

10 years equally spaced colour output in CIELAB for equally spaced rgb-input data in standards and elementary colour output according to DIN 33872

RECS09.PDF, Version 0908

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1. Standard documents in Colour Image Technology

For equally spaced *rgb-colour* input data the International Standard ISO/IEC 15775:1999 and the DIN-standard series DIN 33866-1 to -5:2000 recommend an equally spaced output in CIELAB. This is reached by device linearization according to ISO/IEC TR 19797: 2004. ISO/IEC TR 24705:2005 recommends equal output for equivalent *rgb*, *w*, *k*, and *cm*y-coordinates which are connected by the so called „1-minus-relation“, for example $c = 1 - r$. For the four equivalent grey scales of the test chart according to DIN-33872-3 (in print) an equal output is produced on the classical black and white printer „Apple-Laser-Writer“ and also on a monitor with the computer operating system *Mac OS X, versions 10.0 and 10.1: 2002*. Newer versions of *Mac OS X* produce up to four and *Adobe Reader* up to three different grey scales, some look chromatic. Reasons for this „colour chaos“ in the office colour output are a variety of new technologies, and the ICC-colour management according to ISO 15076-1. For the user this “standard” offers four output methods, and for the manufacturers and the software it allows nearly any tone scale transformation. For example instead of 256 output possibilities according to 15706-1 the above ISO/IEC-standard documents allow only *one* output and this can be visually evaluated.

Achromatic colours	Elementary colours "Neither-nor"-colours	Device colours Television (TV), Print (PR) Photography (PH)
five achromatic colours:	four elementary colours:	six device colours:
N black (french noir)	R red	C cyanblue
D dark grey	neither yellowish nor blueish	M magentared
Z central grey	G green	Y yellow
H light grey	neither yellowish nor blueish	O orangered
W white	B blue	L leafgreen
	J yellow (french jaune)	V violetblue
	neither greenish nor reddish	

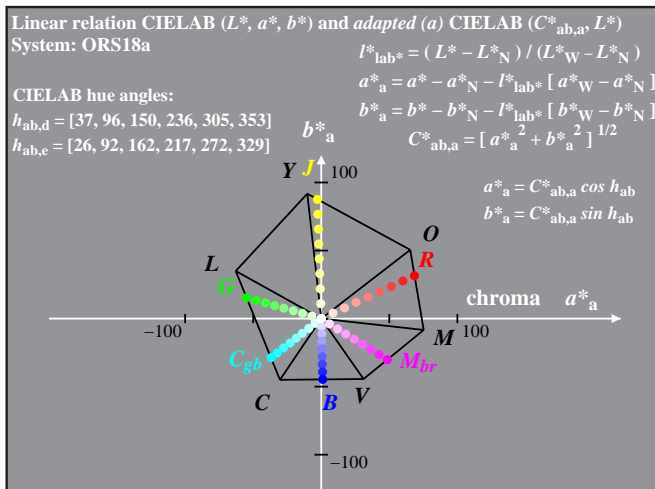
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Tab. 1: Definition of elementary and device colours according to ISO/IEC 15775:1999

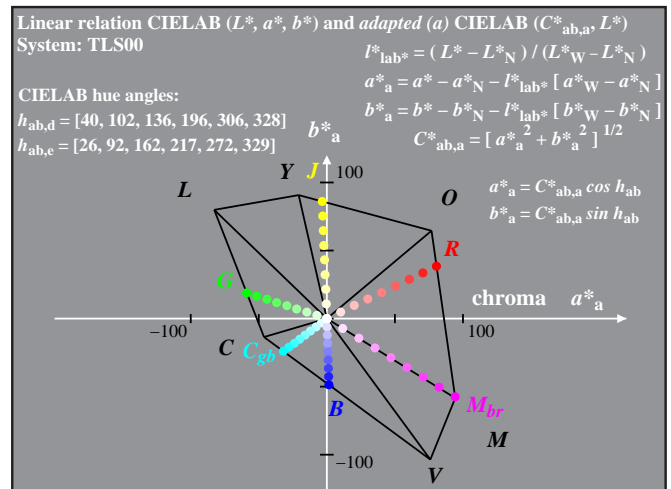
In ISO/IEC 15775:1999 there is a clear distinction between the device and elementary hues (colours) which are *device independent* and defined by visual criteria.

2. New device independent elementary hue output

According to DIN 33872-1 to -6 (in print), see www.ps.bam.de/33872E, it is now intended that any device system produces the *device independent elementary hues Red, Yellow, Green, and Blue RJGB* for the *rgb*-input data (1,0,0), (1,1,0), (0,1,0), (0,0,1) and not the different device hues. In DIN 33872 the CIE-test colours no. 9 to 12 according to CIE publication 13.3 are used to define the elementary hues *RJGB* which have the CIELAB hue angles $h_{ab} = 26, 92, 162,$ and 272 for the CIE-standard illuminant D65, compare (41 pages, 1,4 MByte) www.ps.bam.de/D33872-AE.PDF and CIE R1-47:2009.



De430-31



De430-71

Fig. 1: Device hues OYLCVM of the standard offset system ORS18, the standard monitor TLS00, and the elementary hues RJGB.

The colour atlas *Relative Elementary Colour System RECS:2008* is the *first analog colour system worldwide* which uses the four elementary hues *RJGB* as anchor points. Two middle hues C_{gb} and M_{br} are added in Fig.1. The RECS hue circle has 16 hues (atlas, page 1). The 5- and 16-step colour series are shown for the 16 hues on the pages 2 to 17. They are all equally spaced, both visually and in CIELAB. Page 18 shows a 9x9x9 grid of regularly spaced *rgb*-input colours, see www.ps.bam.de/RECS

