IEC 61966-5

Edition 2.0 2008-11

INTERNATIONAL STANDARD

Multimedia systems and equipment – Colour measurement and management – Part 5: Equipment using plasma display panels

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INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

PRICE CODE V

ICS 33.160.60; 35.180; 31.120

ISBN 2-8318-1016-3

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

MULTIMEDIA SYSTEMS AND EQUIPMENT – COLOUR MEASUREMENT AND MANAGEMENT –

Part 5: Equipment using plasma display panels

FOREWORD

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International Standard IEC 61966-5 has been prepared by technical area 2: Colour measurement and management of IEC technical committee 100: Audio, video and multimedia systems and equipment.

This second edition cancels and replaces the first edition published in 2000. This edition includes the following significant technical changes with respect to the previous edition: Annex A has been deleted as it is no longer relevant.

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

CDV	Report on voting
100/1295/CDV	100/1387/RVC

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

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts of the IEC 61966 series, 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 publication will remain unchanged until the maintenance result date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

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- withdrawn,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

A bilingual version of this publication may be issued at a later date.

INTRODUCTION

A series of methods and parameters for colour measurements and management for use in multimedia systems and equipment is applicable to the assessment of colour production and reproduction. This part of IEC 61966 deals with equipment using plasma display panels (PDP) to display colour images for use in multimedia applications.

The methods of measurement standardized in this part of IEC 61966 are designed to make possible the objective performance assessment and characterization of colour reproduction of PDP displays which accept red – green – blue analogue or digital signals from electrical input terminals and output colour images on PDP display screens. For PDP displays to which analogue signals are applicable, the corresponding digital signals are taken into account. The measured results are intended to be used for the purpose of equipment specific colour control in order to enable colour management in open multimedia systems.

MULTIMEDIA SYSTEMS AND EQUIPMENT – COLOUR MEASUREMENT AND MANAGEMENT –

Part 5: Equipment using plasma display panels

1 Scope

This part of IEC 61966 defines input test signals, measurement conditions, methods of measurement and reporting of the measured data, to be used for colour characterization and colour management of plasma display panels in multimedia systems.

Colour control within equipment is outside the scope of this International Standard. It does not specify limiting values for various parameters.

2 Normative references

The following referenced documents are indispensable for the application 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 60050-845:1987, *International Electrotechnical Vocabulary (IEV) – Chapter 845: Lighting/ CIE 17.4:1987, International Lighting Vocabulary (joint IEC/CIE publication)*

IEC 61966-3:2000, *Multimedia systems and equipment – Colour measurement and management – Part 3: Equipment using cathode ray tubes*

ISO 5-4:1995, *Photography – Density measurements – Part 4: Geometric conditions for reflection density*

ISO 9241-8:1997, *Ergonomic requirements for office work with visual display terminals (VDTs) – Part 8: Requirements for displayed colours*

ISO/CIE 10526:1999, *CIE standard illuminants for colorimetry*

ISO/CIE 10527:1991, *CIE standard colorimetric observers*

CIE 15:2004, *Colorimetry*

3 Terms and definitions

For the purpose of this part of IEC 61966, the definitions of IEC 60050-845/CIE 17.4, as well as the following definitions, apply.

3.1
background
image on a screen of the PDP display other than the interested area of a colour patch

3.2
colour control
effort to convert equipment dependent colour image data to equipment independent data for a specific colour space including tone characteristics

3.3
colour patch, test area
square colour image on a screen of the PDP display subject to be measured for colour reproduction, in which input data for the red, green and blue channels are kept constant within the image area

3.4
CRT
colorimetrically well-controlled equipment using cathode ray tubes to present colour images with digital inputs for reference

3.5
PDP display
any multimedia equipment using plasma display panels to present colour images

3.6
effective screen height
vertical dimension of the effective screen area

3.7
effective screen area
area where a picture can be produced

3.8
normalized (image) signal
input signal normalized by its full scale value, whose level is of interest in calculation and evaluation of colour control function within PDP display, see also equation (1)

3.9
uncertainty (of measurement)
parameter, associated with the result of a measurement, that characterizes the dispersion of the values that could reasonably be attributed to the particular quantity subject to measurement

NOTE See also [16] [1].

[1] Figures in square brackets refer to the bibliography

4 Letters and symbols

The notations consistently adopted in this part of IEC 61966 are summarized below.

A	display area ratio
N	number of bits in digital data for each channel
M	maximum integer for non-negative N-bit system; $M = 2^{N-1}$
D_R	digital data applied to red channel
D_G	digital data applied to green channel
D_B	digital data applied to blue channel
R	normalized input level to red channel
G	normalized input level to green channel
B	normalized input level to blue channel
X	one of measured raw data using spectroradiometers and colorimeters corresponding to tristimulus values
Y	one of measured raw data using spectroradiometers and colorimeters corresponding to tristimulus values in candela per square metre
Z	one of measured raw data using spectroradiometers and colorimeters corresponding to tristimulus values
R'	linearized data for red channel taking into account the tone characteristics of the channel
G'	linearized data for green channel taking into account the tone characteristics of the channel
B'	linearized data for blue channel taking into account the tone characteristics of the channel
X'	one of the tristimulus values normalized by Y_n (candela per square metre) for peak white
Y'	one of the tristimulus values normalized by Y_n (candela per square metre) for peak white
Z'	one of the tristimulus values normalized by Y_n (candela per square metre) for peak white

5 Conditions

5.1 Environmental conditions

All measurements specified in this standard shall be carried out in a dark room. Particular attention should be paid to reflected illumination caused by the ambient objects (desktop, wall, etc.) and to direct illumination from light-emitting indicators of measuring instruments.

A 1 h warm-up time should precede the measurements in 7.2, 9.2, 10.2, 11.2 and 14.2, if not specified by the manufacturer of the equipment.

The mains voltage and frequency shall be at the rated values specified by the manufacturer of a PDP display. When the mains voltage fluctuates, a regulated power supply should be used to maintain the supply voltage within ±5 % of the rated value.

Other environmental conditions such as room temperature and relative humidity shall be reported together with the results of the measurements.

If additional environmental conditions are described in the manufacturer's specifications, these should also be taken into account.

5.2 Conditions of measurements

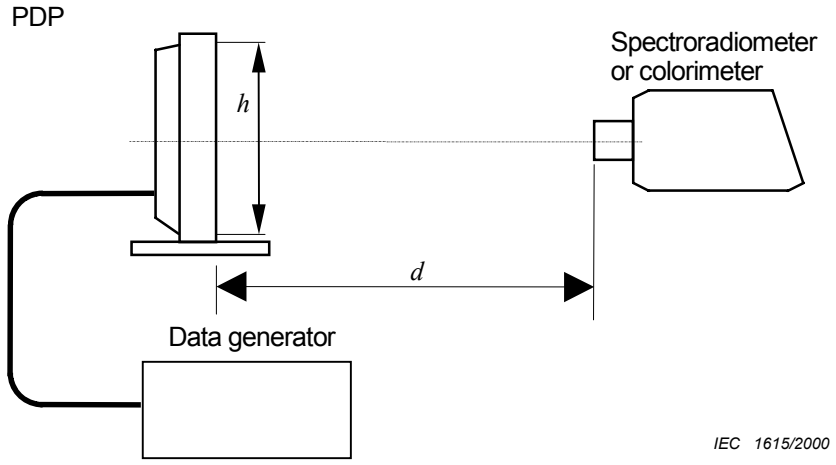
Contrast, brightness and additional adjustments shall be set to the preset positions specified by the manufacturer of the PDP display under measurement. When the adjustment is set to a position other than the preset, the position or corresponding value should be reported with the results of the measurements.

The equipment arrangement for non-contact measurements should be as shown in figure 1. It incorporates a spectroradiometer or a non-contact colorimeter, depending on the characteristics to be measured. The instrument optical axis should be normal to the centre of the surface of the PDP display.

The distance d between the faceplate of the PDP display and the measuring instrument shall be $4\,h$ or larger, where h is the effective screen height of the display, see Figure 1.

NOTE 1 It is recommended to take precautions so that the measurement is not influenced by vibration and that there are no missing picture elements within the field of view of the measuring instrument.

NOTE 2 The measurement area in the colour patch should include more than 500 picture elements.



h the effective screen height

Figure 1 – Equipment arrangement for non-contact measurements

The equipment arrangement for contact measurements should be as shown in Figure 2, where a measurement probe is placed on the faceplate of the PDP display.

