Designation: D 3134 – 97

Standard Practice for Establishing Color and Gloss Tolerances[1]

This standard is issued under the fixed designation D 3134; 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.

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:*

D 523 Test Method for Specular Gloss[2]

D 1535 Practice for Specifying Color by the Munsell System[2]

D 1729 Practice for Visual Evaluation of Color Differences of Opaque Materials[2]

D 2244 Test Method for Calculation of Color Differences from Instrumentally Measured Color Coordinates[2]

D 3964 Practice for the Selection of Coating Specimens for Appearance Measurement[2]

D 4449 Test Method for Visual Evaluation of Gloss Differences Between Surfaces of Similar Appearance[2]

D 5531 Guide for the Preparation, Maintenance, and Distribution of Physical Product Standards for Color and Geometric Appearance of Coatings[2]

E 284 Terminology of Appearance[2]

E 308 Practice for Computing the Colors of Objects by Using the CIE System[2]

E 312 Practice for Description and Selection of Conditions for Photographing Specimens[2]

E 805 Practice for Identification of Instrumental Methods of Color and Color-Difference Measurement of Materials[2]

E 1164 Practice for Obtaining Spectrophotometric Data for Object-Color Evaluation[2]

E 1331 Test Method for Reflectance Factor and Color by Spectrophotometry Using Hemispherical Geometry[2]

E 1345 Practice for Reducing the Effect of Variability of Color Measurements by the Use of Multiple Measurements[2]

E 1349 Test Method for Reflectance Factor and Color by Spectrophotometry Using Bidirectional Geometry[2]

E 1360 Practice for Specifying Color Using the Optical Society of America Uniform Color Scales System[2]

E 1499 Guide to the Selection, Evaluation, and Training of Observers[2]

E 1541 Practice for Specifying and Matching Color Using the Colorcurve System[2]

E 1708 Practice for Electronic Interchange of Color and Appearance Data[2]

2.2 *CIE Publication:*

[1] This practice is under the jurisdiction of ASTM Committee E12.11 on Visual Methods and is the direct responsibility of Subcommittee E-12 on Appearance of Materials.

Current edition approved Feb. 10, 1997. Published September 1997. Originally published as D 3134 – 72 T. Last previous edition D 3134 – 89.

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

No. 15.2 Colorimetry 2nd ed.[3]

3. Terminology

3.1 *Definitions*—For definitions of terms related to this practice see Terminology E 284.

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 D 1729, 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 D 3964 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 D 5531 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 E 805 and either Test Method E 1331 or Test Method E 1349 to correctly identify the instrumental measurement method. Measure the color in accordance with Practices E 1164 and E 805. Report the color as described in Practice E 308. 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 E 1345.

7.1.1.2 *Visual Color Assessment*—Use Guide E 1499 to select an observer for the assessment. Assess and specify the color in terms of a color system described in Practices D 1535, E 1360, or E 1541.

7.1.1.3 Measure the gloss in accordance with Test Method D 523, or evaluate it in accordance with Test Method D 4449.

7.1.1.4 Employ photography for permanently recording the appearance of the surface texture (see Practice E 312). While Practice D 3134 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 D 1729).

7.2 *Selection and Specification of Color Tolerances*:

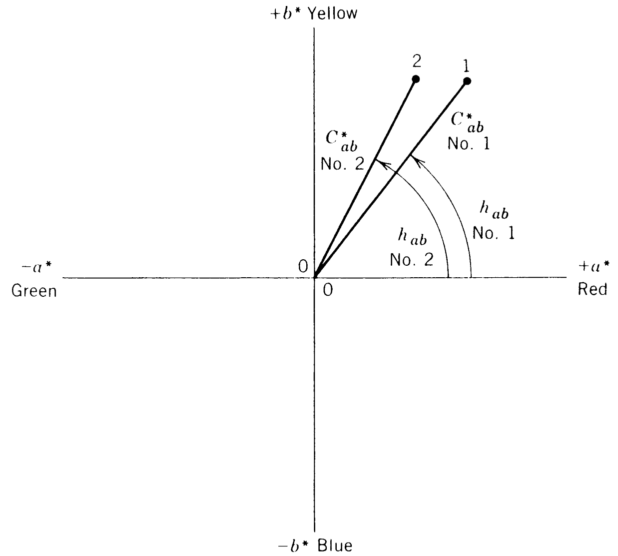
7.2.1 The purchaser and the seller shall agree on color tolerances with respect to a previously selected standard and on the color scales in which they are expressed. Selection of the magnitude and direction of color tolerances shall be based on careful consideration of all applicable factors. For example, 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. 15.2 and Practice E 308.

