Development of analog and digital ISO/IEC- and DIN-standards for specifying image reproduction and for colour management

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Abstract

The four analog ISO/IEC-test charts in reflectance mode according to ISO/IEC 15775 are designed for the test of colour copiers. The test charts include many image elements. e. g. Siemens-stars, Landolt-rings and 16 step equally spaced colour scales according to CIELAB. Most important for image technology is the ISO/IEC pictorial image B1 which includes a 16 step grey scale and 16 CIE-test colours.This image comes in 5 resolutions between 128 x 192, 256 x 384, and 2048 x 3096 pixels. For analog production the digital ISO/IEC-test charts are described in ISO/IEC 15775.

Some applications of the digital and analog ISO/IEC-test charts for printers, monitors and scanners will be discussed. Recently three methods to optimize the ISO/IEC-test chart output have been developed. Between the digital input values and the CIELAB colour difference of the 16 step colour series a linear relationship is produced. This linear property allows new and very simple colour management methods. The application of these methods for the production of the reference ISO/IEC-test charts and for colour management of slide and negative film images as function of exposure is shown.

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 Standard DIS ISO/IEC 19839-X are based on equivalent colour series. Both use **digital** and **analog** test charts and approximately the same layout. Fig. 1 shows 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.

Input	Output	Input and output media and applications			Standard or Draft
		Input media	Output media	Application	
-	-	-	-	**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**

Figure 1: Analog and digital ISO/IEC-test charts according to ISO/IEC 15775 and DIS ISO/IEC 19839-1 to -4.

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**

INFDE000:DETNK00.PS

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

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 in application for colour devices now.

The different productions will be shown, e. g. in halftone and continuous tone and in reflectance and transmittance mode. Some problems of measurement (e. g. fluorescent photographic material) and the accuracy of production is important for applications.

A flat area lamp which is shown at this workshop has the chromaticity of D65. A transparent ISO/IEC-test chart on top of this equipment defines a reference monitor for comparison with display output.

1. Digital and analog ISO/IEC-test charts and reproduction

1.1 General

The **digital** and **analog** test charts for the assessment of copier outputs are defined in ISO/IEC 15775. The original digital file format *PostScript* (PS) is transformed to different equivalent formats, e. g. *Portable Document Format* (PDF).

According to ISO/IEC 15775 the **digital** ISO/IEC-test charts (digital files) are on the web server with the URL: http://o2.ps.bam.de and www.ps.bam.de.The **analog** ISO/IEC-test charts according to ISO/IEC 15775 will be produced in reflectance and transmittance mode for D65 illumination.

1.2 Content of test charts

There are two achromatic ISO/IEC-test charts with high and medium lightness contrast which is used in Photography and offset printing. The two chromatic ISO/IEC-test charts are defined by the three primary colours CMY and the three mixture colours OLV of this primary colours. Fig. 3 and 4 show two ISO/IEC-test charts, one achromatic and one chromatic. The test charts include a frame and picture area with different test elements like Siemens-stars, Landolt-rings and line screens. All colours in the standard are defined by CIELAB data based on the CIELAB coordinates of offset printing for D65 [3

1.3 Content of achromatic ISO/IEC-test chart no. 3

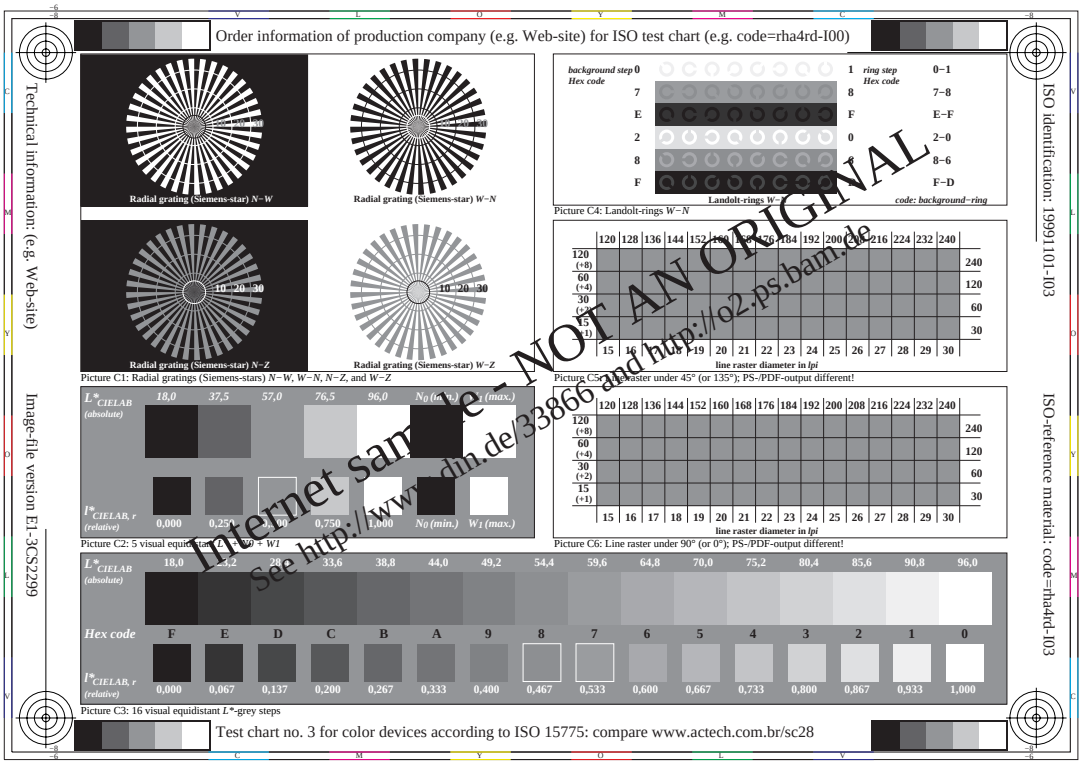

Figure 3: Frame and picture area of ISO/IEC-test chart no. 3 according to ISO/IEC 15775

1.4 Content of chromatic ISO/IEC-test chart no. 4 with *OLV*-colours

Figure 4: Frame and picture area of ISO/IEC-test chart no. 4 according to ISO/IEC 15775

