Designation: G183 – 05

Standard Practice for Field Use of Pyranometers, Pyrheliometers and UV Radiometers[1]

This standard is issued under the fixed designation G183; 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 practice describes deployment conditions, maintenance requirements, verification procedures and calibration frequencies for use of pyranometers, pyrheliometers and UV radiometers in outdoor testing environments. This practice also discusses the conditions that dictate the level of accuracy required for instruments of different classes.

1.2 While both pyranometers and UV radiometers may be employed indoors to measure light radiation sources, the measurement of ultraviolet and light radiation in accelerated weathering enclosures using manufactured light sources generally requires specialized radiometric instruments. Use of radiometric instrumentation to measure laboratory light sources is covered in ISO 9370.

NOTE 1—An ASTM standard that is similar to ISO 9370 is under development and deals with the instrumental determination of irradiance and radiant exposure in weathering tests.

1.3 The characterization of radiometers is outside the scope of the activities required of users of radiometers, as contemplated by this standard.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E772 Terminology Relating to Solar Energy Conversion

G7 Practice for Atmospheric Environmental Exposure Testing of Nonmetallic Materials

G24 Practice for Conducting Exposures to Daylight Filtered Through Glass

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

G113 Terminology Relating to Natural and Artificial Weathering Tests of Nonmetallic Materials

2.2 *ISO Standards:*

ISO 877 Plastics—Methods of Exposure to Direct Weathering, Indirect Weathering Using Glass-Filtered Daylight and Indirect Weathering by Daylight Using Fresnel Mirrors[3]

ISO 9060 Solar Energy—Specification and Classification of Instruments for Measuring Hemispherical Solar and Direct Solar Radiation[3]

ISO 9370 Plastics—Instrumental Determination of Radiant Exposure in Weathering Tests—General Guidance[3]

ISO TR 9901 Solar Energy—Field Pyranometers—Recommended Practice for Use[3]

2.3 *Other Reference:*

World Meteorological Organization (WMO), 1983 "Measurement of Radiation," *Guide to Meteorological Instruments and Methods of Observation*, fifth ed., WMO-No. 8, Geneva

3. Terminology

3.1 *Definitions*—The definitions given in Terminologies E772 and G113 are applicable to this practice.

4. Radiometer Selection

4.1 *Criteria for the Selection of Radiometers*:

4.1.1 There are several criteria that need to be considered for selection of the radiometer that will be used:

4.1.1.1 Function specific criteria, such as whether a pyranometer, pyrheliometer or UV radiometer is required,

4.1.1.2 Task specific criteria, such as the accuracy requirements for the selected incident angle and temperature ranges, and maximum response time,

4.1.1.3 Operational criteria, such as dimensions, weight, stability and maintenance, and

4.1.1.4 Economic criteria, such as when networks have to be equipped, or whether the instrument is being acquired for internal reference purposes, or for research purposes, etc.

4.2 *Selection Related to Radiometer Type*:

4.2.1 Pyranometers, which measure global solar irradiance in the 300 to 2500-nm wavelength region, are required to assess the hemispherical solar irradiance on surfaces of test specimens mounted on weathering test racks that are used by

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

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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] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

the outdoor weathering exposure community. Typically, pyranometers are required to measure the exposure levels specified in the applicable ASTM and/or ISO outdoor weathering standards such as those described in Practices G7, G24, G90, and ISO 877.

4.2.2 Pyrheliometers, which measure direct (or, beam) solar irradiance in the 300 to 2500-nm wavelength region, are required to assess the solar irradiance reflected onto the target board by the mirrors of Fresnel Reflecting Concentrators used in outdoor accelerated tests specified by ASTM and ISO Standards described in Practice G90 and ISO 877.

4.2.3 Ultraviolet radiometers are either broad band or narrow band instruments covering defined wavelength regions of the solar ultraviolet spectrum.

4.2.3.1 Broad-band UV radiometers usually are designed to measure either UV-A, UV-B or some component of both UV-A and UV-B radiation.

NOTE 2—Certain UV radiometers that are designated as total ultraviolet radiometers are advertised to measure over the total wavelength range from the so called UV cutoff at approximately 300 nm to 385 or 400 nm, but in fact measure mostly UV-A radiation by virtue of their very low responsivity to wavelengths below 315 nm.

4.2.3.2 Narrow-band UV radiometers are essentially constructed using interference filters that isolate narrow bands of radiation having FWHM values of 20 nm, or less; their center wavelengths (CW) may reside anywhere in the UV spectrum from 280 to 400 nm wavelength—depending on the application for which they are intended.

