UL 61730-2

STANDARD FOR SAFETY

Photovoltaic (PV) Module Safety Qualification – Part 2: Requirements for Testing

UL Standard for Safety for Photovoltaic (PV) Module Safety Qualification – Part 2: Requirements for Testing, UL 61730-2

Second Edition, Dated October 28, 2022

Summary of Topics

This new edition of ANSI/UL 61730-2 dated October 28, 2022 includes the following changes in requirements:

- ***Update of IEC TS 62915 References to UL 62915***
- ***Correction of Clause DVA.1 to Correlate with the Intent of Clause DVA.3***
- ***Change Fire Type Glass Description in Table 10.17DV.4.6.1 to not Overlap***
- ***New Fire Type Additions 35 – 40 in Fire Type Testing, Section 10.17DV.4***

UL 61730-2 second edition is an adoption of IEC 61730-2, Photovoltaic (PV) Module Safety Qualification – Part 2: Requirements for Testing (Second Edition, issued by the IEC August 2016). Please note that the National Difference document incorporates all of the U.S. national differences for UL 61730-2.

The new and revised requirements are substantially in accordance with Proposal(s) on this subject dated July 8, 2022.

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OCTOBER 28, 2022

ANSI/UL 61730-2-2022

UL 61730-2

Photovoltaic (PV) Module Safety Qualification – Part 2: Requirements for Testing

First Edition – December, 2017

Second Edition

October 28, 2022

This ANSI/UL Standard for Safety consists of the Second Edition.

The most recent designation of ANSI/UL 61730-2 as an American National Standard (ANSI) occurred on October 28, 2022. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, Title Page, or Preface. The National Difference Page and IEC Foreword are also excluded from the ANSI approval of IEC-based standards.

Comments or proposals for revisions on any part of the Standard may be submitted to UL at any time. Proposals should be submitted via a Proposal Request in UL's On-Line Collaborative Standards Development System (CSDS) at https://csds.ul.com.

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PREFACE

This UL Standard is based on IEC Publication IEC 61730-2: Second edition Photovoltaic (PV) Module Safety Qualification – Part 2: Requirements for Testing. IEC publication IEC 61730-2 is copyrighted by the IEC.

This edition has been issued to satisfy UL Standards policy and to align the UL edition number with the IEC edition number.

Note – Although the intended primary application of this Standard is stated in its Scope, it is important to note that it remains the responsibility of the users of the Standard to judge its suitability for their particular purpose.

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NATIONAL DIFFERENCES

National Differences from the text of International Electrotechnical Commission (IEC) Publication IEC 61730-2, Photovoltaic (PV) Module Safety Qualification – Part 2: Requirements for Testing, copyright 2016, are indicated by notations (differences) and are presented in bold text.

There are five types of National Differences as noted below. The difference type is noted on the first line of the National Difference in the standard. The standard may not include all types of these National Differences.

DR – These are National Differences based on the **national regulatory requirements**.

D1 – These are National Differences which are based on **basic safety principles and requirements**, elimination of which would compromise safety for consumers and users of products.

D2 – These are National Differences from IEC requirements based on existing **safety practices**. These requirements reflect national safety practices, where empirical substantiation (for the IEC or national requirement) is not available or the text has not been included in the IEC standard.

DC – These are National Differences based on the **component standards** and will not be deleted until a particular component standard is harmonized with the IEC component standard.

DE – These are National Differences based on **editorial comments or corrections**.

Each national difference contains a description of what the national difference entails. Typically one of the following words is used to explain how the text of the national difference is to be applied to the base IEC text:

Addition / Add - An addition entails adding a complete new numbered clause, subclause, table, figure, or annex. Addition is not meant to include adding select words to the base IEC text.

Modification / Modify - A modification is an altering of the existing base IEC text such as the addition, replacement or deletion of certain words or the replacement of an entire clause, subclause, table, figure, or annex of the base IEC text.

Deletion / Delete - A deletion entails complete deletion of an entire numbered clause, subclause, table, figure, or annex without any replacement text.

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FOREWORD

INTERNATIONAL ELECTROTECHNICAL COMMISSION

PHOTOVOLTAIC (PV) MODULE SAFETY QUALIFICATION – Part 2: Requirements for testing

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as “IEC Publication(s)”). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and nongovernmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.

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6) All users should ensure that they have the latest edition of this publication.

7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.

8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.

9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

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 cm^2 instead of 6,5 cm^2).

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.

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PHOTOVOLTAIC (PV) MODULE SAFETY QUALIFICATION – Part 2: Requirements for Testing

1 Scope

The scope of IEC 61730-1 is also applicable to this part of IEC 61730. While IEC 61730-1 outlines the requirements of construction, this 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*

2DV DR *Addition of the following:*

UL 790, *Standard Test Methods for Fire Tests of Roof Coverings*

UL 2703, *Mounting Systems, Mounting Devices, Clamping/Retention Devices, and Ground Lugs for Use with Flat-Plate Photovoltaic Modules and Panels*

UL 62915, *Photovoltaic (PV) Modules – Type Approval, Design and Safety Qualification – Retesting*

ANSI/NFPA 70, *National Electrical Code*

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 Module safety tests are labelled MST.

Table 1 to Table 5 show the origin of the required tests. For some tests, the third column shows for information the origin of the tests, but the appropriate test requirements are given in Clauses 10.1 and 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 test	–	**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	IEC 60950-1	–
MST 05	Durability of markings	ISO 8124-1	–
MST 06	Sharp edge test	–	–
MST 07	Bypass diode functionality test	–	–

Table 2DV D2 *Modification of Table 2:*

Delete the line for MST 04.

4.4 Electric 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.			

Table 4DV DR *Modification of Table 4:*

Delete the line for MST 24.

4.6 Mechanical stress tests

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

Table 5
Mechanical stress tests

Test	Title	References in 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.

Table 6
Required tests, depending on the Class

Class according to IEC 61140			Tests
II	0	III	
			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
			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
			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
			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
			Mechanical stress tests:
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 needs not 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.

Table 6 Continued on Next Page

Table 6 Continued

Class according to IEC 61140			Tests
II	0	III	
[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.			

Table 6DV D2 *Modification of Table 6:*

Delete the line for MST 04 and also delete the line for MST 24.

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/m^2 cycle from the front side of the specimen and from the backside during the second 60 kWh/m^2 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.

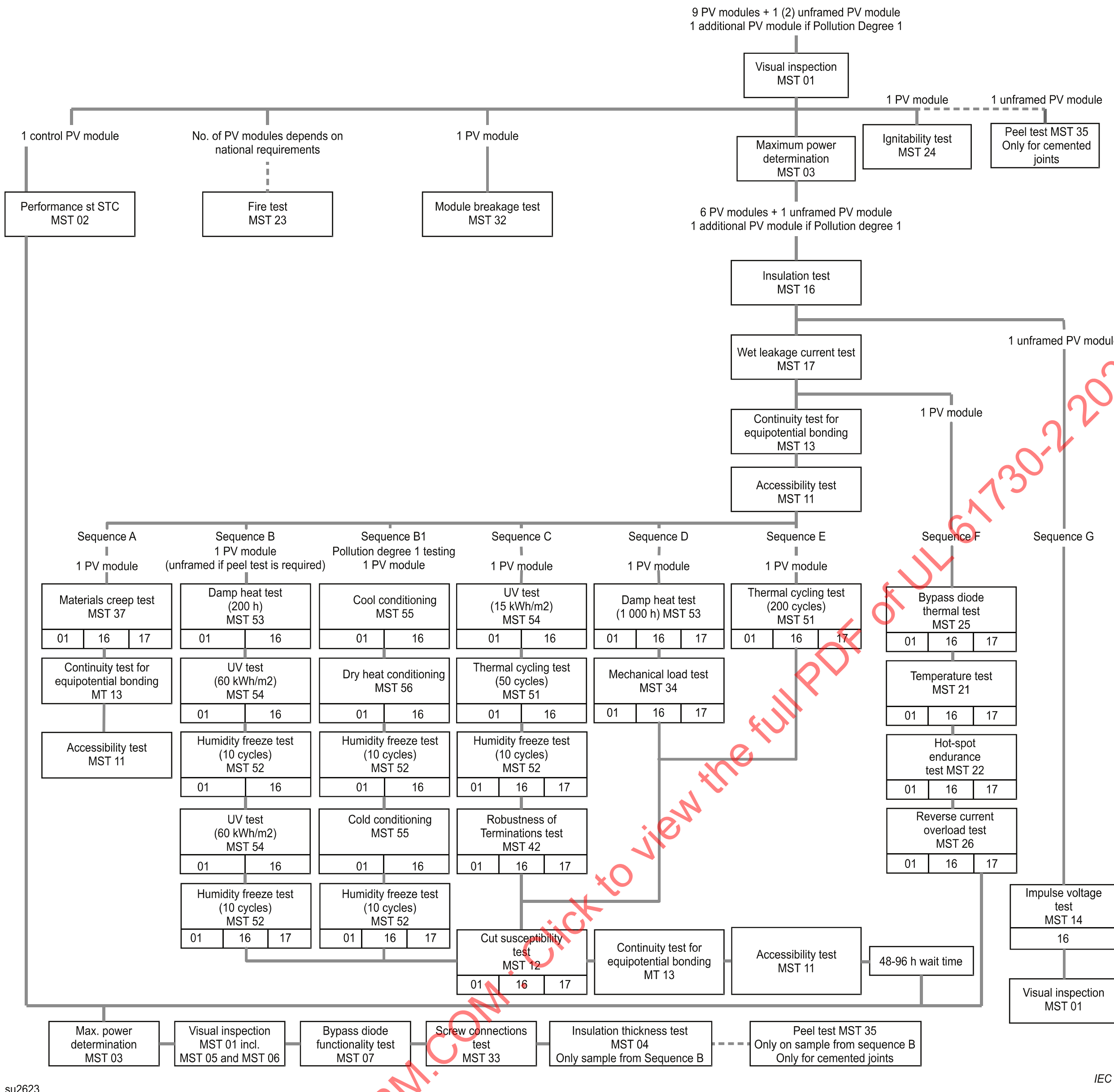

Figure 1

Test sequences

Figure 1DV D2 ***Modification of Figure 1:***

Delete the box for MST 04 and also delete the box for MST 24.

