TECHNICAL REPORT

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Information technology — Office machines — Device output of 16 colour scales, output linearization method (LM) and specification of the reproduction properties

Technologies de l'information — Machines de bureau — Sortie de dispositif des échelles 16 couleurs, méthode linéaire de sortie (LM) et spécification des propriétés de reproduction

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Foreword

ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations, governmental and non-governmental, in liaison with ISO and IEC, also take part in the work. In the field of information technology, ISO and IEC have established a joint technical committee, ISO/IEC JTC 1.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of the joint technical committee is to prepare International Standards. Draft International Standards adopted by the joint technical committee are circulated to national bodies for voting. Publication as an International Standard requires approval by at least 75 % of the national bodies casting a vote.

In exceptional circumstances, the joint technical committee may propose the publication of a Technical Report of one of the following types:

— type 1, when the required support cannot be obtained for the publication of an International Standard, despite repeated efforts;

— type 2, when the subject is still under technical development or where for any other reason there is the future but not immediate possibility of an agreement on an International Standard;

— type 3, when the joint technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example).

Technical Reports of types 1 and 2 are subject to review within three years of publication, to decide whether they can be transformed into International Standards. Technical Reports of type 3 do not necessarily have to be reviewed until the data they provide are considered to be no longer valid or useful.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO and IEC shall not be held responsible for identifying any or all such patent rights.

ISO/IEC TR 19797, was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 28, *Office equipment*.

Introduction

Purpose and justification

The method in this Technical Report produces a linear relationship between the linear digital input data and the output data produced for a visual relative CIELAB scale. Using this method for a digital input value of 0.5 a mean grey of 0.5 on a visual scale is produced. On the visual scale the values for white and black are 0 and 1 in relative CIELAB space. The method has been already developed (there was a SC28 study period of one year, Project 18 of the SC28 Berlin 2000 Plenary). Example files are on the Internet in various file formats (see SC28 Document j28N493). The output will be within a visual tolerance of 6 CIELAB units independent of the file format used (see graphs on page 13–15 and on BAM-Internet addresses listed in Annex B). For a given file format the CIELAB values of the first output must be measured. The measured CIELAB data are included in a modified output file which produces the linearized output which will be equally spaced in CIELAB. Various cases are given below:

1. PS (PostScript) file on a PS printer then the new PS output file on the PS printer produces the 16 step equally spaced output.

2. PDF file on any printer then the new PDF output file is produced by the software *Adobe Acrobat Distiller or equivalent* from a PS file. The PDF output file produces the 16 step equally spaced output.

3. GIF file on any printer then the new GIF output file is produced by the software *Adobe Illustrator or equivalent* from a PS file. The GIF output file produces the 16 step equally spaced output.

The method is similar for other file formats and the output result is within a visual tolerance of 6 CIELAB units independent of the file format used.

> Advantages: If the CIELAB data of the first output are used then the linearization method (LM) leads to the same relative CIELAB output within visual tolerances of 6 CIELAB values (1 step of 16 steps, see graphs on pages 13–15) independent of e. g. application software, file format, printer driver and paper.
>
> Remark: If the intended output is linearly spaced in relative CIELAB space (see ISO/IEC 15 775) then in most cases the colour differences between the first and the linearized output and the intended output are reduced by a factor 3 to 6.

Information technology — Office machines — Device output of 16 colour scales, output linearization method (LM) and specification of the reproduction properties

1. Scope

A digital file is used to produce 16 step colour scales on a colour printer between the white paper and the 6 chromatic colours and black. The intended 16 step colour scales are defined in figures B4 and D4 of the ISO/IEC-test charts for colour copiers according to ISO/IEC 15775. The digital file format may be PostScript (PS), Portable document (PDF), GIF, HTM or equivalent. Within the different file formats the 16 step colour scales are defined by 16 digital values between 0 and 1, e. g. by 0, 1/15, 2/15 to 15/15 in CMY coordinates. The first output is measured and by the linearization method (LM) of this Technical Report, a visually equally spaced output is produced in relative CIELAB units, e. g. between the white paper and the six device colours and black. There is a table of output values and a graph for the first and linearized output. This method produces a linear relationship between the linear digital input data and the output data on a visual relative CIELAB scale for the colour primaries. The visual uniformity of overprint scales can be improved by this method. The method is applicable for systems that do not have colour management or as a linearization method for devices that could be used as a setup_state for colour management. The aim of this method is to produce equal CIELAB spacing. The equal spacing of the steps achieved in the linearization method may be adapted to various purposes. The accuracy and repeatability of this method is expected to be within 6 CIELAB units. Other methods may be appropriate for applications requiring greater accuracy.

Note: Any first output can be used for this linearization method (LM) even though the first output depends e. g. on application software, file format, printer driver, paper and other parameters.

2. Normative References

The following referenced documents are indispensable for the application of this document, For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/IEC 15775: 1999, *Information technology – Office machines – Method of specifying image reproduction of colour copying machines by analog test charts – Realisation and application*

ISO/CIE 10526:1991, *CIE standard colorimetric illuminants*

ISO/CIE 10527:1991, *CIE standard colorimetric observers*

CIE-pub. 15.2:1986, *Colorimetry*

ITU-R BT.709-2:1995, *Parameter Values for the HDTV Standards for Production and International Program Exchange*

IEC/CIE 17.4:1987, *International lighting vocabulary, 4th edition, Joint publication IEC/CIE*

DIN 33866-1 to -5:2000, *Information technology – Office machines – Colour image reproduction devices,* Part 1: *Method of specifying image reproduction of colour devices by digital and analog test charts*

3. Terms and Definitions

3.1 Definitions

For the purposes of this document, the following terms and definitions apply.

NOTE The definitions are taken from ISO/IEC 15775 and IEC/CIE 17.4. The definitions are adapted to the ISO/IEC Directives Part 2. The CIE/IEC definitions are adapted slightly to agree with the ISO/IEC Directives.

3.1.1
standard tristimulus values *X, Y, Z* and colorimetric parameters *L*a*b**
describe the psychophysical colour

NOTE 1 Standard tristimulus values *X, Y, Z* are mostly obtained as an immediate result of a colour measurement.

NOTE 2 As standard tristimulus values *X, Y, Z* only allow statements referring to equality of two colours, for statements made beyond that, e. g. concerning the kind and size of colour differences, non-linear transformations of *X, Y, Z* into other colorimetric parameters systems preferably into the colorimetric parameters *L*, a*, b** are necessary (compare CIE publ. 17.4)

NOTE 3 Within this Technical Report the abbreviation ***LAB**** for the colorimatric parameters ***L*a*b**** is used. For *relative* CIELAB coordinates the abbreviation ***lab**** is used.

3.1.2
colour difference ΔE^*_{ab}
specifies the size of the difference between two colour stimuli

3.1.3
***-image (“star-image“)**
includes colours defined by the colorimetric parameters *L*a*b** of the CIELAB colour system.

NOTE The *-image (“star-image“) includes colours (of the colour pixels or areas) which are defined either in absolute *(LAB*)* or relative *(lab*)* coordinates.

3.1.4
***’-image (“star-prime-image“)**
includes colours produced by a standard reproduction process of a colour device and is different than the *-image.

NOTE The *’-image (“star-prime-image“) has different colorimetric parameters *L*’a*’b*’* (*’-coordinates) compared to the *-image (“star-image“) with *L*a*b** parameters defined either in absolute *(LAB*)* or relative *(lab*)* coordinates.

3.1.5
’*-image (“prime-star-image“)
is produced by the standard reproduction process of a colour device and is different than the *-image (“star-image“).

NOTE The ’*-image (“prime-star-image“) is called the inverse image and includes *L’*a’*b’** parameters defined either in absolute *(LAB*)* or relative *(lab*)* coordinates.

3.1.6
standard image transformation
changes a *-image (“star-image“) into a *’-image (“star-prime-image“) (Fig. 1) or changes a ’*-image (“prime-star-image“) into a *-image (“star-image“) (Fig. 2)

3.1.7
inverse image transformation
changes a *-image (“star-image“) into a ’*-image (“prime-star-image“) (Fig. 2) or changes a *’-image (“star-prime-image“) into a *-image (“star-image“) (Fig. 1)

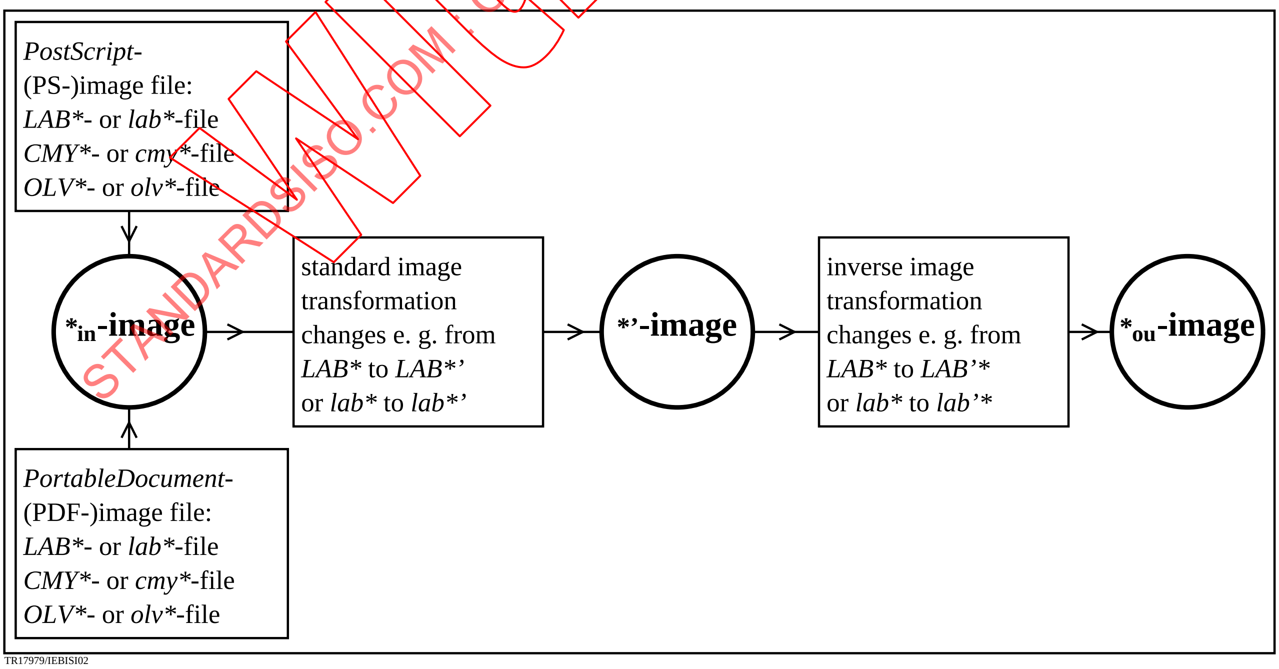


Figure 1: Standard and inverse image transformation

Fig. 1 shows that the standard image transformation changes a *-image (“star-image“) into a *’-image (“star-prime-image“) and that the inverse image transformation changes a *’-image (“star-prime-image“) into a *-image (“star-image“)

