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TECHNICAL SPECIFICATION

colour inside

Multimedia systems and equipment – Colour measurement and management – Part 13: Measurement method of display colour properties depending on observers

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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MULTIMEDIA SYSTEMS AND EQUIPMENT – COLOUR MEASUREMENT AND MANAGEMENT –

Part 13: Measurement method of display colour properties depending on observers

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IEC TS 61966-13 has been prepared by technical area 2: Colour measurement and management, of IEC technical committee 100: Audio, video and multimedia systems and equipment. It is a Technical Specification.

The text of this Technical Specification is based on the following documents:

Draft	Report on voting
100/3928/DTS	100/4023/RVDTS

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this Technical Specification is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

A list of all parts in the IEC 61966 series, published under the general title *Multimedia systems and equipment – Colour measurement and management*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn, or
- revised.

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INTRODUCTION

In colorimetry, metamerism or metameric failure is defined as a perceived matching of two colours with different spectral power distributions (SPDs). Illuminant metamerism occurs when two objects match in colour under a specific illuminant, but mismatch under another illuminant with a different SPD. Likewise, observer metamerism (OM) is defined by two stimuli with different SPDs that match in colour for a specific observer. However, the stimuli might not match for another observer. OM is caused by the normal variations in the spectral responsivities of various observers. In other words, observers do not have identical colour-matching functions (CMFs). An observer model that takes into consideration the age and the field size of observers with respect to a standard observer standard observer has already been standardised in the CIE (CIE Pub. 170-1:2006).

Meanwhile, display manufacturers and users have required measurement methods of the OM which occurs in display uses. For example, with the development of display technology and grafting of display technology to various application fields and mass distribution, it has become a common situation for users to use multiple displays at the same time. When using multiple displays at the same time, a user can display the same colour through the calibration process. However, this is only valid for certain observers because of OM. Also, when users watch a single display, there could be observer dependency in colour perception even though the display is calibrated.

Based on the CIE standards and research results of OM, a new Technical Specification is suggested to measure the difference in display colour properties according to the observer in an objective way, excluding subjective effects of evaluators.

MULTIMEDIA SYSTEMS AND EQUIPMENT – COLOUR MEASUREMENT AND MANAGEMENT –

Part 13: Measurement method of display colour properties depending on observers

1 Scope

This document defines an objective colour difference metric and a measurement method for observer metamerism caused by displays with different spectral power distributions. This document also specifies the measuring equipment, conditions and methods that are necessary to obtain the metric. This document applies to light-emitting or backlit transmitting colour displays measured under dark-room conditions.

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 11664-4, *Colorimetry – Part 4: CIE 1976 L*a*b* colour space*

ISO/CIE 11664-6, *Colorimetry – Part 6: CIEDE2000 colour-difference formula*

CIE 170-1:2006, *Fundamental chromaticity diagram with physiological axes – Part 1*

CIE 170-2:2015, *Fundamental chromaticity diagram with physiological axes – Part 2*

3 Terms and definitions

3.1 Terms and definitions

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

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

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1.1
observer metamerism
differences in metameric matches when made by different observers

Note 1 to entry: Identical spectral pairs will be identified as the same colour for all observers with their individual CMFs. However, when the spectral power distributions of the two stimuli differ, and only metameric matching is possible, a match made by one observer will typically not match for other observers. This is also called metameric failure. See entry [1] of the Bibliography.

3.1.2
observer metamerism index
value of colour difference due to observer metamerism characteristics of a display

Note 1 to entry: Metamerism indices exist for illuminant metamerism but not for observer metamerism.

3.1.3
ORU
optical radiant unit
unit in a display from which light of a distinct spectral power distribution is radiated

Note 1 to entry: Unit can be present in direct-view and projection displays with temporally and/or spatially fused colour. In the case of projection, spectral irradiance is measured.

