IEC 62759-1

Edition 2.0 2022-06
COMMENTED VERSION

INTERNATIONAL STANDARD

colour inside

Photovoltaic (PV) modules – Transportation testing – Part 1: Transportation and shipping of module package units

IEC 62759-1:2022-06 CMV(en)

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Photovoltaic (PV) modules – Transportation testing – Part 1: Transportation and shipping of module package units

INTERNATIONAL ELECTROTECHNICAL COMMISSION

ICS 27.160

ISBN 978-2-8322-3979-7

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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PHOTOVOLTAIC (PV) MODULES – TRANSPORTATION TESTING –

Part 1: Transportation and shipping of module package units

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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This commented version (CMV) of the official standard IEC 62759-1:2022 edition 2.0 allows the user to identify the changes made to the previous IEC 62759-1:2015 edition 1.0. Furthermore, comments from IEC TC 82 experts are provided to explain the reasons of the most relevant changes, or to clarify any part of the content.

A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text. Experts' comments are identified by a blue-background number. Mouse over a number to display a pop-up note with the comment.

This publication contains the CMV and the official standard. The full list of comments is available at the end of the CMV.

IEC 62759-1 has been prepared by IEC technical committee 82: Solar photovoltaic energy systems. It is an International Standard.

This second edition cancels and replaces the first edition published in 2015. This edition constitutes a technical revision.

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

a) Cancellation of tests and references to relevant standards for CPV.
b) Deletion of different classes for PV modules.
c) Deletion of requirement for minimum 10 modules per shipping unit.
d) Implementation of stabilization as intermediate measurement.
e) Addition of pass/fail criteria.
f) Change of requirements for retesting.
g) Change of number of cycles in dynamic mechanical load test. See also clause 6.4.2.1.

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

Draft	Report on voting
82/2029/FDIS	82/2052/RVD

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

The language used for the development of this International Standard is English.

A list of all parts in the IEC 62759 series, published under the general title *Photovoltaic (PV) modules – Transportation testing*, can be found on the IEC website.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

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

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

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

PHOTOVOLTAIC (PV) MODULES – TRANSPORTATION TESTING –

Part 1: Transportation and shipping of module package units

1 Scope ~~and object~~

Photovoltaic (PV) modules are electrical devices intended for continuous outdoor exposure during their lifetime. Existing type approval standards do not consider mechanical stresses that may occur during transportation to the PV installation destination.

This part of IEC 62759 describes methods for the simulation of transportation of complete package units of modules and combined subsequent environmental impacts~~, it does however not include pass/fail criteria~~. 1

~~This standard is designed so that its test sequence can co-ordinate with those of IEC 61215 or IEC 61646, so that a single set of samples may be used to perform both the transportation simulation and performance evaluation of a photovoltaic module design. This standard applies to flat plate photovoltaic modules, but may also be used as a basis for testing of CPV modules and assemblies.~~ 2

A list of design modifications which require a retest is provided in Annex B.

This document applies to flat plate photovoltaic modules.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60068-2-27:2008, *Environmental testing – Part 2-27: Tests – Test Ea and guidance: Shock*

~~IEC 60068-2-64, *Environmental testing – Part 2-64: Tests – Test Fh: Vibration, broadband random and guidance*~~

IEC TS 60904-13, *Photovoltaic devices – Part 13: Electroluminescence of photovoltaic modules*

~~IEC 61215:2005, *Crystalline silicon terrestrial photovoltaic (PV) modules – Design qualification and type approval*~~

IEC 61215-1:2021, *Terrestrial photovoltaic (PV) modules – Design qualification and type approval – Part 1: Test requirements*

IEC 61215-2:2021, *Terrestrial photovoltaic (PV) modules – Design qualification and type approval – Part 2: Test procedures*

~~IEC 61646:2008, *Thin-film terrestrial photovoltaic (PV) modules – Design qualification and type approval*~~

IEC 61730-2:~~2004~~2022, *Photovoltaic (PV) module safety qualification – Part 2: Requirements for testing*

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

~~IEC 62108:2007, *Concentrator photovoltaic (CPV) modules and assemblies – Design qualification and type approval*~~

IEC TS 62782:2016, ~~*Dynamic mechanical load testing for*~~ *Photovoltaic (PV) modules – Cyclic (dynamic) mechanical load testing* ~~(to be published)~~

~~ISO 13355, *Packaging – Complete, filled transport packages and unit loads – Vertical random vibration test*~~

ASTM D880-92~~:2008~~, *Standard Test Method for Impact Testing for Shipping Containers and Systems*

~~ASTM D4169:2008, *Standard Practice for Performance Testing of Shipping Containers and Systems*~~

ASTM D4169-16, *Standard Practice for Performance Testing of Shipping Containers and Systems*

ASTM D4728:2006, *Standard Test Method for Random Vibration Testing of Shipping Containers*

ASTM D5277-92~~:1992~~, *Test method for performing programmed horizontal impact using an inclined impact tester*

ISTA 3E:~~2009~~2017, *Unitized Loads of Same Product*

~~MIL-STD-810G, *Test Method Standard for Environmental Engineering Considerations and Laboratory Tests*~~

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC TS 61836~~:1999~~ and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1
bandwidth
difference in Hz between the upper and lower limits of a frequency band

Note 1 to entry: For the purposes of the described test method, the bandwidth may be considered equivalent to the frequency resolution of a spectrum analysis.

3.2
overall g_{RMS}
square root of the integral of power spectral density over the total frequency range

Note 1 to entry: It describes the severity or harshness of the testing grade.

3.3
root mean square
RMS
square root of the mean square value

Note 1 to entry: In the exclusive case of a sine wave, the RMS value is 0,707 times peak value.

3.4
random vibration
oscillation whose instantaneous amplitude is not prescribed for any given instant in time

Note 1 to entry: The instantaneous amplitudes of a random vibration are prescribed by a probability distribution function, the integral of which, over a given amplitude range, will give the probable percentage of time that the amplitude will fall within that range.

Note 2 to entry: Random vibration contains no periodic or quasi-periodic components.

3.5
packaging
material and technology used to protect goods from transportation stresses and separate individual units from each other

3.6
power spectral density
PSD
expression of random vibration in terms of mean square acceleration per unit of frequency~~. The units are g^2/Hz (g^2/cycles/s).~~

Note 1 to entry: Power spectral density is the limit of the mean square amplitude in a given rectangular waveband divided by the bandwidth, as the bandwidth approaches zero.

Note 2 to entry: The units are $(m/s^2)^2$/Hz, it is equal to m^2/s^3. The coherent non-SI unit is g^2/Hz.

~~**3.7**~~
~~**grade A PV modules**~~
~~100 % functional modules without any visual or functional defects~~

~~**3.8**~~
~~**grade B or lower PV modules**~~
~~grade B or lower modules may have visual or functional defects. The modules should be equivalent to grade A modules regarding their mass, size and mechanical behavior.~~

4 Sampling

As test samples for the basic transportation and shock test methods, a shipping unit of PV modules, shall be taken at random from a production batch or batches. When the test samples are prototypes of a new design and not from production, this fact shall be noted in the test report. The shipping unit shall contain the usual ~~amount~~ number of PV modules. ~~This test procedure is however designed for shipping units containing at least 10 modules. For further testing (path A and B for PV modules) at least six grade A modules are needed from the shipping unit.~~ **3**

Further three ~~grade A~~ PV modules are to be taken from a separate shipping unit not undergoing any transportation simulation.

~~Grade B or lower modules can be used to fill up the shipping system (uniform distribution) of samples, completing it to a regular shipping unit. Each individual substitute shall cover the same mass, size and bending stiffness as the modules to be tested in the subsequent environmental impact tests.~~

~~The shipping unit shall contain at least 25 % grade A modules. If the shipping unit contains less than 24 modules at least six grade A modules shall be provided.~~

~~In case of horizontal shipping the bottom and the top of the shipping unit shall be made up with grade A modules and in case of vertical shipping the outer modules of the shipping unit shall be made up with grade A modules.~~

Use the regular shipment packaging materials with the modules, as marketed and designed by the manufacturer.

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

The modules shall be complete in every detail, including a type label and shall be accompanied by the manufacturer's handling, mounting, shipping/packaging and installation instructions, including the information of the maximum permissible system voltage.

The test specimen of shipping unit shall be packed in accordance with the standard procedures used to ship modules to customers.

~~NOTE For CPV modules the sample numbers may vary, as shipping units may be much larger.~~

5 Handling

The test samples shall be handled with suitable care prior to the application of the tests described in this document. It ~~shall~~ should be ensured that the test samples are not exposed to additional mechanical impacts in form of shocks, rough handling, dropping, etc.

For the transportation from the manufacturer to the test laboratory special care should be taken to avoid any kind of damage. A special packaging concept, e.g. an additional packaging, special transportation method, etc., may be considered for this particular shipping route (manufacturer – test site). Testing shall be carried out without additional packaging.

6 Testing procedures

6.1 General

Performance measurements, visual inspection, insulation and wet leakage current testing shall be performed in accordance with ~~IEC 61215:2005 respectively IEC 61646:2008, 10.2, 10.3 and 10.15~~ IEC 61215-2:2021, MQT 01, MQT 02, and in accordance with IEC 61730-2:2022, MST 16 and MST 17 as ~~relative~~ reference initial and control measurements. ~~Electroluminescence or thermal images can be used to support the evaluation of the samples initial and intermediate status (e. g. micro cracks, defects, etc.).~~

~~The initial and visual inspection in accordance with IEC 61215:2005, 10.1 or IEC 61646:2008, 10.1 for PV modules and IEC 62108:2007, 10.1 for CPV modules shall also be part of the assessment.~~

Electroluminescence images according to IEC TS 60904-13 may be used to detect cracks which are not visible at initial and intermediate status (no pass/fail criteria are specified).

