**Designation: D3134 – 97(Reapproved 2008)ε1**

# Standard Practice for
# Establishing Color and Gloss Tolerances[1]

This standard is issued under the fixed designation D3134; 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.

ε1 NOTE—Corrections were made editorially in Footnote 4, 7.2.1, and Section 12 in December 2008.

## INTRODUCTION

Permissible color and gloss deviations from a standard are generally dependent upon the color discrimination of the observer, on the lighting and surround in which the material is viewed, and on special considerations related to the design, manufacture, and practical usage of the colored material or object. The tolerances, therefore, may be influenced by economic, technical, psychological, and practical requirements. In many circumstances, acceptability of color and gloss deviations from a standard may differ appreciably from the perceptibility of deviations such as on-tone fading preferences, large tolerances for luminance variation, nongreen bias, or nonyellow bias. With proper allowances, perceptibility data can be used as an aid to develop permissible tolerances. Finally, the sum of all these considerations should result in a specification acceptable to both buyer and seller.

## 1. Scope

1.1 This practice describes a procedure for establishing tolerances and evaluating the color and gloss of specimens with respect to specified standards. This practice is appropriate for nonfluorescent opaque specimens.

1.2 This practice does not indicate the extent of tolerances, but gives guidance on how they can be set. For product specification, the tolerances between specimens and the specified standard should be agreed upon between the purchaser and the seller.

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:*[2]
D523 Test Method for Specular Gloss
D1535 Practice for Specifying Color by the Munsell System
D1729 Practice for Visual Appraisal of Colors and Color Differences of Diffusely-Illuminated Opaque Materials
D2244 Practice for Calculation of Color Tolerances and Color Differences from Instrumentally Measured Color Coordinates
D3964 Practice for Selection of Coating Specimens for Appearance Measurements
D4449 Test Method for Visual Evaluation of Gloss Differences Between Surfaces of Similar Appearance
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
E312 Practice for Description and Selection of Conditions for Photographing Specimens Using Analog (Film) Cameras and Digital Still Cameras (DSC)
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
E1331 Test Method for Reflectance Factor and Color by Spectrophotometry Using Hemispherical Geometry
E1345 Practice for Reducing the Effect of Variability of Color Measurement by Use of Multiple Measurements
E1349 Test Method for Reflectance Factor and Color by Spectrophotometry Using Bidirectional (45°:0° or 0°:45°) Geometry

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[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 Dec. 1, 2008. Published December 2008. Originally approved in 1972. Last previous edition approved in 2003 as D3134 – 97 (2003). DOI: 10.1520/D3134-97R08E01.

[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.

E1360 Practice for Specifying Color by Using the Optical Society of America Uniform Color Scales System

E1499 Guide for Selection, Evaluation, and Training of Observers

E1541 Practice for Specifying and Matching Color Using the Colorcurve System (Withdrawn 2007)[3]

E1708 Practice for Electronic Interchange of Color and Appearance Data

2.2 *CIE Publication:*

No. CIE S 014-4/E2007 Colorimetry 2nd ed.[4]

## 3. Terminology

3.1 *Definitions*—For definitions of terms related to this practice see Terminology E284.

## 4. Summary of Practice

4.1 This practice consists of recommendations for the selection of a standard, the necessary physical measurements to assess the permanence of the standard to reproduce it when needed, and to establish tolerances.

4.2 Recommendations are given for the determination of the conformance of a specimen to preestablished color and gloss tolerances by instrumental or visual means.

## 5. Significance and Use

5.1 Color specifications are centered around exact positions in color space. Correspondingly, gloss specifications are centered around an exact position on the gloss scale. Because it is difficult to achieve these exact positions repeatedly, it is necessary to specify tolerances that are acceptable to both the buyer and the seller. This practice details the procedure for accomplishing this goal.

## 6. Specimens

6.1 The exact method of preparation of the specimen shall be agreed upon between the purchaser and the seller. However, for the highest precision in instrumental measurements the specimens should be opaque, uniform in color, plane, and uniform in texture. The specimens should be relatively permanent, and capable of being cleaned. Preferred sizes of specimens for visual evaluation are given in Practice D1729, the specific size being governed by the use of the specimens.

## 7. Procedure

7.1 *Selection and Specification of Color and Gloss Standard:*

7.1.1 Select a standard in accordance with Practice D3964 that is preferably the same type of material as the specimens to be evaluated for color or gloss, or both. Prepare, in sufficient quantity, secondary standards in accordance with Guide D5531 that are representative of the desired color and gloss, in the permanent material. Standards should have the same spectral characteristics as the manufactured product. This is usually accomplished by use of the same colorant composition, incorporated in the same manner into the same material. The standard should have the same texture as the manufactured product.

