100/3928/DTS

DRAFT TECHNICAL SPECIFICATION (DTS)

PROJECT NUMBER: **IEC TS 61966-13 ED1**	
DATE OF CIRCULATION: **2023-05-12**	CLOSING DATE FOR VOTING: **2023-08-04**
SUPERSEDES DOCUMENTS: **100/3795/CD, 100/3911/CC**	

IEC TA 2 : COLOUR MEASUREMENT AND MANAGEMENT			
SECRETARIAT: United States of America	SECRETARY: Mr Michael Dolan		
OF INTEREST TO THE FOLLOWING COMMITTEES:			
FUNCTIONS CONCERNED:			
☐ EMC	☐ ENVIRONMENT	☐ QUALITY ASSURANCE	☐ SAFETY

This document is still under study and subject to change. It should not be used for reference purposes.

Recipients of this document are invited to submit, with their comments, notification of any relevant patent rights of which they are aware and to provide supporting documentation.

Recipients of this document are invited to submit, with their comments, notification of any local regulations or technical reasons that may exist and should be considered should this proposal proceed, recognizing that failure to address such requirements could result in the need for new or existing “In Some Countries” clauses. (SEE AC/22/2007 OR NEW GUIDANCE DOC).

TITLE:

Multimedia systems and equipment - Colour measurement and management - Part 13: Measurement method of Display Colour Properties Depending on Observers (TA 2)

PROPOSED STABILITY DATE: 2026

NOTE FROM TC/SC OFFICERS:

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

____

Measurement Method of Display Colour Properties Depending on Observers

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
6) All users should ensure that they have the latest edition of this publication.
7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

International Standard IEC XXXXX has been prepared by IEC technical committee 100: Audio, video and multimedia systems and equipment

The text of this standard is based on the following documents:

XXX	Report on voting
100/XXX/XXX	100/XXX/XXX

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 International Standard 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/standardsdev/publications.

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

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

INTRODUCTION

In colorimetry, metamerism or metameric failure is defined as a perceived matching of colours while two colours having 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 could 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). The observer model considering the age and the field size of observers different from the standard observer has already been standardised in the CIE (CIE Pub. 170-1:2006).

Meanwhile, display manufacturers and users have required the measuring methods of the OM which occurs in display uses. For example, as 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, 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.

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.

IEC 60050-845, *International Electrotechnical Vocabulary - Part 845:Lighting* (available at www.electropedia.org)

IEC 62977-2-1:2021, *Electronic displays - Part 2-1: Measurements of optical characteristics - Fundamental measurements*

CIE 015:2018, *Colorimetry, 4th Edition*

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. 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.[1]

3.1.2 Observer metamerism index

The value of colour difference due to observer metamerism characteristics of a display.

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

3.1.3 Optical radiant unit (ORU)

A unit in a display from which light of a distinct spectral power distribution is radiated.

Note 1: 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 optical-radiant-unit (ORU) display

Display with more than three optical radiant units with different spectral power distributions.

3.2 Abbreviations

For the purpose of this document, the following abbreviated terms apply.

ABC	Automatic brightness control
CCT	Correlated colour temperature
CIE	Commission Internationale de L'Eclairage (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

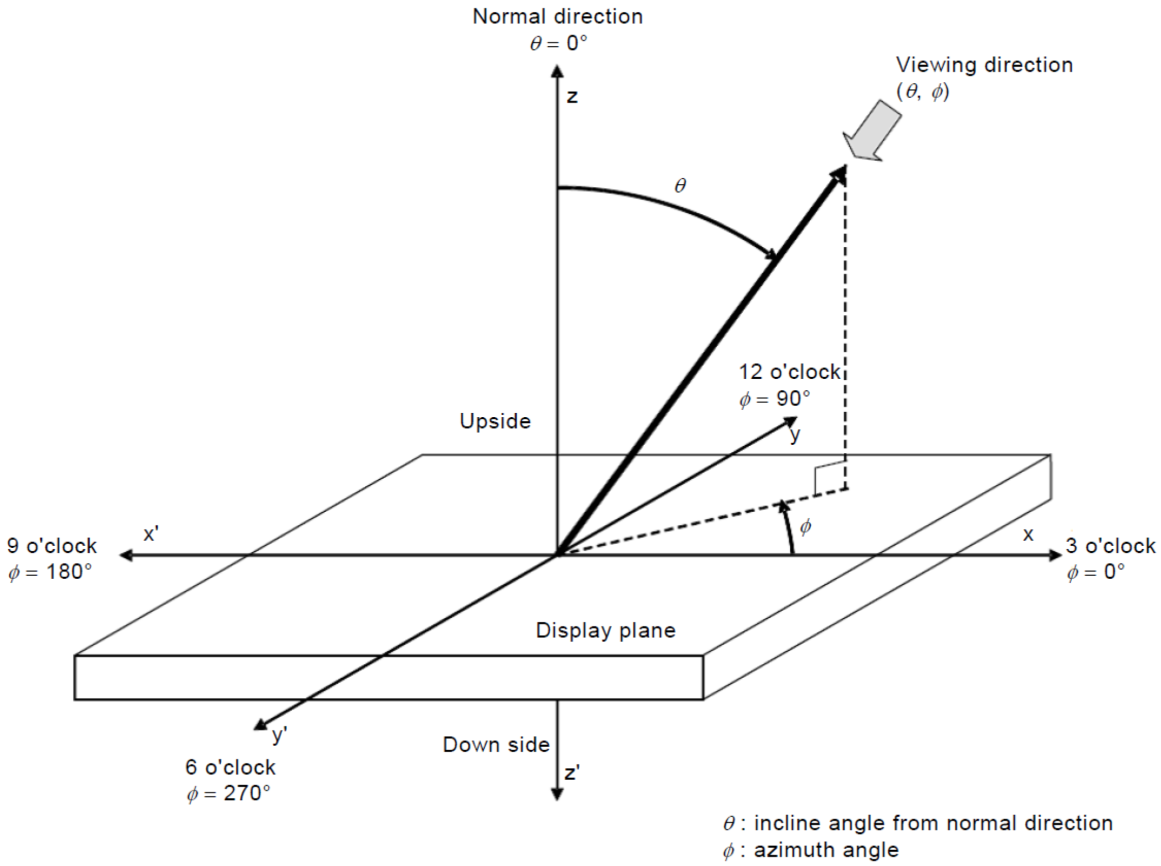
The system configurations and/or operating conditions of the measuring equipment shall comply with the structure specified in each item.

To ensure reliable measurements, the following requirements apply to the light measuring equipment, listed below:

1) Spectroradiometer: the wavelength range shall be 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 magnitudes. Details of this correction method are discussed in Reference [2]. If the obtained luminance is lower than LMD limitation, the lower limit of the LMD shall be recorded with measured luminance

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
- 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.

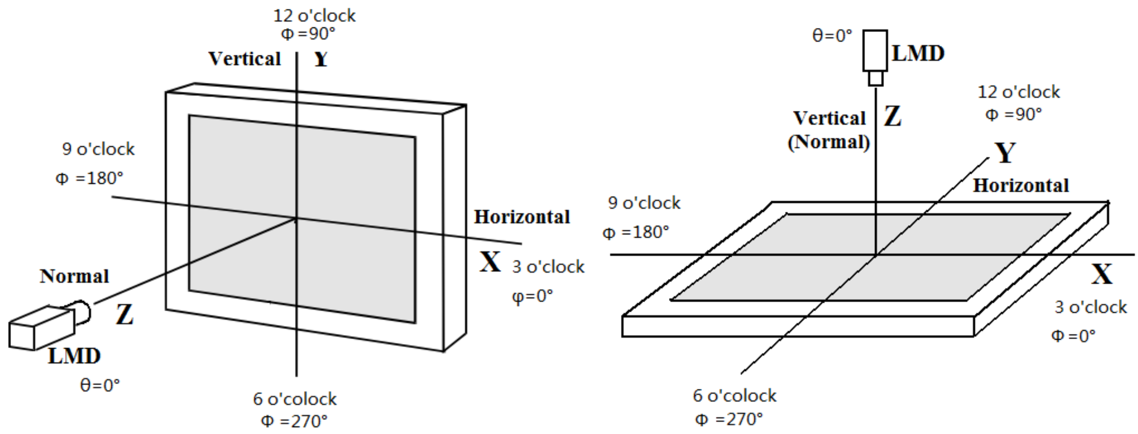
5.4 Standard measuring dark-room conditions

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 1s 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 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 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 will 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 it 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 United Nations world population prospect 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 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 [1] [4], 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.

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, a driving power supply, and driving signal equipment.

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

6.3.3 Measurement method

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.

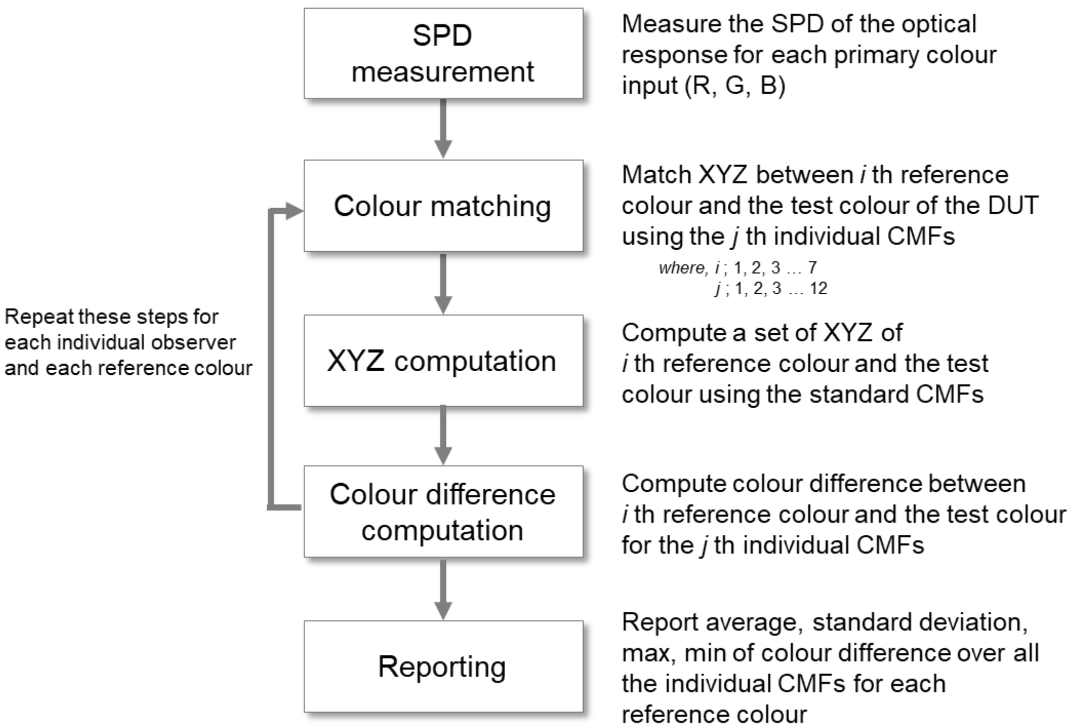


Figure 3 – Flowchart of the overall evaluation method

6.3.3.1 SPD measurement

1) Render the three area centre box patterns corresponding to normalised {R, G, B} input signals {1,0,0}, {0,1,0}, and {0,0,1} or, for 8-bit grey quantization, {255,0,0}, {0,255,0}, and {0,0,255}, respectively. Figure 4 shows an example of a centre box pattern with an APL of 4%. If the DUT exhibits loading, reduce the APL with a requirement of minimum 0.5%, making sure that the measurement field covers subpixels corresponding to at least 500 input pixels.

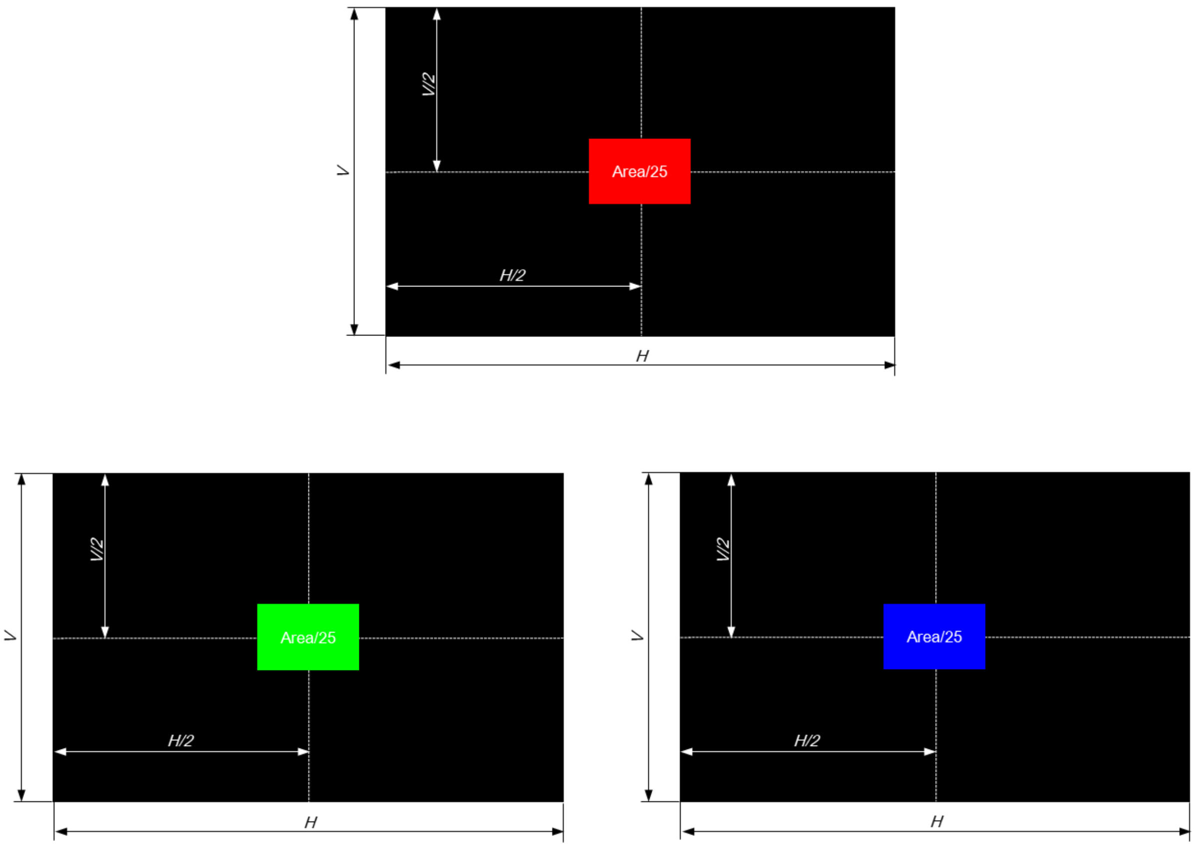


Figure 4 – 4% area centre box patterns of primary colours

2) Align the LMD perpendicular to the display surface (θ = 0, φ = 0), and position it to the centre of the display.

