INTERNATIONAL

Designation: ~~E424 – 71 (Reapproved 2007)~~ E424 – 71 (Reapproved 2015)

Standard Test Methods for Solar Energy Transmittance and Reflectance (Terrestrial) of Sheet Materials[1]

This standard is issued under the fixed designation E424; 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.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope

1.1 These test methods cover the measurement of solar energy transmittance and reflectance (terrestrial) of materials in sheet form. Method A, using a spectrophotometer, is applicable for both transmittance and reflectance and is the referee method. Method B is applicable only for measurement of transmittance using a pyranometer in an enclosure and the sun as the energy source. Specimens for Method A are limited in size by the geometry of the spectrophotometer while Method B requires a specimen 0.61 m^2 (2 ft^2). For the materials studied by the drafting task group, both test methods give essentially equivalent results.

1.2 *This standard does not purport to address all of the safety problems, 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:*[2]

E259 Practice for Preparation of Pressed Powder White Reflectance Factor Transfer Standards for Hemispherical and Bi-Directional Geometries

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

E308 Practice for Computing the Colors of Objects by Using the CIE System

3. Definitions

3.1 *solar absorptance*—the ratio of absorbed to incident radiant solar energy (equal to unity minus the reflectance and transmittance).

3.2 *solar admittance*—solar heat transfer taking into account reradiated and convected energy.

3.3 *solar energy*—for these methods the direct radiation from the sun at sea level over the solar spectrum as defined in 3.2, its intensity being expressed in watts per unit area.

3.4 *solar reflectance*—the percent of solar radiation (watts/unit area) reflected by a material.

3.5 *solar spectrum*—for the purposes of these methods the solar spectrum at sea level extending from 350 to 2500 nm.

3.6 *solar transmittance*—the percent of solar radiation (watts/unit area) transmitted by a material.

4. Summary of Methods

4.1 *Method A*—Measurements of spectral transmittance, or reflectance *versus* a magnesium oxide standard, are made using an integrating sphere spectrophotometer over the spectral range from 350 to 2500 nm. The illumination and viewing mode shall be normal-diffuse or diffuse-normal. The solar energy transmitted or reflected is obtained by integrating over a standard solar energy distribution curve using weighted or selected ordinates for the appropriate solar-energy distribution. The distribution at sea level, air mass 2, is used.

[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 Systems and Materials.

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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.

4.2 *Method B*—Using the sun as the source and a pyranometer as a detector the specimen is made the cover of an enclosure with the plane of the specimen perpendicular to the incident radiation; transmittance is measured as the ratio of the energy transmitted to the incident energy. (The apparatus of Method B has been used for the measurement of solar-energy reflectance but there is insufficient experience with this technique for standardization at present.)

5. Significance and Use

5.1 Solar-energy transmittance and reflectance are important factors in the heat admission through fenestration, most commonly through glass or plastics. (See Appendix X3.) These methods provide a means of measuring these factors under fixed conditions of incidence and viewing. While the data may be of assistance to designers in the selection and specification of glazing materials, the solar-energy transmittance and reflectance are not sufficient to define the rate of heat transfer without information on other important factors. The methods have been found practical for both transparent and translucent materials as well as for those with transmittances reduced by highly reflective coatings. Method B is particularly suitable for the measurement of transmittance of inhomogeneous, patterned, or corrugated materials since the transmittance is averaged over a large area.

6. Method A—Spectrophotometric Method

6.1 *Apparatus:*

6.1.1 *Spectrophotometer*—An integrating sphere spectrophotometer, by means of which the spectral characteristics of the test specimen or material may be determined throughout the solar spectrum. For some materials the spectrum region from 350 to 1800 nm may be sufficient. The design shall be such that the specimen may be placed in direct contact with the sphere aperture for both transmission and reflection, so that the incident radiation is within 6° of perpendicularity to the plane of the specimen.[3]

6.1.2 *Standards:*

6.1.2.1 For transmitting specimens, incident radiation shall be used as the standard relative to which the transmitted light is evaluated. Paired reflecting standards are used, prepared in duplicate as described below.

6.1.2.2 For reflecting specimens, use smoked magnesium oxide (MgO) as a standard as the closest practicable approximation of the completely reflecting, completely diffusing surface for the region from 300 to 2100 nm. The preferred standard is a layer (at least 2.0 mm in thickness) freshly prepared from collected smoke of burning magnesium (Recommend Practice E259). Pressed barium sulfate ($BaSO_4$) or MgO are not recommended because of poor reflecting properties beyond 1000 nm.

6.1.3 *Specimen Backing for Reflectance Measurement*—Transparent and translucent specimens shall be backed by a light trap or a diffusing black material which is known to absorb the near infrared. The backing shall reflect no more than 1 % at all wavelengths from 350 to 2500 nm as determined using the spectrophotometer.

6.2 *Test Specimens:*

6.2.1 Opaque specimens shall have at least one plane surface; transparent and translucent specimens shall have two surfaces that are essentially plane and parallel.

6.2.2 Comparison of translucent materials is highly dependent on the geometry of the specific instrument being used. It is recommended that the specimen be placed in direct contact with the sphere to minimize and control loss of scattered radiation.

6.2.3 For specularly reflecting specimens the sphere conditions, especially where the reflected beam strikes the sphere wall, shall be known to be highly reflecting (95 % or higher). It is recommended that a freshly coated sphere be used especially when measuring translucent or specularly reflecting specimens.

