edge test described in ISO 8124-1 can be performed to confirm compliance.~~

10.7.1 Purpose

All accessible PV module surfaces shall be smooth and free from sharp edges, burrs, etc., which may damage the insulation of conductors or pose a risk of injury during intended use, handling or maintenance.

10.7.2 Apparatus

The apparatus is as follows:

The apparatus should be moveable along the edge to be tested, while executing a steady force of $6,672 (\pm 0,133)$ N to the centre of a piece of round steel cylinder (curved side), with an outside diameter of 12,7 mm, as depicted in Figure 3. The round steel cylinder is the tester head.

The piece of round steel is to be wrapped with three layers of tape, the two outer layers act as sensing tapes; the inner layer acts as an indicating tape, or the tapes are to be applied to a 15,9 mm removable sleeve that is placed onto the 12,7 mm steel head, as depicted in Figure 3.

Indicating tape (inner layer) – $19,1 (\pm 0,2)$ mm wide, adhesive backed, single-adhesive coated, vinyl foam tape, black in colour, having the tape properties given in Table 7.

Sensing tape No. 2 (middle layer) – $19,1 (\pm 0,2)$ mm wide, double-adhesive coated, vinyl foam tape, white in colour, having the tape properties given in Table 7.

Sensing tape No. 1 (outer layer) – $19,1 (\pm 0,2)$ mm wide, single-adhesive coated skived tetrafluorethylene tape – natural colour, having the tape properties given in Table 7.

Each tape is to be applied over approximately 180 degrees of the circumference of the test head to prevent stretching of the tape. The tapes are not to be stretched when positioned on the head.

NOTE 1 A UL 1439 compliant test tool is sufficient to meet this requirement and is available commercially.

NOTE 2 The test equipment is similar to that described in IEC TR 62854.

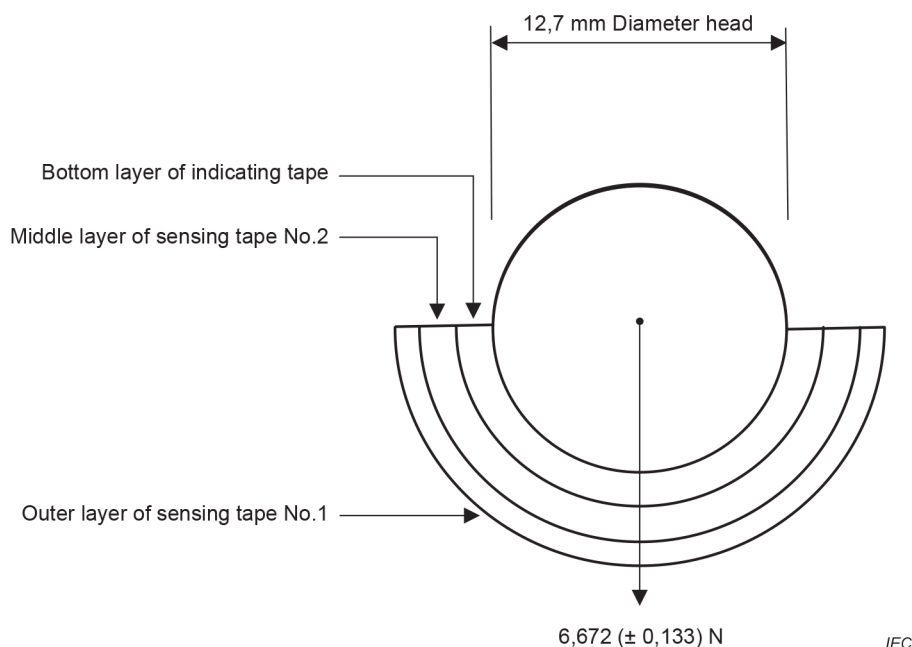


Figure 3 – Test apparatus MST 06

Table 7 – Tapes for test finger

	Indicating tape black vinyl foam tape	Tape No.2 white vinyl foam tape	Tape No.1 polytetrafluorethylene tape
Thickness [mm]	1,14 to 2,03	0,64 to 1,02	Total with adhesive backing: 0,114 Backing only: 0,064 to 0,089
Density [kg/m³]	400 to 433	224 to 321	-

10.7.3 Procedure

The procedure is as follows.

For the purposes of reproducibility this test is conducted under the conditions of module and room temperature each of $23\text{ °C} \pm 5\text{ °C}$ and relative humidity of less than 75 %.

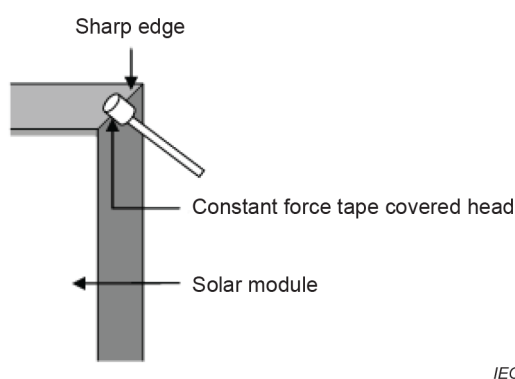
Compliance of sharp edges shall be checked by initial inspection (four (five) samples total each from sequences B (B1 if PD1), C, D, E of Figure 1).

The curved face of the tester head shall be covered with three layers of tape in the order described in 10.7.2.

The centre of the tape-covered head of the sharp-edge tester shall be positioned on the edge to be tested in the manner illustrated in Figure 4.

The tape-covered head exerts a constant force of $6,672 (\pm 0,133)\text{ N}$ on the edge to be tested.

With contact to the edge, the tester shall immediately be moved along the edge and then back to its starting position without removal of the tester from the edge. The total distance should not exceed 100 mm. The time of travel is not to take longer than 5 s nor less than 2 s. It shall then be withdrawn from the edge.



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Figure 4 – Position of test apparatus

The tape-covered head shall be then examined to determine whether or not penetration has occurred through the two sensing layers. If penetration has occurred through the two sensing layers, the black indicating tape will be visible through the resulting cut.

Each edge tested shall be identified by description of its location.

10.7.4 Final measurements

None.

10.7.5 Pass criteria

The pass criteria are as follows.

The application of the sharp-edge tester to an accessible edge as described in 10.7.3 shall not result in the cutting through of the two outer layers of the sensing tapes so that the black indicating tape will be visible through the resulting cut.

10.8 Bypass diode functionality test MST 07

The test procedure and pass criteria are equivalent to MQT 18.2 in IEC 61215-2. For bifacial modules tested according to Method A the value for short circuit current shall be $I_{sc-aBSI}$.

10.9 Accessibility test MST 11

10.9.1 Purpose

To determine if PV modules are constructed to provide adequate protection against accessibility to hazardous live parts (> 35 V).

10.9.2 Apparatus

The apparatus is as follows:

- a) A cylindrical test fixture Type 11 according to Figure 7 of IEC 61032:1997.
- b) An ohmmeter or continuity tester.

10.9.3 Procedure

The procedure is as follows:

- a) Mount and wire the test PV module as recommended by the manufacturer.
- b) Attach the ohmmeter or continuity tester to the PV module's short-circuited terminals and to the test fixture.
- c) Remove all covers, plugs and connections from the PV module that can be removed without using a tool.
- d) Probe with the test fixture in and around all electrical connectors, junction boxes and any other areas where live parts of the PV module may be accessible.
- e) The test fixture shall be used with an applied force of 10 N.
- f) Monitor the ohmmeter or continuity tester during the probing to determine if the test fixture makes electrical contact to the PV module live parts.

10.9.4 Final measurements

None.