3) Measure the SPDs of the primary colours respectively at the screen centre.

6.3.3.2 Colour matching

4) Calculate the XYZ values of *i*th reference colour using individual CMFs, which stand for the CMFs of *j*th individual observer, as shown in equation (1). See Annex A for individual CMFs and Annex B for the SPDs of reference colours.

$$X'_{r(i,j)} = L_s \cdot k_j \int_{390}^{780} \Phi_{r(i)}(\lambda) \cdot \bar{x}'_j(\lambda)\, d\lambda$$
$$Y'_{r(i,j)} = L_s \cdot k_j \int_{390}^{780} \Phi_{r(i)}(\lambda) \cdot \bar{y}'_j(\lambda)\, d\lambda \qquad (1)$$

$$Z'_{r(i,j)} = L_s \cdot k_j \int_{390}^{780} \Phi_{r(i)}(\lambda) \cdot \bar{z}'_j(\lambda)\, d\lambda$$

where

$X'_{r(i,j)}$, $Y'_{r(i,j)}$ and $Z'_{r(i,j)}$ denote the XYZ values of *i*th reference colour using individual CMFs of *j*th individual observer;

$\bar{x}'_j(\lambda)$, $\bar{y}'_j(\lambda)$ and $\bar{z}'_j(\lambda)$ denote the CMFs of *j*th individual observer;

$\Phi_{r(i)}(\lambda)$ denotes the SPD of *i*th reference colour defined in equation (2);

$$\Phi_{r(i)}(\lambda) = S_{D65}(\lambda) \cdot R_i(\lambda) \tag{2}$$

where

$S_{D65}(\lambda)$ denotes the SPD of CIE Standard D_{65} illuminant;

$R_i(\lambda)$ denotes the spectral reflectance of the *i*th reference colour;

L_s is the scaling factor to match the normalised relative XYZ values of reference colours with the absolute XYZ values of the test colours of the DUT. Here, use the maximum luminance of the DUT as explained in 6.2;

k_j is the normalisation constant for *j*th individual observer and is defined in equation (3).

$$k_j = \frac{1}{\int_{390}^{780} S_{D65}(\lambda) \cdot \bar{y}'_j(\lambda) d\lambda} \tag{3}$$

5) Calculate the weighting factors of SPDs of the DUT response corresponding to the normalised inputs {1,0,0}, {0,1,0}, and {0,0,1}. The colour matching process can be expressed as equation (4) of adding up the SPDs to match the XYZ values of the DUT using the individual CMFs with the reference XYZ values calculated in 4). The weighting factors can be calculated by solving the linear matrix in equation (5) which is derived from equation(4).

$$\begin{bmatrix} X'_{r(i,j)} \\ Y'_{r(i,j)} \\ Z'_{r(i,j)} \end{bmatrix} = \begin{bmatrix} X'_{R(j)} & X'_{G(j)} & X'_{B(j)} \\ Y'_{R(j)} & Y'_{G(j)} & Y'_{B(j)} \\ Z'_{R(j)} & Z'_{G(j)} & Z'_{B(j)} \end{bmatrix} \cdot \begin{bmatrix} w_{R(i,j)} \\ w_{G(i,j)} \\ w_{B(i,j)} \end{bmatrix} \tag{4}$$

$$\begin{bmatrix} w_{R(i,j)} \\ w_{G(i,j)} \\ w_{B(i,j)} \end{bmatrix} = \begin{bmatrix} X'_{R(j)} & X'_{G(j)} & X'_{B(j)} \\ Y'_{R(j)} & Y'_{G(j)} & Y'_{B(j)} \\ Z'_{R(j)} & Z'_{G(j)} & Z'_{B(j)} \end{bmatrix}^{-1} \cdot \begin{bmatrix} X'_{r(i,j)} \\ Y'_{r(i,j)} \\ Z'_{r(i,j)} \end{bmatrix} \tag{5}$$

where

$w_{R(i,j)}$, $w_{G(i,j)}$ and $w_{B(i,j)}$ are the weighting factors calculated from the colour-matching;

$X'_{Q(j)}$, $Y'_{Q(j)}$ and $Z'_{Q(j)}$ (Q = R, G, B) are XYZ stimulus values of primary colours of the DUT using the jth individual observer, and defined in equation (6).

$$X'_{Q(j)} = 683 \int_{390}^{780} \Phi_Q(\lambda) \cdot \bar{x}'_j(\lambda)\, d\lambda \tag{6}$$

$$Y'_{Q(j)} = 683 \int_{390}^{780} \Phi_Q(\lambda) \cdot \bar{y}_j^{'}(\lambda)\, d\lambda$$

$$Z'_{Q(j)} = 683 \int_{390}^{780} \Phi_Q(\lambda) \cdot \bar{z}_j^{'}(\lambda)\, d\lambda$$

where

$\Phi_R(\lambda)$, $\Phi_G(\lambda)$ and $\Phi_B(\lambda)$ are the SPDs of the primary colours, and Q = R, G and B.

As a result, the SPD of the test colour of the DUT matched with the *i*th reference colour can be obtained.

$$\Phi_{t(i,j)}(\lambda) = \begin{bmatrix} w_{R(i,j)} & w_{G(i,j)} & w_{B(i,j)} \end{bmatrix} \cdot \begin{bmatrix} \Phi_R(\lambda) & \Phi_G(\lambda) & \Phi_B(\lambda) \end{bmatrix}^T \tag{7}$$

where

$\Phi_{t(i,j)}(\lambda)$ is the SPD of the test colour matched with the *i*th reference colour for *j*th individual observer.

In case the DUT has more than three ORUs, see Annex D.

6.3.3.3 XYZ computation

6) Calculate the XYZ values of *i*th reference colour using CIE 1931 standard colorimetric observer as shown in equation (8).

$$\begin{aligned} X_{r(i)} &= L_s \cdot k \int_{390}^{780} \Phi_{r(i)}(\lambda) \cdot \bar{x}(\lambda)\, d\lambda \\ Y_{r(i)} &= L_s \cdot k \int_{390}^{780} \Phi_{r(i)}(\lambda) \cdot \bar{y}(\lambda)\, d\lambda \\ Z_{r(i)} &= L_s \cdot k \int_{390}^{780} \Phi_{r(i)}(\lambda) \cdot \bar{z}(\lambda)\, d\lambda \end{aligned} \tag{8}$$

where

$X_{r(i)}$, $Y_{r(i)}$ and $Z_{r(i)}$ are the XYZ values of *i*th reference colour using CIE 1931 standard colorimetric observer;

L_s is the scaling factor and *k* is the normalisation constant for the CIE 1931 standard colorimetric observer defined as equation (9).

$$k = \frac{1}{\int_{390}^{780} S_{D65} \cdot \bar{y}(\lambda) d\lambda} \tag{9}$$

7) Calculate the XYZ values of the test colour using the SPD of the test colour obtained in equation (7) and the CIE 1931 standard colorimetric observer as shown in equation (10).

$$\begin{aligned} X_{t(i,j)} &= 683 \int_{390}^{780} \Phi_{t(i,j)}(\lambda) \cdot \bar{x}(\lambda)\, d\lambda \\ Y_{t(i,j)} &= 683 \int_{390}^{780} \Phi_{t(i,j)}(\lambda) \cdot \bar{y}(\lambda)\, d\lambda \end{aligned} \tag{10}$$

$$Z_{t(i,j)} = 683 \int_{390}^{780} \Phi_{t(i,j)}(\lambda) \cdot \bar{z}(\lambda)\, d\lambda$$

where

$X_{t(i,j)}$, $Y_{t(i,j)}$ and $Z_{t(i,j)}$ are the XYZ values of the test colour matched with *i*th reference colour for *j*th individual observer.

6.3.3.4 Colour difference computation

8) Transform both XYZ value sets obtained in steps 6) and 7) into the three-dimensional CIELAB colour space (per ISO 11664-4). The CIELAB L*, a* and b* values are calculated from the transformed tristimulus values using the following equations:

$$\begin{aligned} L^* &= 116 \cdot f\left(\frac{Y}{Y_n}\right) - 16 \\ a^* &= 500 \cdot \left[f\left(\frac{X}{X_n}\right) - f\left(\frac{Y}{Y_n}\right)\right] \\ b^* &= 200 \cdot \left[f\left(\frac{Y}{Y_n}\right) - f\left(\frac{Z}{Z_n}\right)\right] \end{aligned} \tag{11}$$

where

$$f(t) = \begin{Bmatrix} t^{1/3} & t < \left(\frac{6}{29}\right)^3 \\ \frac{1}{3}\left(\frac{29}{6}\right)^2 t + \frac{16}{116} & otherwise \end{Bmatrix} \tag{12}$$

and X_n, Y_n and Z_n are defined as XYZ tristimulus values of the reference white multiplied by the scaling factor L_s as shown in equation (13);

$$\begin{pmatrix} X_n \\ Y_n \\ Z_n \end{pmatrix} = L_s \cdot \begin{pmatrix} X_{Ref\_W} \\ Y_{Ref\_W} \\ Z_{Ref\_W} \end{pmatrix} \tag{13}$$

where

X_{Ref_W}, Y_{Ref_W} and Z_{Ref_W} are the normalised XYZ values of the reference white, that is the CIE Standard D_{65} illuminant.

$$\begin{aligned} X_{Ref\_W} &= k \int_{390}^{780} S_{D65}(\lambda) \cdot \bar{x}(\lambda)\, d\lambda \\ Y_{Ref\_W} &= k \int_{390}^{780} S_{D65}(\lambda) \cdot \bar{y}(\lambda)\, d\lambda \\ Z_{Ref\_W} &= k \int_{390}^{780} S_{D65}(\lambda) \cdot \bar{z}(\lambda)\, d\lambda \end{aligned} \tag{14}$$

9) Calculate the CIE DE2000 ΔE_{00} between the reference colour and the test colour according to following equations :

$$C^*_{i,ab} = \sqrt{(a^*_i)^2 + (b^*_i)^2} \tag{15}$$

$$\bar{C}^*_{ab} = \left(C^*_{1,ab} + C^*_{2,ab}\right)/2 \tag{16}$$

$$\mathrm{G} = 0.5\left(1 - \sqrt{\frac{(\bar{C}^*_{ab})^7}{(\bar{C}^*_{ab})^7 + 25^7}}\right) \tag{17}$$

$$a'_i = (1 + G)a^*_i \tag{18}$$

$$C'_i = \sqrt{(a'_i)^2 + (b^*_i)^2} \tag{19}$$

$$h'_i = \begin{Bmatrix} 0 & if\ b^*_i = a'_i = 0 \\ \tan^{-1}(b^*_i, a'_i) & otherwise \end{Bmatrix} \tag{20}$$

$$\Delta L' = L^*_2 - L^*_1 \tag{21}$$

$$\Delta C' = C'_2 - C'_1 \tag{22}$$

$$\Delta h'_i = \begin{cases} 0 & C'_2C'_1 = 0 & \\ h'_2 - h'_1 & C'_2C'_1 \neq 0 & |h'_2 - h'_1| \leq 180° \\ (h'_2 - h'_1) - 360 & C'_2C'_1 \neq 0 & (h'_2 - h'_1) > 180° \\ (h'_2 - h'_1) + 360 & C'_2C'_1 \neq 0 & (h'_2 - h'_1) < -180° \end{cases} \tag{23}$$

$$\Delta H' = 2\sqrt{C'_2C'_1}\sin\left(\frac{\Delta h'}{2}\right) \tag{24}$$

$$\overline{L'} = (L^*_2 - L^*_1)/2 \tag{25}$$

$$\overline{C'} = (C'_2 - C'_1)/2 \tag{26}$$

$$\bar{h'} = \begin{cases} \dfrac{h'_2 + h'_1}{2} & |h'_2 + h'_1| \leq 180° & C'_2C'_1 \neq 0 & C'_2C'_1 \neq 0 \\ \dfrac{h'_2 + h'_1 + 360°}{2} & |h'_2 + h'_1| > 180° & (h'_2 + h'_1) < 360° & C'_2C'_1 \neq 0 \\ \dfrac{h'_2 + h'_1 - 360°}{2} & |h'_2 + h'_1| > 180° & (h'_2 + h'_1) \geq 360° & C'_2C'_1 \neq 0 \\ h'_2 + h'_1 & & & C'_2C'_1 \neq 0 \end{cases} \tag{27}$$

$$T = 1 - 0.17\,cos\left(\bar{h'} - 30°\right) + 0.24\,cos\left(2\bar{h'}\right) + 0.32\,cos\left(3\bar{h'} + 6°\right) - 0.2\,cos\left(4\bar{h'} - 63°\right) \tag{28}$$

$$\Delta\theta = 30exp\left\{-\left(\frac{\bar{h}' - 275°}{25}\right)^2\right\} \tag{29}$$

$$R_C = 2\sqrt{\frac{\bar{C}'^7}{\bar{C}'^7 + 25^7}} \tag{30}$$

$$S_L = 1 + \frac{0.015(\bar{L}' - 50)^2}{\sqrt{20 + (\bar{L}' - 50)^2}} \tag{31}$$

$$S_C = 1 + 0.045\bar{C}' \tag{32}$$

$$S_H = 1 + 0.015\bar{C}'T \tag{33}$$

$$R_T = -\sin(2\Delta\theta)R_C \tag{34}$$

$$\Delta E_{00} = \sqrt{\left(\frac{\Delta L'}{k_L S_L}\right)^2 + \left(\frac{\Delta C'}{k_C S_C}\right)^2 + \left(\frac{\Delta H'}{k_H S_H}\right)^2 + R_T\left(\frac{\Delta C'}{k_C S_C}\right)\left(\frac{\Delta H'}{k_H S_H}\right)} \tag{35}$$

10) Repeat the process 4) ~ 10) for each individual observer.
11) Repeat the process 4) ~ 11) for each reference colour.

