Designation: E 1175 – 87 (Reapproved 2003)

Standard Test Method for Determining Solar or Photopic Reflectance, Transmittance, and Absorptance of Materials Using a Large Diameter Integrating Sphere[1]

This standard is issued under the fixed designation E 1175; 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 covers the measurement of the absolute total solar or photopic reflectance, transmittance, or absorptance of materials and surfaces. Although there are several applicable test methods employed for determining the optical properties of materials, they are generally useful only for flat, homogeneous, isotropic specimens. Materials that are patterned, textured, corrugated, or are of unusual size cannot be measured accurately using conventional spectrophotometric techniques, or require numerous measurements to obtain a relevant optical value. The purpose of this test method is to provide a means for making accurate optical property measurements of spatially nonuniform materials.

1.2 This test method is applicable to large specimens of materials having both specular and diffuse optical properties. It is particularly suited to the measurement of the reflectance of opaque materials and the reflectance and transmittance of semitransparent materials including corrugated fiber-reinforced plastic, composite transparent and translucent samples, heavily textured surfaces, and nonhomogeneous materials such as woven wood, window blinds, draperies, etc.

1.3 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.4 *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.* (For specific safety hazards, see Note 1.)

2. Referenced Documents

2.1 *ASTM Standards:*

E 772 Terminology Relating to Solar Energy Conversion[2]

E 892 Tables for Terrestrial Solar Spectral Irradiance at Air Mass 1.5 for a 37° Tilted Surface[3]

E 903 Test Method for Solar Absorptance, Reflectance, and Transmittance of Materials Using Integrating Spheres[2]

3. Terminology

3.1 *Definitions:*

3.1.1 *absorptance*, *n*—see Terminology E 772.

3.1.2 *integrating sphere*—optical device used to either collect flux reflected or transmitted from a sample into a hemisphere or to provide isotropic irradiation of a sample from a complete hemisphere.

3.1.2.1 *Discussion*—It consists of a cavity that is approximately spherical in shape with apertures for admitting and detecting flux and usually having additional apertures over which sample and reference specimens are placed.

3.1.3 *photopic optical properties*, *n*—absorptance, reflectance, and transmittance of a sample evaluated as the weighted average of the measured property, with the wavelength by wavelength of the product of the spectral irradiance for the measurement and the Commission Internationale de l'Eclairage (CIE) photopic spectral response,[4] as the weighting function.

3.1.4 *photopic response*, *n*—spectral response of the average human eye when fully adapted to daylight conditions.

3.1.5 *reflectance*, *n*—see Terminology E 772.

3.1.6 *transmittance*, *n*—see Terminology E 772.

4. Summary of Test Method

4.1 This test method describes a procedure and apparatus for determining the area-averaged optical properties of complex or nonuniform materials and surfaces. This test method employs a large diameter integrating sphere and a source capable of illuminating a representative area of the test specimen's surface.

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[1] These test methods are under the jurisdiction of ASTM Committee E44 on Solar, Geothermal, and Other Alternative Energy Sources and is the direct responsibility of Subcommittee E44.05 on Solar Heating and Cooling Subsystems and Systems.

Current edition approved July 31, 1987. Published September 1987. Originally approved in 1987. Last previous edition approved in 1996 as E 1175–87(1996).

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

[3] *Annual Book of ASTM Standards*, Vol 14.02.

[4] Commission Internationale de l'Eclairage (CIE), International Light Vocabulary, 3rd Ed., Bureau Central de la CIE, Paris, 1970.

4.2 Transmittance is determined with the specimen mounted externally at the sphere entrance port.[5,6] Reflectance is determined by placing the specimen in the center of the integrating sphere,[5] in accordance with the diagram in Fig. A1.2 of Test Method E 903. For measurement of reflectance of partially transmitting samples, the sample should be backed by a black opaque absorber to eliminate the transmitted flux from the measurement.

4.3 The source may be either natural sunlight or an artificial source that closely approximates an Air Mass 1.5 solar energy distribution in accordance with Tables E 892.

4.4 Relevant optical properties are determined by the ratio of the total sphere flux transmitted or reflected by the specimen to the total sphere flux, or both when no specimen is in place.

4.5 The use of a spectrally flat or spectrally sensitive detector determines whether a solar or a photopic optical characteristic is measured.

5. Significance and Use

5.1 To overcome the inadequacies of conventional spectrophotometric measurement techniques when nonhomogeneous materials are measured, a large integrating sphere may be used.[5,6] Since the beam employed in such spheres is large in comparison to the disparaties of the materials being tested, the nonisotropic nature of the specimen being measured is essentially averaged, or integrated out of the measurement, in a single experimental determination.