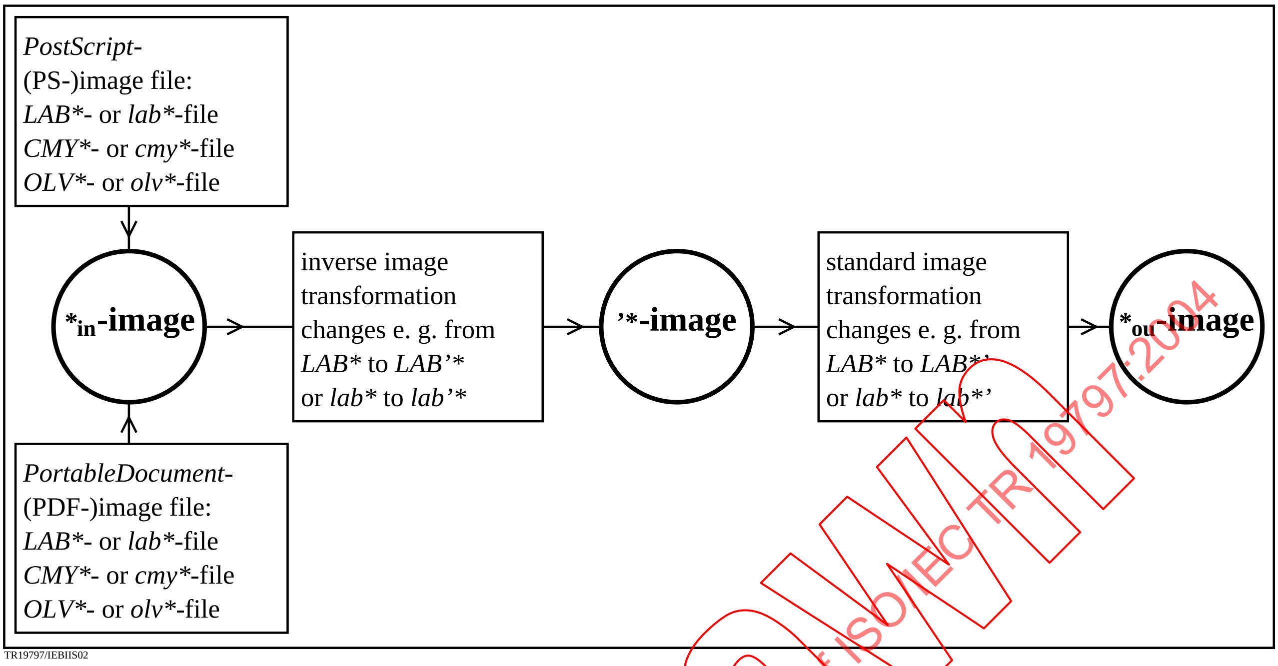


Figure 2: Inverse and standard image transformation

Fig. 2 shows that the inverse image transformation changes a *-image (“star-image“) into a ‘*-image (“prime-star-image“) and that the standard image transformation changes a ‘*-image (“prime-star-image“) into a *-image („star-image“)

4. Overview: Six chromatic reproduction colours and 128 standard colours

There is a variety of colour spaces which can be used for input and output. Any user has to spend a lot of time to learn about the different spaces and to learn the relationship of the different spaces which depends on application.

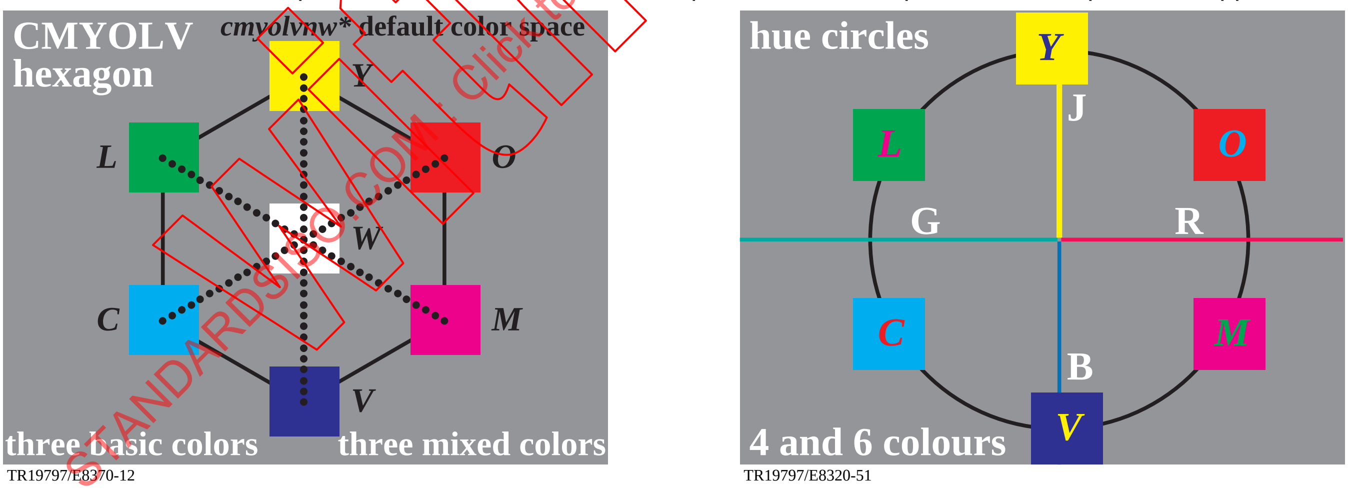


Figure 3: Six reproduction colours CMYOLV and four unique hue colours RJGB

Fig. 3 shows the six chromatic colours **CMYOLV** and Black **N** (=noir) and White **W** of standard offset printing (left). The four unique hue colours **RJGB** are different from the six reproduction colours. Standard non fluorescent offset paper was used to produce the **analog ISO/IEC-test charts which are equally spaced in CIELAB coordinates**. There are productions by DIN and JBMIA (see Annex B.) in reflective and transparent mode. The German DIN-test charts have been measured with the 45/0 measuring geometry for standard illuminant D65 and the CIE 1931 standard observer at BAM *(Laboratory S.13)*. The mean colour difference of CMYOLV compared to the standard data is 2.5 CIELAB, (see the standard DIN 33866-X and the International Standard ISO/IEC 15775).

Remarks: According to the International Standard ISO/IEC 15775 the letters ***j*** (=jaunne=yellow), ***r*** (red), ***g*** (green), and ***b*** (blue) are reserved for the unique hues and the letters ***olv**** (orange red, leaf green, violet blue) are used with a star to indicate the linear relationship to CIELAB. The ***olv**** coordinates are used for the reflective colours and are used in a similar way as the coordinates ***rgb*** of the luminous television colours. The ***cmy**** coordinates are alternate coordinates compared to ***olv**** (see Fig. 3 and Table 1 and 2).

All the 16 step colour series between white and the six chromatic colours CMYOLV (see Fig. 3) and black are equally spaced in the CIELAB colour space. Laser printers produce the six chromatic colours using between three and six colourants. The result is often similar to the six colours CMYOLV of the present analog ISO/IEC-test charts which have been produced by standard offset printing.

The halftone screening of laser printers (or of offset printing) produce colours which are approximately on a line, e. g. between White W and Cyan C in the CIELAB space. This is one basic assumption of the model colour space. In practice the 16 colours between White and Cyan may slightly deviate by less then 3 CIELAB units from the line in CIELAB space. This is much less than the 20 CIELAB unit spacing differences along the line W – C which printers often produce. For the office applications the aim was to reduce the spacing differences of the 16 step series C – W to below 3 CIELAB units. Then all Landolt-rings in the ISO/IEC-test chart output can be recognized. A non-critical user may require that along the line W – C only the cyan coordinate of *cmy** changes between zero and 1 in 15 digital steps of 1/15. The other coordinates are zero. In the alternate coordinate system *olv** the Orange red coordinate is zero and the other two change by equal amounts from zero to 1 in steps of 1/15 (see Table 2).

There were **goals**:
1) Linearization (equal CIELAB spacing) of the seven series W to CMYOLVN and
2) calculation methods to convert to coordinates *cmy** and *olv** from the CIELAB data of the standard (and the analog samples) and vice versa.

Both goals have been achieved by PostScript code called MTL (MTL = Measurement, Transfer and Linearization). If a device is linearized along the lines in CIELAB space then there are linear relationships between the coordinates *cmy*, olv*,* and *LAB** of the CIELAB colour space. The linear relations (and as a result a linear additive metric in CIELAB space in each of the six sectors of Fig. 3) are used in the PS MTL code. Either the ***olv*, cmy*,* or *LAB**** data can be used with an **ISO/IEC-test chart** file to get the **same** output on a printer or monitor.

Table 1: Colour data of the 5 step colour series N – W for four input PS operators (N=noir=Black)

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	**CIELAB** ***LAB* (absolute)*** ***LAB* setcolor***	***l** CIE** ***w* = l**** ***setgray***	**CMYN (CMYK)** ***000n**** ***setcmykcolor***	**CMYN (CMYK)** ***cmy0**** ***setcmykcolor***	**OLV (RGB)** ***www**** ***setrgbcolor***
1,00 N + 0,00 W (black N)	18.01 0.50 -0.46	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	37.36 0.13 0.84	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	56.71 -0.24 2.15	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	76.06 -0.61 3.45	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)	95.41 -0.98 4.76	1,00	0,00 0,00 0,00 0,00	0,00 0,00 0,00 0,00	1,00 1,00 1,00

TR19797/DESERCW2

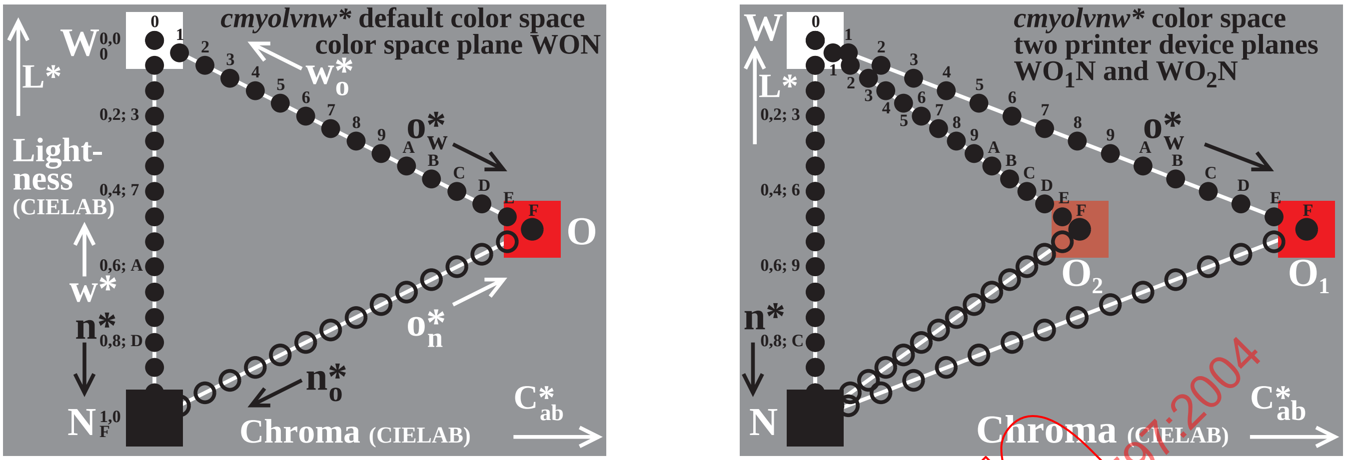
Table 1 include four input *PostScript* (PS) operators which define the same achromatic colours black, three greys and white. Between one and four input data values are necessary for the complete definition of the achromatic colours depending on the colour space

Table 2: Colour data of 5 step colour series C – W for three input PS operators.

