Designation: E 1171 – ~~99~~01

~~An American National Standard~~

Standard Test Methods for Photovoltaic Modules in Cyclic Temperature and Humidity Environments[1]

This standard is issued under the fixed designation E 1171; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 These test methods provide procedures for ~~determining the ability of~~ stressing photovoltaic modules ~~to withstand~~ in simulated temperature and humidity environments. Environmental testing is used to simulate aging of module materials on an accelerated basis.

1.2 Three individual environmental test procedures are defined by these test methods: a thermal cycling procedure, a humidity-freeze cycling procedure, and an extended duration damp heat procedure. Electrical biasing is utilized during the thermal cycling procedure to simulate stresses that are known to occur in field-deployed modules.

1.3 These test methods define mounting methods for modules undergoing environmental testing, and specify parameters that must be recorded and reported.

1.4 These test methods do not establish pass or fail levels. The determination of acceptable or unacceptable results is beyond the scope of these test methods.

1.5 Any of the individual environmental tests may be performed singly, or may be combined into a test sequence with other environmental or non-environmental tests, or both. Certain pre-conditioning tests such as annealing or light soaking may also be necessary or desirable as part of such a sequence. The determination of any such sequencing and pre-conditioning is beyond the scope of this test method.

1.6 These test procedures are limited in duration and therefore the results of these tests cannot be used to determine photovoltaic module lifetimes.

1.7 There is no similar or equivalent ISO standard.

1.~~7~~8 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

[1] Th~~i~~ese test methods ~~is~~ are under the jurisdiction of ASTM Committee E~~-~~44 on Solar, Geothermal, and Other Alternative Energy Sources and is the direct responsibility of Subcommittee E44.09 on Photovoltaic Electrical Power ~~Systems.~~ Conversion.

Current edition approved ~~Oct.~~ June 10, ~~1999.~~ 2001. Published ~~November 1999.~~ September 2001. Originally published as E 1171–~~87~~96. Last previous edition E 1171–9~~7~~6.

E 772 Terminology Relating to Solar Energy Conversion[2]
E 1036 Methods of Testing Electrical Performance of Nonconcentrator Terrestrial Photovoltaic Modules and Arrays Using Reference Cells[2]
E 1328 Terminology Relating to Photovoltaic Solar Energy Conversion[2]
E 1462 Test Methods for Insulation Integrity and Ground Path Continuity of Photovoltaic Modules[2]
E 1799 Practice for Visual Inspections of Photovoltaic Modules[2]
~~E 1830M Test Methods for Determining the Mechanical Integrity of Photovoltaic Modules[2]~~

3. Terminology

3.1 *Definitions—~~d~~*Definitions of terms used in this standard may be found in Terminology E 772 and in Terminology E 1328.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 ~~*ground fault*~~*module ground point*~~—a module fault where any portion of~~—the terminal or lead identified by the~~ module circuitry between~~ manufacturer as the~~ output terminals becomes electrically connected to the module~~ grounding~~ point.~~

~~3.2.2 *open circuit*—a module fault where any portion~~ point of the~~ module circuitry between the output terminals becomes electrically discontinuous.~~ module.

4. Significance and Use

4.1 The useful life of photovoltaic modules may depend on their ability to withstand repeated temperature cycling with varying amounts of moisture in the air. These test methods provide procedures for simulating the effects of cyclic temperature and humidity environments. An extended duration damp heat procedure is provided to simulate the effects of long term exposure to high humidity.

~~4.2 These test methods describe procedures for mounting test modules, conducting the environmental tests, and reporting the results.~~

~~4.2.1 Test~~

4.2 *Mounting*—Test modules are mounted so that they are electrically isolated from each other, and in such a manner to allow free air circulation around the front and back surfaces of the modules.

4.3 *Current Biasing*:

4.3.1 During the thermal cycling procedure, test modules are operated without illumination and with a forward-bias current equal to the maximum power point current at standard reporting conditions (SRC, see Test Methods E 1036) flowing through the module circuitry.

4.3.2 The current biasing is intended to stress the module interconnections and solder bonds in ways similar to those that are believed to be responsible for fill-factor degradation in field-deployed modules.

4.4 *Effects of Test Procedures*—Data generated using these test methods may be used to evaluate and compare the effects of simulated environment on test specimens. These test methods require determination of both visible effects and electrical performance effects.