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.

9DV D1 ***Modification in accordance with the following:***

Replace the reference to IEC TS 62915 with UL 62915 in the second paragraph.

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 Figure 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.

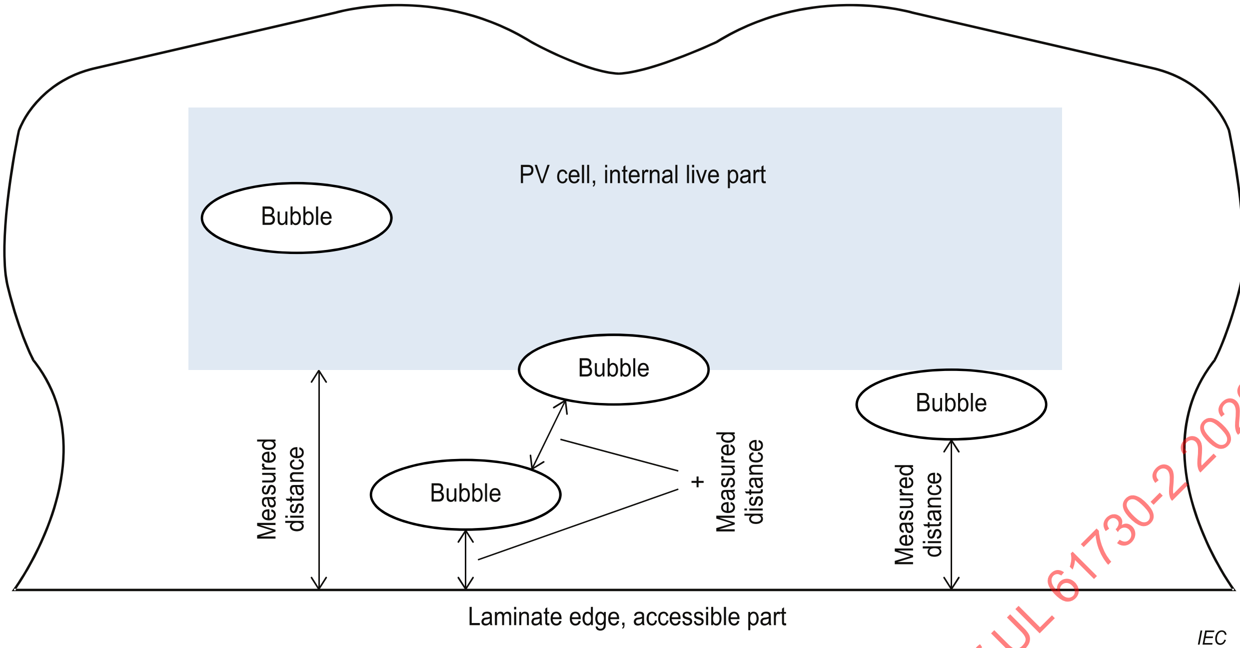

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Figure 2a – Example for delamination assessment when measuring creepage or distance through insulation

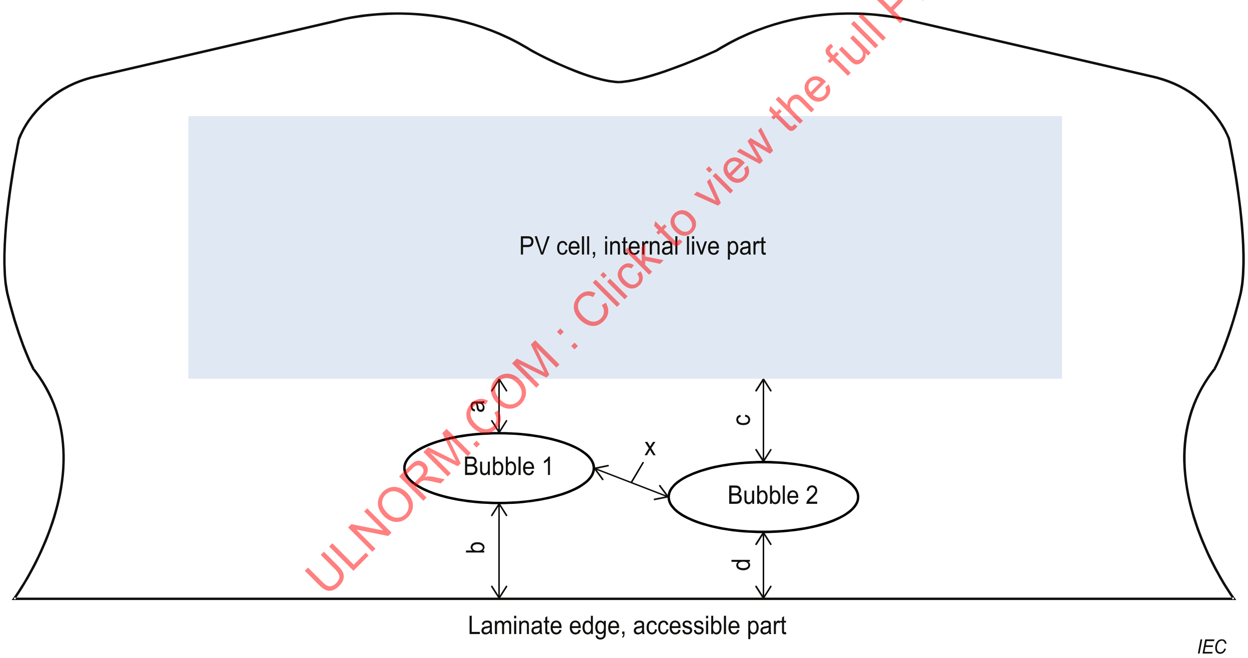

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Figure 2b – Example for delamination distance (x) assessment when measuring creepage or distance through insulation

Figure 2

Assessment of bubbles in edge seals for cemented joints

Example cemented joint:

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

Example creepage distance:

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

10.3 Performance at STC MST 02

10.3.1 Purpose

This test shall verify the rated short-circuit current (I_{sc}) and open-circuit voltage (V_{oc}).

10.3.2 Procedure

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

10.3.3 Pass criteria

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

10.4 Maximum power determination MST 03

10.4.1 Purpose

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

10.4.2 Procedure

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

10.4.3 Pass criteria

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

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

10.5 Insulation thickness test MST 04

10.5.1 Purpose

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

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

This test is not applicable to glass layers.

10.5.2 Procedure

The procedure is as follows:

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

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

b) Applying a suitable method, measure the thickness of the individual layers separating the electric circuitry from the outer surface. The used method shall have a measurement uncertainty not greater than ±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.

10.5DV D2 *Deletion:*

Delete Clause 10.5.

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).

10.9.1DV DR *Modification by replacing Clause 10.9.1 with the following:*

To determine if PV modules are constructed to provide adequate protection against accessibility to hazardous live parts (> 30 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 N ± 0,5 N. The defined shaped object shall be a 0,64 mm ± 0,05 mm thick hardened steel blade sufficiently rigid as not to bend sideways during the test. The tip shall have a top angle of 90° ± 2° and shall be rounded with a radius of 0,115 mm ± 0,025 mm.

Apparatus in Figure 3 is an example and other apparatus proving same test parameters (e.g. force and scratch shape) can also be used if equivalency is verified.

10.10.3 Procedure

The procedure is as follows:

a) Position the PV module horizontally with the test surface facing upward.

b) The test fixture is to be placed on the surface for 1 min and then drawn across the surface of the PV module at a speed of 150 mm/s ± 30 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

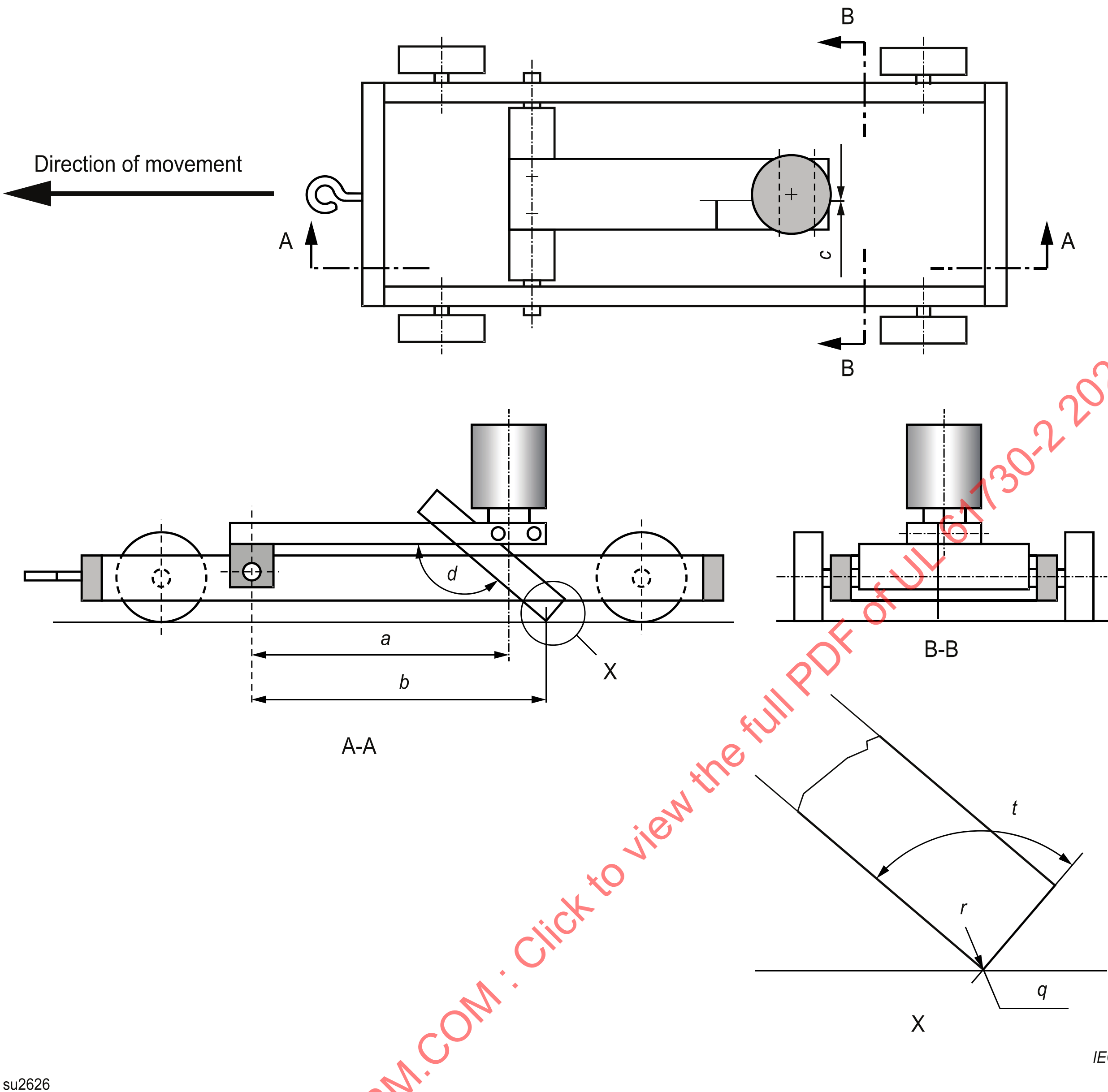
Repeat MST 01, MST 16 and MST 17.