6.3.3.5 Reporting

12) Report maximum, minimum, average and standard deviation of CIE DE2000 ΔE_{00} values over all the individual observers (See Table 1).
13) Report maximum, minimum, average and standard deviation of CIE DE2000 ΔE_{00} values over all the individual observers and all the reference colours to provide a set of representative OMI values (See Table 1).

7 Reporting form

Report maximum, minimum, average and standard deviation values of OMI obtained in 6.3.3.5 using the form shown in Table 1. Also, present a graph showing the spectral plots of metameric pairs of reference colour and DUT as shown in Figure 5.

Table 1 – Reporting form of observer metamerism index

Reference colour (*i*=1~7)	Observer metamerism index			
	Maximum	Minimum	Average	Standard deviation
Macbeth white (1)				
Macbeth red (2)				
Macbeth green (3)				

Macbeth blue (4)				
Macbeth cyan (5)				
Macbeth magenta (6)				
Macbeth yellow (7)				
Total				

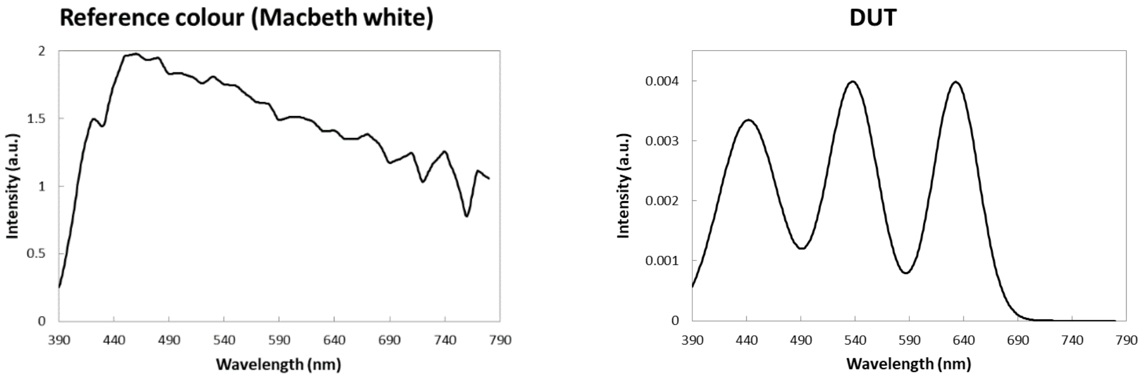


Figure 5 – Reporting example of a graph of colour-matched metameric pair of reference colour and DUT

Annex A
(informative)

Generating a set of individual CMFs

A.1 Age distribution data

When generating a set of individual CMFs using CIE 170-1 and 2, age and field size (F_s) data are required. Among them, F_s can be selected by the standard user in consideration of the application field and the use environment of the DUT. The 2° field size is recommended in this technical specification.

For age distribution data, officially published data could be used. For example, Table A.1 shows age distribution data published by the United Nations world population prospect. [6] Users of this technical specification can use various age distribution data depending on the purpose of measurement, but officially published data should be used. In the case of the CIE 170-1 model, only the age range of 20 to 80 is reflected. Therefore, it is possible to reflect only the age range of 20 to 80 years of age distribution data.

Table A.1 – Example of age distribution data published by the United Nations world population prospect

Location	World		
Time	2020		
Sex	Both		
0-4	677 942	9%	34%
5-9	664 439	9%	
10-14	641 267	8%	
15-19	612 196	8%	
20-24	597 388	8%	8%
25-29	594 692	8%	8%
30-34	605 531	8%	8%
35-39	544 819	7%	7%
40-44	493 789	6%	6%
45-49	479 366	6%	6%
50-54	445 773	6%	6%
55-59	387 849	5%	5%
60-64	322 142	4%	4%
65-69	269 644	3%	3%
70-74	188 677	2%	2%
75-79	123 782	2%	4%
80-84	81 930	1%	2%
85-89	42 186	1%	
90-94	16 680	0%	
95-99	4 134	0%	
100+	573	0%	
Total	7 794 799	100%	100%

Age distribution data determine the number of CMFs dataset. If the data is constructed by 1 year interval, the number of dataset would be more than 150 datasets. If the age interval is 10 years, you get 1/10 of the dataset compared to the first one. For a large number of datasets, the appropriate number of datasets should be applied to the number of iterations of the evaluation. Therefore, it is easy to use the evaluation method to reduce the number of datasets without distorting the statistical significance of the age distribution. In this technical specification, it is recommended to use at least 20 datasets.

A.2 Example of individual CMFs dataset

Table A.2 shows the example of age distribution data. The original data are distribution data consisting of 5-year intervals from 20 to 79 years old, and the total is 100%. The last column is the data in which the number of iterations is reduced without statistical distortion to simplify the measurement as described in A.1. If field size is fixed to 2° and using the reduced age distribution data, a total of 20 individual CMFs is generated and the Table A.3 shows the result.

Table A.2 – Example of age distribution data

Age	Original data [%]	Reduced data [%]
20-24	5%	1%
25-29	15%	3%
30-34	15%	3%
35-39	10%	2%
40-44	10%	2%
45-49	15%	3%
50-54	5%	1%
55-59	5%	1%
60-64	5%	1%
65-69	5%	1%
70-74	5%	1%
75-79	5%	1%
Total	100%	20%

The individual CMFs results using data of Table A.2 are shown in Table A.3 and Table A.4 to Table A.7. The Table A.4 to Table A.7 show the SPDs data of individual CMFs generated with the 2° field size and the median value of each age group (i.e. 22 in the case of 20 to 24), and Table A.3 shows the number of each age group or the corresponding individual CMFs. That number will be used as the weight when calculating average value of the OMI over the age groups or individual observers.

Table A.3 – Total number of individual CMFs example

Individual CMFs (j = 1 ~ 12)	Age range	Age group	Number
1	20-24	22	1
2	25-29	27	3
3	30-34	32	3
4	35-39	37	2
5	40-44	42	2

6	45-49	47	3
7	50-54	52	1
8	55-59	57	1
9	60-64	62	1
10	65-69	67	1
11	70-74	72	1
12	75-79	77	1
Total			20

The $\bar{x}$, $\bar{y}$, $\bar{z}$ data for each age group included in Table A.4 to Table A.7 are the calculated result using the 2° field size matrix in CIE 170-2. The cone fundamentals used in the calculation were calculated through the ocular media optical density function, which is a function reflecting age, and macular pigment optical density function, visual pigment optical density function, which is a function reflecting field size, referring to CIE 170-1. For details, please refer to CIE 170-1 and 170-2.

Note 1: 2° field size matrix in CIE 170-2 is only for the average observer (32-year-old). However, in this document the same matrix is used for all the age groups only to be used for the colour matching process.

Table A.4 – Spectral sensitivity data of the individual CMFs (Age group: 22, 27 and 32)

Age group	22			27			32		
Wavelength (nm)	$\bar{x}'_1$	$\bar{y}'_1$	$\bar{z}'_1$	$\bar{x}'_2$	$\bar{y}'_2$	$\bar{z}'_2$	$\bar{x}'_3$	$\bar{y}'_3$	$\bar{z}'_3$
390	0.00567	0.00068	0.02750	0.00502	0.00058	0.02451	0.00445	0.00049	0.02184
395	0.01237	0.00153	0.06015	0.01115	0.00131	0.05454	0.01005	0.00113	0.04942
400	0.02652	0.00322	0.13006	0.02433	0.00281	0.11994	0.02231	0.00246	0.11055
405	0.05485	0.00631	0.27171	0.05120	0.00561	0.25487	0.04779	0.00498	0.23894
410	0.10077	0.01123	0.50357	0.09536	0.01010	0.47863	0.09023	0.00909	0.45468
415	0.15791	0.01717	0.80074	0.15172	0.01568	0.77213	0.14575	0.01431	0.74416
420	0.21792	0.02390	1.12039	0.21147	0.02203	1.09045	0.20517	0.02030	1.06076
425	0.26188	0.03030	1.36844	0.25632	0.02816	1.34237	0.25083	0.02616	1.31610
430	0.30379	0.03813	1.61285	0.29896	0.03561	1.58968	0.29416	0.03324	1.56603
435	0.32991	0.04696	1.78599	0.32763	0.04423	1.77501	0.32531	0.04164	1.76318
440	0.35118	0.05615	1.93485	0.35117	0.05321	1.93485	0.35109	0.05041	1.93385
445	0.33990	0.06325	1.91165	0.34229	0.06033	1.92372	0.34464	0.05752	1.93485
450	0.31657	0.07048	1.82164	0.32084	0.06761	1.84338	0.32512	0.06483	1.86442
455	0.27487	0.07821	1.62759	0.27989	0.07532	1.65342	0.28499	0.07250	1.67879
460	0.23952	0.09142	1.47910	0.24497	0.08832	1.50733	0.25055	0.08528	1.53531
465	0.21185	0.11305	1.37864	0.21769	0.10958	1.40977	0.22375	0.10618	1.44085
470	0.17109	0.13798	1.20234	0.17643	0.13400	1.23189	0.18206	0.13009	1.26151
475	0.12106	0.16219	0.95551	0.12537	0.15794	0.98163	0.13005	0.15374	1.00793
480	0.07584	0.18810	0.71908	0.07879	0.18357	0.74036	0.08217	0.17907	0.76188
485	0.04225	0.21639	0.53277	0.04384	0.21157	0.54961	0.04592	0.20678	0.56668
490	0.01933	0.24850	0.38747	0.01958	0.24336	0.40040	0.02037	0.23824	0.41355
495	0.00781	0.29675	0.29258	0.00672	0.29110	0.30286	0.00626	0.28545	0.31334
500	0.00568	0.36160	0.22324	0.00309	0.35521	0.23142	0.00124	0.34880	0.23978
505	0.00978	0.44255	0.16101	0.00545	0.43545	0.16719	0.00199	0.42830	0.17353
510	0.02495	0.53644	0.10973	0.01869	0.52883	0.11417	0.01344	0.52113	0.11872
515	0.05585	0.63719	0.07694	0.04764	0.62933	0.08021	0.04058	0.62135	0.08357
520	0.09546	0.73516	0.05233	0.08541	0.72711	0.05463	0.07664	0.71890	0.05701
525	0.14517	0.81122	0.03465	0.13368	0.80346	0.03622	0.12353	0.79551	0.03785
530	0.20209	0.87299	0.02245	0.18948	0.86586	0.02351	0.17826	0.85849	0.02460
535	0.26220	0.92129	0.01439	0.24879	0.91482	0.01508	0.23678	0.90810	0.01580
540	0.33248	0.96662	0.00902	0.31851	0.96116	0.00947	0.30594	0.95544	0.00993
545	0.40321	0.99113	0.00560	0.38918	0.98691	0.00589	0.37652	0.98241	0.00619
550	0.47147	0.99599	0.00345	0.45786	0.99313	0.00363	0.44556	0.98998	0.00382
555	0.54899	1.00370	0.00211	0.53598	1.00219	0.00223	0.52422	1.00040	0.00235
560	0.63280	0.99872	0.00130	0.62065	0.99834	0.00137	0.60967	0.99768	0.00145
565	0.71874	0.98946	0.00080	0.70790	0.99043	0.00084	0.69813	0.99113	0.00089
570	0.81068	0.96984	0.00049	0.80157	0.97209	0.00052	0.79344	0.97409	0.00055
575	0.89538	0.93662	0.00030	0.88841	0.94003	0.00032	0.88231	0.94323	0.00034

580	0.96935	0.88845	0.00019	0.96490	0.89285	0.00020	0.96120	0.89708	0.00021
585	1.05208	0.84930	0.00012	1.05007	0.85440	0.00013	1.04870	0.85936	0.00014
590	1.10629	0.80093	0.00008	1.10677	0.80660	0.00008	1.10781	0.81216	0.00009
595	1.13569	0.74299	0.00005	1.13863	0.74902	0.00005	1.14204	0.75499	0.00006
600	1.14007	0.68051	0.00003	1.14473	0.68643	0.00003	1.14980	0.69229	0.00004
605	1.12072	0.61570	0.00002	1.12712	0.62156	0.00002	1.13386	0.62739	0.00002
610	1.06819	0.54764	0.00001	1.07560	0.55317	0.00002	1.08331	0.55870	0.00002
615	0.99071	0.47959	0.00001	0.99869	0.48472	0.00001	1.00693	0.48986	0.00001
620	0.89793	0.41403	0.00000	0.90589	0.41862	0.00000	0.91406	0.42322	0.00000
625	0.79793	0.35300	0.00000	0.80560	0.35705	0.00000	0.81344	0.36111	0.00000
630	0.67802	0.29116	0.00000	0.68515	0.29469	0.00000	0.69244	0.29824	0.00000
635	0.56260	0.23576	0.00000	0.56901	0.23877	0.00000	0.57556	0.24181	0.00000
640	0.46172	0.18928	0.00000	0.46739	0.19183	0.00000	0.47316	0.19441	0.00000
645	0.37500	0.15068	0.00000	0.37973	0.15274	0.00000	0.38455	0.15482	0.00000
650	0.29216	0.11613	0.00000	0.29594	0.11774	0.00000	0.29979	0.11937	0.00000
655	0.22180	0.08732	0.00000	0.22478	0.08857	0.00000	0.22783	0.08984	0.00000
660	0.16621	0.06484	0.00000	0.16850	0.06579	0.00000	0.17083	0.06674	0.00000
665	0.12299	0.04763	0.00000	0.12468	0.04832	0.00000	0.12641	0.04902	0.00000
670	0.08977	0.03461	0.00000	0.09101	0.03511	0.00000	0.09227	0.03562	0.00000
675	0.06461	0.02483	0.00000	0.06551	0.02519	0.00000	0.06642	0.02556	0.00000
680	0.04584	0.01758	0.00000	0.04647	0.01783	0.00000	0.04712	0.01809	0.00000
685	0.03203	0.01226	0.00000	0.03248	0.01244	0.00000	0.03293	0.01262	0.00000
690	0.02201	0.00842	0.00000	0.02232	0.00854	0.00000	0.02263	0.00867	0.00000
695	0.01533	0.00586	0.00000	0.01554	0.00595	0.00000	0.01576	0.00603	0.00000
700	0.01067	0.00408	0.00000	0.01082	0.00414	0.00000	0.01097	0.00420	0.00000
705	0.00740	0.00283	0.00000	0.00751	0.00287	0.00000	0.00761	0.00291	0.00000
710	0.00507	0.00194	0.00000	0.00514	0.00197	0.00000	0.00522	0.00200	0.00000
715	0.00347	0.00133	0.00000	0.00352	0.00135	0.00000	0.00357	0.00137	0.00000
720	0.00240	0.00092	0.00000	0.00243	0.00093	0.00000	0.00247	0.00095	0.00000
725	0.00166	0.00064	0.00000	0.00168	0.00065	0.00000	0.00170	0.00065	0.00000
730	0.00115	0.00044	0.00000	0.00117	0.00045	0.00000	0.00119	0.00046	0.00000
735	0.00081	0.00031	0.00000	0.00082	0.00031	0.00000	0.00083	0.00032	0.00000
740	0.00056	0.00022	0.00000	0.00057	0.00022	0.00000	0.00058	0.00022	0.00000
745	0.00040	0.00015	0.00000	0.00040	0.00015	0.00000	0.00041	0.00016	0.00000
750	0.00028	0.00011	0.00000	0.00028	0.00011	0.00000	0.00029	0.00011	0.00000
755	0.00020	0.00008	0.00000	0.00020	0.00008	0.00000	0.00020	0.00008	0.00000
760	0.00014	0.00005	0.00000	0.00014	0.00006	0.00000	0.00014	0.00006	0.00000
765	0.00010	0.00004	0.00000	0.00010	0.00004	0.00000	0.00010	0.00004	0.00000
770	0.00007	0.00003	0.00000	0.00007	0.00003	0.00000	0.00007	0.00003	0.00000
775	0.00005	0.00002	0.00000	0.00005	0.00002	0.00000	0.00005	0.00002	0.00000
780	0.00004	0.00001	0.00000	0.00004	0.00002	0.00000	0.00004	0.00002	0.00000

