

Natural Colour Connection Space (NCCS) between input and output for office systems

www.ps.bam.de/BAMAG1F.FM

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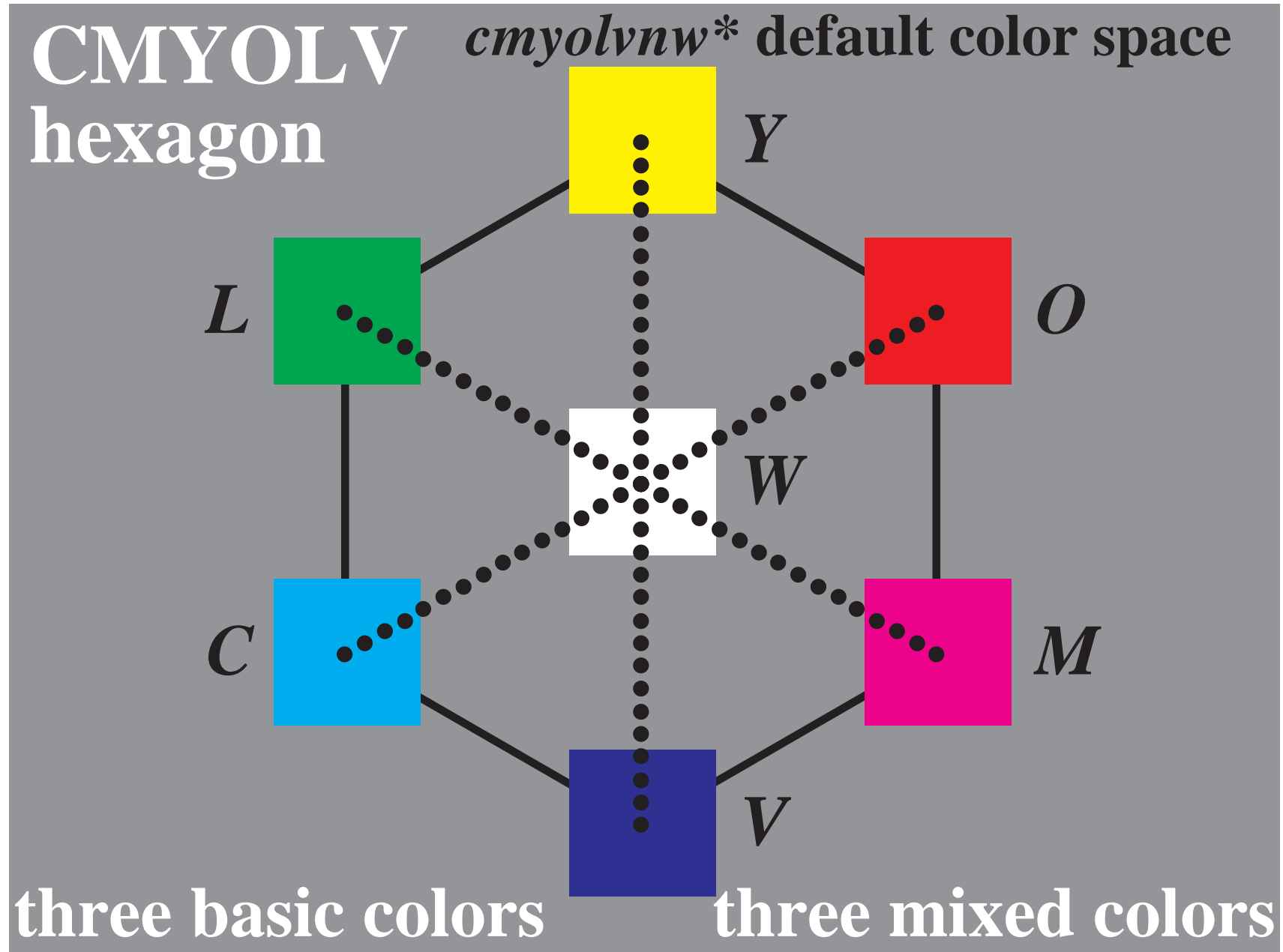
**klaus.richter@bam.de
<http://www.ps.bam.de>**

Overview

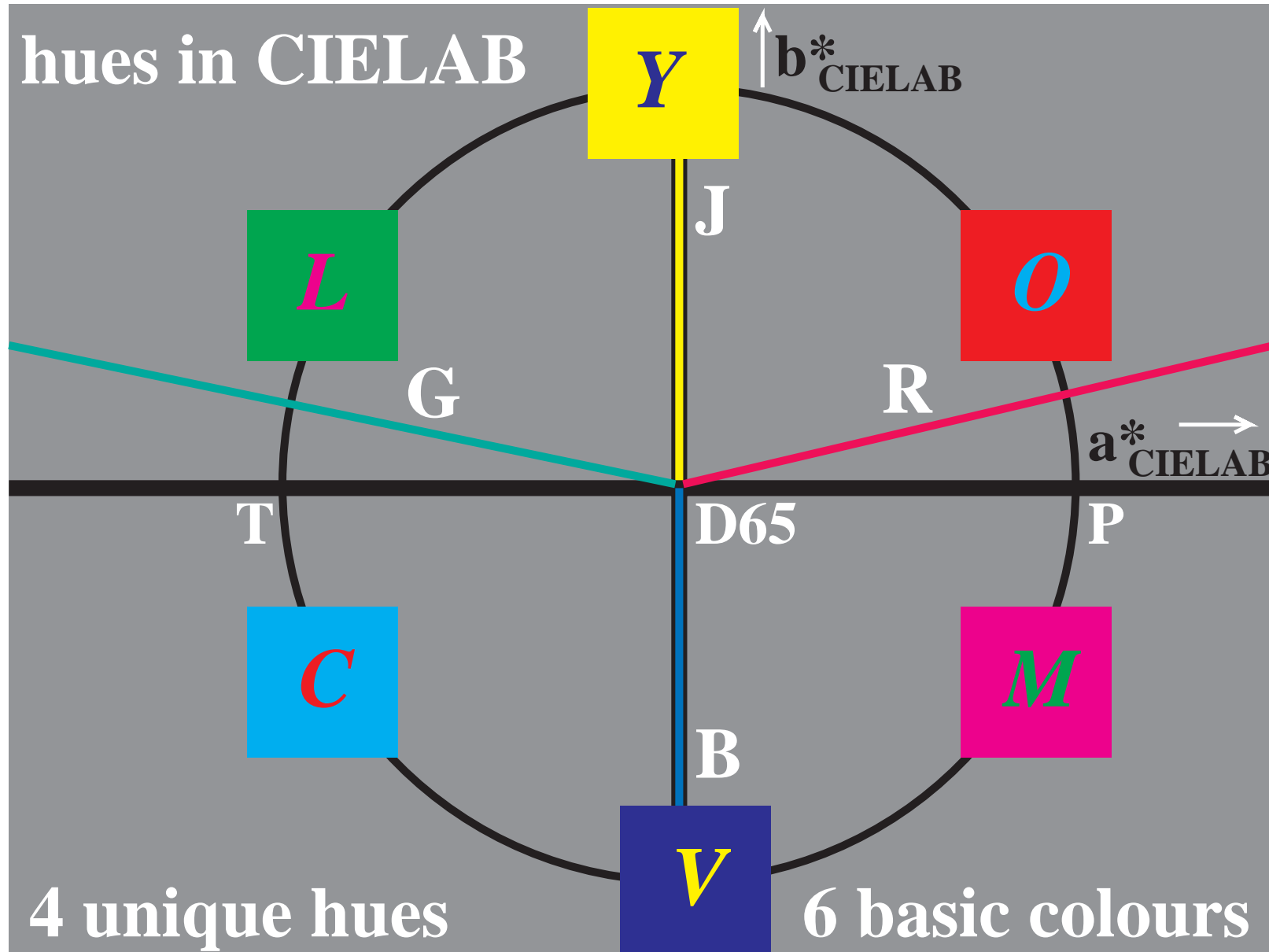
- **Eight basic colours, colour hexagon, double cone**
- **Linear relationships between colour coordinates**
- **16 step output equally spaced in relative CIELAB**
- **the Natural Colour Connection Space (NCCS)**
- **Properties of the NCCS:**
 - for display output of 8 display reflections**
 - for output of elementary colours *RJGB*.**
 - for Device Link Colour Management (DLCM)**
 - for the reproduction of hue, relative chroma and relative CIELAB differences (optimal recognition)**

Summary

Colour Hexagon



Elementary Colour Circle and Hexagon in CIELAB



Standards and Technical Reports

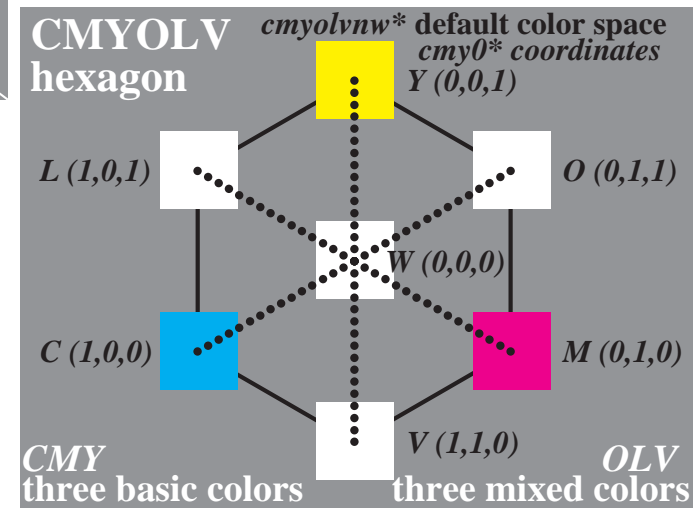
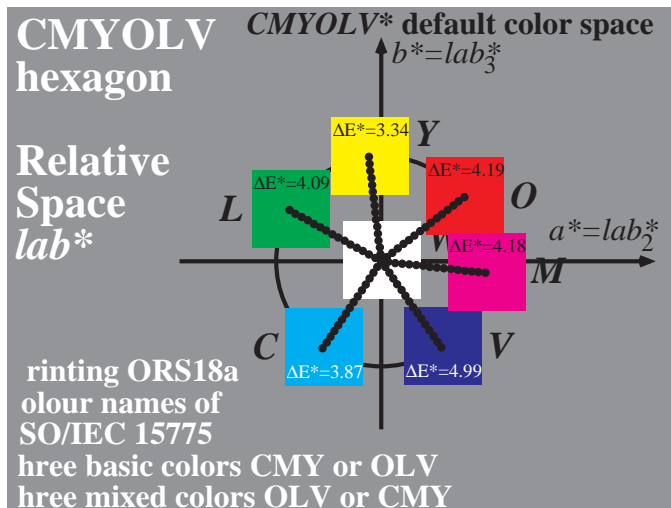
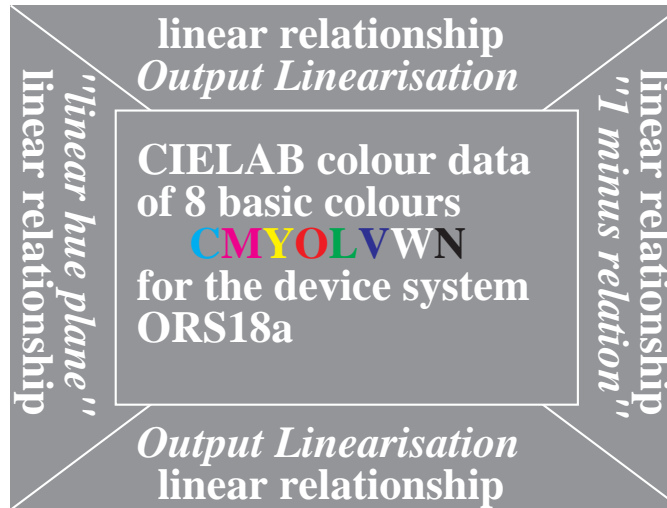
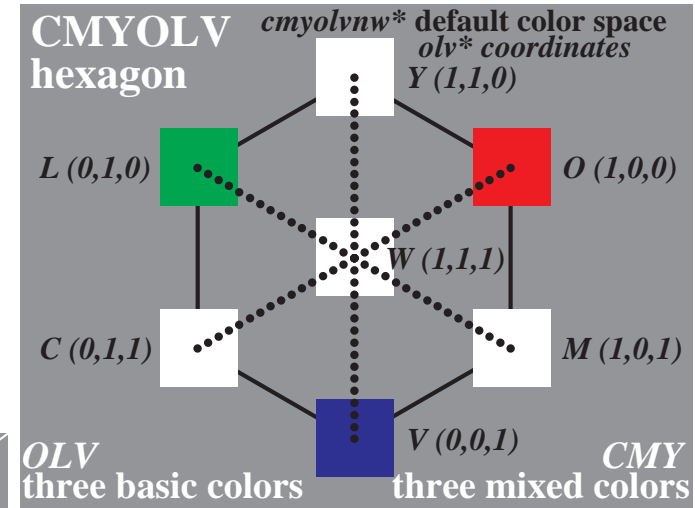
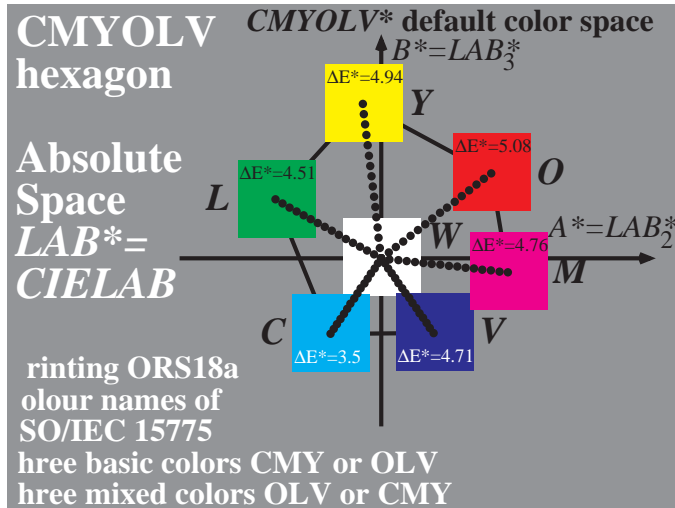
Input	Output	Input and output media and applications			Technical Report (TR) or Standard
		Input media	Output media	Application	
—	—	—	—	Basis	ISO/IEC TR 24705
analog	analog	ISO/IEC-test chart (hardcopy)	Hardcopy	Copier	ISO/IEC 15775
analog	digital	ISO/IEC-test chart (hardcopy)	File	Scanner	ISO/IEC TR 24705
digital	analog	ISO/IEC-test chart (file)	{ Hardcopy Softcopy	Printer Monitor	ISO/IEC TR 24705 ISO/IEC TR 24705