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 mm ± 0,05 mm thick

d 140° angle between horizontal plane and the strips' edge

q Total force exerted at test point 8,9 N ± 0,5 N

r Tip rounded with radius 0,115 mm ± 0,025 mm

t Steel strip top angle 90° ± 2°

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 % ± 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 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).

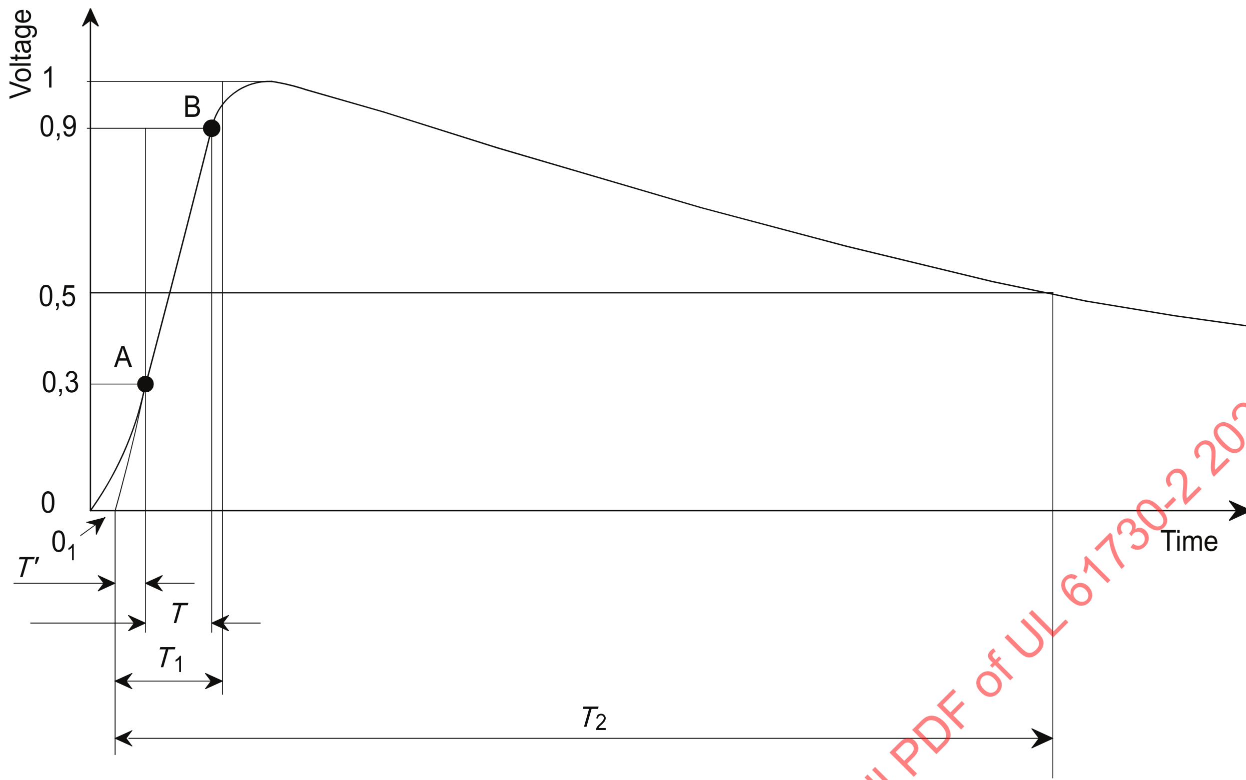
10.12 Impulse voltage test MST 14

10.12.1 Purpose

The purpose of the test is to verify the capability of 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.



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T_1 = 1,2 μs ± 30 %

T_2 = 50 μs ± 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:

a) Disable any voltage limiting device installed on the PV module, if applicable.

b) Cover the whole PV module with a conductive metal foil using a conductive adhesive to achieve best possible contacting and avoid e.g. bubbles that may influence the test result. The adhesive (conducting glue) shall have an electrical resistance < 1 Ω 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.

c) Connect the shorted output terminals of the PV module to the positive terminal of the impulse voltage generator.

d) 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 ± 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.

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 measurements

Repeat visual inspection MST 01 and insulation test MST 16.

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

10.12.5 Pass criteria

The pass criteria are as follows:

a) No evidence of dielectric breakdown or surface tracking of the PV module is observed during the test.

b) No evidence of major visual defects as defined in MST 01.

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

10.13 Insulation test MST 16

10.13.1 Purpose

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

10.13.2 Procedure

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

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

10.13.3 Pass criteria

See MQT 03 of IEC 61215-2.

10.14 Wet leakage current test MST 17

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

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

10.15 Temperature test MST 21

10.15.1 Purpose

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

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

10.15.2 Outdoor method

10.15.2.1 Test apparatus

• A black painted platform constructed of a suitable wooden plate that has sufficient mechanical strength to avoid warping under temperature influence. Behind the board a thermal insulation with a *U* value of less than 0,5 W/(m·K) shall be placed.

• A pyranometer or PV reference device conforming to IEC 60904-2 mounted in the plane of the structure within 30 cm of the test PV module.

• Instruments to measure wind speed down to 0,25 m/s installed approximately 0,7 m above the top of the platform.

• An environmental temperature sensor, with a time constant equal to, or less than, that of the PV module, installed in a shaded enclosure with good ventilation. The sensor shall be placed left or right of the platform so that no thermal interference can occur.

• A temperature monitoring system capable of measuring PV module component temperatures with accuracy of ±2 K.

• A data acquisition system capable of recording the parameters within an interval of no more than 5 s.

• Maximum power point tracking device or a resistive load sized such that at STC the PV module operates near the maximum power point.

10.15.2.2 Procedure

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

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

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

Throughout the test the following parameters shall be monitored:

• temperatures of PV module components and materials, as listed below;

• environmental temperature;

• irradiance;

• wind speed.

The environmental temperature during the test may be in the range of 20 °C to 45 °C. The irradiance during the test shall be between 700 W/m^2 and 1 000 W/m^2.

If the irradiance is other than 1 000 W/m^2, take at least two measurements at other irradiance levels (at least 80 W/m^2 apart) and then make a quadratic extrapolation to determine the corrected module temperature at 1 000 W/m^2 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:

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

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/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 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

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

where T_{CON} is the normalised temperature.

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

Typical component measurement points shall include:

• PV module frontsheet above the centre cell, if non-glass (possible shading of cells by temperature sensor shall be avoided as much as possible).

• PV module backsheet below the centre cell.

• Terminal enclosure interior surface.

• Field wiring terminals.

• Insulation of the field wiring leads.

• External connector bodies (if applicable).

• Bypass diode bodies (if applicable).

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

10.15.4 Pass criteria

The pass criteria are as follows:

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

b) No visual defects as defined in MST 01.

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

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

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.

10.17DV DR ***Modification by replacing Clause 10.17 with the following new Fire test MST 23:***

10.17DV.1 Introduction

A photovoltaic module or panel intended to be mounted or installed on a roof shall be evaluated for fire performance in accordance with 10.17DV.2 or 10.17DV.3, whichever applies. System Fire Class Ratings A, B, or C are only relevant for PV modules or panels with mounting systems in combination with a fire rated roof covering. Mounting systems evaluated in accordance with 10.17DV.3 may be tested with specific “types” of modules as characterized in accordance with 10.17DV.4.

10.17DV.2 Building-Integrated PV Modules

Modules or panels intended for installation integral with or forming a part of the building’s roof structure are referred to as building-integrated photovoltaics (BIPVs) and shall be evaluated in accordance with UL 790, as a Class A, B, or C roof covering material or roof covering system.

10.17DV.3 Building-attached photovoltaic module

Modules that are building-attached PV not building-integrated and are intended for stand-off or rack mounting in combination with a roof covering shall be evaluated in accordance with the tests described in UL 2703, Fire Tests with respect to the fire performance requirements for Class A, B, or C when the module is marked as being fire rated as specified in UL 61730-1, Clause 5.2.2.1. The module with its mounting system is to be evaluated for Class A, B, or C so that the appropriate System Fire Class Rating can be used for building code compliance purposes.

