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Standard Test Method for Transfer of Calibration From Reference to Field Radiometers[1]

This standard is issued under the fixed designation E 824; 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 measurements of total solar and solar ultraviolet irradiance are required in: (*1*) the determination of the energy incident on surfaces and specimens during exposure outdoors to various climatic factors that characterize a test site, (*2*) the determination of solar irradiance and radiant exposure to ascertain the energy available to solar collection devices such as flat-plate collectors, and (*3*) the assessment of the irradiance and radiant exposure in various wavelength bands for meteorological, climatic and earth energy-budget purposes. The solar components of principal interest include total solar radiant exposure (all wavelengths) and various ultraviolet components of natural sunlight that may be of interest, including both total and narrow-band ultraviolet radiant exposure.

This test method for transferring calibration from reference to field instruments is only applicable to pyranometers and radiometers whose field angles closely approach 180° ... instruments which therefore may be said to measure hemispherical radiation, or all radiation incident on a flat surface. Hemispherical radiation includes both the direct and sky (diffuse) geometrical components of sunlight, while global solar irradiance refers only to hemispherical irradiance on a horizontal surface such that the field of view includes all of the hemispherical sky dome.

For the purposes of this test method, the terms pyranometer and radiometer are used interchangeably.

1. Scope

1.1 The method described in this standard applies to the transfer of calibration from reference to field radiometers to be used for measuring and monitoring outdoor radiant exposure levels. This standard has been harmonized with ISO 9847.

1.2 This test method is applicable to field radiometers regardless of the radiation receptor employed, but is limited to radiometers having approximately 180° (2π Steradian), field angles.

1.3 The calibration covered by this test method employs the use of natural sunshine as the source.

1.4 Calibrations of field radiometers may be performed at tilt as well as horizontal (at 0° from the horizontal to the earth). The essential requirement is that the reference radiometer shall have been calibrated at essentially the same tilt from horizontal as the tilt employed in the transfer of calibration.

1.5 The primary reference instrument shall not be used as a field instrument and its exposure to sunlight shall be limited to calibration or intercomparisons.

NOTE 1—At a laboratory where calibrations are performed regularly it is advisable to maintain a group of two or three reference radiometers that are included in every calibration. These serve as controls to detect any instability or irregularity in the standard reference instrument.

1.6 Reference standard instruments shall be stored in a manner as to not degrade their calibration.

1.7 The method of calibration specified for total solar pyranometers shall be traceable to the World Radiometric Reference (WRR) through the calibration methods of the reference standard instruments (Method E 913 and Test Method E 941), and the method of calibration specified for narrow- and broad-band ultraviolet radiometers shall be traceable to the National Institute of Standards and Technology (NIST), or other internationally recognized national standards laboratories.

[1] This test method is under the jurisdiction of ASTM Committee G3 on Durability of Nonmetallic Materials and is the direct responsibility of Subcommittee G3.09 on Solar and Ultraviolet Radiation Measurement Standards.

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1.8 *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 913 Method for Calibration of Reference Pyranometers With Axis Vertical by the Shading Method[2]

E 941 Test Method for Calibration of Reference Pyranometers With Axis Tilted by the Shading Method[2]

E 772 Terminology Relating to Solar Energy Conversion[3]

G 113 Terminology Relating to Natural and Artificial Weathering Test of Nonmetallic Materials[2]

2.2 *Other Standards:*

ISO 9847 Solar Energy[4]—Calibration of Field Pyranometers by Comparison to a Reference Pyranometer

3. Terminology

3.1 *Definitions:*

3.1.1 See Terminology E 772 and G 113 for terminology relating to this test method.

4. Summary of Test Method

4.1 Mount the reference radiometer, or pyranometer, and the field (or test) radiometers, or pyranometers, on a common calibration table for horizontal calibration (Type *A*), on a tilted platform for calibration at tilt (Type *B*), or on an altazimuth or sun-pointing mount for normal-incidence calibration (Type *C*). Adjust the height of the photoreceptor, or radiation receptor, of all instruments to a common elevation.