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 Test Method D 2244 and Method E 308. 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 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 Test Methods D 2244 and Practice E 308 for equations and definitions. The CIELAB 1976 hue-angle and chroma are illustrated in Fig. 1.

[3] Available from the USNC-CIE Publications Office, % Mr. Thomas Lemons, TLA Lighting Consultants, 7 Pond St., Salem, MA 01970–4819.



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

7.2.4 The CIELAB opponent-color red-green coordinate *a**, and the yellow-blue coordinate *b** are defined in Test Method D 2244 and Practice E 308.

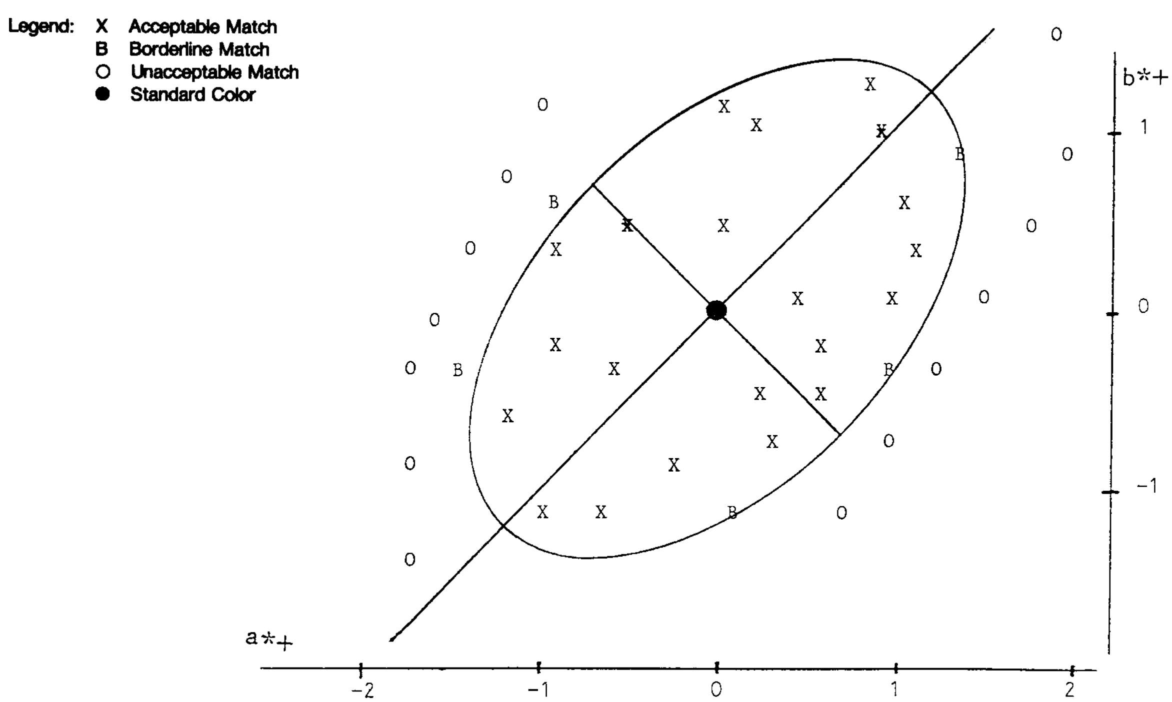
7.2.5 *Graphical Interpretation of Historical Data*:

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.