10.17DV.4 Fire Type Testing

10.17DV.4.1 A module intended for mounting on a roof may be represented by type in accordance with the procedure given below, using the test method provided in Annex DVB of this document. This is done to simplify the evaluation of module types, roof-mounting configurations, and mounting systems. The use of fire typing as given in this section is optional.

10.17DV.4.2 A module intended for mounting on a roof (but not BIPVs) can be classified according to type based on its construction and the results of the fire tests detailed in Annex DVB, Spread of Flame on Top Surface (Section DVB.2) and Burning Brand on Top Surface (Section DVB.3). Module construction types shall be evaluated based on the following characteristics of PV module and construction: (1) the superstrate material; (2) the encapsulant material; (3) the substrate material; and, (4) the frame type and geometry (if any). The following types are representative of common module constructions and their associated fire characteristics:

10.17DV.4.3 A Type 1, 4, or 7 module meets the following requirements:

a) Construction: Glass superstrate of 2.8 mm (0.11 in) ≤ thickness ≤ 4.4 mm (0.17 in); a polymeric encapsulant between the superstrate and cells with a pre-lamination thickness of 0,5 ± 0,3 mm (0,02 ± 0,012 in); either a polymeric encapsulant between the cells and substrate with a pre-lamination thickness of 0,5 ± 0,3 mm (0,02 ± 0,012 in) and a polymeric substrate with nominal thickness no less than 0,30 mm (0,012 in) and no more than 0,64 mm (0,025 in) thickness or a combined substrate and encapsulant that meets the pre-lamination total thickness equal to an encapsulant thickness of 0,45 ±0,2 mm (0,018 ± 0,008 in) and a polymeric substrate with nominal thickness no less than 0,30 mm (0,012 in) and no more than 0,64 mm thickness (0,025 in); and metallic framing protecting the edge of the laminate.

b) Spread of Flame Test on Top Surface: The test shall be conducted using the procedure given in Section DVB.2. For Type 1, the allowable spread of flame of 1,82 m (6 feet) or less in 10 minutes. For Type 4, the allowable spread of flame is 3,96 m (13 feet) or less in 4 minutes. For Type 7, the allowable spread of flame is 2,4 m (8 feet) or less in 10 minutes.

c) Burning Brand Test on Top Surface: The test shall be conducted using the procedure given in Section DVB.3 using a C Brand. For Type 1, 4, and 7, passing results using a C Brand shall be demonstrated.

10.17DV.4.4 A Type 2, 5, or 8 module meets the following requirements:

a) Construction: Glass superstrate of 2.8 mm (0.11 in) ≤ thickness ≤ 4.4 mm (0.17 in); a polymeric encapsulant between the superstrate and cells with a pre-lamination thickness of 0,5 ± 0,3 mm (0,02 ± 0,012 in); either a polymeric encapsulant between the cells and substrate with a pre-lamination thickness of 0,5 ± 0,3 mm (0,02 ± 0,012 in) and a polymeric substrate with nominal thickness between 0,025 mm (0,001 in) and 0,30 mm thickness (0,012 in) or a combined substrate and encapsulant that meets the pre-lamination total thickness equal to an encapsulant thickness of 0,5 ± 0,3 mm (0,02 ± 0,012 in) and a polymeric substrate with nominal thickness between 0,025 mm (0,001 in) and 0,30 mm thickness (0,012 in); and metallic framing protecting the edge of the laminate.

b) Spread of Flame Test on Top Surface: The test shall be conducted using the procedure given in Section DVB.2. For Type 2, the allowable spread of flame of 1,82 m (6 feet) or less in 10 minutes. For Type 5, the allowable spread of flame is 3,96 m (13 feet) or less in 4 minutes. For Type 8, the allowable spread of flame is 2,4 m (8 feet) or less in 10 minutes.

c) Burning Brand Test on Top Surface: The test shall be conducted using the procedure given in Section DVB.3 using a C Brand. For Type 2, 5, and 8, passing results using a C Brand shall be demonstrated.

10.17DV.4.5 A Type 3, 6, 9-15, or a 19-27 module meets the following requirements:

a) Construction: Glass superstrate of 2,67 ±0,76 mm (0,105 ± 0,030 in); polymeric encapsulant with a total pre-lamination thickness of in 0,9 ±0,5 mm (0,035 ± 0,02 in); glass substrate of 2,67 ±0,76 mm (0,105 ± 0,030 in) with metallic framing (Types 19-27) or without metallic framing (Types 3, 6, 9-15).

b) Spread of Flame Test on Top Surface: The test shall be conducted using the procedure given in Section DVB.2. For Type 3, 10, 13, 19, 22, and 25, the allowable spread of flame of 1,82 m (6 feet) or less in 10 minutes. For Type 6, 11, 14, 20, 23 and 26, the allowable spread of flame is 3,96 m (13 feet) or less in 4 minutes. For Type 9, 12, 15, 21, 24 and 27, the allowable spread of flame is 2,4 m (8 feet) or less in 10 minutes.

c) Burning Brand Test on Top Surface: The test shall be conducted using the procedure given in Section DVB.3. For Type 3, 6, and 9, passing results using a C Brand shall be demonstrated. For Type 10, 11, and 12, passing results using a B Brand shall be demonstrated. For Type 13, 14, and 15, passing results using an A Brand shall be demonstrated.

10.17DV.4.5.1 A Type 16, 17, or 18 module or panel meets the following requirements:

a) Construction: Glass superstrate of 2.8 mm (0.11 in) ≤ thickness ≤ 4.4 mm (0.17 in); a polymeric encapsulant between the superstrate and cells with a pre-lamination thickness of 0,5 ± 0,3 mm (0,020 ± 0,012 in); a polymeric encapsulant between the cells and substrate with a pre-lamination thickness of 0,5 ± 0,3 mm (0,020 ± 0,012 in) and a glass substrate of 3,6 ± 0,8 mm (0,14 ± 0,03 in); and metallic framing protecting the edge of the laminate.

b) Spread of Flame Test on Top Surface: The test shall be conducted using the procedure given in Section DVB.2. For Type 16, the allowable spread of flame of 1,82 m (6 feet) or less in 10 minutes. For Type 17, the allowable spread of flame is 3,96 m (13 feet) or less in 4 minutes. For Type 18, the allowable spread of flame is 2,4 m (8 feet) or less in 10 minutes.

c) Burning Brand Test on Top Surface: The test shall be conducted using the procedure given in Section DVB.3 using a C Brand. For Type 16, 17, and 18, passing results using a C Brand shall be demonstrated.

10.17DV.4.5.2 A Type 28, 29, 30 or 34 module or panel meets the following requirements:

a) Construction: Glass superstrate of 2,67 ± 0,76 mm (0,105 ± 0,030 in); a polymeric encapsulant between the superstrate and cells with a pre-lamination thickness of 0,5 ± 0,3 mm (0,020 ± 0,012 in); a polymeric encapsulant between the cells and substrate with a pre-lamination thickness of 0,5 ± 0,3 mm (0,020 ± 0,012 in) and a glass substrate of 2,67 ± 0,76 mm (0,105 ± 0,030 in); and without metallic frame (Type 28 or 34) or with metallic framing (Type 29 or 30).

b) Spread of Flame Test on Top Surface: The test shall be conducted using the procedure given in Section DVB.2. For Type 28, 29, 30 and 34, the allowable spread of flame of 1,82 m (6 feet) or less in 10 minutes.

c) Burning Brand Test on Top Surface: The test shall be conducted using the procedure given in Section DVB.3. For Type 28 and 29, passing results using a C Brand shall be demonstrated. For Type 30 and 34, passing results using an A Brand shall be demonstrated.

10.17DV.4.5.3 A Type 31, 32, 33 module or panel meets the following requirements:

a) Construction: Glass superstrate of 2,0 mm (0,07 in) ≤ thickness < 2,8 mm (0,11 in); a polymeric encapsulant between the superstrate and cells with a pre-lamination thickness of 0,5 ± 0,3 mm (0,02 ± 0,012 in); either a polymeric encapsulant between the cells and substrate with a pre-lamination thickness of 0,5 ± 0,3 mm (0,02 ± 0,012 in) and a polymeric substrate with nominal thickness between 0,025 mm (0,001 in) and 0,30 mm (0,012 in) thickness or a combined substrate and encapsulant that meets the pre-lamination total thickness equal to an encapsulant thickness of 0,5 ± 0,3 mm (0,02 ± 0,012 in); and a polymeric substrate with nominal thickness between 0,025 mm (0,001 in) and thickness 0,30 mm (0,012 in); and metallic framing protecting the edge of the laminate.

b) Spread of Flame Test on Top Surface: The test shall be conducted using the procedure given in Section DVB.2. For Type 31, the allowable spread of flame of 1.82 m (6 feet) or less in 10 minutes. For Type 32, the allowable spread of flame is 3.96 m (13 feet) or less in 4 minutes. For Type 33, the allowable spread of flame is 2.4 m (8 feet) or less in 10 minutes.

c) Burning Brand Test on Top Surface: The test shall be conducted using the procedure given in Section DVB.3 using a C Brand. For Type 31, 32, and 33, passing results using a C Brand shall be demonstrated.

10.17DV.4.5.4 A Type 35, 36, or 37 module meets the following requirements:

a) Construction: Glass superstrate of 2,4 ± 0,4 mm (0,09 ± 0,02 in); a polymeric encapsulant between the superstrate and cells with a pre-lamination thickness of 0,5 ± 0,3 mm (0,02 ± 0,012 in); and a polymeric encapsulant between the cells and substrate with a pre-lamination thickness of 0,5 ± 0,3 mm (0,02 ± 0,012 in) and a substrate thickness of no less than 0,30 mm (0,012 in) and no greater than 0,64 mm (0,025 in), and metallic framing protecting the edge of the laminate.

b) Spread of Flame Test on Top Surface: The test shall be conducted using the procedure given in Section DVB.2. For Type 35, the allowable spread of flame of 1,82 m (6 feet) or less in 10 minutes. For Type 36, the allowable spread of flame is 3,96 m (13 feet) or less in 4 minutes. For Type 37, the allowable spread of flame is 2,4 m (8 feet) or less in 10 minutes.

c) Burning Brand Test on Top Surface: The test shall be conducted using the procedure given in Section DVB.3 using a C Brand. For Type 35, 36, and 37, passing results using a C Brand shall be demonstrated.

