



Designation: E991 – 21

Standard Practice for Color Measurement of Fluorescent Specimens Using the One-Monochromator Method¹

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INTRODUCTION

The fundamental procedure for evaluating the color of a fluorescent object is to obtain spectrometric data for specified illuminating and viewing conditions, and then use this data to compute tristimulus values based on an International Commission on Illumination (CIE) standard observer and a CIE standard illuminant. For a fluorescent object-color specimen, the spectral radiance factors used to calculate tristimulus values are made up of two components — an ordinary reflectance factor and a fluorescence factor ($\beta = \beta_S + \beta_F$). The magnitude of the fluorescent radiance factors, and consequently the measured total radiance factors and derived color values, vary directly with the spectral distribution of the instrument source illuminating the specimen. Consequently, the colorimetry of fluorescent object-color specimens requires greater control of the measurement parameters in order to obtain precise spectrometric and colorimetric data. In order to obtain repeatable and reproducible color values for fluorescent objects it is necessary that the illumination at the specimen surface closely duplicate the standard illuminant used in the color calculations. The considerations involved and the procedures used to obtain spectrometric data and compute colorimetric values for fluorescent specimens using a one-monochromator spectrometer are contained in this practice.

1. Scope

1.1 This practice applies to the instrumental color measurement of fluorescent specimens excited by near ultraviolet and visible radiation that results in fluorescent emission within the visible range. It is not intended for other types of photoluminescent materials such as phosphorescent, chemiluminescent, or electroluminescent, nor is this practice intended for the measurement of the fluorescent properties for chemical analysis.

1.2 This practice describes the instrumental measurement requirements, calibration procedures, and material standards needed for the color measurement of fluorescent specimens when illuminated by simulated daylight approximating CIE Standard Illuminant D65 (CIE D65).

1.3 This practice is limited in scope to colorimetric spectrometers providing continuous broadband polychromatic illumination of the specimen and employing only a viewing monochromator for analyzing the radiation leaving the specimen.

1.4 This practice can be used for calculating total tristimulus values and total chromaticity coordinates for fluorescent colors in the CIE Color System for either the CIE 1931 Standard Colorimetric Observer or the CIE 1964 Supplementary Standard Colorimetric Observer.

1.5 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*²

¹ This practice is under the jurisdiction of ASTM Committee E12 on Color and Appearance and is the direct responsibility of Subcommittee E12.05 on Fluorescence.

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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.

- D985** Test Method for Brightness of Pulp, Paper, and Paperboard (Directional Reflectance at 457 nm) (Withdrawn 2010)³
- D2244** Practice for Calculation of Color Tolerances and Color Differences from Instrumentally Measured Color Coordinates
- E179** Guide for Selection of Geometric Conditions for Measurement of Reflection and Transmission Properties of Materials
- E284** Terminology of Appearance
- E308** Practice for Computing the Colors of Objects by Using the CIE System
- E691** Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method
- E1164** Practice for Obtaining Spectrometric Data for Object-Color Evaluation
- E1247** Practice for Detecting Fluorescence in Object-Color Specimens by Spectrophotometry
- E1345** Practice for Reducing the Effect of Variability of Color Measurement by Use of Multiple Measurements
- E1767** Practice for Specifying the Geometries of Observation and Measurement to Characterize the Appearance of Materials
- E2152** Practice for Computing the Colors of Fluorescent Objects from Bispectral Photometric Data
- E2153** Practice for Obtaining Bispectral Photometric Data for Evaluation of Fluorescent Color
- E2214** Practice for Specifying and Verifying the Performance of Color-Measuring Instruments
- E2301** Test Method for Daytime Colorimetric Properties of Fluorescent Retroreflective Sheeting and Marking Materials for High Visibility Traffic Control and Personal Safety Applications Using 45°:Normal Geometry
- 2.2 *CIE Publications and Standards*:⁴
- CIE Publication CIE15:2018** Colorimetry, 4th Edition
- CIE Publication No. 51.2** A Method for Assessing the Quality of Daylight Simulators for Colorimetry
- CIE Publication No. 76** Intercomparison on Measurement of (Total) Spectral Radiance Factor of Luminescent Specimens
- 2.3 *TAPPI Standards*:⁵
- T 571om-03** Diffuse brightness of paper and paperboard (d/0)
- 2.4 *ISO Standards*:⁶
- ISO 11664-2:2007(E)/CIE S14/E:2006** CIE Standard Illuminants for Colorimetry
- ISO 11475:2017** Paper and board — Determination of CIE whiteness, D65/10 degrees (outdoor daylight)
- ISO 2469:2014** Paper, board and pulps — Measurement of diffuse reflectance factor