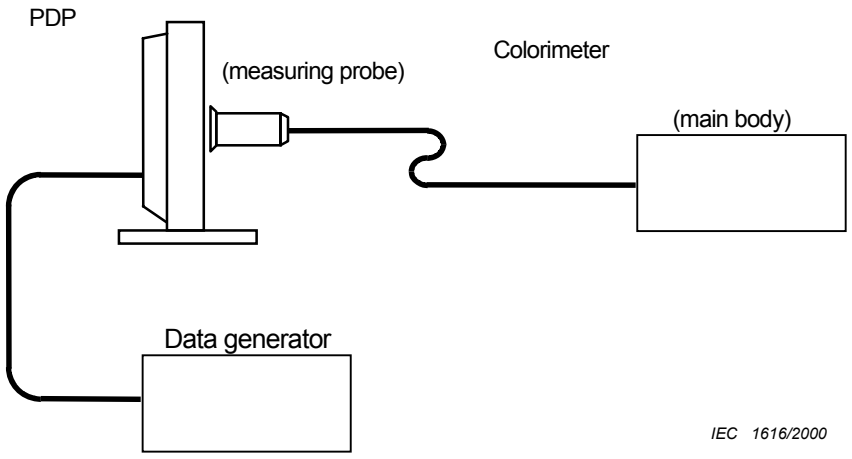
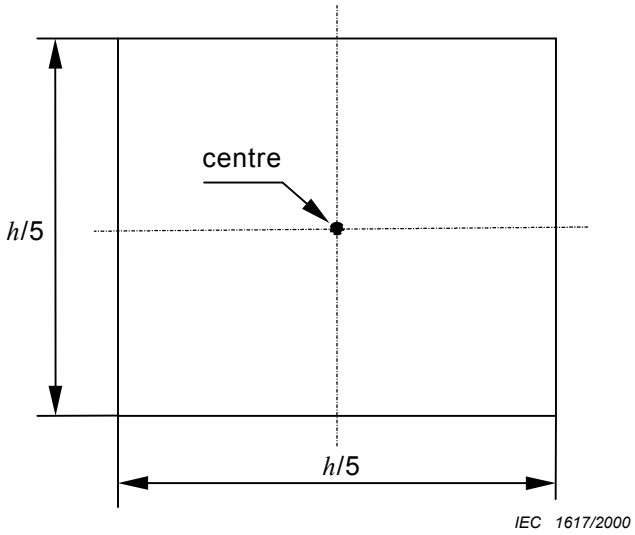


Figure 2 – Equipment arrangement for contact measurements

Test signals applied to red, green and blue channels shall result in a colour patch of the size shown in Figure 3 on the PDP display. The positioning of the colour patch shall be referred to by the centre as in Figure 3. The background shall be black, unless otherwise specified.



h the effective screen height

Figure 3 – Size of a colour patch

The area for measurement shall be circular, centred on the colour patch, with a diameter between 0,05 h and 0,15 h.

5.3 Input digital data

The relationship between input digital data, D_R, D_G, D_B, of N bits and corresponding normalized signal level for calculation shall be

$$R_i = \frac{D_{R_i}}{2^N - 1} \tag{1a}$$

$$G_i = \frac{D_{G_i}}{2^N - 1} \tag{1b}$$

$$B_i = \frac{D_{B_i}}{2^N - 1} \tag{1c}$$

where an index i denotes the i-th measurement step.

NOTE When the input signal is applicable in analogue voltage, the signal level normalized by the maximum input voltage should correspond to the signal level for each step defined in equation (1).

6 Measurement equipment

6.1 Spectroradiometer

A spectroradiometer with the following specifications should be used for the measurements:

a)	wavelength range	including 380 nm to 780 nm
b)	field of view	between 0,1° and 2,0°
c)	wavelength uncertainty	less than 0,5 nm throughout the wavelength range
d)	scanning interval	5 nm or less
e)	bandpass	5 nm or less
f)	repeatability	0,001 in x, y and 0,5 % in luminance (cd/m^2)
g)	uncertainty	0,005 in x, y for red, green, blue and white of a CRT and 4 % in luminance (cd/m^2) for white of the CRT that has a definite x, y and luminance value

The (x, y) is the CIE 1931 chromaticity coordinate specified in CIE 15.

NOTE 1 Periodic calibration should be done with a standard source of known spectral power distribution.

NOTE 2 Further technical details of the design, characterization, and calibration of spectroradiometers can be found in CIE 63 [17] and JIS Z 8724 [7].

NOTE 3 The standard CRT is referred to because no standard PDP displays exist at the time of publication of this part of IEC 61966. When it is available, the standard CRT should be replaced by the standard PDP display.

If the spectroradiometer used for measurements does not meet the above specifications, the model name and specification of the equipment shall be reported together with the results of measurements.

6.2 Colorimeter

The colorimeter should have the following specifications:

a)	measurement area (contact type)	0,05 h to 0,15 h, where h is the effective screen height of the PDP display
b)	field of view (non-contact type)	any value between 0,1° and 2,0°
c)	spectral responsivity	compliant to the CIE 2-degree colour matching functions as defined in ISO/CIE 10527
d)	repeatability	0,001 in x, y and 0,5 % for luminance
e)	uncertainty	0,005 in x, y for red, green, blue and white of the CRT and 4 % in luminance (cd/m^2) for white of the CRT that has a definite x, y and luminance value

The (x, y) is the CIE 1931 chromaticity coordinate defined in CIE 15.

NOTE 1 If the original uncertainty of the colorimeter does not meet this recommendation, correction methods are available to improve the accuracy for the PDP display measurement. (See [5], [6] and [11].)

NOTE 2 The instrument should be calibrated periodically to assure the uncertainty recommendation given in item e) above.

NOTE 3 The standard CRT is referred to because no standard PDP displays exist at the time of publication of this part of IEC 61966. When it is available, the standard CRT should be replaced by the standard PDP display.

The readings of the colorimeter, X, Y (in candela per square metre), and Z shall be normalized by the luminance level of a peak neutral colour (white), Y_n (in candela per square metre), as follows:

$$X' = \frac{X}{Y_n} \tag{2a}$$

$$Y' = \frac{Y}{Y_n} \tag{2b}$$

$$Z' = \frac{Z}{Y_n} \tag{2c}$$

If the colorimeter used for measurements does not meet the above specifications, the model name and specification of the equipment shall be reported together with the results of measurements.

NOTE 4 It is known that small tilt angles of the contact-measuring head on the surface of the PDP display can lead with some instruments to large chromaticity errors. Therefore, care should be taken.

NOTE 5 Synchronization of the colorimeter and scan timing of the PDP display should be taken into account.

7 Spectral characteristics and intensity of the primaries and white

7.1 Characteristics to be measured

Spectral radiance distributions and corresponding tristimulus values for the peak of three primaries, red – green – blue, as well as white.

7.2 Measurement conditions

The arrangement of equipment shall be as in Figure 1 with the spectroradiometer.

The colour signal shall be so generated that the colour patch is positioned at the centre of the PDP display under measurement.

Digital data for the background shall be $D_R = 0$, $D_G = 0$, $D_B = 0$.

7.3 Method of measurement

The centred colour patches shall be generated following the measurement steps as shown in Table 1, where $M = 2^N - 1$ and N is the number of bits per channel.

Table 1 – Input data for peak primaries and peak white

Steps	Colours	D_R	D_G	D_B
1	Peak red	M	0	0
2	Peak green	0	M	0
3	Peak blue	0	0	M
4	Peak white	M	M	M

Spectral radiance distributions $r(\lambda)$, $g(\lambda)$, $b(\lambda)$, $w(\lambda)$ for peak red, green, blue and white images on the PDP display shall be measured successively by the spectroradiometer.

Readings of the spectroradiometer, X_C, Y_C, Z_C, shall also be noted, where the suffix C corresponds to R, G, B for primary colours; and to W for the peak white, respectively.

7.4 Presentation of results

The measured data for spectral radiance distributions shall be reported for peak colours red, green, blue, and white.

The spectral radiance distributions $r(\lambda)$, $g(\lambda)$, $b(\lambda)$ shall be plotted for peak colours red, green, and blue, respectively, as illustrated in Figure 4.

The readings of the spectroradiometer with an emulation function of colorimeters, X_C, Y_C, Z_C, for peak red, green, blue and white shall be reported as a table as shown in Table 2.

