CIELAB 16 step grey scales on printers and monitors by daylight illumination based on ISO/IEC 15775 and DIS ISO/IEC 19839-1 to 4

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Abstract

A **reflective and transparent ISO/IEC-test charts** no. 3 according to **ISO/IEC 15775** and DIS ISO/IEC 19839-1 to -4 is used for different tests of colour reproduction on printers and monitors in the office which is illuminated by daylight D65. The **reflective** ISO/IEC-test chart produced by DIN and JBMA in offset printing has a contrast range of 1:35. The calculation and production of a **transparent** ISO/IEC-test chart is described which produces the same contrast range for a standard 2.5% reflection condition. The **transparent** ISO/IEC-test chart has a contrast range of 1:10.000 and on top of the “white” monitor screen with the standard illumination of 500 lux the office lighting reduces to the standard contrast range between black and white to 1:35. The office illumination changes additionally the 16 step spacing and the appearance of the 16 grey samples on the monitor of both the tranparent test chart on top and of a digital test chart output. The contrast range and the spacing of the 16 grey steps for the printer and the monitor output and the transparent ISO/IEC-test chart which is fixed on a “white” monitor screen can be made equal. The reflective or transparent ISO/IEC-test chart allow to test many properties of the working place in the office, e. i. by recognition of Landolt-rings, line screens, Siemens stars, 16-step spacing etc. The **recognition and spacing** is highly influenced by the office illumination, the luminance and surface reflection properties of the monitor and the **imaging software**.

The procedure to produce **equidistant 16 step grey spacing for the printer and monitor output** is described. The **digital ISO/IEC-test chart** no. 3 which includes CIELAB *L** lightness input data is used to produce a **linear input – output relationship**. It is only necessary to replace the 16 linear (ideal) *L** data in the ISO/IEC-test chart file (in PostScript file format at the beginning) by the 16 *L** output data of the printer or monitor output to produce the intended equally spaced 16 step grey output. In the standard test chart file the *L** lightness input data vary within the standard range between *L**=18.0 and *L**=95.4. In the digital **NP-file** the *L** data are used by the *PostScript* (PS) operator *L* setcolor* for the standard CIELAB colour space. In the digital **CP-file** the *L** data are transferred to relative lightness *w** which is zero for black *N* and 1 for white *W* and the PS operator *w* setgray* is used. The digital **FP-file** includes a *PostScript* MTL code (Measurement, Transfer and Linearisation) which produces a linear relationship between the *w** input data (between 0 and 1) and the *L** lightness output on any printer or monitor. It is described how to use the reflective or transparent ISO/IEC-test charts to produce this linear relationship by visual comparison (or CIELAB or XYZ measurement) with the reference. If the transparent BAM-test chart as refererence is NOT available a training method with a digital test chart as reference is described which leads to the linear input – output relationship. At present often monitors (and printers) show for the 16 grey steps of the achromatic ISO/IEC-test chart no. 3 mean differences of 10 in lightness *L** (between 0 and 25). The method of this paper often allows to reduce the lightness differences from 10 to less then 3 (by a factor 3 to 5). This is then below the tolerance of 3 which is intended in ISO/IEC 15775 for colour copiers. So the output on different printers and monitors will be made very similar.

1. Introduction

The International Standard ISO/IEC 15775 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* was prepared by DIN (as DIN 33866-2). DIN 33866-2 was published in 1998 and ISO/IEC 15775 in 1999 [2].

The committees ISO/IEC JTC1/SC28 and DIN-NI-28: Information technology, Office equipment have worked together to develop the International Standard ISO/IEC 15775 [2]. The German national standards DIN 33866-1 to 5 [1a], ISO/IEC 15775 and the Draft International Standards DIS ISO/IEC 19839-X [1b] are based on equivalent colour series. Both use **digital** and **analog** test charts and the same layout. Fig. 1 and 2 show the relationship of these standards and draft standards.

New colorimetric technologies of the BAM have been used to produce the first set of four DIN-test charts in offset printing (3600 dpi) which are in application for colour devices (for example copiers, printers, scanners and monitors). The first production of (Asian) ISO/IEC-test charts according to ISO/IEC 15775 have been produced in Japan by JBMA (Japan Business Machines Makers Association). In applications the devices including software are used for ISO/IEC-test chart input and output in three different combinations **analog - analog** (copiers), **digital - analog** (printers, monitors) and **analog - digital** (scanners, Photo-CD-systems), compare Fig. 1 and 2.

1.1 Relationship between different standards

Input	Output	Input and output media and applications			Standard
		Input media	Output media	Application	or Draft
-	**-**	-	**-**	**Basis**	**ISO/IEC 19839-1**
analog	**analog**	ISO/IEC-test chart (hardcopy)	Hardcopy	**Copier**	**ISO/IEC 15775**
analog	**digital**	ISO/IEC-test chart (hardcopy)	File	**Scanner**	**ISO/IEC 19839-3**
digital	**analog**	ISO/IEC-test chart (file)	Hardcopy Softcopy	**Printer** **Monitor**	**ISO/IEC 19839-2** **ISO/IEC 19839-4**

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Figure 1: Analog and digital ISO/IEC-test charts according to ISO/IEC standards and drafts.

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**

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Figure 2: Analog and digital DIN-test charts according to DIN 33866-1 to -5

Fig. 1 and 2 show the relationship of the different standards and draft standards in the field of colour offices systems.

1.2 Reflective and transparent ISO/IEC-test charts and applications

New colorimetric technologies of Germany and Japan have been used to produce the four DIN- and ISO/IEC-test charts in offset printing (3600 dpi) which are available by DIN and JBMA and in application for colour devices now.

The achromatic ISO/IEC-test chart no. 3 in **transparent** mode has been produced by the Federal Institute for Materials Research and Testing (BAM) with a contrast of 1:10.000 and is available by BAM.

For application the **transparent ISO/IEC-test chart is fixed on a “white” monitor screen**. It is not critical if there is exactly a standard reflection of 2.5% compared to the monitor white. The 16 grey steps of the transparent ISO/IEC-test chart (produced by BAM) appear with the standard reflection of 2.5% equal compared to the 16 grey steps of the reflective test chart no. 3 (produced by DIN and JBMA).

In the case of **printers** the 16 grey steps of the **reflective** ISO/IEC-test chart serve as **reference** and are compared with the printer output of the **digital** ISO/IEC-test **chart for printers**. In the case of **monitors** the 16 grey steps of the **transparent** ISO/IEC-test chart serve as **reference** and are compared with the monitor output of the **digital** ISO/IEC-test **chart for monitors**. The digital ISO/IEC-test chart for monitors consider the standard reflection of 2.5%.

Remark 1: There is a CIE publication for office lighting which recommends a standard office illumination of 500 lux and of 1000 lux for the special case of colour control. In both cases a standard reflection of 2.5% is assumed which may be reached by a special ”anti reflective coating” of the monitor surface in the case of 1000 lux illumination.

Remark 2: There are flat area lamps (e. g. OSRAM PLANON) with the chromaticity of daylight D65, a luminance of 7000 cd/m^2 (there is a dimming possibility in the range of 5% to 100%) and sizes between 15 and 21 inches on the market. A **transparent** ISO/IEC-test chart on top of this fat area lamp may also define a reference monitor. One may compare this standard **reference monitor** of e.g. 160 cd/m^2 with the digital test chart output on the monitor with equal luminance. It is assumed to have an equal surface reflection of 2.5% of both the reflection of the 16 step grey film surface of the transparent ISO/IEC-test chart and the reflection of the 16 step grey output on the monitor.

The source of the assumed 2.5% reflection of the monitor is based on the room illumination in the office, the reflection properties of the monitor surface and the luminance of a "white" monitor. The standard reflection of 2.5% shifts the CIELAB lightness *L**=0 without room illumination (in a dark room) to the value *L**=18 including the room illumination. In this standard case the lightness *L** of **the 16 grey steps** of the **transparent test chart on the monitor** and the lightness *L** of **the 16 grey steps** of the **reflective ISO/IEC-test chart** no. 3 **appear the same**.

1.3 ISO/IEC-test chart files and linear input – output relationship in CIELAB

The digital input data are not limited to the absolute *L** or relative *w** data. Instead of the *w** input data the *olv** or *cmy** data in the digital files may be used. The colour output of the ISO/IEC-test charts no. 3 can be made identical if instead of the PS operator *w* setgray* the PS operators *olv* setrgbcolor* or *cmy0* setcmykcolor* are used. Therefore the **user requirement for a linear relationship** between the CIELAB input data and the output data is realised for all important **colour workflow methods**. This **linear input – output colour workflow** for offices seems to be both simple and effective. For example the relative lightness data *w**=0.5 will produce a grey which is visually in the middle between the lightness *L** for black *N* and white *W*. The basic user requirement for a linear relationship between input and output is fulfilled and this linear relationship has many advantages for colour image technology.

