

INTERNATIONAL STANDARD



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

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INTERNATIONAL STANDARD



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

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

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CONTENTS

FOREWORD.....	6
1 Scope ~~and object~~	9
2 Normative references	9
~~3 Application classes~~	~~9~~
~~3.1 General.....~~	~~9~~
~~3.2 Class A: General access, hazardous voltage, hazardous power applications~~	~~9~~
~~3.3 Class B: Restricted access, hazardous voltage, hazardous power applications~~	~~9~~
~~3.4 Class C: Limited voltage, limited power applications~~	~~9~~
3 Terms and definitions	12
4 Test categories.....	12
4.1 General.....	12
4.2 ~~Preconditioning~~ Environmental stress tests	12
4.3 General inspection	13
4.4 Electrical shock hazard tests	13
4.5 Fire hazard tests	13
4.6 Mechanical stress tests	14
~~4.7 Component tests~~	~~14~~
5 ~~Application~~ Classes and their necessary test procedures.....	14
6 Sampling	16
7 Test report	16
8 Testing	17
9 Pass criteria	20
10 Test procedures	20
10.1 General.....	20
10.2 Visual inspection MST 01	20
10.2.1 Purpose	20
10.2.2 Procedure.....	20
10.2.3 Pass criteria.....	20
10.3 Performance at STC MST 02	22
10.3.1 Purpose	22
10.3.2 Procedure	22
10.3.3 Pass criteria.....	22
10.4 Maximum power determination MST 03	22
10.4.1 Purpose	22
10.4.2 Procedure	23
10.4.3 Pass criteria.....	23
10.5 Insulation thickness test MST 04	23
10.5.1 Purpose	23
10.5.2 Procedure	23
10.5.3 Pass criteria.....	23
10.6 Durability of markings MST 05	24
10.7 Sharp edge test MST 06.....	24
10.8 Bypass diode functionality test MST 07	24
10.9 Accessibility test MST 11.....	24

10.9.1	Purpose	24
10.9.2	Apparatus	24
10.9.3	Procedure	24
10.9.4	Final measurements	25
10.9.5	Pass criteria	25
10.10	Cut susceptibility test MST 12	25
10.10.1	Purpose	25
10.10.2	Apparatus	25
10.10.3	Procedure	25
10.10.4	Final measurements	25
10.10.5	Pass criteria	26
10.11	Ground Continuity test of equipotential bonding MST 13	27
10.11.1	Purpose	27
10.11.2	Apparatus	28
10.11.3	Procedure	28
10.11.4	Final measurements	28
10.11.5	Pass criteria	28
10.12	Impulse voltage test MST 14	28
10.12.1	Purpose	28
10.12.2	Apparatus	28
10.12.3	Procedure	29
10.12.4	Final measurement	30
10.12.5	Pass criteria	30
10.13	Dielectric withstand Insulation test MST 16	31
10.13.1	Purpose	31
10.13.2	Procedure	31
10.13.3	Pass criteria	31
10.14	Wet leakage current test MST 17	31
10.15	Temperature test MST 21	31
10.15.1	Purpose	31
10.15.2	Outdoor method	33
10.15.3	Solar simulator method	35
10.15.4	Pass criteria	36
10.16	Hot-spot endurance test MST 22	36
10.17	Fire test MST 23	36
10.17.1	Purpose	36
10.18	Ignitability test MST 24	37
10.18.1	Purpose	37
10.18.2	Apparatus	38
10.18.3	Test specimen	38
10.18.4	Conditioning	39
10.18.5	Procedure	39
10.18.6	Duration of test	40
10.18.7	Observations	40
10.18.8	Pass criteria	40
10.19	Bypass diode thermal test MST 25	40
10.20	Reverse current overload test MST 26	40
10.20.1	Purpose	40
10.20.2	Procedure	41

10.20.3	Pass criteria.....	41
10.21	Module breakage test MST 32	42
10.21.1	Purpose	42
10.21.2	Apparatus	42
10.21.3	Procedure	42
10.21.4	Pass criteria.....	43
10.22	Screw connections test MST 33	49
10.22.1	Test for general screw connections MST 33a	49
10.22.2	Test for locking screws MST 33b	50
10.23	Static mechanical load test MST 34	51
10.24	Peel test MST 35	51
10.24.1	Purpose	51
10.24.2	Sample requirements	51
10.24.3	Apparatus	52
10.24.4	Procedure	52
10.24.5	Pass criteria.....	54
10.25	Lap shear strength test MST 36	55
10.25.1	Purpose	55
10.25.2	Test samples	55
10.25.3	Apparatus	56
10.25.4	Procedure	56
10.25.5	Pass criteria.....	57
10.26	Materials creep test MST 37	58
10.26.1	Purpose	58
10.26.2	Apparatus	58
10.26.3	Procedure	58
10.26.4	Final measurements.....	58
10.26.5	Pass criteria.....	58
10.27	Robustness of terminations test MST 42	58
10.28	Thermal cycling test MST 51	59
10.29	Humidity freeze test MST 52.....	59
10.30	Damp heat test MST 53.....	59
10.31	UV test MST 54.....	59
10.32	Cold conditioning MST 55.....	59
10.32.1	Purpose	59
10.32.2	Apparatus	59
10.32.3	Procedure	59
10.32.4	Pass criteria.....	60
10.33	Dry heat conditioning MST 56.....	60
10.33.1	Purpose	60
10.33.2	Apparatus	60
10.33.3	Procedure	60
10.33.4	Pass criteria.....	60
11	~~Component tests~~	~~61~~
11.1	~~Partial discharge test MST 15.....~~	~~61~~
11.2	~~Conduit bending test MST 33~~	~~61~~
11.3	~~Terminal box knockout tests MST 44~~	~~61~~
Annex A	(informative) Recommendations for testing of PV modules from production	61
A.1	General.....	61

A.2	Module output power	61
A.3	Wet insulation test	61
A.4	Visual inspection.....	62
A.5	Bypass diodes	62
A.6	Continuity test of equipotential bonding	62
Annex B (~~normative~~ informative) Fire tests, spread-of-flame and burning-brand tests for PV modules		63
B.1	General.....	68
B.2	Fire test for PV modules based on ENV 1187.....	68
B.2.1	General	68
B.2.2	External fire exposure to roofs	68
B.2.3	Classification according to ISO 13501-5	69
B.3	Fire test for PV modules based on ANSI/UL 1703	70
~~Bibliography.....~~		
Figure 1 – Test sequences.....		19
Figure 2 – Assessment of bubbles in edge seals for cemented joints.....		22
Figure 3 – Cut susceptibility test		27
Figure 4 – Waveform of the impulse voltage following IEC 60060-1		29
Figure 5 – Impactor.....		44
Figure 6 – Impact test frame 1		45
~~Figure 7 – Test fixture assembly.....~~		
Figure 7 – Impact test frame 2		46
Figure 8 – Sample preparation of cemented joints ≤ 10 mm using a release sheet.....		52
Figure 9 – PV module with positions for peel samples on frontsheet or backsheet		53
Figure 10 – Typical peel-off measurement curves		54
Figure 11 – Lap shear test sample for proving cemented joint.....		56
Figure 12 – Lap-shear test flow.....		57
~~Figure A.1 – Test apparatus for fire test.....~~		
~~Figure A.2 – Burning brand construction.....~~		
Figure B.1 – Example of test set-up for fire test		69
Table 1 – ~~Preconditioning~~ Environmental stress tests		12
Table 2 – General inspection test.....		13
Table 3 – Electrical shock hazard tests		13
Table 4 – Fire hazard tests		14
Table 5 – Mechanical stress tests		14
~~Table 6 – Component tests.....~~		
Table 6 – Required tests, depending on the ~~application~~ Class.....		15
Table 7 – Torque tests on screws per IEC 60598-1:2014, Table 4.1.....		50
~~Table 8 – Impulse voltage versus maximum system voltage.....~~		
~~Table 9 – Component temperature limits.....~~		
~~Table 10 – Bending loads.....~~		

INTERNATIONAL ELECTROTECHNICAL COMMISSION

PHOTOVOLTAIC (PV) MODULE SAFETY QUALIFICATION –

Part 2: Requirements for testing

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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,
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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)	–	~~40.11~~ MQT 11	~~40.11~~
MST 52	Humidity freeze (HF10)	–	~~40.12~~ MQT 12	~~40.12~~
MST 53	Damp heat (DH1000)	–	~~40.13~~ MQT 13	~~40.13~~
MST 54	UV preconditioning ~~test~~	–	~~40.10~~ MQT 10	~~40.10~~
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.

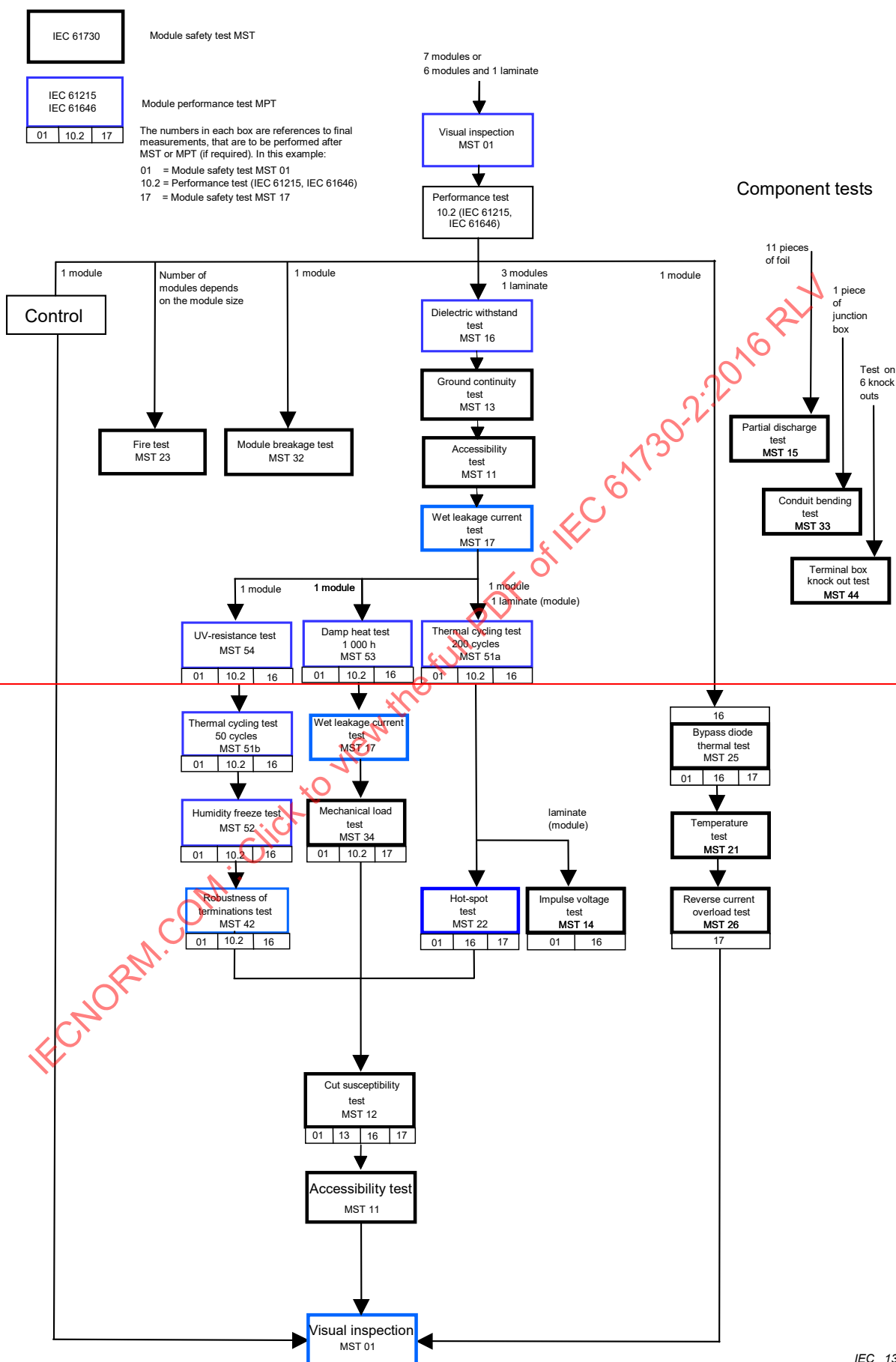
The PV module for sequence B shall be irradiated during the first 60 kWh/m² cycle from the front side of the specimen and from the backside during the second 60 kWh/m² cycle (MST 54). By doing so, the front side and back side of the PV module will be exposed to the same UV dose.

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.



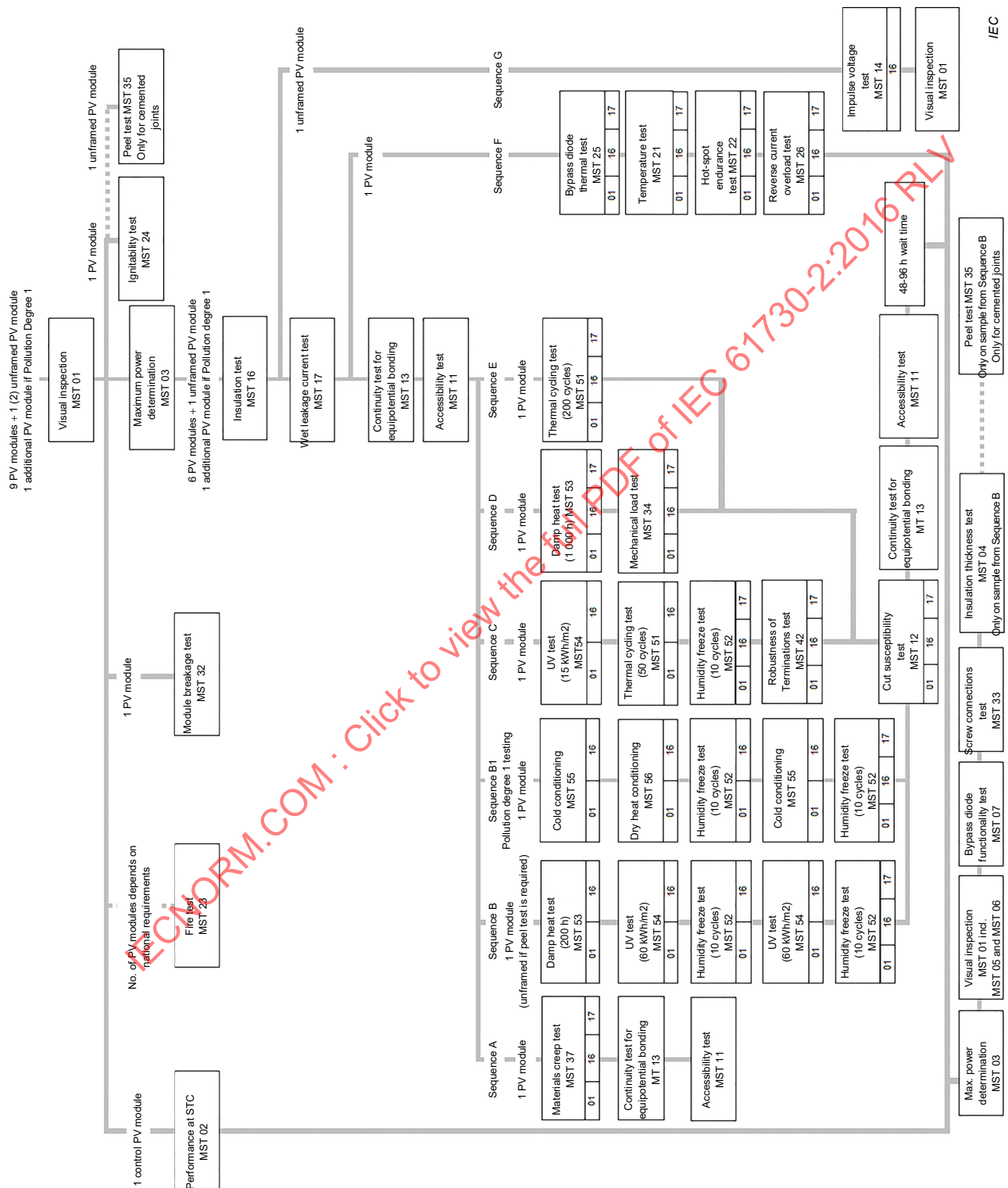


Figure 1 – Test sequences

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.

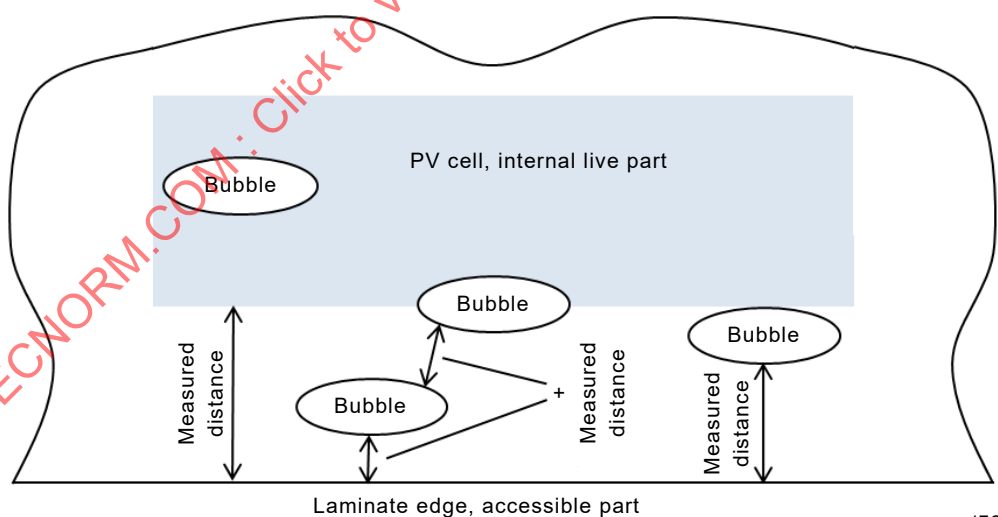
It is advisable to check distances during the initial inspection to validate that the PV module meets the insulation requirements.

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.



IEC

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

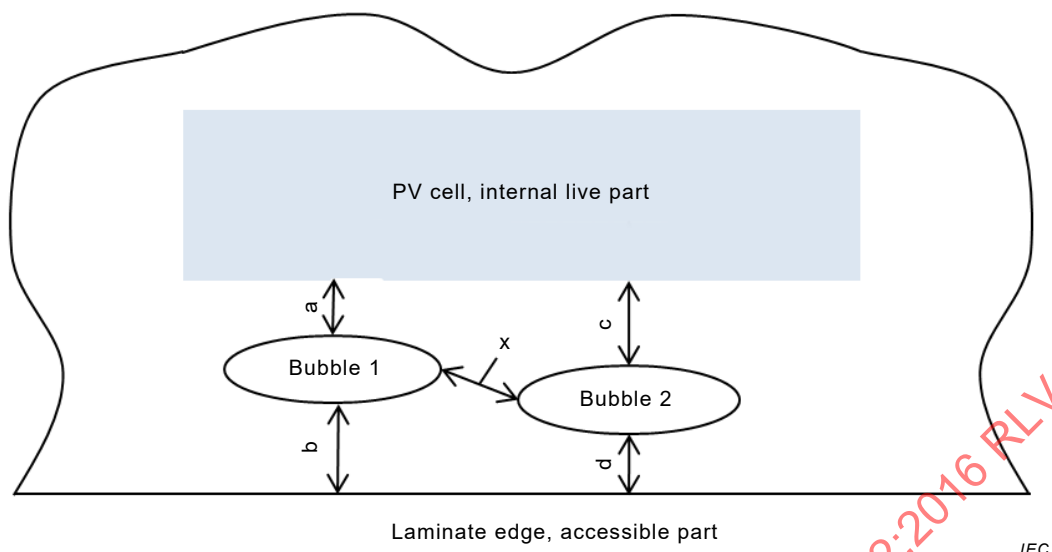


Figure 2b – Example for delamination distance (x) assessment when measuring creepage or distance through insulation

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

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

10.9.3 Procedure

The procedure is as follows:

- Mount and wire the test PV module as recommended by the manufacturer.
- Attach the ohmmeter or continuity tester to the PV module's ~~electric~~ short-circuited terminals and to the test fixture.
- Remove all covers, plugs and connections from the PV module that can be removed without using a tool.
- 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.
- 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 $1\text{ M}\Omega$ ~~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 $0,64\text{ mm} \pm 0,05\text{ mm}$ thick carbon steel blade (for example the back of a hacksaw blade)~~ over the surface of the PV module with an applied force of $8,9\text{ N} \pm 0,5\text{ N}$. 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 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 $150\text{ mm/s} \pm 30\text{ mm/s}$. Repeat the procedure five times in different directions considering the most critical points.
- c) Repeat a) and b) for ~~the rear surface~~ other polymeric surfaces of the PV module if applicable.

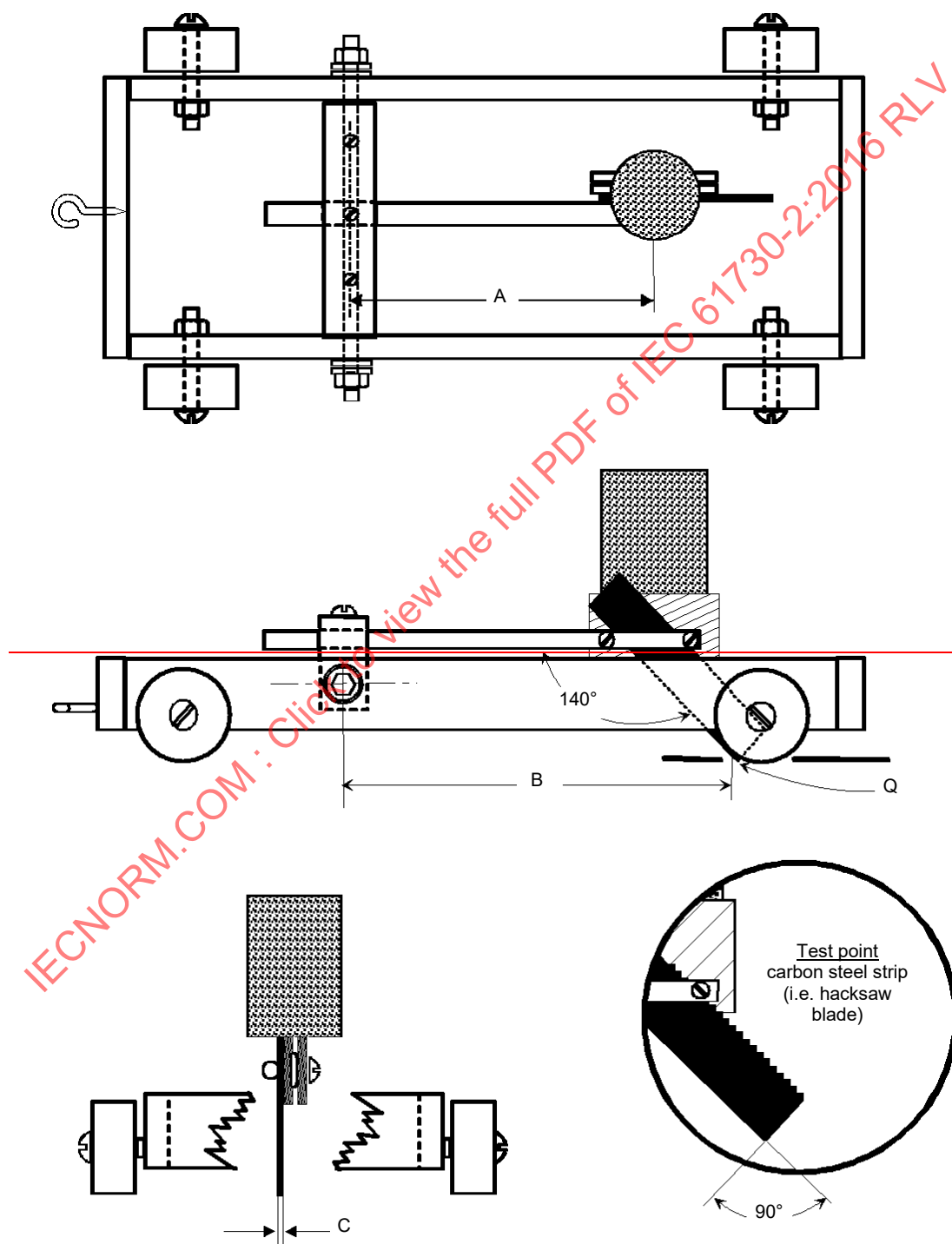
10.10.4 Final measurements

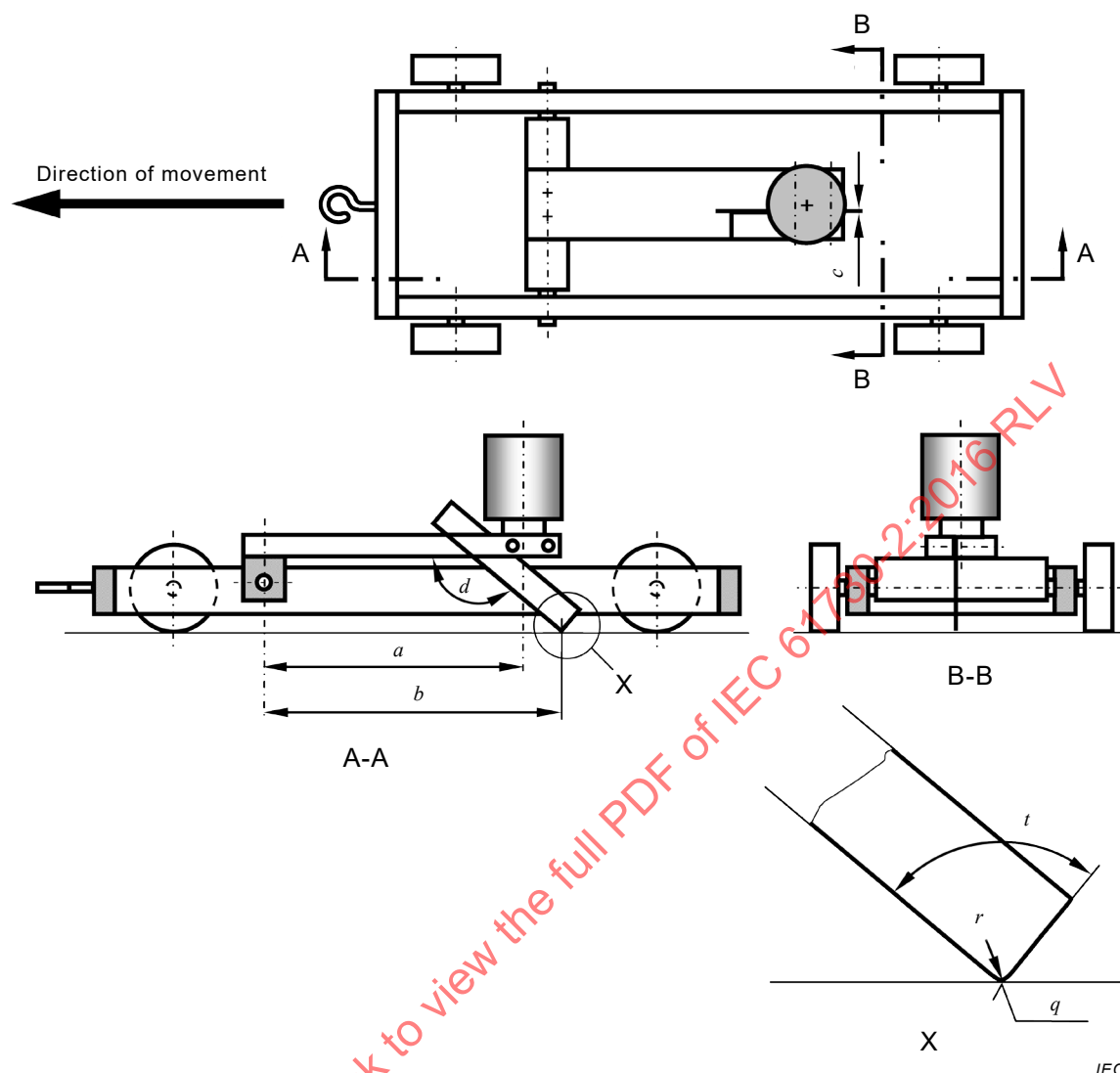
Repeat MST 01, ~~MST 13~~, MST 16 and MST 17.

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.



