Designation: E1040 – 10 (Reapproved 2016)

Standard Specification for Physical Characteristics of Nonconcentrator Terrestrial Photovoltaic Reference Cells[1]

This standard is issued under the fixed designation E1040; 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 specification describes the physical requirements for primary and secondary terrestrial nonconcentrator photovoltaic reference cells. A reference cell is defined as a device that meets the requirements of this specification and is calibrated in accordance with Test Method E1125 or Test Method E1362.

1.2 Reference cells are used in the determination of the electrical performance of photovoltaic devices, as stated in Test Methods E948 and E1036.

1.3 Two reference cell physical specifications are described:

1.3.1 *Small-Cell Package Design*—A small, durable package with a low thermal mass, wide optical field-of-view, and standardized dimensions intended for photovoltaic devices up to 20 by 20 mm, and

1.3.2 *Module-Package Design*—A package intended to simulate the optical and thermal properties of a photovoltaic module design, but electric connections are made to only one photovoltaic cell in order to eliminate problems with calibrating series and parallel connections of cells. Physical dimensions are not standardized.

1.4 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.5 *This standard does not purport to address all of the safety problems, 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]

E772 Terminology of Solar Energy Conversion

E948 Test Method for Electrical Performance of Photovoltaic Cells Using Reference Cells Under Simulated Sunlight

E1036 Test Methods for Electrical Performance of Nonconcentrator Terrestrial Photovoltaic Modules and Arrays Using Reference Cells

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 Methods for Calibration of Non-Concentrator Photovoltaic Non-Primary Reference Cells

2.2 *Military Specification Sheet:*[4]

MS3106C Connector, Plug, Electric, Straight, Solder Contracts, AN Type

3. Terminology

3.1 *Definitions*—For definitions of terms used in this specification, see Terminologies E772 and E1328.

4. Classification

4.1 Two types of reference cells are used in the evaluation of the electrical performance of photovoltaic terrestrial devices:

4.1.1 *Primary Reference Cells*—Reference cells calibrated directly in sunlight in accordance with Test Method E1125.

4.1.2 *Secondary Reference Cells*—Reference cells calibrated against a primary reference cell in accordance with Test Method E1362.

[1] This specification 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.

[4] Available from Superintendent of Documents, U.S. Government Printing Office, N. Capital and H Streets, NW, Washington, DC 20401.

4.2 The two types are not physically or electrically different, but are different in their manner of calibration. Hereafter in this specification, both types of reference cells will be considered alike and referred to only as reference cells.

5. Materials and Manufacture

5.1 *Requirements for Both Reference Cell Designs:*

5.1.1 *Product Marking*— A label, identification mark, or serial number shall be permanently stamped or scribed on the reference-cell holder. This product marking shall identify the device for reference to other documentation containing electrical and mechanical data, including information such as the cell material and manufacturer.

5.1.2 The reference cell shall be constructed using a single photovoltaic cell. Note that in the case of the module-package design, additional cells inside the package are allowed, but are not connected electrically.

5.2 *Small-Cell Package Design:*

5.2.1 The small-cell package design is documented in the literature as the World Photovoltaic Scale (WPVS) reference cell package[5]; the WPVS design meets a number of goals that are important for the small-cell package design. These goals are *(1)* an electrically and thermally conductive body with a low thermal mass, *(2)* standardized mounting holes, *(3)* detachable cables using standardized female connectors on the side of the package, *(4)* standardized temperature sensors, *(5)* a flat rear surface without protrusions, *(6)* permanent identification markings, and *(7)* standardized internal wiring.

5.2.2 *Reference Cell Material*—The WPVS design specifies a monocrystalline float-zone Si solar cell because device stability and quality are desirable for the primary reference cells that constitute the WPVS. For other applications, additional considerations may be more important and therefore the float-zone Si solar cell can be replaced with alternative device types as required, such as polycrystalline Si or GaAs.

5.2.3 *Window*—The WPVS specifies a "durable, smooth front window" to protect the photovoltaic cell. A colored glass or other optical filter may also be used to modify the spectral response of the cell, if necessary for specific applications.

5.2.3.1 Typical window materials are optical quality glass or fused silica with a surface roughness of at most 40 nm/mm.

5.2.3.2 Because many colored glass filters have transmission characteristics that change with time, it may be necessary to increase the frequency of recalibration of reference cells that use colored glass filters.

5.2.4 *Connectors*—Subminiature connectors on one side of the reference cell package avoid problems with integral cables such as broken wires and flexing of thermocouple leads. The connectors should be reliable and compatible with the package size.

[5] Osterwald, C. R., Anevsky, S., Bucher, K., Barua, A. K., Chaudhuri, P., Dubard, J., Emery, K., Hansen, B., King, D., Metzdorf, J., Nagamine, F., Shimokawa, R., Wang, Y. X., Wittchen, T., Zaaiman, W., Zastrow, A., and Zhang, J., "The World Photovoltaic Scale: An International Reference Cell Calibration Program, "Progress in Photovoltaics: Research and Applications, Vol 7, July/August 1999, p. 287.

