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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.

ISO 23603 was prepared as Standard CIE S 012/E by the International Commission on Illumination, which has been recognized by the ISO Council as an international standardizing body. It was adopted by ISO under a special procedure which requires approval by at least 75 % of the member bodes casting a vote, and is published as a joint ISO/CIE edition.

The International Commission on Illumination (abbreviated as CIE from its French title) is an organization devoted to international cooperation and exchange of information among its member countries on all matters relating to the science and art of lighting.

ISO 23603 was prepared by CIE Technical Committee 1-53 *A standard method for assessing the quality of daylight simulators*.

COMMISSION INTERNATIONALE DE L'ECLAIRAGE
INTERNATIONAL COMMISSION ON ILLUMINATION
INTERNATIONALE BELEUCHTUNGSKOMMISSION

CIE S 012/E:2004

Standard

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

Standardmethoden zur Bewertung der spektralen Qualität von Tageslichtsimulatoren für visuelle Beurteilung und Farbmessung

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FOREWORD

Standards produced by the Commission Internationale de l'Eclairage (CIE) are a concise documentation of data defining aspects of light and lighting, for which international harmony requires such unique definition. CIE Standards are therefore a primary source of internationally accepted and agreed data, which can be taken, essentially unaltered, into universal standard systems.

This International Standard has been prepared by CIE Technical Committee 1-53*, "A standard method for assessing the quality of daylight simulators", and was approved by the National Committees of the CIE.

Observed colours of objects depend on the illumination of the objects and the results of colour measurements may depend on the illumination used in the measurement. The CIE has standardized the spectral power distributions of several phases of daylight for use in observing and measuring colour. For practical applications in colour technology, illuminators are designed to illuminate specimens with light simulating one or more of these CIE illuminants. The accuracy of simulation has an important bearing on the accuracy of visual matches and colour measurements. CIE Technical Committee TC1.3 studied methods of assessing the spectral quality of daylight simulators and issued recommendations in the publication: CIE 51-1981 *A method for assessing the quality of daylight simulators for colorimetry*. That publication established the limits of the deviation from the ideal colour that initially qualified a simulator for consideration and established a test method to assign quality grades to simulators. The limits and test method expressed in that publication have been used throughout the world, since 1981. The historical development of the methodology is described in that publication.

This standard is based on the principles and methods described in CIE 51-1981. There are several new features, based on recent research and standardization (JIS, 2000; McCamy, 1996 and 1999). CIE 51-1981 treated CIE Illuminants D55, and D75 as well as CIE standard illuminant D65. CIE Illuminant D50, which is widely used in photographic and colour printing technologies, was included in a later supplement to CIE 51-1981 (CIE 135/3-1999 Visual metamers for assessing the quality of CIE illuminant D50) and is also included in this standard. CIE 51.2-1999 includes both the original publication and the supplement. CIE 51.2-1999 specified limits on colour deviation graphically; this standard specifies the same limits numerically. CIE 51.2-1999 listed wavelength-dependent constants for visible-range assessment over the wavelength range from 400 nm to 700 nm; this standard lists those constants over the range from 380 nm to 780 nm. The constants and wavelength range for ultraviolet-range assessment in CIE 51.2-1999 are retained in this standard. For the special purpose of ultraviolet-range assessment, the wavelength range from 400 nm to 700 nm adequately represents the visible spectrum, because all of the fluorescence emission considered is within that range.

* Chairman of this TC was C. S. McCamy (US), members were: D. H. Alman (US), R. Hirschler (BR), T. Ichijo (JP), J. T. C. van Kemenade (NL), M. R. Luo (UK), M. Pointer (UK), J. Schanda (HU), and J. C. Zwinkels (CA).

INTRODUCTION

The purpose of this assessment is to quantify the suitability of the spectral irradiance distribution of a practical simulator of CIE daylight illuminant D50, D55, D75 or CIE standard daylight illuminant D65 for the visual appraisal or 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 standard quantifies the mismatch when the pairs of virtual specimens are illuminated by the simulator under test and evaluated by the same standard 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 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 resulting from the use of the simulator and the standard observer.

1. SCOPE

This International Standard 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 simulator to be graded by this method.

2. NORMATIVE REFERENCES

The following standards and other documents contain provisions which, through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All publications are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the publications indicated below. Members of CIE, the International Electrotechnical Commission (IEC) and the International Organisation for Standardization (ISO) maintain registers of currently valid international standards.