**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 % $\pm$ 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 ~~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.~~

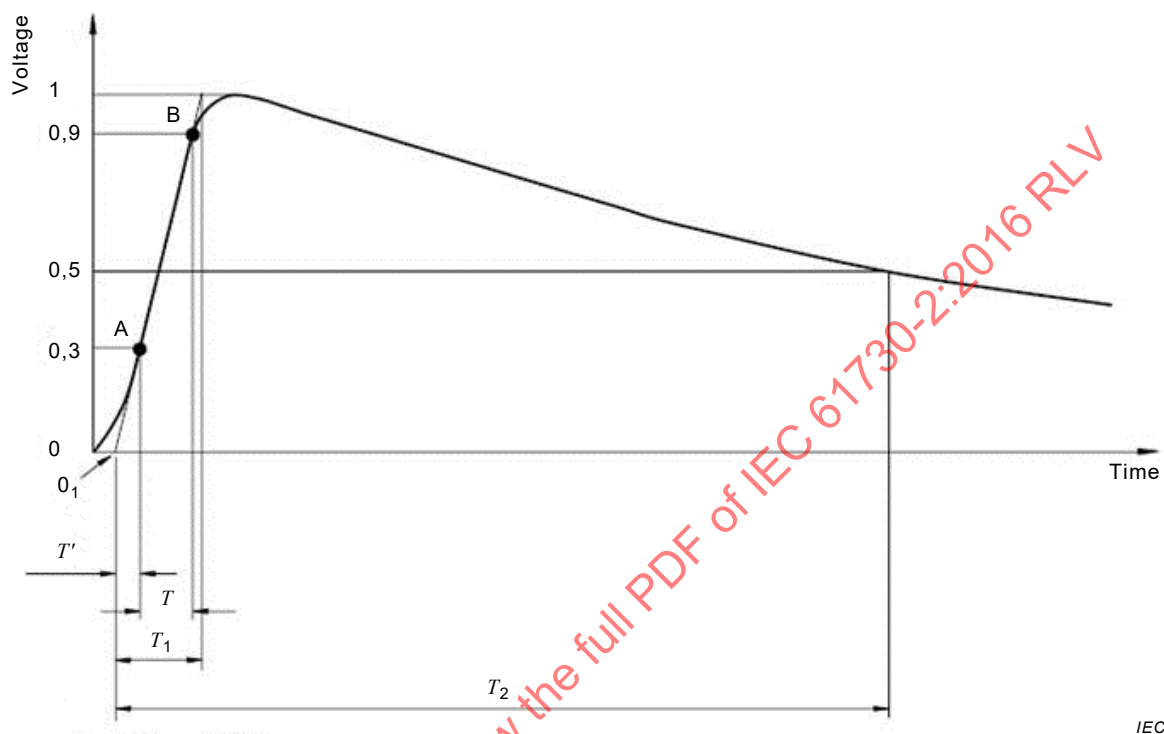
10.12.2 Apparatus

~~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: $U_{\text{Test}}(\text{cemented joint}) = U_{\text{Test}} \cdot 1,35$ 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: $U_{\text{Test}}(\text{cemented joint}) = U_{\text{Test}} \cdot 1,35$ 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 $T_{\text{con}} = T_{\text{obs}} + (40 - T_{\text{amb}})$. 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.

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:

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

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 $1\,000\text{ W/m}^2$ 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 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 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 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.
- 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.~~

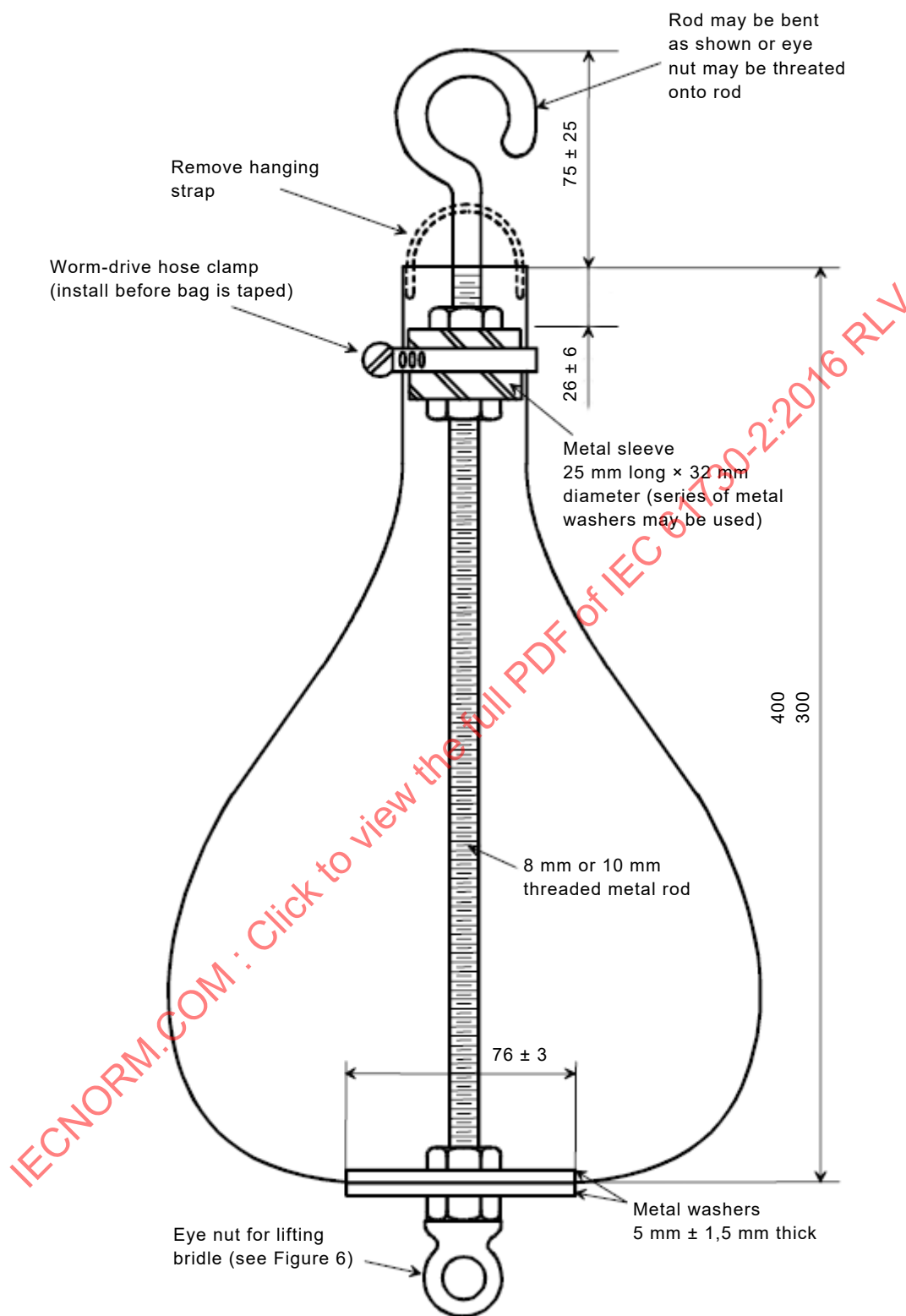
10.21.4 Pass criteria

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 cm² 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 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 61730-1:2016 (form/press/tight fit) a continuity of equipotential bonding test (MST 13) shall be passed successfully before and after MST 32.

Dimensions in millimetres



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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

Dimensions in millimetres

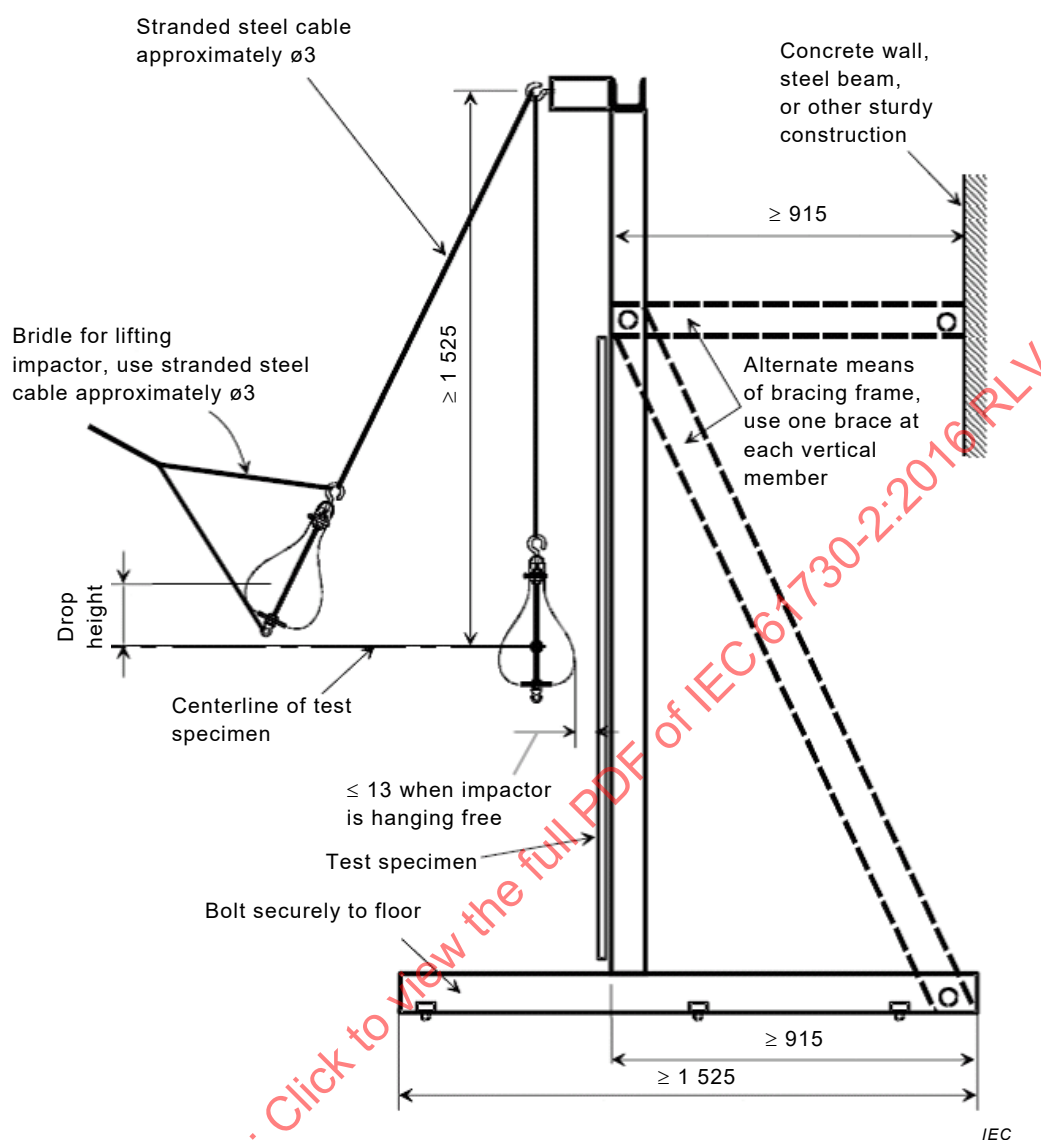
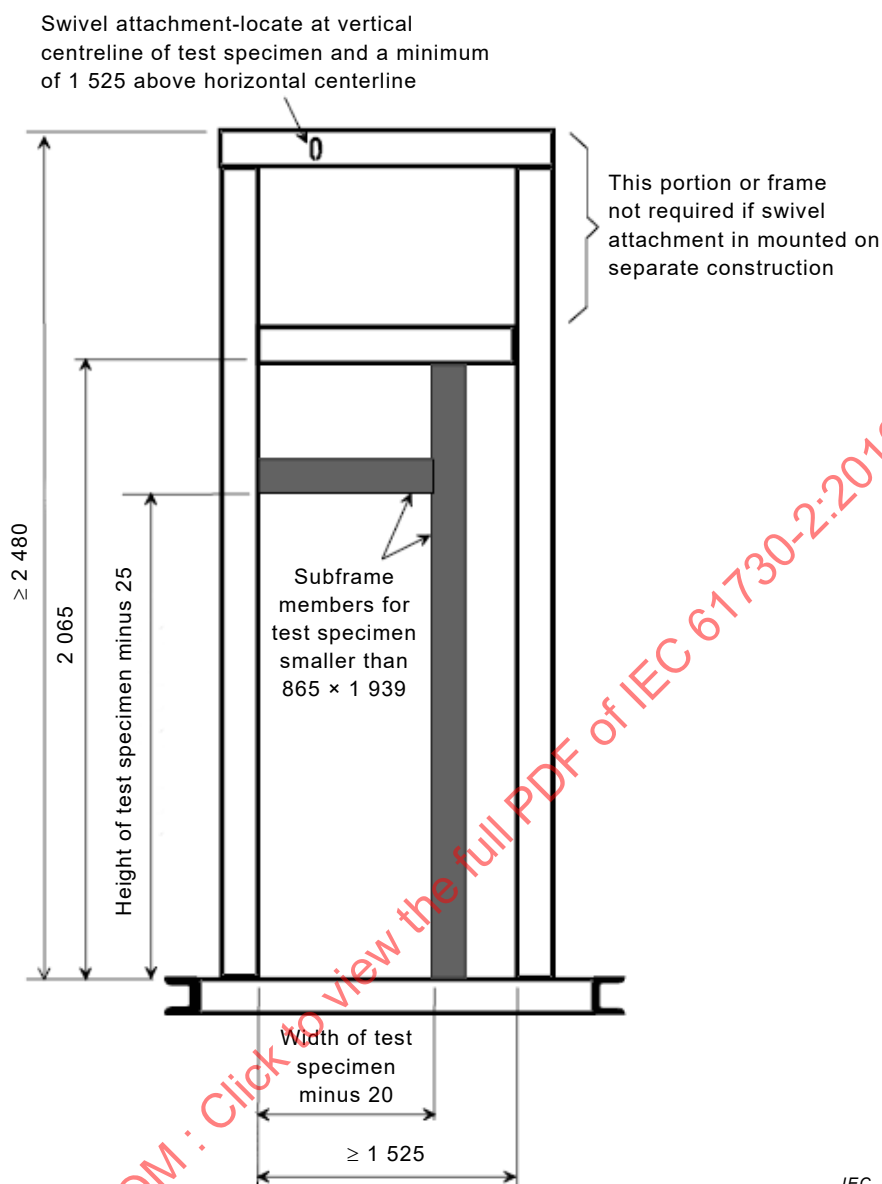


Figure 6 – Impact test frame 1

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 $1,5 \cdot U_{OC}$ (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

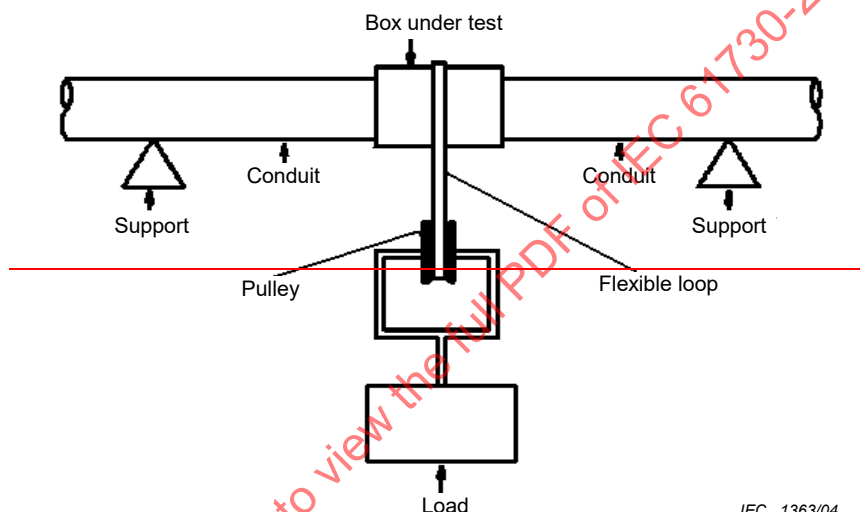


Figure 7 – Test fixture assembly

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:

~~Step 1 — A force of 44,5 N shall be applied to a knockout for 1 min by means of a mandrel, minimum 38 mm long by 6,4 mm diameter, with a flat end. The force is to be applied in a direction perpendicular to the plane of the knockout and at the point most likely to cause movement. Wait 1 h and measure the displacement between the knockouts and the box.~~

~~Step 2 — The knockout shall then be removed by means of a screwdriver, used as a chisel. The edge of a screwdriver blade may be run along the inside edge of the resulting opening once only, to remove any fragile tabs remaining along the edge.~~

~~Step 3 — Repeat steps 1 and 2 on two additional knockouts.~~

~~For a box employing multi-stage knockouts, there shall be no displacement of a larger stage when a smaller stage is removed.~~

~~11.3.4 — Pass criteria~~

~~The knockout shall remain in place after the application of the steady force and the clearance between the knockout and the opening shall not be more than 0,75 mm when measured.~~

~~The knockout shall be easily removed without leaving any sharp edges or causing any damage to the box.~~

10.22 Screw connections test MST 33

10.22.1 Test for general screw connections MST 33a

10.22.1.1 General

Components such as screws and nuts transmitting contact pressure or which are likely to be tightened by the user shall be tightened and loosened five times. Screws and nuts of insulating material shall be removed completely during each operation of loosening of the screws.

The test is made by means of a suitable test screwdriver or spanner, applying a torque as shown in Table 7, except that for screws of insulating material used in cord anchorage and bearing directly on the cable or cord, the torque is 0,5 Nm.

If the manufacturer specifies a higher torque in their installation instructions, that torque shall be used for testing. This shall be noted in the test report.

Table 7 – Torque tests on screws per IEC 60598-1:2014, Table 4.1

Nominal outer thread diameter of screw mm	Torque Nm		
	Type 1	Type 2	Type 3
Up to and including 2,8	0,20	0,40	0,40
Over 2,8 up to and including 3,0	0,25	0,50	0,50
Over 3,0 up to and including 3,2	0,30	0,60	0,50
Over 3,2 up to and including 3,6	0,40	0,80	0,60
Over 3,6 up to and including 4,1	0,70	1,20	0,60
Over 4,1 up to and including 4,7	0,80	1,80	0,90
Over 4,7 up to and including 5,3	0,80	2,00	1,00
Over 5,3 up to and including 6,0	–	2,50	1,25
Over 6,0 up to and including 8,0	–	8,00	4,00
Over 8,0 up to and including 10,0	–	17,00	8,50
Over 10,0 up to and including 12,0	–	29,00	14,50
Over 12,0 up to and including 14,0	–	48,00	24,00
Over 14,0 up to and including 16,0	–	114,00	57,00

The shape of the blade of the screwdriver shall suit the head of the screw to be tested. The screws shall not be tightened in jerks. Damage to covers is neglected.

Type 1 of Table 7 applies to metal screws without heads if the tightened screw does not protrude from the hole.

Type 2 applies to:

- other metal screws and to nuts;
- screws of insulating material
 - having a hexagonal head with the dimensions across flats exceeding the overall thread diameter;
 - having a cylindrical head and a key socket with a cross-corner dimension exceeding the overall thread diameter;
 - having a head with a slot or cross slots, the length of which exceeds 1,5 times the overall thread diameter.

Type 3 applies to other screws of insulating material.

10.22.1.2 Pass criteria

During the test, no damage impairing the further use of the fixing or screwed connection shall occur. After the test, it shall still be possible to introduce the screw or nut made of insulation material in the intended manner.

10.22.2 Test for locking screws MST 33b

10.22.2.1 General

A thread-lock that softens on heating provides satisfactory locking only for screw connections not subject to torsion in normal use. Such connections shall be tested by attempting to loosen locked screws with the following torque:

- 2,5 Nm for thread size $\leq$ M 10 or corresponding diameters;

- 5,0 Nm for thread sizes > M 10 or corresponding diameters.

The test torque shall be applied for 1 min in a clockwise direction and then for 1 min in an anti-clockwise direction at 25 °C and maximum normalized temperature determined by MST 21.

10.22.2.2 Pass criteria

No loosening shall occur.

10.23 Static mechanical load test MST 34

This test is equivalent to MQT 16 in IEC 61215-2.

MQT 15 can be omitted.

10.23.1.1 Pass criteria

- a) Requirements apply as in IEC 61215-2 MQT 16;
- b) MST 13 shall meet the same requirements.

10.24 Peel test MST 35

10.24.1 Purpose

The purpose of this test is to qualify insulation as a cemented joint. It shall provide confidence regarding the durability of the adhesion between different layers of rigid-to-flexible or flexible-to-flexible constructions of the PV module stack. The test method is taken from ISO 813 and determines the adhesive strength between polymeric materials bonded on a frontsheet or backsheet.

The test is not required, if clearance and creepage distances as required by class, pollution degree and material group are in accordance with either the figures in Table 3 or Table 4 of IEC 61730-1, respectively.

This test is not applicable to rigid-to-rigid bonded assemblies (e.g. glass/glass PV modules). Assessment is done by MST 36.

10.24.2 Sample requirements

For cemented joints with a width ≤ 10 mm the following procedure shall be used to prepare 2 special laminates (1 reference sample (not-aged) and 1 sample for sequence B testing) in the factory:

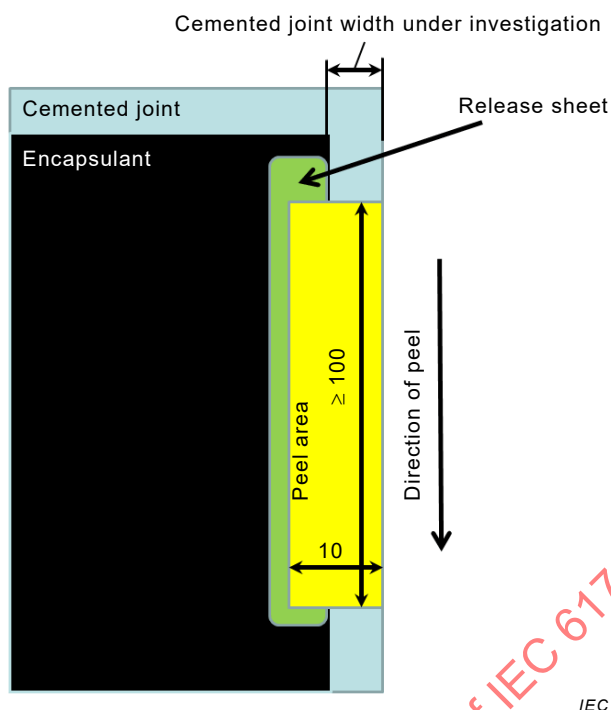
The sample shall be prepared as illustrated in Figure 8 for all locations as specified in Figure 9. A release sheet (e.g. Teflon) is to be inserted along the boundary of the cemented joint under test between the encapsulant layer and the backsheet. This is to ensure that the peel test is only conducted on the cemented joint area and not at a combination of cemented joint and encapsulant. It shall be close to the cemented joint but shall not penetrate the cemented joint area. For final peel-sample preparation and cutting procedure refer to 10.24.4.

If non-rigid frontsheets and rigid backsheet are used the procedure shall be applied from the front side.

If frontsheet and backsheet are non-rigid the procedure shall be applied from both sides, keeping the surface that is not peeled flat to a plate e.g. with an adhesive.

For qualification of cemented joints > 10 mm no special preparation is needed. A typical laminate shall be used.

Dimensions in millimetres



NOTE The yellow area highlights the cuts for the peel test after conditioning.

Figure 8 – Sample preparation of cemented joints ≤ 10 mm using a release sheet

10.24.3 Apparatus

The apparatus is as follows:

- Tensile-testing machine, complying with the requirements of ISO 5893, capable of measuring force with an accuracy corresponding to class 1 and with a rate of traverse of the moving grip of $50 \text{ mm/min} \pm 5 \text{ mm/min}$.
- Fixture, for holding the test piece to the moving grip of the testing machine in a) so that the direction of pull to cause separation is at all times during the test $90^\circ \pm 10^\circ$ to the plane of the bond between the polymer and the rigid backsheet, i.e. making an angle of 90° with the surface of the fixture.

10.24.4 Procedure

An unconditioned unframed reference PV module (typically a new module) and one unframed PV module that has undergone test sequence B of Figure 1 are used for the peel test. Each module shall be treated according to the following procedure:

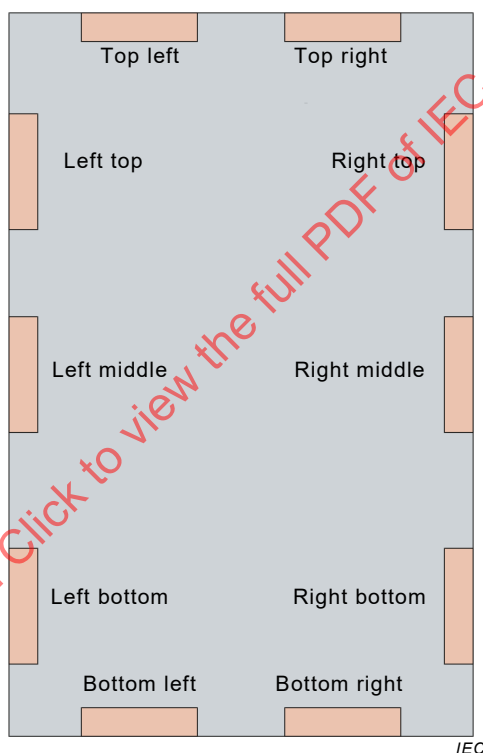
- Condition the samples for at least 16 h at $23^\circ\text{C} \pm 2^\circ\text{C}$, $50\% \text{ RH} \pm 10\% \text{ RH}$ immediately before the test in accordance with the requirements of ISO 23529.
- Cemented joint width > 10 mm (laminate):
After conditioning ten (5 per interface) strips of $10 \text{ mm} \pm 0,5 \text{ mm}$ width and at least 100 mm length shall be cut at the flexible frontsheet or flexible backsheet of the samples as shown in Figure 9. Five strips are to be cut per adhesion interface. Adhesion interfaces to be evaluated for classification as cemented joints may include flexible frontsheet or flexible backsheet to cemented joint material (5 peels), and cemented joint material to rigid backsheet or rigid frontsheets (5 peels). The strips shall be cut from the same side of the module, however the depth of the cut shall be to the appropriate adhesion interface.
- Cemented joint width ≤ 10 mm (special laminate):

After conditioning ten strips of $10 \text{ mm} \pm 0,5 \text{ mm}$ width and at least 100 mm length shall be cut out of the samples as shown in Figure 9. Five strips are to be cut per adhesion interface. Adhesion interfaces to be evaluated for classification as cemented joints may include flexible frontsheet or flexible backsheet to cemented joint material (5 peels), and cemented joint material to rigid backsheet or rigid frontsheet (5 peels). The strips shall be cut from the same side of the module.

The first cut (position see Figure 9, cut area see yellow box in Figure 8) will allow peel testing of the backsheet to cemented joint material interface (total 5 peels). For investigation of the rigid frontsheet to cemented joint material interface the remaining encapsulant shall be cut to the rigid frontsheet (second cut, underneath yellow box in Figure 8 along release sheet and cemented joint) such that peel will not be influenced by the encapsulant. Care shall be taken that the cemented joint as such is not influenced (total 5 peels).

If other areas in a PV module shall be classified as cemented joint, the locations shown in Figure 9 may be extended to other relevant areas. The concept of release sheet insertion for cemented joints width $\leq 10 \text{ mm}$ shall be adopted.

Report the areas where the strips have been cut (e.g. by picture with dimensions).



IEC

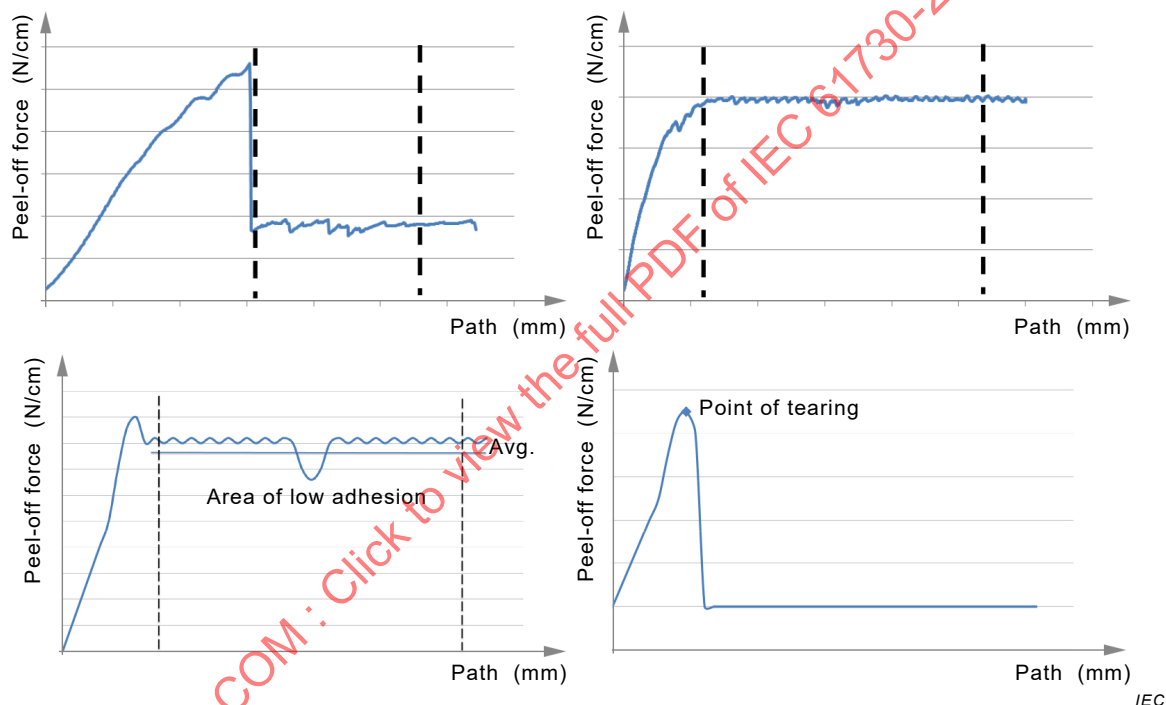
Figure 9 – PV module with positions for peel samples on frontsheet or backsheet

- a) The depth of the cut shall be sufficient to completely cut through to the layer of which adhesion shall be measured, but shall not significantly infringe the layer below. A fraction of the strip sufficient in length to be gripped by the machine shall be separated manually at the interface under investigation. The strip shall be mounted perpendicularly to the moving grip of the testing machine. Start with the peel test and continue until the complete strip under test is peeled off. The peel strength shall be measured over a length of at least 60 mm.