WINWS04/T1TA000.PS

Input	Output	Input and output media and applications			Standard
		Input media	Output media	Application	
-	-	-	-	Basis	DIN 33866-1
analog	analog	DIN-test chart (hardcopy)	Hardcopy	Copier	DIN 33866-2
analog	digital	DIN-test chart (hardcopy)	File	Scanner	DIN 33866-4
digital	analog	DIN-test chart (file)	{ Hardcopy Softcopy	Printer Monitor	DIN 33866-3 DIN 33866-5

DINWS04/T1TADIN.PS

Linear relationship of colour coordinates



Corresponding colour coordinates

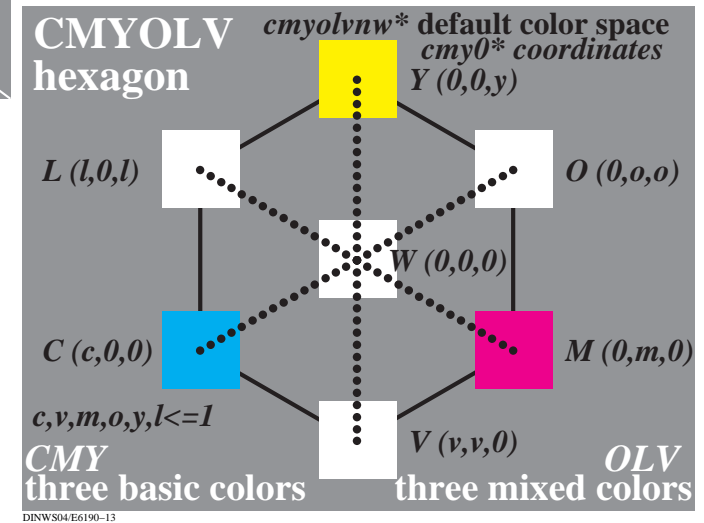
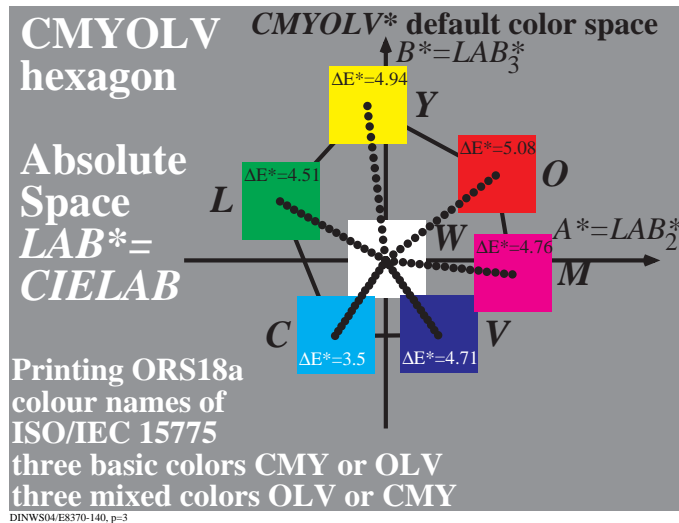
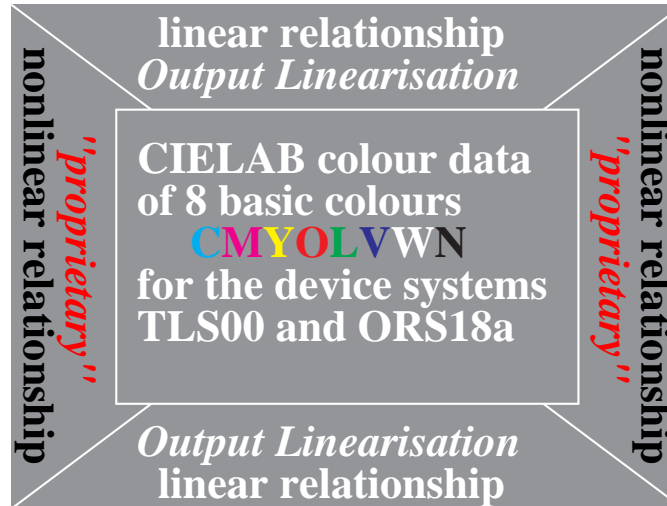
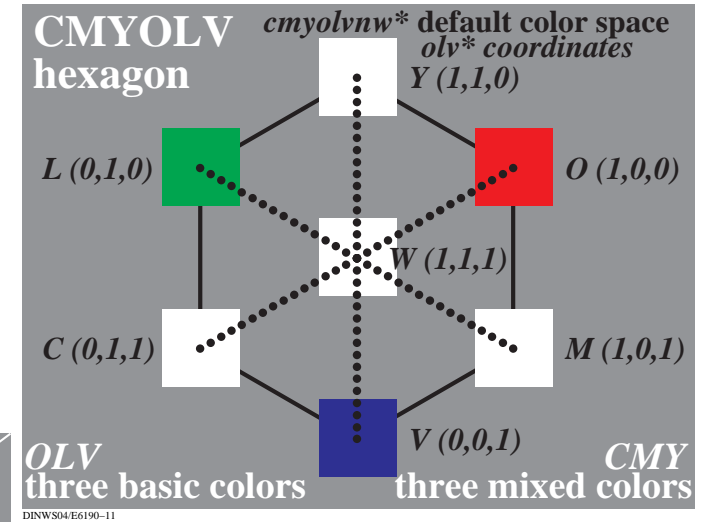
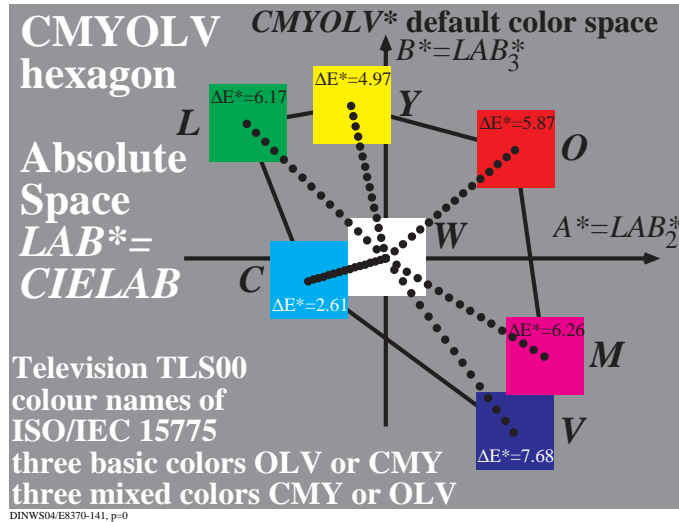
5 steps of grey series black - white (N - W)	Colour space, colour space coordinates and PostScript operator calculations according to ISO/IEC 15775:1999-12			
Linear mixture between black and white in CIELAB colour space	<i>L*</i> CIE <i>w*</i> = <i>l*</i> <i>setgray</i>	CMYN (CMYK) <i>000n*</i> <i>setcmykcolor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

DINWS04/DESERCW0.PS

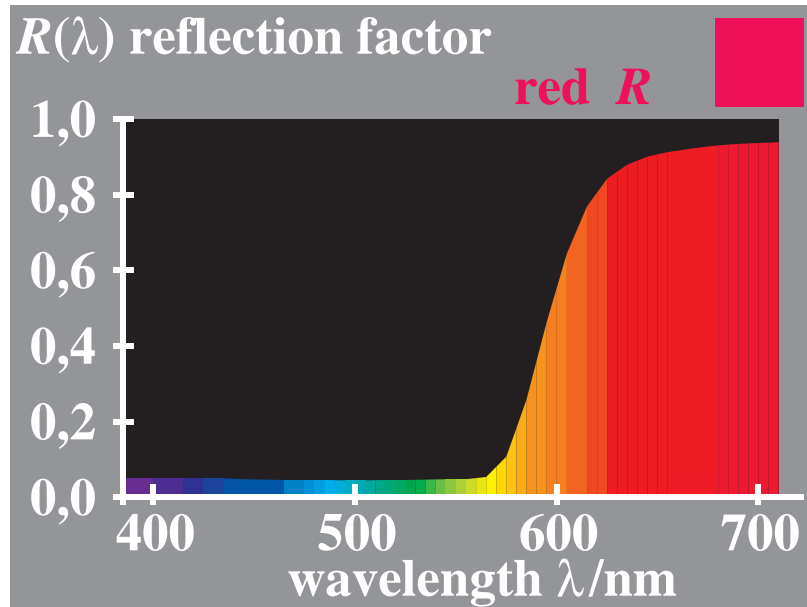
5 steps of colour series cyan blue - white (C - W)	Colour space, colour space coordinates and PostScript operator calculations according to ISO/IEC 15775:1999-12		
Linear mixture between cyan blue and white in CIELAB colour space	CIELAB <i>LAB*</i> (absolute) <i>LAB*</i> <i>setcolor</i>	CMYN (CMYK) <i>cmy0*</i> (relative) <i>cmy0*</i> <i>setcmykcolor</i>	OLV (RGB) <i>olv*</i> (relative) <i>olv*</i> <i>setrgbcolor</i>
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

DINWS04/DESERCW1.PS

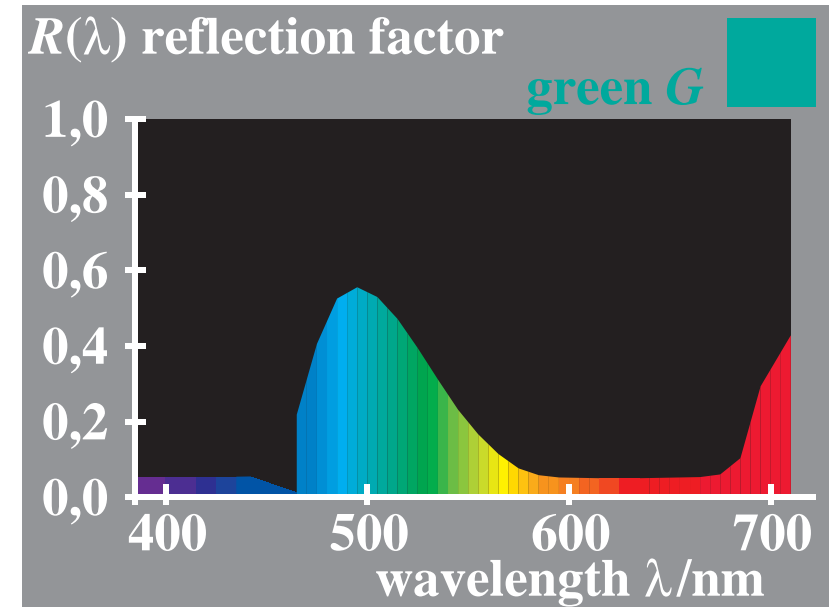
relationship of display and printer colour coordinates



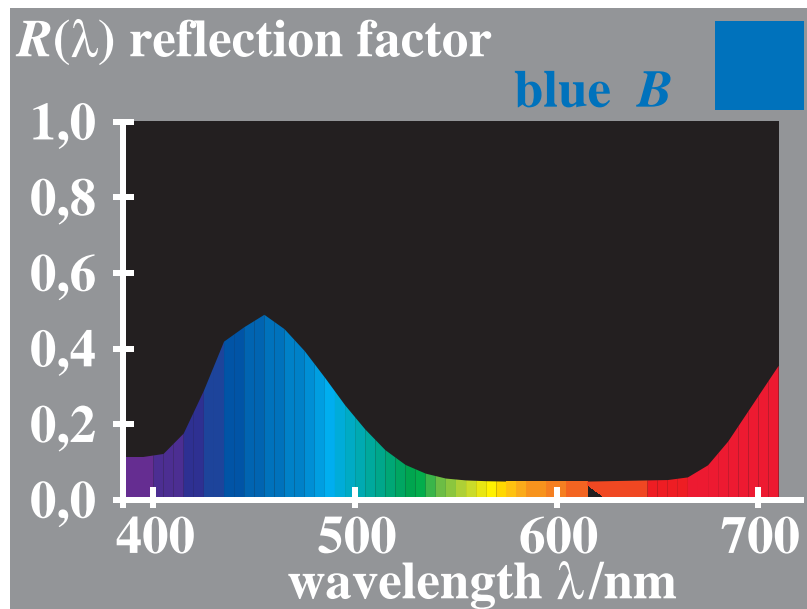
Mate surface colours with reflection $Y_r=4.0$