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

TR19797/DESERCW1

Table 2 includes three input *PostScript* (PS) operators which define the same chromatic colour series between Cyan blue and White. There are ISO/IEC-test chart files which use the different PS operators of Table 1 and 2.



TR19797/E6190-2Y, TR19797/E6190-2z.

Figure 4: Equal spacing in relative CIELAB in hue planes WO_xN for different devices x.

Fig. 4 shows the 16 step colour series **equally spaced in relative CIELAB** in the hue plane WON (left) for the default device and in the hue planes WO_1N and WO_2N for two other different devices. The CIELAB chroma C^*_{ab} of the devices 1 and 2 is larger or smaller (right) compared to the default chroma (left) but the **relative spacing** in CIELAB is equal in all cases. The dark dots show the 16 step colour series which this Technical Report will produce on a printer. The coordinates used in this Technical Report are

n^* (relative blackness)

n^* changes from 0 to 1 (decimal) or from 0 to F (hexadecimal, 4bit) for the series White W to Black N (W–N).

o^*_w (relative orange redness of the whitish series w)

o^*_w changes from 0 to 1 (decimal) or from 0 to F (hexadecimal, 4bit) for the series White W to Orange red O (W–O). There are some other coordinates, e. g. relative whiteness w^* and relative orange redness of the blackish series o^*_n in Fig. 4 which have simple relationships to the above two relative coordinates and also to the CIELAB coordinates.

Remark 1: The method of this Technical Report is not designed to produce equal steps for the series O–N, O_1–N and O_2–N (hollow circles) but experimental and theoretical studies show that the spacing of this series is close to equal relative spacing if the method of this Technical Report is used.

Remark 2: For many applications the relative spacing of the whitish series W–O is more important compared to the blackish series O–N. For instance both for best differentiation of 16 colour steps and low toner consumption the series W–O is appropriate.

Remark 3: The ISO/IEC-test charts according to ISO/IEC 15775 include the 16 step default colour series W–O and W–N for the test of colour copiers.

It is within the **scope** of this Technical Report that the **relative spacing in CIELAB can be made the same** for all devices as shown in Fig. 4. Then the recognition of e.g. the 16 step series W–O, W–O_1 and W–O_2 is constant as long as the chroma of the colour O_2 is not too small. The colour difference of the default series W–O is about 120. For 16 steps this means that there is a colour difference in CIELAB of 8 (=120/15) between two adjacent colour steps. The perception threshold for the colour difference of colours side by side is about 1 CIELAB unit and for colours spatially separated about 3 in CIELAB units. For printers in the worst-case a reduction of the chroma of O_2 to 50% compared to the default chroma of O may be assumed. Even in this worst-case the colour difference (about 5 = 75/15 in CIELAB) is much above threshold for both adjacent and separated colour steps for the colour series between W–O_2.

The ISO/IEC-test charts 2 and 4 according to ISO/IEC 15775 include 8 colour series of 16 steps colours in Fig. B4 and D4. There are 128 standard colours which are shown in Fig. 5

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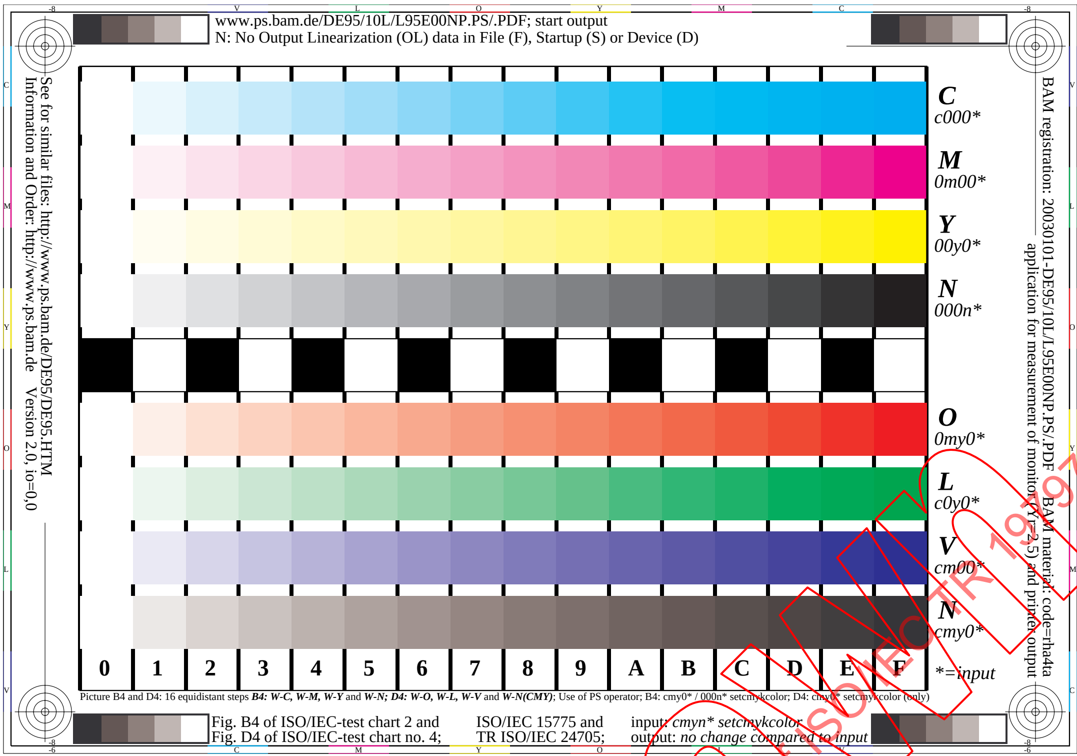


Figure 5: First output of 128 standard colours defined in this ISO/IEC Technical Report

Fig. 5 shows the 128 standard colours which can be made equally spaced in CIELAB for hardcopy output for any device using this Technical Report. Equal relative spacing of the 8 series is possible on any printer using any computer operating system, any file format and any application as far as we know. The digital file of this Technical Report uses relative ***cmy**** colour coordinates together with the PostScript operator *setcmykcolor* to verify this property for the different parameters.

Remark 1: Fig. 13 of this Technical Report will show a linearized output of the 8 colour series.
Remark 2: A list of files which include the original files of Fig. 5 and Fig.13 is at

http://www.ps.bam.de/DE95/DE95.HTM

5. Colorimetric definition of the colour series in ISO/IEC-test charts

Four analog **ISO/IEC-test charts** according to **ISO/IEC 15775** are designed for the test of colour copiers. The International Standard ISO/IEC 15775 includes the *L*a*b** reference data of the CIELAB space and the corresponding *cmy** data of the colours used in the test charts.

Table 3: Intended printing (PR) and television (TV) colours and comparison

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*

TR19797/IETA131

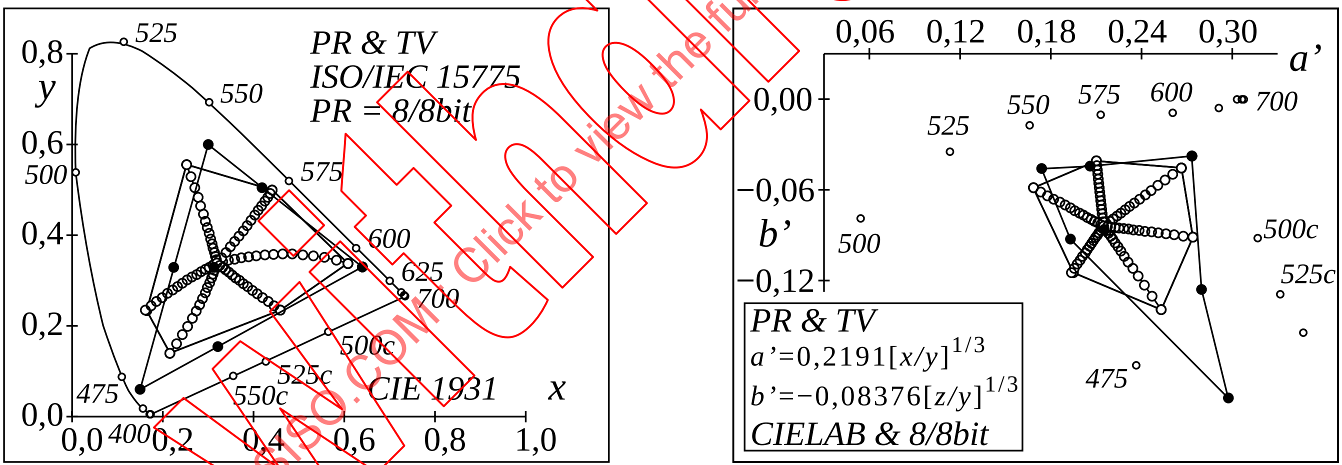
Table 3 shows CIELAB data of the colours *CMYOLVNW*$_{PR}$ of Printing (PR) and for additional information also the colours *CMYOLVNW*$_{TV}$ of Television (TV). There are differences up to ΔE^*_{ab} = 74 for the colour violet blue *V* (called blue *B* in television). The average difference is $\Delta E^*_{ab,m}$ = 31,5. This is about ten times the difference which a user would accept as reasonable. Different printers show a much lower mean difference which may be as low as 10 CIELAB units.

The user often wishes a relative colorimetric reproduction. To do this, the colour reproduction properties of the different devices must be linearized. This linearization is often sufficient for a colorimetric reproduction in offices or may serve as setup-state for colour management.

In this Technical Report the output linearization (OL) of the 16 step equidistant colour series according to CIELAB will be described. The series between the colour White W and the six colours CMYOLV (Fig. B4 and D4) as well as the series between White W and Black N will be linearized. Equally spaced *cmy** digital data 0, 1/15, 2/15, ..., 14/15, 15/15=1 will be used for input in the digital file. After linearization the reproduction colours will then be approximately equally spaced on each printer. The output tolerance will be within the tolerances of 3 CIELAB units for any office printer device system.

This Technical Report uses ***cmy** data in the digital files**. With additional Output Linearization (OL), the 16 step colour series are produced with equal spacing in CIELAB. The 16 step series are produced by linearized device systems with an accuracy of better than 3 CIELAB, which is reasonable for the office environment. **The CIELAB colour difference is often reduced by a factor 3 to 5** for the 16 step series on the surface of the colour solid.

