Designation: E 1348 – 02

Standard Test Method for Transmittance and Color by Spectrophotometry Using Hemispherical Geometry[1]

This standard is issued under the fixed designation E 1348; 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 describes the instrumental measurement of the transmission properties and color of object-color specimens by the use of a spectrophotometer or spectrocolorimeter with a hemispherical optical measuring system, such as an integrating sphere.

1.2 This test method is generally suitable for all fully transparent specimens without regard for the specimen position relative to the transmission port of the instrument. Translucent specimens, however, must be placed flush against the transmission port of the sphere.

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:*

D 1003 Test Method for Haze and Luminous Transmittance of Transparent Plastics[2]

D 2244 Practice for Calculation of Color Tolerances and Color Differences from Instrumentally Measured Color Coordinates[3]

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 308 Practice for Computing the Colors of Objects by Using the CIE System[3]

E 805 Practice for Identification of Instrumental Methods of Color or Color-Difference Measurement of Materials[3]

E 1164 Practice for Obtaining Spectrophotometric Data for Object-Color Evaluation[3]

3. Terminology

3.1 *Definitions:*

3.1.1 The definitions in Guide E 179, Terminology E 284, and Practice E 1164 are applicable to this test method.

4. Summary of Test Method

4.1 This test method provides a procedure for measuring the transmittance of transmitting specimens by using a spectrophotometer or spectrocolorimeter equipped with a hemispherical optical measuring system such as an integrating sphere.

4.2 This test method includes procedures for calibrating the instrument and for selecting specimens suitable for precision measurement.

4.3 This test method is satisfactory for all fully transparent specimens with plane and parallel surfaces. When possible, the user should select the position of the specimen in the transmission compartment to provide either essentially total or essentially regular transmittance, depending on the end use of the measured data.

4.4 Accurate measurement of translucent specimens requires that the specimen be placed flush against the transmission port of the integrating sphere (see Practice E 1164, 8.1.4).

4.5 Most modern spectrophotometers have the capacity to compute the color coordinates of the specimen during the measurement. When this is the case, the user of this test method must select the color system, observer, and illuminant (see Practice E 308, Section 6).

5. Significance and Use

5.1 The most direct and accessible methods for obtaining the color coordinates of object colors are by instrumental measurement using spectrophotometers or colorimeters with either hemispherical or bidirectional optical measuring systems. This test method provides procedures for such measurement by transmittance spectrophotometry using a hemispherical optical measuring system.

5.2 This test method is especially suitable for measurement of the following types of specimens (see also Guide E 179 and Practice E 805):

5.2.1 Fully transparent specimens (free from turbidity, haze, or translucency), and

5.2.2 Translucent or hazy specimens, provided that the

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[2] *Annual Book of ASTM Standards,* Vol 08.01.

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

specimen can be placed flush against the transmission port of the integrating sphere.

5.3 This test method is not recommended for measurement of transparent or translucent retroreflective or fluorescent specimens.

6. Apparatus

6.1 *Spectrophotometer or Spectrocolorimeter*, designed for the measurement of color coordinates of transmitting specimens by use of integrating-sphere geometry.

6.2 *Calibration Standards*, either supplied by the instrument manufacturer or obtained separately, as follows (see Practice E 1164, Section 10):

6.2.1 *White Tile or Pressed-Powder Reflectance Standard*, to be placed at the reflection port of the integrating sphere (mandatory).

6.2.2 *Calibration Standards*, for (*1*) setting or verifying zero on the photometric scale; (*2*) verifying the wavelength scale, and (*3*) evaluating stray light (optional).

6.2.3 *Verification Standards (recommended)* (see Practice E 1164, 10.5).

7. Test Specimen

7.1 For highest precision and accuracy, select specimens with the following properties (see Practice E 1164, Section 9):

7.1.1 High material uniformity and freedom from blemishes in the area to be measured, and

7.1.2 Specimens that have two essentially plane and parallel surfaces, and that have a standard thickness, if one is defined.

8. Calibration and Verification

8.1 Calibrate or verify the calibration of the following quantities (see Practice E 1164, Section 10):

8.1.1 Zero setting of the transmittance scale (mandatory),

8.1.2 Wavelength scale (recommended), and

8.1.3 Stray-light level (optional).

8.2 Calibrate the full-scale value of the transmittance scale of the instrument with no transmitting specimen in place and the white reflectance standard at the reflection port. Follow the instrument manufacturer's instructions (mandatory).

NOTE 1—For maximum accuracy of measurement of translucent specimens, the white standard at the reflection port should have the same reflectance as that of the lining of the integrating sphere.

8.3 Verify the accuracy of the measured results by measurement of a series of verification standards (recommended) (see Practice E 1164, 10.5).

9. Procedure

9.1 When required, select the color scales, observer, and illuminant to be used in the computation of color coordinates (see Practice E 308, Section 6).

9.2 Select settings of other options, such as wavelength range and interval, when required. Follow the instrument manufacturer's instructions or specified procedures.

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

9.4 For the measurement of fully transparent specimens, place the specimen in the transmission compartment of the instrument.

9.4.1 If total transmittance is desired, place the specimen flush against the transmission measurement port of the integrating sphere.

9.4.2 If regular transmittance is desired, place the specimen in the transmission compartment, but as far away from the sphere port as possible.

9.5 For the measurement of translucent specimens, place the specimen in the transmission compartment, flush against the transmission measurement port of the integrating sphere. For maximum accuracy in the measurements, the white standard at the reflection port should have the same reflectance as that of the lining of the integrating sphere (see Practice E 1164, 8.1.4).

NOTE 2—When the size and centering of the light beam at the reflection measurement port of the integrating sphere can be properly adjusted according to Test Method D 1003, it is possible to measure transmission haze accurately. A set of haze standards should be used to verify the accuracy of the measurements.

9.6 Measure the specimen, following the instrument manufacturer's instructions.

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

10. Calculation

10.1 Perform any desired calculations of color coordinates that are not made automatically by the instrument (see Practice D 2244 and Practice E 308).

11. Report

11.1 Report the following information:

11.1.1 Specimen description (see Practice E 1164, 12.1.1),

11.1.2 Date of measurement,

11.1.3 Instrument parameters and specimen position as selected in Section 9, and

11.1.4 Measurement results, in the form of tables of transmittance versus wavelength or color-scale values.

12. Precision and Bias

12.1 *Precision*—The precision estimates are composed of three additive terms. The first term represents the noise component of any measurement. The second term represents measurement uncertainty introduced by factors dependent upon the first derivative of the transmittance function of the specimen. The third term represents uncertainty introduced by factors dependent upon the absolute magnitude of the transmittance value at any wavelength. For complex transmittance functions such as a didymium filter a more complex model of the derivative is required than the linear model offered here. Hence complex spectra may be expected to fail the test described below at or near their transmittance maxima and minima. In addition, reporting intervals greater than 10 nm may also fail.

12.1.1 *Repeatability*—Measurements should be considered suspect if the sample standard deviation of four spectral transmittance values measured under repeatability conditions is larger at most wavelengths than the limit defined by the following equation:

$$^{\sigma}MAX(\lambda) = 0.02 + ABS\left[\frac{(T(\lambda - 10) - T(\lambda + 10))}{200}\right] + \frac{T(\lambda)}{1000} \quad (1)$$

$^{\sigma}MAX(\lambda)$ = maximum allowable sample standard deviation at any wavelength
$T(\lambda)$ = mean of four readings of T at that wavelength and the units of T(λ) are percent transmittance
λ = wavelength in nm currently under consideration.

The units of the calculated limit are therefore percent transmittance. A 10 nm wavelength measurement interval is assumed in this example. For measurements at 20 nm interval, the constants in the second additive term are −20, 20, and 400 respectively. In either case, the first and last measured intervals are ignored.

12.1.2 *Reproducibility*—Measurements should be considered suspect if the absolute value of the difference between two spectral transmittance values measured under reproducibility conditions is larger at most wavelengths than the limit defined by the following equation:

$$\Delta T(\lambda) = 0.08 + ABS\left[\frac{(T(\lambda - 10) - T(\lambda + 10))}{200}\right] + \frac{T(\lambda)}{100} \quad (2)$$

where the units, symbols, and procedure are identical to those of Eq 1.

NOTE 3—Sometimes one of the two spectral transmittance values measured under reproducibility conditions is the set of tabular values of a calibration verification standard, and the other set of values is that verification standard measured on an individual instrument for the purpose of verification of calibration of the instrument. Under these conditions, if the pair fails the above test, the instrument may be considered suspect, and may fail calibration verification.

12.2 *Bias*—There is no known bias in this method.

13. Keywords

13.1 color; integrating sphere; spectrophotometer; transmittance