Remark: In this paper mainly the PS operators *L* setcolor* (in CIELAB space) and *w* setgray* (in relative CIELAB space) are studied. The output by the PS-operator ***w* setgray* serves as reference.**

PS-operator used (*star coordinates) in NP-file	**PS-operator used (* star coordinates) in CP-file**	**PS-operator used '* dash-star coordinat. in FP-file**	**PS- or PDF-file compatible to the following software 1-------2-------3------4-------5**
L* setcolor L7**0**E00**NP**.PS/PDF	nnn0* setcmykcolor L7**0**E00**CP**.PS/PDF	nnn0'* setcmykcolor L7**0**E00**FP**.PS/PDF	Yes---Yes----No[1)]---Yes---Yes
L* setcolor L7**1**E00**NP**.PS/PDF	000n* setcmykcolor L7**1**E00**CP**.PS/PDF	000n'* setcmykcolor L7**1**E00**FP**.PS/PDF	Yes---Yes----No[1)]---Yes---Yes
L* setcolor L7**2**E00**NP**.PS/PDF	w* setgray L7**1**E00**CP**.PS/PDF	w'* setgray L7**2**E00**FP**.PS/PDF	Yes---Yes----No[1)]----Yes---Yes
L* setcolor L7**3**E00**NP**.PS/PDF	www* setrgbcolor L7**1**E00**CP**.PS/PDF	www'* setrgbcolor L7**3**E00**FP**.PS/PDF	Yes---Yes----No[1)]----Yes---Yes
nnn0* setcmykcolor L7**5**E00**NP**.PS/PDF	–	nnn0'* setcmykcolor L7**5**E00**FP**.PS/PDF	Yes---Yes----Yes---Yes---Yes
000n* setcmykcolor L7**6**E00**NP**.PS/PDF	–	000n'* setcmykcolor L7**6**E00**FP**.PS/PDF	Yes---Yes----Yes---Yes---Yes
w* setgray L7**7**E00**NP**.PS/PDF	–	w'* setgray L7**7**E00**FP**.PS/PDF	Yes---Yes----Yes---Yes---Yes
www* setrgbcolor L7**8**E00**NP**.PS/PDF	–	www'* setrgbcolor L7**8**E00**FP**.PS/PDF	Yes---Yes----Yes---Yes---Yes

[1)] because not compatible with the *LAB* setcolor* definition

Table 1: PS-operators used in three different ISO/IEC-test chart files (NP, CP, FP)

All ISO/IEC-test chart files of Table 1 in the format PS and PDF are for free on the internet, go for download to:

http://www.ps.bam.de/DE70/DE70D.HTM

The files in the PS-format may be used to transfer to other file formats which are specific for the three software examples (numbers according to Table 1):

1. *Adobe Acrobat Distiller 3.0* or later (produces PDF-files from PS-files)
2. *Adobe Photoshop 5.0* or later
3. *Adobe Illustrator 8.0* (some are not compatible with the *LAB* setcolor* definition)

The files in the PDF-format (produced from PS-files by *Adobe Acrobat Distiller*) may be used for the output on monitors or printers using the two software examples (numbers according to Table 1):

4. *Adobe Acrobat 3.0* or later and *Adobe Reader 3.0* or later
5. *Macintosh OS X Preview* (This software images PDF-files similar to *Acrobat Reader*)

According to CIELAB colorimetry the output of the sixteen files L7iE00**NP**.PDF (i=5,6,7,8), L7iE00**CP**.PDF (i=0,1,2,3), and L7iE00**FP**.PDF (i=0,1,2,3, 5,6,7,8) should be the same if e. g. the software Acrobat Reader 4.0 is used. But in application there are large differences, e. g. the software *Adobe Reader* produces for the corresponding data (according to CIELAB colorimetry) different output. If for example on the **monitor** the mean gray of Fig. C3 produced by

***w** setgray = 0.5 setgray**

is the **reference** then the following colours produced look very bown instead of grey

www0* setcmykcolor = 0.5 0.5 0.5 0.0 setcmykcolor

Often the input data

0.45 0.32 0.32 0.0 setcmykcolor

produce a **similar grey output** on the monitor (the data necessary for mean grey output seem to be based on professional offset printing with special subtractive pinting inks but this is not discussed here).

Low cost printers and half of the colour PostScript printers (of 10 PS printers tested) show the same effect. The other half of the PostScript printers produce approximately the same output as for 0.5 setgray and as expected by colorimetry. This situation is very confusing for the user and this is the basic reason why international standards of ISO/IEC are necessary for colour reproduction of office equipment.

2. Basic data for the 16 step CIELAB spacing on printers and monitors

System PR18eqs	Color	L*c	a*c	b*c	$C^*_{ab,c}$	Xc	Yc	Zc	Yc/88.59
LAB*c (c=CIE)	00,F	18.01	0.5	-0.46	0.69	2.42	2.52	2.81	0.0284
(CIELAB according	01,E	23.17	0.4	-0.11	0.42	3.69	3.85	4.22	0.0435
to ISO/IEC 15775	02,D	28.33	0.3	0.23	0.38	5.33	5.58	6.02	0.063
and DIS ISO/IEC 19839-1)	03,C	33.49	0.2	0.58	0.61	7.4	7.77	8.29	0.0877
	04,B	38.65	0.1	0.92	0.93	9.95	10.46	11.06	0.118
Lightness series N-W	05,A	43.81	0.0	1.27	1.27	13.03	13.71	14.38	0.1547
Reflective data [Yc]eqs	06,9	48.97	-0.09	1.62	1.62	16.68	17.57	18.31	0.1983
	07,8	54.13	-0.19	1.97	1.98	20.96	22.1	22.91	0.2494
equally spaced (eqs)	08,7	59.29	-0.28	2.32	2.34	25.92	27.34	28.21	0.3086
in CIELAB color space	09,6	64.45	-0.38	2.67	2.7	31.6	33.36	34.27	0.3765
	10,5	69.61	-0.48	3.02	3.06	38.05	40.2	41.15	0.4537
CIE luminance factor Y	11,4	74.77	-0.58	3.37	3.42	45.33	47.91	48.88	0.5408
of white equal to 88.59	12,3	79.93	-0.68	3.71	3.78	53.49	56.56	57.53	0.6384
	13,2	85.09	-0.78	4.06	4.14	62.57	66.18	67.15	0.7471
[Yc]eqs	14,1	90.25	-0.88	4.41	4.5	72.62	76.84	77.78	0.8674
	15,0	95.41	-0.98	4.76	4.86	83.69	88.59	89.48	1.0
	Color	**L*sa**	**a*sa**	**b*sa**	$C^*_{ab,sa}$	**Xsa**	**Ysa**	**Zsa**	**Ysa/88.59**
LAB*sa	00,F	18.01	0.0	0.0	0.0	2.4	2.52	2.74	0.0284
(sytem adapted	01,E	23.17	0.0	0.0	0.0	3.66	3.85	4.19	0.0435
and CIELAB cero point)	02,D	28.33	0.0	0.0	0.0	5.3	5.58	6.08	0.063
	03,C	33.49	0.0	0.0	0.0	7.38	7.77	8.46	0.0877
Lightness series N-W	04,B	38.65	0.0	0.0	0.0	9.94	10.46	11.39	0.118
Refelctive data [Ysa]eqs	05,A	43.81	0.0	0.0	0.0	13.03	13.71	14.93	0.1547
	06,9	48.97	0.0	0.0	0.0	16.7	17.57	19.13	0.1983
equally spaced (eqs)	07,8	54.13	0.0	0.0	0.0	21.0	22.1	24.06	0.2494
in CIELAB color space	08,7	59.29	0.0	0.0	0.0	25.99	27.34	29.78	0.3086
	09,6	64.45	0.0	0.0	0.0	31.71	33.36	36.33	0.3765
CIE luminance factor Y	10,5	69.61	0.0	0.0	0.0	38.21	40.2	43.78	0.4537
of white equal to 88.59	11,4	74.77	0.0	0.0	0.0	45.54	47.91	52.18	0.5408
	12,3	79.93	0.0	0.0	0.0	53.76	56.56	61.59	0.6384
[Ysa]eqs = [Yc]eqs	13,2	85.09	0.0	0.0	0.0	62.91	66.18	72.07	0.7471
	14,1	90.25	0.0	0.0	0.0	73.04	76.84	83.68	0.8674
	15,0	95.41	0.0	0.0	0.0	84.21	88.59	96.48	1.0

Table 2: Basic data of the 16 step greys which are equally spaced in the printing (PR18) system

For the equally spaced greys in offset printing Table 2 shows the transfer of the CIELAB data to the **s**ystem **a**dapted (**sa**) CIELAB data.able 2 shows the CIELAB and XYZ data of the 16 step grey series which are equally spaced in CIELAB for different applications. The CIELAB data of the 5 and 16 equally spaced grey samples (see Fig. C2 and C3 of the test chart) are given in ISO/IEC 15775. The white non fluorescent standard offset paper used for the ISO/IEC-test chart production by DIN and JBMA is yellowish and has the CIELAB and XYZ coordinates given in Table 2.

The a* and b* coordinates are not zero for white and similar for black. They are different for white and black. Similar deviations are the case for real monitors and other devices. For all applications therefore real measurement data must be transferred to **s**ystem **a**dapted (**sa**) coordinates, see Table 2. The system adapted (sa) coordinates allow the comparison of the printer and monitor output data by colorimetry and allow to compare the output of different printers and the output of different monitors..

