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AMERICAN SOCIETY FOR TESTING AND MATERIALS
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Standard Test Method for Reflectance Factor and Color by Spectrophotometry Using Hemispherical Geometry[1]

This standard is issued under the fixed designation E 1331; 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 reflection 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 The test method is suitable for use with most object-color specimens. However, it should not be used for retroreflective specimens or for fluorescent specimens when highest accuracy is desired. Specimens having intermediate-gloss surfaces should preferably not be measured by use of this geometry.

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 2244 Test Method for Calculation of Color Differences from Instrumentally Measured Color Coordinates[2]

E 179 Guide for Selection of Geometric Conditions for Measurement of Reflection and Transmission Properties of Materials[2]

E 284 Terminology Relating to Appearance of Materials[2]

E 308 Practice for Computing the Colors of Objects by Using the CIE System[2]

E 805 Practice for Identification of Instrumental Methods of Color or Color-Difference Measurement of Materials[2]

E 991 Practice for Color Measurement of Fluorescent Specimens[2]

E 1164 Practice for Obtaining Spectrophotometric Data for Object-Color Evaluation[2]

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 reflectance factors of reflecting object-color 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 Most modern spectrophotometers have the capacity to compute the color coordinates of the specimen immediately following the measurement. When this is the case, the user must select the color system, observer, and illuminant (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 reflectance spectrophotometry using a hemispherical optical measuring system.

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

5.2.1 All types of object-color specimens to obtain data for use in computer colorant formulation.

5.2.2 Object-color specimens for color assessment.

5.2.2.1 For the measurement of plane-surface high-gloss specimens, the specular component should generally be excluded during the measurement.

5.2.2.2 For the measurement of plane-surface intermediate-gloss specimens and of textured-surface specimens, including textiles, where the first-surface reflection component may be distributed over a wide range of angles, measurement may be made with the specular component included, but the resulting color coordinates may not correlate best with visual judgments of the color. The use of bidirectional geometry, such as 45/0 or 0/45, may lead to better correlations.

5.2.2.3 For the measurement of plane-surface, low-gloss (matte) specimens, the specular component may either be

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

excluded or included, as no significant difference in the results should be apparent.

5.2.3 Specimens with bare metal surfaces for color assessment. For this application, the specular component should generally be included during the measurement.

5.3 This test method is not recommended for measurement of the following types of specimens, for which the use of bidirectional measurement geometry (0/45 or 45/0) is preferable (Guide E 179):

5.3.1 Object-color specimens of intermediate gloss,

5.3.2 Retroreflective specimens, and

5.3.3 Fluorescent specimens (Practice E 991).

5.3.3.1 When there is doubt as to whether the specular component of reflection should be included or excluded, both measurements should be made, and the results correlated with visual judgments. Thereafter, the method with higher visual correlation should be utilized.

5.3.3.2 When measurements of two specimens whose gloss, or texture, are substantially different from each other, are to be utilized in a color-difference comparison, generally the specular component should be included in each measurement. This has the effect of including in both measurements all the first surface reflections whether diffuse or specular. These first surface reflections are subtracted from each other in the color-difference equation, and differences in the body color remain, which is what is usually sought.

6. Apparatus

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

6.2 *Calibration standards*, either supplied by the instrument manufacturer or obtained separately, as follows (Practice E 1164, Section 9):

6.2.1 *White standard*, of hemispherical reflectance factor (mandatory). (A standard of bidirectional reflectance factor is not satisfactory and should not be used.)

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) (Practice E 1164, 9.5).

7. Specimen Selection

7.1 For highest precision and accuracy, select specimens with the following properties:

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

7.1.2 Opaque specimens that have at least one plane surface, and

7.1.3 Translucent specimens that have two essentially plane and parallel surfaces and that have a standard thickness, when one is specified (Practice E 1164, 10.1.3).

8. Calibration and Verification

8.1 Set the instrument for inclusion or exclusion of the specular component of reflection; set the same as will be used in 8.4 (if carried out) or 9.1.

8.2 Calibrate or verify the calibration of the following (Practice E 1164, Section 9):

8.2.1 Zero setting of the reflectance scale (mandatory),

8.2.2 Wavelength scale (recommended), and

8.2.3 Stray-light level (optional).

8.3 Calibrate the full-scale value of the reflectance scale of the instrument by use of the white reflectance standard (mandatory). Follow the instrument manufacturer's instructions.

8.4 Verify the accuracy of the instrumental data by measurement of a series of verification standards (recommended) (Practice E 1164, 9.5). Select the appropriate color scales, observer, and illuminant for the computation of color coordinates before measurement.

NOTE 1—If the verification standards require a different selection of including or excluding the specular component than does 9.1, select the appropriate condition for measurement of the verification standards in 8.1, complete 8.4; select the correct setting for specimen measurement (9.1), repeat 8.3, and proceed to 9.2.

9. Procedure

9.1 Select inclusion or exclusion of the specular component of reflection (5.2).

9.2 When required, select the color scales, observer, and illuminant for the computation of color coordinates (Practice E 308, Section 6).

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

9.4 If the specimen is translucent, select specified black or white backing material. See Practice E 1164, 10.1.3, for further instructions on measuring translucent specimens.

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

9.6 Place the specimen, with backing material if required, against the reflectance measurement port of the integrating sphere.

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

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

10. Calculations

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

11. Report

11.1 Report the following information:

11.1.1 Specimen description (Practice E 1164, 1212.1.1),

11.1.2 Date of measurement,

11.1.3 Instrument parameters selected in 9.1-9.4, and

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

12. Precision and Bias

12.1 *Precision*:

12.1.1 *Repeatability*—Results reported in the literature,[3] obtained by the use of modern measuring instruments, expressed in terms of CIELAB color differences (see Practice E 308) are within 0.1 units. On this scale, the smallest color difference that can be reliably observed is of the order of 0.5 unit, commercial color tolerances range upward from about one unit.

12.1.2 *Reproducibility*—The reproducibility within a group of similar instruments was reported to be about 0.2 unit.[4] Inter-instrument agreement comparing different types of instruments, especially if different types of illuminating and viewing conditions are involved, is likely to be an order of magnitude poorer.

12.2 Two measurements should be considered suspect if they differ by more than the previous figures applicable to the two measurements.

13. Keywords

13.1 color; hemispherical geometry; reflectance; reflectance factor; spectrophotometry

[3] Billmeyer, F. W., Jr., and Alessi, P. J., "Assessment of Color-Measuring Instruments," *Color Research and Application*, Vol 6, 1981, pp. 195–202.

[4] Stanziola, R., Momeroff, B., and Hemmendinger, H., "The SpectroSensor—A New Generation Spectrophotometer," *Color Research and Application*, Vol 4, 1979, pp. 157–163.