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Standard Test Method for Determination of the Spectral Mismatch Parameter Between a Photovoltaic Device and a Photovoltaic Reference Cell [1]

This standard is issued under the fixed designation E973; 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 a procedure for the determination of a spectral mismatch parameter used in performance testing of photovoltaic devices.

1.2 The spectral mismatch parameter is a measure of the error, introduced in the testing of a photovoltaic device, caused by mismatch between the spectral responses of the photovoltaic device and the photovoltaic reference cell, as well as mismatch between the test light source and the reference spectral irradiance distribution to which the photovoltaic reference cell was calibrated. Examples of reference spectral irradiance distributions are Tables E490 or G173.

1.3 The spectral mismatch parameter can be used to correct photovoltaic performance data for spectral mismatch error.

1.4 This test method is intended for use with linear photovoltaic devices.

1.5 The values stated in SI units are to be regarded as 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:*[2]

E490 Standard Solar Constant and Zero Air Mass Solar Spectral Irradiance Tables
E772 Terminology of Solar Energy Conversion
E948 Test Method for Electrical Performance of Photovoltaic Cells Using Reference Cells Under Simulated Sunlight
E1021 Test Method for Spectral Responsivity Measurements of Photovoltaic Devices
E1036 Test Methods for Electrical Performance of Nonconcentrator Terrestrial Photovoltaic Modules and Arrays Using Reference Cells
E1039 Test Method for Calibration of Silicon Non-Concentrator Photovoltaic Primary Reference Cells Under Global Irradiation (Withdrawn 2004)[3]
E1125 Test Method for Calibration of Primary Non-Concentrator Terrestrial Photovoltaic Reference Cells Using a Tabular Spectrum
E1328 Terminology Relating to Photovoltaic Solar Energy Conversion (Withdrawn 2012)[3]
E1362 Test Method for Calibration of Non-Concentrator Photovoltaic Secondary Reference Cells
G138 Test Method for Calibration of a Spectroradiometer Using a Standard Source of Irradiance
G173 Tables for Reference Solar Spectral Irradiances: Direct Normal and Hemispherical on 37° Tilted Surface
SI10 Standard for Use of the International System of Units (SI): The Modern Metric System

3. Terminology

3.1 *Definitions*—Definitions of terms used in this test method may be found in Terminology E772 and Terminology E1328.

3.2 *Definitions of Terms Specific to This Standard:*

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[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.

[3] The last approved version of this historical standard is referenced on www.astm.org.

3.2.1 *test light source, n*—a source of illumination whose spectral irradiance will be used for the spectral mismatch calculation.

3.3 *Symbols*—The following symbols and units are used in this test method:
M—spectral mismatch parameter,
ε—measurement error in short-circuit current,
λ—wavelength, μm or nm,
$R_r(\lambda)$—spectral response of reference cell, AW^{-1},
$R_t(\lambda)$—spectral response of photovoltaic device, AW^{-1},
E—irradiance, Wm^{-2},
$E(\lambda)$—spectral irradiance, $Wm^{-2}\ \mu m^{-1}$ or $Wm^{-2}\ nm^{-1}$, and
$E_o(\lambda)$—reference spectral irradiance, $Wm^{-2}\ \mu m^{-1}$ or $Wm^{-2}\ nm^{-1}$.

NOTE 1—Following normal SI rules for compound units (see Practice SI10), the units for spectral irradiance, the derivative of irradiance with respect to wavelength $dE/d(\lambda)$, would be Wm^{-3}. However, to avoid possible confusion with a volumetric power density unit and for convenience in numerical calculations, it is common practice to separate the wavelength in the compound unit. This compound unit is also used in Tables G173 .

4. Summary of Test Method

4.1 Determination of the spectral mismatch parameter M requires the spectral response characteristics of the photovoltaic device and the spectral irradiance distribution of the test light source, along with the spectral response and the reference spectral irradiance distribution used for the reference cell calibration.

4.2 Because all four spectral quantities appear in both the numerator and the denominator in the calculation of the spectral mismatch parameter (see 8.1), multiplicative calibration errors cancel, and therefore only relative quantities are needed, although absolute spectral quantities may be used if available.

5. Significance and Use

5.1 The calculated error in the photovoltaic device current determined from the spectral mismatch parameter can be used to determine if a measurement will be within specified limits before the actual measurement is performed.

5.2 The spectral mismatch parameter also provides a means of correcting the error in the measured device current due to spectral mismatch.

5.2.1 The spectral mismatch parameter is formulated as the fractional error in the short-circuit current due to spectral differences.[4,5]

5.2.2 Error due to spectral mismatch can be corrected by dividing the measured photovoltaic cell current by M, a procedure used in Test Methods E948 and E1036.

6. Apparatus

6.1 In addition to the apparatus required by Test Methods E1021, the following apparatus is required.

6.1.1 *Spectral Irradiance Measurement Instrument*—A spectroradiometer, defined in Test Method G138, calibrated according to Test Method G138.

6.1.1.1 The wavelength resolution shall be no greater than 10 nm.

6.1.1.2 The wavelength pass-bandwidth shall be no greater than 6 nm.

6.1.1.3 The wavelength range shall be wide enough to include the spectral response of the photovoltaic device and the photovoltaic reference cell.

6.1.1.4 The spectral irradiance measurement instrument must be able to scan the required wavelength range in a time period short enough such that the spectral irradiance at any wavelength does not vary more than ± 5 % during the entire scan.

7. Procedure

7.1 Determine the spectral response $R_t(\lambda)$ of the photovoltaic device using Test Methods E1021.

7.2 Obtain the spectral response $R_r(\lambda)$ of the photovoltaic reference cell.

NOTE 2—Test Methods E1039, E1125, and E1362 require the spectral response to be provided as part of the reference cell calibration certificate.

7.3 Measure the spectral irradiance $E(\lambda)$ of the test light source, using the spectral irradiance measurement instrument (see 6.1.1).

7.4 Obtain the reference spectral irradiance distribution $E_o(\lambda)$ that corresponds to the calibration of the photovoltaic reference cell, such as Tables E490 or G173.

[4] Seaman, C., "Calibration of Solar Cells by the Reference Cell Method—The Spectral Mismatch Problem," *Solar Energy*, Vol 29, 1982, pp. 291–298.
[5] Osterwald, C. R., "Translation of Device Performance Measurements to Reference Conditions," *Solar Cells*, Vol 18, 1986, pp. 269–279.