Improved visual and material efficiency for colour output in image technology by colorimetric methods

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Overview

Introduction

- ISO/IEC-test charts with 16 step colour series
- Colour circle, colour double cone and hexagon
- Goal of Colorimetric Image Technology (CIT)
- Linear mixture of colour F in CIELAB hexagon
- Standard 16 step colour series for ORS18 and TLS00
- Device dependent relative CIELAB space equations
- Reference offset and light dependent monitor space
- Visual efficiency of colour monitor output
- Colour triangle for chromatic and black generation
- 12 coordinates of colorimetric image technology
- Material efficiency of colour printer output

Introduction

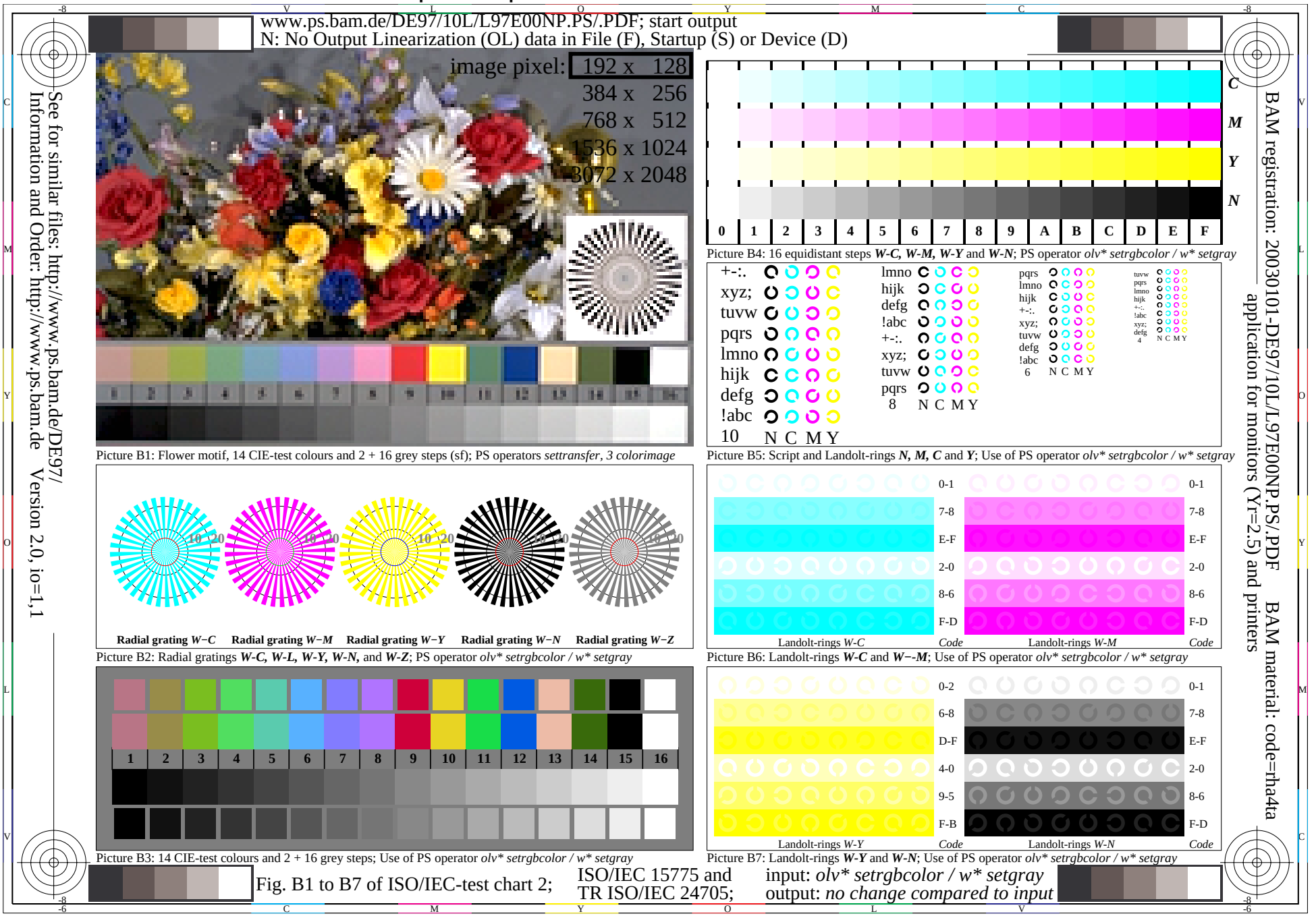
– Different ISO/IEC standards and technical reports define analog and digital ISO/IEC-test charts for the different applications colour copiers, printers, scanners, monitors and projection screens.

–The ISO/IEC-test charts include 16 step colour scales which are visually equally spaced and show equal distances in the CIELAB colour space

– On any colour output device high visual efficiency is reached if the 16 steps appear equally spaced.

– Then the ISO/IEC-Landolt-rings are recognized in the shadow, the mean and the high light areas.

Figure 1: ISO/IES-test chart for the test of monitor or printer output



Introduction continued

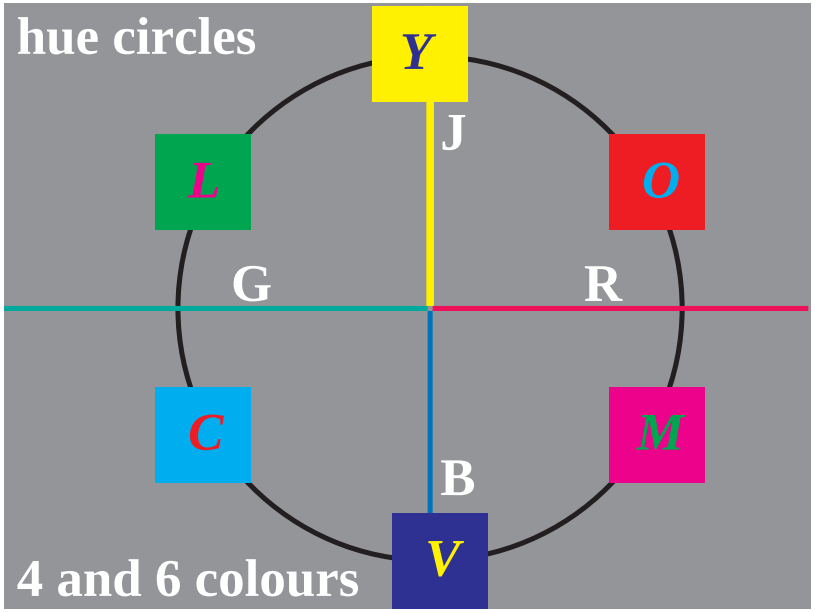
– The colour monitor output reaches high efficiency if the 16 steps are recognized and equally spaced.

– Equal monitor spacing often is destroyed with the illumination at the office work place and a (large) correction is needed

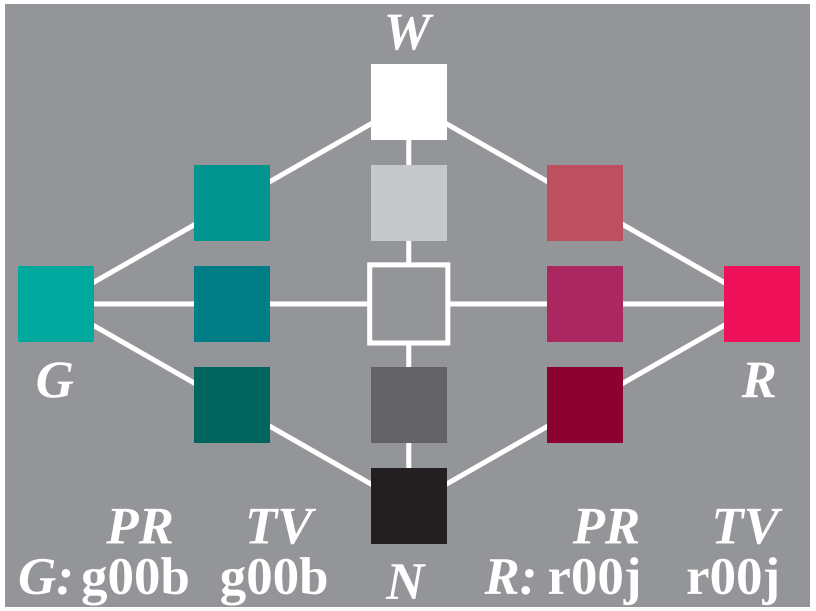
– The colour printer output reaches high efficiency if the output uses as much as possible black ink.