Table A.5 – Spectral sensitivity data of the individual CMFs (Age group: 37, 42 and 47)

Age group	37			42			47		
Wavelength (nm)	$\bar{x}'_4$	$\bar{y}'_4$	$\bar{z}'_4$	$\bar{x}'_5$	$\bar{y}'_5$	$\bar{z}'_5$	$\bar{x}'_6$	$\bar{y}'_6$	$\bar{z}'_6$
390	0.00392	0.00041	0.01934	0.00346	0.00035	0.01713	0.00305	0.00029	0.01517
395	0.00901	0.00097	0.04452	0.00808	0.00083	0.04011	0.00725	0.00071	0.03614
400	0.02036	0.00214	0.10131	0.01858	0.00187	0.09284	0.01697	0.00163	0.08508
405	0.04438	0.00442	0.22273	0.04122	0.00393	0.20761	0.03829	0.00349	0.19352
410	0.08493	0.00818	0.42944	0.07996	0.00736	0.40560	0.07529	0.00662	0.38309
415	0.13927	0.01307	0.71307	0.13310	0.01193	0.68328	0.12722	0.01089	0.65473
420	0.19799	0.01871	1.02593	0.19108	0.01724	0.99226	0.18445	0.01589	0.95968
425	0.24410	0.02430	1.28293	0.23758	0.02258	1.25059	0.23126	0.02097	1.21907
430	0.28780	0.03103	1.53385	0.28161	0.02897	1.50234	0.27557	0.02704	1.47147
435	0.32114	0.03921	1.74135	0.31706	0.03691	1.71979	0.31304	0.03475	1.69850
440	0.34893	0.04776	1.92172	0.34682	0.04525	1.90967	0.34474	0.04287	1.89769
445	0.34492	0.05485	1.93485	0.34521	0.05229	1.93485	0.34551	0.04986	1.93485
450	0.32741	0.06216	1.87484	0.32974	0.05960	1.88532	0.33209	0.05715	1.89586
455	0.28832	0.06979	1.69474	0.29171	0.06718	1.71083	0.29514	0.06466	1.72709
460	0.25456	0.08235	1.55481	0.25864	0.07953	1.57456	0.26279	0.07680	1.59455
465	0.22838	0.10288	1.46414	0.23311	0.09969	1.48781	0.23794	0.09660	1.51187
470	0.18647	0.12630	1.28441	0.19100	0.12262	1.30772	0.19564	0.11904	1.33146
475	0.13380	0.14965	1.02899	0.13769	0.14567	1.05048	0.14171	0.14180	1.07243
480	0.08489	0.17468	0.77950	0.08774	0.17040	0.79753	0.09074	0.16623	0.81599
485	0.04754	0.20210	0.58093	0.04931	0.19752	0.59553	0.05122	0.19305	0.61050

490	0.02087	0.23323	0.42467	0.02151	0.22833	0.43609	0.02230	0.22354	0.44781
495	0.00562	0.27991	0.32232	0.00513	0.27448	0.33155	0.00480	0.26916	0.34104
500	-0.00069	0.34251	0.24701	-0.00246	0.33634	0.25446	-0.00405	0.33028	0.26213
505	-0.00146	0.42127	0.17906	-0.00474	0.41436	0.18478	-0.00783	0.40757	0.19067
510	0.00827	0.51355	0.12275	0.00328	0.50609	0.12692	-0.00152	0.49874	0.13122
515	0.03362	0.61348	0.08658	0.02687	0.60571	0.08969	0.02031	0.59805	0.09291
520	0.06800	0.71079	0.05914	0.05956	0.70278	0.06136	0.05133	0.69487	0.06366
525	0.11353	0.78765	0.03933	0.10372	0.77987	0.04086	0.09410	0.77218	0.04246
530	0.16719	0.85121	0.02560	0.15629	0.84399	0.02663	0.14556	0.83684	0.02771
535	0.22492	0.90143	0.01646	0.21320	0.89483	0.01715	0.20164	0.88829	0.01787
540	0.29350	0.94976	0.01036	0.28117	0.94413	0.01081	0.26897	0.93854	0.01128
545	0.36395	0.97794	0.00646	0.35147	0.97350	0.00675	0.33908	0.96909	0.00706
550	0.43331	0.98684	0.00400	0.42112	0.98373	0.00419	0.40898	0.98065	0.00438
555	0.51247	0.99862	0.00246	0.50075	0.99685	0.00258	0.48904	0.99510	0.00270
560	0.59868	0.99703	0.00152	0.58769	0.99640	0.00159	0.57669	0.99577	0.00167
565	0.68834	0.99184	0.00094	0.67850	0.99257	0.00098	0.66863	0.99330	0.00103
570	0.78525	0.97611	0.00058	0.77700	0.97814	0.00061	0.76869	0.98019	0.00064
575	0.87614	0.94645	0.00036	0.86989	0.94970	0.00038	0.86357	0.95296	0.00040
580	0.95742	0.90134	0.00023	0.95356	0.90562	0.00024	0.94962	0.90994	0.00025
585	1.04727	0.86436	0.00014	1.04577	0.86940	0.00015	1.04419	0.87447	0.00016
590	1.10880	0.81777	0.00009	1.10972	0.82343	0.00010	1.11059	0.82913	0.00010
595	1.14542	0.76101	0.00006	1.14876	0.76708	0.00006	1.15207	0.77321	0.00007
600	1.15485	0.69822	0.00004	1.15990	0.70420	0.00004	1.16493	0.71023	0.00004
605	1.14061	0.63328	0.00003	1.14739	0.63923	0.00003	1.15417	0.64524	0.00003
610	1.09105	0.56428	0.00002	1.09882	0.56992	0.00002	1.10664	0.57562	0.00002
615	1.01522	0.49506	0.00001	1.02356	0.50032	0.00001	1.03196	0.50563	0.00001
620	0.92229	0.42787	0.00000	0.93058	0.43258	0.00000	0.93894	0.43734	0.00000
625	0.82135	0.36523	0.00000	0.82933	0.36939	0.00000	0.83738	0.37360	0.00000
630	0.69979	0.30184	0.00000	0.70722	0.30548	0.00000	0.71472	0.30916	0.00000
635	0.58217	0.24490	0.00000	0.58885	0.24802	0.00000	0.59561	0.25118	0.00000
640	0.47900	0.19702	0.00000	0.48491	0.19967	0.00000	0.49089	0.20235	0.00000
645	0.38943	0.15693	0.00000	0.39437	0.15906	0.00000	0.39937	0.16123	0.00000
650	0.30368	0.12102	0.00000	0.30762	0.12270	0.00000	0.31162	0.12440	0.00000
655	0.23091	0.09113	0.00000	0.23403	0.09243	0.00000	0.23720	0.09375	0.00000
660	0.17319	0.06771	0.00000	0.17558	0.06870	0.00000	0.17801	0.06970	0.00000
665	0.12816	0.04973	0.00000	0.12994	0.05046	0.00000	0.13174	0.05119	0.00000
670	0.09355	0.03613	0.00000	0.09485	0.03666	0.00000	0.09616	0.03719	0.00000
675	0.06734	0.02593	0.00000	0.06828	0.02630	0.00000	0.06922	0.02668	0.00000
680	0.04777	0.01835	0.00000	0.04844	0.01862	0.00000	0.04911	0.01889	0.00000
685	0.03339	0.01281	0.00000	0.03385	0.01299	0.00000	0.03432	0.01318	0.00000
690	0.02294	0.00879	0.00000	0.02326	0.00892	0.00000	0.02359	0.00905	0.00000
695	0.01598	0.00612	0.00000	0.01620	0.00621	0.00000	0.01643	0.00630	0.00000
700	0.01112	0.00426	0.00000	0.01128	0.00432	0.00000	0.01144	0.00438	0.00000
705	0.00772	0.00295	0.00000	0.00782	0.00300	0.00000	0.00793	0.00304	0.00000
710	0.00529	0.00203	0.00000	0.00536	0.00206	0.00000	0.00544	0.00208	0.00000
715	0.00362	0.00139	0.00000	0.00367	0.00141	0.00000	0.00372	0.00143	0.00000
720	0.00250	0.00096	0.00000	0.00254	0.00097	0.00000	0.00257	0.00099	0.00000
725	0.00173	0.00066	0.00000	0.00175	0.00067	0.00000	0.00178	0.00068	0.00000
730	0.00120	0.00046	0.00000	0.00122	0.00047	0.00000	0.00124	0.00048	0.00000
735	0.00084	0.00032	0.00000	0.00085	0.00033	0.00000	0.00086	0.00033	0.00000
740	0.00058	0.00023	0.00000	0.00059	0.00023	0.00000	0.00060	0.00023	0.00000
745	0.00041	0.00016	0.00000	0.00042	0.00016	0.00000	0.00042	0.00016	0.00000
750	0.00029	0.00011	0.00000	0.00029	0.00011	0.00000	0.00030	0.00012	0.00000
755	0.00021	0.00008	0.00000	0.00021	0.00008	0.00000	0.00021	0.00008	0.00000
760	0.00015	0.00006	0.00000	0.00015	0.00006	0.00000	0.00015	0.00006	0.00000
765	0.00010	0.00004	0.00000	0.00011	0.00004	0.00000	0.00011	0.00004	0.00000
770	0.00008	0.00003	0.00000	0.00008	0.00003	0.00000	0.00008	0.00003	0.00000
775	0.00005	0.00002	0.00000	0.00005	0.00002	0.00000	0.00006	0.00002	0.00000
780	0.00004	0.00002	0.00000	0.00004	0.00002	0.00000	0.00004	0.00002	0.00000

Table A.6 – Spectral sensitivity data of the individual CMFs (Age group: 52, 57 and 62)

Age group	52			57			62		
Wavelength (nm)	$\bar{x}'_7$	$\bar{y}'_7$	$\bar{z}'_7$	$\bar{x}'_8$	$\bar{y}'_8$	$\bar{z}'_8$	$\bar{x}'_9$	$\bar{y}'_9$	$\bar{z}'_9$
390	0.00269	0.00025	0.01344	0.00238	0.00021	0.01191	0.00186	0.00015	0.00940
395	0.00651	0.00061	0.03256	0.00584	0.00053	0.02934	0.00474	0.00039	0.02394