10.9.5 Pass criteria

The pass criteria are as follows:

- a) At no time during the test there shall be a resistance of less than 1 MΩ between the test fixture and the PV module live parts.
- b) At no time during the test shall the probe contact any live electrical part.

This test is performed at the beginning and the end of the sequence according to Figure 1, but also can be used at any time during the test sequence if there is any reason to believe that active electric circuitry has been exposed by one of the other tests.

10.10 Cut susceptibility test MST 12

10.10.1 Purpose

To determine whether any front and rear surfaces of the PV module made of polymeric materials are capable of withstanding routine handling during installation and maintenance without exposing personnel to the danger of electric shock.

This test is not applicable to rigid-to-rigid bonded assemblies (e.g. glass/glass PV modules).

10.10.2 Apparatus

A test fixture as shown in Figure 5, designed to draw a defined shaped object over the surface of the PV module with an applied force of $8,9 \text{ N} \pm 0,5 \text{ N}$. The defined shaped object shall be a $0,64 \text{ mm} \pm 0,05 \text{ mm}$ thick hardened steel blade sufficiently rigid as not to bend sideways during the test. The tip shall have a top angle of $90^\circ \pm 2^\circ$ and shall be rounded with a radius of $0,115 \text{ mm} \pm 0,025 \text{ mm}$.

Apparatus in Figure 5 is an example and other apparatus proving same test parameters (e.g. force and scratch shape) can also be used if equivalency is verified.

10.10.3 Procedure

The procedure is as follows:

- a) Position the PV module horizontally with the test surface facing upward.
- b) The test fixture is to be placed on the surface for 1 min and then drawn across the surface of the PV module at a speed of $150 \text{ mm/s} \pm 30 \text{ mm/s}$. Repeat the procedure five times in different directions considering the most critical points.
- c) Repeat a) and b) for other polymeric surfaces of the PV module if applicable.

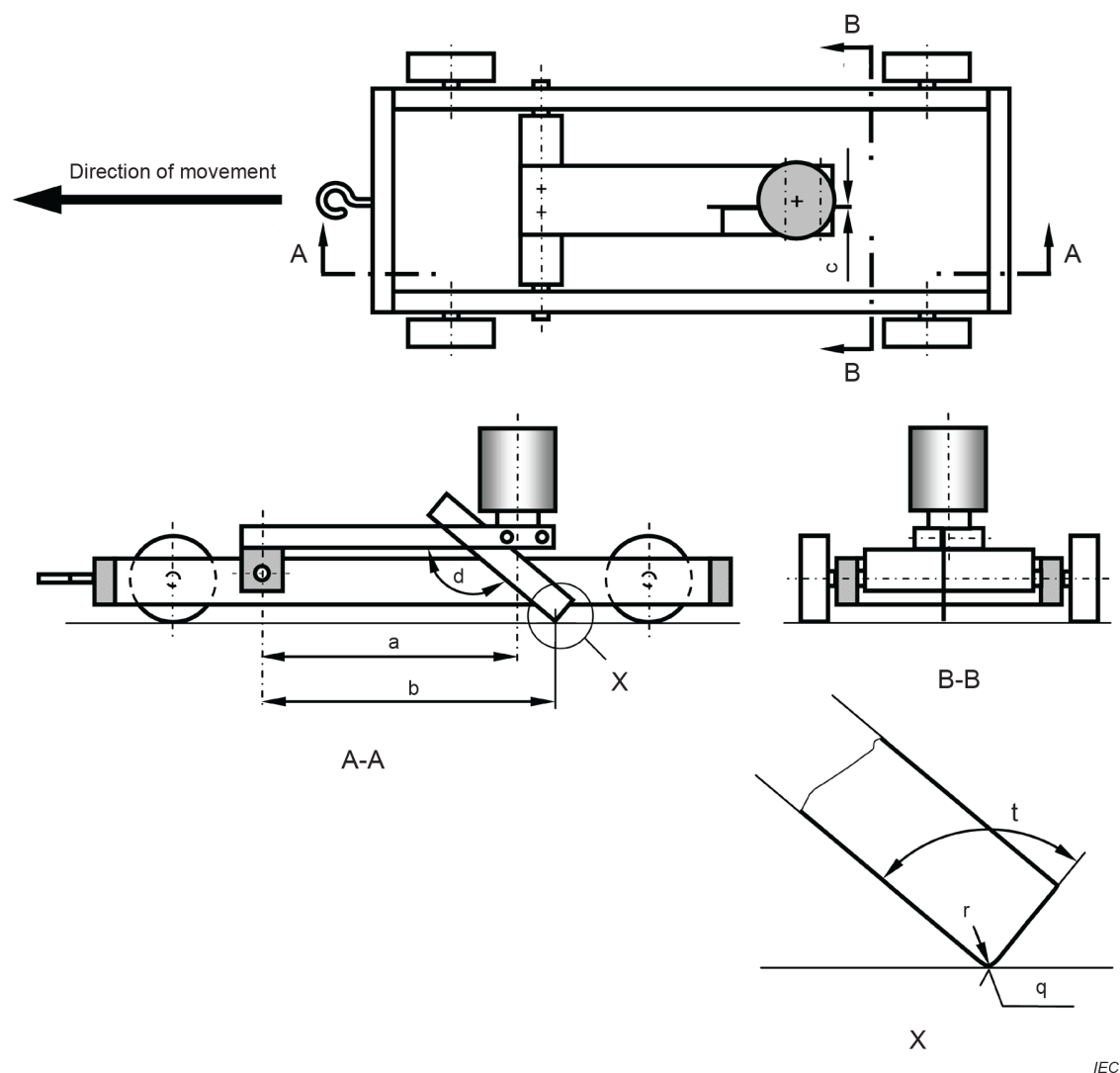
10.10.4 Final measurements

Repeat MST 01, MST 16 and MST 17. For MST 16, conductive foil meeting the requirements described in IEC 61215-2 MQT 03 shall be placed over all areas that were subjected to the cutting stress, and the foil shall extend at least 1 cm past all cut areas.

10.10.5 Pass criteria

The pass criteria are as follows:

- a) No visual evidence that the frontsheet or backsheet surfaces have been cut exposing the active circuitry of the PV module.
- b) MST 16, MST 17 shall meet the same requirements as for the initial measurements.



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- a 150 mm from axis to centre of weight
- b 170 mm from axis to test point
- c Carbon steel strip $0,64 \text{ mm} \pm 0,05 \text{ mm}$ thick
- d 140° angle between horizontal plane and the strips' edge
- q Total force exerted at test point $8,9 \text{ N} \pm 0,5 \text{ N}$
- r Tip rounded with radius $0,115 \text{ mm} \pm 0,025 \text{ mm}$
- t Steel strip top angle $90^\circ \pm 2^\circ$

Figure 5 – Cut susceptibility test**10.11 Continuity test of equipotential bonding MST 13****10.11.1 Purpose**

The purpose of this test is to verify the continuous path between accessible conductive parts that are in direct contact with each other (e.g. parts of a metallic frame).

10.11.2 Apparatus

The apparatus is as follows:

- a) A constant current supply capable of producing a current that is 2,5 times the maximum overcurrent protection rating of the PV module under test.

b) A suitable voltmeter.

According to IEC 61730-1 the maximum overcurrent protection rating has to be provided by the manufacturer. The maximum overcurrent protection rating is verified in MST 26.

NOTE Common types of overcurrent protection devices are fuses or circuit breakers.