To provide better comparability of the peel test the use of a template for the sample preparation is recommended.

The length of the piece of strip mounted to the grip depends on the grip design. Usually 10 mm is sufficient. In case more is needed the extra length is to be considered during sample preparation.

- b) Place the test piece symmetrically in the fixture. Place the free end of the strip in the grip. Move the grip of the tensile-testing machine at $50 \text{ mm/min} \pm 5 \text{ mm/min}$ until separation is complete. Record the force required to cause separation.
- c) A time versus force plot over the full length of the test piece shall be made.
- d) Report the adhesion strength in newton per mm, by dividing the force (in N) recorded by the width of the test piece (in mm). Report whether adhesive or cohesive failure has been observed for each peel.
- e) Only such samples shall be considered showing a continuous peel-off characteristic for at least 20 mm. The mean value of that continuous phase shall be considered when applying the pass criteria (10.23.4). Even if the measured maximum force deviates significantly from the continuous force (compare Figure 10 left) the continuous fraction of the measurement shall be considered.
- f) In case visual inspection (MST 01) reveals bubbles or delaminations spaced 20 mm or less apart in the area of the peel, the test shall be conducted such that the affected areas are covered by the peel test. In case of a single large bubble this area shall be covered by the peel test.



- Top left : peak force does not reflect actual adhesion properties and shall be excluded from mean value calculation.
- Top right: optimal curve, evaluation of the continuous part of the curve.
- Bottom left: peel strength curve with local weak adhesion and resulting average.
- Bottom right: force at point of tearing (sample breakage).

Figure 10 – Typical peel-off measurement curves

10.24.5 Pass criteria

The PV module shall be judged to have successfully passed the peel test if the loss of adhesion force of the arithmetic mean M for the respective interface of unconditioned ($M1$) and after stress test of sequence B ($M2$) is below 50 %. The difference is determined by comparing the mean value of the results of the two samples tested.

$$0,5 < \frac{\sum_1^n M2}{\sum_1^n M1}$$

For each PV module type 5 samples at each interface shall be tested. The value relevant for the pass criteria is the mean value of the 5 samples. In case measurements of samples are discarded following criteria above, at least the 3 samples with the lowest adhesion force shall be evaluated. If needed additional samples shall be prepared and evaluated.

If the adhesion force of the interface to be evaluated cannot be obtained (e.g. cohesive failure within the cemented joint) or adhesion failure of other included interfaces or tearing or breaking of the sample during testing then the measured peak force before failure shall be used for evaluation.

If no locations meeting the requirements from 10.24.2 and the requirements from Figure 2 can be identified and tested, the sample has failed the test.

10.25 Lap shear strength test MST 36

10.25.1 Purpose

The purpose of this test is to qualify insulation as a cemented joint. It shall provide confidence regarding the durability of the adhesion between rigid-to-rigid bonded assemblies (e.g. glass/glass PV modules) for cemented joints of the PV module stack. The test is described in ISO 4587 and determines the adhesive strength of rigid substructures bonded by polymeric material.

The test is not required, if clearance and creepage distances as required by class, pollution degree and material group are in accordance with either the figures in Table 3 or Table 4 of IEC 61730-1, respectively.

This test is not applicable to rigid-to-flexible or flexible-to-flexible bonded assemblies (e.g. glass/foil or foil/foil PV modules). For rigid-to-flexible or flexible-to-flexible bonded assemblies MST 35 applies.

10.25.2 Test samples

20 samples in accordance to ISO 4587:2003 made up of identical materials, thicknesses and glass surface structure for frontglass, backglass and adhesive (cemented joint) as the end product (PV module). The adhesive bond of samples shall be representative in every aspect to the end product and hence be built using equivalent production parameters including methods of edge delete and treatment, see Figure 11.

If heat strengthened glass is used in production an equivalent non-tempered glass that is easier to cut samples from can be used.

Dimensions in millimetres

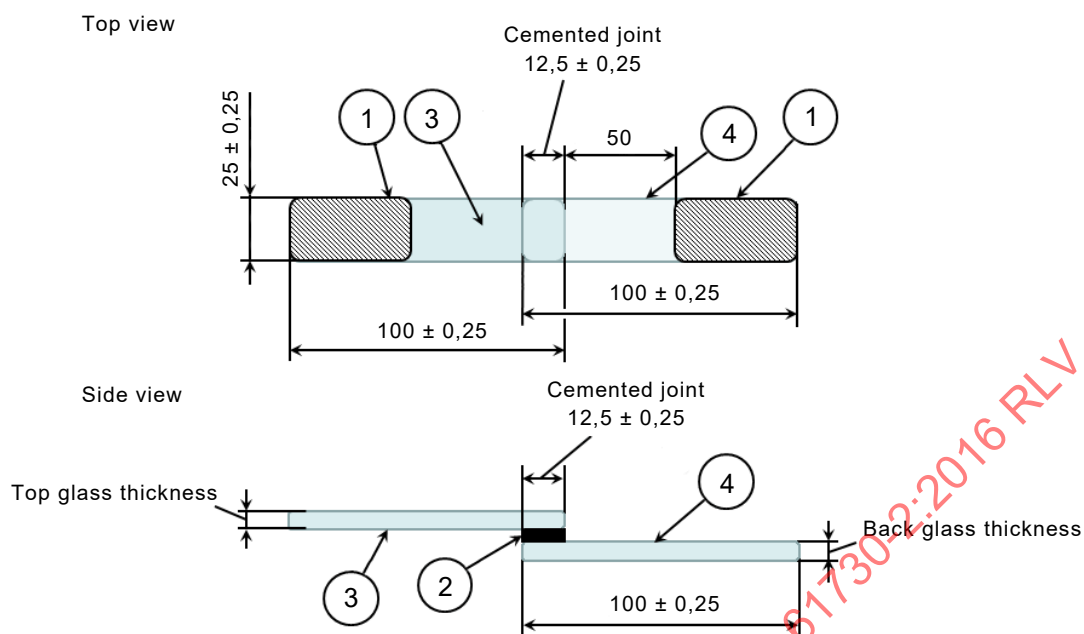


Figure 11 – Lap shear test sample for proving cemented joint

10.25.3 Apparatus

The apparatus (tensile-testing machine) is specified in ISO 4587:2003, Clause 4.

10.25.4 Procedure

A total of 20 bonded test coupons shall be prepared as described in 10.25.2. 10 bonded test coupons are used to determine the pre-weathering breaking force (M1) and 10 bonded test coupons are used to determine the post-weathering breaking force (M2). The test flow is given in Figure 12. In the first UV-test the front glass is exposed to the UV and in the second step the back glass.

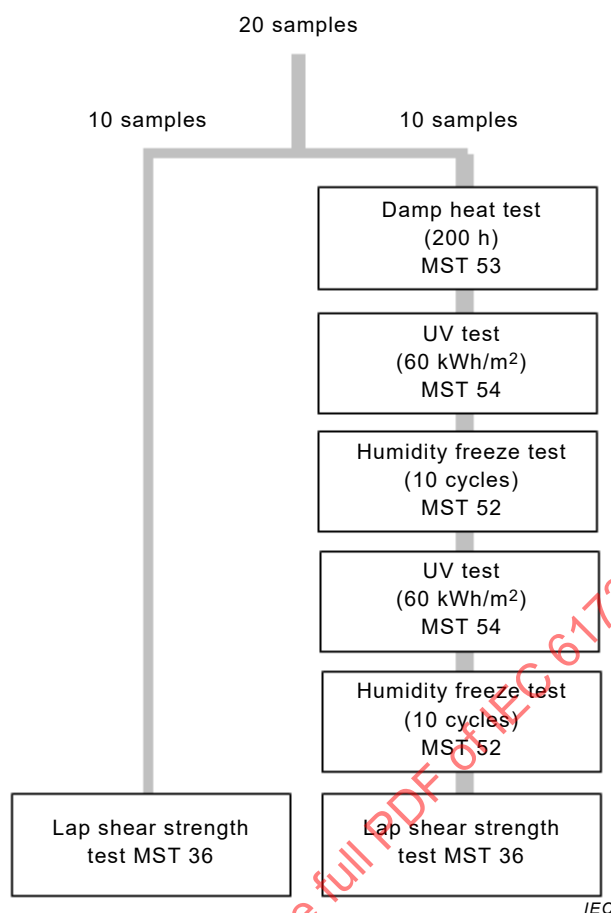


Figure 12 – Lap-shear test flow

Condition the samples for at least 16 h at $23\text{ °C} \pm 2\text{ °C}$, $50\% \text{ RH} \pm 10\% \text{ RH}$ immediately before the test in accordance with the requirements of ISO 23529.

Operate the machine as described in ISO 4587:2003.

Record the highest force during rupture as the breaking force for that specimen.

NOTE The speed resulting from the values in ISO 4587:2003 is equivalent to about 0,8 mm/min.

10.25.5 Pass criteria

The PV module design shall be judged to have successfully passed the lap shear strength test if the loss in arithmetic mean M (for all 10 samples) of the breaking force for the respective interface before and after weathering is less than 50 %. The difference is determined by comparing the results of the two batches of samples tested.

$$0,5 < \frac{\sum_{i=1}^{10} M2}{\sum_{i=1}^{10} M1}$$

NOTE The lap shear strength, in MPa, is calculated by dividing the breaking force, in newton, by the shear area, in square millimetres.

In case of the rigid part breaking apart from the interfaces of investigation a thicker or stronger glass shall be used. A suitable support for the glass may also be sufficient.

10.26 Materials creep test MST 37

10.26.1 Purpose

The purpose of the material creep test is to validate that the materials used in the PV module will not show creep or lose adhesion when operated at the highest temperatures that PV modules normally experience in the field. In particular the test shall determine possible creep between the following interfaces:

- frontsheet to backsheet;
- frontsheet or backsheet to directly attached mounting system (e.g. back rail);
- junction box to backsheet respectively frontsheet.

This test is not required to be performed if creep at all interfaces is prevented by mechanical mounting means not relying on adhesion alone.

10.26.2 Apparatus

- a) A climatic chamber with automatic temperature control with means for circulating the air inside capable of subjecting one or more PV modules to the conditions specified in 10.26.3.
- b) Means for mounting or supporting the PV module in the chamber, so as to allow free circulation of the surrounding air.
- c) Means for measuring and recording the temperature of the PV module to an accuracy of $\pm 1\text{ }^{\circ}\text{C}$.

10.26.3 Procedure

- a) Attach a suitable temperature sensor to the front or back surface of the PV module near the middle.
- b) Install the PV module at room temperature in the climatic chamber using the worst case mounting method described in the installation manual. Each PV module is to be mounted at the maximum angle permissible as per the installation manual; if no maximum is given the PV module is to be mounted vertically in the test chamber.
- c) After closing the chamber, subject the PV module to $105\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$, no extra humidity shall be induced to the chamber. If the module type under assessment is designed for use in only open rack configurations the temperature is $90\text{ }^{\circ}\text{C} \pm 3\text{ }^{\circ}\text{C}$ instead.
- d) Throughout the test record the PV module temperature. Maintain the PV module at the specified temperature for 200 h.

10.26.4 Final measurements

After allowing the PV module to reach room temperature, repeat tests MST 01, MST 11, MST 13, MST 16, and MST 17.

10.26.5 Pass criteria

Additionally to the pass criteria in the tests listed under 10.26.4 the following criteria shall be met:

Meet the creepage and clearance distances as specified in either Table 3 or Table 4 of IEC 61730-1:2016 depending on the PV module Class according to IEC 61140.

10.27 Robustness of terminations test MST 42

This test is equivalent to MQT 14.1 and MQT 14.2 in IEC 61215-2 and shall be performed subsequently. MQT 14.2 shall also be performed for junction boxes compliant to IEC 62790 as required by IEC 61730-1.

MQT 15 can be omitted.

10.28 Thermal cycling test MST 51

This test is equivalent to MQT 11 in IEC 61215-2. Technology specific variations of the test are to be found in the sub-parts IEC 61215-1-x (x is 1 to 4). Figure 1 shows which version (50 cycles or 200 cycles) is to be applied with the samples.

MQT 15 can be omitted.

10.29 Humidity freeze test MST 52

This test is equivalent to MQT 12 in IEC 61215-2.

MQT 15 can be omitted.

10.30 Damp heat test MST 53

This test is equivalent to MQT 13 in IEC 61215-2. In this standard two versions of the test are applied. One with the standard duration as described in IEC 61215-2 (1 000 h) and one with a reduced duration of 200 h. The applicable test version is defined in Figure 1.

MQT 15 can be omitted.

10.31 UV test MST 54

This test is equivalent to MQT 10 in IEC 61215-2 except that in this standard two different UV doses are applied. One with the standard UV dose as described in IEC 61215-2 and one with an increased dose equal to four times the IEC 61215-2 dose that is applied twice during sequence B. 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. By doing so, the front side and back side of the PV module will be exposed to the same UV dose. The applicable UV dose of MST 54 to be applied is defined in Figure 1.

MQT 15 can be omitted.

10.32 Cold conditioning MST 55

10.32.1 Purpose

The purpose of this test is to evaluate a PV module for applicability of Pollution Degree PD=1. The test and the test sequence are in accordance to IEC 61010-1 and adapted to be applicable for PV modules.

10.32.2 Apparatus

The test shall be performed in a climatic chamber capable to fulfil requirements of test procedure. The climatic chamber shall fulfil requirements of IEC 60068-3-5.

10.32.3 Procedure

Cold conditioning shall be performed as defined in IEC 60068-2-1, procedure Ab.

- a) Attach a suitable temperature sensor to the front or back surface of the PV module near the middle.
- b) Place the PV module in the climatic chamber.
- c) After closing the chamber, subject the PV module to $-40\text{ °C} \pm 3\text{ °C}$ for 48 h.

NOTE Temperature tolerances are taken from IEC 60068-2-1, 6.2.

10.32.4 Pass criteria

The pass criteria are as follows:

- a) No evidence of major visual defects as defined in MST 01.
- b) MST 16 shall meet the same requirements as for the initial measurements.

10.33 Dry heat conditioning MST 56

10.33.1 Purpose

The purpose of this test is to evaluate a PV module for applicability of Pollution Degree PD = 1. The test and the test sequence are in accordance to IEC 61010-1 and adapted to be applicable for PV modules.

10.33.2 Apparatus

The test shall be performed in a climatic chamber capable to fulfil requirements of test procedure. The climatic chamber shall fulfil requirements of IEC 60068-3-5.

10.33.3 Procedure

Dry heat conditioning shall be performed as defined in IEC 60068-2-2, procedure Ab.

- a) Attach a suitable temperature sensor to the front or back surface of the PV module near the middle.
- b) Place the PV module in the climatic chamber.
- c) After closing the chamber, subject the PV module to $105\text{ °C} \pm 5\text{ °C}$ less than 50 % relative humidity for 200 h. If the PV module type under assessment is designed for use in only open rack configurations the temperature is $90\text{ °C} \pm 3\text{ °C}$ instead.

NOTE Temperature tolerances are taken from IEC 60068-2-2, 6.2.

10.33.4 Pass criteria

The pass criteria are as follows:

- a) No evidence of major visual defects as defined in MST 01.
- b) MST 16 shall meet the same requirements as for the initial measurements.

Annex A (informative)

Recommendations for testing of PV modules from production

A.1 General

This Annex provides guidance how to verify that the production PV modules continue to meet the minimum safety requirements of this standard. Where applicable time based production line measurements may be performed. The tests are to be understood as recommendations and can be replaced by other test procedures that can be expected to yield the same information.

Provisions shall be taken to capture an error of the indication device due to malfunction of the device.

These recommendations can be used to harmonise factory surveillance practices regarding production line measurements.

The information from production line tests may be required within factory surveillance work of certification bodies.

A.2 Module output power

It is recommended that electrical output power is verified on the final wiring configuration on a 100 % basis. Results from I-V curve measurements can also be used to verify that the current and voltage rating falls within the specification. All production values of I_{sc} and V_{oc} shall be covered by the tolerances of the product qualified under IEC 61730. Possible stabilisation effects shall be considered if changes of I_{sc} and V_{oc} are expected during operation in sunlight. This test will also verify that bypass diodes are not shorted.

A.3 Wet insulation test

This test verifies that the insulation properties of outer surfaces of the production PV modules meet the electrical safety requirements of this standard.

The test is conducted in accordance with MST 17 and performed at a sampling rate of at least 1 PV module per laminator per working shift. Test samples shall be put aside until all sealants have set (take into account curing times) and then tested in a batch later.

The sampling rate may be increased or lowered depending on the measurement results.

The test voltage is based on the definition of test MST 17 including a factor Y .

$$U_{TEST} = U_{SYS} \times Y$$

$Y = 1$ is used for a minimum test duration of 1 min. $Y = 1,2$ is used for a minimum test duration of 5 s. Ramp-up time for test voltage is chosen such that no time induced breakdown will occur. During the test no breakdown of test voltage shall occur.

The temperature range of the water is 15 °C to 45 °C. The leakage current shall be corrected to 25 °C using a demonstrated correction factor for the PV module, to be determined for each PV module type.

For frameless PV module designs, a 100 % sampling rate is recommended (e.g. to filter production line breakage failures prior to boxing) as part of final tests on module prior to labelling.

For PV modules with cemented joints 100 % sampling rate is recommended. U_{Test} shall be increased by a factor of 1,35 additionally as required by IEC 61730-1:2016, 5.6.3.4.

A.4 Visual inspection

Visual inspection is performed on a 100 % basis aiming to verify that clearance distances (distances of live parts to PV module edges) are within the product specification. It is recommended to do this inspection before the framing process if applicable.

Special care shall be taken if cemented joints are used for insulation. PV modules utilizing cemented joints shall be inspected along all edges and areas with cemented joints on a 100 % basis aimed to verifying the cemented joint spacing visual inspection criteria as defined in 10.2.3 c) are met.

A.5 Bypass diodes

The verification that bypass diodes are working properly is performed on 100 % sampling rate.

Three alternative test methods can be applied:

- a) Perform successive additional I-V measurements in conjunction with maximum power determination with one cell of each string in the interconnection circuit completely shaded. The bypass diode belonging to this string is working properly, if the characteristic bend in the I-V curve is observed.
- b) A conductivity test can be performed with the PV module terminals connected in reverse polarity to a current source. The current flow and voltage drop across the PV module terminals can be used as indicator that the diodes are working properly.
- c) The I-V characteristics of all diodes can be verified just before their assembly. If the bypass diodes are in the junction box this could be done through measurement at the corresponding terminals of the junction box. A precondition for the latter method is an appropriate plan to mitigate possible influence of electrostatic discharges on the diodes in production.

NOTE Bypass diode verification procedures might be MQT 18.2 from IEC 61215-2 and IEC TS 62916.

A.6 Continuity test of equipotential bonding

PV modules provided with a connection for equipotential bonding are subjected to a continuity test for equipotential bonding (MST 13). At a sampling rate of 1 PV module per framing station per working shift demonstrate the electrical continuity between the grounding connection and all accessible conductive parts. Any appropriate indication device may be employed (current supply in conjunction with current and voltage measurement).

PV modules that have no frames or equipotential bonding locations identified shall be exempt from this requirement.

Annex B (~~normative~~ informative)

Fire tests, spread-of-flame and burning-brand tests for PV modules

~~A.1~~ General

~~The fire resistance test of this document is a basic test. For PV modules integrated in buildings, in general, national regulations and requirements shall be fulfilled. If such requirements are not available, the following international standards give information for tests, which could be used:~~

~~ISO 834-1, Fire resistance tests — Elements of building construction — Part 1: General requirements~~

~~ISO 834-3, Fire resistance tests — Elements of building construction — Part 3: Commentary on test method and test data application~~

~~ISO 5657, Reaction to fire tests — Ignitability of building products using a radiant heat source~~

~~The proposed tests described below are derived from ANSI/UL 790.~~

~~All dimensions are approximate.~~

~~A.2~~ Test apparatus and set-up

~~A.2.1 As illustrated in Figure A.1, the apparatus used for the tests described in this Clause is to consist of the following:~~

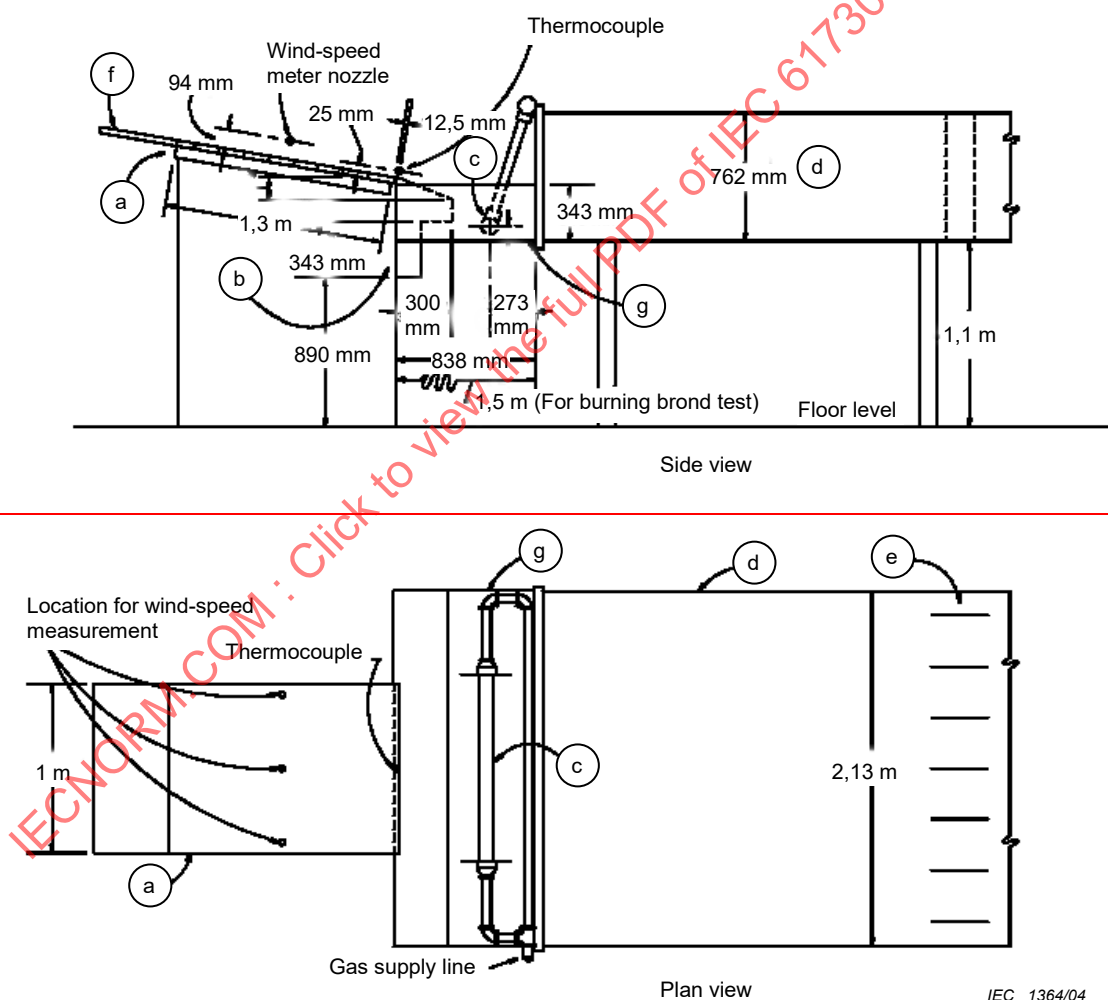
- ~~a) A test deck to which the materials to be tested are applied, mounted on a frame. The pitch of the frame is to be adjustable.~~
- ~~b) A construction of non-combustible boards, mounted on the front of the frame to simulate eaves and cornices.~~
- ~~c) A gas burner (for intermittent flame, spread-of flame, and flying brand tests) consisting of a 1,12 m length of nominal 50 mm (60,3 mm OD) pipe having a 12,7 mm wide, 910 mm long slot in the side toward the test deck. The burner is to be supplied with gas at both ends through nominal 25 mm (33,4 mm OD) pipe to provide uniform gas pressure at the burner assembly.~~
- ~~d) A blower and air duct for providing the required wind conditions. The air introduced by the blower is to be taken from outside the test room.~~
- ~~e) Adjustable fins mounted inside the air duct to straighten the air stream and reduce turbulence.~~
- ~~f) A baffle mounted on the back edge of the test deck to prevent backfiring under the deck.~~
- ~~g) Non-combustible boards extending from the sides and bottom of the air duct to the simulated eaves and cornice construction mentioned in b) (not used during burning brand test).~~

~~A.2.2 The tests shall be conducted in a room vented to the outside air to relieve the air pressure created by the blower. During these tests, all doors and windows in the room are to be closed, and the room otherwise controlled as necessary to prevent outside wind and weather conditions from affecting the test results. Tests shall not be conducted if the room temperature is less than 10 °C or more than 32 °C.~~

~~A.2.3 For these tests, mortar (cement mix, lime, and water) shall be troweled into the joint formed by the leading edge of the roof covering material and the framework of the carriage, to prevent air or the test flame from travelling under the material being tested.~~

~~A.2.4 During the tests, the test decks shall be subjected to an air current that flows uniformly over the top surface of the roof covering material, as determined by a pre-test calibration of the equipment using a bare 1 m by 1,3 m plywood deck. At points mid way up the slope of the bare deck, with the deck positioned at an incline of 127 mm of rise to 300 mm of horizontal run, the velocity of the air current is to be $(19 \pm 0,8)$ km/h, as measured at the centre and at each of two locations measured 76 mm from each edge of the deck, with each measurement being 94 mm above the surface of the deck. Any direct reading instrument with scale graduated in increments of not more than 6 m/min or any timed instrument with scale graduated (for a 1 min timed reading) in increments of not more than 1,5 m/min is acceptable.~~

~~A.2.5 For these tests, the test decks shall be at an incline of 127 mm per 300 mm; except that built-up roof coverings are to be tested at the maximum incline recommended by the manufacturer, but not more than 127 mm to 300 mm.~~



~~The letters in the Figure correspond to the list in A.2.1.~~

Figure A.1 – Test apparatus for fire test

A.3 — Spread-of-flame test

A.3.1 A test sample is to be mounted, and luminous gas flame applied, as described in 6.1 of ANSI/UL 790. The test is to be conducted with the module or panel oriented with respect to the test flame, such that the flame impinges only on the top surface of the module or panel.

A.3.2 The sample area of the test material should be no less than 1 m in width for all classes, 1,82 m minimum length for fire safety class A, 2,4 m minimum length for fire safety class B, or 3,9 m minimum length for fire safety class C, as measured from the leading edge of the sample.

A.3.3 For a fire safety class A or B test, the gas flame is to be applied continuously for 10 min or until the spread of flame (flaming of the material being tested) permanently recedes from a point of maximum spread, whichever is the shorter duration. For a fire safety class C test, the gas flame is to be applied for 4 min and then removed.

A.3.4 During and after the application of the test flame, the test sample is to be observed for the distance to which flaming of the material has spread, production of flaming or glowing brands, and displacement of portions of the test sample. The observation is to continue until the flame has permanently receded from a point of maximum spread.

A.4 — Burning brand test

A.4.1 — General

A test deck is to be mounted as described in 6.1 of ANSI/UL 790, except that the framework is to be 1,5 m from the air duct outlet (see Figure A.1), and the gas piping and burner are to be removed so as not to obstruct the air flow.

A.4.2 — Size and construction of brands

A.4.2.1 The brands to be used in these tests are to be as shown in Figure A.2 and are to be constructed as specified in A.4.2.2 to A.4.2.4. Prior to the test, the brands are to be conditioned in an oven at 40 °C to 49 °C for at least 24 h.

A.4.2.2 The fire safety class A brand is to consist of a grid, 300 mm square and approximately 57 mm thick, made of kiln-dried Douglas fir pine lumber that is free from knots and pitch pockets. The brand is to be made of 36 strips of lumber each 19,1 mm by 19,1 mm by 300 mm long, placed in 3 layers of 12 strips each, with strips placed 6,4 mm apart. These strips are to be placed at right angles to those in adjoining layers and are to be nailed, using 38,1 mm long (No. 16 gage) nails, or stapled, using No. 16 gage steel wire staples having a 5,6 mm crown and 31,8 mm legs, at each end of each strip on one face, and in a diagonal pattern, as shown in Figure A.2, on the other face. The dry weight of the finished brand is to be $(2\,000 \pm 150)$ g at the time of the test.