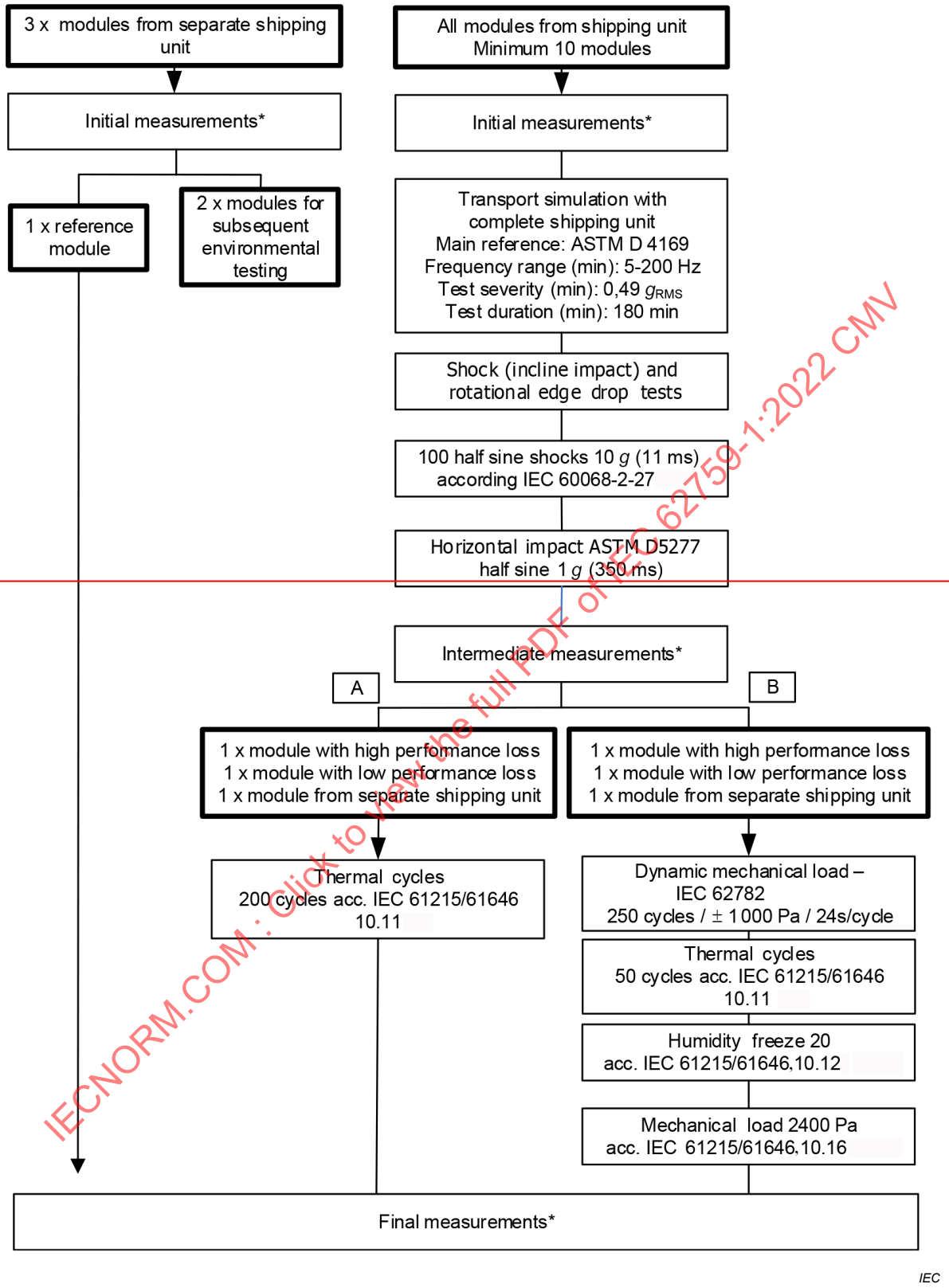
The actual transportation test is shown in Figure 1 ~~for PV modules; Figure 2 shows a possible test sequence for CPV modules~~. The sequences of combined transportation stress testing and the possible effects of these impacts on the PV modules shall detect early failures in regards to future life time stresses.

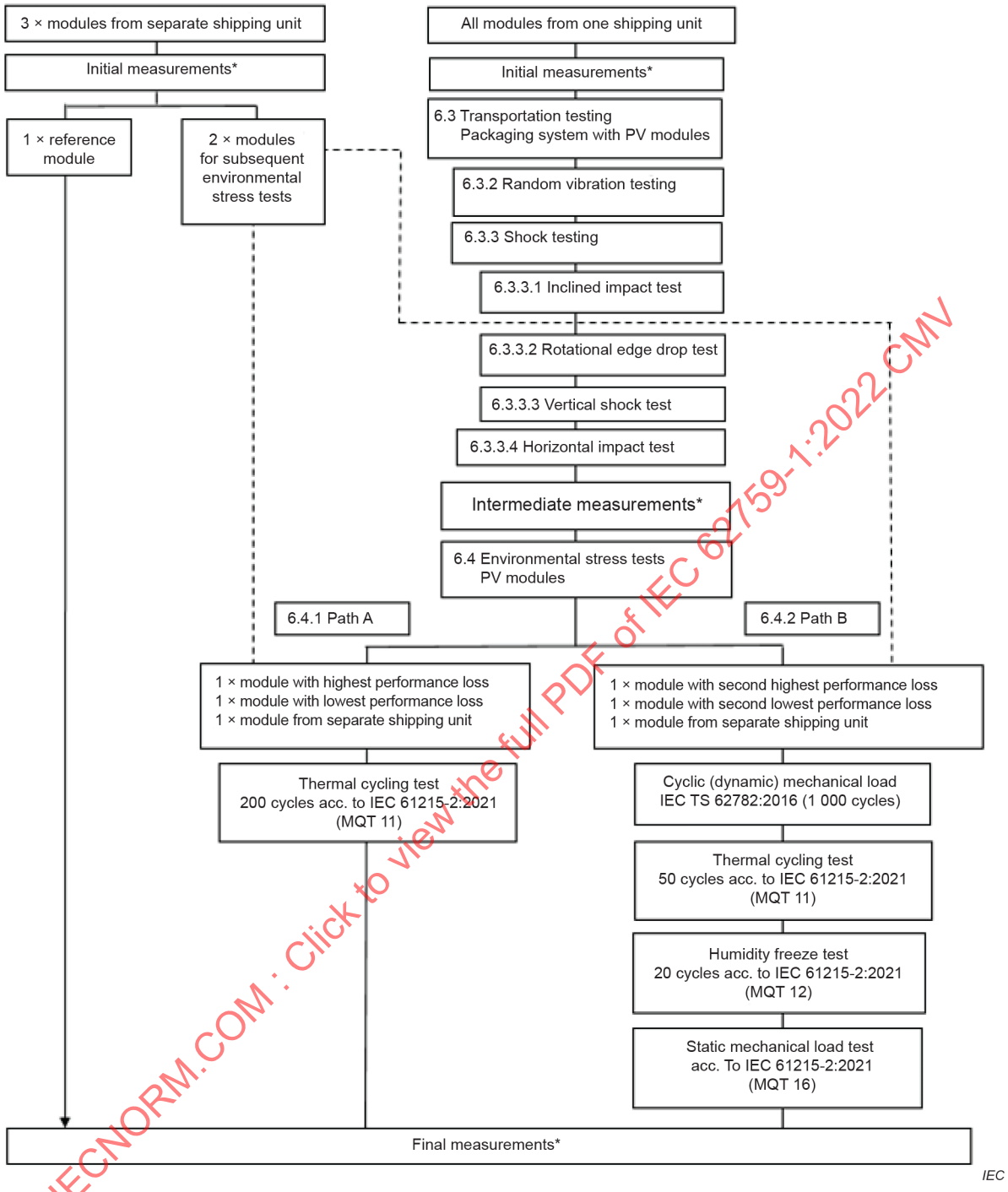
~~If a manufacturer wishes to combine the testing to this standard with type approval testing, sequence A of Figure 1 can also be used in conjunction with IEC 61215 respectively IEC 61646 testing. Combined testing will increase the risk of failure in type approval testing, as the transportation testing will pose additional stress to the samples.~~ **4**

~~Sequence B of Figure 1 could be extended with the UV preconditioning test and then also be coordinated with IEC 61215 respectively IEC 61646.~~

~~The proposed test sequence in Figure 2 for CPV modules can also be adjusted to coordinate with IEC 62108. The sequence shall be adjusted depending on whether receivers or modules are tested. For receivers, instead of the pre-thermal cycling and humidity freeze test, the thermal cycling test according to IEC 62108:2007, 10.8 may be performed.~~

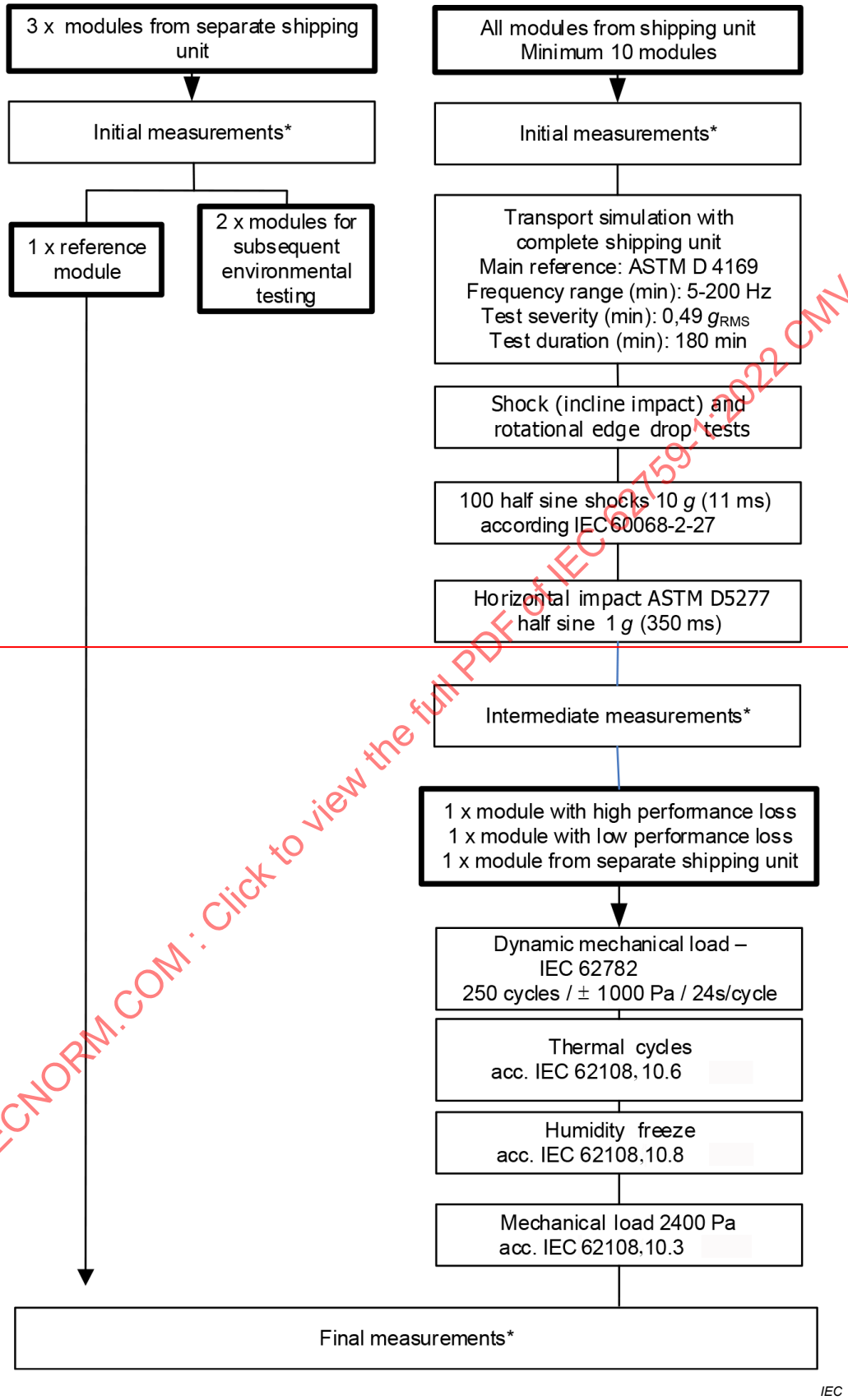
Separate modules, that have not undergone any transportation testing, are also subjected to the stress tests in sequences A and B. ~~Failures induced by the transportation simulation and potentially worsen defects due to the environmental stress tests shall be identified in comparison to the modules tested without any transportation pre-damages.~~ These modules shall be used to identify if defects are caused by transportation test and subsequent environmental test, or by environmental test only.





* See 6.2 for details on measurements.