–The material efficiency is low if the grey colours are printed by three chromatic colours on top of each other. In this case the cost per page increase by up to a factor 9.

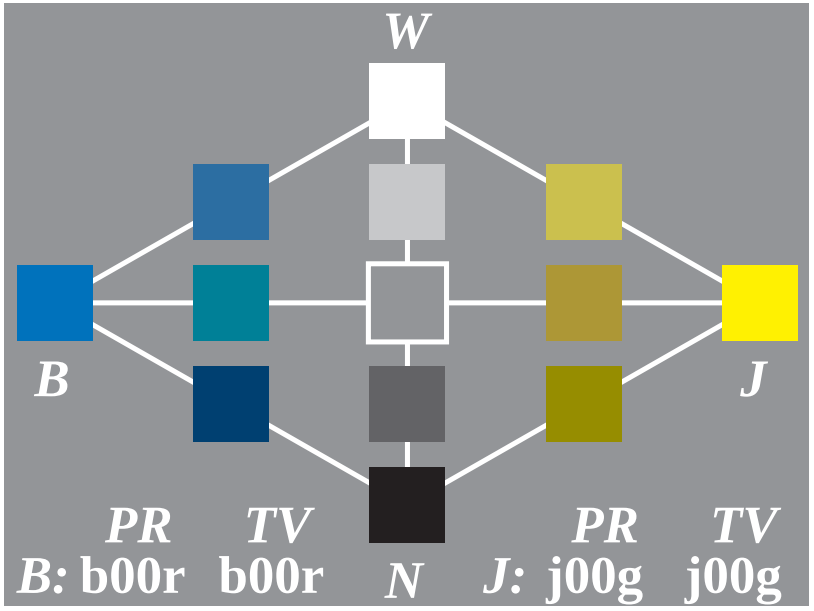
Figure 2: Colour Circle, Colour Double Cone and Colour Hexagon



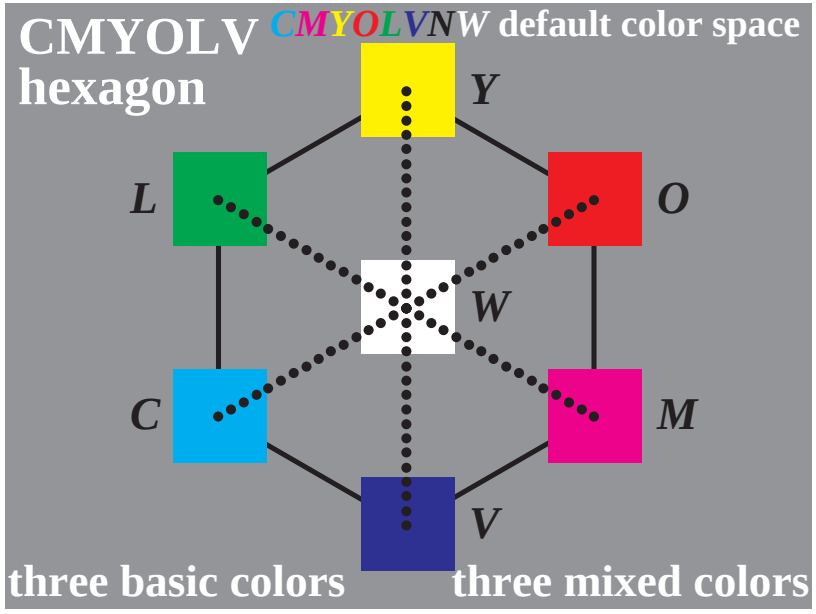
LE410−3, 4 and 6 colours in hue circle



LE410−7, Double cone: Hue planes R and G



LE410−8, Double cone: Hue planes J and B



LE410−1, 16 step colours in regular hexagon

Figure 3: Colour order Systems and Colorimetric Image Technology (CIT)

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 Colour System (CIELAB):
LCH*, lightness, chroma, hue

Munsell Colour System:
VCH*, lightness (Value), Chroma, Hue

Natural Colour System (NCS):
nce*: blackness, chromaticness, elementary hue

Information technology of printers
Measured for CIE illuminants D65 or D50

Device system name and coordinates:

Printer system (illuminant D65 or D50):
cmy, 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!

New: Application connection by coordinates *olv*, cmy*, nce*, ...* and 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

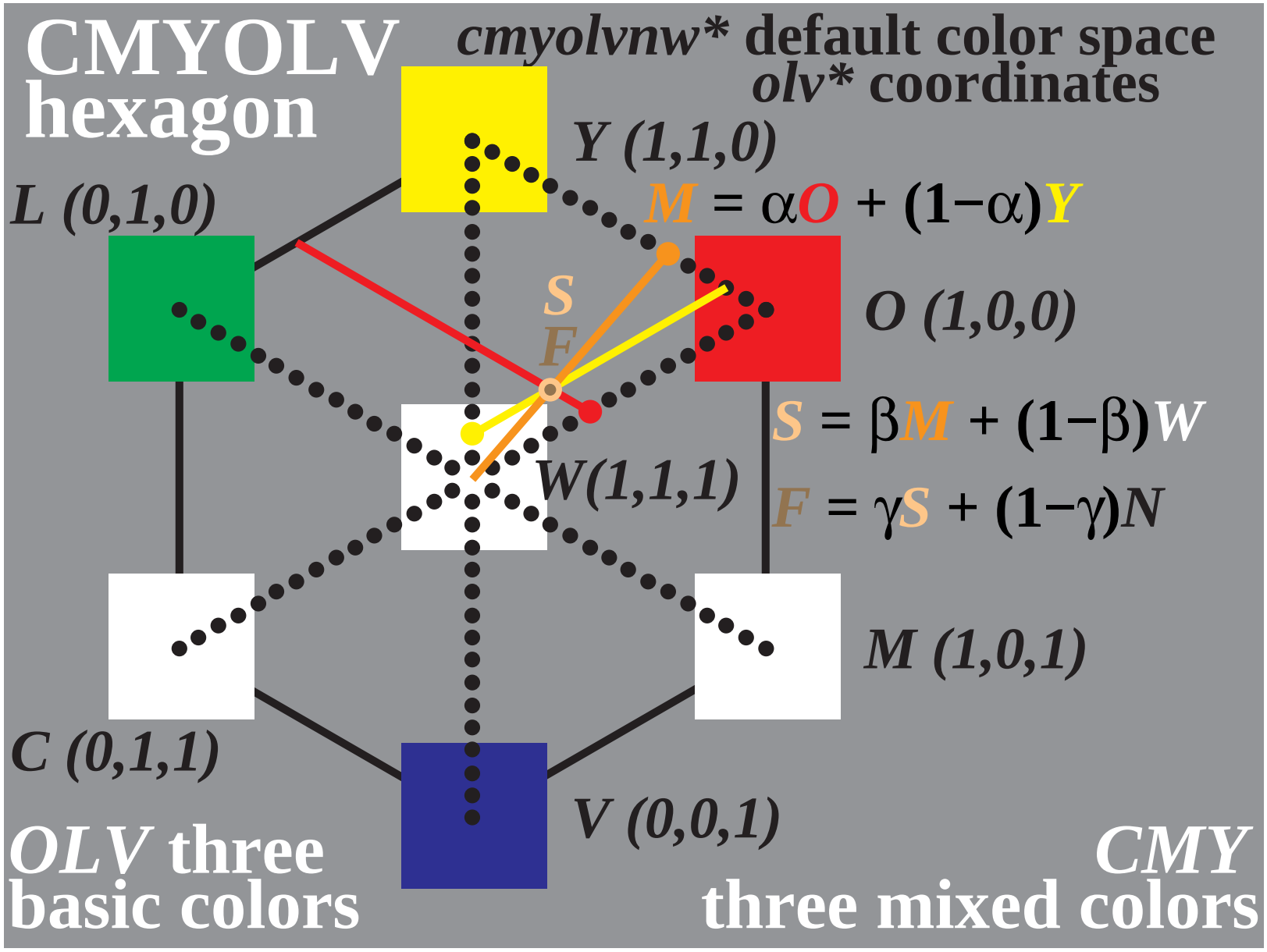
lch*: relative lightness, chromaticness, hue