7.1.1.1 In order to obtain a permanent record, use Practice E805 and either Test Method E1331 or Test Method E1349 to correctly identify the instrumental measurement method. Measure the color in accordance with Practices E1164 and E805. Report the color as described in Practice E308. Do this even if the standard is textured. (If the standard is textured, note the texture orientation during measurement.) The variability of the measurements due to texture may be reduced by following the recommendations outlined in Practice E1345.

7.1.1.2 *Visual Color Assessment*—Use Guide E1499 to select an observer for the assessment. Assess and specify the color in terms of a color system described in Practices D1535, E1360, or E1541.

7.1.1.3 Measure the gloss in accordance with Test Method D523, or evaluate it in accordance with Test Method D4449.

7.1.1.4 Employ photography for permanently recording the appearance of the surface texture (see Practice E312). While Practice D3134 does not deal with texture tolerances or specifications, it should be recognized that significant differences in surface texture between standard and test specimens significantly affect both color and gloss, whether examined visually or instrumentally. In the case of visual evaluation of the effect of color and gloss, differences can be minimized by strict adherence to recommended illuminating and viewing geometry (see Practice D1729).

7.2 *Selection and Specification of Color Tolerances:*

7.2.1 The purchaser and the seller shall agree on color tolerances with respect to a previously selected standard and on the color scales in which they are expressed. Selection of the magnitude and direction of color tolerances shall be based on careful consideration of all applicable factors. For example, tolerances may be selected on the basis of perceptibility of the magnitude of color difference, rejection of or closer limits on certain directions of color difference, and costs of controlling the magnitude and direction of color difference. Recommendations on color scales appear in CIE Publication No. CIE S 014-4/E2007 and Practice E308.

7.2.1.1 Express color differences between the specimen and the standard in terms of a set of three independent parameters. The CIE 1976 L*a*b* (CIELAB) approximately uniform color space and color difference equations have been recommended for use by the International Commission on Illumination (CIE). See Practice D2244 and Practice E308. While this color metric (CIELAB) is convenient for expressing color differences, it must be understood that a given calculated color difference in one region of color space may not represent the same visual difference in other regions of color space.

7.2.2 Gloss differences can affect instrumental measurement of color differences. Large gloss differences between visually identical colors can cause their color measurements to exhibit larger color differences than in fact exist. When using historical data to establish color tolerances, exercise care to limit the specimens to those that have quite similar gloss values. When

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[3] The last approved version of this historical standard is referenced on www.astm.org.

[4] Available from CIE (International Commission on Illumination), http://www.techstreet.com.

establishing gloss tolerances, be aware that changes in gloss values may have an effect upon color measurements.

7.2.3 When color difference formulae are used in practice, it is often desirable to identify the components of color difference, in terms of correlates of lightness, hue, and perceived chroma (saturation). It is also desirable to express color specifications in terms of such correlates. The CIE terminology appropriate to this usage is CIE 1976 lightness, CIE 1976 hue-angle, $h_{ab}$, and CIE 1976 chroma, $C^*_{ab}$. Refer to Practice D2244 and Practice E308 for equations and definitions. The CIELAB 1976 hue-angle and chroma are illustrated in Fig. 1.

7.2.4 The CIELAB opponent-color red-green coordinate $a^*$, and the yellow-blue coordinate $b^*$ are defined in Practice D2244 and Practice E308.

7.2.5 *Graphical Interpretation of Historical Data:*

7.2.5.1 Color tolerances can be determined from a graphical interpretation of historical data (batches accepted, rejected, or considered borderline). Fig. 2 (*a*) and Fig. 3(*b*) show plots of specimens rated by multiple observers with respect to how well they match a standard, along with figures defining the tolerances. To illustrate the principle recommended: (*1*) rate a number of specimens for acceptability, (*2*) plot them, and (*3*) prepare to draw the tolerance figure dictated by the data.

7.2.5.2 In such cases it is customary to plot the hue angle of the standard by drawing a line from the origin (0, 0) through the standard color on the $a^*b^*$ plot. This line of constant hue becomes the major axis. Similarly, a line perpendicular to the constant-hue line and passing through the standard color is a line of constant chroma (or saturation) and becomes the minor

axis of the ellipse, if the data plot indicates the ellipse should be symmetrical around the standard color. These lines assist in drawing the tolerance ellipse, Fig. 2(*a*).