NOTE 3—While the World Meteorological Organization (WMO) and the International Standards Organization (ISO) have established requirements for Secondary Standard and First-, Second- and Third-class pyranometers and pyrheliometers, specifications and required operational characteristics of different classes of ultraviolet radiometers have not been addressed by either organization.

NOTE 4—First-class instruments are not necessary for all applications.

4.3 *Selection Related to Measuring Specifications*:

4.3.1 As a first step, all possible ranges of measuring parameters such as temperature, irradiance levels, angles of incidence, tilt angles, and station latitude, must be compiled.

4.3.2 Next, documentation must be compiled of available information about the technical characteristics, and the technical and physical specifications of the relevant radiometers given by:

4.3.2.1 The WMO and ISO classification of pyranometers given in the WMO Guide, and in ISO 9060 and ISO 9370 (which together define the specifications to be met by different categories of pyranometers and pyrheliometers),

4.3.2.2 The data specification sheets obtained from the manufacturer, and

4.3.2.3 Preferably, data on the technical characteristics and performance obtained from independent sources such as independent testing laboratories, research institutes and government laboratories.

4.3.3 If the accuracy of the highest category of instrument is insufficient for the application contemplated, the following recommendations are given:

4.3.3.1 Hemispherical solar radiation may be measured by the simultaneous deployment of a pyrheliometer and a continuously shaded secondary standard pyranometer to achieve accuracies that are greater than can be achieved by a secondary standard pyranometer alone,

4.3.3.2 Direct (beam) solar radiation may be measured using an absolute cavity pyrheliometer employing electrical substitution of thermally absorbed radiation to achieve accuracies that are greater than can be achieved by a First-class pyrheliometer, and

4.3.3.3 Specific ultraviolet wavelength bands may be determined by integration of the selected wavelength bands using a scanning spectroradiometer possessing good slit function and narrow band pass characteristics to achieve accuracies that are greater than the most accurate narrow or broad band ultraviolet radiometers currently commercially available.

5. Practice for Use—General

5.1 *Installation of Radiometers*:

5.1.1 When performing measurements in support of testing, the test object and the field radiometer shall be equally exposed with respect to field of view, ground radiation and any stray light that may be present. This means that the test surface and the radiometer shall receive the same irradiance.

5.1.2 When used to determine the irradiance accumulated on solar concentrating devices such as the Fresnel reflecting concentrators used in the practice of Practice G90, and other types of solar concentrators, it is essential that the collection system of the solar concentrators, such as the flat mirrors used in the practice of Practice G90, do not receive direct irradiance that is unavailable to the optical system that connotes the pyrheliometer required.

5.1.3 The need for easy access to the radiometer for maintenance operations shall be considered in selecting the installation site, mount, etc.

5.2 *Electrical Installation*:

5.2.1 The electrical cable employed shall be secured firmly to the mounting stand to minimize the possibility of breakage or intermittent disconnection in severe weather.

5.2.2 Wherever possible, the electrical cable shall be protected and buried underground—particularly when recording devices, controllers, or converters are located at a distance. Use of shielded cable is highly recommended. The cable, recorder and other electronic devices, shall be connected by a very low resistance conductor to a common ground.

5.2.3 Contact the manufacturer of the radiometer being installed to establish the maximum allowable cable length permissible for the instrument's impedance so as to preclude significant signal loss (see 5.4.5.2 for additional requirements).

5.2.4 When hard wiring electrical connections, all exposed junctions shall be weatherproofed and protected from physical damage.

5.2.5 Establish and identify the polarity of all relevant connections prior to connecting to the recording device, converters, or controllers. Make all connections in accordance with the manufacturer's instructions.

5.3 *Required Maintenance Activities*:

5.3.1 *Inspection*:

5.3.1.1 Whenever possible, inspect radiometers employed in continuous operation at least once each day. Inspection and maintenance activities of specific attributes described in the following sections should be carried out daily, monthly and yearly as indicated.

NOTE 5—It should be noted that the quality of data obtained using total solar and solar ultraviolet radiometers depends strongly on the amount of personal attention given during the observation program.

5.3.2 *Daily Routine Inspection and Maintenance*:

5.3.2.1 The exterior glass domes and/or diffusers or windows, shall be inspected daily and cleaned at least once each week or more often whenever dust or other deposits are visible. Cleaning shall occur by spraying with deionized water and wiping dry with non-abrasive and lint-free cloth or tissue. It is recommended that this inspection and possible cleaning be performed early each day.

5.3.2.2 If frozen snow, glazed frost, hoar frost or rime is present, remove the deposit very gently, initially with the sparing use of a de-icing fluid, after which the window shall be wiped clean and dry.

