Designation: E 1597 – 99

Standard Test Method for Saltwater Pressure Immersion and Temperature Testing of Photovoltaic Modules for Marine Environments[1]

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1. Scope

1.1 This test method provides a procedure for determining the ability of photovoltaic modules to withstand repeated immersion or splash exposure by seawater as might be encountered when installed in a marine environment, such as a floating aid-to-navigation. A combined environmental cycling exposure with modules repeatedly submerged in simulated saltwater at varying temperatures and under repetitive pressurization provides an accelerated basis for evaluation of aging effects of a marine environment on module materials and construction.

1.2 This test method defines photovoltaic module test specimens and requirements for positioning modules for test, references suitable methods for determining changes in electrical performance and characteristics, and specifies parameters which must be recorded and reported.

1.3 This test method does not establish pass or fail levels. The determination of acceptable or unacceptable results is beyond the scope of this test method.

1.4 There is no similar or equivalent ISO Standard.

1.5 *Units*—The values stated in SI units are to be regarded as the standard. No other units of measurement are included in this standard.

1.6 *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:*

D 1141 Specification for Substitute Ocean Water[2]

E 772 Terminology Relating to Solar Energy Conversion[3]

E 1036 Test Methods for Electrical Performance of Nonconcentrator Terrestrial Photovoltaic Modules and Arrays Using Reference Cells[3]

E 1328 Terminology Relating to Photovoltaic Solar Energy Conversion[3]

E 1462 Test Methods for Insulation Integrity and Ground Path Continuity of Photovoltaic Modules[3]

3. Terminology

3.1 *Definitions*—Definitions of terms used in this test method may be found in Terminology E 772 and Terminology E 1328.

3.2 *Definition of Term Specific to This Standard:*

3.2.1 **PIT**, *n*—Pressure, Immersion, and Temperature.

4. Significance and Use

4.1 The useful life of photovoltaic modules deployed in marine applications (such as floating aids-to-navigation) may depend on the ability to withstand repeated exposure to salt atmosphere, immersion in seawater, and the temperature changes associated with seawater splash falling on modules operating in sunlight. The effects of these exposures may be physical or electrical changes in the module, or both.

4.2 This test method describes a procedure for positioning the test specimen, conducting a cyclical combined pressure, immersion, and temperature (PIT) test, and reporting the results. It also references methods for conducting module electrical performance and insulation integrity tests.

4.3 Data generated by this test method may be used to evaluate and compare the effects of a simulated marine environment on test specimens. This test method requires recording of visible effects as well as electrical performance.

4.3.1 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.

5. Apparatus

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

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[2] *Annual Book of ASTM Standards*, Vol 11.02.

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

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5.1.1 *PIT Chamber*—A thermally insulated, pressure-resistant test apparatus with a main chamber of sufficient volume to submerge the test modules in simulated seawater solution. A means of pressurizing the chamber with compressed air to 35 kPa is required. Two secondary holding tanks are required for storing prescribed volumes of simulated seawater solution maintained at low temperature, 6 ± 3°C, and high temperature, 45 ± 5°C, respectively. Auxiliary pumps and valves for transferring solutions between the holding tanks and the testing chamber are also needed. All equipment shall be constructed from corrosion resistant materials. Baffles or diffusers shall be employed to prevent mechanical shock to the test samples while pumping simulated seawater.

6. Procedure

6.1 *Test Lot Selection*—Select a minimum of four modules considered to be representative of the type to be tested. Reserve one of the four modules as a control sample. If the lot represents more than one size of modules employing the same encapsulation system design, at least two modules of each size shall be tested. No disassembly, alteration of, or modification to the samples or any part thereof shall be permitted during the test sequence.

6.2 *Electrical Tests*— Perform the following electrical tests on all samples, including the control, prior to the PIT cycling tests:

6.2.1 *Electrical Performance*—Measure and record the electrical performance of each module. An acceptable method for non-concentrator modules is Test Methods E 1036.

6.2.2 *Ground Path Continuity Test*—Test any module with a grounding terminal to determine the maximum resistance between the grounding terminal or lead and any accessible conductive part using 7.3 of Test Method E 1462.