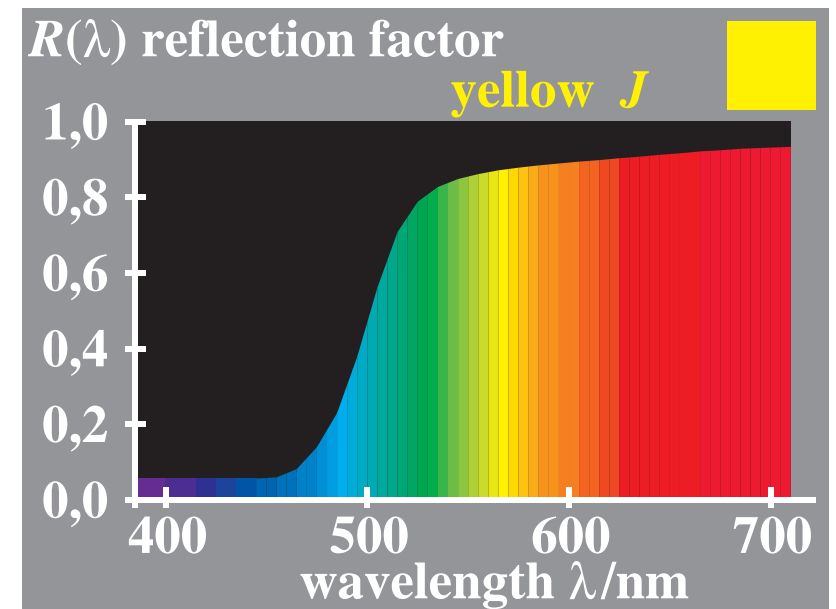
TR24705/E8141-7N



TR24705/E8150-1N

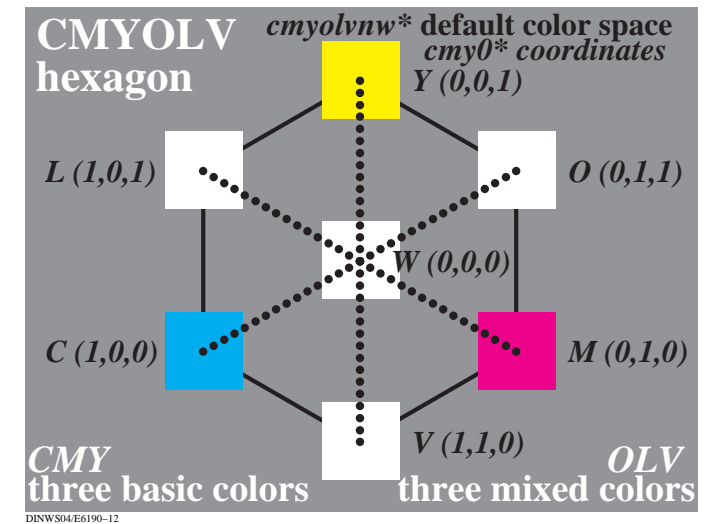
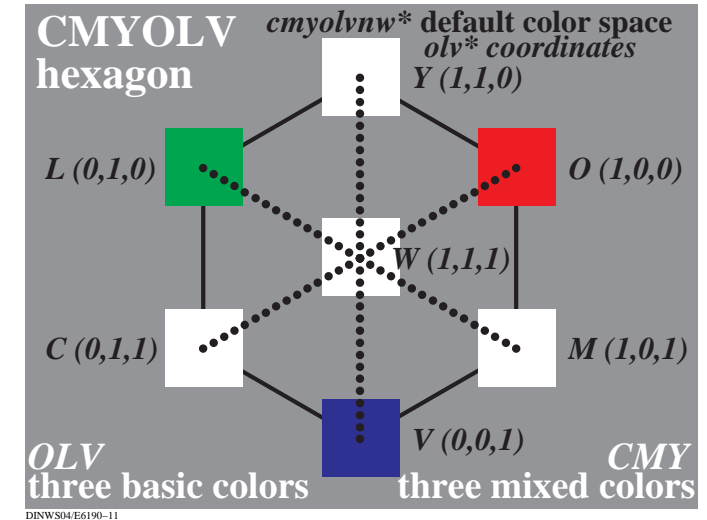
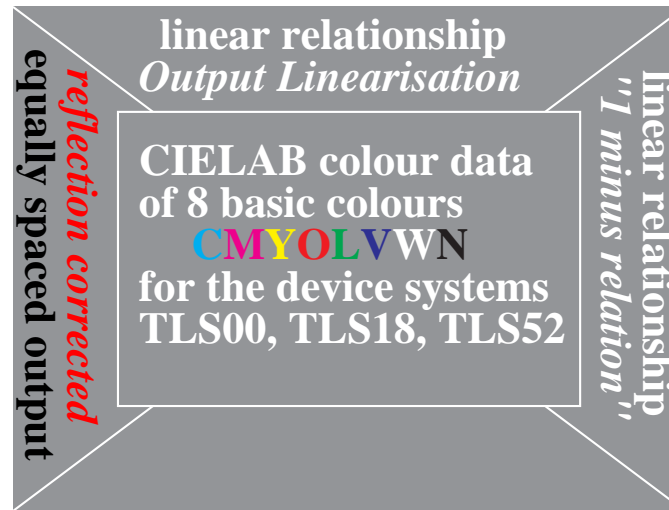
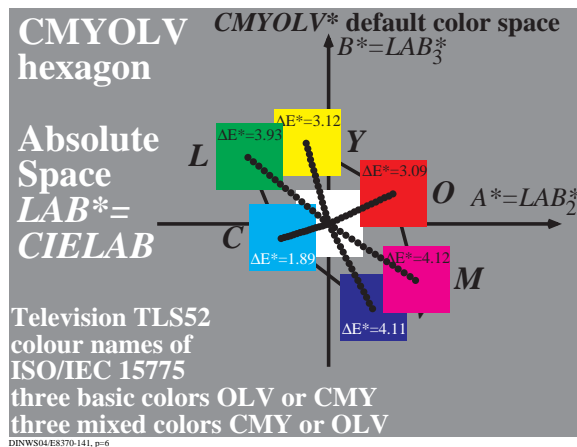
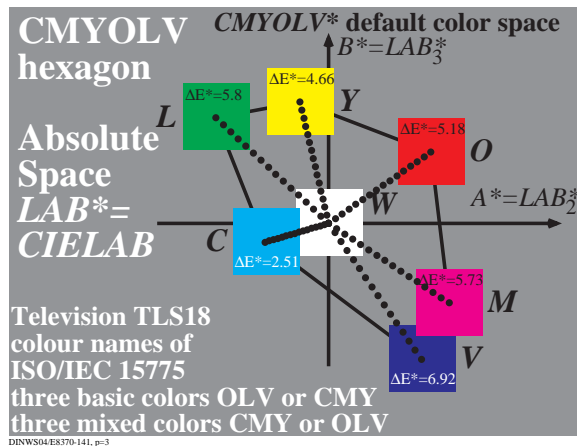
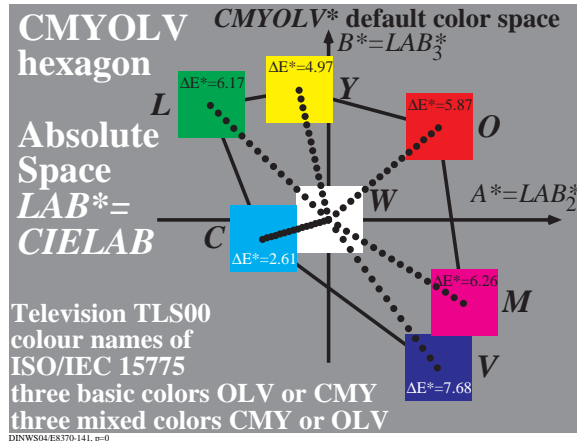


TR24705/E8141-8N

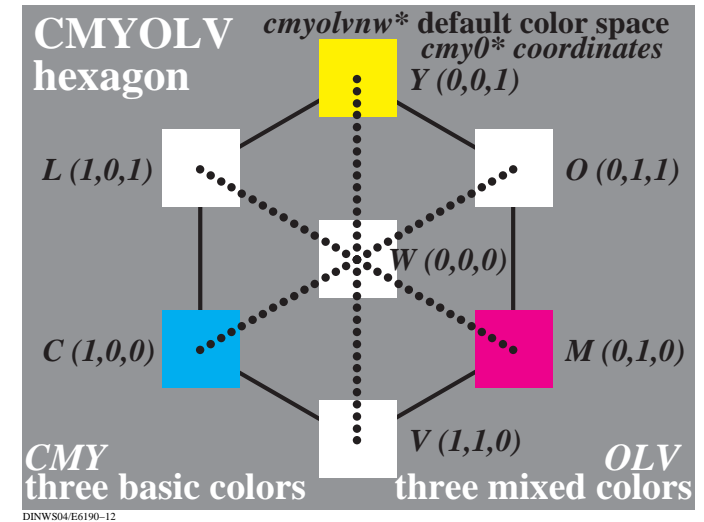
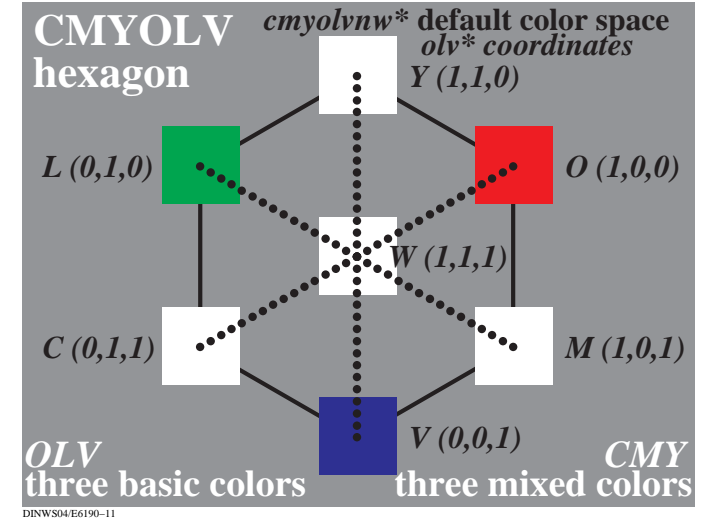
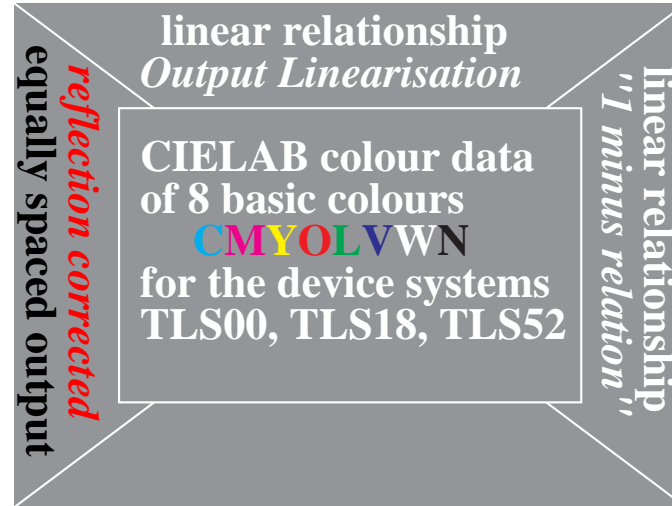
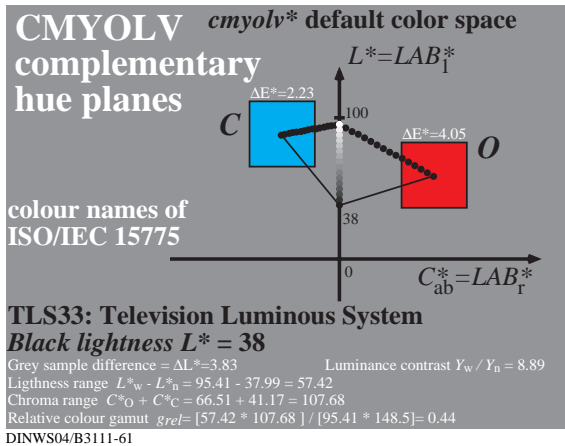
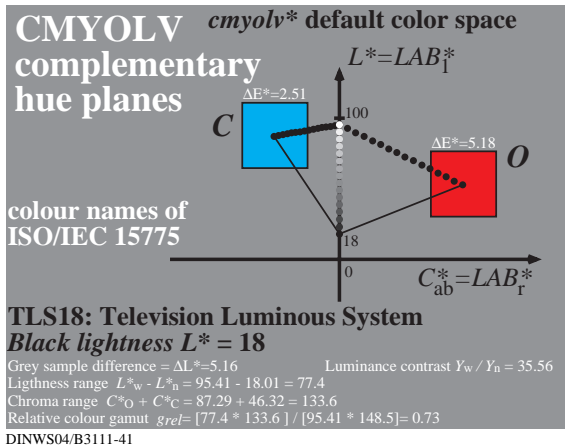
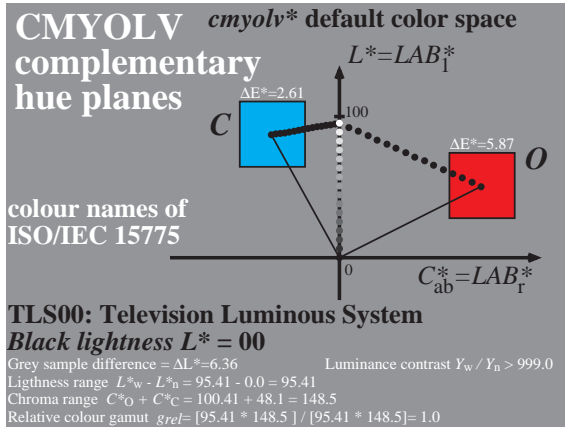