Figure 1 – Test sequences for PV modules 5



~~* See 6.2 for details on measurements.~~

~~Figure 2 – Test sequences for CPV modules~~

6.2 Measurements

Each initial, intermediate and final measurement shall characterize the electrical performance of the PV modules and document the influence of the stress tests. The initial, intermediate and final measurements are:

- Visual inspection according to ~~IEC 61215:2005, IEC 61646:2008, respectively IEC 62108:2007, 10.1~~ IEC 61215-2:2021 (MQT 01)
- Stabilization (optional for intermediate measurements) according to IEC 61215-2:2021 (MQT 19) **6**
- Maximum power determination according to ~~IEC 61215:2005, IEC 61646:2008, respectively IEC 62108:2007, 10.2~~ IEC 61215-2:2021 (MQT 02)
- Insulation test according to ~~IEC 61215:2005, IEC 61646:2008, 10.3 respectively IEC 62108:2007, 10.4~~ IEC 61730-2:2022 (MST 16)
- ~~Ground~~ Continuity test of equipotential bonding according to ~~IEC 61730-2:2004,10.4 respectively IEC 62108, 10.3~~ IEC 61730-2:2021 (MST 13)
- Wet leakage current test according to ~~IEC 61215:2005, IEC 61646:2008, 10.15 respectively IEC 62108, 10.5~~ IEC 61730-2:2022 (MST 17)
- ~~Optionally electroluminescence (only for PV modules) or infrared imaging can be used for analysing modules for cracked or broken solar cells, etc.~~
- Electroluminescence images according to IEC TS 60904-13 or alternative methods, e.g. dark I-V, may be used to detect cracks which are not visible at initial and intermediate status (no pass/fail criteria are specified).

NOTE While the maximum power determination is only a ~~relative~~ reference measurement, some PV technologies may ~~require preconditioning~~ need stabilization according to their respective type approval standard to arrive at meaningful data.

6.3 Transportation testing

6.3.1 General

Performing tests of random vibration and various shock tests on the complete package system of modules simulates road transportation and the related mechanical impacts on shipping units and the ~~(C)~~ PV modules that are contained within.

The packaged-product shall be stored at laboratory ambient temperature and humidity for 12 h prior to starting the tests.

NOTE Sequence B of Figure 1 can be extended by the UV preconditioning test to be able to coordinate with IEC 61215 ~~or IEC 61646~~ if desired.

While the ~~(C)~~ PV modules are carefully unpacked, the modules shall be marked: the original packaging ~~situation~~ state and the module position, e.g. vertically or horizontally stacked within the ~~package~~ shipping unit shall be adequately documented.

After the initial measurements described in 6.2, the modules shall be restored to their original packaged condition in order to perform the tests described in 6.3.2 and 6.3.3.

6.3.2 Random vibration testing

6.3.2.1 Purpose

Transportation simulation is achieved through a random vibration test. Truck transportation is considered to be the most severe method of long distance transportation for shipping goods. The truck transportation test therefore covers most other means of transportation.

6.3.2.2 Apparatus

Test equipment as described in ASTM D4728:2006, Clause 5 – Apparatus shall be used.

6.3.2.3 Procedure

The transportation simulation shall be performed in accordance with ASTM D4169-16 with one complete stack of modules:

The applied test profile shall meet the following requirements:

a) A frequency range ~~of within 5~~ from 1 Hz **7** to 200 Hz.

b) A test severity not below ~~0,49~~ 0,54 g_{RMS} **8** as described in Annex A.

c) The test duration shall last at least 180 min.

d) Excitation axis: vertical.

Following the random vibration test, a series of shock tests shall be carried out on the shipping unit.

6.3.3 Shock testing

6.3.3.1 Incline impact test

6.3.3.1.1 Purpose

The incline impact test shall be performed to simulate stress potentially caused by forklift transportation.

6.3.3.1.2 Apparatus

Test equipment as described in ASTM D880-92 shall be used.

6.3.3.1.3 Procedure

The procedure as described in ISTA 3E Test Block 2 shall be followed.

6.3.3.2 Rotational edge drop test

6.3.3.2.1 Purpose

A rotational edge drop test shall be performed to test the integrity of the shipping supporting units pallet.

6.3.3.2.2 Apparatus

Test equipment as described in ISTA 3E Test Block 3 shall be used.

6.3.3.2.3 Procedure

The procedure as described in ISTA 3E Test Block 3 shall be followed.

6.3.3.3 Vertical shock test

6.3.3.3.1 Purpose

A shock test according to IEC 60068-2-27 shall be performed. This test procedure simulates stresses as may be caused by potholes or sidewalk edges which are not covered by the random vibration test.

6.3.3.3.2 Apparatus

Test equipment as described in IEC 60068-2-27:2008, Clause 4 shall be used.

The following deviation will be tolerated, if the applied variations are explained and clearly documented in the report:

- Extension of the mounting table in order to fit larger package units in an appropriate way.

6.3.3.3.3 Procedure

100 half sinusoidal shocks with duration of 11 ms shall be applied vertically (z direction).

6.3.3.4 Horizontal impact test

6.3.3.4.1 Purpose

For testing the integrity of the shipping unit regarding internal displacements or displacements of the shipping goods against the pallet, an incline impact test shall be performed in accordance with ASTM D5277-92. This test simulates sudden deceleration and sideward acceleration in curves during truck transportation.

6.3.3.4.2 Apparatus

Test equipment as described in ASTM D5277-92 shall be used.

6.3.3.4.3 Procedure

A test according to ASTM D5277-92 “test method for performing programmed horizontal impact using an incline impact tester” shall be performed. The difference compared to the incline impact test is that the shipping unit is decelerated on the transport sledge / transport vehicle.

The pallet has to be restrained, and the load on top of the pallet has to be unrestrained.

The characteristic of this impact shall be half sinusoidal shock like. The half sinus shock shall have a deceleration of 1 g and a length of 350 ms and shall be applied on each horizontal side.

It is common to start with an initial value of 0,3 g and increase the deceleration stepwise until the integrity of the shipping unit is damaged or the end value of 1 g is reached.

6.4 Environmental stress tests

~~**6.4.1 PV modules**~~

6.4.1 Path A

6.4.1.1 General

The transportation test is followed by a thermal cycling test in accordance with ~~IEC 61215:2005 respectively IEC 61646:2008, 10.11~~ IEC 61215-2:2021 MQT 11 for 200 cycles. ~~During this thermal cycle test no current flow is required unless this test protocol is combined with an IEC 61215 respectively IEC 61646 type approval. Continuity of the circuit through the module shall still be measured using a current flow of less than 0,5 % of short circuit current of the module under test.~~

6.4.1.2 Sample allocation for path A

a) 1 x module (highest power loss relative to initial measurement after transport simulation);

b) 1 x module (lowest power loss relative to initial measurement after transport simulation);

c) 1 x module from separate shipping unit.

NOTE The thermal cycling test represents the worst case variability of temperature in temperate climates. In general, PV modules are multilayer products. Each material (layer) has a different thermal expansion. This causes stress between the layers while thermal cycling. The cells, the joints and cell/string connectors may be especially prone to strains.

6.4.2 Path B

6.4.2.1 General

The transportation test is followed by a dynamic mechanical load test according to IEC TS 62782 (1 000 cycles), a thermal cycling test according to ~~IEC 61215 respectively IEC 61646, 10.11~~ IEC 61215-2:2021 MQT 11 with 50 cycles and a humidity-freeze test according to ~~IEC 61215 respectively IEC 61646, 10.12~~ IEC 61215-2:2021 MQT 12 with 20 cycles. The sequence concludes with a mechanical load test according to ~~IEC 61215 respectively IEC 61646, 10.16~~ MQT 16 of IEC 61215-2:2021 in upwards and downwards direction.

The dynamic mechanical load test for photovoltaic modules is described in IEC TS 62782. The module shall be installed according to the installation manual of the manufacturer. If different mounting techniques are possible, the worst case mounting situation shall be applied.

6.4.2.2 Sample allocation for path B

a) 1 x module (second **9** highest power loss relative to initial measurement after transport simulation);

b) 1 x module (second lowest power loss relative to initial measurement after transport simulation);

c) 1 x module from separate shipping unit.

~~**6.4.2 CPV modules and receivers**~~

~~The transportation test is followed by a dynamic mechanical load test acc. to IEC 62782, a pre-thermal cycle test and a humidity freeze test according to IEC 62108:2007, 10.8. The sequence concludes with a mechanical load test according to IEC 62108:2007, 10.13.~~

~~The dynamic mechanical load test for photovoltaic modules is described in IEC 62782. The CPV module shall be installed according to the installation manual of the manufacturer. If different mounting techniques are possible, the worst case mounting situation shall be applied.~~

~~**Sample allocation for CPV modules and receivers**~~

~~a) 1 × module (highest power loss relative to initial measurement after transport simulation);~~

~~b) 1 × module (lowest power loss relative to initial measurement after transport simulation);~~

~~c) 1 × modules from separate shipping unit.~~

7 Pass criteria **10**

A shipping unit design for PV modules shall be judged to have passed the qualification tests, and therefore to be type approved, if each PV module test sample meets all the following criteria:

a) After the complete test sequence (of path A and B), the maximum power output drop of each module $P_{\max}$ shall be less than 5 %, referenced to the module's initial measured power output $P_{\max}$ (Lab, Initial). Each test sample shall meet the following criterion:

$$P_{\max}(\text{Lab, Final}) \geq 0{,}95 \times P_{\max}(\text{Lab, Initial}) \times \left(1 - \frac{r|\%|}{100}\right) \quad (1)$$

where

r is the reproducibility according to IEC 61215-1;

P_{max}(Lab, Final) is the final measured maximum power output;

P_{max}(Lab, Initial) is the initial measured maximum power output.

The reproducibility r shall be calculated as defined in IEC 61215-1 using the levels given in the technology specific parts of IEC 61215-1.

b) No sample has shown any open circuit during the tests.

c) There is no visual evidence of a major defect, as defined in IEC 61215-1: 2021, Clause 8.

d) The prescribed insulation test requirements are met after the tests at the initial, intermediate and final measurements.

e) The prescribed wet leakage current test requirements are met at the initial, intermediate and final measurements.

f) The requirements of the continuity test of equipotential bonding are met at the initial, intermediate and final measurements.

g) Specific requirements of the individual tests in path A and B are met.

8 Reporting

Each test report shall include at least the following information:

a) a title;

b) name and address of the test laboratory and location where the tests were carried out;

c) unique identification of the report and of each page;

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) the applied standard for transportation testing and the used test profile, any deviations from, additions to or exclusions from the test method, and any other information relevant to a specific test, such as environmental conditions, or the irradiation dose in kWh/m^2 at which stability is reached;

k) measurements, examinations and derived results supported by tables, graphs, sketches and photographs, respectively electroluminescence ~~or thermal images~~, if applicable. Of particular importance are results indicating power loss or damages caused by the testing;

l) information about any abnormalities like movement of the modules inside the packaging, or damages of the packaging system;

m) camera properties of electroluminescence ~~and thermal imaging~~ devices as well as the used current on the PV module and the exposure time, if applicable;

n) a statement of the estimated uncertainty of the test results (where relevant);

o) a signature and title, or equivalent identification of the person(s) accepting responsibility for the content of the certificate or report, and the date of issue;

p) where relevant, a statement to the effect that the results relate only to the items tested;

q) 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.