5.3.2.3 After heavy dew, rain, sleet, snow or frost buildup, check to determine if condensation is present inside the dome, or on the receptor or diffuser surface. If condensation is discovered inside the dome, on the receptor or diffuser surface of domed radiometers, the instrument's manufacturer shall be contacted to determine a course of action.

NOTE 6—The user may attempt to "dry out" the radiometer by elevating its temperature, either in natural sunlight or in the laboratory, to 50°C. If the condensation is eliminated, the radiometer's calibration constant shall be checked prior to being returned to service.

5.3.2.4 When hard-to-remove deposits of air pollution or local contamination is observed on a radiometer's exterior window, first apply deionized or distilled water on the surface. If the use of a detergent solution is indicated, a prepare a 2 % solution of a mild dish washing detergent and gently apply to the surface. Use a soft, lint-free muslin cloth to gently rub the surface if required. In either case, thoroughly rinse the surface with deionized or distilled water, after which it the window shall be wiped clean and dry. Water spots should not be evident on the surface. However, care should be exercised to avoid scratching the surface.

5.3.2.5 When used, check the operational state of the ventilator or air blower at least weekly and note any unusual noise for subsequent attention.

5.3.2.6 Perform a cursory check of the output data on at least a weekly basis to determine if data being recorded are plausible in relation to the conditions being experienced.

5.3.3 *Monthly Routine Inspection and Maintenance*:

5.3.3.1 Examine the color-indicating desiccant for all instruments where the silica gel container is accessible. If moisture is indicated, replace the desiccant.

NOTE 7—If desiccant is consumed rapidly, the cause might be a defective seal of the instrument's window, a defective electrical connection into the instrument case, or a defective O-ring associated with the desiccant chamber.

5.3.3.2 Attention should be paid to the transmission and amplification of signals. Perform both visual and electrical checks of the cable and amplifier (when used). These inspections shall also be performed when any component of a measuring system has been replaced, or after any anomalies have been detected in the data.

5.3.4 *Quarterly Inspection and Maintenance*:

5.3.4.1 In those radiometers where the desiccant is not visible, remove the desiccant cover and inspect the desiccant for dryness. If moisture is indicated, replace the desiccant. Care should be exercised to ensure that the desiccant container's cover is closed completely (manufacturer's instructions should be followed with respect to ensuring the tightness of the cover, or cap).

5.3.4.2 Verify that the responsivities of all radiometers have not changed to the extent that they are out of tolerance. This can be done by comparison to another radiometer that has the same spectral response function[4] or by determination that the ratio of, for example, UV-B to UV-A irradiance has remained essentially the same (if both measurements are being performed), or, as will usually be the case, if the ratio of total solar UV irradiance to total solar irradiance has remained essentially the same for clear day solar noon conditions.

5.3.5 *Semi-annual Inspection and Maintenance*:

5.3.5.1 Use an inclinometer[5] to determine the inclination of all radiometers mounted at tilts from the horizontal. Inspect the inclination angles of all pyranometers and UV-radiometers including the spirit level of all horizontally mounted radiometers.

5.3.6 *Yearly Inspection and Maintenance*:

5.3.6.1 When calibration schedules do not require annual re calibration, special attention should be paid to the possibility of drift in the sensitivity (that is, the calibration factor) of the radiometer. This shall be accomplished by use of either a field re calibrator (in the case of certain UV-A and UV-B radiometers) or a field reference radiometer maintained by the testing/measuring facility for that purpose.

5.3.6.2 Inspect all radiometers for general deterioration of the instrument—including domes and windows (to detect chips, cracks, or the development of any optical disparity), the receiver coating (to detect discoloration, loss of material, checking, or cracks), and seals (to detect severe discoloration, cracking, degradation, etc.).

5.3.6.3 When either drift in sensitivity greater than the tolerance established by the testing/measuring facility, or greater than permitted by the applicable standards or specifications, or when any degradation of instrument components is noted, the manufacturer should be contacted to determine the advisability of either replacing the instrument or returning the instrument for refurbishment.

NOTE 8—In the event that component degradation is observed, a field sensitivity check should be performed prior to contacting the manufacturer.

5.3.6.4 When used, inspect the air channels of ventilators or blowers and remove any dirt and debris that may have collected.

5.4 *Recording of Measured Data*:

5.4.1 Recording systems fall into three principal classes:

[4] This is most easily achieved by comparing with a UV radiometer of the same model.

[5] A protractor scale equipped with a rotatable spirit level.

5.4.1.1 Those providing a series of individual values,

5.4.1.2 Continuous-line or intermittent-dot recorders providing autographic traces, and,

NOTE 9—Potentiometric strip-chart recorders with integration and voltage time integrators are in wide use.

5.4.1.3 Automatic data acquisition systems which can deliver either individual values or integrated totals over a specified period of time.