The **user's desire for a linear relationship between CIELAB output data and *cmy** input data** can be realized. This **linear CIELAB – *cmy** colour workflow** for offices seems to be both simple and effective. The yellowness data *y**=0.5 will produce a yellow in CIELAB space visually in the middle between white W and yellow Y. This is similar for the other series, e. g. white – black. The linear relationship between *cmy** and CIELAB has many advantages for colour image technology. Slightly different output colours compared to the intended CIELAB colours can be corrected in the digital input file by using the linear CIELAB difference of the output and the intended CIELAB colour.



TR19797/E6110−1N TR19797/E6110−3X

Figure 6: 96 Standard printing colours in the *(x,y)* and *(a',b')* chromaticity diagram

The 16 step colour series produced in offset printing within the **analog** ISO/IEC-test charts are defined in CIELAB colour space in Table 1 and Annex H in the International Standard ISO/IEC 15775. The six chromatic standard colours of both printing (open circles) and television (black dots) are shown in the CIE *(x,y)* chromaticity diagram *(left).* Additionally the 16-step colour series between White *W* (chromaticity D65) and the six chromatic colours *CMYOLV* are shown in the *(a',b')* chromaticity diagram.

The definitions of the coordinates *a'* and *b'* are given in Fig. 6 *(right)* and remain constant for the so called shadow series of equal chromaticity *(x,y)* which have different luminance reflectance factors *Y.*

The analog DIN-test charts produced by DIN for DIN 33866-1 to 5 and the analog ISO/IEC-test charts produced by JBMIA for ISO/IEC 15775 include all the 16-step colour series shown in Fig. 5 as real samples.

The accuracy of the production is within the intended 3 CIELAB units. There are colour series which change only in *c* (Cyanblue)* between 0, 0.063, 0.133, etc., 0.933 1.000 (0/15, 1/15, etc., 15/15 corresponding to the 16 steps) for constant *m**=0 and *y**=0 and similarly for the series *m*, y*, o*, l*, v**, and *n*.*

Note: The conversion to *cmy** and *olv** coordinates from *LAB** coordinates and vice versa can be done by a *PostScript* (PS) computer program and by other programming languages.

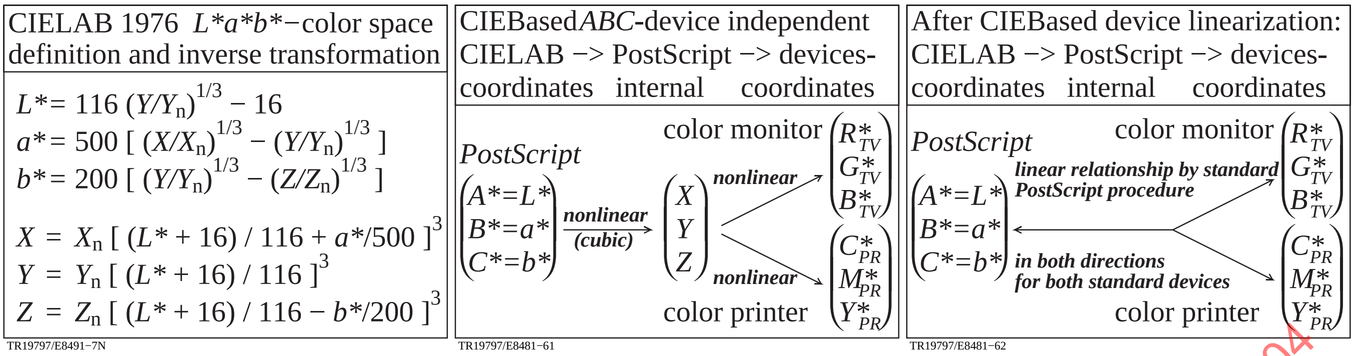


Figure 7: Digital – analog reproduction of PostScript by one linear function *(right)*

Fig. 7 shows the mathematical relationship between the CIELAB 1976 data *L**, *a** and *b** and the CIEXYZ 1931 data *X*, *Y* and *Z* (left). There is a CIE modification of the equation below *Y*=0,8 but such a low luminance factor *Y* data does not exist for the reflective colours of printers. For example the colour black N has a luminance factor *Y*=2,5 which corresponds to the lightness *L**=18.

The CIEXYZ system is used as internal reference system in the *Adobe PostScript* programming language. (see Annex B.) The middle figure shows the use of the CIE **nonlinear cubic transformation** from *LAB** to *XYZ* and **another nonlinear transformation** between *XYZ* and the monitor device coordinates here called *RGB** instead of *OLV**.

The International Standard ISO/IEC 15775 uses the more simple and effective way to define the relative **device coordinates *cmy** as linear function of *L* a* b**** *(right)*

6. Model output of 16 step *LAB** colours and inverse correction

6.1 Printer output of the ISO/IEC-test chart of this Technical report

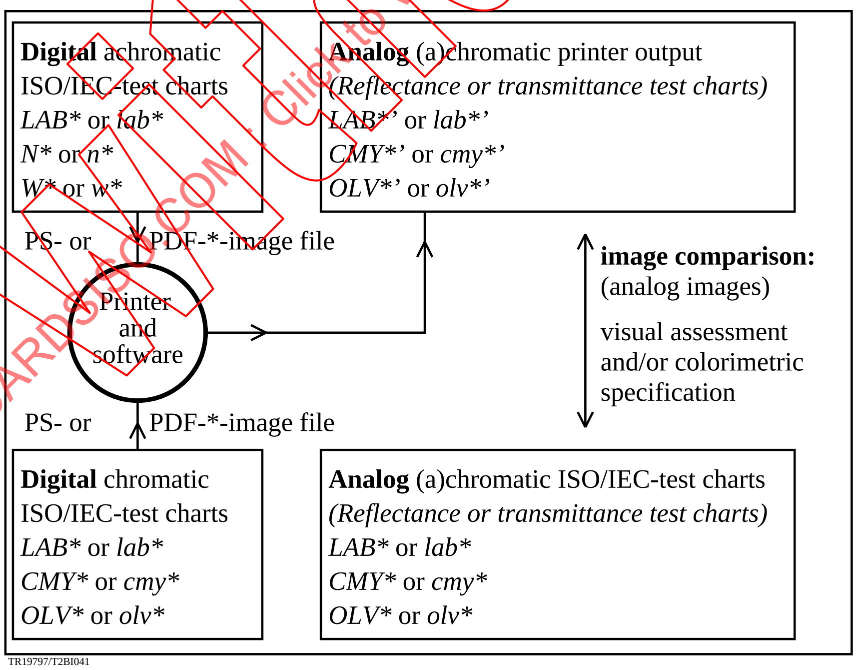


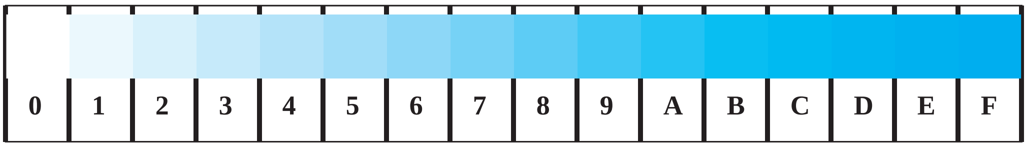
Figure 8: Specification of image reproduction for the printer system: "digital – analog"

Fig. 8 shows the specification of the image reproduction for the printer output by visual assessment and/or colorimetric measurement. The **analog printer** output (reproduction) is to be compared with the **analog** reference (the **analog** original of the ISO/IEC-test chart)

6.2 Simple model for standard and inverse image transformation

For Output Linearization (OL) the definitions of standard and inverse image transformation of section 2 are useful.

N: w* - x c*
LAB* setcolor_to_
cmy0* setcmykcolor



Different colour coordinates of this colour series; **Model of square output *' (star-prime) and correction by inverse square root input '* (prime-star)**

Series N: w* - x c* Transfer: LAB*_to_cmy* and other colour coordinates:

LAB*PR18	95.41 -0.97 4.76	92.96 -2.95 1.59	90.51 -4.92 -1.56	88.05 -6.9 -4.73	85.6 -8.87 -7.89	83.15 -10.85 -11.06	80.7 -12.82 -14.23	78.25 -14.8 -17.39	75.79 -16.78 -20.56	73.34 -18.75 -23.72	70.89 -20.73 -26.89	68.44 -22.7 -30.06	65.99 -24.68 -33.22	63.53 -26.66 -36.39	61.08 -28.63 -39.55	58.63 -30.61 -42.72
cmy*wPR18	0.0 0.0 0.0	0.07 0.0 0.0	0.13 0.0 0.0	0.2 0.0 0.0	0.27 0.0 0.0	0.33 0.0 0.0	0.4 0.0 0.0	0.47 0.0 0.0	0.53 0.0 0.0	0.6 0.0 0.0	0.67 0.0 0.0	0.73 0.0 0.0	0.8 0.0 0.0	0.87 0.0 0.0	0.93 0.0 0.0	1.0 0.0 0.0
LAB*'PR18 (star-prime)	**95.41 -0.97 4.76**	**90.67 -4.79 -1.35**	**86.26 -8.35 -7.05**	**82.17 -11.64 -12.33**	**78.41 -14.67 -17.18**	**74.98 -17.43 -21.61**	**71.87 -19.94 -25.62**	**69.09 -22.18 -29.21**	**66.64 -24.15 -32.38**	**64.51 -25.86 -35.12**	**62.72 -27.31 -37.44**	**61.25 -28.5 -39.34**	**60.1 -29.42 -40.82**	**59.28 -30.08 -41.88**	**58.79 -30.47 -42.51**	**58.63 -30.61 -42.72**
cmy'*wPR18 (prime-star)	**0.0 0.0001 0.0**	**0.0338 0.0001 0.0**	**0.069 0.0001 0.0**	**0.1055 0.0001 0.0**	**0.1435 0.0001 0.0**	**0.1834 0.0001 0.0**	**0.2253 0.0001 0.0**	**0.2696 0.0001 0.0**	**0.3167 0.0001 0.0**	**0.3674 0.0001 0.0**	**0.4225 0.0001 0.0**	**0.4834 0.0001 0.0**	**0.5526 0.0001 0.0**	**0.6346 0.0001 0.0**	**0.7415 0.0001 0.0**	**0.9996 0.0001 0.0001**
LAB*PR18 (corrected)	95.41 -0.97 4.76	92.96 -2.95 1.59	90.51 -4.92 -1.56	88.05 -6.9 -4.73	85.6 -8.87 -7.89	83.15 -10.85 -11.06	80.7 -12.82 -14.23	78.25 -14.8 -17.39	75.79 -16.78 -20.56	73.34 -18.75 -23.72	70.89 -20.73 -26.89	68.44 -22.7 -30.06	65.99 -24.68 -33.22	63.53 -26.66 -36.39	61.08 -28.63 -39.55	58.63 -30.61 -42.72

File http://www.ps.bam.de/DE48/X10/X41E00NP.PS/.PDF for similar files, see http://www.ps.bam.de/DE48/DE48.HTM

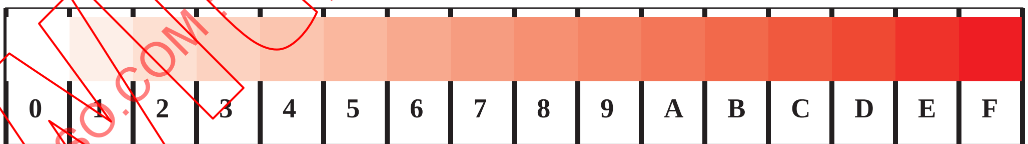
TR19797/X41E00NP

Figure 9: Cyan colours in *LAB and *cmy** and inverse of the first output by the MTL code**

Fig. 9 shows the transformation from *LAB** to *cmy**. It is assumed that the first output data is *LAB*'* (star-prime) which is defined by a square root now. The first output of the square root *LAB*'* data are corrected in Fig. 9 by the MTL code. The intended output data *LAB*PR18* are calculated by using the inverse *cmy'** (prime-star) data. Therefore then the input and output LAB* data correspond as intended.