Annex A
(~~normative~~ informative)

Test profiles

A.1 Overview

For informative purposes, the following PSD test profiles are shown and analyzed according to the criteria defined in Clause 6.The main reference for transport testing is the PSD profile out of the standard ASTM D4169. Other PSD profiles also fulfill the transportation testing requirements. The relevant frequency range for examination is between ~~5~~ 1 Hz and 200 Hz. The result of the analysis is shown in Table A.1. The listed test profiles fulfill the requirements which are defined in Clause 6. The result of the analysis is shown in Table A.1. The listed test profiles pass the requirements defined in Clause 6.

Table A.1 – Severity of common transport test profiles: complete and in range (~~5~~ 1 Hz to 200 Hz)

Name test profile	~~g_{RMS} (5 Hz – 200 Hz)~~	g_{RMS} complete profile
Main reference: ASTM D4169 (truck medium)	~~0,499~~	0,520
ISTA 3 E	~~0,504~~	0,540
MIL STD 810G /~~IEC 60064-2-64~~ IEC 60068-2-64	~~0,950~~	1,040
ISO 13355	~~0,583~~	0,590

The resonance of PV modules depends on the construction, including mass, size and stiffness. Tests have shown that the slowest fundamental resonance of a PV module is ~ 5 Hz. Most transportation test profiles have the majority of the energy between the frequencies of ~~5~~ 1 Hz and 200 Hz. A reasonable benchmark for different transportation test profiles for PV modules should therefore only include vibrations between ~~5~~ 1 Hz and 200 Hz.

A.2 Data points of appropriate PSD test profiles

~~The following Tables A.2 to A.5 identify the profile boundaries of the PSD excitation profiles analysed and shown in Table A.1 and Figure A.1.~~

~~**Table A.2 – Main reference ASTM D4169 (truck medium)**~~

~~Frequency Hz~~	~~g^2/Hz~~
~~1~~	~~0,00005~~
~~4~~	~~0,01~~
~~16~~	~~0,01~~
~~40~~	~~0,001~~
~~80~~	~~0,001~~
~~200~~	~~0,00001~~
	~~0,520 g_{RMS}~~

~~**Table A.3 – Grid points ISO 13355**~~

~~Frequency Hz~~	~~g^2/Hz~~
~~3~~	~~0,0005~~
~~6~~	~~0,012~~
~~18~~	~~0,012~~
~~40~~	~~0,001~~
~~200~~	~~0,0005~~
	~~0,590 g_{RMS}~~

~~**Table A.4 – IEC 60068-2-64 / MIL-STD-810G**~~

~~Frequency Hz~~	~~g^2/Hz~~
~~5~~	~~0,015~~
~~40~~	~~0,015~~
~~500~~	~~0,00015~~
	~~1,040 g_{RMS}~~

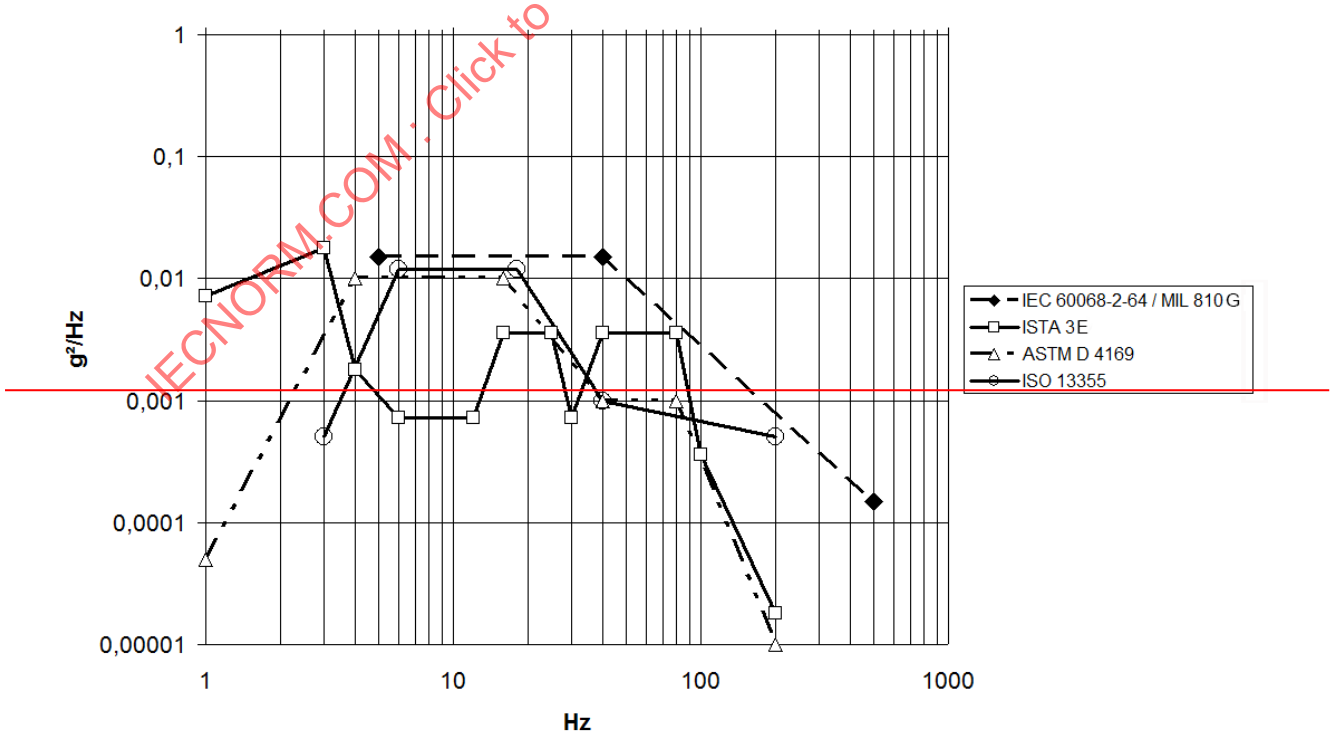
~~**Table A.5 – ISTA 3E**~~

~~Frequency Hz~~	~~g^2/Hz~~
~~1~~	~~0,0072~~
~~3~~	~~0,018~~
~~4~~	~~0,0018~~
~~6~~	~~0,00072~~
~~12~~	~~0,00072~~
~~16~~	~~0,0036~~
~~25~~	~~0,0036~~
~~30~~	~~0,00072~~
~~40~~	~~0,0036~~
~~80~~	~~0,0036~~
~~100~~	~~0,00036~~
~~200~~	~~0,000018~~
	~~0,540 g_{RMS}~~

The following profile has been chosen for the testing of PV shipping units. Table A.2 identifies the profile boundaries of the PSD excitation profiles analysed and shown in Table A.1 and Figure A.1.

Table A.2 – ASTM D4169-16 (medium) and ISTA 3E:2017

Frequency Hz	PSD level g^2/Hz
1	0,00072
3	0,018
4	0,018
6	0,00072
12	0,00072
16	0,0036
25	0,0036
30	0,00072
40	0,0036
80	0,0036
100	0,00036
200	0,000018
Overall g_{RMS}: 0,540 g_{RMS}	



IEC

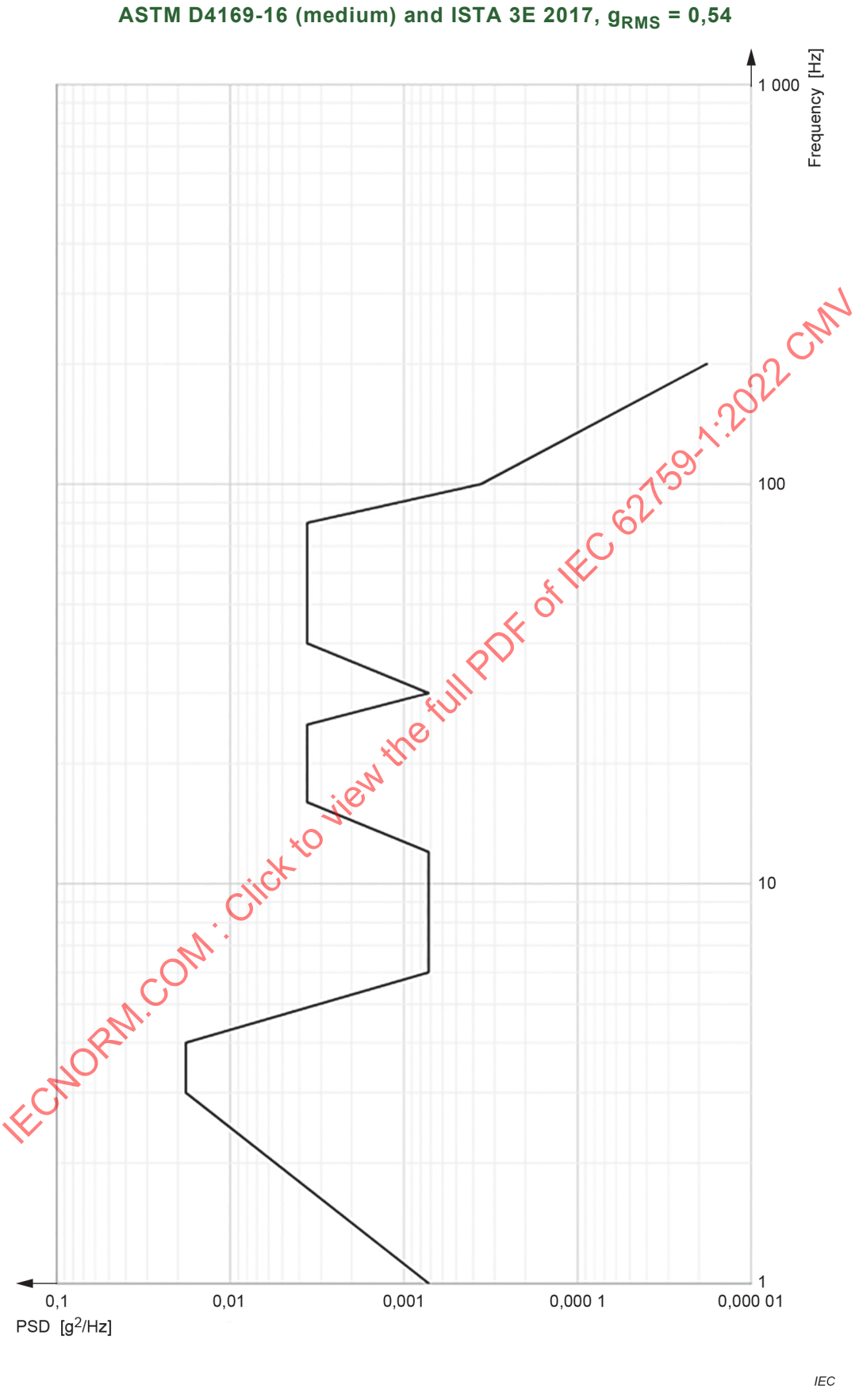


Figure A.1 – Appropriate PSD test profile

Annex B
(normative)

Retesting 11

B.1 Overview of transportation tests after modification

If PV modules have been modified in their design, as the transportation tests listed in Table B.1, the transportation tests shall be performed.

For any change of packaging material, profile, dimensions or assembly, a complete retest has to be evaluated. 12

No test repetition is required for thin-film specific design modifications:

– Modification to cell technology.
– Modification to interconnect material or technique.
– Modification to front contact.
– Modification to cell layout.
– Modification to back contact.
– Modification to edge deletion.