3.1.4
multi-ORU
multi optical-radiant-unit display
display with more than three optical radiant units with different spectral power distributions

3.2 Abbreviations

ABC	automatic brightness control
CCT	correlated colour temperature
CIE	Commission Internationale de L'Éclairage (International Commission on Illumination)
CIELAB	CIE 1976 (L*a*b*) colour space
CMFs	colour-matching functions
DUT	device under test
FS	field size
LMD	light-measuring device
OM	observer metamerism
ORU	optical radiant unit
SPD	spectral power distribution

4 Measuring equipment

4.1 Light-measuring devices

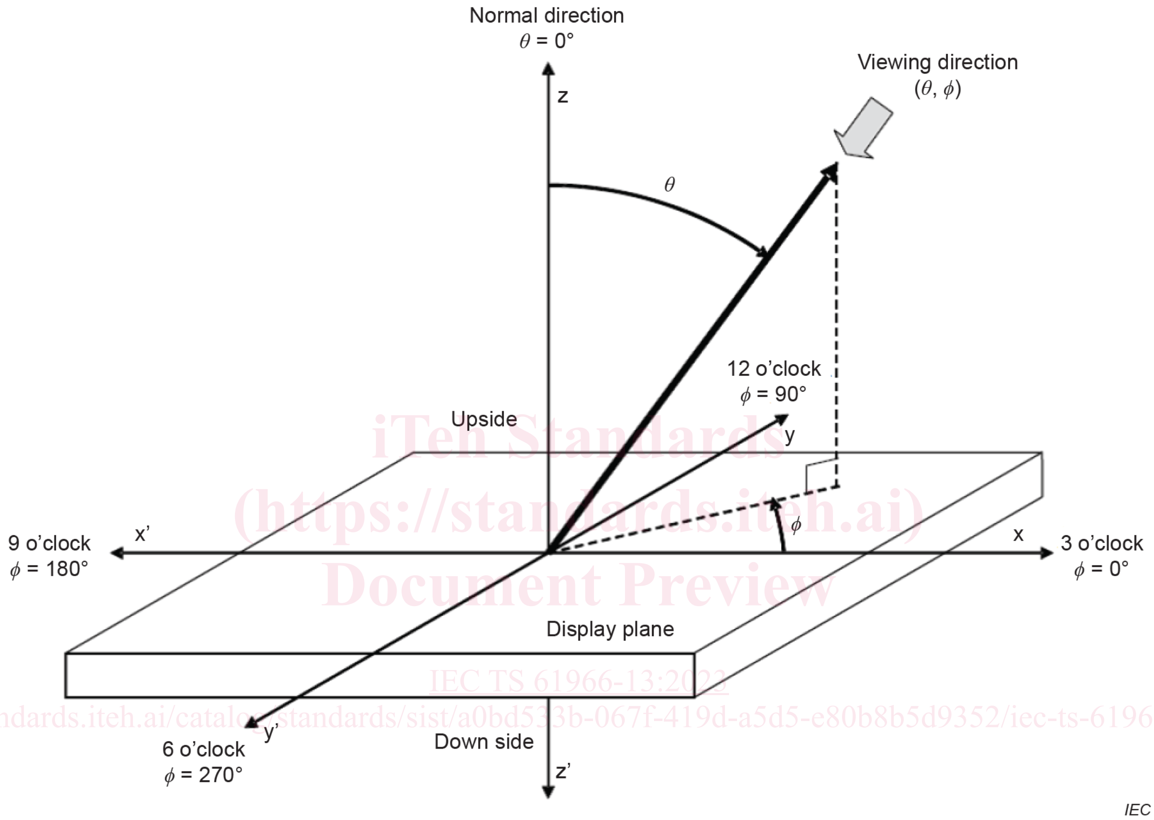
The system configurations and/or operating conditions of the measuring equipment shall comply with the structure specified in each item.

