

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

This second edition cancels and replaces the first edition of IEC 61730-2, issued in 2004 and its amendment 1 (2011), and constitutes a technical revision.

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

- a) Rearrange test sequences.
- b) MST 01: Visual inspection: added nameplate requirement and modified pass criteria.
- c) Added sharp edge test MST 06.
- d) Added insulation thickness test MST 04.
- e) MST 11: Accessibility test: defined force for test finger.
- f) MST 12: Cut susceptibility test: defined blade radius for cut test.
- g) MST 14: removed preconditioning requirement TC200 from Figure 1.
- h) MST 15: Partial discharge test removed.
- i) Renamed dielectric breakdown test MST 16 to insulation test.
- j) MST 21: Temperature test: rewritten test procedure; removed short circuit mode; allow alternative indoor test method.
- k) MST 23: Fire test: subclause rewritten; fire test requirements related to national building codes; moved optional test description to informative annex.
- l) Added ignitability test MST 24.
- m) MST 26: Reverse current overload test: changed specification of wooden board.
- n) MST 32: Module breakage test: defined new dimensions of impactor to allow other filling compounds; consider variety of mounting techniques for glass breakage test; reduced impact height to only 300 mm; corrected diameter of opening according to referenced standard (65 cm² instead of 6,5 cm²).
- o) Added screw connection test MST 33.
- p) Added peel test MST 35 for proof of cemented joints.
- q) Added lap shear strength test MST 36 for proof of cemented joints.
- r) Added materials creep test MST 37.
- s) Added PV module test sequence with moisture and UV to stress polymers to Figure 1. The new UV sequence was added as a response to the Kyoto meeting, where it was decided to add a coupon test and a PV module test sequence. As it is not possible to perform the ISO UV test on PV modules (no affordable equipment available) it was decided to rely on already available PV module test equipment. R&D work has shown that cycling UV and HF are best to age polymers in PV modules.
- t) Added new sequence for Pollution Degree (PD) testing (sequence B1).
- u) Added annex: Recommendations for testing of PV modules from production.

The text of this standard is based on the following documents:

FDIS	Report on voting
82/1129/FDIS	82/1147/RVD

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

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC website under "<http://webstore.iec.ch>" in the data related to the specific publication. At this date, the publication will be

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

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PHOTOVOLTAIC (PV) MODULE SAFETY QUALIFICATION –

Part 2: Requirements for testing

1 ~~Scope and object~~

~~This part of IEC 61730 describes the testing requirements for photovoltaic (PV) modules in order to provide safe electrical and mechanical operation during their expected lifetime. Specific topics are provided to assess the prevention of electrical shock, fire hazards, and personal injury due to mechanical and environmental stresses. IEC 61730-1 pertains to the particular requirements of construction. This part of IEC 61730 outlines the requirements of testing.~~

~~This standard attempts to define the basic requirements for various application classes of photovoltaic modules, but it cannot be considered to encompass all national or regional building codes. The specific requirements for marine and vehicle applications are not covered. This standard is not applicable to modules with integrated AC inverters (AC modules).~~

~~This standard is designed so that its test sequence can co-ordinate with those of IEC 61215 or IEC 61646, so that a single set of samples may be used to perform both the safety and performance evaluation of a photovoltaic module design.~~

~~The test sequences of this standard are arranged in an optimal way so that tests of IEC 61215 or IEC 61646 can be used as basic preconditioning tests.~~

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 part of the standard lists the tests a PV module is required to fulfill for safety qualification. IEC 61730-2 is applied for safety qualification only in conjunction with IEC 61730-1.

~~NOTE 1~~ The sequence of tests required in this standard may not test for all possible safety aspects associated with the use of PV modules in all possible applications. This standard 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's design, location, restrictions on access and maintenance procedures.

The objective of this standard 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. The standard 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.

~~NOTE 2~~ The additional testing requirements outlined in relevant ISO standards, or the national or local codes which govern the installation and use of these PV modules in their intended locations, should be considered in addition to the requirements contained within this standard.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. 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 60068-1, *Environmental testing – Part 1: General and guidance*~~

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

~~IEC 60410, *Sampling plans and procedures for inspection by attributes*~~

IEC 60068-2-2, *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, *Luminaires – Part 1: General requirements and tests*

IEC 60664-1:1992 2007, *Insulation co-ordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests*

~~Amendment 2 (2002)~~

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 solar cells devices*

~~IEC 60904-6, *Photovoltaic devices – Part 6: Requirements for reference solar modules*~~

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

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

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 61215:2004 (all parts), ~~Crystalline silicon~~ 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 61646:1996, *Thin-film Terrestrial photovoltaic (PV) modules – Design qualification and type approval*~~

IEC 61730-1:2004 2016, *Photovoltaic (PV) module safety qualification – Part 1: Requirements for construction*

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

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, *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 514C, *Non-metallic outlet boxes, flush device boxes and covers*~~

~~ANSI/UL 790, *Tests for Fire Resistance of Roof Covering Materials*~~

~~ANSI/UL 1703, *Flat – Plate Photovoltaic Modules and Panels*~~

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

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

~~3 – Application classes~~

~~3.1 General~~

~~Photovoltaic modules may be installed in many different applications. Therefore, it is important to evaluate the potential hazards associated with those applications and to evaluate the construction of the module accordingly.~~

~~Relevant safety requirements and necessary tests shall be performed to verify the conformance to the requirements of that application class. This clause defines those application classes and construction qualities required for each class.~~

~~Application classes for PV modules are defined as follows:~~

~~3.2 Class A: General access, hazardous voltage, hazardous power applications~~

~~Modules rated for use in this application class may be used in systems operating at greater than 50 V DC or 240 W, where general contact access is anticipated. Modules qualified for safety through IEC 61730-1 and this part of IEC 61730 within this application class are considered to meet the requirements for safety class II.~~

~~3.3 Class B: Restricted access, hazardous voltage, hazardous power applications~~

~~Modules rated for use in this application class are restricted to systems protected from public access by fences, location, etc. Modules evaluated within this application class provide protection by basic insulation, are considered to meet the requirements for safety class 0.~~

~~3.4 Class C: Limited voltage, limited power applications~~

~~Modules rated for use in this application class are restricted to systems operating at less than 50 V DC and 240 W, where general contact access is anticipated. Modules qualified for safety through IEC 61730-1 and this part of IEC 61730 within this application class are considered to meet the requirements for safety class III.~~

~~NOTE Safety classes are defined within IEC 61140.~~

3 Terms and definitions

The Clause of Part 1 applies.

4 Test categories

4.1 General

The hazards described in the following subclause might influence ~~the lifetime and~~ 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.

Tables 1 to 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 10.32. The ~~rest of the~~ other tests are based on or are identical to the module qualification tests MQT defined in the IEC 61215 series ~~IEC 61646~~. References to the relevant ~~Clauses~~ tests are given in the last ~~two~~ columns. Some of the IEC 61215 ~~IEC 61646~~-based tests were modified for IEC 61730-2 and are included in 10.1 through 10.32.

4.2 ~~Preconditioning~~ Environmental stress tests

Table 1 – ~~Preconditioning~~ Environmental stress tests

Test	Title	Referenced standards	~~According to~~ Based on	
			IEC 61215-2	~~IEC 61646~~
MST 51	Thermal cycling (TC50 or TC200)	–	~~10.11~~ MQT 11	~~10.11~~
MST 52	Humidity freeze (HF10)	–	~~10.12~~ MQT 12	~~10.12~~
MST 53	Damp heat (DH1000)	–	~~10.13~~ MQT 13	~~10.13~~
MST 54	UV preconditioning ~~test~~	–	~~10.10~~ MQT 10	~~10.10~~
MST 55	Cold conditioning	IEC 60068-2-1	–	
MST 56	Dry hot conditioning	IEC 60068-2-2	–	

4.3 General inspection

Table 2 – General inspection test

Test	Title	Referenced standards	According to ~~Based on~~	
			IEC 61215-2	~~IEC 61646~~
MST 01	Visual inspection	–	~~10.1~~ MQT 01	~~10.1~~
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	–	–	

4.4 Electrical shock hazard tests

These tests are designed to assess the risk to ~~personnel~~ persons due to shock or injury ~~because of~~ 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	According to ~~Based on~~	
			IEC 61215-2	~~IEC 61646~~
MST 11	Accessibility test	~~ANSI/UL 1703~~ IEC 61032	–	
MST 12	Cut susceptibility test ~~(not required for glass surfaces)~~	ANSI/UL 1703:2015	–	
MST 13	~~Ground~~ Continuity test for equipotential bonding ~~(not required unless metal framed)~~	ANSI/UL 1703:2015	–	
MST 14	Impulse voltage test	IEC 60664-1	–	
MST 16	~~Dielectric withstand~~ Insulation test	–	~~10.3*~~ MQT 03	~~10.3*~~
MST 17	Wet leakage current test	–	~~10.15~~ MQT 15	~~10.20~~
MST 42	Robustness of terminations test	IEC 62790	~~10.14~~ MQT 14	~~10.14~~
* ~~The pass/fail criteria differ from those given in IEC 61215 and IEC 61646.~~				