4.~~3~~4.1 Effects on modules may vary from none to significant changes. Some physical changes in the module may be visible when there are no apparent electrical changes in the module. Similarly, electrical changes may occur with no visible changes in the module.

4.~~3~~4.2 All conditions of measurement, effects of cycling, and any deviations from this test method must be described in the report so that an assessment of their significance can be made.

4.~~4~~5 *Sequencing*—If these test methods are performed as part of a combined sequence with other environmental or non-environmental tests, the results of the final electrical tests (~~7~~6.2) and visual inspection (~~7~~6.3) determined at the end of one test may be used as the initial electrical tests and visual inspection for the next test; duplication of these tests is not necessary unless so specified.

5. Apparatus

5.1 In addition to the apparatus required for Test Methods E 1036 and E 1462 the following apparatus is required.

5.2 *Environmental Chamber(s)*—A chamber or chambers in which modules are mounted during the environmental tests.

5.2.1 Air temperature throughout the working volume shall be within ±2°C of that specified.

5.2.2 Relative humidity shall be controlled within ±5 % of that specified. For temperatures below 80°C, relative humidity control is not required.

5.2.3 Provisions for monitoring and recording the chamber temperature and relative humidity throughout the environmental testing shall be provided.

5.3 *Temperature Measurement Equipment*—An instrument or instruments used to measure module temperature during the environmental testing with a resolution of at least 0.1°C, and a total error of less than ±2°C of reading.

5.3.1 Temperature sensors suitable for the test temperature range, such as thermocouples or thermistors, shall be attached to the portions of the modules likely to exhibit the longest thermal time constant. For flat-plate modules, attach the sensors near the

[2] *Annual Book of ASTM Standards*, Vol 12.02.

middle of the front or back surfaces of the modules.

5.3.2 If more than one module of identical design and construction is tested simultaneously, it is not necessary to monitor the temperature of all identical modules.

~~5.4 *Ground Fault and Open Circuit Monitoring Equipment*—An electrical circuit attached to all test modules which can detect ground faults and open circuits. The equipment must monitor and record the state of the module circuitry throughout the environmental testing. An acceptable apparatus is described in Annex A1 of Test Methods E 1830M.~~

~~5.4.1 Modules that lack a grounding terminal identified by the module manufacturer are not required to be monitored for ground faults.~~

~~5.5~~ *Test Frame*—A frame inside the environmental chamber which ~~adequately~~ supports the test modules during the test procedures.

5.~~5~~4.1 It is not required to mount the test modules at an angle such as when modules are installed as part of an array; they may be mounted vertically to facilitate testing multiple modules inside the environmental chamber.

5.~~5~~4.2 The test modules shall be mounted in a manner that allows free air circulation around the modules.

5.~~5~~4.3 The test frame should be constructed such that corrosion of the test frame during the environmental testing does not adversely affect the test modules.

5.5 *Current-Biasing Power Supply*—A dc power supply capable of operating a test module at a point on the dark forward current-voltage curve equal to the maximum power current at SRC during the thermal cycling procedure.

5.5.1 Provisions must be made for removing the current bias when the module temperature is less than 20°C.

5.5.2 The current biasing power supply should be capable of setting a voltage compliance limit equal to 1.25 times the open-circuit voltage at SRC to prevent over-voltage operation of the test modules at high temperatures.

6. Procedure

6.1 *Sample Selection and Test Sequence*—Although the temperature cycling, humidity-freeze cycling, and damp heat procedures may be performed individually, the requirements of any test sequence (see 1.5 and 4.~~4~~5) may determine the order in which the environmental tests are performed, and also may impose restrictions on which test modules are to be subjected to individual procedures. The sequencing may also specify when modules undergo electrical testing (see 6.2) and visual inspections (see 6.3).

6.1.1 A typical combined thermal and humidity-freeze cycling sequence is illustrated in Fig. 1.

6.2 *Electrical Tests*—Perform the following electrical tests before and after each of the test procedures.

6.2.1 *Electrical Performance*—Measure and record the electrical performance of each module. A suitable method for nonconcentrator modules is Test Methods E 1036.