If for a real device the device output data give by measurement the square root output data *LAB*'* (star-prime), then the default linear *LAB** data in the MTL code must be replaced by the square root output data *LAB*'* and then the *cmy'** (prime-star) data are calculated automatically by the MTL code. The corrections by the MTL code work for **any output data *LAB*'*** of the device. The *LAB*'* measurement data must define a monotone 16 step data set (the distance between the colour and white must continuously decrease in CIELAB space) which seems the case for any real device studied up to now.

N: w* - x o*
LAB* setcolor_to_
cmy0* setcmykcolor



Different colour coordinates of this colour series; **Model of square output *' (star-prime) and correction by inverse square root input '* (prime-star)**

Series N: w* - x o* Transfer: LAB*_to_cmy* and other colour coordinates:

LAB*PR18	95.41 -0.97 4.76	92.25 3.44 7.91	89.08 7.86 11.07	85.92 12.28 14.22	82.75 16.7 17.38	79.59 21.12 20.53	76.42 25.54 23.69	73.26 29.96 26.84	70.09 34.38 30.0	66.93 38.8 33.15	63.76 43.22 36.31	60.6 47.64 39.46	57.43 52.06 42.61	54.27 56.48 45.77	51.1 60.9 48.92	47.94 65.32 52.08
cmy*wPR18	0.0 0.0 0.0	0.0 0.07 0.07	0.0 0.13 0.13	0.0 0.2 0.2	0.0 0.27 0.27	0.0 0.33 0.33	0.0 0.4 0.4	0.0 0.47 0.47	0.0 0.53 0.53	0.0 0.6 0.6	0.0 0.67 0.67	0.0 0.73 0.73	0.0 0.8 0.8	0.0 0.87 0.87	0.0 0.93 0.93	0.0 1.0 1.0
LAB*'PR18 (star-prime)	**95.41 -0.97 4.76**	**89.29 7.57 10.86**	**83.6 15.52 16.54**	**78.32 22.89 21.79**	**73.47 29.66 26.63**	**69.04 35.85 31.05**	**65.03 41.45 35.04**	**61.44 46.46 38.62**	**58.28 50.88 41.77**	**55.54 54.71 44.51**	**53.21 57.95 46.82**	**51.32 60.6 48.71**	**49.84 62.67 50.19**	**48.78 64.14 51.24**	**48.15 65.02 51.87**	**47.94 65.32 52.08**
cmy'*PR18 (prime-star)	**0.0 0.0001 0.0**	**0.0 0.034 0.0338**	**0.0 0.0691 0.069**	**0.0 0.1056 0.1055**	**0.0 0.1437 0.1436**	**0.0 0.1836 0.1835**	**0.0 0.2255 0.2254**	**0.0 0.2698 0.2697**	**0.0 0.3169 0.3169**	**0.0 0.3676 0.3675**	**0.0 0.4227 0.4226**	**0.0 0.4837 0.4836**	**0.0 0.5528 0.5528**	**0.0 0.6349 0.6349**	**0.0 0.7419 0.7418**	**0.0 1.0 1.0001**
LAB*PR18 (corrected)	95.41 -0.97 4.76	92.25 3.44 7.91	89.08 7.86 11.07	85.92 12.28 14.22	82.75 16.7 17.38	79.59 21.12 20.53	76.42 25.54 23.69	73.26 29.96 26.84	70.09 34.38 30.0	66.93 38.8 33.15	63.76 43.22 36.31	60.6 47.64 39.46	57.43 52.06 42.61	54.27 56.48 45.77	51.1 60.9 48.92	47.94 65.32 52.08

File http://www.ps.bam.de/DE49/X10/X41E00NP.PS/.PDF for similar files, see http://www.ps.bam.de/DE49/DE49.HTM

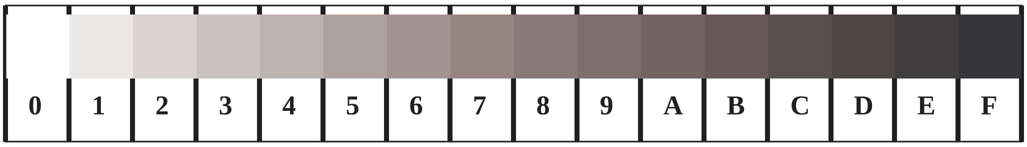
TR19797/X41E01NP

Figure 10: Orange red colours in *LAB and *cmy** and inverse of the first output by the MTL code.**

Fig. 10 is similar to Fig. 9. Instead of the cyan series the orange red *o** series is used. The device square root data

LAB'* are corrected by the MTL code to the data *LAB**. So again the input and output correspond.

N: w - x cmy**
LAB setcolor_to_*
cmy0 setcmykcolor*



Different colour coordinates of this colour series; ***Model of square output *' (star-prime) and correction by inverse square root input '* (prime-star)***

Series N: w* - x cmy*	Transfer: LAB*_to_cmy* and other colour coordinates:															
LAB*PR18	95.41	90.25	85.09	79.93	74.77	69.61	64.45	59.29	54.13	48.97	43.81	38.65	33.49	28.33	23.17	18.01
	-0.97	-0.87	-0.77	-0.67	-0.58	-0.48	-0.38	-0.28	-0.18	-0.08	0.01	0.11	0.2	0.3	0.4	0.5
	4.76	4.41	4.06	3.72	3.37	3.02	2.67	2.32	1.98	1.63	1.28	0.93	0.58	0.24	-0.1	-0.45
cmy*wPR18	0.0	0.07	0.13	0.2	0.27	0.33	0.4	0.47	0.53	0.6	0.67	0.73	0.8	0.87	0.93	1.0
	0.0	0.07	0.13	0.2	0.27	0.33	0.4	0.47	0.53	0.6	0.67	0.73	0.8	0.87	0.93	1.0
	0.0	0.07	0.13	0.2	0.27	0.33	0.4	0.47	0.53	0.6	0.67	0.73	0.8	0.87	0.93	1.0
LAB*'PR18	**95.41**	**85.43**	**76.15**	**67.55**	**59.63**	**52.41**	**45.87**	**40.03**	**34.87**	**30.39**	**26.61**	**23.51**	**21.11**	**19.39**	**18.35**	**18.01**
(star-prime)	**-0.97**	**-0.78**	**-0.6**	**-0.44**	**-0.29**	**-0.15**	**-0.02**	**0.08**	**0.18**	**0.26**	**0.34**	**0.39**	**0.44**	**0.47**	**0.49**	**0.5**
	4.76	**4.09**	**3.46**	**2.88**	**2.35**	**1.86**	**1.42**	**1.02**	**0.68**	**0.38**	**0.12**	**-0.08**	**-0.24**	**-0.36**	**-0.43**	**-0.45**
cmy'*PR18	**0.0**	**0.0338**	**0.069**	**0.1055**	**0.1436**	**0.1834**	**0.2253**	**0.2696**	**0.3168**	**0.3675**	**0.4226**	**0.4836**	**0.5527**	**0.6348**	**0.7418**	**1.0**
(prime-star)	**0.0001**	**0.034**	**0.0691**	**0.1056**	**0.1437**	**0.1835**	**0.2254**	**0.2697**	**0.3169**	**0.3676**	**0.4227**	**0.4836**	**0.5528**	**0.6349**	**0.7418**	**1.0**
	0.0	**0.0339**	**0.069**	**0.1055**	**0.1436**	**0.1835**	**0.2254**	**0.2697**	**0.3169**	**0.3676**	**0.4227**	**0.4836**	**0.5528**	**0.6349**	**0.7419**	**1.0001**
LAB*PR18	95.41	90.25	85.09	79.93	74.77	69.61	64.45	59.29	54.13	48.97	43.81	38.65	33.49	28.33	23.17	18.01
(corrected)	-0.97	-0.87	-0.77	-0.67	-0.58	-0.48	-0.38	-0.28	-0.18	-0.08	0.01	0.11	0.2	0.3	0.4	0.5
	4.76	4.41	4.06	3.72	3.37	3.02	2.67	2.32	1.98	1.63	1.28	0.93	0.58	0.24	-0.1	-0.45

File http://www.ps.bam.de/DE49/X10/X44E00NP.PS/.PDF *for similar files, see http://www.ps.bam.de/DE49/DE49.HTM*

Figure 11: Grey colours in *LAB and *cmy** and inverse of the first output by the MTL code.**

Fig. 11 is similar to Fig. 9 and 10. The achromatic grey series is used here. The device square root data *LAB*'* are corrected by the MTL code to the data *LAB**. So again the input and output correspond.

The methods shown in figures 8 to 11 are of much importance for both users and manufacturers. The user will get a 16 step equally spaced device output if the manufacturer installs within the printer or the printer driver the MTL code which includes the first output measurement data *LAB*'*. If the user is still not satisfied with this default data the user can design his own additional MTL code for a specific paper or application.

7. Places for the Measurement, Transfer and Linearization (MTL) PS code

Within the PostScript file the **MTL** (Measurement, Transfer and Linearization) **PS code converts from the *LAB** to the *cmy** coordinates** and to the other coordinates **and vice versa**. This MTL PS code also 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 adjust the output in the intended direction. This paper uses the **MTL code in the file header** but it could be stored instead in:

1. The PS printer
2. The PostScript Printer Driver (PPD file)
3. The Adobe Acrobat Distiller Startup directory

The **MTL code** (MTL Measurement, Transfer and Linearization) includes a Colour Measurement (CM) *LAB*'* data table of the 128 standard colours, the Colour Coordinate Transfer (CT) code, the Input Linearization (IL) code (for scanners) and the Output Linearization (OL) code (for printers and monitors). Here only parts of a general standard MTL code are used for the printer output. The main feature is to calculate for the first output the *cmy'** input data from the measured *LAB*'* for the first output data and to produce the intended linear *LAB** output data which correspond to the intended *cmy** input data.