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	~~According to~~ Based on	
			IEC 61215-2	~~IEC 61646~~
MST 21	Temperature test	ANSI/UL 1703:2015	–	
MST 22	Hot-spot ~~endurance~~ test	–	~~40-9~~ MQT 09	~~40-9~~
MST 23*	Fire test	~~ANSI/UL 790~~ –	National/Local code	
MST 24	Ignitability test	ISO 11925-2	–	
MST 25	Bypass diode thermal test	–	~~40-18~~ MQT 18	
MST 26	Reverse current overload test	ANSI/UL 1703:2015	–	
* 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	~~According to~~ Based on	
			IEC 61215-2	~~IEC 61646~~
MST 32	Module breakage test	ANSI Z97.1	–	
MST 33	Screw connection test	IEC 60598-1	–	
MST 34	Mechanical load test	–	~~40-16~~ MQT 16	~~40-16~~
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	

~~4.7 Component tests~~

~~Table 6 – Component tests~~

Test	Title	References in Standards	According to	
			IEC 61215	IEC 61646
MST 15	Partial discharge test	IEC 60664-1		
MST 33	Conduit bending	ANSI/UL 514C		
MST 44	Terminal box knock-out test	ANSI/UL 514C		

5 ~~Application~~ Classes and their necessary test procedures

The specific tests to which a PV module will be subjected, depending on the ~~application~~ 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.

~~NOTE This test sequence has been designed so that IEC 61730-2 can be performed in conjunction with IEC 61215 or IEC 61646. In this way, the environmental stress tests in IEC 61215 or IEC 61646 can serve as the preconditioning tests for IEC 61730-2.~~

Table 6 – Required tests, depending on the ~~application~~ Class

Application Class according to IEC 61140			Tests
A II	B 0	C III	
X	X	X	~~Preconditioning~~ 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 DH1000)
X	X	X	MST 54 UV ~~resistance~~ pre-conditioning (15 kWh/m ² or 60 kWh/m ²)
X ¹	X ¹	X ¹	MST 55 Cold conditioning
X ¹	X ¹	X ¹	MST 56 Dry hot 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	X	-	MST 04 Insulation thickness
X	X	X	MST 05 Durability of markings
X	X	X	MST 06 Sharp edge test
X	X	-	Electrical shock hazard tests:
X	X	-	MST 11 Accessibility test
X	X	-	MST 12 Cut susceptibility test
X	X	X -	MST 13 ~~Ground~~ Continuity test for equipotential bonding
X	X ²	-	MST 14 Impulse voltage test
X	X ²	-	~~MST 16 Dielectric withstand 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	Fire hazard tests:
X	X	X	MST 21 Temperature test
X	X	X	MST 22 Hot-spot ~~endurance~~ test
X ^{**2}	- X ²	- X ²	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 Mechanical load test
X ^{3,5}	X ^{3,5}	X ^{3,5}	MST 35 Peel test
X ^{4,5}	X ^{4,5}	X ^{4,5}	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. ~~* Different test levels for application classes A and B.~~ ~~** Minimum fire resistance class C is necessary for building roof mounted modules.~~ ¹ Only required to prove reduction of Pollution Degree PD=2 to PD=1. ² 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. ³ This test is not applicable to rigid-to-rigid bonded assemblies (e.g. glass/glass PV modules). ⁴ This test is not applicable to rigid-to-flexible or flexible-to-flexible bonded assemblies. ⁵ Only required for proof of cemented joints around the PV module edges.			

6 Sampling

~~Nine~~ Six PV modules and ~~a laminate⁴ (a one unframed PV module)~~ are used for safety testing (plus spares as desired) ~~and additional modules as required for the fire test shall be taken at random from a production batch or batches, in accordance with the procedure given in IEC 60410.~~ In order to prove reduction of Pollution Degree to PD 1, one additional PV module is required.

If cemented joints are to be qualified 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.
- 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, MST 32, and MST 37 PV modules 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 be taken at random from a production batch or batches.

Additional PV modules for MST 23 might be necessary (PV modules 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 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, ~~including the maximum permissible system voltage.~~ 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).

7 Test report

The results of the assessment against IEC 61730-1 and IEC 61730-2 shall be laid down in ~~a 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 ~~to~~ 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 ~~certification or~~ 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;

⁴ ~~If the module is only used with frame and the frame is an essential part to fulfil the isolation requirement, the laminate can be replaced by a module.~~

- 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, ~~safety~~ 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 ~~certificate or~~ 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 ~~certificate or~~ 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 ~~preconditioning~~ environmental stress tests of 4.2 are met. Each box in Figure 1 refers to the corresponding subclause as described in Clause 4.

NOTE 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 10.33. Some tests are identical to tests in IEC 61215-2/~~IEC 61646~~ and are ~~detailed~~ referenced in Clause 4 ~~instead~~. In carrying out these tests, the manufacturer's handling, mounting, and connection instructions shall be strictly observed.

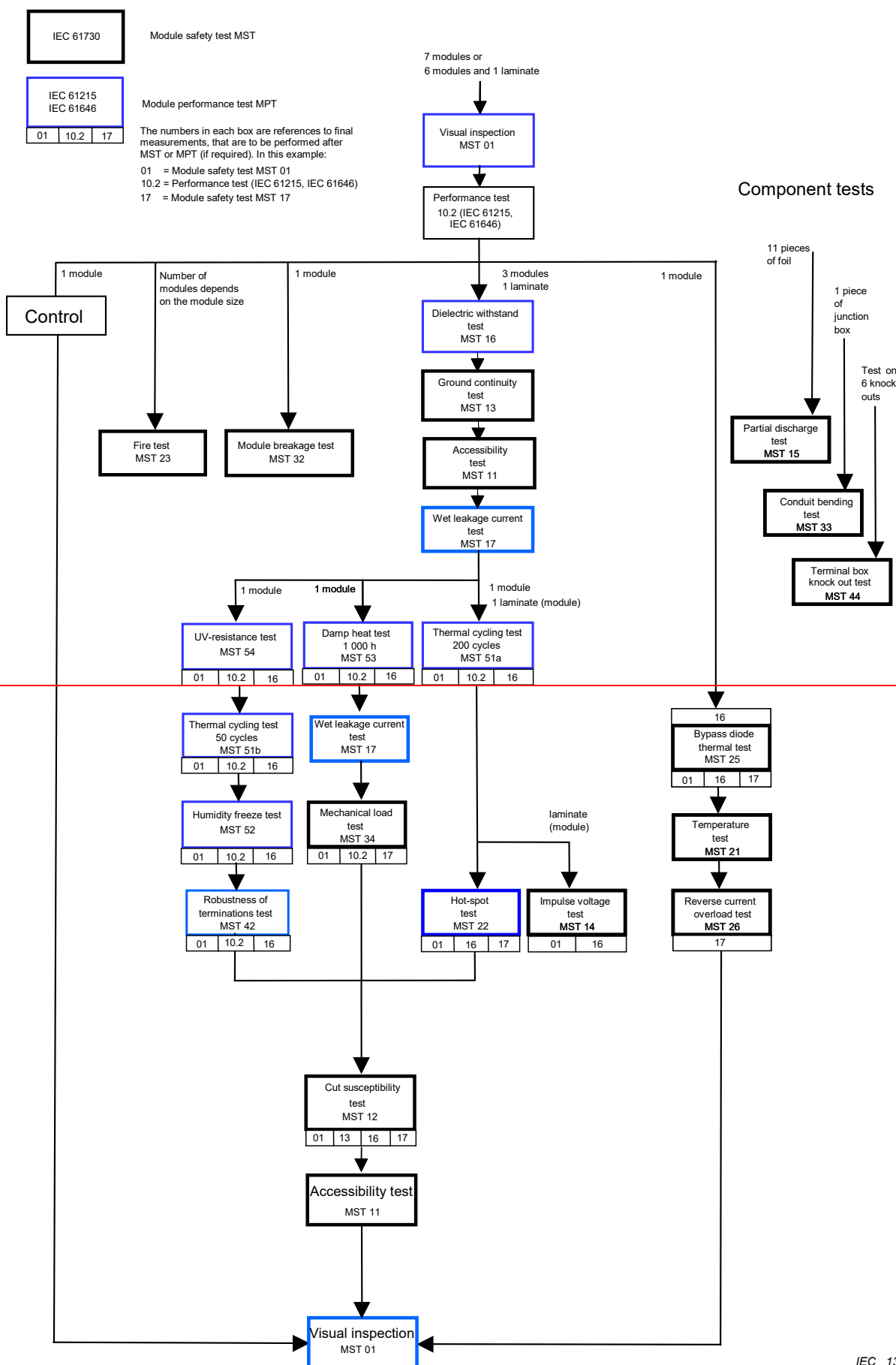
The PV module for sequence B shall be irradiated during the first 60 kWh/m² cycle from the front side of the specimen and from the backside during the second 60 kWh/m² cycle (MST 54). By doing so, the front side and back side of the PV module will be exposed to the same UV dose.