3. Affine transformations for colour image technology

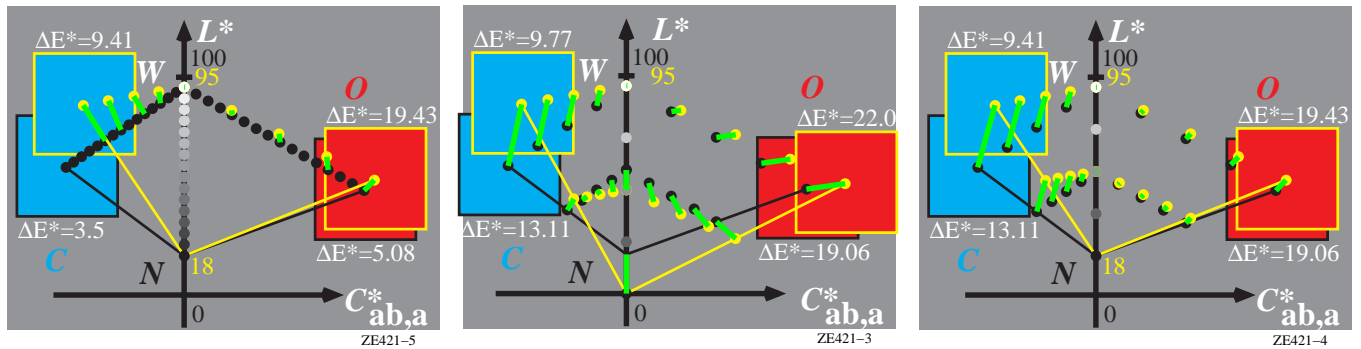


Fig. 2: ICC- and affine transformations between a monitor (yellow) and a printer (black) in a CIELAB hue plane ($C^*_{ab,a}$, L^*)

Fig. 2 shows the two device gamuts of either the standard monitor TLS00 or TLS18 (yellow) and standard offset printing ORS18 (black) according to ISO/IEC 15775. In any of the three parts the two device gamuts are very different. The usual ICC transformation according to ISO 15706-1 is shown in the left figure. In general ICC calculates the ORS18 colours (black) which have the lowest colour difference compared to the TLS18 colours (yellow), see left part. Therefore in print only the common colours of both systems TLS18 and ORS18 are reproduced. Therefore many light colours Cyan blue look equal in the print and many possible chromatic colour Cyan blue in the print are not printed. This is a large disadvantage for both the users and the manufacturers.

Therefore ICC colour management systems often produce colours Cyan blue colours of less chroma and the user is disappointed. The manufacturer has created colours of high chroma to allow a brilliant output but the colour of high chroma are not printed. To solve the requests of the users the manufacturer have looked for solutions and have developed own proprietary transformations.

The colorimetric solution is an affine transformation and this is appropriate for standardization. The affine transformation is shown in the middle and right part of Fig. 2. There is only one solution for the affine transformation and there is an infinite transformation number according to ICC colour management. The many advantages of the affine transformations will lead to an improved colour management with many advantages for both users and manufacturers. The equally spaced colour series can be evaluated visually and specified by colour measurement. This is a further advantage of the affine transformation. There is no possibility of a visual evaluation for the ICC colour management according to Fig. 2 (left).

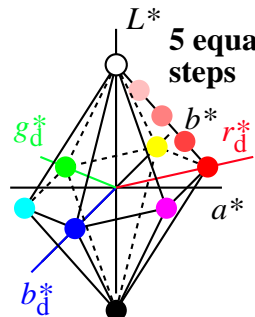
8 Device (d) colours in CIELAB: OYLCVM and NW

New hexagon-triangle system based on device (d) colours: $rgb^*_d = olv^*$ with **linear relations** between rgb^*_d and LCH^* (compare linear relations between rgb_{sRGB} and L^*)

Equations $rgb^*_d - LCH^*$ in both directions have been published, see: Richter, CIE-Proceedings, Beijing, 2008, Volume 3 und DIN 33872-1

Three equations (tables) are needed for office applications:

$rgb_d - LCH^*$	for a 9x9x9 grid of equally spaced rgb_d -input data
$rgb^*_d - LCH^*$	a 9x9x9 grid of equally spaced data rgb^*_d and LCH^*
$rgb'_d - LCH^*$	Device output linearisation by $rgb_d \rightarrow rgb'_d$



5 equal steps

Fig. 3: Eight device colours in the 3-dimensional CIELAB space L^* , a^* , b^*

Fig. 3 shows the eight device (d) colours in the 3-dimensional CIELAB space L^* , a^* , b^* . It is indicated that a 5-step series between Orange red O and White W shall be equally spaced in the 3-dimensional CIELAB space for equally spaced rgb_d -input data of the device (d). Three relations (equations, tables) are valid for every device which lead to the final transformation $rgb_d - rgb'_d$.

1. The output for a 9x9x9 grid of equally spaced rgb_d -input data is measured. The CIELAB data L^* , C^*_{ab} , $h_{ab} = LCH^*$ (lightness L^* , chroma C^*_{ab} , and hue angle h_{ab}) differ usually compared to the intended LCH^* data and are therefore called LCH^{**} ($**$ = star-prime data according to ISO/IEC 15775).
2. If the eight device (d) colours are defined in CIELAB, then linear equations between rgb^*_d and LCH^* exist, see Richter (2008a) and DIN 33872-1.
3. If there is a cloud of output data LCH^{**} for rgb_d -input data, then the inverse input data rgb'_d can be calculated for any intended output data LCH^* which the device can produce. All the intended and possible output data LCH^* are described by the hexagon double cone in Fig. 3.

In the following the output relation $rgb_d - LCH^{**}$ is measured and used to plot the measured LCH output colours in different CIELAB diagrams. Then different linearization methods are applied which all use a filter transformation $rgb_d \rightarrow rgb'_d$ to produce the intended colours LCH^* . Usually the six device hues which are different for any device are produced. A new aim is to produce the

six elementary hues on any device, compare Fig. 1. Methods and applications for elementary hue output on different devices have been published by Richter (2009). DIN 33872-1 and the CIE-Report R1-47:2009 defines the hue angles of the elementary hues and recommends for the CIE standard illuminant D65 and the CIE 2-degree observer the CIELAB hue angles 26, 92, 162, and 272 degree of the CIE-test colours no. 9 to 12 according to CIE Publ. 13.3.