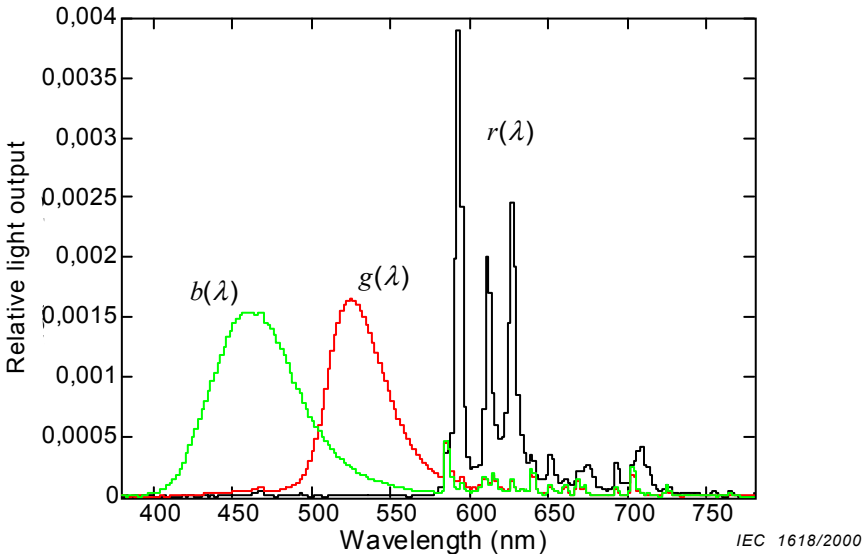


Figure 4 – An example of the spectral radiance distributions $r(\lambda)$, $g(\lambda)$, $b(\lambda)$

Table 2 – Example of reporting form for colours in maximum excitations

Colours	X	Y cd/m^2	Z
Peak red	34,77	19,73	0,64
Peak green	16,18	40,82	5,12
Peak blue	17,59	14,37	75,53
Peak white	67,83	73,73	82,59

8 Basic colorimetric characteristics

8.1 Characteristics to be measured

Linear relation between maximum input excitation and the tristimulus values of light output.

8.2 Method of calculation

The reported results of measurement in 7.4 shall be used to obtain tristimulus values to characterize the three primaries, red – green – blue, as well as white. The luminance in candela per square metre shall be normalized as in equation (3) for red, green, blue and white replacing the suffix C by R, G, B, and W, respectively;

$$X'_C = \frac{X_C}{Y_n} \tag{3a}$$

$$Y'_C = \frac{Y_C}{Y_n} \tag{3b}$$

$$Z'_C = \frac{Z_C}{Y_n} \tag{3c}$$

where the normalization factor Y_n is the measured luminance value in candela per square metre for peak white, which is reported in Table 2.

The CIE 1931 x, y chromaticity coordinate values, x_C, y_C, z_C shall be calculated for primary colours and for white as defined in CIE 15, where suffix C corresponds to R, G, B for primary colours, and to W for white, respectively.

$$x_C = \frac{X'_C}{X'_C + Y'_C + Z'_C} \tag{4a}$$

$$y_C = \frac{Y'_C}{X'_C + Y'_C + Z'_C} \tag{4b}$$

$$z_C = 1 - x_C - y_C \tag{4c}$$

The elements of a 3×3 matrix, $\mathbf{S}$, defined as

$$\begin{pmatrix} X' \\ Y' \\ Z' \end{pmatrix} = \mathbf{S} \begin{pmatrix} R \\ G \\ B \end{pmatrix} \tag{5}$$

shall be decided as in

$$S = \begin{pmatrix} x_R/y_R & x_G/y_G & x_B/y_B \\ 1 & 1 & 1 \\ z_R/y_R & z_G/y_G & z_B/y_B \end{pmatrix} \begin{pmatrix} S_R & 0 & 0 \\ 0 & S_G & 0 \\ 0 & 0 & S_B \end{pmatrix} \quad (6)$$

where S_R, S_G, S_B are solutions of equation (7);

$$\begin{pmatrix} x_R/y_R & x_G/y_G & x_B/y_B \\ 1 & 1 & 1 \\ z_R/y_R & z_G/y_G & z_B/y_B \end{pmatrix} \begin{pmatrix} S_R \\ S_G \\ S_B \end{pmatrix} = \begin{pmatrix} x_W/y_W \\ 1 \\ z_W/y_W \end{pmatrix} \quad (7)$$

and R, G and B are defined by equation (1) and have the values 0 or 1 corresponding to peak excitations.

8.3 Presentation of results

The tristimulus values multiplied by 100 and the CIE 1931 x, y chromaticity coordinate values shall be reported as a table, as shown in Table 3.

Table 3 – Example of reporting form

Colours	Tristimulus values			Chromaticity coordinates	
	X'	Y'	Z'	x	y
Peak red	47,16	26,76	0,87	0,636	0,358
Peak green	21,94	55,36	6,94	0,265	0,657
Peak blue	23,86	19,49	102,44	0,164	0,134
Peak white	92,00	100,00	112,02	0,303	0,329
NOTE CIE 1976 UCS coordinate values, u', v', and CIELAB values, L^*, a^*, b^* defined in CIE 15 may additionally be reported.					

The coefficient matrix in equation (5) shall be reported as shown.

$$\mathbf{S} = \begin{pmatrix} 0{,}463\ 3 & 0{,}213\ 5 & 0{,}243\ 2 \\ 0{,}262\ 9 & 0{,}538\ 5 & 0{,}198\ 6 \\ 0{,}008\ 5 & 0{,}067\ 6 & 1{,}044\ 1 \end{pmatrix}$$

The correlated colour temperature, defined in 9.5 of CIE 15, for peak white shall also be calculated and reported in kelvins, together with the deviation δ_{uv}.

NOTE For the recommended procedure to calculate correlated colour temperatures, refer to [15].

9 Tone characteristics

9.1 Characteristics to be measured

Non-linear transfer relationship between the normalized input signal level applied to each of the red, green and blue channels and the normalized tristimulus values measured on a PDP display.

9.2 Measurement conditions

The arrangement of equipment shall be as in Figure 1 with colorimeter or Figure 2.

The input data D_{R_i}, D_{G_i}, D_{B_i} for measurement step i shall be so applied as to generate colour patches positioned at the centre of the PDP display under measurement (see Figure 3).

The digital input data for the background shall be $D_R = 0$, $D_G = 0$, $D_B = 0$.

NOTE 1 For the relationship between digital data D_R, D_G, D_B and values of R, G, B, see equation (1).

NOTE 2 If the analogue input is used, the input signal should be of the same level which corresponds to the digital data.

9.3 Method of measurement

The centred colour patches shall be displayed for values of input data D_R, D_G and D_B from 0, $\frac{1}{m}2^N$, $\frac{2}{m}2^N$, ..., to $M = 2^N - 1$

where

m + 1 is the number of data and should be at least 33;

N is the number of bits per channel.

For the red channel measurement, $D_G = D_B = 0$; for the green channel, $D_R = D_B = 0$, and for the blue channel, $D_R = D_G = 0$ shall be kept, respectively.

The readings of the colorimeter for each colour patch on the PDP display shall be recorded successively and noted as X_C^i, Y_C^i, Z_C^i, where the subscript C shall be replaced by R, G and B, for the red, green, and blue channels, respectively; and the superscript i corresponds to measurement steps, i = 0, 1, 2,... m.

The measured tristimulus values shall be normalized by the values corresponding to the maximum excitation for the last step m with input data $M = 2^N - 1$.

$$X''_{iC} = \frac{X_C^i}{X_C^m} \tag{8a}$$

$$Y''_{iC} = \frac{Y_C^i}{Y_C^m} \tag{8b}$$

$$Z''_{iC} = \frac{Z_C^i}{Z_C^m} \tag{8c}$$

where the subscript C shall be replaced by R, G and B.