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Basic test colour name	Intended CIELAB data CMYN (ISO 2846−1) Reference (r)			Intended CIELAB data RGB (ITU-R BT.709-2) Output (o)			CIELAB differences of test colours Difference (o−r)			CIELAB-test colour difference
	L^*_r	a^*_r	b^*_r	L^*_o	a^*_o	b^*_o	ΔL^*_{o-r}	Δa^*_{o-r}	Δb^*_{o-r}	ΔE^*_{ab}
C	58.62	−30.62	−42.74	86.88	−46.17	−13.56	28.26	−15.54	29.18	43.5
M	48.13	75.2	−6.79	57.3	94.35	−20.7	9.17	19.15	−13.9	25.38
Y	90.37	−11.15	96.17	92.66	−20.7	90.75	2.29	−9.54	−5.41	11.22
O	47.94	65.31	52.07	50.5	76.92	64.55	2.56	11.61	12.48	17.24
L	50.9	−62.96	36.71	83.63	−82.76	79.9	32.73	−19.79	43.19	57.69
V	25.72	31.45	−44.35	30.39	76.06	−103.59	4.67	44.61	−59.23	74.31
N	18.01	0.5	−0.46	1.57	0.0	0.0	−16.43	−0.49	0.47	16.45
W	95.41	−0.98	4.76	95.41	0.01	0.01	0.0	1.0	−4.74	4.85
Average CIELAB colour difference:									$\Delta E^*_{ab,m}$ =	***31.3***

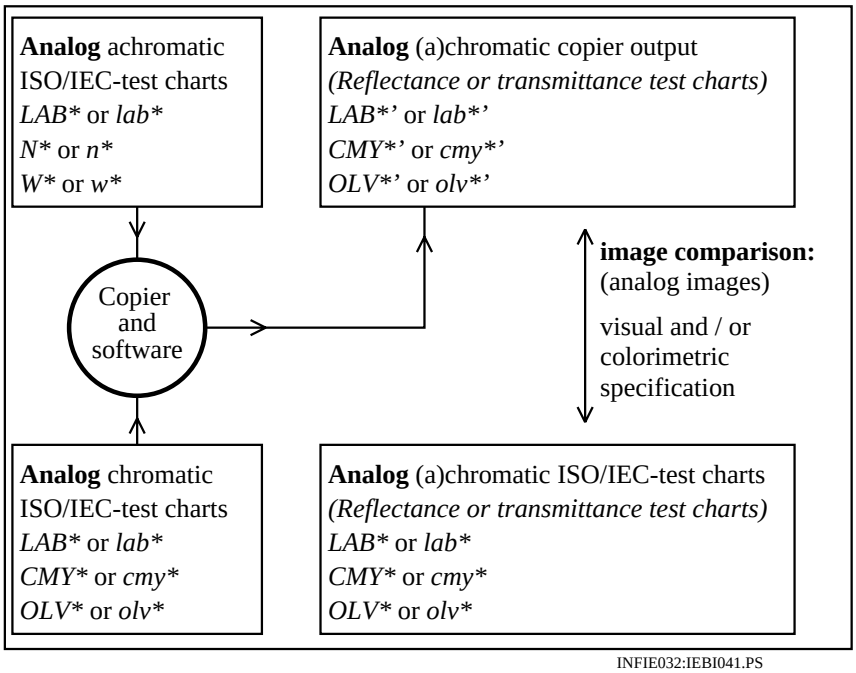
INFDE031:DETA131.PS 2x2

Table 1: Intended printing (PR) and television (TV) colours and comparison

Table 1 shows the printing colours compared to the television colours defined in ITU-R BT709.2 for CIE-standard illuminant D65 and the 2°-standard observer. Table 1 shows the differences between the colours $CMYOLVNW_{PR}$ and $CMYOLVNW_{TV}$. There are differences up to ΔE^*_{ab} = 74 for the colour violet blue *V* (called blue *B* in television) and the average difference is $\Delta E^*_{ab,m}$ = 31,5. This is about ten times the difference which a user accepts as tolerance. The user often wishes a colorimetric reproduction and then the colour properties of the different devices must be linearized. This linearization is often sufficient for a colorimeric reproduction in offices or serves as setup-state for colour management.

2. Reproduction processes analog – digital – analog

2.1 Copier analog - analog reproduction



INFIE032:IEBI041.PS

Figure 5: Colour output of the analog ISO/IEC-test charts on a colour copier

Fig. 5 shows the image comparison of the copier output with the original

2.2 CIELAB scanners and cameras

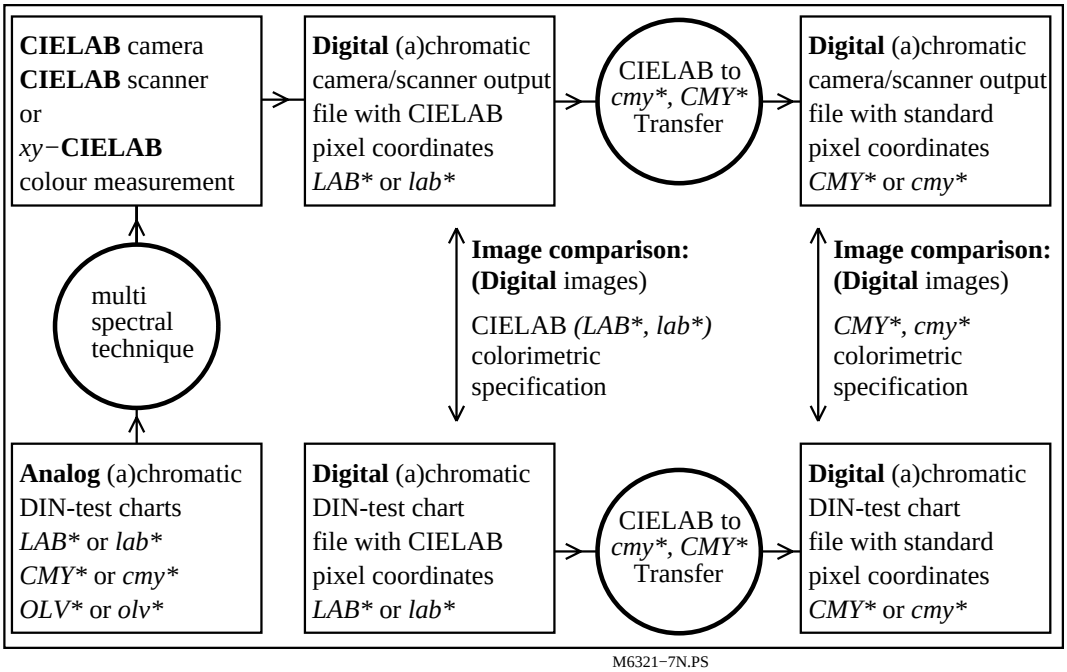


Figure 6: Ideal input scan with CIELAB cameras and CIELAB scanners as reference process
Fig. 6 shows an ideal input scan and the transfer of CIELAB to *CMY** coordinates.

