Designation: G130 – 12 (Reapproved 2020)

Standard Test Method for Calibration of Narrow- and Broad-Band Ultraviolet Radiometers Using a Spectroradiometer[1]

This standard is issued under the fixed designation G130; 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 ultraviolet irradiance are required in the determination of the radiant exposure of both total and selected narrow bands of ultraviolet radiation for the determination of exposure levels in (*1*) outdoor weathering of materials, (*2*) indoor accelerated exposure testing of materials using manufactured light sources, and (*3*) UV-A and UV-B ultraviolet radiation in terms both of the assessment of climatic parameters and the changes that may be taking place in the solar ultraviolet radiation reaching earth.

Although meteorological measurements usually require calibration of pyranometers and radiometers oriented with axis vertical, applications associated with materials testing require an assessment of the calibration accuracy at orientations with the axis horizontal (usually associated with testing in indoor exposure cabinets) or with the axis at angles typically up to 45° or greater from the horizontal (for outdoor exposure testing). These calibrations also require that deviations from the cosine law, tilt effects, and temperature sensitivity be either known and documented for the instrument model or determined on individual instruments.

This test method requires calibrations traceable to primary reference standards maintained by a national metrological laboratory that has participated in intercomparisons of standards of spectral irradiance.

1. Scope

1.1 This test method covers the calibration of ultraviolet light-measuring radiometers possessing either narrow- or broad-band spectral response distributions using either a scanning or a linear-diode-array spectroradiometer as the primary reference instrument. For transfer of calibration from radiometers calibrated by this test method to other instruments, Test Method E824 should be used.

NOTE 1—Special precautions must be taken when a diode-array spectroradiometer is employed in the calibration of filter radiometers having spectral response distributions below 320-nm wavelength. Such precautions are described in detail in subsequent sections of this test method.

1.2 This test method is limited to calibrations of radiometers against light sources that the radiometers will be used to measure during field use.

NOTE 2—For example, an ultraviolet radiometer calibrated against natural sunlight cannot be employed to measure the total ultraviolet irradiance of a fluorescent ultraviolet lamp.

1.3 Calibrations performed using this test method may be against natural sunlight, Xenon-arc burners, metal halide burners, tungsten and tungsten-halogen lamps, fluorescent lamps, etc.

1.4 Radiometers that may be calibrated by this test method include narrow-, broad-, and wide-band ultraviolet radiometers, and narrow-, broad, and wide-band visible-region-only radiometers, or radiometers having wavelength response distributions that fall into both the ultraviolet and visible regions.

NOTE 3—For purposes of this test method, narrow-band radiometers are those with $\Delta\lambda \leq 20$ nm, broad-band radiometers are those with 20 nm $\leq \Delta\lambda \leq 70$ nm, and wide-band radiometers are those with $\Delta\lambda \geq 70$ nm.

NOTE 4—For purposes of this test method, the ultraviolet region is defined as the region from 285 to 400-nm wavelength, and the visible region is defined as the region from 400 to 750-nm wavelength. The ultraviolet region is further defined as being either UV-A with radiation of wavelengths from 315 to 400 nm, or UV-B with radiation from 285 to 315-nm wavelength.

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

Current edition approved June 1, 2020. Published July 2020. Originally approved in 1995. Last previous edition approved in 2012 as G130 – 12. DOI: 10.1520/G0130-12R20.

1.5 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E772 Terminology of Solar Energy Conversion

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

E973 Test Method for Determination of the Spectral Mismatch Parameter Between a Photovoltaic Device and a Photovoltaic Reference Cell

G138 Test Method for Calibration of a Spectroradiometer Using a Standard Source of Irradiance

2.2 *Other Documents: CIE Publication No. 63 The Spectrodiometric Measurement of Light Sources*

3. Terminology

3.1 *Definitions:*

3.1.1 *broad-band radiometer—*radiometerric detectors with interference filters or cut-on/cut-off filter pairs having a FWHM between 20 and 70 nm and with tolerances in center (peak) wavelength and FWHM no greater than ±2 nm.

3.1.2 *diode array detector—*a detector with from a number of silicon photodiodes affixed side-by-side in a linear array and mounted in the focal plane of the exit slit of a monochromator.

3.1.3 *full width at half maximum (FWHM)—*in a bandpass filter, the interval between wavelengths at which transmittance is 50 % of the peak, frequently referred to as bandwidth.