6.3 *Calibration:*

6.3.1 *Photometric*—The calibration of the photometric scale shall be done as recommended by the manufacturer. It shall be carefully executed at reasonable time intervals to ensure accuracy over the entire range.

6.3.2 *Wavelength*—Periodic calibrations should be made of the wavelength scales. Procedures for wavelength calibration may be found in Recommended Practice E275. A didymium filter has also been used for this purpose. Although the absorption peaks have been defined for specific resolution in the visible spectrum it also has peaks in the near infrared; however, the wavelength of the peaks must be agreed upon, using a specific instrument.

6.4 *Procedure:*

6.4.1 *Transmittance*—Obtain spectral transmittance data relative to air. For measurement of transmittance of translucent specimens, place freshly prepared matched smoked MgO surfaces at the specimen and reference ports at the rear of the sphere (Note 1). The interior of the sphere should be freshly coated with MgO and in good condition.

NOTE 1—Magnesium oxide standards may be considered matched if on interchanging them the percent reflectance is altered by no more than 1 % at any wavelength between 350 and 1800 nm.

6.4.2 *Reflectance*—Obtain spectral directional reflectance data relative to MgO. Include the specular component in the reflectance measurement. Back the test specimen with a black diffuse surface if it is not opaque. Depending on the required accuracy, use the measured values directly or make corrections for instrumental 0 and 100 % lines (see Method E308).

[3] For additional apparatus specifications see Recommended Practice E308.

6.5 *Calculation*—Solar energy transmittance or reflectance is calculated by integration. The distribution of solar energy as reported by Parry Moon[4] for sea level and air mass 2 shall be used.

6.5.1 *Weighted Ordinates*—Obtain the total solar energy transmittance, T_{se}, and reflectance, R_{se}, in percent, by integrating the spectral transmittance (reflectance) over the standard solar energy distribution as follows:

$$T_{se} \text{ or } R_{se} = \sum_{\lambda=350\text{nm}}^{\lambda=2100\text{ nm}} T_{\lambda} \left(\text{or } R_{\lambda}\right) \times E_{\lambda} \quad (1)$$

Eλ for air mass 2, at 50-nm intervals, normalized to 100, is given in Appendix X1.

6.5.1.1 This integration is easily programmed for automatic computation.

6.5.2 *Selected Ordinates*—Integration is done by reading the transmittance or reflectance at selected wavelengths and calculating their average. Appendix X2 lists 20 selected ordinates for integration.[5]

6.6 *Report*—The report shall include the following:

6.6.1 Complete identification of the material tested, and whether translucent, clear, or specularly reflecting,

6.6.2 Solar *T* percent or Solar *R* percent, or both, to the nearest 0.1 %,

6.6.3 Specimen thickness,

6.6.4 Identification of the instrument used, and

6.6.5 Integration method.

7. Method B—Pyranometer Method

NOTE 2—The pyranometer is used to measure total global (sun and sky) radiation (previously designated a 180° pyroheliometer; presently the latter word refers to a normal incidence measurement of direct solar radiation). See IGY Instruction Manual, Part VI, *Radiation Instruments*, Pergamon Press, New York, NY.

7.1 *Apparatus:*

7.1.1 *Enclosure*—The apparatus that has been used successfully is a box capable of supporting a 0.61-m^2 (24-$in.^2$) specimen. The box, which would normally be about 0.66-m^2 (26-$in.^2$) outside, should be capable of being faced in any direction, as on a universal mount. The inside of the box should be painted flat black.[3] A typical unit is shown in Fig. 1.

7.1.2 *Sensor:*

7.1.2.1 The sensing element of this instrument is a pyranometer consisting of concentric rings, or wedges of thermopiles, colored alternately black and white. The voltage output of this sensor is proportional to the intensity of the total incident solar irradiation. The spectral sensitivity of this instrument extends from the ultraviolet to infrared wavelengths (280 to 2800 nm), thus encompassing all the solar spectrum. The pyranometer should be located inside the box so that the sensing thermopile is approximately 50 mm (2 in.) from the center of the bottom plane of the sample.

[4] *Journal of the Franklin Institute*, Vol 230, 1940, p. 583, or *Smithsonian Physical Tables*, Table 1, Vol 815, 1954, p. 273.

[5] Olson, O. H., "Selected Ordinates for Solar Absorptivity Calculations," *Applied Optics*, Vol 2, No. 1, January 1963.

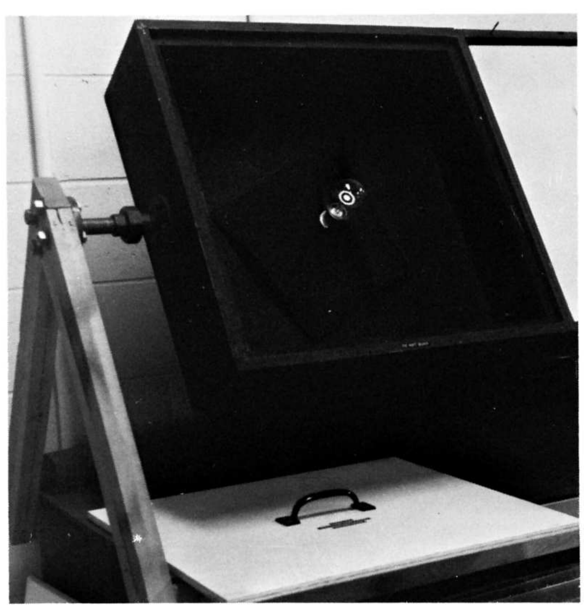

FIG. 1 Typical Unit with Pyranometer Mounted in Black Box