System TV18eqs	**Color**	**L*c**	**a*c**	**b*c**	**$C^*_{ab,c}$**	**Xc**	**Yc**	**Zc**	**Yc/88.59**
LAB*c (c=CIE)	00,F	18.01	0.0	0.0	0.01	2.4	2.52	2.74	0.0284
(CIELAB according	01,E	23.17	0.0	0.0	0.01	3.66	3.85	4.19	0.0435
to ISO/IEC 15775	02,D	28.33	0.0	0.0	0.01	5.3	5.58	6.08	0.063
and DIS ISO/IEC 19839-1)	03,C	33.49	0.0	0.0	0.01	7.38	7.77	8.46	0.0877
	04,B	38.65	0.0	0.0	0.01	9.94	10.46	11.39	0.118
Lightness series N-W	05,A	43.81	0.0	0.0	0.01	13.03	13.71	14.93	0.1547
Transparent data [Yc]eqs	06,9	48.97	0.0	0.0	0.01	16.7	17.57	19.13	0.1983
	07,8	54.13	0.0	0.0	0.01	21.0	22.1	24.06	0.2494
equally spaced (eqs)	08,7	59.29	0.0	0.0	0.01	25.99	27.34	29.78	0.3086
in CIELAB color space	09,6	64.45	0.0	0.0	0.01	31.71	33.36	36.33	0.3765
	10,5	69.61	0.0	0.0	0.01	38.21	40.2	43.78	0.4537
CIE luminance factor Y	11,4	74.77	0.0	0.0	0.01	45.54	47.91	52.18	0.5408
of white equal to 88.59	12,3	79.93	0.0	0.0	0.01	53.76	56.56	61.59	0.6384
	13,2	85.09	0.0	0.0	0.01	62.91	66.18	72.07	0.7471
[Yc]eqs	14,1	90.25	0.0	0.0	0.01	73.04	76.84	83.68	0.8674
	15,0	95.41	0.0	0.0	0.01	84.21	88.59	96.48	1.0
System TV00nes	**Color**	**L*rs**	**a*rs**	**b*rs**	**$C^*_{ab,rs}$**	**Xrs**	**Yrs**	**Zrs**	**Yrs/86.07**
LAB*rs	00,F	0.0	0.0	-0.05	0.06	0.0 (=2.4-2.4)	0.0 (=2.52-2.52)	0.0 (=2.74-2.74)	0.0
(subtracted: 2.52% reflectance	01,E	11.49	-0.14	-0.04	0.16	1.26 (=3.66-2.4)	1.33 (=3.85-2.52)	1.45 (=4.19-2.74)	0.0155
and CIELAB cero point)	02,D	20.29	-0.07	-0.02	0.09	2.9 (=5.3-2.4)	3.06 (=5.58-2.52)	3.34 (=6.08-2.74)	0.0356
	03,C	27.42	-0.05	-0.01	0.06	4.98 (=7.38-2.4)	5.25 (=7.77-2.52)	5.72 (=8.46-2.74)	0.0609
Lightness series N-W	04,B	33.85	-0.04	0.0	0.05	7.54 (=9.94-2.4)	7.94 (=10.46-2.52)	8.65 (=11.39-2.74)	0.0922
subtracted: Yr = 2.52	05,A	39.89	-0.03	0.0	0.04	10.63 (=13.03-2.4)	11.19 (=13.71-2.52)	12.19 (=14.93-2.74)	0.13
from refletance data [Ysa]eqs	06,9	45.7	-0.02	0.0	0.03	14.3 (=16.7-2.4)	15.05 (=17.57-2.52)	16.39 (=19.13-2.74)	0.1748
	07,8	51.36	-0.01	0.0	0.03	18.6 (=21.0-2.4)	19.58 (=22.1-2.52)	21.32 (=24.06-2.74)	0.2274
Now NOT equally spaced	08,7	56.9	-0.01	0.0	0.02	23.59 (=25.99-2.4)	24.82 (=27.34-2.52)	27.04 (=29.78-2.74)	0.2884
in CIELAB color space	09,6	62.37	-0.01	0.0	0.02	29.31 (=31.71-2.4)	30.84 (=33.36-2.52)	33.59 (=36.33-2.74)	0.3583
	10,5	67.78	-0.01	0.0	0.02	35.81 (=38.21-2.4)	37.68 (=40.2-2.52)	41.04 (=43.78-2.74)	0.4377
CIE luminance factor Y	11,4	73.15	0.0	0.0	0.02	43.14 (=45.54-2.4)	45.39 (=47.91-2.52)	49.44 (=52.18-2.74)	0.5274
of white equal to 88.59 - 2.52	12,3	78.48	0.0	0.0	0.02	51.36 (=53.76-2.4)	54.04 (=56.56-2.52)	58.85 (=61.59-2.74)	0.6278
	13,2	83.79	0.0	0.0	0.02	60.51 (=62.91-2.4)	63.66 (=66.18-2.52)	69.33 (=72.07-2.74)	0.7396
Yrs = [Yc]eqs - r	14,1	89.08	0.0	0.0	0.01	70.64 (=73.04-2.4)	74.32 (=76.84-2.52)	80.94 (=83.68-2.74)	0.8635
	15,0	94.34	0.0	0.0	0.01	81.81 (=84.21-2.4)	86.07 (=88.59-2.52)	93.74 (=96.48-2.74)	1.0

Table 3: Basic data of the 16 step greys which are equally spaced in the television (TV18) system.

System TV27eqs	**Color**	**L*c**	**a*c**	**b*c**	**$C^*_{ab,c}$**	**Xc**	**Yc**	**Zc**	**Yc/88.59**
LAB*c (c=CIE)	00,F	26.73	0.0	0.0	0.01	4.75	5.0	5.44	0.0564
(CIELAB according	01,E	31.31	0.0	0.0	0.01	6.45	6.78	7.39	0.0766
to ISO/IEC 15775	02,D	35.89	0.0	0.0	0.01	8.51	8.95	9.75	0.101
and DIS ISO/IEC 19839-1)	03,C	40.47	0.0	0.0	0.01	10.96	11.53	12.56	0.1302
	04,B	45.04	0.0	0.0	0.01	13.85	14.57	15.87	0.1645
Lightness series N-W	05,A	49.62	0.0	0.0	0.01	17.21	18.11	19.72	0.2044
Transparent data [Yc]eqs	06,9	54.2	0.0	0.0	0.01	21.07	22.17	24.14	0.2502
	07,8	58.78	0.0	0.0	0.01	25.47	26.79	29.18	0.3024
equally spaced (eqs)	08,7	63.36	0.0	0.0	0.01	30.43	32.02	34.87	0.3614
in CIELAB color space	09,6	67.94	0.0	0.0	0.01	36.01	37.89	41.26	0.4277
	10,5	72.52	0.0	0.0	0.01	42.23	44.43	48.39	0.5015
CIE luminance factor Y	11,4	77.1	0.0	0.0	0.01	49.13	51.69	56.29	0.5835
of white equal to 88.59	12,3	81.67	0.0	0.0	0.01	56.74	59.7	65.01	0.6739
	13,2	86.25	0.0	0.0	0.01	65.1	68.49	74.59	0.7731
[Yc]eqs	14,1	90.83	0.0	0.0	0.01	74.25	78.11	85.06	0.8817
	15,0	95.41	0.0	0.0	0.01	84.21	88.59	96.48	1.0
System TV00nes	**Color**	**L*rs**	**a*rs**	**b*rs**	**$C^*_{ab,rs}$**	**Xrs**	**Yrs**	**Zrs**	**Yrs/83.59**
LAB*rs	00,F	0.0	0.04	-0.04	0.06	0.0 (=4.75-4.75)	0.0 (=5.0-5.0)	0.0 (=5.44-5.44)	0.0
(subtracted: 5.0% reflectance	01,E	14.31	0.06	-0.03	0.08	1.7 (=6.45-4.75)	1.78 (=6.78-5.0)	1.95 (=7.39-5.44)	0.0213
and CIELAB cero point)	02,D	23.5	0.04	-0.02	0.05	3.76 (=8.51-4.75)	3.95 (=8.95-5.0)	4.31 (=9.75-5.44)	0.0472
	03,C	30.72	0.03	-0.01	0.03	6.21 (=10.96-4.75)	6.53 (=11.53-5.0)	7.12 (=12.56-5.44)	0.0782
Lightness series N-W	04,B	37.07	0.02	0.0	0.03	9.1 (=13.85-4.75)	9.57 (=14.57-5.0)	10.43 (=15.87-5.44)	0.1145
subtracted: Yr = 5.0	05,A	42.92	0.02	0.0	0.02	12.46 (=17.21-4.75)	13.11 (=18.11-5.0)	14.28 (=19.72-5.44)	0.1568
from refletance data [Ysa]eqs	06,9	48.47	0.01	0.0	0.02	16.32 (=21.07-4.75)	17.17 (=22.17-5.0)	18.7 (=24.14-5.44)	0.2053
	07,8	53.8	0.01	0.0	0.02	20.72 (=25.47-4.75)	21.79 (=26.79-5.0)	23.74 (=29.18-5.44)	0.2607
Now NOT equally spaced	08,7	58.99	0.01	0.0	0.02	25.68 (=30.43-4.75)	27.02 (=32.02-5.0)	29.43 (=34.87-5.44)	0.3232
in CIELAB color space	09,6	64.07	0.01	0.0	0.02	31.26 (=36.01-4.75)	32.89 (=37.89-5.0)	35.82 (=41.26-5.44)	0.3934
	10,5	69.06	0.01	0.0	0.01	37.48 (=42.23-4.75)	39.43 (=44.43-5.0)	42.95 (=48.39-5.44)	0.4717
CIE luminance factor Y	11,4	73.99	0.01	0.0	0.01	44.38 (=49.13-4.75)	46.69 (=51.69-5.0)	50.85 (=56.29-5.44)	0.5585
of white equal to 88.59 - 5.0	12,3	78.87	0.01	0.0	0.01	51.99 (=56.74-4.75)	54.7 (=59.7-5.0)	59.57 (=65.01-5.44)	0.6543
	13,2	83.7	0.01	0.0	0.01	60.35 (=65.1-4.75)	63.49 (=68.49-5.0)	69.15 (=74.59-5.44)	0.7596
Yrs = [Yc]eqs - r	14,1	88.5	0.01	0.0	0.01	69.5 (=74.25-4.75)	73.11 (=78.11-5.0)	79.62 (=85.06-5.44)	0.8746
	15,0	93.27	0.0	0.0	0.01	79.46 (=84.21-4.75)	83.59 (=88.59-5.0)	91.04 (=96.48-5.44)	1.0

Table 4: Basic data of the 16 step greys which are equally spaced in the television (TV27) system

For the equally spaced greys on the monitor Table 3 shows the transfer of the CIELAB data to the **r**eflection

subtracted (**rs**) CIELAB data. A standard 2.5% reflection of the monitor surface is used for the calculations. This leads to data in a system TV00 which has for black *N* the lightness *L**=0 instead of *L**=18. The lightness *L** of white is reduced by a small amount from 95.4 to 94.3

For the equally spaced greys on the monitor Table 4 shows the transfer of the CIELAB data to the **r**eflection **s**ubtracted (**rs)** CIELAB data. A standard 5.0% reflection of the monitor surface is used for the calculations. This leads to data in a system TV00 which has for black *N* the lightness *L**=0 instead of *L**=27. The lightness *L** of white is reduced by a small amount from 95.4 to 93.3.

For application the **transparent ISO/IEC-test chart is mounted on a white monitor screen**. It is not critical if there is exactly a standard reflection of 2.5% compared to the monitor white. The 16 grey steps of the transparent ISO/IEC-test chart (produced by BAM) appear with the standard reflection of 2.5% equal compared to the 16 grey steps of the reflective test chart no. 3 (produced by DIN and JBMA).

For many working places the 5.0% reflection is more realistic (we have measured some by tele spectrophotometers) but the 2.5% reflection seems to be appropriate with the following improvements:

1. increasing luminance of the monitors
2. an anti reflective coating of the monitors surface
3. grey (and not white) clothes of the observers
4. grey walls opposite the screen.