400	0.01549	0.00143	0.07796	0.01415	0.00124	0.07145	0.01186	0.00096	0.06025
405	0.03558	0.00309	0.18038	0.03307	0.00275	0.16814	0.02866	0.00218	0.14654
410	0.07091	0.00596	0.36183	0.06679	0.00536	0.34175	0.05942	0.00436	0.30553
415	0.12162	0.00994	0.62738	0.11629	0.00908	0.60117	0.10647	0.00760	0.55268
420	0.17806	0.01464	0.92818	0.17192	0.01350	0.89771	0.16039	0.01151	0.84027
425	0.22514	0.01948	1.18834	0.21920	0.01810	1.15838	0.20783	0.01568	1.10085
430	0.26969	0.02525	1.44123	0.26397	0.02357	1.41162	0.25280	0.02061	1.35394
435	0.30910	0.03272	1.67747	0.30524	0.03081	1.65670	0.29736	0.02738	1.61472
440	0.34269	0.04062	1.88579	0.34067	0.03848	1.87396	0.33616	0.03462	1.84839
445	0.34583	0.04754	1.93485	0.34616	0.04533	1.93485	0.34610	0.04129	1.93182
450	0.33446	0.05480	1.90646	0.33686	0.05254	1.91711	0.34080	0.04839	1.93485
455	0.29861	0.06225	1.74349	0.30213	0.05992	1.76005	0.30832	0.05560	1.78972
460	0.26700	0.07416	1.61480	0.27128	0.07162	1.63531	0.27900	0.06687	1.67309
465	0.24287	0.09361	1.53631	0.24789	0.09070	1.56114	0.25712	0.08524	1.60780
470	0.20041	0.11558	1.35563	0.20529	0.11221	1.38024	0.21425	0.10585	1.42686
475	0.14586	0.13803	1.09483	0.15014	0.13437	1.11770	0.15801	0.12740	1.16147
480	0.09387	0.16216	0.83486	0.09715	0.15820	0.85418	0.10306	0.15061	0.89141
485	0.05328	0.18869	0.62584	0.05547	0.18443	0.64157	0.05926	0.17623	0.67207
490	0.02324	0.21885	0.45985	0.02431	0.21426	0.47222	0.02587	0.20538	0.49630
495	0.00462	0.26394	0.35081	0.00459	0.25883	0.36086	0.00389	0.24890	0.38052
500	-0.00548	0.32434	0.27003	-0.00675	0.31851	0.27817	-0.01003	0.30711	0.29416
505	-0.01074	0.40090	0.19676	-0.01348	0.39434	0.20304	-0.01985	0.38144	0.21542
510	-0.00612	0.49151	0.13567	-0.01055	0.48439	0.14028	-0.02051	0.47025	0.14939
515	0.01395	0.59049	0.09625	0.00777	0.58304	0.09971	-0.00598	0.56809	0.10659
520	0.04328	0.68706	0.06604	0.03543	0.67935	0.06852	0.01803	0.66372	0.07345
525	0.08466	0.76458	0.04411	0.07541	0.75705	0.04583	0.05493	0.74165	0.04927
530	0.13500	0.82977	0.02883	0.12460	0.82276	0.03000	0.10155	0.80820	0.03235
535	0.19022	0.88180	0.01861	0.17896	0.87537	0.01939	0.15390	0.86180	0.02096
540	0.25690	0.93299	0.01177	0.24495	0.92749	0.01228	0.21819	0.91556	0.01331
545	0.32678	0.96471	0.00737	0.31457	0.96036	0.00770	0.28702	0.95056	0.00837
550	0.39690	0.97758	0.00458	0.38488	0.97453	0.00480	0.35745	0.96716	0.00523
555	0.47736	0.99337	0.00283	0.46570	0.99165	0.00297	0.43872	0.98677	0.00324
560	0.56568	0.99516	0.00175	0.55467	0.99456	0.00184	0.52876	0.99179	0.00201
565	0.65873	0.99405	0.00109	0.64879	0.99481	0.00114	0.62476	0.99464	0.00125
570	0.76032	0.98225	0.00067	0.75190	0.98433	0.00071	0.73065	0.98669	0.00078
575	0.85718	0.95624	0.00042	0.85071	0.95955	0.00044	0.83318	0.96430	0.00049
580	0.94561	0.91428	0.00027	0.94151	0.91866	0.00028	0.92862	0.92552	0.00031
585	1.04254	0.87959	0.00017	1.04082	0.88474	0.00018	1.03256	0.89314	0.00020
590	1.11140	0.83487	0.00011	1.11215	0.84067	0.00011	1.10882	0.85038	0.00013
595	1.15534	0.77939	0.00007	1.15858	0.78563	0.00007	1.16028	0.79628	0.00008
600	1.16994	0.71633	0.00005	1.17494	0.72248	0.00005	1.18037	0.73305	0.00005
605	1.16097	0.65131	0.00003	1.16778	0.65744	0.00003	1.17706	0.66809	0.00004
610	1.11448	0.58138	0.00002	1.12237	0.58721	0.00002	1.13412	0.59737	0.00002
615	1.04041	0.51100	0.00001	1.04892	0.51643	0.00001	1.06229	0.52597	0.00002
620	0.94736	0.44215	0.00000	0.95585	0.44702	0.00000	0.96961	0.45559	0.00000
625	0.84550	0.37786	0.00000	0.85370	0.38217	0.00000	0.86727	0.38977	0.00000
630	0.72230	0.31290	0.00000	0.72995	0.31667	0.00000	0.74289	0.32338	0.00000
635	0.60245	0.25438	0.00000	0.60935	0.25762	0.00000	0.62122	0.26341	0.00000
640	0.49694	0.20507	0.00000	0.50306	0.20782	0.00000	0.51372	0.21277	0.00000
645	0.40443	0.16343	0.00000	0.40956	0.16566	0.00000	0.41853	0.16966	0.00000
650	0.31566	0.12612	0.00000	0.31975	0.12787	0.00000	0.32695	0.13101	0.00000
655	0.24040	0.09510	0.00000	0.24365	0.09646	0.00000	0.24940	0.09891	0.00000
660	0.18047	0.07071	0.00000	0.18296	0.07174	0.00000	0.18738	0.07359	0.00000
665	0.13356	0.05193	0.00000	0.13541	0.05268	0.00000	0.13870	0.05405	0.00000
670	0.09750	0.03773	0.00000	0.09885	0.03828	0.00000	0.10125	0.03926	0.00000
675	0.07019	0.02707	0.00000	0.07116	0.02746	0.00000	0.07289	0.02817	0.00000
680	0.04979	0.01916	0.00000	0.05049	0.01944	0.00000	0.05172	0.01994	0.00000
685	0.03480	0.01337	0.00000	0.03528	0.01356	0.00000	0.03615	0.01391	0.00000
690	0.02392	0.00918	0.00000	0.02425	0.00931	0.00000	0.02484	0.00955	0.00000
695	0.01665	0.00639	0.00000	0.01689	0.00648	0.00000	0.01730	0.00665	0.00000
700	0.01159	0.00445	0.00000	0.01176	0.00451	0.00000	0.01204	0.00463	0.00000
705	0.00804	0.00309	0.00000	0.00816	0.00313	0.00000	0.00835	0.00321	0.00000
710	0.00551	0.00212	0.00000	0.00559	0.00215	0.00000	0.00573	0.00220	0.00000
715	0.00377	0.00145	0.00000	0.00383	0.00147	0.00000	0.00392	0.00151	0.00000
720	0.00261	0.00100	0.00000	0.00264	0.00102	0.00000	0.00271	0.00104	0.00000
725	0.00180	0.00069	0.00000	0.00183	0.00070	0.00000	0.00187	0.00072	0.00000
730	0.00125	0.00048	0.00000	0.00127	0.00049	0.00000	0.00130	0.00050	0.00000
735	0.00087	0.00034	0.00000	0.00089	0.00034	0.00000	0.00091	0.00035	0.00000
740	0.00061	0.00024	0.00000	0.00062	0.00024	0.00000	0.00063	0.00025	0.00000

745	0.00043	0.00017	0.00000	0.00044	0.00017	0.00000	0.00045	0.00017	0.00000
750	0.00030	0.00012	0.00000	0.00031	0.00012	0.00000	0.00031	0.00012	0.00000
755	0.00021	0.00008	0.00000	0.00022	0.00008	0.00000	0.00022	0.00009	0.00000
760	0.00015	0.00006	0.00000	0.00015	0.00006	0.00000	0.00016	0.00006	0.00000
765	0.00011	0.00004	0.00000	0.00011	0.00004	0.00000	0.00011	0.00004	0.00000
770	0.00008	0.00003	0.00000	0.00008	0.00003	0.00000	0.00008	0.00003	0.00000
775	0.00006	0.00002	0.00000	0.00006	0.00002	0.00000	0.00006	0.00002	0.00000
780	0.00004	0.00002	0.00000	0.00004	0.00002	0.00000	0.00004	0.00002	0.00000

Table A.7 – Spectral sensitivity data of the individual CMFs (Age group: 67, 72 and 77)

Age group	67			72			77		
Wavelength (nm)	$\bar{x}'_{10}$	$\bar{y}'_{10}$	$\bar{z}'_{10}$	$\bar{x}'_{11}$	$\bar{y}'_{11}$	$\bar{z}'_{11}$	$\bar{x}'_{12}$	$\bar{y}'_{12}$	$\bar{z}'_{12}$
390	0.00121	0.00008	0.00616	0.00079	0.00005	0.00403	0.00051	0.00003	0.00264
395	0.00325	0.00023	0.01659	0.00224	0.00014	0.01150	0.00154	0.00008	0.00797
400	0.00862	0.00061	0.04420	0.00628	0.00038	0.03243	0.00458	0.00024	0.02379
405	0.02208	0.00146	0.11378	0.01703	0.00098	0.08835	0.01315	0.00065	0.06860
410	0.04787	0.00306	0.24790	0.03862	0.00215	0.20114	0.03119	0.00149	0.16320
415	0.09013	0.00559	0.47053	0.07638	0.00412	0.40060	0.06478	0.00301	0.34106
420	0.14021	0.00874	0.73790	0.12269	0.00664	0.64800	0.10744	0.00501	0.56906
425	0.18673	0.01223	0.99238	0.16792	0.00954	0.89460	0.15112	0.00739	0.80645
430	0.23106	0.01635	1.24010	0.21134	0.01297	1.13583	0.19344	0.01021	1.04033
435	0.27981	0.02234	1.52048	0.26345	0.01823	1.43173	0.24821	0.01476	1.34817
440	0.32328	0.02885	1.77667	0.31105	0.02404	1.70774	0.29948	0.01988	1.64148
445	0.34037	0.03514	1.89624	0.33486	0.02992	1.86131	0.32966	0.02527	1.82703
450	0.34193	0.04197	1.93485	0.34317	0.03641	1.93485	0.34465	0.03134	1.93485
455	0.31385	0.04886	1.81302	0.31958	0.04294	1.83663	0.32567	0.03745	1.86055
460	0.28766	0.05939	1.71287	0.29669	0.05275	1.75359	0.30631	0.04650	1.79528
465	0.26880	0.07657	1.66489	0.28115	0.06880	1.72401	0.29447	0.06134	1.78522
470	0.22619	0.09569	1.48718	0.23899	0.08653	1.55005	0.25303	0.07764	1.61558
475	0.16899	0.11619	1.22146	0.18106	0.10600	1.28455	0.19469	0.09595	1.35089
480	0.11156	0.13835	0.94434	0.12131	0.12711	1.00042	0.13281	0.11589	1.05982
485	0.06480	0.16290	0.71663	0.07170	0.15062	0.76414	0.08050	0.13819	0.81481
490	0.02811	0.19090	0.53223	0.03179	0.17747	0.57076	0.03751	0.16372	0.61208
495	0.00266	0.23261	0.41040	0.00302	0.21744	0.44263	0.00562	0.20169	0.47738
500	-0.01534	0.28835	0.31881	-0.01886	0.27079	0.34553	-0.01987	0.25234	0.37449
505	-0.03019	0.36010	0.23481	-0.03851	0.34003	0.25594	-0.04406	0.31860	0.27897
510	-0.03680	0.44675	0.16390	-0.05089	0.42450	0.17982	-0.06198	0.40026	0.19728
515	-0.02868	0.54309	0.11771	-0.04906	0.51929	0.12999	-0.06630	0.49272	0.14354
520	-0.01091	0.63748	0.08151	-0.03744	0.61240	0.09045	-0.06082	0.58378	0.10037
525	0.02059	0.71565	0.05494	-0.01138	0.69070	0.06127	-0.04041	0.66149	0.06832
530	0.06260	0.78350	0.03625	0.02589	0.75970	0.04062	-0.00830	0.73097	0.04552
535	0.11131	0.83867	0.02358	0.07077	0.81633	0.02653	0.03226	0.78847	0.02985
540	0.17238	0.89513	0.01505	0.12832	0.87532	0.01701	0.08560	0.84937	0.01924
545	0.23949	0.93364	0.00951	0.19333	0.91720	0.01081	0.14766	0.89413	0.01228
550	0.30975	0.95433	0.00597	0.26300	0.94185	0.00682	0.21578	0.92238	0.00778
555	0.39141	0.97813	0.00372	0.34461	0.96976	0.00427	0.29628	0.95407	0.00490
560	0.48297	0.98676	0.00232	0.43733	0.98194	0.00267	0.38907	0.96963	0.00308
565	0.58187	0.99404	0.00145	0.53871	0.99363	0.00168	0.49169	0.98558	0.00194
570	0.69225	0.99047	0.00091	0.65322	0.99443	0.00106	0.60902	0.99074	0.00123
575	0.80099	0.97223	0.00057	0.76788	0.98039	0.00067	0.72835	0.98102	0.00078
580	0.90433	0.93716	0.00036	0.87894	0.94909	0.00043	0.84601	0.95378	0.00050
585	1.01625	0.90747	0.00023	0.99882	0.92218	0.00027	0.97278	0.92992	0.00032
590	1.10108	0.86705	0.00015	1.09230	0.88416	0.00018	1.07416	0.89468	0.00021
595	1.16143	0.81466	0.00010	1.16172	0.83356	0.00012	1.15219	0.84633	0.00014
600	1.18821	0.75131	0.00006	1.19544	0.77013	0.00008	1.19278	0.78333	0.00009
605	1.19184	0.68653	0.00004	1.20630	0.70556	0.00005	1.21101	0.71953	0.00006
610	1.15345	0.61501	0.00003	1.17274	0.63324	0.00003	1.18275	0.64696	0.00004
615	1.08470	0.54255	0.00002	1.10731	0.55970	0.00002	1.12135	0.57293	0.00003
620	0.99289	0.47050	0.00000	1.01653	0.48594	0.00000	1.03246	0.49801	0.00000
625	0.89042	0.40303	0.00000	0.91404	0.41676	0.00000	0.93087	0.42762	0.00000
630	0.76510	0.33509	0.00000	0.78788	0.34725	0.00000	0.80493	0.35706	0.00000
635	0.64171	0.27355	0.00000	0.66280	0.28409	0.00000	0.67920	0.29275	0.00000
640	0.53221	0.22144	0.00000	0.55132	0.23048	0.00000	0.56663	0.23803	0.00000
645	0.43413	0.17668	0.00000	0.45029	0.18400	0.00000	0.46337	0.19014	0.00000
650	0.33950	0.13652	0.00000	0.35250	0.14228	0.00000	0.36312	0.14713	0.00000

655	0.25944	0.10324	0.00000	0.26987	0.10775	0.00000	0.27852	0.11159	0.00000
660	0.19512	0.07687	0.00000	0.20317	0.08028	0.00000	0.20989	0.08320	0.00000
665	0.14445	0.05644	0.00000	0.15043	0.05895	0.00000	0.15543	0.06109	0.00000
670	0.10546	0.04100	0.00000	0.10984	0.04282	0.00000	0.11350	0.04437	0.00000
675	0.07593	0.02942	0.00000	0.07908	0.03072	0.00000	0.08172	0.03183	0.00000
680	0.05387	0.02082	0.00000	0.05611	0.02174	0.00000	0.05799	0.02253	0.00000
685	0.03765	0.01453	0.00000	0.03922	0.01517	0.00000	0.04053	0.01572	0.00000
690	0.02588	0.00997	0.00000	0.02695	0.01042	0.00000	0.02786	0.01079	0.00000
695	0.01802	0.00694	0.00000	0.01877	0.00725	0.00000	0.01940	0.00751	0.00000
700	0.01255	0.00483	0.00000	0.01307	0.00505	0.00000	0.01351	0.00523	0.00000
705	0.00870	0.00335	0.00000	0.00907	0.00350	0.00000	0.00937	0.00363	0.00000
710	0.00596	0.00230	0.00000	0.00621	0.00240	0.00000	0.00642	0.00249	0.00000
715	0.00408	0.00157	0.00000	0.00425	0.00164	0.00000	0.00440	0.00170	0.00000
720	0.00282	0.00109	0.00000	0.00294	0.00114	0.00000	0.00304	0.00118	0.00000
725	0.00195	0.00075	0.00000	0.00203	0.00079	0.00000	0.00210	0.00082	0.00000
730	0.00136	0.00053	0.00000	0.00141	0.00055	0.00000	0.00146	0.00057	0.00000
735	0.00095	0.00037	0.00000	0.00099	0.00038	0.00000	0.00102	0.00040	0.00000
740	0.00066	0.00026	0.00000	0.00069	0.00027	0.00000	0.00071	0.00028	0.00000
745	0.00046	0.00018	0.00000	0.00048	0.00019	0.00000	0.00050	0.00020	0.00000
750	0.00033	0.00013	0.00000	0.00034	0.00013	0.00000	0.00035	0.00014	0.00000
755	0.00023	0.00009	0.00000	0.00024	0.00009	0.00000	0.00025	0.00010	0.00000
760	0.00016	0.00006	0.00000	0.00017	0.00007	0.00000	0.00018	0.00007	0.00000
765	0.00012	0.00005	0.00000	0.00012	0.00005	0.00000	0.00013	0.00005	0.00000
770	0.00008	0.00003	0.00000	0.00009	0.00003	0.00000	0.00009	0.00004	0.00000
775	0.00006	0.00002	0.00000	0.00006	0.00003	0.00000	0.00007	0.00003	0.00000
780	0.00004	0.00002	0.00000	0.00005	0.00002	0.00000	0.00005	0.00002	0.00000

Annex B
(informative)

Reference colour SPDs data

Table B.1 shows CIE daylight D65 illuminant, seven reference colours, Macbeth white, red, green, blue, cyan, magenta, and yellow SPDs.