4. Start and linearized output in device and elementary hue planes of CIELAB space

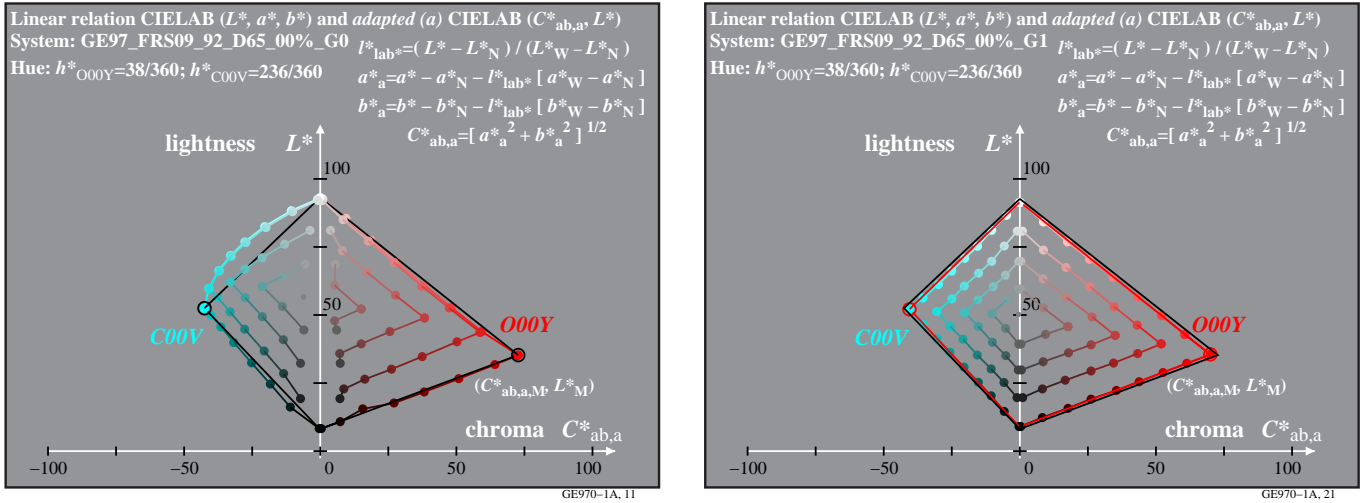


Fig. 4: Start and linearized output of a photo printer, and CIELAB data (right) with a linear relationship to the *rgb*-input data. Equally spaced *rgb*-input data produce a visual efficient CIELAB output for *rgb*-monitors and -printers. For *cm*yk-(PostScript)-printers grey is only produced with black. This produces an output with high visual and material efficiency, see examples for many devices with measurement data of start and linearized output, <http://idisk.me.com/klaus.richter-Public/index.html> First methods for a linearized output of device hues are given in ISO/IEC 17797:2004, Richter (2006), Witt (2006) and Richter (2007). New Methods for a linearized output of elementary hues are published in DIN 33872, and by Richter (2007), Richter (2008a) and Richter (2009). The production of the Colour Atlas RECS is one application. One example for both the device and elementary hue output is given for a real photo printer in Fig. 5 and Fig. 6.

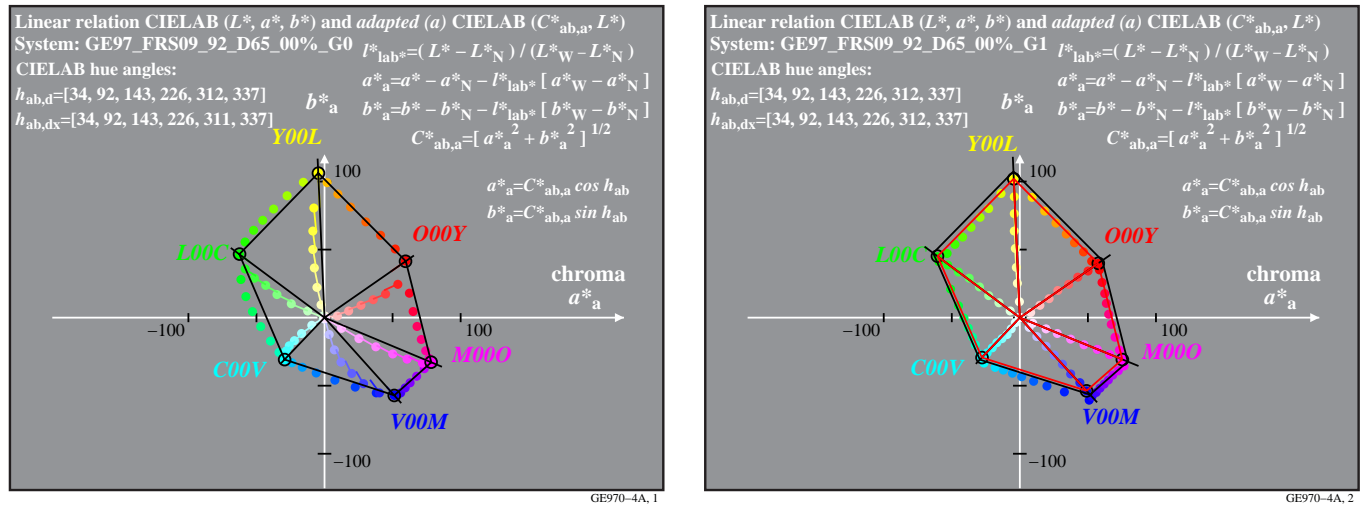


Fig. 5: Start and linearized device hue output for a photo printer in the adapted CIELAB diagram (a^*_a, b^*_a). Fig. 5 shows a start (left) and linearized (right) output for the device hues (black). The output colours of a photo printer are shown in the adapted CIELAB diagram (a^*_a, b^*_a). The linearized output (right) shows colours of constant CIELAB hue angle. The device (d) hue angles $h_{ab,d}$ are defined by the six *rgb*-input data (1, 0, 0), (1, 1, 0), (0, 1, 0), (0, 1, 1), (0, 0, 1), and (1, 0, 1) of the six device colours OYL \overline{CVM} and are given in Fig. 5. For a 95%-range of the lightness L^* and chroma C^*_{ab} a 9x9x9-table $rgb \rightarrow rgb'_{olV^*}$ has been calculated and used for the output of the 9-step series.

