Designation: E 1585 – 93

Standard Test Method for Measuring and Calculating Emittance of Architectural Flat Glass Products Using Spectrometric Measurements[1]

This standard is issued under the fixed designation E 1585; 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 determination of the normal and hemispherical emittance of a specular surface. This test method describes the spectrometric measurement of the near-normal specular reflectance in the mid-infrared range from 5 to at least 25 µm. It includes the calculation procedures required to determine the normal and hemispherical emittance of said object.

1.2 This test method includes calibration instructions for the spectrometer and procedures for selecting reflectance-reference standards.

1.3 This test method is generally suitable for any flat, specular-reflecting specimen. It is recommended for measuring emittance of architectural glazing materials such as glass (coated and uncoated), etc. This test method is not suitable for determining the emittance of an object that is transparent in the specified range of infrared radiation.

1.4 This test method is suitable for determining the emittance of an object based on blackbody weighting at a specified temperature (typically 23°C (73°F)), as would be needed to determine the thermal performance (U-Value/SC/SHGC) of a window assembly.

1.5 The values stated in SI units are to be regarded as the standard. The inch-pound units given in parentheses are for information only.

1.6 *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.*

2. Referenced Documents

2.1 *ASTM Standards:*

C 1164 Practice for Evaluation of Limestone or Lime Uniformity from a Single Source[2]

E 179 Guide for Selection of Geometric Conditions for Measurement of Reflection and Transmission Properties of Materials[3]

E 284 Terminology of Appearance[3]

E 932 Practice for Describing and Measuring Performance of Dispersive Infrared Spectrophotometers[4]

3. Terminology

3.1 *Definitions:*

3.1.1 The definitions contained in Terminology E 284 are applicable to this test method.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *blackbody*—a perfect emitter and absorber of thermal radiation. A blackbody emits radiant energy at each wavelength at the maximum rate possible as a consequence of its temperature and absorbs all incident radiant flux.

3.2.2 *emissivity, E*—a term reserved for the emittance for the restricted case of an opaque and homogeneous material.

3.2.3 *emittance, e*—a term that describes the ability of a body to emit radiation. It is defined as the ratio of the rate of radiant emission of the body, as a consequence of temperature only, to the corresponding emission of a perfect emitter (blackbody) at the same temperature.

3.2.4 *hemispherical emittance*, e_h— emittance of a source averaged over all the radial directions of the overspreading hemisphere.

3.2.5 *normal emittance*, e_n—emittance of a source into the direction normal to its surface.

3.2.6 *spectral emittance*, $e_{n,\lambda}$ $e_{h,\lambda}$—emittance based on the radiant energy per unit wavelength band.

3.2.7 *specular reflectance*—reflection in a sharply defined direction equal to the angle of incidence from a smooth interface between homogeneous materials, that is, obeying the law of reflection.

4. Significance and Use

4.1 The thermal performance of glazing materials utilized in building facades plays a major role in the consumption and conservation of energy. Emittance is one of the important attributes used to calculate the thermal performance or U-value of glazing materials.

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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.

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[2] *Annual Book of ASTM Standards*, Vol 04.01.

[3] *Annual Book of ASTM Standards*, Vol 06.01.

[4] *Annual Book of ASTM Standards*, Vol 03.06.

4.2 The hemispherical emittance, based on weighting with the radiation of a blackbody at 23°C (73°F), is the accepted criterion for assessing the thermal performance of glazing assemblies. Kirchhoff's law states that spectral emittance is equal to spectral absorptance under equilibrium; therefore, spectral absorptance may be considered to be synonymous with spectral emittance. Because the sum of absorptance or emittance, reflectance and transmittance is equal to unity (Law of Energy Conservation), the reflectance of an opaque object may also be considered equivalent to its emittance (glass is opaque between 5.0 and > 50 µm). Hence, spectral emittance can be derived from spectral reflectance data.

4.3 This test method recognizes that there are other uses of surface emittance, for example, heat transfer during glass tempering, for which this test method is not applicable.

4.4 This test method is not intended for measurement of substrates that are transparent to infrared radiation, such as certain plastics, etc.

5. Apparatus

5.1 Spectrometer and specular reflectance accessory(s) designed for the measurement of specular reflectance in the range of 5 (2000 cm^{-1}) to ≥25 µm (400 cm^{-1}) at 1 µm intervals (17 cm^{-1} at 25 µm).[5]

5.2 Spectrometer must have purge capability to eliminate absorption due to moisture and carbon dioxide in the atmosphere.

