Designation: D1729 – 16

Standard Practice for Visual Appraisal of Colors and Color Differences of Diffusely-Illuminated Opaque Materials[1]

This standard is issued under the fixed designation D1729; 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.

This standard has been approved for use by agencies of the U.S. Department of Defense.

INTRODUCTION

The colors of materials depend on the geometric and spectral nature of the illuminating and viewing conditions. This practice specifies standard conditions for appraising the colors and color differences of opaque specimens that are diffusely illuminated. Daylight, the natural illuminant, is usually of primary interest, but natural daylight is highly variable and is not available at night or in interior rooms, so simulated daylight is generally used. Colors may match under a light source with one spectral power distribution, but not under another, so the match is usually confirmed under another very different source. An incandescent lamp of low correlated color temperature has long been used to detect mismatches likely to appear under yellower phases of daylight or incandescent light. Industrial color matchers often verify the match with the kind of light likely to be found where the product is sold or used. Judgments should be made by observers with superior color vision as rated with the FM-100 Hue Test. Even so, there may be substantial individual differences in judgments.

1. Scope

1.1 This practice specifies the equipment and procedures for visual appraisal of the colors and color differences of opaque materials that are diffusely illuminated. These specifications are of critical importance in color matching. This practice requires judgments by observers with a minimum of normal color vision and preferably superior as rated with the FM-100 Hue Test as specified in Guide E1499.

1.2 Critical visual appraisal of colors and color differences of materials such as metallic and pearlescent paints requires illumination that is nearly a geometric simulation of direct sunlight, because such directional illumination permits observation of the sparkle (glitter) and goniochromatism that characterize such materials. Such viewing conditions are beyond the scope of this practice.

1.3 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

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]

D523 Test Method for Specular Gloss
D1535 Practice for Specifying Color by the Munsell System
D4086 Practice for Visual Evaluation of Metamerism
D5531 Guide for Preparation, Maintenance, and Distribution of Physical Product Standards for Color and Geometric Appearance of Coatings
E284 Terminology of Appearance
E308 Practice for Computing the Colors of Objects by Using the CIE System

[1] This practice is under the jurisdiction of ASTM Committee E12 on Color and Appearance and is the direct responsibility of Subcommittee E12.11 on Visual Methods.

Current edition approved Jan. 1, 2016. Published February 2016. Originally approved in 1960. Last previous edition approved in 2009 as D1729 – 96 (2009). DOI: 10.1520/D1729-16.

This standard has been approved for use by agencies of the Department of Defense to replace Method 4249.1 of Federal Test Method Standard No 141. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

[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.

E1164 Practice for Obtaining Spectrometric Data for Object-Color Evaluation
E1499 Guide for Selection, Evaluation, and Training of Observers
2.2 *ISO/CIE Standard:*[3]
ISO 10526 CIE Standard Colorimetric Illuminants (1991)
ISO 3664-2009 Graphic Technology and photography—Viewing conditions

3. Terminology

3.1 For definitions of appearance terms used in this practice, refer to Terminology E284.

4. Significance and Use

4.1 Although color measuring instruments are widely used, color matches are usually checked visually. The standardization of visual examination has greatly improved the uniformity of products and the accuracy of color matches.

4.2 The use of this practice is essential for critical color matching but is also recommended for any color appraisal, such as the choice or approval of a color. This practice is widely used in industry to choose colors, exhibit colors reproducibility, inspect incoming materials, monitor color producing processes, and inspect finished goods. Visual appraisal is particularly important when the product inspected is not of the same material as the color standard to which it is compared.

4.2.1 *Observers*—This practice is based on the fundamental assumption that the observer has superior color vision and is trained and experienced in observing and classifying color differences. The significance of the results depends on that being so. The selection, evaluation, and training of observers are treated in Guide E1499.

4.2.2 *Illumination*—Simulated average daylight, D65, is recommended by the International Commission on Illumination (CIE). D50 is recommended for applications involving color photography or color printing as specified in ISO 3364-2009.

5. Observers

5.1 The validity of the results obtained by this practice depends on visual judgments by an observer or observers having superior color vision. Even among normal observers, there may be substantial individual variations. Color specifications dependent on this practice may require averaging the results obtained by a specified number of observers. The nature of an observer's color vision can be ascertained by visual tests. Observers should be tested periodically, because an individual's color vision can change (see Guide E1499).

6. Apparatus

6.1 The apparatus shall consist of luminaires or viewing booth, specimen table, surround, and ambient field having the following spectral, photometric, and geometric characteristics:

6.1.1 *Spectral Power Distribution*—The spectral power distribution of the radiant flux incident on the specimens depends not only on the source used, but on the nature of any diffuser employed and any reflecting surfaces, including those in the ambient field, that reflect flux to the specimens.