2.3 Analog - digital - analog reproduction

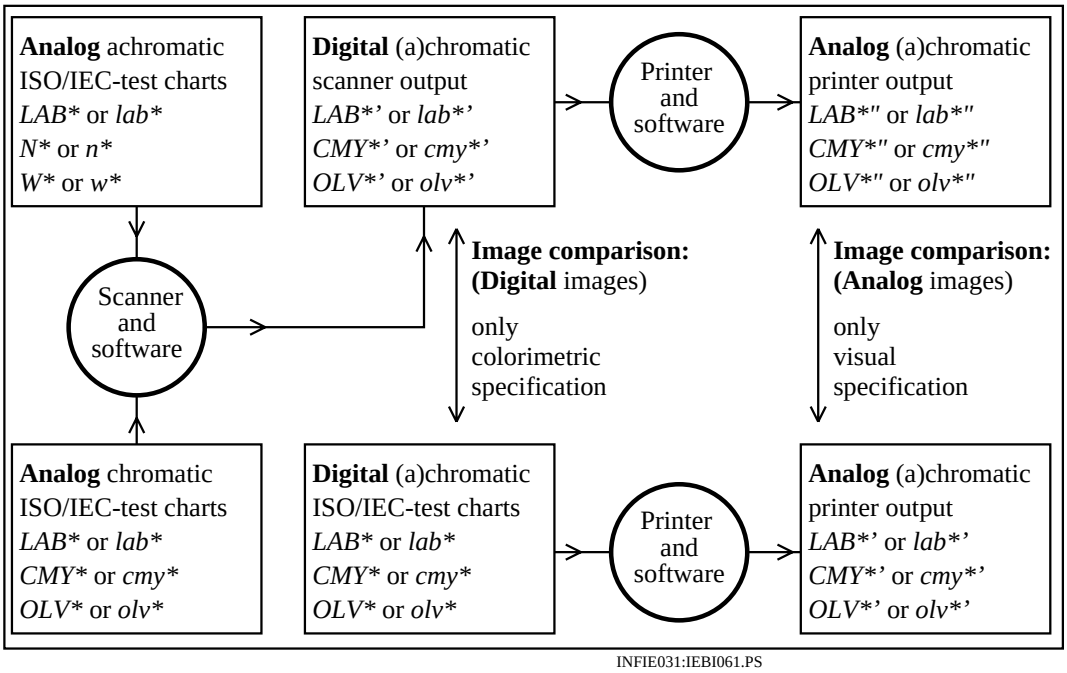


Figure 7: Input and Output of ISO/IEC-test charts with many modifications and no corrections
Fig. 7 shows a real input scan and the additional modifications made by the printer and the software.

2.4 Input and output linearization of analog - digital - analog reproduction

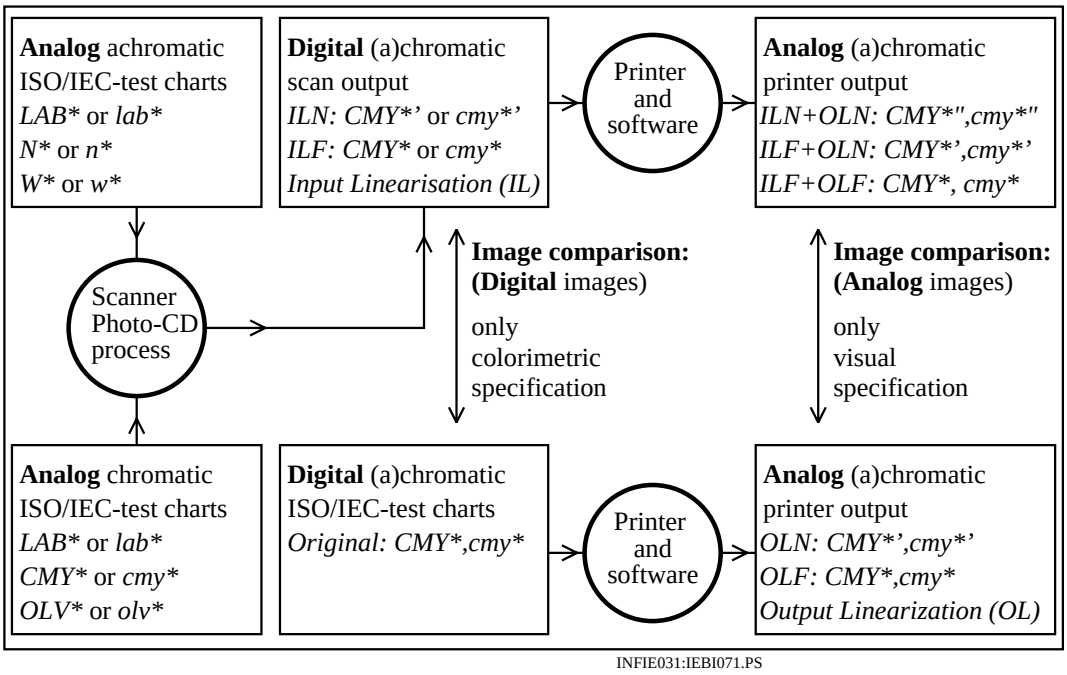


Figure 8: Input and Output Linearisation (IL and OL) of ISO/IEC-test charts

In Fig. 8 the Input Linearization (IL) in the File (F) produces the original *CMY** data. Similar the Output Linearization (OL) produces the original *CMY** data which is intended by the original digital standard ISO/IEC-test chart file with *CMY** coordinates.

3. Linear scales in ISO/IEC-test charts according to ISO/IEC 15775

The produced colours series of ISO/IEC-test charts are **linear** in CIELAB colour space, e. g. between White *W* and Cyanblue *C* for the 16 equally spaced steps both in *L** (lightness) and *C** (chroma).