10.11.3 Procedure

The procedure is as follows:

- a) Select the manufacturer's designated point for equipotential bonding and the recommended connection. Attach to one terminal of the constant current supply.
- b) Select an adjacent (connected) exposed conductive component with the greatest physical displacement from the grounding point and attach to the other terminal of the current supply.
- c) Attach the voltmeter to the two conductive components attached to the current supply in proximity to the current leads.
- d) Apply a current $250 \% \pm 10 \%$ of the maximum overcurrent protection rating of the PV module for a minimum of 2 min.
- e) Measure the applied current and the resultant voltage drop.
- f) Reduce the current to zero.
- g) Repeat for all other accessible conductive parts.
- h) Repeat the test for all connection(s), terminal(s), and/or wire(s) included or specified by the manufacturer for grounding the PV module.

10.11.4 Final measurements

None.

10.11.5 Pass criteria

The resistance between the selected exposed conductive component and every other conductive component of the PV module shall be less than $0,1 \Omega$. The resistance shall be calculated from the applied current and the resulting voltage drop measured at the connection points of the PV module (e.g. frame).

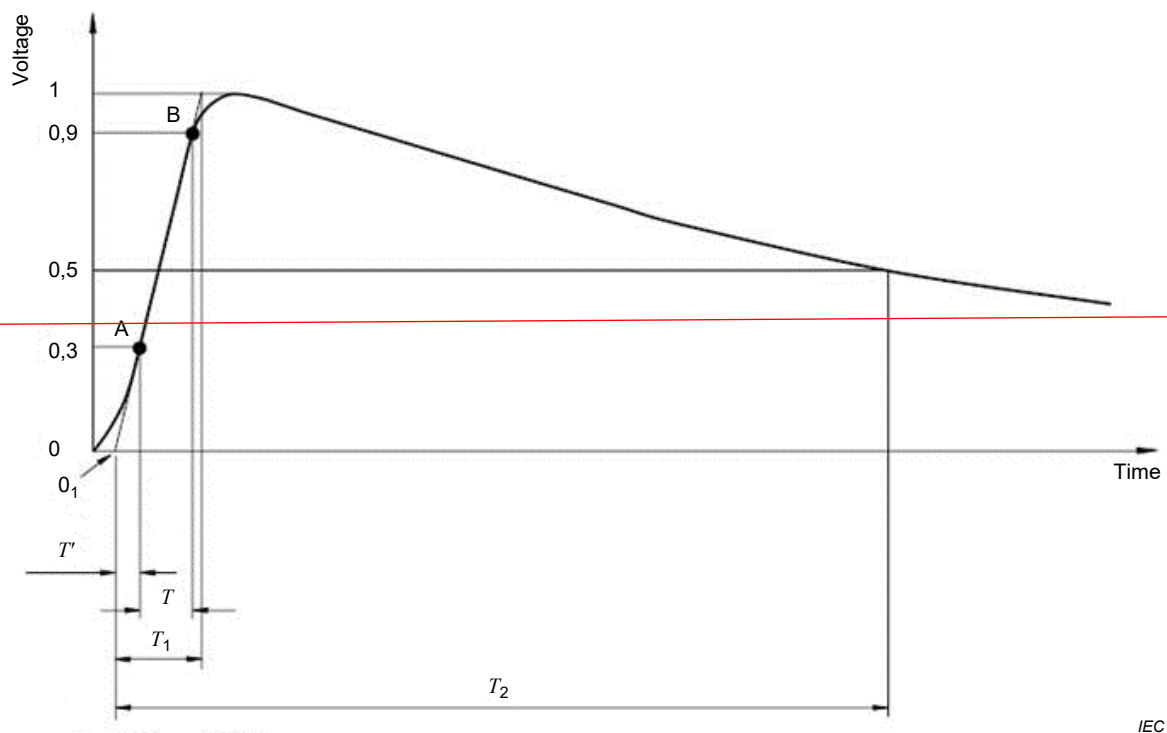
10.12 Impulse voltage test MST 14

10.12.1 Purpose

The purpose of the test is to verify the capability of insulation of the PV module to withstand over-voltages of atmospheric origin. It also covers over-voltages due to switching of low-voltage equipment.

10.12.2 Apparatus

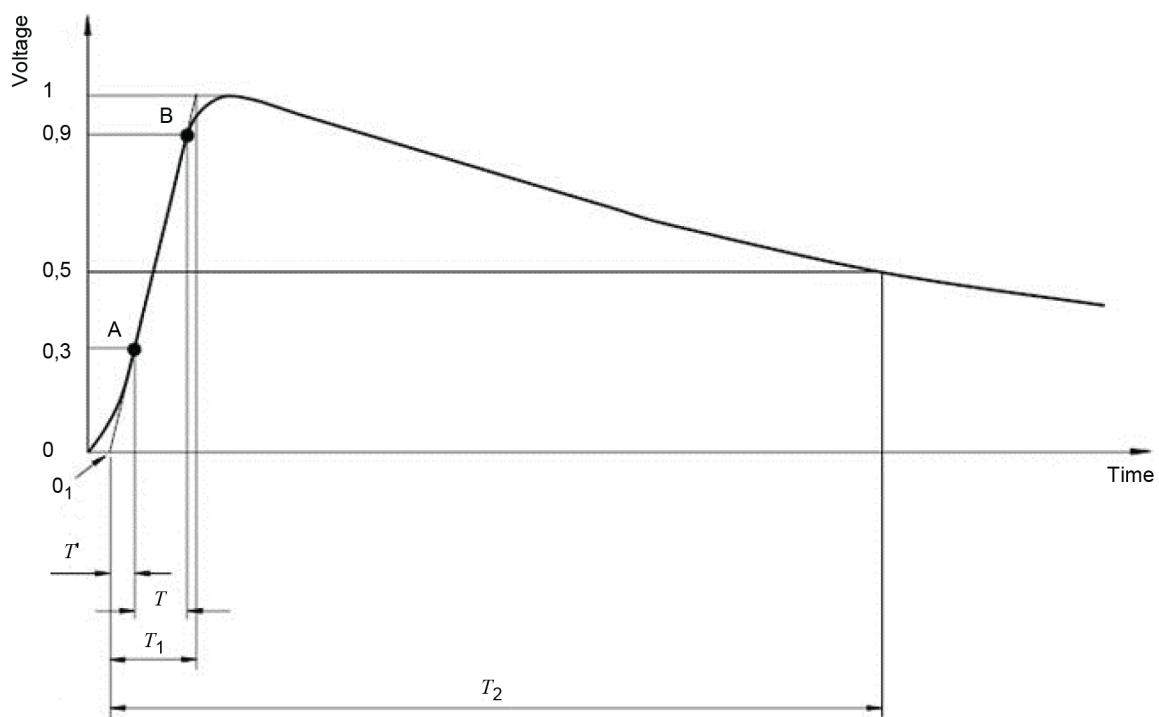
The test equipment and procedure shall comply with IEC 60060-1. Due to the variable and comparably high capacity of many samples, compensation measures may be applicable to fulfil the required waveform tolerances, see Figure 6.



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$$T_1 = 1,2 \mu\text{s} \pm 30 \%$$

$$T_2 = 50 \mu\text{s} \pm 20 \%$$



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$T_1 = 0,84 \mu\text{s}$ up to $3,12 \mu\text{s}$. (T_1 can be calculated with T divided by 0,6)

$T_2 = 40 \mu\text{s}$ up to $60 \mu\text{s}$

NOTE The parameter 0_1 is the start point of the impulse voltage. In a diagram with linear time scale this is the intersection point of the time axis and the line defined by points A and B.

Figure 6 – Waveform of the impulse voltage following IEC 60060-1

10.12.3 Procedure

This test is performed on an unframed PV module. If the frame is an integral part of the edge insulation the test can be done with the framed PV module. The impulse voltage test shall be performed in accordance with IEC 60060-1.