6.1.1.1 Daylight illumination shall be a spectral simulation of daylight of one or more of the following two kinds: average daylight, designated CIE Illuminant D_{65}; or, for applications involving color photography or color printing, CIE Illuminant D_{50}. The spectra of these illuminants are specified in Practice E308 and CIE Publication 15:2004.[4] The quality of the simulation of daylight shall be assessed by the method specified in the latest revision of ISO/CIE 23603:2005, previously designated as Publication 51.[5] For critical appraisal of colors and color differences, the category determined by that method shall be BC(CIELAB) or better. This rating ensures that the source provides ultraviolet and visible power in the right proportions to make both nonfluorescent and fluorescent materials look very nearly the way they would in the corresponding phase of natural daylight. Users of this practice should be aware of the fact that neither correlated color temperature nor chromaticity alone qualifies simulated daylight for this purpose.

6.1.1.2 Incandescent illumination shall have the spectral quality of the light from an incandescent lamp commonly used for home and business lighting, approximately simulating CIE Illuminant A, specified in Practice E308 and ISO/CIE 10526.

6.1.1.3 Incandescent illumination of low correlated color temperature shall have spectral quality similar to that of a Planckian radiator having a color temperature of 2300 K. This source is referred to as "Horizon Daylight" because it simulates the spectra of early morning sunrise and late day sunset. This light is commonly produced by incandescent lamps operated at half their rated voltage.[6]

6.1.1.4 Fluorescent lamps are often provided. Those most often used are of the type known as "cool white" approximately simulating CIE Illuminant F2, and the type known as "three-band" approximately simulating CIE Illuminant F11 and F12. The spectra of these illuminants are specified in Practice E308 and ISO/CIE 10526. Recently, due to energy legislation, lamps simulating CIE Illuminant F2 have been limited to smaller sizes as used in specialty appliance applications.

6.1.1.5 One or several of these kinds of illumination, or other kinds, as specified, may be provided in a luminaire or viewing booth. Provision must be made for selecting any one of the sources independently. The blending of a broadband daylight source with incandescent illumination has shown to be effective in detecting metamerism in some color matching applications.

[3] Available from U.S. National Committee of the CIE (International Commission on Illumination), C/o Thomas M. Lemons, TLA-Lighting Consultants, Inc., 7 Pond St., Salem, MA 01970, http://www.cie-usnc.org.

[4] CIE Publication 15:2004, *Colorimetry*, 3rd ed., Central Bureau of the CIE, Vienna, 2004 (see footnote 3).

[5] ISO/CIE 23603:2005, *A Method for Assessing the Quality of Daylight Simulators for Colorimetry*, Central Bureau of the CIE, Vienna, (see footnote 3).

[6] The equations describing Planckian radiators and tables of their distributions can be found in Wyszecki, G., and Stiles, W. S., *Color Science Concepts and Methods, Quantitative Data and Formulae*, 2nd ed., John Wiley & Sons, Inc., New York, NY, 1982.

6.1.2 *Photometric Conditions*—For critical evaluation of color differences of materials of medium lightness, the illumination at the center of the viewed area shall be 1080 to 1340 lx (100 to 125 fc). For general evaluation of materials of medium lightness, the illumination shall be between 810 and 1880 lx (75 and 175 fc). In either case, for viewing very light materials, the illumination may be as low as 540 lx (50 fc), and for viewing very dark materials it may be as high as 2150 lx (200 fc). This higher level of illumination is usually obtained by holding the specimens nearer the source.

6.1.3 *Geometric Conditions*—The illumination shall be provided by an extended-area source located above the specimens and shall be sufficiently directional to reveal the texture of specimens. The illuminance shall be uniform over the viewing area, within ±20 %, with no abrupt changes apparent to the observer.

6.1.4 *Surround and Ambient Field*—The surround, the portion of the visual field immediately surrounding the specimens, shall be the color having the Munsell notation given in Table 1 for the evaluation category involved. The ambient visual field, the field of view seen when the observer glances away from the specimens, such as the interior surfaces of a viewing booth or the nearby walls of a viewing room, shall be the color having the Munsell notation given in Table 1 for the evaluation category involved.

6.1.4.1 The gloss of the surround and the ambient field shall be no greater than 15 on the 60° gloss scale described in Test Method D523.

6.1.4.2 When glossy or highly saturated specimens are compared, it is important to avoid observing light specularly reflected by them. Black velvet or other matte black material should be placed in the ambient field, so its dark image is reflected by the specimens.