10.17DV.4.5.5 A Type 38, 39, or 40 module meets the following requirements:

a) Construction: Glass superstrate with a thickness of 1,6 ± 0,3 mm (0,06 ± 0,012 in); a polymeric encapsulant between the superstrate and cells with a pre-lamination thickness of 0,5 ± 0,3 mm (0,02 ± 0,012 in); and a polymeric encapsulant between the cells and substrate with a pre-lamination thickness of 0,5 ± 0,3 mm (0,02 ± 0,012 in) and a glass substrate with a thickness 1,6 ± 0,3 mm (0,06 ± 0,012 in); and metallic framing protecting the edge of the laminate.

b) Spread of Flame Test on Top Surface: The test shall be conducted using the procedure given in Section DVB.2. For Type 38, the allowable spread of flame of 1,82 m (6 feet) or less in 10 minutes. For Type 39, the allowable spread of flame is 3,96 m (13 feet) or less in 4 minutes. For Type 40, the allowable spread of flame is 2,4 m (8 feet) or less in 10 minutes.

c) Burning Brand Test on Top Surface: The test shall be conducted using the procedure given in Section DVB.3 using a C Brand. For Types 38, 39, and 40, passing results using a C Brand shall be demonstrated.

10.17DV.4.6 New types of PV modules with other constructions and fire performance can be defined as needed. Table 10.17DV.4.6.1 lists the types of PV modules based on construction and fire performance. The fire performance of these other constructions shall be tested in accordance with Sections DVB.2 and DVB.3.

Table 10.17DV.4.6.1
Construction and fire performance for PV module types [a]

<table>
<tr><th></th><th>Superstrate</th><th>Encapsulant (Super/Cell)</th><th>Encapsulant (Cell/Sub)</th><th>Substrate</th><th>Frame</th><th colspan="2">Fire Performance</th></tr>
<tr><th>Type</th><th>Material/Thickness</th><th>Material/Thickness</th><th>Material/Thickness</th><th>Material/Thickness</th><th>Material</th><th>Spread of Flame</th><th>Burning Brand</th></tr>
<tr><td>1</td><td rowspan="9">Glass/ 2,8 mm (0,11 in) ≤ thickness ≤ 4,4 mm (0,17 in)</td><td rowspan="9">Polymer / 0,5 ± 0,3 mm (0,02 ± 0,012 in)</td><td rowspan="9">Polymer / 0,5 ± 0,3 mm (0,02 ± 0,012 in)</td><td rowspan="3">Polymer / 0,30 mm (0,012 in) ≤ thickness ≤ 0,64 mm (0,025 in)</td><td rowspan="9">Metallic</td><td>1,82 m (6 feet) or less in 10 minutes</td><td rowspan="9">C Brand</td></tr>
<tr><td>4</td><td>3,96 m (13 feet) or less in 4 minutes</td></tr>
<tr><td>7</td><td>2,4 m (8 feet) or less in 10 minutes</td></tr>
<tr><td>2</td><td rowspan="3">Polymer / 0,025 mm (0,001 in) ≤ thickness < 0,30 mm (0,012 in)</td><td>1,82 m (6 feet) or less in 10 minutes</td></tr>
<tr><td>5</td><td>3,96 m (13 feet) or less in 4 minutes</td></tr>
<tr><td>8</td><td>2,4 m (8 feet) or less in 10 minutes</td></tr>
<tr><td>16</td><td rowspan="3">Glass / 3,6 ± 0,8 mm (0,14 ± 0,03 in)</td><td>1,82 m (6 feet) or less in 10 minutes</td></tr>
<tr><td>17</td><td>3,96 m (13 feet) or less in 4 minutes</td></tr>
<tr><td>18</td><td>2,4 m (8 feet) or less in 10 minutes</td></tr>
<tr><td>3</td><td rowspan="8">Glass / 2,67 ± 0,76 mm (0,105 ± 0,030 in)</td><td rowspan="8">N/A</td><td rowspan="8">Polymer / 0,9 ± 0,5 mm (0,035 ± 0,02 in)</td><td rowspan="8">Glass / 2,67 ± 0,76 mm (0,105 ± 0,030 in)</td><td rowspan="3">None</td><td>1,82 m (6 feet) or less in 10 minutes</td><td rowspan="6">C Brand</td></tr>
<tr><td>6</td><td>3,96 m (13 feet) or less in 4 minutes</td></tr>
<tr><td>9</td><td>2,4 m (8 feet) or less in 10 minutes</td></tr>
<tr><td>19</td><td rowspan="3">Metallic</td><td>1,82 m (6 feet) or less in 10 minutes</td></tr>
<tr><td>20</td><td>3,96 m (13 feet) or less in 4 minutes</td></tr>
<tr><td>21</td><td>2,4 m (8 feet) or less in 10 minutes</td></tr>
<tr><td>10</td><td rowspan="2">None</td><td>1,82 m (6 feet) or less in 10 minutes</td><td rowspan="2">B Brand</td></tr>
<tr><td>11</td><td>3,96 m (13 feet) or less in 4 minutes</td></tr>
</table>

Table 10.17DV.4.6.1 Continued on Next Page

Table 10.17DV.4.6.1 Continued

	Superstrate	Encapsulant (Super/Cell)	Encapsulant (Cell/Sub)	Substrate	Frame	Fire Performance	
Type	Material/Thickness	Material/Thickness	Material/Thickness	Material/Thickness	Material	Spread of Flame	Burning Brand
12						2,4 m (8 feet) or less in 10 minutes	
13						1,82 m (6 feet) or less in 10 minutes	A Brand
14						3,96 m (13 feet) or less in 4 minutes	
15						2,4 m (8 feet) or less in 10 minutes	
22					Metallic	1,82 m (6 feet) or less in 10 minutes	B Brand
23						3,96 m (13 feet) or less in 4 minutes	
24						2,4 m (8 feet) or less in 10 minutes	
25						1,82 m (6 feet) or less in 10 minutes	A Brand
26						3,96 m (13 feet) or less in 4 minutes	
27						2,4 m (8 feet) or less in 10 minutes	
28		Polymer / 0,5 ± 0,3 mm (0,020 ± 0,012 in)	Polymer / 0,5 ± 0,3 mm (0,020 ± 0,012 in)		None	1,82 m (6 feet) or less in 10 minutes	C Brand
29					Metallic	1,82 m (6 feet) or less in 10 minutes	
30						1,82 m (6 feet) or less in 10 minutes	A Brand
31	Glass/ 2,0 mm (0.07 in) ≤ thickness < 2,8 mm (0.11 in)			Polymer / 0,025 mm (0,001 in) ≤ thickness < 0,30 mm (0,012 in)	Metallic	1,82 m (6 feet) or less in 10 minutes	C Brand
32						3,96 m (13 feet) or less in 4 minutes	
33						2,4 m (8 feet) or less in 10 minutes	
34	Glass / 2,67 ± 0,76 mm (0,105 ± 0,030 in)			Glass / 2,67 ± 0,76 mm (0,105 ± 0,030 in)	None	1,82 m (6 feet) or less in 10 minutes	A Brand

Table 10.17DV.4.6.1 Continued on Next Page

Table 10.17DV.4.6.1 Continued

	Superstrate	Encapsulant (Super/Cell)	Encapsulant (Cell/Sub)	Substrate	Frame	Fire Performance	
Type	Material/Thickness	Material/Thickness	Material/Thickness	Material/Thickness	Material	Spread of Flame	Burning Brand
35	Glass / 2,4 ± 0,4 mm (0,09 ± 0,02 in)	Polymer / 0,5 ± 0,3 mm (0,020 ± 0,012 in)	Polymer / 0,5 ± 0,3 mm (0,020 ± 0,012 in)	Polymer / 0,30 mm (0,012 in) ≤ thickness ≤ 0,64 mm (0,025 in)	Metallic	1,82 m (6 feet) or less in 10 minutes	C Brand
36						3,96 m (13 feet) or less in 4 minutes	
37						2,4 m (8 feet) or less in 10 minutes	
38	Glass / 1,6 ± 0,3 mm (0,06 ± 0,012 in	Polymer / 0,5 ± 0,3 mm (0,020 ± 0,012 in)	Polymer / 0,5 ± 0,3 mm (0,020 ± 0,012 in)	Glass / 1,6 ± 0,3 mm (0,06 ± 0,012 in	Metallic	1,82 m (6 feet) or less in 10 minutes	C Brand
39						3,96 m (13 feet) or less in 4 minutes	
40						2,4 m (8 feet) or less in 10 minutes	

[a] Full requirements in 10.17DV.4.3 – 10.17DV.4.6 supersede this table.

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 ignitibility 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 °C ± 5 °C and a relative humidity of 50 % ± 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 °C ± 2 °C and a relative humidity of 50 % ± 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.

<u>Surface exposure</u>

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.

<u>Edge exposure</u>

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 noncombustible 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.

10.18DV D2 *Deletion:*

Delete Clause 10.18.

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/m^2 to 30 g/m^2 (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/m^2. 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.

10.20.2DV D2 ***Modification by replacing Clause 10.20.2 with the following:***

The PV module under test is to be installed with the front side facing down. The minimum distance of this front side to the surface below shall be determined by the manufacturer's documentation. If the documentation contains multiple mounting alternatives the one with the shortest clearance shall be utilized for the test. The sample front side is to be mounted in direct contact to a solid support if one of the documentation alternatives is direct mounting to surfaces or if no minimum clearance is defined therein. The supporting surface shall be of material that does not deform under hot temperatures. The thermal conductivity of the support shall be not higher than 0,5 W/(m·K).