The intermediate control measurements (MST 01, MST 16, MST 17) after each stress test 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 tests 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 impacts 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.



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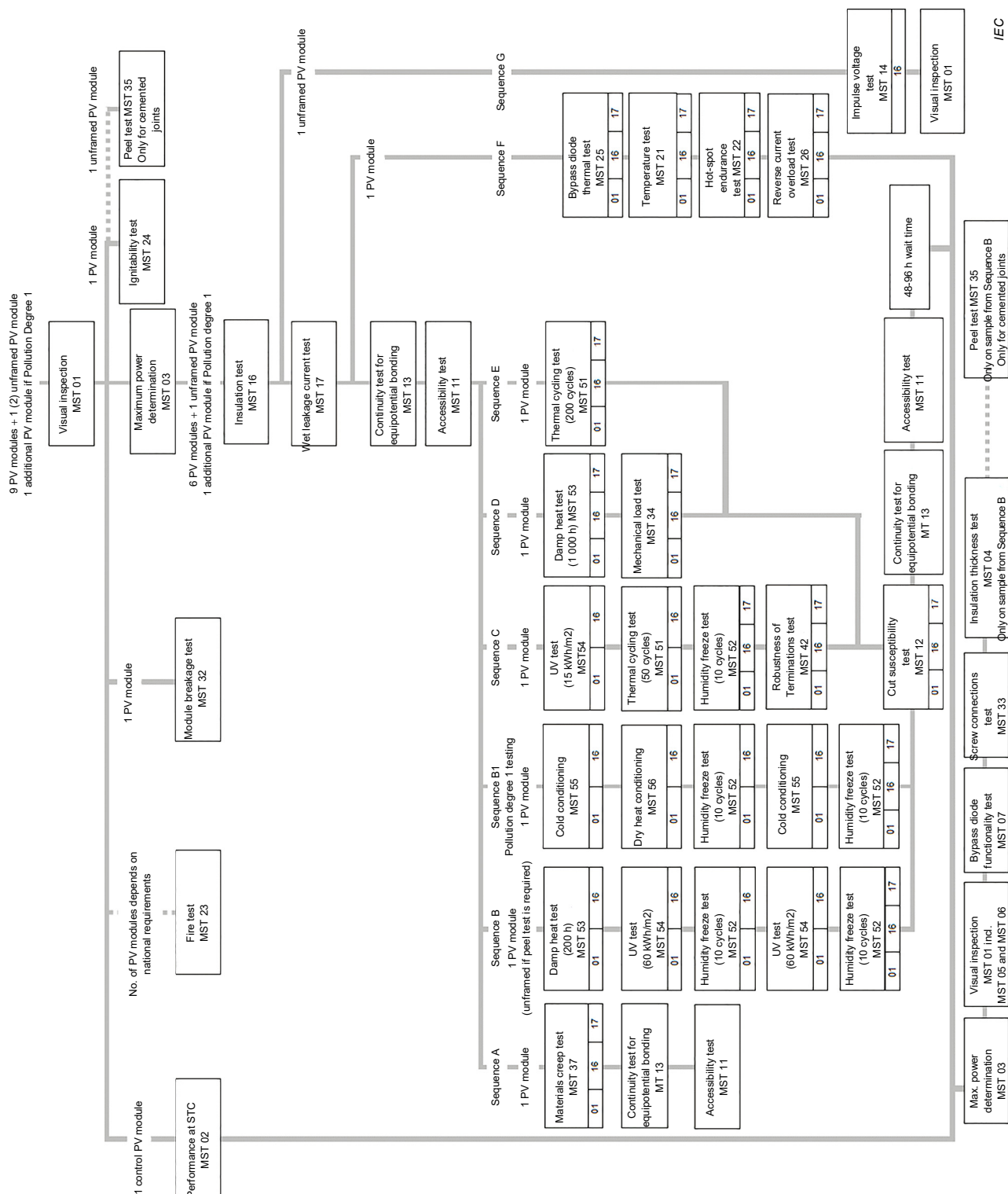


Figure 1 – Test sequences

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9 Pass criteria

The ~~module~~ 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 standard if any sample fails in one or more of the tests.

~~If any module does not meet these test criteria, the module product under evaluation shall be deemed not to have met the safety test requirements.~~

~~NOTE The nature of the failure will determine the extent of re-testing requirements.~~

In case of failure the manufacturer is recommended to 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 ~~10.4~~ MQT 01 of IEC 61215-2 ~~IEC 61646~~ with the additional inspection criteria of

- any other conditions which may affect safety;
- ~~• markings not consistent with Clause 11 of IEC 61730-1.~~
- during final inspection check compliance of markings with 5.2 of IEC 61730-1:2016 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 61730-1:2016. See Figure 2a and 2b for examples of creepage distance measurement. Bubbles are assumed to be conductive for this evaluation. For clearance and creepage assessment check Figure B.2 of IEC 61730-1:2016.

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

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 ~~approval~~, the following are considered to be major visual defects:

- a) broken, cracked, or torn external surfaces;
- b) bent or misaligned external surfaces, including ~~superstrates, substrates, frontsheet, backsheet~~, frames and junction boxes to the extent that the safety of the PV module would be impaired;
- ~~c) bubbles or delaminations forming a continuous path between any part of the electrical circuit and the edge of the module, or which exhibited significant growth during the testing and would, if testing were continued, reach such a condition;~~
- c) in cemented joints bubbles or delaminations with closest distances to each other ≤ 2 times the minimum required distance through cemented joint (see Tables 3 and 4 of IEC 61730-1:2016) 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) evidence of any molten or burned encapsulant, back sheet, diode or active PV component;~~
- 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 61730-1:2016) 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 61730-1:2016 and the durability of markings test (MST 05) at final inspection;
- i) edges not complying with MST 06 sharp edge test at final inspection.

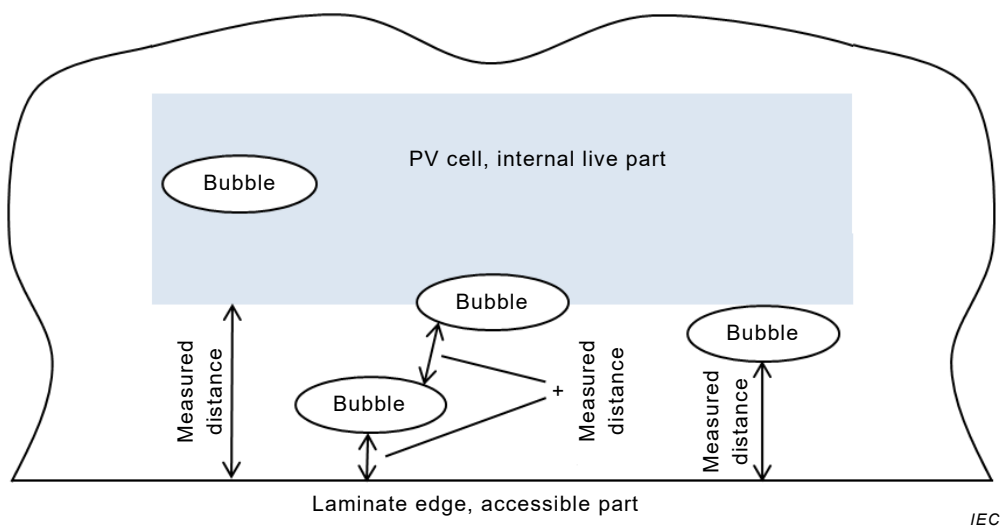
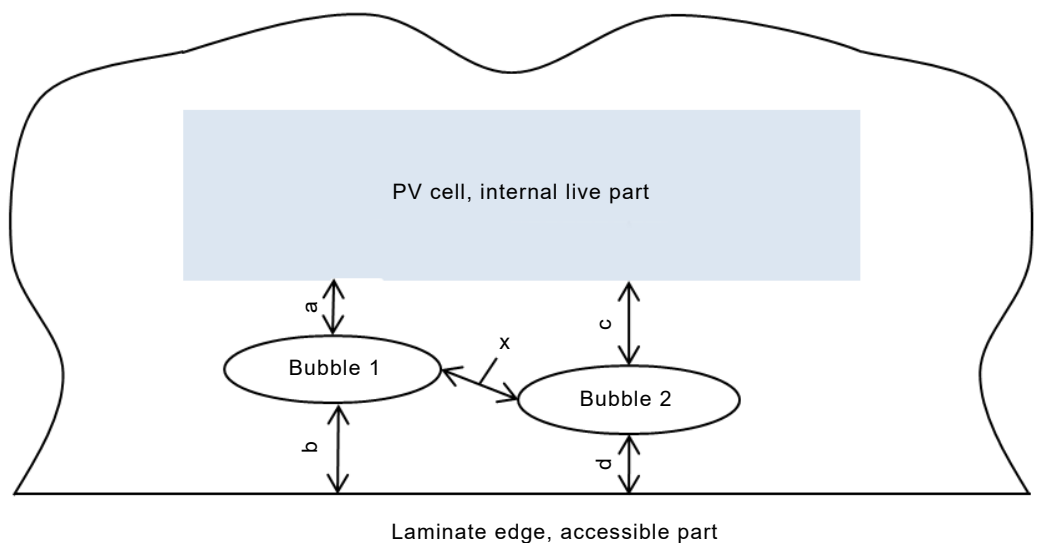


Figure 2a – Example for delamination assessment when measuring creepage or distance through insulation



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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

Example 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 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}).

