Visual Efficiency for Image Output on Colour Monitors

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For the English (VISE) and the German (VISG) version of this paper see the URLs (16 pages, 1.1 Mbyte)

http://www.ps.bam.de/VISE05.PDF

http://www.ps.bam.de/VISG05.PDF

For the English (UBAE) and the German (UBAG) version of a similar paper on material efficiency see the URLs (5 pages, 90 kByte)

http://www.ps.bam.de/UBAE05.PDF

http://www.ps.bam.de/UBAG05.PDF

Abstract

For the monitor work place in the office an efficient reproduction of 16 step grey scales and an efficient recognition of grey Landolt-rings is developed. This method considers the office illumination and the reflection of the office light on the monitor surface in relation to the white monitor screen which all together are called here the **visual properties** at the work place. A monitor system includes all software and hardware components between the PDF test chart input and the monitor test chart output.

For the evaluation the grey ISO/IEC-test chart no. 3 according to ISO/IEC 15775 and ISO/IEC TR 24705 is used. Two visual Yes/No decisions are required to determine the monitor output properties at any work place. The method is additionally applicable for the data projector output on a screen in the (daylight) illuminated office. Visually it is to be decided if the 16 grey steps and the Landolt-rings are recognized or not (**two Yes/No decisions**). In most cases there are either two Yes or two No decisions.

1. Introduction

The BAM had taken a leading role in the development of the standards DIN 33866-1 to -5:2000 to specify the image reproduction properties of copiers, scanners, printers and monitors. DIN 33866-2 for colour copiers corresponds to the International Standard ISO/IEC 15775:1999 edited by the author of this paper. The International Technical Report ISO/IEC TR 24705:2005 (under publication and also edited by the author) corresponds to the other parts of DIN 33866-X. The part DIN 33866-4 and the corresponding part in ISO/IEC TR 24705 (chapter 13 to 15) is designed for monitor systems. The monitor system includes the hardware and software to produce the monitor output. *PostScript* (PS) and *Portable Documen*t (PDF) files are used to test the reproduction properties at work places. At the work place the real monitor or the data projector output is tested with real applications in the office environment.

2. Increasing output on displays and ergonomic requirements

At work places and in many other applications (mobile phone, digital cameras, projection screens) there is an increasing amount of displayed images. The softcopy outputs are more and more preferred compared to hardcopy outputs on paper both for black and white and for colour.

Therefore the test of the reproduction properties depends on evaluation methods of the output compared to an intended output defined by colorimetry. By colorimetry colours and coloured lights (radiation in the visible range) can be measured according to the methods defined by the Commission International de l'Eclairage (CIE).

For many years there exist minimum ergonomic requirements of ISO TC 159/WG4/SC2 "Ergonomics of human system interaction - Ergonomic requirements and measurement techniques for electronic visual display" in ISO 18789-X

Since 2003 ISO TC159/WG4/SC2 works on a improved standard series ISO 9421-301 to -307 which is in 2005 at the CD stage of the ISO standardization procedure.

3. Overview of the evaluation methods for the monitor output properties

There is an increasing amount of images with at least 16 grey steps out of 4096 (16 x 16 x 16) colour steps.

At the monitor work place there are many different lighting and reflection conditions based on the different daylight and artificial illuminations and the different monitor reflection properties. Recent screen technologies show especially an increase of the screen luminance. Therefore in the application the resulting luminance ratio increases between white and black which leads to higher lightness contrast ranges.

The luminance ratio of white and black on the monitor is often similar compared to the luminance ratio of white paper with the black text. On paper the luminance reflectance is Y= 89 for white and Y=2.5 for black (standard for copier test chart no. 3 according to ISO/IEC 15775). The corresponding lightness is L^*=95.4 for white and L^*=18 for black. Therefore the luminance ratio is 89:2.5 = 38:1 and the lightness ratio is 95.4:18 = 5.3:1.

For data projectors on the screen and in a room with daylight conditions at least a luminance ratio of 2:1 is required by ergonomic standards. This corresponds to a lightness contrast range of 95.4:70 = 1.4:1. It is surprising that this extreme condition still allows to see the 16 grey steps and the Landolt-rings. By colorimetry there are 25 lightness steps between L^*=70 and L^*=95.4. If $\Delta L^* = 1$ is taken as distinguishable step then 25 step may be recognized in the lightness range 70 to 95 and 77 steps in the standard lightness range 18 to 95 which corresponds to the luminance reflectance Y= 89 for white and Y=2.5 for black.

4. Files for the test of the visual efficiency of the monitor output

There are two test files which produce both a 16 step grey scale and Landolt-rings on page number one. The output of both files differs by other graphic test elements on the page one. For high luminance contrast (>100:1) the 5 step and 16 step grey scales should appear equally spaced.

The first file produces the ISO/IEC-test chart no. 3 according to ISO/IEC 15775 and ISO/IEC TR 24705 on the uneven pages 1 to 15 and the corresponding input - output relationships on the even pages 2 to 16.

Test file no. 1 which produces 16 pages (compare Fig. 1 to 6), see the URL (1.8 Mbyte, 16 pages)

http://www.ps.bam.de/ME15/10L/L15E00FP.PDF

The second file produces the 5 and 16 step grey scale of ISO/IEC-test chart no. 3 according to ISO/IEC 15775 and ISO/IEC TR 24705 on pages 1 and 3 and the corresponding input - output relationships on pages 2 and 4.

Test file no. 2 which produces 4 pages (compare Fig. 7 to 9), see the URL (150 kByte, 4 pages)

http://www.ps.bam.de/ME14/10L/L14E00FP.PDF

If the monitor system has approximately an input – output relationship (gamma curve) which considers the **visual properties** at the work place then the first page of both PDF files shows equally spaced 16 step grey scales and all Landolt-rings are recognized (**two Yes evaluations**). In this case the intended visual efficiency of the monitor output is reached.

In this case no further action is necessary. The monitor output at the work place is appropriate.

If there is at least **one No evaluation** then the input – output relationship is out of balance and an action described in the next section is appropriate.

> NOTE: One must have in mind that in offices the **visual properties** may change a lot during day time between sunrise and sunset and by the artificial lighting. There is the goal of a user driven 8 step adjustment possibility at the work place by either the software or the hardware. Up to now there seem to be no such application on the market. Especially for data projections in a daylight office there is a need for such an 8 step adjustment possibility. The 16 page file of this paper is one possibility to realize the user needs. This leads to an output which corresponds to the variable reflection conditions.

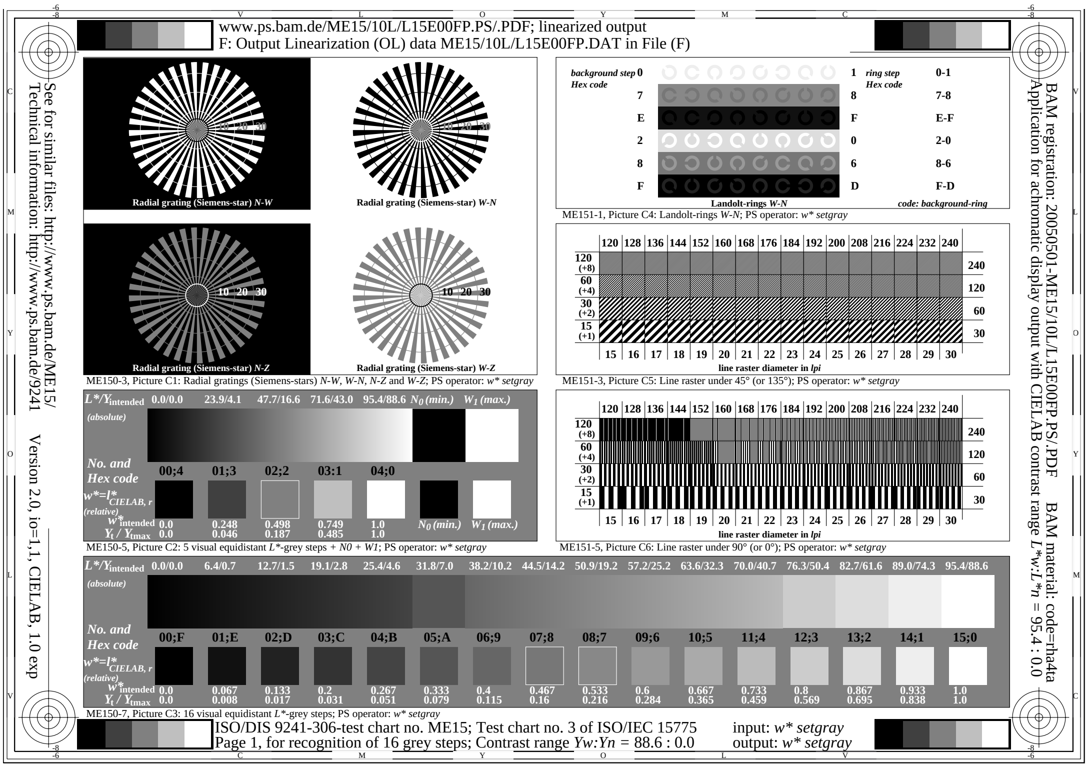


Figure 1: ISO/IEC-test chart no. 3 according to ISO/IEC 15775, page no. 1 for the high contrast range

Fig. 1 shows the ISO/IEC-test chart no. 3 according to ISO/IEC 15775 for the high contrast range ($Y_W : Y_N$ = 88.6 : 0.0, $L^*_W : L^*_N$ = 95.4 : 0.0) and appears on the output page no. 1

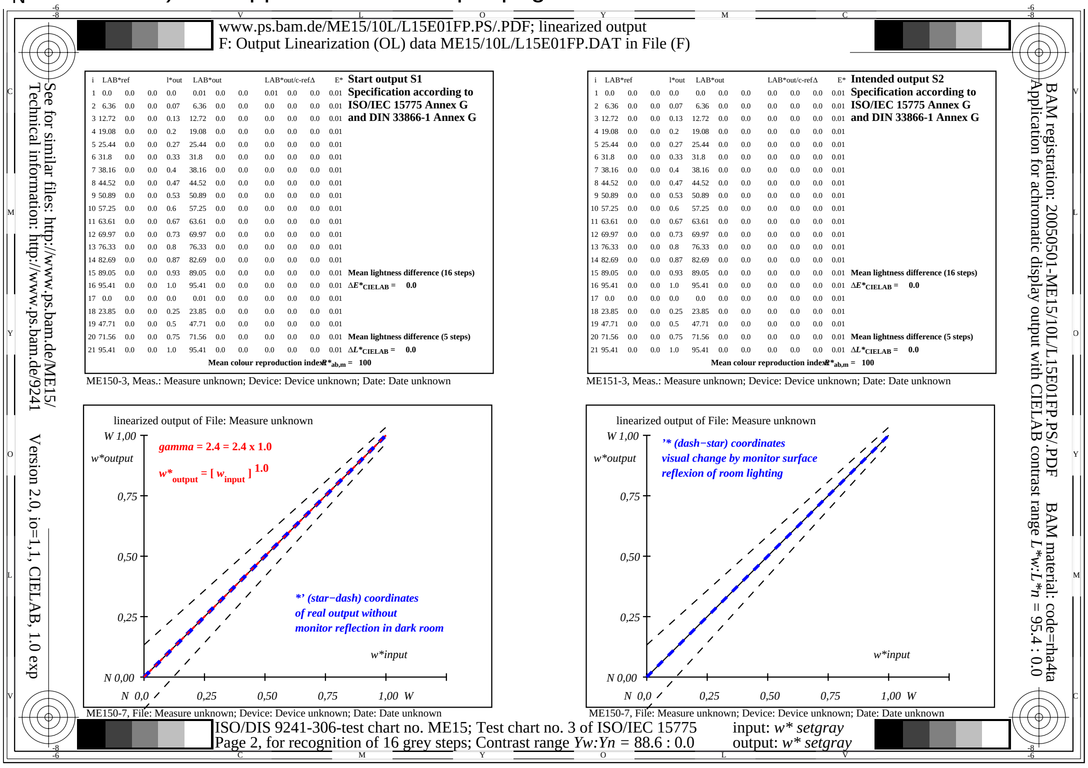


Figure 2: Ideal input – output relationship, page no. 2 for the high contrast range

Fig. 2 shows the ideal input – output relationship of a monitor system for the high contrast range ($Y_W : Y_N$ = 88.6 : 0.0, $L^*_W : L^*_N$ = 95.4 : 0.0) and appears on the output page no. 2. The input values may be the equal *rgb* values of the *sRGB* colour space (IEC 61966-2-1) and the output values the relative CIELAB lightness $l^* = (L^* - L^*_N) / (L^*_W - L^*_N)$. The CIELAB lightness values L^* between the black lightness L^*_N (=noir) and the white lightness L^*_W are given in the above tables. They are equally spaced between the value zero and the value 95.4. For monitors and white standard offset paper the lightness is normalized to the same value L^*_W = 95.4 for comparison, compare ISO/IEC 15775 and ISO/IEC TR 24705. In the following figures the black lightness L^*_N changes from 0 to 18 (Fig. 3 and 4) up to 70 (Fig. 5 and 6). This leads to large changes of the lightness and luminance contrast.