A.4.2.3 The fire safety class B brand is to consist of a grid, 150 mm square and approximately 57 mm thick, made of kiln-dried Douglas fir lumber that is free from knots and pitch pockets. The brand is to be made of 18 strips of lumber 19,1 mm by 19,1 mm and 150 mm long, placed in 3 layers of 6 strips each, with strips spaced 6,4 mm apart. The strips are to be placed at right angles to those in adjoining layers and are to be nailed, using 38,1 mm long (No. 16 gage) nails, or stapled, using No. 16 gage steel wire staples having a 5,6 mm crown and 31,8 mm legs, at each end of each strip on one face, as shown in Figure A.2, and in a diagonal pattern on the other face. The dry weight of the finished brand is to be (500 ± 50) g at the time of the test.

A.4.2.4 The fire safety class C brand is to consist of a piece of kiln-dried non-resinous white pine lumber that is free from knots and pitch pockets. The brand is to measure 38,1 mm by 38,1 mm by 19,8 mm, and a saw cut groove (kerf) 3,2 mm wide is to be cut across the centre of both the top and bottom faces to a depth of one half the thickness of the brand, and at right

~~angles to each other. The dry weight of the finished brand is to be $(9,25 \pm 1,25)$ g at the time of the test.~~

~~A.4.3 Ignition of brands~~

~~**A.4.3.1** Before application to the test deck, the brands are to be ignited so as to burn freely in still air, as described in A.4.3.2, A.4.3.3 or A.4.3.4, as applicable. The flame of the gas burner used to ignite the brands is to essentially envelop the brands during the process of ignition. The temperature of the igniting flame is to be (888 ± 10) °C, measured 58,7 mm above the top of the burner. The burner is to be shielded from drafts.~~

~~**A.4.3.2** Fire safety class A brands are to be exposed to the flame for 5 min, during which time they are to be rotated to present each surface to the flame as follows:~~

- ~~a) each (300 by 300) mm face for 30 s,~~
- ~~b) each (57 by 300) mm face for 45 s,~~
- ~~c) each (300 by 300) mm face again for 30 s.~~

~~**A.4.3.3** Fire safety class B brands are to be exposed to the flame for 4 min, during which time they are to be rotated to present each surface to the flame as follows:~~

- ~~a) each (150 by 150) mm face for 30 s,~~
- ~~b) each (7 by 150) mm face for 30 s,~~
- ~~c) each (150 by 150) mm face again for 30 s.~~

~~**A.4.3.4** Fire safety class C brands are to be exposed to the flame for 2 min, during which time they are to be rotated so as to present each of the 38 mm by 38 mm faces to the flame for 1 min.~~

~~A.4.4 Test conditions~~

~~A.4.4.1 Fire safety class A test~~

~~**A.4.4.1.1** A brand is to be placed on the surface of each test deck at the most vulnerable location (point of minimum coverage over deck joint) with respect to ignition of the deck, but in no case closer than 100 mm from either side or 300 mm from the top or bottom edge of the test sample. The brand is to be placed so that the strips in both the upper and lower layers are parallel to the direction of air flow. The brand is to be secured to the deck by a soft iron wire.~~

~~**A.4.4.1.2** The brand shall be placed so that it is centered on the test sample, or in the location where the test sample is most vulnerable to ignition.~~

~~A.4.4.2 Fire safety class B test~~

~~A brand is to be placed on the surface of the test sample at each of the two most vulnerable locations with respect to ignition of the sample (see 8.4.2.2 of ANSI/UL 790). Each brand is to be positioned with its upper edge no closer than 152 mm from each side or 300 mm from the top or bottom edge of the sample. The brands are to be placed so that the strips in both the upper and lower layers are parallel to the direction of air flow. They are to be secured to the deck by a soft iron wire (No. 18 B&S gage (0,82 mm)). The second brand is not to be applied until all burning resulting from the first brand has ceased.~~

~~A.4.4.3 Fire safety class C test~~

~~Twenty ignited brands are to be placed on each treated wood shingles deck at 1 min or 2 min intervals. No brand is to be placed closer than 100 mm to the point where a previous brand was located. See 8.4.3.2 (ANSI/UL 790) for securing of brands in place and relative positioning of brand saw kerfs.~~

A.4.5 Duration of test

Each individual test, whether fire safety class A, B, or C, is to be continued until the brand is consumed and until all evidence of flame, glow, and smoke has disappeared from both the exposed surface of the material being tested and the underside of the test deck, or until unacceptable results occur, but not for more than 1,5 h for a fire safety class A or B test. The results of tests in which the brands do not show progressive and substantially complete consumption after application to the test sample shall be disregarded.

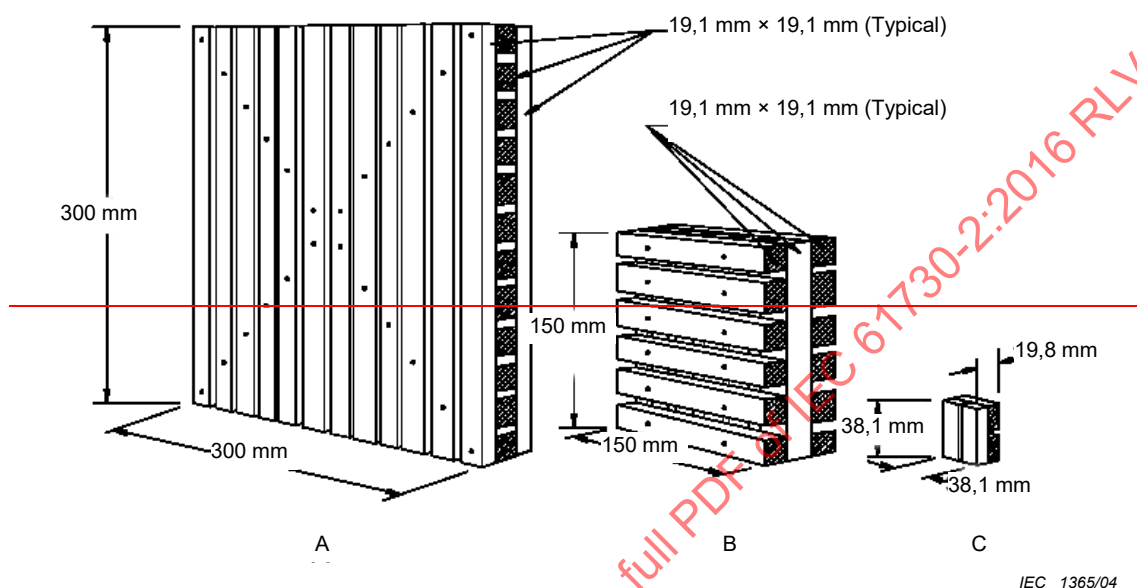


Figure A.2 Burning brand construction

A.5 Observations

During the tests, observations shall be made for the appearance of sustained flaming on the underside of the test deck, production of flaming or glowing brands of roof covering material, displacement of the test sample, and the exposure or falling away of portions of the roof deck.

A.6 Conditions of acceptance

At no time during the spread of flame or burning brand tests shall:

- Any portion of the module or panel be blown off or fall off the test deck in the form of flaming or glowing brands.
- Portions of the roof deck, or portions of a module or panel intended for installation integral with or forming a part of the building roof structure, fall away in the form of glowing particles.
- The flame spread beyond 1,82 m for fire safety class A, 2,4 m for fire safety class B, or 3,9 m for fire safety class C rating. The flame spread is to be measured from the leading edge of the sample.
- There be significant lateral spread of flame from the path directly exposed to the test flame. Spread of flame includes flaming on both the top surface (the surface to which the external flame is applied) and in any intermediate channel, such as the space between stand off or integral modules and the roof.

B.1 General

PV modules mounted in or on buildings, in general, shall fulfil national building and construction regulations and requirements. If such requirements are not available, the following international and national standards give information for tests, which could be used:

ISO 834-1, *Fire-resistance tests – Elements of building construction – Part 1: General requirements*

ISO 834-3, *Fire-resistance tests – Elements of building construction – Part 3: Commentary on test method and test data application*

ISO 5657, *Reaction to fire tests – Ignitability of building products using a radiant heat source*

ISO 13501-5:2005, *Fire classification of construction products and building elements – Part 5: Classification using data from external fire exposure to roofs tests*

ENV 1187-1 through -4, *Test methods for roof coverings under the influence of a thermal attack of burning brands and radiant heat*

ANSI/UL 790: *Standard Test Methods for Fire Tests of Roof Coverings*

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

B.2 Fire test for PV modules based on ENV 1187

B.2.1 General

The ENV 1187 fire test methods, parts 1 to 4, differ in terms of radiant heat, the used brands, additional air flow (wind simulation), tilt angles, amount and size of the demanded test specimen. The pass criteria for each test method are described in ISO 13501-5.

In general building integrated PV systems shall be tested in conjunction with a defined mounting system following the installation instruction of the PV module manufacturer. When testing PV modules, the mounting material and the joints between PV modules as well as sealing materials have to be considered and included in the test set-up.

The test sample requirements for the test method based on ENV 1187-1 (classification B_{ROOF} (t1)) are described below to provide an example.

B.2.2 External fire exposure to roofs

Part 1: Methods of test simulating exposure to burning brands, without wind or supplementary radiant heat.

The test can be performed for either one or both roof tilt angle ranges of 0° to 45° at 15° and for roof tilt ranges of 45° to 90° at 45°.

Requirements per roof pitch:

- A realistic roof construction including cross beams and all attachment parts with the PV modules installed the same as in a final system installation shall be provided by the PV module manufacturer.
- The minimum size for a test deck is 0,8 m × 1,8 m. Since it is also necessary to test transverse and vertical joints, several samples may be required to build up the complete test deck.

Figure B.1 shows an example test set-up for the fire test following ENV 1187-1.

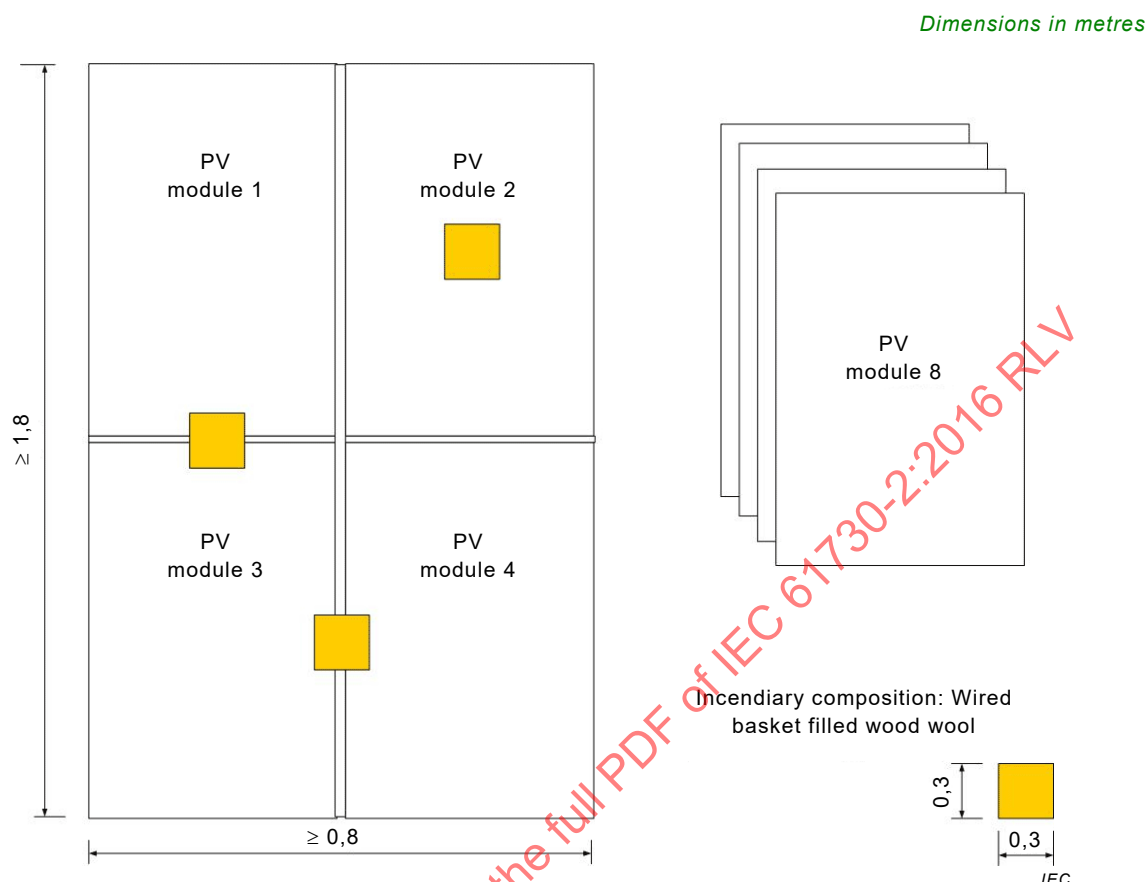


Figure B.1 – Example of test set-up for fire test

- Four PV modules are required for each test (if different pitch angles have to be considered, the amount of samples increases accordingly). One vertical and one horizontal joint on top of the roof and two centric applied incendiary compositions on one PV module are tested. Thereby fire passing and the influences of a possible lower functional layer as for example thermal insulation and sealing are tested.
- For building integrated PV modules the procedure of the positioning of the incendiary compositions shall be according to the above defined instructions for all ENV 1187 test methods.
- For building added PV modules the fire test can be limited to only one PV module and a centred brand, as long as there are no polymeric material used at interconnections (joints), mounting or frame parts.

B.2.3 Classification according to ISO 13501-5

Classification criteria:

- External and internal fire spread up to $< 0,7$ m.
- External and internal fire spread down to $< 0,6$ m.
- Maximum burned external and internal length $< 0,8$ m.
- No burning material as flaming droplet and debris material of the fire exposed area.
- No burning or glowing pieces which pierce the roof construction.
- No openings (due to burning through) > 25 mm².
- Total amount of all openings due to burning through $< 4\,500$ mm².

- Sideward fire spread does not reach the border of the test area.
- No internal glowing.
- Maximum radius of fire spread on “horizontal” roofs, external and internal < 0,2 m.

B.3 Fire test for PV modules based on ANSI/UL 1703

Fire resistance of PV modules installed on or over building rooftops has been proven to depend on more than just PV module flammability characteristics. In fact, fire resistance of PV modules is highly dependent on the combination and configuration of roofing materials, rack mounting systems, and the PV modules as a system. As a result of these findings, the PV system fire tests were developed to establish fire resistance classifications for PV systems consistent with the fire classification of roofing materials.

To reduce the number of tests required to cover every possible combination of PV modules with PV racking systems and roofing materials two new concepts were introduced:

- a) Optional PV module typing that groups PV modules with similar constructions, flame spread characteristics and burning brand characteristics. This allows replacement of a PV module of a particular type with any PV module of the same type without affecting the PV system fire rating.
- b) Use of common roofing materials for the test that meet specific performance requirements to represent all roofing materials. One set of roofing material construction and performance requirements has been established for steep-slope roof applications and another for low-slope roof applications.

PV system fire performance construction and PV module type requirements are detailed in ANSI/UL 1703:2015, section 16. Test methods for PV system fire performance classifications are specified in ANSI/UL 1703:2015, section 31.

PV modules intended to be integrated into a building structure (BIPV modules) are evaluated for fire classifications as roofing materials under UL 790 requirements as specified in ANSI/UL 1703:2015, section 16.

To assess basic fire propagation behavior of PV modules not considering its mounting system ANSI/UL 1703:2015, section 31.1.2 and section 31.1.3 can be used.

Bibliography

~~IEC 60068-2-21:1999, Environmental testing — Part 2-21: Tests — Test U: Robustness of terminations and integral mounting devices~~

~~IEC 60364-1:2001, Electrical installations of buildings — Part 1: Fundamental principles, assessment of general characteristics, definitions~~

~~IEC 60529:1989, Degrees of protection provided by enclosures (IP Code)~~

~~IEC 61345:1998, UV test for photovoltaic (PV) modules~~

~~IEC 61721:1995, Susceptibility of a photovoltaic (PV) module to accidental impact damage (resistance to impact test)~~

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INTERNATIONAL STANDARD

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

**Qualification pour la sûreté de fonctionnement des modules photovoltaïques
(PV) –
Partie 2: Exigences pour les essais**

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CONTENTS

FOREWORD.....	6
1 Scope.....	8
2 Normative references	8
3 Terms and definitions	10
4 Test categories.....	10
4.1 General.....	10
4.2 Environmental stress tests	10
4.3 General inspection	10
4.4 Electrical shock hazard tests	11
4.5 Fire hazard tests	11
4.6 Mechanical stress tests	11
5 Classes and their necessary test procedures.....	12
6 Sampling	14
7 Test report	14
8 Testing	15
9 Pass criteria	17
10 Test procedures	17
10.1 General.....	17
10.2 Visual inspection MST 01	17
10.2.1 Purpose	17
10.2.2 Procedure.....	17
10.2.3 Pass criteria.....	17
10.3 Performance at STC MST 02	19
10.3.1 Purpose	19
10.3.2 Procedure.....	19
10.3.3 Pass criteria.....	19
10.4 Maximum power determination MST 03	19
10.4.1 Purpose.....	19
10.4.2 Procedure.....	19
10.4.3 Pass criteria.....	19
10.5 Insulation thickness test MST 04	19
10.5.1 Purpose	19
10.5.2 Procedure.....	20
10.5.3 Pass criteria.....	20
10.6 Durability of markings MST 05.....	20
10.7 Sharp edge test MST 06.....	20
10.8 Bypass diode functionality test MST 07.....	21
10.9 Accessibility test MST 11.....	21
10.9.1 Purpose	21
10.9.2 Apparatus	21
10.9.3 Procedure.....	21
10.9.4 Final measurements.....	21
10.9.5 Pass criteria.....	21
10.10 Cut susceptibility test MST 12	21
10.10.1 Purpose	21
10.10.2 Apparatus	22

10.10.3	Procedure	22
10.10.4	Final measurements	22
10.10.5	Pass criteria	22
10.11	Continuity test of equipotential bonding MST 13	23
10.11.1	Purpose	23
10.11.2	Apparatus	23
10.11.3	Procedure	24
10.11.4	Final measurements	24
10.11.5	Pass criteria	24
10.12	Impulse voltage test MST 14	24
10.12.1	Purpose	24
10.12.2	Apparatus	24
10.12.3	Procedure	25
10.12.4	Final measurement	26
10.12.5	Pass criteria	26
10.13	Insulation test MST 16	26
10.13.1	Purpose	26
10.13.2	Procedure	26
10.13.3	Pass criteria	26
10.14	Wet leakage current test MST 17	26
10.15	Temperature test MST 21	27
10.15.1	Purpose	27
10.15.2	Outdoor method	27
10.15.3	Solar simulator method	28
10.15.4	Pass criteria	30
10.16	Hot-spot endurance test MST 22	30
10.17	Fire test MST 23	30
10.17.1	Purpose	30
10.18	Ignitability test MST 24	31
10.18.1	Purpose	31
10.18.2	Apparatus	31
10.18.3	Test specimen	32
10.18.4	Conditioning	32
10.18.5	Procedure	32
10.18.6	Duration of test	33
10.18.7	Observations	33
10.18.8	Pass criteria	33
10.19	Bypass diode thermal test MST 25	34
10.20	Reverse current overload test MST 26	34
10.20.1	Purpose	34
10.20.2	Procedure	34
10.20.3	Pass criteria	34
10.21	Module breakage test MST 32	35
10.21.1	Purpose	35
10.21.2	Apparatus	35
10.21.3	Procedure	35
10.21.4	Pass criteria	35
10.22	Screw connections test MST 33	38
10.22.1	Test for general screw connections MST 33a	38

10.22.2	Test for locking screws MST 33b	40
10.23	Static mechanical load test MST 34	40
10.24	Peel test MST 35	40
10.24.1	Purpose	40
10.24.2	Sample requirements	40
10.24.3	Apparatus	41
10.24.4	Procedure	41
10.24.5	Pass criteria	44
10.25	Lap shear strength test MST 36	44
10.25.1	Purpose	44
10.25.2	Test samples	44
10.25.3	Apparatus	45
10.25.4	Procedure	45
10.25.5	Pass criteria	46
10.26	Materials creep test MST 37	47
10.26.1	Purpose	47
10.26.2	Apparatus	47
10.26.3	Procedure	47
10.26.4	Final measurements	47
10.26.5	Pass criteria	47
10.27	Robustness of terminations test MST 42	47
10.28	Thermal cycling test MST 51	48
10.29	Humidity freeze test MST 52	48
10.30	Damp heat test MST 53	48
10.31	UV test MST 54	48
10.32	Cold conditioning MST 55	48
10.32.1	Purpose	48
10.32.2	Apparatus	48
10.32.3	Procedure	48
10.32.4	Pass criteria	49
10.33	Dry heat conditioning MST 56	49
10.33.1	Purpose	49
10.33.2	Apparatus	49
10.33.3	Procedure	49
10.33.4	Pass criteria	49
Annex A	(informative) Recommendations for testing of PV modules from production	50
A.1	General	50
A.2	Module output power	50
A.3	Wet insulation test	50
A.4	Visual inspection	51
A.5	Bypass diodes	51
A.6	Continuity test of equipotential bonding	51
Annex B	(informative) Fire tests, spread-of-flame and burning-brand tests for PV modules	52
B.1	General	52
B.2	Fire test for PV modules based on ENV 1187	52
B.2.1	General	52
B.2.2	External fire exposure to roofs	52
B.2.3	Classification according to ISO 13501-5	53

B.3 Fire test for PV modules based on ANSI/UL 1703	54
Figure 1 – Test sequences	16
Figure 2 – Assessment of bubbles in edge seals for cemented joints	18
Figure 3 – Cut susceptibility test	23
Figure 4 – Waveform of the impulse voltage following IEC 60060-1	25
Figure 5 – Impactor	36
Figure 6 – Impact test frame 1	37
Figure 7 – Impact test frame 2	38
Figure 8 – Sample preparation of cemented joints ≤ 10 mm using a release sheet	41
Figure 9 – PV module with positions for peel samples on frontsheet or backsheet	42
Figure 10 – Typical peel-off measurement curves	43
Figure 11 – Lap shear test sample for proving cemented joint	45
Figure 12 – Lap-shear test flow	46
Figure B.1 – Example of test set-up for fire test	53
Table 1 – Environmental stress tests	10
Table 2 – General inspection test	10
Table 3 – Electrical shock hazard tests	11
Table 4 – Fire hazard tests	11
Table 5 – Mechanical stress tests	12
Table 6 – Required tests, depending on the Class	13
Table 7 – Torque tests on screws per IEC 60598-1:2014, Table 4.1	39

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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.

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

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 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.

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 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.

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

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 60664-1:2007, *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 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, *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 Z97.1:2009, *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 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 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 other tests are based on or are identical to the module qualification tests MQT 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 10.32.

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 (DH1000)	–	MQT 13
MST 54	UV preconditioning	–	MQT 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	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	–	–

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	–
MST 16	Insulation test	–	MQT 03
MST 17	Wet leakage current test	–	MQT 15
MST 42	Robustness of terminations test	IEC 62790	MQT 14

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*	Fire test	–	National/Local code
MST 24	Ignitability test	ISO 11925-2	–
MST 25	Bypass diode thermal test	–	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	Based on
			IEC 61215-2
MST 32	Module breakage test	ANSI Z97.1	–
MST 33	Screw connection test	IEC 60598-1	–
MST 34	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

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.

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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 DH1000)
X	X	X	MST 54 UV 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	-	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	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. 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 PV modules and one unframed PV module 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 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. 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 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 10.33. 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.

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.

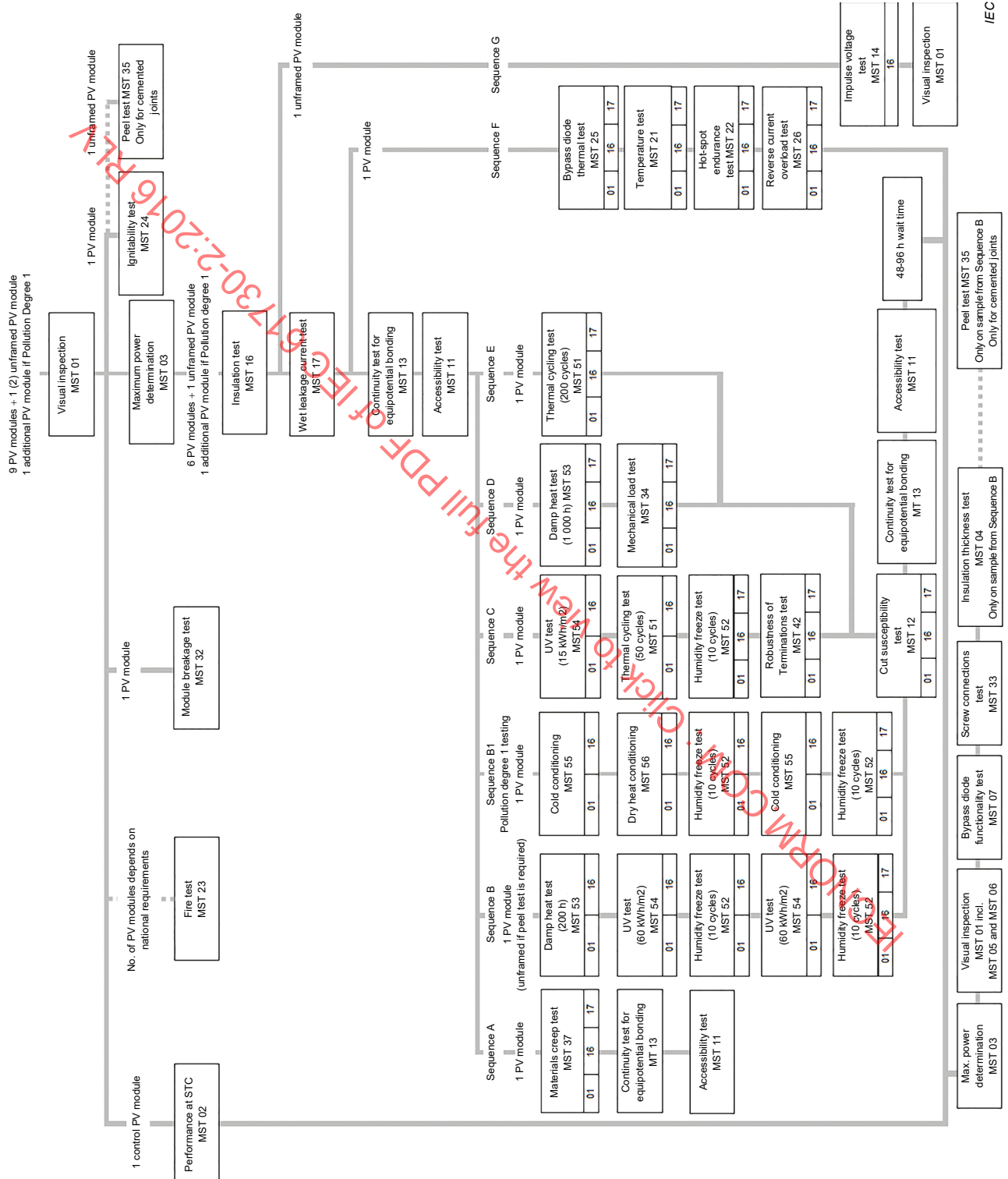


Figure 1 – Test sequences

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

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 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 61730-1:2016 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, 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 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) 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.