For the purposes of test reproducibility this test is conducted under the conditions of room temperature and relative humidity of less than 75 %. The procedure is as follows:

- a) Disable any voltage limiting device installed on the PV module, if applicable.
- b) Cover the whole PV module with a conductive metal foil using a conductive adhesive to achieve best possible contacting and avoid e.g. bubbles that may influence the test result. The adhesive (conducting glue) shall have an electrical resistance $< 1 \Omega$ related to an area of 625 mm^2 . Care shall be taken to avoid particle or air enclosure between the foil and the PV module as much as possible. Connect the foil either to the negative or to the positive terminal of the impulse voltage generator.
- c) Connect the shorted output terminals of the PV module either to the positive terminal (in case that the foil is connected to the negative terminal) or to the negative terminal (in case that the foil is connected to the positive terminal) of the impulse voltage generator.
- d) Apply the surge impulse voltage with a waveform as shown in Figure 6 by the impulse voltage generator. According to IEC 60060-1 the surge impulse peak voltage shall be within $\pm 3 \%$ of the value given in Table B.1 of IEC 61730-1:20162022.

Linear interpolation of the voltages given in Table B.1 of IEC 61730-1:20162022 is allowed for intermediate values of maximum system voltage.

- e) The waveform of the pulse shall be ~~observed~~ verified by an oscilloscope connected as close to the short-circuited PV module terminals as possible or with sufficient terminating impedance on the measurement cable connections. The rise time and the pulse duration shall be checked for each test for compliance with Figure 6.

Care should be taken that probes are appropriate to guarantee a reproducible measurement.

NOTE In IEC 60060-1 a test voltage function is defined, representing the response of insulations applicable for signal filtering.

- f) Three successive pulses shall be applied.
- g) Change the polarity of ~~the terminals of~~ the pulse ~~generator~~ and apply three successive pulses.

10.12.4 Final measurement

Repeat visual inspection MST 01 and insulation test MST 16.

If a breakdown occurred, the conductive foil may need to be removed for the visual inspection to identify location of breakdown for analysis. The foil should not be removed until after the Insulation test MST 16 has been performed.

10.12.5 Pass criteria

The pass criteria are as follows:

- a) No evidence of dielectric breakdown or surface tracking of the PV module is observed during the test.
- b) No evidence of major visual defects as defined in MST 01.
- c) MST 16 shall meet the same requirements as for the initial measurements.

10.13 Insulation test MST 16

~~10.13.1 Purpose~~

~~The purpose of this test is, to determine whether the PV module is sufficiently well insulated between current carrying parts and the frame or other outside accessible components.~~

~~10.13.2 Procedure~~

~~This test is identical to MQT 03 of IEC 61215-2 with test levels depending on the Class and the maximum system voltage. The maximum test voltage U_{Test} shall be equal to 2 000 V plus four times the maximum system voltage for Class II and equal to 1 000 V plus two times the maximum system voltage for Class 0. For Class III the test voltage is 500 V.~~

~~Cemented joints within PV modules shall be tested with an increased test voltage. The following applies: $U_{Test}(\text{cemented joint}) = U_{Test} \cdot 1,35$ as required by IEC 61730-1. All non-cemented joints shall be tested with normal U_{Test} .~~

~~10.13.3 Pass criteria~~

~~See MQT 03 of IEC 61215-2.~~

This test is equivalent to MQT 03 of IEC 61215-2.

10.14 Wet leakage current test MST 17

This test is equivalent to MQT 15 in IEC 61215-2.

Cemented joints within PV modules shall be tested with an increased test voltage. The following applies: $U_{Test}(\text{cemented joint}) = U_{Test} \cdot 1,35$ as required by IEC 61730-1. All non-cemented joints shall be tested with normal U_{Test} .

10.15 Placeholder section, formerly Temperature test MST 21

~~10.15.1 Purpose~~

~~This temperature test is designed to determine the maximum reference temperatures for various components and materials used to construct the PV module, in order to verify the suitability of their use.~~

~~The test can be performed under natural sunlight or by use of a solar simulator with a cold sky.~~

~~10.15.2 Outdoor method~~

~~10.15.2.1 Test apparatus~~

- ~~• A black painted platform constructed of a suitable wooden plate that has sufficient mechanical strength to avoid warping under temperature influence. Behind the board a thermal insulation with a U value of less than 0,5 W/(m·K) shall be placed.~~
- ~~• A pyranometer or PV reference device conforming to IEC 60904-2 mounted in the plane of the structure within 30 cm of the test PV module.~~
- ~~• Instruments to measure wind speed down to 0,25 m/s installed approximately 0,7 m above the top of the platform.~~
- ~~• An environmental temperature sensor, with a time constant equal to, or less than, that of the PV module, installed in a shaded enclosure with good ventilation. The sensor shall be placed left or right of the platform so that no thermal interference can occur.~~

- ~~A temperature monitoring system capable of measuring PV module component temperatures with accuracy of ± 2 K.~~
- ~~A data acquisition system capable of recording the parameters within an interval of no more than 5 s.~~
- ~~Maximum power point tracking device or a resistive load sized such that at STC the PV module operates near the maximum power point.~~

10.15.2.2 Procedure

~~The PV module under test shall be mounted sunny side up onto the black painted platform in accordance with the manufacturer's installation instructions. If the instructions offer more than one option, the option providing the worst case thermal conditions shall be used. If no indications have been provided for spacing, the test PV module shall be mounted horizontally and directly flat on the platform without spacing.~~

~~The black painted side of the wooden platform shall face the test sample and the platform shall extend at least 60 cm beyond the PV module on all sides unless the PV module is installed directly next to other PV modules of similar dimensions.~~

~~The PV module under test shall be connected to the resistive load or maximum power point tracking device.~~

~~Throughout the test the following parameters shall be monitored:~~

- ~~temperatures of PV module components and materials, as listed below;~~
- ~~environmental temperature;~~
- ~~irradiance;~~
- ~~wind speed.~~

~~The environmental temperature during the test may be in the range of 20 °C to 45 °C. The irradiance during the test shall be between 700 W/m² and 1 000 W/m².~~

~~If the irradiance is other than 1 000 W/m², take at least two measurements at other irradiance levels (at least 80 W/m² apart) and then make a quadratic extrapolation to determine the corrected module temperature at 1 000 W/m² irradiance.~~

~~It is permissible to reposition (track) the test platform to maintain a consistent irradiance level throughout the test.~~

~~All data shall be taken at wind speeds of less than 1 m/s.~~

~~Stabilised temperature data for each test location shall be collected. Thermal stability has been attained when three successive averaged values, taken 5 min apart, indicate a change in temperatures of less than ± 2 K. Averaged values in this context are calculated from the readings taken over a 1 min interval.~~

~~The measured component temperatures (T_{OBS}) shall be normalised by the addition of the difference between the 40 °C reference environmental temperature and the measured environmental temperature (T_{ENV}) according to the formula:~~

$$\underline{T_{CON} = T_{OBS} + (40\text{ °C} - T_{ENV})}$$

~~where T_{CON} is the normalised temperature.~~

~~If an unacceptable performance is encountered during the temperature test and the performance is attributed to a test condition that although within the limits specified may be considered more severe than necessary – for example an ambient temperature near the limits allowed – the test may be conducted under conditions closer to the norm.~~

~~Typical component measurement points shall include:~~

- ~~• PV module frontsheet above the centre cell, if non-glass (possible shading of cells by temperature sensor shall be avoided as much as possible).~~
- ~~• PV module backsheet below the centre cell.~~
- ~~• Terminal enclosure interior surface.~~
- ~~• Field wiring terminals.~~
- ~~• Insulation of the field wiring leads.~~
- ~~• External connector bodies (if applicable).~~
- ~~• Bypass diode bodies (if applicable).~~

