Designation: E 805 – 01a

Standard Practice for Identification of Instrumental Methods of Color or Color-Difference Measurement of Materials[1]

This standard is issued under the fixed designation E 805; 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 practice covers the documentation of instrumental measurement of color or color difference for current communication or for future reference. The practice is applicable to instrumental measurements of materials where color is seen by reflected, transmitted or emitted light and any combinations of one or more of these processes. The practice is recommended for documentation of methodology in interlaboratory color-measurement programs.

1.2 An adequate identification of an instrumental measure of color or color-difference consists of five parts:

1.2.1 Nature and source of available samples and the form of specimens actually measured,

1.2.2 Instrumental conditions of measurement, including instrument geometrical and spectral conditions of measurement,

1.2.3 Standards used,

1.2.4 Data acquisition procedure, and

1.2.5 Color scales employed.

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 whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

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

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

D 5386 Test Method for Color of Liquids Using Tristimulus Colorimetry[3]

D 6166 Test Method for Color of Naval Stores and Related Products (Instrumental Determination of Gardner Color)[4]

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

E 259 Practice for Preparation of Pressed Powder White Reflectance Factor Transfer Standards for Hemispherical and Bi-Directional Geometries[2]

E 284 Terminology of Appearance[2]

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

E 313 Practice for Calculating Yellowness and Whiteness Indices from Instrumentally Measured Color Coordinates[2]

E 991 Practice for Color Measurement of Fluorescent Specimens[2]

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

E 1247 Test Method for Identifying Fluorescence in Object-Color Specimens by Spectrophotometry[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 Measurement by Use of Multiple Measurements[2]

E 1347 Test Method for Color and Color- Difference Measurement by Tristimulus (Filter) Colorimetry[2]

E 1348 Test Method for Transmittance and Color by Spectrophotometry Using Hemispherical Geometry[2]

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

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

E 1767 Practice for Specifying the Geometry of Observations and Measurements to Characterize the Appearance of Materials[2]

E 2152 Practice for Computing the Colors of Fluorescent Objects from Bispectral Photometric Data[2]

E 2153 Practice for Obtaining Bispectral Photometric Data for Evaluation of Fluorescent Color[2]

2.2 *CIE Document:*

CIE Publication 51 A Method for Assessing the Quality of

[1] This practice is under the jurisdiction of ASTM Committee E12 on Color and Appearance and is the direct responsibility of Subcommittee E12.04 on Color and Appearance Analysis.

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

[3] *Annual Book of ASTM Standards,* Vol 06.04.

[4] *Annual Book of ASTM Standards,* Vol 06.03.

Daylight Simulators for Colorimetry[5]

3. Terminology

3.1 Definitions of terms in Terminology E 284 are applicable to this practice.

4. Significance and Use

4.1 The options available in methods for the measurement of color or color-difference are many. These involve choices in: (*1*) specimens, (*2*) geometric and spectral properties of instruments, (*3*) calibration bases for standards used, (*4*) procedure for sample handling including conditioning, (*5*) procedure for taking data, and (*6*) equations for converting instrumental data to final results. Once the measurements have been made, it is essential to document what has been done for the purpose of inter-laboratory comparisons, or for future use. A sample form is provided in Fig. 1 to record identifying information applicable to any instrumental method of color or color-difference measurement.

4.2 Refer to Guide E 179, Practices E 991, E 1164, E 1345, E 1708, E 1767, and E 2152 and Test Methods D 5386, D 6166, E 1247, E 1331, E 1347, E 1348, and E 1349 for specific details of measurements.

5. Identification of Samples and Specimens

5.1 *Identification of Samples and Specimens*:

5.1.1 Identify samples by material and form, together with markings or document identification.

5.1.2 Mark each specimen with a serial number or letter, and other identifying markings.

5.2 *Description of Specimens*—For specific forms of specimens, additional identification shall be included:

[5] Available from USNC/CIE Publications Office, TLA-Lighting Consultants, Inc., 7 Pond St., Salem, MA 01970–4819.

