Proposal for a Reportership in CIE Division 8
Output Linearization Methods for Devices in Image Technology

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For recent publications of the TUB group see: http://130.149.60.45/~farbmetrik/XY91FEN.html

Title

Output Linearization Methods for Devices in Image Technology

Terms of Reference

Make proposals for the application of simple and 3D Output Linearization Methods and for the content of CIE Technical Reports. The reports may cover the device and the elementary hue output in the areas:

1. Output on displays for 8 display reflections (see ISO 9241-306)
2. Output on printers

For example a working draft WD2 (similar to N1171) developed first for ISO TC 159/WG2/SC4 “Visual Display Requirements” may serve as a starting point for display applications. Later CIE and ISO members may produce a CIE Technical Report for Display Output Linearization.

Background information

ISO 9241-306, Annex D, describes eight ambient luminance reflections between L_r=0% and L_r=40% compared to a reference White (L_r=100%).

Two ISO-test charts according to ISO 9241-306 allow to linearize the *Whole Display Output (WDO)* including any file output or only a *Device File Output (DFO)* on the computer display and/or an external display, for example a data projector.

http://www.ps.bam.de/ME16/10L/L16E00NP.PDF

The influence of the ambient light is simulated in (16 pages, 1,7 Mbyte)

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

To a high degree the ambient light deletes the equal spacing of 16 steps in the dark room. For example 5 dark grey steps may look equal and black as shown in the following example for an example display reflection of 40% which may occur for a projector display in room with much daylight.