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

nce*: blackness, chromaticness, elementary hue

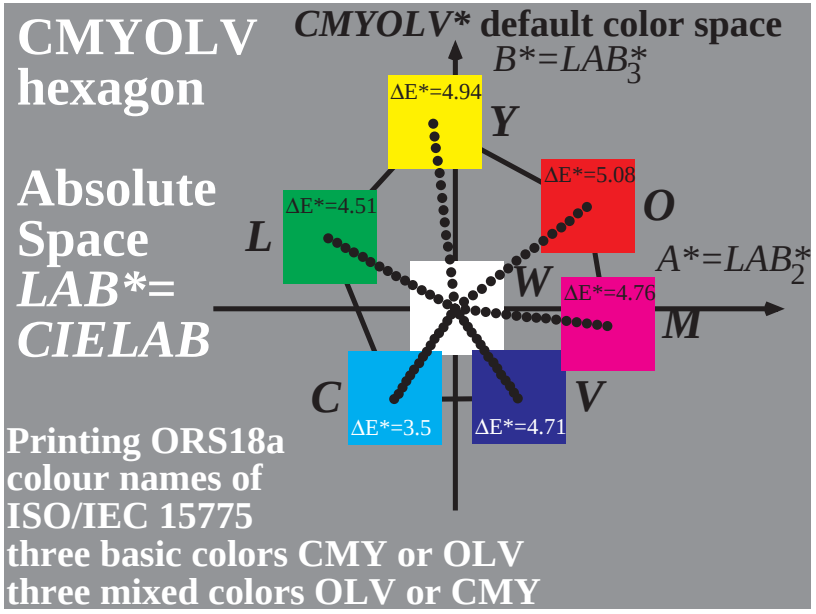
LE430−3, Application connection with coordinates *olv*, cmy*, tch*, tce*, nce*, ...* and linear relationship to *LAB**

Figure 4: Components α, β, χ of colour F mixed by 4 colours O,Y,N,W in sector O-Y

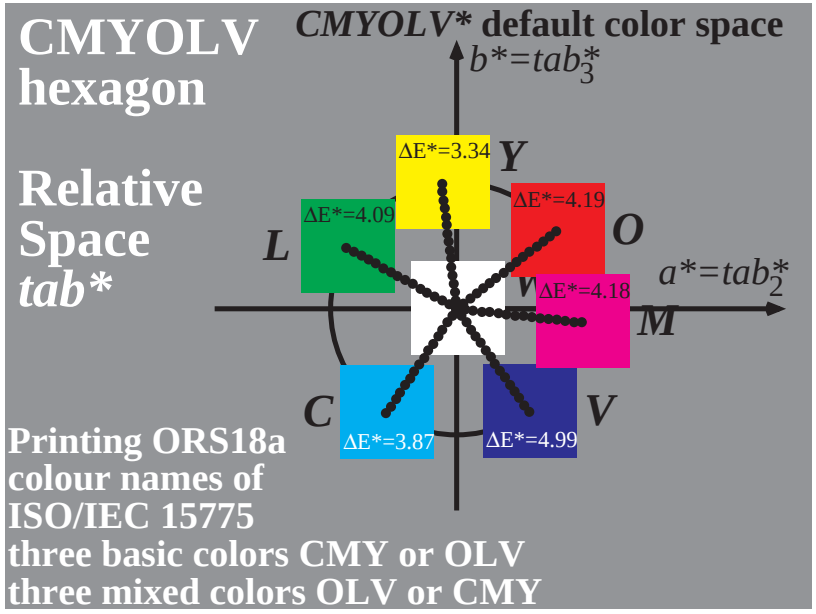


ME310−1, Colorimetric linear hexagon mixture α, β, γ

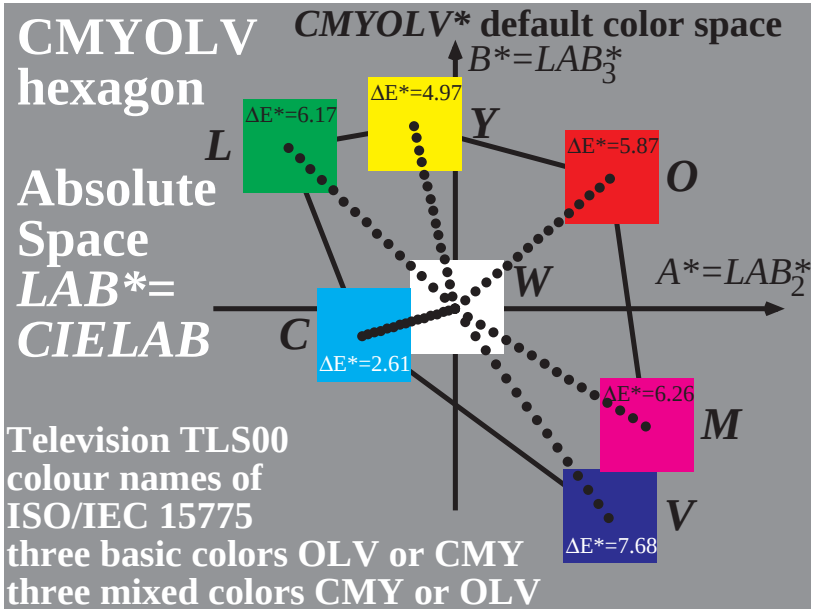
Figure 5: Colour coordinates *LAB and *lab** of printing ORS18a and television TLS00**



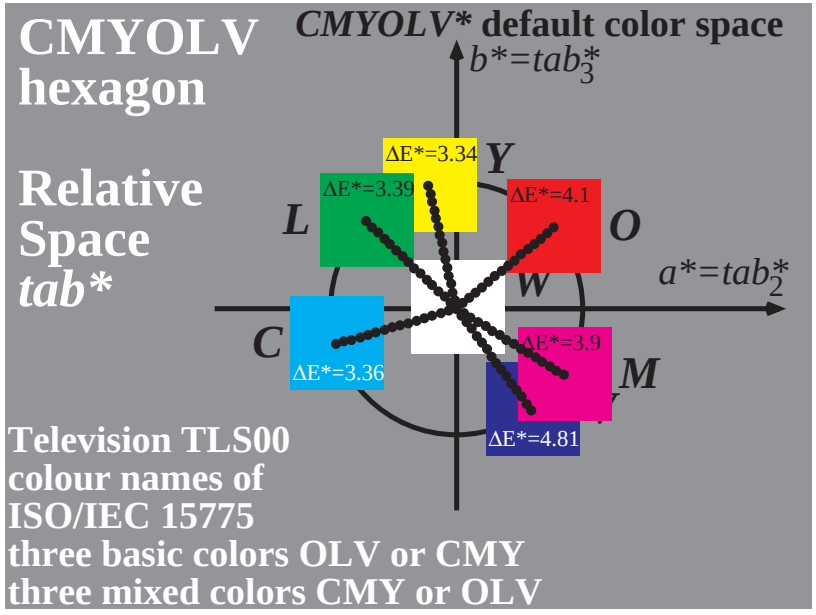
BE370−4, ORS18a in hue plane *AB** of *LAB**



BE380−4, ORS18a in hue plane *ab** of *tab**



BE390−1, TLS00 in plane *AB** of *LAB**



BE381−1, TLS00 in hue plane *ab** of *tab**

Figure 6: Calculation of device dependent relative CIELAB colour coordinates

Connection equations between the NCCS and the CIELAB space

For the calculations lightness L*, chroma C*ab and hue H* of CIELAB are used.

