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ANSI/IES TM-30-18

IES Method for Evaluating Light Source Color Rendition

Approved American National Standard
ANSI

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Prepared by the IES Color Committee:

Wendy Luedtke, *Chair*
Jason Livingston, *Co-Chair*

E. Bretschneider*
A. David
W. Davis
T. Esposito
A. Feldman*
P. Fini
F. Florentine*
M. Royer
M. Wei
J. Fuller*
J. Gaines*
T. Hensley
K. Houser
S. Lavoie*
N. Miller*
H. Ratafia
L. Whitehead
M. Wood
M. Raz*

*Advisory

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The TM-30-18 EXCEL calculation tool files are available for download with the PDF of the TM-30-18 standard at ies.org/store.

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1.0 INTRODUCTION

Accurately quantifying the color rendition characteristics of a light source is a complex problem. Color rendition affects many subjective perceptual attributes of a space, including naturalness, vividness, preference, normalness, and visual clarity. Traditionally, there have been distinct approaches for characterizing color rendition, focusing on concepts such as color fidelity, color discrimination, or color preference, and often relying on a single-number characterization. These approaches vary in their relationship to any given subjective impression. Regardless of approach, there is no one metric or measure that can accurately quantify all subjective perceptions of color rendition or identify the most desirable light source for every application.[1,2] A precise and robust method for comprehensively characterizing color rendition is critical to specifying appropriate light sources and optimizing spectral characteristics of light sources.

This Technical Memorandum describes a method for evaluating light source color rendition that takes an objective and statistical approach, quantifying both overall average properties (color fidelity, gamut area) and hue-specific properties (fidelity, chroma shift, hue shift) of a light source using numerical and graphical techniques. It is important to note that it does not attempt to directly characterize human perceptions, such as color preference, or to provide a single number that captures the combined color rendition qualities of a light source. Using various combinations of the included measures, the user is expected to be able to rely on experience and/or design guidelines to determine what is most appropriate for a specific application. This document focuses only on describing the objective characterization techniques; it does not relate values to a subjective evaluation.

This Technical Memorandum consolidates and synthesizes numerous research efforts that have been ongoing for several years, and was developed by representatives of the manufacturing, specification, and research segments of the lighting industry.

1.1 Calculation Components

This document is a tool comprising a set of measures that are all based on a standardized calculation procedure. The method is based on theoretically comparing the appearance of a set of color samples as rendered by a test light source and a reference illuminant, quantified with a model of human vision. Thus, the method includes three primary components: a system for defining the reference illuminant, specification of the color samples, and implementation of a model of human vision. An overview of each component is provided here.

The method described in this document compares color samples as rendered by a given test source and a reference illuminant at the same correlated color temperature (CCT), with the reference illuminant being Planckian radiation up to and including 4000 K, a proportional blend of Planckian radiation and a CIE daylight (D) series illuminant between 4001 K and 4999 K, or a CIE D series illuminant at or above 5000 K. This familiar reference-based approach is compatible with a typical lighting design process, where color temperature is decided before color rendition is considered. The implications of choosing this system for defining the reference illuminant—based on the 2015 version of this document, IES TM-30-15—have been documented in "What is the Reference? An Examination of Alternatives to the Reference Sources Used in IES TM-30-15."[3] It is important to note that all measures specified in this document rely on the same reference scheme, allowing for a cohesive system.

This method utilizes 99 color evaluation samples (CES)—each represented by a spectral reflectance function—to quantify the difference in color rendition between the test source and reference illuminant. The samples were statistically down-selected from an initial collection of more than 100,000 measured objects, in order to be representative of the world of possible colors.[4-6] A majority of the more than 100,000 spectral reflectance functions considered came from the University of Leeds database,[7] which is itself a meta-base containing objects of various origins: textiles, plastics, skin tones, color systems. The Leeds database also includes the Standard Object Colour Spectra (SOCS) database,[8] which contains printed materials, skin tones, natural objects, paints, and textiles. Additional data included natural objects,[9,10] flowers,[11] skin tones,[12] and paints.[9,13]

Finally, embedded within this method is the most current uniform color space, CAM02-UCS,[14-16] which is based on CIECAM02[17-19] and its native chromatic adaptation transformation. This color space was chosen because of its greater uniformity than CIELAB, and is important for ensuring the uniformity of the CES across color space and at a wide range of CCTs.[5,14,20] The CIE 1964 10° standard colorimetric observer[21] is used for all calculations except in determining CCT, where the definition calls for use of the CIE 1931 2° standard colorimetric observer.[22] This model of human vision helps ensure that color differences are appropriately scaled.

