Designation: C 1649 – 08

Standard Practice for Instrumental Transmittance Measurement of Color for Flat Glass, Coated and Uncoated[1]

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1. Scope

1.1 This practice provides guidelines for the instrumental transmittance measurement of the color of coated and uncoated transparent glass. See Terminology E 284.

1.2 The practice specifically excludes fluorescent and iridescent samples.

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]

D 2244 Practice for Calculation of Color Tolerances and Color Differences from Instrumentally Measured Color Coordinates

E 284 Terminology of Appearance

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

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

E 1164 Practice for Obtaining Spectrometric Data for Object-Color Evaluation

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

2.2 *CIE Standard:*[3]

CIE 15:2004 Colorimetry

3. Summary of Practice

3.1 The color of transparent glass is measured in the total transmittance mode on a CIE-conforming diffuse instrument. (See Guide E 179 and Test Method E 1348.) The glass color is expressed in CIE tristimulus values based on spectral transmittance measurements over the full CIE spectral range of 350 – 780 nm with a maximum 10-nm band pass. (See CIE 15:2004 and Practice E 308.) For color measurement, use of a truncated spectral range of 400 – 700 nm is acceptable. (See CIE 15:2004.) Further information on the UV absorbing characteristics of the glass or glass coating, or both, may be determined by examining the spectral data in the 350 - 400 nm range. If the instrument allows spectral measurement above 700 nm, useful information on the IR transmittance characteristics of the glass or glass coating may also be determined. If coatings are present, they are assumed to reflect and partially transmit light.

4. Significance and Use

4.1 Color measurement quantifies the transmitted color for glass. The user defines an acceptable range of color appropriate for the end use. A typical quality concern for transmittance color measurement of glass products is verification of lot-to-lot color consistency for end-user acceptance.

4.2 If the transmitted color of a glass product is consistent from lot-to-lot and within agreed supplier-buyer acceptance criteria, the product's color is expected to be consistent and acceptable for end-use.

5. Apparatus

5.1 For color measurements, a CIE-conforming diffuse sphere instrument capable of making transmission measurements in the total transmittance mode is required.

5.2 In addition, a device for mounting the glass sample flush at the transmission port is required.

5.3 The instrument and associated color quality software/firmware shall be capable of converting measured spectral transmittance data to CIE L*, a* b*; Hunter L, a, b; or Y, *x*, *y* values calculated for CIE illuminant D65 and the CIE 1964 10 degree standard observer. (See Practice E 1164.) Any of those mappings will serve as a full numerical color descriptor. (See Practice E 308.) CIE Y transmittance can also serve as an

[1] This practice is under the jurisdiction of ASTM Committee C14 on Glass and Glass Products and is the direct responsibility of Subcommittee C14.11 on Optical Properties.

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[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.

[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.

over-all indicator of transmission. For other illuminant/observer combinations, see Practice E 308 for guidance in use. For effective communication of color values between sites, color measurements must be expressed in the same color scale, illuminant, and standard observer.

5.4 The expression of a color difference in terms of rectangular, polar, or elliptical color differences shall serve to quantify the difference between target product color and lot color. See Practice D 2244.

6. Materials

6.1 Samples are uncoated or partially reflective coated transparent glass with defined substrate, coating compositions, and thicknesses.

7. Hazards

7.1 Consult Material Safety Data Sheets, and local regulations for all materials used in this test method.

8. Color Instrument Calibration and Set up Procedure

8.1 Prepare instrument for operation by following the instrument manufacturer's instructions.

8.2 Use instrument standardization to set the color instrument to the assigned values for the transmission standards supplied by the manufacturer or other suitable reference material.

8.3 To verify consistency over time in the performance of the color instrument, read and record color values of an instrument diagnostic standard (such as a color standard or didymium filter) at regular intervals. Care should be taken to visually inspect these standards for any significant visual abrasion and replace it if warranted.

8.4 As the stability characteristics of coated and un-coated glass are generally good, the user may, at their option, read and record color values for a coated glass sample to document consistency in the measurement method over time. Care should be taken to visually inspect the coated glass sample for any significant visual abrasion and replace it if warranted.

9. Measurement Method

9.1 Place the glass sample at the transmittance measurement port.

9.2 At a minimum, scan the sample over the range of wavelengths required for measurement. Two scans with a 90º rotation of the samples are preferable. If practical and possible, scan at least one other area of the sample as well.

9.3 *Correction for reflection loss of uncoated glass (optional)*:

9.3.1 Because of historical practices, some industries apply a correction for reflection loss to the transmittance and others do not. As a result, specifications based on transmitted color measurements of glass may differ from industry segment to industry segment. Typically, the architectural glass industry does not use the correction, but the container glass industry does. The user of this document is advised to ascertain industry segment practices before deciding to apply or not apply the reflection correction.

9.3.2 When required by the respective glass industry, the correction is (See Appendix X1.):

$$T_{corrected} = k_T T_{measured} \quad (1)$$

Where:

$$k_T = \left[\frac{2 n_{air} n_{glass}}{(n_{air}^2 + n_{glass}^2)} \right]$$

10. Report

10.1 Report the following information:

10.1.1 Sample identification,

10.1.2 Color scale, illuminant, standard observer, instrument geometry and transmittance mode,

10.1.3 Sample preparation and presentation conditions, including number and pattern of readings averaged, and

10.1.4 Average color or color difference values, or both, relative to a product standard color to nearest hundredth of a unit.

NOTE 1—Sample preparation includes items of glass description such as the type and form (single layer versus multi-layer IG; laminated, pattern and thickness), as well as the surface preparation technique (cleaning method prior to measurement, polishing).

NOTE 2—Sample presentation includes any side or positional information; the area of view measured in each reading; the number of readings averaged and if readings were taken in a specific pattern.

10.1.5 The CIE Y value may also be reported to nearest hundredths of a unit, as an instrumental measurement of the overall transmittance of the transparent glass.

11. Keywords

11.1 coatings; glass; transmittance

APPENDIX

X1. REFLECTION LOSS CALCULATIONS

X1.1 Reflection loss, R at the sample surface is determined by the refractive indices:

$$R' = \left(\frac{n_{air} - n_{glass}}{n_{air} + n_{glass}}\right)^2 \quad \text{(X1.1)}$$

X1.2 Expressed as a correction factor for transmission:

$$k'_T = \frac{4n_{air}\, n_{glass}}{(n_{air} + n_{glass})^2} = 1 - R' \quad \text{(X1.2)}$$

X1.3 Because the glass sample has two reflecting surfaces, total reflection loss is:

$$R = \frac{2R'}{1 + R'} \quad \text{(X1.3)}$$

X1.4 As a result, the correction factor for transmission becomes:

$$k_T = \frac{2n_{air}\, n_{glass}}{n_{air}^2 + n_{air}^2} = 1 - R \quad \text{(X1.4)}$$

X1.5 Approximate refractive indices (relative to air) for some commercial glasses:[4]

Containers and windows (soda-lime silica)	1.52
Laboratory ware (borosilicate)	1.47
Other borosilicate	1.48
Fiber glass (E-glass)	1.55
High lead	1.54
Fused silica	1.45

[4] Handbook of Glass Properties, Bansal and Doremus, Editors, Chapters 1 and 2, Academic Press, 1986.