To ensure reliable measurements, the spectroradiometer shall have a wavelength range of at least from 380 nm to 780 nm, and the wavelength scale accuracy shall be less than 1 nm. The relative luminance uncertainty of measured luminance (relative to CIE illuminant A source) shall not be greater than 4 % for luminance values over 0,1 cd/m^2 and not be greater than 10 % for luminance values 0,1 cd/m^2 and below. Note that errors from spectral stray light within a spectroradiometer can be significant and shall be corrected. A simple matrix method may be used to correct the stray light errors, by which stray light errors can be reduced for one to two orders of magnitude. Details of this correction method are discussed in Reference [1][1]. If the obtained luminance is lower than LMD limitation, the lower limit of the LMD shall be recorded with measured luminance.

[1] Numbers in square brackets refer to the Bibliography.

4.2 Viewing direction coordinate system

The viewing direction is the direction under which the observer looks at the spot of interest on the display. During the measurement, the LMD is replacing the observer, looking from the same direction at a specified spot (i.e. measuring spot, measurement field) on the DUT. The viewing direction is conveniently defined by two angles: the angle of inclination θ (related to the surface normal of the DUT) and the angle of rotation ϕ (also called azimuth angle) as illustrated in Figure 1. The azimuth angle is related to the directions on a watch-dial as follows: ϕ = 0° is referred to as the 3 o'clock direction ("right"), ϕ = 90° as the 12 o'clock direction ("top"), ϕ = 180° as the 9 o'clock direction ("left") and ϕ = 270° as the 6 o'clock direction ("bottom").



Key

θ: incline angle from normal direction

ϕ: azimuth angle

3 o'clock: right edge of the screen as seen from the user

6 o'clock: bottom edge of the screen as seen from the user

9 o'clock: left edge of the screen as seen from the user

12 o'clock: top edge of the screen as seen from the user

Figure 1 – Representation of the viewing direction (equivalent to the direction of measurement) by the angle of inclination, θ and the angle of rotation (azimuth angle), ϕ in a polar coordinate system

5 Measuring conditions

5.1 Standard measuring environmental conditions

Measurements shall be carried out under standard environmental conditions:

- Temperature: 25 ºC ± 3 ºC,
- Relative humidity: 25 % RH to 85 % RH,
- Atmospheric pressure: 86 kPa to 106 kPa.

When different environmental conditions are used, they shall be noted in the measurement report.

5.2 Power supply

The power supply for driving the DUT shall be adjusted to the rated voltage ± 0,5 %. In addition, the frequency of power supply shall provide the rated frequency ± 0,2 %.

5.3 Warm-up time

Measurements shall be carried out after sufficient warm-up. Warm-up time is defined as the time elapsed from when the supply source is switched on, and a 100 % grey level of input signal is applied to the DUT, until repeated measurements of the display show a variation in luminance of no more than 2 % per minute and 5 % per hour.

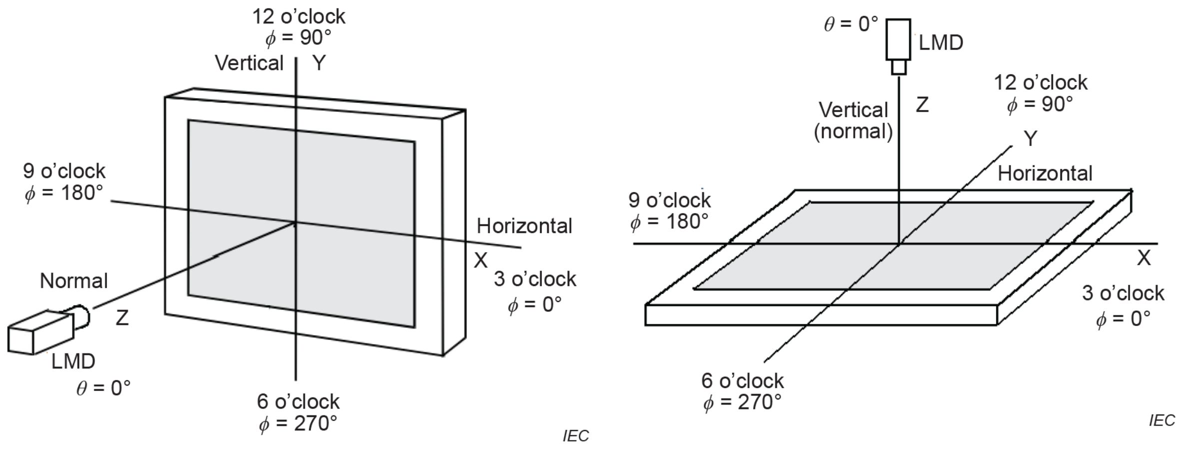
5.4 Standard measuring dark-room conditions