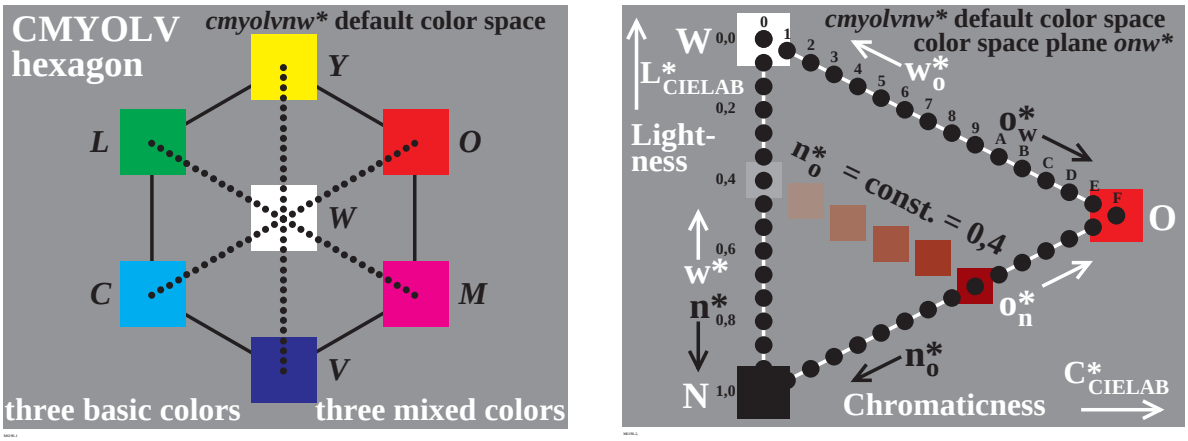


Figure 9: Hexagon of *CMYOLV* colours with 16 steps *(left)* and colour triangle in the hue plane *N – O –W* with both 16 step series *W - O* and *W - N (right)*

Figure 9 shows the main six different colour series *(left)* and additional series White - Black in the colour triangle *(right)*. All the series have been produced in analog ISO/IEC-test charts according to ISO/IEC 15775 by both DIN in Germany and JBMA in Japan. Manufacturers of colour devices are changing the firmware (or the software in the device) to reach a linear input-output relationship for printers, scanners and others by using the digital and analog ISO/IEC-test charts. Devices with approximately linear properties reproduce often the intended colours and then there is no need for colour management systems. In application the setup-state for colour management are linearized devices for both the

analog - digital (e. g. scanners) input part and the digital - analog (e. g. printers) output part.

Therefore it is of large importance to develop linear relationships. We will start to linearize the digital - analog output process. Then the input process and finally the whole process from the analog input (original scene) to the analog output (colorimetric reproduction of the original scene) will be studied

4. Output Linearization (OL) of 128 standard colours

The ISO/IEC-test chart include 8 colour series of 16 steps each in Fig. B4 and D4 of the ISO/IEC-test charts 2 and 4. The 128 standard colours are shown in Fig. 11. In Fig. 13 the intended colours are produced by Output Linearization (OL). For this CIELAB colour measurement of the start output of Fig. 11 is necessary. CIELAB measurement of the Fig. 13 shows that the intended colours are within the user tolerance of about 3 CIELAB units by Output Linearization (OL)

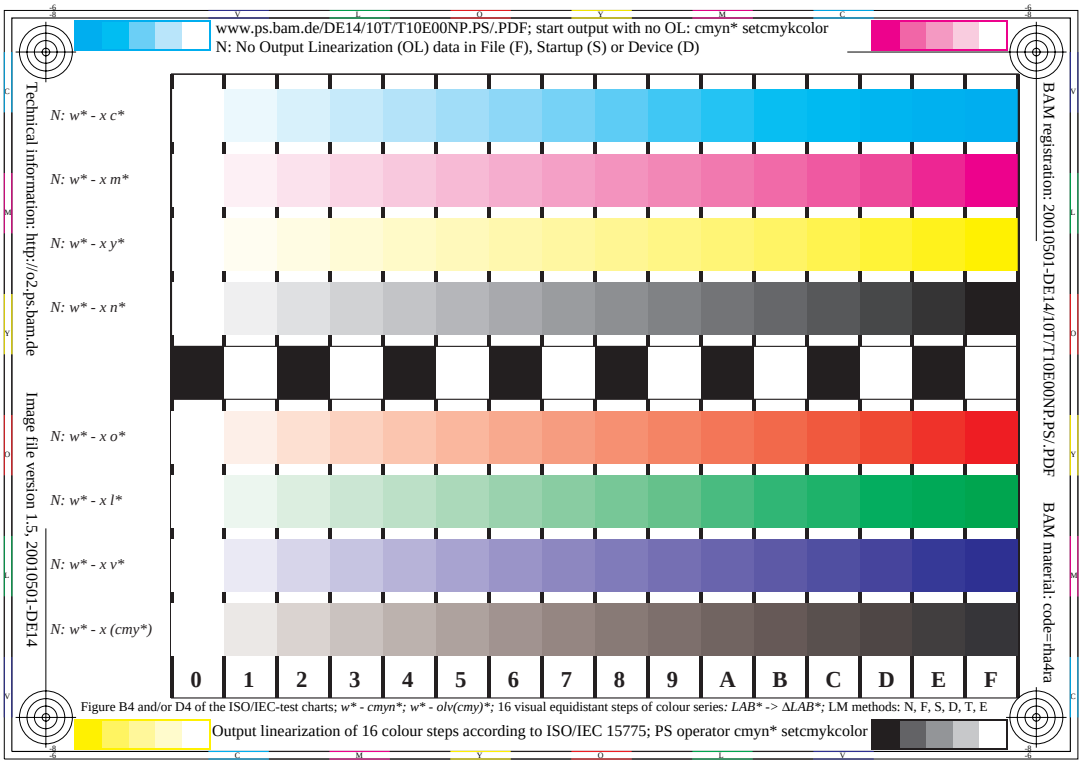


Figure 10: Start output of Fig. B4 and D4 of ISO/IEC-test charts no. 2 and 4.