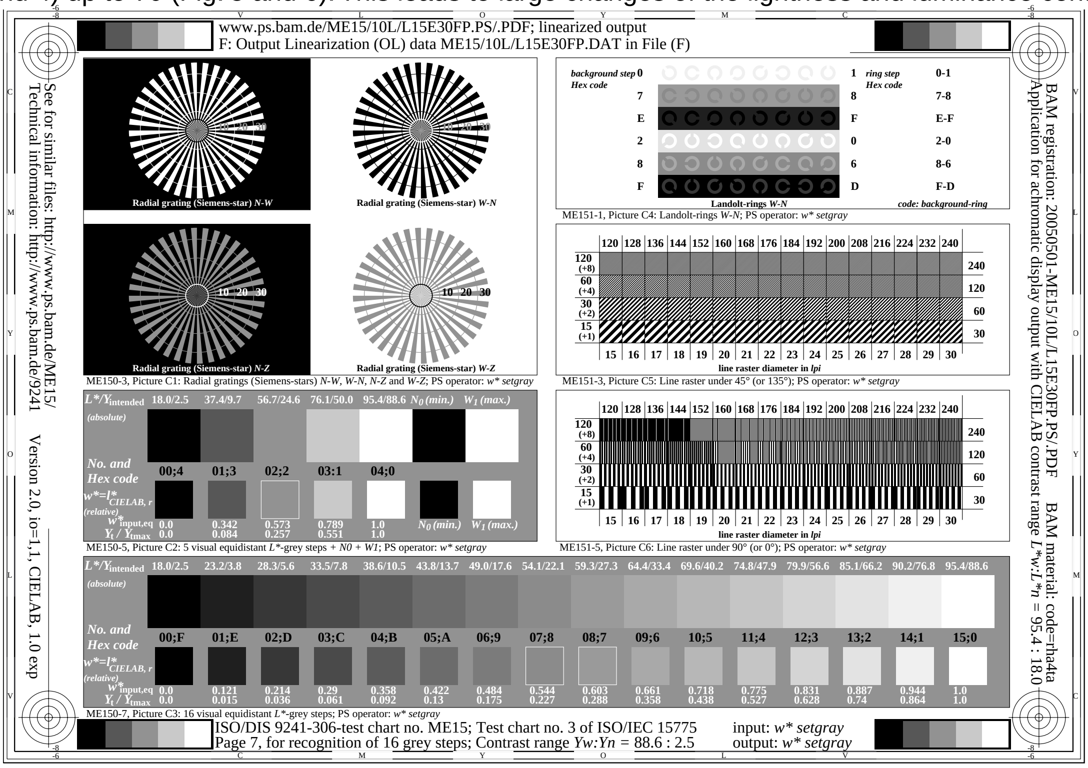


Figure 3: ISO/IEC-test chart no. 3 according to ISO/IEC 15775, page no. 7 for the medium contrast range

Fig. 3 shows the ISO/IEC-test chart no. 3 according to ISO/IEC 15775 for the medium contrast range ($Y_W : Y_N$ = 88.6 : 2.5, $L^*_W : L^*_N$ = 95.4 : 18.0) and appears on the output page no. 7.

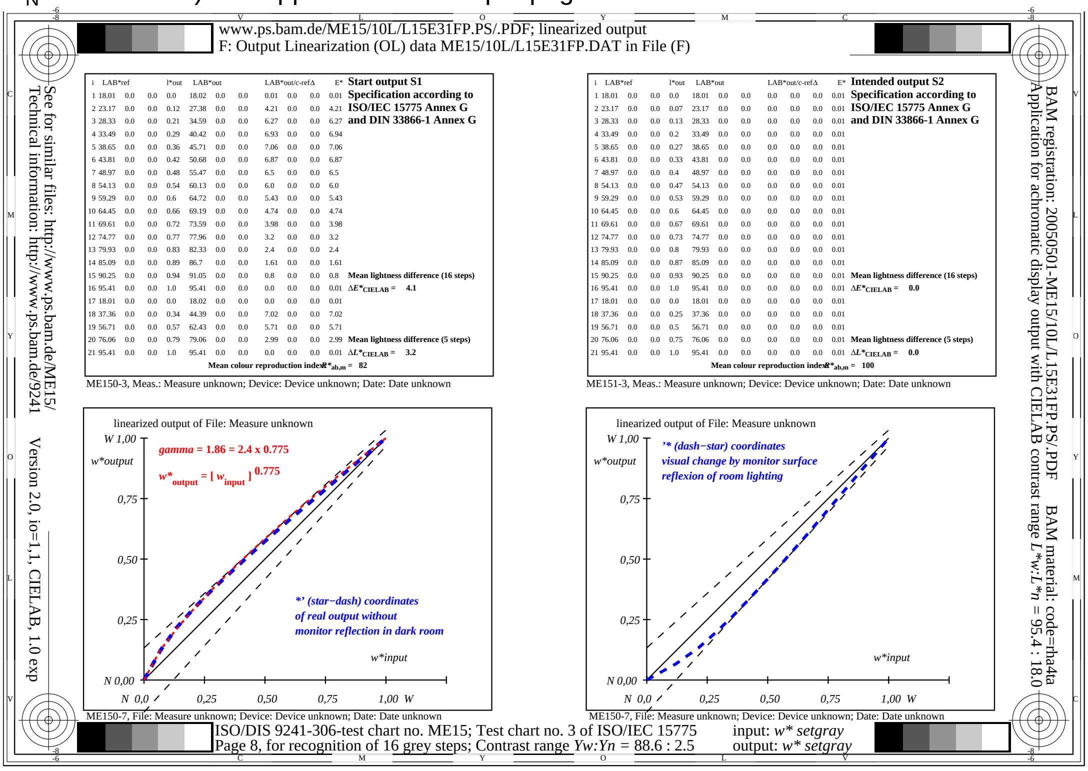


Figure 4: Input – output relationship, page no. 8 for the standard medium contrast range

Fig. 4 shows the input – output relationship of a monitor system for the medium standard contrast range ($Y_W : Y_N$ = 88.6 : 2.5, $L^*_W : L^*_N$ = 95.4 : 18) and appears on the output page no. 8. In the dark room the output appears lighter (table and figure on left side). The daylight reflection on the monitor surface creates the inverse input – output relationship. This leads finally to the equally spaced output values of the lightness in the right top table. Luminance measurements lead approximately to the same values. Without the monitor surface reflection the output values

LAB^*_{out} of the lightness are not equally spaced, compare left top table.

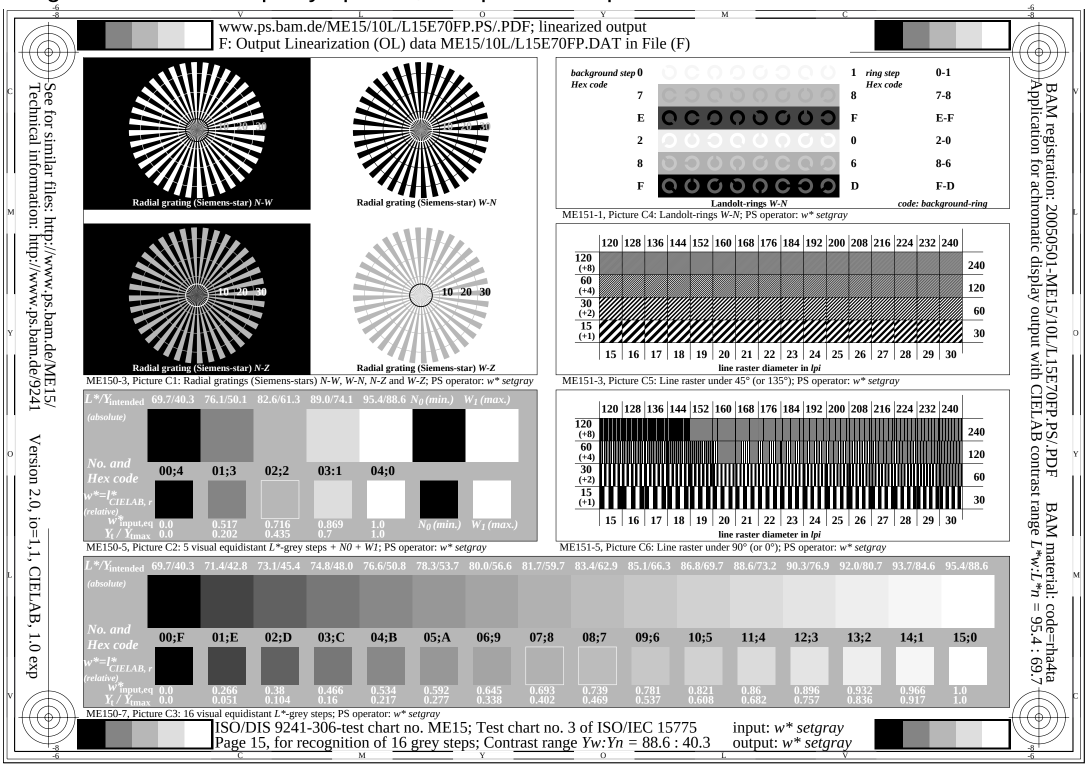


Figure 5: ISO/IEC-test chart no. 3 according to ISO/IEC 15775, page no. 15 for the low contrast range

Fig. 5 shows the ISO/IEC-test chart no. 3 according to ISO/IEC 15775 for the low contrast range ($Y_W : Y_N$ = 88.6 : 40.6, $L^*_W : L^*_N$ = 95.4 : 70.0) and appears as the output page no. 15

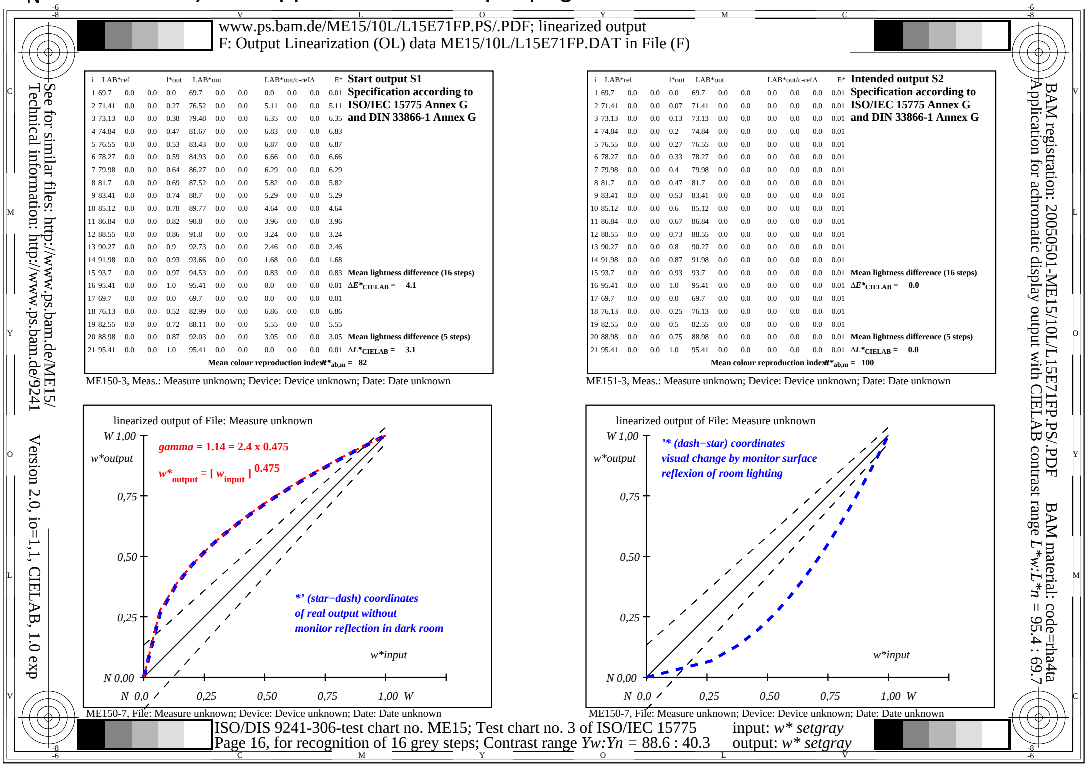


Figure 6: Input – output relationship, page no. 16 for the low contrast range

Fig. 6 shows the input – output relationship of a monitor system for the low contrast range ($Y_W : Y_N$ = 88.6 : 40, $L^*_W : L^*_N$ = 95.4 : 70) and appears on the output page no. 16. This low contrast range may appear on the projection screen if data projectors are used in the daylight office. The calculated mean lightness difference are equal in Fig. 4 and 6 (value 4.1). In the low contrast range there is a reduced lightness range ΔL^* = 25 instead of much larger lightness range ΔL^* = 77 for the medium contrast range. A gray scale which includes in the dark room much too less steps in the dark area appears equally spaced in the daylight office if the luminance contrast ratio is about 2:1.

The following 3 figures are produced by the “4 page file”. The output page no. 2 is similar to Fig. 2 and is not shown.

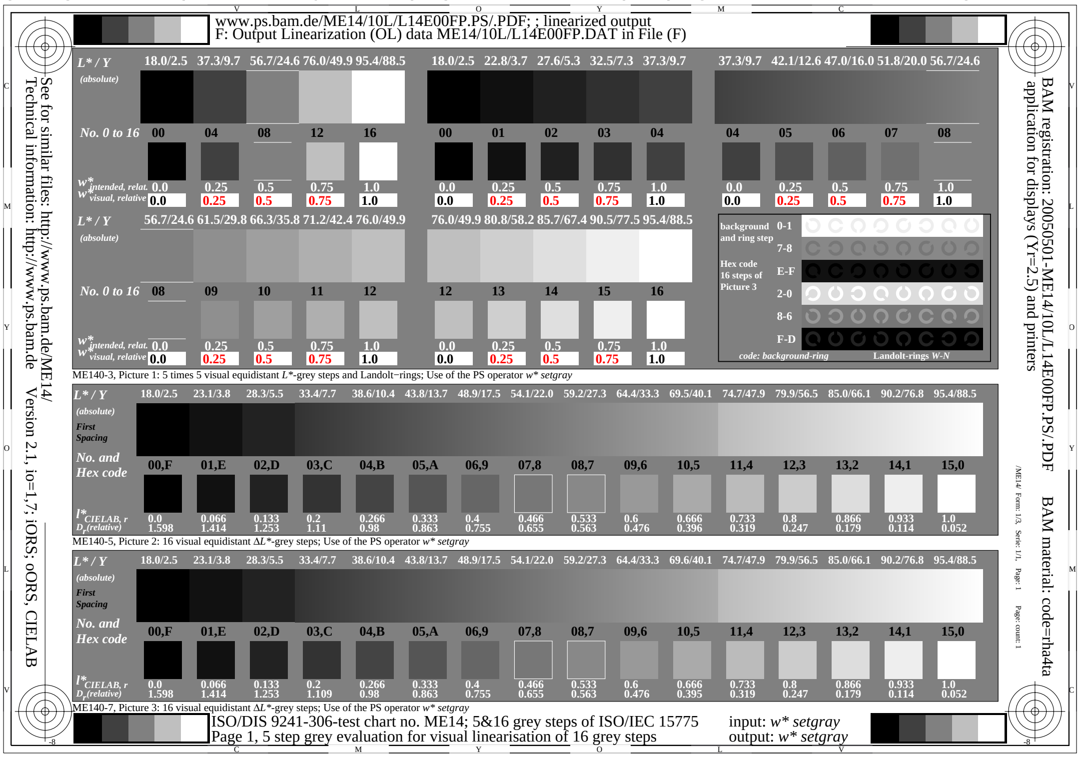


Figure 7: ISO/IEC-test chart no. 3 according to ISO/IEC 15775, page no. 1 for the large contrast range

Fig. 7 shows the 5 and 16 step grey scales of the ISO/IEC-test chart no. 3 according to ISO/IEC 15775. This page no. 1 should be equally spaced for the high contrast range ($Y_W : Y_N$ = 88.6 : 0.0, $L^*_W : L^*_N$ = 95.4 : 0.0) and appears on the output page no. 1

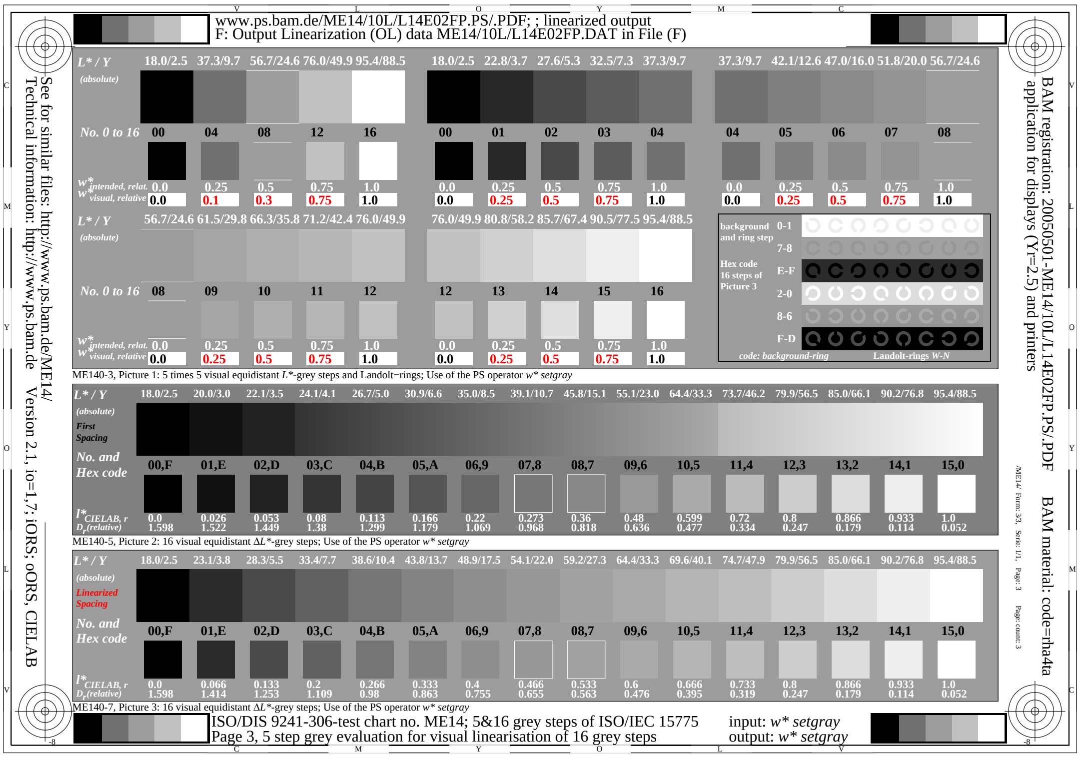


Figure 8: 5 and 16 step grey scales of the ISO/IEC-test chart no. 3, page no. 3 for the actual contrast range

Fig. 8 shows the 5 and 16 step grey scales of the ISO/IEC-test chart no. 3 according to ISO/IEC 15775. This page no. 3 serves for the actual contrast range ($Y_W : Y_N$ = 88.6 : X, $L^*_W : L^*_N$ = 95.4 : Y) and appears on the output page no. 3. The values X and Y are unknown and may be determined by luminance measurement of white and black with a luminance meter in the actual viewing situation.

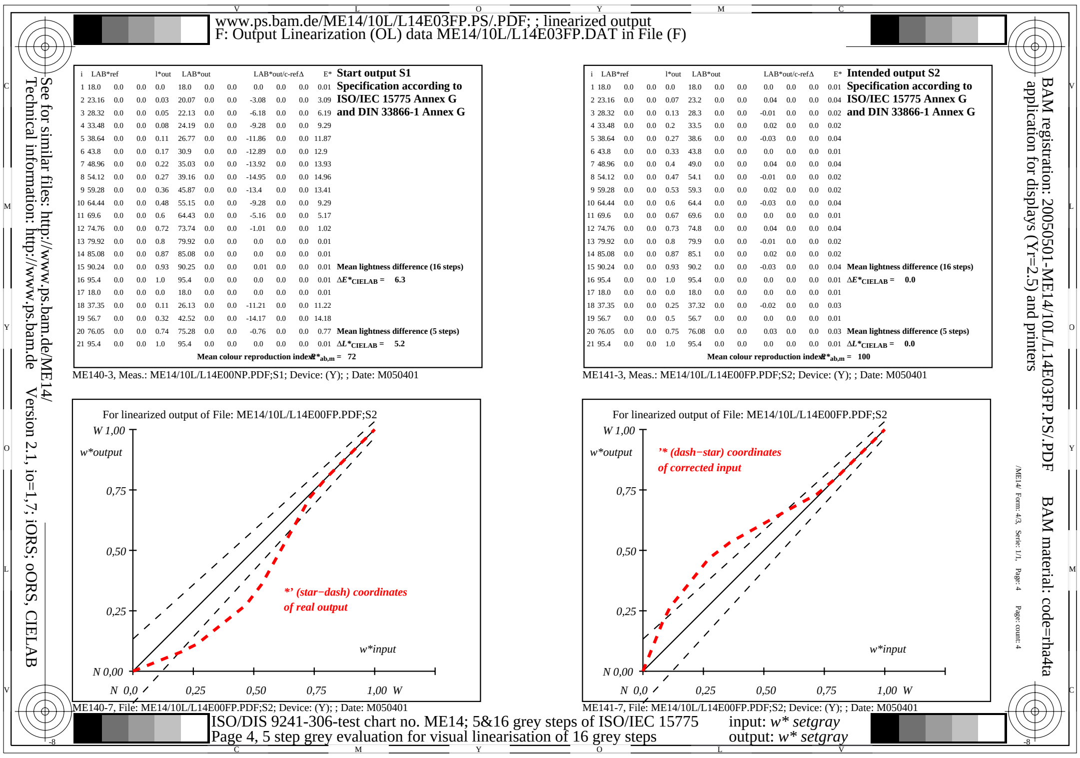


Figure 9: Input - output relationship of 16 and 5 grey steps, page no. 4 for the actual contrast range

Fig. 9 shows the input - output relationship of 16 and 5 grey step scale for the actual contrast range ($Y_W : Y_N$ = 88.6 : X, $L^*_W : L^*_N$ = 95.4 : Y) and appears on the output page no. 4. The values X and Y may be determined by luminance measurement of white and black with a luminance meter in the actual viewing situation.

5. Determination of the input – output relation (Gamma slope)

There is the goal to produce a 16 step equally spaced output in the actual viewing situation. There are **two Yes decisions** if this goal is reached.

In many cases it is important to know the input - output relationship of the monitor system in the actual viewing condition. This may help to produce the changes if the illumination conditions change. The Fig. 1, 3, 5 and 9 show different input - output relationships (left side) and the inverse relationships (right side). There are two methods with the two PDF files (see above) to determine the input - output relationship.

5.1 Determination of the input – output relation by the 16 page PDF test file

This test file simulates eight **visual properties** at work places with monitor luminance contrast ratios of white and black in the range between > 100:1 and 2:1. Usually at least one of the eight uneven pages, for example page 7, will lead to the **two Yes decisions** and all others will lead to two No decisions. If there are two or more adjacent uneven pages which lead to the **two Yes decisions** then the visually more efficient page should be chosen. If for example page no. 7 leads by this method to the **two Yes decisions** then the **visual properties** at the work place are known and the corresponding input – output relationship is presented on the next page no. 8.

5.2 Determination of the input – output relation by the 4 page PDF test file

This test file serves to determine directly the **visual properties** at the actual monitor work place and requires some technical knowledge of the user. At least for the main 5 step grey scale between black and white (with scale values 0 and 1) within the file the three scale values 0.25, 0.50, 0.75 for the three grey steps must be replaced by the three actual values. Therefore a visual evaluation of the three values is require by the user.

If the three visual values are included in the file then the new output will present new pages 3 and 4. The new output page no. 3 should lead to **two Yes decisions** and the output page no. 4 shows the actual input - output relation.

5.3 Inverse input – output relation as basis for improved output

If either the 16 or 4 page PDF file leads to **two Yes decisions** then in both cases the input – output relationship and the inverse relationship is known and can be used to correct the gamma of the monitor system in the next section 6.

If either the 16 or 4 page PDF file shows at least **one No decision** then the test fails and something is completely wrong with the monitor system or the test method. In this case professional help is appropriate to locate the source of this unusual property.

6. Intended visual efficiency for the monitor output

In both cases of section 5 the input – output relationship (Gamma curve) and the inverse relationship is shown. The “inverse” gamma curve is presented in the file output, for example for the page no. 7 on the page no. 8. The “inverse” gamma curve is to be included in the monitor operating system or the monitor hardware (if possible).

After including the actual inverse input – output relationship (gamma curve) of section 5 which considers the **visual properties** at the work place then the following is expected:

The output of page no. 1 of both either the 16 or 4 page test file should lead to **two Yes evaluations.** Then the intended visual efficiency for the monitor output is reached.

By this method the first page of both PDF files shows usually an equally spaced 16 step grey scale and all the Landolt-rings are recognized (**two Yes evaluations**).

In this case no further action is necessary.

If either the 16 or 4 page PDF file shows at least **one No decision** with page no. 1, then the test fails and something is completely wrong with the monitor system or the test method. In this case professional help is appropriate to locate the source of this unusual property.

7. Consumer requirements for ergonomic monitor output

The new standard series ISO 9241-301 to -307 will define the minimum ergonomic requirements for display output. The grey test charts of this paper are proposed for ISO/CD 9241-306 “Work place assessment”.

The intended 16 step equally spaced grey output and the recognition of all the Landolt-rings is proposed as one minimum ergonomic requirement.

For the field of colour similar requirements are intended which are based on the 16 step equally spaced colour scales of ISO/IEC 15775 and ISO/IEC TR 24705.

8. Requirements for user friendly colorimetric coordinates

The users require user friendly colorimetric coordinates for the description of the colours in Information Technology (IT). The Information Technology uses often *rgb*-colour coordinates (amounts of each colour in red, green and blue) which are completely non obvious for the users and confuse the users very much. For the four colour printer output and by colorimetry the *rgb*-coordinates can be transferred to output required *cmyk*-coordinates which are similar non obvious for the users and confuse the users very much.

For user friendly colorimetric coordinates the following definition applies:

> **Colorimetric coordinates,**
> device or colour order system coordinates which have a mathematical (often linear) relationship to the device independent coordinates lightness, chroma and hue of the CIELAB system

The next Figures 10 and 12 show colorimetric coordinates for 5 step grey and colour series which are equally spaced between black (N) and white (W) and cyan blue (C) and white (W).

5 steps of grey series black - white (N - W)	Colour space, colour space coordinates and PostScript operator calculations according to ISO/IEC 15775:1999-12			
Linear mixture between black and white in CIELAB colour space	***L**** **CIE** *w* = l** *setgray*	**CMYN (CMYK)** *000n** *setcmykcolor*	**CMYN (CMYK)** *cmy0** *setcmykcolor*	**OLV (RGB)** *www** *setrgbcolor*
1,00 N + 0,00 W (black N)	0,00	0,00 0,00 0,00 1,00	1,00 1,00 1,00 0,00	0,00 0,00 0,00
0,75 N + 0,25 W	0,25	0,00 0,00 0,00 0,75	0,75 0,75 0,75 0,00	0,25 0,25 0,25
0,50 N + 0,50 W	0,50	0,00 0,00 0,00 0,50	0,50 0,50 0,50 0,00	0,50 0,50 0,50
0,25 N + 0,75 W	0,75	0,00 0,00 0,00 0,25	0,25 0,25 0,25 0,00	0,75 0,75 0,75
0,00 N + 1,00 W (white W)	1,00	0,00 0,00 0,00 0,00	0,00 0,00 0,00 0,00	1,00 1,00 1,00

LE420−1, colorimetric relationship of *w**, *000n**, *cmy0**, *www** for a 5 step grey scale: black − white

5 steps of colour series black - white (N - W)	Colour space, colour space coordinates and PostScript operator calculations according to ISO/IEC 15775:1999-12		
Linear mixture between black and white in CIELAB colour space	**CIELAB adapted** ***LAB*a (adapted)*** ***LAB*a setcolor***	**CIELAB relative** ***lab*tch = tch**** ***tch* setcolor***	**CIELAB relative** ***lab*ncE = ncE**** ***ncE* setcolor***
1,00 N + 0,00 W (black N)	18.01 0.00 0.00	0,00 0,00 −	1,00 0,00 −
0,75 N + 0,25 W	37.35 0.00 0.00	0,25 0,00 −	0,75 0,00 −
0,50 N + 0,50 W	56.70 0.00 0.00	0,50 0,00 −	0,50 0,00 −
0,25 N + 0,75 W	76.05 0.00 0.00	0,75 0,00 −	0,25 0,00 −
0,00 N + 1,00 W (white W)	95.41 0.00 0.00	1,00 0,00 −	0,00 0,00 −

LE420−7, colorimetric relationship of *LAB*a*, *tch**, *ncE** for a 5 step grey scale: black − white

Figure 10: Equivalent colorimetric coordinates for 5 step grey scales

Fig. 10 shows equivalent colorimetric coordinates for a five step grey scale between black (N) and white (W). The coordinates of the upper part are used in Fig. 11 and in a corresponding file which should produce four identical grey scales. If the output is not equally spaced, then the method of ISO/IEC TR 19797 for linearization may be used.

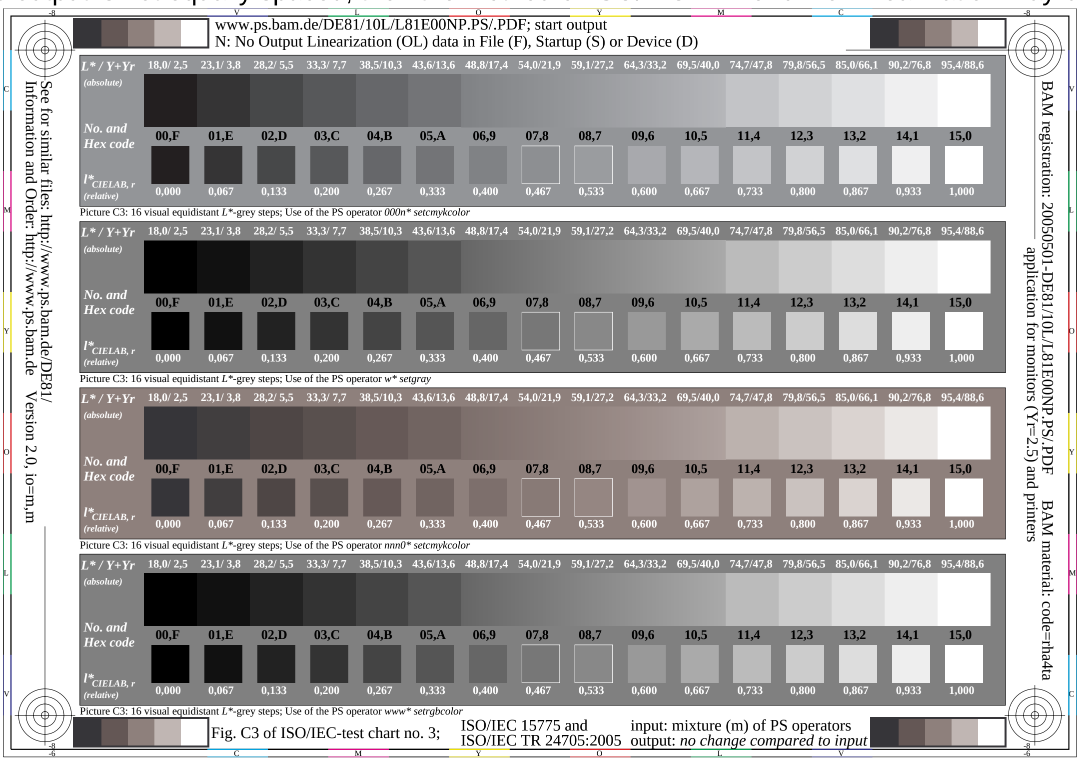


Figure 11: Four 16 step grey scales defined by 4 equivalent colorimetric coordinates

Fig. 11 shows four 16 step grey scales which are defined by 4 equivalent colorimetric coordinates. There are software products which lead approximately to equal output on monitors or printers. There are others which completely fail and produce four different grey scales. For the test of monitor and printer system properties at the work place one can download this file of Fig. 11 from the URL

http://www.ps.bam.de/DE81/10L/L81E00NP.PDF

5 steps of colour series cyan blue - white (C - W)	**Colour space, colour space coordinates and PostScript operator calculations according to ISO/IEC 15775:1999-12**		
Linear mixture between cyan blue and white in CIELAB colour space	**CIELAB absolute** ***LAB*LAB = LAB* LAB* setcolor***	**CIELAB relative** ***lab*cmy0 = cmy0* cmy0* setcmykcolor***	**CIELAB relative** ***lab*olv = olv* olv* setrgbcolor***
1,00 C + 0,00 W (cyan blue C)	58.62 -30.62 -42.74	1,00 0,00 0,00 0,00	0,00 1,00 1,00
0,75 C + 0,25 W	67.82 -23.21 -30.86	0,75 0,00 0,00 0,00	0,25 1,00 1,00
0,50 C + 0,50 W	77.02 -15.80 -18.98	0,50 0,00 0,00 0,00	0,50 1,00 1,00
0,25 C + 0,75 W	86.21 -8.39 -7.11	0,25 0,00 0,00 0,00	0,75 1,00 1,00
0,00 C + 1,00 W (white W)	95.41 -0.98 4.76	0,00 0,00 0,00 0,00	1,00 1,00 1,00

LE421−1, colorimetric relationship of *LAB*a, cmy0*, olv** for a 5 step scale: cyan blue − white

5 steps of colour series cyan blue - white (C - W)	**Colour space, colour space coordinates and PostScript operator calculations according to ISO/IEC 15775:1999-12**		
Linear mixture between cyan blue and white in CIELAB colour space	**CIELAB absolute** ***LAB*LCHa = LCH*a LCH*a setcolor***	**CIELAB relative** ***lab*tch = tch* tch* setcolor***	**CIELAB relative** ***lab*ncE = ncE* ncE* setcolor***
1,00 C + 0,00 W (cyan blue C)	58.62 54.29 236.0	0.500 1.000 0.656	0.000 1.000 g21b
0,75 C + 0,25 W	67.82 40.51 236.0	0.625 0.750 0.656	0.000 0.750 g21b
0,50 C + 0,50 W	77.02 27.14 236.0	0.750 0.500 0.656	0.000 0.500 g21b
0,25 C + 0,75 W	86.21 13.57 236.0	0.875 0.250 0.656	0.000 0.250 g21b
0,00 C + 1,00 W (white W)	95.41 0.01 −	1.000 0.001 −	0.000 0.001 −

LE421−7, colorimetric relationship of *LCH*a, tch*, ncE** for a 5 step scale: cyan blue − white

Figure 12: Equivalent colorimetric coordinates for a 5 step colour scale

Fig. 12 shows equivalent colorimetric coordinates for a five step colour scale between cyan blue (C) and white (W). All colorimetric coordinates are used to produce 6 identical cyan blue scales which should look additionally equally spaced.

Not all colorimetric coordinates are user friendly. Among the six possibilities of Fig. 12 only the last three (***LCH****, ***tch**** and ***ncE****) may be called user friendly.

equivalent colorimetric colour coordinates

System: *ORS18*

J50G’

olvi3*Fa: 0.6, 0.525, 0.45, 1.0
cmyn3*Fa: 0.4, 0.475, 0.55,
olvi4*Fa: 1.0, 0.875, 0.75, 0.6
cmyn4*Fa: 0.0, 0.125, 0.25, 0.4

J50G’

Inform. Techn. (IT) relative:				
*olvi3**	0.525	0.6	0.45	(1.0)
*cmyn3**	0.475	0.4	0.55	(0.0)
*olvi4**	0.875	1.0	0.75	0.6
*cmyn4**	0.125	0.0	0.25	0.4
CIELAB absolute:				
*LAB*LAB*	60.73	−5.8	11.92	
*LAB*LABa*	60.73	−5.47	9.5	
*LAB*TCHa*	52.5	10.97	119.98	
CIELAB relative:				
*lab*lab*	0.552	−0.074	0.13	
*lab*tch*	0.525	0.15	0.333	
*lab*nch*	0.4	0.15	0.333	
Natural Colour (NC) relative:				
*lab*lrj*	0.552	−0.086	0.122	
*lab*tce*	0.525	0.15	0.349	
*lab*ncE*	0.4	0.15	j39g	

J’

Inform. Techn. (IT) relative:				
*olvi3**	0.6	0.6	0.45	(1.0)
*cmyn3**	0.4	0.4	0.55	(0.0)
*olvi4**	1.0	1.0	0.75	0.6
*cmyn4**	0.0	0.0	0.25	0.4
CIELAB absolute:				
*LAB*LAB*	63.69	−1.91	16.38	
*LAB*LABa*	63.69	−1.53	13.76	
*LAB*TCHa*	52.5	13.85	96.38	
CIELAB relative:				
*lab*lab*	0.59	−0.016	0.149	
*lab*tch*	0.525	0.15	0.268	
*lab*nch*	0.4	0.15	0.268	
Natural Colour (NC) relative:				
*lab*lrj*	0.59	−0.013	0.149	
*lab*tce*	0.525	0.15	0.265	
*lab*ncE*	0.4	0.15	j05g	

R50J’

Inform. Techn. (IT) relative:				
*olvi3**	0.6	0.525	0.45	(1.0)
*cmyn3**	0.4	0.475	0.55	(0.0)
*olvi4**	1.0	0.875	0.75	0.6
*cmyn4**	0.0	0.125	0.25	0.4
CIELAB absolute:				
*LAB*LAB*	60.51	3.82	13.07	
*LAB*LABa*	60.51	4.13	10.67	
*LAB*TCHa*	52.5	11.44	68.82	
CIELAB relative:				
*lab*lab*	0.549	0.054	0.14	
*lab*tch*	0.525	0.15	0.191	
*lab*nch*	0.4	0.15	0.191	
Natural Colour (NC) relative:				
*lab*lrj*	0.549	0.079	0.128	
*lab*tce*	0.525	0.15	0.162	
*lab*ncE*	0.4	0.15	r64j	

All data for the colour R50J’

R50J’

LAB*Fa: 60.51, 4.13, 10.67
LCH*Fa: 60.51, 11.44, 68.82

LAB*Ma: 69.15, 27.56, 71.13
LCH*Ma: 69.15, 76.29, 68.82

LAB*Sa: 88.85, 6.89, 17.78
LCH*Sa: 88.85, 19.07, 68.82

LAB*Qa: 31.96, 7.52, 19.4
LCH*Qa: 31.96, 20.81, 68.82

LAB*Xa: 80.97, 15.16, 39.12
LCH*Xa: 80.97, 41.96, 68.82

G’

G’

Inform. Techn. (IT) relative:				
*olvi3**	0.45	0.6	0.45	(1.0)
*cmyn3**	0.55	0.4	0.55	(0.0)
*olvi4**	0.75	1.0	0.75	0.6
*cmyn4**	0.25	0.0	0.25	0.4
CIELAB absolute:				
*LAB*LAB*	57.77	−9.68	7.46	
*LAB*LABa*	57.77	−9.42	5.24	
*LAB*TCHa*	52.5	10.79	150.91	
CIELAB relative:				
*lab*lab*	0.514	−0.13	0.073	
*lab*tch*	0.525	0.15	0.419	
*lab*nch*	0.4	0.15	0.419	
Natural Colour (NC) relative:				
*lab*lrj*	0.514	−0.144	0.038	
*lab*tce*	0.525	0.15	0.46	
*lab*ncE*	0.4	0.15	j83g	

(neutral)

Inform. Techn. (IT) relative:				
*olvi3**	0.525	0.525	0.525	(1.0)
*cmyn3**	0.475	0.475	0.475	(0.0)
*olvi4**	1.0	1.0	1.0	0.525
*cmyn4**	0.0	0.0	0.0	0.475
CIELAB absolute:				
*LAB*LAB*	58.65	−0.27	2.28	
*LAB*LABa*	58.65	0.0	0.0	
*LAB*TCHa*	52.5	0.0	−	
CIELAB relative:				
*lab*lab*	0.525	0.0	0.0	
*lab*tch*	0.525	0.0	−	
*lab*nch*	0.475	0.0	−	
Natural Colour (NC) relative:				
*lab*lrj*	0.525	0.0	0.0	
*lab*tce*	0.525	0.0	−	
*lab*ncE*	0.475	0.0	−	

R’

Inform. Techn. (IT) relative:				
*olvi3**	0.6	0.45	0.45	(1.0)
*cmyn3**	0.4	0.55	0.55	(0.0)
*olvi4**	1.0	0.75	0.75	0.6
*cmyn4**	0.0	0.25	0.25	0.4
CIELAB absolute:				
*LAB*LAB*	57.33	9.55	9.76	
*LAB*LABa*	57.33	9.81	7.58	
*LAB*TCHa*	52.5	12.39	37.69	
CIELAB relative:				
*lab*lab*	0.508	0.119	0.092	
*lab*tch*	0.525	0.15	0.105	
*lab*nch*	0.4	0.15	0.105	
Natural Colour (NC) relative:				
*lab*lrj*	0.508	0.144	0.042	
*lab*tce*	0.525	0.15	0.046	
*lab*ncE*	0.4	0.15	r18j	

R’

olvi3*Fa: 0.6, 0.525, 0.45
tch*Fa: 0.525, 0.15, 0.191
ncw*Fa: 0.4, 0.15, 0.45
olvi3*Ma: 1.0, 0.5, 0.0
tch*Ma: 0.5, 1.0, 0.191
ncw*Ma: 0.0, 1.0, 0.0
olvi3*Sa: 1.0, 0.875, 0.75,
tch*Sa: 0.875, 0.25, 0.191
ncw*Sa: 0.0, 0.25, 0.75
olvi3*Qa: 0.273, 0.136, 0.0,
tch*Qa: 0.136, 0.273, 0.191
ncw*Qa: 0.727, 0.273, 0.0
olvi3*Xa: 1.0, 0.725, 0.45,
tch*Xa: 0.725, 0.55, 0.191
ncw*Xa: 0.0, 0.55, 0.45

PS colour operator output:

left: *olvi3* (rgb) setrgbcolor*

top: *cmyn3* setcmykcolor*

right: *cmyn4* setcmykcolor*

bottom: *LAB*LAB setcolor*

*LAB*LAB*: 60.51, 4.13, 10.67*

*LAB*LABx: 60.51, 4.13, 10.67*

G50B’

Input colours:

C, V, M, O, OY, Y, YL, L

Elementary hue reference:

CIE−test colours 9 to 12

G50B’

Inform. Techn. (IT) relative:				
*olvi3**	0.45	0.6	0.6	(1.0)
*cmyn3**	0.55	0.4	0.4	(0.0)
*olvi4**	0.75	1.0	1.0	0.6
*cmyn4**	0.25	0.0	0.0	0.4
CIELAB absolute:				
*LAB*LAB*	58.93	−4.83	−4.45	
*LAB*LABa*	58.93	−4.54	−6.74	
*LAB*TCHa*	52.5	8.14	236.02	
CIELAB relative:				
*lab*lab*	0.529	−0.083	−0.123	
*lab*tch*	0.525	0.15	0.656	
*lab*nch*	0.4	0.15	0.656	
Natural Colour (NC) relative:				
*lab*lrj*	0.529	−0.073	−0.13	
*lab*tce*	0.525	0.15	0.668	
*lab*ncE*	0.4	0.15	g67b	

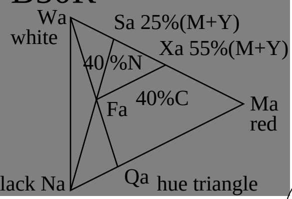
B’

Inform. Techn. (IT) relative:				
*olvi3**	0.45	0.45	0.6	(1.0)
*cmyn3**	0.55	0.55	0.4	(0.0)
*olvi4**	0.75	0.75	1.0	0.6
*cmyn4**	0.25	0.25	0.0	0.4
CIELAB absolute:				
*LAB*LAB*	54.0	4.47	−4.69	
*LAB*LABa*	54.0	4.66	−6.65	
*LAB*TCHa*	52.5	8.13	305.0	
CIELAB relative:				
*lab*lab*	0.465	0.086	−0.122	
*lab*tch*	0.525	0.15	0.847	
*lab*nch*	0.4	0.15	0.847	
Natural Colour (NC) relative:				
*lab*lrj*	0.465	0.067	−0.133	
*lab*tce*	0.525	0.15	0.823	
*lab*ncE*	0.4	0.15	b29r	

B50R’

Inform. Techn. (IT) relative:				
*olvi3**	0.6	0.45	0.6	(1.0)
*cmyn3**	0.4	0.55	0.4	(0.0)
*olvi4**	1.0	0.75	1.0	0.6
*cmyn4**	0.0	0.25	0.0	0.4
CIELAB absolute:				
*LAB*LAB*	57.36	11.03	0.93	
*LAB*LABa*	57.36	11.29	−1.24	
*LAB*TCHa*	52.5	11.36	353.66	
CIELAB relative:				
*lab*lab*	0.508	0.149	−0.016	
*lab*tch*	0.525	0.15	0.982	
*lab*nch*	0.4	0.15	0.982	
Natural Colour (NC) relative:				
*lab*lrj*	0.508	0.136	−0.063	
*lab*tce*	0.525	0.15	0.93	
*lab*ncE*	0.4	0.15	b72r	

B50R’



G50J’ B’ B50R’

ME500−7, Approximation of elementary and intermediate colours (8 colours); Device dependent colour coordinates *cmyn*ORS18* as transfer input; individual colour calculation without hue tables

Test chart ME47: Elementary colours RJGB’ (prime)
Approximation: 4 Elementary and 4 intermediate colours

Transfer via: *cmy0*ORS18 setcmykcolor*
output: *no change compared to input*

See for similar files: http://www.ps.bam.de/ME47/
Technical information: http://www.ps.bam.de
Version 3.0, io=1,1

BAM registration: 20050101-ME47/10L/L47E00NP.PS/.PDF
application for measurement of printer or monitor systems

BAM material: code=rha4ta

/ME47/ Form: 1/6, Serie: 1/4, Page: 1

Page count: 1

Visual Efficiency for Image Output on Colour Monitors

Figure 13: Equivalent colorimetric coordinates in 12 different colour systems

Fig. 13 shows as example the calculation of equivalent (corresponding) colorimetric coordinates in 12 different colour systems, for example by the coordinates ***ncE*** (relative blackness, chromaticness and elementary hue) of the Swedish Standard NCS (Natural Colour System).

Fig. 13 shows the colours *Fa* of 8 hues which are located within in a hue colour triangle (down left in Fig. 13). The colours *Fa* may be mixed by three chromatic colours *CMY* (chromatic generation) or from two chromatic colours and black *N* (black generation), for example by 55%*(M+Y)* + 40%*C* or 25%(*M*+*Y)* + 40%*N*. The achromatic colour black *N* is often by a factor 3 less expensive compared to the chromatic colours *CMY*. The costs for the production of the colour *Fa* by black generation are therefore reduced for the colour *Fa* to 24% compared to chromatic generation.

Fig. 13 produces the three rectangle colours on each square edge with the first three triples of equivalent colour coordinates. In newer applications (since 2002) the three colours are by monitor output often very different, sometimes the first two or all three are equal in a printer output.

BAM filter produce equal output colours both with the monitor or printer system according to the user requirement for the 12 equivalent colour coordinates which are used in corresponding PS- and PDF-BAM-test charts. This is the technical basis for a Colorimetric Image Technology (CIT), compare the papers (21 pages, 1.4 Mbyte)

http://www.ps.bam.de/BAMW05.PDF

and (30 pages, 1.2 Mbyte)

http://www.ps.bam.de/AWG05.PDF

9. Related developments in other standard areas

CIELAB cameras of the BAMVIII.34-working group measure directly the CIELAB colour data of the image pixels. The last Meeting of the Advisory Working Group of ISO/IEC JTC1/SC28 has decided to produce an ISO/IEC Technical Report in this area. This ISO/IEC Technical Report will include calculation methods, which allow a transfer from the CIELAB coordinates to any of these colorimetric device coordinates and vice versa.

The colorimetric device coordinates are defined by mathematical (often linear) relationships to the CIELAB data. This relationship is based on the CIELAB data of the eight device colours CMYOLVNW (cyan blue, magenta red, yellow, orange red, leaf green, violet blue, black (=noir), white), see the paper about the linear relationship to CIELAB under the URL (5 pages, 100 kByte)

http://www.ps.bam.de/CIE05.PDF

In the standard area there are an additional developments for example by the standards IEC 61966-2-1 add ISO/DIS 15706-1:2005 which define coordinates and methods for “Colour Management”.

Since about 15 years until 2002 the output of the four grey scales defined by the *PostScript* operators *setgray, setrgbcolor* and *setcymkcolor* was equal and often equally spaced, compare Fig. 11. The coordinates of these PS operators are shown in Fig. 10 which are considered as colorimetric equivalent. Then equal output is intended.

In 2002 since introduction of “Colour Management” in the colour workflow between input and output then instead of four equal grey scales often four different grey scales are produced, for example with *Adobe Reader Version 6.0* (2004). This produces a grey chaos output on the monitors (and printers).

Similar problems appear for chromatic colours. For colours defined by equivalent *olv** and *cmy** colorimetric coordinates (compare Fig. 12) the BAM-PDF-test charts may show differences by up to 25 CIELAB. This corresponds approximately to one third of the difference black-white on a device. Sometimes no difference appears on a printer and 25 CIELAB appear on a monitor and sometimes vice versa. There are solutions for the user requirement of equal output for equivalent colorimetric coordinates.

A solution of the colour chaos is the BAM-filter method which produces identical output for equivalent *olv** and *cmy** colorimetric coordinates and for the 11 other colorimetric coordinates of Fig. 13.

10. Conclusions

– The 16 step output on monitors is based on digital values which are equally spaced in the range between 0 and 1, for example by the values 0, 1/15, 2/15, ..., 14/15, 1. The standard 16 step input data are used for the 16 grey steps of page one of the two standard PDF files.

– The 16 step output should be equally spaced but the visual spacing depends to a high degree on the luminance contrast ratio on the screen which may vary between > 100:1 and 2:1 at the office work place.

– There are two PDF files which both use the standard 16 step input data on page no. 1.

A 16 page test file considers 8 different luminance contrast ratios between >100:1 and 2:1 at the uneven pages 1 to 15. At a given office work place only one page of eight looks equally spaced. The corresponding input - output relationship is then shown on the corresponding even page and is used to produce an equal spacing for the standard input values.

A 4 page test file allows directly to determine the input - output relationship at any office work place by visual evaluation of 5 step grey scales. The corresponding input - output relationship is then shown on page 4 and is used to produce an equal output spacing for the standard input values on page 3.

– It is intended to use either the 16 page or the 4 page output to produce a 16 step equally spaced output. At any given office work place page one of both the 16 page or 4 page output produces then an equally spaced output for the 16 step standard input data.

11. Standards, Technical Reports and References

The author was active as a leader for the standards [1] to [3] and was editor of the International documents [4] to [7].

[1] **DIN 33870:2000:** Requirements and tests for the remanufacturing of used toner modules black for electrophotographic printers, copiers and fax machines (Anforderungen und Prüfungen für die Aufbereitung von gebrauchten Tonermodulen schwarz für elektrophotographische Drucker, Kopierer und Fernkopierer)

[2] **DIN 33871-1:2003:** Requirements for remanufacturing of used inkjet heads and inkjet tanks of inkjet printers (Aufbereitung von gebrauchten Tintendruckköpfen und Tintentanks für Tintenstrahldrucker)

[3] **DIN 33866-1 bis 5:2000**: Information technology – Office machines – Machines for colour image reproduction: Method for specifying image reproduction of colour devices by digital and analog test charts (100 pages), This standard includes analog DIN-test charts no. 1 to 4.

[4] **ISO/IEC DIS 19839-1 bis -4:2000**; Information technology - Office machines - Colour image reproduction equipment, Methods for specifying image reproduction of colour devices by digital and analog test charts

[5] **ISO/IEC 15775:1999**; Information technology – Office machines – Machines for colour image reproduction - Method of specifying image reproduction of colour copying machines by analog test charts – Realisation and application (50 pages). There are 3 analog ISO/IEC-test charts no. 2 to 4 of JMBIA in Japan.

[6] **ISO/IEC TR 19797:2004**, Information technology - Device output of 16-step colour scales, output linearization method (LM) and specification of the reproduction properties, ISO/IEC JTC1/SC28 (21pages). For an old public version of this document see the URL (21 pages, 280 kByte)

http://www.jbmia.or.jp/sc28/sc28docs/j28n656.zip

[7] **ISO/IEC TR 24705:2005** (under publication), Method of specifying image reproduction of colour devices by digital and analog test charts, (79 pages). For an old public version of this document see the URL (79 pages, 1.5 MByte)

http://www.jbmia.or.jp/sc28/sc28docs/j28n689.zip

[8] Richter, K. (2004), Natural colour connection space (NCCS) between input and output for office systems, International Semina on Information Office Equipment Standardization, Korean Agency for Technology and Standards, pages 71-92, see the URL (1.4 MByte, 27 pages)

http://www.ps.bam.de/BAMAG1.PDF

[9] Richter, K. (2005), Linear relationship between CIELAB and device coordinates for Colorimetric Image Technology (CIT), see the URL (140 kByte, 6 pages)

http://www.ps.bam.de/CIE05.PDF

[10] Richter, K. (2005), Improved visual and material efficiency for colour output in image technology by colorimetric methods, see the URL (21 pages, 1.4 Mbyte)

http://www.ps.bam.de/BAMW05.PDF

[11] Richter, K. (2005), Colorimetric Image Technology (CIT), German proposals for International Standards and Technical Specifications or Reports of ISO/IEC JTC1/SC28, see the URL (30 pages, 1.2 Mbyte)

http://www.ps.bam.de/AWG05.PDF

Remark 1: For several specific “New Work Item Proposals” which are shown in [11], see the URL

http://www.ps.bam.de/NWIP/

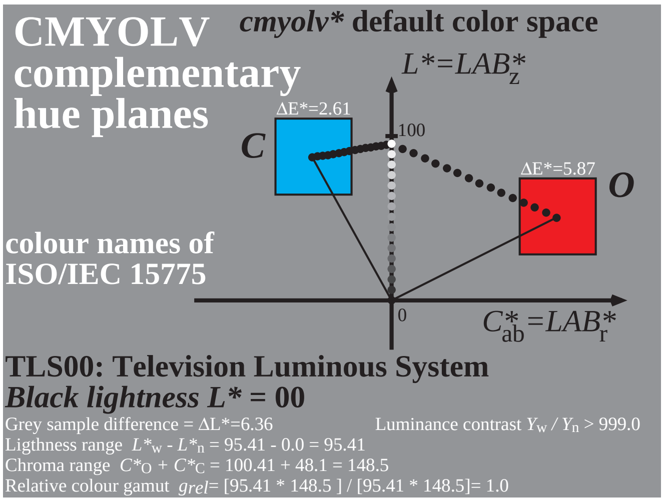
Remark 2: For further publications and analog and digital BAM-, DIN-, CEN- and ISO/IEC-test charts, see (> 1 Million connections/per year since 2002):

http://www.ps.bam.de

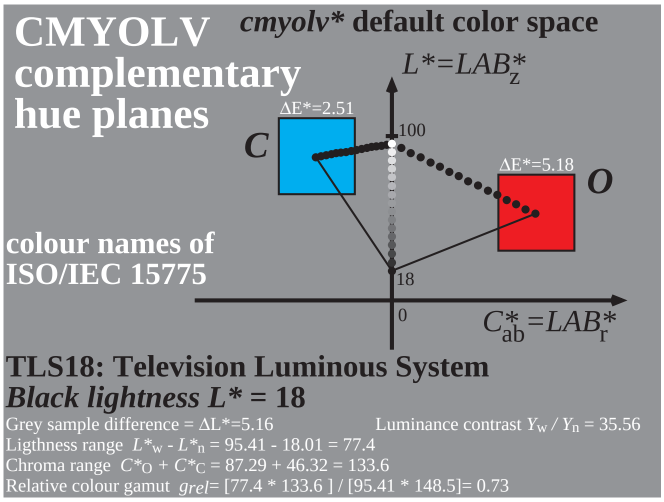
Annex A: Colorimetric data of monitor systems

There are International Standards which include the CIEXYZ and CIELAB data of the monitor systems for CIE standard illuminant D65. For different daylight reflection conditions on the monitor surface in the office tables are given in ISO/IEC TR 24705:2005. The figures of this paper are based on these tables but eight instead of 4 conditions are used. Therefore Fig. 15 and 16 include the CIE data for eight conditions.

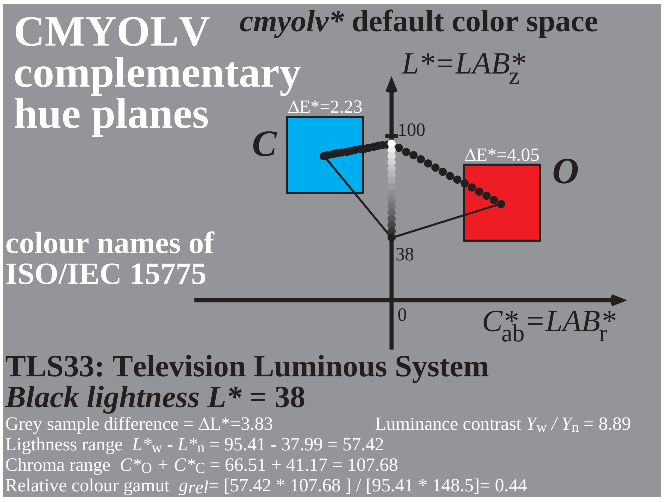
Both the grey and chromatic colours change and therefore all CIE data are included in this Annex.



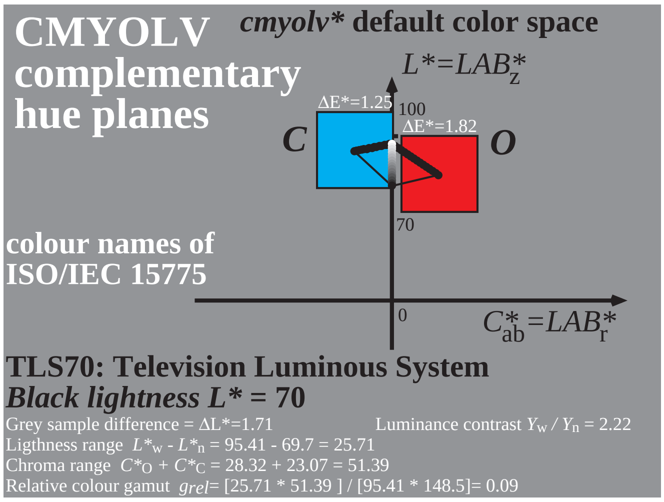
BE391−1, TLS00 in hue plane *C*−*O* of *LAB**



BE391−4, TRS18 in hue plane *C*−*O* of *LAB**



BE391−6, TLS38 in hue plane *C*−*O* of *LAB**



BE391−8, TLS70 in hue plane *C*−*O* of *LAB**

Figure 14: Change of the monitor colours in the CIELAB space by different contrast ratios in the office

Fig. 14 shows the change of the monitor colours in the CIELAB space by different contrast ratios in the office. The hues Orange red *O* and Cyan blue *C* are given in a $C^*_{ab} - L^*$ diagram of the CIELAB space.

Additionally the colour gamut is calculated compared to the ideal case (dark room and no reflections). The lightness range reduces to 30% and the colour gamut reduces to about 9% for the luminance ratio 2:1 compared to the high luminance ratio (>100:1).

The following figures 15 and 16 show the colorimetric data of monitor systems for the standard contrast ratio and for both the 4 high and the 4 low contrast ratios.

For similar data for offset, see the URL

http://www.ps.bam.de/LE48/10L/L48E00NP.PDF

www.ps.bam.de/LE49/10L/L49E00NP.PS/.PDF; start output
N: No Output Linearization (OL) data in File (F), Startup (S) or Device (D)

Colorimetric data of "Standard Original": Television Reflective System TRS18 for CIE lightness L*=18 of black

System TRS18	Color	$L^*=LAB^*_1$	$a^*=LAB^*_2$	$b^*=LAB^*_3$	$C^*_{ab}=LAB^*_r$	$X=XYZ_1$	$Y=XYZ_2$	$Z=XYZ_3$	x	y	Y/88.59
(Reflective CIE, Y_N=2.52	C	87.14	−44.42	−13.12	46.33	48.72	70.29	94.79	0.2279	0.3288	0.7934
and CIELAB cero point)	V (B)	31.9	24.46	−37.38	44.68	9.36	7.04	23.51	0.2346	0.1764	0.0795
(CIELAB according	M	59.01	89.33	−19.43	91.42	53.43	27.04	44.82	0.4265	0.2158	0.3052
to ISO/IEC 15775)	O (R)	52.76	71.63	49.88	87.29	37.9	20.83	4.41	0.6003	0.3299	0.2351
	Y	92.74	−20.03	84.97	87.3	68.68	82.37	14.66	0.4144	0.4971	0.9298
	L (G)	84.0	−78.99	73.94	108.2	33.17	64.07	13.0	0.3009	0.5812	0.7231
	N	18.01	0.0	0.0	0.01	2.4	2.52	2.74	0.3127	0.329	0.0284
	W	95.41	0.0	0.0	0.01	84.21	88.59	96.48	0.3127	0.329	1.0
	N0	0.01	0.0	0.0	0.01	0.0	0.0	0.0	0.3127	0.329	0.0
	W1	100.0	0.0	0.0	0.01	95.05	100.0	108.9	0.3127	0.329	1.1288

Calculated colorimetric data: Television Luminous Systeme (TLSxx) for CIE lightness L*=xx=00, 06, 11, 18 of black

System TLS00	Color	$L^*=LAB^*_1$	$a^*=LAB^*_2$	$b^*=LAB^*_3$	$C^*_r=LAB^*_r$	$X=XYZ_1$	$Y=XYZ_2$	$Z=XYZ_3$	x	y	Y/88.59
(Display reflection	C	86.88	−46.15	−13.54	48.11	47.68 (=47.68+0.0)	69.76 (=69.76+0.0)	94.74 (=94.74+0.0)	0.2247	0.3288	0.7874
Yr=0.0)	V (B)	25.72	31.45	−44.28	54.32	7.17 (=7.17+0.0)	4.65 (=4.65+0.0)	21.37 (=21.37+0.0)	0.2161	0.1402	0.0525
	M	57.31	94.35	−20.68	96.59	52.53 (=52.53+0.0)	25.24 (=25.24+0.0)	43.31 (=43.31+0.0)	0.4339	0.2084	0.2849
	O (R)	50.5	76.91	64.55	100.41	36.54 (=36.54+0.0)	18.84 (=18.84+0.0)	1.71 (=1.71+0.0)	0.64	0.33	0.2127
	Y	92.66	−20.68	90.75	93.08	68.22 (=68.22+0.0)	82.19 (=82.19+0.0)	12.27 (=12.27+0.0)	0.4194	0.5052	0.9278
	L (G)	83.62	−82.74	79.9	115.03	31.68 (=31.68+0.0)	63.35 (=63.35+0.0)	10.55 (=10.55+0.0)	0.3	0.6	0.715
	N	0.0	0.0	0.0	0.0	0.0 (=0.0+0.0)	0.0 (=0.0+0.0)	0.0 (=0.0+0.0)	0.2789	0.2934	0.0
	W	95.41	0.0	0.0	0.0	84.21 (=84.21+0.0)	88.59 (=88.59+0.0)	96.48 (=96.48+0.0)	0.3127	0.329	1.0
	N0	0.0	0.0	0.0	0.0	−2.45 (=−2.45+0.0)	−2.58 (=−2.58+0.0)	−2.81 (=−2.81+0.0)	0.3127	0.329	−0.0292
	W1	100.13	0.0	0.0	0.0	95.37 (=95.37+0.0)	100.33 (=100.33+0.0)	109.26 (=109.26+0.0)	0.3127	0.329	1.1325

System TLS06	Color	$L^*=LAB^*_1$	$a^*=LAB^*_2$	$b^*=LAB^*_3$	$C^*_r=LAB^*_r$	$X=XYZ_1$	$Y=XYZ_2$	$Z=XYZ_3$	x	y	Y/88.59
(Display reflection	C	86.94	−45.72	−13.43	47.66	47.94 (=47.34+0.6)	69.89 (=69.26+0.63)	94.75 (=94.06+0.69)	0.2255	0.3288	0.7889
Yr=0.63)	V (B)	27.44	29.31	−42.29	51.46	7.72 (=7.12+0.6)	5.25 (=4.62+0.63)	21.91 (=21.22+0.69)	0.2214	0.1505	0.0593
	M	57.74	93.06	−20.36	95.26	52.75 (=52.16+0.6)	25.69 (=25.06+0.63)	43.68 (=43.0+0.69)	0.432	0.2103	0.2899
	O (R)	51.08	75.54	59.69	96.28	36.88 (=36.28+0.6)	19.34 (=18.71+0.63)	2.39 (=1.7+0.69)	0.6293	0.33	0.2183
	Y	92.68	−20.51	89.24	91.57	68.34 (=67.74+0.6)	82.24 (=81.61+0.63)	12.87 (=12.18+0.69)	0.4181	0.5032	0.9283
	L (G)	83.72	−81.79	78.32	113.25	32.05 (=31.45+0.6)	63.53 (=62.9+0.63)	11.17 (=10.48+0.69)	0.3003	0.5951	0.7171
	N	5.69	0.0	0.0	0.0	0.6 (=0.0+0.6)	0.63 (=0.0+0.63)	0.69 (=0.0+0.69)	0.3127	0.329	0.0071
	W	95.41	0.0	0.0	0.0	84.21 (=83.61+0.6)	88.59 (=87.96+0.63)	96.48 (=95.79+0.69)	0.3127	0.329	1.0
	N0	0.0	0.0	0.0	0.0	−1.84 (=−2.44+0.6)	−1.93 (=−2.56+0.63)	−2.11 (=−2.79+0.69)	0.3127	0.329	−0.0218
	W1	100.1	0.0	0.0	0.0	95.29 (=94.69+0.6)	100.25 (=99.62+0.63)	109.17 (=108.49+0.69)	0.3127	0.329	1.1316

System TLS11	Color	$L^*=LAB^*_1$	$a^*=LAB^*_2$	$b^*=LAB^*_3$	$C^*_r=LAB^*_r$	$X=XYZ_1$	$Y=XYZ_2$	$Z=XYZ_3$	x	y	Y/88.59
(Display reflection	C	87.01	−45.28	−13.33	47.22	48.2 (=47.0+1.2)	70.02 (=68.76+1.26)	94.76 (=93.39+1.37)	0.2263	0.3288	0.7904
Yr=1.26)	V (B)	29.02	27.48	−40.49	48.94	8.27 (=7.07+1.2)	5.85 (=4.59+1.26)	22.44 (=21.07+1.37)	0.2262	0.16	0.066
	M	58.17	91.8	−20.04	93.96	52.98 (=51.78+1.2)	26.14 (=24.88+1.26)	44.06 (=42.69+1.37)	0.4301	0.2122	0.295
	O (R)	51.65	74.2	55.83	92.86	37.22 (=36.02+1.2)	19.84 (=18.58+1.26)	3.06 (=1.69+1.37)	0.6191	0.3299	0.2239
	Y	92.7	−20.35	87.77	90.1	68.45 (=67.25+1.2)	82.28 (=81.02+1.26)	13.47 (=12.09+1.37)	0.4169	0.5011	0.9288
	L (G)	83.81	−80.85	76.81	111.52	32.43 (=31.23+1.2)	63.71 (=62.45+1.26)	11.78 (=10.4+1.37)	0.3005	0.5904	0.7191
	N	10.99	0.0	0.0	0.0	1.2 (=0.0+1.2)	1.26 (=0.0+1.26)	1.37 (=0.0+1.37)	0.3127	0.329	0.0142
	W	95.41	0.0	0.0	0.0	84.21 (=83.01+1.2)	88.59 (=87.33+1.26)	96.48 (=95.11+1.37)	0.3127	0.329	1.0
	N0	0.0	0.0	0.0	0.0	−1.22 (=−2.42+1.2)	−1.29 (=−2.55+1.26)	−1.4 (=−2.77+1.37)	0.3127	0.329	−0.0145
	W1	100.06	0.0	0.0	0.0	95.21 (=94.01+1.2)	100.17 (=98.91+1.26)	109.08 (=107.71+1.37)	0.3127	0.329	1.1306

System TLS18	Color	$L^*=LAB^*_1$	$a^*=LAB^*_2$	$b^*=LAB^*_3$	$C^*_r=LAB^*_r$	$X=XYZ_1$	$Y=XYZ_2$	$Z=XYZ_3$	x	y	Y/88.59
(Display reflection	C	87.14	−44.42	−13.12	46.33	48.72 (=46.32+2.4)	70.29 (=67.77+2.52)	94.79 (=92.04+2.74)	0.2279	0.3288	0.7934
Yr=2.52)	V (B)	31.9	24.46	−37.38	44.68	9.36 (=6.97+2.4)	7.04 (=4.52+2.52)	23.51 (=20.76+2.74)	0.2346	0.1764	0.0795
	M	59.01	89.33	−19.43	91.42	53.43 (=51.03+2.4)	27.04 (=24.52+2.52)	44.82 (=42.07+2.74)	0.4265	0.2158	0.3052
	O (R)	52.76	71.63	49.88	87.29	37.9 (=35.5+2.4)	20.83 (=18.31+2.52)	4.41 (=1.66+2.74)	0.6003	0.3299	0.2351
	Y	92.74	−20.03	84.97	87.3	68.68 (=66.28+2.4)	82.37 (=79.85+2.52)	14.66 (=11.92+2.74)	0.4144	0.4971	0.9298
	L (G)	84.0	−78.99	73.94	108.2	33.17 (=30.78+2.4)	64.07 (=61.55+2.52)	13.0 (=10.25+2.74)	0.3009	0.5812	0.7231
	N	18.01	0.0	0.0	0.0	2.4 (=0.0+2.4)	2.52 (=0.0+2.52)	2.74 (=0.0+2.74)	0.3127	0.329	0.0284
	W	95.41	0.0	0.0	0.0	84.21 (=81.81+2.4)	88.59 (=86.07+2.52)	96.48 (=93.73+2.74)	0.3127	0.329	1.0
	N0	0.01	0.0	0.0	0.0	0.0 (=−2.38+2.4)	0.0 (=−2.51+2.52)	0.0 (=−2.73+2.74)	0.3037	0.3196	0.0
	W1	100.0	0.0	0.0	0.0	95.05 (=92.65+2.4)	100.0 (=97.48+2.52)	108.9 (=106.16+2.74)	0.3127	0.329	1.1288

LE490−7N, Colorimetric data of Television Reflective System TRS18 and of Television Luminous Systems TLS00/06/11/18

BAM-test chart no. LE49; colorimetric coordinates
TRS18 and Television Luminous Systems TLS=00, 06, 11, 18

input: *cmy0* setcmykcolor*
output: *no change compared to input*

See for similar files: http://www.ps.bam.de/LE49/
Technical information: http://www.ps.bam.de Version 2.1, io=1,1

BAM registration: 20040901-LE49/10L/L49E00NP.PS/.PDF
application for measurement of printer or monitor systems

BAM material: code=rha4ta

/LE49/ Form: 1/2, Serie: 1/1, Page: 1 Page: count: 1

Visual Efficiency for Image Output on Colour Monitors

BAM

Figure 15: Colorimetric data of television systems for standard and four high contrast rations,

Figure 16: Colorimetric data of television systems for standard and four low contrast rations

See for similar files: http://www.ps.bam.de/LE49/
Technical information: http://www.ps.bam.de Version 2.1, io=1,1

www.ps.bam.de/LE49/10L/L49E01NP.PS/.PDF; start output
N: No Output Linearization (OL) data in File (F), Startup (S) or Device (D)

Colorimetric data of "Standard Original": Television Reflective System TRS18 for CIE lightness L*=18 of black

System TRS18

(Reflective CIE, Y_N=2.52 and CIELAB cero point) (CIELAB according to ISO/IEC 15775)

Color	$L^*=LAB^*_1$	$a^*=LAB^*_2$	$b^*=LAB^*_3$	$C^*_{ab}=LAB^*_r$	$X=XYZ_1$	$Y=XYZ_2$	$Z=XYZ_3$	x	y	Y/88.59
C	87.14	−44.42	−13.12	46.33	48.72	70.29	94.79	0.2279	0.3288	0.7934
V (B)	31.9	24.46	−37.38	44.68	9.36	7.04	23.51	0.2346	0.1764	0.0795
M	59.01	89.33	−19.43	91.42	53.43	27.04	44.82	0.4265	0.2158	0.3052
O (R)	52.76	71.63	49.88	87.29	37.9	20.83	4.41	0.6003	0.3299	0.2351
Y	92.74	−20.03	84.97	87.3	68.68	82.37	14.66	0.4144	0.4971	0.9298
L (G)	84.0	−78.99	73.94	108.2	33.17	64.07	13.0	0.3009	0.5812	0.7231
N	18.01	0.0	0.0	0.01	2.4	2.52	2.74	0.3127	0.329	0.0284
W	95.41	0.0	0.0	0.01	84.21	88.59	96.48	0.3127	0.329	1.0
N0	0.01	0.0	0.0	0.01	0.0	0.0	0.0	0.3127	0.329	0.0
W1	100.0	0.0	0.0	0.01	95.05	100.0	108.9	0.3127	0.329	1.1288

Calculated colorimetric data: Television Luminous Systeme (TLSxx) for CIE lightness L*=xx=27, 33, 52, 70 of black

System TLS27

(Display reflection Yr=5.04)

Color	$L^*=LAB^*_1$	$a^*=LAB^*_2$	$b^*=LAB^*_3$	$C^*_r=LAB^*_r$	$X=XYZ_1$	$Y=XYZ_2$	$Z=XYZ_3$	x	y	Y/88.59
C	87.4	−42.72	−12.7	44.58	49.76 (=44.96+4.79)	70.83 (=65.79+5.04)	94.84 (=89.35+5.49)	0.231	0.3288	0.7995
V (B)	36.8	20.12	−32.47	38.2	11.56 (=6.76+4.79)	9.43 (=4.39+5.04)	25.64 (=20.16+5.49)	0.2478	0.2022	0.1064
M	60.64	84.61	−18.27	86.56	54.33 (=49.54+4.79)	28.84 (=23.8+5.04)	46.33 (=40.84+5.49)	0.4195	0.2227	0.3255
O (R)	54.88	66.84	41.69	78.78	39.25 (=34.46+4.79)	22.81 (=17.77+5.04)	7.1 (=1.62+5.49)	0.5675	0.3298	0.2575
Y	92.82	−19.39	79.81	82.13	69.13 (=64.34+4.79)	82.56 (=77.52+5.04)	17.06 (=11.57+5.49)	0.4097	0.4892	0.9319
L (G)	84.37	−75.39	68.76	102.04	34.67 (=29.88+4.79)	64.78 (=59.74+5.04)	15.44 (=9.95+5.49)	0.3017	0.5639	0.7313
N	26.85	0.0	0.0	0.0	4.79 (=0.0+4.79)	5.04 (=0.0+5.04)	5.49 (=0.0+5.49)	0.3127	0.329	0.0569
W	95.41	0.0	0.0	0.0	84.21 (=79.42+4.79)	88.59 (=83.55+5.04)	96.48 (=90.99+5.49)	0.3127	0.329	1.0
N0	18.34	0.0	0.0	0.0	2.47 (=−2.31+4.79)	2.59 (=−2.44+5.04)	2.83 (=−2.65+5.49)	0.3127	0.329	0.0293
W1	99.87	0.0	0.0	0.0	94.73 (=89.94+4.79)	99.67 (=94.63+5.04)	108.54 (=103.05+5.49)	0.3127	0.329	1.125

System TLS38

(Display reflection Yr=10.08)

Color	$L^*=LAB^*_1$	$a^*=LAB^*_2$	$b^*=LAB^*_3$	$C^*_r=LAB^*_r$	$X=XYZ_1$	$Y=XYZ_2$	$Z=XYZ_3$	x	y	Y/88.59
C	87.92	−39.42	−11.87	41.19	51.83 (=42.25+9.58)	71.9 (=61.82+10.08)	94.94 (=83.96+10.98)	0.237	0.3288	0.8116
V (B)	44.52	14.84	−25.65	29.64	15.94 (=6.36+9.58)	14.2 (=4.12+10.08)	29.92 (=18.94+10.98)	0.2654	0.2365	0.1603
M	63.71	75.92	−16.19	77.63	56.13 (=46.55+9.58)	32.45 (=22.37+10.08)	49.36 (=38.38+10.98)	0.407	0.2352	0.3662
O (R)	58.77	58.45	31.73	66.5	41.97 (=32.38+9.58)	26.78 (=16.7+10.08)	12.49 (=1.52+10.98)	0.5166	0.3296	0.3023
Y	92.98	−18.11	70.81	73.09	70.04 (=60.46+9.58)	82.92 (=72.84+10.08)	21.85 (=10.87+10.98)	0.4007	0.4743	0.936
L (G)	85.11	−68.58	60.02	91.14	37.66 (=28.08+9.58)	66.22 (=56.14+10.08)	20.33 (=9.35+10.98)	0.3032	0.5331	0.7475
N	37.99	0.0	0.0	0.0	9.58 (=0.0+9.58)	10.08 (=0.0+10.08)	10.98 (=0.0+10.98)	0.3127	0.329	0.1138
W	95.41	0.0	0.0	0.0	84.21 (=74.63+9.58)	88.59 (=78.51+10.08)	96.48 (=85.5+10.98)	0.3127	0.329	1.0
N0	33.53	0.0	0.0	0.0	7.4 (=−2.17+9.58)	7.78 (=−2.29+10.08)	8.47 (=−2.49+10.98)	0.3127	0.329	0.0878
W1	99.61	0.0	0.0	0.0	94.1 (=84.52+9.58)	99.0 (=88.92+10.08)	107.81 (=96.83+10.98)	0.3127	0.329	1.1174

System TLS52

(Display reflection Yr=20.16)

Color	$L^*=LAB^*_1$	$a^*=LAB^*_2$	$b^*=LAB^*_3$	$C^*_r=LAB^*_r$	$X=XYZ_1$	$Y=XYZ_2$	$Z=XYZ_3$	x	y	Y/88.59
C	88.94	−33.19	−10.24	34.75	55.99 (=36.83+19.16)	74.04 (=53.88+20.16)	95.13 (=73.18+21.95)	0.2487	0.3288	0.8358
V (B)	55.84	9.42	−17.5	19.88	24.7 (=5.54+19.16)	23.75 (=3.59+20.16)	38.46 (=16.51+21.95)	0.2842	0.2733	0.2681
M	69.22	60.95	−12.72	62.27	59.74 (=40.58+19.16)	39.65 (=19.49+20.16)	55.41 (=33.45+21.95)	0.3859	0.2562	0.4476
O (R)	65.53	45.06	20.98	49.71	47.39 (=28.23+19.16)	34.72 (=14.56+20.16)	23.28 (=1.32+21.95)	0.4497	0.3294	0.3919
Y	93.3	−15.61	56.27	58.4	71.86 (=52.7+19.16)	83.65 (=63.49+20.16)	31.43 (=9.48+21.95)	0.3844	0.4475	0.9442
L (G)	86.55	−56.31	46.52	73.05	43.63 (=24.47+19.16)	69.09 (=48.93+20.16)	30.11 (=8.15+21.95)	0.3055	0.4837	0.7799
N	52.02	0.0	0.0	0.0	19.16 (=0.0+19.16)	20.16 (=0.0+20.16)	21.95 (=0.0+21.95)	0.3127	0.329	0.2276
W	95.41	0.0	0.0	0.0	84.21 (=65.05+19.16)	88.59 (=68.43+20.16)	96.48 (=74.52+21.95)	0.3127	0.329	1.0
N0	49.69	0.0	0.0	0.0	17.26 (=−1.89+19.16)	18.16 (=−1.99+20.16)	19.77 (=−2.17+21.95)	0.3127	0.329	0.205
W1	99.09	0.0	0.0	0.0	92.83 (=73.67+19.16)	97.66 (=77.5+20.16)	106.35 (=84.4+21.95)	0.3127	0.329	1.1024

System TLS70

(Display reflection Yr=40.32)

Color	$L^*=LAB^*_1$	$a^*=LAB^*_2$	$b^*=LAB^*_3$	$C^*_r=LAB^*_r$	$X=XYZ_1$	$Y=XYZ_2$	$Z=XYZ_3$	x	y	Y/88.59
C	90.93	−21.96	−7.08	23.09	64.3 (=25.98+38.32)	78.33 (=38.01+40.32)	95.53 (=51.62+43.91)	0.27	0.3289	0.8841
V (B)	71.46	4.57	−9.01	10.11	42.23 (=3.91+38.32)	42.86 (=2.54+40.32)	55.55 (=11.65+43.91)	0.3003	0.3047	0.4837
M	78.5	37.52	−7.58	38.28	66.95 (=28.62+38.32)	54.07 (=13.75+40.32)	67.51 (=23.6+43.91)	0.3551	0.2868	0.6103
O (R)	76.43	26.27	10.57	28.31	58.24 (=19.91+38.32)	50.59 (=10.27+40.32)	44.84 (=0.93+43.91)	0.379	0.3292	0.571
Y	93.93	−10.77	34.63	36.27	75.5 (=37.17+38.32)	85.11 (=44.79+40.32)	50.59 (=6.69+43.91)	0.3575	0.403	0.9606
L (G)	89.32	−35.81	27.64	45.25	55.59 (=17.26+38.32)	74.84 (=34.52+40.32)	49.66 (=5.75+43.91)	0.3087	0.4156	0.8447
N	69.7	0.0	0.0	0.0	38.32 (=0.0+38.32)	40.32 (=0.0+40.32)	43.91 (=0.0+43.91)	0.3127	0.329	0.4551
W	95.41	0.0	0.0	0.0	84.21 (=45.88+38.32)	88.59 (=48.27+40.32)	96.48 (=52.57+43.91)	0.3127	0.329	1.0
N0	68.68	0.0	0.0	0.0	36.98 (=−1.33+38.32)	38.91 (=−1.4+40.32)	42.37 (=−1.53+43.91)	0.3127	0.329	0.4392
W1	98.03	0.0	0.0	0.0	90.29 (=51.96+38.32)	94.99 (=54.67+40.32)	103.44 (=59.54+43.91)	0.3127	0.329	1.0722

LE490−7N, Colorimetric data of Television Reflective System TRS18 and of Television Luminous Systems TLS18/27/38/52/70

BAM-test chart no. LE49; colorimetric coordinates
TRS18 and Television Luminous Systems TLS=27, 38, 52, 70

input: *cmy0* setcmykcolor*
output: *no change compared to input*

BAM

Visual Efficiency for Image Output on Colour Monitors

BAM registration: 20040901-LE49/10L/L49E01NP.PS/.PDF
application for measurement of printer or monitor systems

BAM material: code=rha4ta

/LE49/ Form: 2/2, Serie: 1/1, Page: 2 Page: count: 2