TR24705/E8141-6N

relationship of display reflection colour coordinate in a*b*-planes



relationship of display reflection colour coordinates in L*C*-plane



Application of colour in daily life or in Information Technology (IT):

Design, architecture, art, industrial products
Measured for CIE standard illuminant D65
colour order system: name and coordinates

RAL Design System (CIELAB):

*LCH**, lightness, chroma, hue

Munsell Colour System:

*VCH**, lightness (Value), Chroma, Hue

Natural Colour System (NCS):

*nce**: blackness, chromaticness, elementary hue

New: Application connection by coordinates *olv, *cmv**, *tce**, ... und linear relation to *LAB****

CIELAB: *LAB** : lightness, red–green and yellow–blue chroma; *LCH** : lightness, chroma, hue

Definition of device coordinates similar to coordinates of colour order systems

*lch**: relative lightness, chromaticness, hue

*tch**, *tce**: triangle lightness, chromaticness, hue or elementary hue

*nce**: blackness, chromaticness, elementary hue

Information technology of printers

Measured for CIE "other" illuminant D50

Device system name and coordinates:

Printer system (illuminant D50):

cmv, content of "cyan", "magenta", "yellow"

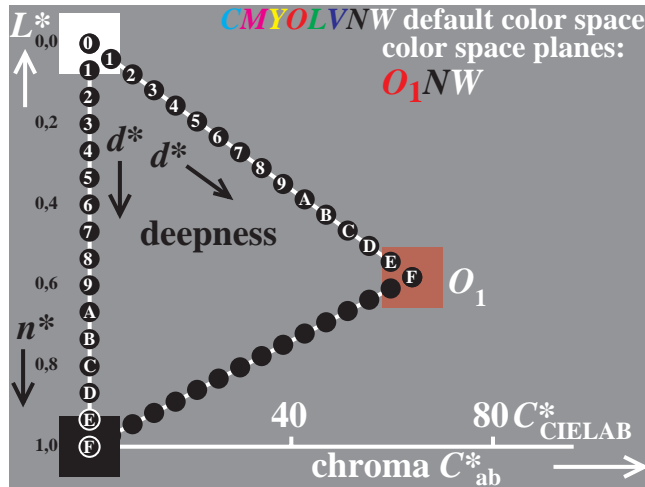
Display system (standard illuminant D65):

rgb/sRGB, content of "red", "green", "blue"

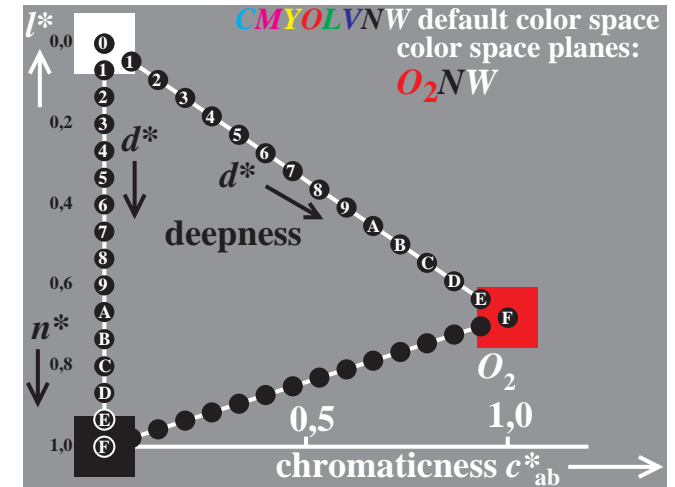
IT colour coordinates confuse the users!

Nearly no connection to colour order systems!

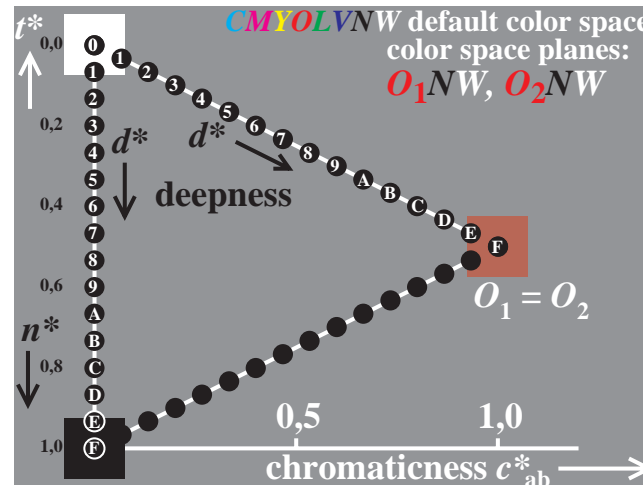
Relative Equidistant Colour Input and Output of 16 steps Colour series



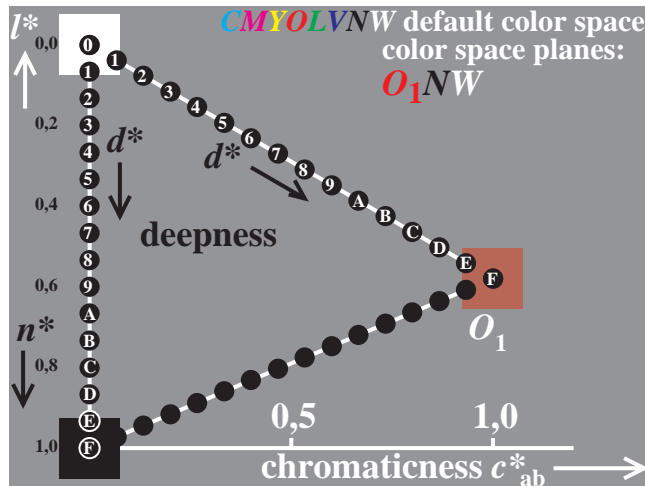
BE090-2N, lightness L^* , chroma C^*_{ab} of O_1



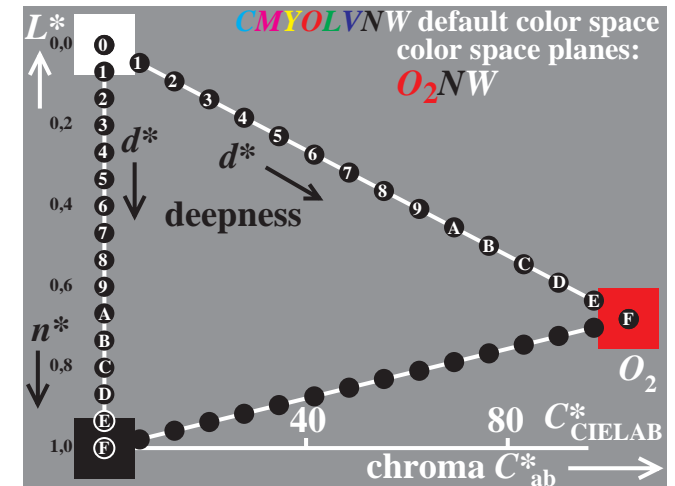
BE090-5N, lightness l^* , chromaticness c^*_{ab}



BE090-4N, lightness t^* , chromaticness c^*_{ab}

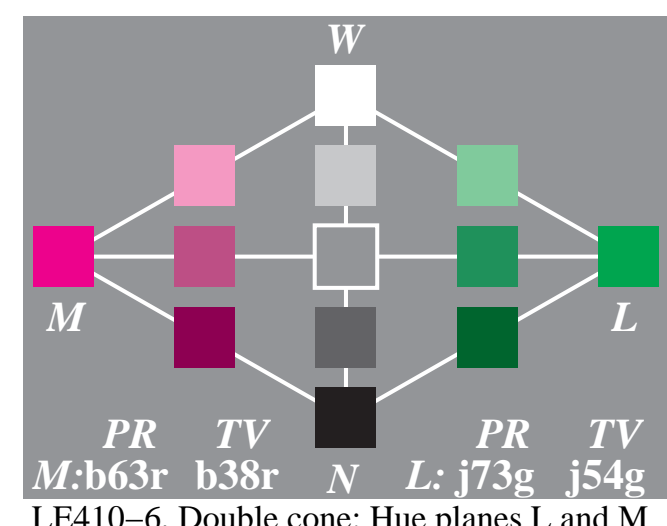
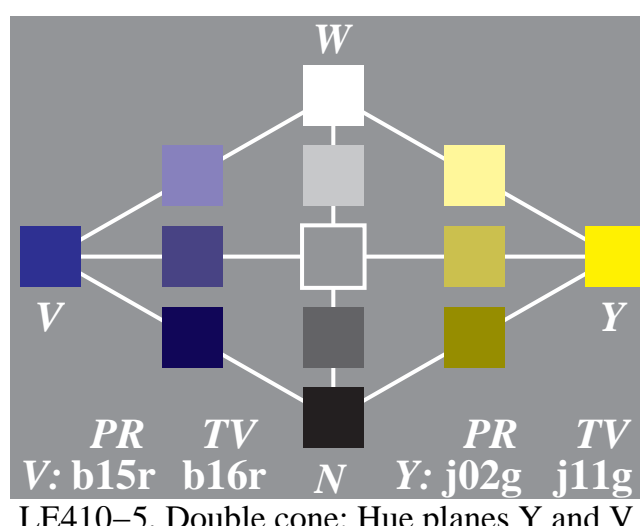
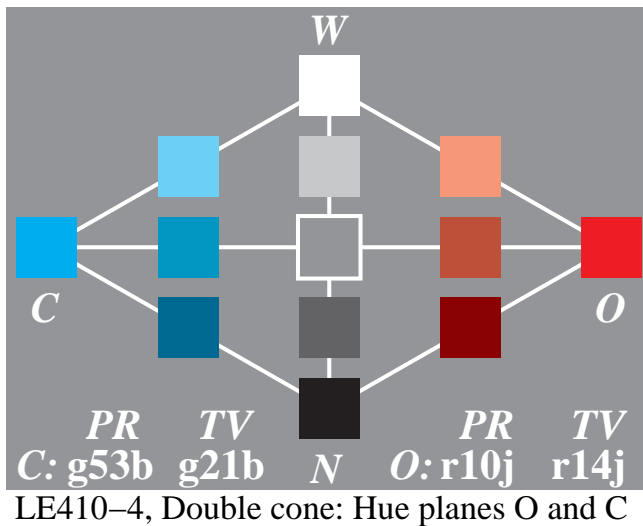
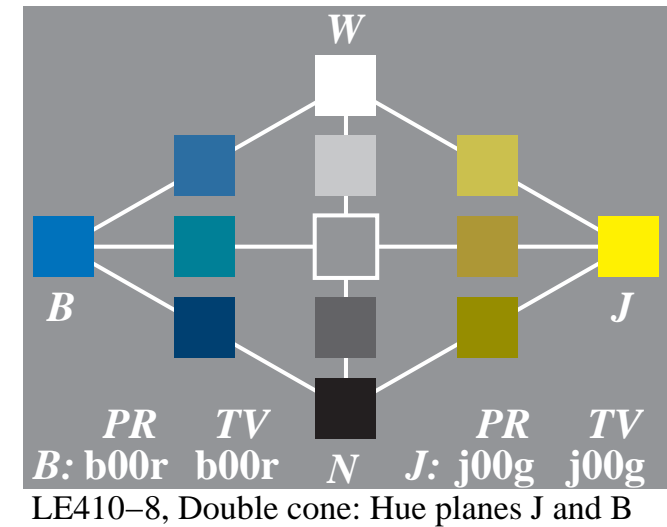
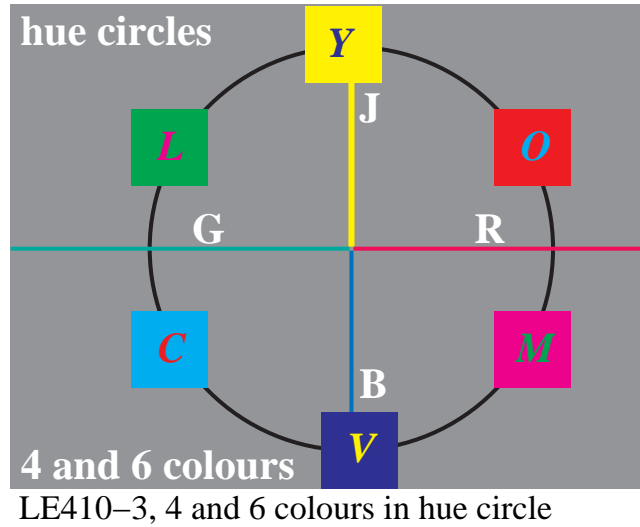
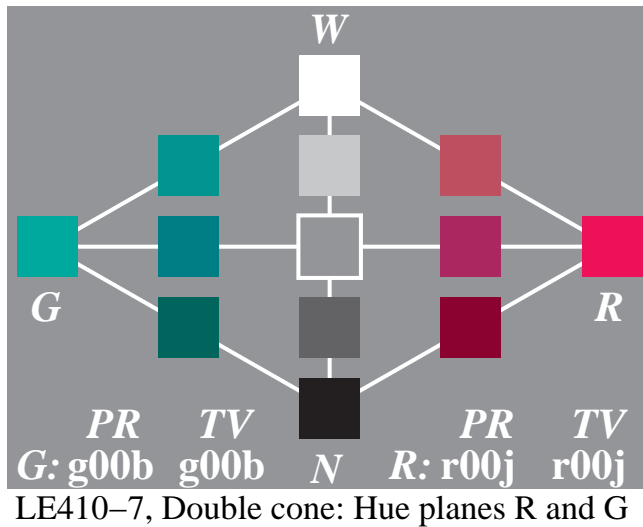