9.4 Presentation of results

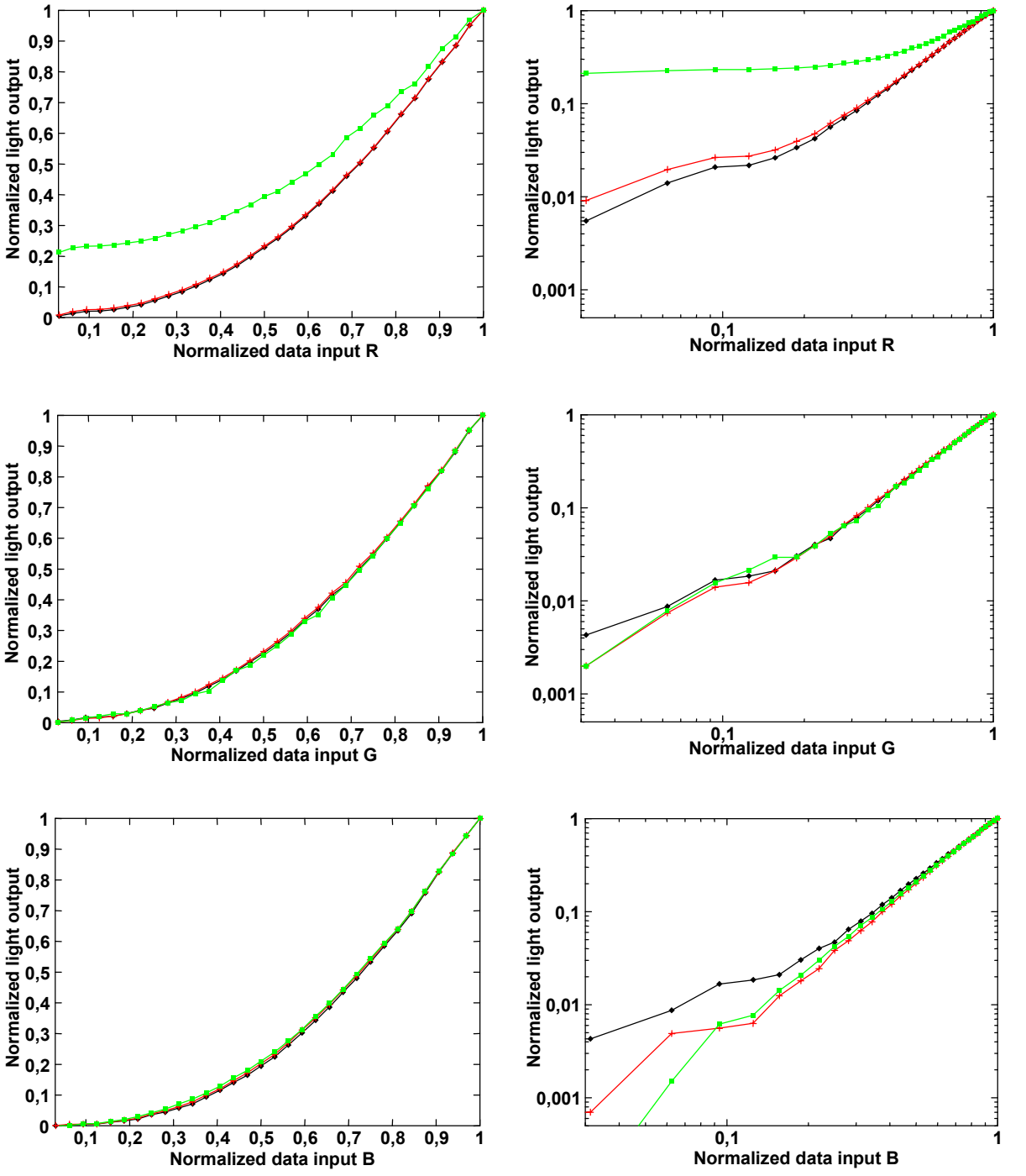


Figure 5 – Measured points and interpolated curves

The measured and normalized data X''_{i_C}, Y''_{i_C} and Z''_{i_C} for $0 \le i \le m$ shall be reported as linear and logarithmic plots for $C =$ R, G, B with the interpolated non-linear transfer relation, as shown in Figure 5.

The basic normalized data defined by equation (8) shall also be reported as shown in Table 4.

Table 4 – An example set of basic normalized data for tone characteristics

i	X''_R	Y''_R	Z''_R	X''_G	Y''_G	Z''_G	X''_B	Y''_B	Z''_B
0	0,004 9	0,008 1	0,205 0	0,003 7	0,002 2	0,017 6	0,0000	0,000 7	0,0000
1	0,005 5	0,009 1	0,212 5	0,004 3	0,002 0	0,002 0	0,000 6	0,000 7	0,000 1
2	0,014 0	0,019 6	0,226 8	0,008 7	0,007 4	0,007 8	0,002 8	0,004 9	0,001 5
3	0,020 8	0,026 4	0,232 1	0,016 7	0,014 0	0,015 6	0,004 5	0,005 6	0,006 2
4	0,021 7	0,027 3	0,233 0	0,018 5	0,015 7	0,021 5	0,005 7	0,006 3	0,007 7
5	0,026 2	0,031 8	0,237 1	0,021 0	0,021 1	0,029 3	0,011 4	0,012 5	0,014 2
6	0,033 8	0,039 4	0,242 7	0,030 3	0,028 9	0,029 3	0,015 9	0,018 1	0,020 8
7	0,042 1	0,047 5	0,248 7	0,040 2	0,039 0	0,039 1	0,022 7	0,024 4	0,029 9
8	0,056 2	0,061 6	0,258 7	0,047 0	0,049 8	0,052 7	0,036 4	0,038 3	0,042 5
9	0,069 9	0,075 3	0,270 9	0,064 3	0,066 2	0,064 5	0,044 9	0,048 7	0,054 3
10	0,084 4	0,089 7	0,282 6	0,079 1	0,082 4	0,072 3	0,058 0	0,062 6	0,071 0
11	0,103 3	0,108 5	0,295 8	0,095 8	0,100 7	0,093 8	0,071 6	0,077 9	0,086 7
12	0,123 4	0,128 5	0,308 3	0,118 7	0,123 8	0,103 5	0,093 8	0,100 2	0,107 1
13	0,144 0	0,149 0	0,327 0	0,140 3	0,145 1	0,136 7	0,116 0	0,120 4	0,128 6
14	0,169 9	0,174 7	0,347 6	0,168 1	0,172 5	0,169 9	0,141 0	0,146 8	0,155 8
15	0,197 3	0,202 0	0,368 1	0,197 2	0,201 5	0,185 5	0,164 9	0,172 6	0,180 9
16	0,229 2	0,233 8	0,394 5	0,226 2	0,231 9	0,218 8	0,194 4	0,202 5	0,210 0
17	0,258 4	0,262 9	0,411 4	0,258 3	0,264 2	0,250 0	0,224 6	0,232 4	0,239 8
18	0,293 1	0,297 3	0,440 6	0,292 3	0,298 3	0,287 1	0,263 2	0,270 7	0,275 9
19	0,330 3	0,334 5	0,467 5	0,333 7	0,340 0	0,330 1	0,302 4	0,311 8	0,313 8
20	0,370 2	0,374 0	0,498 9	0,369 6	0,375 7	0,351 6	0,343 9	0,351 4	0,356 9
21	0,412 2	0,415 8	0,530 6	0,414 7	0,421 6	0,406 3	0,386 0	0,395 3	0,399 4
22	0,460 1	0,463 6	0,585 9	0,448 1	0,456 1	0,447 3	0,434 9	0,441 9	0,444 7
23	0,502 7	0,505 7	0,616 4	0,500 6	0,509 1	0,496 1	0,480 4	0,488 5	0,493 3
24	0,551 8	0,554 7	0,658 3	0,546 4	0,552 0	0,543 0	0,533 3	0,540 0	0,544 8
25	0,604 9	0,607 4	0,689 4	0,597 7	0,603 7	0,599 6	0,585 0	0,590 8	0,595 3
26	0,661 1	0,663 5	0,735 9	0,652 0	0,656 4	0,650 4	0,634 5	0,639 5	0,640 1
27	0,713 7	0,715 8	0,761 4	0,705 8	0,711 5	0,707 0	0,690 7	0,697 3	0,697 3
28	0,775 6	0,777 6	0,817 0	0,766 4	0,770 3	0,761 7	0,757 2	0,761 3	0,762 2
29	0,832 1	0,833 2	0,876 2	0,819 5	0,822 3	0,818 4	0,825 5	0,826 7	0,829 5
30	0,885 2	0,886 0	0,914 5	0,880 1	0,885 8	0,882 8	0,885 7	0,888 0	0,885 2
31	0,951 5	0,951 9	0,970 4	0,949 3	0,951 5	0,951 2	0,943 7	0,944 3	0,943 5
32	1,000 0	1,000 0	1,000 0	1,000 0	1,000 0	1,000 0	1,000 0	1,000 0	1,000 0

10 Inter-channel dependency

10.1 Characteristics to be measured

Inter-channel relationship between input data and tristimulus values, X', Y', Z', of displayed colours.