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.

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).

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 dti 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 61730-1:2016 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 61730-1:2016 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 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 60335-1:2013, 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.

10.8 Bypass diode functionality test MST 07

The test procedure and pass criteria are equivalent to MQT 18.2 in IEC 61215-2.

10.9 Accessibility test MST 11

10.9.1 Purpose

To determine if ~~uninsulated electrical connections represent a shock hazard to personnel~~ 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 ~~electric~~ 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, ~~plugs~~, junction boxes and any other areas where ~~the electrical circuit~~ 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 ~~electric circuitry~~ live parts.

10.9.4 Final measurements

None.

~~10.2.5~~ Requirements

10.9.5 Pass criteria

The pass criteria are as follows:

- a) At no time during the test shall there be a resistance of less than 1 M Ω ~~resistance~~ between the test fixture and the PV module ~~electric circuit~~ 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 derived from ANSI/UL 1703.~~

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 3, designed to draw a defined shaped object, ~~a 0,64 mm $\pm$ 0,05 mm thick carbon steel blade (for example the back of a hacksaw blade)~~ over the surface of the PV module with an applied force of 8,9 N $\pm$ 0,5 N. The defined shaped object shall be a 0,64 mm $\pm$ 0,05 mm thick hardened steel blade sufficiently rigid as not to bend sideways during the test. The tip shall have a top angle of 90° $\pm$ 2° and shall be rounded with a radius of 0,115 mm $\pm$ 0,025 mm.

Apparatus in Figure 3 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 ~~front~~ 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 mm/s $\pm$ 30 mm/s. Repeat the procedure five times in different directions considering the most critical points.
- c) Repeat a) and b) for ~~the rear surface~~ other polymeric surfaces of the PV module if applicable.

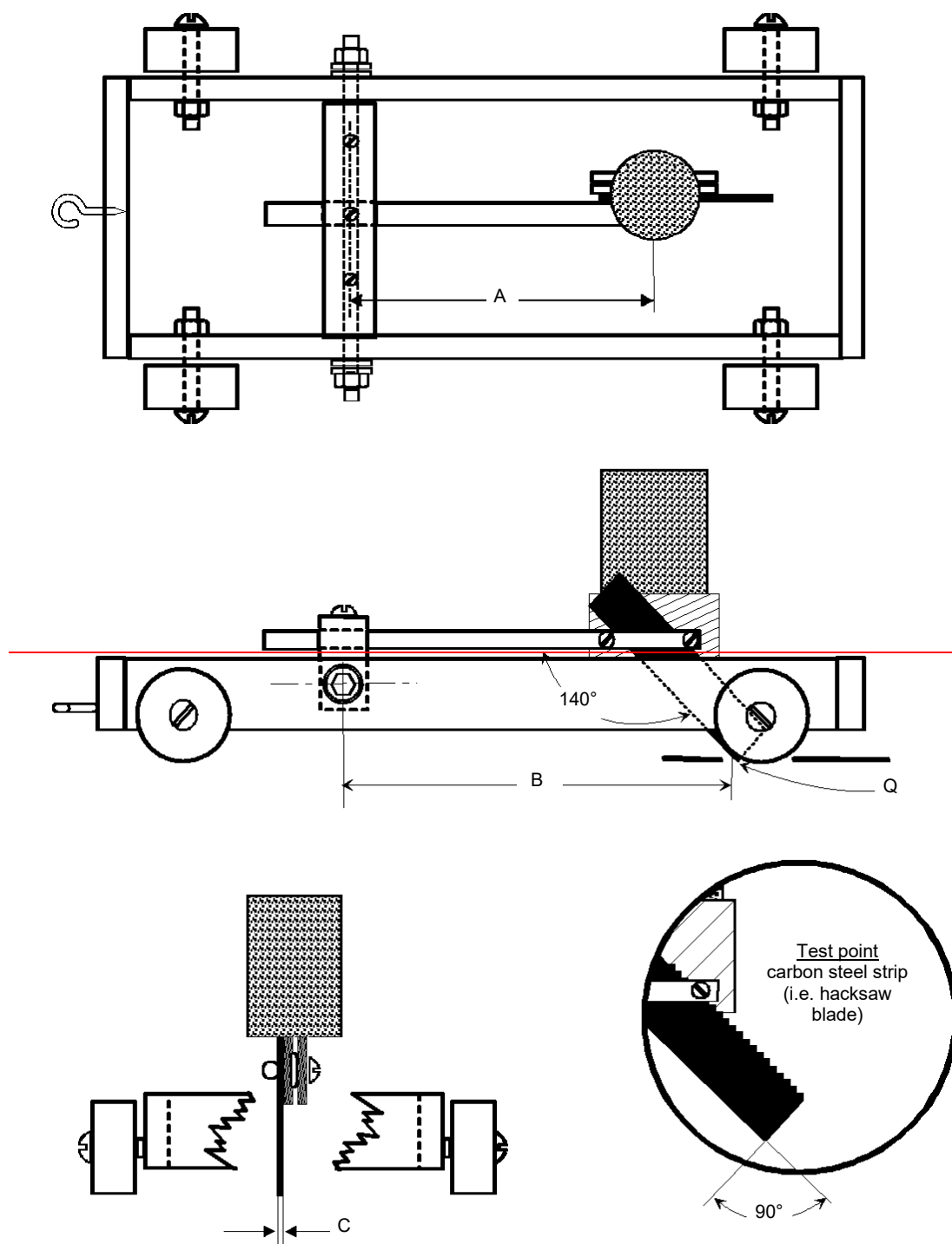
10.10.4 Final measurements

Repeat MST 01, ~~MST 13~~, MST 16 and MST 17.