BE090-3N, lightness l^* , chromaticness c^*_{ab}



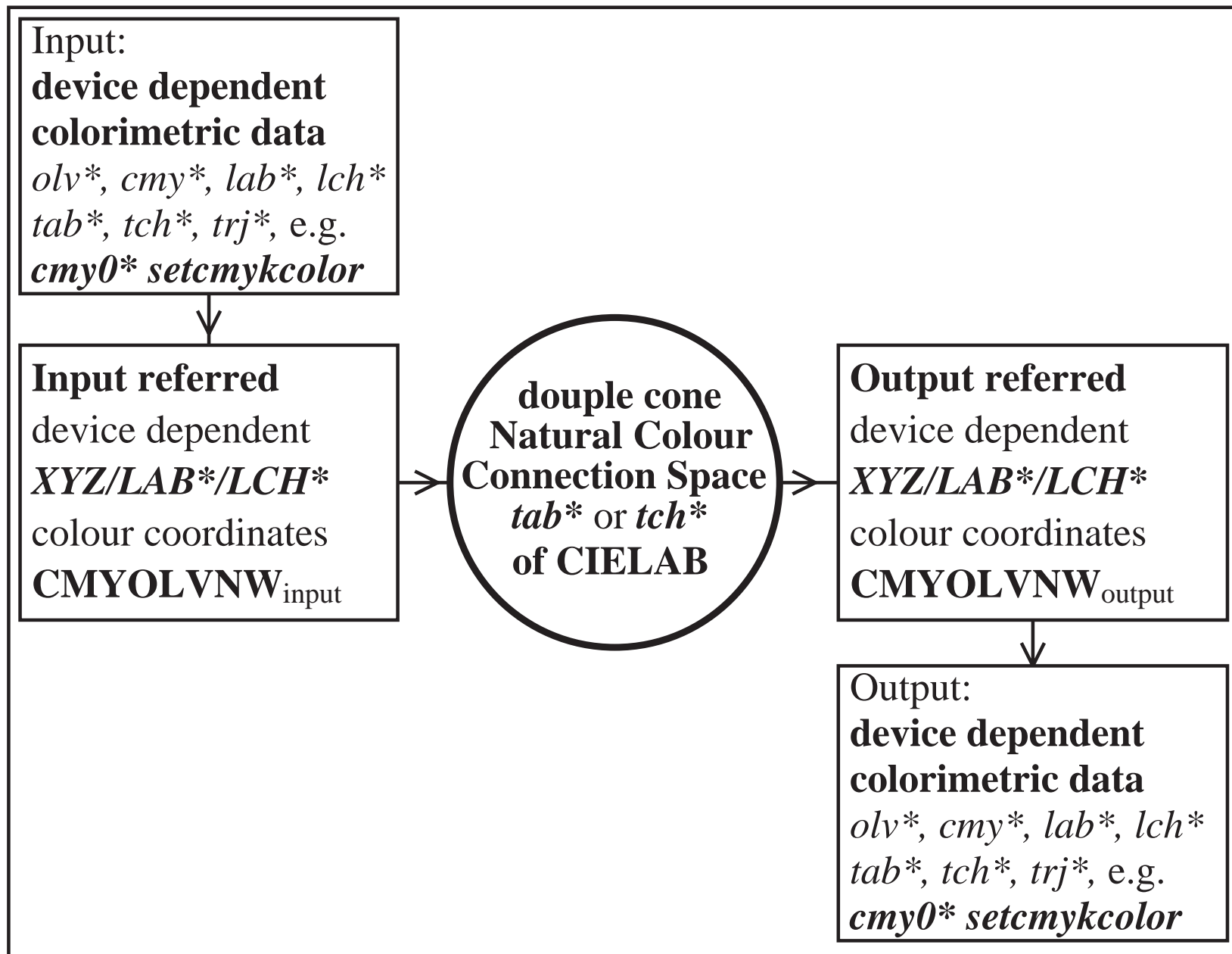
BE090-6N, lightness L^* , chroma C^*_{ab} of O_2

Hue circle and hue planes

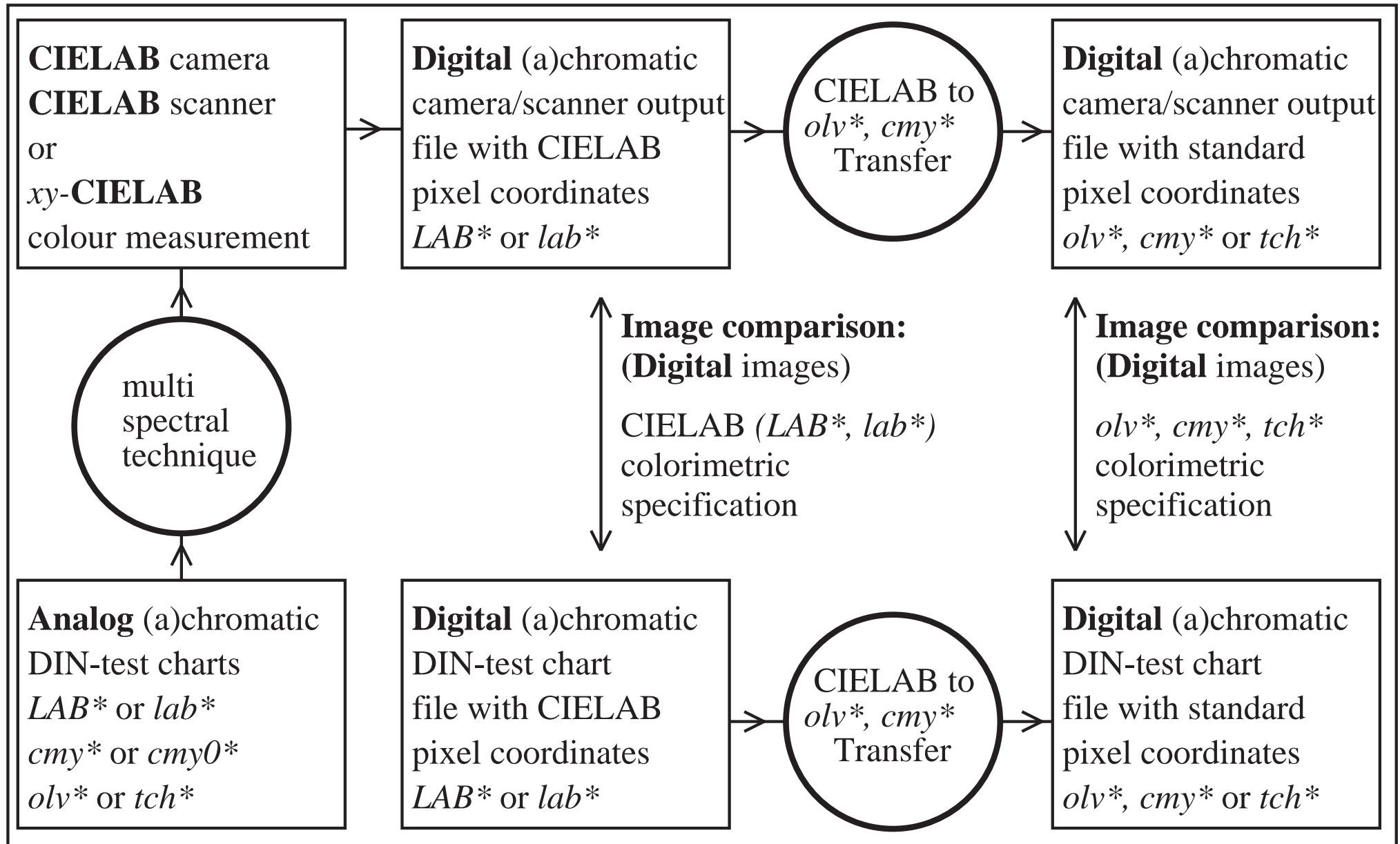


Colour order systems are based on a double cone with a circular basis (Ostwald, NCS). The Natural Colour System (NCS) uses three coordinates “elementary hue, blackness and chromaticness”

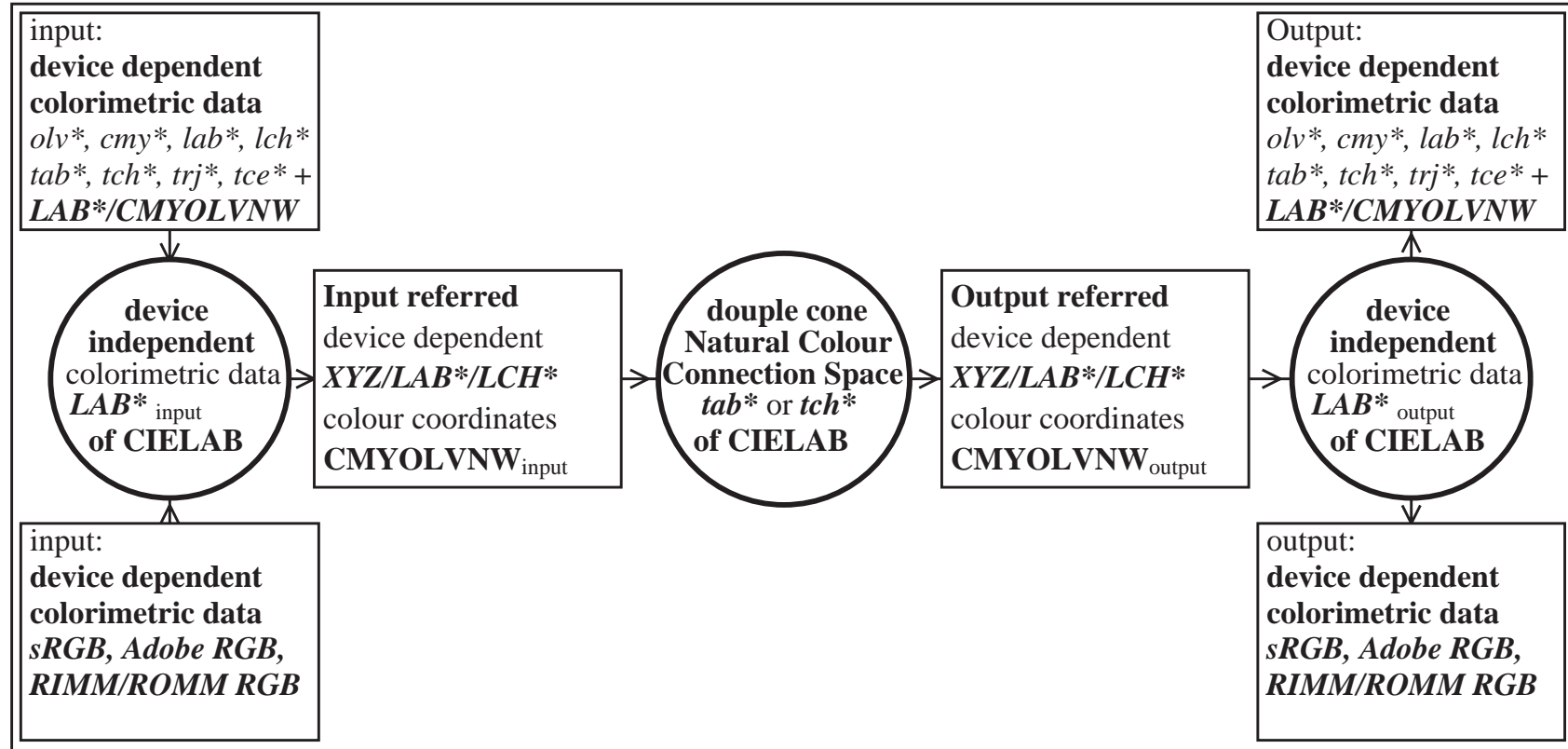
Natural Colour Connection Space (NCCS) between input and output



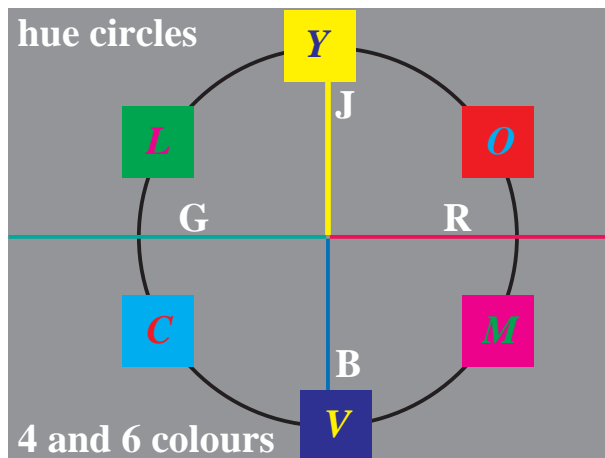
LE450-7, Transfer from device dependent *cmy0** data; output via NCCS with new *cmy0**