~~Due to the many possible variations in construction, more than one data gathering point for each cited location may be used, at the discretion of the test laboratory.~~

~~10.15.3 Solar simulator method~~

~~10.15.3.1 Test apparatus~~

- ~~• A continuous source sun simulator class BBC or better according to IEC 60904-9 shining from top to the horizontally mounted test platform with an average irradiance of 1 000 W/m² in the area of testing (PV module area plus 20 cm surrounding the PV module).~~
- ~~• Reference cell to measure the irradiance in the test plane.~~
- ~~• Cold sky to avoid heat from the light source influencing the test results.~~
- ~~• A black painted test platform parallel to the light source which has sufficient mechanical strength to avoid warping under temperature influence.~~
- ~~• Means for mounting the test PV module directly flat to the test platform.~~
- ~~• A handheld anemometer to ensure a wind speed during the test of < 0,25 m/s; typically the wind speed will be close to 0 m/s during the test.~~
- ~~• An air temperature sensor, with a time constant equal to, or less than, that of the PV module, installed in a shaded enclosure with good ventilation. The sensor shall be placed left or right of the platform so that no thermal interference can occur.~~
- ~~• A temperature monitoring system capable of measuring PV module component temperatures with an accuracy of ± 2 K.~~
- ~~• A data acquisition system capable of recording the parameters within an interval of no more than 5 s.~~
- ~~• Maximum power point tracking device or a resistive load sized such that at STC the PV module operates near the maximum power point.~~

~~10.15.3.2 Procedure~~

~~The PV module under test shall be mounted sunny side up onto the black painted platform in accordance with the manufacturer's installation instructions. If the instructions offer more than one option, the option providing the worst case thermal conditions shall be used. If no indications have been provided for spacing, the test PV module shall be mounted horizontally and directly flat to the platform without spacing.~~

~~The black painted test area shall face the test sample and the platform shall extend at least 60 cm beyond the PV module on all sides unless the PV module is installed directly next to other PV modules of similar dimensions.~~

~~The PV module under test shall be connected to the resistive load or maximum power point tracking device.~~

~~Throughout the test the following parameters shall be monitored:~~

- ~~• temperatures of PV module components and materials, as listed below;~~
- ~~• air temperature;~~
- ~~• irradiance;~~
- ~~• wind speed, if required (during the test the wind speed is typically close to 0 m/s).~~

~~The air temperature during the test shall be maintained within ± 3 K (the cold sky will ensure that the air in the simulator test room is not heating up).~~

~~Stabilised temperature data for each test location shall be collected. Thermal stability has been attained when three successive averaged values, taken 5 min apart, indicate a change in temperatures of less than ± 2 K. Averaged values in this context are calculated from the readings taken over a 5 min interval.~~

~~The measured component temperatures (T_{OBS}) shall be normalised by the addition of the difference between the 40°C reference air temperature and the measured air temperature (T_{AIR}) according to the formula~~

$$\underline{T_{CON} = T_{OBS} + (40^{\circ}\text{C} - T_{AIR})}$$

~~where T_{CON} is the normalised temperature.~~

~~If an unacceptable performance is encountered during the temperature test and the performance is attributed to a test condition that although within the limits specified may be considered more severe than necessary—for example an ambient temperature near the limits allowed—the test may be conducted under conditions closer to the norm.~~

~~Typical component measurement points shall include:~~

- ~~• PV module frontsheet above the centre cell, if non-glass (possible shading of cells by temperature sensor shall be avoided as much as possible).~~
- ~~• PV module backsheet below the centre cell.~~
- ~~• Terminal enclosure interior surface.~~
- ~~• Field wiring terminals.~~
- ~~• Insulation of the field wiring leads.~~
- ~~• External connector bodies (if applicable).~~
- ~~• Bypass diode bodies (if applicable).~~

~~Due to the many possible variations in construction, more than one data gathering point for each cited location may be used, at the discretion of the test laboratory.~~

10.15.4 Pass criteria

~~The pass criteria are as follows:~~

- ~~a) No measured temperatures exceed any of the applicable temperature limits (e.g. TI/RTE/RTI) of surfaces, materials, or components. Thermal material requirements are given in 5.5 of IEC 61730-1:2016.~~
- ~~b) No visual defects as defined in MST 01.~~

~~c) MST 16, MST 17 shall meet the same requirements as for the initial measurements.~~

~~IEC 61730-1 requires reporting of the maximum measured operating temperature as determined by this test method.~~

The temperature test MST 21 is no longer a part of this document. This section is preserved so that, in the following sections of the document, the MST numbers match the section numbers.

10.16 Hot-spot endurance test MST 22

~~This test is equivalent to MQT 09 in IEC 61215-2. Technology specific test descriptions are to be found in parts 1-x of the IEC 61215 series.~~

This test is equivalent to MQT 09 in IEC 61215-2 this test is applicable with the following modification: Instead of BSI for bifacial modules the test shall be performed with applied bifacial stress irradiance (*aBSI*).

10.17 Fire test MST 23

~~10.17.1 Purpose~~

PV modules may be exposed to external fire conditions, and therefore should be tested for their fire-resistance characteristics when exposed to a fire source originating from outside the PV module, which may include the building on which they are installed or into which they are integrated, or from an adjacent building. Fire resistance requirements for a PV module intended for building applications are defined in local or national building codes.

PV modules as building product – i.e. serving as roof covering materials, elements for building integration or that are mounted on buildings – are subject to specific safety requirements originating from national building codes.

It shall be noted that fundamental requirements for fire safety are not internationally harmonised. It is therefore not possible to define general requirements for fire safety of PV modules as recognition of test results is commonly not practiced.

Fire test requirements are to be included as national differences in this standard. Countries where resistance of building products to external fire or radiant heat is not covered by building codes may refer to Annex B.

10.18 Ignitability test MST 24

10.18.1 Purpose

This test determines the ignitability of PV modules by direct small flame impingement under zero impressed irradiance by external heat sources using vertically oriented test specimens. The test does not replace a fire test; it assesses ignitability, not flammability of outer surfaces of a module. The test method is based on ISO 11925-2:2020.

The test can be performed on full-size PV modules, as preparation of specimens according to ISO 11925-2:2010/2020 (Clause 5) may not always be possible. The ~~test procedure requirements~~ given in ISO 11925-2:2010/2020, Clauses 4 to 8, are therefore modified as described below.

If compliance to ISO 11925-2:2020 can be proven by existing approvals, this test can be omitted.

If specimens can be prepared that comply with Clause 5 of ISO 11925-2:2010/2020 and that are identical to the PV module type under test with respect to their material composition, the test procedure given in [Clause 7 of ISO 11925-2:2020](#) may be used without modifications.

NOTE—The performance of ignitability tests can be dangerous, e.g. as toxic gases can be released. In addition special precautions should be taken when handling test specimens during testing.

10.18.2 Apparatus

10.18.2.1 General

Clause 4 of ISO 11925-2:2010/2020 applies with the following modifications. Subclauses 4.8, 4.11 and 4.12 of ISO 11925-2:2010/2020 do not apply.

10.18.2.2 ~~Test cabinet~~ Combustion chamber

This subclause deviates from 4.2 of ISO 11925-2:2010/2020.

~~The test cabinet shall be capable of providing an environment of $23\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$ and a relative humidity of $50\% \pm 20\%$ throughout the test.~~ A suitable exhaust system shall ensure, that the air speed 5 cm from the surface of the specimen is not more than 0,2 m/s in vertical direction and 0,1 m/s in horizontal direction.

10.18.2.3 Burner

This subclause deviates from 4.3 of ISO 11925-2:2010/2020.