Table B.1 – Retests

Item	Design modification	Modification to module requiring retest
1	Frontsheet	for different material, i.e. any change in specification of the material or any of its layers, for glass: reduction of thickness by more than 10 %; non-glass: change of thickness by more than 20 % of any one of the individual layers and if there is a reduction in the strengthening process (for example retest if change from tempered glass to heat strengthened or annealed)
2	Encapsulation system	for reduction in thickness of total encapsulation by more than 20 % prior to processing; for different material, e.g. change from EVA to PVB or Polyolefine
3	Cell technology and size	only for c-Si: for change in nominal cell thickness bigger than 10 % and different size (± 10 %) of cell or use of cut cells (e.g. halved) change in cell technology
4	Cell and string interconnect material	only for c-Si: for significant change in solder material, or substitution from metallic solder to conductive adhesive; reduction of (total) cross-section of interconnect material (e.g., more busbars / more busbars with less width)
5	Backsheet	for different material, i.e. any change in specification of the material or any of its layers; glass: reduction of thickness by more than 10 %; non-glass: change of thickness by more than 20 % of any one of the individual layers for glass, if there is a reduction in the strengthening process (e.g. retest if change is from tempered to heat strengthened or annealed glass)
6	Electrical termination	Retest not required
7	Bypass diode	Retest not required
8	Electrical circuitry	Retest not required
9	Edge sealing	Retest not required
10	Frame / mounting structure	for different shape and/or cross-section of frame or mounting construction; reduction of surface area in contact between laminate and frame per linear dimension; different material including adhesive;; change in frame corner design; change in frame adhesive; change from framed to frameless PV module or vice versa

Item	Design modification	Modification to module requiring retest
11	Module size	for increase by more than 20 % of length, width or area
12	Higher / lower output power	Retest not required
13	Increase of over-current protection rating	Retest not required
14	Increase of system voltage	Retest not required
15	Cell fixing tape	Retest not required
16	Type label	Retest not required

Bibliography

IEC 60068-2-64, *Environmental testing – Part 2-64: Tests – Test Fh: Vibration, broadband random and guidance*

ISO 13355:2016, *Packaging – Complete, filled transport packages and unit loads – Vertical random vibration test*

MIL STD 810G, *Test Method Standard for Environmental Engineering Considerations and Laboratory Tests*

List of comments

1 This has been the reason why a new edition had to be created. In the previous edition only requirements for testing have been listed, but no pass/fail criteria. So the testing labs had to define their own criteria. To have globally the same requirements the pass/fail criteria have been added.

2 The subsequent tests after conditioning are explicit for flat plate modules.

3 To increase accuracy of assessment it has been decided that only fully operational samples shall be used.

4 The test sequences are not aligned anymore, so the option of a combined testing has been deleted.

5 Several issues have been modified in relevant clauses, so Figure 1 had to be modified, too.

6 This new requirement is mandatory for evaluation of power degradation, and therefore for pass/fail criteria.

7 To cover standard and realistic truck transportation stress the frequencies between 1 Hz and 5 Hz had to be added.

8 To cover standard and realistic truck transportation stress the test severity has been increased. See also reference to ISTA 3E:2017.

9 This way it is precisely described which sample has to be used.

10 This section has been added to enable the assessment of the results.

11 The retesting table has been added to clarify which modifications of the modules require a full transportation retest.

12 In general all changes have to be assessed, and it has to be evaluated if a retest has to be performed.

IEC 62759-1

Edition 2.0 2022-07

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Photovoltaic (PV) modules – Transportation testing – Part 1: Transportation and shipping of module package units

Modules photovoltaïques (PV) – Essais de transport – Partie 1: Transport et expédition d'unités d'emballage de modules

IEC 62759-1:2022-07(en-fr)

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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PHOTOVOLTAIC (PV) MODULES – TRANSPORTATION TESTING –

Part 1: Transportation and shipping of module package units

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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IEC 62759-1 has been prepared by IEC technical committee 82: Solar photovoltaic energy systems. It is an International Standard.

This second edition cancels and replaces the first edition published in 2015. This edition constitutes a technical revision.

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

a) Cancellation of tests and references to relevant standards for CPV.
b) Deletion of different classes for PV modules.
c) Deletion of requirement for minimum 10 modules per shipping unit.
d) Implementation of stabilization as intermediate measurement.
e) Addition of pass/fail criteria.
f) Change of requirements for retesting.

g) Change of number of cycles in dynamic mechanical load test. See also clause 6.4.2.1.

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

Draft	Report on voting
82/2029/FDIS	82/2052/RVD

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

The language used for the development of this International Standard is English.

A list of all parts in the IEC 62759 series, published under the general title *Photovoltaic (PV) modules – Transportation testing*, can be found on the IEC website.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

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

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

PHOTOVOLTAIC (PV) MODULES – TRANSPORTATION TESTING –

Part 1: Transportation and shipping of module package units

1 Scope

Photovoltaic (PV) modules are electrical devices intended for continuous outdoor exposure during their lifetime. Existing type approval standards do not consider mechanical stresses that may occur during transportation to the PV installation destination.

This part of IEC 62759 describes methods for the simulation of transportation of complete package units of modules and combined subsequent environmental impacts.

A list of design modifications which require a retest is provided in Annex B.

This document applies to flat plate photovoltaic modules.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60068-2-27:2008, *Environmental testing – Part 2-27: Tests – Test Ea and guidance: Shock*

IEC TS 60904-13, *Photovoltaic devices – Part 13: Electroluminescence of photovoltaic modules*

IEC 61215-1:2021, *Terrestrial photovoltaic (PV) modules – Design qualification and type approval – Part 1: Test requirements*

IEC 61215-2:2021, *Terrestrial photovoltaic (PV) modules – Design qualification and type approval – Part 2: Test procedures*

IEC 61730-2:2022, *Photovoltaic (PV) module safety qualification – Part 2: Requirements for testing*

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

IEC TS 62782:2016, *Photovoltaic (PV) modules – Cyclic (dynamic) mechanical load testing*

ASTM D880-92, *Standard Test Method for Impact Testing for Shipping Containers and Systems*

ASTM D4169-16, *Standard Practice for Performance Testing of Shipping Containers and Systems*

ASTM D4728:2006, *Standard Test Method for Random Vibration Testing of Shipping Containers*

ASTM D5277-92, *Test method for performing programmed horizontal impact using an inclined impact tester*

ISTA 3E:2017, *Unitized Loads of Same Product*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC TS 61836 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1
bandwidth
difference in Hz between the upper and lower limits of a frequency band

Note 1 to entry: For the purposes of the described test method, the bandwidth may be considered equivalent to the frequency resolution of a spectrum analysis.

3.2
overall g_{RMS}
square root of the integral of power spectral density over the total frequency range

Note 1 to entry: It describes the severity or harshness of the testing grade.

3.3
root mean square
RMS
square root of the mean square value

Note 1 to entry: In the exclusive case of a sine wave, the RMS value is 0,707 times peak value.

3.4
random vibration
oscillation whose instantaneous amplitude is not prescribed for any given instant in time

Note 1 to entry: The instantaneous amplitudes of a random vibration are prescribed by a probability distribution function, the integral of which, over a given amplitude range, will give the probable percentage of time that the amplitude will fall within that range.

Note 2 to entry: Random vibration contains no periodic or quasi-periodic components.

3.5
packaging
material and technology used to protect goods from transportation stresses and separate individual units from each other

3.6
power spectral density
PSD
expression of random vibration in terms of mean square acceleration per unit of frequency

Note 1 to entry: Power spectral density is the limit of the mean square amplitude in a given rectangular waveband divided by the bandwidth, as the bandwidth approaches zero.

Note 2 to entry: The units are $(m/s^2)^2/Hz$, it is equal to m^2/s^3. The coherent non-SI unit is g^2/Hz.

4 Sampling

As test samples for the basic transportation and shock test methods, a shipping unit of PV modules, shall be taken at random from a production batch or batches. When the test samples are prototypes of a new design and not from production, this fact shall be noted in the test report. The shipping unit shall contain the usual number of PV modules.

Further three PV modules are to be taken from a separate shipping unit not undergoing any transportation simulation.

Use the regular shipment packaging materials with the modules, as marketed and designed by the manufacturer.

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

The modules shall be complete in every detail, including a type label and shall be accompanied by the manufacturer's handling, mounting, shipping/packaging and installation instructions, including the information of the maximum permissible system voltage.

The test specimen of shipping unit shall be packed in accordance with the standard procedures used to ship modules to customers.

5 Handling

The test samples shall be handled with suitable care prior to the application of the tests described in this document. It should be ensured that the test samples are not exposed to additional mechanical impacts in form of shocks, rough handling, dropping, etc.

For the transportation from the manufacturer to the test laboratory special care should be taken to avoid any kind of damage. A special packaging concept, e.g. an additional packaging, special transportation method, etc., may be considered for this particular shipping route (manufacturer – test site). Testing shall be carried out without additional packaging.

6 Testing procedures

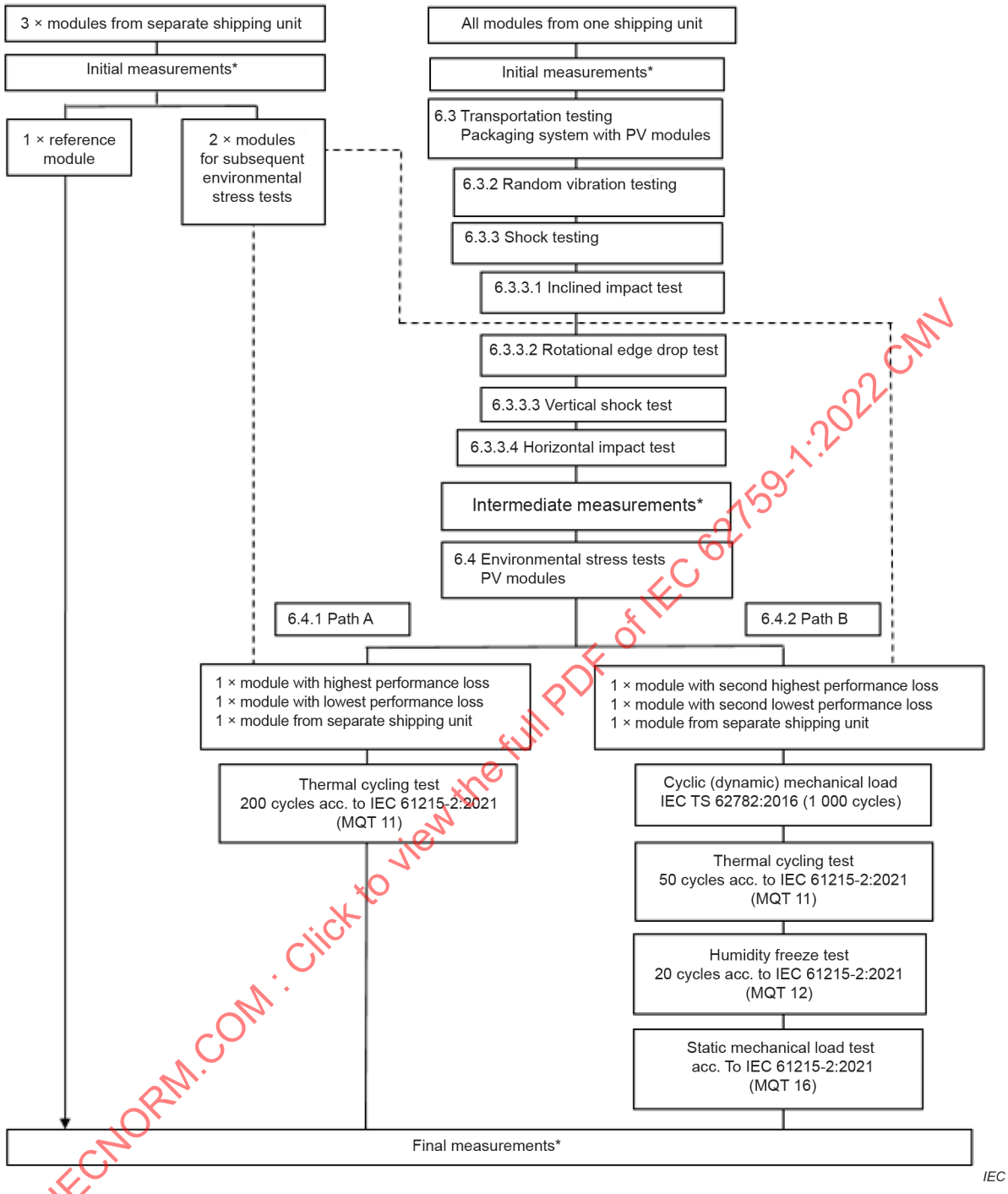
6.1 General

Performance measurements, visual inspection, insulation and wet leakage current testing shall be performed in accordance with IEC 61215-2:2021, MQT 01, MQT 02, and in accordance with IEC 61730-2:2022, MST 16 and MST 17 as reference initial and control measurements.