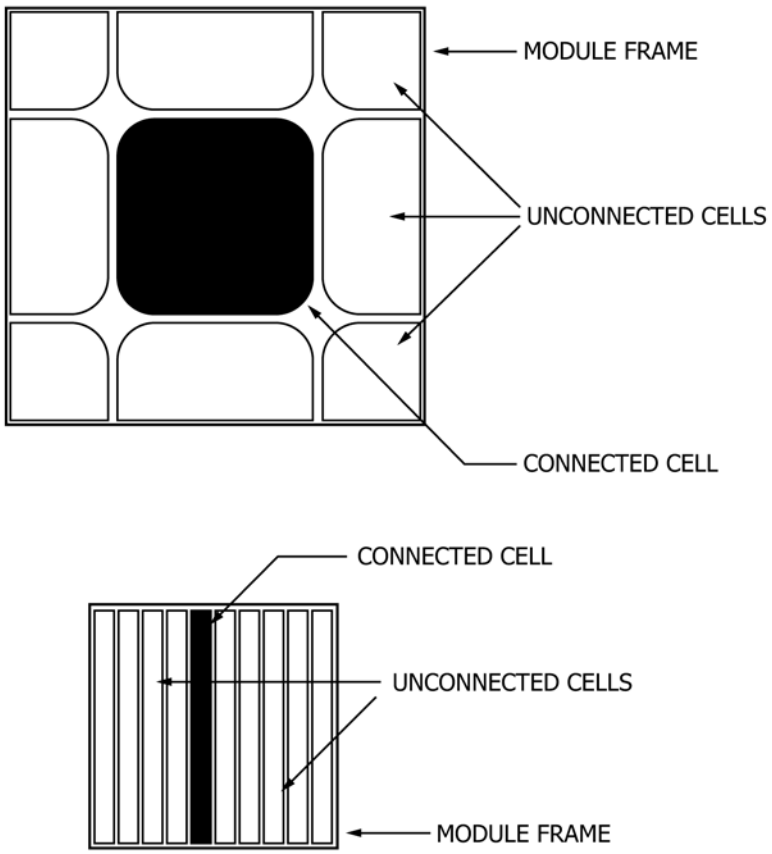

FIG. 1 Two Examples of Module-Package Reference Cell Configurations

5.3 *Module-Package Design*—Because the module-package design is intended to simulate the thermal and optical properties of an actual module, the physical dimensions are not standardized. Instead, materials and assembly techniques for the reference cell are as similar as possible to the actual module materials and assembly techniques. The electrical and optical environments, as seen by the connected cell, are therefore similar to actual modules. Two possible configurations of module-package reference cells are shown in Fig. 1.

5.3.1 The upper configuration in Fig. 1 is a substrate solar cell surrounded by pieces of unconnected solar cells laminated in a typical module package.

5.3.2 The lower configuration in Fig. 1 simulates a monolithic superstrate design where individual cells are series-connected in a module, but for the reference cell one device in the series string is isolated and connected to the reference cell leads.

5.3.3 Because the size of module-package reference cells can be much larger than the single-cell package, module-package reference cells are normally calibrated against a primary reference cell. Therefore, module-package cells are typically secondary reference cells.

5.3.4 *Electrical Connector*—The standard electrical connector shall be MS3106A14S-2S,[6] as specified in Military Specification Sheet MS3106A. The leads from one side of the solar cell shall be connected to contacts A and D on the connector, and the leads from the opposite side shall be connected to contacts B and C.

5.3.5 *Electrical Connections*—The electrical connections to the photovoltaic cell shall consist of a four-wire contact system (Kelvin probe), with two wires connected to the top contact of the cell, and two wires to the bottom contact. A minimum length of 1 m of 1.0 mm (AWG 18) diameter four-conductor cable with an ultraviolet-stable outer cover rated for outdoor usage is recommended.

5.3.6 *Temperature Sensor*—A temperature sensor shall be attached in a way that will ensure good thermal contact with the photovoltaic cell. To minimize heating during illumination, the temperature sensor is normally located behind the photovoltaic cell. The temperature sensor cable should be able to withstand flexing and connect-disconnect cycles to measurement equipment during use without breaking. Thermocouple wire should not be allowed to bend or flex at locations where temperature gradients are likely to occur.

6. Documentation

6.1 A reference cell shall be accompanied by documentation of its calibration constant, cell area, current-voltage characteristic, temperature coefficient, and spectral response. All material used in its construction shall be identified. The photovoltaic cell used should be identified by the following information, if available: manufacturer, production lot, production date, and relevant device design features, such as resistivity, anti-reflectance coating, front surface preparation, back surface preparation, or contact materials.

7. Keywords

7.1 cell; package; photovoltaics, reference

[6] Available from Amphenol Corp., 358 Hall Ave., Wallingford, CT 06492, as part No. MS3106A14S-2S.