A gas burner complying with 4.3 of ISO 11925-2:2010/2020 shall be employed, which can be used vertically or tilted at 45° to the vertical axis. In addition the burner shall be rotatable around its vertical axis so that the test flame can be applied to concealed specimen components (e.g. frame parts). The burner shall be mounted so that it can be moved towards and away from the specimen jerk free. During the flame application, the burner shall remain in a fixed position. Spacers according to 4.9.2 and 4.9.3 of ISO 11925-2:2010/2020 are used to position the burner.

The burner shall be fitted with a fine adjustment valve to ensure accurate control of the flame height.

10.18.2.4 Specimen holder

This clause deviates from 4.5 and 4.6 of ISO 11925-2:2010/2020.

The specimen holder shall be constructed such that it allows the specimen to be safely fixed in a vertical position. The bottom side of the specimen shall have an exposed width of at least 30 cm for flame impingement. The specimen shall be placed so that the flame impingement can be determined reliably. The specimen holder shall be able to accommodate specimens of various sizes in both, lengthwise and crosswise orientation.

10.18.3 Test specimen

10.18.3.1 General

This subclause supersedes Clause 5 of ISO 11925-2:2010/2020.

Subclauses 5.1, 5.3 and 5.5 of ISO 11925-2:2010/2020 do not apply.

10.18.3.2 Dimensions

This subclause deviates from 5.2 of ISO 11925-2:2010/2020.

If PV modules are tested they are to be tested in their original size. For type families, a representative PV module type may be selected for testing that has the same material

composition as the PV modules it represents. It is sufficient to test one PV module size for PV modules of a type family.

10.18.3.3 Number of specimens

This subclause deviates from 5.4 of ISO 11925-2:20102020.

Typically one PV module is sufficient to perform all required tests. The flame application points shall be selected and marked in accordance with 10.18.5.1.

10.18.4 Conditioning

This subclause supersedes Clause 6 of ISO 11925-2:20102020.

The specimens shall be conditioned at a temperature of $23\text{ °C} \pm 2\text{ °C}$ and a relative humidity of $50\% \pm 5\%$ for a minimum period of 48 h.

The specimens shall be arranged within the conditioning environment in such a way that air can circulate around each individual specimen.

10.18.5 Procedure

10.18.5.1 General

Clause 7 of ISO 11925-2:20102020 applies with the following modifications.

10.18.5.2 Preliminary operations

This subclause deviates from 7.2 of ISO 11925-2:20102020.

The specimen shall be fixed in the specimen holder and aligned vertically using a level.

Check to make sure that the air velocities at the surface of the specimen comply with 10.18.2.2.

All exposed combustible materials shall be tested. Materials present in different thicknesses shall be tested at least at the thickest and the thinnest point. The flame application points are set according to 4.9.2 (edge exposure) and 4.9.3 (surface exposure) of ISO 11925-2:20102020 and shall be marked. Each test shall be performed on three comparable specimen locations.

Components such as junction boxes, cables and connectors do not need to be tested with this test method as these components have separate flammability requirements specified in IEC 61730-1. Similarly, non-combustible materials such as glass and metal do not need to be tested with this test method.

10.18.5.3 Testing operations

Subclauses 7.3.1 and 7.3.2 of ISO 11925-2:20102020 apply. With respect to 7.3.2, a flame application time of 15 s applies.

The exposure conditions described in 7.3.3 of ISO 11925-2:20102020 are modified as follows.

a) Surface exposure

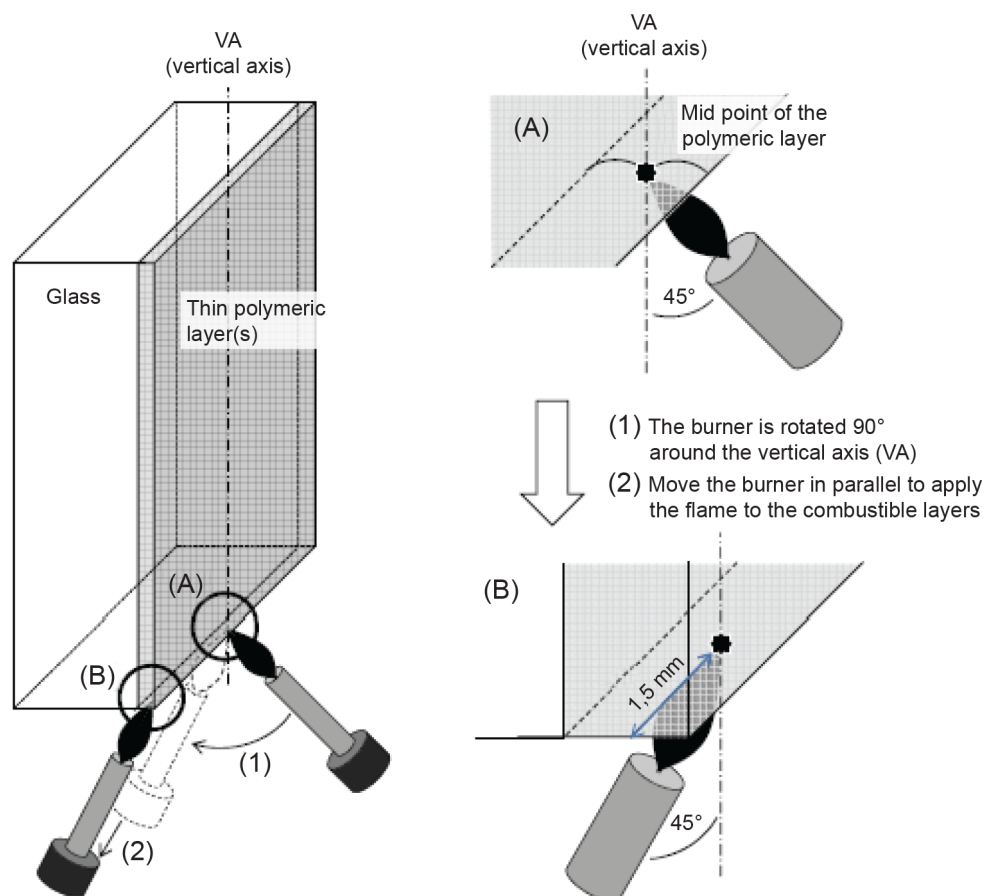
The flame shall be applied at least 40 mm above the bottom edge of the specimen. Each different surface, which may be exposed in practice, shall be tested.

b) Edge exposure

The flame shall be applied to the bottom edge of the specimen. The flame application point is located 1,5 mm behind the leading edge. If the edges of the specimen are made of non