The luminance contribution from the background illumination reflected off the test display shall be < 0.01 cd/m^2. If these conditions are not satisfied, then background subtraction is required and it shall be noted in the measurement report. In addition, if the sensitivity of the LMD is inadequate to measure these low levels, then the lower limit of the LMD shall be noted in the measurement report.

5.5 Standard set-up conditions

By default, the display shall be installed in the vertical position (Figure 2a), but the horizontal alternative (Figure 2b) is also allowed. When the latter alternative is used, it shall be noted in the measurement report.

The display shall be configured to the factory settings, default settings, or any viewing mode agreed on by the supplier and the customer, and the settings recorded in the test report. These settings shall be held constant for all measurements. It is important, however, to make sure that not only the adjustments are kept constant, but also that the resulting physical quantities remain constant during the measurement. This is not automatically the case because of, for example, warm-up effects or auto-dimming features. Any automatic luminance or gain control shall be turned off. Otherwise it should be noted in the report. The automatic brightness control (ABC) or ambient light control, which can reduce the display luminance level with dim ambient illumination, shall be turned off. If that is not possible, it is recommended to set it to turn on no lower than 300 lx to minimize the influence of the ABC as specified in IEC 62087-3:2015, 6.4.4. The state of the ABC shall be reported. In addition, if the display has an auto-dimming feature which reduces to less than 95 % of original luminance when a static image is displayed after a prolonged time, then a black frame shall be input and the display luminance shall be measured with 1 s sampling time until the display recovers its original luminance with 5 % error prior to rendering and measuring the desired test pattern. The measurements shall be completed before the dimming feature is triggered. When the display has the option to be set for different viewing modes, the viewing mode shall be defined by the test specification, and be used with consistency for all measurements. Additional viewing modes can also be measured. The viewing mode used during testing shall be reported. The display should be operated in a mode that does not have over-scan.



a) Primary installation **b) Alternative installation**

Figure 2 – DUT Installation conditions

6 Measuring methods

6.1 Individual colour-matching functions

CIE presented XYZ tristimulus representation based on cone fundamentals from the technical reports CIE 170-1 and CIE 170-2 in 2006 and 2015, respectively. In CIE 170-1, the cone fundamentals are defined as the spectral sensitivity functions, which are the long-wave sensitive (L-), medium-wave sensitive (M-) and short-wave sensitive (S-) cones, and effects of age and field size are incorporated. In CIE 170-2, linear transformations of the cone fundamentals in the form of cone-fundamental-based XYZ tristimulus values are presented for 2° and 10° field sizes. Thus, if the age and field size of an observer are given, corresponding XYZ tristimulus values can be computed based on CIE 170-1 and 170-2 technical reports. In this Technical Specification, the field size is set to 2°. The colour-matching functions of individual observers transformed from the cone fundamentals will be defined as individual CMFs, and they shall be used to compute the XYZ tristimulus values. Also, CIE CMFs which mean the functions $\bar{x}(\lambda)$, $\bar{y}(\lambda)$, $\bar{z}(\lambda)$ in the CIE 1931 standard colorimetric system will be called standard CMFs to distinguish them from the individual CMFs.

Since age is the only variable of the individual CMFs, age distribution data is necessary when deciding the weight of each individual CMFs. For the data on age distribution, only officially published data should be used. A representative example is the United Nations World Population Prospects data. Annex A shows an example of generating an individual CMFs dataset. Prepare a set of individual CMFs by referring to the method in Annex A and use it in the evaluation method.