1

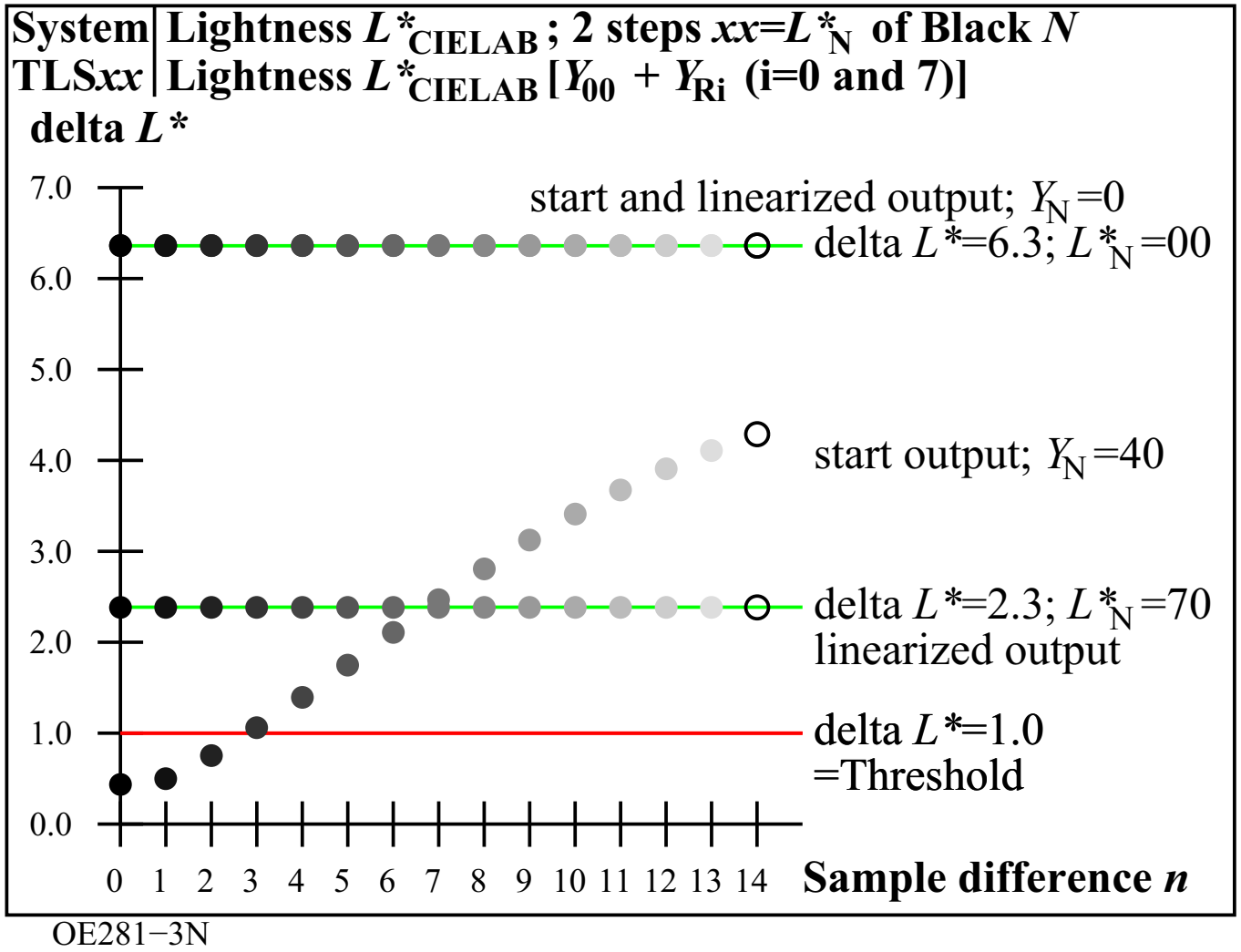

Fig. 1 Change of 15 sample differences by an ambient reflection L_r=40%

Similar changes appear for chromatic series which are included in the ISO/IEC-test chart 4 of ISO/IEC 15775 and ISO/IEC TR 24705.

ISO 9241-306, section 5.8 “Fidelity” says:
“A new methodology for assessing colour is under development, see Annex D”.
Remark: The above ISO/IEC-test chart 4 was accepted for colour applications at the last meeting of ISO TC159/WG2/SC4 in June 2011.

ISO 9241-306, section 5.8.1 “Gray Scale and Gamma” recommends:
“Perform a visual inspection and an output linearization procedure. See Annex D.”

Table B.1, section 5.8.1 “Gray Scale and Gamma” says that the “Fidelity of Gray Scale and Gamma” depends on
1. the display itself (for example output may change by the display age)
2. the application software (for example different versions)
3. the physical environmental conditions (display luminance reflection)

Annex D shows how the output of the black and white ISO-test chart ME16 according to ISO 9241-306 can be linearized at work places for different displays, application software, and environmental conditions, and for the whole display output.