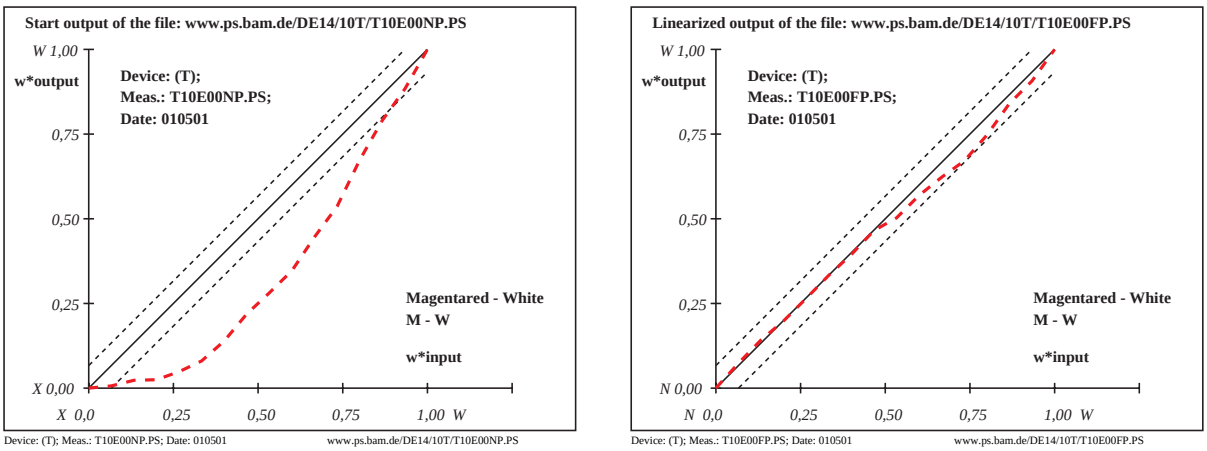


Figure 11: Input - Output relationship of the start output and the linearized output

Fig. 11 shows the relationship between the input and output data for the start and optimized output.

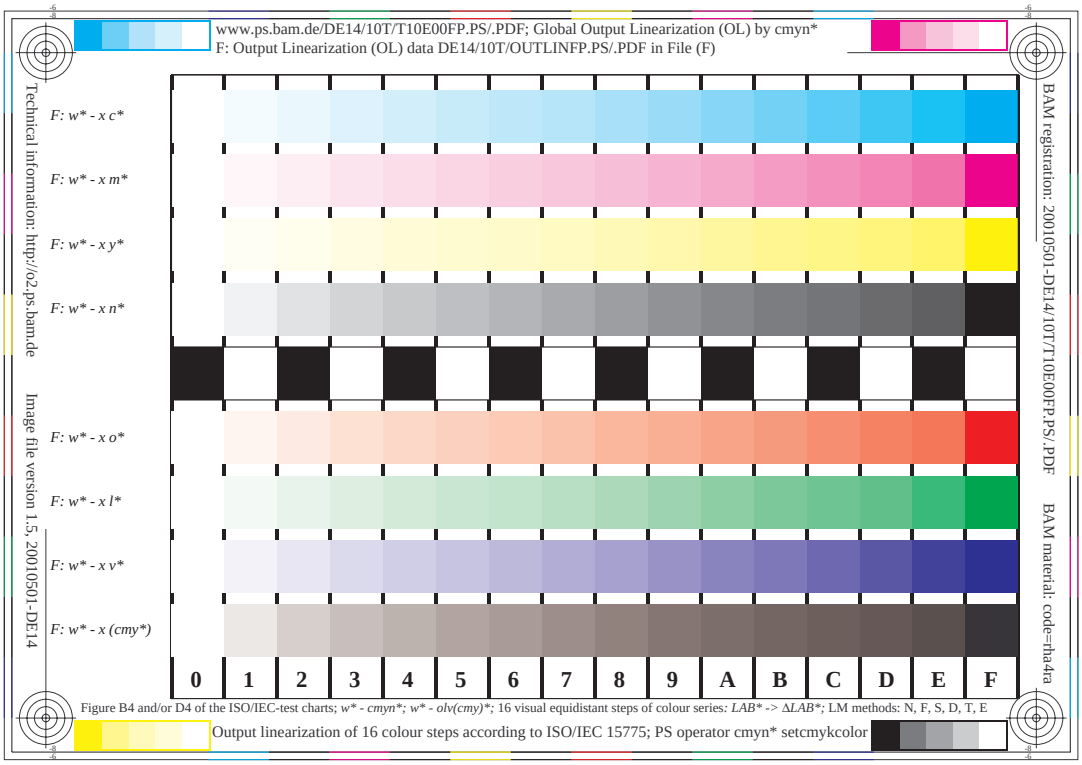


Figure 12: Output Linearisation (OL) of Fig. B4 and D4 of ISO/IEC-test charts no. 2 and 4 using CIELAB measurement data of the 128 standard colours.

The measurement data one can find at the beginning of the file belonging to Fig. 12. The URL is given at the top.

Fig. 12 shows the 128 standard colours of Fig. B4 and D4 of the ISO/IEC-test charts. Most devices, e. g. printers, show the output of the 16 step colour series not equally spaced for equally spaced digital input data. This can be determined by CIELAB colour measurement. The calculation of the relative colour distance between e. g. Cyan and White for the 16 colour steps will give numbers between 0 and 1 not equally spaced.

Instead of the equally spaced digital input values between 0 and 1 (0, 1/15, 2/15, ..., 14/15, 15/15) one can calculate new digital input values on the scale between 0 and 1 to get an equally spaced output (0, 1/15, 2/15, ..., 14/15, 15/15) on the visual relative CIELAB scale.

The calculations are based on the measurement on the 128 CIELAB data. The CIELAB data of a device must replace the default data at the beginning of the PostScript file. The programming language PostScript is used to make the calculations. A user must only replace the CIELAB data and the PostScript interpreter is producing the equidistant output on the relative CIELAB scale.

Figure 12 shows such an output for a special printer. For example by the software Adobe Illustrator one can check the digital input data of Fig. 10 (equally spaced) and Fig. 12 (changed by CIELAB measurement).

Fig. 13 shows Fig. B4 to B7 and D4 to D7 of the ISO/IEC-test charts. Many of the 16 colour steps are not visible and therefore it is also impossible to recognize the corresponding Landolt-rings. Output Linearization which is applied in Fig. 14 shows the 16 steps and all the Landolt-rings as intended by the user.