The relationship depending upon channel interaction shall be defined as follows:

$$\begin{pmatrix} X' \\ Y' \\ Z' \end{pmatrix} = \mathbf{S} \times \mathbf{T} \begin{pmatrix} 1 \\ R' \\ G' \\ B' \\ R'G' \\ G'B' \\ B'R' \\ R'G'B' \end{pmatrix} \tag{9}$$

where the variables R', G', B' are data obtained by interpolation of measured data, which are reported as X''_{R}, Y''_{G}, Z''_{B} in Table 4, namely

$$\begin{aligned} R' &= X''_{\mathrm{R}} \\ G' &= Y''_{\mathrm{G}} \\ B' &= Z''_{\mathrm{B}} \end{aligned} \tag{10}$$

and dependent variables X', Y', Z' are measured and normalized tristimulus values of light output in accordance with equation (2). In equation (9), $\mathbf{S}$ is the matrix reported in 8.3 and $\mathbf{T}$ is 3 × 8 matrix as follows:

$$\mathbf{S} = \begin{pmatrix} s_{11} & s_{12} & s_{13} \\ s_{21} & s_{22} & s_{23} \\ s_{31} & s_{32} & s_{33} \end{pmatrix}$$

$$\mathbf{T} = \left(\begin{array}{c|ccc|ccc|c} t0_X & t1_X & t2_X & t3_X & t4_X & t5_X & t6_X & t7_X \\ t0_Y & t1_Y & t2_Y & t3_Y & t4_Y & t5_Y & t6_Y & t7_Y \\ t0_Z & t1_Z & t2_Z & t3_Z & t4_Z & t5_Z & t6_Z & t7_Z \end{array}\right)$$

NOTE The matrix $\mathbf{S}$ obtained and reported in 8.3 defines the dominant relation, and the matrix $\mathbf{T}$ defines the inter-channel relations among red – green – blue channels.

10.2 Measurement conditions

The arrangement of equipment should be as in Figure 1 or Figure 2.

The input signal shall be so applied as to generate the colour patch of Figure 3 positioned at the centre of the screen of the PDP display under measurement.

The input data for the background shall be $D_{\mathrm{R}} = 0$, $D_{\mathrm{G}} = 0$, and $D_{\mathrm{B}} = 0$.

10.3 Method of measurement

The centred colour patches shall be displayed with the input data following the measurement steps as shown in Table 5 for 32 colours.

Table 5 – Digital inputs to generate colour patches for measurement of inter-channel dependency

Step, i	Colour	D_R	D_G	D_B
1	Grey 1	D_1	D_1	D_1
2	Grey 2	D_2	D_2	D_2
3	Grey 3	D_3	D_3	D_3
4	Grey 4	D_4	D_4	D_4
5	Grey 5	D_5	D_5	D_5
6	Grey 6	D_6	D_6	D_6
7	Grey 7	D_7	D_7	D_7
8	Grey 8	D_8	D_8	D_8
9	Red 1	D_4	D_0	D_0
10	Red 2	D_6	D_2	D_2
11	Red 3	D_8	D_0	D_0
12	Red 4	D_8	D_4	D_4
13	Green 1	D_0	D_4	D_0
14	Green 2	D_2	D_6	D_2
15	Green 3	D_0	D_8	D_0
16	Green 4	D_4	D_8	D_4
17	Blue 1	D_0	D_0	D_4
18	Blue 2	D_2	D_2	D_6
19	Blue 3	D_0	D_0	D_8
20	Blue 4	D_4	D_4	D_8
21	Yellow 1	D_4	D_4	D_0
22	Yellow 2	D_6	D_6	D_2
23	Yellow 3	D_8	D_8	D_0
24	Yellow 4	D_8	D_8	D_4
25	Magenta 1	D_4	D_0	D_4
26	Magenta 2	D_6	D_2	D_6
27	Magenta 3	D_8	D_0	D_8
28	Magenta 4	D_8	D_4	D_8
29	Cyan 1	D_0	D_4	D_4
30	Cyan 2	D_2	D_6	D_6
31	Cyan 3	D_0	D_8	D_8
32	Cyan 4	D_4	D_8	D_8

In Table 5, the values of data D_k shall be

$$D_k = \begin{cases} 2^{N-3}k & \text{for } k = 0,...,7, \\ 2^{N-3}k - 1 & \text{for } k = 8. \end{cases}$$

where N is the number of bits per channel.

The tristimulus values X'_i, Y'_i, Z'_i, normalized in accordance with equation (2), shall successively be measured by the colorimeter for $i = 1$ to $i = 32$ for all colour patches on the PDP display.

The data $R'_i = X''_{\mathrm{R}_i}$, $G'_i = Y''_{\mathrm{G}_i}$, and $B'_i = Z''_{\mathrm{B}_i}$, corresponding to D_{R_i}, D_{G_i}, D_{B_i} in Table 5, shall be calculated by interpolation using the set of data reported in Table 4. Values of coefficient matrix, $\mathbf{T}$, defined in equation (9) shall be calculated as follows:

$$\mathbf{T} = \mathbf{S}^{-1}\left(\left(\mathbf{D}^t\mathbf{D}\right)^{-1}\mathbf{D}^t\mathbf{A}\right)^t$$

where the matrices $\mathbf{D}$ and $\mathbf{A}$ are defined as follows:

$$\mathbf{D} = \left(\begin{array}{c|ccc|ccc|c} 1 & R'_1 & G'_1 & B'_1 & R'_1G'_1 & G'_1B'_1 & B'_1R'_1 & R'_1G'_1B'_1 \\ 1 & R'_2 & G'_2 & B'_2 & R'_2G'_2 & G'_2B'_2 & B'_2R'_2 & R'_2G'_2B'_2 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 1 & R'_{32} & G'_{32} & B'_{32} & R'_{32}G'_{32} & G'_{32}B'_{32} & B'_{32}R'_{32} & R'_{32}G'_{32}B'_{32} \end{array}\right)$$

$$\mathbf{A} = \begin{pmatrix} X'_1 & Y'_1 & Z'_1 \\ X'_2 & Y'_2 & Z'_2 \\ \vdots & \vdots & \vdots \\ X'_{32} & Y'_{32} & Z'_{32} \end{pmatrix}$$

10.4 Presentation of results

The matrix $\mathbf{T}$ shall be reported as shown below.

$$\mathbf{T} = \left(\begin{array}{ccc|ccc|ccc} -0{,}009\,8 & 1{,}077\,6 & 0{,}007\,2 & 0{,}024\,5 & -0{,}047\,7 & 0{,}002\,3 & -0{,}049\,9 & 0{,}028\,0 \\ 0{,}003\,9 & -0{,}008\,9 & 0{,}995\,2 & -0{,}007\,6 & 0{,}076\,4 & 0{,}082\,1 & 0{,}015\,5 & -0{,}191\,3 \\ 0{,}004\,3 & -0{,}006\,7 & -0{,}004\,3 & 1{,}055\,0 & 0{,}012\,0 & 0{,}064\,6 & 0{,}049\,5 & -0{,}129\,4 \end{array}\right)$$

The measured and normalized data shall also be reported as shown in Table 6.

Table 6 – Example of normalized tristimulus values (the matrix A)

i	X'	Y'	Z'
1	0,011 4	0,013 5	0,011 3
2	0,044 2	0,048 7	0,053 4
3	0,109 3	0,120 9	0,131 2
4	0,209 4	0,228 9	0,254 8
5	0,346 9	0,376 7	0,429 4
6	0,519 7	0,558 3	0,647 1
7	0,724 5	0,774 0	0,898 8
8	0,938 7	1,000 0	1,164 2
9	0,108 5	0,062 2	0,001 7
10	0,292 2	0,190 0	0,058 0
11	0,495 9	0,281 3	0,008 4
12	0,601 7	0,453 1	0,262 9
13	0,049 5	0,124 8	0,016 2
14	0,153 9	0,321 9	0,090 2
15	0,215 5	0,541 5	0,069 6
16	0,381 2	0,650 9	0,310 5
17	0,058 3	0,048 8	0,236 7
18	0,179 8	0,159 6	0,608 3
19	0,265 0	0,215 3	1,111 5
20	0,424 6	0,403 0	1,129 5
21	0,148 1	0,184 9	0,012 7
22	0,390 1	0,469 4	0,092 4
23	0,701 7	0,838 7	0,077 7
24	0,764 4	0,892 4	0,329 8
25	0,165 1	0,109 6	0,247 2
26	0,419 8	0,298 1	0,630 7
27	0,748 6	0,490 0	1,154 9
28	0,803 3	0,624 7	1,171 9
29	0,127 4	0,192 2	0,270 6
30	0,312 1	0,457 5	0,666 0
31	0,507 7	0,802 2	1,235 9
32	0,616 3	0,859 8	1,236 6

11 Spatial non-uniformity

11.1 Characteristics to be measured

Non-uniformity of lightness (see IEC 60050-845, IEV 845-03-54 and IEV 845-03-56) and chromaticity coordinates over the entire PDP display screen.