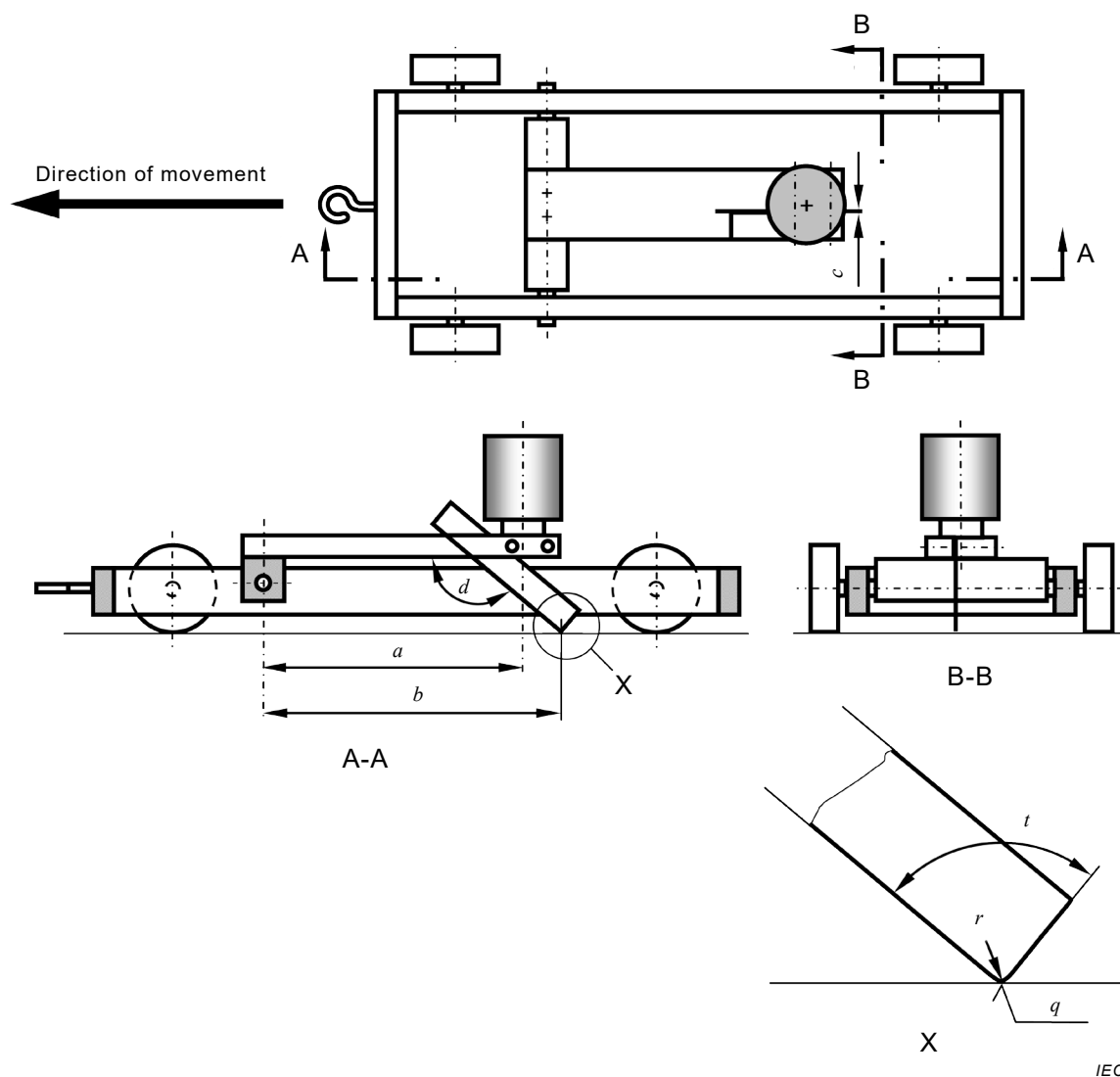
10.10.5 Pass criteria

The pass criteria are as follows:

- No visual evidence that the ~~superstrate~~ **frontsheet** or ~~substrate~~ **backsheet** surfaces have been cut exposing the active circuitry of the **PV** module.
- ~~MST 13~~, MST 16, MST 17 shall meet the same requirements as for the initial measurements.



IEC 1358/04



IEC

Key

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

Figure 3 – Cut susceptibility test**10.11 ~~Ground~~ Continuity test of equipotential bonding MST 13****10.11.1 Purpose**

~~To demonstrate that there is a conductive path between all exposed conductive surfaces of the module, so that the exposed conductive surfaces can be adequately grounded in a PV system. This test is required only if the module has exposed conductive parts such as a metal frame or a metallic junction box.~~

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. ~~See MST 26.~~
- b) A suitable voltmeter.

~~NOTE~~ 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 ~~grounding~~ point **for equipotential bonding** and the recommended ~~grounding~~ 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 ~~2,5 times~~ **250 % ± 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 ~~the test on one additional frame component~~ **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 ~~each~~ **every** other conductive component of the PV module shall be less than 0,1 Ω. **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 ~~the solid~~ insulation of the PV module to withstand over-voltages of atmospheric origin. It also covers over-voltages due to switching of low-voltage equipment.

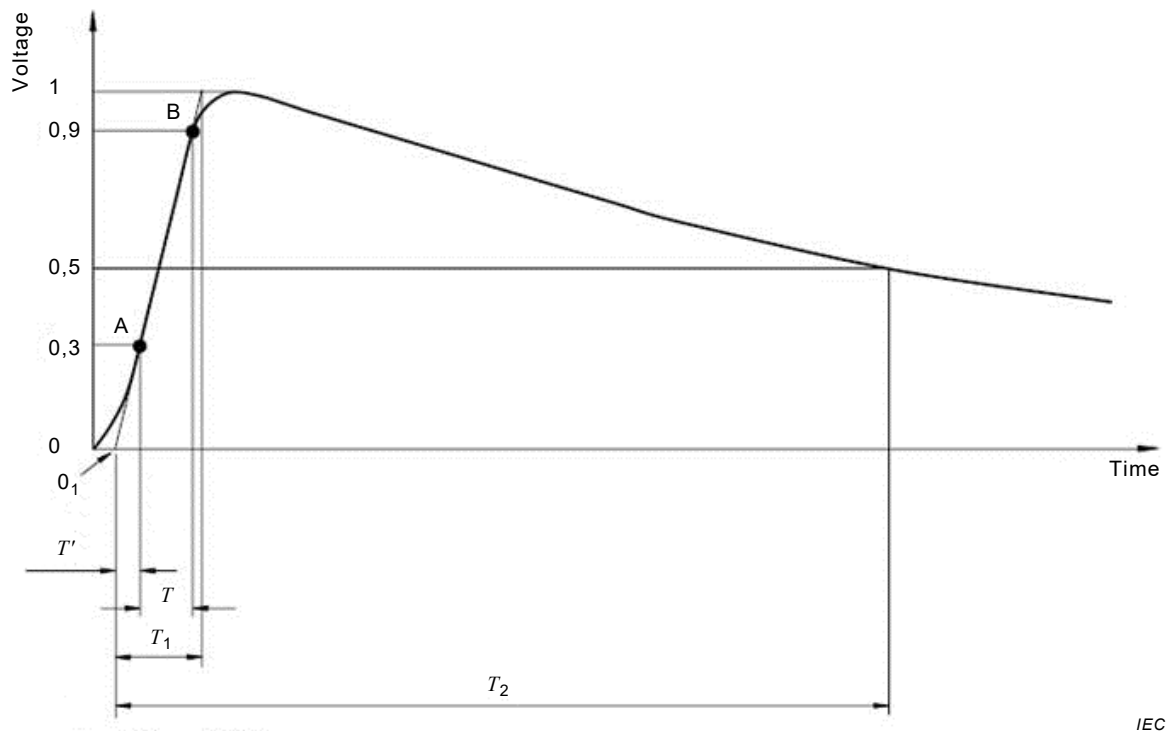
~~NOTE If the PV module is not going to be sold without frame, the impulse voltage test should be done with the module framed.~~

10.12.2 Apparatus

~~The apparatus is as follows:~~

- ~~a) Impulse voltage generator.~~
~~b) Oscilloscope.~~

The test equipment and procedure shall comply with IEC 60060-1, see Figure 4. Due to the variable and comparably high capacity of many samples compensation measures may be applicable to fulfil the required waveform tolerances.



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

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

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 4 – 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:

- Disable any voltage limiting device installed on the PV module, if applicable.
- Cover the whole PV module with a ~~copper~~ 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 to the negative terminal of the impulse voltage generator.
- Connect the shorted output terminals of the PV module to the positive terminal of the impulse voltage generator.

~~Specification of the foil:~~

- ~~1) Thickness copper 0,03 mm to 0,05 mm.~~
- ~~2) Conducting glue (conductivity $<1 \Omega$, measuring area: 625 mm²).~~
- ~~3) Total thickness 0,05 mm to 0,07 mm.~~

- d) ~~With no illumination,~~ Apply the surge impulse voltage with a waveform as shown in Figure 4 by the impulse voltage generator. ~~The waveform of the pulse shall be observed by an oscilloscope and the rise time and the pulse duration shall be checked for each test.~~ According to IEC 60060-1 the surge impulse voltage shall be within $\pm 3 \%$ of the value given in Table B.1 of IEC 61730-1:2016.

Linear interpolation of the voltages given in Table B.1 of IEC 61730-1:2016 is allowed for intermediate values of maximum system voltage.

~~NOTE 1 According to 2.2.2.1.1 of IEC 60664-1, modules belong to the over voltage category III. The test level has been reduced by one step because systems are normally equipped with over voltage protection devices. On the other hand, to verify reinforced insulation (as required for application class A and safety class II), the level for application class A has been increased by one step.~~

Table 8 – Impulse voltage versus maximum system voltage

Maximum system voltage V	Impulse voltage	
	Application class A V	Application class B V
100	1 500	800
150	2 500	1 500
300	4 000	2 500
600	6 000	4 000
1 000	8 000	6 000

~~NOTE 2 Linear interpolation is allowed for intermediate values of maximum system voltage.~~

- e) The waveform of the pulse shall be observed 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, and the rise time and the pulse duration shall be checked for each test.

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 ~~10.4~~ MST 01.

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

10.13 ~~Dielectric withstand~~ Insulation test MST 16

10.13.1 Purpose

The purpose of this test is to determine whether ~~or not~~ the PV module is sufficiently well insulated between current carrying parts and the frame or ~~the other outside-world accessible components~~.

~~The test shall be made on modules at ambient temperature of the surrounding atmosphere (see IEC 60068-1) and in a relative humidity not exceeding 75 %.~~

10.13.2 Procedure

This test is identical ~~with test 10.3~~ to MQT 03 of IEC 61215-2/~~IEC 61646~~ with test levels depending on the ~~application~~ 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 ~~application class A~~ Class II and equal to 1 000 V plus two times the maximum system voltage for ~~application class B~~ 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/~~IEC 61646~~.

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 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 ~~establish~~ 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.

~~10.7.2 Test conditions~~

~~The ambient temperature during the test may be in the range of 20 °C to 55 °C.~~

~~The irradiance during the test shall be no less than 700 W/m² measured coplanar with the module by a calibrated device with the accuracy to ±5 % in accordance with IEC 60904-2 and IEC 60904-6. All data shall be taken at wind speeds of less than 1 m/s.~~

10.7.3 Procedure

The module under test shall be mounted on a platform constructed of wood, pressed wood, or plywood, approximately 19 mm thick. The platform is to be painted flat black on the side facing the test sample. The platform shall extend at least 60 cm beyond the module on all sides.

