Designation: E 1651 – 94 (Reapproved 1999)

Standard Test Method for Total Luminous Reflectance Factor by Use of 30/t Integrating-Sphere Geometry[1]

This standard is issued under the fixed designation E 1651; 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

This test method has a long but undocumented history. The electric lighting industry for many years used a visual reflectometer with 30° unidirectional illumination and a sphere to collect all the reflected light so as to obtain a measure of total luminous reflectance factor, specular plus diffuse, for 30/*t* geometry. The original visual design was later equipped with a photovoltaic cell and microammeter. The lighting industry has preferred to maintain this geometry rather than to use a standard CIE geometry, such as 6/*t*. In 1975, the original 30/*t* geometry was incorporated in an instrument of modern design. This test method documents the calibration and measurement procedures for such an instrument.

1. Scope

1.1 This test method covers measurement of total luminous reflectance factor of opaque, nonfluorescent specimens by use of an integrating-sphere reflectometer with illumination at an angle of 30° from the surface normal and diffuse viewing with specular component included.

1.2 This test method is intended to be used for evaluation of total luminous reflectance factor of reflector lighting sheet material. It may be used for evaluation of other material when its specific geometry has been found to be applicable.

1.3 *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:*

E 177 Practice for Use of the Terms Precision and Bias in ASTM Standards[2]

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

E 259 Practice for Preparation of Pressed Powder White Reflectance Factor Transfer Standards for Hemispherical and Bi-Directional Geometries[3]

E 284 Terminology of Appearance[3]

E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method[2]

E 1345 Practice for Reducing the Effect of Variability of Color Measurement by Use of Multiple Measurements[3]

E 1347 Test Method for Color and Color-Difference Measurements by Tristimulus (Filter) Colorimetry[3]

3. Terminology

3.1 Definitions in Guide E 179 and Terminology E 284 are applicable to this test method.

4. Summary of Test Method

4.1 This test method requires the use of a reflectometer equipped with an integrating sphere with an angle of illumination of 30° to the surface normal and diffuse viewing with the specular component included. In other respects, the details of the instrument geometry are as specified in Guide E 179. The use of the 30° angle of illumination allows complete collection of flux reflected at angles near the specular angle.

4.2 This test method utilizes only the *Y* tristimulus function, leading to the measurement of luminous reflectance. In other respects, the spectral characteristics and methodology used are similar to those described in Test Method E 1347. It should be noted that, when and if suitable equipment is available,

[1] This test method is under the jurisdiction of ASTM Committee E-12 on Color andAppearance and is the direct responsibility of Subcommittee E12.02 on Spectrophotometry and Colorimetry.

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

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

spectrophotometric measurement is equally as acceptable as the (filter) colorimetric method described in this test method.

5. Significance and Use

5.1 Procedures of this test method provide a quantitative measure of total luminous reflectance, which is related to reflection efficiency of lighting reflectors. This test method is extensively used to assess total reflectance factor of reflector sheet used in the manufacture of lighting fixtures.

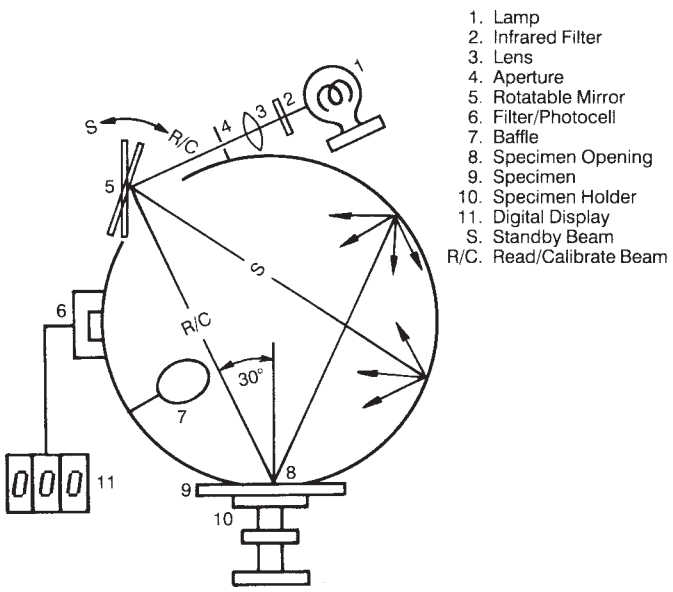

FIG. 1 Schematic Diagram of Reflectometer

5.2 The measurement of this test method includes both specularly and diffusely reflected light, weighted by the CIE spectral luminous efficiency function $V(\lambda)$ of the eye to provide a reasonable approximation of visual assessment.