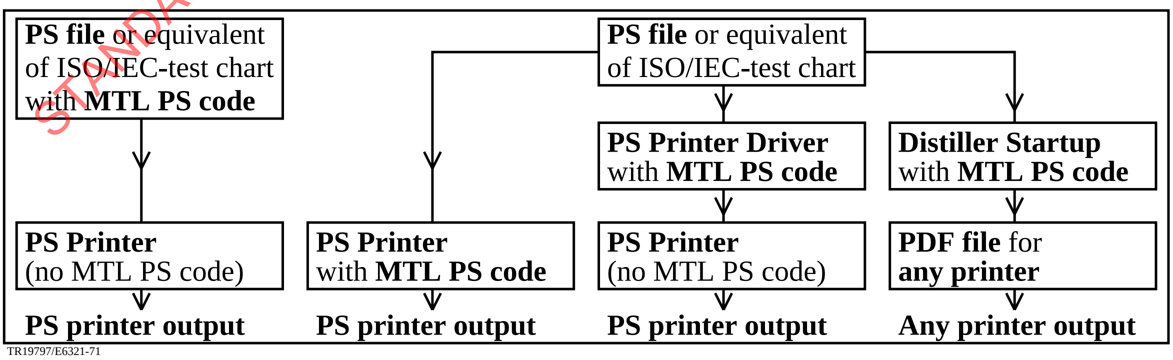


Figure 12: MTL (Measurement, Transfer and Linearization) PS code and Printer Output

Fig. 12 shows the different possibilities of where the MTL code can be placed within the CIELAB - *cmy** colour workflow. The PS file of the ISO/IEC-test chart is used for the output in this Technical Report.

Any PS file (according to our experience) which has been produced from **any application** on **any computer operating system** is **varied by this MTL code** in the same manner if the **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. 12.

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.

8. Input–Output relationship of a colour laser printer (T) using the MTL code

8.1 Output Linearization of the 128 standard colours on a laser printer

Figure 13: Output Linearization (OL) of the 128 standard colours using output CIELAB data.

One may compare the output of Fig. 13 with Fig. 5 which was reproduced with **No** Output Linearization (OL). In Fig. 13 all 16 steps can be seen on the printer (T). This is reached by including the first output measurement data *LAB*'* at one of the different places listed in Fig. 12.

Fig. 13 includes the *LAB** measurement data at the beginning of the file and the URL of this file is given at the top.

Fig. 13 shows the 128 standard colours of this Technical Report. Most printer systems produce 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** for Fig. 5 but **equally spaced** after correction as shown in the right side of Fig. 13.

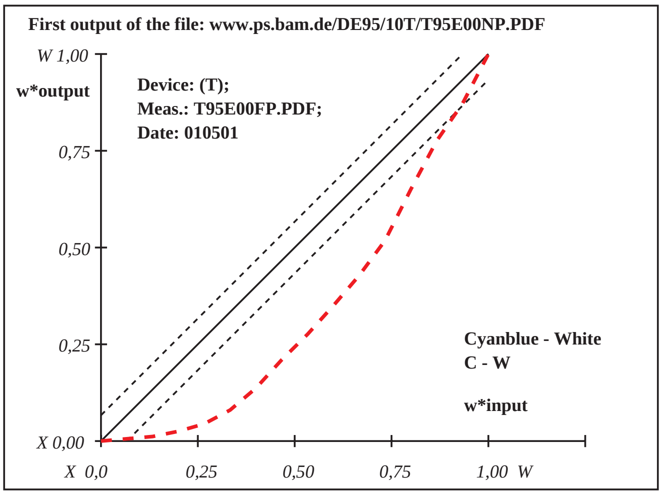
Instead of the equally spaced digital input values between 0 and 1 (0, 1/15, 2/15, ..., 14/15, 15/15) one can calculate new digital input values on the scale between 0 and 1 to get an equally spaced output (0, 1/15, 2/15, ..., 14/15, 15/15) on the visual relative CIELAB scale. Fig. 9 to 11 show examples how to calculate the inverse input data *cmy'** (dash-star) from the output data *cmy*'* (star-prime).

The calculations are based on the measurement on the 128 CIELAB color patches. 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 will produce the equidistant output on the relative CIELAB scale.

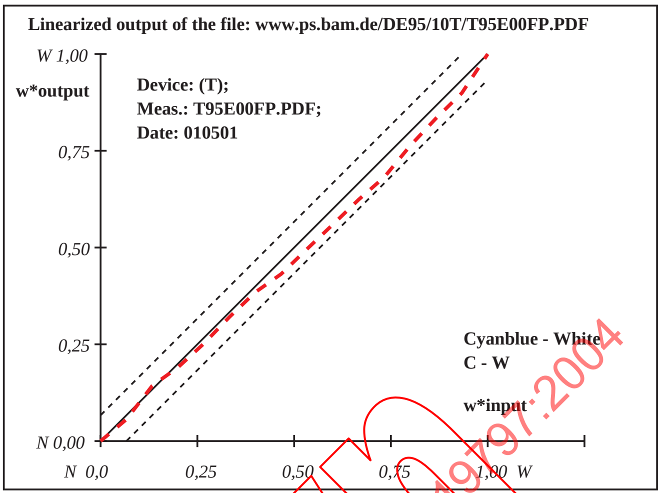
8.2 First and linearized output for 8 colour series on a laser printer

Figure 13 shows the linearized output for laser printer. For example by the software *Adobe Illustrator or equivalent* one can check the digital input data of Fig. 5 (equally spaced) and Fig. 13 (changed by CIELAB measurement).

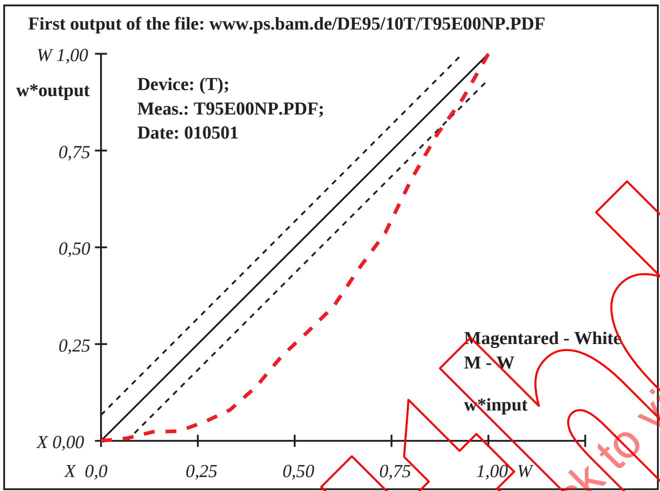
The output of the digital ISO/IEC-test chart of Fig. 5 and 13 has produced on one example printer the following input-output relationship with No and with Output Linearization (OL) (left and right).



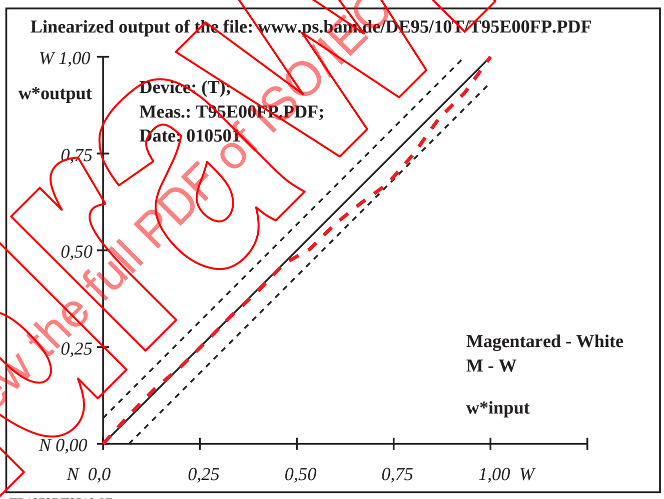
TR19797/T9510-1N



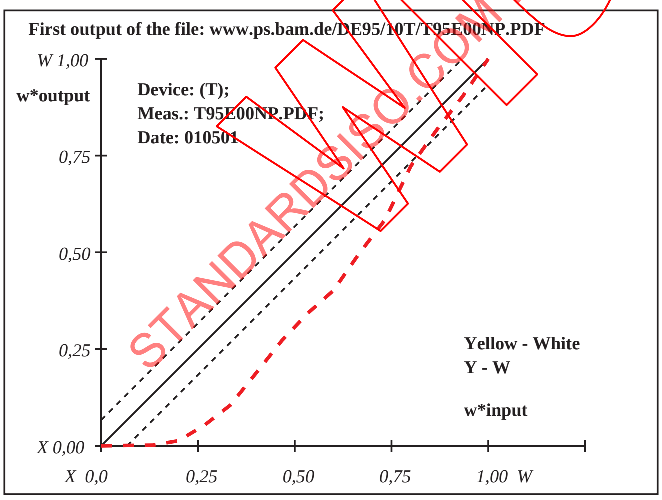
TR19797/T9510-1F



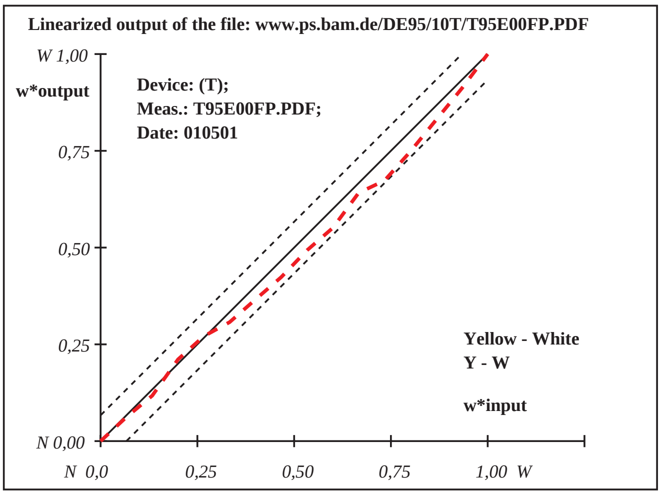
TR19797/T9510-2N



TR19797/T9510-2F



TR19797/T9510-3N



TR19797/T9510-3F

Figure 14: Input-output relationship for the first and linearized output of 8 colour series

In Fig. 14 the 8 standard colour series of the 128 standard colours of this Technical Report are shown for the first and the linearized output.