5.2 Solar and photopic optical properties may be measured either with monofunctional spheres individually tailored for the measurement of either transmittance[6] or reflectance, or may be measured with a single multifunctional sphere that is employed to measure both transmittance and reflectance.[5]

5.3 A multifunctional sphere is used for making total solar transmittance measurements in both a directional-hemispherical and a directional-directional mode. The solar absorptance can be evaluated in a single measurement as one minus the sum of the directional hemispherical reflectance and transmittance. When a sample at the center of the sphere is supported by its rim, the sum of the reflectance and transmittance can be measured as a function of the angle of incidence. The solar absorptance is then one minus the measured absorptance plus transmittance.

6. Apparatus

6.1 An integrating sphere having a minimum radius of 1 m and a maximum ratio of entrance aperture area to total sphere area of 1:200. The circular port defining the entrance aperture shall have a diameter of not less than 230 mm (approximately 9 in.), although a port diameter of 300 mm (approximately 12 in.) is preferred.

6.2 The sphere shall be mounted in such a manner as to permit precision illumination of the sample at directions of incidence from 0° (normal incidence) to 60° from normal in the transmittance mode, using natural sunlight as source. When employing an artificial source for either simulated solar or photopic measurements, the off-angle mechanism may either be made a part of the sphere (with a fixed position lamp) or a part of the source assembly (with a fixed position sphere).

6.3 For reflectance measurements, a center-positioned sample mount that has two degrees of freedom is required: in and out of the sample beam, and rotation about the sample beam to provide incident angles from 0° to ±60°. The sample mount shall be designed so that the flux transmitted by the sample is absorbed, for measurement of reflectance, or so that the sample is supported by its rim for simultaneous measurement of reflectance plus transmittance.

6.4 The interior of the integrating sphere shall be uniformly coated with a spectrally flat paint having a minimum hemispherical reflectance of 0.85 in the spectral region of interest. For photopic measurements only, nearly any flat interior white paint will suffice. For solar and ultraviolet measurements, a good barium sulfate-pigmented sphere paint is required.

6.5 A stable source illuminant having a spectral distribution approximating that of a standard solar spectrum of Air Mass 1.5 (Tables E 892) shall be employed for simulated solar measurements. Other sources may be employed for photopic measurements if the spectral energy distribution is essentially flat in the 475 to 650-nm region.

6.6 For natural sunshine illumination, a solar siderostat (or heliostat) arrangement is required to provide uniform illumination (unless the sphere is itself operated in an altazimuthal tracking mode). Data should be taken during the time of day that ensures a normal incident global (hemispherical) irradiance of at least 900 W/m^2.

NOTE 1—**Warning:** Suitable eye protection is required when working with concentrated sunlight as would be encountered in using a solar siderostat. Manipulations of the reflectors for periodic maintenance, or for sample mounting can accidentally reflect concentrated sunlight upon the face. Sunglasses having high extinction for ultraviolet light are the most important precaution. Reflective glasses will prevent accidental burning of the retina by concentrated infrared light.

6.7 In both natural sunshine and artificial source illumination, suitable circular light baffles are required to focus light onto the entrance port. Focusing is especially critical in the reflectance mode. The size of the beam shall not exceed 50 % of the size of the entrance port, or 45 % of the vertical dimension of specimens destined for measurements at 60° normal incidence.

6.8 A suitable detector/recorder system capable of measuring the flux over the spectral regions of interest is required. The system should be capable of resolving a signal of 1 part in 200 and should be linear to 2 % at full scale illumination.

6.9 The detector shall be baffled from the entrance port to preclude direct illumination of the photoreceptor. The detector shall be mounted in the sphere wall at 90° to the plane of the entrance aperture either at the bottom or top of the sphere.

6.10 For directional-directional measurements of transmittance employing an occulting tube, the dimensions "L" (Fig. 1) should be between one and two sphere radii, the exact dimension depending on the baffle diameters and the solid angle of excitance desired.

[5] Zerlaut, G. A., and Anderson, T. E., "A Large-Multipurpose, Solar-Illuminated Integrating Sphere," *Optical Materials Technology for Energy Efficiency and Solar Energy Conversion III*, SPIE Vol 502, 1984, p. 152.

[6] Kessel, J., and Selkowitz, S., "Integrating Sphere Measurements of Directional-Hemispherical Transmittance of Window Systems," Journal of Illuminant Engineering Society, No. 1, 1984, p. 136.