1

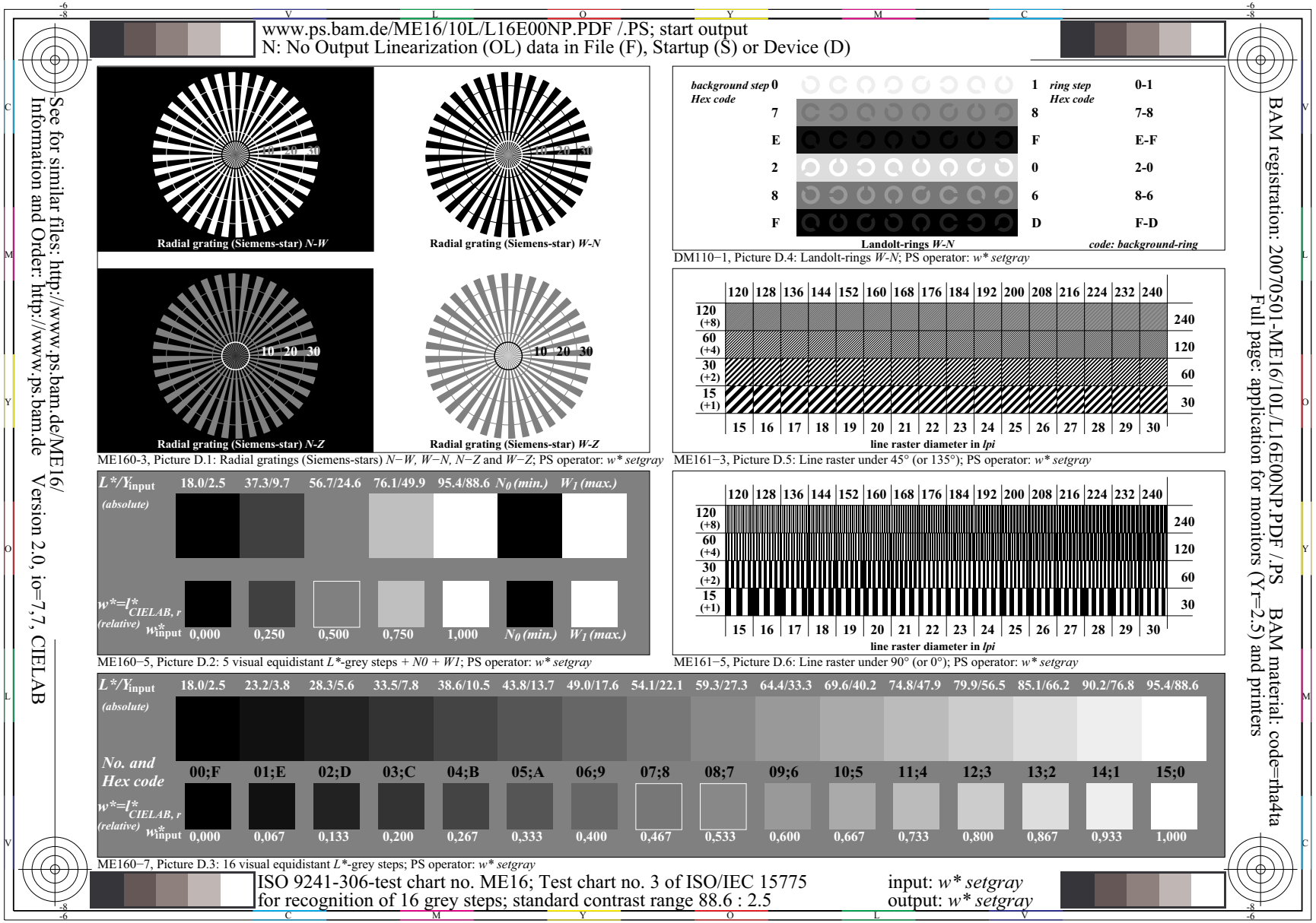

Fig. 2: ISO-test chart ME16 according to ISO 9241-306, Annex D

1

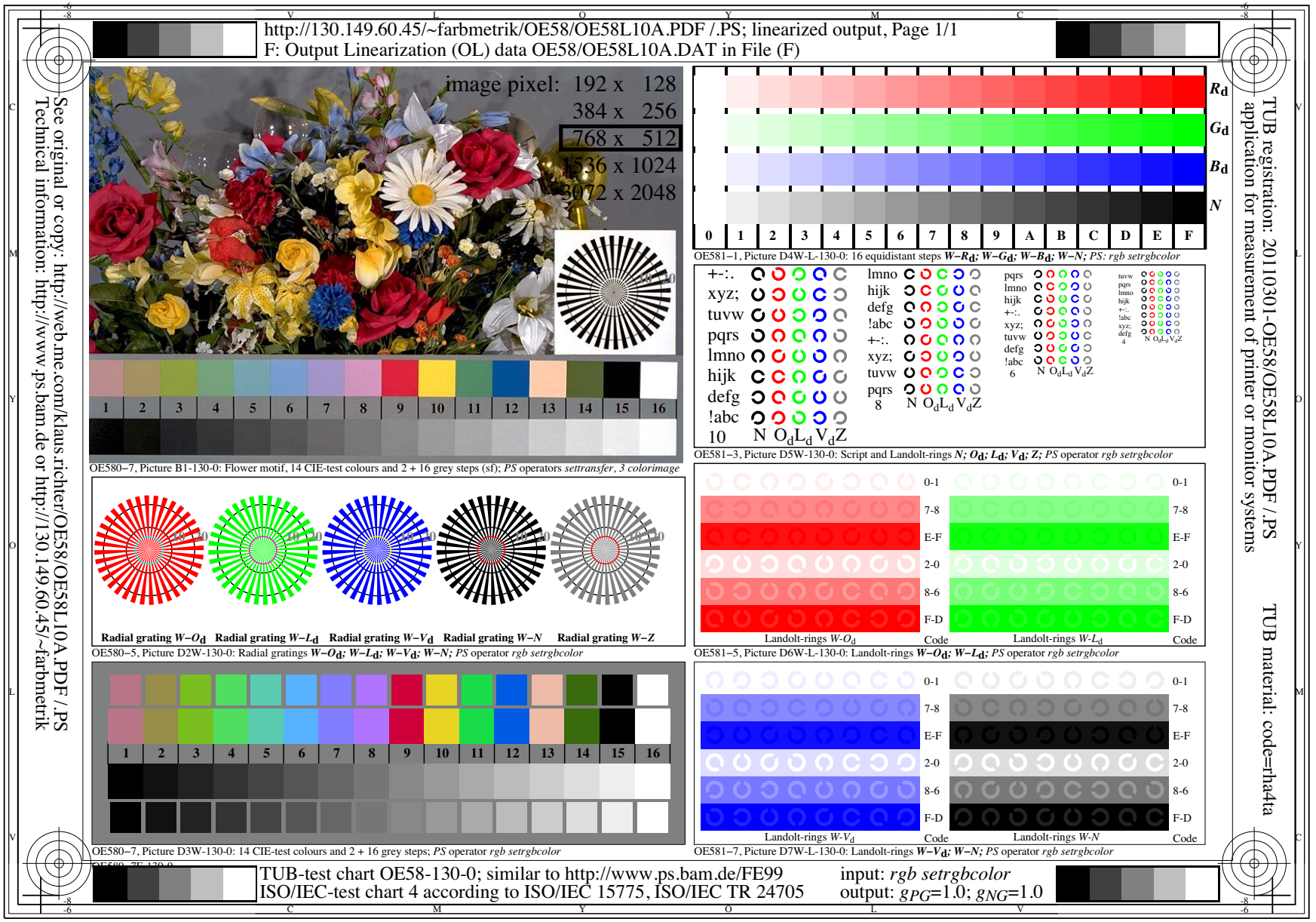

Fig. 3: ISO-test chart 4 according to ISO/IEC 15775, ISO/IEC TR 24705

1

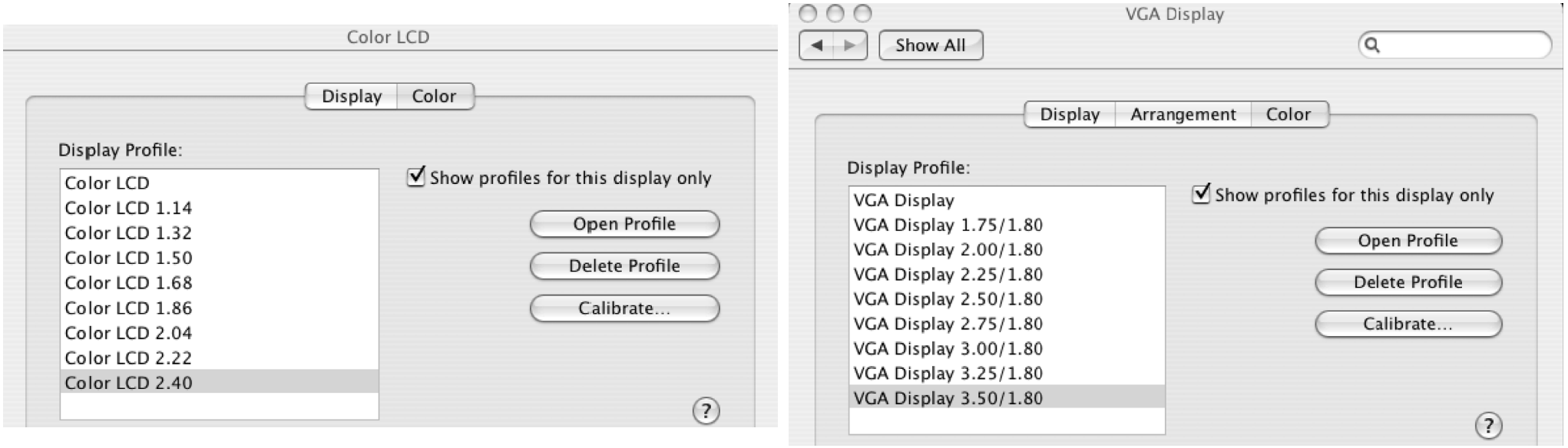

Fig 4: Eight Display Gamma Profiles (*DG_PR*) for Output Linearization.

The different Gamma Profiles can be created on a *Mac* computer by the operation tool *"Display, Color, Calibrate"* which allows to create the eight different *Display Gamma Profiles* separately for the computer display and the external display. The created eight *Mac* profiles *DG_PR* (see Fig. 4) may be used also on *Windows*.

A "click" on any of the eight *DG_PR* changes the output of the whole display. One *DG_PR* of the eight may be chosen for the work place environment for a time range with approximately constant display reflection.