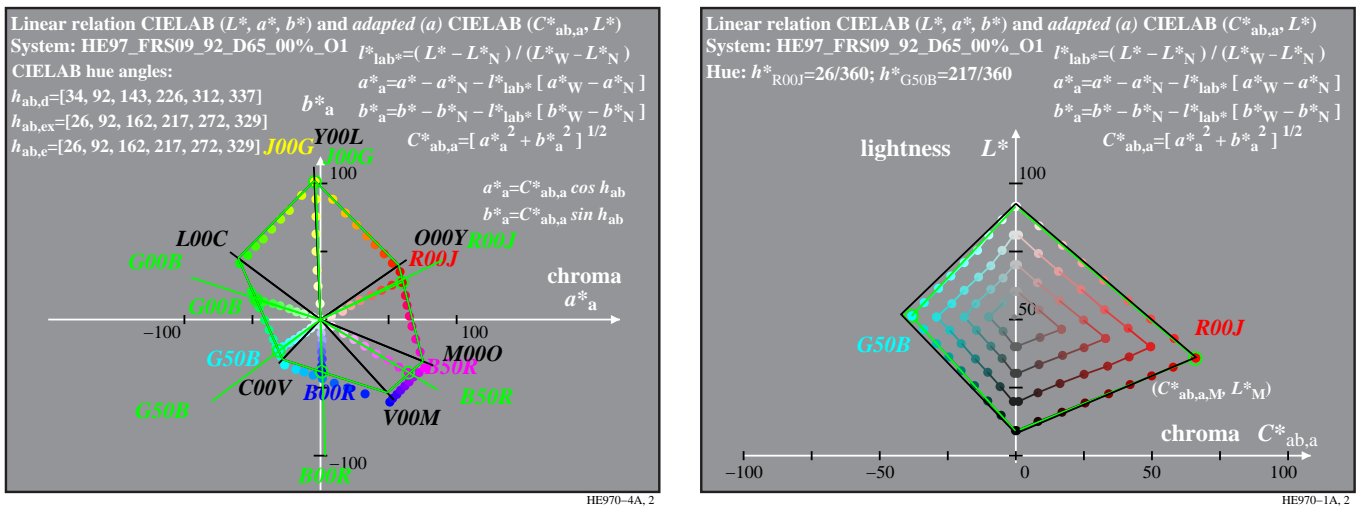


Fig. 6: Linearized elementary hue output in the CIELAB diagram (a^*_a , b^*_a) and a hue plane (contrast reduction 95%)
 Fig. 6 shows the intended output colours of a photo printer in the adapted CIELAB diagram (a^*_a , b^*_a) and in a hue plane ($C^*_{ab,a}$, L^*). Fig. 6 shows (left) the device (black) hues and a linearized output for the elementary (green) hues (left) and the six elementary (e) hue angles $h_{ab,e}$ of the elementary colours $RJGB$ and C_{gb} and M_{br} . For a 95%-range of lightness L^* and chroma C^*_{ab} a $9 \times 9 \times 9$ -table $rgb \rightarrow rgb^*_{rgb^*}$ has been calculated and used for the printer output. The printer output shows a high equal spacing.

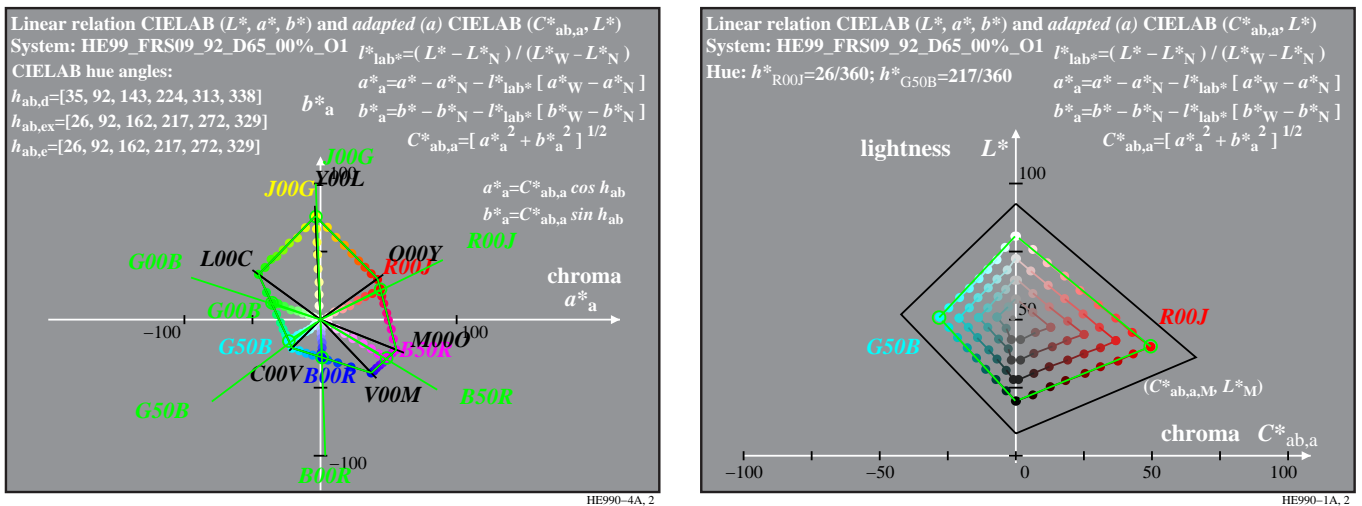


Fig. 7: Linearized elementary hue output in the CIELAB diagram (a^*_a , b^*_a) and a hue plane (contrast reduction 70%)
 Fig. 7 shows a 70%-contrast instead of the 95%-contrast for lightness L^* and chroma C^*_{ab} in Fig. 6.

5. Contrast enhancement produces security problems

Contrast reductions appear often, for example if a digital camera takes a low contrast scene. Then many users prefer for the printer and monitor output a contrast enhancement. This is one reason that many printer manufacturers increase automatically the contrast. However this increase of contrast produces a security problem for many office documents which will not any more show many colour details of light, dark, and very chromatic colours included in the input file. If contrast enhancement is active then for many different rgb -input data the output colours may look equal. Such an output example is shown for a new laser printer using rgb - and $cmymk$ -input data. This printer is on the market as rgb - and $PostScript$ -laser printer (about 280 \$)

