Designation: G214 – 23

Standard Test Method for Integration of Digital Spectral Data for Weathering and Durability Applications[1]

This standard is issued under the fixed designation G214; 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 test method specifies a single relatively simple method to implement, common integration technique, the Modified Trapezoid Rule, to integrate digital or tabulated spectral data. The intent is to produce greater consistency and comparability of weathering and durability test results between various exposure regimes, calculation of materials properties, and laboratories with respect to numerical results that depend upon the integration of spectral distribution data.

1.2 Weathering and durability testing often requires the computation of the effects of radiant exposure of materials to various optical radiation sources, including lamps with varying spectral power distributions and outdoor and simulated sunlight. Changes in the spectrally dependent optical properties of materials, in combination with exposure source spectral data, are often used to evaluate the effect of exposure to radiant sources, develop activation spectra (Practice G178), and classify, evaluate, or rate sources with respect to reference or exposure source spectral distributions. Another important application is the integration of the original spectrally dependent optical properties of materials in combination with exposure source spectral data to determine the total energy absorbed by a material from various exposure sources.

1.3 The data applications described in 1.2 often require the use of tabulated reference spectral distributions, digital spectral data produced by modern instrumentation, and the integrated version of that data, or combinations (primarily multiplication) of spectrally dependent data.

1.4 Computation of the material responses to exposure to radiant sources mentioned above require the integration of measured wavelength dependent digital data, sometimes in conjunction with tabulated wavelength dependent reference or comparison data.

1.5 The term "integration" in the previous sections refers to the numerical approximation to the true integral of continuous functions, represented by discrete, digital data. There are numerous mathematical techniques for performing numerical integration. Each method provides different levels of complexity, accuracy, ease of implementation and computational efficiency, and, of course, resultant magnitudes. Hulstrom, Bird and Riordan (**1**)[2] demonstrate the differences between results for rectangular (963.56 W/m^2), trapezoid rule (962.53 W/m^2), and modified trapezoid rule (963.75 W/m^2) integration for a single solar spectrum. Thus the need for a standard integration technique to simplify the comparison of results from different laboratories, measurement instrumentation, or exposure regimes.

1.6 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.7 *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.*

1.8 *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:*[3]

E275 Practice for Describing and Measuring Performance of Ultraviolet and Visible Spectrophotometers

E424 Test Methods for Solar Energy Transmittance and Reflectance (Terrestrial) of Sheet Materials

E490 Standard Solar Constant and Zero Air Mass Solar Spectral Irradiance Tables

E772 Terminology of Solar Energy Conversion

[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.

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[2] The boldface numbers in parentheses refer to a list of references at the end of this standard.

[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.

E903 Test Method for Solar Absorptance, Reflectance, and Transmittance of Materials Using Integrating Spheres
E927 Classification for Solar Simulators for Electrical Performance Testing of Photovoltaic Devices
E971 Practice for Calculation of Photometric Transmittance and Reflectance of Materials to Solar Radiation
E972 Test Method for Solar Photometric Transmittance of Sheet Materials Using Sunlight
E973 Test Method for Determination of the Spectral Mismatch Parameter Between a Photovoltaic Device and a Photovoltaic Reference Cell
G113 Terminology Relating to Natural and Artificial Weathering Tests of Nonmetallic Materials
G130 Test Method for Calibration of Narrow- and Broad-Band Ultraviolet Radiometers Using a Spectroradiometer
G138 Test Method for Calibration of a Spectroradiometer Using a Standard Source of Irradiance
G151 Practice for Exposing Nonmetallic Materials in Accelerated Test Devices that Use Laboratory Light Sources
G173 Tables for Reference Solar Spectral Irradiances: Direct Normal and Hemispherical on 37° Tilted Surface
G177 Tables for Reference Solar Ultraviolet Spectral Distributions: Hemispherical on 37° Tilted Surface
G178 Practice for Determining the Activation Spectrum of a Material (Wavelength Sensitivity to an Exposure Source) Using the Sharp Cut-On Filter or Spectrographic Technique
G197 Table for Reference Solar Spectral Distributions: Direct and Diffuse on 20° Tilted and Vertical Surfaces
G207 Test Method for Indoor Transfer of Calibration from Reference to Field Pyranometers

3. Terminology

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

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *first difference, n*—the difference, $d1_i$, between adjacent ordinate values, $d1_i = y_i+1 - y_i$. An approximation of the first derivative of the function represented by the tabulated data.

3.2.2 *second difference, n*—the difference $d2_i$, between adjacent first differences (as defined in 3.2.1) in tabulated data; namely $d2_i = d1_i+1 - d1_i$. An approximation of the second derivative of the function represented by the tabulated data.

3.3 For the purposes of this standard, the terms “integral” and “integration” are used in the sense of a computed numerical approximation to a definite integral of continuous functions represented by tabulated or measured numerical (digital) data as functions of wavelength. The approximations are computed as the summation of discrete magnitudes computed according to the method. The data to be integrated may be interpolated to achieve consistent wavelength intervals.

4. Summary of Test Method

4.1 To compute the integral of the products of two spectral data sets, such as a reference Spectrum, E(λ), (for example reference spectra such as Standard Tables G173, G177, and G197), or the spectral content of calibration or other sources (as in Test Methods G207, G130, and G138) and measured or tabulated spectral optical property data, R(λ) such as transmittance or reflectance as measured in accordance with Test Method E903 and E424 and Practice E971, or spectral mismatch errors such as in Test Method E973, it is necessary for all data sets to have identical wavelength (λi) and wavelength intervals (λi+1 – λi). Then the appropriate products $E(\lambda i)\cdot R(\lambda i)$ are computed and treated using the procedures in 12.1 to 12.3. If the spectral wavelength intervals are different, one data set (usually with the smallest or shortest wavelength interval, should be selected as the data set, M(λ), with which to match all other data sets wavelength intervals. The other data sets should be interpolated, using linear interpolation, to obtain values at wavelength values and intervals identical to the selected M(λ).

4.1.1 When interpolating data sets, it is recommended that the data set with the coarsest or largest wavelength step size or interval be interpolated to the step size of the data set with the smaller step size or interval.

4.2 Compute an estimate for the absolute error in the integration based on the wavelength limits for the integral, the average wavelength interval of the data, and the average of the second differences of the spectral data. Compute the estimated relative (percentage) error in integral approximation based on the total integral and absolute error values (see Section 15 on precision and bias).

5. Significance and Use

5.1 Weathering and durability testing often requires the computation of the effects of radiant exposure of materials to various optical radiation sources, including lamps with varying spectral power distributions and outdoor and simulated sunlight as in Test Methods E972, G130, and G207.

5.2 The purpose of this test method is to foster greater consistency and comparability of weathering and durability test results between various exposure regimes, calculation of materials properties, and laboratories with respect to numerical results that depend upon the integration of spectral distribution data.

5.3 Changes in the optical properties of materials such as spectral reflectance, transmittance, or absorptance are often the measure of material stability or usefulness in various applications. Computation of the material responses to exposure to radiant sources mentioned above requires the integration of measured wavelength-dependent digital data, sometimes in conjunction with tabulated wavelength-dependent reference or comparison data.

5.4 This test method specifies and describes the Modified Trapezoid Rule as a single reasonably accurate and easily implemented integration technique for computing approximations of spectral source and optical property integrals.

5.5 The method includes a procedure for estimating the approximate absolute and relative (percent) error in the estimated spectral integrals.

5.6 The method includes a procedure to construct data sets that match in spectral wavelength and spectral wavelength