Designation: E816 – 15

Standard Test Method for Calibration of Pyrheliometers by Comparison to Reference Pyrheliometers[1]

This standard is issued under the fixed designation E816; 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.

INTRODUCTION

Accurate and precise measurement of the direct (beam) radiation component of sunlight are required in *(1)* the calibration of reference pyranometers by the shading disk or optical occluding methods, *(2)* determination of the energy collected by concentrating solar collectors, including exposure levels achieved in use of Practice G90 dealing with Fresnel-reflecting concentrator test machines, and *(3)* the assessment of the direct beam for energy budget analyses, geographic mapping of solar energy, and as an aid in the determination of the concentration of aerosol and particulate pollution, and water vapor effects.

This test method requires calibration to the World Radiometric Reference (WRR), maintained by the World Meteorological Organization (WMO), Geneva. The Intercomparison of Absolute Cavity Pyrheliometers, also called Absolute Cavity Radiometers, on which the WRR depends, is covered by procedures adopted by WMO and by various U.S. Organizations who occasionally convene such intercomparisons for the purpose of transferring the WRR to the United States, and to maintaining the WRR in the United States. These procedures are not covered by this test method.

1. Scope

1.1 This test method has been harmonized with, and is technically equivalent to, ISO 9059.

1.2 Two types of calibrations are covered by this test method. One is the calibration of a secondary reference pyrheliometer using an absolute cavity pyrheliometer as the primary standard pyrheliometer, and the other is the transfer of calibration from a secondary reference to one or more field pyrheliometers. This test method prescribes the calibration procedures and the calibration hierarchy, or traceability, for transfer of the calibrations.

NOTE 1—It is not uncommon, and is indeed desirable, for both the reference and field pyrheliometers to be of the same manufacturer and model designation.

1.3 This test method is relevant primarily for the calibration of reference pyrheliometers with field angles of 5 to 6°, using as the primary reference instrument a self-calibrating absolute cavity pyrheliometer having field angles of about 5°. Pyrheliometers with field angles greater than 6.5° shall not be designated as reference pyrheliometers.

1.4 When this test method is used to transfer calibration to field pyrheliometers having field angles both less than 5° or greater than 6.5°, it will be necessary to employ the procedure defined by Angstrom and Rodhe.[2]

1.5 This test method requires that the spectral response of the absolute cavity chosen as the primary standard pyrheliometer be nonselective over the range from 0.3 to 10 µm wavelength. Both reference and field pyrheliometers covered by this test method shall be nonselective over a range from 0.3 to 4 µm wavelength.

1.6 The primary and secondary reference pyrheliometers shall not be field instruments and their exposure to sunlight shall be limited to calibration or intercomparisons. These reference instruments shall be stored in an isolated cabinet or room equipped with standard laboratory temperature and humidity control.

NOTE 2—At a laboratory where calibrations are performed regularly, it is advisable to maintain a group of two or three secondary reference pyrheliometers that are included in every calibration. These serve as controls to detect any instability or irregularity in the standard reference pyrheliometer.

1.7 This test method is applicable to calibration procedures using natural sunshine only.

[1] This test method is under the jurisdiction of ASTM Committee G03 on Weathering and Durabilityand is the direct responsibility of Subcommittee G03.09 on Radiometry.

Current edition approved Feb. 1, 2015. Published February 2015. Originally approved in 1981. Last previous edition approved in 2010 as E816 – 05(2010). DOI: 10.1520/E0816-15.

[2] Angstrom, A., and Rodhe, B., "Pyrheliometric Measurements with Special Regard to the Circumsolar Sky Radiation," *Tellus*, Vol 18, 1966, pp. 25–33.

2. Referenced Documents

2.1 *ASTM Standards:*[3]

E772 Terminology of Solar Energy Conversion

E824 Test Method for Transfer of Calibration From Reference to Field Radiometers

G90 Practice for Performing Accelerated Outdoor Weathering of Nonmetallic Materials Using Concentrated Natural Sunlight

G167 Test Method for Calibration of a Pyranometer Using a Pyrheliometer

2.2 *ISO Standards:*[4]

ISO 9059 Calibration of Field Pyrheliometers by Comparison to a Reference Pyrheliometer

ISO 9060 Specification and Classification of Instruments for Measuring Hemispherical Solar and Direct Solar Radiation

ISO TR 9673 The Instrumental Measurement of Sunlight for Determining Exposure Levels

ISO 9846 Calibration of a Pyranometer Using a Pyrheliometer

2.3 *WMO Standard:*

Guide to Meteorological Instruments and Methods of Observation, Seventh ed., WMO-No. 8[5]

3. Terminology

3.1 *Definitions:*

3.1.1 The relevant definitions of Terminology E772 apply to the calibration method described in this test method.

3.1.2 *absolute cavity pyrheliometer*—see *self-calibrating absolute cavity pyrheliometer*.

