Designation: E 1040 – 98

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

This standard is issued under the fixed designation E 1040; 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 Method E 1039, Test Method E 1125, or Test Method E 1362.

1.2 Reference cells are used in the determination of the electrical performance of photovoltaic devices, as stated in Test Methods E 948 and Methods E 1036.

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 These reference cells are intended to be used in applications where a significant fraction of the irradiance has incidence angles less than 30°, with respect to normal as defined in Specification E 927.

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 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:*

E 772 Terminology Relating to Solar Energy Conversion[2]

E 927 Specification for Solar Simulation for Terrestrial Photovoltaic Testing[2]

E 948 Test Methods for Electrical Performance of Nonconcentrator Terrestrial Photovoltaic Cells Using Reference Cells[2]

E 1036 Test Methods for Electrical Performance of Nonconcentrator Terrestrial Photovoltaic Modules and Arrays Using Reference Cells[2]

E 1039 Test Method for Calibration and Characterization of Non-Concentrator Terrestrial Photovoltaic Reference Cells Under Global Irradiation[2]

E 1125 Test Method for Calibration of Primary Non-Concentrator Terrestrial Photovoltaic Reference Cells Using a Tabular Spectrum[2]

E 1328 Terminology Relating to Photovoltaic Solar Energy Conversion[2]

E 1362 Test Method for Calibration of Non-Concentrator Photovoltaic Secondary Reference Cells[2]

2.2 *Military Specification Sheet:*

MS3106C Connector, Plug, Electric, Straight, Solder Contracts, AN Type[3]

3. Terminology

3.1 *Definitions*—For definitions of terms used in this specification, see Terminologies E 772 and E 1328.

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 Method E 1039 or Test Method E 1125, and

[1] This specification 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 Systems.

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

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

4.1.2 *Secondary Reference Cells*—Reference cells calibrated against a primary reference cell in accordance with Test Method E 1362.

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 *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 of 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. The standard electrical connector shall be MS3106A14S-2S,[4] 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.

5.1.2 *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.

5.1.3 *Temperature Sensor*—A temperature sensor, capable of temperature measurement to ±1°C uncertainty, 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.

5.1.4 The reference cell shall be constructed using a single photovoltaic cell.

5.2 *Small-Cell Package Design*:

5.2.1 *Physical Dimensions*—The standardized physical dimensions of the small-cell package design are shown in Fig. 1. It is recommended that these dimensions be adhered to in order to minimize potential problems with mounting non-standard reference cells in test fixtures and to keep the thermal mass of the reference cell as low as possible.

5.2.2 *Surface Finish*— All surfaces within the inner chamber that houses the photovoltaic cell and within the cell's field-of-view should have non-reflecting surfaces with an absorptance of 0.95 or better in the photovoltaic cell's wavelength response band. This requirement suppresses internal reflections that can cause measurement errors. The aluminum surface finish specified in Fig. 1 satisfies this requirement.

5.2.3 *Bonding Adhesive*— Any material used for bonding should be compatible with the photovoltaic cell and not cause electrical or optical degradation of the photovoltaic cell. The material's physical characteristics should be stable over the time of intended use and acceptable for outdoor use.

5.2.4 *Field-of-View*— The field-of-view ϕ, as defined in Fig. 1, should be at least 160° to minimize measurement errors when non-normal irradiation impinges on the reference cell.

5.2.5 *Window*—Use of a window is recommended 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.

5.2.5.1 If a clear window is used, the optical transmission of the window should be constant within ±1 % in the photovoltaic cell wavelength response band, with a mean transmission of at least 85 %. Typical window materials are optical quality glass or fused silica with a surface flatness of at least 40 nm/mm.[5]

5.2.5.2 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.

5.2.6 *Pottant*—A pottant may be used to encapsulate the photovoltaic cell and suppress internal reflections by index-of-refraction matching to the window material.[6]

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. 2.

5.3.1 The upper configuration in Fig. 2 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. 2 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.

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

[5] Corning 7940 fused silica, available from Corning Inc., Materials Business, MP21-3, Corning, NY 14831, has been found satisfactory for this purpose.

[6] A pottant that has been used with fused silica windows is a General Electric silicone with the following part numbers: silicone resin GE RTV615A, curing agent GE RTV615B, and silicone primer SS4120. Available from General Electric Co., Waterford, NY 12188.

