

SEMI PV23-1011 (Reapproved 0818) TEST METHOD FOR MECHANICAL VIBRATION OF CRYSTALLINE SILICON PHOTOVOLTAIC (PV) MODULES IN SHIPPING ENVIRONMENT

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1 Purpose

1.1 Reliability is an issue that is particularly important in the photovoltaic (PV) industry. Module buyers invest their money on both the performance and reliability of the product. The most promising solution to minimize the cost to both the customer and the manufacturer is to conduct tests prior to shipping, ensuring that the module can withstand the environmental conditions.

1.2 This Standard aims to provide a common test method to evaluate damages to PV modules due to mechanical vibration occurring during transportation and shipment. Module manufacturers and buyers, or any other interested party, can thus have a common testing standard to refer to when desired. This Standard is also expected to accelerate development of safer means of module protection during transportation.

1.3 The results of this Test Method provide information on the level of module protection provided by the packaging design.

2 Scope

2.1 *Basic Test System Requirements* — This Standard states the basic vibration test system requirements.

2.2 *Testing Procedure* — The general testing procedures are provided with a flowchart, including the vibration test and the pre-test and post-test examination of the PV module performance, according to current IEC standards. These specifications for the vibration, including the frequency range and power spectral density, etc., corresponding to particular means of transportation are chosen by the user according to existing standards (e.g., ASTM, MIL-STD or ISTA) or other sources.

2.3 *Sampling Method* — Usually multiple PV modules are stacked and shipped together in a unit. It is unnecessary, time-consuming and cost-intensive to carry out full performance tests on all modules in the same stack. Therefore, recommendations are made on how to select the modules that shall undergo the pre-test and post-test examinations.

2.4 *Sample Report and Data Formats* — Results and relevant information are stated in the final test report to the customer, and in recommended report and data formats.

NOTICE: SEMI Standards and Safety Guidelines do not purport to address all safety issues associated with their use. It is the responsibility of the users of the Documents to establish appropriate safety and health practices, and determine the applicability of regulatory or other limitations prior to use.

3 Limitations

3.1 This Document does not specify and therefore does not restrict the package design of the shipping unit.

3.2 This Test Method does not provide the specifications of the vibration, such as the power spectral density (PSD) profile and the test time since some customers may require different types of vibration specifications depending on the means of transportation or the location of manufacturing.

4 Referenced Standards and Documents

4.1 ASTM Standards¹

ASTM D4728 — Standard Test Method for Random Vibration Testing for Shipping Containers

ASTM D4169 — Standard Practice for Performance Testing of Shipping Containers and Systems

ASTM D4332 — Standard Practice for Conditioning Containers, Packages, or Packaging Components for Testing

4.2 IEC Standards²

IEC 61215 — Crystalline Silicon Terrestrial Photovoltaic (PV) Modules – Design Qualification and Type Approval

IEC 61730-2 — Photovoltaic (PV) Module Safety Qualification Part 2: Requirements for Testing

IEC 60068-2-64 — Environmental Testing – Part 2-64: Tests – Test Fh: Vibration, Broadband Random and Guidance

4.3 ISO Standard³

ISO 2233 — Packaging – Complete, Filled Transport Packages and Unit Loads – Conditioning for Testing

4.4 Military Standard⁴

MIL-STD-810 — Environmental Engineering Considerations and Laboratory Tests

NOTICE: Unless otherwise indicated, all documents cited shall be the latest published versions.

5 Terminology

5.1 Abbreviations and Acronyms

5.1.1 *PSD* — power spectral density

5.1.2 *PV* — photovoltaic

5.2 Definitions

5.2.1 *customer* — an individual or a company who uses this Standard.

5.2.2 *dummy module* — a device mechanically equivalent (such as in mass, mass distribution, linear dimensions, and rigidity), for the purposes of vibration testing, to a PV module.

5.2.3 *test module* — a module that undergoes the pre-test and post-test examinations for the evaluation of damages caused by vibration.

5.2.4 *test specimen* — a complete, filled transport package or unit load that is effectively identical to that during the actual transportation or shipping.

5.2.5 *test module locations* — the locations in the stacked modules where test modules are to be placed during the vibration test.

5.2.6 *vibration test specification* — data required to perform a vibration test using the apparatus in § 6, including the power spectral density, overall root-mean-square of the acceleration and the test duration.

6 Apparatus

6.1 *Vibration Table (Shaker)* — The vibration table must be sufficiently large to contain the whole test specimen. It shall be sufficiently strong and rigid in order to deliver the vibration specification, in terms of power, displacement and frequency range. In cases where the test specimen might fall off the table during testing, low fences should be

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² International Electrotechnical Commission, 3 rue de Varembe, Case Postale 131, CH-1211 Geneva 20, Switzerland; Telephone: +41.22.919.02.11, Fax: +41.22.919.03.00, <http://www.iec.ch>

³ International Organization for Standardization, ISO Central Secretariat, BIBC II, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland; Telephone: +41.22.749.01.11, <http://www.iso.org>

⁴ Available from EverySpec; <http://www.everyspec.com>

used to restrict sideways movements. The vibration table shall be horizontal within a maximum angular deviation of 0.3°.