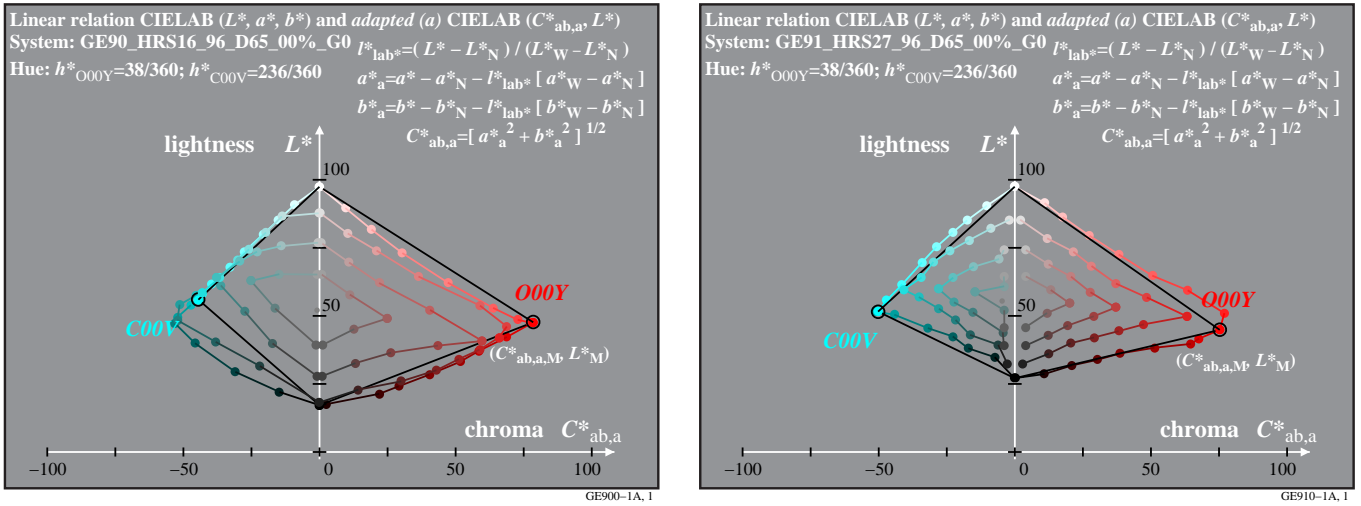


Fig. 8: Start output in a hue plane (C^*_{ab} , L^*) for a new laser printer (2009) for *rgb*- and *cmy0*-input data.

Fig. 8 shows the start output of this laser printer or *rgb*- and *cmy0*-input data (left and right). The output for the *rgb*-input data appears more irregular and the lightness range is larger both compared to *cmy0*-input data. The contrast enhancement (left) lets disappear many of the regular colour steps which are included in the *rgb*-input data, for example if the *rgb*-test chart according to DIN 33872-4 is used. Because of the irregular *rgb*-output it seems not appropriate to try to linearize this printer for *rgb*-input data.

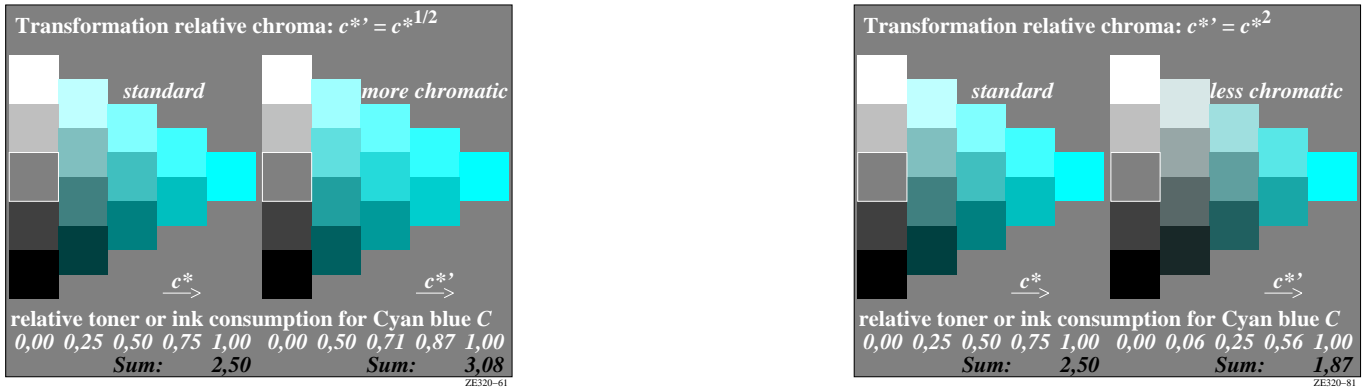


Fig. 9: Relative toner and ink consumption for a change of relative chroma c^* to $c^{*'}$ with a more and less chromatic output.

Fig. 9 shows an example of the relative toner and ink consumption if the relative chroma c^* is changed to $c^{*'}$ with a more and less chromatic output. According to the formulas given (square root or square change) the toner consumption increases or decreases by more than 20% compared to the standard (linearized) output. Therefore three problems arise if *contrast enhancement* is active:

- the visual efficiency is reduced
- there may be *security problem* for office documents
- the material efficiency is reduced by more than 20%

6. Methods for a high visual and material efficiency and a large colour gamut for a new laser printer

According to Fig. 8 the *cmy0*-input data produce a more regular output but a lower lightness range. For $c=m=y=1$ the lightness is only $L^*=27$ instead of $L^*=15$ for $r=g=b=0$. However approximately $L^*=15$ is reached with the *cmyk*-input data for $c=m=y=0$ and $k=1$ (not shown here). If for example for a series Cyan blue C – Black N the amount of C is reduced from 1 to 0 and at the same time the amount of N is increased from 0 to 1, then the intended large lightness range between $L^*=15$ and $L^*=95$, and the large colour gamut in the colour area of large deepness (Fig. 8, left) can be reached by *cmyk*-input data. By this technology the grey scale is only printed by the black colour which increases the material efficiency and produces at the same time a high visual efficiency, and additionally a large colour gamut is reached. Equally spaced output steps in CIELAB are reached for all series between Black N and the chromatic colours $X=OYLCVM$ and White W. The following figures will focus to reach the device independent *elementary* hue output with the new example laser printer.