5.3 The specular reflectance accessory used for the measurement is an all-reflective optical system in which the calibration mirror(s) or samples(s) are located at a 1:1 optical conjugate of the monochromator entrance slits. The angle of incidence with respect to the normal of the sample must be 10° or less to minimize the effects of polarization (see Guide E 179).

5.4 For double-beam spectrometers a reflectance accessory identical to the one placed in the sample beam can be placed in the reference beam to reduce the increased noise due to the different path length.

6. Specimen Selection

6.1 For highest precision and bias, select specimens with the following properties:

6.1.1 High material uniformity and freedom from blemishes in the area to be measured. However, blemishes observed under visible illumination might not affect with measurements in the infrared.

6.1.2 Surface to be measured should be flat across two or three times the measurement area.

6.2 For coatings subject to aging and atmospheric attack, the specimen to be measured must be fresh and in good condition.

7. Calibration

7.1 *Reflectance Standards*:

7.1.1 Aluminum, copper, gold, and silver mirrors may all have a reflectance of more than 98.5 % at 10 µm. Aluminum coatings,[6] however, are the least susceptible to both mechanical and chemical degradation. Therefore, aluminum is the material of choice for both transfer and working standards of high reflectance.

7.1.2 The recommended secondary (or transfer) reflectance standard is an undamaged, front-surface aluminum mirror on glass in good condition (free of surface scratches and other contamination). Calibrate the transfer standard from 5 to ≥25 µm against a primary standard.[7] If no calibration data is available for a specific aluminum mirror the data given in Table 1 may be used. The accuracy of a measurement using calibration data from Table 1 is ±0.5 %.

7.1.3 Working reflectance standards should be front surface aluminum mirrors on glass from a reputable manufacturer. Calibrate the working standards against the transfer standard at least once per month or whenever a change in the condition of the working standard is suspected. The working standard may have a protective overcoat of SiO, SiO_2, Al_2O_3, or other noninterfering material.

7.2 *Baseline Settings/Recording*—Set the baseline for the reflectance scale of the spectrometer by following the instructions provided by the instrument manufacturer. These instructions may only cover the case of transmission and will vary

TABLE 1 Absolute Reflectance Versus Wavelength of an Aged Evaporated Aluminum Mirror[A]

Wavelength, µm	Absolute Reflectance	Wavelength, µm	Absolute Reflectance	Wavelength, µm	Absolute Reflectance
0.4	0.9076	1.5	0.9658	24	0.9861
0.45	0.9061	2	0.9699	26	0.9864
0.5	0.9034	3	0.9736	28	0.9867
0.55	0.9032	4	0.9758	30	0.9870
0.6	0.9027	5	0.9772	32	0.9872
0.65	0.8976	6	0.9784	34[B]	0.9877
0.7	0.8886	7	0.9794	36[B]	0.9879
0.75	0.8761	8	0.9801	38[B]	0.9881
0.775	0.8678	9	0.9807	40[B]	0.9883
0.8	0.8596	10	0.9812	42[B]	0.9885
0.825	0.8556	11	0.9816	44[B]	0.9887
0.85	0.8596	12	0.9821	46[B]	0.9888
0.875	0.8730	13	0.9826	48[B]	0.9890
0.9	0.8894	14	0.9830	50[B]	0.9891
0.925	0.9030	16	0.9838	52[B]	0.9892
0.95	0.9154	18	0.9845	54[B]	0.9893
1	0.9324	20	0.9852	56[B]	0.9893
1.2	0.9585	22	0.9856	58[B]	0.9894

[A] See Footnote 12.
[B] Extrapolated data.

[5] This procedure requires that measurements be taken up to 25 µm. Measurements covering the range up to 40 µm or even 50 µm, however, should be recorded, if the equipment permits. For samples with significant variation in the extended range, unacceptable error could result (see Section 8).

[6] Gold has a flatter and higher reflectance in the infrared (99 %) compared to aluminum, but it needs to be handled with very extreme care, which makes it an impractical choice.

[7] Calibrated primary standards are available from: National Physical Laboratory, Teddington, Middlesex, TW11 0LW Great Britain. The cost of calibration (at the time of this writing, December 1992) from 5 to 55 µm is £ 580 for the first mirror and £ 420 for each subsequent mirror plus the cost of the mirror. The uncertainty of measurement is ±0.3 % absolute value. The cost of NPL uncalibrated mirrors is £ 65 for an aluminum mirror, and £ 200 for an aluminum mirror with an aluminum oxide coating which can be cleaned. Calibration is also available for mirrors not supplied by NPL. At this time NIST does not have the capability to provide or calibrate reference mirrors in the thermal infrared. An instrument for measuring absolute reflectivity is under development.