The ambient air temperature for the test shall be 20 ± 5 °C. The ambient air of the test environment shall be still with no forced circulation. 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/m^2. 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.

Any blocking diode (not bypass diodes) provided shall be defeated (short-circuited). 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 maximum 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 hottest point(s) shall be determined after 1 h, for instance by infrared camera. When the hottest point(s) are determined and tagged the current shall be turned off allowing the sample to cool down to room temperature. After that (a) thermocouple(s) shall be attached to this point(s) by means compatible with the highest temperatures allowed. Suitable thermocouple types for the maximum permitted temperature shall be used. Such thermocouples are for instance types T, K and E of IEC 60584, the standard for thermocouples. The sample shall be reheated by applying a reverse current equal to I_{TEST} for 2 h, or until final results are known per Pass criteria below, whichever takes place first.

At the end of the test the temperature(s) measured by the thermocouple(s) shall be recorded.

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 UL 61730-1 the maximum over-current rating has to be provided by the manufacturer.

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

NOTE 2 As guidance on the use of IR-cameras the Technical Specification for "Photovoltaic (PV) systems – Requirements for testing, documentation and maintenance – Part 3: Photovoltaic modules and plants – Outdoor infrared thermography", IEC TS 62446-3, may be used.

NOTE 3 As guideline for PV module temperature measurement for performance measurements or for monitoring, Annex B of UL 61724-1, may be used. Fixation of thermocouples per this reference is suggested. Ordinary tape is not likely a candidate for such an attachment means.

10.20.3 Pass criteria

The pass criteria are as follows:

a) There shall not be flaming of the PV module, nor flaming or charring of the tissue paper in contact with the PV module.

b) MST 01 shall meet the same requirements as for the initial measurements.

c) 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.

10.20.3DV D2 *Modification by replacing Clause 10.20.3 with the following:*

The pass criteria are as follows:

a) There shall not be flaming of the PV module or any of its components.

b) MST 01 shall meet the same requirements as for the initial measurements.

c) 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.

e) The highest measured surface temperature during the test shall be below or equal to 150°C.

10.21 Module breakage test MST 32

10.21.1 Purpose

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

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 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 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):

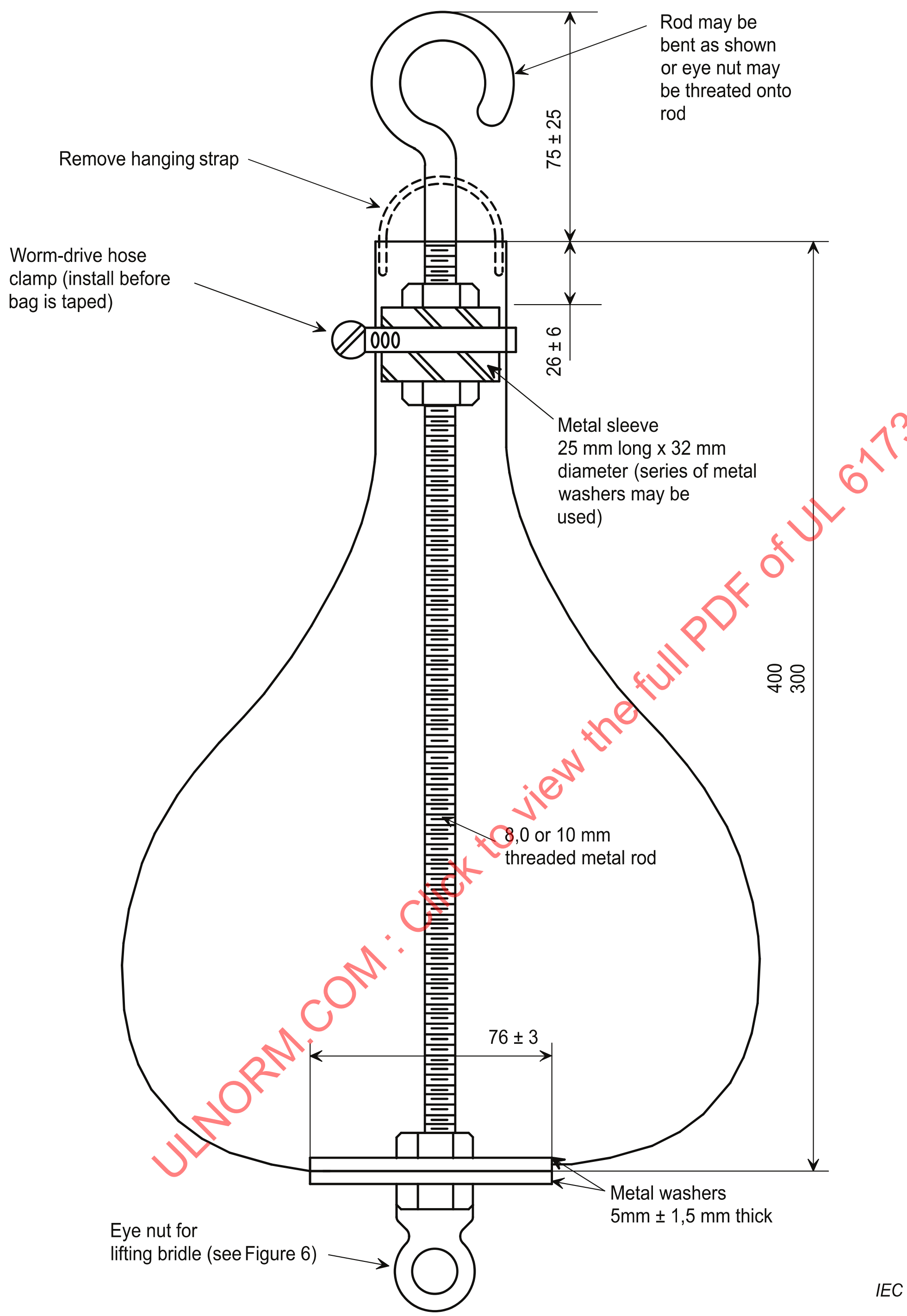
a) The PV module may not separate from the mounting structure or from the framing.

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



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Filled bag has a total weight of assembly of 45,5 kg ± 0,5 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