6. Apparatus

6.1 *Reflectometer*, [4] with a hemispherical optical measuring system as described in 6.1.1, capable of measuring CIE 1931 tristimulus value *Y* for CIE standard illuminant *C* (total luminous reflectance). A diagram of a suitable reflectometer is given in Fig. 1 and is described as follows:

6.1.1 The light from quartz-tungsten-halogen lamp, (*1*), passes through infrared absorbing filter, (*2*), is collected by lens, (*3*), apertured, (*4*), and reflects off rotary mirror, (*5*). When in position *S* (standby) the light beam reflects off the sphere wall. The total reflected light integrated by the sphere is read by the filter/photocell combination, (*6*), and is stored in memory. A light stop or baffle (*7*) keeps the photocell from viewing any portion of the specimen. When the mirror is rotated to the R/C (read/calibrate) position, the light beam illuminates the specimen, (*9*), through specimen opening, (*8*). Total reflectance (consisting of specular and diffuse components) is integrated by the sphere and read by the filter/photocell. The digital display, (*11*), shows the ratio of this reflectance to that stored in memory, displayed in percent.

6.1.2 The optical characteristics of the integrating sphere and its coating shall be as recommended in Guide E 179 except that the angle of illumination shall be 30 ± 1° with a maximum aperture angle of 10°. Viewing shall be diffuse, with the specular component included. The measured area shall be a circle with area 6.5 cm^2; otherwise multiple measurements shall be made and averaged to achieve an equivalent specimen area (see 8.2.3).

6.1.3 The spectral responsivity of the illuminator-filter-receiver combination shall match that of the CIE spectral luminous efficiency function $V(\lambda)$ when combined with CIE standard illuminant *C* if a filter-type reflectometer is used. Use of spectrophotometric apparatus is allowable if it fulfils the geometric requirements of 6.1.2.

6.2 *Calibration Standards*, either supplied by the manufacturer or obtained separately. The standards, one white and one black, must be flat, opaque, glossy ceramic glass or porcelain enamel plaques at least 75 by 75 mm.

6.2.1 *White Reflecting Tile or Standard (Mandatory)*—This instrument standard shall be calibrated by use of 30/*t* geometry against barium sulfate as a transfer standard. The barium sulfate shall be calibrated by use of hemispherical geometry against the perfect reflecting diffuser as the primary standard (see Practice E 259).

6.2.2 *Calibration Standard, Black* for setting or verifying the zero reading of the instrument.

7. Test Specimens

7.1 For highest precision and accuracy, select specimens from representative samples of the surfaces being measured. They must be opaque, clean, dry, and flat. If special preparation of the specimens is required, the users of the test method shall agree in advance on the technique of their preparation.

8. Procedure

8.1 *Calibration*:

8.1.1 Calibrate the reflectometer by use of the white and black standards, following the manufacturer's recommendations (*mandatory*). After such calibration the instrument must read the assigned standard values within ±0.1 unit of total reflectance factor.

8.2 *Measurement*:

8.2.1 Handle the specimen carefully; avoid touching the area to be measured. When necessary, clean the specimen by an agreed upon procedure.

8.2.2 Measure the specimen, by rotating the mirror to the read/calibrate position and record the total reflectance factor.

8.2.3 Make a total of four measurements, rotating the specimen 90° after each measurement. If the four readings differ by less than 0.2, any single reading will suffice; otherwise average the four readings (see also Practice E 1345).

8.2.4 Transcribe the data required for the report, when not printed by the instrument.

[4] The sole source of supply of reflectometers such as the TR-1 or TR-2 Total Reflectometers known to the committee at this time is Technidyne Corporation, 100 Quality Avenue, New Albany, IN 47150. If you are aware of alternative suppliers, please provide this information to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

9. Report

9.1 Report the following information:

9.1.1 Name, model and manufacturer of instrument,

9.1.2 Calibration standards used,

9.1.3 Description and size of specimen,

9.1.4 Number of measurements taken,

9.1.5 Individual measured values, and

9.1.6 Average value of total luminous reflectance factor of the specimen.

10. Precision and Bias

10.1 *Precision*:

10.1.1 An interlaboratory study was performed to determine the repeatability and reproducibility of this test method. (The terms *repeatability* and *reproducibility* are used as defined in Practice E 177.) The specimens included six groups of lighting reflector sheets, mirrored sheets, and ceramic plaques. Seven laboratories measured 29 samples six times, in random order. The experimental procedures and analysis of the data were performed in accordance with Practice E 691.

10.1.2 The resulting information on reproducibility and repeatability is given in Table 1, in which each test result is the average of 42 measurements.

TABLE 1 Summary of Precision Data for Total Luminous Reflectance

Group	Number of Samples	95 % Repeatability Limit, *r*	95 % Reproducibility Limit, *R*	Repeatability Standard Deviation, *Sr*	Reproducibility Standard Deviation, *SR*
Anodized aluminum	6	0.498	0.721	0.178	0.258
White painted sheet	6	0.293	1.381	0.105	0.493
Gray plaques	6	0.359	0.967	0.128	0.345
Black plaques	1	0.497	0.522	0.177	0.187
Highly specular	5	0.277	0.333	0.099	0.199
Semi-specular	5	0.200	0.306	0.713	0.109

10.2 *Bias*—Bias cannot be determined since there is no accepted referee method for determining absolute values of total luminous reflectance with 30/*t* geometry.

11. Keywords

11.1 reflectance; reflectometer; total luminous reflectance