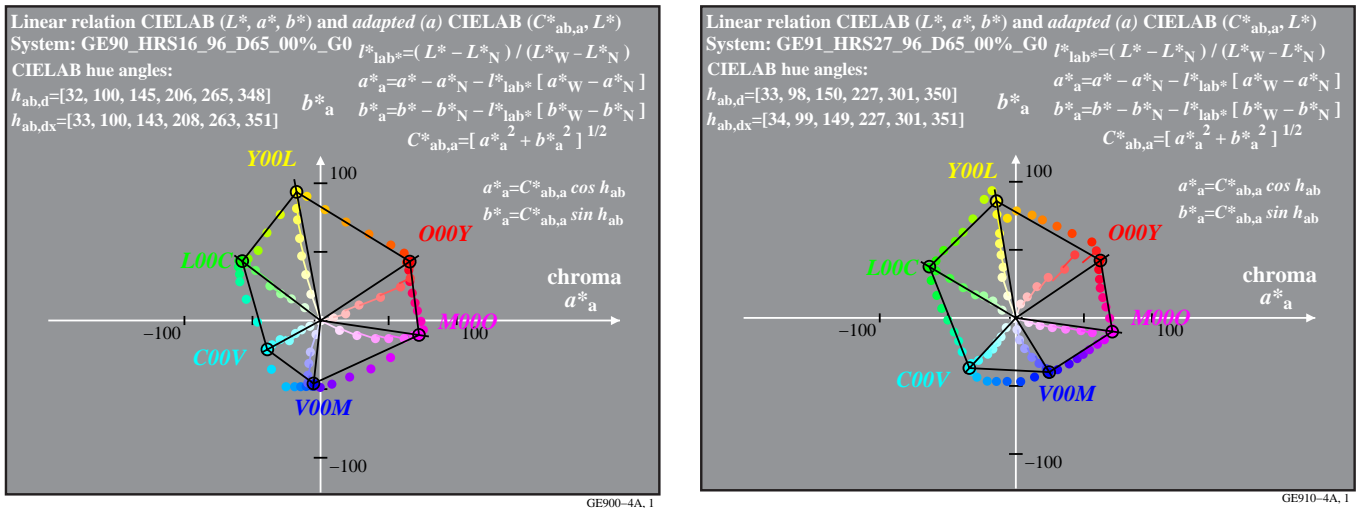


Fig. 10: Start output of the example laser printer for *rgb*- and *cmY0*-input data in the CIELAB diagram (a^*_a, b^*_a).

Fig. 10 shows that different CIELAB hue angles $h_{ab}=265$ and 301 are produced for the *rgb*-input data $0\ 0\ 1$ *setrgbcolor* and the complementary *cmY0*-input data $1\ 1\ 0\ 0$ *setcmYkcolor*. Therefore the answer is NO if this printer output is tested for equal output and for equivalent *rgb* and *cmzK0* input data according to the YES/NO criteria of DIN 33872-4. However, for the above *rgb*-input data approximately the elementary hue Blue B is produced ($h_{ab}=272$) and for *cmY0*-input data a very reddish blue is produced. Therefore if this printer output is tested according to elementary hue output of DIN 33872-5 a YES for *rgb*-input data and a NO for *cmYk*-input data is expected. It seems that the produced blue of this printer for *rgb*-input considers already the goal of DIN 33872-5 which is in agreement with the visual elementary hue perception.

A new technical reason for this decision of the printer manufacturer may be a nearly elementary Blue B output of many LCD screen on the market, which differ by more than 35 degrees compared to the standard CRT monitors according to ISO/IEC 15775 and IEC 61966-2-1. This angle deviation is about 8 times larger compared to the standard deviation (4 degree), if elementary blue is visually determined, see CIE Report R1-47:2009.

7. Linearized device and elementary hue output for an example laser printer for *cmY0*-input data

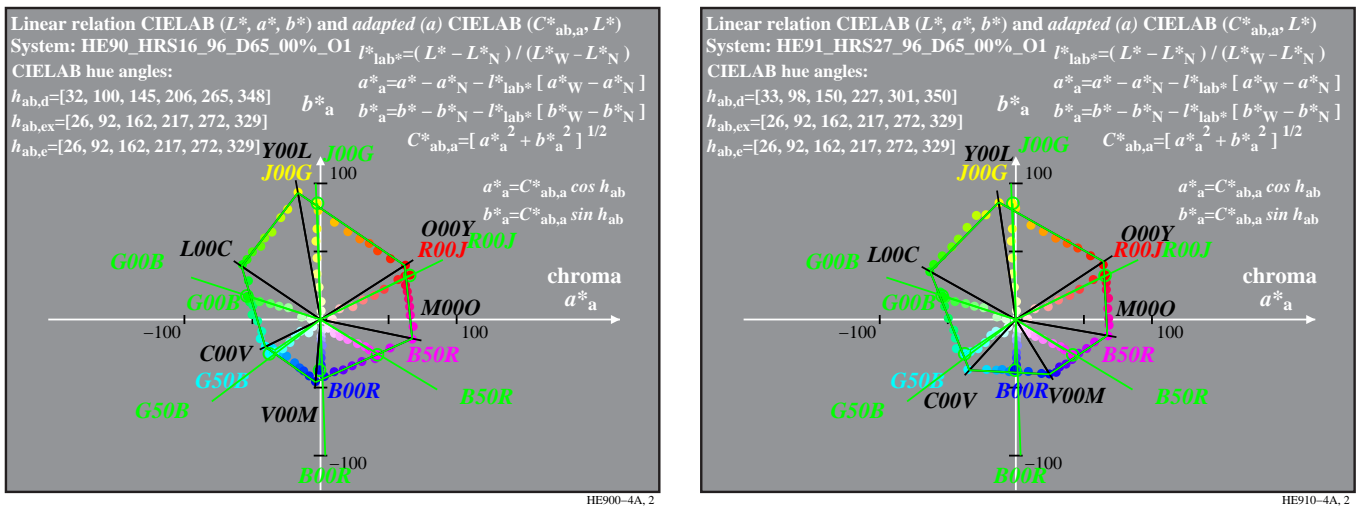


Fig. 11: Linearized output for *rgb*- and *cmY0*-input data for elementary hue output in the CIELAB diagram (a^*_a, b^*_a).

Fig. 11 shows the linearized laser printer output for *rgb*- and *cmY0*-input data and for elementary hue output in the CIELAB diagram (a^*_a, b^*_a). The six device (black) and elementary hues (green) are given. The maximal device colours and hues differ for this new laser printer for the six *rgb*-input colours $(1, 0, 0), (1, 1, 0), (0, 1, 0), (0, 1, 1), (0, 0, 1),$ and $(1, 0, 1)$. and the corresponding *cmY0*-input colours which are connected by the 1-minus-relation. For many other printers on the market these maximal output colours are still identical and there is only a difference for colours within the hexagon.

Instead of the curved lines for the hue series in the start output (Fig. 10) the linearized output (Fig. 11) shows approximately lines for the hue series in the CIELAB diagram (a^*_a, b^*_a). In Fig. 11 (left) there is agreement with the ergonomic requirement of ISO TC 159/SC4/WG2 to produce the three elementary hues *RGB* for the *rgb*-input data $(1, 0, 0), (0, 1, 0),$ and $(0, 0, 1)$. Additionally the elementary hue angle difference is for the six elementary colours approximately equal (60 degree) compared to many device hues, compare for example the low hue angle difference between *V* and *M* of the standard monitor TLS00 in Fig. 1 (right).