The module under test shall be mounted to the platform in accordance with the manufacturer's installation instructions. If the instructions offer more than one option, the option providing the worst case shall be used. If no indications have been provided, the test module shall be mounted directly to the platform.

The module component temperatures shall be measured by a calibrated device or system, with an maximum uncertainty of $\pm 2^\circ\text{C}$.

The module is to be operated under both open and short circuit conditions, and stabilised temperature data for each test location shall be collected in each condition. Thermal stability has been attained when three successive readings, taken 5 min apart, indicate a change in temperature of less than $\pm 1^\circ\text{C}$.

The measured component temperatures (T_{obs}) shall be normalised by the addition of the difference between the 40°C reference ambient and the measured ambient temperature (T_{amb}) according to the equation $T_{\text{cor}} = T_{\text{obs}} + (40 - T_{\text{amb}})$. T_{cor} 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.

If the irradiance is other than $1\,000\text{ W/m}^2$, temperatures for more than two irradiance levels with at least 80 W/m^2 apart between the levels shall be determined, and a quadratic extrapolation conducted to determine the temperature under $1\,000\text{ W/m}^2$ irradiance.

Typical measurement points include:

- Module superstrate above the centre cell.
- Module substrate below the centre cell.
- Terminal enclosure interior surface.
- Terminal enclosure interior air space.
- Field wiring terminals.
- Insulation of the field wiring leads.
- External connector bodies (if so equipped).
- Diode bodies (if so equipped).

NOTE 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.

10.7.4 Requirements

The requirements are as follows:

- a) No measured temperatures exceed any of the temperature limits of surfaces, materials, or components, as described in Table 9; or
- b) No creeping, distortion, sagging, charring or similar damage to any part of the module as indicated in 10.1.

Table 9 — Component temperature limits

Part, material or component	Temperature limits °C
~~Insulating materials: ^{a)}~~	
~~Polymeric~~	~~a)~~
~~Fiber~~	~~90~~
~~Laminated phenolic composition~~	~~125~~
~~Molded phenolic composition~~	~~150~~
~~Field wiring terminals, metal parts~~	~~30 above ambient~~
~~Field wiring compartments that wires may contact ^{d)}~~	~~a) or ^{d)}, whichever is greater, or ^{b)}~~
~~Insulated conductors~~	~~d)~~
~~Mounting surface (frame) and adjacent structural members~~	~~90~~
~~a) — The material's relative thermal index (RTI), less 20 °C.~~ ~~b) — If a marking is provided to state the minimum temperature rating of the conductors to be used, the terminals at points within a wiring compartment may exceed the value specified but shall not attain a temperature higher than 90 °C.~~ ~~c) — Higher temperatures than specified are acceptable if it can be determined that the higher temperatures will not cause a risk of fire or electric shock.~~ ~~d) — Temperatures measured on insulated conductors shall not exceed the rated temperature of the conductor.~~	

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:

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

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 $1\,000\text{ W/m}^2$ 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 $< 0,25\text{ m/s}$; 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 $\pm 2\text{ K}$.
- 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 $\pm 3\text{ K}$ (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 $\pm 2\text{ K}$. 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

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

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.

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.

10.17 Fire test MST 23

10.17.1 Purpose

~~These requirements establish the fundamental fire resistance of PV modules serving either as roof covering materials or mounted onto a building over an existing roof. These modules may be exposed to fire conditions, and therefore need to indicate their fire resistance characteristics when exposed to a fire source originating from outside the building on which they are installed. The modules are not required to function after the test.~~

~~NOTE These tests specify fundamental requirements and may not be sufficient to satisfy the requirements for a module intended for building applications according to local or national building code requirements. Additional testing, beyond or in addition to these cited tests, may be required.~~

~~The fire resistance classes range from Class C (fundamental fire resistance), to Class B to Class A (highest fire resistance). A minimum fire resistance rating of Class C is necessary for any building-mounted module. Certification to a higher level may be considered in order to satisfy specific application requirements.~~

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.

~~10.8.2 Approach~~

~~A PV module used in place of classified roofing material or mounted to or above an existing classified roofing material needs to comply with a single burning brand and spread of flame test, in accordance with the test outlined in Annex A, which are based on ANSI/UL 790. Sufficient samples shall be provided to create a single test assembly for a single spread of flame and a single burning brand test.~~

~~Products that comply with these tests are not readily flammable, afford a measurable degree of fire protection to the roof deck, do not slip from position, and are not expected to produce flying brands.~~

~~10.8.3 Pass criteria~~

~~The PV module system shall attain a fire resistance classification by compliance with the stated requirements of Annex A. Compliance with a single burning brand and spread of flame test is required for modules mounted over an existing roof covering. Additional sequential testing, such as that outlined in ANSI/UL 790, is required for modules acting as a roof covering material.~~

~~NOTE It is the intention of IEC Technical Committee 82 to use international standards, such as ISO 834, for fire resistance testing PV modules. Until this standard is available, the tests described here will be required as minimum safety qualification.~~

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.

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

If compliance to ISO 11925-2 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 and that are identical to the PV module type under test with respect to their material composition, the test procedure given in ISO 11925-2 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 applies with the following modifications. Subclauses 4.8, 4.11 and 4.12 of ISO 11925-2:2010 do not apply.

10.18.2.2 Test cabinet

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

The test cabinet shall be capable of providing an environment of $23\text{ °C} \pm 5\text{ °C}$ 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.

A gas burner complying with 4.3 of ISO 11925-2:2010 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 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.

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.

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

10.18.3.2 Dimensions

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

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 11925-2:2010.

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 11925-2:2010.

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 11925-2:2010 applies with the following modifications.

10.18.5.2 Preliminary operations

This subclause deviates from 7.2 of ISO 11925-2:2010.

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 10.18.2.1.

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 11925-2:2010 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 11925-2:2010 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 11925-2:2010 are modified as follows.

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.

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.

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

10.18.6 Duration of test

Subclause 7.4.1 of ISO 11925-2:2010 applies (15 s flame application time 20 s total test duration).

10.18.7 Observations

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.

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 ~~tabbing~~ 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.

10.20.2 Procedure

The PV module under test is to be placed with its ~~superstrate~~ frontsheet face down onto a ~~9 mm thick soft pine board~~ 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 ~~of cheesecloth. The cheesecloth is to be untreated cotton cloth, running 26 m²/kg to 28 m²/kg and have a "thread count" of 32 by 28.~~ The density of both pieces of white tissue paper should conform to 12 g/m² to 30 g/m² (ISO 4046-4).

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. 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 ~~tests~~ current (~~I_{test}~~) (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}~~ 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.

~~NOTE Concerning the maximum overcurrent protection rating, see 12.2 of IEC 61730-1.~~

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

10.20.3 Pass criteria

The pass criteria are as follows:

- There shall not be flaming of the PV module, nor flaming or charring of the ~~cheesecloth~~ and tissue paper in contact with the PV module.
- MST 01 shall meet the same requirements as for the initial measurements.
- MST 16 shall meet the same requirements as for the initial measurements.
- MST 17 shall meet the same requirements as for the initial measurements.

10.21 Module breakage test MST 32

10.21.1 Purpose

The purpose of this test is to provide confidence that ~~cutting or piercing~~ risk of physical injuries can be minimized if the PV module is broken in its specified installation.

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

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.

~~10.10.2 Background~~

~~The test described herein is derived from ANSI Z97.1, Impact test.~~

10.21.2 Apparatus

The apparatus is as follows:

- a) ~~Impactors shall be leather punching bags of similar shape and size. The bag shall be filled to the required weight using chilled lead shot or pellets (2,5 mm to 3,0 mm in diameter – No. 7½ shot). Figure 4 shows the designs for the impactor bag. The exterior of the bag shall be wrapped with tape as shown in the figures. During testing, the impactor shall be completely covered with a 1,3 cm wide glass filament reinforced pressure sensitive tape. (See Figure 4).~~

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 the Figure 5 in order to avoid uneven surfaces like stitching. When filled, the impactor bag shall have dimensions as described in Figure 5 and a weight of $45,5 \text{ kg} \pm 0,5 \text{ kg}$. 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 6 and Figure 7 shall be provided to minimise movement and deflection during testing. The structure framing and bracing shall be steel channel (approximately $100 \text{ mm} \times 200 \text{ mm}$ or larger) and shall have a minimum moment of inertia of approximately 187 cm^4 . 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.
- c) ~~When an impactor bag is filled with lead shot, it will weigh approximately 45,5 kg, and will be capable of delivering 542 J of kinetic energy when swung through a 1,2 m vertical drop.~~