Within a hue triangle (CIELAB hue angle *H** = const.) there is the classical Ostwald equation: relative blackness + relative chromaticness + relative whiteness equals 1

or $\boldsymbol{n^*} + \boldsymbol{c^*} + \boldsymbol{w^*} = 1 \qquad (0 \le \boldsymbol{n^*, c^*, w^*} \le 1)$ (1)

A hue triangle in the CIELAB space is defined by the CIELAB coordinates of the given colour (F), the colours Black (N), White (W) and the colour of maximum chroma (M). For the colour F the **relative** coordinates chromaticness ***c**** , lightness ***l**** , triangle lightness ***t**** , whiteness ***w**** and blackness ***n**** may be calculated in the following sequence of the equations (2) to (6).

$$\boldsymbol{c^*}\,(F) = C^*ab\,(F) / C^*ab\,(M) \quad (2)$$

$$\boldsymbol{l^*}\,(F) = [\,L^*\,(F) - L^*\,(N)\,] / [\,L^*\,(W) - L^*\,(N)\,] \quad (3)$$

$$\boldsymbol{t^*}\,(F) = \boldsymbol{l^*}\,(F) - \boldsymbol{c^*}\,\{\,[\,L^*\,(M) - L^*\,(N)\,] / [\,L^*\,(W) - L^*\,(N)\,] - 0.5\,\} \quad (4)$$

$$\boldsymbol{w^*}\,(F) = \boldsymbol{t^*}\,(F) - 0.5\,\boldsymbol{c^*}\,(F) \quad (5)$$

$$\boldsymbol{n^*}\,(F) = 1 - \boldsymbol{c^*}\,(F) - \boldsymbol{w^*}\,(F) \quad (6)$$

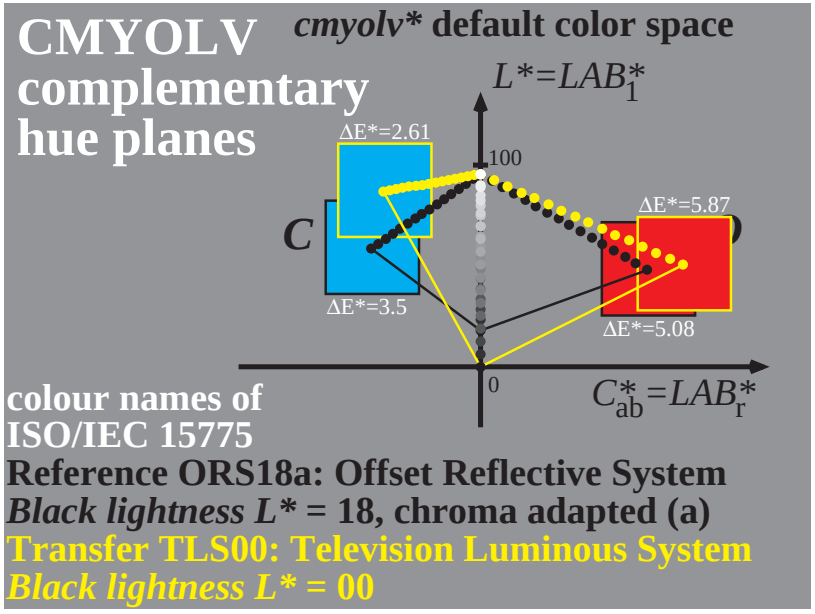
The coordinates of the new relative device dependent space NCCS (small letters) are given in **bold** and *italics* and the CIELAB coordinates (capital letters) are given only in *italics* for easy identification.The coordinates are completed by the relative hue ($0 \le \boldsymbol{h^*} \le 1$) and two cartesian components $-1 \le \boldsymbol{a^*, b^*} \le 1$

$$\boldsymbol{h^*}\,(F) = H^*\,(F) / 360 \quad (7)$$

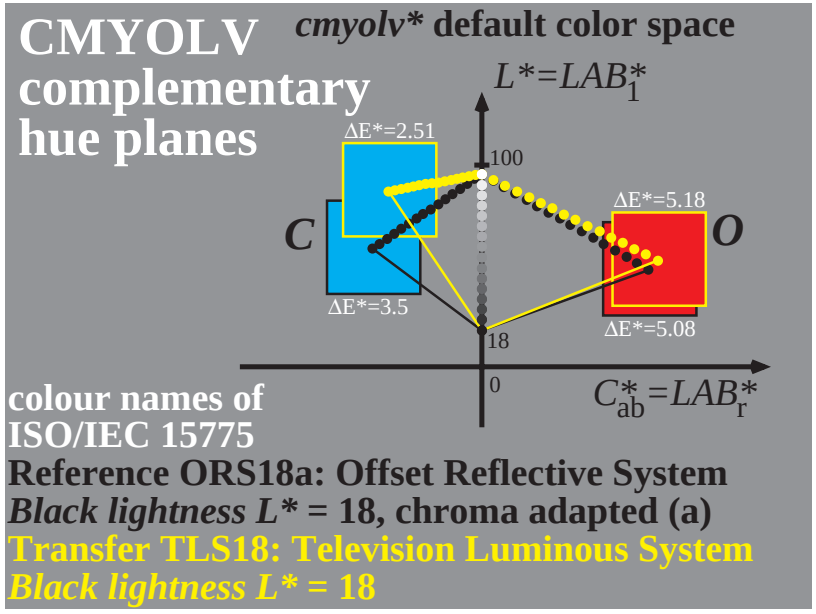
$$\boldsymbol{a^*}\,(F) = \boldsymbol{c^*}\,(F)\,\cos\,(H^*\,(F)) \quad (8)$$

$$\boldsymbol{b^*}\,(F) = \boldsymbol{c^*}\,(F)\,\sin\,(H^*\,(F)) \quad (9)$$

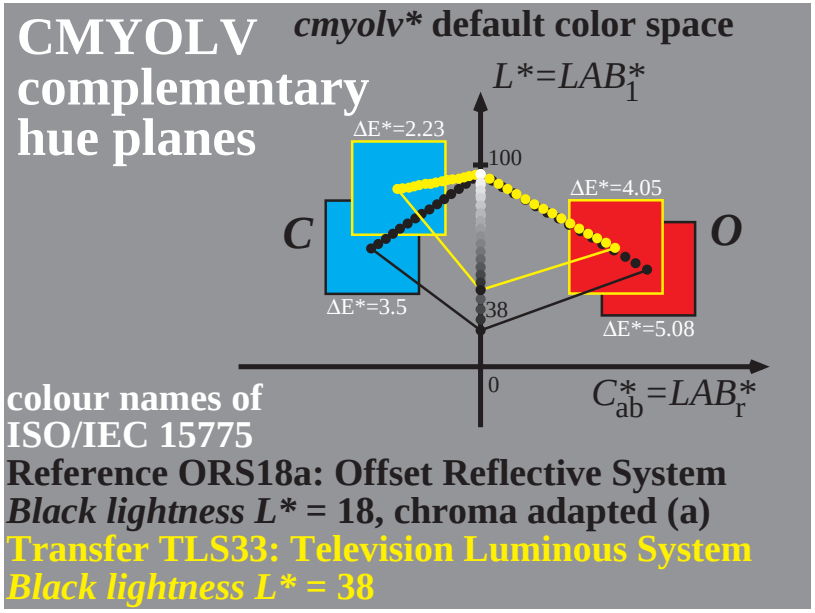
Figure 7: Reference offset colours and change of monitor colours by room light



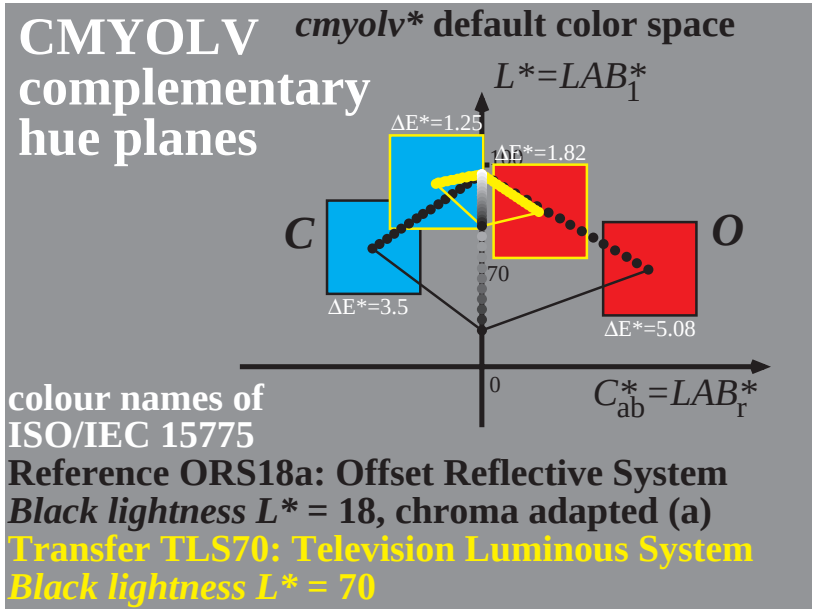
BE340−1, ORS18a − TLS00 in hue plane $O-C$