3.1.3 *direct radiation, direct solar radiation, and direct (beam) radiation*—radiation received from a small solid angle centered on the sun's disk, on a given plane whose normal (perpendicular to the plane) points to the center of the sun's disk (see ISO 9060). That component of sunlight is the beam between an observer, or instrument, and the sun within a solid conical angle centered on the sun's disk and having a total included planar field angle of, for the purposes of this test method, 5 to 6°.

3.1.4 *field pyrheliometer*—pyrheliometers that are designed and used for long-term field measurements of direct solar radiation. These pyrheliometers are weatherproof and therefore possess windows, usually quartz, at the field aperture that pass all solar radiation in the range from 0.3 to 4 µm wavelength.

3.1.5 *opening angle*—with radius of field aperture denoted by R and the distance between the field and receiver apertures denoted by l, the opening angle is defined for right circular cones by the equation:

$$Z_o = \tan^{-1} R/l \tag{1}$$

The field angle is double the opening angle.

3.1.6 *primary standard pyrheliometers*—pyrheliometers, selected from the group of absolute pyrheliometers (see *self-calibrating absolute cavity pyrheliometer*).

3.1.7 *reference pyrheliometer*—pyrheliometers of any category serving as a reference in calibration transfer procedures. They are selected and well-tested instruments (see Table 2 of ISO 9060), that have a low rate of yearly change in responsivity. The reference pyrheliometer may be of the same type, class, and manufacturer as the field radiometers in which case it is specially chosen for calibration transfer purposes and is termed a secondary standard pyrheliometer (see ISO 9060), or it may be of the self-calibrating cavity type (see *self-calibrating absolute cavity pyrheliometer*).

3.1.8 *secondary standard pyrheliometer*—pyrheliometers of high precision and stability whose calibration factors are derived from primary standard pyrheliometers. This group comprises absolute cavity pyrheliometers that do not fulfill the requirements of a primary standard pyrheliometer as described in 3.1.6.

3.1.9 *self-calibrating absolute cavity pyrheliometer*—a radiometer consisting of either a single- or dual-conical heated cavity that, during the self-calibration mode, displays the power required to produce a thermopile reference signal that is identical to the sampling signal obtained when viewing the sun with an open aperture. The reference signal is produced by the thermopile in response to the cavity irradiance resulting from heat supplied by a cavity heater with the aperture closed.

3.1.10 *slope angle*—with radius of the sensor denoted by r, the radius of the limiting aperture is denoted by R, and the distance between aperture and sensor denoted by l, the slope angle equation is defined as:

$$S = \mathrm{arcTan}\,(R - r)/l \tag{2}$$

3.2 *Acronyms:*

3.2.1 *ACR*—Absolute Cavity Radiometer

3.2.2 *ANSI*—American National Standards Institute

3.2.3 *ARM*—Atmospheric RadiationMeasurement Program

3.2.4 *DOE*—Department of Energy

3.2.5 *GUM*—(ISO) Guide to Uncertainty in Measurements

3.2.6 *IPC*—International Pyrheliometer comparison

3.2.7 *ISO*—International Standards Organization

3.2.8 *NCSL*—National Council of Standards Laboratories

3.2.9 *NIST*—National Institute of Standards and Technology

3.2.10 *NREL*—National Renewable Energy Laboratory

3.2.11 *PMOD*—Physical Meteorological Observatory Davos

3.2.12 *SAC*—Singapore Accreditation Council

3.2.13 *SINGLAS*—Singapore Laboratory Accreditation Service

3.2.14 *UKAS*—United Kingdom Accrediation Service

3.2.15 *WRC*—World Radiation Center

3.2.16 *WRR*—World Radiometric Reference

3.2.17 *WMO*—World Meteorological Organization

[3] 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.

[4] Available from International Organization for Standardization (ISO), 1, ch. de la Voie-Creuse, CP 56, CH-1211 Geneva 20, Switzerland, http://www.iso.org.

[5] Available from World Meterological Organization, 7bis, avenue de la Paix, CP. 2300, CH-1211 Geneva 2, Switzerland, www.wmo.int.