5. Output Linearisation (OL) of chromatic ISO/IEC-test charts

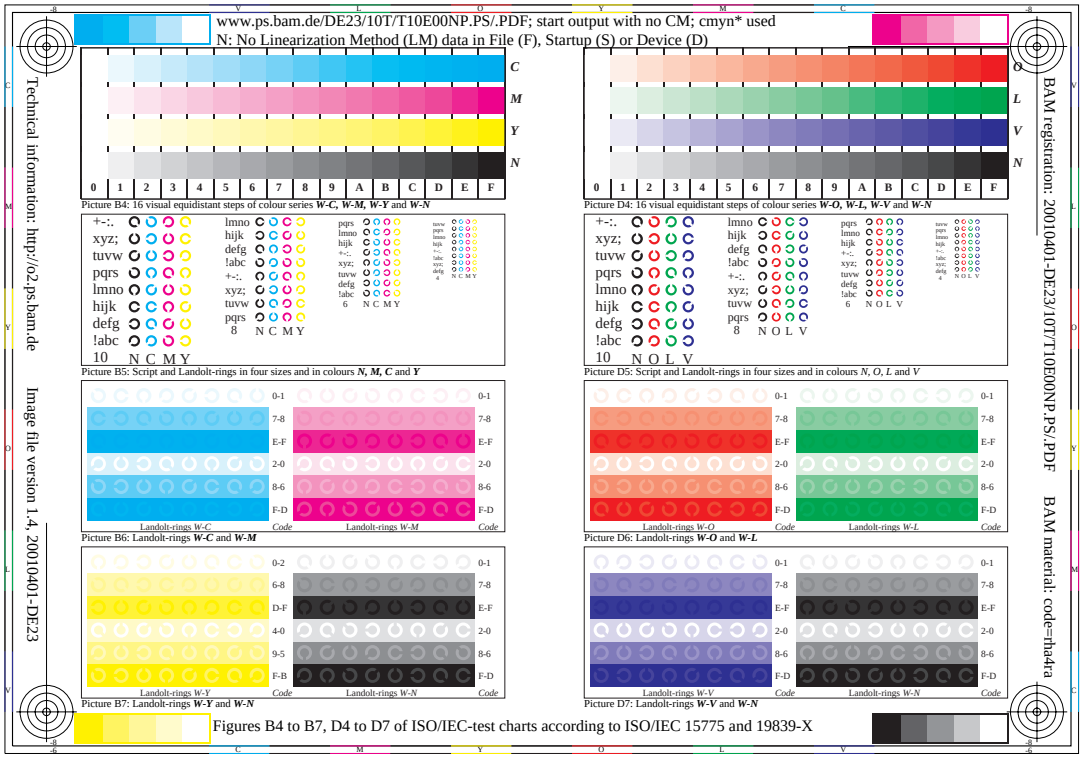


Figure 13: Start output of Fig. B4 to B7 and D4 to D7 of ISO/IEC-test charts no. 2 and 4.

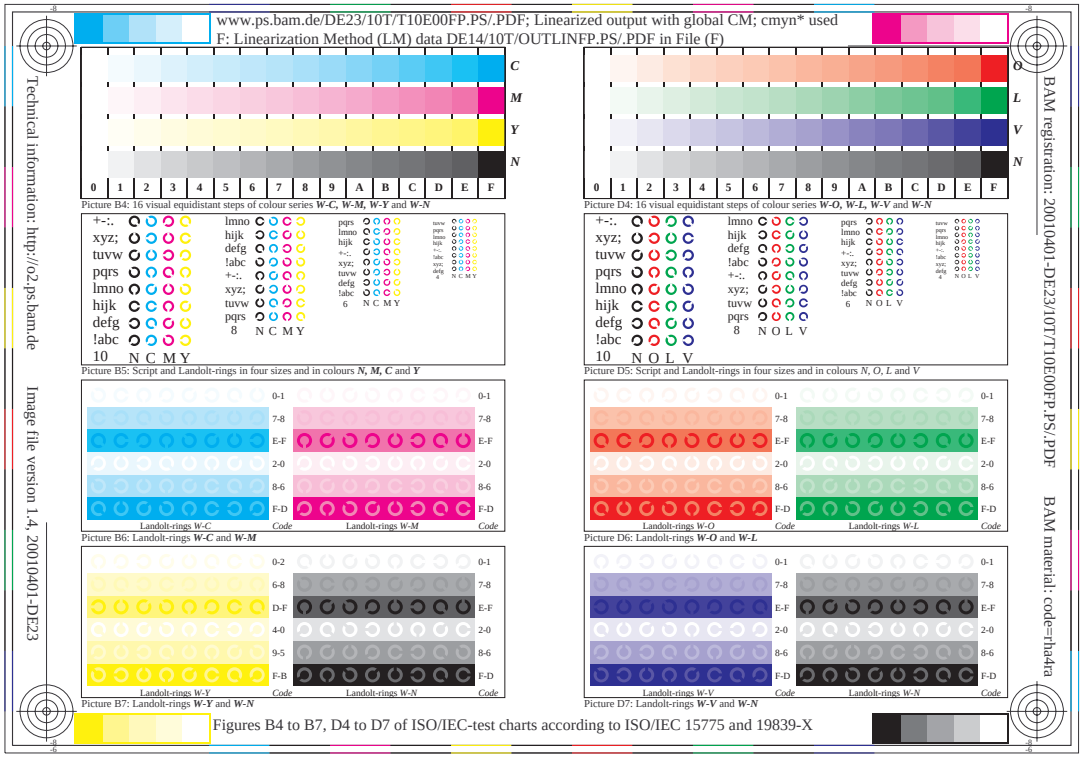


Figure 14: Output Linearisation (OL) of Fig. B4 to B7 and D4 to D7 of ISO/IEC-test charts no. 2 and 4 using CIELAB measurement data of the 128 standard colours in Fig. B4 and D4.

The measurement data one can find at the beginning of the file belonging to Fig. 13. The URL is given in Fig. 14 at the top.

6. Input and Output Linearisation (IL and OL) of 32 standard colours

6.1 Input Linearisation (IL) of 32 standard colours in Photo-CD images

It is the task to linearize both the input and the output of office devices. This includes the output digital data of the Photo-CD process. In this process the image of the original with 32 ISO/IEC-test colours is taken on photographic slide or negative film. A 14 bit scanner produced the 8 bit image files on a Photo-CD in 5 resolutions from 192 x 128 to 3072 x 2048 pixels, compare also K. Richter [4] and [5] for the basis and more about automatic colour management with this images. The 32 ISO/IEC-test colours are shown in the following Figures 15 and 16. A slide filme (sf) and normal exposure (+0.0) has been used.

Three different modifications have been used in each figure, each modofication shows the 32 ISO/IEC-test colours. There are analog - digital input processes (ad) and digital - analog (da) output processes. The intended colours may change by the each process from * (star) to * ´ (star-dash) coordinates. A linearization process (IL or OL) may produce the original data * (star) again.