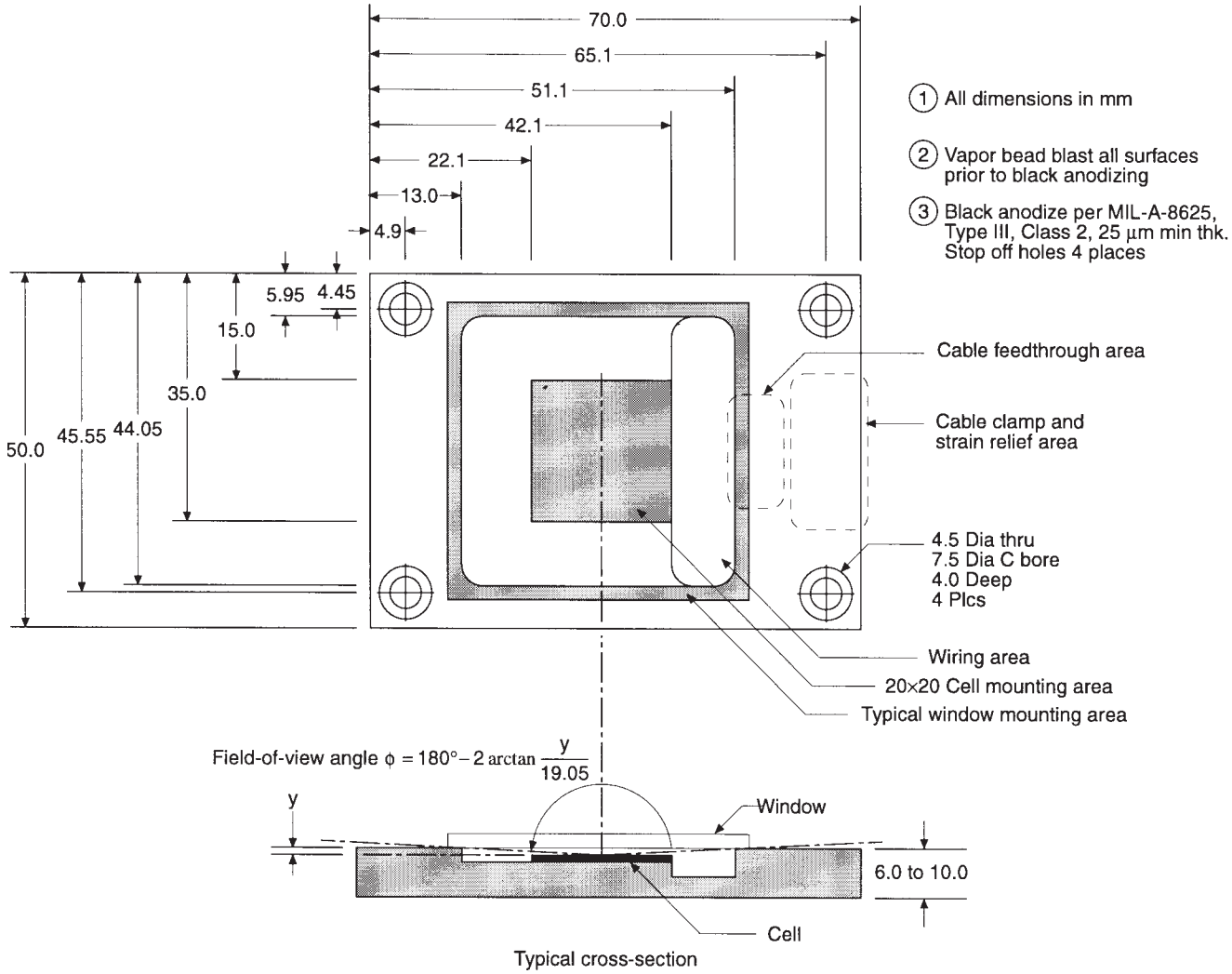

FIG. 1 Physical Dimensions of Small-Cell Package Design

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

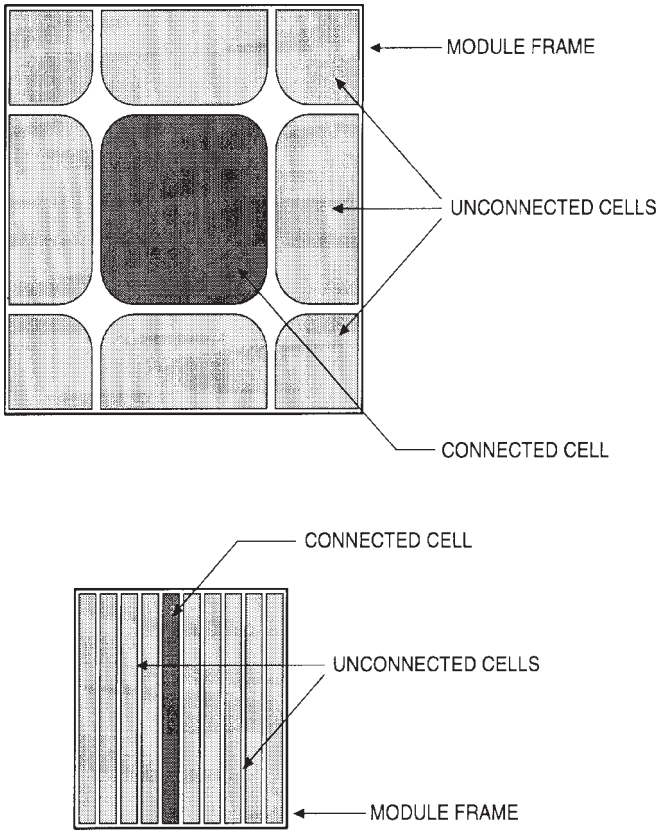

FIG. 2 Two Examples of Module-Package Reference Cell Configurations