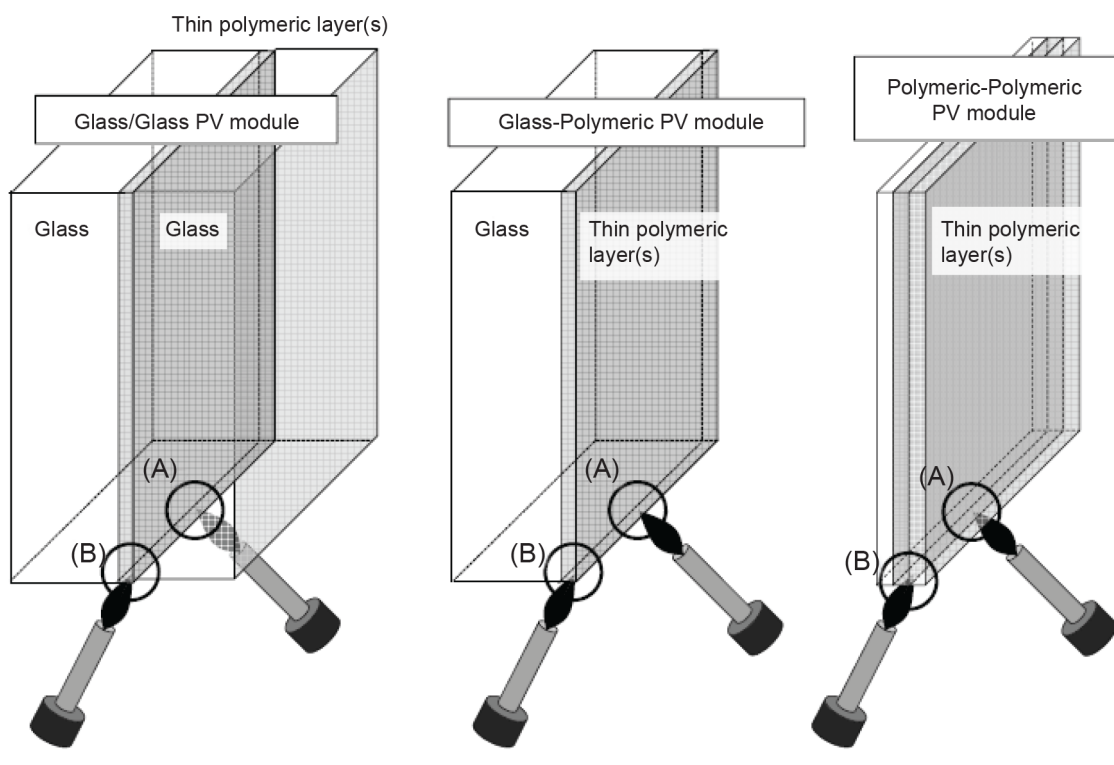
combustible materials (e.g. metal frame), edge exposure may be omitted. Where accessible to direct flame exposure, it may be necessary to test frame adhesives.

For multi-layer products with unprotected edges, additional tests shall be performed. In this case, the burner shall be rotated 90° around its vertical axis to apply the flame to the combustible layers at the side edges of the specimen as shown in Figure 7.



IEC

a) Application of burner for a multilayer glass-polymer module



IEC

b) Overview: Application of burner for glass-glass, glass-polymeric, and polymeric-polymeric PV modules

Figure 7 – Application of burner for multilayer products

Subclause 7.3.4 of ISO 11925-2:~~2010~~2020 does not apply.

10.18.6 Duration of test

Subclause 7.4.1 of ISO 11925-2:~~2010~~2020 applies (15 s flame application time 20 s total test duration), 7.4.2 of ISO 11925-2:2020 does not apply.

10.18.7 ~~Observations~~ Expression of results

This subclause supersedes Clause 8 of ISO 11925-2:2020.

The type of flame application shall be noted (surface exposure and/or edge exposure).

For each test, the following results shall be recorded:

- a) whether ignition occurs;
- b) whether the flame tip reaches a height of 150 mm above the flame application point, and the time at which this occurs;
- c) the maximum flame height during the test;
- d) observations regarding the behavior of the specimen;
- e) the length of the destroyed area.

10.18.8 Pass criteria

~~This subclause supersedes Clause 8 of ISO 11925-2:2010.~~

No ignition or, under conditions of surface flame attack and, where required, edge flame attack, with 15 s exposure time, there shall be no flame spread in excess of 150 mm vertically from the point of application of the test flame within 20 s from the time of application.

10.19 Bypass diode thermal test MST 25

This test is equivalent to MQT 18 in IEC 61215-2. Both, MQT 18.1 and MQT 18.2 shall be performed. For bifacial modules the test shall be performed with $I_{SC-aBSI}$ instead of I_{SC-BSI} .

10.20 Reverse current overload test MST 26

10.20.1 Purpose

PV modules contain electrically conductive material contained in an insulating system. Under reverse current fault conditions the electrical conductors and the cells of the PV module are forced to dissipate energy as heat prior to circuit interruption by an over-current protector installed in the system. This test is intended to determine the acceptability of the risk of ignition or fire from this condition or other catastrophic thermal damage to the module.

10.20.2 Apparatus

- a) The temperature shall be recorded by an infrared camera with the following specifications and settings:
 - Emissivity ϵ : 0,95 for polymeric materials
 - 0,90 for glass surfaces
 - Resolution: 1 pixel corresponds to < 5 mm
 - Thermal sensitivity: $\leq 0,1$ K at 30 °C
 - Absolute error of measurement: ± 5 K
 - Measurement range: $0 - 200$ °C
 - Spectral response: $8 - 14$ μm

b) Means for applying a continuous current as specified in Procedure 10.20.3.

10.20.3 Procedure

~~The PV module under test is to be placed with its frontsheet face down onto a support that has sufficient mechanical strength to avoid warping under temperature influence, covered by a single layer of white tissue paper. The thermal conductivity of the support shall be not higher than 0,5 W/(m·K). The back surface of the PV module shall be completely covered and in contact with a single layer of white tissue paper. The density of both pieces of white tissue paper should conform to 12 g/m² to 30 g/m² (ISO 4046-4).~~

The PV module under test should be mounted with the module sunny side down if junction box is mounted on the rear side. The front to underlying surface clearance shall be the minimum clearance specified in the manufacturer's mounting instructions. If the instructions offer more than one option, the option providing the worst-case clearance shall be used. If no indications have been provided for spacing, or if the module manufacturer allows mounting flush to the supporting surface within the product mounting guidelines, the module front or rear shall be mounted in contact on a solid support that has sufficient mechanical strength to avoid warping under temperature influence. The thermal conductivity of the support shall be not higher than 0,5 W/(m·K).

Care shall be taken to mount the module in a manner that avoids interference with the junction boxes or similar height obstructions. As a result, front-mounted junction boxes should be tested with the module rear surface mounted to the test structure and if junction boxes are mounted on the rear surface, the module shall be flush-mounted to the front surface.

Any blocking diode (not bypass diodes) provided shall be defeated (short-circuited). The test shall be conducted in an area free of drafts (see IEC 60695-2-10 for comparable requirements).

The irradiance on the cell area of the PV module shall be less than 50 W/m² to be ensured through a dark environment. In case there is a possible contribution to the photocurrent of the PV module (e.g. through a transparent back side or a bifacial cell concept) this shall be ensured through a dark environment. An additional shading cover to the back is not allowed since it would influence the thermal insulation.

A laboratory DC power supply shall be connected to the PV module with positive output connected to the positive terminal of the PV module. The applied reverse current (I_{TEST}) shall be equal to 135 % of the PV module's overcurrent protection rating, as provided by the manufacturer. The test supply current should be limited to the value of I_{TEST} , and the test supply voltage shall be increased to cause the reverse current to flow through the PV module. ~~The test shall be continued for 2 h, or until ultimate results are known (i.e. test failures as for example due to glass breakage or flaming), whichever occurs first.~~ During a 2 h test period the temperature shall be recorded and the hottest point determined, by using an infrared camera. The camera orientation shall be perpendicular to the module plane. Care shall be taken to avoid intense heat or light sources that might reflect on the glass surface. The test shall be conducted at ambient air temperature of 23 °C ± 5 °C in an environment where the ambient air is still with no forced circulation.

Throughout the test the current flow shall be kept stable within ± 2 % (this may require the voltage to be adjusted).

The maximum over-current protection rating of a PV module can be interpreted as the PV module series fuse rating. A series fuse may be required in the installation of PV arrays. According to IEC 61730-1 the maximum over-current rating has to be provided by the manufacturer.

NOTE 1 A method to determine the PV module's limiting reverse current I_R capacity can be found in EN 50380:2003.

NOTE 2 IEC TS 62446-3 provides guidance on the use of IR-cameras.