These data are provided by the Munsell Colour Science Laboratory (URL: http://www.cis.rit.edu/research/mcsl2/online/cie.php).

Table B.1 – Relative SPDs of CIE daylight D65 illuminant and seven reference colours

Wavelength (nm)	D65	Reference colour (i = 1 ~ 7)						
		1	2	3	4	5	6	7
		Macbeth White	Macbeth Red	Macbeth Green	Macbeth Blue	Macbeth Cyan	Macbeth Magenta	Macbeth Yellow
380	49.9755	0.153	0.052	0.055	0.069	0.093	0.118	0.054
385	52.3118	0.189	0.052	0.056	0.081	0.11	0.142	0.053
390	54.6482	0.245	0.052	0.057	0.096	0.134	0.179	0.054
395	68.7015	0.319	0.052	0.058	0.114	0.164	0.228	0.053
400	82.7549	0.409	0.051	0.058	0.136	0.195	0.283	0.053
405	87.1204	0.536	0.051	0.058	0.156	0.22	0.322	0.053
410	91.486	0.671	0.05	0.059	0.175	0.238	0.343	0.053
415	92.4589	0.772	0.05	0.059	0.193	0.249	0.354	0.052
420	93.4318	0.84	0.049	0.059	0.208	0.258	0.359	0.052
425	90.057	0.868	0.049	0.06	0.224	0.27	0.357	0.052
430	86.6823	0.878	0.049	0.062	0.244	0.281	0.35	0.053
435	95.7736	0.882	0.049	0.063	0.265	0.296	0.339	0.053
440	104.865	0.883	0.049	0.065	0.29	0.315	0.327	0.053
445	110.936	0.885	0.049	0.067	0.316	0.334	0.313	0.054
450	117.008	0.886	0.049	0.07	0.335	0.352	0.298	0.055
455	117.41	0.886	0.048	0.074	0.342	0.37	0.282	0.056
460	117.812	0.887	0.048	0.078	0.338	0.391	0.267	0.059
465	116.336	0.888	0.047	0.084	0.324	0.414	0.253	0.065
470	114.861	0.888	0.047	0.091	0.302	0.434	0.239	0.075
475	115.392	0.888	0.046	0.101	0.273	0.449	0.225	0.093
480	115.923	0.888	0.045	0.113	0.239	0.458	0.209	0.121
485	112.367	0.888	0.045	0.125	0.205	0.461	0.195	0.157
490	108.811	0.888	0.044	0.14	0.172	0.457	0.182	0.202
495	109.082	0.888	0.044	0.157	0.144	0.447	0.172	0.252
500	109.354	0.887	0.044	0.18	0.12	0.433	0.163	0.303
505	108.578	0.887	0.044	0.208	0.101	0.414	0.155	0.351
510	107.802	0.887	0.044	0.244	0.086	0.392	0.146	0.394
515	106.296	0.887	0.044	0.286	0.074	0.366	0.135	0.436
520	104.79	0.887	0.044	0.324	0.066	0.339	0.124	0.475
525	106.239	0.887	0.044	0.351	0.059	0.31	0.113	0.512

530	107.689	0.887	0.044	0.363	0.054	0.282	0.106	0.544
535	106.047	0.887	0.044	0.363	0.051	0.255	0.102	0.572
540	104.405	0.887	0.045	0.355	0.048	0.228	0.102	0.597
545	104.225	0.886	0.046	0.342	0.046	0.204	0.105	0.615
550	104.046	0.886	0.047	0.323	0.045	0.18	0.107	0.63
555	102.023	0.887	0.048	0.303	0.044	0.159	0.107	0.645
560	100	0.887	0.05	0.281	0.043	0.141	0.106	0.66
565	98.1671	0.887	0.053	0.26	0.042	0.126	0.107	0.673
570	96.3342	0.888	0.057	0.238	0.041	0.114	0.112	0.686
575	96.0611	0.888	0.063	0.217	0.041	0.104	0.123	0.698
580	95.788	0.887	0.072	0.196	0.04	0.097	0.141	0.708
585	92.2368	0.886	0.086	0.177	0.04	0.092	0.166	0.718
590	88.6856	0.886	0.109	0.158	0.04	0.088	0.198	0.726
595	89.3459	0.886	0.143	0.14	0.04	0.083	0.235	0.732
600	90.0062	0.887	0.192	0.124	0.039	0.08	0.279	0.737
605	89.8026	0.888	0.256	0.111	0.039	0.077	0.333	0.742
610	89.5991	0.889	0.332	0.101	0.04	0.075	0.394	0.746
615	88.6489	0.89	0.413	0.094	0.04	0.074	0.46	0.749
620	87.6987	0.891	0.486	0.089	0.04	0.073	0.522	0.753
625	85.4936	0.891	0.55	0.086	0.04	0.073	0.58	0.757
630	83.2886	0.891	0.598	0.084	0.041	0.073	0.628	0.761
635	83.4939	0.891	0.631	0.082	0.041	0.073	0.666	0.765
640	83.6992	0.89	0.654	0.08	0.042	0.073	0.696	0.768
645	81.863	0.889	0.672	0.078	0.042	0.073	0.722	0.772
650	80.0268	0.889	0.686	0.077	0.042	0.074	0.742	0.777
655	80.1207	0.889	0.694	0.076	0.043	0.075	0.756	0.779
660	80.2146	0.889	0.7	0.075	0.043	0.076	0.766	0.78
665	81.2462	0.889	0.704	0.075	0.043	0.076	0.774	0.78
670	82.2778	0.888	0.707	0.075	0.044	0.077	0.78	0.781
675	80.281	0.888	0.712	0.077	0.044	0.076	0.785	0.782
680	78.2842	0.888	0.718	0.078	0.044	0.075	0.791	0.785
685	74.0027	0.888	0.721	0.08	0.044	0.074	0.794	0.785
690	69.7213	0.888	0.724	0.082	0.045	0.074	0.798	0.787
695	70.6652	0.888	0.727	0.085	0.046	0.073	0.801	0.789
700	71.6091	0.888	0.729	0.088	0.048	0.072	0.804	0.792
705	72.979	0.887	0.73	0.089	0.05	0.072	0.806	0.792
710	74.349	0.886	0.73	0.089	0.051	0.071	0.807	0.793
715	67.9765	0.886	0.729	0.09	0.053	0.073	0.807	0.792
720	61.604	0.886	0.727	0.09	0.056	0.075	0.807	0.79
725	65.7448	0.885	0.728	0.09	0.06	0.078	0.81	0.792
730	69.8856	0.885	0.729	0.089	0.064	0.082	0.813	0.792
735	72.4863	0.885	0.729	0.092	0.07	0.09	0.814	0.79
740	75.087	0.884	0.727	0.094	0.079	0.1	0.813	0.787
745	69.3398	0.884	0.723	0.097	0.091	0.116	0.81	0.782
750	63.5927	0.883	0.721	0.102	0.104	0.133	0.808	0.778

755	55.0054	0.882	0.724	0.106	0.12	0.154	0.811	0.78
760	46.4182	0.882	0.728	0.11	0.138	0.176	0.814	0.782
765	56.6118	0.881	0.727	0.111	0.154	0.191	0.813	0.781
770	66.8054	0.88	0.702	0.112	0.168	0.2	0.785	0.752
775	65.0941	0.88	0.68	0.112	0.186	0.208	0.765	0.728
780	63.3828	0.879	0.664	0.112	0.204	0.214	0.752	0.71

Table B.2 shows the XYZ data converted from the SPDs data in Table B.1. Reference colours, CIE D65 illuminant, and CIE 1931 standard colorimetric observer were applied.

Table B.2 – Reference XYZ values using CIE 1931 standard colorimetric observer

		X	Y	Z
Reference white		0.9504	1.0000	1.0885
Reference colour	Macbeth white	0.8413	0.8873	0.9536
	Macbeth red	0.2020	0.1185	0.0520
	Macbeth green	0.1451	0.2355	0.0954
	Macbeth blue	0.0840	0.0624	0.2993
	Macbeth cyan	0.1449	0.1988	0.3951
	Macbeth magenta	0.2944	0.1930	0.3026
	Macbeth yellow	0.5605	0.5962	0.0959

Annex C
(informative)

Measurement method of observer metamerism between different displays

C.1 General

Evaluating the colour difference of several observations using a reference colour is an important part of evaluating the performance of a display. However, when it is necessary to evaluate the observer colour difference between different displays, a direct comparison between each display is required. This annex describes the process for evaluating the OMI between different displays.

C.2 Reference colours and measurement method

In order to evaluate the observer-dependent colour properties of two different displays, two displays are defined as DUT A and DUT B. The reference colours are the same as in the main body. The standard set-up condition and measuring condition are also the same as sub-clause 6.3. Measurement process is as follows.

a) Carry out the steps 1) to 7) in 6.3.3 with the DUT A to obtain XYZ tristimulus values for each individual observer.

b) Repeat the process a) with the DUT B.

c) Calculate the CIE DE2000 ΔE_{00} between the DUT A and the DUT B for each individual observer as described in 6.3.3 9).

d) Repeat the process a) to c) for each reference colour.

e) Report observer metamerism indices using the reporting form in Table 1.

Annex D
(informative)

Colour-matching process for multi-ORU DUTs

If the DUT has more than three ORUs (i.e. multi-ORU DUT such as RGBW, RGBY etc.), and the multi-ORU rendering algorithm is unknown, calculate the test SPD match as follows.

a) Perform adjustment of input RGB signals for the DUT until the colour difference between reference colour and the initial test colour becomes smaller than 1.0 in CIE ΔE_{00}.

b) Measure the SPD of the initial test colour that was adjusted at step a) and calculate XYZ of the initial test colour.

c) Select the most three significant ORUs for the DUT. If the ORUs include R, G and B, those are recommended.

d) Solve the weighting factors of three significant ORUs using following equation.

$$\begin{bmatrix} X'_{r(i,j)} \\ Y'_{r(i,j)} \\ Z'_{r(i,j)} \end{bmatrix} = \begin{bmatrix} X'_{t(i,j),n} \\ Y'_{t(i,j),n} \\ Z'_{t(i,j),n} \end{bmatrix} + \begin{bmatrix} X'_{1(j)} & X'_{2(j)} & X'_{3(j)} \\ Y'_{1(j)} & Y'_{2(j)} & Y'_{3(j)} \\ Z'_{1(j)} & Z'_{2(j)} & Z'_{3(j)} \end{bmatrix} \cdot \begin{bmatrix} w_{1(i,j)} \\ w_{2(i,j)} \\ w_{3(i,j)} \end{bmatrix} \tag{36}$$

$$\begin{bmatrix} w_{1(i,j)} \\ w_{2(i,j)} \\ w_{3(i,j)} \end{bmatrix} = \begin{bmatrix} X'_{1(j)} & X'_{2(j)} & X'_{3(j)} \\ Y'_{1(j)} & Y'_{2(j)} & Y'_{3(j)} \\ Z'_{1(j)} & Z'_{2(j)} & Z'_{3(j)} \end{bmatrix}^{-1} \cdot \begin{bmatrix} X'_{r(i,j)} - X'_{t(i,j),n} \\ Y'_{r(i,j)} - Y'_{t(i,j),n} \\ Z'_{r(i,j)} - Z'_{t(i,j),n} \end{bmatrix} \tag{37}$$

where

$X'_{t(i,j),n}$, $Y'_{t(i,j),n}$ and $Z'_{t(i,j),n}$ denote the XYZ values of the initial test colour measured in step b);

$X'_{q(j)}$, $Y'_{q(j)}$ and $Z'_{q(j)}$ are the XYZ values (q = 1, 2 and 3 which denote three significant ORUs) calculated in step b), which are of *i*th reference colour using individual CMFs of *j*th individual observer;

$w_{q(i,j)}$ is weighting factor calculated from step d), and q also has 1, 2 and 3 for the three significant ORUs.

e) The final test spectral distribution can be obtained as below.

$$\Phi_{t(i,j)}(\lambda) = \Phi_{t(i,j),n}(\lambda) + [w_{1(i,j)} \quad w_{2(i,j)} \quad w_{3(i,j)}] \cdot [\Phi_1(\lambda) \quad \Phi_2(\lambda) \quad \Phi_3(\lambda)]^T \tag{38}$$

where

$\Phi_{t(i,j),n}(\lambda)$ is the SPD of the initial test colour measured in step b);

$\Phi_q(\lambda)$ is the SPD of the significant ORU (q = 1, 2 and 3).

Note 1: This method can be applied when testers are able to measure the independent SPD of single ORU. If testers are not able to radiate and measure SPD of single ORU, this method cannot be applied.

Note 2: Out-of-gamut chromaticity can be judged by representing them on the CIE 1931 xy chromaticity diagram. Then exclude and report any reference colour patch illuminated by D65 that is outside the DUT chromaticity gamut boundary.

Note 3: It is recommended the luminance is set with an input signal that is 1.2 times higher than the luminance of the match target. After that, the R, G and B input signals are finely adjusted to perform colour matching.