6.2.2 *Ground Path Continuity*—Test any module with a grounding terminal identified by the module manufacturer to determine the maximum resistance between the grounding terminal or lead and any accessible conductive part using ~~7.3~~ the ground path continuity test of Test Methods E 1462.

6.2.3 ~~*Insulation Integrity*~~*Dielectric Voltage Withstand*—Subject each module to a test of the ~~electrical isolation capability according to 7.1 and 7.2~~ dielectric voltage withstand test of Test Methods E 1462.

6.2.3.1 The test voltage shall be equivalent to twice the specified maximum system voltage (typically open-circuit voltage at

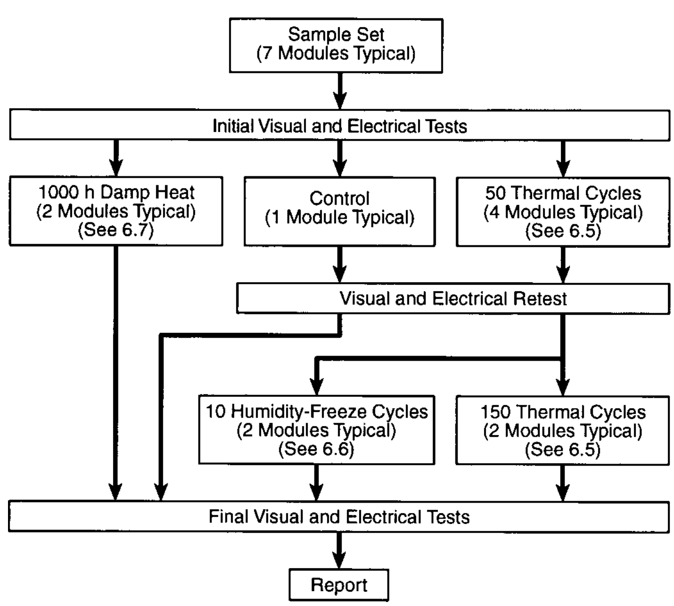

FIG. 1 Typical Environmental Test Sequence

0°C cell temperature) plus 1000~~ Vdc.~~ V. If the maximum system voltage is less than 30~~ Vdc,~~ V, employ a dc test voltage of 500 ~~Vdc.~~ V.

6.3 *Visual Inspection*—Visually inspect each module before and after each of the environmental test procedures to determine the presence or absence of anomalies or defects according to Practice E 1799.

6.4 *Instrumentation*~~:~~

~~6.4.1 Attach—~~Attach one or more temperature sensors to the exterior of the module following the requirements of 5.3.

~~6.4.2 Attach the ground fault and open circuit monitoring equipment specified in 5.4.~~

6.5 *Thermal Cycling Procedure*:

6.5.1 Mount the test modules inside the environmental chamber according to the requirements of 5.~~5~~4.

6.5.2 Connect the test modules to the current-biasing power supply and verify that the biasing is interrupted when the module temperature is less than 20°C.

6.5.3 Subject the module to a −40°C to +90°C thermal cycling test in accordance with the profile shown in Fig. 2 and the following requirements.

6.5.~~2~~3.1 The temperature shall vary approximately linearly with time at a rate not exceeding 100°C/h and with a period not greater than 6 h per cycle (from ambient to –40°C to +90°C to ambient).

6.5.3.2 Because the current biasing will dissipate heat in the test module, the temperature profile of the environmental chamber may need to be adjusted to prevent exceeding the maximum module temperature of Fig. 2.

6.5.3.3 Relative humidity in the chamber shall not exceed 50 % when temperatures are above 25°C.

6.5.~~2.~~3.4 Minimum holding time at the temperature extremes shall be 0.5 h.

6.5.~~3~~4 Continue the thermal cycling until the required number of cycles is completed.

6.5.~~3~~4.1 The temperature cycling may be interrupted and the chamber be opened~~ at 50 cycle intervals~~ for optional visual or electrical retest, or both, during the time the module temperature is at 25 ± 5°C. Such interruptions are typically done at 50-cycle intervals.

6.5.~~4~~5 ~~R~~Disconnect the current-biasing power supply and remove the modules from the environmental chamber.

