Designation: E1455 – 17 (Reapproved 2022)

Standard Practice for Obtaining Colorimetric Data from a Visual Display Unit Using Tristimulus Colorimeters[1]

This standard is issued under the fixed designation E1455; 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

This practice provides directions for correcting the results obtained with tristimulus colorimeters when measuring the tristimulus values or chromaticity coordinates of colored displays. Tristimulus colorimeters approximate the CIE color matching functions $\bar{x}(\lambda)$, $\bar{y}(\lambda)$, $\bar{z}(\lambda)$ to make these measurements. The errors generated in measuring colors on a display may be minimized using this practice.

1. Scope

1.1 This practice is intended as an aid for improving the accuracy of colorimetric measurements made with tristimulus colorimeters on visual display units, such as cathode ray tubes (CRTs) and self-luminous flat-panel displays. It explains a useful step in the analysis of colorimetric data that takes advantage of the fact that light from such displays consists of an additive mixture of three primary colored lights. However, it is not a complete specification of how such measurements should be made.

1.2 This practice is limited to display devices and colorimetric instruments that meet linearity criteria as defined in the practice. It is not concerned with effects that might cause measurement bias such as temporal or geometric differences between the instrument being optimized and the instrument used for reference.

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

1.4 *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]

E284 Terminology of Appearance

E1336 Test Method for Obtaining Colorimetric Data From a Visual Display Unit by Spectroradiometry

E1341 Practice for Obtaining Spectroradiometric Data from Radiant Sources for Colorimetry

2.2 *ISO/CIE Standard:*

ISO 11664–1:2007(E)/CIE S 014–1/E:2006 Joint Standard ISO/CIE Standard: Colorimetry Part 1 – CIE Standard Colorimetric Observers[3]

3. Terminology

3.1 *Definitions*—Unless otherwise stated, definitions of appearance terms in Terminology E284 are applicable to this practice.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *calibration, n—in reference to a tristimulus colorimeter*, the process performed outside of this practice to adjust the tristimulus colorimeter to provide the best possible results for average or predefined conditions.

3.2.2 *compatible, adj—in reference to a tristimulus colorimeter*, one so designed as to automate the procedure described in this practice.

3.2.3 *optimization, n—in reference to a tristimulus colorimeter*, the process performed pursuant to this practice to adjust the tristimulus colorimeter or to interpret its readings to provide better results when applied to a particular display device.

[1] This practice is under the jurisdiction of ASTM Committee E12 on Color and Appearance and is the direct responsibility of Subcommittee E12.06 on Display, Imaging and Imaging Colorimetry.

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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] Currently available from CIE (Commission International on Illumination), http://www.techstreet.com.

4. Summary of Practice

4.1 Tristimulus colorimeters comprised of three or four detector channels are, in general, not amenable to accurate calibration that holds for all manner of usage with different illuminated devices and objects. This is because the spectral responsivities of their detector channels do not exactly match the defined Commission Internationale de L'Éclairage (CIE) $\bar{x}(\lambda)$, $\bar{y}(\lambda)$, $\bar{z}(\lambda)$ functions. Factory or subsequent calibration reflects judgments and compromises that may not be readily apparent. Nevertheless, this practice provides guidance on how such a tristimulus colorimeter may be optimized for use with a particular video display device, providing better accuracy with that device than its more general calibration provides. An optimization matrix transforms the instrumental (measured) CIE *X, Y, Z* values into adjusted *X, Y, Z* values that are closer to the ideal. This matrix is determined by reference to a colorimeter with higher intrinsic accuracy. The method derives from the fact that the color stimulus functions from display devices are linear combinations of three primary functions and are not entirely arbitrary.

5. Significance and Use

5.1 This practice may be applied when tristimulus colorimeters are used to measure the colors produced on self-luminous video display devices such as CRTs and flat-panel displays, including electroluminescent (EL) panels, light emitting diodes (LEDs) field emission displays (FEDs), and back-lit liquid crystal displays (LCDs). This practice is not meant to be a complete description of a procedure to measure the color coordinates of a display. Rather, it provides a method for obtaining more accurate results when certain conditions are met. It may be used by any person engaged in the measurement of color on display devices who has access to the requisite equipment.

