INTERNATIONAL

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Standard Test Method for Rating Electrical Performance of Concentrator Terrestrial Photovoltaic Modules and Systems Under Natural Sunlight[1]

This standard is issued under the fixed designation E 2527; 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 This test method covers the determination of the electrical performance of photovoltaic concentrator modules and systems under natural sunlight using a normal incidence pyrheliometer.

1.2The test method is limited to modules and systems where the concentrated irradiance on the component cells is greater than 5000 Wm^{-2} at the direct normal rating irradiance.

1.2 The test method is limited to module assemblies and systems where the geometric concentration ratio specified by the manufacturer is greater than 5.

1.3 This test method applies to concentrators that use passive cooling where the cell temperature is related to the air temperature.

1.4 Measurements under a variety of conditions are allowed; results are reported under a select set of concentrator reporting conditions to facilitate comparison of results.

1.5 This test method applies only to concentrator terrestrial modules and systems.

1.6 This test method assumes that the module or system electrical performance characteristics do not change during the period of test.

1.7 The performance rating determined by this test method applies only at the period of the test, and implies no past or future performance level.

1.8 *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:*[2]

D 6176 Practice for Measuring Surface Atmospheric Temperature with Electrical Resistance Temperature Sensors

E 772 Terminology Relating to Solar Energy Conversion

E 816 Test Method for Calibration of Pyrheliometers by Comparison to Reference Pyrheliometers

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

E 1328 Terminology Relating to Photovoltaic Solar Energy Conversion

2.2 *IEEE Standard:*

IEEE 929-2000 Recommended Practice for Utility Interface of Photovoltaic (PV) Power Systems

3. Terminology

3.1 *Definitions*—Definitions of terms used in this test method may be found in Terminology E 772, Terminology E 1328, and IEEE Standard 929.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *Concentrator Reporting Conditions*, *n*— the ambient temperature, wind speed, and direct normal solar irradiance to which concentrator module or system performance data are corrected..

3.2.2 *system*, *n*—a photovoltaic module or array connected to an inverter.

3.3 *Symbols:* The following symbols and units are used in this test method:

[1] This test method is under the jurisdiction of ASTM Committee E44 on Solar, Geothermal and Other Alternative Energy Sources and is the direct responsibility of Subcommittee E44.09 on Photovoltaic Electric Power Conversion.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

E = direct normal irradiance, Wm^{-2}
E_o = ~~rating~~reporting direct normal irradiance of 850 Wm^{-2}
P = maximum power, W
P_o = maximum power at concentrator reporting conditions (E_o, T_o, and V_o), W
T_a = ambient temperature, °C
T_o = ~~rating~~reporting ambient temperature of 20°C
v = wind speed, ms^{-1}
v_o = ~~rating~~reporting wind speed of 4 ms^{-1}

4. Summary of Test Method

4.1 Determining the performance of a photovoltaic module or system under natural sunlight consists of measuring the maximum power over a range of irradiance and air temperature.

4.2 A multiple linear regression is used to rate the maximum power[3] at standard concentrator reporting conditions, defined as T_o = 20°C, v_o = 4 ms^{-1}, E_o = 850 Wm^{-2}.

4.2.1 A direct normal irradiance of 850 Wm^{-2} was selected from a resource assessment study[4] that showed when the global normal solar irradiance is near the 1000 Wm^{-2} used in rating flat-plate photovoltaic modules, the direct normal irradiance is about 850 Wm^{-2}.

4.3 The actual test data and the performance results are then reported.

5. Significance and Use

5.1 It is the intent of this test method to provide a recognized procedure for testing and reporting the electrical performance of a photovoltaic concentrator module or system.

5.2 If an inverter is used as part of the system, this test method can provide a dc or ac rating or both. The dc or ac rating depends on whether the inverter input or output is monitored.

5.3 The test results may be used for comparison among a group of modules or systems from a single source. They also may be used to compare diverse designs, such as products from different manufacturers. Repeated measurements of the same module or system may be used for the study of changes in device performance over a long period of time or as a result of stress testing.

5.4 The test method is limited to modules and systems where the concentrated irradiance on the component cells is greater than 5000 Wm^{-2} at E_o. This limitation is necessary because the total irradiance is measured with a radiometer with a field of view less than 6° and because the correlation between the direct irradiance and the power produced decreases with increasing concentrator field of view.

5.5 This test method assumes that the regression equation accurately predicts the concentrator performance as a function of total irradiance with a fixed spectral irradiance, wind speed, and air temperature. The spectral distribution will be seasonal and site specific because of optical air mass, water vapor, aerosols, and other meteorological variables.

6. Apparatus

6.1 *Test Fixture*—A platform that maintains an incidence angle to the sun of less than 0.5°. If the manufacturer's specifications require more accurate tracking than 0.5° incidence angle, the manufacturer's specifications should be followed. Concentrator systems shall be tested as installed.

6.2 *Air Temperature Measurement Equipment*—The instrument or instruments used to measure the temperature of the air shall have a resolution of at least 0.1°C, and shall have a total error of less than ±1°C of reading. The instrument sensor should be between 1 and 10 m upwind from the geometrical center of the receiver and be mounted at least 2 m above the ground. Further details on air temperature measurements can be found in Practice D 6176.

6.3 *Irradiance Measurement Equipment*— A secondary reference pyrheliometer calibrated according to Test Method E 816.

6.4 *Wind Speed Measurement Equipment*— The instrument used to measure the wind speed should have an uncertainty of less than 0.5 ms^{-1}~~. The instrument should be between 1 and 20 m from the geometrical center of the receiver and be mounted at least 2 m above the ground. Because there are many possible system configurations, care should be taken to minimize effects on the instrument readings from the system or nearby obstacles. Averaging readings from multiple instruments for large systems may be required. ~~. The instrument should be between 1 and 10 m away from the nearest edge of the receiver and be mounted at least 2 m above the ground. Ideally, the instrument should be at the center height of the receiver and located in the direction of the prevailing wind. Care should be taken that the instrument readings are not affected by the test fixture or nearby obstacles.

6.5 *Power Measurement Equipment*—Examples of acceptable instrumentation to measure the output power of the module or system under test include:

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[3] Hester, S. I., Townsend, W. T., Clements, W. T., and Stolte, W. J., "PVUSA Lessons Learned from Startup and Early Operation," Proc. of the 21st IEEE Photovoltaics Spec. Conf., IEEE, New York, NY, 1990, pp. 937-943.

[4] Kurtz, S., Myers, D., Townsend, T., Whitaker, C., Maish, A., Hulstrom, R., and Emery, K., "Outdoor Rating Conditions for Photovoltaic Modules and Systems," *Solar Energy Mater. Solar Cells* 62, 2000, pp. 379-391.