The 2.5% reflection is chosen as standard in DIS ISO/IEC 19839-4:2001-09, see

http://www.ps.bam.de/IEDIS/IEDIS.HTM

3. Digital and analog ISO/IEC-test charts for printers and monitors

3.1 Content and output of the achromatic ISO/IEC-test chart no. 3

The **analog** test charts for the assessment of copier outputs are defined in ISO/IEC 15775. Corresponding ISO/IEC-test charts for the output on printers and monitors are defined in DIS ISO/IEC 19839-1 to -4 or DIN 33866-1 to -5. The original digital file format *PostScript* (PS) has been transformed to different equivalent formats, e. g. *Portable Document Format* (PDF) by the software *Adobe Acrobat Distiller*. The PS or PDF files with the intended colours have been used for the production of the **analog** ISO/IEC-test charts in Germany and Japan. According to ISO/IEC 15775 the **digital** ISO/IEC-test charts (digital files) are on the web servers, see the URL:

http://www.ps.bam.de

Analog ISO/IEC-test charts according to ISO/IEC 15775 and DIS 19839-1 to -4 or DIN 33866-1 to -5 have been produced in reflectance and transmittance mode for D65.

The achromatic ISO/IEC-test chart no. 3 is based on the standard contrast range of offset printing. The CIELAB lightness *L** varies between *L**=18.0 for black (N = french noir) and *L**=95.4 for white (W). There are different colour spaces and corresponding PostScript (PS) operators which allow to reproduce the 16 step equidistant grey colours, see Table 1.

We will study both the **printer device output with the reflective ISO/IEC-test chart** as reference (clause 4) and the **monitor device output with transparent ISO/IEC-test chart** as reference (clause 5).

Remark 1: In general the output of the digital ISO/IEC-test charts is different on the different devices, e. g. for different printers and different monitors. The CIELAB lightness *L** data of the output depend additionally on the colour space and the PS operators used and on the device output driver and on the software and hardware settings used, please make some tests with the files in Table 1 for your office equipment.

Remark 2: During the following tests it is necessary **not** to change any software and hardware settings. In case of the monitor output it is required that the room illumination in the office is constant during the test.

Remark 3: If **as reference** the ISO/IEC-test chart in **reflective** mode produced by DIN or JBMA is **not** available then an equidistant grey scale of a colour order system, e. g. the RAL Design System, may be used to determine the *L** data of the start grey scale output on the printer (see section 4)

Remark 4: If **as reference** the ISO/IEC-test chart in **transparent** mode produced by BAM is **not** available then the start grey scale output on the monitor may be used as a reference for the training of the method and the “linearisation” of the monitor output (see section 6)

3.2 ISO/IEC-test chart no. 3 (NP-file) using the PS operator *L* setcolor*

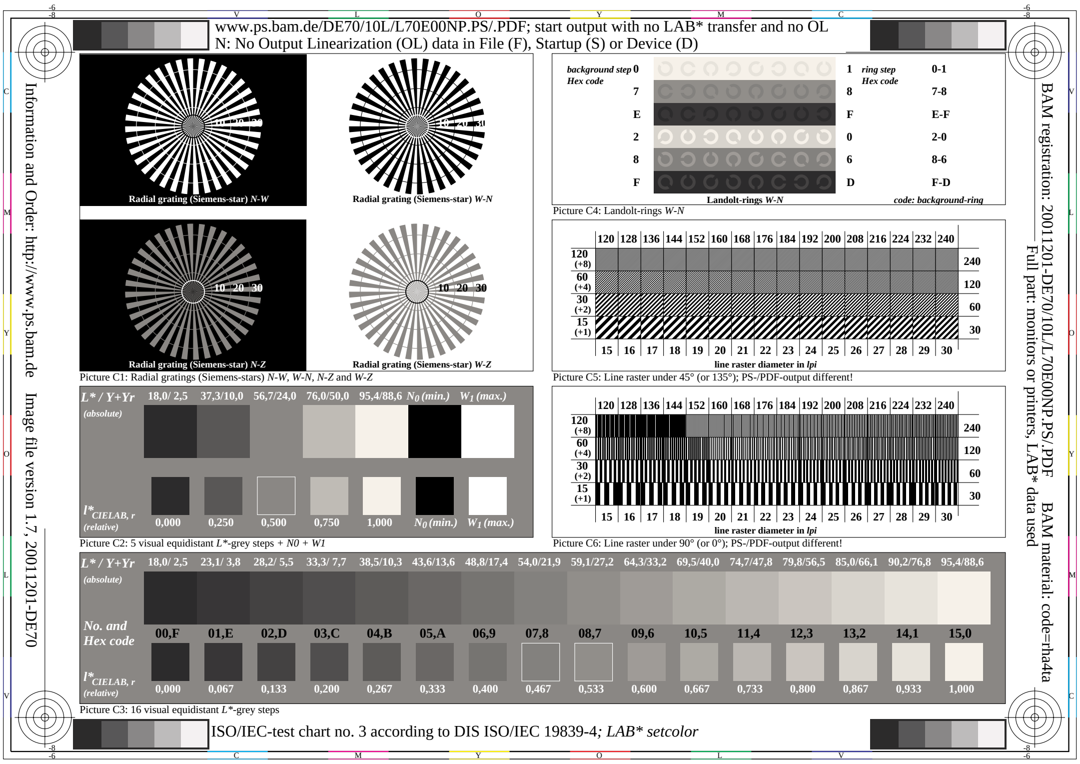

Figure 3: Frame and picture area of ISO/IEC-test chart using the PS operator *L* setcolor*

Fig. 3 shows the output for the PS operator *L* setcolor.* White appears greyish compared to the white paper and black appears greyish compared to the offset black. The PS operator *L* setcolor* produces the correct white and black only if the lightness *L**=100 and *L**=0 are used for white and black and not *L**=95.4 and *L**=18.0. Fig. 3 has been produced by the NP-file:

www.ps.bam.de/DE72/10L/L72E00NP.PDF

3.3 ISO/IEC-test chart no. 3 (CP-file) using the PS operator *w* setgray*

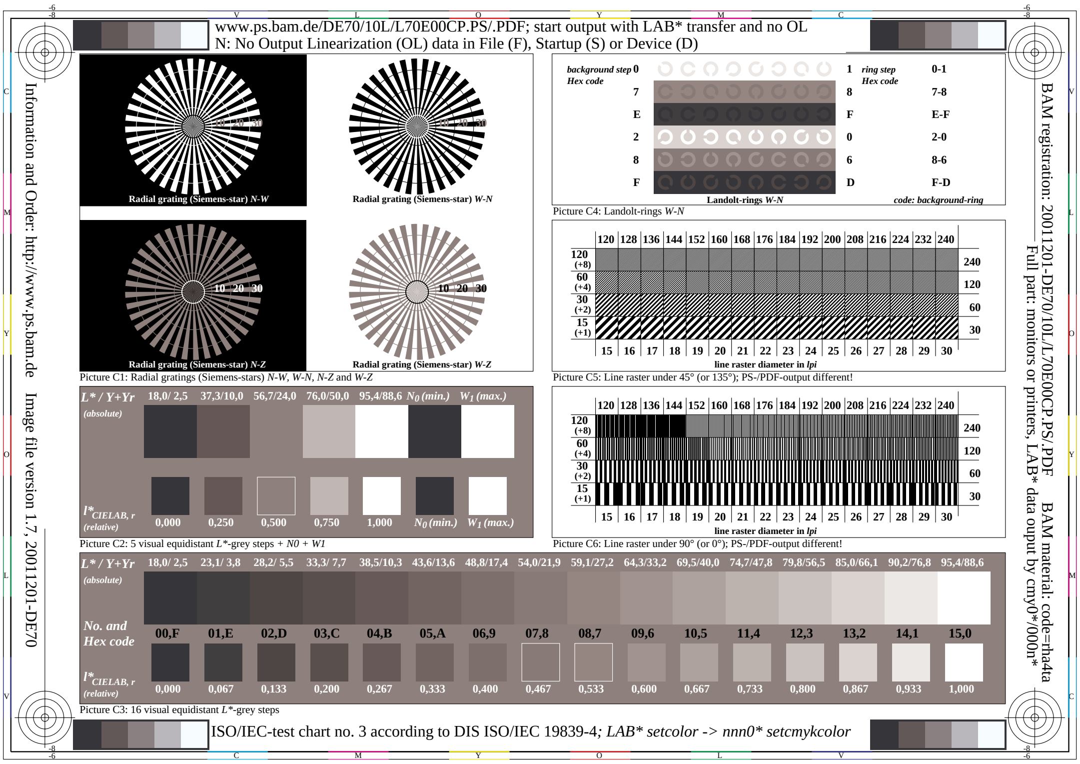

Figure 4: Frame and picture area of the ISO/IEC-test chart using the PS operator *w* setgray*

Fig. 3 and 4 show the output for the PS operators *L* setcolor* and *w* setgray*. The CIELAB lightness *L** and the relative lightness *w* = (L* - L*n) / (L*w - L*n) = (L** - 18.0) / (95.4 - 18.0) is used. The output is different. The output failure of Fig. 3 for white and black is corrected in Fig. 4. Fig. 4 has been produced by the CP-file:

www.ps.bam.de/DE72/10L/L72E00CP.PDF

Within the file the PS operator *L** is transferred to *w* setgray*. In general the spacing of the 16 grey steps of a device is different compared to the standard spacing with an *L** difference of 5.2 between two neighbouring grey colours. It is intended to see all the 16 steps and to make them equidistant. This reference spacing is realized in the standard ISO/IEC-test chart no. 3 produced by DIN and JBMA.

Remark: There are other methods to transfer *L* setcolor* to *nnn0* setcmykcolor*, *000n* setcmykcolor* or to *www* setrgbcolor*. The output spacing may be different compared to the output spacing of *w* setgray*. It is intended to have the same output spacing independent of the colour space and the PS operator used. To reach this goal it is required to use instead of *w* setgray* the other PS operator *nnn0* setcmykcolor*, *000n* setcmykcolor* or *www* setrgbcolor*. Files for this other cases are available, compare Table 1.

There are two methods to make the output spacing equidistant. Use one of the two methods:

1. visual method by visual comparison of the grey output with the reference *L** grey samples and a
2. colorimetric method by lightness *L** measurement of the grey samples of the output.

In both cases it is required to determine the 16 *L** lightness data of the output. compare clause 5 to 7.