3.1.4 *narrow-band radiometer—*a relative term generally applied to radiometers with interference filters with FWHM ≤20 nm and with tolerances in center (peak) wavelength and FWHM no greater than± 2 nm.

3.1.5 *National Metrological Institution (NMI)—*A nation's internationally recognized standardization laboratory.

3.1.5.1 *Discussion—*The International Bureau of Weights and Measurements (abbreviation BIPM from the French terms) establishes the recognition through Mutual Recognition Agreements. See http://www.bipm.org/en/cipm-mra. The NMI for the United States of America is the National Institute for Standards and Technology (NIST).

3.1.6 *scanning monochromator—*an instrument for isolating narrow bands of wavelength of light that admits broadband light through an entrance slit, directs the light to a dispersive element (prism or grating), and uses either a single, or several interchangeable, detector(s) mounted at an exit slit. The detector is presented with dispersed light by sweeping the spectrum across the slit to illuminate the detector with a succession of different very narrow wavelength light distributions. The detector may be either a photomultiplier tube (PMT) or silicon photodiode (visible), or an ultraviolet-enhanced PMT or silicon photodiode (ultraviolet and visible), or a lead sulfide cell or other solid state detector (near infrared), etc. The dispersed spectrum is swept across the exit slit using a mechanical stage that rotates the element, usually under the control of an external microprocessor or computer.

3.1.7 *spectroradiometer—*a radiometer consisting of a monochromator with special acceptance optics mounted to the entrance aperture and a detector mounted to the exit aperture, usually provided with electronic or computer encoding of wavelength and radiometric intensity. The monochromator of such instruments is either of the linear diode (often called *diode array*) or the scanning type.

3.1.8 *wide-band radiometer—*a relative term generally applied to radiometers with combinations of cut-off and cut-on filters with FWHM greater than 70 nm.

3.2 For other terms relating to this test method, see Terminology E772.

4. Significance and Use

4.1 This test method represents the preferable means for calibrating both narrow-band and broad-band ultraviolet radiometers. Calibration of narrow- and broad-band ultraviolet radiometers involving direct measurement of a standard source of spectral irradiance is an alternative method for calibrating ultraviolet radiometers. This approach is valid only if corrections for the spectral response of the instrument and the spectral mismatch between the calibration spectral distribution and the target spectral distribution can be computed. See Test Method E973 for a description of the spectral mismatch calculation.

4.2 The accuracy of this calibration technique is dependent on the condition of the light source (for example, cloudy skies, polluted skies, aged lamps, defective luminaires, etc.), and on source alignment, source to receptor distance, and source power regulation.

NOTE 5—It is conceivable that a radiometer might be calibrated against a light source that represents an arbitrarily chosen degree of aging for its class in order to present to both the test and reference radiometers a spectrum that is most typical for the type.

4.3 Spectroradiometric measurements performed using either an integrating sphere or a cosine receptor (such as a shaped PTFE[3], or Al_2O_3 diffuser plate) provide a measurement of hemispherical spectral irradiance in the plane of the sphere's entrance port. As such, the aspect of the receptor plane relative to the reference light source must be defined (azimuth and tilt from the horizontal for solar measurements, normal incidence with respect to the beam component of sunlight, or normal incidence and the geometrical aspect with respect to an

[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] Polytetrafluoroethylene

artificial light source, or array). It is important that the geometrical aspect between the plane of the spectroradiometer's source optics and that of the radiometer being calibrated be as nearly identical as possible.

NOTE 6—When measuring the hemispherical spectral energy distribution of an array of light sources (for lamps), normal incidence is defined by the condition obtained when the plane of the receiver aperture is parallel to the plane of the lamp, or burner, emitting area.

4.4 Calibration measurements performed using a spectroradiometer equipped with a pyrheliometer-comparison tube (a sky-occluding tube), regardless of whether affixed directly to the monochromator's entrance slit, to the end of a fiber optic bundle, or to the aperture of an integrating sphere, shall not be performed unless the radiometer being calibrated is configured as a pyrheliometer (possesses a view-limiting device having the approximate optical constants of the spectroradiometer's pyrheliometer-comparison tube).

4.5 Spectroradiometric measurements performed using source optics other than the integrating sphere or the "standard" pyrheliometer comparison tube, shall be agreed upon in advance between all involved parties.