(1) Instrumental Method for Measurements of: □ Color □ Color difference of :
_____
(2) Color Scales Used (Section 9): _____
_____
(3) Specimen Description (Section 5)
(a) Form: _____
(b) Additional information (see 5.3) _____
□ thickness (number of layers) □ single layer backed by □ powder (note packing pressure) □ paste □ liquid □ film drawdown (specify thickness and backing material).
(c) Special Considerations:
Sensitivity to Environmental Conditions: temperature:_____,
humidity_____
(d) Specimen Directionality: Specify orientation and rotation _____
(e) Specimen Conditioning: _____

(4) Instrument Description (Section 6)
□ Spectrophotometer □ Tristimulus Colorimeter
Make and model _____
(a) Measurement Mode _____
(b) Geometry: Influx and Efflux Geometry _____
Specular Component included or excluded? _____
Light Trap (if applicable) size, shape, and position _____
Size and Shape of aperture _____
Cover glass at specimen window ___Yes ___ No
Method of Correction _____
(c) Spectral: Lamp _____Filters and elements used _____
Detector _____ Modified by filters and elements _____
(5) Material Standard Used: _____
Date of preparation or calibration:
(6) Reduction of Data: _____
(a) Tristimulus Integration: □ Filter □ Computed from spectral data taken every _____nm over range _____nm to _____nm, with spectral bandwidth _____nm bandpass correction _____E308 Table 5 _____E308 Table 6
(b) Color Difference Equation and Parameters used _____

FIG. 1 Sample Report Form

5.2.1 Solid sheet or web, specify thickness and backing material.

5.2.2 Powder or granular substance (packed or poured); if placed behind window, state material and thickness.

5.2.3 Fiber or yarn, describe form, type of transparent specimen window (if used), pressure on backing plate.

5.2.4 Paste (if placed behind window), state material and thickness.

5.2.5 Liquid (if observed through window), state window material and path length.

5.2.6 Film drawdown, specify film thickness and background.

5.2.7 For gonioapparent materials, identify the direction of illumination and viewing relative to the specimen.

5.2.8 Conditioning, if any.

NOTE 1—When specimens are measured behind glass or other material, specify thickness and material type. In addition, specify the method used for data correction.

6. Identification of Instrument

6.1 Sufficient description of the instrumentation shall be provided to enable one of ordinary skill in the art to reproduce the measurement. The make and model number of the instrument used shall be reported.

6.2 For interlaboratory comparisons, long-term studies, and measurements used to document conformance to a color specification, the physical properties of the instrument shall be identified by it, as follows:

6.2.1 *Mode of Measurement*—such as transmittance factor, reflectance factor, total radiance factor, etc.

6.2.2 *Geometric Properties of Instrument*—following Practice E 1767 the influx geometry and eflux geometry including aperture angles and sizes.

6.2.3 *Specular Component*—where hemispherical illumination or view is employed, or both, but the specular light is excluded by means of a light trap, designate by the words "specular excluded." If a light trap is used, details of its size, shape, and position should be given. Conversely, when the specular component of light is included, specify "specular included."

6.2.4 Give aperture size and shape through which specimens are exposed for measurement and any glass or plastic intervening window(s). Also, note the area of specimen actually illuminated or viewed.

NOTE 2—Measurements of some type of specimens (for example, pearlescent, metal flake or retroreflective materials) may require different and multiple geometries. In these cases, specify the details of all the geometries used.

6.3 *Spectral Properties of Instrument*:

6.3.1 Identify spectral power distribution illuminating the specimen and spectral response of receiver system. The spectral characteristics of the instrument will be affected by the spectral transmittance of filters or other wavelength selective devices in either the illuminating or viewing beams. For photoluminescent specimens, the spectral distribution should be reported in terms of its conformance to a standard illuminant as outlined in CIE Publication 51 and Practice E 991. For non-photoluminescent specimens, the spectral distribution illuminating the specimen can be reported in terms of its conformance to a standard illuminant or its correlated color temperature.

6.3.2 In the absence of a detailed spectral power distribution as in 6.3.1, identify illumination with other terms that indicate the general spectral content, for example: (*1*) CIE Source *A* (gas-filled tungsten lamp at 2856 K correlated color temperature), (*2*) CIE Source *C*, (*3*) simulated daylight *D65* **(1)**[6], (*4*) simulated daylight *D65* **(1)** with pulsed xenon lamp with uv control, (*5*) light emitting diodes (LEDs), etc.

6.3.3 Identify the type and number of dispersive elements on the instrument. Also indicate the spectral bandwidth of the monochromator or identify it as variable if it is.

7. Identification of Standards Used

7.1 *Reference Standard*—The reference white reflectance standard should be the perfect reflecting diffuser. Practice E 259 describes the preparation of reference white reflectance standards.

7.2 *Instrument Standard*—Identify instrument working standard used.

7.3 *Product Standard*—Identify the product standard if used in the measurements.

8. Data

8.1 Identify how many readings were made on each specimen and standard to obtain the test result, indicate if the readings are averaged, and indicate whether or not the specimen was changed in position, rotated, or otherwise handled during the measurement. See Practice E 1345.

8.2 It is important not to imply false precision or accuracy. Therefore, report all data with the appropriate number of significant figures.

8.3 Some specimens (particularly textiles, pulp and paper) are sensitive to variations in temperature (thermochromism) and humidity (hygrochromism). In those cases, these conditions should be recorded.

