Designation: E1331 – 09

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

This standard is issued under the fixed designation E1331; 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 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.4 *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:*[2]

D2244 Practice for Calculation of Color Tolerances and Color Differences from Instrumentally Measured Color Coordinates

E179 Guide for Selection of Geometric Conditions for Measurement of Reflection and Transmission Properties of Materials

E284 Terminology of Appearance

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

E805 Practice for Identification of Instrumental Methods of Color or Color-Difference Measurement of Materials

E991 Practice for Color Measurement of Fluorescent Specimens Using the One-Monochromator Method

E1164 Practice for Obtaining Spectrometric Data for Object-Color Evaluation

E1345 Practice for Reducing the Effect of Variability of Color Measurement by Use of Multiple Measurements

3. Terminology

3.1 *Definitions:*

3.1.1 The definitions in Guide E179, Terminology E284, and Practice E1164 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 (see Practice E308, Procedure).

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 E179 and Practice E805):

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

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

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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.

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 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 E179):

5.3.1 Object-color specimens of intermediate gloss,

5.3.2 Retroreflective specimens, and

5.3.3 Fluorescent specimens (Practice E991).

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 E1164, Standardization and Material Standards):

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 E1164, Standardization and Material Standards).

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 E1164, Test Specimens).

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 E1164, Standardization and Material Standards):

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 E1164, Standardization and Material Standards). 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 (see Practice E308, Procedure).

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 E1164, Test Specimens, 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 (Practice D2244 and Practice E308).

TABLE 1 Specimens, Colorimetric Values, and 95 % Reproducibility Limits

Sample #	Mean L*	Mean a*	Mean b*	95 % Reproducibility Limits in units of ΔE^*_{ab}
A01	41.90	4.89	-13.97	0.35
C01	70.00	23.36	-10.20	0.75
A11	63.62	18.84	6.78	0.54
C11	85.38	1.40	50.42	0.76

11. Report

11.1 Report the following information:

11.1.1 Specimen description (Practice E1164, Report),

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*—The interlaboratory study leading to the results expressed in this precision and bias statement was conducted by a Task Group in Subcommittee E12.93 on Precision and Bias during the period July to September 2003. The results in 12.1.2 and 12.1.4 were obtained by bootstrap procedures. The statistical confidence intervals computed using these procedures were obtained from standard deviations obtained by resampling the variance distribution rather than by directly calculating the standard deviation of the measurements by conventional means.

12.1.1 *Repeatability Samples*— The specimens tested consisted of twelve neutral and colored, high gloss ceramic tiles, BCRA/Ceram Series II. The instrument population consisted of six different instruments in one laboratory. Each specimen was measured ten times on each instrument with the specular component included. Color difference comparisons were made only between measurements of each tile made on the same instrument. The underlying data are known as the 2003 SCAI data from the Munsell Color Science Laboratory.[3]

12.1.2 *Repeatability*—Repeatability conditions are defined as measurements made in the same laboratory using the same test method by the same operator using the same equipment in the shortest possible period of time using specimens taken from one lot of homogeneous material. Two test results obtained under repeatability conditions should be considered suspect to a 95 % repeatability limit if their values differ by more than 0.08 unit, ΔE^*_{ab}.

12.1.3 *Reproducibility Samples*—The Collaborative Testing Service's *Color and Color-Difference Collaborative Reference Program* has surveyed the precision of color and color-difference measurements by sending out pairs of painted chips exhibiting small color differences on a quarterly basis since 1971. The specimens of these surveys consist of opaque matte paint coated on white sealed paper stock and are distributed to the respondents from the same lot of homogeneous material. The specimens are specifically designed to be insensitive to the specular conditions present in the instrument, and no attempt is made to report the possible geometric conditions under which the measurements are made. Table 1 reports results from four specimens from these survey over the two-year period from 2000 to 2002. Approximately 250 instruments are reported in each survey. The instrument population of one of these four surveys consisted of 55 different models from nine different commercial instrument manufacturers. The most frequently reported instrument model accounted for 24 % of the population of instruments. The top four instruments accounted for 47 % of the population, and there were 25 instruments that represented a singular entry of that model in this population.

12.1.4 *Reproducibility*—Reproducibility conditions are defined as measurements made in different laboratories using different equipment using the same test method, each by a different operator using specimens taken from one lot of homogeneous material. Two test results made under reproducibility conditions should be considered suspect to a 95 % reproducibility limit if their values differ by more than the values given in Table 1 under the column headed "95 % Reproducibility Limits."

12.2 *Bias*—It is not possible to determine the bias, if any, of this test method because no accepted reference values are available for the specimens tested.

12.3 The precision statistics for this test method must not be treated as exact mathematical quantities that are applicable to all instruments, uses, and materials. There will be times when differences occur that are greater than those which would be predicted by the interlaboratory study leading to these results. Sometimes these instances occur with greater or smaller frequency than the 95 % probability limit would imply. If more precise information is required in specific circumstances, those laboratories directly involved in a material comparison must conduct interlaboratory studies aimed at the material of interest.

12.4 The user is also referred to Practice E1345 for information on one potential method of increasing the precision of one's measurements.

13. Keywords

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

[3] Proceedings 2003 ISCC-FSCT Symposium on Color and Appearance Instrumentation (SCAI), Chicago, IL, April 14-15, 2003, available from Inter-Society Color Council, 11491 Sunset Hills Rd., Reston, VA, 21190, http://www.iscc.org.