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CIE

Secretariat: CIE

2024-05-24

Standard method of assessing the spectral quality of daylight simulators for visual appraisal and measurement of colour

Méthode normalisée d'évaluation de la qualité spectrale des simulateurs de lumière du jour pour le jugement visuel et la mesure des couleurs

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document was prepared by the International Commission on Illumination (CIE) in cooperation with Technical Committee ISO/TC 274, *Light and lighting*.

This first edition cancels and replaces the first edition (ISO 23603:2005/CIE S 012:2004), which has been technically revised.

The main changes are as follows:

— ~~—~~normative references updated;

— ~~—~~terms and definitions updated;

— ~~—~~minor editorial changes.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at ~~www.iso.org/members.html~~www.iso.org/members.html.

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Introduction

The purpose of the assessment method described in this document is to quantify the suitability of the spectral irradiance distribution of a practical daylight simulator of CIE daylight illuminant D55, D75 or CIE standard daylight illuminants D50 and D65 for the visual appraisal and measurement of colours of fluorescent or non-fluorescent specimens.

The basis for the assessment is the special metamerism index for change in illuminant, using pairs of virtual (rather than real) specimens specified by their reflecting and fluorescing properties. The pairs of specimens are metameric matches under the CIE daylight illuminant, when evaluated with the CIE 1964 standard colorimetric observer. The method described in this document quantifies the mismatch when the pairs of virtual specimens are illuminated by the daylight simulator under test and evaluated by the same standard colorimetric observer.

A visible range metamerism index is derived to quantify the suitability of the simulator for the visible wavelength range.

An ultraviolet range metamerism index is derived using a different set of virtual metameric pairs, each pair having a fluorescent and a non-fluorescent specimen which spectrally match for the CIE daylight illuminant and CIE standard colorimetric observer. The non-fluorescent specimen in each pair is specified by its spectral radiance factor. The fluorescent specimen in each pair is specified by its spectral reflected radiance factor, relative spectral distribution of radiance due to fluorescence and spectral external radiant efficiency of the fluorescent specimen. The ultraviolet range metamerism index quantifies the mismatch due to fluorescence that results from the use of the daylight simulator and the CIE 1964 standard colorimetric observer.

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Standard method of assessing the spectral quality of daylight simulators for visual appraisal and measurement of colour

1 Scope

This document specifies a method of assessing the spectral quality of the irradiance provided by a daylight simulator to be used for visual appraisal of colours or for colour measurements and a method of assigning a quality grade to the simulator. It specifies the maximum permissible deviation of the chromaticity of the simulator from the chromaticity of the CIE standard daylight illuminant or CIE daylight illuminant being simulated for a daylight simulator to be graded by this method.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/CIE 11664~~-~~-1, *Colorimetry — Part 1: CIE standard colorimetric observers*

ISO/CIE 11664~~-~~-2, *Colorimetry — Part 2: CIE standard illuminants*

ISO/CIE 11664~~-~~-4, *Colorimetry — Part 4: CIE 1976 L*a*b* colour space*

ISO/CIE 11664~~-~~-5, *Colorimetry — Part 5: CIE 1976 L*u*v* Colour Space and u′, v′ Uniform Chromaticity Scale Diagram*

CIE 051.2-1999, *A Method for Assessing the Quality of Daylight Simulators for Colorimetry*

CIE 250:2022, *Spectroradiometric measurement of optical radiation sources*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at ~~https://www.iso.org/obp~~https://www.iso.org/obp

— IEC Electropedia: available at ~~https://www.electropedia.org/~~https://www.electropedia.org/

CIE maintains a terminology database for use in standardization at the following address:

— CIE e-ILV: available at ~~https://cie.co.at/e-ilv~~https://cie.co.at/e-ilv

3.1
daylight simulator
device for the visual appraisal or measurement of the colour of materials or surfaces that provides spectral irradiance approximating a CIE standard illuminant representing a phase of daylight

[SOURCE: CIE S 017:2020, Entry 17-23-025]

3.2
quality grade
<~~of an~~ illuminant simulator> class of quality of simulation of the spectral irradiance of a CIE illuminant by a simulator, expressed as a letter symbol A, B, C, D or E, with class A representing the highest quality

[SOURCE: CIE S 017:2020, Entry 17-23-024]

3.3
reflectance factor
R
quotient of the flux reflected in the directions delimited by a given cone with apex at a surface element, Φ_n, and the flux reflected in the same directions by a perfect reflecting diffuser identically irradiated or illuminated, Φ_d

$$R = \frac{\Phi_n}{\Phi_d}$$

$$R = \frac{\Phi_n}{\Phi_d}$$

Note 1 to entry: The definition holds for a surface element, for the part of the reflected radiation contained in a given cone with apex at the surface element, and for incident radiation of given spectral composition, polarization and geometric distribution.