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 to a drop height of 300 mm from the surface of the PV module sample, allow the impactor to stabilize, and then release it to strike the PV module sample.
- c) ~~If no breakage occurs, repeat the sequence of b) from a drop height of 450 mm. If still no breakage occurs, repeat from a distance of 1 220 mm.~~

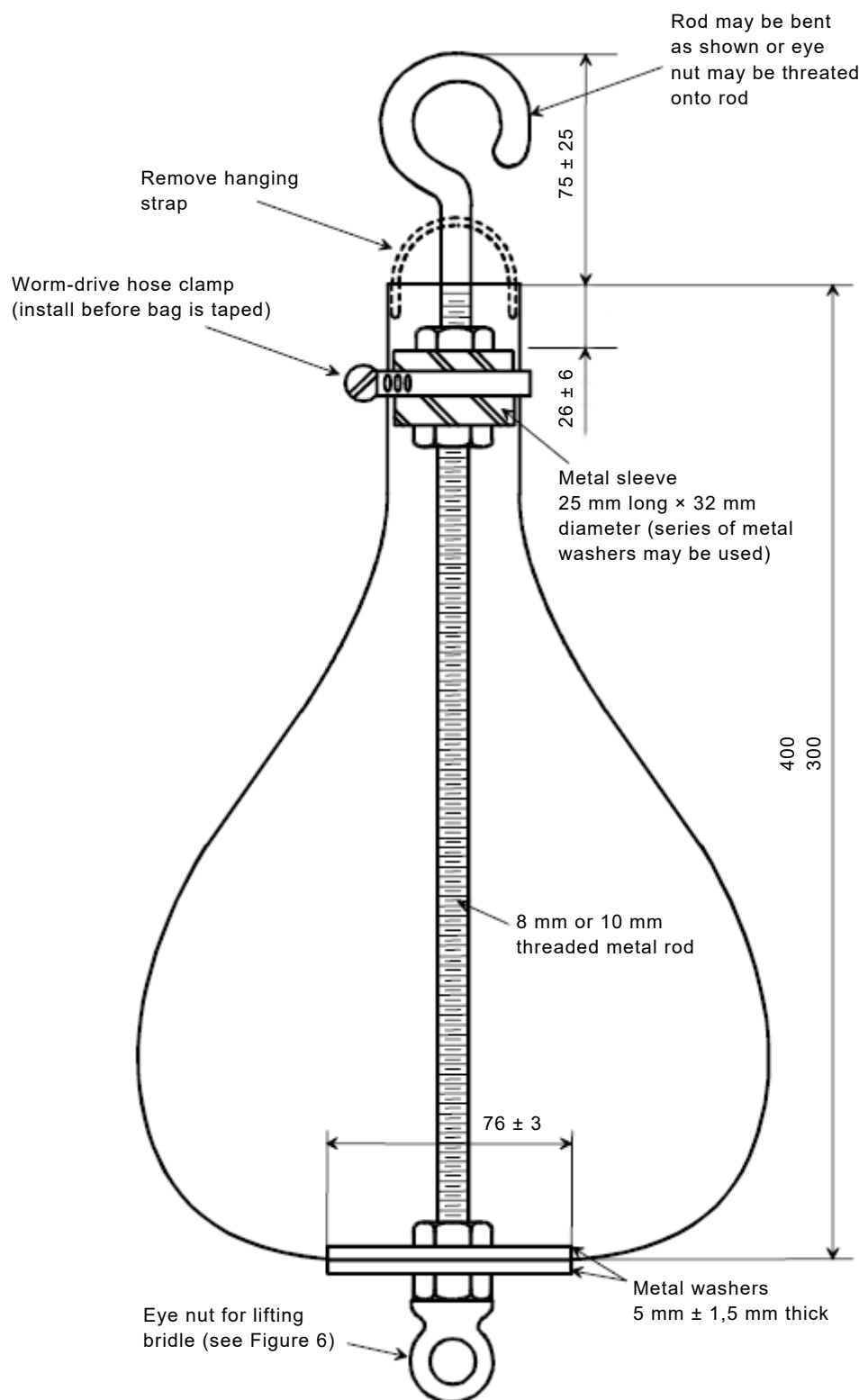
10.21.4 Pass criteria

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

- ~~a) When breakage occurs, no shear or opening large enough for a 76 mm (3 inch) diameter sphere to pass freely shall develop.~~
- ~~c) When breakage occurs, no particles larger than $6,5 \text{ cm}^2$ shall be ejected from the sample.~~
- ~~b) When disintegration occurs, the ten largest crack free particles selected 5 min subsequent to the test shall weigh no more in grams than 16 times the thickness of the sample in millimetres.~~
- ~~d) The sample does not break.~~
- 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 cm^2 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 61730-1:2016 (form/press/tight fit) a continuity of equipotential bonding test (MST 13) shall be passed successfully before and after MST 32.