3.4 ISO/IEC-test chart no. 3 (FP-file) changing the PS operator *w* setgray to w'*setgray*

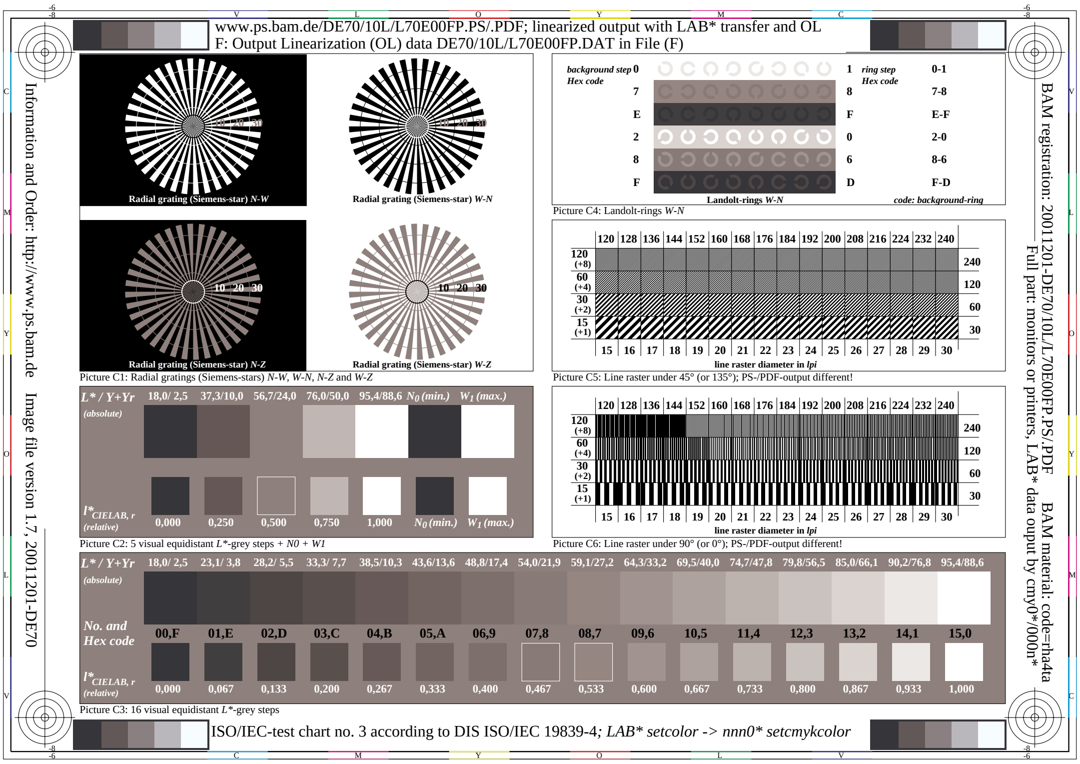

Figure 5: Frame and picture area of ISO/IEC-test chart and changing *w* setgray* to *w'* setgray*

Fig. 5 is produced by the **FP-file** which includes equally spaced measurement data. The *L** data in the FP-file are identical to the reference data *L**=18.0, 23.2, ...,90.2, 95.4.

The visual method is based on the visual comparison of the 16 step grey output, e. g. of a printer, with the DIN reference test chart no. 3 according to DIN 33 866-1 (which corresponds to ISO/IEC 15775 and DIS ISO/IEC 19839-1). In this case the DIN-test chart no. 3 allow to determine visually the lightness *L** for the 16 grey steps of the output.

Remark 1: For the visual determination of the *L** output data the grey output samples may be cutted within the middle (compare Fig. 6) and then compared sample by sample with the reference. Each reference sample has an *L** data and the visual *L** data may be determined by visual interpolation. If two black samples look very similar then e. g. 19.0 and 19.1 may be used to indicate this similarity. It is required to produce visual monotonic (increasing) *L** data for the 16 steps between black and white.

Remark 2: Any other colour order system, e. g. the RAL Design System with a reference *L** grey scale between

*L**=15 and *L**=90, may be used instead to determine the lightness *L** for the 16 grey steps of the output if the DIN-test chart or the ISO/IEC-test chart in reflective mode are not available.

The colorimetric method is based on the measurement of the 16 step grey output, e. g. of a printer. There are different CIELAB measurement devices on the market, e. g. the *Colour Mouse* device of *Colour Savyy (about $500)*, which allow to measure the *LAB** data with any notebook computer.

4. Comparison of printer output and reflective ISO/IEC-test chart as reference

4.1 Reflective colours on a printer

The output of the digital test chart shown in Fig. 5 is used to compare sample by sample with a reference, either

1. the reflective ISO/IEC-test chart no. 3 with the lightness *L** between *L**=18.0 and *L**=95.4 or
2. a colorimetric grey scale of a color order system, e. g. the CIELAB *RAL Design System* with 16 samples between *L**=15 and *L**=90. Fig. 5 is produced by the **FP-file**

http://www.ps.bam.de/DE72/10L/L72E00FP.PS

which includes equally spaced (L=linear) measurement data. The *L** data in the FP-file are identical to the reference data *L**=18.0, 23.2, ...,90.2, 95.4. This file may be used for output on printers and for the measurement of the start and linearized output.

4.2 Procedure for the comparison of the printer and the reflective reference output

There are different steps for the linearisation of the printer output

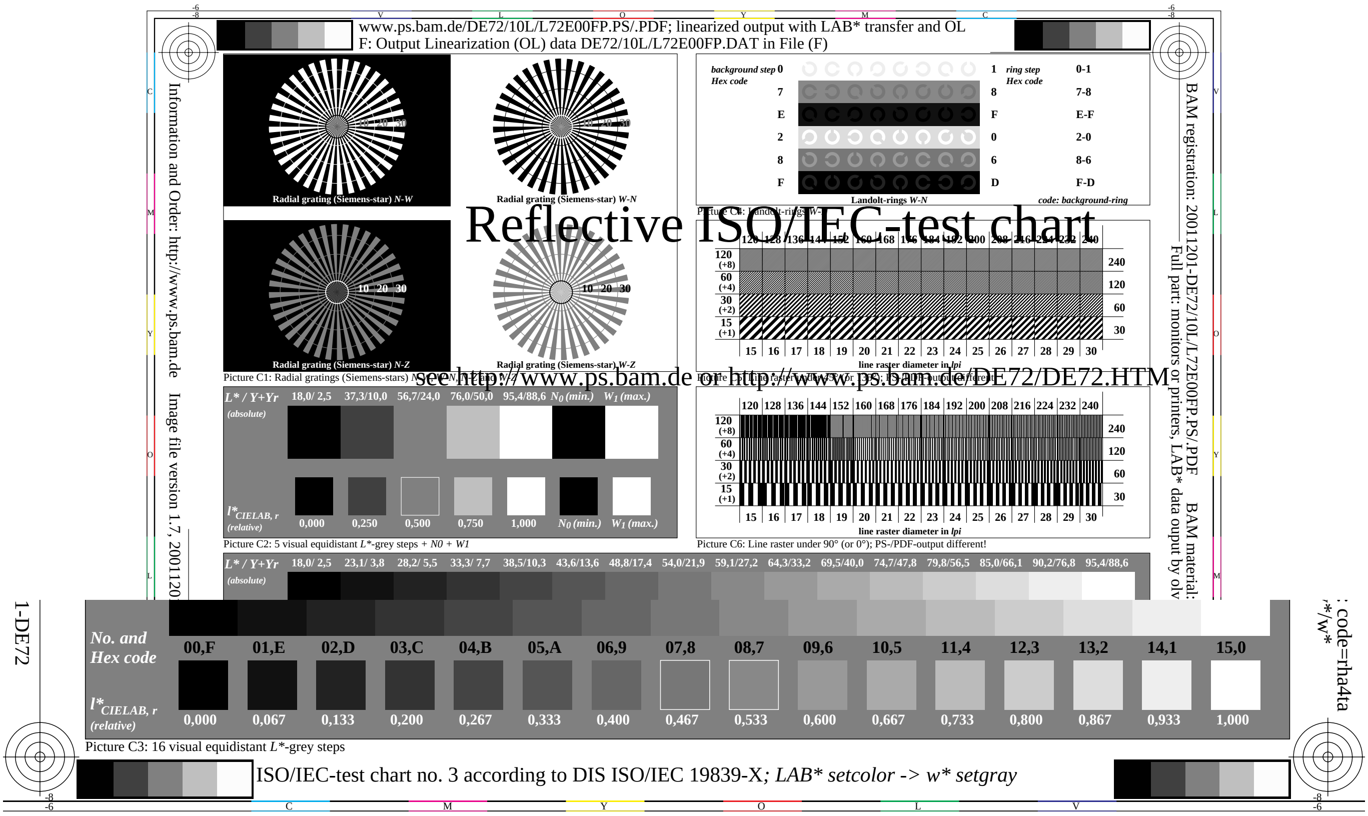

Figure 6: Comparison of the 16 grey samples of the lower and the upper part of Fig. C3

In Fig. 5 and 6 the PS operator *w* setgray* is used. The greys in the lower part must be compared with the greys of the upper part. It is required to evaluate the *L** data of the 16 steps sample by sample. Use for the following test the file (00FP full part of test chart). One can either measure the lightness *L** of the output or one can cut the ouput according to Fig. 6 for the visual comparison of the lower grey output with the DIN- or ISO/IEC-reference.

http://www.ps.bam.de/DE72/10L/L72E00FP.PS

Step 1: Determine visually (or by *L** measurement) the **new** 16 *L** lightness data:

The result may be the following *L** data table, which includes 16 monotonic (increasing) data (compare Fig.7):

```
16.6, 21.9, 27,2, 32,5, 37.8, 43.1, 48,4, 53.7,
```

59.0, 64.3, 69.6, 75,0, 80.3, 85.6, 90.9, 96.0

Step 2: Replace the **old** 16 *L** lightness data:

18.01, 23.17, ... , 90.25, 95.41

(which are equidistant in CIELAB L*) by the **new** *L** data at the beginning of the FP-file by any text editor, see http://www.ps.bam.de/DE72/10L/L72E00FP.PS

Step 3: Save the corrected file with the new data and use the file name L72E00FP**1**.PS. Produce the PDF file L72E00FP**1**.PDF with the software *Adobe Acrobat Distiller* or equivalent.

Step 4: Compare the printer output of the file L72E00FP**1**.PDF with the reference (equidistant reflective ISO/IEC-test chart no. 3 in offset printing of DIN or JBMA as reference).

Result: The output spacing of the 16 steps appears equal in the case of approximately equal black and white compared to the reference. In many cases the black of the printer output is lighter compared to the offset black. Still in this cases the spacing of the 16 steps appears equal. This may be proved by colorimetric measurement of the "linearized" output with the intended linear input – output relationship. Fig 7 shows an example for a real new PostScript printer. The improvement between the start and linearized printer output is about a factor 6.