Electroluminescence images according to IEC TS 60904-13 may be used to detect cracks which are not visible at initial and intermediate status (no pass/fail criteria are specified).

The actual transportation test is shown in Figure 1. The sequences of combined transportation stress testing and the possible effects of these impacts on the PV modules shall detect early failures in regards to future life time stresses.

Separate modules, that have not undergone any transportation testing, are also subjected to the stress tests in sequences A and B. These modules shall be used to identify if defects are caused by transportation test and subsequent environmental test, or by environmental test only.



* See 6.2 for details on measurements.

Figure 1 – Test sequences for PV modules

6.2 Measurements

Each initial, intermediate and final measurement shall characterize the electrical performance of the PV modules and document the influence of the stress tests. The initial, intermediate and final measurements are:

- Visual inspection according to IEC 61215-2:2021 (MQT 01)
- Stabilization (optional for intermediate measurements) according to IEC 61215-2:2021 (MQT 19)
- Maximum power determination according to IEC 61215-2:2021 (MQT 02)

- Insulation test according to IEC 61730-2:2022 (MST 16)
- Continuity test of equipotential bonding according to IEC 61730-2:2021 (MST 13)
- Wet leakage current test according to IEC 61730-2:2022 (MST 17)
- Electroluminescence images according to IEC TS 60904-13 or alternative methods, e.g. dark I-V, may be used to detect cracks which are not visible at initial and intermediate status (no pass/fail criteria are specified).

NOTE While the maximum power determination is only a reference measurement, some PV technologies may need stabilization according to their respective type approval standard to arrive at meaningful data.

6.3 Transportation testing

6.3.1 General

Performing tests of random vibration and various shock tests on the complete package system of modules simulates road transportation and the related mechanical impacts on shipping units and the PV modules that are contained within.

The packaged-product shall be stored at laboratory ambient temperature and humidity for 12 h prior to starting the tests.

NOTE Sequence B of Figure 1 can be extended by the UV preconditioning test to be able to coordinate with IEC 61215 if desired.

While the PV modules are carefully unpacked, the modules shall be marked: the original packaging state and the module position, e.g. vertically or horizontally stacked within the shipping unit shall be adequately documented.

After the initial measurements described in 6.2, the modules shall be restored to their original packaged condition in order to perform the tests described in 6.3.2 and 6.3.3.

6.3.2 Random vibration testing

6.3.2.1 Purpose

Transportation simulation is achieved through a random vibration test. Truck transportation is considered to be the most severe method of long distance transportation for shipping goods. The truck transportation test therefore covers most other means of transportation.

6.3.2.2 Apparatus

Test equipment as described in ASTM D4728:2006, Clause 5 – Apparatus shall be used.

6.3.2.3 Procedure

The transportation simulation shall be performed in accordance with ASTM D4169-16 with one complete stack of modules:

The applied test profile shall meet the following requirements:

a) A frequency range from 1 Hz to 200 Hz.

b) A test severity not below 0,54 g_{RMS} as described in Annex A.

c) The test duration shall last at least 180 min.

d) Excitation axis: vertical.

Following the random vibration test, a series of shock tests shall be carried out on the shipping unit.

6.3.3 Shock testing

6.3.3.1 Incline impact test

6.3.3.1.1 Purpose

The incline impact test shall be performed to simulate stress potentially caused by forklift transportation.

6.3.3.1.2 Apparatus

Test equipment as described in ASTM D880-92 shall be used.

6.3.3.1.3 Procedure

The procedure as described in ISTA 3E Test Block 2 shall be followed.

6.3.3.2 Rotational edge drop test

6.3.3.2.1 Purpose

A rotational edge drop test shall be performed to test the integrity of the shipping supporting units pallet.

6.3.3.2.2 Apparatus

Test equipment as described in ISTA 3E Test Block 3 shall be used.

6.3.3.2.3 Procedure

The procedure as described in ISTA 3E Test Block 3 shall be followed.

6.3.3.3 Vertical shock test

6.3.3.3.1 Purpose

A shock test according to IEC 60068-2-27 shall be performed. This test procedure simulates stresses as may be caused by potholes or sidewalk edges which are not covered by the random vibration test.

6.3.3.3.2 Apparatus

Test equipment as described in IEC 60068-2-27:2008, Clause 4 shall be used.

The following deviation will be tolerated, if the applied variations are explained and clearly documented in the report:

- Extension of the mounting table in order to fit larger package units in an appropriate way.

6.3.3.3.3 Procedure

100 half sinusoidal shocks with duration of 11 ms shall be applied vertically (z direction).

6.3.3.4 Horizontal impact test

6.3.3.4.1 Purpose

For testing the integrity of the shipping unit regarding internal displacements or displacements of the shipping goods against the pallet, an incline impact test shall be performed in accordance with ASTM D5277-92. This test simulates sudden deceleration and sideward acceleration in curves during truck transportation.

6.3.3.4.2 Apparatus

Test equipment as described in ASTM D5277-92 shall be used.

6.3.3.4.3 Procedure

A test according to ASTM D5277-92 “test method for performing programmed horizontal impact using an incline impact tester” shall be performed. The difference compared to the incline impact test is that the shipping unit is decelerated on the transport sledge / transport vehicle.

The pallet has to be restrained, and the load on top of the pallet has to be unrestrained.

The characteristic of this impact shall be half sinusoidal shock like. The half sinus shock shall have a deceleration of 1 g and a length of 350 ms and shall be applied on each horizontal side.

It is common to start with an initial value of 0,3 g and increase the deceleration stepwise until the integrity of the shipping unit is damaged or the end value of 1 g is reached.

6.4 Environmental stress tests

6.4.1 Path A

6.4.1.1 General

The transportation test is followed by a thermal cycling test in accordance with IEC 61215-2:2021 MQT 11 for 200 cycles.

6.4.1.2 Sample allocation for path A

a) 1 x module (highest power loss relative to initial measurement after transport simulation);

b) 1 x module (lowest power loss relative to initial measurement after transport simulation);

c) 1 x module from separate shipping unit.

NOTE The thermal cycling test represents the worst case variability of temperature in temperate climates. In general, PV modules are multilayer products. Each material (layer) has a different thermal expansion. This causes stress between the layers while thermal cycling. The cells, the joints and cell/string connectors may be especially prone to strains.

6.4.2 Path B

6.4.2.1 General

The transportation test is followed by a dynamic mechanical load test according to IEC TS 62782 (1 000 cycles), a thermal cycling test according to IEC 61215-2:2021 MQT 11 with 50 cycles and a humidity-freeze test according to IEC 61215-2:2021 MQT 12 with 20 cycles. The sequence concludes with a mechanical load test according to MQT 16 of IEC 61215-2:2021 in upwards and downwards direction.

The dynamic mechanical load test for photovoltaic modules is described in IEC TS 62782. The module shall be installed according to the installation manual of the manufacturer. If different mounting techniques are possible, the worst case mounting situation shall be applied.

6.4.2.2 Sample allocation for path B

a) 1 x module (second highest power loss relative to initial measurement after transport simulation);

b) 1 x module (second lowest power loss relative to initial measurement after transport simulation);

c) 1 x module from separate shipping unit.

7 Pass criteria

A shipping unit design for PV modules shall be judged to have passed the qualification tests, and therefore to be type approved, if each PV module test sample meets all the following criteria:

a) After the complete test sequence (of path A and B), the maximum power output drop of each module P_{max} shall be less than 5 %, referenced to the module's initial measured power output P_{max} (Lab, Initial). Each test sample shall meet the following criterion:

$$P_{max}(\text{Lab, Final}) \geq 0{,}95 \times P_{max}(\text{Lab, Initial}) \times \left(1 - \frac{r|\%|}{100}\right) \quad (1)$$

where

r is the reproducibility according to IEC 61215-1;

P_{max}(Lab, Final) is the final measured maximum power output;

P_{max}(Lab, Initial) is the initial measured maximum power output;

The reproducibility r shall be calculated as defined in IEC 61215-1 using the levels given in the technology specific parts of IEC 61215-1.

b) No sample has shown any open circuit during the tests.

c) There is no visual evidence of a major defect, as defined in IEC 61215-1: 2021, Clause 8.

d) The prescribed insulation test requirements are met after the tests at the initial, intermediate and final measurements.

e) The prescribed wet leakage current test requirements are met at the initial, intermediate and final measurements.

f) The requirements of the continuity test of equipotential bonding are met at the initial, intermediate and final measurements.

g) Specific requirements of the individual tests in path A and B are met.

8 Reporting

Each test report shall include at least the following information:

a) a title;

b) name and address of the test laboratory and location where the tests were carried out;

c) unique identification of the report and of each page;

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) the applied standard for transportation testing and the used test profile, any deviations from, additions to or exclusions from the test method, and any other information relevant to a specific test, such as environmental conditions, or the irradiation dose in kWh/m^2 at which stability is reached;

k) measurements, examinations and derived results supported by tables, graphs, sketches and photographs, respectively electroluminescence, if applicable. Of particular importance are results indicating power loss or damages caused by the testing;

l) information about any abnormalities like movement of the modules inside the packaging, or damages of the packaging system;

m) camera properties of electroluminescence devices as well as the used current on the PV module and the exposure time, if applicable;

n) a statement of the estimated uncertainty of the test results (where relevant);

o) a signature and title, or equivalent identification of the person(s) accepting responsibility for the content of the certificate or report, and the date of issue;

p) where relevant, a statement to the effect that the results relate only to the items tested;

q) 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.

Annex A
(informative)

Test profiles

A.1 Overview

For informative purposes, the following PSD test profiles are shown and analyzed according to the criteria defined in Clause 6.The main reference for transport testing is the PSD profile out of the standard ASTM D4169. Other PSD profiles also fulfill the transportation testing requirements. The relevant frequency range for examination is between 1 Hz and 200 Hz. The result of the analysis is shown in Table A.1. The listed test profiles fulfill the requirements which are defined in Clause 6. The result of the analysis is shown in Table A.1. The listed test profiles pass the requirements defined in Clause 6.