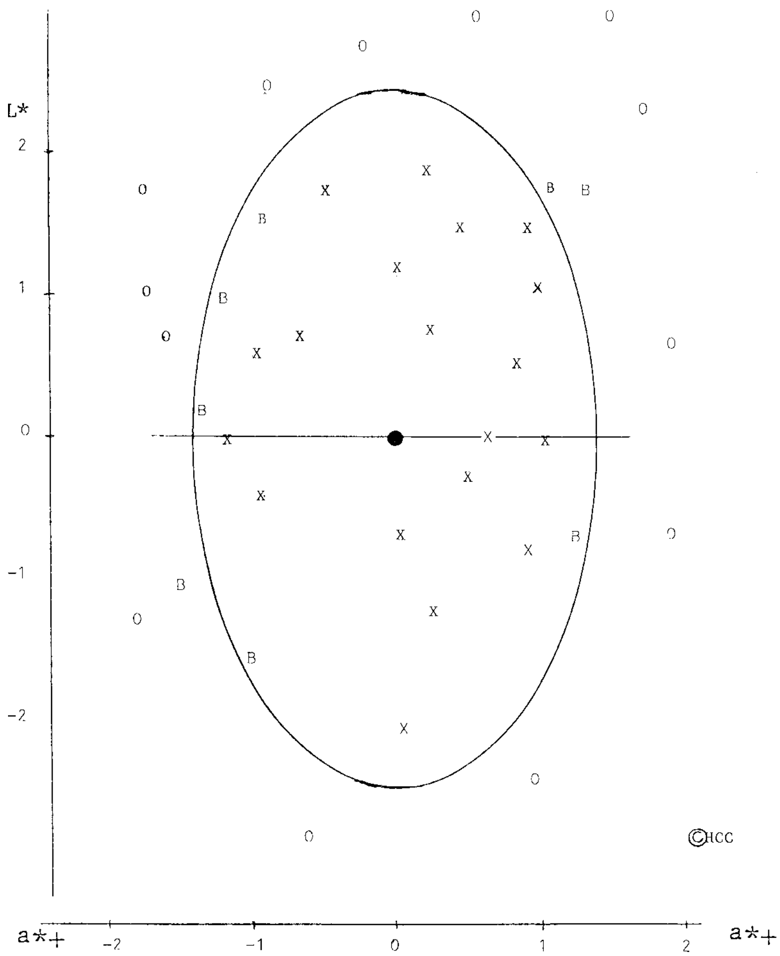
7.2.5.4 The scales on Fig. 2(*a*) and Fig. 3(*b*) are changed from absolute values (*L**, *a**, *b**) into color difference values (ΔL^*, Δa^*, Δb^*) as shown .



(*a*) Chromaticity Tolerances

NOTE 1—The standard color is at the 0,0 point and the tolerance ellipses define permissible differences from it. Fig. 2(a) shows chromaticity tolerances in a* and b*; Fig. 3(b) shows lightness tolerances in L*, with a* data also shown.

FIG. 2 Plots of Instrumental Results on Color Specimens Along With Their Visual Acceptability Ratings



(*b*) Lightness Tolerances

NOTE 1—The standard color is at the 0,0 point and the tolerance ellipses define permissible differences from it. Fig. 2(a) shows chromaticity tolerances in a* and b*; Fig. 3(b) shows lightness tolerances in L*, with a* data also shown.

FIG. 3 Plots of Instrumental Results on Color Specimens Along With Their Visual Acceptability Ratings

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 (ΔE) 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 D 1729. 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 D 523) 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 from it. For example, for a very high gloss requirement, one might specify "80 units minimum.'' Similarly, for a very low gloss the specification might read "3 units maximum,'' with the measurement geometry being indicated in each case.