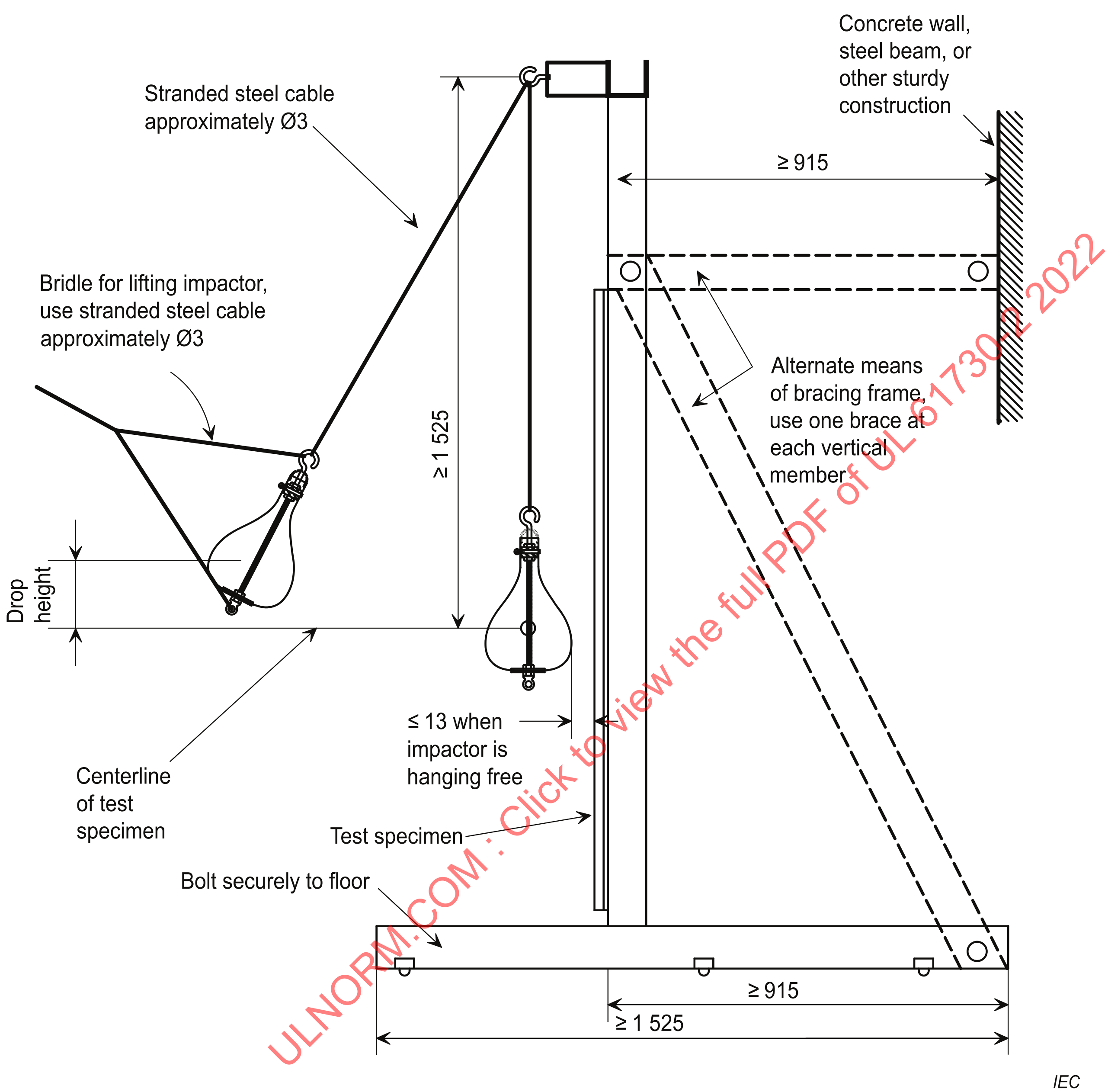

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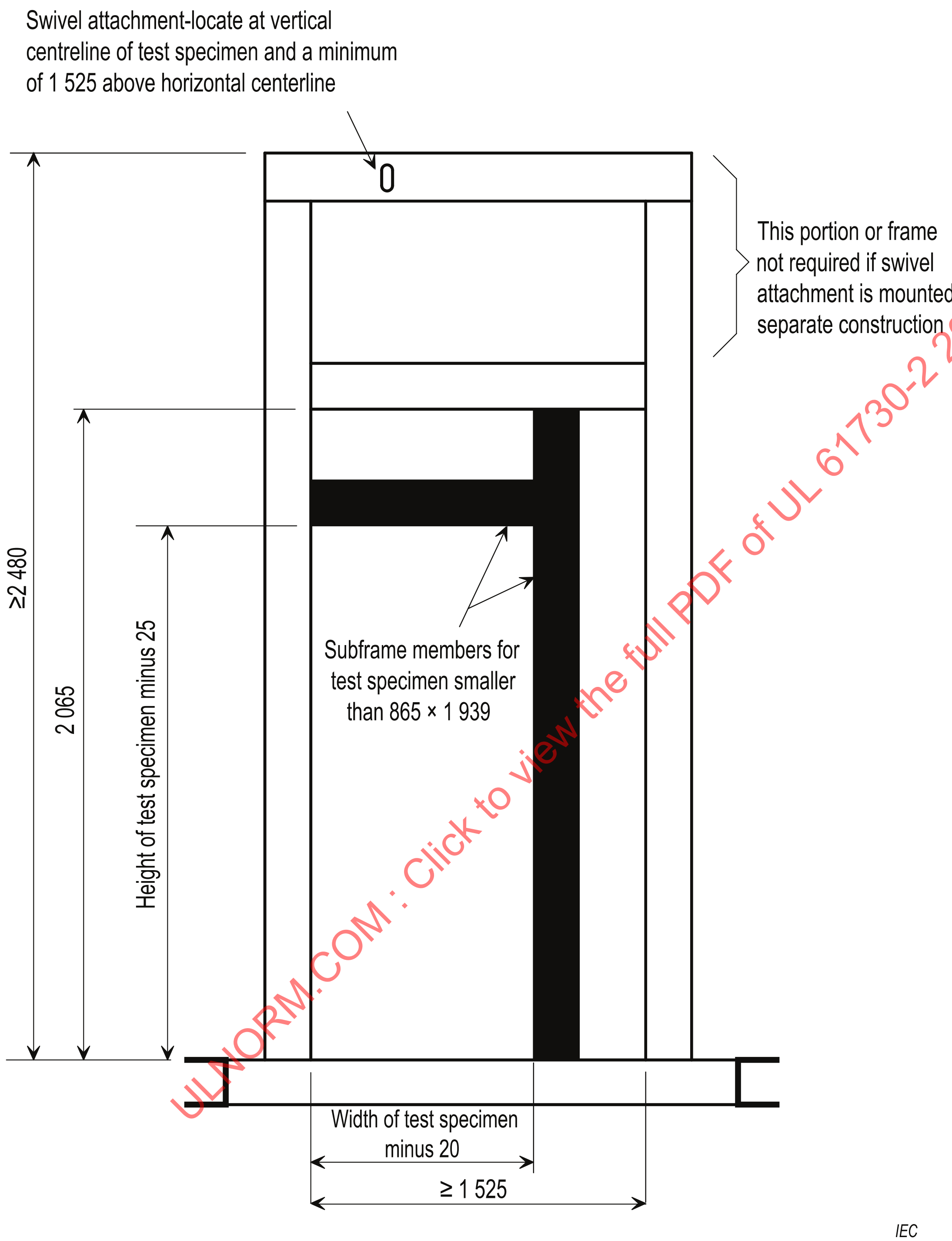
Figure 6

Impact test frame 1

Dimensions in millimetres



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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 ≤ 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.

10.23DV D2 *Modification by replacing Clause 10.23 with the following:*

This test is equivalent to MQT 16 in IEC 61215-2 except Clause 4.16.1, Purpose, shall be replaced by the following:

10.23DV.1 Purpose

This test defines the ability of photovoltaic modules to withstand static load stresses. Among other factors the construction of mounting means, applicable standards, building codes, probability of event occurrence and design assumptions define the minimum required design load for a particular site. Location, climate and application might require higher sampling rates and other safety factors γ_m.

Test-to-fail of a construction, for instance in order to determine the maximum possible test load, is not part of this standard.

Test load definition: Test load = γ_m × design load, with a safety factor $\gamma_m \geq 1{,}5$.

The nameplate marking defines the minimum required design load. Modules without nameplate marking require a minimum design load of 1 600 Pa. This results in a minimum test load of 2 400 Pa. Modules with reduced mechanical load require a minimum design load of 800 Pa specified on the nameplate and documentation. This results in a minimum test load of 1 200 Pa.

NOTE 1 Above specified loads exclude module dead loads, mounting means dead load and underlying structure which nevertheless are factored into mounting structure design calculations. Whereas the module dead load is implicit in the mechanical load test it should be omitted from the above design load which is the total sum of environmental loads. Most building codes use a similar or even lower safety factor. γ_m is not intended to be used in addition to the already applied building code safety factor.

NOTE 2 PV modules may be tested to test loads of 2 400 Pa and 5 400 Pa where additional requirements, such as heavy snow loads, apply for certain installations and climates. Alternate mounting locations and/or configurations, or additional clamps may be required for such higher loads as identified by the module manufacturer in the application documentation. The system designer or installer is responsible for ensuring the module static loads and safety factors are appropriate for the site as per the applicable building code and relevant wind tunnel derived coefficients for the mounting structure.

A higher safety factor γ_m and also higher design load(s) for positive (downward) and negative (upward) may be specified may the manufacturer for certain applications. The documentation shall specify design load(s) and safety factor γ_m for each mounting method.

Example: Design loads as specified by the manufacturer: 3 800 Pa (positive); 2 200 Pa (negative); $\gamma_m = 1{,}5$

Test loads: 5 700 Pa (positive) 3 cycles; 3 300 Pa (negative) 3 cycles

Table 10.23DV.1.1 provides test load examples for different applications

Table 10.23DV.1.1
Test load examples for different applications

Static Mechanical Load Category	Test Load [Pa]	Severity of snow and wind application	Description
Reduced	1 200 ≤ Test Load > 2 400	Low	Licensed professional engineers competent in the specific area under supervision assure compliance to relevant building codes and product installation manuals. Limited to ground-mounted PV power generation plants where climate and/or application allows use.
Default	2 400	Moderate	Due diligence whether the load is sufficient is needed for all installations. Residential applications typically use this category.
Increased	> 2 400	High	Structural engineers calculate minimum required loads. Higher snow load or wind load regions and/or applications require the module to be mechanically stronger.

NOTE Only uniform loads are covered by this test. A standard for non-uniform snow loads IEC 62938 is under development. A standard for un-balanced wind loads is under consideration.

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:

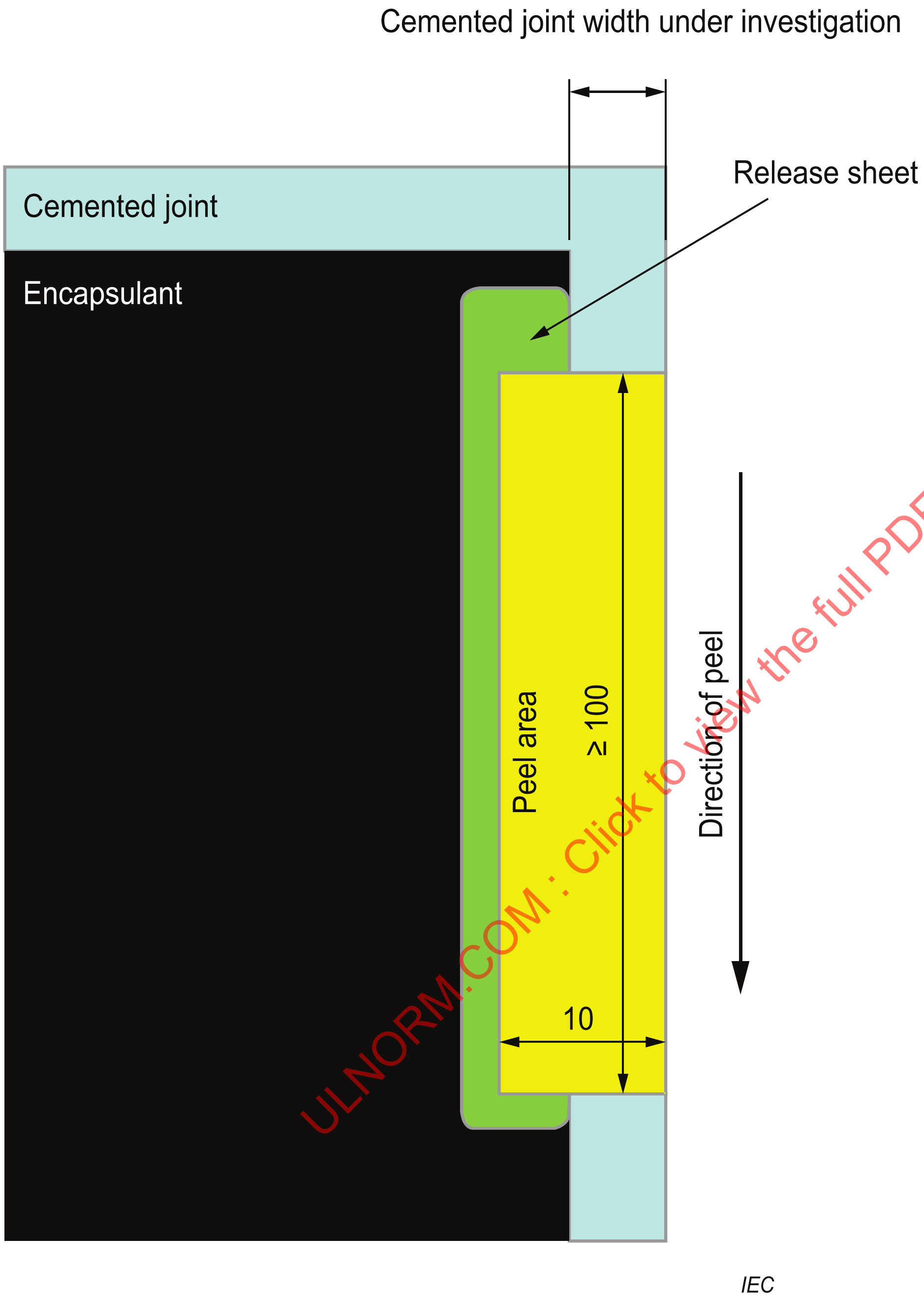
The sample shall be prepared as illustrated in Figure 8 for all locations as specified in Figure 9. A release sheet (e.g. Teflon) is to be inserted along the boundary of the cemented joint under test between the encapsulant layer and the backsheet. This is to ensure that the peel test is only conducted 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