8. Summary

It seems appropriate to have as basic device output properties the following option:

- equally spaced output in CIELAB for equally spaced *rgb*-input data.
This output has a high visual efficiency.
- equal output for equivalent *rgb*- and *cmY0*-input data which are connected by the 1-minus-relation.
This is a simple user wish and shows in addition equal colours in old documents.
- elementary hue output *RGB* for *rgb*-input data (1, 0, 0), (0, 1, 0), and (0, 0, 1).
This hue output is device independent.
- print of the achromatic colours only by the colour Black *N* and not by *CMY*.
This output has high material efficiency.
- use of triangle *rgb*-colour coding with a linear relation to CIELAB.
This *rgb*-coding has a high coding efficiency.

The printer and monitor manufacturer may use a transformation $rgb - rgb'_{rgb^*}$ within the printer or the monitor as a filter to reach many of this aims at once.

If there is an option to send *cmYk*-data to the printer, for example with a *PostScript* printer or with a proof printer in the graphic area, then a transformation $rgb - cmYk'_{rgb^*}$ can be calculated. This transformation may be used in a filter to produce the linearized elementary hue output. The colour atlas of the *Relative Elementary Colour System* with about 2000 colours has been printed by this method. Standard offset printing on standard offset paper has been used, see www.ps.bam.de/RECS

9. Trends for implementation and closing remarks

It is intended to keep the many advantages of the *rgb*-workflow in colour image technology, especially for monitors and not to recommend here any change.

Old documents with mixed input operators produce still the equal output, if the 1-minus-relation is valid in the workflow. This is intended and allows application programs and users still to use there preferred colour operators. An example is given in Annex A.

For *RGB* colour devices and at the time of the output, the computer operating system or the *RGB*-device will filter the *rgb*-input data to the special device data for the elementary hue output. An example how to calculate the filter transformation is given in Annex B.

Remark: If the *rgb*-input data are rgb_{sRGB} -input data according to IEC 61966-2-1, then the filter transformation data $rgb_{sRGB} - rgb'_{rgb^*}$ can be calculated and used. This is similar for any profile data set $rgb - Lab^*$ with a known device gamut.

For *CMYK* colour devices and at the time of the output, the *CMYK*-device will filter the *rgb*-input data to the special *cmYk*-device data for the elementary hue output. Such a transformation has been used for the production of the *Relative Elementary Colour System* in standard offset print on standard offset paper. The atlas RECS serves as a reference for elementary hue output and for the equally spaced output both in CIELAB and visually.

10. References

CIE13.3:1995, Method of measuring and specifying colour rendering of light sources.

CIE R1-47:2009, Hue angles of elementary hues, Thorstein Seim (Norway), Report under CIE Division 1 meeting, Budapest 2009, see CIE Division 1, Meeting Minutes 2009, http://www.cie.co.at/index_ie.html

IEC 61966-2-1, Multimedia systems and equipment - Colour measurement and management - Part 2-1: Colour management - Default RGB colour space - sRGB

ISO 9241-306:2008, Ergonomics of human-system interaction -- Part 306: Field assessment methods for electronic visual displays, Test charts see <http://www.ps.bam.de/ME16/10L/L16E00NP.PDF>

ISO 15076-1:2005, Image technology colour management -- Architecture, profile format and data structure -- Part 1: Based on ICC.1:2004-10

ISO/IEC 15775:1999 & Adm1 2005, Colour reproduction properties of colour copiers.

ISO/IEC TR 19797:2004, Device output of 16-step colour scales, output linearization method (LM) and specification of the reproduction properties, see a public version (20 pages, 280 kByte)

<http://www.jbmia.or.jp/sc28/sc28docs/j28n656.zip>

ISO/IEC TR 24705:2005, Method of specifying image reproduction of colour devices by digital and analog test charts, see a public version (80 pages, 1 Mbyte)

<http://www.jbmia.or.jp/sc28/sc28docs/j28n689.zip>

DIN 33872-1 to -6:2009 (in print), Method of specifying relative colour reproduction with YES/NO criteria. For the DIN-test charts including questions about output properties see

<http://www.ps.bam.de/33872E>

NOTE: An English translation of DIN 33872-1 to 6 is available as document no. j28n1280 in ISO/IEC JTC1/SC28 "Office Equipment"

Richter, Klaus (2006), Device dependent linear relative CIELAB data lab* and colorimetric data for corresponding colour input and output on monitors and printers, CIE030:2006, Proceedings of the ISCC/CIE Expert Symposium '06, "75 years of the CIE Standard Colorimetric Observer", Ottawa Canada, pages 139-144.

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Richter, Klaus (2009), Output Linearization in CIELAB for visual displays with 8 different Luminance reflections of indoor illuminants, Light and Lighting Conference with Special Emphasis on LEDs and Solid State Lighting, Proceedings, Budapest 2009, 10 pages, no. PwDaS-39 on CD.

Witt, Jens (2006), Farbmetrische Methoden zur Herstellung von Prüfvorlagen für Farbkopierer, Farbscanner und Farbmonitore, Dissertation, Berlin University of Technology, Fakultät IV, Elektrotechnik und Informatik, see the URL (186 pages, 8,6 MByte, PDF format)

<http://opus.kobv.de/tuberlin/volltexte/2006/1363/>

Wagenknecht, Hans (2009), Farbmetrische Verarbeitung von Bilddaten von Scanner-Systemen mit geeigneten Prüfvorlagen und Druckerausgabe (only in German with english abstract), Dissertation, Berlin University of Technology, Fakultät IV, Elektrotechnik und Informatik, see the URL (132 pages, 6,3 MByte, PDF format)

<http://opus.kobv.de/tuberlin/volltexte/2009/2291/>

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Further information see www.li.tu-berlin.de under „Veranstaltungen“ and „Publikationen“

<http://idisk.me.com/klaus.richter-Public/index.html>

Overview of Annex A to B:

Annex A shows examples for the realization of the *1-minus-relation*.

Annex B shows some equations for the calculation of the transformations $rgb - rgb'_{olv^*}$ and $rgb - rgb'_{rgb^*}$.

Annex A: Examples for the realization of the 1-minus-relation

This annex A shows how to implement the 1-minus-relation, for example $r = 1 - c$, in a PDF file.