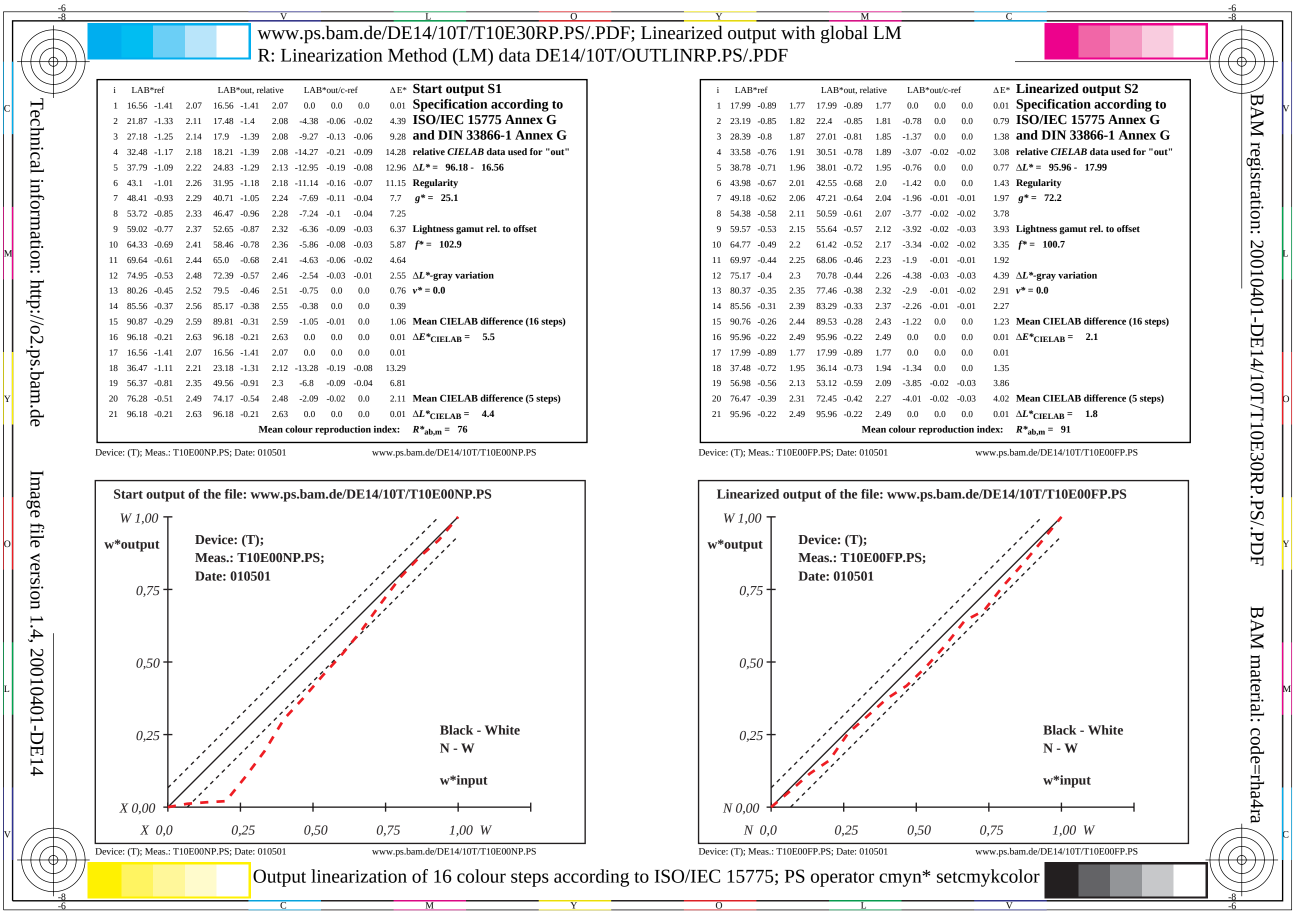

Figure 7: Input - Output relationship of the start output and the linearized output of a printer

Fig. 7 shows an example for the relationship between the input and output data for the start and linearized output. The measurement data of a start output one can find within the MTL code at the beginning of the file belonging to Fig. 5. The URL is given at the top.

It is required to replace the old L=Linear *L** data by the new *L** data of the start output to get the linearized output. The final input – output relationship is shown on the right side of Fig. 7. In the original ISO/IEC-test chart file the device independent CIELAB *L** data are used. The *L** data are first transferred to relative whiteness *w** and then to the inverse relative whiteness w'* (star-dash). The following files use the following PS operators:

1. The **NP**-file uses the PS-operator *L* setcolor*
2. The **CP**-file uses the PS-operator *L* setcolor* and transfers to *w* setgray*
3. The **FP**-file uses the PS-operator *L* setcolor* and transfers to *w* setgray* and then transfers to *w'* setgray*

If the L=Linear data are in the FP-file, then the inverse image data w'* (dash-star) are identical to the *w** (star) data.

Remark: For the L=Linear data the inverse data are the L=Linear data. For the Q=Quadratic data the inverse data are the S=Square root data. For S=Square root data the inverse data are the Q=Quadratic data. For any 16 step monotonic (increasing) data series the inverse data can be calculated easily.

5. Comparison of monitor output and transparent ISO/IEC-test chart as reference

5.1 Luminous colours on a monitor

The file output of the digital ISO/IEC-test chart on a monitor appears luminous. The comparison of this output with a reference output in luminous mode (transparent test chart) is easier then a comparison with a reference output in reflective mode (reflective test chart). We will compare here the digital output on the monitor with the analog reference test chart both in luminous mode.

The **transparent** ISO/IEC-test chart no. 3 which is available and then fixed on the white monitor screen produces an equidistant grey series in luminous mode for the standard 2.5% reflection on the monitor (or on the film material) surface. The transparent ISO/IEC-test chart is produced on black and white imaging film material which has a contrast range of 1: 10.000 between white and black. Contrast ranges larger then 1:300 and up to 1: 255^2 = 1:65.000 may be measured on monitor screens.

5.2 Standard 2.5% reflection if the monitor colours are viewed

The room illumination in the office reduces the contrast range of 1:10.00 down to 1:35 (= 2.5:88.6 which corresponds to L*n=18 or Yn=2.5 for black N and L*w=95.4 or Yw=88.6 for white W). The contrast range depends on the reflection properties of the monitor surface, the white monitor luminance and the illuminance in the office. There is a CIE recommendation for an illuminance of 500 lux in the office which corresponds to 160 (= 500 / 3.14) cd/m^2. Modern CRT monitors have a similar luminance. In the standard case of DIS ISO/IEC 19839-4:2001-09 a reflection luminance of 2.5% compared to the white monitor luminance is assumed. About 2.5% which are reflected by the surface of the monitor screen in the direction of the eyes of the observer who sits in front of the monitor reduce the contrast to 1:35.

Modern LCD monitors may have a white luminance up to 300 cd/m^2. But at present the colours of the LCD monitors are additionally much dependent on the viewing angle and therefore they are not appropriate for colour reproduction and comparison. New LCD monitors based e. g. on the *OSRAM PLANON* flat area lamp show much less dependence on the viewing angle and have twice the luminance. At present a reflection luminance of 5% (contrast range 1:18) is often more usual at many office working places, compare the data in Table 4.

If the contrast is less (e. g. 1:18) compared to the standard case 1:35 at the office working place (compare the black on the monitor with the black on the reflective ISO/IEC-test chart no. 3) this is not so critical for the following test. The change from 2.5% to 5.0% reflection shifts the scale by 9 in lightness *L** which is half compared to the change from 0.0% to 2.5% reflection with a shift of 18 in lightness *L** (compare Table 3 and 4).

There are different methods to increase the present contrast in the offices from 1:18 (Yr=5%) to about 1:35 (Yr=2.5%), e. g. by increasing the monitor luminance, by the reducing the room illumination, or by using darker walls opposite to the monitor, or by changing light clothes of the observer to darker clothes.

5.3 Procedure for the comparison of the digital and the transparent reference output

The output of the 16 steps of the file L72E02FP.PDF (02FP=lower part) must be compared sample by sample with the output of the file L72E01FP. PDF (upper part), compare Fig. 6 for the case of printers

If the **transparent** test chart is available then choose the **transparent** ISO/IEC-test chart no. 3 as **reference** (available from BAM with the label L72E01FP.PDF (01FP: upper part of the test chart)).

If the **transparent** test chart is NOT available then choose the output of the **digital** ISO/IEC-test chart no. 3 as **reference.** This test with the file F72E01FP.PDF (01FP: upper part of the test chart) is described in clause 5.

In summary he **reference** output is either the transparent ISO/IEC-test chart (this section) or the output of the corresponding digital ISO/IEC-test chart file (next section).

Remark: The procedure is described in the following for the test chart files L72*FP.PDF. The files L7i*FP.PDF (i=0,1,3,4,..,9) may be used instead. In all cases the same transparent ISO/IEC-test chart no. 3 according to ISO/ IEC 15775 (available from BAM) serves as reference.

For the following test it is required to fix the **transparent** ISO/IEC-test chart no. 3 on a white monitor screen. There are three versions of the **transparent** ISO/IEC-test chart no. 3:
1. the full part (00FP) which includes all the figures. C1 to C5 of the ISO/IEC-test chart no. 3, compare Fig. 5

2. the upper part (01FP) where the lower part of the 16 step grey scale in Fig. C3 is missing, compare Fig. 8
3. the lower part (02FP) with only the lower part of the 16 step grey scale in Fig. C3, compare Fig. 8

Step 1: Produce the output of the file L72E02FP.PDF (02FP: lower part of Fig. C3) on the monitor by the software *Adobe Reader* or equivalent. Use the option "magnify to 150%" of *Adobe Reader* to produce larger samples of this output compared to the reference. Magnification will show horizontal and vertical rulers which allow to shift the grey samples vertically and horizontally for any later comparison.