Note 2 to entry: The reflectance factor is also defined spectrally and is called spectral reflectance factor, $R(\lambda)$.

Note 3 to entry: The ideal isotropic (Lambertian) diffuser with reflectance or transmittance equal to 1 is called a perfect diffuser.

Note 4 to entry: For regularly reflecting surfaces that are irradiated or illuminated by a beam of small solid angle, the reflectance factor can be much larger than 1 if the cone includes the mirror image of the source.

Note 5 to entry: If the solid angle of the cone approaches 2π sr, the reflectance factor approaches the reflectance for the same conditions of irradiation.

Note 6 to entry: If the solid angle of the cone approaches 0 sr, the reflectance factor approaches the radiance factor or luminance factor for the same conditions of irradiation.

Note 7 to entry: The reflectance factor has unit one.

[SOURCE: CIE S 017:2020, Entry 17-24-070, modified — Notes 8 and 9 to entry omitted.]

3.4
radiance factor
β_e
quotient of the radiance of a surface element in a specified direction, $L_{e,n}$ and the radiance of the perfect reflecting diffuser or perfect transmitting diffuser identically irradiated and viewed, $L_{e,d}$

$$\beta_e = \frac{L_{e,n}}{L_{e,d}}$$

$$\beta_e = \frac{L_{e,n}}{L_{e,d}}$$

Note 1 to entry: The definition holds for a surface element of a non-self-radiating medium, in a specified direction and under specified conditions of irradiation.

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Note 2 to entry: Radiance factor is equivalent to reflectance factor or luminance factor when the cone angle is infinitely small, and is equivalent to reflectance when the cone angle is 2π sr. These quantities are also defined spectrally and called spectral radiance factor, $\beta(\lambda)$, and spectral reflectance factor, $R(\lambda)$.

Note 3 to entry: The ideal isotropic (Lambertian) diffuser with reflectance or transmittance equal to 1 is called a perfect diffuser.

Note 4 to entry: For photoluminescent media, the radiance factor contains two components, the reflected radiance factor, β_R, and the luminescent radiance factor, β_L. The sum of reflected radiance factor and luminescent radiance factor is the total radiance factor, β_T: $\beta_T = \beta_R + \beta_L$.

The subscript R is used here for the reflected radiance factor because it is more intuitive than the traditional S and avoids confusion with the use of S to denote a state of polarization.

Note 5 to entry: The radiance factor has unit one.

[SOURCE: CIE S 017:2020, Entry 17-24-075, modified — symbol β deleted; Notes 6 and 7 to entry omitted.]

3.5
reflected radiance factor
β_R
quotient of the reflected radiance at a point on a surface of a non-self-radiating medium in a given direction and that of the perfect reflecting diffuser identically irradiated and viewed

Note 1 to entry: In general, the reflected radiance factor from a surface does not depend upon the relative spectral distribution of the irradiation. This is not the case for a photoluminescent surface, where it is necessary to specify this quantity.

Note 2 to entry: The reflected radiance factor has unit one.

[SOURCE: CIE S 017:2020, Entry 17-21-104, modified — Note 3 to entry omitted.]

3.6
fluorescent radiance factor
β_F
<surface element of a non-self-radiating medium, in a given direction, under specified conditions of irradiation> ratio of the radiance due to fluorescence of the specimen to the radiance of the perfect reflecting diffuser identically irradiated and viewed

3.7
fluorescent radiant efficiency
quotient of the integrated value of the radiant flux of all wavelengths emitted by fluorescence (fluorescence band) and the radiant excitation power irradiating the fluorescent material for a given excitation wavelength

Note 1 to entry: The fluorescent radiant efficiency is a measure of the external radiant efficiency of the fluorescent material; the internal radiant efficiency is obtained by taking a quotient of the emitted radiation and the radiant excitation power that is absorbed by the fluorescent material.

Note 2 to entry: In this definition the excitation wavelength is considered to be monochromatic. However, in practice, the excitation radiation will have a wavelength range and distribution.

Note 3 to entry: Fluorescence is understood to include both fluorescent and phosphorescent phenomena with time constants short enough to be ignored for the application.

Note 4 to entry: The fluorescent radiant efficiency has unit one.

[SOURCE: CIE S 017:2020, Entry 17-24-042]

3.8
spectral external radiant efficiency of the fluorescent specimen
Q(λ')
quotient of the total radiant flux of all wavelengths emitted by the fluorescent process for an excitation wavelength and the *total radiant excitation* ~~(3.9)~~(3.9) power irradiating the fluorescent material

Note 1 to entry: This quantity is also measured in relative terms by comparison to the radiant flux reflected from the perfect reflecting diffuser identically irradiated and viewed for a given excitation wavelength.