6.2 Reference colours

To evaluate the observer-dependent colour rendering properties of a display, a set of reference colours to be compared with the DUT's spectral response to input test signals, is required. In this Technical Specification, the set is defined by the Macbeth colour checker patches 13-19 and the CIE D65 illuminant. Even though a variety of colour sets as reference colours have been used in the previous studies [2][3], only seven colours were selected as the reference colours. If it is necessary to evaluate a display using more colours, it is recommended to select a set of colours uniformly sampled in the CIE 1976 L*a*b* colour space with D65 as reference white.

For the illuminant of the reference colours, CIE standard illuminant D65 is used. The SPDs of the seven reference colours are summarised in Annex B. The D65 SPD in Annex B is normalised data, and in this Technical Specification, D65 SPD should be rescaled to have maximum luminance of the DUT.

6.3 Observer metamerism index

6.3.1 Purpose

The purpose of this method is to evaluate the observer metamerism of a display. See Annex E for a working example regarding the measurement and calculation process.

6.3.2 Measuring conditions

The following measuring conditions apply:

a) Apparatus: an LMD to measure spectral radiance and luminance of the DUT; a driving power source; a driving signal equipment; and a geometric mechanism as illustrated in Figure 2.

b) Standard measuring environmental conditions; dark-room conditions; standard setup conditions.

6.3.3 Measurement method

6.3.3.1 General

The evaluation method of observer metamerism index consists of five steps: SPD measurement, colour matching, XYZ computation, colour difference computation and reporting. The flowchart of the overall evaluation method is shown in the Figure 3.

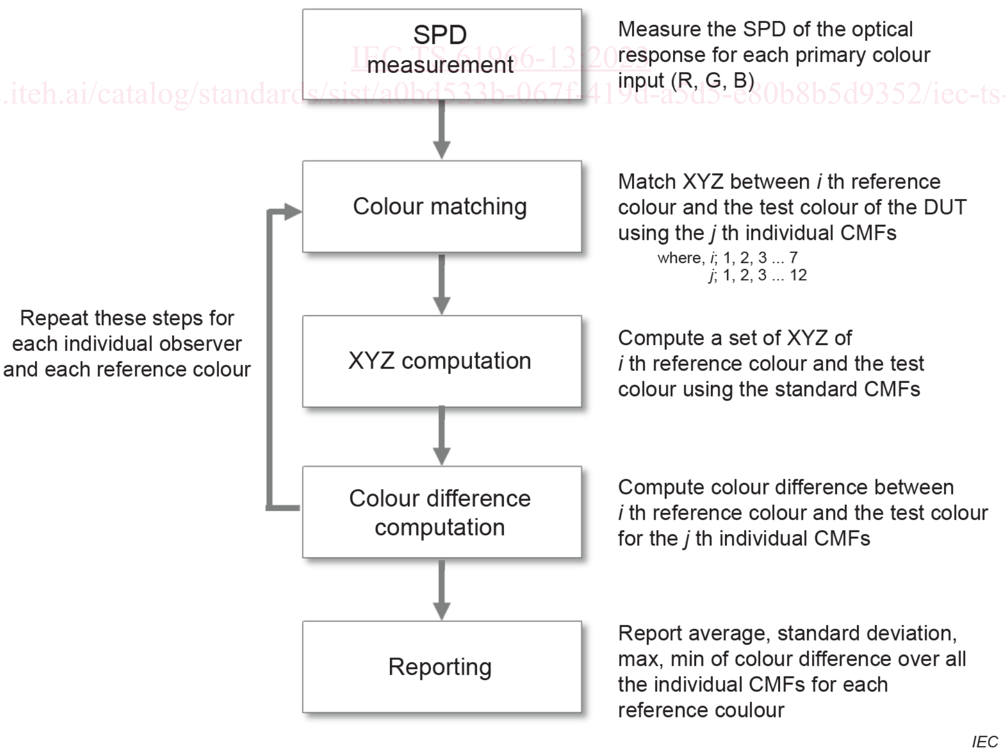


Figure 3 – Flowchart of the overall evaluation method