It is possible (and expected) that scientific advances related to any calculation component included in this Technical Memorandum will subsequently lead to updates to the method.

1.2 Calculated Measures

Using a unified calculation system, this Technical Memorandum (TM) provides equations and direction for calculating 50 primary numerical measures and one graphic (color vector graphic). The 50 numerical measures include 1 average color fidelity measure (fidelity index, R_f), 1 gamut area measure (gamut index, R_g), 16 hue-specific fidelity measures (local color fidelity, $R_{f,hj}$), 16 hue-specific measures of chroma shift (local chroma shift, $R_{cs,hj}$), and 16 hue-specific measures of hue shift (local hue shift, $R_{hs,hj}$). Whereas R_f and R_g are global averages, the hue-specific local chroma shift and local hue shift values are important for characterizing *gamut shape*, which is the pattern of hue and chroma shift for different hues. Equations to calculate a sample-specific color fidelity value for each of the 99 CES (sample fidelity, $R_{f,CESi}$) are also provided. This document is accompanied by software to aid in calculation and display of the results.

The measures included within this TM are intended to be used in various combinations—or in isolation—depending on the needs of a given application and design intent. This document does not establish performance thresholds, nor does it provide direction on how to do so, for any of the measures. Some experiments have been completed that relate the measures of this TM to subjective evaluations and propose performance thresholds.[23-26]

1.3 Changes from IES TM-30-15

This document replaces IES TM-30-15. The following technical changes have been made:

- For color samples with no native data outside the range of 400 to 700 nm, the extrapolation method was changed from a logarithm-based extrapolation to a flat extrapolation.
- The range encompassing the blended reference was changed from 4501 – 5499 K to 4001 – 4999 K.
- The scaling factor used in color fidelity calculations was changed from 7.54 to 6.73.

These changes have no material effect on the rank order of light sources for any of the included measures. They make IES R_f (ANSI/IES TM-30-18) and CIE R_f (CIE 224:2017[27]) equivalent measures. CIE 224:2017 is limited only to color fidelity, and its scope does not include measures for color rendition considerations beyond color fidelity.

This revision also provides greater clarity on the derivation of the color vector graphic, and specifies the equations used to calculate local chroma shift and local hue shift.

2.0 SCOPE

This evaluation method is applicable to light sources and lighting systems intended for general illumination of indoor spaces and some outdoor settings, at light levels where photopic vision is dominant. It is best suited to characterize nominally white light sources (i.e., those that fall on or near the Planckian locus). If a light source's chromaticity falls outside of the chromaticity bins defined in ANSI C77.388-2017,[8] then calculations based on this TM should be interpreted with caution.

3.0 CORE CALCULATIONS

3.1 Colorimetric Observer

Tristimulus values for the color evaluation samples shall be determined using the CIE 1964 10° standard colorimetric observer, with color matching functions (CMFs) $\bar{x}_{10}(\lambda)$, $\bar{y}_{10}(\lambda)$, $\bar{z}_{10}(\lambda)$.[10] The 1 nm-increment table is available in CIE 15:2004, *Colorimetry* – Part 1: CIE Standard Colorimetric Observers.[21] The exception is in determining the CCT of the test source, which by definition requires the use of the CIE 1931 2° standard colorimetric observer.[17,21,22] It should also be noted that, for light source specifications, the CIE 1931 standard colorimetric observer [$\bar{x}(\lambda)$, $\bar{y}(\lambda)$, $\bar{z}(\lambda)$] is used to calculate chromaticity coordinates (x, y) and (u', v'). The 1964 10° CMFs are used for light sources in this document only for the purpose of calculating color rendition measures.

3.2 Test Source

The relative spectral power distribution (SPD) of the light source in question (*test source*) is denoted $S_t(\lambda)$. The necessary wavelength range is described in **Section 3.5**. The tristimulus values of the test source shall be calculated as follows: