

# **Perceived and Device Black and White as Reference Colours in Image Technology**

<http://www.li.tu-berlin.de/F/ISCC08.PDF>

(27 pages, 1 MByte)

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<http://www.ps.bam.de> or <http://www.li.tu-berlin.de>

This paper has been presented at the “Black and White Conference” of the Inter-Society-Colour-Council in Portland (November 15, 2008) and will be published at the above web-sites

A new German draft standard DIN E 33872-1 to 6:2007 on relative colour reproduction with many DIN-test charts has been published. For titles and the DIN-test charts see

<http://www.ps.bam.de/33872E>

The DIN-test charts are freely available in the internet together with questions about output properties for monitor and/or printer output on the last page of every DIN-test chart file.

A new Relative Elementary Colour System RECS has been printed in Standard Offset Printing with a 16-step elementary hue circle. About 2000 colours of the 16 hues with 5- and 16-step colour scales have been printed. They serve as reference colours for input and output in image technology, see

<http://www.ps.bam.de/RECS>

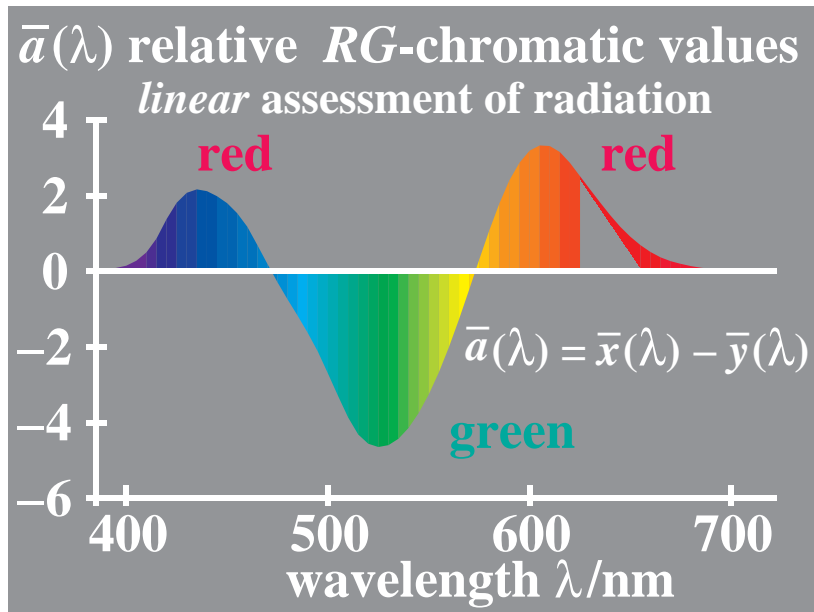
## **Introduction**

- **Colour names for device and elementary colours according to ISO/IEC 15775**
- **Spectral elementary colours**
- **Colour double cone with device or elementary hues**
- **Elementary hue circle and *rgb*\* colour coordinates**
- **5- and 16-step colour scales for elementary hue *B***
- **Output colours defined by *rgb* and *cmy0* coordinates**

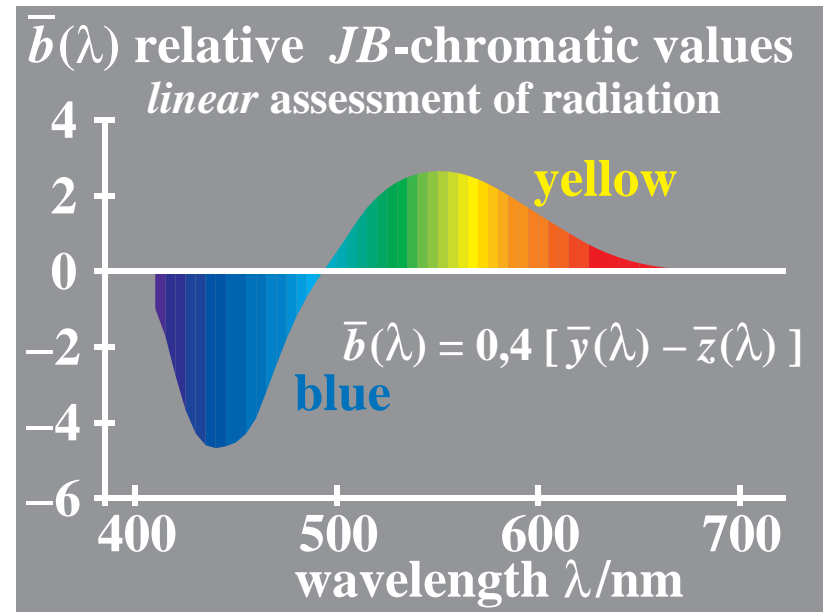
Definition of elementary colours according to ISO/IEC 15775 and spectral chromatic values

Achromatic colours	Elementary colours <i>"Neither-nor"-colours</i>	Device colours <i>Television (TV), Print (PR) Photography (PH)</i>
<i>five achromatic colours:</i>	<i>four elementary colours:</i>	<i>six device colours:</i>
<i>N</i> black (french noir)	<i>R</i> red <i>neither yellowish nor blueish</i>	<i>C</i> cyanblue
<i>D</i> dark grey	<i>G</i> green <i>neither yellowish nor blueish</i>	<i>M</i> magentared
<i>Z</i> central grey	<i>B</i> blue <i>neither greenish nor reddish</i>	<i>Y</i> yellow
<i>H</i> light grey	<i>J</i> yellow (french jaune) <i>neither greenish nor reddish</i>	<i>O</i> orangered
<i>W</i> white		<i>L</i> leafgreen
		<i>V</i> violetblue

YE980-31

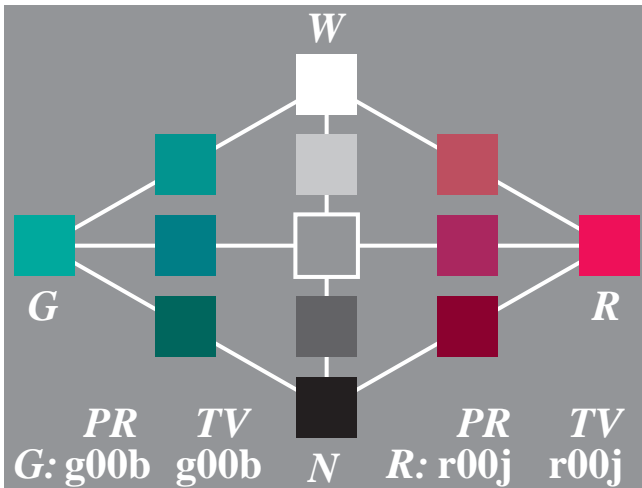


XE351-11

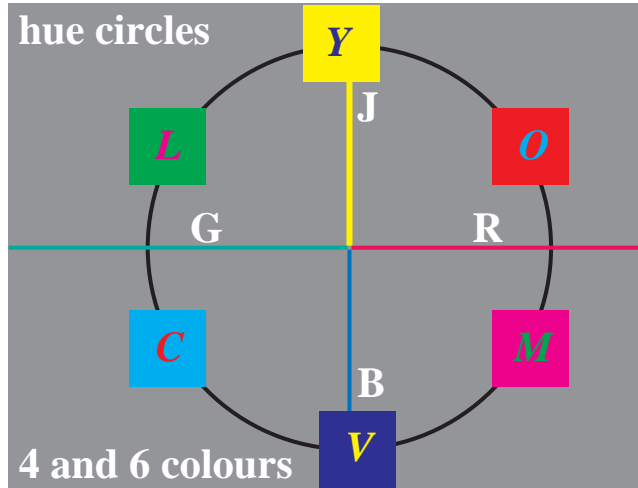


XE351-21

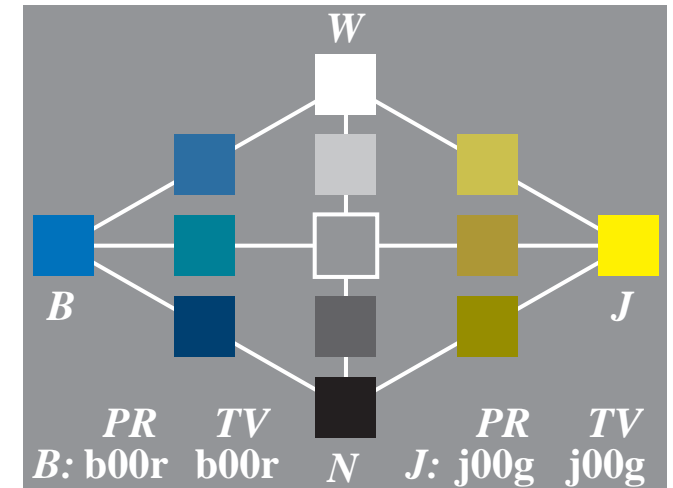
Elementary hue circle and different hue planes of a colour double cone



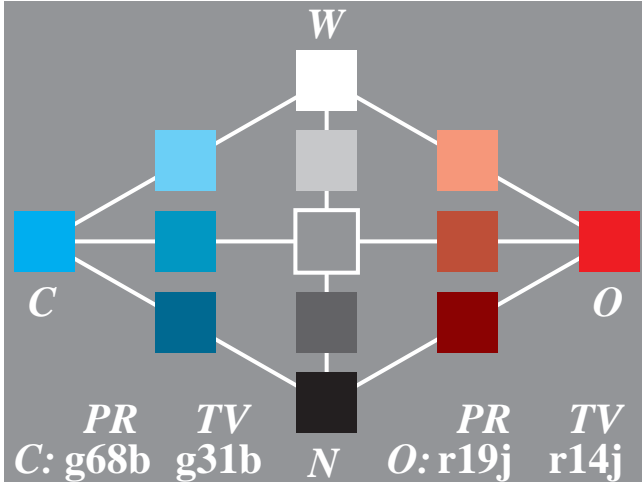
ZE410-7



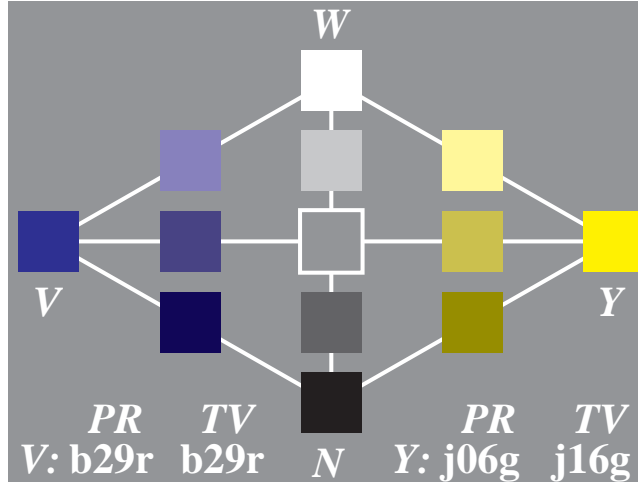
ZE410-3



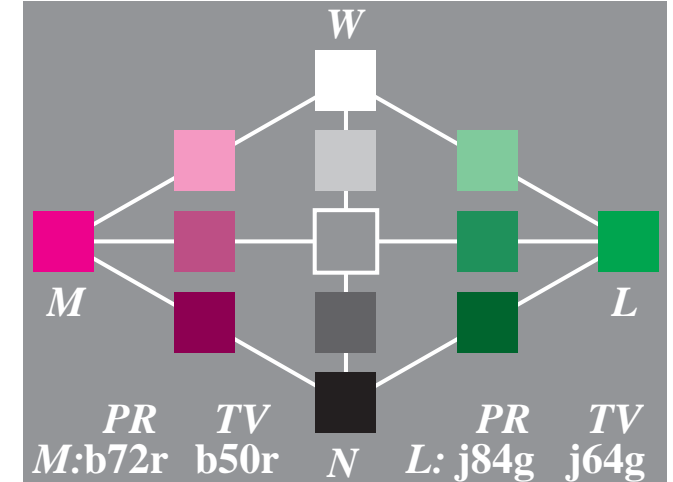
ZE410-8



ZE410-4



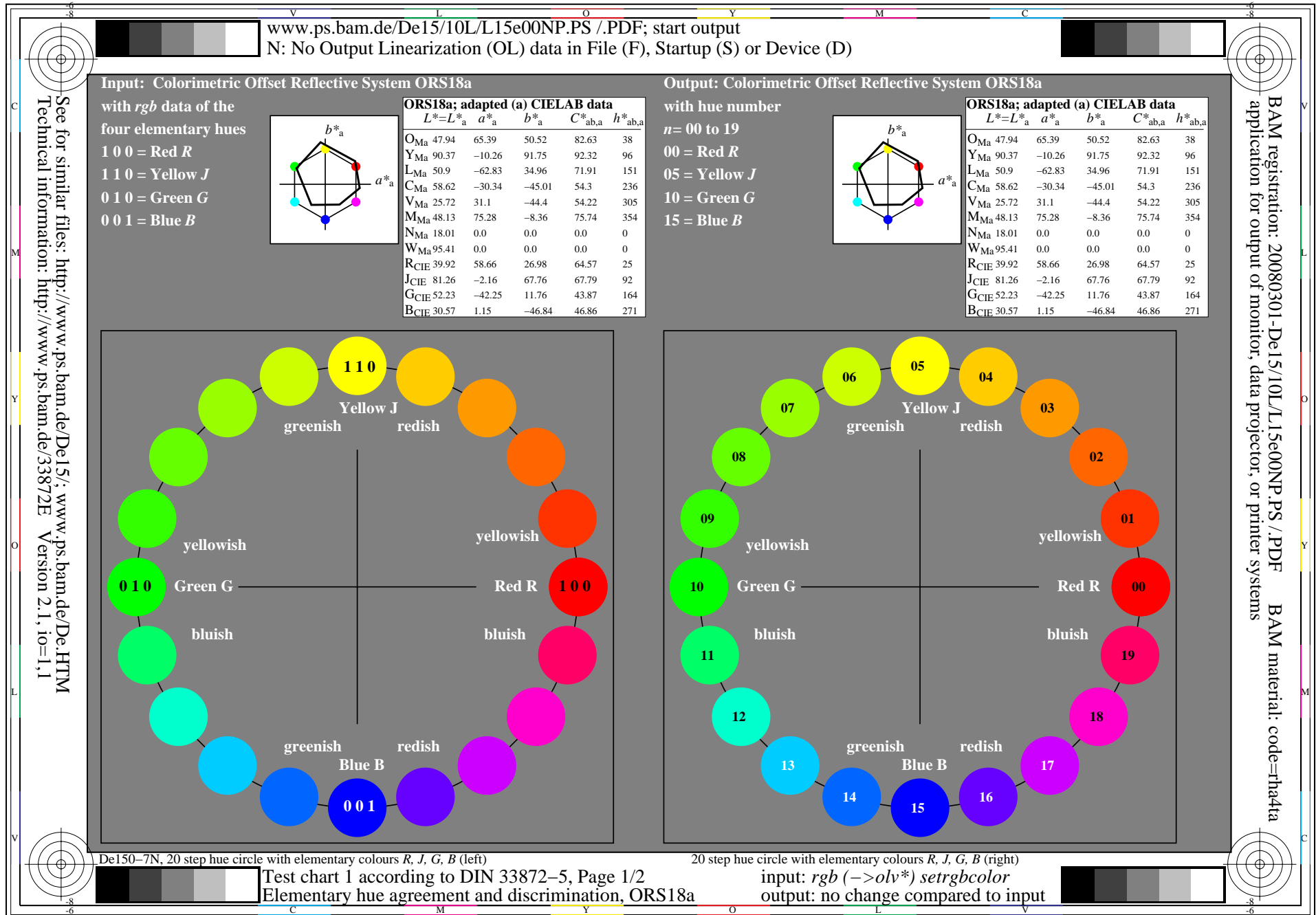
ZE410-5



ZE410-6

Colour order systems are based on a double cone with a circular basis (Ostwald, NCS). The *Natural Colour System* (NCS) uses three coordinates  $ncu^*$  (relative blackness  $n^*$ , relative chroma  $c^*$ , elementary hue text  $u^*$ )

Input data  $rgb=(1, 0, 0), (1, 1, 0), (0, 1, 0), (0, 0, 1)$  intended for elementary colour output

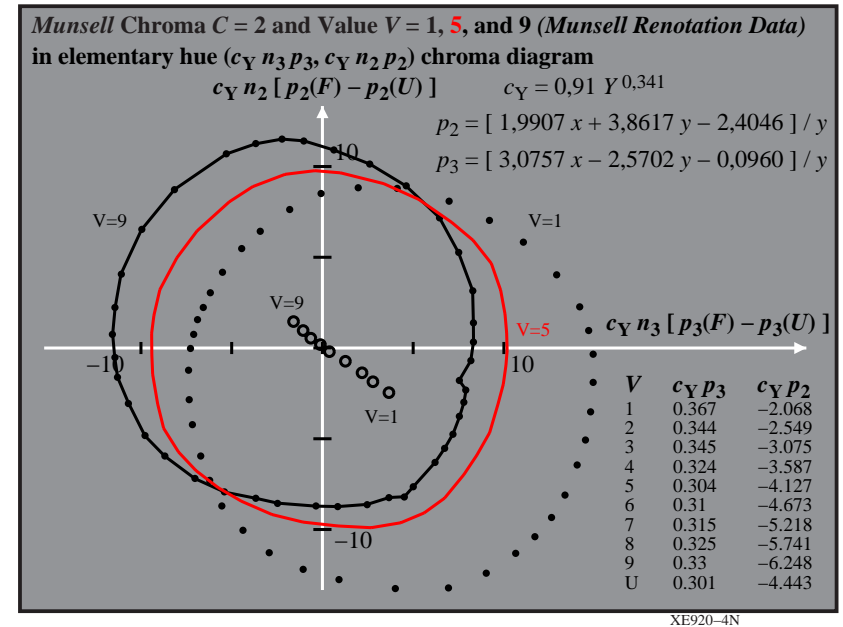
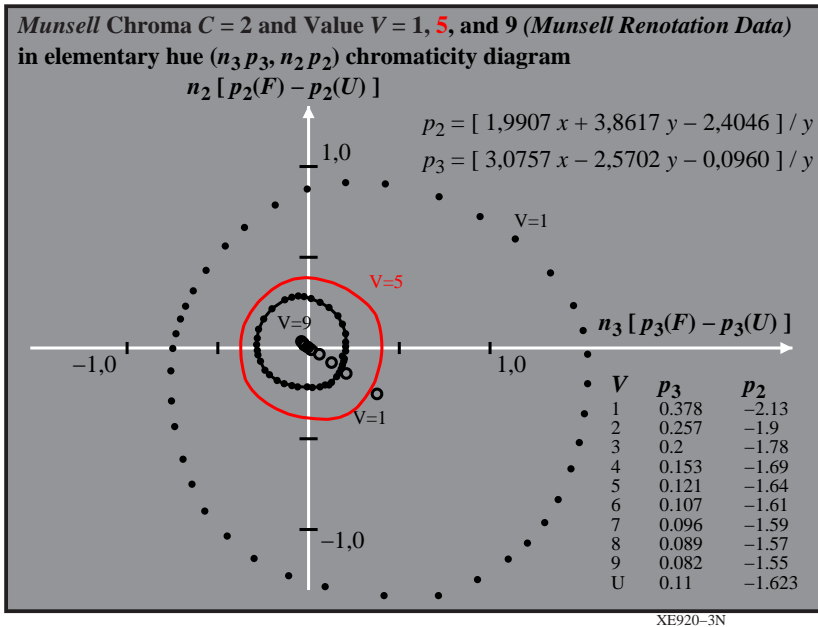
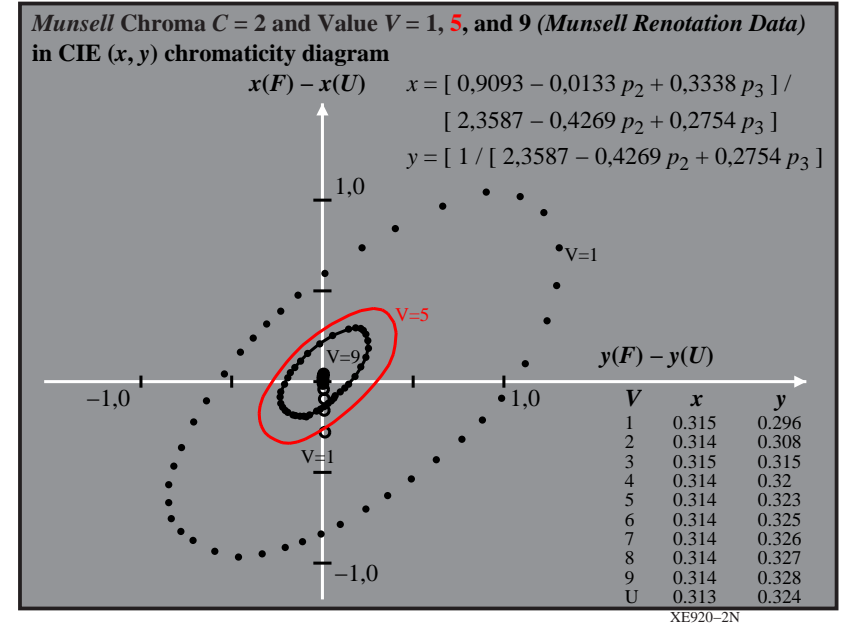
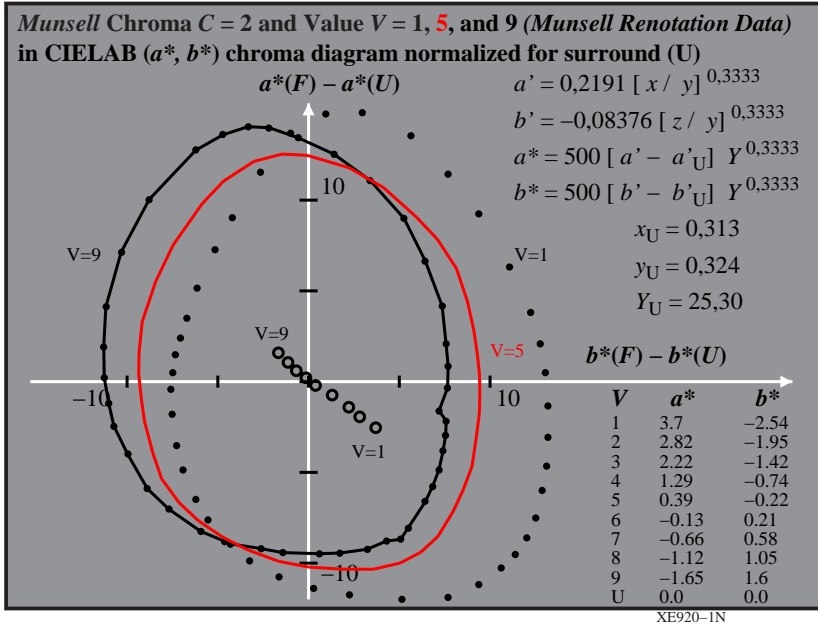




## **Content of the “Black and White” part**

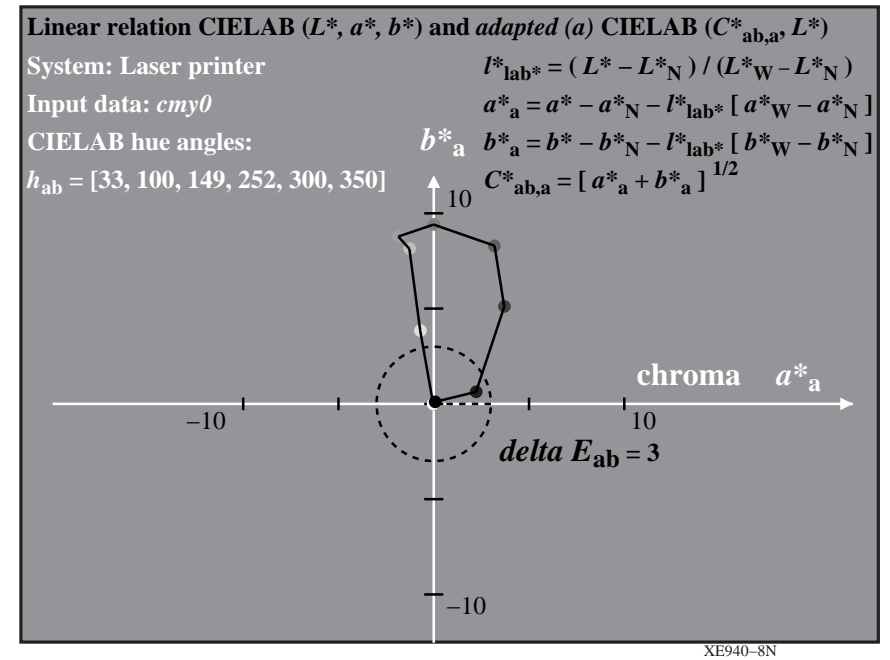
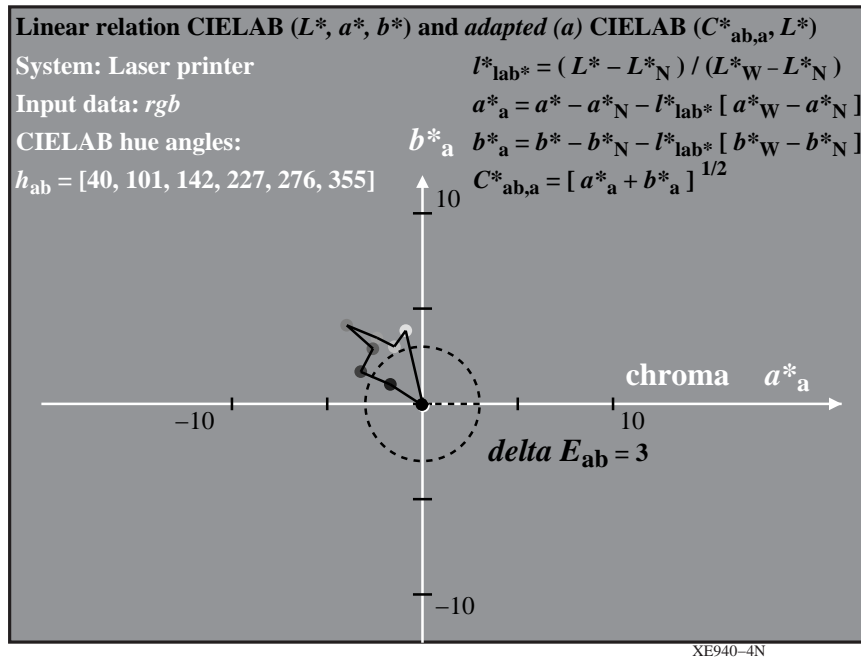
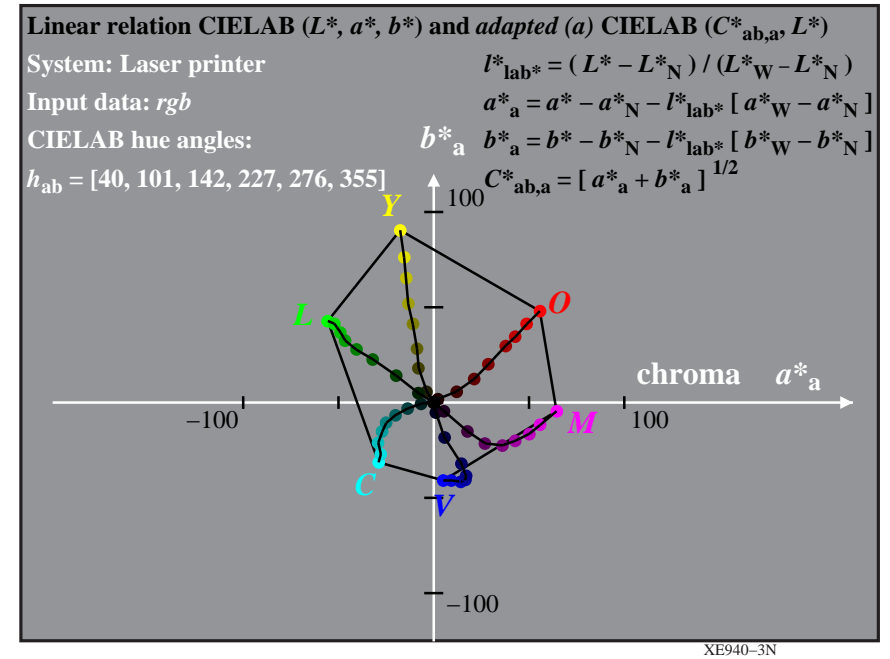
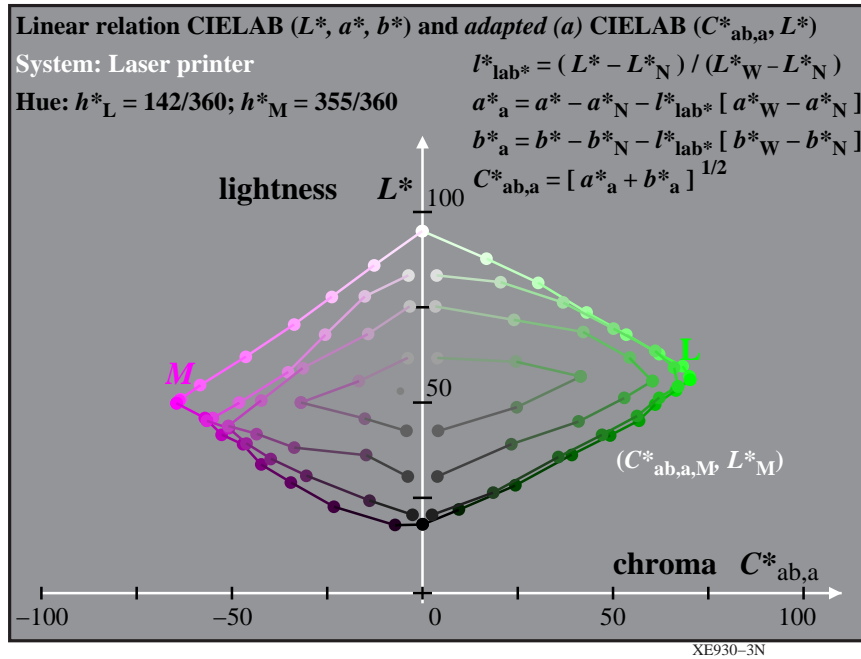
- Chroma 2 colours of *Munsell Renotation* definition**
- Shift of achromatic point along diagonal *j50g – b50r***
- Chromatic and achromatic properties of laser printer**
- Achromatic coordinates of standard offset printing**
- Achromatic test chart according to DIN 33872-3**
- Achromatic test chart according to ISO 9241-306**
- ISO-test chart projection in a daylighted office**
- ISO-test chart monitor viewing in mixed illumination**

## Munsell Renotation Colours of Chroma 2 and Values 2, 5, and 8 in different diagrams





Output example of two laser printers in CIELAB ( $L^*$ ,  $a^*$ ,  $b^*$ ) and ( $a^*$ ,  $b^*$ ) diagrams



Achromatic standard offset colours only printed with black colorant and *PostScript* operators for achromatic colours

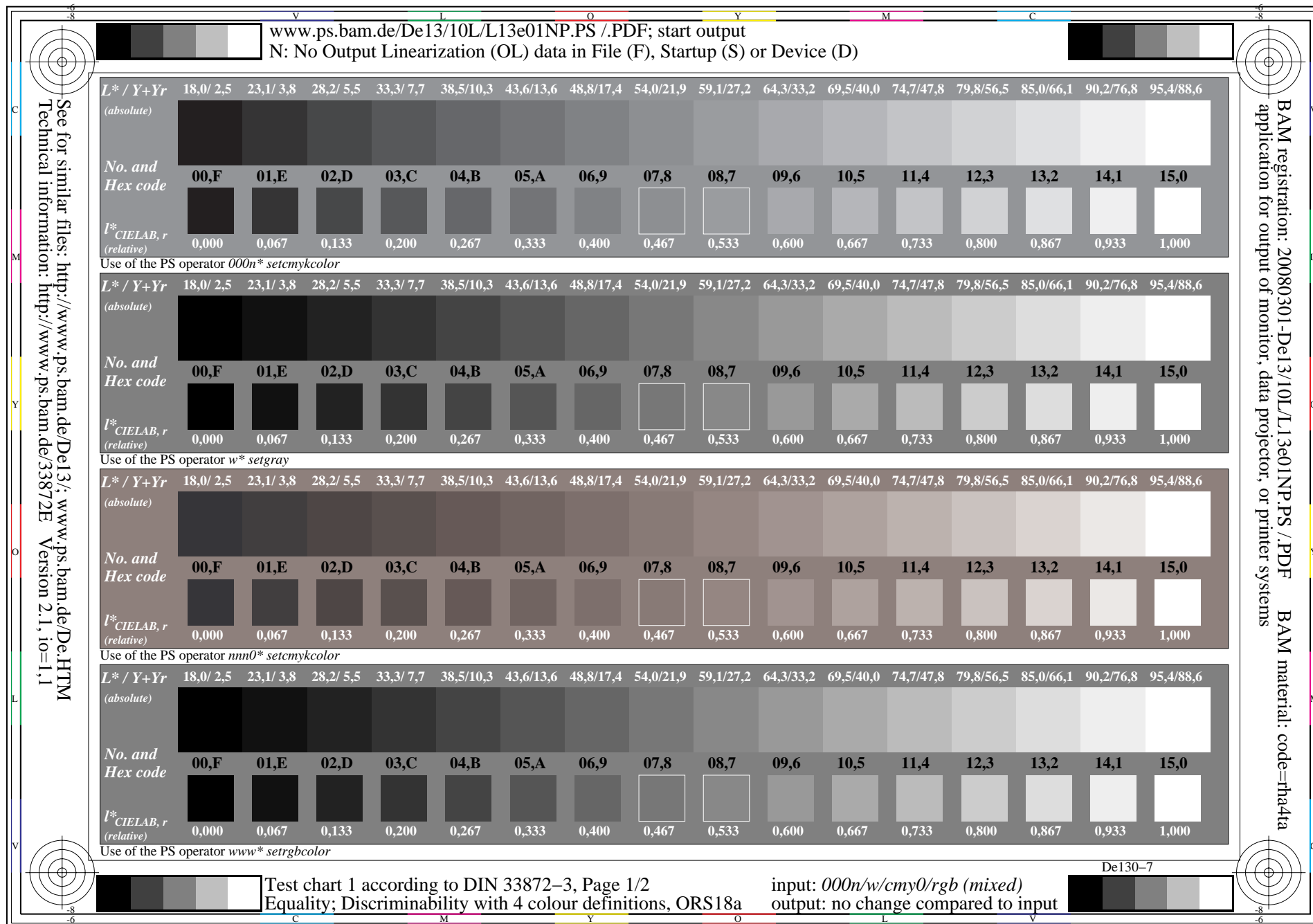
<b>5 steps of colour series black – white (N – W)</b>	<b>Colour space, colour space coordinates and PostScript operator according to ISO/IEC 15775:1999 and DIN E 33872–1:2007</b>								
<b>Linear mixture between black and white in CIELAB colour space</b>	<i>Standard CIELAB</i> $LAB^*LAB^* = LAB^*$ <i>LAB^* setcolor</i>		<i>adapted CIELAB</i> $LAB^*LAB^*_a = LAB^*_a$ <i>LAB^*_a setcolor</i>		<i>relative CIELAB</i> $lab^*rgb^* = rgb^*$ <i>rgb^* setrgbcolor</i>				
1,00 N + 0,00 W (black N)	18,01	0,50	-0,40	18,01	0,00	0,00	0,00	0,00	0,00
0,75 N + 0,25 W	37,35	0,10	0,80	37,35	0,00	0,00	0,25	0,25	0,25
0,50 N + 0,50 W	56,70	-0,10	2,10	56,70	0,00	0,00	0,50	0,50	0,50
0,25 N + 0,75 W	76,05	-0,50	-3,40	76,05	0,00	0,00	0,75	0,75	0,75
0,00 N + 1,00 W (white W)	95,41	-0,98	4,76	95,41	0,00	0,00	1,00	1,00	1,00

XE960–31

<b>5 steps of grey series black – white (N – W)</b>	<b>Colour space, colour space coordinates and PostScript operator according to ISO/IEC 15775:1999-12 and DIN E 33872–1:2007</b>											
<b>Linear mixture between black and white in CIELAB colour space</b>	<i>relative CIELAB</i>											
	<i>lab^*w^*</i> <i>setgray</i>	<i>lab^*000n^* = 000n^*</i> <i>000n^* setcmykcolor</i>				<i>lab^*cmy0^* = cmy0^*</i> <i>cmy0^* setcmykcolor</i>				<i>lab^*olv^* = olv^*</i> <i>olv^* setrgbcolor</i>		
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

YE920–11

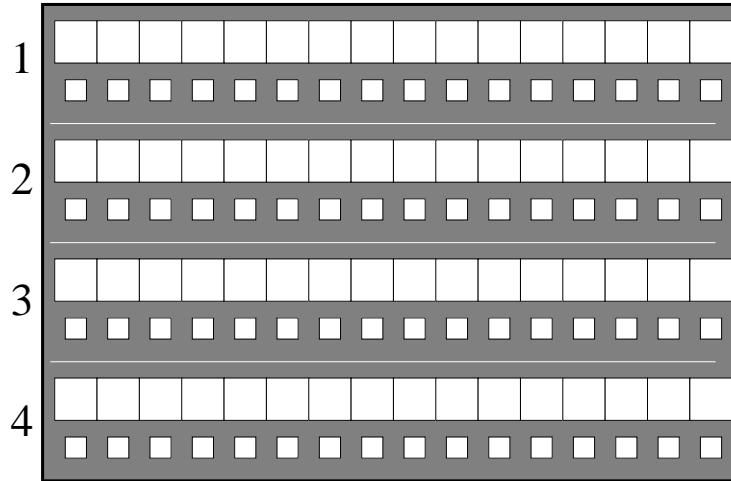
## Output example of DIN-test chart according to DIN 33872-3



Yes/No decision "Equality" of DIN-test chart output according to DIN 33872-3

**Equality of grey series by four grey definitions (Yes/No decision)**

Layout example: 16 step grey series with four grey definitions



Black N                  16 steps                  White W

There are two basic colours on each page:  
Black N and White W in mean grey background.

There are adjacent (upper row) and separate grey samples (lower row). This gives eight grey series.

In each column the four adjacent greys should be equal.

The four grey series are defined by four different PS-operators.

This test uses only the four upper adjacent grey series N–W.

For the upper grey series and in each column the four greys should be equal for **all** the 16 steps.

**Are in each column the four greys for all the 16 steps equal?                  underline: Yes/No**

**Only in case of "No":**

Is row no. 3 most different compared to all others ?                  underline: Yes/No

Are the series no. 1, no. 2, and no. 4 equal?                  underline: Yes/No

**Only in case of "No":**

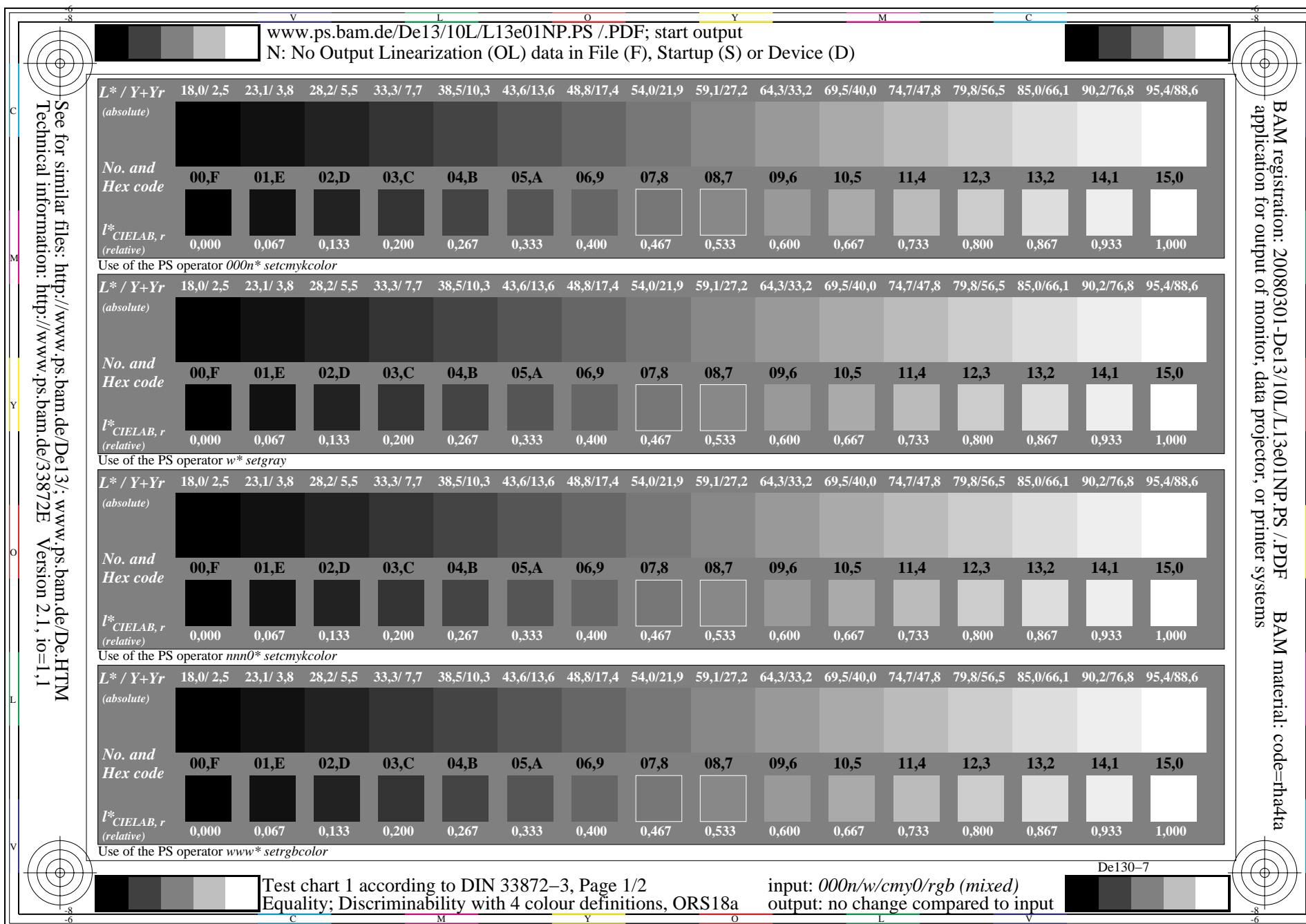
Are the rows no. 2 and no. 4 equal ?                  underline: Yes/No

Remarks, e. q. other equality: .....

.....



## Example of DIN-test chart output according to DIN 33872-3



## Achromatic ISO-test chart according to ISO 9241-306 for office work places and 8 ambient reflection conditions

See for similar files: <http://www.ps.bam.de/ME16/>  
 Technical information: <http://www.ps.bam.de/9241>

Version 2.0, io=7,7

www.ps.bam.de/ME16/10L/L16E00NP.PS/.PDF; start output  
 N: No Output Linearization (OL) data in File (F), Startup (S) or Device (D)

Radial grating (Siemens-star) N-W      Radial grating (Siemens-star) W-N  
 Radial grating (Siemens-star) N-Z      Radial grating (Siemens-star) W-Z

ME160-3, Element A: Radial gratings (Siemens-stars) N-W, W-N, N-Z and W-Z; PS operator:  $w^*_{setgray}$

background step 0      ring step 0-1  
 Hex code      Hex code

7	8
E	F
2	0
8	6
F	D

Landolt-rings W-N      code: background-ring

DMI10-1, Element D: Landolt-rings W-N; PS operator:  $w^*_{setgray}$

	120	128	136	144	152	160	168	176	184	192	200	208	216	224	232	240	
120 (+8)																	240
60 (+4)																	120
30 (+2)																	60
15 (+1)																	30
	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	

line raster diameter in lpi

ME161-3, Element E: Line raster under 45° (or 135°); PS operator:  $w^*_{setgray}$

	120	128	136	144	152	160	168	176	184	192	200	208	216	224	232	240	
120 (+8)																	240
60 (+4)																	120
30 (+2)																	60
15 (+1)																	30
	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	

line raster diameter in lpi

ME161-5, Element F: Line raster under 90° (or 0°); PS operator:  $w^*_{setgray}$

$L^*/Y_{input}$ (absolute)	18.0/2.5	37.3/9.7	56.7/24.6	76.1/49.9	95.4/88.6	$N_0$ (min.)	$W_1$ (max.)	
$w^*=I^*_{CIELAB, r}$ (relative) $w^*_{input}$	0,000	0,250	0,500	0,750	1,000	$N_0$ (min.)	$W_1$ (max.)	

ME160-5, Element B: 5 visual equidistant  $L^*$ -grey steps +  $N_0$  +  $W_1$ ; PS operator:  $w^*_{setgray}$

$L^*/Y_{input}$ (absolute)	18.0/2.5	23.2/3.8	28.3/5.6	33.5/7.8	38.6/10.5	43.8/13.7	49.0/17.6	54.1/22.1	59.3/27.3	64.4/33.3	69.6/40.2	74.8/47.9	79.9/56.5	85.1/66.2	90.2/76.8	95.4/88.6
No. and Hex code	00;F	01;E	02;D	03;C	04;B	05;A	06;9	07;8	08;7	09;6	10;5	11;4	12;3	13;2	14;1	15;0
$w^*=I^*_{CIELAB, r}$ (relative) $w^*_{input}$	0,000	0,067	0,133	0,200	0,267	0,333	0,400	0,467	0,533	0,600	0,667	0,733	0,800	0,867	0,933	1,000

ME160-7, Element C: 16 visual equidistant  $L^*$ -grey steps; PS operator:  $w^*_{setgray}$

Test chart ME16 according to ISO 9241-306; test chart 3 according to ISO/IEC 15775 input:  $w^*_{setgray}$   
 Page 1/1; recognition of 16 grey steps; standard contrast range 88.6 : 2.5      output:  $w^*_{setgray}$

BAM registration: 20080401-ME16/10L/L16E00NP.PS/.PDF      BAM material: code=rh4t4  
 Application for achromatic display output with CIELAB contrast range  $L^*_{w}:L^*_n = 95.4 : 18.0$

Scaling of grey colours for different surround and ambient light

<b>TLsxx</b> <b>Grey</b>	<b>Normalisation <math>Y_w=100.0</math></b> $L_N^*$ 00 19 76 00+a				<b>Normalisation <math>Y_w=100.0</math></b> $L_N^*$ 00 19 76 00+a			
<b>Code</b>	<b>CIELAB lightness <math>L^*</math></b>				<b>CIE tristimulus value <math>Y</math></b>			
00, F	0.0	19.4	76.1	76.1	0.0	2.8	50.0	50.0
03, C	20.0	35.5	80.9	77.0	3.0	8.8	58.2	51.5
06, 9	40.0	51.6	85.6	79.4	11.3	19.8	67.3	55.6
09, 6	60.0	67.8	90.4	84.0	28.1	37.7	77.2	64.1
12, 3	80.0	83.9	95.2	90.9	56.7	63.8	88.1	78.3
15, 0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
<b>TLsxx</b> <b>Grey</b>	<b>Normalisation <math>Y_w=88.59</math></b> $L_N^*$ 00 18 72 00+a				<b>Normalisation <math>Y_w=88.59</math></b> $L_N^*$ 00 18 72 00+a			
<b>Code</b>	<b>CIELAB lightness <math>L^*</math></b>				<b>CIE tristimulus value <math>Y</math></b>			
00, F	0.0	18.0	72.4	72.4	0.0	2.5	44.3	44.3
03, C	19.1	33.5	77.0	73.3	2.8	7.8	51.6	45.7
06, 9	38.2	49.0	81.6	75.7	10.2	17.6	59.6	49.4
09, 6	57.2	64.5	86.2	80.1	25.2	33.4	68.4	56.9
12, 3	76.3	79.9	90.8	86.8	50.4	56.6	78.1	69.5
15, 0	95.4	95.4	95.4	95.4	88.6	88.6	88.6	88.6



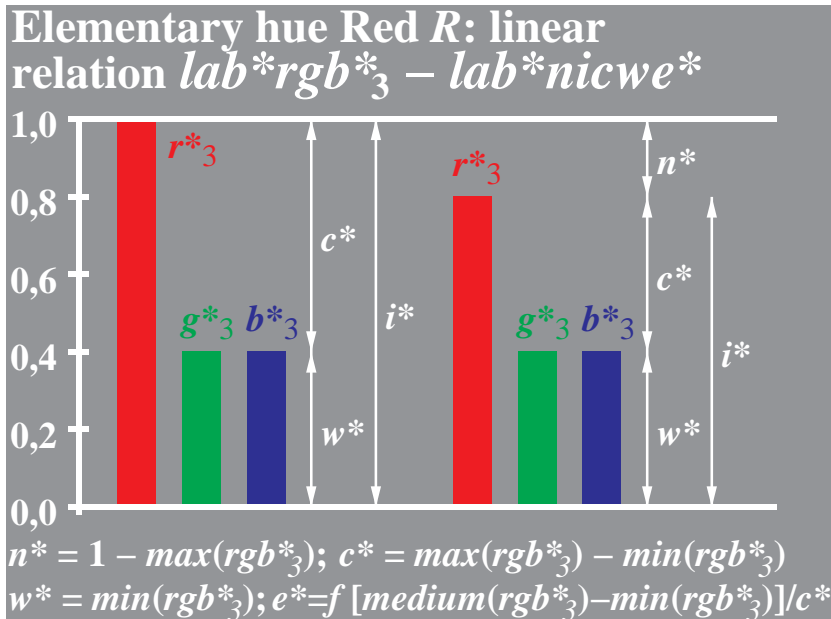
## Mixture of illuminants and achromatic colour Black

Illuminant change	CIE-Tristimulus values					CIELAB data				
	<i>X</i>	<i>Y</i>	<i>Z</i>	<i>x</i>	<i>y</i>	<i>L*</i>	<i>a*</i>	<i>b*</i>	<i>C*<sub>ab</sub></i>	<i>h<sub>ab</sub></i>
86,07% <b>N</b>	0.01	0.01	0.01	0.313	0.329	0.08	0.0	0.0	0.0	0.0
<b>D65 W</b>	81.8	86.07	93.71	0.313	0.329	94.34	0.0	0.0	0.0	0.0
+2,52% <b>N</b>	0.0	0.0	0.0	0.313	0.329	0.0	0.0	0.0	0.0	0.0
<b>D65 W</b>	2.4	2.52	2.74	0.313	0.329	18.01	0.0	0.0	0.0	0.0
Sum <b>N</b>	2.4	2.53	2.75	0.313	0.329	18.05	0.01	0.01	0.01	32.0
Sum <b>W</b>	84.2	88.59	96.46	0.313	0.329	95.41	0.0	0.0	0.0	0.0
86,07% <b>N</b>	0.01	0.01	0.01	0.313	0.329	0.08	0.0	0.0	0.0	0.0
<b>D65 W</b>	81.8	86.07	93.71	0.313	0.329	94.34	0.0	0.0	0.0	0.0
+2,52% <b>N</b>	0.0	0.0	0.0	0.346	0.359	0.0	0.0	0.0	0.0	0.0
<b>D50 W</b>	2.43	2.52	2.08	0.346	0.359	18.01	0.0	0.0	0.0	0.0
Sum <b>N</b>	2.44	2.53	2.09	0.346	0.358	18.05	0.71	5.17	5.22	82.1
Sum <b>W</b>	84.23	88.59	95.79	0.314	0.33	95.41	0.07	0.44	0.45	81.5
86,07% <b>N</b>	0.01	0.01	0.01	0.313	0.329	0.08	0.0	0.0	0.0	0.0
<b>D65 W</b>	81.8	86.07	93.71	0.313	0.329	94.34	0.0	0.0	0.0	0.0
+2,52% <b>N</b>	0.0	0.0	0.0	0.448	0.407	0.0	0.0	0.0	0.0	0.0
<b>A W</b>	2.77	2.52	0.9	0.448	0.407	18.01	0.0	0.0	0.0	0.0
Sum <b>N</b>	2.78	2.53	0.91	0.447	0.407	18.05	7.24	18.17	19.56	68.3
Sum <b>W</b>	84.57	88.59	94.61	0.316	0.331	95.41	0.71	1.23	1.42	60.1

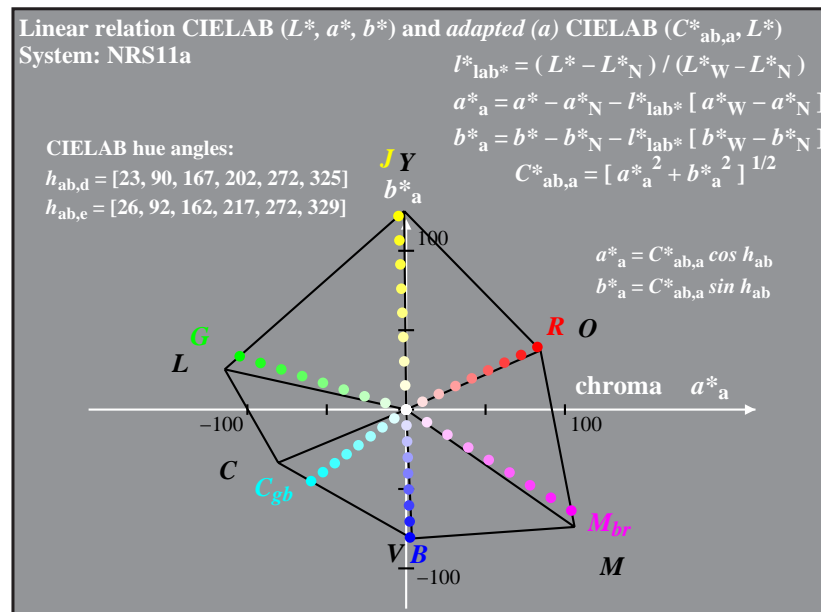
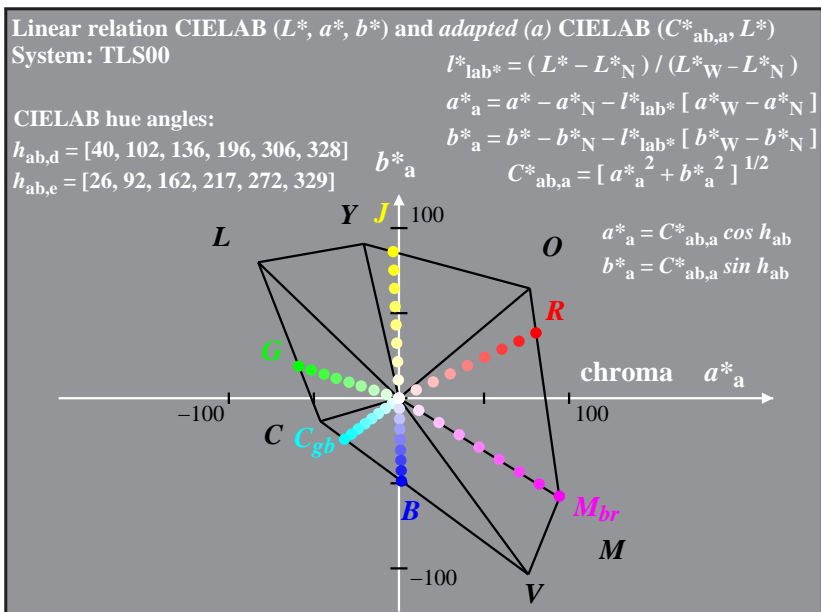
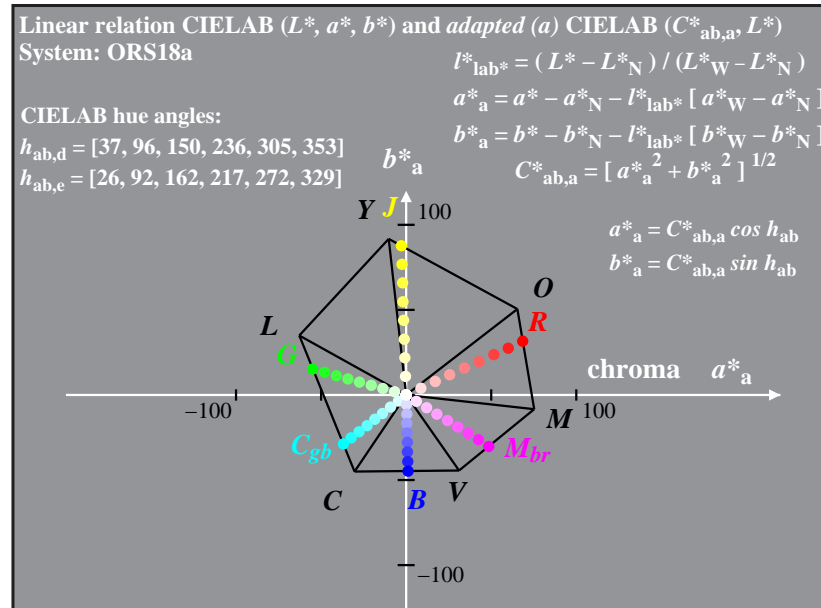
## **Content of a part “Colour Separation Methods”**

- Device and elementary hues in CIELAB ( $a^*, b^*$ )**
- 5-step and 16-step colours of elementary hue blue  $B$**
- Colour separation method by  $cmy0^*$**
- Intelligent colour separation method by  $cmyn^*$**
- Relative Elementary Colour System RECS**
  - about 2000 colours in standard offset printing**
  - 16-step elementary colour circle**
  - 5-step and 16-step colour scales**
  - intelligent colour separation**
  - 1080 standard colours within 9x9x9  $rgb$  grids**
  - ISO/IEC-test charts for office devices according to ISO/IEC 15775 and ISO/IEC TR 24705**

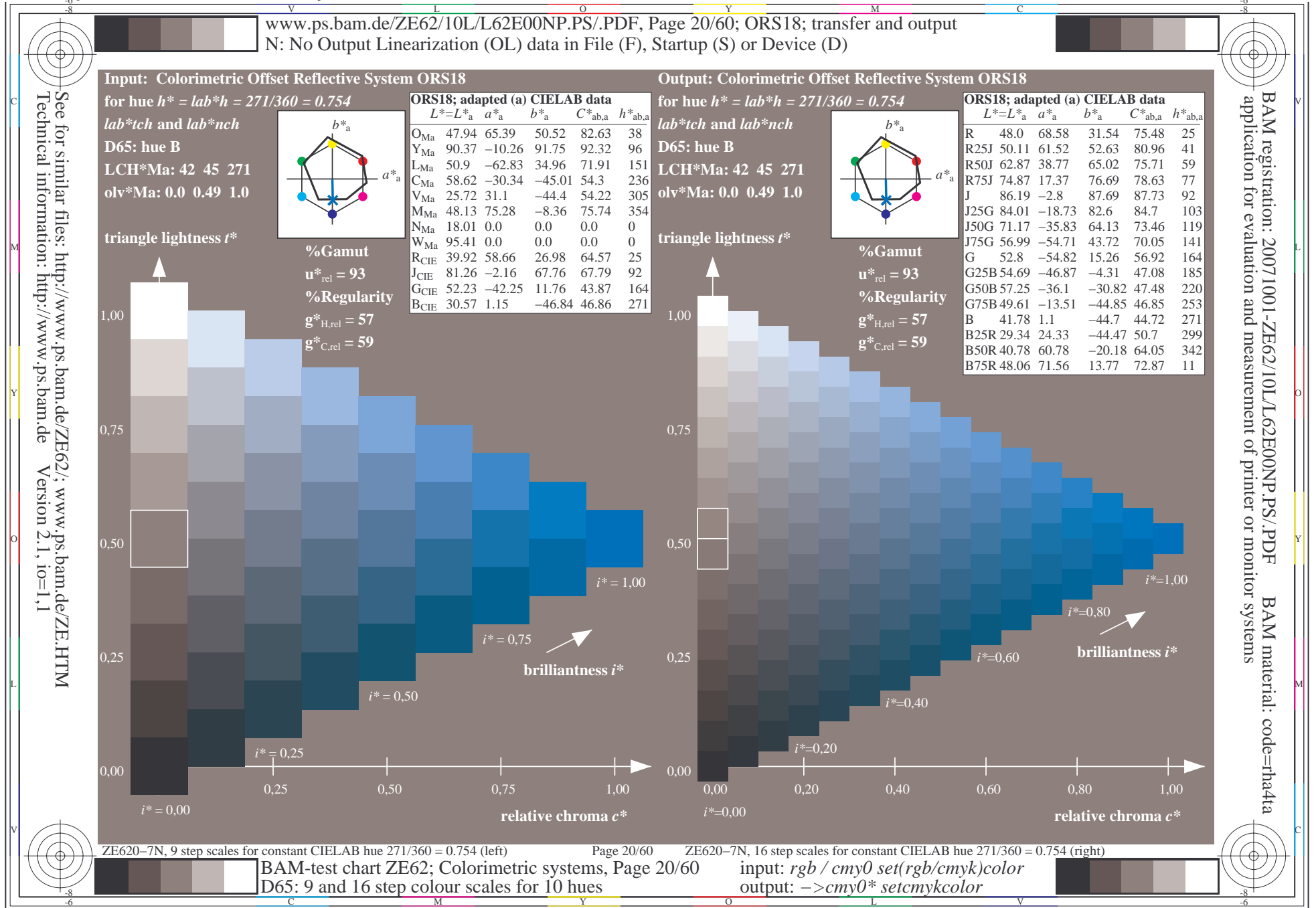
Elementary colour coordinates  $rgb^*$  and relation to colour coordinates  $nicme^*$ ; Device and elementary hues in CIELAB diagrams ( $a^*, b^*$ )