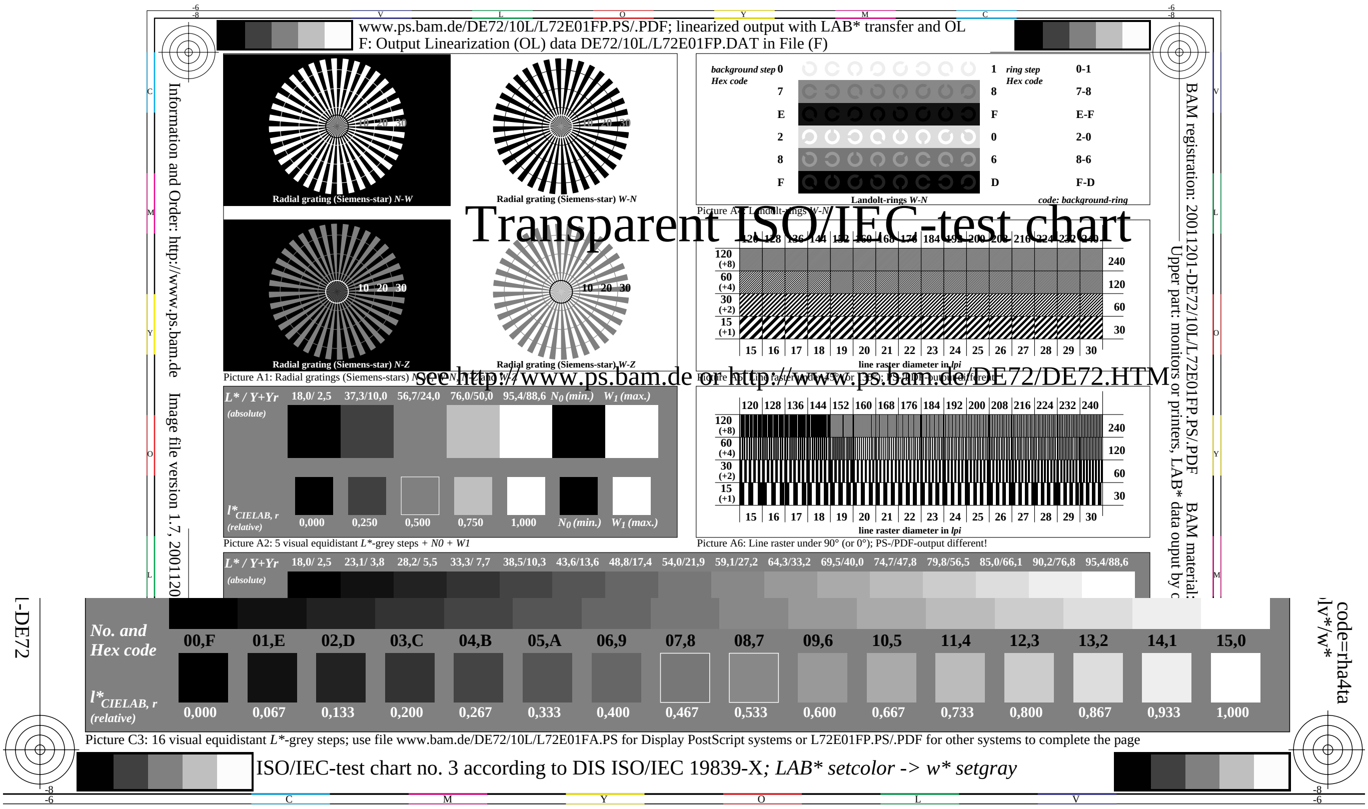

Figure 8: Comparison of the digital and the transparent reference output

Step 2: Shift the window with the 16 grey steps to the lower part of the monitor screen and use the large upper white part to fix the transparent ISO/IEC-test chart no. 3 on the white monitor screen. The grey samples of the transparent test chart may be fixed adjacent to the grey samples of the digital output, see Fig. 8.

Step 3: The 16 grey samples of the digital output of the file L72E02FP.PDF (02FP: lower part of Fig. C3) must be compared sample by sample with the reference.

Remark: It is recommended to shift for this comparison any sample by the vertical and horizontal rulers of the Acrobat Reader window. The whole window may be shifted in case of larger differences.

Remark: The white samples 15,0 of the reference and the digital output are the same. The black samples will appear the same if the monitor screen is adjusted to black (In this case the standard PAL monitor produces for the digital input value 1/255 the monitor luminance (1/255)*(1/255)=1/100.000 which appears equal black compared to the transparent reference with the contrast range 1:10.000). Then compare the remaining 14 samples and determine the L^* data by visual comparison and interpolation of the L^* lightness data.

Step 4: Replace in the file L72E02FP.PS the original (L=Linear) data of the series white-black W-N by the visual comparison data by any editor, e. g. the observer visual estimation 18.0, 18.4, 19.4, ..., 85.4, 95.4 must replace the old data 18.01, 23.17, ... , 90.25, 95.41 (which are equidistant in CIELAB L^*, compare Table 3).

Step 5: Save the corrected file with the new data and use the file name L72E02FP**2**.PS. Produce the PDF file L72E05FP**2**.PDF with the software *Adobe Acrobat Distiller*.

Step 6: Compare the monitor output of the file L72E02FP**2**.PDF with the reference

Result: The output of the 16 steps appears equal for the digital output and transparent ISO/IEC-test chart as reference!

Remark 1: If a *Display PostScript System (e. g. Mac OS X Server, Application Yap)* is used for the test, then it is recommended to use the FA.PS files (the PF.PDF files only distinguish by output name from the FA.PDF files and the "P" indicates the "PDF file" method used).

Remark 2. Different versions of the software *Adobe Acrobat Distiller* may produce different PDF files with different output. If the PDF files are used for the test then it is recommended NOT to use the PDF files from the BAM server but to download the corresponding PS files and to use the local *Adobe Acrobat Distiller* version with the local settings of this software to transfer the PS files to the PDF files for the whole test.

6. Comparison of monitor output and digital ISO/IEC-test charts as reference

6.1 Luminous colours on a monitor

It is intended to produce both the **upper part and the lower part** of the ISO/IEC-test chart no. 3 by a **digital** file. It is intended to compare the **start** output of the **lower part** with the **upper part** which serves as **reference**.

Remark: This reference may not show 16 steps which are equally spaced.

This section simulates the **linearisation** method. This section is appropriate if a transparent ISO/IEC-test chart is **not** available. Fig. 8 has shown the content of the **transparent** ISO/IEC-test chart no. 3. Now instead of fixing the **transparent** ISO/IEC-test chart on the white monitor screen the **digital** ISO/IEC-test chart no. 3 (the file L72E01FP.PDF) is used to produce an **analog** output on the screen as **reference.**

Remark: It may happen that the digital output of the file L72E01FP.PDF may not look like the 16 step grey output with 16 equidistant gray steps. In a worse case less then 16 different grey steps may be produced on the monitor by the digital file L72E01FP.PDF. But even less than 16 steps will not destroy the value of the following comparison test procedure.

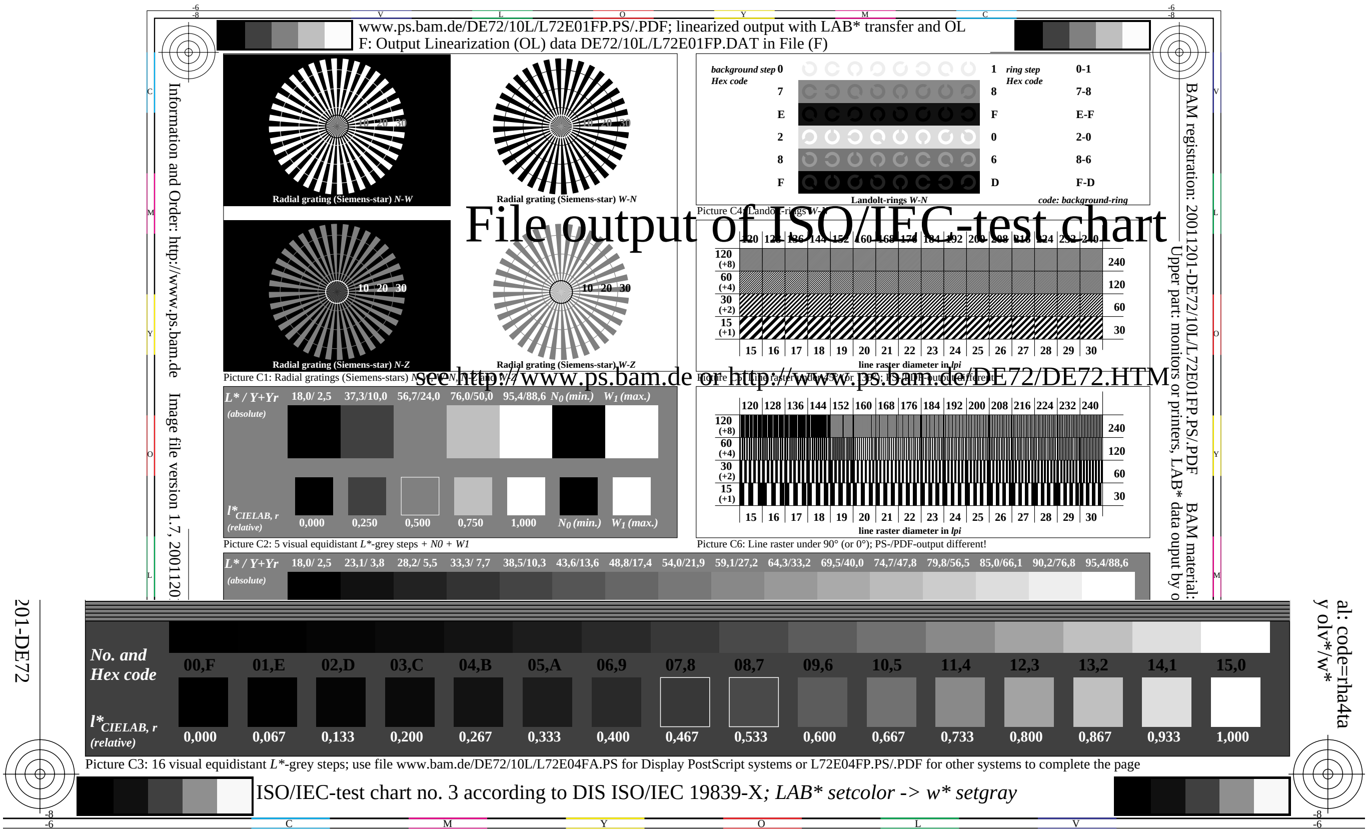

Figure 9: Comparison of the two digital file outputs of the upper and lower part of the ISO/IEC-test chart

6.2 Procedure for the comparison of the digital and the digital reference output

Step 1: Produce the output of the file L72E05FP.PDF (05FP: lower part of Fig. C3) on the monitor by the software *Adobe Reader* or equivalent. Use the option "magnify to 150%" of *Adobe Reader* to produce larger samples of this output compared to the reference. Magnification will show horizontal and vertical rulers which allow to shift the grey samples vertically and horizontally for any later comparison. Shift the window with the 16 grey steps to the lower part of the monitor screen. Use the vertical rulers to locate the 16 steps at the upper border (about 6 mm) of the *Adobe Reader* screen.