Annex E
(informative)

Working example of observer metamerism index

E.1 Purpose

This annex aims to provide a working example regarding the measurement and calculation process in 6.3 to the readers of this technical specification.

E.2 DUT

For this annex, an arbitrarily generated display with optical characteristics as shown in Table D.1 below was used. The optical characteristics and R, G, B, W spectra of the display are shown in the Table D.1, Figure D.1 and Table D.6. For convenience of explanation, the used DUT satisfies the additivity law and the gamma was set to 2.2.

Table D.1 – Optical properties of the DUT

	X	Y	Z	x	y
White	190.08	200.00	217.89	0.3126	0.3290
Red	99.31	46.63	0.03	0.6803	0.3195
Green	53.71	140.52	8.92	0.2644	0.6917
Blue	37.05	12.85	208.95	0.1431	0.0496
Gamma	2.2				

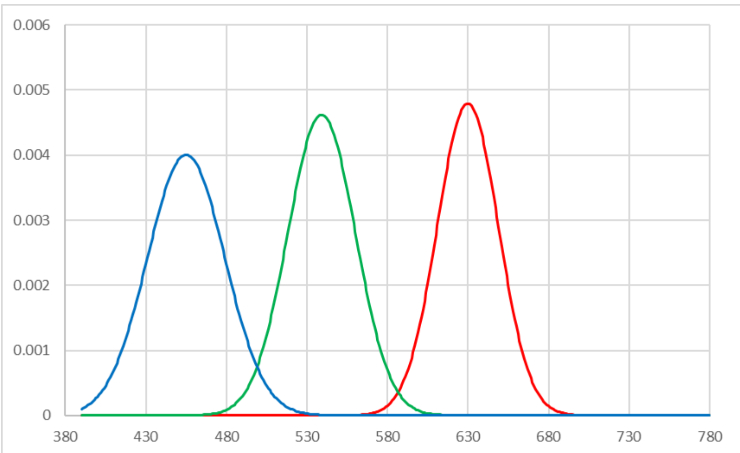


Figure D.1 – RGB primary spectrum of the DUT

E.3 Process

In case the DUT satisfies colour additivity, the SPD of the colour-matched DUT should be obtained by calculating the weighting factors of primary colours SPDs as explained in 6.3.

E.3.1 Colour-matching

In the colour matching stage, the goal is to make the colour difference between the reference colour and the test pattern displayed on the DUT as small as possible.

E.3.1.1 Reference colour XYZ

Calculate the XYZ value of each reference colour and each individual CMFs using equation (1). In case of the Macbeth white colour (Table B.1) under D65 illuminant and the age group 22's individual CMFs (Table A.4), the result of XYZ is (178.06, 188.95, 196.77). Other XYZ values of the reference colour are listed in Table D.2.

Table D.2 – Reference colour XYZ values of age group 22 individual CMFs

Reference colour	X	Y	Z
Macbeth white	178.06	188.95	196.77
Macbeth red	42.39	25.43	10.88
Macbeth green	31.26	48.92	18.55
Macbeth blue	17.05	14.45	61.83
Macbeth cyan	30.13	43.33	79.63
Macbeth magenta	61.91	42.14	65.38
Macbeth yellow	119.69	124.23	17.85

E.3.1.2 Calculating R, G and B weighting factors

Calculate the R, G and B weighting factors of the DUT to match the reference colour and the DUT colour as described in 6.3.3. The R, G and B weighting factors of the matched colour (age group 22) are listed in Table D.3. Refer to the below Table D.7 for the results of the other age groups.

Table D.3 – R, G and B weighting factors of the matched colours (age group 22)

Reference colour	Weighting factor		
	R	G	B
Macbeth white	0.8889	0.8914	0.8956
Macbeth red	0.3636	0.0428	0.0497
Macbeth green	0.1037	0.2953	0.0783
Macbeth blue	0.0360	0.0511	0.2880
Macbeth cyan	0.0225	0.2478	0.3657
Macbeth magenta	0.4293	0.1037	0.3031
Macbeth yellow	0.7894	0.5808	0.0669

E.3.2 Calculating the SPD of the DUT

Calculate the SPD of the test colour which was colour matched in process 5).

E.3.3 XYZ computation

Calculate the XYZ values of the matched colour, Macbeth white of DUT using CIE 1931 standard colorimetric observer as shown in equation (10).

E.3.4 Colour difference computation

Calculate the CIE DE2000 ΔE_{00} between the reference colour and the DUT according to equations (15) ~ (35). Reference XYZ data using CIE 1931 standard colorimetric observer are in Table B.2. The OMI calculation result of all 7 reference colours and age groups are listed in Table D.4.

Table D.4 – OMI calculation result of all 7 colours and age groups

Age group	Observer metamerism index						
	Macbeth white	Macbeth red	Macbeth green	Macbeth blue	Macbeth cyan	Macbeth magenta	Macbeth yellow
22	1.22	0.48	0.13	0.12	1.16	1.17	0.04
27	1.02	0.43	0.13	0.12	0.95	1.05	0.15
32	0.87	0.39	0.13	0.11	0.74	0.93	0.27
37	0.78	0.35	0.12	0.11	0.55	0.81	0.39
42	0.77	0.31	0.12	0.10	0.42	0.71	0.51
47	0.83	0.27	0.12	0.10	0.41	0.60	0.63
52	0.94	0.24	0.13	0.11	0.52	0.50	0.76
57	1.09	0.21	0.13	0.11	0.70	0.41	0.88
62	1.40	0.16	0.15	0.12	1.12	0.25	1.12
67	1.97	0.09	0.21	0.15	1.89	0.19	1.55
72	2.52	0.04	0.29	0.18	2.68	0.39	1.97
77	3.06	0.03	0.39	0.22	3.47	0.61	2.41

E.3.5 Reporting

Report maximum, minimum, average and standard deviation of OMI values for each reference colour, and present a pair of graphs showing the spectral plots of metameric pairs of reference colour and DUT colour. Here, one metameric pair of Macbeth white is given as an example.

Table D.5 – Reporting of OMI results

Reference colour	Observer metamerism index			
	Maximum	Minimum	Average	Standard deviation
Macbeth white	3.06	0.77	1.37	0.75
Macbeth red	0.48	0.03	0.25	0.15
Macbeth green	0.39	0.12	0.17	0.09
Macbeth blue	0.22	0.10	0.13	0.04
Macbeth cyan	3.47	0.41	1.22	0.98
Macbeth magenta	1.17	0.19	0.64	0.31

Macbeth yellow	2.41	0.04	0.89	0.74
Total	3.47	0.03	0.67	0.72

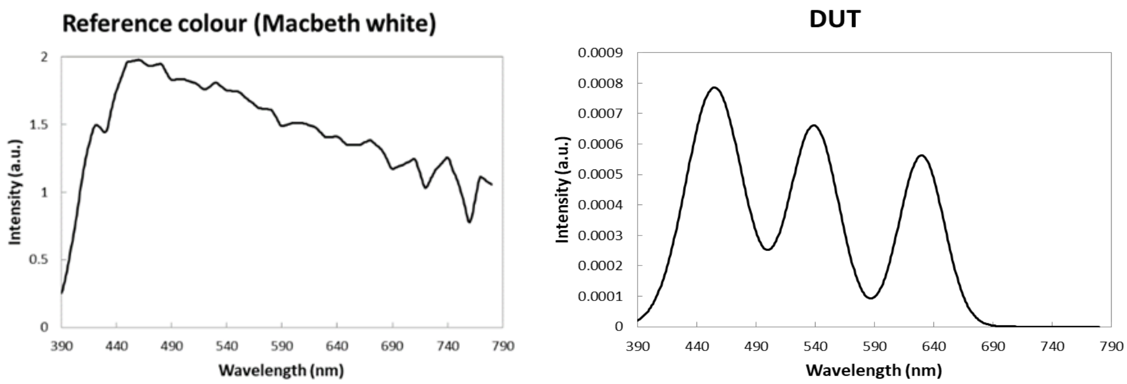


Figure E.2 – Example of graphs of colour-matched metameric pair of reference colour (Macbeth white) and test colour of the DUT

Table D.6 – R, G, B, W spectra of the DUT

Wavelength (nm)	Red	Green	Blue	White
390	0	0	0.000101	0.000101
391	0	0	0.000114	0.000114
392	0	0	0.000128	0.000128
393	0	0	0.000142	0.000142
394	0	0	0.00016	0.00016
395	0	0	0.000178	0.000178
396	0	0	0.000196	0.000196
397	0	0	0.000215	0.000215
398	0	0	0.000238	0.000238
399	0	0	0.000265	0.000265
400	0	0	0.000288	0.000288
401	0	0	0.00032	0.00032
402	0	0	0.000352	0.000352
403	0	0	0.000384	0.000384
404	0	0	0.00042	0.00042
405	0	0	0.000457	0.000457
406	0	0	0.000498	0.000498
407	0	0	0.000544	0.000544
408	0	0	0.000589	0.000589
409	0	0	0.00064	0.00064

410	0	0	0.00069	0.00069
411	0	0	0.000745	0.000745
412	0	0	0.000804	0.000804
413	0	0	0.000868	0.000868
414	0	0	0.000932	0.000932
415	0	0	0.001001	0.001001
416	0	0	0.001069	0.001069
417	0	0	0.001142	0.001142
418	0	0	0.00122	0.00122
419	0	0	0.001302	0.001302
420	0	0	0.001384	0.001384
421	0	0	0.001467	0.001467
422	0	0	0.001558	0.001558
423	0	0	0.001645	0.001645
424	0	0	0.001741	0.001741
425	0	0	0.001832	0.001832
426	0	0	0.001933	0.001933
427	0	0	0.002029	0.002029
428	0	0	0.002129	0.002129
429	0	0	0.00223	0.00223
430	0	0	0.00233	0.00233
431	0	0	0.002431	0.002431
432	0	0	0.002531	0.002531
433	0	0	0.002632	0.002632
434	0	0	0.002732	0.002732
435	0	0	0.002833	0.002833
436	0	0	0.002929	0.002929
437	0	0	0.003025	0.003025
438	0	0	0.003116	0.003116
439	0	0	0.003207	0.003207
440	0	0	0.003294	0.003294
441	0	0	0.003381	0.003381
442	0	0	0.003459	0.003459
443	0	0	0.003536	0.003536
444	0	0	0.003605	0.003605
445	0	0	0.003673	0.003673
446	0	0	0.003733	0.003733
447	0	0	0.003788	0.003788
448	0	0	0.003838	0.003838

449	0	0	0.003883	0.003883
450	0	0	0.00392	0.00392
451	0	0	0.003952	0.003952
452	0	0	0.003975	0.003975
453	0	0	0.003993	0.003993
454	0	0	0.004002	0.004002
455	0	0	0.004007	0.004007
456	0	0	0.004002	0.004002
457	0	0	0.003993	0.003993
458	0	0	0.003975	0.003975
459	0	0.000006	0.003952	0.003958
460	0	0.000006	0.00392	0.003926
461	0	0.000006	0.003883	0.00389
462	0	0.000006	0.003838	0.003844
463	0	0.000006	0.003788	0.003794
464	0	0.000006	0.003733	0.003739
465	0	0.000006	0.003673	0.00368
466	0	0.000012	0.003605	0.003617
467	0	0.000012	0.003536	0.003549
468	0	0.000012	0.003459	0.003471
469	0	0.000019	0.003381	0.0034
470	0	0.000019	0.003294	0.003313
471	0	0.000025	0.003207	0.003232
472	0	0.000025	0.003116	0.003141
473	0	0.000031	0.003025	0.003056
474	0	0.000037	0.002929	0.002966
475	0	0.000044	0.002833	0.002876
476	0	0.00005	0.002732	0.002782
477	0	0.000056	0.002632	0.002688
478	0	0.000069	0.002531	0.0026
479	0	0.000075	0.002431	0.002506
480	0	0.000087	0.00233	0.002417
481	0	0.0001	0.00223	0.002329
482	0	0.000112	0.002129	0.002241
483	0	0.000131	0.002029	0.00216
484	0	0.00015	0.001933	0.002082
485	0	0.000169	0.001832	0.002001
486	0	0.000187	0.001741	0.001928
487	0	0.000212	0.001645	0.001857

488	0	0.000237	0.001558	0.001795
489	0	0.000268	0.001467	0.001735
490	0	0.0003	0.001384	0.001684
491	0	0.000337	0.001302	0.001639
492	0	0.000375	0.00122	0.001594
493	0	0.000412	0.001142	0.001554
494	0	0.000462	0.001069	0.001531
495	0	0.000512	0.001001	0.001513
496	0	0.000562	0.000932	0.001494
497	0	0.000618	0.000868	0.001486
498	0	0.000681	0.000804	0.001485
499	0	0.000749	0.000745	0.001494
500	0	0.000818	0.00069	0.001508
501	0	0.000893	0.00064	0.001532
502	0	0.000968	0.000589	0.001557
503	0	0.001055	0.000544	0.001599
504	0	0.001143	0.000498	0.001641
505	0	0.001236	0.000457	0.001693
506	0	0.001336	0.00042	0.001756
507	0	0.001436	0.000384	0.00182
508	0	0.001542	0.000352	0.001894
509	0	0.001655	0.00032	0.001974
510	0	0.001767	0.000288	0.002055
511	0	0.001886	0.000265	0.002151
512	0	0.00201	0.000238	0.002248
513	0	0.002135	0.000215	0.00235
514	0	0.00226	0.000196	0.002457
515	0	0.002391	0.000178	0.002569
516	0	0.002522	0.00016	0.002682
517	0	0.002653	0.000142	0.002795
518	0	0.002791	0.000128	0.002919
519	0	0.002922	0.000114	0.003036
520	0	0.003053	0.000101	0.003154
521	0	0.003184	0.000091	0.003276
522	0	0.003315	0.000082	0.003398
523	0	0.003446	0.000073	0.00352
524	0	0.003565	0.000064	0.003629
525	0	0.00369	0.000055	0.003745
526	0	0.003802	0.00005	0.003853