CIE 15:2004. *Colorimetry, 3rd edition*.
CIE 17.4-1987. *International Lighting Vocabulary,* ILV (joint IEC/CIE publication)..
CIE 51.2-1999. *A method for assessing the quality of daylight simulators for colorimetry*.
CIE 63-1984. *The spectroradiometric measurement of light sources*.
ISO 10526/CIE S 005-1999. *CIE standard illuminants for colorimetry*.
ISO/CIE 10527-1991. *Colorimetric observers*.

3. DEFINITIONS AND SYMBOLS

For the purposes of this standard, the following definitions and symbols apply. Definitions and symbols used in this standard, but not listed here, conform to CIE 17.4-1987 and CIE 15:2004.

3.1 simulator*

device that provides spectral irradiance approximating that of a CIE standard daylight illuminant or CIE daylight illuminant, for visual appraisal or measurement of colours

3.2 quality grade*

class of quality of simulation of the spectral irradiance of a CIE standard illuminant or CIE illuminant by a simulator, expressed as a letter symbol A, B, C, D, or E, with class A representing the highest quality

3.3 reflectance factor (at a surface element, for the part of the reflected radiation contained in a given cone with the apex at the surface element, and for incident radiation of a given spectral composition, polarization and geometrical distribution) (see ILV 845-04-64)

ratio of the radiant or luminous flux reflected in the directions delimited by the given cone to that reflected in the same directions by a perfect reflecting diffuser identically irradiated or illuminated
Symbol: R

3.4 reflected radiance factor* (at a representative element of the surface of a non-self-radiating medium, in a given direction, under specified conditions of irradiation)

ratio of the radiance due to reflection of the medium in the given direction to the radiance of a perfect reflecting diffuser identically irradiated
Symbol: β_R

3.5 fluorescent radiance factor* (at a 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
Symbol: β_F

3.6 total radiance factor* (at a representative element of the surface of a non-self-radiating medium, in a given direction, under specified conditions of irradiation)

sum of the reflected radiance factor β_R and the fluorescent radiance factor β_F
Symbol: β_T

3.7 fluorescent radiant efficiency*

ratio of the radiant power emitted by fluorescence for a given spectral excitation, to the spectral radiant excitation power irradiating the fluorescent material

3.8 spectral external radiant efficiency of the fluorescent specimen*

ratio of the total radiant power emitted by the fluorescent process for an excitation wavelength λ' to the total radiant excitation power irradiating the fluorescent material
Symbol: $Q(\lambda')$, where λ' is the excitation wavelength

3.9 total radiant excitation*

total radiant power irradiating the specimen that is capable of exciting fluorescence
Symbol: N

3.10 relative spectral distribution of radiance due to fluorescence*

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

* New definition. Not in CIE 17.4-1987.

4. REQUIREMENTS

4.1 Chromaticity tolerance

The first requirement of a 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 standard, the CIE 1976 u'_{10} v'_{10} chromaticity difference between the light of the simulator and that of the CIE daylight illuminant shall not exceed 0,015. (See CIE 15:2004.)

4.2 Quality grade

The chromaticity requirement described in paragraph 4.1 having been met, and a metamerism index having been determined by the method of this standard, the spectral quality of simulation shall be classified, using a letter symbol indicating a quality grade, according to 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 simulator has a quality grade of B for the visible spectrum and C for the ultraviolet spectrum. (Daylight simulators having these grades 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 simulator shall be measured by spectroradiometry for the near ultraviolet and visible spectrum, in the wavelength range from 300 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 of shorter wavelengths, coming from the sun, is absorbed in the earth's atmosphere, so it is absent in natural daylight.

The relative spectral irradiance shall be measured at 5 nm intervals and over 5 nm bands, at wavelengths from 300 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 simulator includes spectral lines, as is the case when fluorescent lamps are used, the spectral data are treated by the method in CIE 63-1984 *The spectroradiometric measurement of light sources*.

5.2 Computations

5.2.1 Normalization

The spectral irradiance of the simulator is normalized so the assessment is independent of the absolute value of irradiance. The normalized irradiance is computed by equation (5.1):

$$S_{\mathrm{n}}(\lambda) = \frac{100 \cdot S(\lambda)}{\sum_{300}^{780} S(\lambda) \cdot \bar{y}_{10}(\lambda) \cdot \Delta\lambda} \tag{5.1}$$

where $S(\lambda)$ is the measured irradiance, the subscript n denotes the normalized quantity, $\bar{y}_{10}(\lambda)$ is one of the colour matching functions of the CIE 1964 standard colorimetric observer (see ISO/CIE 10527-1991), $\Delta\lambda$ is the wavelength interval used for the summation, and the summation is over the wavelength range from 300 nm to 780 nm.