As shown in Fig. 1 the dark gray steps appear darker and for example four grays in the dark room may appear black if daylight is in the projection room.

This effect can be simulated by a Gamma larger 1, for example

$w^*_{in} = 0.5$ and Gamma = 2 leads to $w^*_{out} = 0.5^2 = 0.25$.

Therefore the output appears darker.

The darkness can be changed by a profile *DG_PR* with Gamma = 0.5:

$w^*_{in} = 0.25$ and Gamma = 0.5 leads to $w^*_{out} = 0.25^{0.5} = 0.5$.

In the case that a profile is **not** available then within the file the Gamma can be changed. In this case the output is lighter for Gamma <1. The visual spacing is then large near black. In daylight offices the spacing near black gets equally spaced for an appropriate Gamma (>1). The file ME15 according to ISO 92412-306 simulates this condition.

A similar colour file of ISO/IEC 15775 and ISO/IEC TR 24705 for eight display reflections is used for the case that a *DG_PR* is not available.

Summary

For the intended *Whole Device Output (WDO)* the one page colour file
http://130.149.60.45/~farbmetrik/OE58/OE58L10A.PDF

may be used instead of the one page achromatic file
http://www.ps.bam.de/ME16/10L/L16E00NP.PDF

There is an easy realization of the intended change of the *Whole Device Output (WDO)* for both *Mac* and *Windows*.
The intended output is reached on *Windows*, if for example *Windows* is additionally installed on a *Mac* (realized for the *Mac* software *Parallels*).

If a *Device Gamma Profile* (*DG_PR*) is **not** available, then for the intended *Device File Output* (DFO) the colour file
http://130.149.60.45/~farbmetrik/OE58/OE58LXPA.PDF

may be used instead of the 16 page file
http://www.ps.bam.de/ME15/10L/L15E00FP.PDF

The image of both colour files (flower motive with CIE-test colours) is defined in ISO/IEC 15775 and ISO/IEC TR 24705.
The Reportership may consider the present ISO files and related drafts.