11.2 Measurement conditions

The arrangement of the equipment should be as in Figure 2.

11.3 Method of measurement

The data $D_R = M$, $D_G = M$, and $D_B = M$ shall be applied to display white over the entire PDP display surface, where $M = 2^N - 1$ and N is the number of bits per channel.

Tristimulus values, X_i, Y_i, Z_i, shall be measured using the colorimeter at 25-point ($1 \leq i \leq 25$) as shown in Figure 6.

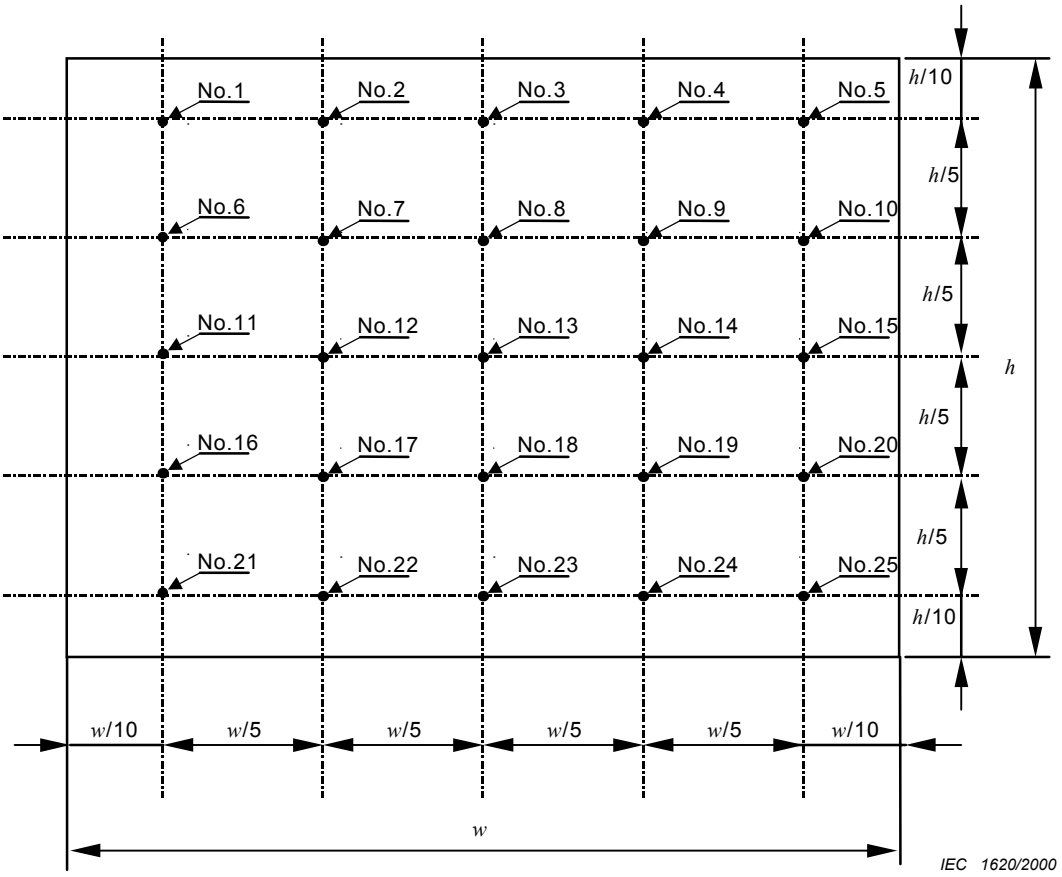


Figure 6 – Measurement points for spatial non-uniformity

The following colour differences in the CIE 15 1976 UCS and in the CIE 1976 $L^*a^*b^*$ colour space shall be calculated with reference to the data X_{13}, Y_{13}, Z_{13} which correspond to the centre of the PDP display.

$$\Delta u'_i = u'_i - u'_{13} \tag{11a}$$

$$\Delta v'_i = v'_i - v'_{13} \tag{11b}$$

$$\Delta u'v'_i = \sqrt{\Delta u'^2_i + \Delta v'^2_i} \tag{11c}$$

$$\Delta L^*_i = L^*_i - L^*_{13} \tag{11d}$$

$$\Delta C^*_{ab_i} = \sqrt{a^{*2}_i + b^{*2}_i} - \sqrt{a^{*2}_{13} + b^{*2}_{13}} \tag{11e}$$

where u', v' and L^*, a^*, b^* are defined in CIE 15 as in

$$u'_i = \frac{4X_i}{X_i + 15Y_i + 3Z_i} \tag{12a}$$

$$v'_i = \frac{9Y_i}{X_i + 15Y_i + 3Z_i} \tag{12b}$$

$$L^*_i = 116\left(\frac{Y_i}{Y_{13}}\right)^{\frac{1}{3}} - 16 \tag{13a}$$

$$a^*_i = 500\left\{\left(\frac{X_i}{X_{13}}\right)^{\frac{1}{3}} - \left(\frac{Y_i}{Y_{13}}\right)^{\frac{1}{3}}\right\} \tag{13b}$$

$$b^*_i = 200\left\{\left(\frac{Y_i}{Y_{13}}\right)^{\frac{1}{3}} - \left(\frac{Z_i}{Z_{13}}\right)^{\frac{1}{3}}\right\} \tag{13c}$$

NOTE These equations are valid for $\frac{Y_i}{Y_{13}} \geq 0{,}008\,856$

11.4 Presentation of results

As the indices of non-uniformity, the calculated results, $\Delta u'$, $\Delta v'$, $\Delta u'v'$, ΔL^* and ΔC^*_{ab} for $1 \leq i \leq 25$ shall be reported as shown in Table 7. For interpretation and requirement for the values of $\Delta u'v'$, ISO 9241-8 shall be referred to.

Table 7 – Example of reporting form

Position	$\Delta u'$	$\Delta v'$	$\Delta u'v'$	ΔL^*	ΔC^*_{ab}
1	–0,009 0	–0,006 0	0,018 2	–0,75	8,50
2	–0,003 0	–0,010 1	0,010 5	0,47	8,91
3	0,000 7	–0,005 7	0,005 7	–1,44	5,39
4	–0,008 5	–0,007 9	0,011 6	0,35	9,11
5	–0,007 0	–0,002 7	0,007 5	4,12	6,41
6	0,000 1	–0,007 0	0,007 0	–0,15	6,47
7	0,001 2	–0,008 9	0,009 0	–0,04	8,58
8	0,000 5	–0,002 3	0,002 4	2,23	2,35
9	0,000 7	–0,008 3	0,008 3	2,19	7,98
10	–0,005 5	–0,008 6	0,012 1	0,29	8,10
11	–0,006 4	–0,005 7	0,008 6	–2,24	6,52
12	–0,000 6	–0,009 7	0,009 7	–0,29	8,70
13	0,000 0	0,000 0	0,000 0	0,00	0,00
14	–0,005 8	–0,004 3	0,007 2	–0,37	5,65
15	–0,004 8	–0,010 8	0,011 8	–1,02	9,54
16	0,001 7	–0,010 1	0,010 2	–1,33	9,66
17	–0,005 7	–0,004 2	0,007 0	0,86	5,65
18	–0,001 9	–0,001 1	0,002 2	3,18	1,80
19	–0,002 0	–0,008 7	0,008 9	2,86	7,83
20	–0,001 5	–0,009 5	0,009 6	2,71	8,65
21	0,001 2	–0,007 3	0,007 4	2,93	7,31
22	0,001 4	–0,009 3	0,009 4	2,33	9,19
23	0,002 0	–0,008 2	0,008 4	1,73	8,30
24	–0,003 6	–0,008 5	0,009 2	4,20	7,85
25	–0,007 2	–0,004 1	0,008 3	2,69	6,76

12 Temporal stability

12.1 Short-term stability

12.1.1 Characteristics to be measured

Stability of colour reproduction upon first turning on the PDP display.

