Designation: E 1347 – 03

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

This standard is issued under the fixed designation E 1347; 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 specimens resulting in color coordinates and color difference values by using a tristimulus (filter) colorimeter, also known as a color-difference meter. This test method does not apply to the use of a spectrocolorimeter, which is a spectrophotometer that is normally capable of producing as output colorimetric data, but not the underlying spectral data from which color coordinates are calculated. Measurement by using a spectrocolorimeter is covered in Practice E 1164 and methods on color measurement by spectrophotometry.

1.2 Provision is made in this test method for the measurement of color coordinates and color differences by reflected 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 or 0/45 geometry. Provision is also made for measurement by transmitted light using a hemispherical optical measuring system.

1.3 Because of the limited absolute accuracy of tristimulus (filter) 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. The use of a product standard of suitable stability is highly desirable.

1.4 Because of the inability of tristimulus (filter) colorimeters to detect metamerism or paramerism, or to correctly measure metameric or parameric pairs 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.

1.5 While this test method is generally suitable for all object-color specimens, it should not be used without observing certain restrictions on the geometries and standardization procedures appropriate for different types of specimens and uses, and on the spectral character (metamerism or paramerism) of specimens and standards.

1.6 *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 Practice for Calculation of Color Tolerances and Color Differences from Instrumentally Measured Color Coordinates[2]

D 4086 Practice for Visual Evaluation of Metamerism[2]

E 167 Practice for Goniophotometry of Objects and Materials[2]

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

E 284 Terminology of Appearance[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 and Terminology E 284 are applicable to this test method.

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 (filter) 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

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

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 and 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 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 When the specimens are retroreflective or fluorescent, only bidirectional geometry is to be used.

4.1.6 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, one utilizing a white standard of reflectance factor, the other 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 E 1164). 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).

4.2.3 The restrictions to nonmetameric, nonparameric specimens apply to the considerations of this section and throughout.

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

4.4 Most modern colorimeters can 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 Practices D 2244).

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 tristimulus (filter) 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 or fluorescent specimens by this test method, the use of bidirectional geometry is preferred for maximum accuracy (see Guide E 179, Practice E 805, and Practice E 991).

5.4 A requirement for the use of a tristimulus (filter) colorimeter to obtain accurate color coordinates is that the combination of source, filter, and detector characteristics duplicate accurately the combined characteristics of a CIE standard illuminant and observer. When this requirement is not met, this test method requires the use of local standards for improving accuracy in the measurement of color coordinates (see also 4.2). For the measurement of small color differences between nonmetameric, nonparameric specimens, accuracy in absolute color coordinates is less important and standardization of the colorimeter by use of a white standard is satisfactory. However, accurate color-difference measurement requires that specimen pairs be neither metameric nor parameric, that is, the members have similar spectral and geometric characteristics.

[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.