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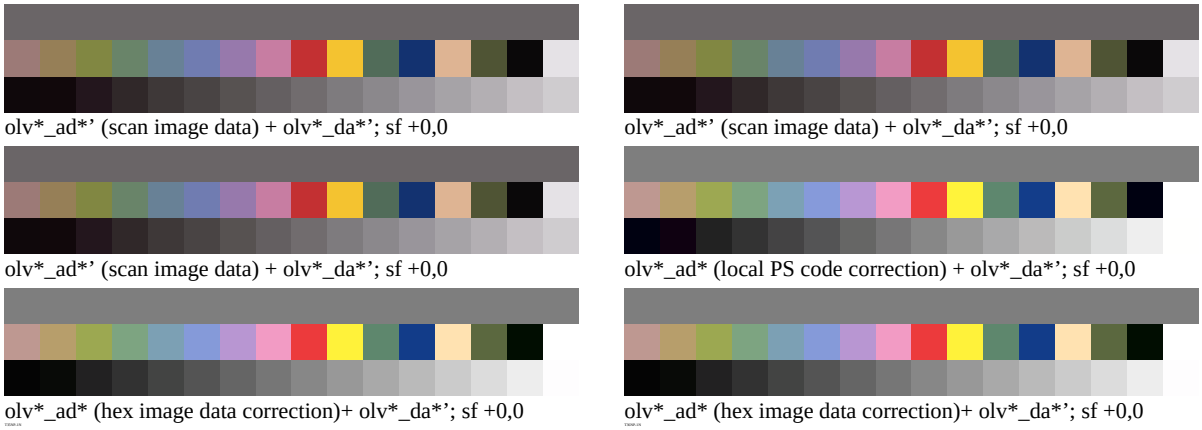

Figure 15: Two Photo-CD raw scans and hex image data Input Linearisation (IL, left); the middle Photo-CD raw scan on the right side is modified by Input Linearisation (IL) using PS code within the file.

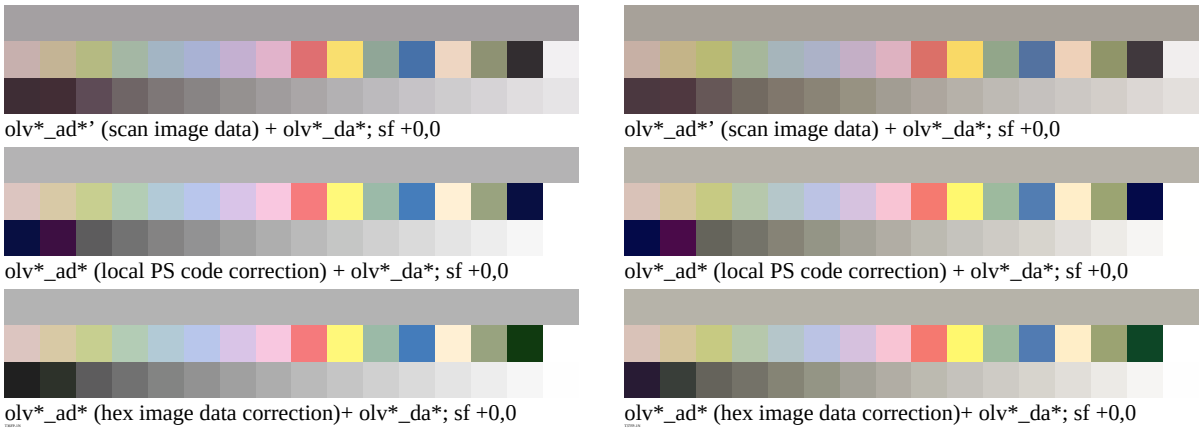

Figure 16: Same as Fig. 14 but additional square root (sqrt) example output modification (left and right) defined at the beginning of the files.

Fig. 16 is not a real output linearization. A model square root function is used to show that this function will produce a different output compared to Fig. 16. In real application the CIELAB measurement data of the 32 ISO/IEC-test colours must be used for Output Linearization (OL).

Fig. 17 and 18 show the Input and Output (srqt model) Linearization for slide and negative film. The slide exposure has been varied by under exposure between -1.5 stops and over exposure of +1.5 stops. The variation for negative film was between -2.0 stops and +4.0 stops. After Input Linearisation the visual appearance is very similar for all the modifications.

7. Input and Output Linearisation (IL and OL) of Photo-CD images

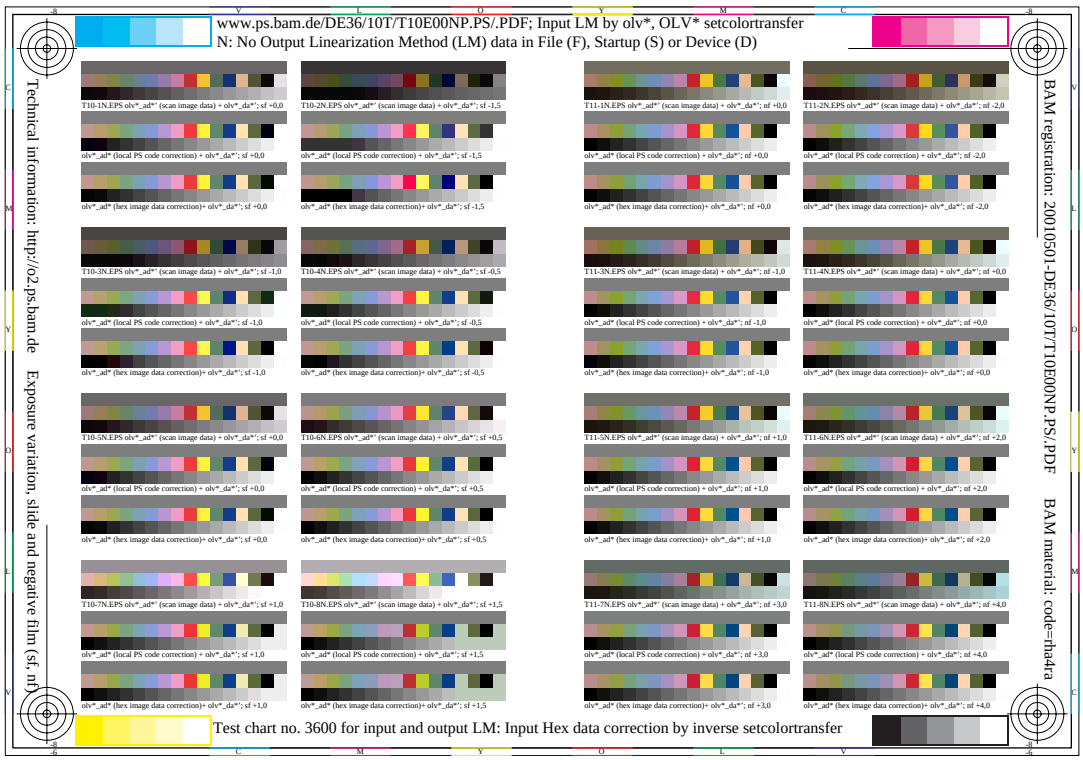

Figure 17: Input Linearization of the Photo-CD process for slide and negative film