Table A.1 – Severity of common transport test profiles: complete and in range (1 Hz to 200 Hz)

Name test profile		g_{RMS} complete profile
Main reference: ASTM D4169 (truck medium)		0,520
ISTA 3 E		0,540
MIL STD 810G / IEC 60068-2-64		1,040
ISO 13355		0,590

The resonance of PV modules depends on the construction, including mass, size and stiffness. Tests have shown that the slowest fundamental resonance of a PV module is ~ 5 Hz. Most transportation test profiles have the majority of the energy between the frequencies of 1 Hz and 200 Hz. A reasonable benchmark for different transportation test profiles for PV modules should therefore only include vibrations between 1 Hz and 200 Hz.

A.2 Data points of appropriate PSD test profiles

The following profile has been chosen for the testing of PV shipping units. Table A.2 identifies the profile boundaries of the PSD excitation profiles analysed and shown in Table A.1 and Figure A.1.

Table A.2 – ASTM D4169-16 (medium) and ISTA 3E:2017

Frequency Hz	PSD level g^2/Hz
1	0,00072
3	0,018
4	0,018
6	0,00072
12	0,00072
16	0,0036
25	0,0036
30	0,00072
40	0,0036
80	0,0036
100	0,00036
200	0,000018
	Overall g_{RMS}: 0,540 g_{RMS}

ASTM D4169-16 (medium) and ISTA 3E 2017, g_{RMS} = 0,54

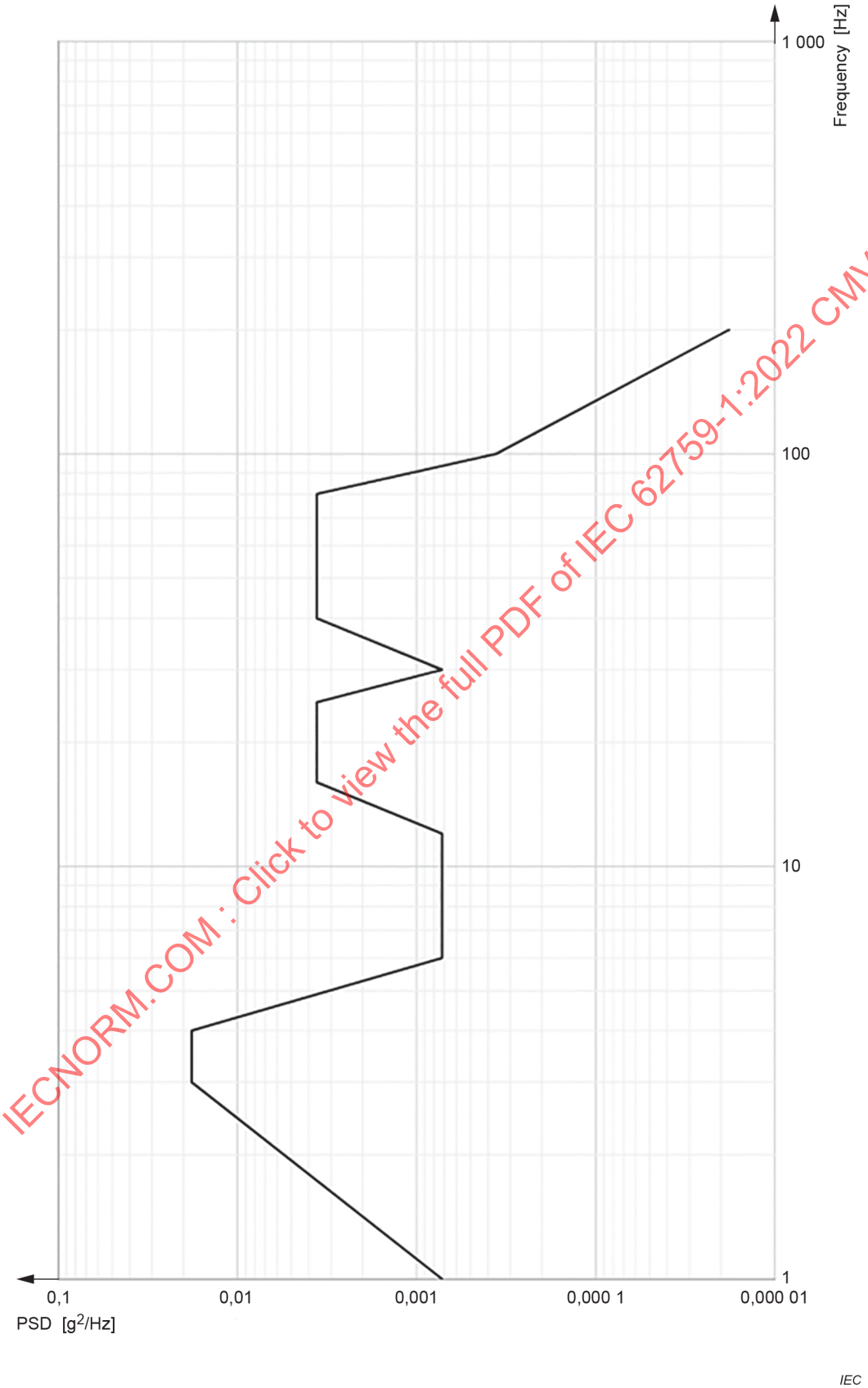


Figure A.1 – Appropriate PSD test profile

Annex B
(normative)

Retesting

B.1 Overview of transportation tests after modification

If PV modules have been modified in their design, as the transportation tests listed in Table B.1, the transportation tests shall be performed.

For any change of packaging material, profile, dimensions or assembly, a complete retest has to be evaluated.

No test repetition is required for thin-film specific design modifications:

– Modification to cell technology.
– Modification to interconnect material or technique.
– Modification to front contact.
– Modification to cell layout.
– Modification to back contact.
– Modification to edge deletion.

Table B.1 – Retests

Item	Design modification	Modification to module requiring retest
1	Frontsheet	for different material, i.e. any change in specification of the material or any of its layers, for glass: reduction of thickness by more than 10 %; non-glass: change of thickness by more than 20 % of any one of the individual layers and if there is a reduction in the strengthening process (for example retest if change from tempered glass to heat strengthened or annealed)
2	Encapsulation system	for reduction in thickness of total encapsulation by more than 20 % prior to processing; for different material, e.g. change from EVA to PVB or Polyolefine
3	Cell technology and size	only for c-Si: for change in nominal cell thickness bigger than 10 % and different size (± 10 %) of cell or use of cut cells (e.g. halved) change in cell technology
4	Cell and string interconnect material	only for c-Si: for significant change in solder material, or substitution from metallic solder to conductive adhesive; reduction of (total) cross-section of interconnect material (e.g., more busbars / more busbars with less width)
5	Backsheet	for different material, i.e. any change in specification of the material or any of its layers; glass: reduction of thickness by more than 10 %; non-glass: change of thickness by more than 20 % of any one of the individual layers for glass, if there is a reduction in the strengthening process (e.g. retest if change is from tempered to heat strengthened or annealed glass)
6	Electrical termination	Retest not required
7	Bypass diode	Retest not required
8	Electrical circuitry	Retest not required
9	Edge sealing	Retest not required
10	Frame / mounting structure	for different shape and/or cross-section of frame or mounting construction; reduction of surface area in contact between laminate and frame per linear dimension; different material including adhesive;; change in frame corner design; change in frame adhesive; change from framed to frameless PV module or vice versa

Item	Design modification	Modification to module requiring retest
11	Module size	for increase by more than 20 % of length, width or area
12	Higher / lower output power	Retest not required
13	Increase of over-current protection rating	Retest not required
14	Increase of system voltage	Retest not required
15	Cell fixing tape	Retest not required
16	Type label	Retest not required

Bibliography

IEC 60068-2-64, *Environmental testing – Part 2-64: Tests – Test Fh: Vibration, broadband random and guidance*

ISO 13355:2016, *Packaging – Complete, filled transport packages and unit loads – Vertical random vibration test*

MIL STD 810G, *Test Method Standard for Environmental Engineering Considerations and Laboratory Tests*

SOMMAIRE

COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

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MODULES PHOTOVOLTAÏQUES (PV) – ESSAIS DE TRANSPORT –

Partie 1: Transport et expédition d'unités d'emballage de modules

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L'IEC 62759-1 a été établie par le comité d'études 82 de l'IEC: Systèmes de conversion photovoltaïque de l'énergie solaire. Il s'agit d'une Norme internationale.

Cette deuxième édition annule et remplace la première édition parue en 2015. Elle constitue une révision technique.

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

a) annulation des essais et des références relatifs aux normes applicables aux modules photovoltaïques à concentration (CPV);
b) suppression des différentes classes de modules PV;
c) suppression du minimum exigé de 10 modules par colis d'expédition;
d) mise en place de la stabilisation comme mesurage intermédiaire;

e) ajout des critères d'acceptation/de rejet;

f) modification des exigences pour les contre-essais;

g) modification du nombre de cycles dans l'essai de charge mécanique dynamique. Voir aussi l'article 6.4.2.1.

Le texte de cette Norme internationale est issu des documents suivants:

Projet	Rapport de vote
82/2029/FDIS	82/2052/RVD

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

La langue employée pour l'élaboration de cette Norme internationale est l'anglais.

Une liste de toutes les parties de la série IEC 62759, publiées sous le titre général *Modules photovoltaïques (PV) – Essais de transport*, peut être consultée sur le site web de l'IEC.

Ce document a été rédigé selon les Directives ISO/IEC, Partie 2, il a été développé selon les Directives ISO/IEC, Partie 1 et les Directives ISO/IEC, Supplément IEC, disponibles sous www.iec.ch/members_experts/refdocs. Les principaux types de documents développés par l'IEC sont décrits plus en détail sous www.iec.ch/standardsdev/publications.

Le comité a décidé que le contenu de ce document ne sera pas modifié avant la date de stabilité indiquée sur le site web de l'IEC sous webstore.iec.ch dans les données relatives au document recherché. À cette date, le document sera

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MODULES PHOTOVOLTAÏQUES (PV) – ESSAIS DE TRANSPORT –

Partie 1: Transport et expédition d'unités d'emballage de modules

1 Domaine d'application

Les modules photovoltaïques (PV - photovoltaic) sont des dispositifs électriques destinés à une exposition extérieure continue pendant leur durée de vie. Les normes d'homologation existantes ne prennent pas en considération les contraintes mécaniques pouvant survenir au cours du transport vers la destination d'installation du PV.

La présente partie de l'IEC 62759 décrit les méthodes de simulation de transport de l'ensemble des unités d'emballage des modules et des impacts environnementaux résultants combinés.

L'Annexe B fournit une liste des modifications de la conception qui exige un contre-essai.

Le présent document s'applique aux modules photovoltaïques à plaque plane.