3. Terminology

3.1 *Definitions*—The definitions contained in Guide **E179**, Terminology **E284**, Practice **E1164**, Practice **E1767**, and Practice **E2153** are applicable to this practice.

3.2 *Definitions of Terms Specific to This Standard*:

3.2.1 *fluorescence, n*—this standard uses the term “fluorescence” as a general term, including both true fluorescence (with a luminescent decay time of less than 10^{-8} s) and phosphorescence with a delay time short enough to be indistinguishable from fluorescence for the purpose of colorimetry (see Practice **E2153**).

3.2.2 *fluorescent white, n*—white and near white specimens containing fluorescent whitening agents.

3.2.3 *near ultraviolet radiation, n*—optical radiation within the wavelength range from 300 to 380 nm.

3.2.4 *referee procedure, n*—a mutually agree upon testing procedure utilized to resolve disputes over instrumentally tested material properties that are expressed numerically.

4. Summary of Practice

4.1 This practice applies to the instrumental color measurement of fluorescent specimens that are excited by near ultraviolet and visible radiation and emit within the visible range. For methods to determine whether specimens exhibit fluorescence see Practice **E1247**. This practice provides procedures for measuring the total spectral radiance factors of fluorescent object-color specimens under simulated daylight approximating CIE D65 using a one-monochromator colorimetric spectrometer and calculating total tristimulus values (XYZ) and total chromaticity coordinates (x,y) in the CIE Color System for either the CIE 1931 Standard Colorimetric Observer or the CIE 1964 Supplementary Standard Colorimetric Observer (see CIE Publication 15).

4.2 The instrument source should provide broadband illumination of the specimen from 300 to 780 nm and the spectral distribution of the illumination on the specimen should closely duplicate CIE D65 (see ISO 11664-2:2007(E) /CIE S14/E:2006). When highest measurement precision and reproducibility are required, the wavelength range should extend from 300 to 830 nm. Precise colorimetry of ultraviolet-activated fluorescent specimens requires the instrument provide significant illumination intensity below 380 nm. For the measurement of visible-activated fluorescent specimens, which have negligible excitation below 380 nm, it is only required that the illumination on the specimen provide a close match to CIE D65 over the wavelength range 380 to 780 nm.

4.3 The colorimetric spectrometer should employ a bidirectional optical measuring system with 45:0 or 0:45 illuminating and viewing geometry. The wavelength dispersive element (monochromator) shall be positioned between the specimen and the detector system (see CIE Pub. 76). The instrument may employ annular, circumferential, or uniplanar influx or efflux optics. The use of Practice **E1767** functional notation is recommended for the complete description of instrumentation geometry including cone angles, aperture size, etc. When the

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

⁴ Available from the CIE Webshop (www.cie.co.at) or from the National Committees of the CIE (for the USA cie-usnc.org).

⁵ Available from Technical Association of the Pulp and Paper Industry (TAPPI), 15 Technology Parkway South, Norcross, GA 30092, <http://www.tappi.org>.

⁶ Available from International Organization for Standardization (ISO), ISO Central Secretariat, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, <http://www.iso.org>.