7.3.4 If tolerance standards are prepared to show visually the upper and lower limits for gloss, they should preferably be of the same color and material as the standard. However, commercially available gloss scales showing a large number of samples of the same color, in a variety of glosses, can be used. Compare the specimen with the visual standards under the viewing conditions described in Practice D 1729.

7.4 *Tolerance Classification*:

7.4.1 Tolerances should be set by agreement between the purchaser and the seller. However, at times the purchaser is either unknown (as in the case of consumer products) or unequipped to determine tolerances based on instrumental measurement. In such cases, the seller shall set tolerances unilaterally, based upon such considerations as the economics of the production process, known buyer requirements, and similar products.

7.4.2 While a CIELAB color difference applicable to one region of color space may not be transferable to other regions of color space, it is a useful basis for setting tighter or more liberal tolerances in the original color region. Thus, if a lightness tolerance of ±2.0 ($\Delta L^* = \pm 2.0$) units was selected as intermediate, around a specific color, one might then choose ±1.5 units in L^* as a tight tolerance, or ±2.5 units as a more liberal tolerance. These numbers are intended only as examples, and should not be considered as recommendations.

7.4.3 Keep in mind that the total color difference is a combination of those allowed for each of the three attributes, so that a small incremental increase in each attribute results in a substantial increase in total tolerance volume. (A 10 % increase in each attribute equals a 33 % increase in volume). Conversely, one must realize that some tolerance is necessary; exact color matches are seldom seen. A modest reduction in tolerance can cause an important increase in difficulty of matching, with a corresponding increase in cost.

7.4.4 Liberal tolerances are used, typically, when the product is very small, the material used is difficult to color accurately or the products exhibit large variations in other appearance attributes (texture or gloss) which tend to mask color differences or are seen only from a distance. Examples are color-coded electronic parts and wires, colored masonry, and porcelain insulators on poles. Tight tolerances are used for finishes on consumer products, such as, automobiles and major appliances. Tentative tolerances can be based on the guidelines given in 7.4.5 and 7.4.6.

7.4.5 *Color Tolerances*:

7.4.5.1 Symmetrical color tolerances around a standard color can be specified in terms of the overall color difference (ΔE) in CIELAB units (see Test Method D 2244 and Practice E 308), as shown in the following example. These are examples only, not recommendations.

Tolerance Designation	CIELAB Color Difference, ΔE
A	1.0
B	2.0
C	3.0

In this example the *A* tolerance is the tightest, while the *C* tolerance is the most liberal.

7.4.5.2 The most frequently encountered industrial tolerances provide for different limits for the visual color attributes of hue, lightness, and saturation or chroma. Asymmetrical color tolerances around a standard color represent the usual case, because there are important differences between equally perceptible and equally acceptable differences. While it is beyond the scope of this practice to discuss these differentials in detail, it can be stated that the usual tolerance specification requires hue tolerances to be relatively tighter, and lightness tolerances to be less tight, with saturation or chroma tolerances between these. Variations from this exist.

7.4.5.3 Tolerances are preferably set experimentally by classifying specimens visually against a visual standard, then measuring the specimens and standard and plotting the values on a CIELAB Δa^*, Δb^* constant-lightness (L^*) plane. The expected result is that visually acceptable specimens will be grouped about the standard (plotted as $\Delta a^* = \Delta b^* = 0$), so that a line enclosing them forms a figure on the $\Delta a^* \Delta b^*$ plane.

7.4.5.4 A lightness tolerance ΔL^* must also be established. A rough approximation is the lightness difference ΔL^* for colors that match the standard in hue and saturation. It is however, more accurate to plot differences ΔL^* and either Δa^* or Δb^*, whichever results vary more. Again, it is expected that a figure can be drawn enclosing the data range for acceptable specimens.

7.4.5.5 Only specimens that fall within the defined limits are acceptable. If both figures can be approximated by circles of similar radii, it may be appropriate to specify a maximum total color difference ΔE as the tolerance.