6.2.3 *Insulation Current Leakage Test*—Subject each module to a test of the electrical isolation capability according to 7.1 of Test Method E 1462.

6.2.4 *Insulation Resistance Test*—Measure the insulation resistance of each module using 7.2 of Test Method E 1462.

6.3 *Visual Inspection*:

6.3.1 Visually inspect each module to determine the presence or absence of defects or anomalies. Such anomalies or defects may include delaminations or voids, discolorations, corrosion, or cracks in any part of the assembly. Consider defects to be any obvious deviations from acceptable appearance, as defined by the user of the test method.

6.3.2 Record the results of the visual examination using photographs or a diagram of the specimen, or both, showing the location and type of defect.

6.4 *Sample Installation in PIT Chamber*—Provide each test sample with a means of sealing any open junction box fittings or feedthroughs if equipped with pigtails. Position the module in the test chamber. Extend any module electrical leads above the maximum expected saltwater depth.

6.5 *Simulated Seawater Preparation*—Prepare a simulated seawater solution of sufficient quantity to fill both holding tanks. An acceptable solution consists of a mixture of 3.63 kg of dry sea salt for every 94.6 litres of tap water, as in Specification D 1141. The relative density of the solution should be 1.025 ± 0.005 at 15°C. Adjust and maintain the solution temperatures in the two holding tanks to 6 ± 3°C and 45 ± 5°C, respectively.

6.6 *Test Sequence*:

6.6.1 Pump the hot seawater solution into the PIT chamber until the test samples are submerged. The pumping time shall be 3 ± 1 min.

6.6.2 Pressurize the PIT chamber with compressed air to 35 ± 1 kPa and hold for a minimum of 3 min.

6.6.3 Depressurize the chamber to atmospheric pressure and hold for a minimum of 2 min.

6.6.4 Repeat 6.6.2 and 6.6.3 for a total of five pressurization cycles.

6.6.5 Pump the hot seawater solution out of the PIT chamber and into the hot holding tank. The pumping time shall be 3 ± 1 min.

6.6.6 Pump the cold seawater solution into the PIT chamber until the test samples are submerged. The pumping time shall be 3 ± 1 min.

6.6.7 Repeat 6.6.2 and 6.6.3.

6.6.8 Pump the cold seawater solution out of the PIT chamber and into the cold holding tank. The pumping time shall be 3 ± 1 min.

6.6.9 Repeat 6.6.1 through 6.6.8 for a total of 500 hot-cold PIT cycles.

6.7 Remove the test samples from the PIT chamber and dry the external surfaces of the modules. Only towel drying by blotting, or free air drying of the samples shall be permitted. Compressed air, heated air, scrubbing with a towel, or other methods of drying the modules is not permitted.

6.8 Within 1 h after removal from the PIT chamber, repeat the insulation current leakage (6.2.3) and the insulation resistance (6.2.4) tests on all modules.

6.9 Rinse the samples with tap water to remove any encrusted salt and dry the external surfaces, adhering to the provisions of 6.7.

6.10 Repeat the ground path continuity (6.2.2) and electrical performance (6.2.1) tests on all modules.

6.11 Repeat the visual inspection (6.3) of all modules.

7. Report

7.1 The test report shall include the following information as a minimum:

7.1.1 Module fabrication,

7.1.2 Description of module construction,

7.1.3 A line drawing or photograph of the module showing the orientation during testing and the location of temperature sensing devices,

7.1.4 Description of electrical measurement equipment, and measurement conditions or parameters,

7.1.5 Description of any apparent changes due to testing, with sketches or photographs,

7.1.6 Results of changes between pre- and post-testing electrical tests, if any, including comparison to control sample test results,

7.1.7 A brief description of the PIT chamber used and exact number of PIT cycles performed, and

7.1.8 Any deviations from the standard test procedure, such as interruptions.

8. Precision and Bias

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

9. Keywords

9.1 corrosion; energy; environmental; immersion; modules; photovoltaics; pressure; saltwater; solar; temperature

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