4.6 Calibration measurements that meet the requirements of this test method are traceable to a national metrological laboratory that has participated in intercomparisons of standards of spectral irradiance, largely through the traceability of the standard lamps and associated power supplies employed to calibrate the spectroradiometer according to G138, the manufacturer's specified procedures, or CIE Publication 63.

4.7 The accuracy of calibration measurements performed employing a spectroradiometer is dependent on, among other requirements, the degree to which the temperature of the mechanical components of the monochromator are maintained during field measurements in relation to those that prevailed during calibration of the spectroradiometer. [1]

5. Apparatus

5.1 *Reference Spectroradiometers:*

5.1.1 The spectroradiometer employed as the reference radiometer shall, regardless of whether it consists of a scanning or a linear-diode-array monochromator, be calibrated in accordance with the procedures specified by G138. CIE Publication 63, or specific calibration procedures required by the manufacturer.[4] and the manufacturer.

5.1.1.1 It is recommended that the reference spectroradiometer, or one of its exact type, has been a participating spectroradiometer in an intercomparison of spectroradiometers either managed, sponsored, or sanctioned by a national metrological laboratory, or another appropriate body. Such interlaboratory comparisons should include the spectral range of interest in the application. See references [2-6]

5.1.1.2 Alternatively, it is recommended that the reference spectroradiometer shall be calibrated by measurement of a primary spectral irradiance standard reference lamp source produced by a national metrological laboratory,(NMI) or measurement of a transfer standard lamp generated by comparison with a primary standard of spectral irradiance lamp..The traceability of the lamp calibration source and attendant uncertainty shall be reported.

5.1.2 If a linear diode-array spectroradiometer is used as the reference, it shall possess focusing optics internal to the monochromator and a linear diode array detector with a sufficient number of diodes that, together, result in a resolving power of 1 nm or less. The monochromator's dispersive element shall be a holographic grating, and the spectroradiometer's acceptance optics shall consist of either an integrating sphere with appropriately sized and oriented light entrance port, or a shaped translucent diffuser plate whose deviation from true cosine response is small and known. A further requirement is that the stray light rejection be determined for any diode-array spectroradiometers used to perform this test method and that it be 10^5 or greater in the spectral region for which calibration is required.

5.1.2.1 A diode-array spectroradiometer shall not be used as the reference instrument for ultraviolet wavelengths shorter than 300-nm wavelength. Further, when used in the wavelength region between 300 and 320-nm wavelength, evidence shall be presented with the calibration reports, or certificates, showing that the stray light has been eliminated by a combination of internal baffling, merging of two determinations in which the wavelength region below 320-nm is measured employing secondary filters to reject all wavelengths longer than 320 nm, other techniques, or combinations of these.

5.1.3 When an integrating sphere is used, the exit port (to the monochromator) and entrance port (that represents the receiver) should be oriented 90° to each other and the sphere should be equipped with a baffle to occlude all light that might reach the exit directly from the entrance port.

5.1.4 When a pyrheliometer-comparison tube, or other view-limiting device, is used for the purpose of calibrating, for example, ultraviolet pyrheliometers, the pyrheliometer-comparison tube should ideally be affixed to the entrance port of the integrating sphere such that the sphere's entrance port becomes the aperture stop of the view-limiting device. Under most circumstances, the pyrheliometer comparison tube should possess the optical geometry defined by the World Meterorological Organization, the principal one being a 5.6° field of view.

NOTE 7—When the sphere's entrance port is the occluder's aperture stop, no calibration of the spectroradiometer is required independent of the calibration with only the integrating sphere in place. If the occluder's aperture stop is integral with the occluder and of different smaller dimension than the sphere's entrance port, the spectroradiometer must be calibrated with the occluder attached to the integrating sphere ... resulting in greater uncertainties and the possibilities of significant errors.

5.2 *Computational Facilities*—The computer-based computational facilities used to import the raw data with respect to wavelength and intensity should be capable of providing analyzed spectral irradiance information integrated across any wavelength band chosen.

5.3 *Instrument Mounts:*

5.3.1 *Equatorial Mount*—An altazimuthal or equatorial, follow-the sun mount that is equipped with a platform on

[4] The *Spectrodiometric Measurement of Light Sources*, Publication No. 63, The International Commission on Illumination (CIE).