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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:

a) 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 mm/min ± 5 mm/min.

b) 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° ± 10° 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:

a) 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.

b) Cemented joint width > 10 mm (laminate):

After conditioning ten (5 per interface) strips of 10 mm ± 0,5 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 ≤ 10 mm (special laminate):

After conditioning ten strips of 10 mm ± 0,5 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 ≤ 10 mm shall be adopted.

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

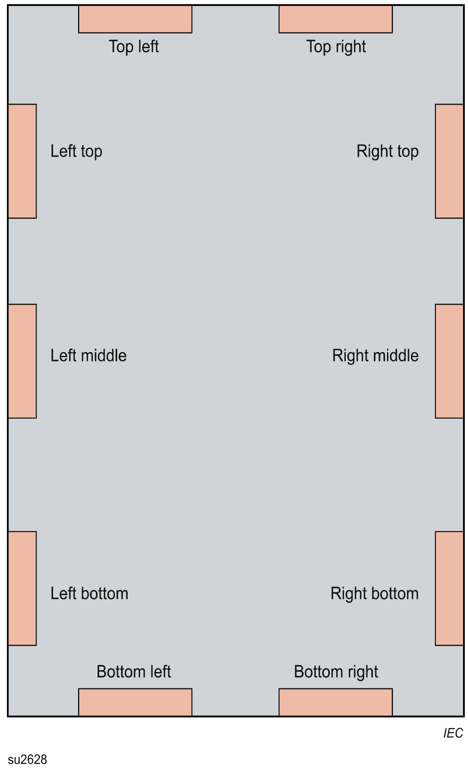


Figure 9

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 griped 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 mm/min ± 5 mm/min until separation is complete. Record the force required to cause separation.

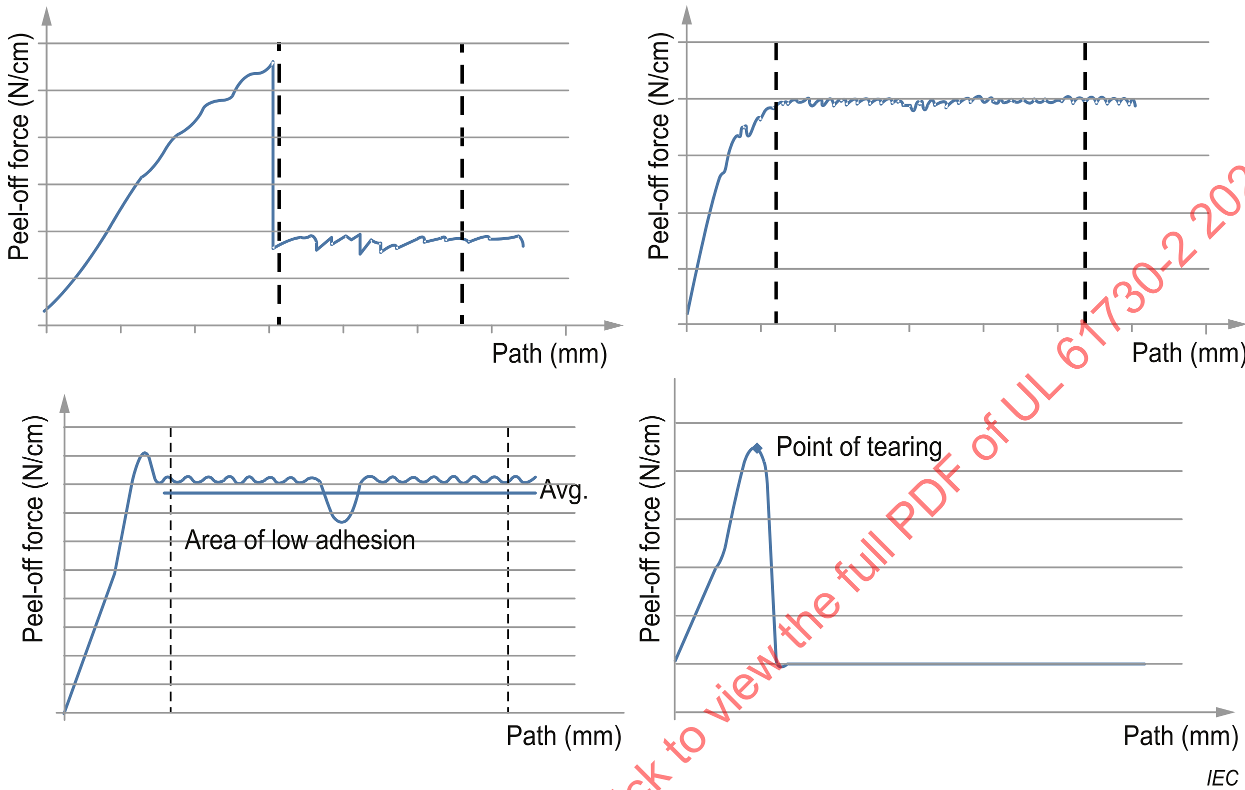
f) A time versus force plot over the full length of the test piece shall be made.

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.



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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.

$$0,5 < \frac{\Sigma_1^n M2}{\Sigma_1^n M1}$$

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.

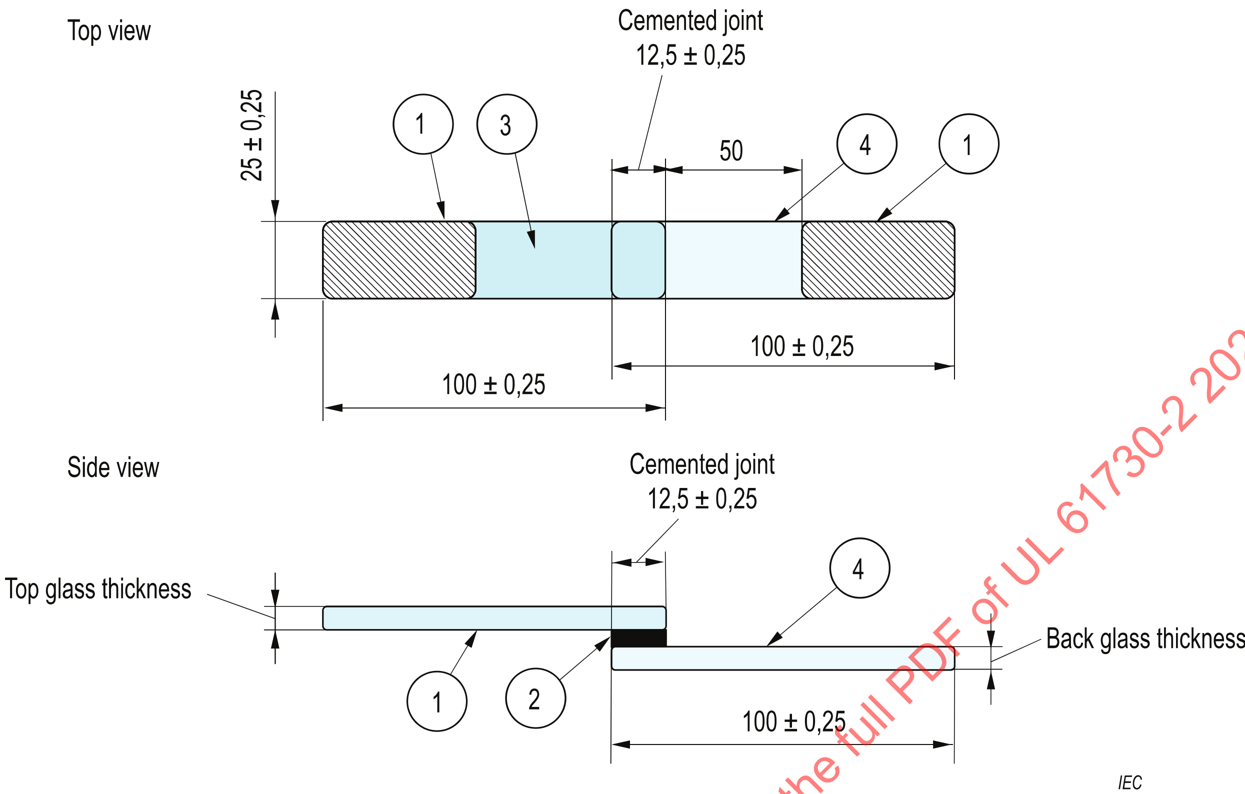
This test is not applicable to rigid-to-flexible or flexible-to-flexible bonded assemblies (e.g. glass/foil or foil/foil PV modules). For rigid-to-flexible or flexible-to-flexible bonded assemblies MST 35 applies.

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



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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