Step 2: Produce the output of the file L72E01FP.PDF (01FP: upper part of the test chart) on the monitor by the software *Adobe Reader* or equivalent. Shift the window of the lower part adjacent, compare Fig. 9.

Remark: We have not found a way to delete the *Adobe Reader* border, so it is not possible to have the grey steps directly adjacent, compare Fig. 9.

Step 3: The 16 grey samples of the digital output of the file L72E05FP.PDF (05FP: lower part of the test chart, only lower part of Fig. C3) must be compared sample by sample with the reference.

Remark: It is recommended to shift for this comparison any sample by the horizontal rulers of the lower Acrobat Reader window. The whole lower window may be shifted in case of larger differences.

Remark: The white samples 15(0) of the reference and digital output are the same. The black samples will appear the same if the monitor screen is adjusted to black (In this case the standard PAL monitor produces for the digital input value 1/255 the monitor luminance (1/255)*(1/255)=1/100.000 which appears equal black compared to the transparent reference with the contrast range 1:10.000). Then compare the remaining 14 samples and determine the *L** data by visual comparison and interpolation of the *L** lightness data.

Step 4: Replace in the file L72E05FP.PS the original (L=Linear) data of the series white-black W-N by the visual comparison data by any editor, e. g. the observer visual estimation 18.0, 18.4, 19.4, ..., 85.4, 95.4 must replace the old data 18.01, 23.17, ... , 90.25, 95.41 (which are equidistant in CIELAB *L**, compare Table 3).

Step 5: Save the corrected file with the new data and use the file name L72E05FP**3**.PS. Produce the PDF file L72E05FP**3**.PDF with the software *Adobe Acrobat Distiller*.

Step 6: Compare the monitor output of the file L72E05FP**3**.PDF with the reference

Result: The output of the 16 steps appears equal for the digital output and transparent ISO/IEC-test chart as reference!

Remark 1: If a *Display PostScript System (e. g. Mac OS X Server, Application Yap)* is used for the test, then it is recommended to use the FA.PS files (the PF.PDF files only distinguish by output name from the FA.PDF files and the "P" indicates the "PDF file" method used).

Remark 2. Different versions of the software *Adobe Acrobat Distiller* may produce different PDF files with different output. If the PDF files are used for the test then it is recommended NOT to use the PDF files from the BAM server but to download the corresponding PS files and to use the local *Adobe Acrobat Distiller* version with the local settings of this software to transfer the PS files to the PDF files for the whole test.

7. Output procedures of digital ISO/IEC-test chart no. 3

7.1 Use of the PostScript MTL code for output of the digital ISO/IEC-test chart no. 3

Within the PostScript FP-file the **MTL** (Measurement, Transfer and Linearisation) **code transfers from the absolute *L** coordinates to the relative *w** coordinates**. For this the **MTL code uses a PostScript program code procedure LAB*_to_cmy***. This MTL PS code forms the file header and makes the calculations within the file if the device output is produced. There are at least three other methods to determine the output in the intended direction. This paper uses the **MTL code in the file header** but it can be stored instead in:

1. The *PostScript* printer memory (M)
2. The *PostScript* Printer Driver (D) (in the PPD file)
3. The *Adobe Acrobat Distiller* Startup (S) directory.

The method no. 3 can be used for both printers and monitors, compare Fig. 11

The **MTL code** (MTL Measurement, Transfer and Linearisation) includes a Colour Measurement (CM) data table of the 128 standard colours, the Colour Coordinate Transfer (CT) code, the Input Linearisation (IL) code (for scanners) and the Output Linearisation (OL) code (for printers and monitors). In some output examples only parts of a general standard MTL code are used.

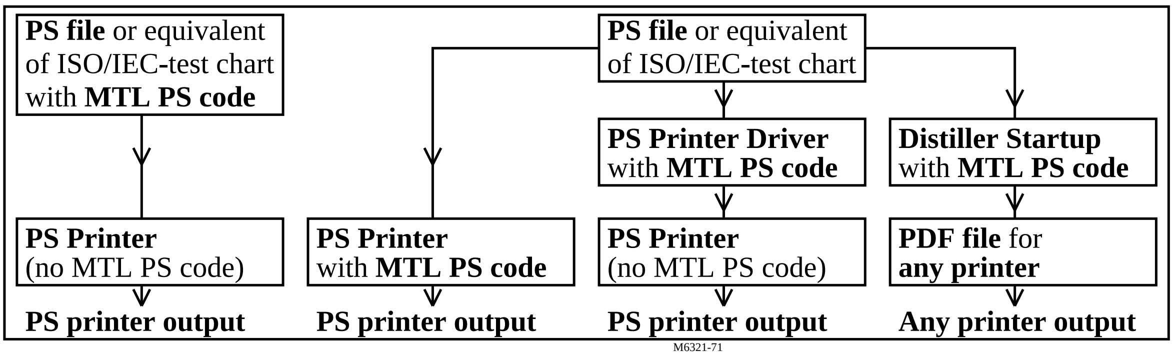

Figure 10: MTL (Measurement, Transfer and Linearisation) PS code and Printer Output

Fig. 10 shows the different possibilities how to use the MTL code within the CIELAB - *w** colour workflow. The PS file of an ISO/IEC-test chart is used for output.

Any PS file (according to our experience) which can be produced from **any application** on **any computer operating system** is **varied by this MTL code** in the same manner if this **MTL code is stored on one of the four different places:** the file, the PS printer device, the PPD file, the Distiller startup, see Fig. 11

The Distiller startup directory will add this code to the PS file to be distilled and will therefore change the produced PDF file. The produced PDF file will change the output on any device in the intended direction.

7.2 Use of the MTL code for printers and monitors within the *Distiller Startup Directory*

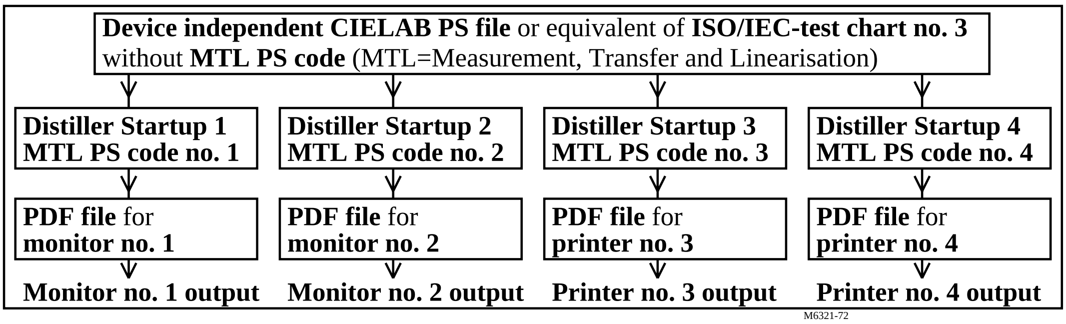

Figure 11: Four Distiller Startup Directories with 4 MTL PS codes for output on 2 printers and 2 monitors

Fig. 11 shows an **ISO/IEC-test chart file with device independent colour definition in CIELAB colour space** within the PS file. The PS-format will be transferred by *Adobe Acrobat Distiller* to a PDF-file for output on any device. There are four copies of the *Adobe Acrobat Distiller* program on the desktop in four different directories. Each directories has its own *Distiller Startup* subdirectory. The four subdirectories differ by the four **PS MTL codes measured for four different devices** (2 printers and two monitors, one monitor may be a video beamer). The four MTL codes are specific for the four different output devices. The PS-file of the ISO/IEC-test chart with device independent colours will produce four different PDF-files intended for the output on two different printers and on the two different monitors.

With the present software version of the PS MTL code the output of the 16 grey steps will be equally spaced in relative CIELAB colour space on all four output devices. The spacing is equal according to CIELAB between the device dependent black and white of the different devices.

Remark: The MTL code includes **absolute** CIELAB data of the devices. In one of the next versions of the software the reproduction in **absolute** CIELAB space will be implemented. For examples some photo printers have a larger lightness range e. g. between L^*=10 and L^*=96 compare to the standard offset range. It will be possible to reproduce exactly the offset contrast range and the offset spacing between L^*=18 and L^*=95.4, compare Table 2, on all devices with a high contrast range.

8. Summary

The BAM was the leader for the development of the **analog and digital DIN- and ISO/IEC-test charts** to be used for the different colour office devices, e. g. colour copiers, printers, monitors and scanners.

Within the digital files of this paper the **colours of the ISO/IEC-test charts** are defined by ***LAB** *(CIELAB) data** which are transferred to relative whiteness ***w** *data** within the files.

The relative whiteness *w** and the relative blackness *n*=1-w** data are used by different PS-operators: *w* setgray, www* setrgbcolor, nnn0* setcmykcolor, 000n* sercmykcolor.*

Output Linearisation (OL) produces linear scales in both *LAB and *w** space** for the colours in the ISO/IEC-test charts.

The **reproduction property** of the intended colours is in many cases for **linearized** devices within the intended accuracy for offices (3 in CIELAB)

If a colour management method is already included in the colour workflow it is expected that the new method improves the output.

In many cases the new method is satisfying the imaging demands in offices to a high degree. There may be no need for other colour management methods in the office.

Remark: According to a New Work Item (NWI) of ISO/IEC JTC1/SC28 (international vote published in Nov. 2001) the linearisation procedure will appear in an ISO/IEC JTC1/SC28 technical report with K. Richter as editor.

9. References

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DIN 33866-4, Edition:2000-10; Part 4: Method for specifying image reproduction of colour devices by analog input and digital output for colour image reproduction devices: analog - digital (scanners) - Realisation and application
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