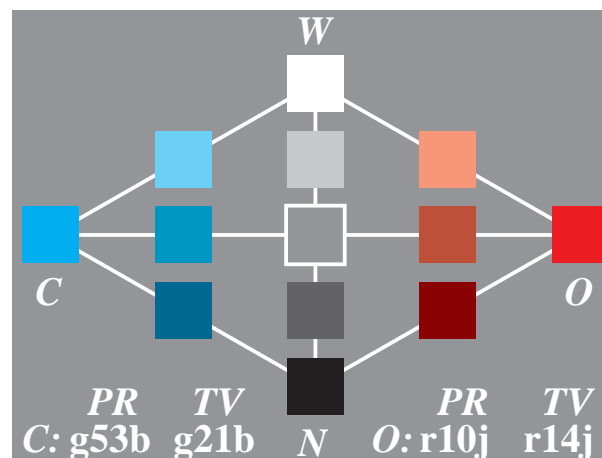
Natural Colour Connection Space (NCCS) for CIELAB input and output data



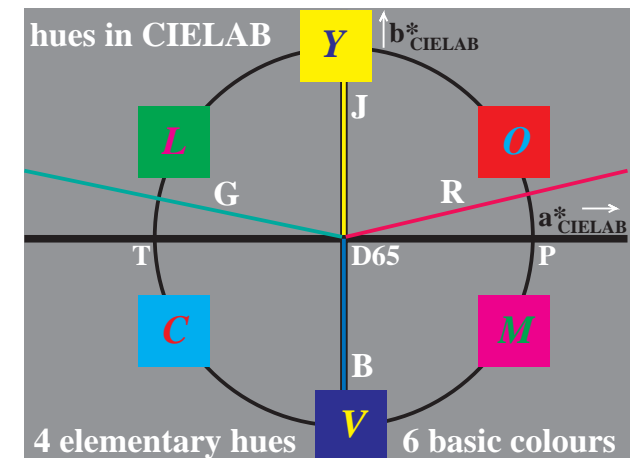
LE450-3, Transfer to device independent LAB*/LCH* data; output via the Natural Colour Connection Space tab*/tch*



LE410-3, 4 and 6 colours in hue circle



LE410-4, Double cone: Hue planes O and C

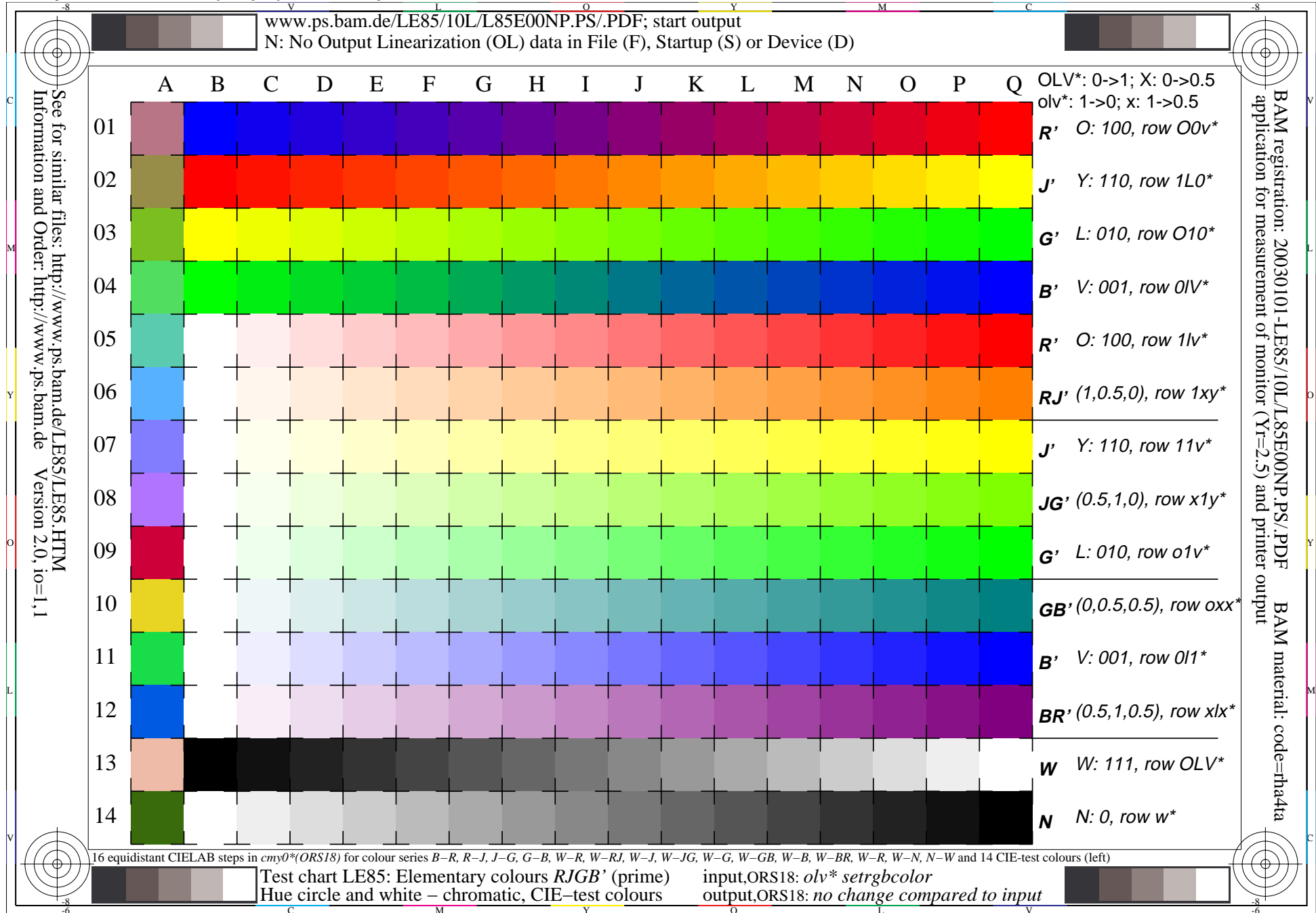


LE410-2, Elementary hues RJGB in CIELAB

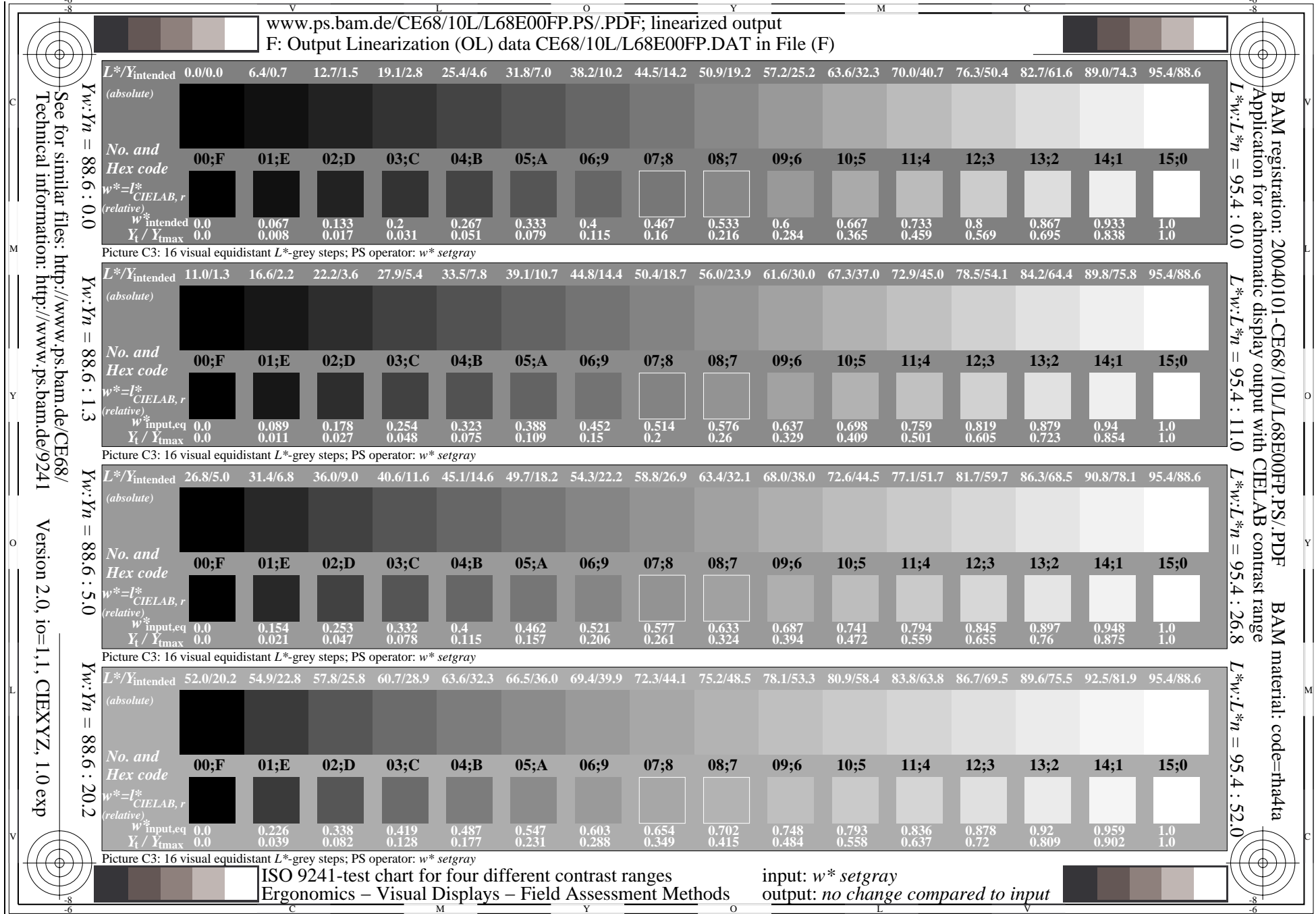
International Symposium Office Equipment, 2004, Nov. 11, Seoul



Elementary hue circle RJGB (simple) and 16 step series White - Chromatic



Equally spaced CIE coordinates of displays, four display reflections





Reproduction properties of the Achromatic Test Chart Output

Test of 16 visual equidistant L*-grey steps acc. to picture A3

Are the steps on the upper row distinguishable?

If No: How many steps can be distinguished?

Yes/No
of the given 16 steps: Steps

Test of the Landolt-rings N-W acc. to picture A4

Is the recognition frequency of the Landolt-rings > 50% (5 of 8 at least)?

background – ring	
0 – 1	Yes/No
7 – 8	Yes/No
E – F	Yes/No
2 – 0	Yes/No
8 – 6	Yes/No
F – D	Yes/No

Test of the line screen under 45° acc. to picture A5

Can equally spaced lines be seen?

Visual testing: for radial diameter from 15 to 60 lpi

Test with a magnifying glass (e.g. 6x):

Yes/No
- from 15 lpi: to lpi

ISO/IEC-test chart no. 1, no display reflection ($Y_r=0$)

www.ps.bam.de/CE65/10L/L65E00FP.PS/.PDF; linearized output
 F: Output Linearization (OL) data CE65/10L/L65E00FP.DAT in File (F)

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

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

7		8	7-8
E		F	E-F
2		0	2-0
8		6	8-6
F		D	F-D

Landolt-rings W-N code: background-ring

Picture C1: Radial gratings (Siemens-stars) N-W, W-N, N-Z and W-Z; PS operator: $w^* \text{ setgray}$

$L^*/Y_i^{\text{intended}}$	0.0/0.0	23.9/4.1	47.7/16.6	71.6/43.0	95.4/88.6	$N_0(\text{min.})$	$W_1(\text{max.})$
(absolute)							
No. and Hex code	00;4	01;3	02;2	03;1	04;0		
$w^* = I^*_{\text{CIELAB}, r}$							
(relative)							
W_i^{intended}	0.0	0.248	0.498	0.749	1.0	$N_0(\text{min.})$	$W_1(\text{max.})$
Y_i / Y_{imax}	0.0	0.046	0.187	0.485	1.0		

Picture C4: Landolt-rings W-N; PS operator: $w^* \text{ setgray}$

	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																

Picture C5: Line raster under 45° (or 135°); PS operator: $w^* \text{ setgray}$

	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																

Picture C6: Line raster under 90° (or 0°); PS operator: $w^* \text{ setgray}$

$L^*/Y_i^{\text{intended}}$	0.0/0.0	6.4/0.7	12.7/1.5	19.1/2.8	25.4/4.6	31.8/7.0	38.2/10.2	44.5/14.2	50.9/19.2	57.2/25.2	63.6/32.3	70.0/40.7	76.3/50.4	82.7/61.6	89.0/74.3	95.4/88.6
(absolute)																
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
$w^* = I^*_{\text{CIELAB}, r}$																
(relative)																
W_i^{intended}	0.0	0.067	0.133	0.2	0.267	0.333	0.4	0.467	0.533	0.6	0.667	0.733	0.8	0.867	0.933	1.0
Y_i / Y_{imax}	0.0	0.008	0.017	0.031	0.051	0.079	0.115	0.16	0.216	0.284	0.365	0.459	0.569	0.695	0.838	1.0

Picture C2: 5 visual equidistant L^* -grey steps + N_0 + W_1 ; PS operator: $w^* \text{ setgray}$