12.1.2 Measurement conditions

The arrangement of the equipment should be as in Figure 1 or Figure 2.

The PDP display shall be turned off for more than 2 h before the measurement.

12.1.3 Method of measurement

The input data D_R = M, D_G = M, and D_B = M shall be applied with the result so that the entire surface of the PDP display becomes white, where $M = 2^N - 1$ and N is the number of bits per channel.

The luminance Y in candela per square metre and the chromaticity coordinate values x, y as in the CIE 1931 diagram shall be measured using the colorimeter at the centre of the screen every minute for a duration of 2 h.

The time average of the measured luminance $\overline{Y}$ shall be calculated as follows:

$$\overline{Y} = \frac{1}{120} \sum_{i=1}^{120} Y_i \tag{14}$$

12.1.4 Presentation of results

The luminance Y versus time shall be plotted as a graph, where the vertical axis shall be from $\overline{Y} - 10$ (in candela per square metre) to $\overline{Y} + 10$ (in candela per square metre).

The chromaticity values x, y shall also be plotted as curves, where the vertical axis shall be from 0,2 to 0,4, as shown in Figure 7.

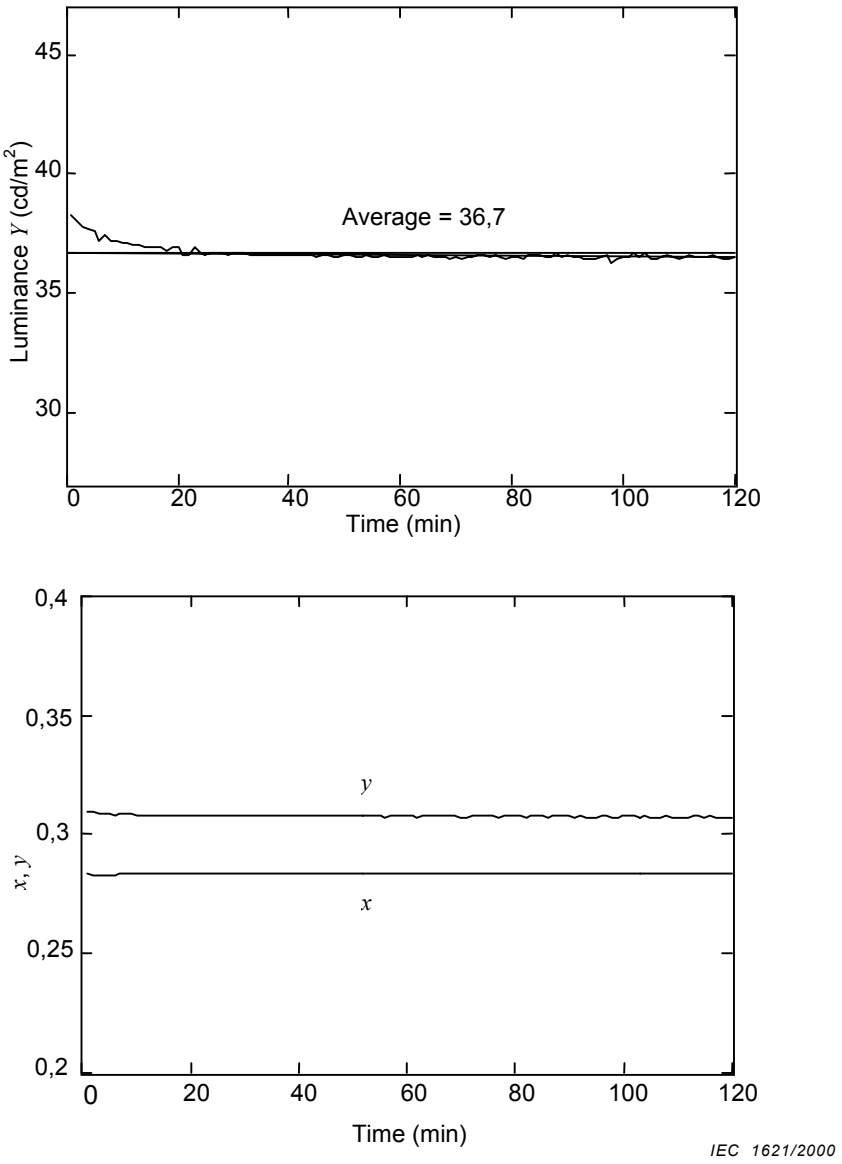


Figure 7 – Example plots for short-term stability

12.2 Mid-term stability

12.2.1 Characteristics to be measured

Stability of colour reproduction of PDP displays in daily use.

12.2.2 Measurement conditions

The arrangement of the equipment shall be as shown in Figure 1 or Figure 2.

The PDP display shall be turned off for more than 2 h before the measurement.

12.2.3 Method of measurement

The input data D_R = M, D_G = M, et D_B = M shall be applied to produce white on the entire surface of the PDP display, where $M = 2^N - 1$ and N is the number of bits per channel.

The luminance in candela per square metre and chromaticity coordinate values x, y as in the CIE 1931 diagram shall be measured using the colorimeter at the centre of the screen every 10 min for a duration of 24 h.

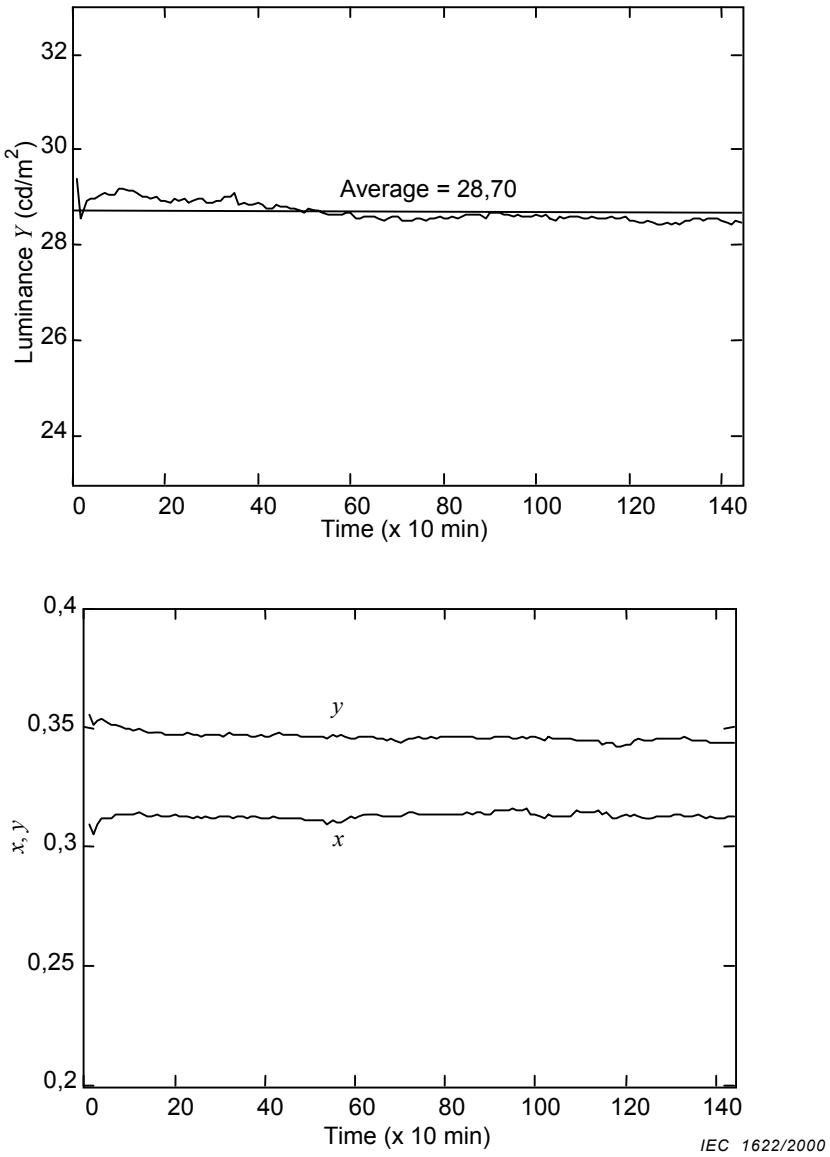
The time average of the measured luminance $\overline{Y}$ shall be calculated as follows:

$$\overline{Y} = \frac{1}{144} \sum_{i=1}^{144} Y_i \qquad (15)$$

12.2.4 Presentation of results

The luminance Y versus time shall be plotted as a graph, where the vertical axis shall be from $\overline{Y} - 5$ (in candela per square metre) to $\overline{Y} + 5$ (in candela per square metre).