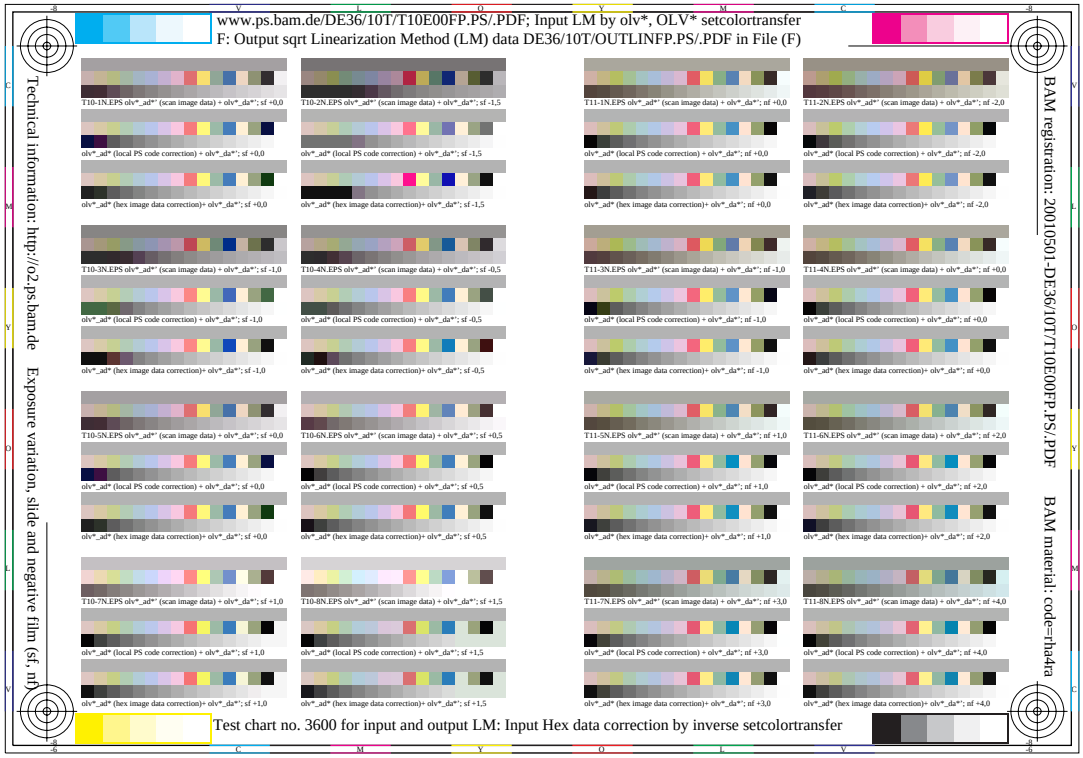

Figure 18: Input Linearization and additional square root output modification compared to Fig. 16

Fig. 17 and 18 show very similar results independent of film material (slide and negative) and exposure e. g. between -2.0 stops and + 4.0 stops for negative film.

8. Summary

The BAM was the leader for the development of the **analog and digital DIN- and ISO/IEC-test charts** for the different office devices.

Input and Output Linearization (IL and OL) of ISO/IEC-test charts allow to describe the colour by linear equations for the different office devices.

The BAM has developed methods to linearize both the **analog - digital input** process and the **digital - analog output** process for any device - software combinations.

Linearization is a basis to describe the whole imaging process between the **original scene** and the **reproduction**.

The **reproduction property** of the original scene is in many cases for **linear** devices within the intended accuracy and a colour management method is then often not necessary.

9. References

[1a] DIN 33866 „Information technology – Office machines – Machines for colour image reproduction“ :

Part 1: *Method of specifying image reproduction by **digital** and **analog** DIN-test charts – Classification and principles, draft May 1999, standard DIN 33866-1 in print.*

Part 2: *Method of specifying image reproduction of colour copying machines by **analog** test charts – Realisation and application. (May 1998, revised standard DIN 33866-2 in print)*

Part 3: *Method of specifying image reproduction with **digital** input and **analog** output as **hardcopy** of colour image devices: **“digital** – **analog”** (printers) – Realisation and application, draft May 1999, standard DIN 33866-3 in print.*

Part 4: *Method of specifying image reproduction with **analog** input and **digital** output of colour image devices: **“analog** – **digital”** (scanners) – Realisation and application, draft Nov. 1999, standard DIN 33866-4 in print.*

Part 5: *Method of specifying image reproduction with **digital** input and **analog** output as **softcopy** of colour image devices: **“digital** – **analog”** (monitors) – Realisation and application, draft Nov. 1999, standard DIN 33866-5 in print.*

[1b] ISO/IEC DIS 19839-1 to 4: 2000-04 „Information technology – Office machines – Machines for colour image reproduction“;

Part 1: *Method of specifying image reproduction by **digital** and **analog** DIN-test charts – Classification and principles*

Part 2: *Method of specifying image reproduction with **digital** input and **analog** output as **hardcopy** of colour image devices: **“digital** – **analog”** (printers) – Realisation and application*

Part 3: *Method of specifying image reproduction with **analog** input and **digital** output of colour image devices: **“analog** – **digital”** (scanners) – Realisation and application*

Part 4: *Method of specifying image reproduction with **digital** input and **analog** output as **softcopy** of colour image devices: **“digital** – **analog”** (monitors) – Realisation and application*

[2] 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*“, 1999-12-01

[3] ISO 2846–1:1997, *Graphic technology – Colour and transparency of ink sets for four-colour-printing – Part 1: Sheetfed and heat-set web offset lithographic printing.*

[4] ITU-R BT.709–2:1995, *Parameter Values for the HDTV Standards for Production and International Programme Exchange.*

[5] Klaus Richter, Computergrafik und Farbmetrik, VDE-Verlag, Berlin, 1996, with 500 colour figures in PS and PDF on CD-ROM, ISBN 3-8007-1775-12

[6] Klaus Richter, Automatic colour management for variable processes between original and reproduction using 16 colours of ISO/IEC 15775, CIS2000, Uni Derby, England, p. 197-204, 321-328