BE340−2, ORS18a − TLS18 in hue plane $O-C$

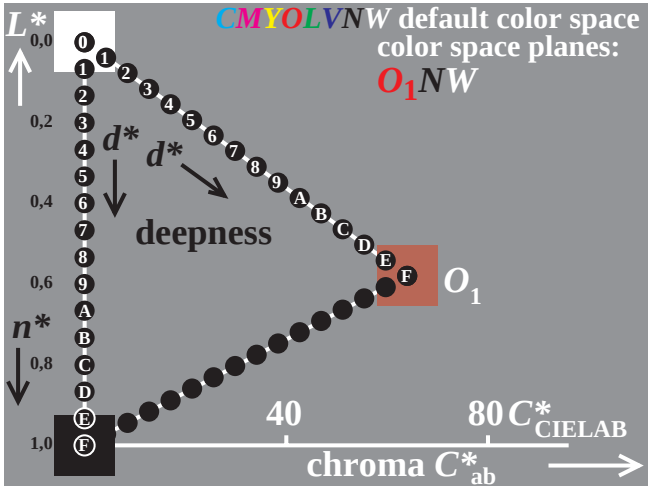


BE340−3, ORS18a − TLS33 in hue plane $O-C$

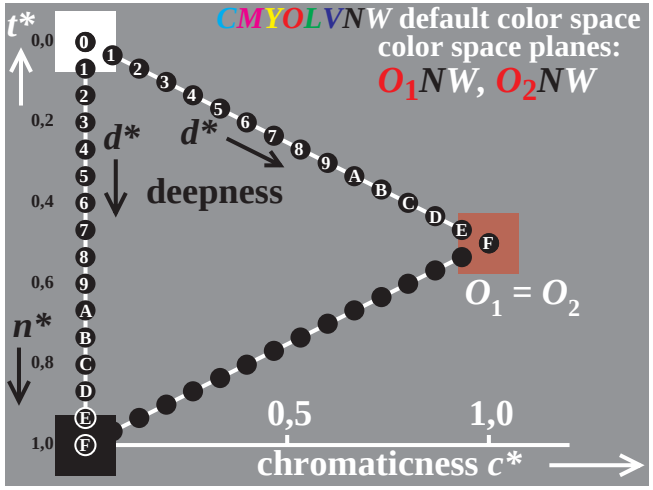


BE340−4, ORS18a − TLS70 in hue plane $O-C$

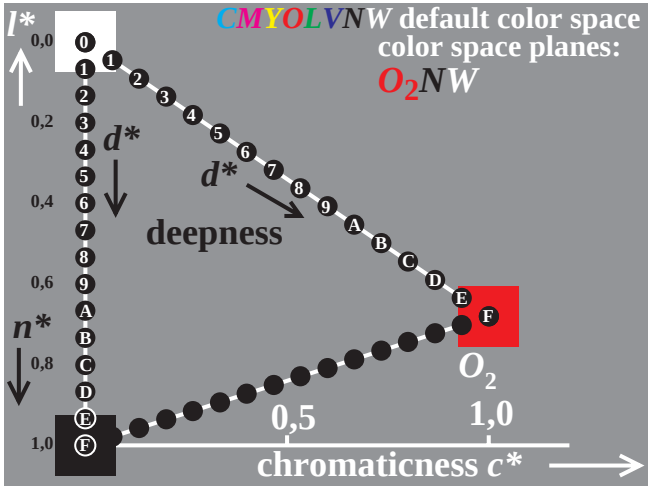
Figure 8: 16 steps from Input to output via NCCS



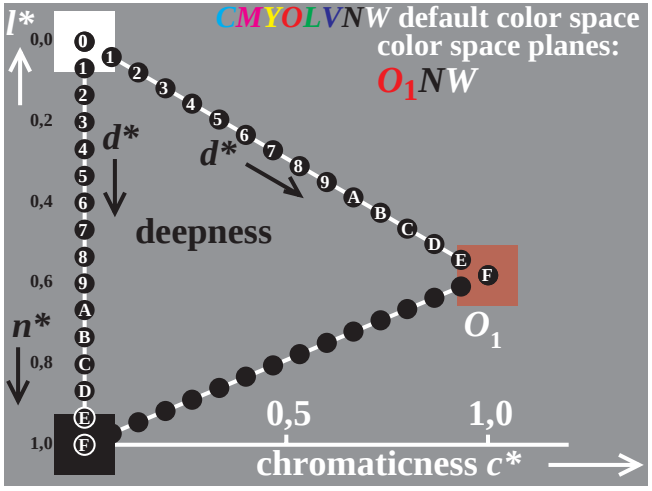
BE090−2, lightness L^*, chroma C^*_{ab} of O1



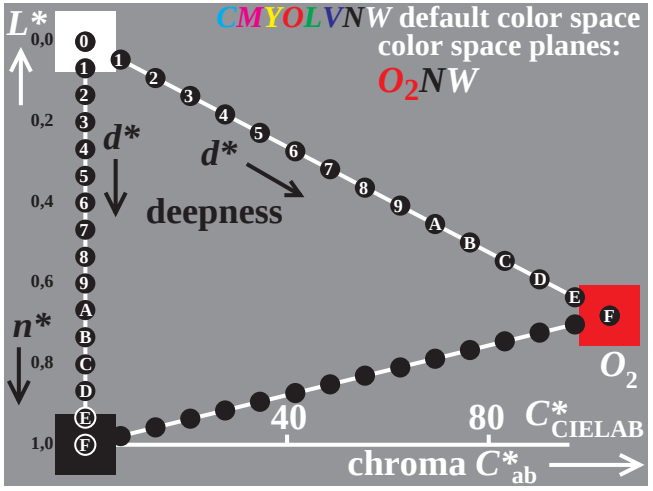
BE090−4, lightness t^*, chromaticness c^*