4.2 Ensure that the pyranometer's, or radiometer's, azimuth reference marks point in a common direction.

NOTE 2—Current convention is to use the electrical connector as the azimuth reference and to point it towards the equator and downward. The reasons are (*1*) this convention diminishes the possibility of moisture intrusion into the connector, and (*2*) it ensures that instruments with disparities in the hemispherical domes, or with domes not properly centered over the receptor, are not operated in such a manner that they amplify deviations from the cosine law.

4.3 For a transfer of calibration to a field instrument that will be used in a tilted position the following conditions must be met: The reference instrument must have a calibration at the desired tilt angle; both instruments must be oriented at the tilt angle and facing the equator.

4.4 The analog voltage signal from each radiometer is measured, digitized, and stored using a calibrated data-acquisition instrument, or system. A minimum of fifteen 10-min measurement sequences are obtained, each sequence comprising a minimum of 21 instantaneous readings. It is preferable that a larger number of measurement sequences be performed over several days duration and that data be taken in early morning or late afternoon, as well as near solar noon.

NOTE 3—Transfer of calibration to both total and narrow-band ultraviolet radiometers may require a larger number of measurement sequences in order to account for spectral changes due to changing air mass both early and late in the day, and to the loss of north-sky ultraviolet when calibrating at tilts.

4.5 The data are mathematically ratioed, employing the instrument constant of the reference instrument to determine the instrument constant of the radiometer being calibrated. The mean value and the standard deviation are determined.

5. Significance and Use

5.1 The methods described represent the preferable means for calibration of field radiometers employing standard reference radiometers. Other methods involve the employment of an optical bench and essentially a point source of artificial light. While these methods are useful for cosine and azimuth correction analyses, they suffer from foreground view factor and directionality problems. Transfer of calibration indoors using artificial sources is not covered by this test method.

5.2 Traceability of calibration of global pyranometers is accomplished when employing the method using a reference global pyranometer that has been calibrated, and is traceable to the World Radiometric Reference (WRR). For the purposes of this test method, traceability shall have been established if a parent instrument in the calibration chain participated in either the International Pyrheliometric Comparison VI (IPC VI), Davos (held in October 1985), or IPC VII, Davos (held in November, 1990). Traceability of calibration of narrow- and broad-band radiometers is accomplished when employing the method using a reference ultraviolet radiometer that has been calibrated and is traceable to the National Institute of Standards and Technology (NIST), or other national standards organizations. See Zerlaut[5] for a discussion of the WRR, the IPC's and their results.

5.2.1 The reference global pyranometer (for example, one measuring hemispherical solar radiation at all wavelengths) shall have been calibrated by the shading-disk method against one of the following instruments:

5.2.1.1 An absolute cavity pyrheliometer that participated in one of the above IPC's (and therefore possesses a WRR reduction factor),

5.2.1.2 A WMO First Class pyrheliometer that was calibrated by direct transfer from such an absolute cavity.

5.2.2 Alternatively, the reference pyranometer may have been calibrated by direct transfer from a World Meteorological Organization (WMO) First Class pyranometer that was calibrated by the shading-disk method against an absolute cavity pyrheliometer possessing a WRR reduction factor, or by direct transfer from a WMO Standard Pyranometer (see WMO's Guide WMO—No. 8[6] for a discussion of the classification of solar radiometers).

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[2] *Annual Book of ASTM Standards*, Vol 06.01.

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

[4] Available from International Standards Organization (ISO), 1 Rue De Varembre, Geneva, Switzerland CH-1211 20.

[5] Zerlaut, G. A., "Solar Radiation Instrumentation," Chapter 5 in *Solar Resources*, The MIT Press, Cambridge, MA, 1989, pp. 173–308.

[6] WMO—No. 8, "Guide to Meteorological Instruments and Methods of Observation," Fifth Ed., World Meteorological Organization, Geneva, Switzerland, 1983.