7.2.5.3 To determine lightness tolerances it is necessary to plot the data for the same colors on a graph showing $L^*$ along with either $a^*$ and $b^*$, and draw a tolerance ellipse as in Fig. 3(*b*). The choice between $a^*$ and $b^*$ is dictated by which of these attributes cover the greater range.

7.2.5.4 The scales on Fig. 2(*a*) and Fig. 3(*b*) are changed from absolute values ($L^*$, $a^*$, $b^*$) into color difference values ($\Delta L^*$, $\Delta a^*$, $\Delta b^*$) as shown.

7.2.6 When tolerances for each color attribute (hue, lightness, and saturation or chroma) are symmetrical in the plus and minus directions, the graphical representation is a regular geometric figure that can be represented mathematically, as by the equation for an ellipse or an ellipsoid. It is also common to represent color tolerances by a set of six points: light and dark limits, low and high saturation limits, and two adjacent hue limits. Such representation may involve some sacrifice in accuracy of the tolerance specification and should be used with care.

7.2.7 In general, color tolerances will not be symmetrically located in all directions about the standard color in any color space. (see Fig. 2(*a*) and Fig. 3(*b*)). However, in some instances the asymmetry may be small enough that the color tolerances may be represented by a single, overall color difference ($\Delta E$) that represents the radius of a sphere about the standard in color space.

7.2.8 Finally, there are many deviations from the regular geometric figures described in 7.2.6 and depicted in Fig. 2(*a*) and Fig. 3(*b*). The nongreen and nonyellow biases mentioned in the introduction are but two of these. For example, the tolerance figure may not be regular; perhaps it will be an ovoid instead of an ellipse; its major axis may deviate from the direction of constant hue; and the standard color may be far from its center. Frequently when it is necessary to set color tolerances, the amount of historical accept-reject data will be too modest for this purpose. It is therefore necessary to monitor tolerances, once set, to ensure that they appropriately address the color quality control requirement.

7.2.9 When tolerance standards are prepared to illustrate the color in the hue, lightness, and saturation or chroma attributes of color space and to allow visual interpretation of the conformity of color, inspection should be under specified light sources following the recommendations in Practice D1729. Gonioapparent coatings or materials require special methodologies for viewing and measurement.

7.3 *Selection and Specification of Gloss Tolerances:*

7.3.1 The gloss tolerances around the gloss of the standard may be expressed in gloss units (See Test Method D523) or as a percent.

7.3.2 With few exceptions, the visual gloss tolerance will be symmetrical around the nominal value of the standard. It will be necessary to determine experimentally the instrumental readings that correspond to the required visual differences.

7.3.3 When the gloss desired is at or near the maximum or minimum gloss attainable, it is customary to specify a single gloss reading and the direction in which the data may depart
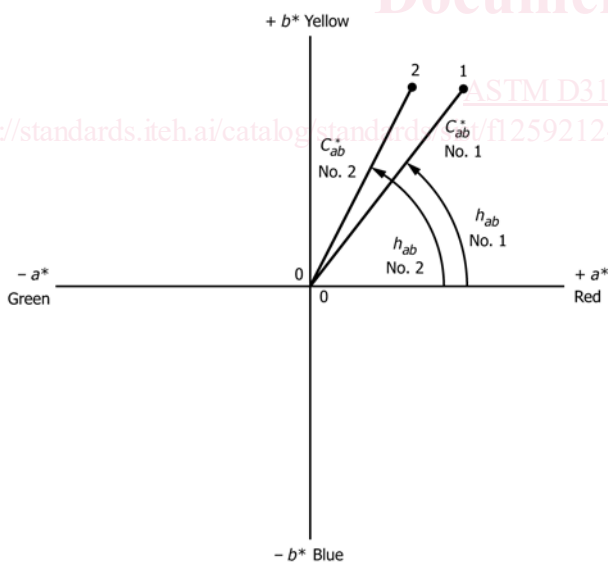


NOTE 1—Hue angle is measured in degrees starting with $h_{ab} = 0$ in the $+ a^*$ (red) direction and increasing counterclockwise. Chroma is measured as the length of the line from the neutral point ($a^* = b^* = 0$) to the sample point. Sample Point 2 has a larger value of $h_{ab}$ than Point 1 and therefore is yellower in hue. Point 2 also has a smaller value of $C_{ab}^*$ than Point 1 and is therefore lower in chroma or duller.

NOTE 2—Original source is Billmeyer, F. W., Jr., and Saltzman, M., *Principles of Color Technology*, 2nd ed., John Wiley and Sons, New York, NY, 1981. (Reprinted by permission of John Wiley & Sons, the copyright owner.)

**FIG. 1 CIE 1976 L\* a \* b\* (CIELAB) Hue Angle and Chroma**