NOTE 10—Microprocessor controlled data loggers using a variety of support systems for data storage have become common.

5.4.2 *Sampling Rate*:

5.4.2.1 When making instantaneous individual readings, choose the length of the interval over which the series of readings extends and the number of readings comprising the measurement so as to ensure that the derived mean affords a representative value for the desired time interval. This applies equally to a series of readings recorded by means of a fast response multi-channel automatic data logging system and to a series of measurements recorded manually using a millivoltmeter or potentiometer.

5.4.2.2 The frequency of the readings depends on the application and the system characteristics as illustrated by the following questions:

(a) What is the smallest time interval of interest?

(b) What are the response time and accuracy of the radiometer being used?

(c) Are the measurements to be instantaneous values obtained from a sample-hold instrument or short time integrated values obtained with an integrator (that is, a voltage/frequency converter and a counter)?

(d) Does the data acquisition system compress data?

5.4.2.3 Depending on the answers to these questions, the sampling rate can range from one sample measurement per minute to one sample per second, or faster. Generally, for the calculation of average values over periods of between 0.1 and 1.0 h, 100 samples allow the average values to be estimated with sufficient accuracy.

NOTE 11—In solar energy applications, a pyranometer or pyrheliometer output is only one of several parameters being measured. Special attention must be given to ensure that all measurements are made simultaneously, or at a time interval much shorter than the rate of change of the irradiance and the response time of the radiometer.

5.4.2.4 The recommended method is to take readings with a short-term integration, to apply a data check and then to perform data compression corresponding to a suitable interval.

NOTE 12—This is only possible with complex data acquisition systems.

5.4.3 *Integration of Data*:

5.4.3.1 There are two systems of data integration: *(1)* Analog using an operational amplifier connected to the integrator, and *(2)* digital by sampling the voltage output from the pyranometer.

5.4.3.2 When using analog integration, check the precision and linearity of the integration system on a monthly basis.

5.4.3.3 When using digital sampling, check the precision of the analog/digital converter, as well as the validity of the sampling frequency, at appropriate intervals. Follow the manufacturer's instructions for sampling frequency.

5.4.4 *Time Base*:

5.4.4.1 Time accuracy shall be linked to a recognized universal time reference and should be better than 1 min. It is therefore necessary to check the reference time at appropriate intervals.

NOTE 13—Reference to Radio Station WWVB, 60kHz, Ft. Collins, CO, which is operated by the National Institute of Standards and Technology, is recommended. It is noted that inexpensive quartz-crystal single-frequency radios set to this frequency are available from various sources.

5.4.4.2 When comparing solar and ultraviolet irradiance data between weathering sites, the data should be referenced to solar time to facilitate analysis. The equation-of-time may be used to compute the solar time from local time.

5.4.5 *Impedance Considerations*:

5.4.5.1 The internal impedance of the amplifier, recorder, or data logger, shall be at least 1000 times the value of the impedance of the radiometer being used. If this is not the case, corrections must be applied.

5.4.5.2 The length of the cable and its cross-section must be such that the resistance of the cable will not be greater than the internal impedance of the radiometers in use. The impedance of the instrument and cabling together shall in any case be less than one-one-thousandths of the internal resistance of the recording device employed.

5.4.5.3 To minimize any effects of impedance mismatch, position voltage/current converters as close as possible to the radiometer.

5.4.6 *Accuracy of the Electronics*:

5.4.6.1 Radiometer outputs are usually of the order of millivolts. Although electrical instrumentation is usually shielded, the radiometer's sensor, the body of the radiometer, and the cabling are nonetheless vulnerable to electromagnetic noise, or interference (EMI), which can produce very-short-term voltage changes. For this reason, it is preferable to integrate the output signal electronically using an appropriate voltage/frequency converter employing an integration time of at least 1 s for each reading.

5.4.6.2 The resolving power of the data acquisition system shall be at least a factor of 100 (two orders magnitude) better than that of the radiometer's output signal (in terms of millivolts). Attention should be given to the fact that a radiometer's millivolt signal can vary over two to three orders of magnitude—particularly in the case of UV radiometers.

5.4.6.3 Temperature is a source of deviation in data acquisition systems, and may be a source of significant error for very hot climates. The temperature response of the various components of the measuring system, which includes the radiometer and the data acquisition system, should be known.

NOTE 14—For example, the system drift can be determined as the square root of the sum of the squares of the individual component drifts.

5.4.6.4 As an alternative to use of an external calibration service whose calibrations are traceable to NIST, the following procedure may be used: Remove the radiometer from the measurement circuit. Then, using a calibrated and traceable DC voltage source having the same impedance as the radiometer, check the data acquisition system on an annual basis to determine any differences between input values and recorded