8.4 In addition, some colorants exhibit reversible color changes (photochromism) upon exposure to strong sources of illumination. In those cases, when using instruments with direct illumination by strong broad-band sources, the time of exposure to the instrument's measurement port shall be kept to a minimum, and time shall be recorded.

9. Color Scales

9.1 *Illuminant*—For non-photoluminescent specimens, the illuminant used in the computation of color coordinates from spectral data may have a different spectral power distribution from that of the instrument source (see 6.2.4), the former being normally one of the CIE illuminants (*A, C*, or *D65*) identified in Table 1.1.1 of Ref **(1)** and in Practice E 308. In the case of photoluminescent specimens being measured on instruments with polychromatic illumination and a dispersing element between the specimen and detector, the spectral distribution of the illuminant used for the computation of color coordinates from spectral data shall be the same as that of the instrument illuminator.

[6] The boldface numbers in parentheses refer to the list of references at the end of this practice.

9.2 *Standard Observer*—Identify Standard Observer as CIE 1931 (2°) or CIE 1964 (10°). (See Ref **(2)**, Tables 2.1 and 2.2, respectively, and Practice E 308 or E 2153 for photoluminescent specimens.)

9.3 Identify the wavelength interval used for tristimulus integration of spectral data and the origin of the tristimulus weighting factors used (see Practice E 308 or E 2153 for photoluminescent specimens.).

9.4 *Color Scales*—Identify color scales as either:

9.4.1 Trichromatic Color Scales including:

9.4.1.1 *Tristimulus Values (X, Y, Z)* (Ref **(1)** and Practice E 308 or E 2153 for photoluminescent specimens.)

9.4.1.2 *Tristimulus Value Y and chromaticity coordinates x and y (Ref* **(1)** *and Practice E 308).*

9.4.1.3 *Opponent-Color Scales*. (Reference standard white color remains at $L = 100$, $a = 0$, $b = 0$, regardless of the illuminant, but color values for other specimens change with illuminant.)

(a) CIE 1976 L*, a*, b* (CIELAB) (Ref **(1)**, Practice E 308 and Test Method D 2244).

(b) Hunter L_H, a_H, b_H (1958) (Ref **(2)** and Test Method D 2244).

NOTE 3—Other scales occasionally used are:
(*a*) *Hunter L′, a′, b′* scales for clear liquids and bare metals **(2)**.
(*b*) *CIE 1976 L*, u*, v* (CIELUV)* **(1)**.
(*c*) *Munsell Color Notation* by visual or instrumental means (Practice D 1535).

9.4.2 The following scales used exclusively for color difference:

9.4.2.1 *Friele-MacAdam-Chickering* (FMC-2) (Ref **(3)** and Test Method D 2244),

9.4.2.2 *CMC* (Ref **(4)**), and

9.4.2.3 *CIE94* (Ref **(5)**).

NOTE 4—State the color difference equation used and all the values for all the variable parameters in the equation.

9.4.3 One-dimensional Color Scales including:

9.4.3.1 *Gardner Color Scale (Test Method D 6166*).

9.4.3.2 *Platinum Cobalt Color Scale (Test Method D 5386*).

NOTE 5—Some one-dimensional color scales are calculated from the tristimulus values measured, see Practice E 313.

10. Report Form

10.1 A sample report form is given in Fig. 1.

11. Keywords

11.1 color; color difference; colorimetry; data format; documentation; instrumental measurement—color/light; reflectance and reflectivity; spectrophotometry; transmittance and reflectance

REFERENCES

(**1**) CIE Publication No. 15.2, *Colorimetry 2d ed.*, Central Bureau of the CIE, Vienna, 1986, available from USNC-CIE Publications Office, c/o TLA Lighting Consultants, Inc., 72 Loring Avenue, Salem, MA 01970.

(**2**) Hunter, R. S., and Harold, R. W., *The Measurement of Appearance*, 2d ed., John Wiley and Sons, Inc., New York, N. Y., 1987.

(**3**) Chickering, K. D., "FMC Color-Difference Formulas' Clarification Concerning Usage," *Journal of the Optical Society of America*, Vol 61, 1971, pp. 118–122.

(**4**) McDonald, R., "Acceptability and Perceptibility Decisions Using the CMC Colour Difference Formula," *Textile Chemist and Colorists* , Vol 20, No. 6, 1988, pp. 31–37, and Errata, Vol. 20, No. 8, 1998, p. 10.

(**5**) CIE Publiction No. 116–1995, Industrial Colour-Difference Evaluation, Vienna, 1995, available from UNNC-CIE Publications Office, c/o TLA Lighting Consultants, Inc., 72 Loring Avenue, Salem, MA 01970.