BE090−5, lightness l^*, chromaticness c^*

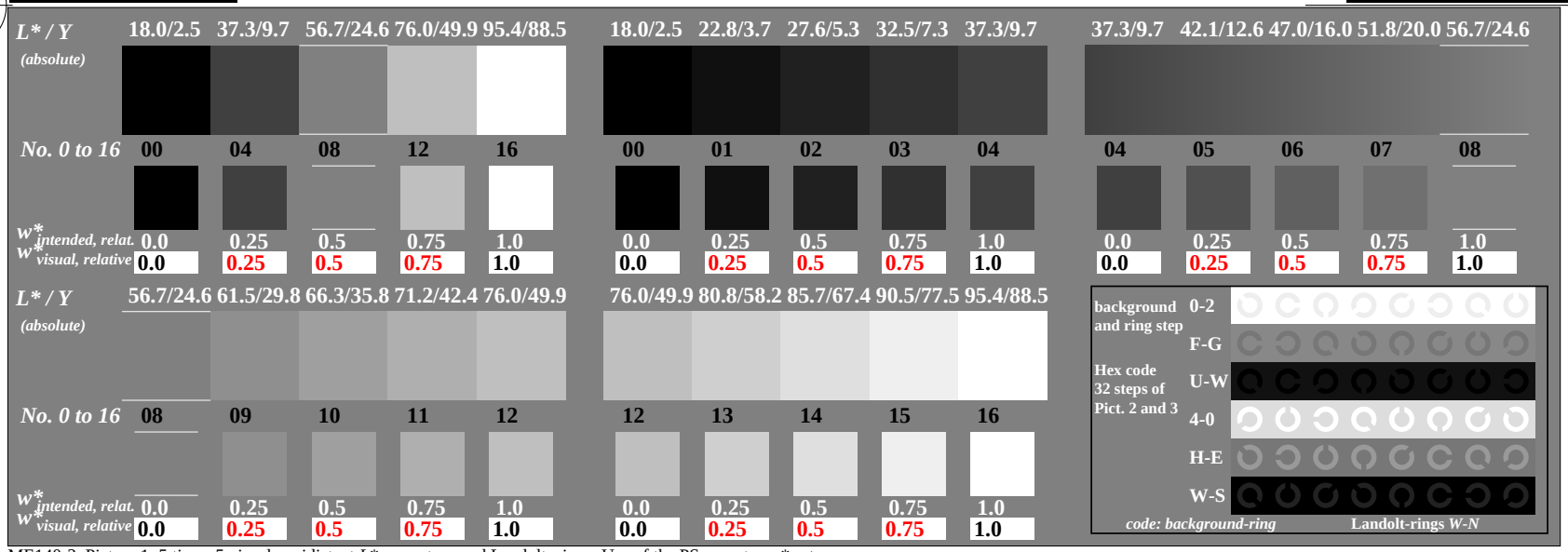


BE090−3, lightness l^*, chromaticness c^*

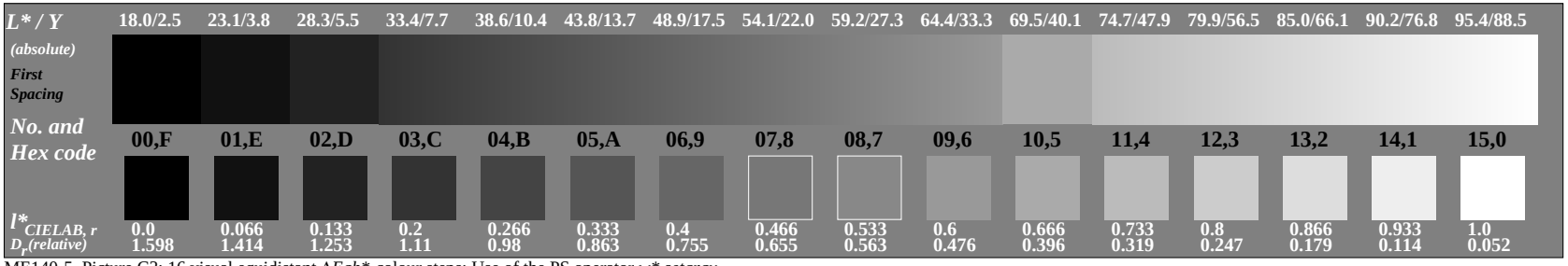


BE090−6, lightness L^*, chroma C^*_{ab} of O2

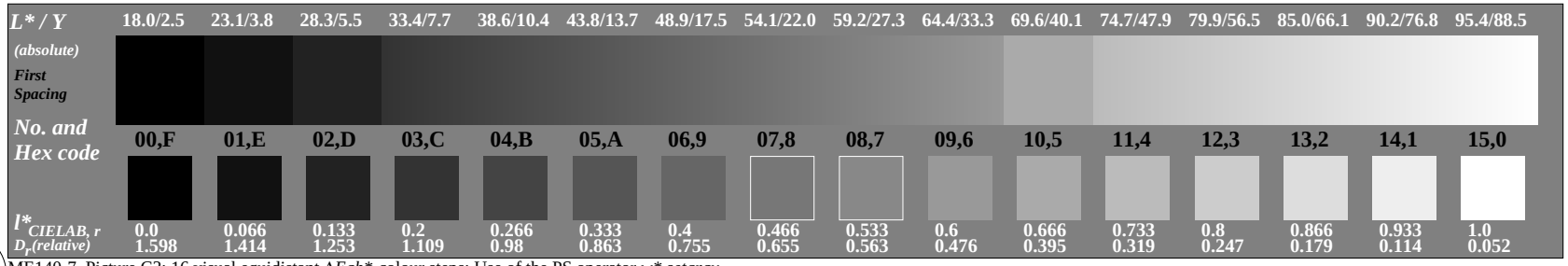
Figure 9: Work place assessment of 5 step grey scales



ME140-3, Picture 1: 5 times 5 visual equidistant *L**-grey steps and Landolt−rings; Use of the PS operator *w* setgray*



ME140-5, Picture C3: 16 visual equidistant Δ*Eab**-colour steps; Use of the PS operator *w* setgray*



ME140-7, Picture C3: 16 visual equidistant Δ*Eab**-colour steps; Use of the PS operator *w* setgray*

ISO/CD 9241-306-test chart no. ME14; 5 & 16 grey steps of ISO/IEC 15775 input: *w* setgray*
Page 1, 5 step grey evaluation for visual linearisation of 16 grey steps output: *w* setgray*

See for similar files: http://www.ps.bam.de/ME14/
Technical information: http://www.ps.bam.de Version 2.1, io=1,7; iORS; oORS, CIELAB

BAM registration: 20050501-ME14/10L/L14E00FP.PS/.PDF BAM material: code=rha4ta
application for displays (Yr=2.5) and printers

/ME14/ Form: 1/3, Serie: 1/1, Page: 1 Page: count: 1

Figure 10: Linearized ouput with 5 step work place assessment

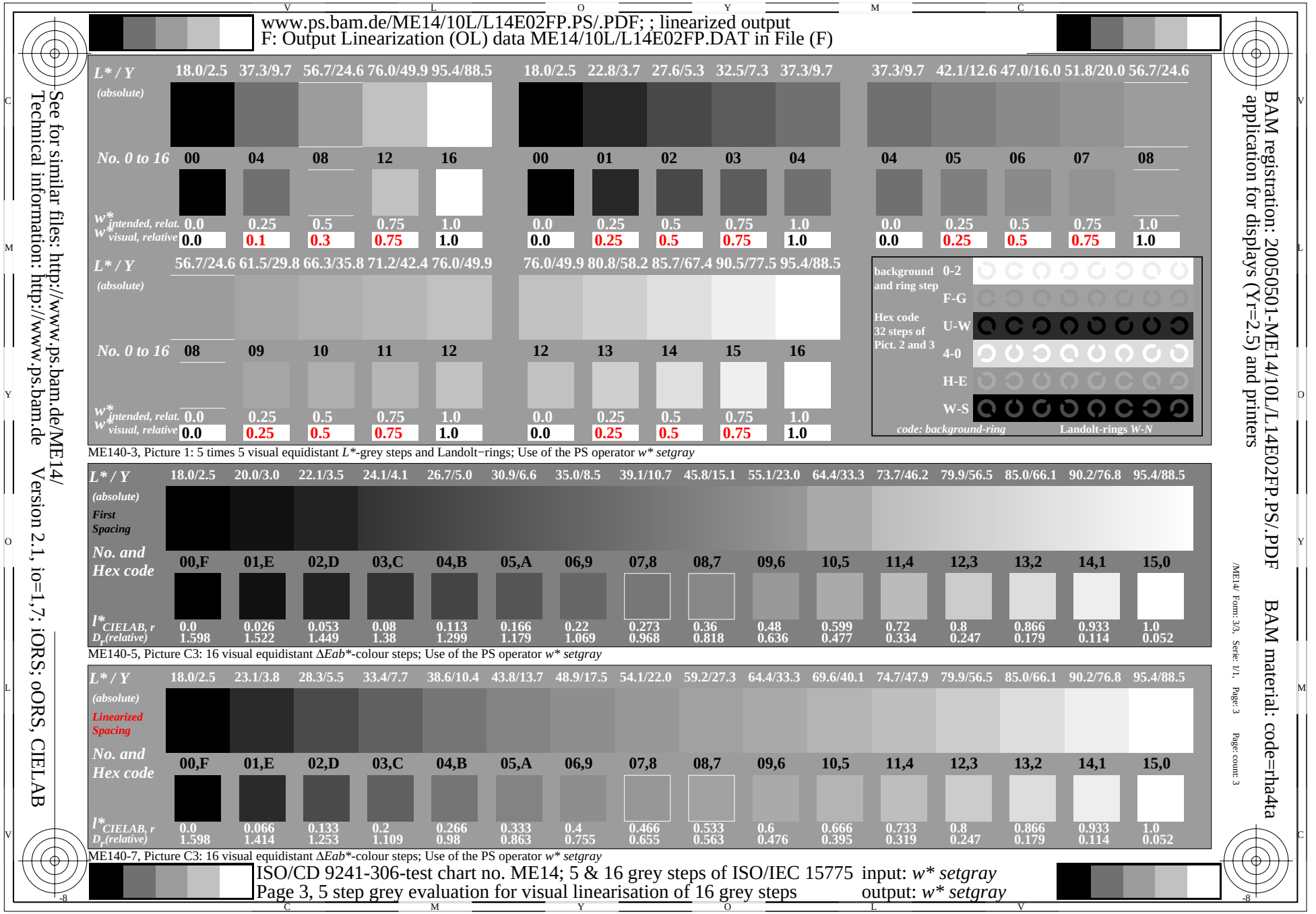


Figure 11: input - output relationship and inverse relation for output linearisation