2 Références normatives

Les documents suivants sont cités dans le texte de sorte qu'ils constituent, pour tout ou partie de leur contenu, des exigences du présent document. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

IEC 60068-2-27:2008, *Essais d'environnement – Partie 2-27: Essais – Essai Ea et guide: Chocs*

IEC TS 60904-13, *Photovoltaic devices – Part 13: Electroluminescence of photovoltaic modules* (disponible en anglais seulement)

IEC 61215-1:2021, *Modules photovoltaïques (PV) pour applications terrestres – Qualification de la conception et homologation – Partie 1: Exigences d'essai*

IEC 61215-2:2021, *Modules photovoltaïques (PV) pour applications terrestres – Qualification de la conception et homologation – Partie 2: Procédures d'essai*

IEC 61730-2, *Qualification pour la sûreté de fonctionnement des modules photovoltaïques (PV) – Partie 2: Exigences pour les essais*

IEC TS 61836, *Solar photovoltaic (PV) energy systems – Terms, definitions and symbols* (disponible en anglais seulement)

IEC TS 62782:2016, *Photovoltaic (PV) modules – Cyclic (dynamic) mechanical load testing* (disponible en anglais seulement)

ASTM D880-92, *Standard Test Method for Impact Testing for Shipping Containers and Systems*

ASTM D4169-16, *Standard Practice for Performance Testing of Shipping Containers and Systems*

ASTM D4728:2006, *Standard Test Method for Random Vibration Testing of Shipping Containers*

ASTM D5277-92, *Test method for performing programmed horizontal impact using an inclined impact tester*

ISTA 3E:2017, *Unitized Loads of Same Product*

3 Termes et définitions

Pour les besoins du présent document, les termes et définitions de l'IEC TS 61836 ainsi que les suivants s'appliquent.

L'ISO et l'IEC tiennent à jour des bases de données terminologiques destinées à être utilisées en normalisation, consultables aux adresses suivantes:

- IEC Electropedia: disponible à l'adresse http://www.electropedia.org/
- ISO Online browsing platform: disponible à l'adresse http://www.iso.org/obp

3.1
largeur de bande
différence en Hz entre les limites supérieure et inférieure d'une bande de fréquences

Note 1 à l'article: Pour les besoins de la méthode d'essai décrite, la largeur de bande peut être considérée comme équivalente à la résolution en fréquence d'une analyse spectrale.

3.2
g_{RMS} totale
racine carrée de l'intégrale de la densité spectrale de puissance sur l'ensemble de la plage de fréquences

Note 1 à l'article: Elle décrit la sévérité ou la rigueur de la classe des essais.

3.3
valeur quadratique moyenne
RMS
racine carrée de la valeur quadratique moyenne

Note 1 à l'article: Dans le cas d'une onde sinusoïdale uniquement, la valeur RMS représente 0,707 fois la valeur de crête.

Note 2 à l'article: L'abréviation "RMS" est dérivée du terme anglais développé correspondant "root mean square".

3.4
vibration aléatoire
oscillation dont l'amplitude instantanée n'est pas spécifiée pour un instant donné quelconque

Note 1 à l'article: Les amplitudes instantanées d'une vibration aléatoire sont spécifiées par une fonction de distribution de probabilités, dont l'intégrale, dans une plage d'amplitude donnée, indique, en pourcentage, la durée probable pendant laquelle l'amplitude se situe dans cette plage.

Note 2 à l'article: La vibration aléatoire ne contient pas de composante périodique ou quasi périodique.

3.5
emballage
matériau et technologie utilisés pour protéger les marchandises des contraintes de transport et séparer les unités individuelles les unes des autres

3.6
densité spectrale de puissance
PSD
expression de la vibration aléatoire en termes d'accélération quadratique moyenne par unité de fréquence

Note 1 à l'article: La densité spectrale de puissance est la limite de l'amplitude quadratique moyenne dans une gamme d'ondes rectangulaires donnée, divisée par la largeur de bande, la largeur de bande approchant de zéro.

Note 2 à l'article: Les unités sont $(m/s^2)^2/Hz$ et elle est égale à m^2/s^3. L'unité non SI pertinente est g^2/Hz.

Note 3 à l'article: L'abréviation "PSD" est dérivée du terme anglais développé correspondant "power spectral density".

4 Échantillonnage

Un colis d'expédition de modules PV doit être prélevé de façon aléatoire dans un ou plusieurs lots de production afin de constituer les échantillons d'essai pour le transport de base et les méthodes d'essai de chocs. Lorsque les échantillons d'essai sont des prototypes

d'une nouvelle conception et non issus de la production, ce fait doit être noté dans le rapport d'essai. Le colis d'expédition doit contenir le nombre habituel de modules PV.

Trois autres modules PV doivent être prélevés d'un colis d'expédition séparé qui n'est pas soumis à une simulation de transport.

Utiliser pour les modules les matériaux d'emballage d'expédition habituels tels que commercialisés et conçus par le fabricant.

Les modules doivent avoir été fabriqués dans des matériaux et des composants spécifiés, conformément aux dessins et aux fiches de processus applicables et doivent avoir été soumis à l'examen, au contrôle de qualité et aux procédures d'acceptation de production normaux du fabricant.

Les modules doivent être complets à tous égards, y compris une indication du type, et doivent être accompagnés des instructions du fabricant concernant la manipulation, le montage, l'expédition/l'emballage et l'installation, y compris les informations concernant la tension de réseau maximale admissible.

L'éprouvette d'essai du colis d'expédition doit être emballée conformément aux procédures normalisées utilisées pour expédier des modules aux clients.

5 Manipulation

Les échantillons d'essai doivent être manipulés avec les précautions appropriées avant l'application des essais décrits dans le présent document. Il convient de vérifier que les échantillons d'essai ne sont pas exposés à des impacts mécaniques supplémentaires, sous la forme de chocs, d'une manipulation brutale, de chutes, etc.

Pour le transport du fabricant au laboratoire d'essai, il convient de prendre des précautions particulières pour éviter tout dommage. Un concept d'emballage spécial (par exemple, un emballage supplémentaire, une méthode de transport spéciale, etc.), peut être envisagé pour ce trajet d'expédition particulier (fabricant – site d'essai). Les essais doivent être effectués sans emballage supplémentaire.

6 Procédures d'essai

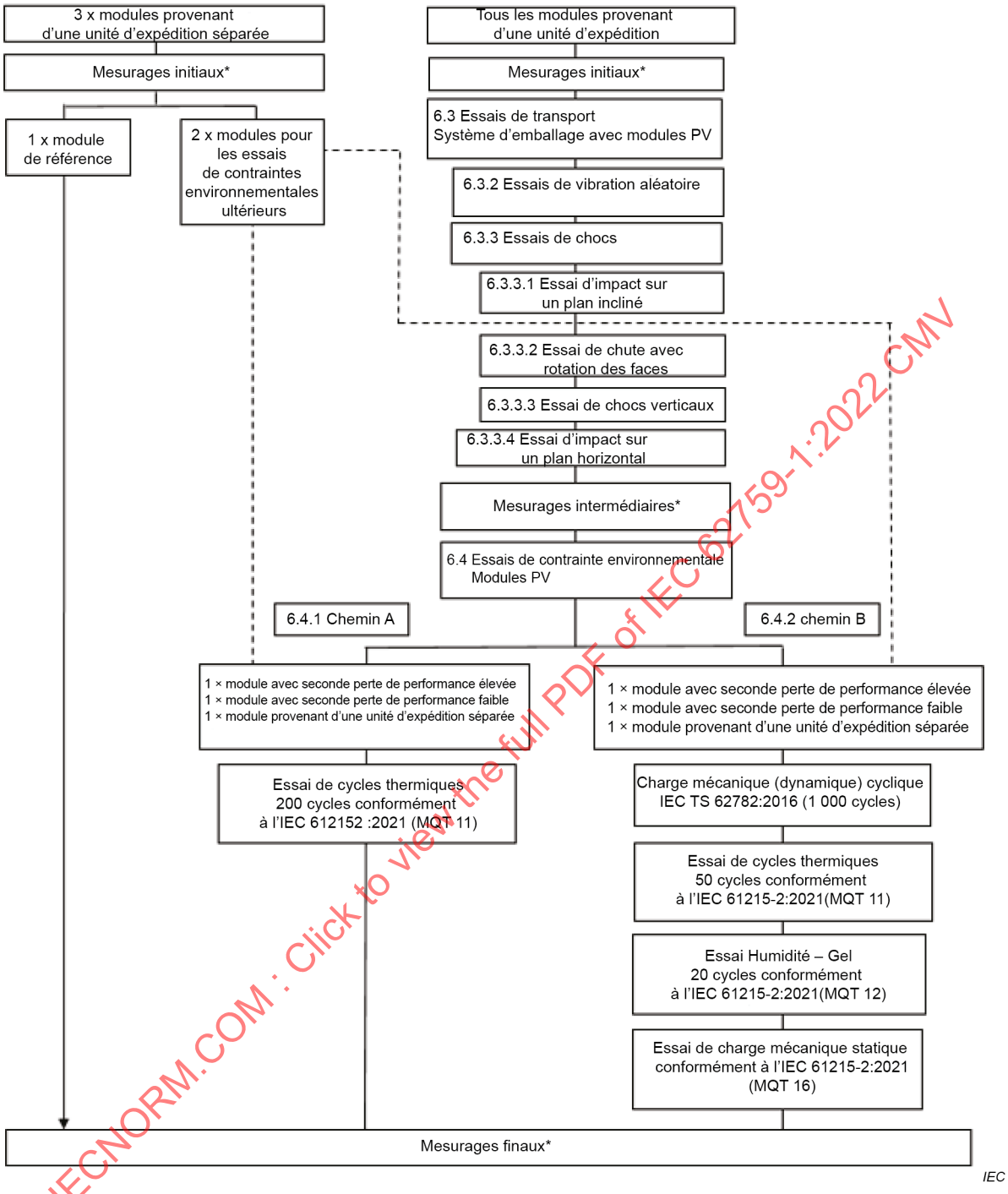
6.1 Généralités

Les mesurages de performance, l'examen visuel ainsi que l'essai diélectrique et l'essai de courant de fuite en milieu humide doivent être effectués conformément à l'IEC 61215-2:2021, MQT 01, MQT 02 et conformément à l'IEC 61730-2:2022, MST 16 et MST 17, comme mesurages initiaux de référence et de contrôle.

Les images d'électroluminescence conformes à l'IEC TS 60904-13 peuvent être utilisées pour détecter les fissures invisibles à des états initial et intermédiaire (les critères d'acceptation/de rejet ne sont pas spécifiés).

L'essai de transport réel est représenté à la Figure 1. Les séquences d'essais combinés de contraintes de transport et des effets possibles de ces impacts sur les modules PV doivent détecter les défaillances précoces par rapport aux contraintes apparaissant ultérieurement au cours de la durée de vie.

Les modules séparés, non soumis aux essais de transport, sont aussi soumis aux essais de contrainte dans les séquences A et B. Ces modules doivent être utilisés pour identifier si les défauts sont provoqués par l'essai de transport et l'essai d'environnement résultant, ou uniquement par l'essai d'environnement.



* Voir le paragraphe 6.2 pour des précisions sur les mesurages.

Figure 1 – Séquences d'essai pour modules PV

6.2 Mesurages

Chaque mesurage initial, intermédiaire et final doit caractériser les performances électriques des modules PV et documenter l'influence des essais de contrainte. Les mesurages initiaux, intermédiaires et finaux sont:

- l'examen visuel conformément à l'IEC 61215-2:2021 (MQT 01);
- la stabilisation (facultative pour les mesurages intermédiaires) conformément à l'IEC 61215-2:2021 (MQT 19);
- la détermination de la puissance maximale conformément à l'IEC 61215-2:2021 (MQT 02);
- l'essai diélectrique conformément à l'IEC 61730-2:2022 (MST 16);