Picture C3: 16 visual equidistant L^* -grey steps; PS operator: $w^* \text{ setgray}$

ISO 9241-test chart for contrast range $Y_w:Y_n = 88.6 : 0.0$
 Ergonomics – Visual Displays – Field Assessment Methods

input: $w^* \text{ setgray}$
 output: no change compared to input

Version 2.0, io=1.1, CIEXYZ, 1.0 exp

BAM registration: 20040101-CE65/10L/L65E00FP.PS/.PDF BAM material: code=rh4ta
 Application for achromatic display output with CIE LAB contrast range $L^*:L^*_n = 95.4 : 0.0$

ISO/IEC-test chart no. 1, display reflection (Yr=20)

See for similar files: <http://www.ps.bam.de/CE65/>
 Technical information: <http://www.ps.bam.de/9241>
 Version 2.0, io=1,1, CIEXYZ, 1.0 exp

www.ps.bam.de/CE65/10L/L65E60FP.PS/.PDF; linearized output
 F: Output Linearization (OL) data CE65/10L/L65E60FP.DAT in File (F)

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

Picture C1: Radial gratings (Siemens-stars) N-W, W-N, N-Z and W-Z; PS operator: w* setgray

background step 0	1 ring step	0-1
Hex code	Hex code	
7	8	7-8
E	F	E-F
2	0	2-0
8	6	8-6
F	D	F-D

Landolt-rings W-N code: background-ring

Picture C4: 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

Picture C5: 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

Picture C6: Line raster under 90° (or 0°); PS operator: w* setgray

BAM registration: 20040101-CE65/10L/L65E60FP.PS/.PDF BAM material: code=rh4ta
 Application for achromatic display output with CIELAB contrast range $L^*:w^*:L^*n = 95.4 : 52.0$

L^*/Y_t intended	52.0/20.2	62.9/31.4	73.7/46.3	84.6/65.2	95.4/88.6	N_0 (min.)	W_I (max.)
(absolute)							
No. and Hex code	00;4	01;3	02;2	03;1	04;0		
$w^*=L^*/CIELAB_r$ (relative)							
$w^*_{input,eq}$	0.0	0.472	0.678	0.847	1.0	N_0 (min.)	W_I (max.)
Y_t/Y_{tmax}	0.0	0.165	0.381	0.657	1.0		

Picture C2: 5 visual equidistant L^* -grey steps + N_0 + W_I ; PS operator: w* setgray

L^*/Y_t intended	52.0/20.2	54.9/22.8	57.8/25.8	60.7/28.9	63.6/32.3	66.5/36.0	69.4/39.9	72.3/44.1	75.2/48.5	78.1/53.3	80.9/58.4	83.8/63.8	86.7/69.5	89.6/75.5	92.5/81.9	95.4/88.6
(absolute)																
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
$w^*=L^*/CIELAB_r$ (relative)																
$w^*_{input,eq}$	0.0	0.226	0.338	0.419	0.487	0.547	0.603	0.654	0.702	0.748	0.793	0.836	0.878	0.92	0.959	1.0
Y_t/Y_{tmax}	0.0	0.039	0.082	0.128	0.177	0.231	0.288	0.349	0.415	0.484	0.558	0.637	0.72	0.809	0.902	1.0

Picture C3: 16 visual equidistant L^* -grey steps; PS operator: w* setgray

ISO 9241-test chart for contrast range $Y_w:Y_n = 88.6 : 20.2$ input: w* setgray
 Ergonomics – Visual Displays – Field Assessment Methods output: no change compared to input


Chromatic ISO/IEC-Test Chart

Information and Order: <http://www.ps.bam.de>
 Image file version 1.9, 20021011-DE96

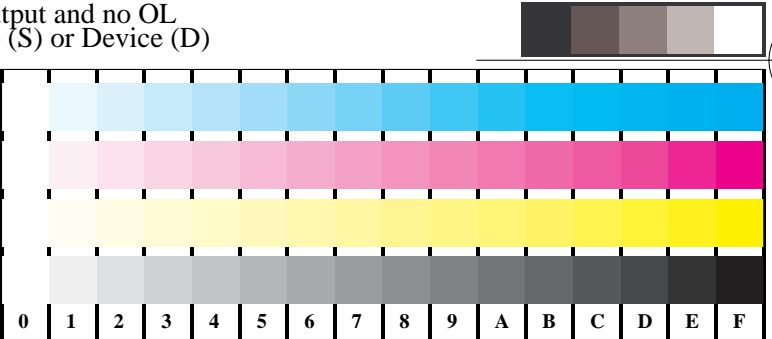
www.ps.bam.de/DE96/10L/L96E02NP.PS/.PDF; start output and no OL
 N: No Output Linearization (OL) data in File (F), Startup (S) or Device (D)

image pixel: **192 x 128**
 384 x 256
 768 x 512
 1536 x 1024
 3072 x 2048

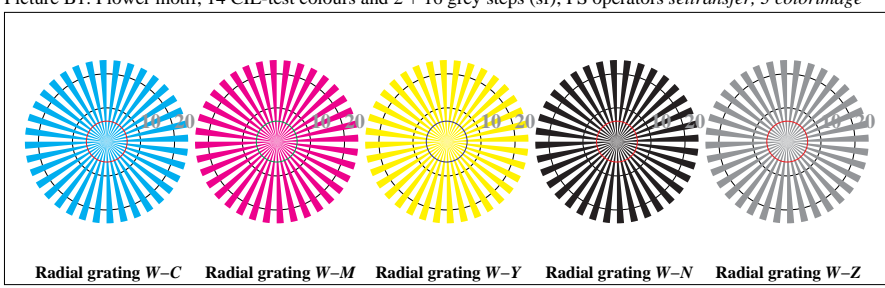
BAM registration: 20021011-DE96/10L/L96E02NP.PS/.PDF
 BAM material: code=rha4ta



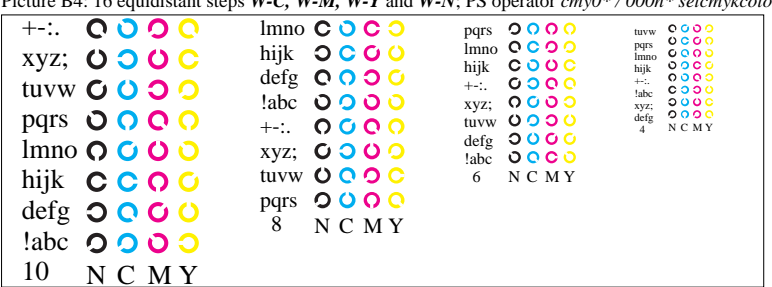
Picture B1: Flower motif, 14 CIE-test colours and 2 + 16 grey steps (sf); PS operators *settransfer*, 3 *colorimage*



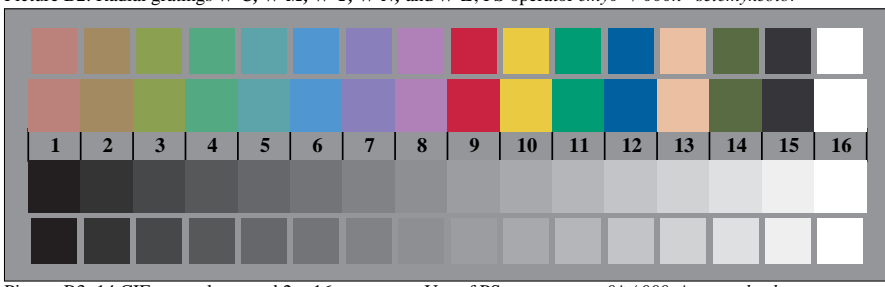
Picture B4: 16 equidistant steps *W-C*, *W-M*, *W-Y* and *W-N*; PS operator *cmy0*/000n* setcmykcolor*



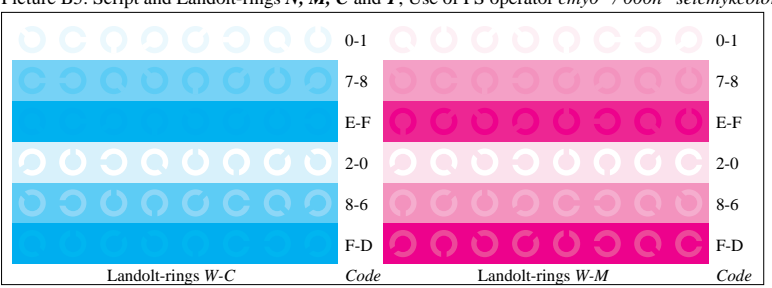
Picture B2: Radial gratings *W-C*, *W-M*, *W-Y*, *W-N*, and *W-Z*; PS operator *cmy0*/000n* setcmykcolor*




Picture B5: Script and Landolt-rings *N*, *M*, *C* and *Y*; Use of PS operator *cmy0*/000n* setcmykcolor*



Picture B3: 14 CIE-test colours and 2 + 16 grey steps; Use of PS operator *cmy0*/000n* setcmykcolor*



Picture B6: Landolt-rings *W-C* and *W-M*; Use of PS operator *cmy0*/000n* setcmykcolor*



Picture B7: Landolt-rings *W-Y* and *W-N*; Use of PS operator *cmy0*/000n* setcmykcolor*

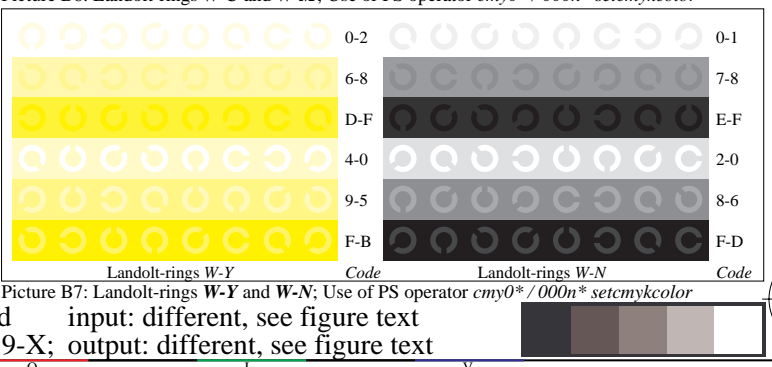
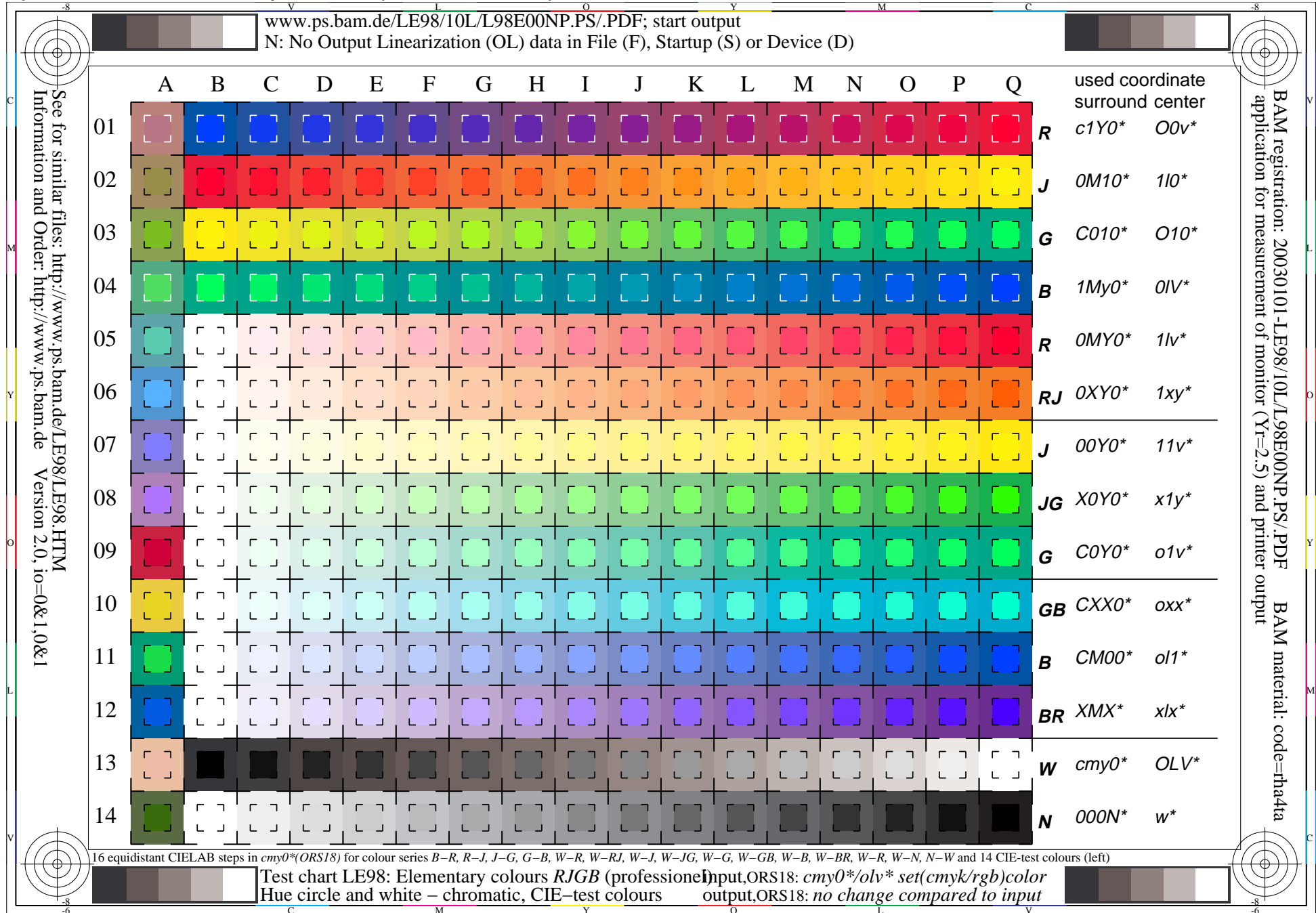