www.ps.bam.de/ME14/10L/L14E03FP.PS/.PDF; ; linearized output
F: Output Linearization (OL) data ME14/10L/L14E03FP.DAT in File (F)

i	LAB*ref			d*	LAB*out			LAB*out/c-ref	Δ		E*	**Start output S1**
1	18.0	0.0	0.0	0.0	18.0	0.0	0.0	0.0	0.0	0.0	0.01	**Specification according to**
2	23.16	0.0	0.0	0.03	20.07	0.0	0.0	-3.08	0.0	0.0	3.09	**ISO/IEC 15775 Annex G**
3	28.32	0.0	0.0	0.05	22.13	0.0	0.0	-6.18	0.0	0.0	6.19	**and DIN 33866-1 Annex G**
4	33.48	0.0	0.0	0.08	24.19	0.0	0.0	-9.28	0.0	0.0	9.29	
5	38.64	0.0	0.0	0.11	26.77	0.0	0.0	-11.86	0.0	0.0	11.87	
6	43.8	0.0	0.0	0.17	30.9	0.0	0.0	-12.89	0.0	0.0	12.9	
7	48.96	0.0	0.0	0.22	35.03	0.0	0.0	-13.92	0.0	0.0	13.93	
8	54.12	0.0	0.0	0.27	39.16	0.0	0.0	-14.95	0.0	0.0	14.96	
9	59.28	0.0	0.0	0.36	45.87	0.0	0.0	-13.4	0.0	0.0	13.41	
10	64.44	0.0	0.0	0.48	55.15	0.0	0.0	-9.28	0.0	0.0	9.29	
11	69.6	0.0	0.0	0.6	64.43	0.0	0.0	-5.16	0.0	0.0	5.17	
12	74.76	0.0	0.0	0.72	73.74	0.0	0.0	-1.01	0.0	0.0	1.02	
13	79.92	0.0	0.0	0.8	79.92	0.0	0.0	0.0	0.0	0.0	0.01	
14	85.08	0.0	0.0	0.87	85.08	0.0	0.0	0.0	0.0	0.0	0.01	
15	90.24	0.0	0.0	0.93	90.25	0.0	0.0	0.01	0.0	0.0	0.01	**Mean lightness difference (16 steps)**
16	95.4	0.0	0.0	1.0	95.4	0.0	0.0	0.0	0.0	0.0	0.01	**ΔE^*_{CIELAB} = 6.3**
17	18.0	0.0	0.0	0.0	18.0	0.0	0.0	0.0	0.0	0.0	0.01	
18	37.35	0.0	0.0	0.11	26.13	0.0	0.0	-11.21	0.0	0.0	11.22	
19	56.7	0.0	0.0	0.32	42.52	0.0	0.0	-14.17	0.0	0.0	14.18	
20	76.05	0.0	0.0	0.74	75.28	0.0	0.0	-0.76	0.0	0.0	0.77	**Mean lightness difference (5 steps)**
21	95.4	0.0	0.0	1.0	95.4	0.0	0.0	0.0	0.0	0.0	0.01	**ΔL^*_{CIELAB} = 5.2**

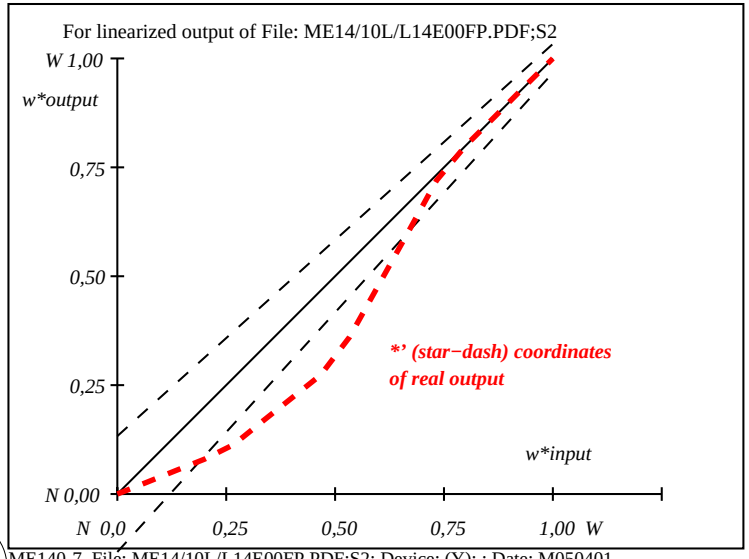
Mean colour reproduction index $R^*_{ab,m}$ = 72

ME140-3, Meas.: ME14/10L/L14E00NP.PDF;S1; Device: (Y); ; Date: M050401

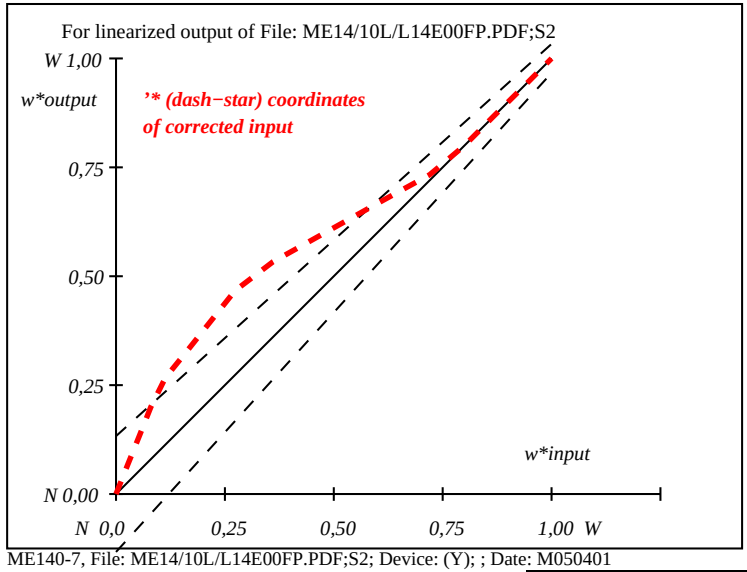
i	LAB*ref			d*	LAB*out			LAB*out/c-ref	Δ		E*	**Intended output S2**
1	18.0	0.0	0.0	0.0	18.0	0.0	0.0	0.0	0.0	0.0	0.01	**Specification according to**
2	23.16	0.0	0.0	0.07	23.2	0.0	0.0	0.04	0.0	0.0	0.04	**ISO/IEC 15775 Annex G**
3	28.32	0.0	0.0	0.13	28.3	0.0	0.0	-0.01	0.0	0.0	0.02	**and DIN 33866-1 Annex G**
4	33.48	0.0	0.0	0.2	33.5	0.0	0.0	0.02	0.0	0.0	0.02	
5	38.64	0.0	0.0	0.27	38.6	0.0	0.0	-0.03	0.0	0.0	0.04	
6	43.8	0.0	0.0	0.33	43.8	0.0	0.0	0.0	0.0	0.0	0.01	
7	48.96	0.0	0.0	0.4	49.0	0.0	0.0	0.04	0.0	0.0	0.04	
8	54.12	0.0	0.0	0.47	54.1	0.0	0.0	-0.01	0.0	0.0	0.02	
9	59.28	0.0	0.0	0.53	59.3	0.0	0.0	0.02	0.0	0.0	0.02	
10	64.44	0.0	0.0	0.6	64.4	0.0	0.0	-0.03	0.0	0.0	0.04	
11	69.6	0.0	0.0	0.67	69.6	0.0	0.0	0.0	0.0	0.0	0.01	
12	74.76	0.0	0.0	0.73	74.8	0.0	0.0	0.04	0.0	0.0	0.04	
13	79.92	0.0	0.0	0.8	79.9	0.0	0.0	-0.01	0.0	0.0	0.02	
14	85.08	0.0	0.0	0.87	85.1	0.0	0.0	0.02	0.0	0.0	0.02	
15	90.24	0.0	0.0	0.93	90.2	0.0	0.0	-0.03	0.0	0.0	0.04	**Mean lightness difference (16 steps)**
16	95.4	0.0	0.0	1.0	95.4	0.0	0.0	0.0	0.0	0.0	0.01	**ΔE^*_{CIELAB} = 0.0**
17	18.0	0.0	0.0	0.0	18.0	0.0	0.0	0.0	0.0	0.0	0.01	
18	37.35	0.0	0.0	0.25	37.32	0.0	0.0	-0.02	0.0	0.0	0.03	
19	56.7	0.0	0.0	0.5	56.7	0.0	0.0	0.0	0.0	0.0	0.01	
20	76.05	0.0	0.0	0.75	76.08	0.0	0.0	0.03	0.0	0.0	0.03	**Mean lightness difference (5 steps)**
21	95.4	0.0	0.0	1.0	95.4	0.0	0.0	0.0	0.0	0.0	0.01	**ΔL^*_{CIELAB} = 0.0**