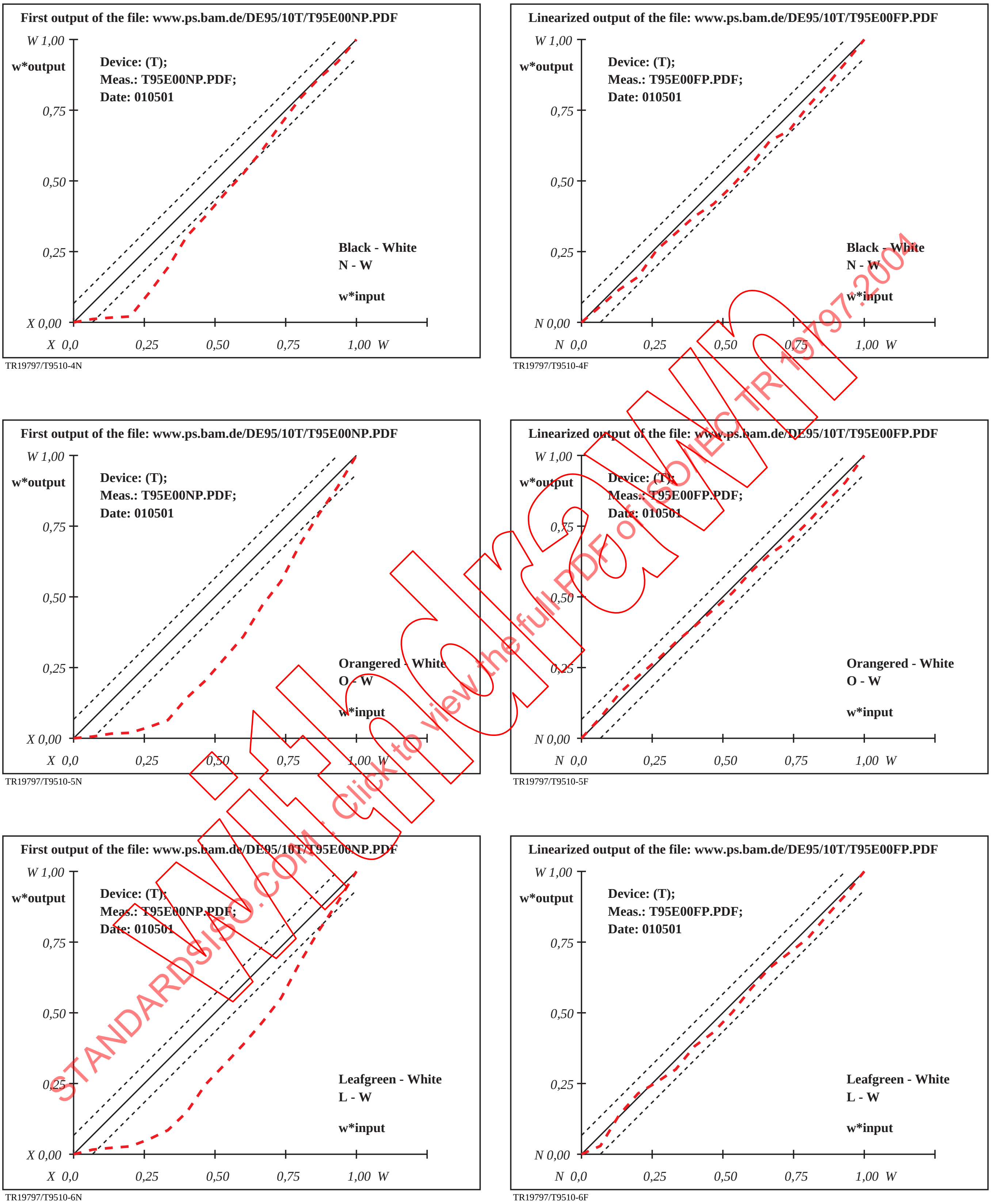


Figure 14: Input-output relationship for the first and linearized output of 8 colour series

In Fig. 14 the 8 standard colour series of the 128 standard colours of this Technical Report are shown for the first and the linearized output.

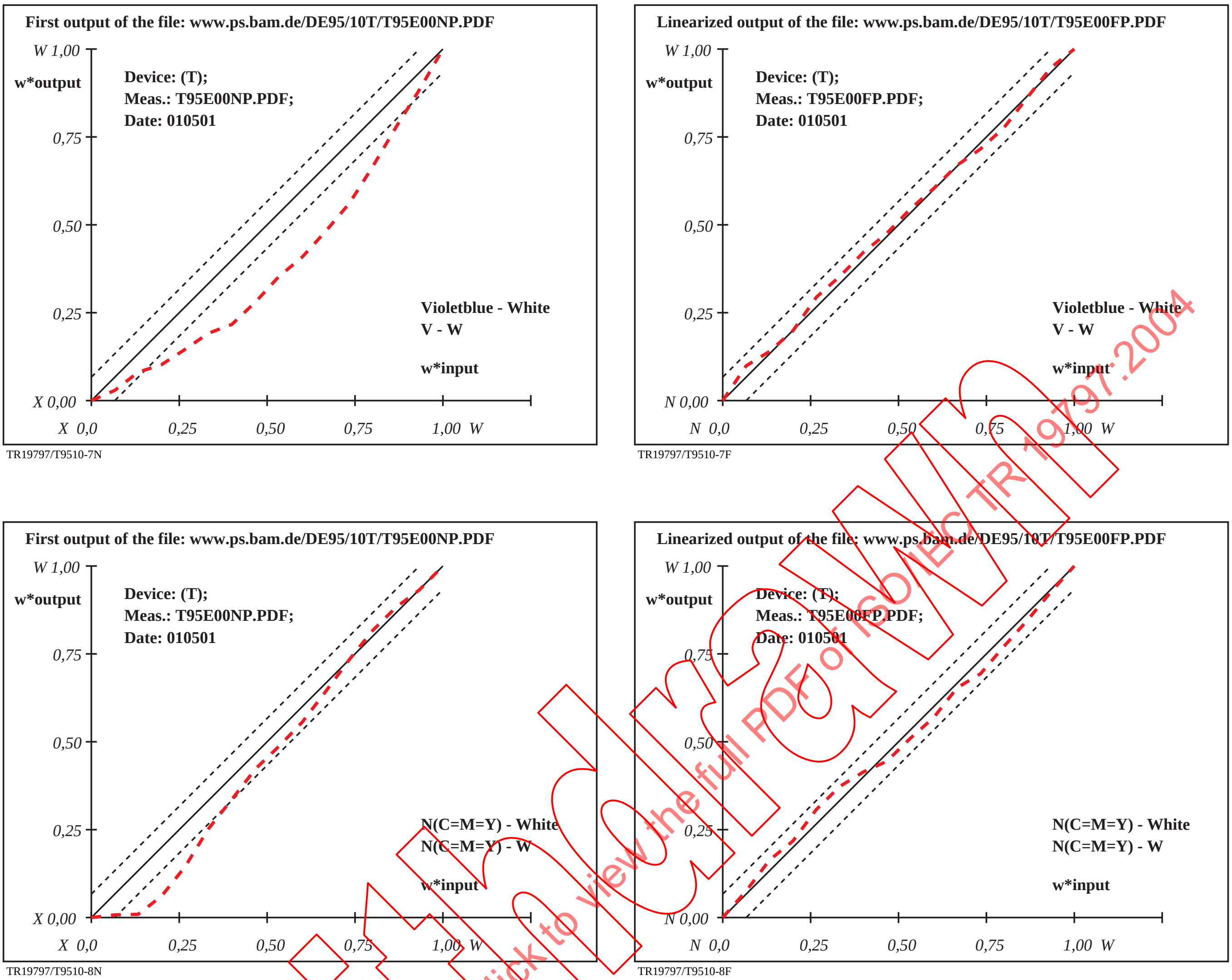


Figure 14: Input-output relationship for the first and linearized output of 8 colour series

In Fig. 14 the 8 standard colour series of the 128 standard colours of this Technical Report are shown for the first and the linearized output.

Table 4: Test results for the first output and the linearized PS and PDF output of three printers

Specification according to ISO/IEC 15775 by the mean of 16 CIELAB colour differences of the actual output compared to the reference output defined by the printer colours CMYN or OLV(CMY) and W	Device F Foto colour printer; Output files: F14E00NA.PS and F14E00FA.PS Result (R) in table and graphic form (8 pages): F14E00RA.PDF	Device O Laser colour printer; Output files: O14E00NA.PS and O14E00FA.PS Result (R) in table and graphic form (8 pages): O14E00RA.PDF	Device O Laser colour printer; Output files: O14E00NP.PDF and O14E00FP.PDF Result (R) in table and graphic form (8 pages): O14E00RP.PDF	Device T Laser colour printer; Output files: T14E00NA.PS and T14E00FA.PS Result (R) in table and graphic form (8 pages): T14E00RA.PDF	Device T Laser colour printer; Output files: T14E00NP.PDF and T14E00FP.PDF Result (R) in table and graphic form (8 pages): T14E00RP.PDF
Mean of 16 Cyanblue (C - W) colour differences	8.3 for the start output 0.4 for the linearized output	4.9 for the start output 1.3 for the linearized output	12.8 for the start output 2.6 for the linearized output	5.9 for the start output 1.4 for the optimzed output	11.9 for the start output 1.7 for the linearized output
Mean of 16 Magentared (M - W) colour differences	12.4 for the start output 0.9 for the linearized output	11.1 for the start output 2.3 for the linearized output	7.0 for the start output 1.6 for the linearized output	7.2 for the start output 2.2 for the optimzed output	14.8 for the start output 1.8 for the linearized output
Mean of 16 Yellow (Y - W) colour differences	2.7 for the start output 1.8 for the linearized output	17.1 for the start output 2.1 for the linearized output	6.9 for the start output 2.0 for the linearized output	6.2 for the start output 2.9 for the optimzed output	13.9 for the start output 2.8 for the linearized output
Mean of 16 Black (N - W) colour differences	1.9 for the start output 0.3 for the linearized output	6.1 for the start output 0.8 for the linearized output	2.2 for the start output 1.2 for the linearized output	2.7 for the start output 0.9 for the optimzed output	5.5 for the start output 2.1 for the linearized output
Mean of 16 Orangred (O - W) colour differences	3.5 for the start output 1.1 for the linearized output	10.3 for the start output 3.3 for the linearized output	7.8 for the start output 1.1 for the linearized output	8.9 for the start output 2.3 for the linearized output	15.3 for the start output 1.6 for the linearized output
Mean of 16 Leafgreen (L - W) colour differences	5.0 for the start output 1.2 for the linearized output	12.6 for the start output 1.9 for the linearized output	7.0 for the start output 1.4 for the linearized output	6.2 for the start output 2.8 for the linearized output	13.8 for the start output 1.8 for the linearized output
Mean of 16 Violettblue (V - W) colour differences	9.2 for the start output 0.6 for the linearized output	5.0 for the start output 2.4 for the linearized output	10.4 for the start output 1.2 for the linearized output	4.5 for the start output 1.7 for the linearized output	8.9 for the start output 0.9 for the linearized output
Mean of 16 Black (CMY - W) colour differences	1.4 for the start output 0.3 for the linearized output	6.3 for the start output 0.7 for the linearized output	12.2 for the start output 0.8 for the linearized output	3.0 for the start output 0.4 for the linearized output	3.8 for the start output 1.6 for the linearized output

Table 4 specifies the reproduction properties of the colour series W – CMYN and W – OLV(CMY) of three different printers (F, O and T) in real tests. The PS operator *cmyn* setcmykcolor* (* = relative coordinates in CIELAB colour space) was used. For all printers a PS output was produced. A PDF output was produced on the printers O and T. The PS and PDF accuracy is often very different. The improvement of the 16 step spacing is 300% to 600% (the relative CIELAB differences are reduced by a factor 3 to 6) by Output Linearization (OL). This is a large improvement for the office area. It may not be sufficient for professional applications but it is very simple to install and simple to modify for different requirements, e. g. for a change of the output paper.