10.20.4 Pass criteria

The pass criteria are as follows:

- ~~a) There shall not be flaming of the PV module, nor flaming or charring of the tissue paper in contact with the PV module.~~
- a) MST 01 shall meet the same requirements as for the initial measurements.
- b) MST 16 shall meet the same requirements as for the initial measurements.
- c) MST 17 shall meet the same requirements as for the initial measurements.
- d) The maximum external module surface temperature during the test as measured by the infrared camera shall not exceed 170 °C.

10.21 Module breakage test MST 32

10.21.1 Purpose

The purpose of this test is to provide confidence that risk of physical injuries can be minimized if the PV module is broken in its specified installation. It does not cover electric shock, only e.g. piercing cuts and fall through injuries.

For building integrated or overhead applications additional tests may be required according to relevant building codes.

Class 0 modules for use in restricted areas are not required to be tested.

NOTE 1 MST 32 is based on ANSI Z97.1

~~NOTE 2 It does not cover electric shock, only e.g. piercing cuts and fall-through injuries.~~

10.21.2 Apparatus

The apparatus is as follows:

- a) The impactor shall be a bag made of a suitable material and capable to be filled to the required weight using a suitable filling material (e.g. steel balls or pellets). The exterior of the bag shall be wrapped with tape as shown in Figure 8 in order to avoid uneven surfaces like stitching. When filled, the impactor bag shall have dimensions as described in Figure 8 and a weight of 45,5 kg ± 0,5 kg. The ratio of widest diameter to height shall be between 1:1,5 to 1:1,4.
- b) A test frame similar to that shown in Figure 9 and Figure 10 shall be provided with sufficient stiffness to minimise movement and deflection during testing. ~~The structure framing and bracing shall be steel channel (approximately 100 mm × 200 mm or larger) and shall have a minimum moment of inertia of approximately 187 cm⁴.~~ The frame shall be welded or securely bolted at the corners to minimize twisting during impact. It shall also be bolted to the floor to prevent movement during impact testing.

NOTE Structure framing and bracing made from steel channel (approximately 100 mm × 200 mm or larger) with a minimum moment of inertia of approximately 187 cm⁴ has been found to provide sufficient stiffness.

10.21.3 Procedure

Mount the PV module sample so that it is centred and rigid on the test frame using the method and parts described by the manufacturer including a defined torque if screws are used for mounting. If different mounting options are possible the test shall cover the range of mounting techniques.

The procedure is as follows:

- a) At rest the impactor bag shall hang no more than 13 mm from the surface of the PV module sample and no more than 50 mm from the centre of the PV module sample.

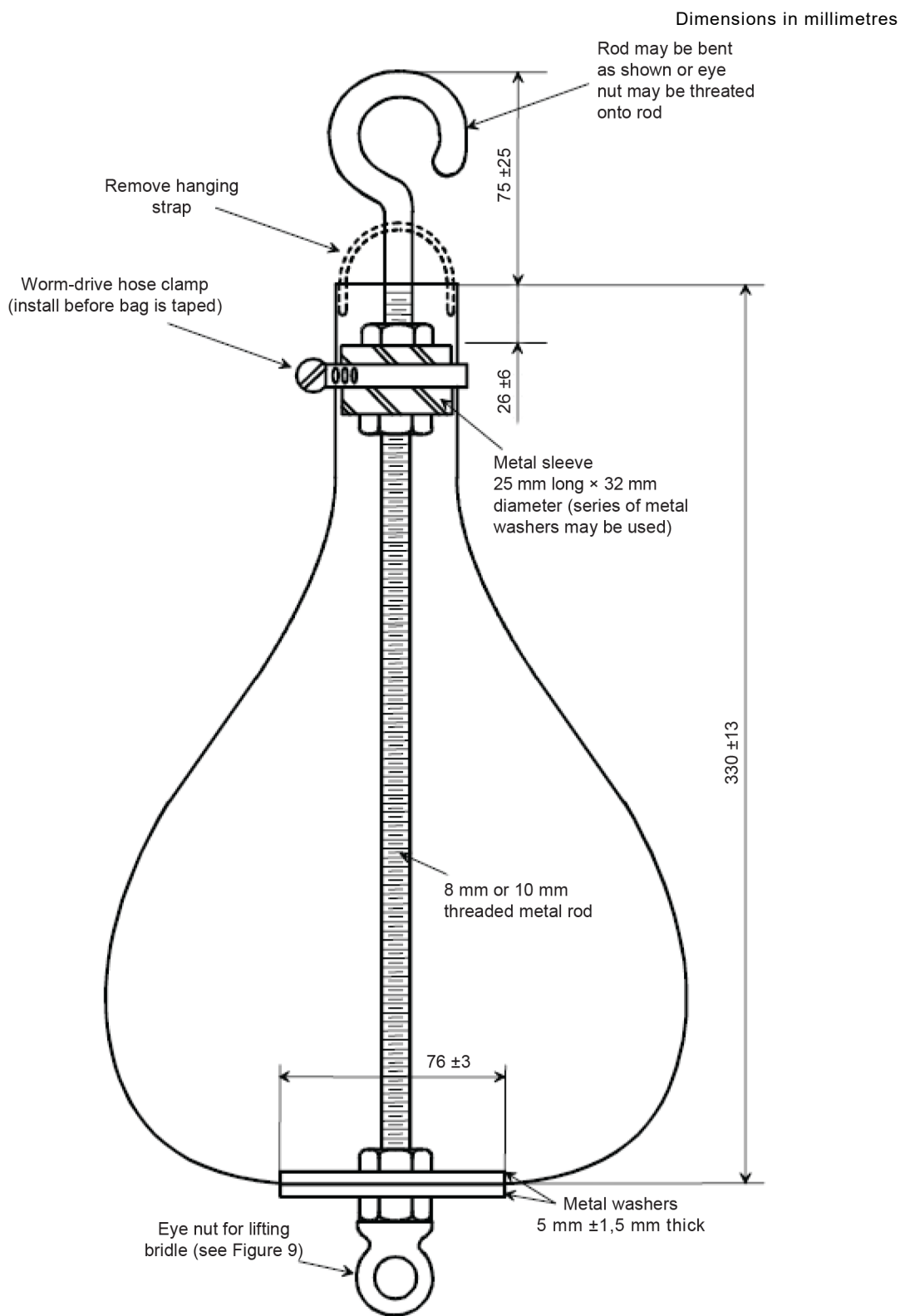
- b) Lift the impactor centre to a drop height of 300 mm from the ~~surface of the PV module~~ ~~sample~~ centre of its resting position (see Figure 9), allow the impactor to stabilize, and then release it to strike the PV module sample.

10.21.4 Pass criteria

The PV module shall be judged to have successfully passed the module breakage test if it meets the following criteria: a) and either b) or c):

- a) The PV module may not separate from the mounting structure or from the framing.
- b) No breakage occurs.
- c) If breakage of the PV module occurs, no shear or opening large enough for a 76 mm diameter sphere to pass freely shall develop and no particles larger than 65 cm² shall be ejected from the sample. In order to allow measurement of the particles, breakage into smaller pieces shall be avoided when dropping on the floor, e.g. by a cushion.

If the test specimen has to be checked according to 5.4.5 of IEC 61730-1:20162022 (form/press/tight fit) a continuity of equipotential bonding test (MST 13) shall be passed successfully before and after MST 32.



IEC

Filled bag has a total weight of assembly of $45,5 \text{ kg} \pm 0,5 \text{ kg}$.

Tape bag with 13 mm wide tape use 3 rolls (165 m) and tape in diagonal, overlapping manner. Cover entire surface of bag. Tape neck separately.

Figure 8 – Impactor