Annex A: **Device and Elementary Hue Output, and 1-Minus-Relation**

[1]

Achromatic colours, intermediate colours	**Elementary colours** *"Neither-nor"-colours*	**Device colours** ***Television (TV), Print (PR) Photography (PH)***
five achromatic colours:	*four elementary (e) colours:*	*six device (d) colours:*
N black (french noir)	$R = R_e$ red *neither yellowish nor blueish*	$C = C_d$ cyan blue
D dark grey	$G = G_e$ green *neither yellowish nor blueish*	$M = M_d$ magenta red
Z central grey	$B = B_e$ blue *neither greenish nor reddish*	$Y = Y_d$ yellow
H light grey	$J = Y_e$ yellow (french jaune) *neither greenish nor reddish*	$O = R_d$ orange red
W white		$L = G_d$ leaf green
two intermediate colours:		$V = B_d$ violet blue
$C_e = G_e 50 B_e$ green-blue		
$M_e = B_e 50 R_e$ blue-red		

YE980–3

Fig. A.1: Achromatic and chromatic device (d) and elementary (e) colors

There are six device (d) colours. The four elementary (e) colours and the intermediate colours C_e and M_e form six *device-independent* "elementary" colours. A visual output test of the *device-independent* elementary hue output (DEH) is appropriate by *ergonomic* reasons. Compare test chart output for DH (Device Hue) and DEH in Fig. 8.

1

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	***relative* CIELAB**			
	lab*w*$_d$ *setgray	***lab*000n* = 000n*$_d$ *000n*$_d$ *setcmykcolor***	***lab*cmy0* = cmy0*$_d$ *cmy0*$_d$ *setcmykcolor***	***lab*olv* = rgb*$_d$ *rgb*$_d$ *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

Part 1 YE920–1

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	***Standard* CIELAB *LAB*LAB* = LAB* LAB* setcolor***	***relative* CIELAB *lab*cmy0* = cmy0*$_d$ *cmy0*$_d$ *setcmykcolor***	***relative* CIELAB *lab*olv* = rgb*$_d$ *rgb*$_d$ *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

Part 1 YE920–5

Fig. A.2 Test of equal output for equivalent colour coordinates.

1

Frame File PostScript Code for 1-Minus-Relation (1MR)
and line 05 to change setgray to setrgbcolor
and line 09 to change setcmykcolor to setrgbcolor

```
01 %!PS-Adobe-3.0 EPSF-3.0 YK00L2FF.PS 20110301
02 /1MR-0000 {%BEG procedure 1MR-0000
03 %1MR-Transform of setgray and setcmykcolor to FFM_setrgbcolor
04
05 /setgray {%BEG procedure setgray to setrgbcolor
06           dup dup FFM_setrgbcolor
07          } def %END procedure setgray to setrgbcolor
08
09 /setcmykcolor {%BEG procedure setcmykcolor to setrgbcolor
10 /FFM_k exch def /FFM_y exch def /FFM_m exch def /FFM_c exch def
11 FFM_k 0 eq {1 FFM_c sub 1 FFM_m sub 1 FFM_y sub FFM_setrgbcolor}
12            {1 FFM_k sub dup dup FFM_setrgbcolor} ifelse
13               } def %END procedure setcmykcolor to setrgbcolor
14
15 } def %END procedure 1MR-0000
```

Remarks:
The FF_PS code includes: /FFM_setrgbcolor {setrgbcolor} bind def
Then setgray and setcmykcolor is changed to standard setrgbcolor

OE471–3N

Fig. A.3: *PostScript* program code for the 1-Minus-Relation (1MR)
This PS code is used by the Frame File and other Linearization Methods to produce equal output for the relative CIELAB coordinates of Fig. A.2.

