Designation: E 1362 – 99

Standard Test Method for Calibration of Non-Concentrator Photovoltaic Secondary Reference Cells[1]

This standard is issued under the fixed designation E 1362; 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 calibration and characterization of secondary terrestrial photovoltaic reference cells to a desired reference spectral irradiance distribution. The recommended physical requirements for these reference cells are described in Specification E 1040. Reference cells are principally used in the determination of the electrical performance of a photovoltaic device.

1.2 Secondary reference cells are calibrated indoors using simulated sunlight or outdoors in natural sunlight by reference to a primary reference cell previously calibrated to the same desired reference spectral irradiance distribution.

1.3 Secondary reference cells calibrated according to this test method will have the same radiometric traceability as the of the primary reference cell used for the calibration. Therefore, if the primary reference cell is traceable to the World Radiometric Reference (WRR, see Test Method E 816), the resulting secondary reference cell will also be traceable to the WRR.

1.4 This test method applies only to the calibration of a photovoltaic cell that demonstrates a linear short-circuit current versus irradiance characteristic over its intended range of use, as defined in Test Method E 1143.

1.5 This test method applies only to the calibration of a photovoltaic cell that has been fabricated using a single photovoltaic junction.

1.6 There is no similar or equivalent ISO standard.

1.7 *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:*

E 490 Solar Constant and Air Mass Zero Solar Spectral Irradiance Tables[2]

E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method[3]

E 772 Terminology Relating to Solar Energy Conversion[4]

E 816 Specification for Calibration of Pyrheliometers by Comparison to Reference Pyrheliometers[5]

E 891 Tables for Terrestrial Direct Normal Solar Spectral Irradiance for Air Mass 1.5[5]

E 892 Tables for Terrestrial Solar Spectral Irradiance at Air Mass 1.5 for a 37° Tilted Surface[5]

E 927 Specification for Solar Simulation for Terrestrial Photovoltaic Testing[4]

E 948 Test Method for Electrical Performance of Photovoltaic Cells Using Reference Cells Under Simulated Sunlight[4]

E 973 Test Method for Determination of the Spectral Mismatch Parameter Between a Photovoltaic Device and a Photovoltaic Reference Cell[4]

E 1021 Test Methods for Measuring Spectral Response of Photovoltaic Cells[4]

E 1039 Test Method for Calibration and Characterization of Non-Concentrator Terrestrial Photovoltaic Reference Cells Under Global Irradiation[4]

E 1040 Specification for Physical Characteristics of Non-Concentrator Terrestrial Photovoltaic Reference Cells[4]

E 1125 Test Method for Calibration of Primary Non-Concentrator Terrestrial Photovoltaic Reference Cells Using a Tabular Spectrum[4]

E 1143 Test Method for Determining the Linearity of a Photovoltaic Device Parameter With Respect to a Test Parameter[4]

E 1328 Terminology Relating to Photovoltaic Solar Energy Conversion[4]

[1] This test method is 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 Electric Power Conversion.

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[2] *Annual Book of ASTM Standards*, Vol 15.03.

[3] *Annual Book of ASTM Standards*, Vol 14.02.

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

[5] *Annual Book of ASTM Standards*, Vol 14.04.

3. Terminology

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

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *cell temperature, °C*, *n*—the temperature of the semiconductor junction of a photovoltaic cell.

3.2.2 *junction temperature*, *n*—synonym for **cell temperature**.

3.2.3 *test light source*, *n*—a source of radiant energy used for the secondary reference cell calibration.