5.2 This practice defines a class of tristimulus colorimeters that may be said to be compatible with this practice.

6. Background of Practice

6.1 *Colorimetry:*

6.1.1 Color measurement instruments consist, in general, of means to measure radiometric power as transmitted through a number of bandpass filters. Most commonly, electrical devices are used to measure the filtered light. They may be used with different filters in succession, or multiple devices may be used concurrently. In instruments called spectroradiometers, the radiometric power is measured through a large number (typically 30 to 500) of narrowband filters. (Practice E1341 describes how a monochromator or polychromator (spectrograph) may be employed to filter and measure light in separate bands on the order of 1-nm wide.) In instruments called tristimulus colorimeters, the radiometric power is measured through three or four wideband filters. These filters may be constructed from dispersive elements (prisms and gratings) or from materials with selective spectral transmission or reflection. The latter may be either uniform or comprised of different patches, in a mosaic pattern, that provide the desired overall effect.

6.1.2 No matter how many filters are used, or in what manner, the goal of the measurement process is to determine tristimulus values *X, Y, Z*. For light with a color stimulus function $\Phi(\lambda)$,

$$X = k \int_{360\,nm}^{830\,nm} \Phi(\lambda)\bar{x}(\lambda)d\lambda \tag{1}$$

$$Y = k \int_{360\,nm}^{830\,nm} \Phi(\lambda)\bar{y}(\lambda)d\lambda$$

$$Z = k \int_{360\,nm}^{830\,nm} \Phi(\lambda)\bar{z}(\lambda)d\lambda$$

where:

k is 683 lm/W for emissive devices, such as displays, and $\bar{x}(\lambda)$, $\bar{y}(\lambda)$, $\bar{z}(\lambda)$ are color-matching functions. While the standard definition of *X, Y, Z* requires the use of the CIE 1931 2° color-matching functions, the mathematics described in this practice would also be applicable to any other set of color-matching functions, such as the CIE 1964 10° functions.

These equations (Eq 1) are defined by ISO in its Standard ISO 11664–1:2007(E)/CIE S 014–1E:2006 and the CIE in its publication Publ. 015(**1**).[4]

6.1.3 In practice, color measurement instruments compute *X, Y, Z* by the summation of the signals as measured through the various filters, each signal being multiplied by an appropriate calibration factor. In matrix notation:

$$\begin{bmatrix} X_m \\ Y_m \\ Z_m \end{bmatrix} = \begin{bmatrix} C_{X1}\, C_{X2}\, C_{X3} \ldots C_{Xf} \\ C_{Y1}\, C_{Y2}\, C_{Y3} \ldots C_{Yf} \\ C_{Z1}\, C_{Z2}\, C_{Z3} \ldots C_{Zf} \end{bmatrix} \begin{bmatrix} F_1 \\ F_2 \\ F_3 \\ \vdots \\ F_f \end{bmatrix} \tag{2}$$

where:

F_1, F_2, F_3, through F_f are the electrical signals from the f filtered detectors and the C_{ij} are calibration coefficients. X_m, Y_m, Z_m have subscripts to indicate that they are measured values rather than ideal ones.

6.1.4 In this practice, we presume that the color measuring instrument is linear: that each signal F_a is strictly proportional to the received optical power, that any zero-offset (background in darkness) is removed, that the proportionality for signal F_a is not affected by the value of signal F_b, and in the case of closely packed detectors (such as charge-coupled device (CCD) detector elements) no signal F_a spills over and affects signal F_b as it approaches saturation. These presumptions are amenable to experimental verification using methods beyond the scope of this practice (**2**).

6.1.5 The values of the matrix elements C_{ij} may be determined using criteria that depends on the design and intended application of the instrument. The full extent of this subject is beyond the scope of this practice. However, in general, for spectroradiometers ($f \approx 30$ to 500), C_{Xj} reflects the tabulated value of (λ) near the center wavelength of Filter j as well as the

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