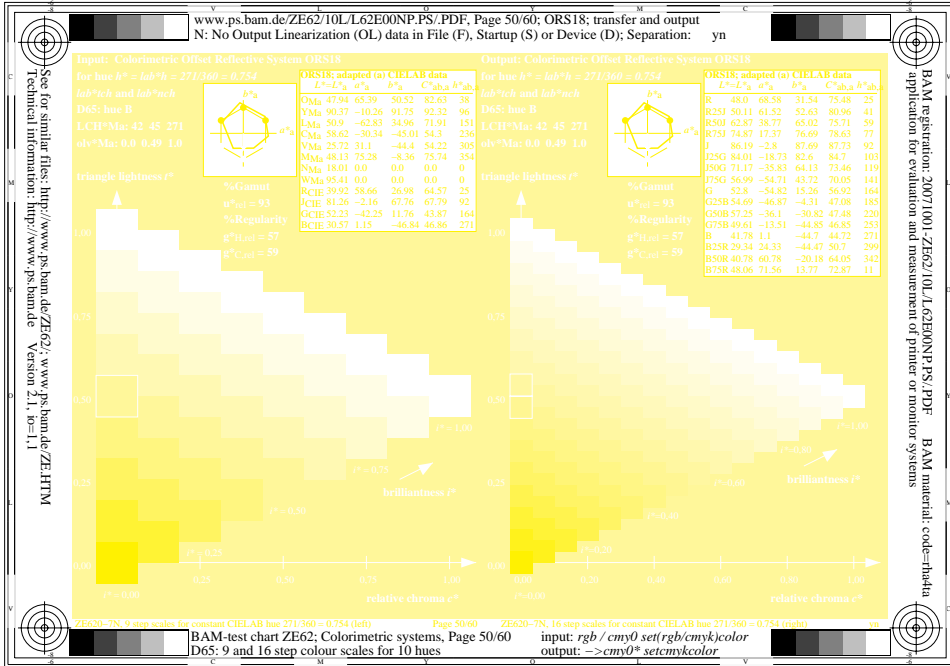
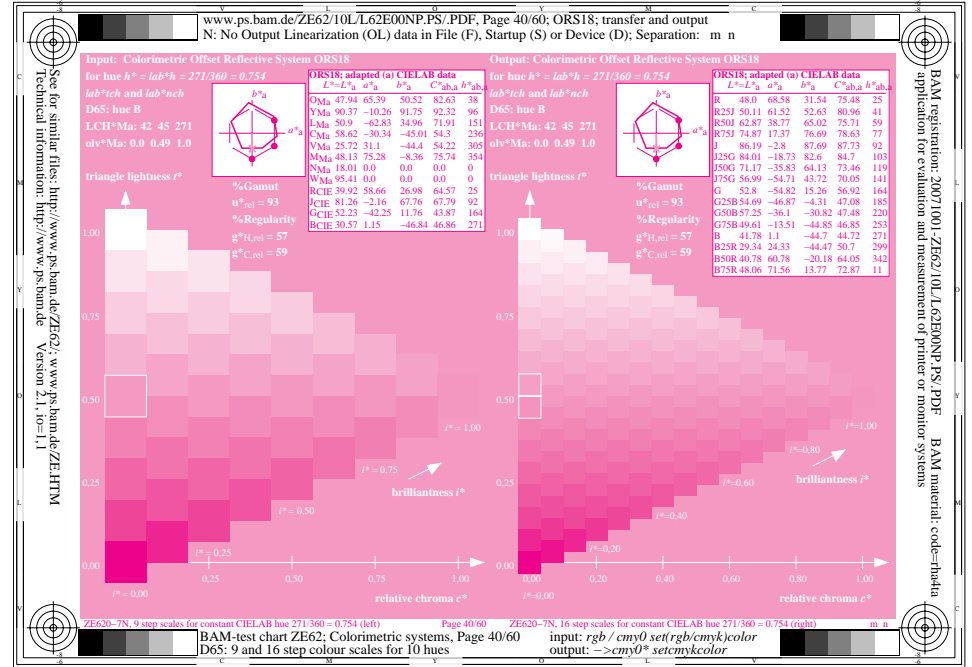
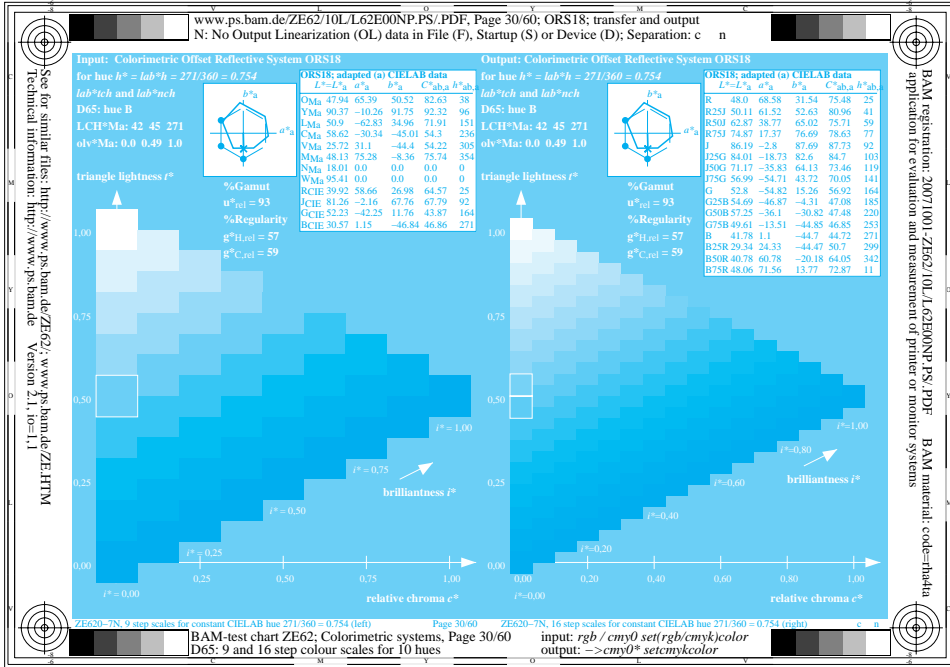
ZE430-1



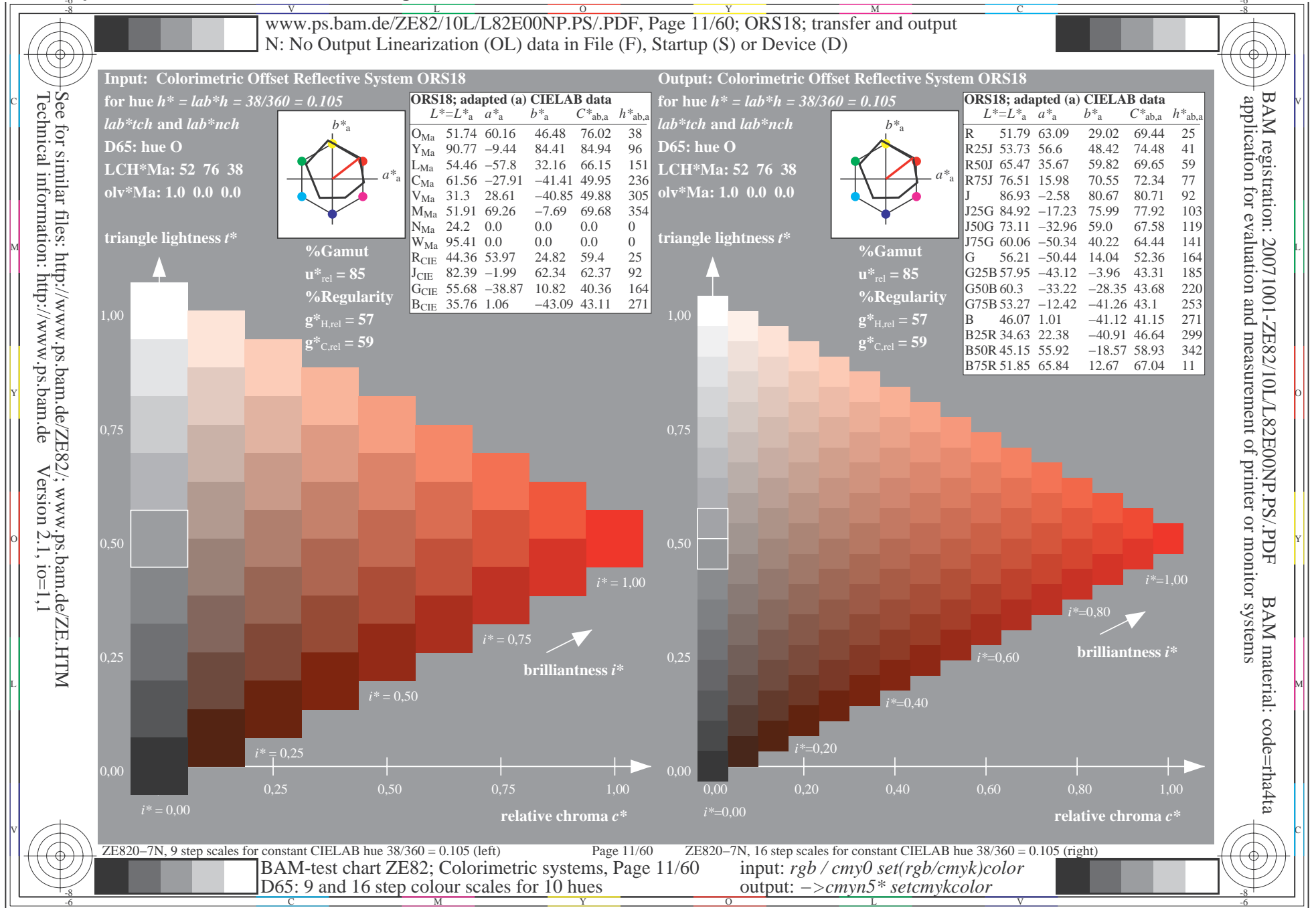
## 9 and 16 step colour scales of elementary hue Blue B



## 4 colour separation for Blue B with low material efficiency using only chromatic colorants



## 9- and 16-step colour scales of device colour Orange red O





## Summary

- Device dependent and elementary colour systems.
- Model for perceived black and white
- Equations  $rgb^* \leftrightarrow LCH^*$  for linearized devices.
- Output with high visual efficiency (16 output steps are equally spaced) based on output linearisation.
- Output with high material efficiency (grey is printed by only black and not with chromatic colorants) based on an improved separation technology.
- Relative Elementary Colour System RECS available as analog and digital colour atlas. Serves as reference for input and output in image technology for copiers, scanners, cameras, printers, monitors.



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