3.3 *Symbols*:

3.3.1 The following symbols and units are used in this test method:

C—calibration constant, Am^2W^{-1},
E—irradiance, Wm^{-2},
E_t—total irradiance, Wm^{-2},
I—current, A,
I_p—primary reference cell short-circuit current, A,
I_s—secondary reference cell short-circuit current, A,
I_{sc}—*short-circuit current, A,*
L—collimator length, m,
M—spectral mismatch parameter,
n—total number of data points,
r—collimator receiving aperture radius, m,
R—collimator opening aperture radius, m,
R_a—absolute spectral response, AW^{-1},
R_r—relative spectral response,
S—standard deviation,
T—temperature, °C,
α—temperature coefficient of reference cell, $°C^{-1}$,
θ_o—*collimator opening angle, °, and*
λ—wavelength, nm or μm.

3.3.2 Symbolic quantities that are functions of wavelength appear as $X(\lambda)$.

4. Summary of Test Method

4.1 The calibration of a secondary photovoltaic reference cell consists of measuring the short-circuit current of the cell under natural or simulated sunlight using a primary reference cell to measure the incident irradiance. In addition to the short-circuit current, the relative spectral response of the cell to be calibrated and the relative spectral irradiance of the light source must be determined. Errors in the short-circuit current due to the spectral irradiance of the light source and the spectral response of the primary reference cell are then corrected by dividing the short-circuit current by the spectral mismatch parameter. Also, if the temperature of the cell is not 25 ± 1°C, the temperature coefficient for the short-circuit current is needed. The list of necessary test methods is as follows:

4.1.1 The spectral response of the cell to be calibrated is determined in accordance with Test Methods E 1021.

4.1.2 The cell's short-circuit current temperature coefficient is determined experimentally by measuring short-circuit current at various temperatures and computing the temperature coefficient.

4.1.3 Linearity of short-circuit current versus irradiance is determined in accordance with Test Method E 1143.

4.1.4 The relative spectral distribution of the light source is determined using a spectral irradiance measurement instrument as specified in Test Method E 973.

5. Significance and Use

5.1 The electrical output of photovoltaic devices is dependent on the spectral content of the source illumination and its intensity. To make accurate measurements of the performance of photovoltaic devices under a variety of light sources, it is necessary to account for the error in the short-circuit current that occurs if the relative spectral response of the primary reference cell is not identical to the spectral response of the cell to be calibrated. A similar error occurs if the spectral irradiance distribution of the test light source is not identical to the desired reference spectral irradiance distribution. These errors are accounted for by the spectral mismatch parameter M (Test Method E 973), a quantitative measure of the error in the short-circuit current measurement. It is the intent of this test method to provide a recognized procedure for calibrating, characterizing, and reporting the calibration data for secondary photovoltaic reference cells.

5.2 A secondary reference cell is calibrated to the same reference spectral irradiance distribution as the primary reference cell used during the calibration. Primary reference cells can be calibrated by use of Test Method E 1125 or Test Method E 1039.

NOTE 1—No standards for calibration of reference cells to the extraterrestrial spectral irradiance distribution presently exist.

5.3 A secondary reference cell should be recalibrated yearly, or every six months if the cell is in continuous use outdoors.

5.4 Recommended physical characteristics of reference cells are provided in Specification E 1040.

6. Apparatus

6.1 *Normal Incidence Tracking Platform* (for calibrations conducted in natural sunlight)—A tracking platform used to follow the sun that holds both the primary reference cell and the cell to be calibrated. The tracker shall be able to track the sun to within ±0.5° during the calibration procedure.

6.1.1 When the calibration is performed in direct natural sunlight, each cell and the spectral irradiance measurement (see 6.7) shall have collimators that meet the requirements of Annex A1 of Test Method E 1125.

6.1.2 When the calibration is performed in global normal conditions, no significant energy reflected from surrounding buildings or any other surfaces in the vicinity of the test stand shall be allowed onto the reference cells for the duration of the calibration period. Care shall be taken to conduct the calibration in a location or manner such that a condition of high ground reflectance is avoided. If significant reflection can occur, provision shall be made on the tracker to shield the reference cells by the use of a horizon shield. This horizon shield shall consist of a black nonreflecting surface, and shall, as viewed by each reference cell, block the view downward from the local horizon to the lowest extremes of the field of view.