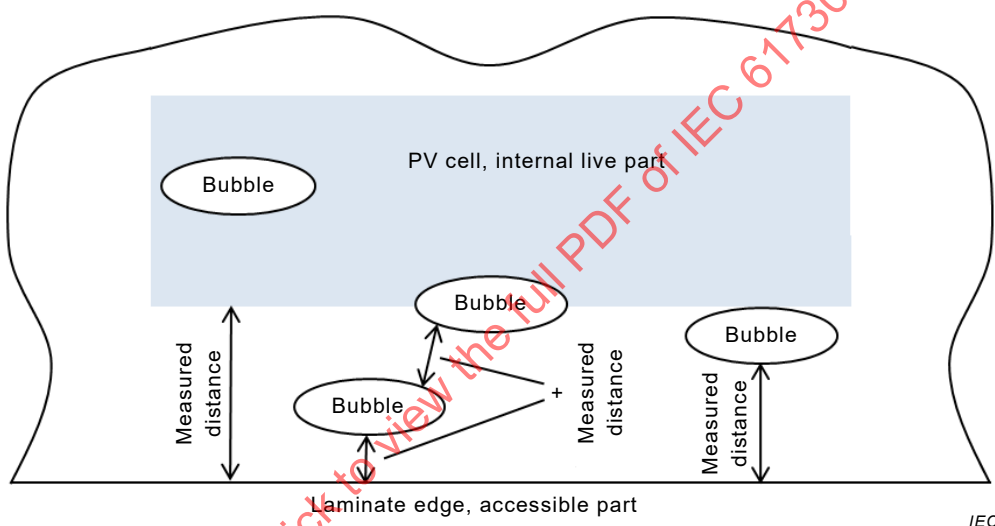


Figure 2a – Example for delamination assessment when measuring creepage or distance through insulation

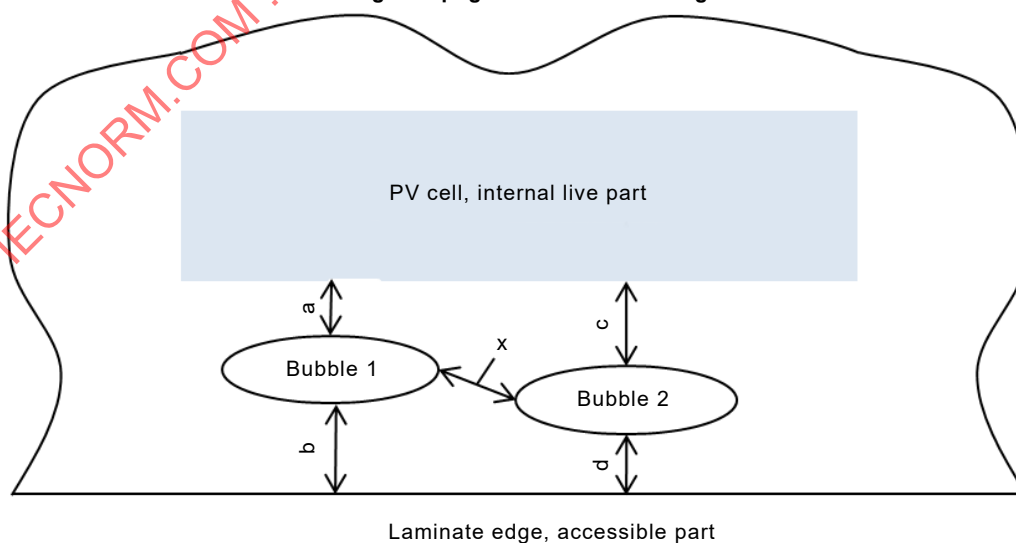


Figure 2b – Example for delamination distance (x) assessment when measuring creepage or distance through insulation

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 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 shall there 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 3, 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 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 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.

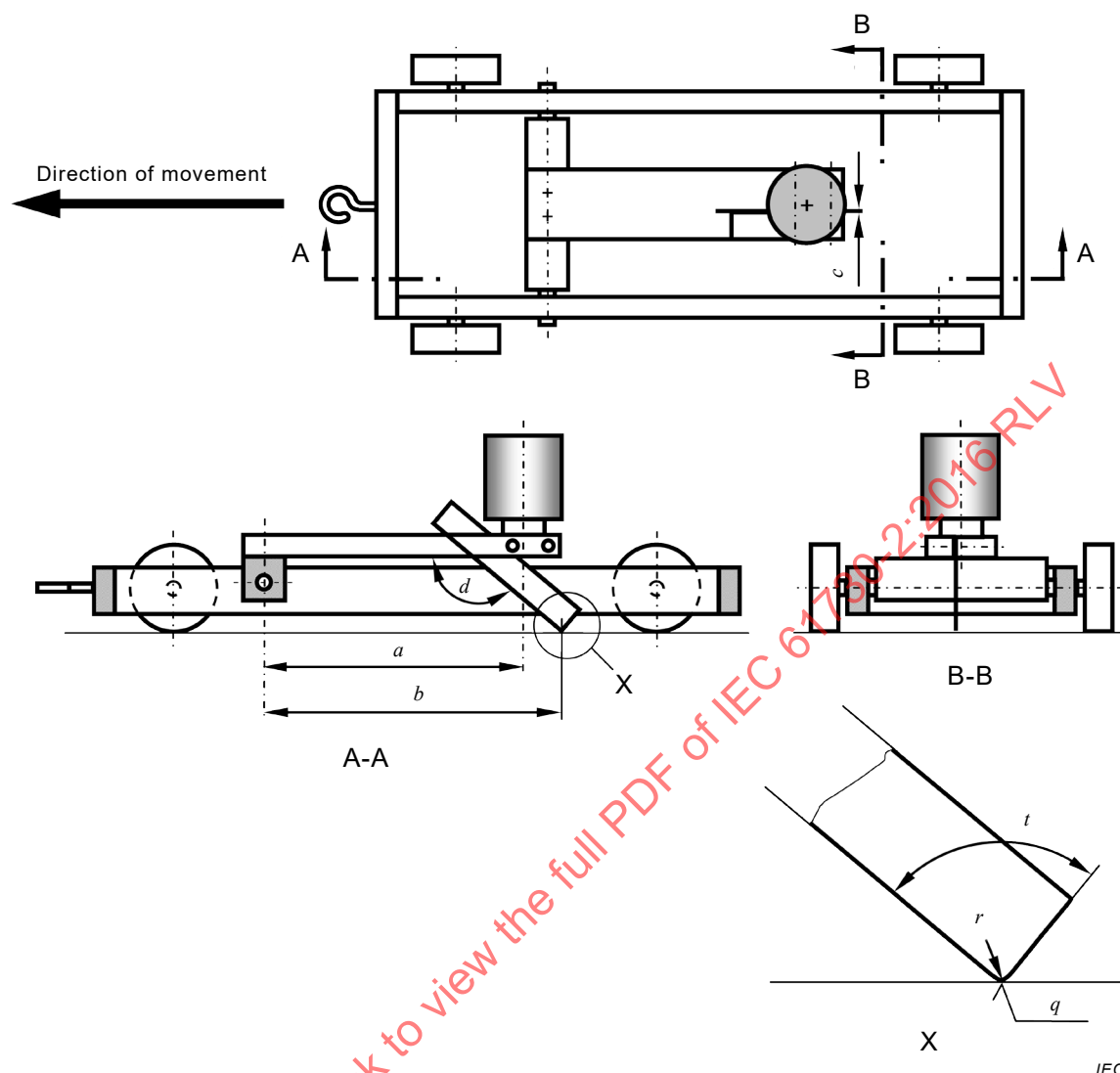
10.10.4 Final measurements

Repeat MST 01, MST 16 and MST 17.

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.

**Key**

- a* 150 mm from axis to center 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 3 – 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).

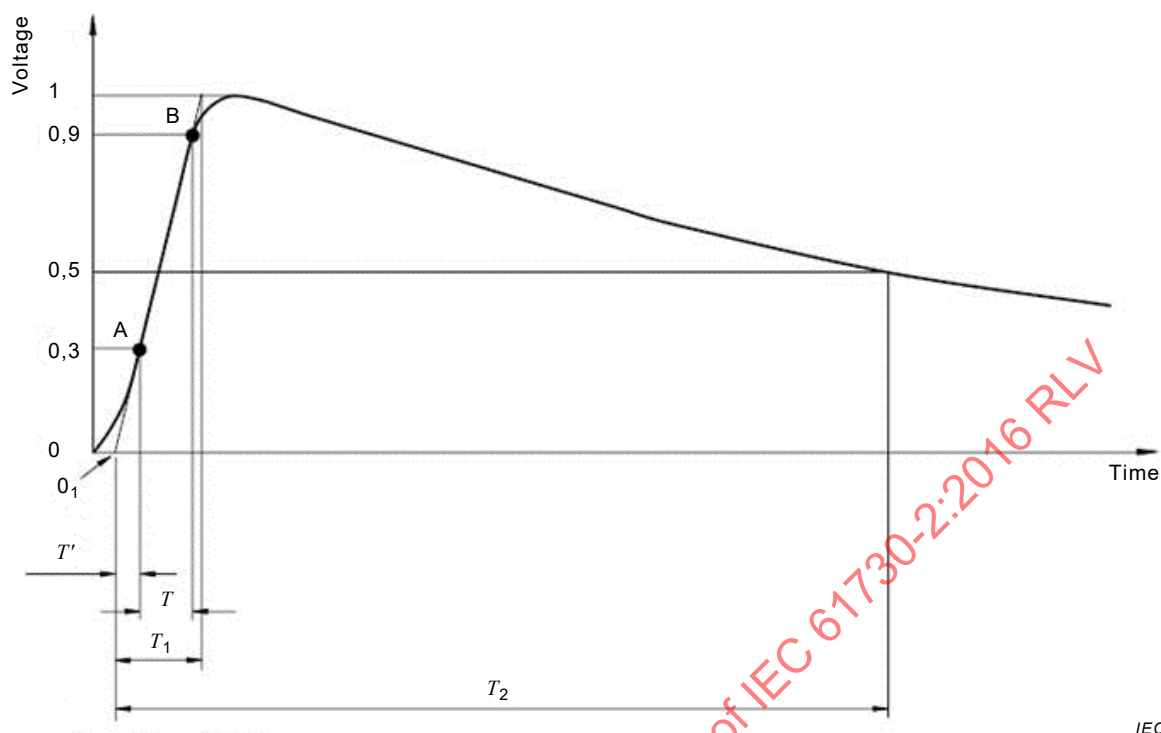
10.12 Impulse voltage test MST 14

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, 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 O_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 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.
- Apply the surge impulse voltage with a waveform as shown in Figure 4 by the impulse voltage generator. 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.

- 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 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: $U_{\text{Test}}(\text{cemented joint}) = U_{\text{Test}} \cdot 1,35$ 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.

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: $U_{\text{Test}}(\text{cemented joint}) = U_{\text{Test}} \cdot 1,35$ 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 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 $0,5 \text{ W/(m}\cdot\text{K)}$ 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 $0,25 \text{ m/s}$ installed approximately $0,7 \text{ m}$ 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 $\pm 2 \text{ K}$.
- 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.

10.15.2.2 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 $20 \text{ }^{\circ}\text{C}$ to $45 \text{ }^{\circ}\text{C}$. The irradiance during the test shall be between 700 W/m^2 and $1\,000 \text{ W/m}^2$.

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:

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

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

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

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

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.

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 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 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).

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 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.

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 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.

d) 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 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.

10.21.2 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 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.

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.

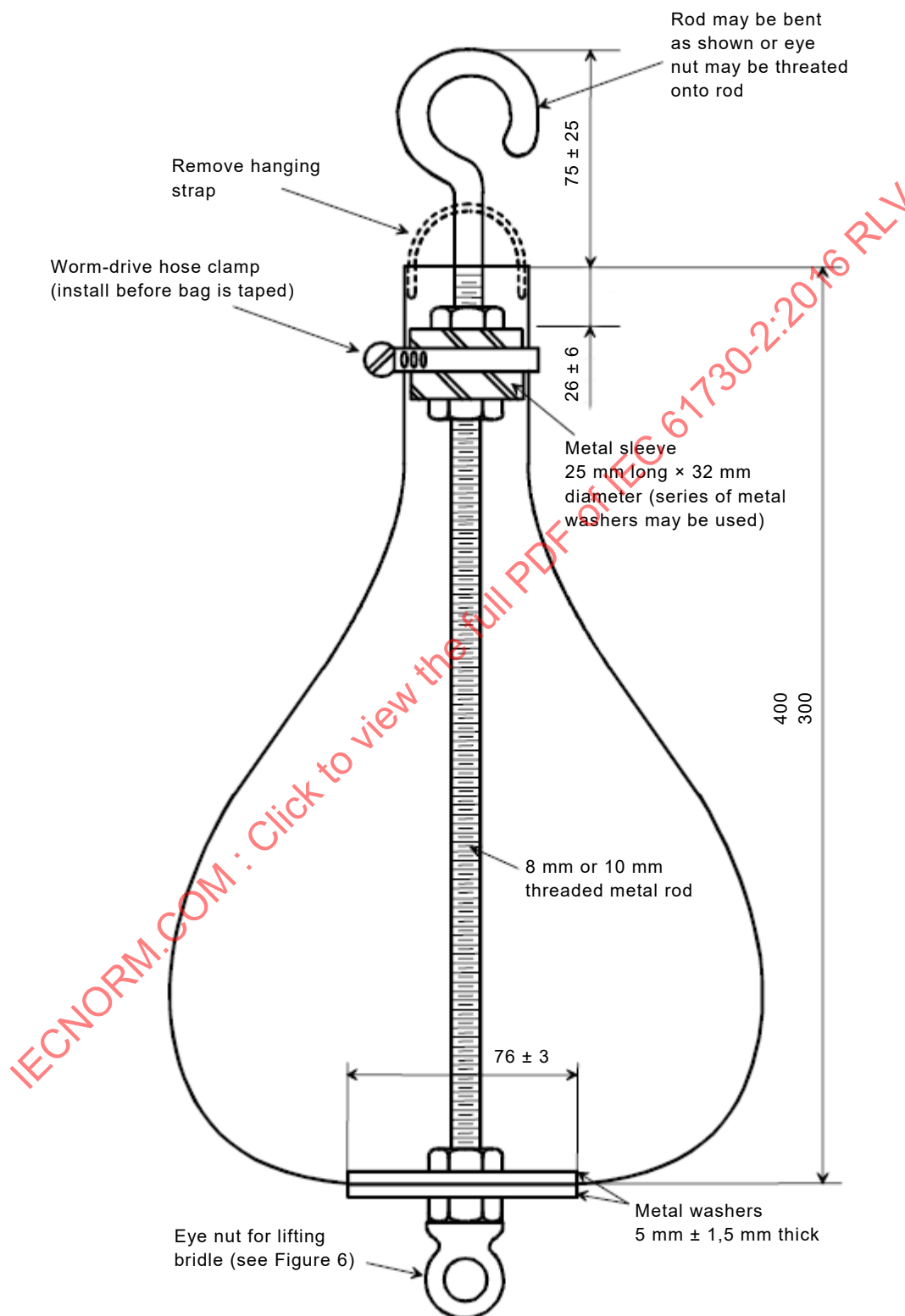
10.21.4 Pass criteria

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 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

Dimensions in millimetres

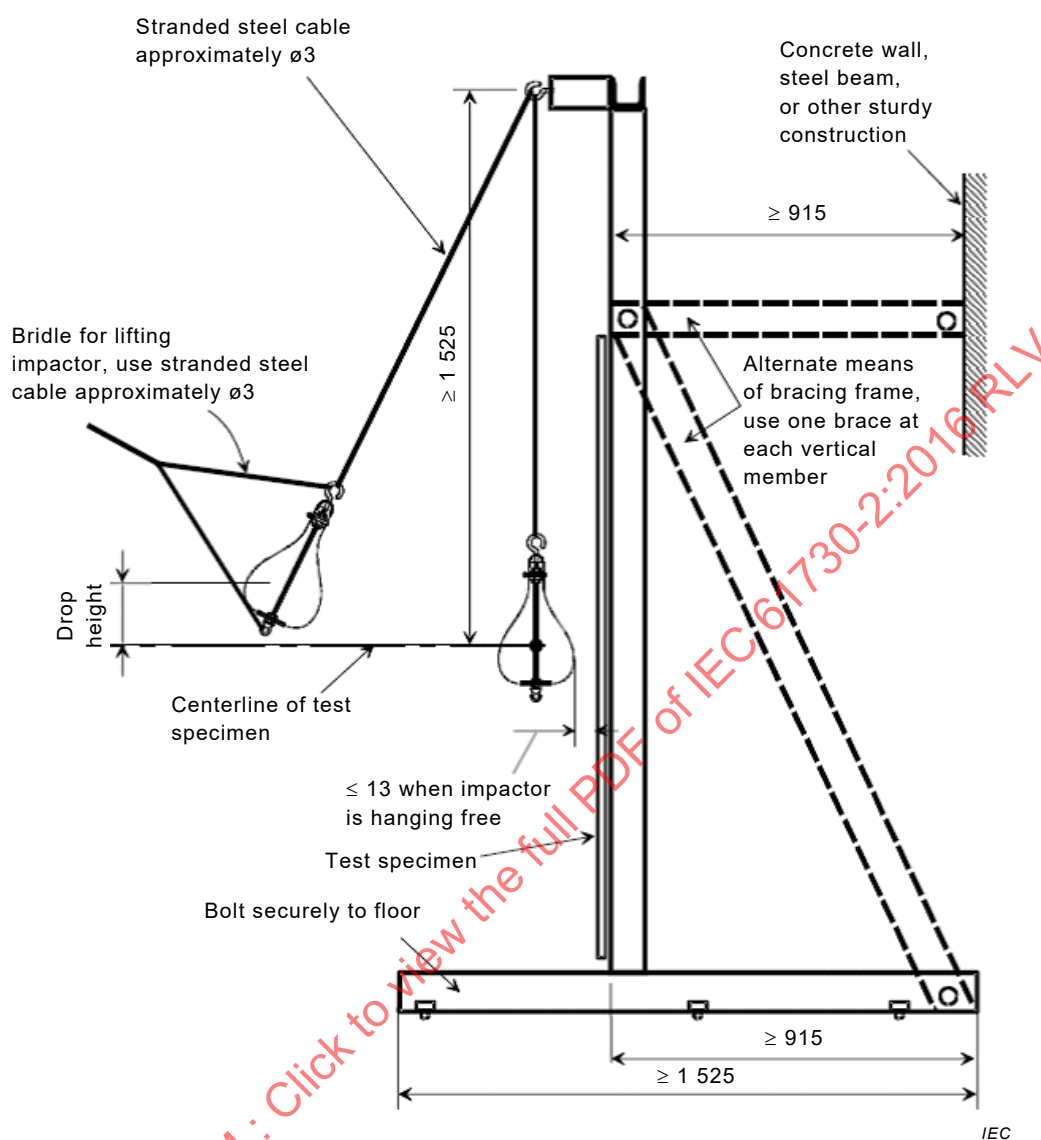
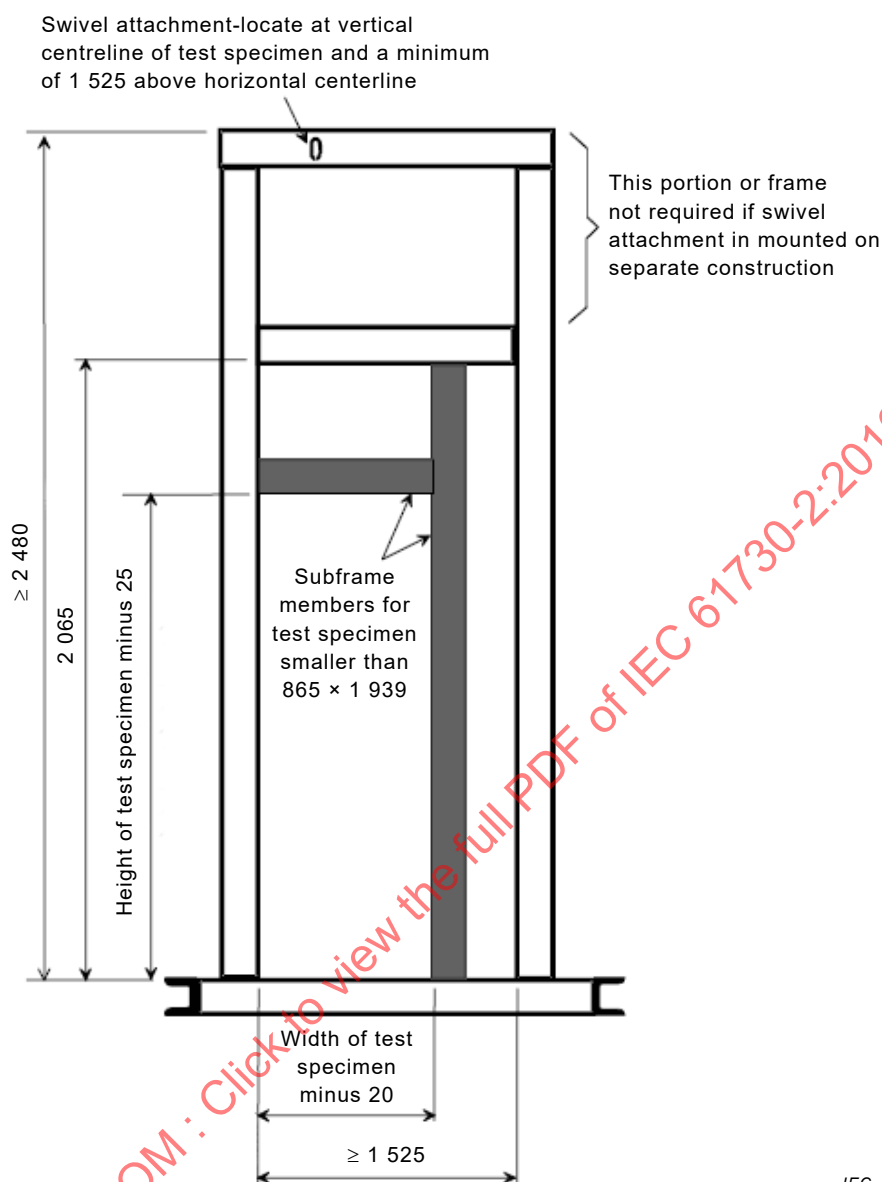


Figure 6 – Impact test frame 1

Dimensions in millimetres



IEC

Clamping frame for holding test specimen not shown.

Figure 7 – Impact test frame 2

10.22 Screw connections test MST 33

10.22.1 Test for general screw connections MST 33a

10.22.1.1 General

Components such as screws and nuts transmitting contact pressure or which are likely to be tightened by the user shall be tightened and loosened five times. Screws and nuts of insulating material shall be removed completely during each operation of loosening of the screws.

The test is made by means of a suitable test screwdriver or spanner, applying a torque as shown in Table 7, except that for screws of insulating material used in cord anchorage and bearing directly on the cable or cord, the torque is 0,5 Nm.

If the manufacturer specifies a higher torque in their installation instructions, that torque shall be used for testing. This shall be noted in the test report.

Table 7 – Torque tests on screws per IEC 60598-1:2014, Table 4.1

Nominal outer thread diameter of screw mm	Torque Nm		
	Type 1	Type 2	Type 3
Up to and including 2,8	0,20	0,40	0,40
Over 2,8 up to and including 3,0	0,25	0,50	0,50
Over 3,0 up to and including 3,2	0,30	0,60	0,50
Over 3,2 up to and including 3,6	0,40	0,80	0,60
Over 3,6 up to and including 4,1	0,70	1,20	0,60
Over 4,1 up to and including 4,7	0,80	1,80	0,90
Over 4,7 up to and including 5,3	0,80	2,00	1,00
Over 5,3 up to and including 6,0	–	2,50	1,25
Over 6,0 up to and including 8,0	–	8,00	4,00
Over 8,0 up to and including 10,0	–	17,00	8,50
Over 10,0 up to and including 12,0	–	29,00	14,50
Over 12,0 up to and including 14,0	–	48,00	24,00
Over 14,0 up to and including 16,0	–	114,00	57,00

The shape of the blade of the screwdriver shall suit the head of the screw to be tested. The screws shall not be tightened in jerks. Damage to covers is neglected.

Type 1 of Table 7 applies to metal screws without heads if the tightened screw does not protrude from the hole.

Type 2 applies to:

- other metal screws and to nuts;
- screws of insulating material
 - having a hexagonal head with the dimensions across flats exceeding the overall thread diameter;
 - having a cylindrical head and a key socket with a cross-corner dimension exceeding the overall thread diameter;
 - having a head with a slot or cross slots, the length of which exceeds 1,5 times the overall thread diameter.

Type 3 applies to other screws of insulating material.

10.22.1.2 Pass criteria

During the test, no damage impairing the further use of the fixing or screwed connection shall occur. After the test, it shall still be possible to introduce the screw or nut made of insulation material in the intended manner.

10.22.2 Test for locking screws MST 33b

10.22.2.1 General

A thread-lock that softens on heating provides satisfactory locking only for screw connections not subject to torsion in normal use. Such connections shall be tested by attempting to loosen locked screws with the following torque:

- 2,5 Nm for thread size $\leq$ M 10 or corresponding diameters;
- 5,0 Nm for thread sizes $>$ M 10 or corresponding diameters.

The test torque shall be applied for 1 min in a clockwise direction and then for 1 min in an anti-clockwise direction at 25 °C and maximum normalized temperature determined by MST 21.

10.22.2.2 Pass criteria

No loosening shall occur.

10.23 Static mechanical load test MST 34

This test is equivalent to MQT 16 in IEC 61215-2.

MQT 15 can be omitted.

10.23.1.1 Pass criteria

- a) Requirements apply as in IEC 61215-2 MQT 16;
- b) MST 13 shall meet the same requirements

10.24 Peel test MST 35

10.24.1 Purpose

The purpose of this test is to qualify insulation as a cemented joint. It shall provide confidence regarding the durability of the adhesion between different layers of rigid-to-flexible or flexible-to-flexible constructions of the PV module stack. The test method is taken from ISO 813 and determines the adhesive strength between polymeric materials bonded on a frontsheet or backsheet.

The test is not required, if clearance and creepage distances as required by class, pollution degree and material group are in accordance with either the figures in Table 3 or Table 4 of IEC 61730-1, respectively.

This test is not applicable to rigid-to-rigid bonded assemblies (e.g. glass/glass PV modules). Assessment is done by MST 36.

10.24.2 Sample requirements

For cemented joints with a width $\leq$ 10 mm the following procedure shall be used to prepare 2 special laminates (1 reference sample (not-aged) and 1 sample for sequence B testing) in the factory:

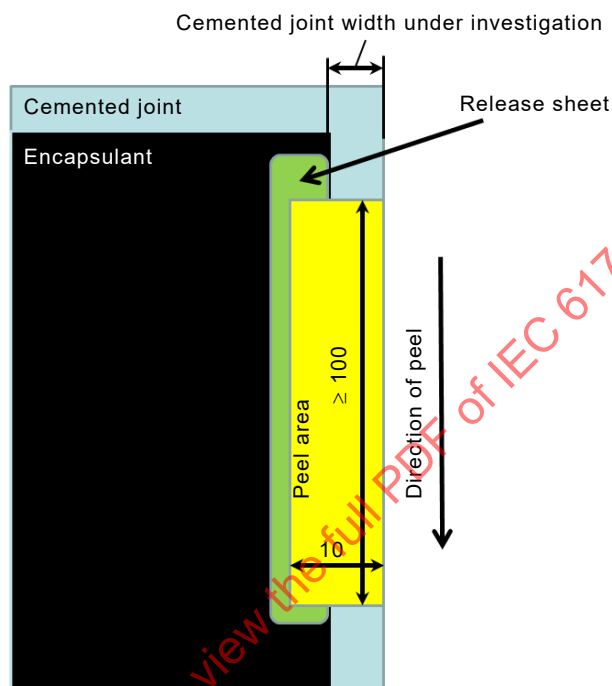
The sample shall be prepared as illustrated in Figure 8 for all locations as specified in Figure 9. A release sheet (e.g. Teflon) is to be inserted along the boundary of the cemented joint under test between the encapsulant layer and the backsheet. This is to ensure that the peel test is only conducted on the cemented joint area and not at a combination of cemented joint and encapsulant. It shall be close to the cemented joint but shall not penetrate the cemented joint area. For final peel-sample preparation and cutting procedure refer to 10.24.4.

If non-rigid frontsheets and rigid backsheet are used the procedure shall be applied from the front side.

If frontsheets and backsheet are non-rigid the procedure shall be applied from both sides, keeping the surface that is not peeled flat to a plate e.g. with an adhesive.

For qualification of cemented joints > 10 mm no special preparation is needed. A typical laminate shall be used.

Dimensions in millimetres



IEC

NOTE The yellow area highlights the cuts for the peel test after conditioning.

Figure 8 – Sample preparation of cemented joints ≤ 10 mm using a release sheet

10.24.3 Apparatus

The apparatus is as follows:

- Tensile testing machine, complying with the requirements of ISO 5893, capable of measuring force with an accuracy corresponding to class 1 and with a rate of traverse of the moving grip of $50 \text{ mm/min} \pm 5 \text{ mm/min}$.
- Fixture, for holding the test piece to the moving grip of the testing machine in a) so that the direction of pull to cause separation is at all times during the test $90^\circ \pm 10^\circ$ to the plane of the bond between the polymer and the rigid backsheet, i.e. making an angle of 90° with the surface of the fixture.

10.24.4 Procedure

An unconditioned unframed reference PV module (typically a new module) and one unframed PV module that has undergone test sequence B of Figure 1 are used for the peel test. Each module shall be treated according to the following procedure:

- Condition the samples for at least 16 h at $23^\circ\text{C} \pm 2^\circ\text{C}$, $50\% \text{ RH} \pm 10\% \text{ RH}$ immediately before the test in accordance with the requirements of ISO 23529.
- Cemented joint width > 10 mm (laminate):

After conditioning ten (5 per interface) strips of $10 \text{ mm} \pm 0,5 \text{ mm}$ width and at least 100 mm length shall be cut at the flexible frontsheet or flexible backsheet of the samples as shown in Figure 9. Five strips are to be cut per adhesion interface. Adhesion interfaces to be evaluated for classification as cemented joints may include flexible frontsheet or flexible backsheet to cemented joint material (5 peels), and cemented joint material to rigid backsheet or rigid frontsheets (5 peels). The strips shall be cut from the same side of the module, however the depth of the cut shall be to the appropriate adhesion interface.