Mean colour reproduction index $R^*_{ab,m}$ = 100

ME141-3, Meas.: ME14/10L/L14E00FP.PDF;S2; Device: (Y); ; Date: M050401



ME140-7, File: ME14/10L/L14E00FP.PDF;S2; Device: (Y); ; Date: M050401



ME140-7, File: ME14/10L/L14E00FP.PDF;S2; Device: (Y); ; Date: M050401

ISO/CD 9241-306-test chart no. ME14; 5 & 16 grey steps of ISO/IEC 15775 input: *w* setgray*
Page 4, 5 step grey evaluation for visual linearisation of 16 grey steps output: *w* setgray*

See for similar files: http://www.ps.bam.de/ME14/
Technical information: http://www.ps.bam.de Version 2.1, io=1,7; iORS; oORS, CIELAB

BAM registration: 20050501-ME14/10L/L14E03FP.PS/.PDF BAM material: code=rha4ta
application for displays (Yr=2.5) and printers
/ME14/ Form: 4/3, Serie: 1/1, Page: 4 Page: count: 4

-8

Figure 12: Colour triangle for chromatic and black generation

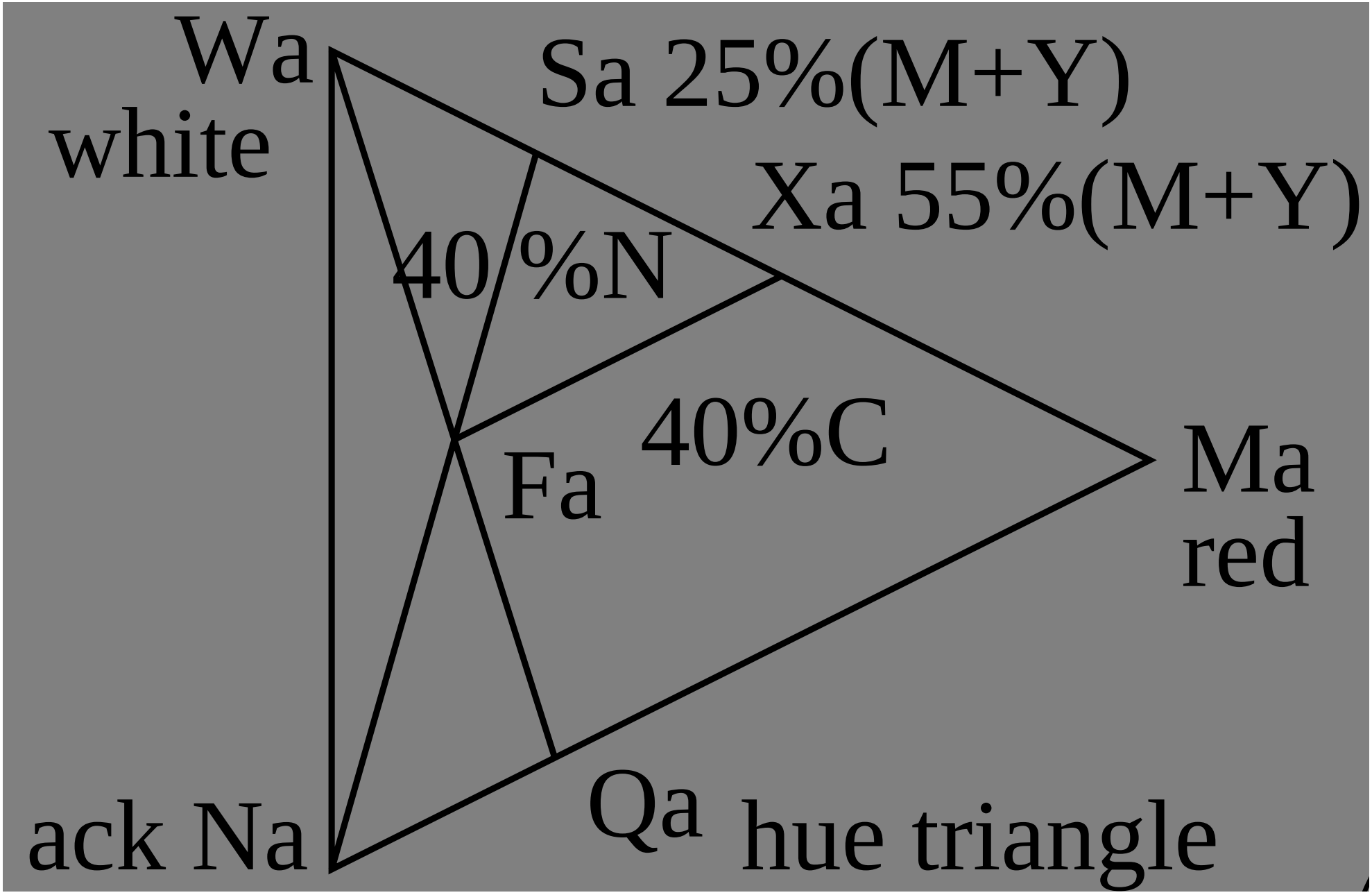


Figure 13: Calculation of Colour Coordinates

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	

Figure 14: Cost per page without and with black generation

BAM VIII.34-initiative:“Material efficiency of colour printer output”

Goal: Improvement of the **“Material efficiency” of printer output**
by equal costs per page and equivalent reproduction properties
according to DIN 33870 and DIN 33871-1:

The **material efficiency** is improved

– up to the **factor 3** if **remanufactured cartridges** are used
(lower prices compared to the original cartridges)

– up to the **factor 3** if **black generation** is applied instead of chromatic generation

– up to the **factor 9** if both **remanufactured cartridges** are used
and black generation is applied

If the user requirement of “grey image output” instead of “colour image output” is realized in the printer driver then there is an improvement

– up to the **factor 9** if **grey image output** instea **of colour image output** is applied

– up to the **factor 27** if both **remanufactured cartidges**
and grey image output is applied

Summary

- There are new colorimetric methods for the scan and relative reproduction of 16 step colour series
- The linearization of the monitor or printer system is a basis for high efficiency
- Linearization maintains the details, for example the recognition of Landolt-rings on any device
- Colorimetric Image Technology (CIT) is the basis for an efficient output on monitors annd printers
- Visual efficiency of monitor output is improved if colorimetric methods consider the room light
- Material efficiency of printout is improved by up to a factor 27 if colorimetric black generation is used

Standards, Technical Reports and References

The author was active as a leader for the standards [1] to [3] and was editor of the international standard 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, 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

[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)

[7] **ISO/IEC TR 24705:2005** (under publication), Method of specifying image reproduction of colour devices by digital and analog test charts, (79 pages)

[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), Material efficiency for image output on colour printers. In English and German versions see the URLs (6 pages, 88 kByte)

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

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

[11] Richter, K. (2005), Visual efficiency for image output on colour monitors, In English and German versions see the URLs (10 pages, 1 MByte)

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

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

Remark: 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