527	0	0.003915	0.000046	0.00396
528	0	0.004021	0.000041	0.004062
529	0	0.004114	0.000037	0.004151
530	0	0.004208	0.000032	0.00424
531	0	0.004289	0.000027	0.004317
532	0	0.004364	0.000023	0.004387
533	0	0.004427	0.000018	0.004445
534	0	0.004489	0.000018	0.004507
535	0	0.004533	0.000014	0.004547
536	0	0.00457	0.000014	0.004584
537	0	0.004595	0.000014	0.004609
538	0	0.004614	0.000009	0.004623
539	0	0.00462	0.000009	0.004629
540	0	0.004614	0.000009	0.004623
541	0	0.004601	0.000005	0.004606
542	0	0.004577	0.000005	0.004581
543	0	0.004539	0.000005	0.004544
544	0	0.004495	0.000005	0.0045
545	0	0.004439	0.000005	0.004444
546	0	0.004377	0.000005	0.004381
547	0	0.004302	0.000005	0.004306
548	0	0.004221	0	0.004221
549	0	0.004133	0	0.004133
550	0	0.00404	0	0.00404
551	0	0.003933	0	0.003933
552	0	0.003827	0	0.003827
553	0	0.003709	0	0.003709
554	0	0.00359	0	0.00359
555	0	0.003471	0	0.003471
556	0	0.00334	0	0.00334
557	0	0.003215	0	0.003215
558	0	0.003084	0	0.003084
559	0.000008	0.002947	0	0.002955
560	0.000008	0.002816	0	0.002823
561	0.000008	0.002685	0	0.002692
562	0.000008	0.002547	0	0.002555
563	0.000008	0.002416	0	0.002424
564	0.000015	0.002285	0	0.0023
565	0.000015	0.00216	0	0.002175

566	0.000015	0.002035	0	0.002051
567	0.000023	0.001911	0	0.001933
568	0.000023	0.001792	0	0.001815
569	0.00003	0.00168	0	0.00171
570	0.00003	0.001567	0	0.001597
571	0.000038	0.001455	0	0.001493
572	0.000045	0.001355	0	0.0014
573	0.000053	0.001255	0	0.001308
574	0.000061	0.001161	0	0.001222
575	0.000076	0.001074	0	0.00115
576	0.000083	0.000986	0	0.00107
577	0.000098	0.000905	0	0.001004
578	0.000114	0.00083	0	0.000944
579	0.000136	0.000762	0	0.000898
580	0.000151	0.000693	0	0.000844
581	0.000174	0.000631	0	0.000805
582	0.000197	0.000574	0	0.000771
583	0.000227	0.000518	0	0.000745
584	0.000257	0.000468	0	0.000726
585	0.000295	0.000425	0	0.00072
586	0.000333	0.000381	0	0.000714
587	0.000371	0.000343	0	0.000714
588	0.000424	0.000306	0	0.00073
589	0.000469	0.000275	0	0.000744
590	0.00053	0.000243	0	0.000773
591	0.00059	0.000219	0	0.000809
592	0.000659	0.000194	0	0.000852
593	0.000727	0.000169	0	0.000895
594	0.000802	0.00015	0	0.000952
595	0.000886	0.000131	0	0.001017
596	0.000976	0.000119	0	0.001095
597	0.001067	0.000106	0	0.001173
598	0.001173	0.000087	0	0.001261
599	0.001279	0.000081	0	0.00136
600	0.001393	0.000069	0	0.001461
601	0.001506	0.000062	0	0.001569
602	0.001627	0.00005	0	0.001677
603	0.001756	0.000044	0	0.0018
604	0.001892	0.000037	0	0.00193

605	0.002029	0.000031	0	0.00206
606	0.002172	0.000031	0	0.002204
607	0.002316	0.000025	0	0.002341
608	0.002468	0.000019	0	0.002486
609	0.002619	0.000019	0	0.002638
610	0.00277	0.000012	0	0.002783
611	0.002922	0.000012	0	0.002934
612	0.003073	0.000012	0	0.003086
613	0.003224	0.000012	0	0.003237
614	0.003376	0.000006	0	0.003382
615	0.003527	0.000006	0	0.003533
616	0.003671	0.000006	0	0.003677
617	0.003807	0.000006	0	0.003814
618	0.003944	0.000006	0	0.00395
619	0.004065	0.000006	0	0.004071
620	0.004186	0	0	0.004186
621	0.004299	0	0	0.004299
622	0.004398	0	0	0.004398
623	0.004489	0	0	0.004489
624	0.004572	0	0	0.004572
625	0.00464	0	0	0.00464
626	0.004693	0	0	0.004693
627	0.004738	0	0	0.004738
628	0.004769	0	0	0.004769
629	0.004791	0	0	0.004791
630	0.004791	0	0	0.004791
631	0.004784	0	0	0.004784
632	0.004761	0	0	0.004761
633	0.004731	0	0	0.004731
634	0.004685	0	0	0.004685
635	0.004625	0	0	0.004625
636	0.004557	0	0	0.004557
637	0.004473	0	0	0.004473
638	0.004375	0	0	0.004375
639	0.004277	0	0	0.004277
640	0.004163	0	0	0.004163
641	0.004042	0	0	0.004042
642	0.003913	0	0	0.003913
643	0.003777	0	0	0.003777

644	0.003641	0	0	0.003641
645	0.003497	0	0	0.003497
646	0.003346	0	0	0.003346
647	0.003194	0	0	0.003194
648	0.003043	0	0	0.003043
649	0.002891	0	0	0.002891
650	0.00274	0	0	0.00274
651	0.002589	0	0	0.002589
652	0.002437	0	0	0.002437
653	0.002286	0	0	0.002286
654	0.002142	0	0	0.002142
655	0.002006	0	0	0.002006
656	0.00187	0	0	0.00187
657	0.001733	0	0	0.001733
658	0.001605	0	0	0.001605
659	0.001484	0	0	0.001484
660	0.00137	0	0	0.00137
661	0.001256	0	0	0.001256
662	0.001151	0	0	0.001151
663	0.001052	0	0	0.001052
664	0.000961	0	0	0.000961
665	0.00087	0	0	0.00087
666	0.000787	0	0	0.000787
667	0.000712	0	0	0.000712
668	0.000643	0	0	0.000643
669	0.000575	0	0	0.000575
670	0.000515	0	0	0.000515
671	0.000462	0	0	0.000462
672	0.000409	0	0	0.000409
673	0.000363	0	0	0.000363
674	0.000325	0	0	0.000325
675	0.000288	0	0	0.000288
676	0.00025	0	0	0.00025
677	0.00022	0	0	0.00022
678	0.000197	0	0	0.000197
679	0.000167	0	0	0.000167
680	0.000151	0	0	0.000151
681	0.000129	0	0	0.000129
682	0.000114	0	0	0.000114

683	0.000098	0	0	0.000098
684	0.000083	0	0	0.000083
685	0.000068	0	0	0.000068
686	0.000061	0	0	0.000061
687	0.000053	0	0	0.000053
688	0.000045	0	0	0.000045
689	0.000038	0	0	0.000038
690	0.00003	0	0	0.00003
691	0.00003	0	0	0.00003
692	0.000023	0	0	0.000023
693	0.000023	0	0	0.000023
694	0.000015	0	0	0.000015
695	0.000015	0	0	0.000015
696	0.000008	0	0	0.000008
697	0.000008	0	0	0.000008
698	0.000008	0	0	0.000008
699	0.000008	0	0	0.000008
700	0.000008	0	0	0.000008
701	0.000008	0	0	0.000008
702	0	0	0	0
703	0	0	0	0
704	0	0	0	0
705	0	0	0	0
706	0	0	0	0
707	0	0	0	0
708	0	0	0	0
709	0	0	0	0
710	0	0	0	0
711	0	0	0	0
712	0	0	0	0
713	0	0	0	0
714	0	0	0	0
715	0	0	0	0
716	0	0	0	0
717	0	0	0	0
718	0	0	0	0
719	0	0	0	0
720	0	0	0	0
721	0	0	0	0

722	0	0	0	0
723	0	0	0	0
724	0	0	0	0
725	0	0	0	0
726	0	0	0	0
727	0	0	0	0
728	0	0	0	0
729	0	0	0	0
730	0	0	0	0
731	0	0	0	0
732	0	0	0	0
733	0	0	0	0
734	0	0	0	0
735	0	0	0	0
736	0	0	0	0
737	0	0	0	0
738	0	0	0	0
739	0	0	0	0
740	0	0	0	0
741	0	0	0	0
742	0	0	0	0
743	0	0	0	0
744	0	0	0	0
745	0	0	0	0
746	0	0	0	0
747	0	0	0	0
748	0	0	0	0
749	0	0	0	0
750	0	0	0	0
751	0	0	0	0
752	0	0	0	0
753	0	0	0	0
754	0	0	0	0
755	0	0	0	0
756	0	0	0	0
757	0	0	0	0
758	0	0	0	0
759	0	0	0	0
760	0	0	0	0

761	0	0	0	0
762	0	0	0	0
763	0	0	0	0
764	0	0	0	0
765	0	0	0	0
766	0	0	0	0
767	0	0	0	0
768	0	0	0	0
769	0	0	0	0
770	0	0	0	0
771	0	0	0	0
772	0	0	0	0
773	0	0	0	0
774	0	0	0	0
775	0	0	0	0
776	0	0	0	0
777	0	0	0	0
778	0	0	0	0
779	0	0	0	0
780	0	0	0	0

Table D.7 – R, G and B weighting factors of the matched colours

Reference colour	Age group	Weighting factor			Reference colour	Age group	Weighting factor		
		R	G	B			R	G	B
Macbeth White	22	0.8889	0.8914	0.8956	Macbeth Cyan	22	0.0225	0.2478	0.3657
	27	0.8878	0.8922	0.8938		27	0.0238	0.2469	0.3661
	32	0.8867	0.8929	0.8921		32	0.0250	0.2461	0.3666
	37	0.8857	0.8937	0.8906		37	0.0262	0.2452	0.3672
	42	0.8847	0.8945	0.8891		42	0.0274	0.2443	0.3678
	47	0.8837	0.8953	0.8878		47	0.0285	0.2434	0.3684
	52	0.8827	0.8961	0.8867		52	0.0296	0.2426	0.3691
	57	0.8817	0.8969	0.8856		57	0.0307	0.2417	0.3699
	62	0.8798	0.8985	0.8838		62	0.0327	0.2400	0.3714
	67	0.8766	0.9012	0.8816		67	0.0359	0.2373	0.3744
	72	0.8733	0.9041	0.8805		72	0.0389	0.2346	0.3778
	77	0.8699	0.9072	0.8802		77	0.0415	0.2320	0.3815
Macbeth Red	22	0.3636	0.0428	0.0497	Macbeth Magenta	22	0.4293	0.1037	0.3031
	27	0.3636	0.0428	0.0495		27	0.4288	0.1041	0.3012
	32	0.3637	0.0428	0.0493		32	0.4285	0.1045	0.2994
	37	0.3638	0.0428	0.0492		37	0.4281	0.1049	0.2977
	42	0.3639	0.0428	0.0490		42	0.4278	0.1052	0.2960
	47	0.3640	0.0428	0.0489		47	0.4275	0.1055	0.2944

	52	0.3640	0.0428	0.0488		52	0.4272	0.1058	0.2929
	57	0.3641	0.0428	0.0486		57	0.4269	0.1061	0.2914
	62	0.3643	0.0427	0.0484		62	0.4265	0.1066	0.2888
	67	0.3646	0.0427	0.0481		67	0.4260	0.1074	0.2846
	72	0.3650	0.0426	0.0479		72	0.4256	0.1080	0.2810
	77	0.3653	0.0425	0.0478		77	0.4253	0.1086	0.2779
Macbeth Green	22	0.1037	0.2953	0.0783	Macbeth Yellow	22	0.7894	0.5808	0.0669
	27	0.1037	0.2953	0.0784		27	0.7879	0.5819	0.0669
	32	0.1037	0.2953	0.0785		32	0.7864	0.5830	0.0670
	37	0.1037	0.2953	0.0786		37	0.7849	0.5841	0.0670
	42	0.1037	0.2953	0.0787		42	0.7834	0.5852	0.0671
	47	0.1036	0.2953	0.0788		47	0.7819	0.5864	0.0672
	52	0.1036	0.2954	0.0789		52	0.7804	0.5875	0.0673
	57	0.1035	0.2954	0.0791		57	0.7788	0.5887	0.0674
	62	0.1034	0.2955	0.0794		62	0.7760	0.5910	0.0676
	67	0.1032	0.2956	0.0800		67	0.7710	0.5951	0.0680
	72	0.1030	0.2958	0.0807		72	0.7661	0.5994	0.0684
	77	0.1026	0.2961	0.0815		77	0.7612	0.6039	0.0689
Macbeth Blue	22	0.0360	0.0511	0.2880					
	27	0.0360	0.0511	0.2878					
	32	0.0360	0.0511	0.2875					
	37	0.0360	0.0511	0.2874					
	42	0.0361	0.0511	0.2872					
	47	0.0361	0.0511	0.2870					
	52	0.0361	0.0510	0.2869					
	57	0.0362	0.0510	0.2868					
	62	0.0363	0.0510	0.2866					
	67	0.0364	0.0508	0.2865					
	72	0.0365	0.0507	0.2866					
	77	0.0366	0.0506	0.2868					

Bibliography

[1] M. D. Fairchild and D. R. Wyble, “Mean Observer Metamerism and the Selection of Display Primaries”, *Color and Imaging Conference*, pp 151-156, 2007

[2] Y. Zong, S. W. Brown, K. R. Lykke and Y. Ohno, “Correction of stray light in spectroradiometers and imaging instruments”, *Proc. CIE*, Vol. 178, pp D2-33- D2-36

[3] D. C. Montgomery, *Introduction to Statistical Quality Control*, 6th ed. New York: Wiley, 2009

[4] D. L. Long and M. D. Fairchild, “Modeling observer variability and metamerism failure in electronic colour displays”, *Journal of Imaging Science and Technology*, Vol. 58, pp 030402-1-030402-14, 2014 [doi:10.2352/j.imagingsci.technol.2014.58.3.030402]

[5] International Committee for Display Metrology, *Information Display Measurements Standard*, Ver. 1.1, 2021 [doi:10.55410/rodv2343]

[6] United Nations world population prospect [doi:population.un.org/wpp], access date : Sep 1st, 2020

[7] Y. Park, M. J. Murdoch, “Efficiently evaluating the effect of color gamut and spectral bandwidth on observer metamerism in high dynamic range displays”, *Journal of the Society for Information Display*, pp 1-19, 2021 [doi:10.1002/jsid.1027]

[8] Y. Park, M. J. Murdoch, “Effect of color gamut and luminance on observer metamerism in HDR displays”, *Colour and Imaging Conference*, pp 237-243, 2020 [doi:10.2352/issn.2169-2629.2020.28.38]

___