9. Basic Transformations between *LAB** and *cmy**

Table 5: CIELAB and CIEXYZ data of printing (PR) system PR18 according to ISO/IEC 15775

System PR18	**Color**	**L*=LAB*c$_1$**	**a*=LAB*c$_2$**	**b*=LAB*c$_3$**	**C*$_{ab}$=LAB*c$_r$**	**X=XYZc$_1$**	**Y=XYZc$_2$**	**Z=XYZc$_3$**	**x**	**y**	**Y/88.59**
LAB*c (c=CIE)	C	58.62	-30.62	-42.74	52.59	18.74	26.62	68.55	0.1645	0.2337	0.3005
(CIELAB according	V	25.72	31.45	-44.35	54.38	7.17	4.65	21.41	0.2158	0.14	0.0525
to ISO/IEC 15775)	M	48.13	75.2	-6.79	75.51	33.06	16.9	22.01	0.4594	0.2348	0.1907
	O	47.94	65.31	52.07	83.53	30.13	16.75	2.68	0.608	0.338	0.189
	Y	90.37	-11.15	96.17	96.82	68.07	77.11	9.03	0.4414	0.5	0.8703
	L	50.9	-62.96	36.71	72.89	8.71	19.18	6.62	0.2523	0.5559	0.2165
	N	18.01	0.5	-0.46	0.69	2.42	2.52	2.81	0.3122	0.3251	0.0284
	W	95.41	-0.98	4.76	4.86	83.69	88.59	89.48	0.3197	0.3384	1.0
	N0	0.01	0.84	-1.68	1.89	0.02	0.0	0.12	0.1518	0.0078	0.0
	W1	100.0	-1.07	5.06	5.17	94.44	100.0	100.84	0.3198	0.3387	1.1288
	Color	**L*sa=LAB*sa$_1$**	**a*sa=LAB*sa$_2$**	**b*sa=LAB*sa$_3$**	**C*sa$_{ab}$=LAB*sa$_r$**	**Xsa=XYZsa$_1$**	**Ysa=XYZsa$_2$**	**Zsa=XYZsa$_3$**	**xsa**	**ysa**	**Ysa/88.59**
LAB*sa	C	58.62	-30.34	-45.01	54.3	18.79	26.62	71.32	0.161	0.228	0.3005
(sytem adapted	V	25.72	31.1	-44.4	54.22	7.14	4.65	21.44	0.2148	0.14	0.0525
and CIELAB cero point)	M	48.13	75.28	-8.36	75.74	33.08	16.9	22.9	0.4539	0.2319	0.1907
	O	47.94	65.39	50.52	82.63	30.15	16.75	2.9	0.6054	0.3363	0.189
	Y	90.37	-10.26	91.75	92.32	68.47	77.11	10.48	0.4388	0.4941	0.8703
	L	50.9	-62.83	34.96	71.91	8.72	19.18	7.07	0.2494	0.5484	0.2165
	N	18.01	0.0	0.0	0.0	2.4	2.52	2.74	0.3127	0.329	0.0284
	W	95.41	0.0	0.0	0.0	84.21	88.59	96.48	0.3127	0.329	1.0
	N0	0.01	0.0	0.0	0.01	0.0	0.0	0.0	0.2505	0.3104	0.0
	W1	100.0	0.0	0.0	0.01	95.05	100.0	108.92	0.3127	0.329	1.1288
	Color	**L*s0=LAB*s0$_1$**	**a*s0=LAB*s0$_2$**	**b*s0=LAB*s0$_3$**	**C*s0$_{ab}$=LABs0*$_r$**						
LAB*s0	C	40.61	-30.34	-45.01	54.3						
(system adapted	V	7.71	31.1	-44.4	54.22						
and cero point at black N)	M	30.12	75.28	-8.36	75.74						
	O	29.93	65.39	50.52	82.63						
	Y	72.36	-10.26	91.75	92.32						
	L	32.89	-62.83	34.96	71.91						
	N	0.0	0.0	0.0	0.0						
	W	77.4	0.0	0.0	0.0						
	N0	-17.99	0.0	0.0	0.01						
	W1	81.99	0.0	0.0	0.01						

Basic CIELAB (LAB*c) and CIEXYZ (XYZ) colour data for CIE illuminant D65 and for the CIE 2 degree observer and for the CIE 45/0 measurement geometry

for the reference ISO/IEC-test charts
in reflectance mode

defined by the standard printing (PR) system PR18 according to ISO/IEC 15775, Table 7 and 8

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Table 5 shows the CIELAB and CIEXYZ data of the offset printing system PR18 according to ISO/IEC 15775. The *LAB**$_c$ (c=CIE) data are transferred to CIEXYZ and CIE chromaticity *(x,y).* The relative luminance reflectance is normalized to white W in the last column.

The second part of the Table 5 shows the data which are called *LAB*sa* (system adapted = *sa*). The *a** and *b** data of black N and white W are different from zero for standard offset printing, e. g. the reference paper is a yellowish tint.

A linear shift as function of CIE lightness *L** transfers the *a** and *b** data for all achromatic colours to zero and changes the six basic colours by a numerical amount which is small compared to the recommended tolerance of 3 CIELAB units and the reference scales of about 80 units between white and black and white and the 6 basic colours.

The third part of the Table 5 shows the data which are called *LAB*s0* (system adapted to zero = *s0)*. The zero point of black N is at zero which allows to use simpler equations for the different coordinate transformations

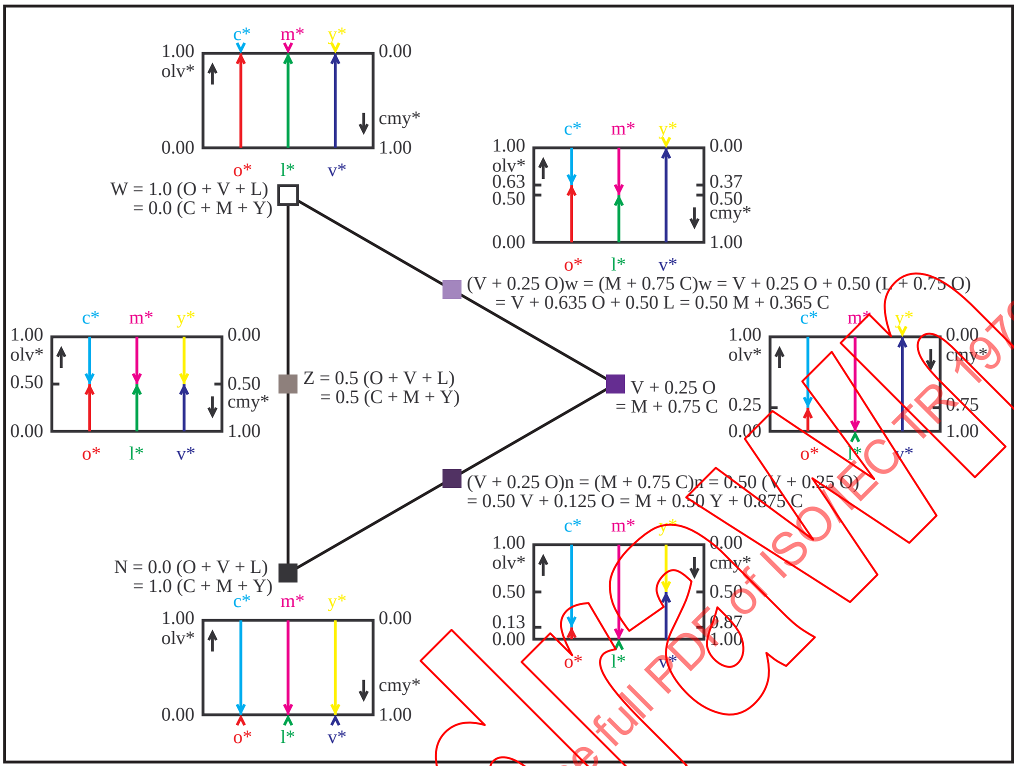

Figure 15: Relationship between *olv and *cmy** *colour data for the hue 1.00M + 0.75C**

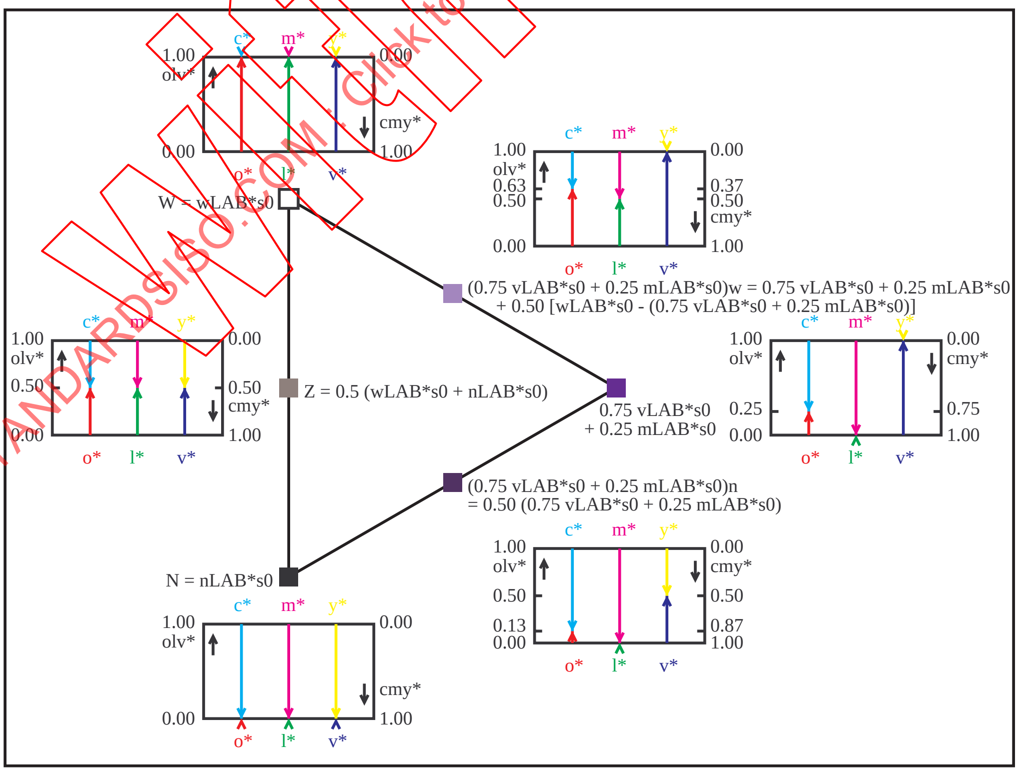

Figure 16: Relationship between *LAB and *cmy** *colour data for the hue 1.00M + 0.75C**