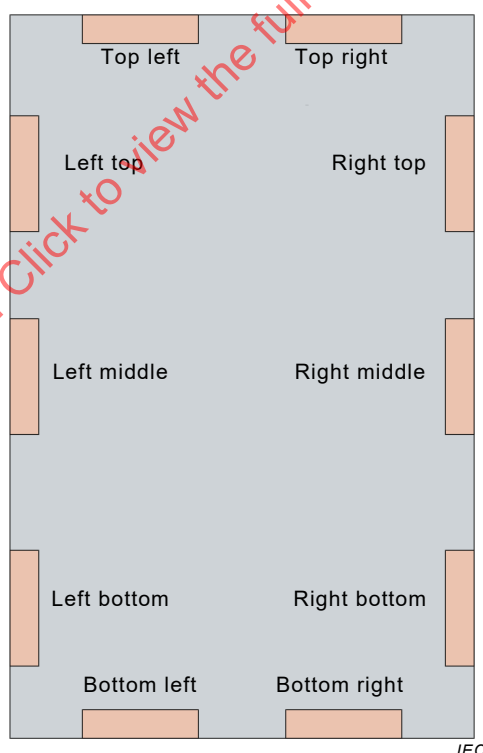
c) Cemented joint width $\leq 10 \text{ mm}$ (special laminate):

After conditioning ten strips of $10 \text{ mm} \pm 0,5 \text{ mm}$ width and at least 100 mm length shall be cut out of the samples as shown in Figure 9. Five strips are to be cut per adhesion interface. Adhesion interfaces to be evaluated for classification as cemented joints may include flexible frontsheet or flexible backsheet to cemented joint material (5 peels), and cemented joint material to rigid backsheet or rigid frontsheets (5 peels). The strips shall be cut from the same side of the module.

The first cut (position see Figure 9, cut area see yellow box in Figure 8) will allow peel testing of the backsheet to cemented joint material interface (total 5 peels). For investigation of the rigid frontsheet to cemented joint material interface the remaining encapsulant shall be cut to the rigid frontsheet (second cut, underneath yellow box in Figure 8 along release sheet and cemented joint) such that peel will not be influenced by the encapsulant. Care shall be taken that the cemented joint as such is not influenced (total 5 peels).

If other areas in a PV module shall be classified as cemented joint, the locations shown in Figure 9 may be extended to other relevant areas. The concept of release sheet insertion for cemented joints width $\leq 10 \text{ mm}$ shall be adopted.

Report the areas where the strips have been cut (e.g. by picture with dimensions).



IEC

Figure 9 – PV module with positions for peel samples on frontsheet or backsheet

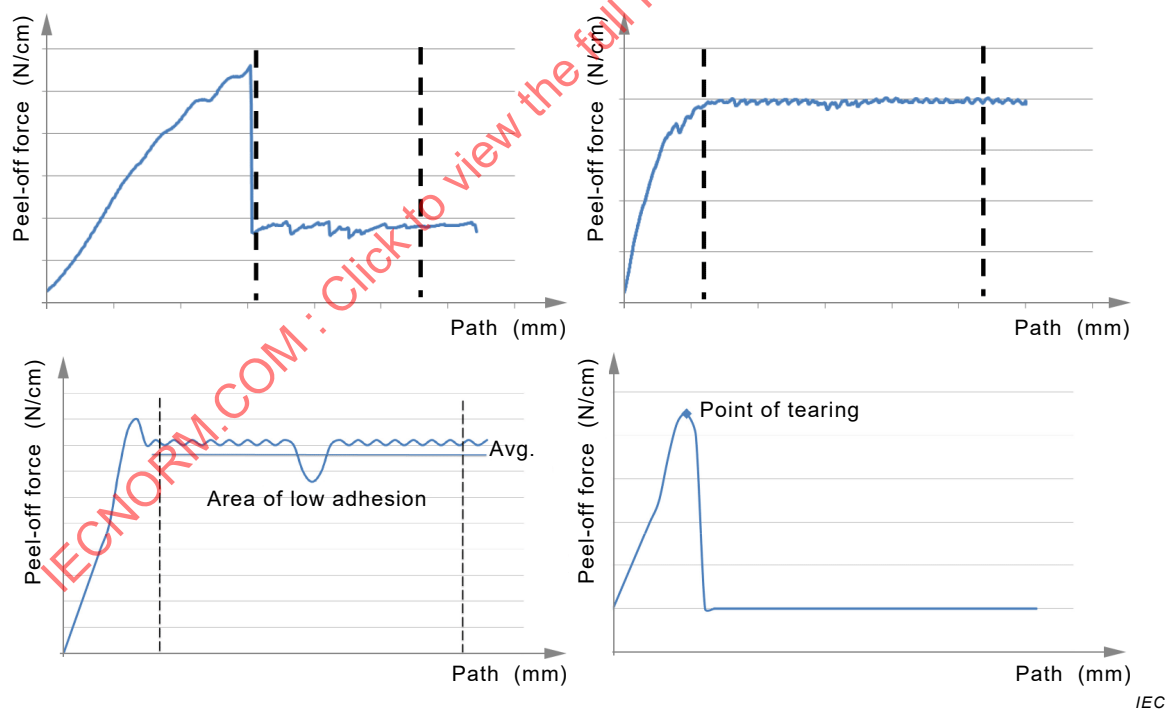
- d) The depth of the cut shall be sufficient to completely cut through to the layer of which adhesion shall be measured, but shall not significantly infringe the layer below. A fraction of the strip sufficient in length to be gripped by the machine shall be separated manually at the interface under investigation. The strip shall be mounted perpendicularly to the moving grip of the testing machine. Start with the peel test and continue until the complete strip

under test is peeled off. The peel strength shall be measured over a length of at least 60 mm.

To provide better comparability of the peel test the use of a template for the sample preparation is recommended.

The length of the piece of strip mounted to the grip depends on the grip design. Usually 10 mm is sufficient. In case more is needed the extra length is to be considered during sample preparation.

- e) Place the test piece symmetrically in the fixture. Place the free end of the strip in the grip. Move the grip of the tensile-testing machine at $50 \text{ mm/min} \pm 5 \text{ mm/min}$ until separation is complete. Record the force required to cause separation.
- f) A time versus force plot over the full length of the test piece shall be made.
- g) Report the adhesion strength in newton per mm, by dividing the force (in N) recorded by the width of the test piece (in mm). Report whether adhesive or cohesive failure has been observed for each peel.
- h) Only such samples shall be considered showing a continuous peel-off characteristic for at least 20 mm. The mean value of that continuous phase shall be considered when applying the pass criteria (10.23.4). Even if the measured maximum force deviates significantly from the continuous force (compare Figure 10 left) the continuous fraction of the measurement shall be considered.
- i) In case visual inspection (MST 01) reveals bubbles or delaminations spaced 20 mm or less apart in the area of the peel, the test shall be conducted such that the affected areas are covered by the peel test. In case of a single large bubble this area shall be covered by the peel test.



- Top left : peak force does not reflect actual adhesion properties and shall be excluded from mean value calculation.
- Top right: optimal curve, evaluation of the continuous part of the curve.
- Bottom left: peel strength curve with local weak adhesion and resulting average.
- Bottom right: force at point of tearing (sample breakage).

Figure 10 – Typical peel-off measurement curves

10.24.5 Pass criteria

The PV module shall be judged to have successfully passed the peel test if the loss of adhesion force of the arithmetic mean M for the respective interface of unconditioned (M1) and after stress test of sequence B (M2) is below 50 %. The difference is determined by comparing the mean value of the results of the two samples tested.

$$0,5 < \frac{\sum_1^n M2}{\sum_1^n M1}$$

For each PV module type 5 samples at each interface shall be tested. The value relevant for the pass criteria is the mean value of the 5 samples. In case measurements of samples are discarded following criteria above, at least the 3 samples with the lowest adhesion force shall be evaluated. If needed additional samples shall be prepared and evaluated.

If the adhesion force of the interface to be evaluated cannot be obtained (e.g. cohesive failure within the cemented joint) or adhesion failure of other included interfaces or tearing or breaking of the sample during testing then the measured peak force before failure shall be used for evaluation.

If no locations meeting the requirements from 10.24.2 and the requirements from Figure 2 can be identified and tested, the sample has failed the test.

10.25 Lap shear strength test MST 36

10.25.1 Purpose

The purpose of this test is to qualify insulation as a cemented joint. It shall provide confidence regarding the durability of the adhesion between rigid-to-rigid bonded assemblies (e.g. glass/glass PV modules) for cemented joints of the PV module stack. The test is described in ISO 4587 and determines the adhesive strength of rigid substructures bonded by polymeric material.

The test is not required, if clearance and creepage distances as required by class, pollution degree and material group are in accordance with either the figures in Table 3 or Table 4 of IEC 61730-1, respectively.

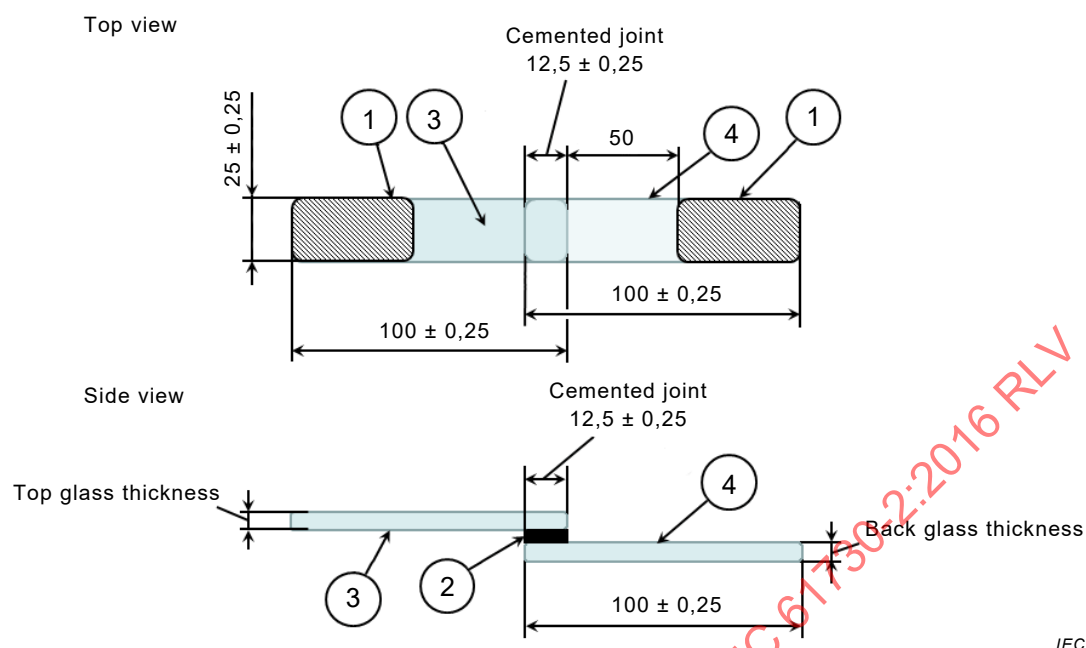
This test is not applicable to rigid-to-flexible or flexible-to-flexible bonded assemblies (e.g. glass/foil or foil/foil PV modules). For rigid-to-flexible or flexible-to-flexible bonded assemblies MST 35 applies.

10.25.2 Test samples

20 samples in accordance to ISO 4587:2003 made up of identical materials, thicknesses and glass surface structure for frontglass, backglass and adhesive (cemented joint) as the end product (PV module). The adhesive bond of samples shall be representative in every aspect to the end product and hence be built using equivalent production parameters including methods of edge delete and treatment, see Figure 11.

If heat strengthened glass is used in production an equivalent non-tempered glass that is easier to cut samples from can be used.

Dimensions in millimetres



IEC

Key

- 1 Area held in grips
- 2 Cemented joint
- 3 PV module front glass
- 4 PV module back glass

Figure 11 – Lap shear test sample for proving cemented joint**10.25.3 Apparatus**

The apparatus (tensile-testing machine) is specified in ISO 4587:2003, Clause 4.

10.25.4 Procedure

A total of 20 bonded test coupons shall be prepared as described in 10.25.2. 10 bonded test coupons are used to determine the pre-weathering breaking force (M1) and 10 bonded test coupons are used to determine the post-weathering breaking force (M2). The test flow is given in Figure 12. In the first UV-test the front glass is exposed to the UV and in the second step the back glass.

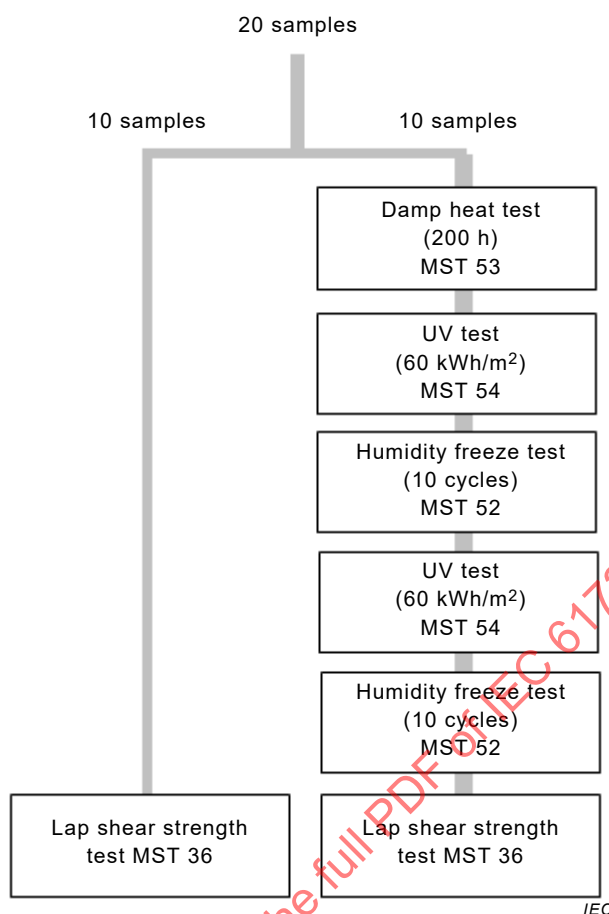


Figure 12 – Lap-shear test flow

Condition the samples for at least 16 h at 23 °C ± 2 °C, 50 % RH ± 10 % RH immediately before the test in accordance with the requirements of ISO 23529.

Operate the machine as described in ISO 4587:2003.

Record the highest force during rupture as the breaking force for that specimen.

NOTE The speed resulting from the values in ISO 4587:2003 is equivalent to about 0,8 mm/min.

10.25.5 Pass criteria

The PV module design shall be judged to have successfully passed the lap shear strength test if the loss in arithmetic mean M (for all 10 samples) of the breaking force for the respective interface before and after weathering is less than 50 %. The difference is determined by comparing the results of the two batches of samples tested.

$$0,5 < \frac{\sum_{i=1}^{10} M2}{\sum_{i=1}^{10} M1}$$

NOTE The lap shear strength, in MPa, is calculated by dividing the breaking force, in newton, by the shear area, in square millimetres.

In case of the rigid part breaking apart from the interfaces of investigation a thicker or stronger glass shall be used. A suitable support for the glass may also be sufficient.

10.26 Materials creep test MST 37

10.26.1 Purpose

The purpose of the material creep test is to validate that the materials used in the PV module will not show creep or lose adhesion when operated at the highest temperatures that PV modules normally experience in the field. In particular the test shall determine possible creep between the following interfaces:

- frontsheet to backsheet;
- frontsheet or backsheet to directly attached mounting system (e.g. back rail);
- junction box to backsheet respectively frontsheet.

This test is not required to be performed if creep at all interfaces is prevented by mechanical mounting means not relying on adhesion alone.

10.26.2 Apparatus

- A climatic chamber with automatic temperature control with means for circulating the air inside capable of subjecting one or more PV modules to the conditions specified in 10.26.3.
- Means for mounting or supporting the PV module in the chamber, so as to allow free circulation of the surrounding air.
- Means for measuring and recording the temperature of the PV module to an accuracy of $\pm 1\text{ }^{\circ}\text{C}$.

10.26.3 Procedure

- Attach a suitable temperature sensor to the front or back surface of the PV module near the middle.
- Install the PV module at room temperature in the climatic chamber using the worst case mounting method described in the installation manual. Each PV module is to be mounted at the maximum angle permissible as per the installation manual; if no maximum is given the PV module is to be mounted vertically in the test chamber.
- After closing the chamber, subject the PV module to $105\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$, no extra humidity shall be induced to the chamber. If the module type under assessment is designed for use in only open rack configurations the temperature is $90\text{ }^{\circ}\text{C} \pm 3\text{ }^{\circ}\text{C}$ instead.
- Throughout the test, record the PV module temperature. Maintain the PV module at the specified temperature for 200 h.

10.26.4 Final measurements

After allowing the PV module to reach room temperature, repeat tests MST 01, MST 11, MST 13, MST 16, and MST 17.

10.26.5 Pass criteria

Additionally to the pass criteria in the tests listed under 10.26.4 the following criteria shall be met:

Meet the creepage and clearance distances as specified in either Table 3 or Table 4 of IEC 61730-1:2016 depending on the PV module Class according to IEC 61140.

10.27 Robustness of terminations test MST 42

This test is equivalent to MQT 14.1 and MQT 14.2 in IEC 61215-2 and shall be performed subsequently. MQT 14.2 shall also be performed for junction boxes compliant to IEC 62790 as required by IEC 61730-1.

MQT 15 can be omitted.

10.28 Thermal cycling test MST 51

This test is equivalent to MQT 11 in IEC 61215-2. Technology specific variations of the test are to be found in the sub-parts IEC 61215-1-x (x is 1 to 4). Figure 1 shows which version (50 cycles or 200 cycles) is to be applied with the samples.

MQT 15 can be omitted.

10.29 Humidity freeze test MST 52

This test is equivalent to MQT 12 in IEC 61215-2.

MQT 15 can be omitted.

10.30 Damp heat test MST 53

This test is equivalent to MQT 13 in IEC 61215-2. In this standard two versions of the test are applied. One with the standard duration as described in IEC 61215-2 (1 000 h) and one with a reduced duration of 200 h. The applicable test version is defined in Figure 1.

MQT 15 can be omitted.

10.31 UV test MST 54

This test is equivalent to MQT 10 in IEC 61215-2 except that in this standard two different UV doses are applied. One with the standard UV dose as described in IEC 61215-2 and one with an increased dose equal to four times the IEC 61215-2 dose that is applied twice during sequence B. 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. By doing so, the front side and back side of the PV module will be exposed to the same UV dose. The applicable UV dose of MST 54 to be applied is defined in Figure 1.

MQT 15 can be omitted.

10.32 Cold conditioning MST 55

10.32.1 Purpose

The purpose of this test is to evaluate a PV module for applicability of Pollution Degree PD=1. The test and the test sequence are in accordance to IEC 61010-1 and adapted to be applicable for PV modules.

10.32.2 Apparatus

The test shall be performed in a climatic chamber capable to fulfil requirements of test procedure. The climatic chamber shall fulfil requirements of IEC 60068-3-5.

10.32.3 Procedure

Cold conditioning shall be performed as defined in IEC 60068-2-1, procedure Ab.

- Attach a suitable temperature sensor to the front or back surface of the PV module near the middle.
- Place the PV module in the climatic chamber.
- After closing the chamber, subject the PV module to $-40\text{ °C} \pm 3\text{ °C}$ for 48 h.

NOTE Temperature tolerances are taken from IEC 60068-2-1, 6.2.

10.32.4 Pass criteria

The pass criteria are as follows:

- a) No evidence of major visual defects as defined in MST 01.
- b) MST 16 shall meet the same requirements as for the initial measurements.

10.33 Dry heat conditioning MST 56

10.33.1 Purpose

The purpose of this test is to evaluate a PV module for applicability of Pollution Degree PD = 1. The test and the test sequence are in accordance to IEC 61010-1 and adapted to be applicable for PV modules.

10.33.2 Apparatus

The test shall be performed in a climatic chamber capable to fulfil requirements of test procedure. The climatic chamber shall fulfil requirements of IEC 60068-3-5.

10.33.3 Procedure

Dry heat conditioning shall be performed as defined in IEC 60068-2-2, procedure Ab.

- a) Attach a suitable temperature sensor to the front or back surface of the PV module near the middle.
- b) Place the PV module in the climatic chamber.
- c) After closing the chamber, subject the PV module to $105\text{ °C} \pm 5\text{ °C}$ less than 50 % relative humidity for 200 h. If the PV module type under assessment is designed for use in only open rack configurations the temperature is $90\text{ °C} \pm 3\text{ °C}$ instead.

NOTE Temperature tolerances are taken from IEC 60068-2-2, 6.2.

10.33.4 Pass criteria

The pass criteria are as follows:

- a) No evidence of major visual defects as defined in MST 01.
- b) MST 16 shall meet the same requirements as for the initial measurements.

Annex A (informative)

Recommendations for testing of PV modules from production

A.1 General

This Annex provides guidance how to verify that the production PV modules continue to meet the minimum safety requirements of this standard. Where applicable time based production line measurements may be performed. The tests are to be understood as recommendations and can be replaced by other test procedures that can be expected to yield the same information.

Provisions shall be taken to capture an error of the indication device due to malfunction of the device.

These recommendations can be used to harmonise factory surveillance practices regarding production line measurements.

The information from production line tests may be required within factory surveillance work of certification bodies.

A.2 Module output power

It is recommended that electrical output power is verified on the final wiring configuration on a 100 % basis. Results from I-V curve measurements can also be used to verify that the current and voltage rating falls within the specification. All production values of I_{sc} and V_{oc} shall be covered by the tolerances of the product qualified under IEC 61730. Possible stabilisation effects shall be considered if changes of I_{sc} and V_{oc} are expected during operation in sunlight. This test will also verify that bypass diodes are not shorted.

A.3 Wet insulation test

This test verifies that the insulation properties of outer surfaces of the production PV modules meet the electrical safety requirements of this standard.

The test is conducted in accordance with MST 17 and performed at a sampling rate of at least 1 PV module per laminator per working shift. Test samples shall be put aside until all sealants have set (take into account curing times) and then tested in a batch later.

The sampling rate may be increased or lowered depending on the measurement results.

The test voltage is based on the definition of test MST 17 including a factor Y .

$$U_{TEST} = U_{SYS} \times Y$$

$Y = 1$ is used for a minimum test duration of 1 min. $Y = 1,2$ is used for a minimum test duration of 5 s. Ramp-up time for test voltage is chosen such that no time induced breakdown will occur. During the test no breakdown of test voltage shall occur.

The temperature range of the water is 15 °C to 45 °C. The leakage current shall be corrected to 25 °C using a demonstrated correction factor for the PV module, to be determined for each PV module type.

For frameless PV module designs, a 100 % sampling rate is recommended (e.g. to filter production line breakage failures prior to boxing) as part of final tests on module prior to labelling.

For PV modules with cemented joints 100 % sampling rate is recommended. U_{Test} shall be increased by a factor of 1,35 additionally as required by IEC 61730-1:2016, 5.6.3.4.

A.4 Visual inspection

Visual inspection is performed on a 100 % basis aiming to verify that clearance distances (distances of live parts to PV module edges) are within the product specification. It is recommended to do this inspection before the framing process if applicable.

Special care shall be taken if cemented joints are used for insulation. PV modules utilizing cemented joints shall be inspected along all edges and areas with cemented joints on a 100 % basis aimed to verifying the cemented joint spacing visual inspection criteria as defined in 10.2.3 c) are met.

A.5 Bypass diodes

The verification that bypass diodes are working properly is performed on 100 % sampling rate.

Three alternative test methods can be applied:

- a) Perform successive additional I-V measurements in conjunction with maximum power determination with one cell of each string in the interconnection circuit completely shaded. The bypass diode belonging to this string is working properly, if the characteristic bend in the I-V curve is observed.
- b) A conductivity test can be performed with the PV module terminals connected in reverse polarity to a current source. The current flow and voltage drop across the PV module terminals can be used as indicator that the diodes are working properly.
- c) The I-V characteristics of all diodes can be verified just before their assembly. If the bypass diodes are in the junction box this could be done through measurement at the corresponding terminals of the junction box. A precondition for the latter method is an appropriate plan to mitigate possible influence of electrostatic discharges on the diodes in production.

NOTE Bypass diode verification procedures might be MQT 18.2 from IEC 61215-2 and IEC TS 62916.

A.6 Continuity test of equipotential bonding

PV modules provided with a connection for equipotential bonding are subjected to a continuity test for equipotential bonding (MST 13). At a sampling rate of 1 PV module per framing station per working shift demonstrate the electrical continuity between the grounding connection and all accessible conductive parts. Any appropriate indication device may be employed (current supply in conjunction with current and voltage measurement).

PV modules that have no frames or equipotential bonding locations identified shall be exempt from this requirement.

Annex B (informative)

Fire tests, spread-of-flame and burning-brand tests for PV modules

B.1 General

PV modules mounted in or on buildings, in general, shall fulfil national building and construction regulations and requirements. If such requirements are not available, the following international and national standards give information for tests, which could be used:

ISO 834-1, *Fire-resistance tests – Elements of building construction – Part 1: General requirements*

ISO 834-3, *Fire-resistance tests – Elements of building construction – Part 3: Commentary on test method and test data application*

ISO 5657, *Reaction to fire tests – Ignitability of building products using a radiant heat source*

ISO 13501-5:2005, *Fire classification of construction products and building elements – Part 5: Classification using data from external fire exposure to roofs tests*

ENV 1187-1 through -4, *Test methods for roof coverings under the influence of a thermal attack of burning brands and radiant heat*

ANSI/UL 790: *Standard Test Methods for Fire Tests of Roof Coverings*

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

B.2 Fire test for PV modules based on ENV 1187

B.2.1 General

The ENV 1187 fire test methods, parts 1 to 4, differ in terms of radiant heat, the used brands, additional air flow (wind simulation), tilt angles, amount and size of the demanded test specimen. The pass criteria for each test method are described in ISO 13501-5.

In general building integrated PV systems shall be tested in conjunction with a defined mounting system following the installation instruction of the PV module manufacturer. When testing PV modules, the mounting material and the joints between PV modules as well as sealing materials have to be considered and included in the test set-up.

The test sample requirements for the test method based on ENV 1187-1 (classification B_{ROOF}(t1)) are described below to provide an example.

B.2.2 External fire exposure to roofs

Part 1: Methods of test simulating exposure to burning brands, without wind or supplementary radiant heat.

The test can be performed for either one or both roof tilt angle ranges of 0° to 45° at 15° and for roof tilt ranges of 45° to 90° at 45°.

Requirements per roof pitch:

- A realistic roof construction including cross beams and all attachment parts with the PV modules installed the same as in a final system installation shall be provided by the PV module manufacturer.
- The minimum size for a test deck is 0,8 m × 1,8 m. Since it is also necessary to test transverse and vertical joints, several samples may be required to build up the complete test deck.

Figure B.1 shows an example test set-up for the fire test following ENV 1187-1.

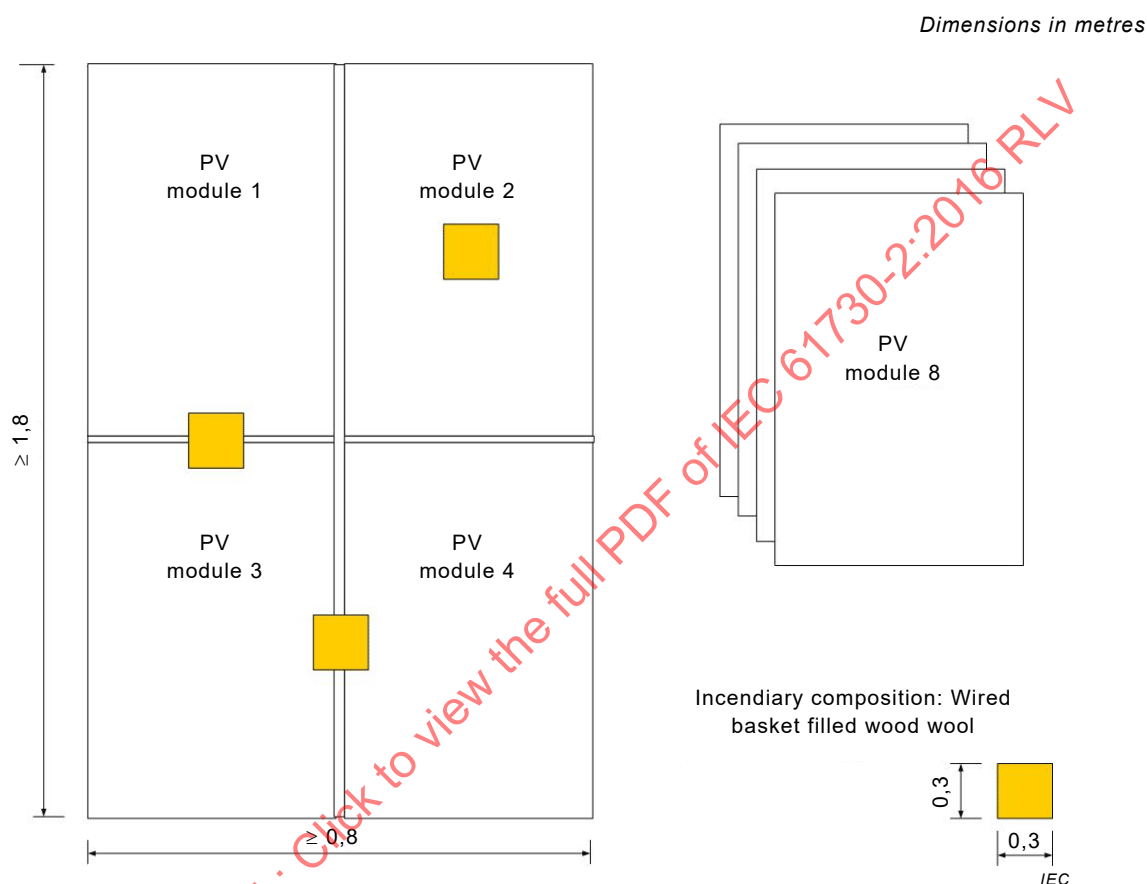


Figure B.1 – Example of test set-up for fire test

- Four PV modules are required for each test (if different pitch angles have to be considered, the amount of samples increases accordingly). One vertical and one horizontal joint on top of the roof and two centric applied incendiary compositions on one PV module are tested. Thereby fire passing and the influences of a possible lower functional layer as for example thermal insulation and sealing are tested.
- For building integrated PV modules the procedure of the positioning of the incendiary compositions shall be according to the above defined instructions for all ENV 1187 test methods.
- For building added PV modules the fire test can be limited to only one PV module and a centred brand, as long as there are no polymeric material used at interconnections (joints), mounting or frame parts.