1

ISO/IEC Testchart according ISO/IEC TR 24705	Original[2] BAM URL for download	New[2] TUB URL for download + FF_LM	1-minus-relation 1MR[1] + DH		Device File Output DFO_i i/8 DG_PS		Whole Device Output WDO_i i/8 DG_PR	
			VG	PG	VG	PG	VG	PG
3n ***(000n)***	A_1: B/DE86	A_1: T/OE50	●[1]	–	●	–	●	–
3w ***(w)***	A_1: B/DE87	A_1: T/OE51	●[1]	–	● ME15	–	● ME16	–
3c ***(cmy0)***	A_1: B/DE88	A_1: T/OE52	●[1]	–	●	–	●	–
3r ***(rgb)***	A_1: B/DE89	A_1: T/OE53	●[1]	–	●	–	●	–
3a ***(all)***	A_4: –	A_4: T/OE54	●[1]	–	●	–	●	–
2C ***(cmy0)***	C_1: B/FE96	C_1: T/OE55	●[1]	●[1]	●	●	●	●
2C ***(cmy0)***	C_1: B/FE98	C_1: T/OE56	●[1]	●[1]	●	●	●	●
4R ***(rgb)***	C_1: B/FE97	C_1: T/OE57	●[1]	●[1]	●	●	●	●
4R ***(rgb)***	C_1: B/FE99	C_1: T/OE58	●[1]	●[1]	●	●	●	●
4r ***(rgb)***	C_1: –	C_1: T/OE59	●[1]	–	●	–	●	–

Abbreviations: 1MR = 1-Minus-Relation; **DH** = Device Hue; ME15/16: ISO 9241-306
cmy0/000n *setcmykcolor;* ***rgb*** *setrgbcolor;* ***w*** *setgray;* **DG** = Device Gamma
VG = Vector Graphics; **PG** = Pixel Graphics; ● = realized; O = possible; – = no PG
Remarks: 1) Realized: *Mac OSX 10/10.1, Adobe FrameMaker 8, Unix, Ghostscript*
2) BAM/ = B/ = http://www.ps.bam.de/; TUB/ = T/ = http://130.149.60.45/~farbmetrik/

OE480−3N

Fig. A.4: ISO-test charts according to ISO/IEC 15775, ISO/IEC TR 24705
The achromatic (no. 3) and chromatic (no. 2 and 4) ISO-test charts are prepared for outputs *DFO*i and *WDO*i (*i*=1 to 8) for 8 display reflections.

1

Testchart measure-ment and output; 1080 colours	**All TUB URL for download + FF_LM**	**1-minus-relation 1MR[1)] + DH** VG	PG	**1-minus-relation 1MR[1)] + DEH** VG	PG	**Device File Output DFO_i i/8 DG_PS** VG	PG	**Whole De-vice Output WDO_i i/8 DG_PR** VG	PG
5g *(all)*	A_1: T/OE90	● [1)]	–	–	–	●	–	●	–
5o *(all)*	A_1: T/OE91	● [1)]	–	–	–	●	–	●	–
5e *(all)*	A_1: T/OE92	● [1)]	–	–	–	●	–	●	–
5G *(all)*	A_1: T/OE93	● [1)]	● [1)]	–	–	●	●	●	●
5E *(all)*	A_4: T/OE94	● [1)]	● [1)]	–	–	●	●	●	●
5g *(all)*	C_1: T/OE95	–	–	● [1)]	–	●	–	●	–
5o *(all)*	C_1: T/OE96	–	–	● [1)]	–	●	–	●	–
5e *(all)*	C_1: T/OE97	–	–	● [1)]	–	●	–	●	–
5G *(all)*	C_1: T/OE98	–	–	● [1)]	● [1)]	●	●	●	●
5E *(all)*	C_1: T/OE99	–	–	● [1)]	● [1)]	●	●	●	●

Abbreviations: 1MR = 1-Minus-Relation; **DG_PS/PR** = Device Gamma PS/Profile
all **=** *cmy0/000n setcmykcolor, rgb setrgbcolor, w setgray;* **–** = either DH or DEH
VG = Vector Graphics; **PG** = Pixel Graphics; ● = realized; O = possible; – = no PG
D(E)H = Device (to Elementary) Hue; TUB/ = T/ = http://130.149.60.45/~farbmetrik/
Remarks: 1) Realized: *Mac OSX 10/10.1, Adobe FrameMaker 8, Unix, Ghostscript*

OE470–7N

Fig. A.5: Colour test chart no. 5 including 9x9x9 colours and an image

As example of Fig. A.5 see the output of the two page file no. 5G:
http://130.149.60.45/~farbmetrik/OE93/OE93L1NA.PDF