6.2 *Availability of Apparatus:*

6.2.1 Equipment meeting the requirements of this practice is commercially available. The most important requirement, which is of particular importance for daylight simulators, is the spectral power distribution of the illumination.

6.2.2 Commercially available illumination meters may be used to measure the photometric conditions.

6.2.3 Paint for the surround and the ambient field may be specified by the Munsell notations given in Table 1.

6.2.4 Commercially available spectroradiometers with a measurement range of 300 to 780 nm and having a minimum band-pass half-width of 5 nm, may be used to measure the spectral power distributions and the CIE method of computation may be accomplished with a personal computer.

6.3 *Maintenance of Apparatus*—Lamps and other apparatus must be maintained. At least once during each 100 h of use, check the apparatus in the following way:

TABLE 1 Color of Surround and Ambient Field[A]

Evaluation Category	Color of Surround	Color of Ambient Field	Maximum Munsell Chroma of Neutrals
Critical	similar to standard	N 5 to N 7	0.2
General	N 5 to N 7	N 5 to N 7	0.3

[A] See Practice D1535.

6.3.1 Replace darkened or burned-out lamps in sets and be sure that all lamps are operating.

6.3.2 Clean the fixtures so dust or films deposited from the atmosphere do not alter the spectral power distributions.

6.3.3 Measure and record illumination levels.

7. Preparation of Specimens

7.1 Specimen preparation, if any, should be fully described in the specification for the material or reference shall be made to a standard method of preparation. Specimens should be planar, uniform in color and gloss, clean, free of defects, and representative of the batch. For maximum precision in color difference evaluation, the specimens should have the same gloss and texture. This fact should be considered in adopting a physical color standard to be matched (see Guide D5531 and Practice E1164).

7.2 The preferred size of specimens is approximately 90 by 165 mm (3½ by 6½ in.). If smaller sizes are used, the precision may be reduced.

8. Procedure

8.1 *Illumination and Viewing*—Place the materials on a table or the bottom of a viewing booth at the distance from the illuminator required to obtain the specified illuminance. The materials should be placed in the same plane, in edge contact, against the appropriate surround material. The specimens should be viewed at a distance of 450 to 600 mm (18 to 24 in.).

8.2 When viewing a glossy surface, it is necessary to avoid seeing the light source specularly reflected by the surface. This may be accomplished by illuminating along the normal to the surface and viewing at 45° to the normal or illuminating at 45° and viewing along the normal (see 6.1.4.2).

8.3 Matte specimens should be viewed along their normal (directly facing the observer) while illuminated at approximately 45° to the normal.

8.4 Some kinds of specimens present different colors when the illuminating and viewing geometry are changed. To detect this effect, each type of specimen should be examined while varying the viewing angle over a wide range. If this effect is present and a good color match is required, the specimens must match over this wide range of angles. The specimens must be held in the same plane, as that plane is varied relative to the source and observer.

8.5 A very small color difference of a yellow-blue kind (as opposed to a red-green kind), such as that involved in judging the yellowness of nearly white materials, may be perceived more readily if the two specimens are visually separated by a very fine black line, such as a black thread.

8.6 *Light Sources*—If otherwise identical specimens have identical reflection and fluorescence spectra, they will match under any light source. Often the spectra are not the same and a match under one light source does not ensure a match under others. This phenomenon is called “metamerism” (see Terminology E284). To test for metamerism, specimens are usually compared under daylight and at least one other source. The other source may be an incandescent lamp or other source

likely to be found where the material is sold or used. The sources to be used are often specified in purchase agreements (see Practice D4086).

8.7 *Evaluation of Color Difference*—Observe color difference components of hue, lightness (or value), and saturation (or chroma), with an indication of the order of prominence of these components. For example, it might be noted that a red specimen is moderately yellower, slightly darker, and very slightly less saturated than the given standard. For critical evaluation, interchange the materials and repeat the evaluation. More precise methodology is described in Practice D1535.

9. Report

9.1 Report the following information:

9.1.1 Lighting equipment, the CIE Category, if known, and the illuminance for each light used,

9.1.2 Category of evaluation, general or critical,

9.1.3 Identification of materials compared and a description of their gloss and surface characteristics,

9.1.4 Observed direction and magnitude of each of the three components of color difference (from one material taken as the standard) for each illumination and viewing angle used, and

9.1.5 The identity of observers by name or code.

10. Keywords

10.1 color; color difference; color matching; lighting; viewing conditions; visual examination—color; visual examination—color difference