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Standard Test Method for Color and Color-Difference Measurement by Tristimulus Colorimetry[1]

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1. Scope

1.1 This test method covers the instrumental measurement of specimens resulting in color coordinates and color difference values by using a tristimulus colorimeter, also known as a tristimulus filter colorimeter or a color-difference meter.

1.2 Provision is made in this test method for the measurement of color coordinates and color differences by reflected or transmitted light using either a hemispherical optical measuring system, such as an integrating sphere, or a bidirectional optical measuring system, such as annular, circumferential, or uniplanar 45:0 and 0:45 geometry.

1.3 Because of the limited absolute accuracy of tristimulus colorimeters, this test method specifies that, when color coordinates are required, the instrument be standardized by use of a standard having similar spectral (color) and geometric characteristics to those of the specimen. This standard is also known as a product standard. The use of a product standard of suitable stability is highly desirable.

1.4 Because tristimulus colorimeters do not provide any information about the reflectance or transmittance curves of the specimens, they cannot be used to gain any information about metamerism or paramerism.

1.5 Because of the inability of tristimulus (filter) colorimeters to detect metamerism or paramerism of specimens, this test method specifies that, when color differences are required, the two specimens must have similar spectral (color) and geometric characteristics. In this case, the instrument may be standardized for reflectance measurement by use of a white reflectance standard or, for transmittance measurement, with no specimen or standard at the specimen position.

1.6 This test method is generally suitable for any nonfluorescent, planar, object-color specimens of all gloss levels. Users must determine whether an instrument complying with this method yields results that are useful to evaluate and characterize retroreflective specimens, or specimens having optical structures.

1.7 This test method does not apply to the use of a spectrocolorimeter, which is a spectrometer that provides colorimetric data, but not the underlying spectral data. Measurement by using a spectrocolorimeter is covered in Practice E1164 and methods on color measurement by spectrophotometry.

1.8 *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
E805 Practice for Identification of Instrumental Methods of Color or Color-Difference Measurement of Materials
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 contained in Guide E179 and Terminology E284 are applicable to this test method.

[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.

4. Summary of Test Method

4.1 This test method provides procedures for measuring object-color specimens in either transmission or reflection with a tristimulus colorimeter (hereafter referred to as a colorimeter) by use of the following geometric conditions and standardization procedures:

4.1.1 Color differences by reflected light of nonmetameric, nonparameric pairs of opaque or translucent specimens by use of either hemispherical geometry, with an integrating sphere, or bidirectional geometry, such as annular, circumferential, or uniplanar 45:0 or 0:45 geometry. The colorimeter may be standardized by use of a white reflectance standard.

4.1.2 Color differences by transmitted light of nonmetameric, nonparameric pairs of transparent or translucent specimens by use of hemispherical geometry. The colorimeter may be standardized by use of a white standard at the reflection port of the integrating sphere with no specimen in place. When translucent specimens are measured, they should be placed flush against the transmission port of the sphere, and the white standard should, for maximum accuracy, have the same reflectance and chemical composition as that of the lining of the integrating sphere.

4.1.3 Color coordinates by reflected light of opaque or translucent specimens by use of either bidirectional or hemispherical geometry. The colorimeter may be standardized by use of a standard having spectral (color) and geometric characteristics similar to those of the specimens. Such standards, often called *hitching-post* standards, are hereafter referred to as local standards.[3]

4.1.4 Color coordinates by transmitted light of transparent or translucent specimens by use of hemispherical geometry. The colorimeter may be standardized by use of a local standard.

4.1.5 This test method is not appropriate for fluorescent specimens.

4.1.6 For the measurement of the daytime color of retroreflective specimens, the 45:0 or 0:45 conditions are normally required. Some modern, high brightness, retroreflective sheeting has been shown to exhibit geometric artifacts if the cone angles are too narrow. In these cases, it may be more appropriate to use larger cone angles, with appropriate tolerances.

4.1.7 When the specimens exhibit directionality, and a colorimeter with uniplanar bidirectional geometry is used, information on directionality may be obtained by measuring the specimens at more than one rotation angle, typically at two angles 90° apart. When such information is not required, these measurements may be averaged, or a colorimeter with annular or circumferential bidirectional geometry may be used.

4.2 This test method includes two different procedures for standardizing the colorimeter. The first procedure utilizes a white standard of known reflectance factor; the second procedure utilizes a local standard.

4.2.1 When absolute values of color coordinates are to be determined, the use of a white standard is recommended only with colorimeters in which there is good conformance of the colorimeter readings to CIE tristimulus values, as determined by measurement of suitable verification standards (see Practice E1164). With instruments not meeting this requirement, the use of local standards is recommended, but only when the signal level (see Note 2) from the use of each colorimeter filter is adequately high.

NOTE 1—Of necessity, the above requirements are in part subjective, as the methods for verifying conformance to the requirements may not be available to the average user. Each user must decide whether the standardization procedure selected results in a loss of accuracy in the measurements that is negligibly small for the purpose for which data are obtained.

NOTE 2—The adequacy of the signal level can be determined by measuring the short-term repeatability without replacement, and ascertaining that the variation in the answer represents less than 30 % of the desired or allowable variation.

4.2.2 When color differences are to be measured, only relative measured values are required for the two members of the color-difference pair, and standardization by use of either a white standard or a local standard is satisfactory. In those cases where a computer program is being used to predict color tolerances, accuracy of the absolute values of the product standard color coordinates may become more important (see 4.2.1).

4.3 Procedures for selecting specimens suitable for precision measurement are included in this test method.

4.4 Most modern colorimeters compute the color coordinates of the specimen during the measurement. When this is the case, the user of this test method must designate the color system to be used in the computation (see Practice D2244).

5. Significance and Use

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

5.2 This test method is suitable for measurement of color differences of nonmetameric, nonparameric pairs of object-color specimens, or color coordinates of most such specimens. A further limitation to the use of colorimeters having hemispherical geometry is the existence of a chromatic integrating-sphere error that prevents accurate measurement of color coordinates when the colorimeter is standardized by use of a white standard.[4]

5.3 For the measurement of retroreflective specimens by this test method, the use of bidirectional geometry is recommended (See Guide E179 and Practice E805).

NOTE 3—To ensure inter-instrument agreement in the measurement of retroreflective specimens, significantly tighter tolerances than those given in Practice E1164 in the section on Influx and Efflux Conditions for 45°:Normal (45:0) and Normal:45° (0:45) Reflectance Factor are required

[3] Hunter, R. S., "Photoelectric Tristimulus Colorimetry with Three Filters," *Journal, Optical Society of America*, Vol 32, 1942, pp. 509–558.

[4] Hoffman, K., "Chromatic Integrating-Sphere Error in Tristimulus Colorimeters," *Journal of Color and Appearance*, Vol 1, No. 2, 1971, pp. 16–21.