B.2.3 Classification according to ISO 13501-5

Classification criteria:

- External and internal fire spread up to < 0,7 m.
- External and internal fire spread down to < 0,6 m.

- Maximum burned external and internal length $< 0,8$ m.
- No burning material as flaming droplet and debris material of the fire exposed area.
- No burning or glowing pieces which pierce the roof construction.
- No openings (due to burning through) > 25 mm².
- Total amount of all openings due to burning through $< 4\,500$ mm².
- Sideward fire spread does not reach the border of the test area.
- No internal glowing.
- Maximum radius of fire spread on “horizontal” roofs, external and internal $< 0,2$ m.

B.3 Fire test for PV modules based on ANSI/UL 1703

Fire resistance of PV modules installed on or over building rooftops has been proven to depend on more than just PV module flammability characteristics. In fact, fire resistance of PV modules is highly dependent on the combination and configuration of roofing materials, rack mounting systems, and the PV modules as a system. As a result of these findings, the PV system fire tests were developed to establish fire resistance classifications for PV systems consistent with the fire classification of roofing materials.

To reduce the number of tests required to cover every possible combination of PV modules with PV racking systems and roofing materials two new concepts were introduced:

- a) Optional PV module typing that groups PV modules with similar constructions, flame spread characteristics and burning brand characteristics. This allows replacement of a PV module of a particular type with any PV module of the same type without affecting the PV system fire rating.
- b) Use of common roofing materials for the test that meet specific performance requirements to represent all roofing materials. One set of roofing material construction and performance requirements has been established for steep-slope roof applications and another for low-slope roof applications.

PV system fire performance construction and PV module type requirements are detailed in ANSI/UL 1703:2015, section 16. Test methods for PV system fire performance classifications are specified in ANSI/UL 1703:2015, section 31.

PV modules intended to be integrated into a building structure (BIPV modules) are evaluated for fire classifications as roofing materials under UL 790 requirements as specified in ANSI/UL 1703:2015, section 16.

To assess basic fire propagation behavior of PV modules not considering its mounting system ANSI/UL 1703:2015, section 31.1.2 and section 31.1.3 can be used.

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SOMMAIRE

AVANT-PROPOS.....	60
1 Domaine d'application.....	63
2 Références normatives	63
3 Termes et définitions	65
4 Catégories d'essais	65
4.1 Généralités	65
4.2 Essais relatifs aux contraintes environnementales	65
4.3 Contrôle général	66
4.4 Essais relatifs aux risques de chocs électriques.....	66
4.5 Essais relatifs aux risques de feu	66
4.6 Essais relatifs aux contraintes mécaniques.....	67
5 Classes et procédures d'essai nécessaires associées	67
6 Echantillonnage.....	69
7 Rapport d'essai	69
8 Essais	70
9 Critères d'acceptation	73
10 Procédures d'essai	73
10.1 Généralités	73
10.2 Examen visuel MST 01.....	73
10.2.1 Objet	73
10.2.2 Procédure.....	73
10.2.3 Critères d'acceptation	73
10.3 Performances dans les conditions normales d'essais MST 02	75
10.3.1 Objet	75
10.3.2 Procédure.....	75
10.3.3 Critères d'acceptation	75
10.4 Détermination de la puissance maximale MST 03	75
10.4.1 Objet	75
10.4.2 Procédure.....	76
10.4.3 Critères d'acceptation	76
10.5 Essai d'épaisseur de l'isolant MST 04	76
10.5.1 Objet	76
10.5.2 Procédure.....	76
10.5.3 Critères d'acceptation	76
10.6 Essai de durabilité des marquages MST 05	77
10.7 Essai des angles vifs MST 06.....	77
10.8 Essai fonctionnel de la diode de dérivation MST 07.....	77
10.9 Essai d'accessibilité MST 11	77
10.9.1 Objet	77
10.9.2 Appareillage	77
10.9.3 Procédure.....	77
10.9.4 Mesures finales.....	78
10.9.5 Critères d'acceptation	78
10.10 Essai de susceptibilité aux rayures MST 12	78
10.10.1 Objet	78
10.10.2 Appareillage	78

10.10.3	Procédure	78
10.10.4	Mesures finales.....	78
10.10.5	Critères d'acceptation	79
10.11	Essai de continuité pour la liaison équipotentielle MST 13.....	80
10.11.1	Objet	80
10.11.2	Appareillage	80
10.11.3	Procédure.....	80
10.11.4	Mesures finales.....	80
10.11.5	Critères d'acceptation	80
10.12	Essai de tension de choc MST 14.....	80
10.12.1	Objet	80
10.12.2	Appareillage	81
10.12.3	Procédure.....	81
10.12.4	Mesure finale	82
10.12.5	Critères d'acceptation	82
10.13	Essai diélectrique MST 16.....	82
10.13.1	Objet	82
10.13.2	Procédure.....	82
10.13.3	Critères d'acceptation	83
10.14	Essai de courant de fuite en milieu humide MST 17	83
10.15	Essai en température MST 21	83
10.15.1	Objet	83
10.15.2	Méthode en site naturel.....	83
10.15.3	Méthode du simulateur solaire.....	85
10.15.4	Critères d'acceptation	86
10.16	Essai de tenue à l'échauffement localisé MST 22.....	87
10.17	Essai de résistance au feu MST 23.....	87
10.17.1	Objet	87
10.18	Essai d'allumabilité MST 24.....	87
10.18.1	Objet	87
10.18.2	Appareillage	88
10.18.3	Eprouvette d'essai	88
10.18.4	Conditionnement.....	89
10.18.5	Procédure.....	89
10.18.6	Durée de l'essai	90
10.18.7	Observations	90
10.18.8	Critères d'acceptation	90
10.19	Essai thermique de la diode de dérivation MST 25.....	90
10.20	Essai de surcharge de courant inverse MST 26.....	90
10.20.1	Objet	90
10.20.2	Procédure.....	91
10.20.3	Critères d'acceptation	91
10.21	Essai de détérioration du module MST 32.....	92
10.21.1	Objet	92
10.21.2	Appareillage	92
10.21.3	Procédure.....	92
10.21.4	Critères d'acceptation	92
10.22	Essai des raccords vissés MST 33.....	95
10.22.1	Essais des raccords vissés généraux MST 33a.....	95

10.22.2	Essai des vis de blocage MST 33b	97
10.23	Essai de charge mécanique statique MST 34	97
10.24	Essai de pelage MST 35	97
10.24.1	Objet	97
10.24.2	Exigences relatives aux échantillons	97
10.24.3	Appareillage	98
10.24.4	Procédure	98
10.24.5	Critères d'acceptation	101
10.25	Essai de cisaillement longitudinal MST 36	102
10.25.1	Objet	102
10.25.2	Echantillons d'essai	102
10.25.3	Appareillage	103
10.25.4	Procédure	103
10.25.5	Critères d'acceptation	104
10.26	Essai de fluage des matériaux MST 37	105
10.26.1	Objet	105
10.26.2	Appareillage	105
10.26.3	Procédure	105
10.26.4	Mesures finales	105
10.26.5	Critères d'acceptation	105
10.27	Essai de robustesse des sorties MST 42	106
10.28	Essai de cycle thermique MST 51	106
10.29	Essai humidité-gel MST 52	106
10.30	Essai de chaleur humide MST 53	106
10.31	Essai aux UV MST 54	106
10.32	Conditionnement au froid MST 55	106
10.32.1	Objet	106
10.32.2	Appareillage	106
10.32.3	Procédure	107
10.32.4	Critères d'acceptation	107
10.33	Conditionnement à chaleur sèche MST 56	107
10.33.1	Objet	107
10.33.2	Appareillage	107
10.33.3	Procédure	107
10.33.4	Critères d'acceptation	107
Annexe A (informative) Recommandations relatives aux essais de modules PV issus de la production		108
A.1	Généralités	108
A.2	Puissance de sortie du module	108
A.3	Essai diélectrique en milieu humide	108
A.4	Examen visuel	109
A.5	Diodes de dérivation	109
A.6	Essai de continuité pour la liaison équipotentielle	109
Annexe B (informative) Essais de résistance au feu, essais de propagation de flammes et essais de brandon incandescent des modules PV		111
B.1	Généralités	111
B.2	Essai de résistance au feu des modules PV basé sur l'ENV 1187	111
B.2.1	Généralités	111
B.2.2	Exposition des toitures à un feu extérieur	111

B.2.3	Classement conformément à l'ISO 13501-5	113
B.3	Essai de résistance au feu des modules PV basé sur l'ANSI/UL 1703.....	113
Figure 1	– Séquences d'essais.....	72
Figure 2	– Evaluation des bulles dans les joints de bordure des joints collés.....	75
Figure 3	– Essai de susceptibilité aux rayures	79
Figure 4	– Forme d'onde de la tension de choc selon l'IEC 60060-1	81
Figure 5	– Outil d'impact	93
Figure 6	– Cadre d'essai d'impact 1.....	94
Figure 7	– Cadre d'essai d'impact 2.....	95
Figure 8	– Préparation d'échantillon de joints collés ≤ 10 mm à l'aide d'une feuille de protection	98
Figure 9	– Module PV avec positions pour les échantillons de pelage sur la face avant ou la face arrière	100
Figure 10	– Courbes types de mesure du pelage	101
Figure 11	– Echantillon pour l'essai de cisaillement longitudinal appliqué au joint collé.....	103
Figure 12	– Séquence d'essai de cisaillement longitudinal	104
Figure B.1	– Exemple de montage d'essai pour l'essai de résistance au feu.....	112
Tableau 1	– Essais relatifs aux contraintes environnementales	65
Tableau 2	– Essai de contrôle général.....	66
Tableau 3	– Essais relatifs aux risques de chocs électriques	66
Tableau 4	– Essais relatifs aux risques de feu	67
Tableau 5	– Essais relatifs aux contraintes mécaniques.....	67
Tableau 6	– Essais exigés selon la classe	68
Tableau 7	– Essais de couple sur les vis selon l'IEC 60598-1:2014, Tableau 4.1	96

COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

**QUALIFICATION POUR LA SÛRETÉ DE FONCTIONNEMENT
DES MODULES PHOTOVOLTAÏQUES (PV) –****Partie 2: Exigences pour les essais****AVANT-PROPOS**

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Cette deuxième édition annule et remplace la première édition de l'IEC 61730-2, parue en 2004 et son amendement 1 (2011). Elle constitue une révision technique.

Cette édition inclut les modifications techniques majeures suivantes par rapport à l'édition précédente:

- a) réorganisation des séquences d'essai;
- b) examen visuel MST 01: ajout de l'exigence relative à la plaque signalétique et modification des critères d'acceptation;
- c) ajout de l'essai des angles vifs MST 06;

- d) ajout de l'essai d'épaisseur de l'isolant MST 04;
- e) essai d'accessibilité MST 11: définition de la force pour le doigt d'essai;
- f) essai de susceptibilité aux rayures MST 12: définition d'un rayon de lame pour l'essai aux rayures;
- g) essai MST 14: suppression de l'exigence de préconditionnement TC200 dans la Figure 1;
- h) suppression de l'essai de décharge partielle MST 15;
- i) rebaptisation de l'essai de claquage diélectrique MST 16 sous le nom d'essai diélectrique;
- j) essai en température MST 21: réécriture de la procédure d'essai; suppression du mode court-circuit; utilisation permise d'une méthode d'essai en intérieur alternative;
- k) essai de résistance au feu MST 23: réécriture du paragraphe; spécification des exigences d'essai de résistance au feu relatives aux codes de construction nationaux; déplacement de la description des essais facultatifs dans une annexe informative;
- l) ajout de l'essai d'allumabilité MST 24;
- m) essai de surcharge de courant inverse MST 26: modification de la spécification relative à la planche de bois;
- n) essai de détérioration du module MST 32: définition de nouvelles dimensions pour l'outil d'impact afin d'admettre d'autres composés de remplissage; étude de techniques de montage variées pour l'essai de bris de verre; diminution de la hauteur d'impact à 300 mm seulement; correction du diamètre d'ouverture conformément à la norme référencée (65 cm² au lieu de 6,5 cm²);
- o) ajout de l'essai des raccords vissés MST 33;
- p) ajout de l'essai de pelage MST 35 pour l'évaluation des joints collés;
- q) ajout de l'essai de cisaillement longitudinal MST 36 pour l'évaluation des joints collés;
- r) ajout de l'essai de fluage des matériaux MST 37;
- s) ajout, dans la Figure 1, de la séquence d'essais à l'humidité et aux rayons ultraviolets des modules PV pour évaluer la résistance des matériaux polymères aux contraintes. La nouvelle séquence d'essais aux UV a été ajoutée en réponse à la réunion de Kyoto, où il a été décidé d'ajouter un essai d'éprouvette ainsi qu'une séquence d'essai des modules PV. Etant donné que l'essai ISO aux UV ne peut pas être réalisé sur les modules PV (aucun équipement abordable n'est disponible), il a été décidé de s'appuyer sur les équipements d'essai de modules PV déjà disponibles. Les travaux de R&D ont montré que les cycles d'UV et de hautes fréquences (HF) sont les mieux adaptés pour évaluer le vieillissement des matériaux polymères dans les modules PV;
- t) ajout d'une nouvelle séquence pour l'essai de degré de pollution (PD) (séquence B1);
- u) ajout de l'Annexe intitulée "Recommandations relatives aux essais de modules PV issus de la production".

Le texte de cette norme est issu des documents suivants:

FDIS	Rapport de vote
82/1129/FDIS	82/1147/RVD

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à l'approbation de cette norme.

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QUALIFICATION POUR LA SÛRETÉ DE FONCTIONNEMENT DES MODULES PHOTOVOLTAÏQUES (PV) –

Partie 2: Exigences pour les essais

1 Domaine d'application

Le domaine d'application de l'IEC 61730-1 s'applique également à la présente partie de l'IEC 61730. Alors que l'IEC 61730-1 définit les exigences de construction, la présente partie de la norme répertorie les essais auxquels un module PV doit satisfaire à des fins de qualification pour la sûreté de fonctionnement. L'IEC 61730-2 n'est appliquée à des fins de qualification pour la sûreté de fonctionnement que conjointement à l'IEC 61730-1.

La séquence d'essais exigée dans la présente norme peut ne pas soumettre à l'essai tous les aspects de sécurité potentiels associés à l'utilisation des modules PV dans toutes les applications possibles. La présente norme utilise la meilleure séquence d'essais disponible au moment de la rédaction de la présente norme. Il convient de tenir compte de certains problèmes (tels que le danger potentiel de chocs électriques posés par un module PV cassé dans un système à haute tension) dans le cadre de la conception du système, de la localisation, des restrictions d'accès et des procédures de maintenance.

L'objectif de la présente norme est de fournir la séquence d'essais destinée à vérifier la sûreté des modules PV dont la construction a été évaluée par l'IEC 61730-1. La séquence d'essais et les critères d'acceptation sont conçus pour détecter le claquage éventuel de composants internes et externes des modules PV, qui entraînerait des incendies, des chocs électriques et/ou des dommages corporels. La norme définit les exigences de base relatives aux essais de sécurité, ainsi que des essais supplémentaires qui sont fonction des applications finales du module PV. Les catégories d'essais incluent un contrôle général, les risques de chocs électriques, le risque de feu, les contraintes mécaniques et les contraintes environnementales.

En plus des exigences contenues dans la présente norme, il convient de prendre en compte les exigences d'essai supplémentaires indiquées dans les normes ISO appropriées ou les codes nationaux ou locaux qui régissent l'installation et l'utilisation de ces modules dans leurs emplacements destinés.

2 Références normatives

Les documents suivants sont cités en référence de manière normative, en intégralité ou en partie, dans le présent document et sont indispensables pour son application. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

IEC 60060-1, *Technique des essais à haute tension – Partie 1: Définitions et exigences générales*

IEC 60068-2-1, *Essais d'environnement – Partie 2-1: Essais – Essai A: Froid*

IEC 60068-2-2, *Essais d'environnement – Partie 2-2: Essais – Essai B: Chaleur sèche*

IEC 60068-3-5, *Essais d'environnement – Partie 3-5: Documentation d'accompagnement et guide – Confirmation des performances des chambres d'essai en température*

IEC 60598-1:2014, *Luminaires – Partie 1: Exigences générales et essais*

IEC 60664-1:2007, *Coordination de l'isolement des matériels dans les systèmes (réseaux) à basse tension – Partie 1: Principes, exigences et essais*

IEC 60695-2-10, *Essais relatifs aux risques du feu – Partie 2-10: Essais au fil incandescent/chauffant – Appareillage et méthode commune d'essai*

IEC 60904-2, *Dispositifs photovoltaïques – Partie 2: Exigences applicables aux dispositifs photovoltaïques de référence*

IEC 60904-9, *Dispositifs photovoltaïques – Partie 9: Exigences pour le fonctionnement des simulateurs solaires*

IEC 60950-1:2005, *Matériels de traitement de l'information – Sécurité – Partie 1: Exigences générales*

IEC 61010-1, *Règles de sécurité pour appareils électriques de mesurage, de régulation et de laboratoire – Partie 1: Exigences générales*

IEC 61032:1997, *Protection des personnes et des matériels par les enveloppes – Calibres d'essai pour la vérification*

IEC 61140, *Protection contre les chocs électriques – Aspects communs aux installations et aux matériels*

IEC 61215 (toutes les parties), *Modules photovoltaïques (PV) pour applications terrestres – Qualification de la conception et homologation*

IEC 61215-2, *Modules photovoltaïques (PV) pour applications terrestres – Qualification de la conception et homologation – Partie 2: Procédures d'essai*

IEC 61730-1:2016, *Qualification pour la sûreté de fonctionnement des modules photovoltaïques (PV) – Partie 1: Exigences pour la construction*

IEC 62790, *Boîtes de jonction pour modules photovoltaïques – Exigences de sécurité et essais*

ISO/IEC 17025, *Exigences générales concernant la compétence des laboratoires d'étalonnages et d'essais*

ISO 813, *Caoutchouc vulcanisé ou thermoplastique – Détermination de l'adhérence à un substrat rigide – Méthode par pelage à angle droit*

ISO 4046-4, *Papier, carton, pâtes et termes connexes – Vocabulaire – Partie 4: Catégories et produits transformés de papier et de carton*

ISO 4587:2003, *Adhésifs – Détermination de la résistance au cisaillement d'assemblages collés rigide sur rigide à recouvrement simple*

ISO 5893, *Appareils d'essai du caoutchouc et des plastiques – Types pour traction, flexion et compression (vitesse de translation constante) – Spécifications*

ISO 8124-1, *Sécurité des jouets – Partie 1: Aspects de sécurité relatifs aux propriétés mécaniques et physiques*

ISO 11925-2:2010, *Essais de réaction au feu – Allumabilité de produits soumis à l'incidence directe de la flamme – Partie 2: Essai à l'aide d'une source à flamme unique*

ISO 23529, *Caoutchouc – Procédures générales pour la préparation et le conditionnement des éprouvettes pour les méthodes d'essais physiques*

ANSI Z97.1:2009, *Standard – Safety Glazing Materials Used in Buildings – Safety Performance Specifications and Methods of Test* (disponible en anglais seulement)

ANSI/UL 1703:2015, *Flat-plate photovoltaic modules and panels* (disponible en anglais seulement)

3 Termes et définitions

L'Article de la Partie 1 s'applique.

4 Catégories d'essais

4.1 Généralités

Les dangers décrits dans le paragraphe suivant pourraient influencer la sûreté des modules PV. Conformément à ces dangers, des procédures et des critères d'essai sont décrits. Les essais spécifiques auxquels un module PV sera soumis dépendront de l'application finale pour laquelle sont spécifiés les essais minimaux à l'Article 5.

NOTE Les essais de sûreté de fonctionnement des modules PV sont désignés sous l'abréviation MST (*Module Safety Test*).

Les Tableaux 1 à 5 présentent l'origine des essais exigés. Pour certains essais, la troisième colonne précise l'origine des essais à titre informatif seulement; les exigences d'essai applicables sont décrites de 10.1 à 10.32. Les autres essais sont basés sur, ou sont identiques aux essais MQT de qualification du module définis dans la série IEC 61215. Les références aux essais applicables sont données dans la dernière colonne. Certains essais basés sur l'IEC 61215 ont été modifiés pour l'IEC 61730-2, et sont inclus de 10.1 à 10.32.

4.2 Essais relatifs aux contraintes environnementales

Tableau 1 – Essais relatifs aux contraintes environnementales

Essai	Titre	Normes référéncées	Basé sur
			IEC 61215-2
MST 51	Cycle thermique (TC50 ou TC200)	–	MQT 11
MST 52	Humidité-gel (HF10)	–	MQT 12
MST 53	Chaleur humide (DH1000)	–	MQT 13
MST 54	Préconditionnement aux UV	–	MQT 10
MST 55	Conditionnement au froid	IEC 60068-2-1	–
MST 56	Conditionnement à chaleur sèche	IEC 60068-2-2	–

4.3 Contrôle général

Tableau 2 – Essai de contrôle général

Essai	Titre	Normes référéncées	Basé sur
			IEC 61215-2
MST 01	Examen visuel	–	MQT 01
MST 02	Performances dans en conditions normales d'essais	–	MQT 6.1
MST 03	Détermination de la puissance maximale	–	MQT 02
MST 04	Epaisseur de l'isolant	–	–
MST 05	Durabilité des marquages	IEC 60950-1	–
MST 06	Essai des angles vifs	ISO 8124-1	–
MST 07	Essai fonctionnel de la diode de dérivation	–	–

4.4 Essais relatifs aux risques de chocs électriques

Ces essais sont conçus pour évaluer les risques encourus par les personnes, dus à des chocs ou des accidents résultant de contacts avec les parties d'un module PV électrifiées électriquement à la suite de la conception, de la construction ou de défauts provoqués par l'environnement ou le fonctionnement.

Tableau 3 – Essais relatifs aux risques de chocs électriques

Essai	Titre	Normes référéncées	Basé sur
			IEC 61215-2
MST 11	Essai d'accessibilité	IEC 61032	–
MST 12	Essai de susceptibilité aux rayures	ANSI/UL 1703:2015	–
MST 13	Essai de continuité pour la liaison équipotentielle	ANSI/UL 1703:2015	–
MST 14	Essai de tension de choc	IEC 60664-1	–
MST 16	Essai diélectrique	–	MQT 03
MST 17	Essai de courant de fuite en milieu humide	–	MQT 15
MST 42	Essai de robustesse des sorties	IEC 62790	MQT 14

4.5 Essais relatifs aux risques de feu

Ces essais évaluent les risques de feu éventuels dus au fonctionnement d'un module PV ou à la défaillance de ses composants.

Tableau 4 – Essais relatifs aux risques de feu

Essai	Titre	Normes référencées	Basé sur
			IEC 61215-2
MST 21	Essai en température	ANSI/UL 1703:2015	–
MST 22	Essai de tenue à l'échauffement localisé	–	MQT 09
MST 23*	Essai de résistance au feu	–	Code national ou local
MST 24	Essai d'allumabilité	ISO 11925-2	–
MST 25	Essai thermique de la diode de dérivation	–	MQT 18
MST 26	Essai de surcharge de courant inverse	ANSI/UL 1703:2015	–
* Les essais de résistance au feu sont réglementés au niveau local et ne sont habituellement exigés qu'aux fins de construction de produits intégrés ou ajoutés au bâtiment, généralement pour vérifier leur capacité de résistance à des incendies provoqués par des sources extérieures.			

4.6 Essais relatifs aux contraintes mécaniques

Ces essais doivent réduire le risque d'accidents dus aux défaillances mécaniques.

Tableau 5 – Essais relatifs aux contraintes mécaniques

Essai	Titre	Normes référencées	Basé sur
			IEC 61215-2
MST 32	Essai de détérioration du module	ANSI Z97.1	–
MST 33	Essai des raccords vissés	IEC 60598-1	–
MST 34	Essai de charge mécanique	–	MQT 16
MST 35	Essai de pelage	ISO 5893	–
MST 36	Essai de cisaillement longitudinal	ISO 4587:2003	–
MST 37	Essai de fluage des matériaux	–	–
MST 42	Essai de robustesse des sorties		MQT 14

5 Classes et procédures d'essai nécessaires associées

Les essais spécifiques auxquels sera soumis un module PV, en fonction de la classe définie dans l'IEC 61730-1 (par référence à l'IEC 61140), sont décrits au Tableau 6. L'ordre suivant lequel les essais sont réalisés doit être conforme à la Figure 1. Certains essais doivent être réalisés comme des essais de préconditionnement.

Tableau 6 – Essais exigés selon la classe

Classe selon l'IEC 61140			Essais
II	0	III	
X	X	X	Essais relatifs aux contraintes environnementales:
X	X	X	MST 51 Cycle thermique (T50 ou T200)
X	X	X	MST 52 Humidité-gel (HF10)
X	X	X	MST 53 Chaleur humide (DH200 ou DH1000)
X	X	X	MST 54 Préconditionnement aux UV (15 kWh/m ² ou 60 kWh/m ²)
X ¹	X ¹	X ¹	MST 55 Conditionnement au froid
X ¹	X ¹	X ¹	MST 56 Conditionnement à chaleur sèche
X	X	X	Essai de contrôle général:
X	X	X	MST 01 Examen visuel
X	X	X	MST 02 Performances dans les conditions normales d'essais
X	X	X	MST 03 Détermination de la puissance maximale
X	X	-	MST 04 Epaisseur de l'isolant
X	X	X	MST 05 Durabilité des marquages
X	X	X	MST 06 Essai des angles vifs
X	X	-	Essais relatifs aux risques de chocs électriques:
X	X	-	MST 11 Essai d'accessibilité
X	X	-	MST 12 Essai de susceptibilité aux rayures
X	X	-	MST 13 Essai de continuité pour la liaison équipotentielle
X	X	-	MST 14 Essai de tension de choc
X	X	X	MST 16 Essai diélectrique
X	X	-	MST 17 Essai de courant de fuite en milieu humide
X	X	X	MST 42 Essai de robustesse des sorties
X	X	X	Essais relatifs aux risques de feu:
X	X	X	MST 21 Essai en température
X	X	X	MST 22 Essai de tenue à l'échauffement localisé
X ²	X ²	X ²	MST 23 Essai de résistance au feu
X	X	X	MST 24 Essai d'allumabilité
X	X	X	MST 25 Essai thermique de la diode de dérivation
X	X	-	MST 26 Essai de surcharge de courant inverse
X	X	X	Essais relatifs aux contraintes mécaniques:
X	X	X	MST 32 Essai de détérioration de module
X	X	X	MST 33 Essai des raccords vissés
X	X	X	MST 34 Essai de charge mécanique
X ^{3,5}	X ^{3,5}	X ^{3,5}	MST 35 Essai de pelage
X ^{4,5}	X ^{4,5}	X ^{4,5}	MST 36 Essai de cisaillement longitudinal
X	X	X	MST 37 Essai de fluage des matériaux
X Essai exigé. - L'essai peut ne pas être réalisé. ¹ Exigé uniquement dans le but de démontrer la réduction du degré de pollution PD=2 à PD=1. ² Les essais de résistance au feu sont réglementés au niveau national et ne sont habituellement exigés qu'aux fins de construction de produits intégrés ou ajoutés au bâtiment. Ainsi, l'applicabilité d'un essai de résistance au feu ne dépend pas de la classe, mais du lieu de montage. ³ Cet essai n'est pas applicable aux assemblages collés rigide sur rigide (p. ex.: modules PV verre/verre). ⁴ Cet essai n'est pas applicable aux assemblages collés rigide sur flexible ou flexible sur flexible. ⁵ Exigé seulement pour l'évaluation des joints collés sur les bords du module PV.			

6 Echantillonnage

Neuf modules PV et un module PV sans cadre sont utilisés pour les essais de sûreté (plus les pièces de rechange le cas échéant). Afin de démontrer la réduction du degré de pollution à PD 1, un module PV supplémentaire est nécessaire.