Dimensions in millimetres

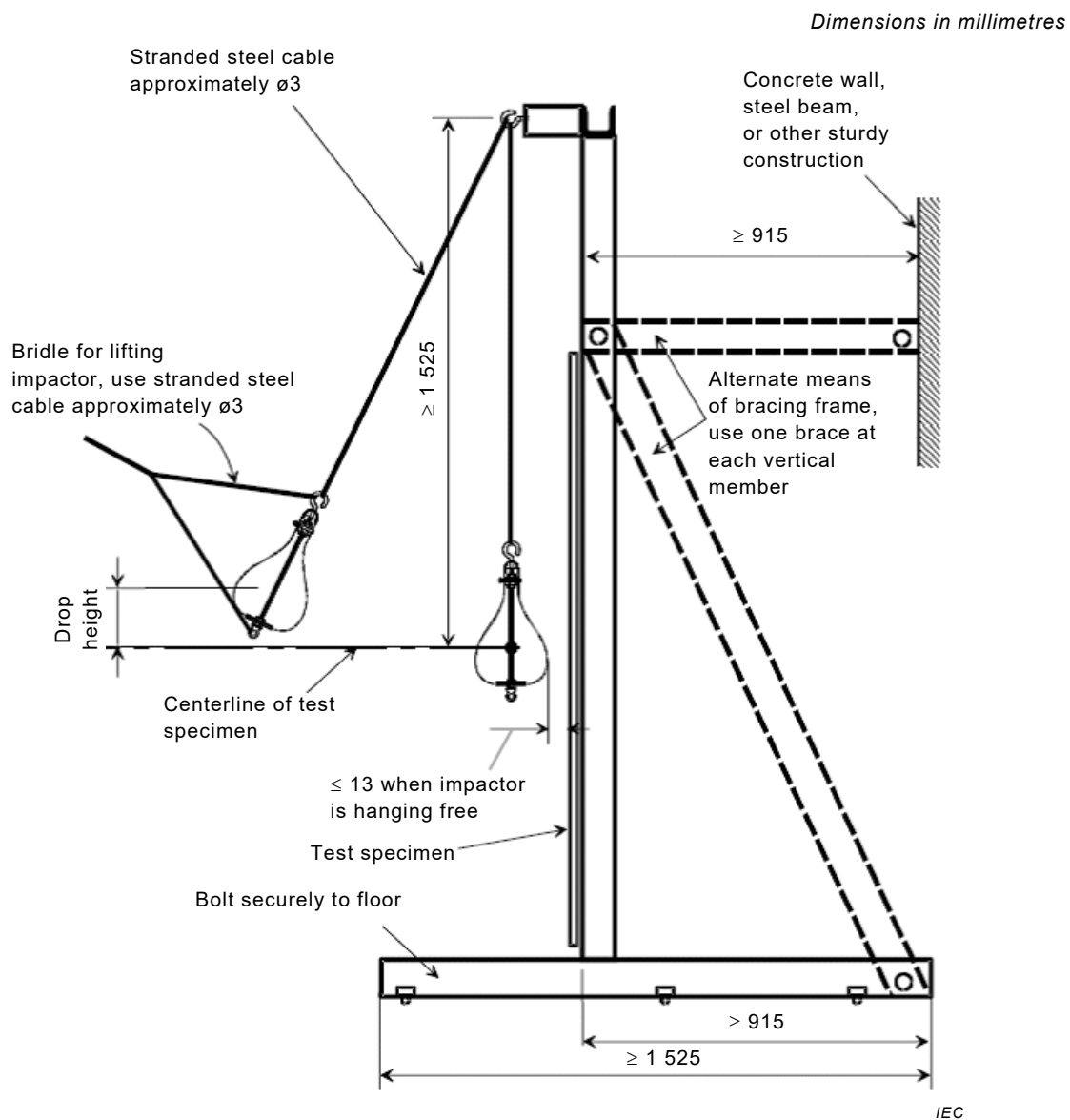


IEC

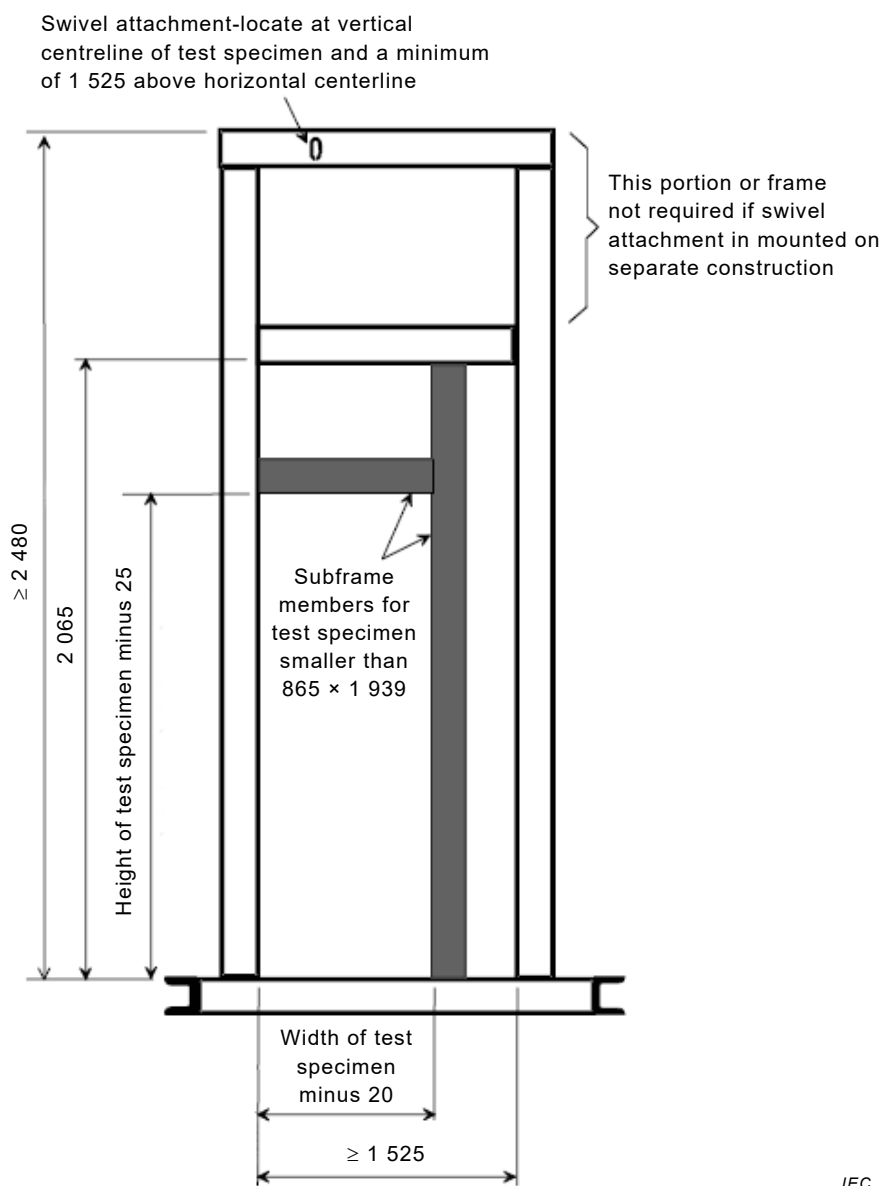
Filled bag has a total weight of assembly of $45,5 \text{ kg} \pm 0,5 \text{ kg}$.

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 5 – Impactor

**Figure 6 – Impact test frame 1**

Dimensions in millimetres



NOTE Clamping frame for holding test specimen not shown.

Figure 7 – Impact test frame 2

11 Component tests

11.1 Partial discharge test MST 15

The test refers to 4.1.2.4 of IEC 60664-1.

11.1.1 Purpose

Polymeric materials intended for use as a superstrate or substrate, without appropriate IEC insulation pre-qualification must comply with the partial discharge test. This test should be applied to any polymeric material serving as a superstrate or substrate (see also IEC 61730-1).

~~11.1.2 — Preconditioning~~

~~It is advisable to perform the partial discharge test before inserting the reverse side foil into the PV modules.~~

~~11.1.3 — Apparatus~~

~~Calibrated charge measuring device or radio interference meter according to IEC 60664-1.~~

~~11.1.4 — Procedure~~

~~The procedure is as follows:~~

- ~~a) According to C.2.1 and Clause D.1 of IEC 60664-1, starting from a value below the maximum system voltage, up to the point at which partial discharge takes place (inception voltage), the test voltage shall be further increased by 10 %.~~
- ~~b) The voltage shall then be lowered to the point at which the partial discharge extinction voltage is reached.~~
- ~~c) The extinction voltage shall be considered to be reached once the charge intensity has dropped to a value of 1 pC. This voltage shall be measured with an accuracy better than 5 %.~~
- ~~d) The partial discharge extinction voltage may be influenced by environmental conditions. These influences are taken into account by a basic safety factor F_4 of 1,2.~~
- ~~e) The hysteresis factor according to 4.1.2.4 of IEC 60664-1 is reduced to 1. The additional safety factor for reinforced insulation $F_3 = 1,25$ is required for safety class A. The initial value of the test voltage is therefore $1,5 U_{OC}$ (system voltage given by the module manufacturer).~~
- ~~f) Repeat the measurement with 10 test samples.~~

~~11.1.5 — Pass criteria~~

~~The solid insulation has passed the test if the mean value minus the standard deviation of the partial discharge extinction voltage is greater than 1,5 times the given maximum system voltage.~~

~~11.2 — Conduit bending test MST 33~~

~~11.2.1 — Purpose~~

~~Modules provided with junction boxes intended for attachment of a permanent wiring system using conduit must provide assurance of the ability of the box construction to withstand load forces which may be applied to the conduit during and after installation.~~

~~11.2.2 — Procedure~~

~~Two 460 mm lengths of proper trade size conduit with appropriate fitting for the box shall be assembled and installed onto the box on opposing surfaces. For boxes intended for use with non-metallic conduit, the conduit test lengths are to be welded to the fittings and allowed to dry no less than 24 h prior to assembly.~~

~~The test assembly, with the box at the centre, is to be placed on supports as illustrated in Figure 7. The supports are to be separated by a distance of 760 mm plus the distance between the ends of the conduit in the box, to give the required bending moment on the sample under test.~~

~~The load specified in Table 10 for the size of conduit used, is to be suspended from the centre of the box for 60 s. During this time, the box and the lengths of conduit shall be rotated through one complete revolution about the major axis of the assembly.~~

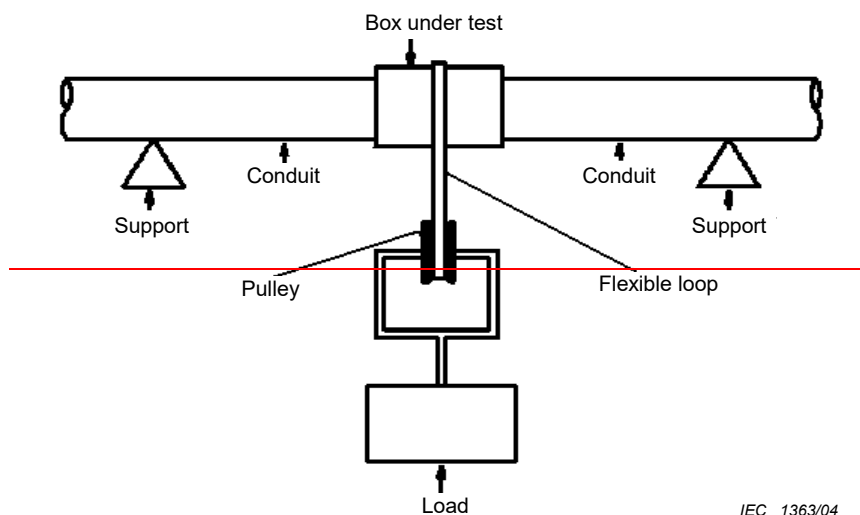
11.2.3 ~~Pass criteria~~

~~The attachment walls of the module junction box shall not rupture or separate from the conduit.~~

~~NOTE If breakage of the conduit occurs prior to damage to the box or separation of the joint, performance of the box is considered acceptable.~~

Table 10 – Bending loads

Trade size of conduit mm	Force load N
13 to 25	220
26 to 50	330
51 to 100	490



IEC 1363/04

Figure 7 – Test fixture assembly

11.3 ~~Terminal box knockout tests MST 44~~

11.3.1 ~~Purpose~~

~~Removable hole covers in the walls of module terminal enclosures (knockouts) shall remain in place under nominal force application and also be easily removed for the field application of permanent wiring system components.~~

11.3.2 ~~Condition~~

~~A sample of the polymeric terminal box with knockouts will be tested in an “as-received” condition at a 25 °C ambient temperature.~~

~~Another sample of the polymeric box is to be conditioned for 5 h in air maintained at 20 °C ±1 °C. The test shall be repeated on the box immediately following this conditioning.~~

11.3.3 ~~Procedure~~

~~The knockout shall be easily removed without leaving any sharp edges or causing any damage to the box. The procedure is as follows:~~