6.6 *Humidity-Freeze Cycle Procedure*:

6.6.1 Mount the test modules inside the environmental chamber according to the requirements of 5.~~5~~4.

6.6.2 Subject the modules to a humidity-freeze cycling test in accordance with the profile shown in Fig. 3.

6.6.3 Continue the humidity-freeze cycling until the required number of cycles is completed.

6.6.4 Remove the modules from he environmental chamber.

6.7 *Damp Heat Exposure Procedure*:

6.7.1 Mount the test modules inside the environmental chamber according to the requirements of 5.~~5~~4.

6.7.2 Raise the chamber air temperature to 85 ± 2°C and the relative humidity to 85 ± 5 %.

6.7.3 Continue the exposure for a total of 1000 h.

6.7.4 Remove the modules from the environmental chamber.

6.7.5 Perform the post-exposure~~ insulation integrity~~ dielectric voltage withstand test (see 6.2.3) within 3 ± 1 h after the modules are removed from the chamber. To satisfy this requirement, the exposure duration may be increased by a maximum of 60 h.

7. Report

7.1 In addition to the reporting requirements of Test Methods E 1036 and E 1462, and Practice E 1799, report as a minimum the following data and information:

7.1.1 Module manufacturer and complete test specimen identification.

7.1.2 Description of module construction.

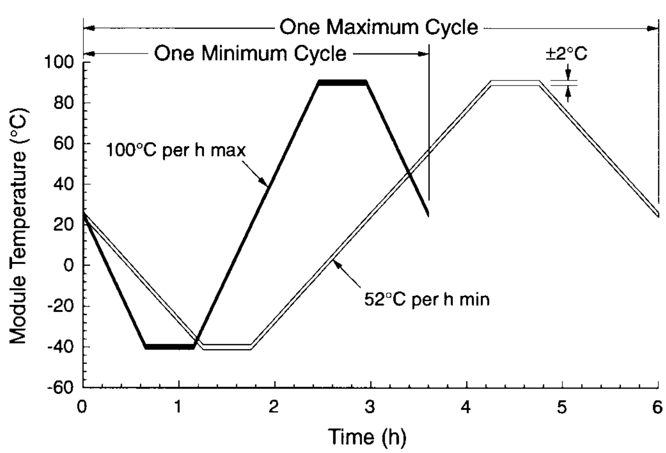

FIG. 2 One Thermal Cycle

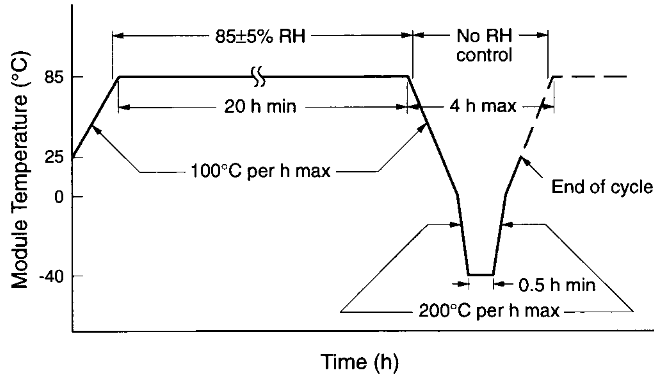

FIG. 3 One Humidity-Freeze Cycle

7.1.3 A line drawing or photograph of the modules showing the orientation during exposure and the location of temperature sensors.

7.1.4 Description of electrical measurement equipment (including continuity and insulation integrity apparatus), and measurement conditions or parameters.

7.1.5 A brief description of the chamber used, the exact number of cycles performed, and the number of hours of damp heat exposure.

7.1.6 Any deviations from this test method such as interruptions in the test cycle.

7.1.7 Any interruptions in the current biasing during thermal cycling caused by open circuits in the module circuitry.

8. Precision and Bias

8.1 The environmental exposures described by this test method do not produce numeric results that would be subject to ASTM procedures for evaluating the precision and bias of this test method. However, the precision and bias of the electrical performance measurements, when performed in accordance with Test Methods E 1036 and E 1462, are subject to the provisions of those test methods.

9. Keywords

9.1 ~~D~~damp ~~H~~ heat ~~E~~ exposure; ~~E~~ environmental ~~T~~ testing; ~~H~~ humidity-~~F~~freeze ~~C~~ cycling; ~~M~~ modules; ~~P~~ photovoltaics; ~~S~~ solar ~~E~~ energy; ~~T~~ thermal ~~C~~ cycling