6.2 *Instrumentation* — Apparatuses including the accelerometers, signal conditioners, analyzers, data display, storage devices and electronic controls are required to measure and control the vibration table. In addition, the instrumentation is required for measuring the response of the tested item. The system shall have a response accurate to within $\pm 5\%$ over the frequency range specified for the test. Accelerometers should be small and light weight enough as to not influence the results of the test or measurement.⁵

7 Preconditioning and Conditioning

7.1 The test specimen shall be conditioned according to the relevant sections in the same document of which the vibration test specification is used. For general or unspecified cases, ASTM D4332 or ISO 2233 are recommended for the conditioning.

8 Vibration Test Specification

8.1 The vibration test specification, including the power spectral density, overall root-mean-square of the acceleration and the test duration, shall be chosen by the customer, usually referring to an existing transportation test standard. For general ground transportation, it is recommended to use the ASTM D4169 Truck Assurance Level II random profile.

8.2 This Standard requires vibration testing only in the vertical direction.

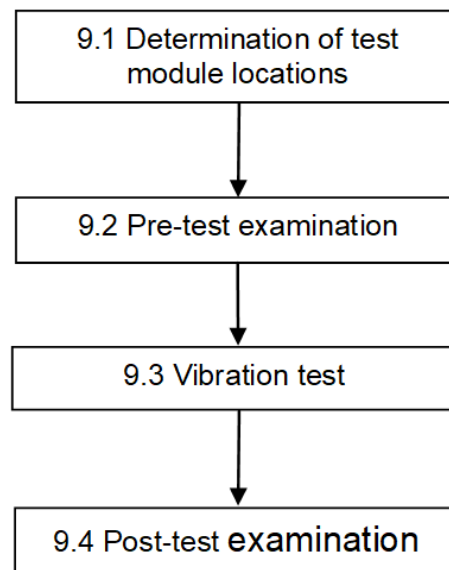


Figure 1
Testing Procedure Flowchart

9 Testing Procedures (See Figure 1)

9.1 *Determination of Test Module Locations* — This test indicates modules in which locations of the shipping unit shall undergo the pre-test and post-test examinations in ¶¶ 9.2 and 9.3, by determining the distribution of the vibration response at various module locations. The modules used in this test may be dummy modules. If the required vibration test specification changes, the test in ¶ 9.1 shall be performed once again.

9.1.1 Place the test specimen on the vibration table. If the vibration table is not big enough to contain the whole base of the package, an extension shall be used. The extended vibration table shall fulfill the requirements in ¶ 6.1.

⁵ More information on suitable instrumentation may be found in the *Shock and Vibration Handbook* (see ¶ 11.1).

9.1.2 Choose uniformly a selection of modules in the package to measure the vibration response distribution. The accelerometers shall be attached to the centers of the modules either on the front or the back sides.

9.1.3 In most cases, modifications (e.g., drilling holes) to the module frames and the container are required to access the measuring points while placing the accelerometers. The modification shall be done as small as possible so as to not alter the mechanical property of the module significantly for the vibration test. For example, for a module frame with frame depth 30 mm (not including the part that holds the glass panel), a circular aperture of diameter 10 mm can be made to the side of a frame, at least 20 cm away from the corners, in order to allow the electrical leads to enter the measuring point (see Figure 2). The electrical lead shall be fixed so that its movement during the vibration test does not affect the measurement. An opening to the container box may also be made to allow the electric lead to access the stack modules inside.

9.1.4 Input the vibration test specifications to the electronic control, and activate the loaded vibration table for a time period of at least 3 minutes. The vibration response of the modules at their centers shall be recorded, to determine the root-mean-squares of the acceleration g_{rms}^d at the center of the modules.

9.1.5 Compare the values of g_{rms}^d from the measured locations, and use the following criteria for the selection of the test module locations:

9.1.5.1 *Method A* — If the values are all within $\pm 50\%$ of the mean g_{rms}^d value, choose any three module locations that are the most convenient for operation.

9.1.5.2 *Method B* — If one or more module locations are outside $\pm 50\%$ of the mean g_{rms}^d value, choose three locations with the largest g_{rms}^d .

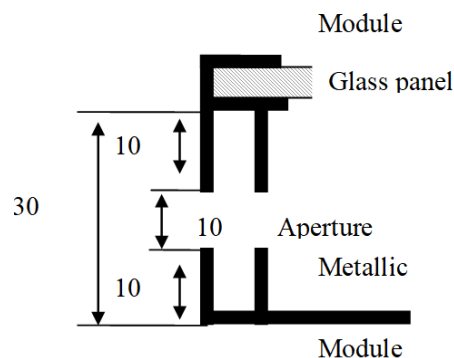


Figure 2
An Aperture Made for the Access of Electrical Leads on the PV Module Frame

9.2 *Pre-Test Examination* — For a shipping unit with three or more modules in a stack, use three test modules. If there are only two modules in the shipping unit, use two test modules; if there is only one, use one. The pre-test examination consists of a selection of IEC tests and measurements on the PV modules according to the items listed in Table 1. If a module fails a test, it should be replaced by a new test module until all tests in ¶ 9.2 are passed.

9.3 Vibration Testing

9.3.1 Place the pre-tested modules at the test module locations determined in step ¶ 9.1. The other modules can be dummy modules.

9.3.2 Attach accelerometers to the centers of the test modules to monitor the vibration response during the vibration test to obtain a root-mean-square acceleration g_{rms}^d . Modifications to the test specimen may be made according to the method in ¶ 9.1.3.

9.3.3 Input the vibration specifications and test for the specified test duration.