Si des joints collés doivent être qualifiés, les conditions suivantes sont exigées:

- pour les constructions verre/flexible et flexible/flexible, un module PV sans cadre est soumis à la séquence d'essai B (un module PV sans cadre supplémentaire est exigé);
- pour les constructions verre/verre, 20 échantillons supplémentaires prélevés conformément à 10.25.2 sont exigés pour l'essai de cisaillement longitudinal (MST 36) destiné à évaluer les joints collés.

Toutes les éprouvettes doivent être identiques d'un point de vue technique (mêmes composants). Pour le MST 24, le MST 32 et le MST 37, des modules PV complets jusque dans les moindres détails, mais ne fonctionnant pas ou présentant une faible puissance, etc., sont acceptables.

Toutes les éprouvettes d'essai, sauf pour le MST 24, le MST 32, le MST 35, le MST 36, et le MST 37, doivent être prélevées au hasard dans un ou de plusieurs lots de production.

Pour le MST 23, des modules PV supplémentaires pourraient être nécessaires (des modules PV complets jusque dans les moindres détails, mais ne fonctionnant pas ou présentant une faible puissance, etc., sont acceptables).

Les modules PV doivent avoir été fabriqués à partir des matériaux et composants spécifiés conformément aux schémas et fiches de procédés correspondants, et doivent avoir été soumis aux procédures normales d'inspection, de contrôle qualité et d'acceptation de la production du fabricant. Les modules PV doivent être complets jusque dans les moindres détails et doivent être accompagnés des instructions de manipulation, de montage et de connexion fournies par le fabricant. Lorsque les modules PV à soumettre aux essais sont des prototypes d'une nouvelle conception et non issus de la production, ce fait doit être noté dans le rapport d'essai (voir Article 7).

7 Rapport d'essai

Les résultats de l'évaluation selon l'IEC 61730-1 et l'IEC 61730-2 doivent être consignés dans un rapport d'essai combiné ou deux rapports d'essai distincts conformément à l'ISO/IEC 17025. Les résultats doivent être énoncés normalement dans un rapport d'essai et doivent inclure toutes les informations exigées par le client et nécessaires à l'interprétation de l'essai et toutes les informations exigées par la méthode utilisée:

- a) un titre;
- b) le nom et l'adresse du laboratoire d'essai, ainsi que le lieu où les essais ont été réalisés;
- c) l'identification unique du rapport et de chaque page;
- d) le nom et l'adresse du client, s'il y a lieu;
- e) la description et l'identification de l'élément soumis aux essais;
- f) la caractérisation et la condition de l'élément d'essai;
- g) la date de réception de l'élément d'essai, ainsi que la ou les dates de l'essai, s'il y a lieu;
- h) l'identification de la méthode d'essai utilisée;
- i) une référence à la procédure d'échantillonnage, s'il y a lieu;
- j) tout écart par rapport à la méthode d'essai, tout complément à la méthode d'essai ou toute exclusion de la méthode d'essai, et toute autre information pertinente pour les essais

spécifiques, telle que les conditions environnementales, la méthode d'essai ou la procédure d'essai;

- k) les mesures, les examens et les résultats dérivés appuyés par des tableaux, graphiques, croquis et photographies selon le cas, y compris la tension maximale des systèmes, la classe selon l'IEC 61140, la technique de montage et toutes les défaillances éventuelles observées;
- l) une déclaration indiquant si l'essai de tension de choc a été réalisé sur le module PV ou sur le stratifié (module PV sans cadre);
- m) une indication de l'incertitude estimée des résultats d'essai (s'il y a lieu);
- n) une signature et un titre, ou une identification équivalente de la ou des personnes acceptant d'être responsables du contenu du rapport, ainsi que la date d'édition;
- o) s'il y a lieu, une déclaration selon laquelle les résultats ne se rapportent qu'aux éléments soumis aux essais;
- p) une spécification indiquant que le rapport ne doit pas être reproduit sauf dans sa totalité, sans l'approbation écrite du laboratoire.

Une copie de ce rapport doit être conservée par le fabricant pour des besoins de référence.

8 Essais

Les modules PV doivent être divisés en groupes et soumis aux essais de sûreté représentés à la Figure 1, réalisés suivant l'ordre spécifié. Les modules PV doivent être choisis de telle manière à satisfaire aux essais relatifs aux contraintes environnementales de 4.2. Chaque encadré de la Figure 1 renvoie au paragraphe correspondant décrit à l'Article 4.

Les modules PV de rechange peuvent être inclus dans le programme d'essai de sûreté, à condition qu'ils aient été soumis aux essais adéquats de résistance à l'environnement afin de satisfaire aux prérequis nécessaires.

Les procédures et les critères d'essai, y compris les mesures initiales et finales si nécessaire, sont décrits de 10.2 à 10.33. Certains essais sont identiques à ceux de l'IEC 61215-2 et sont référencés à l'Article 4. En réalisant ces essais, les instructions de manipulation, de montage et de connexion fournies par le fabricant doivent être observées rigoureusement.

Le module PV de la séquence B doit être irradié durant le premier cycle à 60 kWh/m² à partir de la face avant de l'éprouvette et à partir de la face arrière de l'éprouvette durant le second cycle à 60 kWh/m² (MST 54). Ce faisant, la face avant et la face arrière du module PV seront exposées à la même dose d'UV.

Les mesures de contrôle intermédiaires (MST 01, MST 16, MST 17) après chaque essai de contrainte sont informatives et peuvent être ignorées. Des mesures finales sont nécessaires.

Le délai d'attente (48 h à 96 h) à la fin de la séquence doit assurer un délai minimal entre l'inspection de contrôle immédiate à l'issue de chaque essai de résistance à l'environnement (le délai commence à courir à la fin des essais MST 51, MST 52 et MST 53) et un second examen visuel. Cela permet de tenir compte de possibles variations de défauts visuels apparents quelques heures ou quelques jours après un essai de contrainte environnementale. Le délai d'attente ne s'applique pas aux vérifications de contrôle autres que l'examen visuel.

Les essais de la séquence F peuvent être réalisés sur des modules distincts. Les essais MST 21 et MST 25 peuvent être réalisés sur des échantillons spécialement préparés (thermocouples dans le stratifié ou la boîte de jonction, par exemple). Si l'un des essais individuels de la séquence a un impact sur le résultat de l'un des essais suivants, un échantillon distinct doit être utilisé. L'impact potentiel sur la sortie du module peut être vérifié par MST 02.

Le nombre de modules PV nécessaires pour l'essai de résistance au feu MST 23 dépendra de la procédure d'essai applicable.

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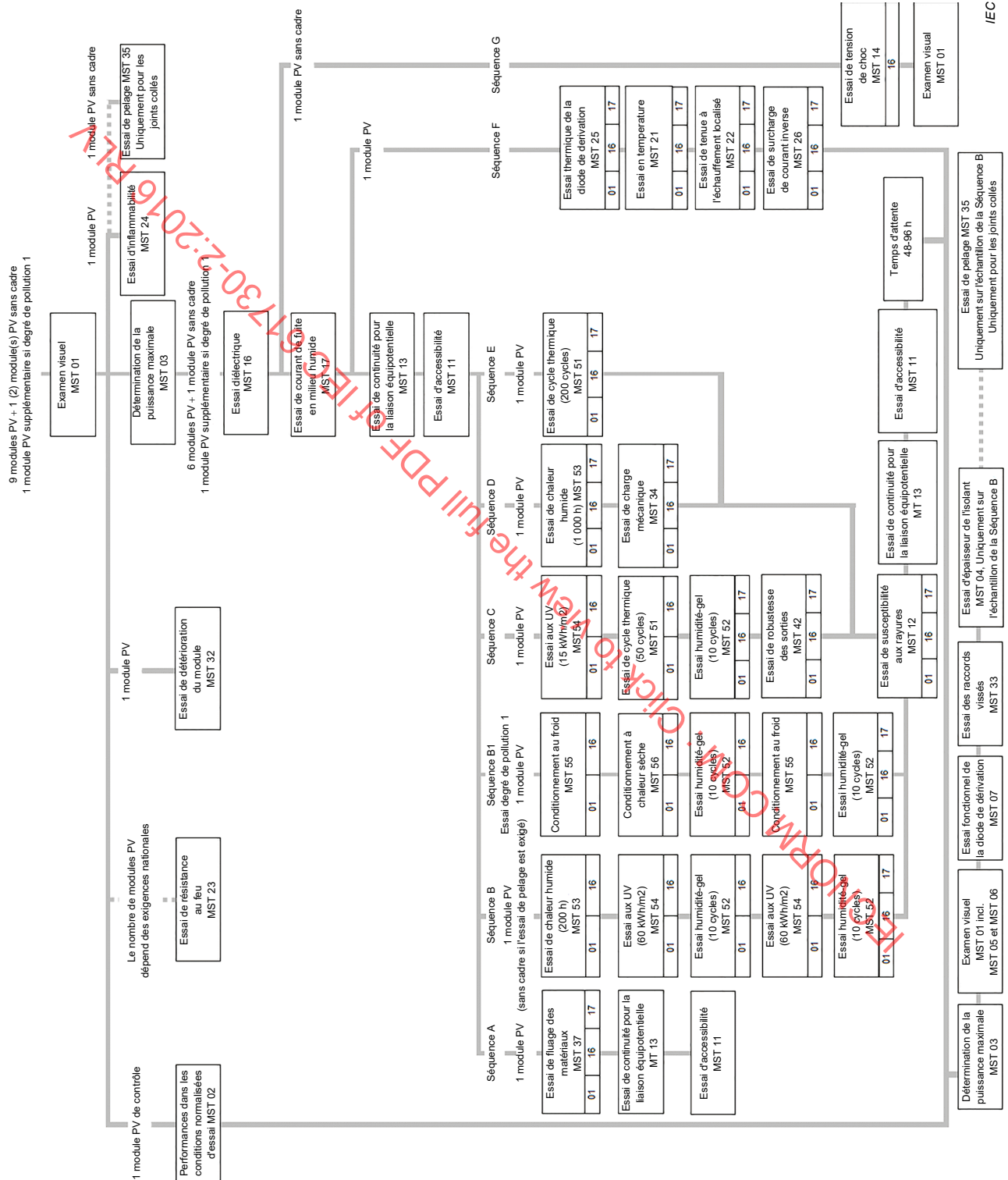


Figure 1 – Séquences d'essais

9 Critères d'acceptation

Le produit à évaluer doit être réputé avoir réussi l'essai de qualification pour la sûreté de fonctionnement si les échantillons d'essai satisfont à l'ensemble des critères de chaque essai individuel, et si aucune interruption de la continuité électrique ne se produit lors des essais de la séquence A à la séquence F. Le produit est reconnu non conforme à la présente norme si l'un des échantillons échoue à un ou plusieurs des essais.

En cas d'échec, il convient que le fabricant élabore une analyse des défaillances et propose des actions correctives. Selon la ou les modifications proposées, un programme de réévaluation peut être défini avant l'essai (IEC TS 62915), incluant une revue de conception selon l'IEC 61730-1.

10 Procédures d'essai

10.1 Généralités

Sauf spécification contraire, toutes les forces appliquées, en Newton (N), doivent présenter une précision de 5 %.

Sauf spécification contraire, tous les couples (Nm) doivent présenter une précision de 5 %.

10.2 Examen visuel MST 01

10.2.1 Objet

L'objectif de cet essai est de détecter et documenter les éventuels défauts visuels et modifications affectant le module PV.

10.2.2 Procédure

Cet essai est identique au MQT 01 de l'IEC 61215-2 auquel s'ajoutent les critères d'inspection suivants:

- toutes les autres conditions pouvant affecter la sûreté;
- lors de l'inspection finale, contrôler la conformité des marquages au 5.2 de l'IEC 61730-1:2016 après l'essai de durabilité des marquages (MST 05) décrit en 10.6;
- lors de l'inspection finale, contrôler les angles vifs de la manière décrite en 10.7 (MST 06);
- lors de l'inspection finale, vérifier les distances minimales définies aux Tableaux 3 et 4 de l'IEC 61730-1:2016. Voir exemples de mesure des lignes de fuite aux Figures 2a et 2b. Pour cette évaluation, les bulles sont réputées conductrices. Pour une évaluation des distances d'isolement et des lignes de fuite, se reporter à la Figure B.2 de l'IEC 61730-1:2016.

Il est recommandé de vérifier les distances lors de l'inspection initiale afin de valider le concept d'isolation du module PV.

Prendre note et/ou photographier la nature et l'emplacement des fissures, bulles ou décollements interlaminaires, etc., qui peuvent se détériorer et nuire à la sûreté du module PV dans la suite des essais. Des défauts visuels autres que les défauts majeurs répertoriés ci-dessous sont acceptables pour les besoins de la qualification de l'essai de sûreté.

10.2.3 Critères d'acceptation

Pour les besoins de cet essai de sûreté, les éléments ci-après sont considérés comme des défauts visuels majeurs:

- a) des surfaces externes cassées, fissurées ou déchirées;
- b) des surfaces extérieures (notamment la face avant, la face arrière, les cadres et les boîtes de jonction) gauchies ou désalignées au point que la sûreté du module PV en serait affectée;
- c) dans les joints collés, les bulles ou décollements interlaminaires présentant les plus courtes distances entre eux ≤ 2 fois la distance minimale exigée à travers le joint collé (voir Tableau 3 et Tableau 4 de l'IEC 61730-1:2016) doivent être évalués comme étant conducteurs et raccordés électriquement. En somme, la plus courte distance entre ces bulles ou décollements interlaminaires à travers le matériau isolant ne doit pas être inférieure à la distance minimale exigée à travers le joint collé. Voir Figure 2b pour consulter un exemple;
- d) pour les collages adhésifs autres que ceux répertoriés en c), les bulles ou décollements interlaminaires présentant les plus courtes distances entre eux ≤ 2 fois la ligne de fuite minimale exigée (voir Tableaux 3 et 4 de l'IEC 61730-1:2016) doivent être évalués comme étant conducteurs et raccordés électriquement. En somme, la plus courte distance entre ces bulles ou décollements interlaminaires à travers le matériau isolant ne doit pas être inférieure à la ligne de fuite minimale exigée, voir Figure 2b pour consulter un exemple;
- e) la perte d'intégrité mécanique au point que la sûreté de l'installation et le fonctionnement du module PV en seraient affectés;
- f) si l'intégrité mécanique dépend de la stratification ou d'autres dispositifs d'adhérence, la somme de la surface des bulles ne doit pas dépasser 1 % de la surface totale du module PV;
- g) un signe évident qu'un composant a fondu ou a brûlé;
- h) des marquages non conformes à 5.2 de l'IEC 61730-1:2016 et à l'essai de durabilité des marquages (MST 05) lors de l'inspection finale;
- i) des angles non conformes à l'essai des angles vifs (MST 06) lors de l'inspection finale.

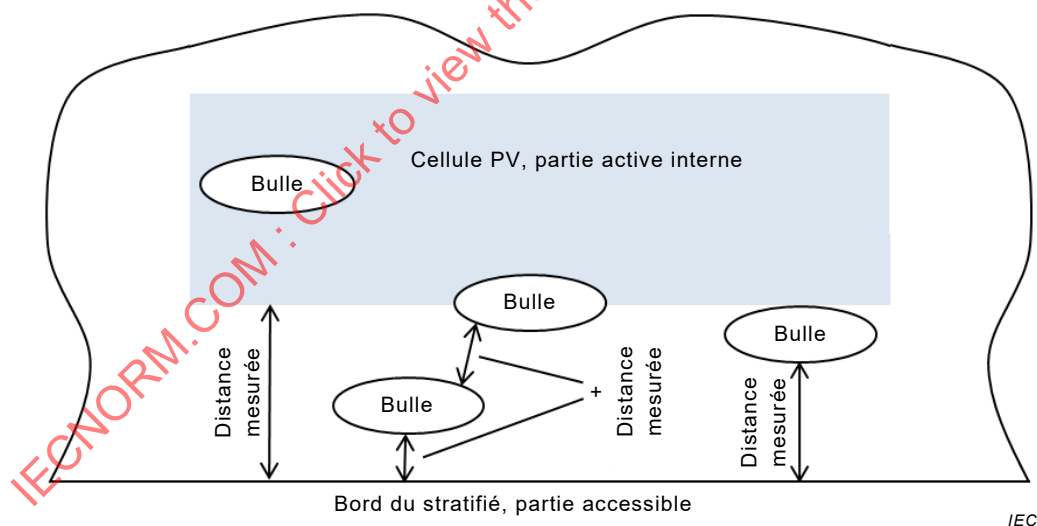


Figure 2a – Exemple d'évaluation des décollements interlaminaires lors de la mesure des lignes de fuite ou des distances à travers l'isolant

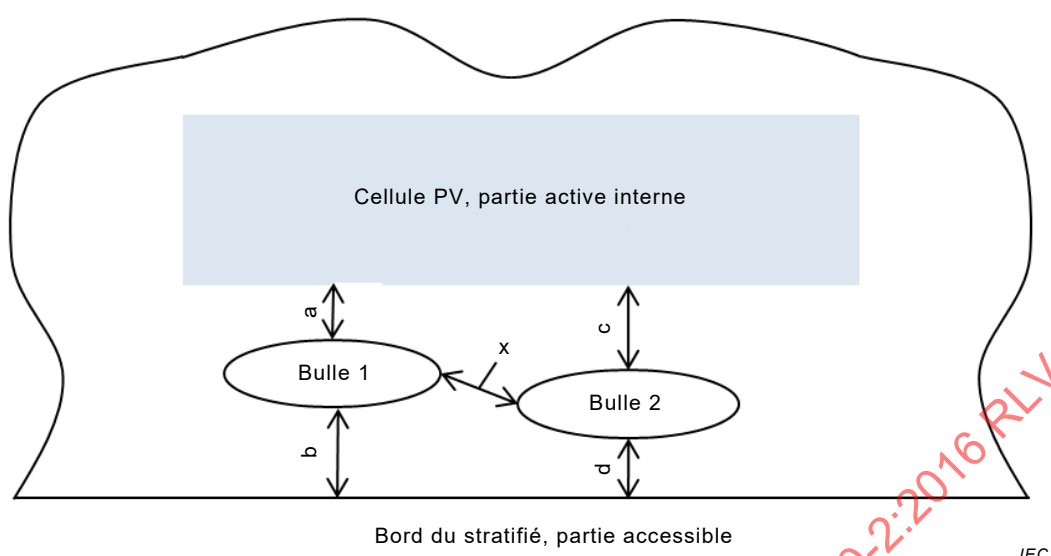


Figure 2b – Exemple d'évaluation de la distance des décollements interlaminaires (x) lors de la mesure des lignes de fuite ou des distances à travers l'isolant

Figure 2 – Evaluation des bulles dans les joints de bordure des joints collés

Exemple de joint collé:

Si la distance x entre les bulles est ≤ 2 fois la distance minimale à travers le joint collé, le plus court trajet à travers l'isolant serait alors mesuré en additionnant les distances a et d . Si la distance x entre les bulles est > 2 fois la distance minimale à travers le joint collé, le plus court trajet serait alors mesuré en additionnant les distances a et b et respectivement en additionnant les distances c et d . La plus courte distance des deux sommes doit satisfaire aux exigences définies dans l'IEC 61730-1.

Exemple de ligne de fuite:

Si la distance x entre les bulles est ≤ 2 fois la ligne de fuite minimale, le plus court trajet le long d'une interface (ligne de fuite) à travers le système d'isolation serait alors mesuré en additionnant les distances a et d . Si la distance x entre les bulles est > 2 fois la ligne de fuite minimale, le plus court trajet le long d'une interface (ligne de fuite) à travers le système d'isolation serait alors mesuré en additionnant les distances a et b et respectivement en additionnant les distances c et d . La plus courte distance des deux sommes doit satisfaire aux exigences définies dans l'IEC 61730-1.

10.3 Performances dans les conditions normales d'essais MST 02

10.3.1 Objet

Cet essai doit vérifier le courant de court-circuit assigné (I_{sc}) et la tension en circuit ouvert (V_{oc}).

10.3.2 Procédure

Le module doit être stabilisé conformément au MQT 19.1 de l'IEC 61215-2. La procédure d'essai est équivalente à celle du MQT 06.1 de l'IEC 61215-2.

10.3.3 Critères d'acceptation

Les valeurs I_{sc} et V_{oc} mesurées doivent être comprises dans les tolérances fournies par le fabricant.

10.4 Détermination de la puissance maximale MST 03

10.4.1 Objet

Cet essai doit vérifier que le module PV présente les caractéristiques électriques d'un dispositif photovoltaïque entièrement fonctionnel.

10.4.2 Procédure

Cet essai est équivalent au MQT 02 de l'IEC 61215-2.

10.4.3 Critères d'acceptation

La courbe I-V ne doit pas présenter de déviations additionnelles ou d'autres caractéristiques inhabituelles par rapport à la courbe I-V initiale prise en compte conformément au MST 02 (résultant d'une "activation" des diodes, par exemple).

NOTE Des dégradations particulièrement hétérogènes des modules PV provoquent des risques de sécurité et des défaillances. Des dégradations de cellules uniques ou de sous-séries peuvent provoquer des échauffements localisés, des températures élevées des modules ou une conduction permanente des diodes. L'objectif du MST 03 est de détecter de tels cas.

10.5 Essai d'épaisseur de l'isolant MST 04

10.5.1 Objet

Cet essai doit vérifier la conformité à l'épaisseur de l'isolant minimale pour les couches minces, spécifiée au Tableau 3 ou au Tableau 4 de l'IEC 61730-1:2016, en fonction de la classe du module PV conformément à l'IEC 61140.

L'essai doit être réalisé sur la face avant et/ou la face arrière de feuilles d'isolation en polymères.

Cet essai n'est pas applicable aux couches de verre.

10.5.2 Procédure

La procédure est la suivante:

- a) Choisir trois emplacements par côté du module PV représentant l'épaisseur minimale du matériau d'isolation en polymères.

NOTE 1 Des épaisseurs minimales habituelles peuvent être trouvées aux liaisons de brasage, aux coins des modules PV sans cadre ou aux indentations de la membrane par la plastifieuse.

- b) En utilisant une méthode adéquate, mesurer l'épaisseur des couches séparant le circuit électrique de la surface externe. La méthode utilisée doit présenter une incertitude de mesure inférieure ou égale à $\pm 10\%$, compte tenu de la reproductibilité. Déterminer ensuite l'épaisseur de la partie des couches représentant l'isolation attendue (voir Figure 4 de l'IEC 61730-1:2016).

NOTE 2 Les méthodes adéquates peuvent être destructives ou non destructives (par exemple, coupe transversale et mesure optique; mesures ultrasoniques, etc.). La méthode au fil à souder est à l'étude pour la mesure des distances à travers l'isolation dans la série IEC 62788.

10.5.3 Critères d'acceptation

L'épaisseur de l'isolant mesurée doit être supérieure aux exigences répertoriées au Tableau 3 ou au Tableau 4 de l'IEC 61730-1:2016 en fonction de la classe du module PV conformément à l'IEC 61140 et en tenant compte de l'incertitude de mesure de l'équipement d'essai.

Les épaisseurs de couche données au Tableau 3 et au Tableau 4 de l'IEC 61730-1:2016 constituent des exigences minimales, c'est pourquoi l'incertitude de mesure doit être déduite de la valeur mesurée.

Exemple: pour une tension de système de 1 000 V et une conception de module PV conforme à la classe II, l'épaisseur restante de l'isolation attendue doit s'élever à 150 μm . Si l'incertitude de mesure de l'équipement est de $\pm 10\%$, la valeur mesurée doit être supérieure ou égale à 165 μm .

10.6 Essai de durabilité des marquages MST 05

Tout marquage exigé au titre de la présente norme doit être durable et lisible. Pour l'examen de la durabilité du marquage, l'effet de l'utilisation normale doit être pris en compte.

La conformité est contrôlée par inspection et en frottant à la main le marquage pendant 15 s avec un morceau de chiffon imbibé d'eau en appliquant une pression moyenne, puis à nouveau pendant 15 s avec un morceau de chiffon imbibé d'essence minérale. Après cet essai, le marquage doit être lisible et les plaques de marquage ne doivent pas pouvoir être déposées facilement et ne doivent pas présenter de gondolage.

L'essence minérale à utiliser pour l'essai est un solvant aliphatique ayant un contenu maximal d'aromatique de 0,1 % en volume, un indice Kauri butanol de 29, un point d'ébullition initial d'environ 65 °C, un point de séchage d'environ 69 °C et une masse par unité de volume d'environ 0,7 kg/l.

NOTE Cet essai est identique à celui de l'IEC 60335-1:2013, 7.14 et de l'IEC 60950-1:2005, 1.7.11.

10.7 Essai des angles vifs MST 06

Les surfaces accessibles du module PV doivent être lisses et dépourvues d'angles vifs, bavures, etc., qui peuvent endommager l'isolation des conducteurs ou occasionner un risque de blessure. La conformité est vérifiée par examen.

Sinon, l'essai des angles vifs décrit dans l'ISO 8124-1 peut être réalisé aux fins de contrôle de conformité.

10.8 Essai fonctionnel de la diode de dérivation MST 07

La procédure d'essai et les critères d'acceptation sont équivalents à ceux du MQT 18.2 de l'IEC 61215-2.

10.9 Essai d'accessibilité MST 11

10.9.1 Objet

L'objectif de cet essai est de déterminer si la construction des modules PV permet une protection adéquate contre l'accessibilité aux parties sous tension dangereuses (> 35 V).

10.9.2 Appareillage

L'appareillage est le suivant:

- a) un dispositif d'essai cylindrique de Type 11 conformément à la Figure 7 de l'IEC 61032:1997;
- b) un ohmmètre ou dispositif d'essai de continuité.

10.9.3 Procédure

La procédure est la suivante:

- a) Monter et connecter le module PV d'essai selon les recommandations du fabricant.
- b) Fixer l'ohmmètre ou dispositif d'essai de continuité aux bornes court-circuitées du module PV et au dispositif d'essai.
- c) Retirer tous les couvercles, les fiches et les connexions du module PV qui peuvent être enlevés sans l'aide d'un outil.
- d) Examiner avec le dispositif d'essai dans et autour de l'ensemble des connecteurs électriques, des boîtes de jonction et autres zones où les parties sous tension du module PV peuvent être accessibles.

- e) Le dispositif d'essai doit être utilisé avec une force appliquée de 10 N.
- f) Contrôler l'ohmmètre ou le dispositif d'essai de continuité au cours de l'essai afin de déterminer si le dispositif d'essai établit un contact électrique avec les parties sous tension du module PV.

10.9.4 Mesures finales

Aucune.

10.9.5 Critères d'acceptation

Les critères d'acceptation sont les suivants:

- a) A aucun moment au cours de l'essai, il ne doit y avoir une résistance inférieure à $1\text{ M}\Omega$ entre le dispositif d'essai et les parties sous tension du module PV.
- b) A aucun moment au cours de l'essai la sonde ne doit être en contact avec une partie active électrique.

Cet essai est réalisé au début et à la fin de la séquence conformément à la Figure 1, mais peut également être utilisé à n'importe quel moment au cours de la séquence d'essais s'il y a toute raison de croire que les circuits électriques actifs ont été exposés par l'un des autres essais.

10.10 Essai de susceptibilité aux rayures MST 12

10.10.1 Objet

L'objectif de cet essai est de déterminer si les surfaces avant et arrière du module PV en matériaux polymères sont capables de résister aux manipulations quotidiennes au cours de l'installation et de l'entretien sans exposer le personnel au danger de choc électrique.

Cet essai n'est pas applicable aux assemblages collés rigide sur rigide (p. ex.: modules PV verre/verre).

10.10.2 Appareillage

Le dispositif d'essai est celui représenté à la Figure 3, destiné à tirer un objet façonné défini sur la surface du module PV avec une force appliquée de $8,9\text{ N} \pm 0,5\text{ N}$. L'objet façonné défini doit être une lame en acier trempé de $0,64\text{ mm} \pm 0,05\text{ mm}$ d'épaisseur, suffisamment rigide pour ne pas se plier latéralement pendant l'essai. La pointe doit avoir un angle d'orientation de $90^\circ \pm 2^\circ$ et doit être arrondie suivant un rayon de $0,115\text{ mm} \pm 0,025\text{ mm}$.

L'appareillage de la Figure 3 est un exemple. D'autres appareillages présentant les mêmes paramètres d'essai (notamment la force et la forme de base) peuvent également être utilisés, si leur équivalence a fait l'objet d'une vérification.

10.10.3 Procédure

La procédure est la suivante:

- a) Positionner le module PV horizontalement, la surface d'essai étant orientée vers le haut.
- b) Le dispositif d'essai doit être placé sur la surface pendant 1 min, puis déplacé sur la surface du module PV à une vitesse de $150\text{ mm/s} \pm 30\text{ mm/s}$. Répéter la procédure cinq fois dans des directions différentes en tenant compte des points les plus critiques.
- c) Répéter a) et b) pour les autres surfaces polymériques du module PV s'il y a lieu.

10.10.4 Mesures finales

Répéter le MST 01, le MST 16 et le MST 17.