The chromaticity values x, y shall also be plotted as curves, where the vertical axis shall be from 0,2 to 0,4, as shown in Figure 8.



NOTE The arrangements of equipment to measure short-term stability and mid-term stability should be the same.

Figure 8 – Example plots for mid-term stability

13 Surface reflection

13.1 Characteristics to be measured

The luminance factor (IEC 60050-845, IEV 845-04-69) of the PDP display surface.

13.2 Measurement conditions

The PDP display under measurement shall be turned off. The faceplate of the PDP display shall be illuminated and measured in the 45/0 geometry according to ISO 5-4, as shown in Figure 9.

The light source shall be an incandescent source having a spectrum close to the CIE Standard Illuminant A (2 856 K ± 100 K) defined in ISO/CIE 10526. The size of the source and the distance to the display shall be chosen so that the angle subtended by the largest dimension of the source from the display centre is less than 5° ± 2,5°. The angle of incidence of the light source shall be set to 45° ± 3°. The spectroradiometer shall measure a circular area of a diameter of 0,05 h to 0,15 h at a distance of $d \geq 4h$, where h is the effective screen height. The spectroradiometer shall be optically shielded from direct illumination from the source.

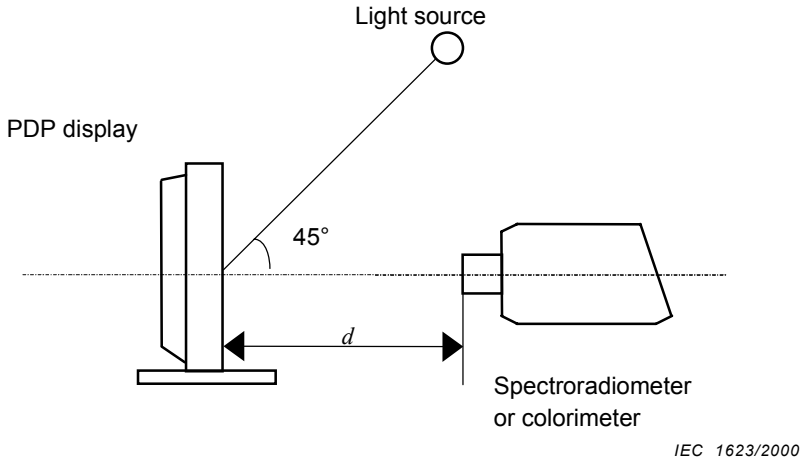


Figure 9 – Equipment arrangement

13.3 Method of measurement

A white diffuse reflectance standard (for example, pressed/sintered polytetrafluoroethylene (PTFE) or barium sulphate), calibrated for 45/0 luminance factor β_p, shall be introduced in place of the CRT screen, and the luminance L_p shall be measured under the illumination.

The PDP display under test shall be placed and the luminance L_s shall be measured under the illumination.

The luminance factor β_s shall be calculated by

$$\beta_s = \frac{\beta_p L_s}{L_p} \tag{16}$$

For an alternative method of measurement, refer to annex B of IEC 61966-3.

NOTE The level of the illumination should be adjusted so that the measurement can be conducted within readable range of the measuring instrument.

13.4 Presentation of results

The luminance factor β_s shall be reported in percentage points, as shown in Table 8.

Table 8 – Example of reporting form

Illuminance cd/m^2		**Luminance factor** %
L_p	L_s	β_s
4,73	113,70	3,91

NOTE 1 See also annex D of IEC 61966-3 for a suggested interpretation of the measured result.

NOTE 2 For evaluation of external light source, refer to annex C of IEC 61966-3.

14 Display area ratio characteristics

14.1 Characteristics to be measured

Relationship between the ratio of displayed white patch against the whole display area and the normalized luminance level of the white patch.

14.2 Measurement conditions

The arrangement of equipment shall be as in Figure 1 with the colorimeter or as in Figure 2.

The colour signal shall be so generated that white patches are positioned at the centre of the screen of the PDP display under measurement.

The digital input data for the background shall be D_R = 0, D_G = 0, and D_B = 0.

14.3 Method of measurement

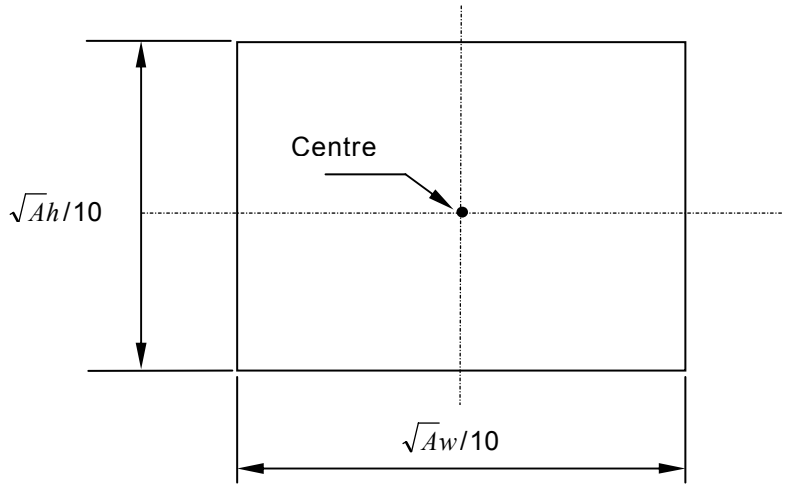
The size of the centred white patch shall be as shown in Figure 10. Display area ratio, A, shall be defined as follows:

$$A = \frac{N_L}{N_C} \times 100\ (\%) \tag{17}$$

where N_L is the number of lit cells and N_C is the number of cells in the whole display area of the PDP display.

The white patches shall be sequentially displayed for 19 equally stepped values of A from $A = 5$, 10, 15,..., to 100. Input data shall be D_R = M, D_G = M, and D_B = M, where $M = 2^{N-1} - 1$ and N is the number of bits per channel.

The luminance Y in candela per square metre and the CIE 1931 chromaticity coordinate values x, y shall be measured using the colorimeter at the centre of each white patch on the PDP display.



A display area ratio

Figure 10 – Specification of a white patch

14.4 Presentation of results

The luminance Y versus the display area ratio A shall be plotted as in Figure 11a. The CIE 1931 chromaticity coordinate values x, y shall also be plotted as curves, where the vertical axis shall be from 0,2 to 0,4, as shown in Figure 11b.

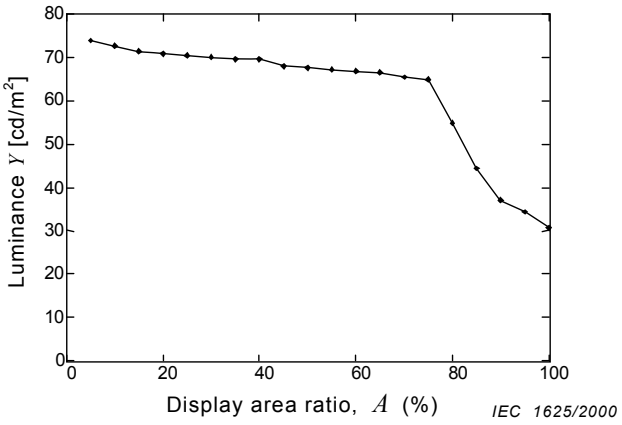


Figure 11a – Luminance versus display area

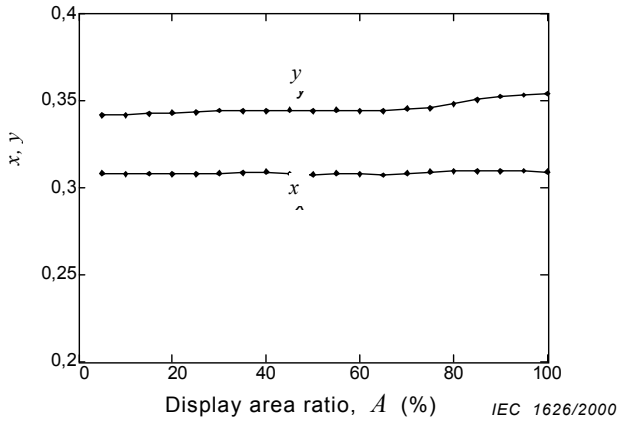


Figure 11b – Chromaticity versus display area

Figure 11 – Example plots for the display area ratio characteristics

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