7.4.6 *Gloss Tolerances*:

7.4.6.1 The usual requirement is that the gloss tolerances above and below the gloss of the standard be visually equal. However, research[4] has shown that even for small gloss differences, equal instrumental gloss values do not necessarily represent equal visual gloss differences. Therefore, it is necessary to specify the high and low gloss tolerances separately.

7.4.6.2 It has been found useful to specify tolerances around a standard gloss in terms of a limiting value (LV). The LV should be experimentally determined so that LV/3 represents the least discernible gloss difference. Tolerances shall be specified in the same Test Method D 523 gloss scale as used to specify the gloss of the standard. The permissible specular gloss tolerances (ΔG) can then be as follows:

Tolerance Designation	Gloss Tolerance, ΔG	
	High	Low
LV/3	+ 4	−6
2LV/3	+ 8	−12
LV	+12	−18

This example is for illustration purposes only. The values

[4] Billmeyer, F. W., Jr., and O'Donnell, F. X. D., *Color Research and Application*, Vol 12, 1987, p. 315.

vary with geometry and with their position on the gloss scale.

7.4.6.3 Other important aspects of gloss, such as distinctness of reflected image, reflection haze, and texture, are not covered by this simple classification scheme.

8. Light Sources

8.1 Because the quality and quantity of illumination is important in visual color difference evaluations, exercise control of the light source. See Practice D 1729.

9. Evaluation of Compliance with Tolerance Limits

9.1 Evaluate compliance either instrumentally or visually.

9.2 For instrumental measurement and calculation of color, Practices E 1164 and E 308 may be applied where spectrophotometers are used. Procedures for measuring and calculating color differences may be found in Test Method D 2244.

9.3 For visual color difference evaluation, Practice D 1729 may be applied.

9.4 For instrumental gloss difference, use Test Method D 523. For visual gloss difference, use Method D 4449.

10. Report

10.1 When a report of evaluation of conformance is required, report the following information:

10.1.1 Designation of standards and specimens,

10.1.2 Color measurement values for the standards and specimens,

10.1.3 Report the measurement conditions (specular included or excluded) and the CIE color-matching functions and illuminant for which the data are computed,

10.1.4 Observed direction and magnitude of color departure from the color standard,

10.1.5 Color instrument manufacturer, model number, and serial number,

10.1.6 Time and date of color measurement,

10.1.7 Time and date of last color instrument calibration,

10.1.8 Designation of calibration standard for color measurement,

10.1.9 Gloss measurements of standard and specimens,

10.1.10 Observed texture differences between standard and specimens,

10.1.11 If visual tolerance standards are employed, the illuminating and viewing conditions used,

10.1.12 Identity of observer or instrument operator by name or code designation,

10.1.13 Identity of color and gloss measuring instruments,

10.1.14 Identity of color space and color difference formula used,

10.1.15 Gloss instrument manufacturer model number and serial number,

10.1.16 Time and date of the gloss measurement,

10.1.17 Time and date of last calibration of gloss meter, and

10.1.18 Designation of calibration standard for gloss measurement.

10.2 Data may be reported in electronic format, see Practice E 1708.

11. Precision and Bias

11.1 The precision of the instrumental measurements is stated in Practice E 1164 and Test Methods D 523, D 2244, E 1331, and E 1349. For both color and gloss measurements, it is important that related measurements be made in consecutive order by the same operator and on the same instrument for maximum precision.

11.2 Much of the precision attainable in visual evaluation depends upon the skill and experience of the observer. Precision is also related to the amount of gloss and color difference portrayed by the physical specimens representing standards and tolerances; the closer these specimens are to each other, the higher the precision.

11.3 *Bias*—There is no definition of an agreed upon reference standard, hence, no basis for defining bias.

12. Keywords

12.1 color; colorcurve system; color difference; color tolerances; gloss; glossmeter; gloss tolerances; Munsell system; Optical Society of America Uniform Color Scales system; spectrophotometer