Note 2 to entry: Fluorescence is understood to include both fluorescent and phosphorescent phenomena with time constants short enough to be ignored for the application.

Note 3 to entry: The spectral external radiant efficiency of the fluorescent specimen has unit one.

[SOURCE: CIE S 017:2020, Entry 17-21-088]

3.9
total radiant excitation
N
total radiant power irradiating the specimen that is capable of exciting fluorescence

3.10
relative spectral distribution of radiance due to fluorescence
F(λ)
ratio of the spectral distribution of radiance due to fluorescence to the sum of the tabulated values of this distribution, i.e. ~~$\Sigma_\lambda F$~~ $\Sigma_\lambda F(\lambda) = 1{,}0$

4 Requirements

4.1 Chromaticity tolerance

The first requirement of a daylight simulator is that the light it provides be nearly the same chromaticity as the light of the CIE daylight illuminant. For a daylight simulator to qualify for classification by this document, the CIE 1976 u'_{10} v'_{10} chromaticity difference in accordance with ISO/CIE 11664-5 between the light of the daylight simulator and that of the CIE daylight illuminant shall not exceed 0,015 in accordance with CIE 051.2-1999.

4.2 Quality grade

The chromaticity requirement described in ~~4.1~~4.1 having been met, and a metamerism index having been determined by the method of this document, the spectral quality of simulation shall be classified, using a letter symbol indicating a quality grade, according to ~~Table 1.~~Table 1.

The quality of spectral simulation is evaluated for the visible spectrum and for the ultraviolet spectrum and separate quality grades are assigned for those two spectral regions. The quality grades are reported as a two-letter symbol, the quality grade for the visible region being stated first. For example, the symbol BC means the daylight simulator has a quality grade of B for the visible spectrum and C for the ultraviolet spectrum. (Daylight simulators having the BC grade have been found useful for many applications.)

5 Test methods

5.1 Spectroradiometry

The relative spectral irradiance (the relative spectral power distribution of the flux incident on the specimen) of the daylight simulator shall be measured by spectroradiometry for the near ultraviolet and visible spectrum, in the wavelength range from 380 nm to 780 nm. The radiometric quantity required is the relative spectral irradiance at the surface to be observed or measured. This procedure takes into account not only the relative spectral radiance of the source but also the spectral effect of any lenses, reflectors, diffusers or filters that affect the relative spectral irradiance.

Devices providing significant spectral irradiance at wavelengths less than 300 nm are not suitable as daylight simulators. Radiant power at wavelengths of less than 300 nm, coming from the sun, is absorbed in the earth's atmosphere, and is insignificant at ground level in natural daylight.

The relative spectral irradiance shall be measured at 5 nm intervals and over 5 nm bands, at wavelengths from 380 nm to 780 nm. This may be accomplished by direct measurement or a combination of measurement and interpolation, depending on the nature of the spectroradiometer and whether the relative spectral irradiance includes some component of a line spectrum. When the spectral power distribution of the daylight simulator includes spectral lines, as is the case when fluorescent lamps are used, the spectral data shall be treated by the method in CIE 250:2022.

5.2 Computations

5.2.1 Normalization

The spectral irradiance of the daylight simulator is normalized so the assessment is independent of the absolute value of irradiance. The normalized irradiance shall be computed by ~~Formula (1).~~Formula (1):

$$S_n(\lambda)=\frac{100\cdot S(\lambda)}{\sum_{380}^{780} S(\lambda)\cdot y_{10}(\lambda)\cdot\Delta\lambda} \quad (1)$$

$$S_n(\lambda)=\frac{100\cdot S(\lambda)}{\sum_{380}^{780} S(\lambda)\cdot \bar{y}_{10}(\lambda)\cdot\Delta\lambda} \quad (1)$$

where

$S(\lambda)$	is the measured irradiance, the subscript n denotes the normalized quantity,
~~$\bar{y}_{10}(\lambda)$~~ $\bar{y}_{10}(\lambda)$	is one of the colour-matching functions of the CIE 1964 standard colorimetric observer in accordance with ISO/CIE 11664-1,
$\Delta\lambda$	is the wavelength interval used for the summation, and the summation is over the wavelength range from 380 nm to 780 nm; $\Delta\lambda$ shall be 5 nm.

5.2.2 Chromaticity deviation

The CIE 1976 u'_{10} v'_{10} chromaticity difference between the light from the daylight simulator and that of the simulated CIE standard daylight illuminant in accordance with ISO/CIE 11664-2 or CIE daylight illuminant shall not exceed 0,015. To facilitate this computation, the chromaticity coordinates of the four respective CIE daylight illuminants as given in CIE 015:2018 are listed in ~~Table 2.~~Table 2.

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