Fig. B1 to B7 of ISO/IEC-test chart 2; DIS ISO/IEC 19839-X; input: different, see figure text; output: different, see figure text

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16 step colour series defined in *cmyn** and *olv** (no MTL code used)



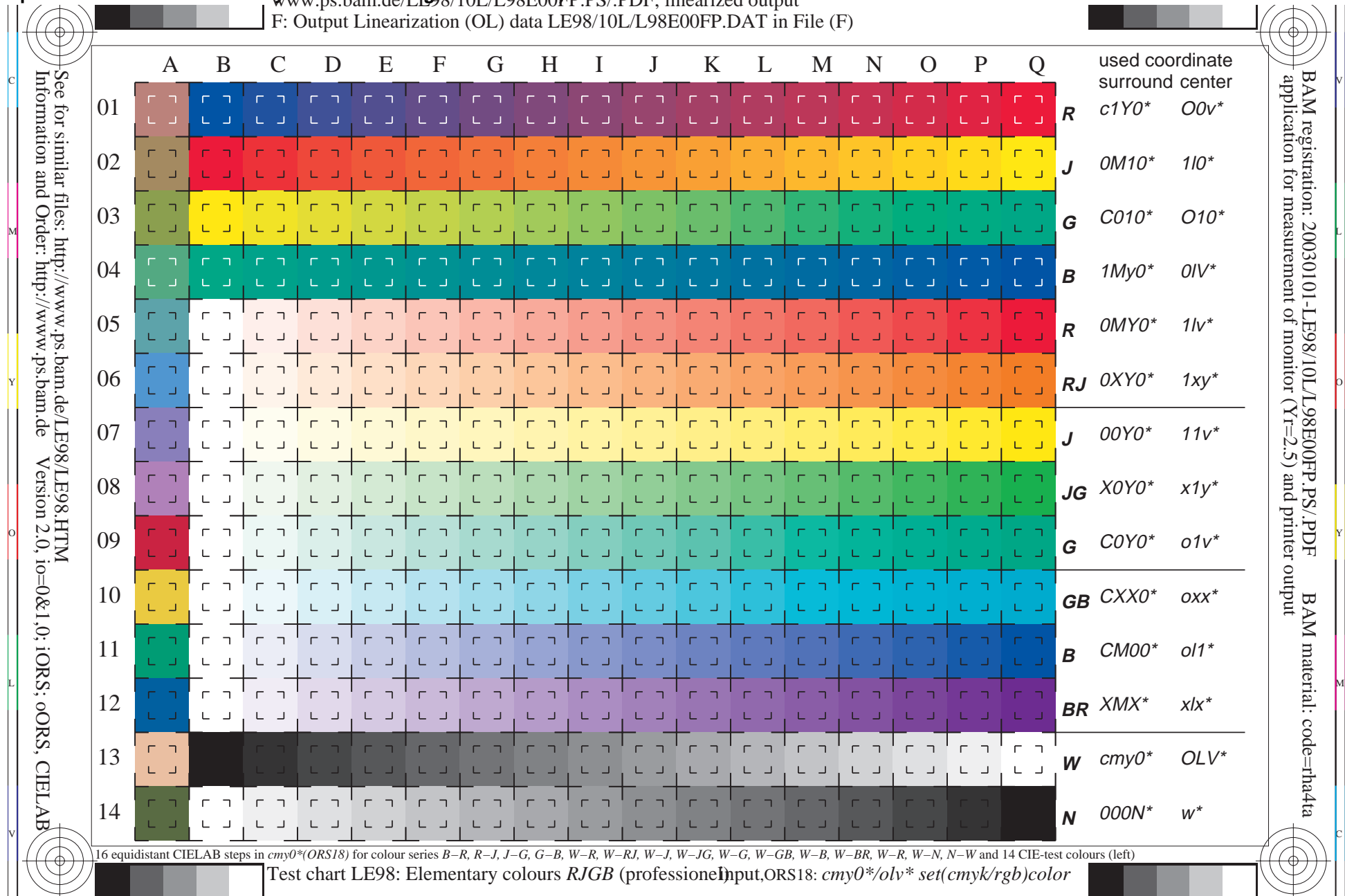
International Symposium Office Equipment, 2004, Nov. 11, Seoul



16 step colour series defined in $cm\dot{y}n^*$ and $ol\dot{v}^*$ using the MTL code)

www.ps.bam.de/LE98/10L/L98E00FP.PS/.PDF; linearized output

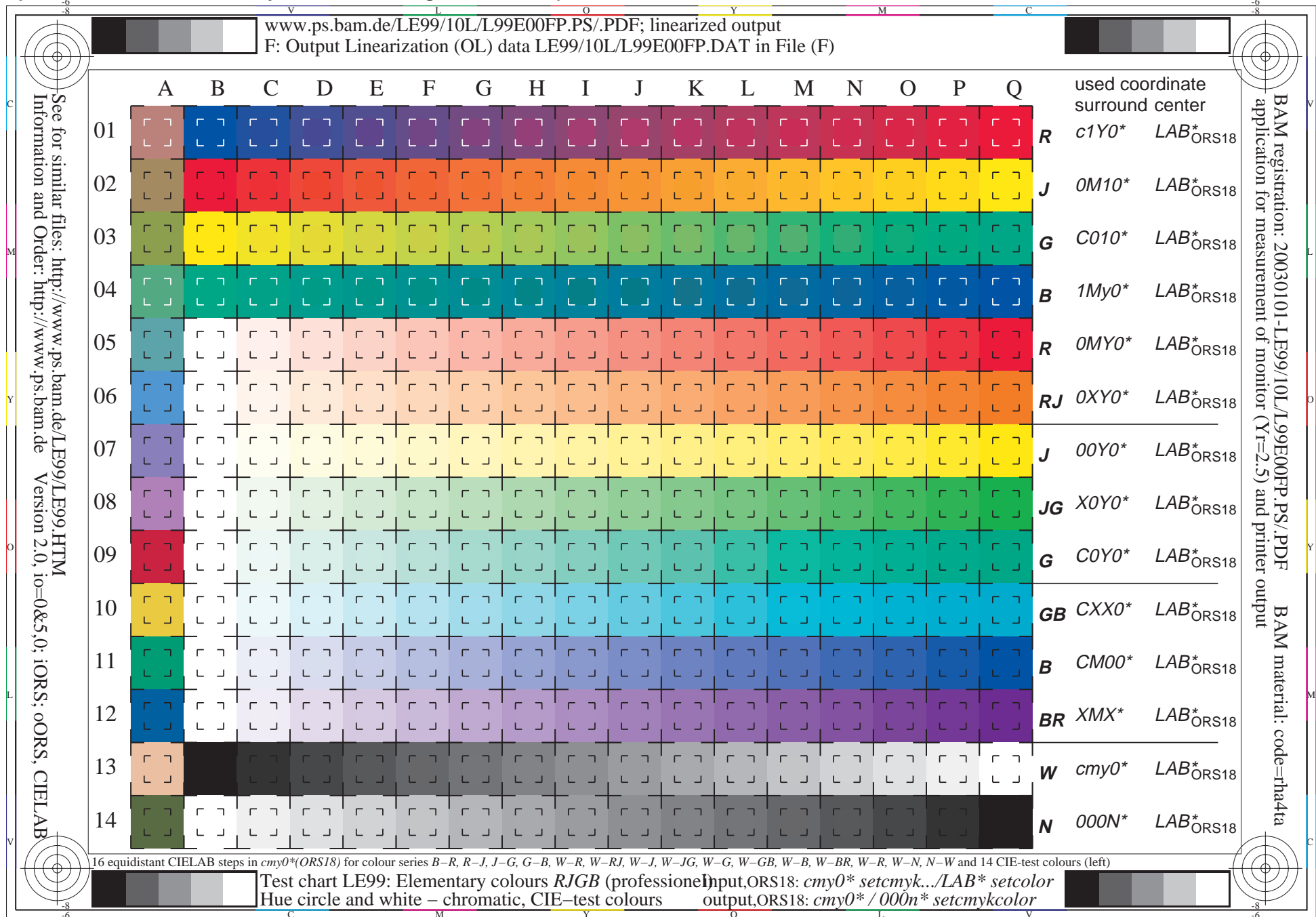
F: Output Linearization (OL) data LE98/10L/L98E00FP.DAT in File (F)



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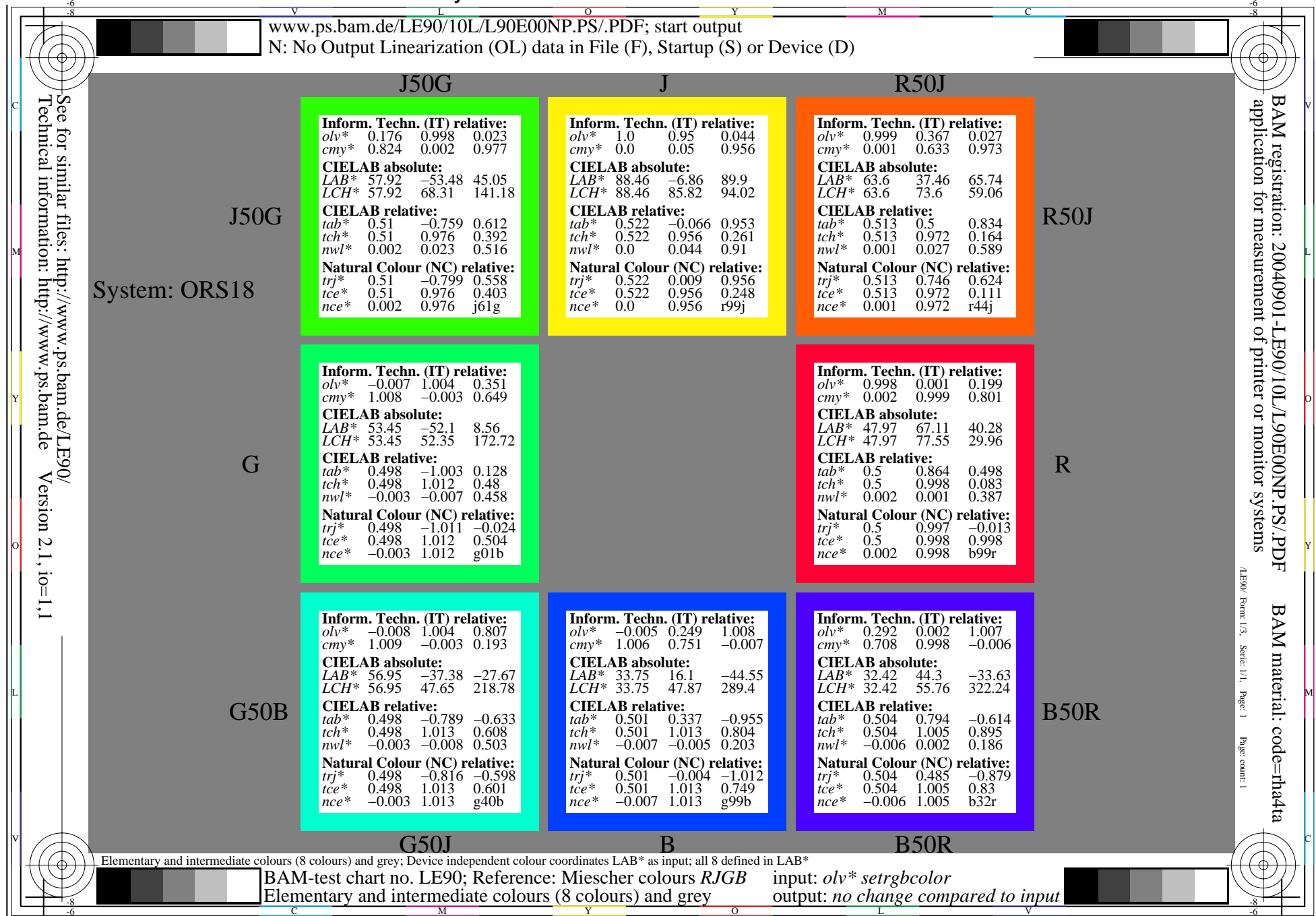
16 step colour series defined in *cmyn** and *LAB** using the MTL code)c



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Alternative colorimetric colour coordinates of elementary hue colour



Summary

- **The Standards ISO/IEC 15775, ISO/IEC TR 19797 and DTR 24705 define ISO/IEC-test charts and eight basic colours in CIELAB**
- **The 8 basic colours form a double cone with a hexagon as basis. A colour is transferred between input and output via the double cone: Natural Colour Connection Space (NCCS, circular basis)
Advantage: Allows maximum detail recognition for any output**
- **The NCCS is used for the display output of 8 different display reflections at work places, for example data projectors.**
- **The NCCS is used for output of device independent elementary colours *RJGB* and for a link between IT and colour order systems**
- **The NCCS has been used for Device Link Colour Management (DLCM) which maintains the hue, the relative chroma and the relative CIELAB differences (maximum recognition of the output).**