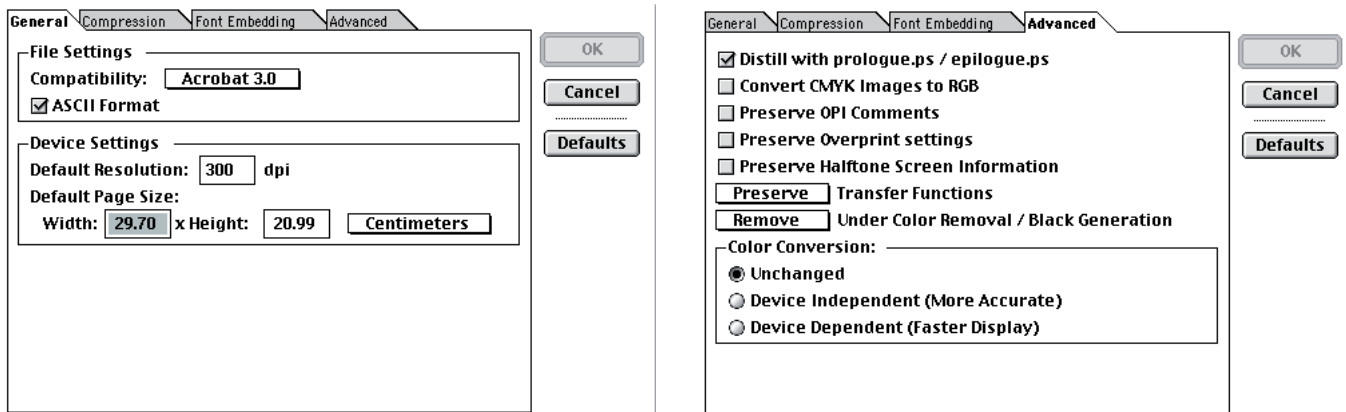


Fig. A.1: Use and settings of the software *Adobe Acrobat Distiller* for implementation of the 1-minus-relation with *prologue.ps*. Fig. A.1 shows the *Landscape (L)* setting (left) and the setting to distill with the file *prologue.ps* (content for *rgb-transfer* see below).

```
% prologue.ps
% prologue-rgbL.ps (Transfer to rgb, L=Landscape setting)
%
% This file can be used to add custom PostScript code that you
% wish to have executed at the beginning of every PostScript job
% being distilled. If the option labelled "Use Prologue.ps and
% Epilogue.ps" is selected in the "Advanced" panel of the "Job
% Options" dialog, the contents of this file will be executed
% before the actual PostScript file is run.
%
% (Processing prologue-rgb_cmy->rgbL.ps...\n) print flush
% Insert your custom PostScript here...

%Early definition of MTLsetgray identical to former setgray, etc.
/MTLsetgray {setgray} bind def
/MTLsetrgbcolor {setrgbcolor} bind def
/MTLsetcmykcolor {setcmykcolor} bind def

/setgray {/MTLw exch def
  /MTLrx MTLw def /MTLgx MTLw def /MTLbx MTLw def
  MTLrx MTLgx MTLbx
  MTLsetrgbcolor} def

/setrgbcolor {/MTLbx exch def /MTLgx exch def /MTLrx exch def
  MTLrx MTLgx MTLbx
  MTLsetrgbcolor} def

/setcmykcolor {/MTLn exch def /MTLy exch def /MTLm exch def /MTLc exch def
  MTLn 0 eq {/MTLrx 1 MTLc sub def
    /MTLgx 1 MTLm sub def
    /MTLbx 1 MTLy sub def}
  {/MTLrx 1 MTLn sub def
    /MTLgx 1 MTLn sub def
    /MTLbx 1 MTLn sub def} ifelse
  MTLrx MTLgx MTLbx
  MTLsetrgbcolor} def
(Done processing prologue-rgb_cmy->rgbL.ps.\n) print flush
% End of file: prologue.ps
```

The content of the file *prologue.ps* in the *Adobe Distiller* directory is used to transfer the data of the three *PS* operators. All data are transferred to the *rgb*-input data for the *PS* operator *rgb setrgbcolor*. One may change (*three times*) the last two lines from

```
MTLrx MTLgx MTLbx          to          1 MTLrx sub 1 MTLgx sub 1 MTLbx sub 0
MTLsetrgbcolor} def      MTLsetcmykcolor} def
```

to transfer the data of the three *PS* operators to the *cmY0*-input data. The transfer works with any *PS*-test file of DIN 33872.

Annex B: Equations for the calculation of the *rgb* – *rgb'*_{*rgb*'*} transform

Annex B includes some basic ideas for the transformation between *rgb*-input data and the change of this input data to reach the intended equally spaced output in CIELAB and at the same time the elementary hue output on any device.

The start output shall be as regular as possible, which is for example usually the case for the standard offset process, the proof printers in the graphic art area, and for *PostScript* printers with *cm**yk*-input data. For the test either the test chart no. 1 for *rgb*-input data and test chart no. 2 for *cm**yk*-input data of DIN 33872-1 may be used.

For professional applications the following *PS*- and *PDF*-test charts with 1080 colours are recommended

<http://www.ps.bam.de/ZE45/10L/L45E00NP.PDF>

<http://www.ps.bam.de/ZE45/10L/L45E00NA.PS>

<http://www.ps.bam.de/ZE46/10L/L46E00NP.PDF>

<http://www.ps.bam.de/ZE46/10L/L46E00NA.PS>

The files produce 6 pages and the file size is 550 kByte for the *PDF* and 150 kByte for the *PS* files. The output of the pages 1 and 2 is identical. On page 3 all colour data of page 1 are transferred by the *1-minus relation* to *rgb*-input data (file L45E00NP.PDF) or *cm**y0*-input data (file L46E00NP.PDF).

For the real photo printer the data of a start and linearized output has been produced with similar files (30 pages, 2,6 Mbyte in *PDF* format with much more data in *LAB*^{*}, *lab*^{*}_{*ol**v*'*}, *lab*^{*}_{*rgb*'*}, etc., see DIN 33872-1)

For the start output with the NP-file, see

<http://idisk.me.com/klaus.richter-Public/GE67/GE67L0NP.PDF>

<http://idisk.me.com/klaus.richter-Public/GE67/GE67L0NA.PS>

For the linearized output with the FP-file the transfer *rgb* → *rgb'*_{*ol**v*'*} = *lab*^{*}_{*ol**v*'*} (device hue output) is within the file

<http://idisk.me.com/klaus.richter-Public/GE67/GE67L0FP.PDF>

For the linearized output with the FP-file the transfer *rgb* → *rgb'*_{*rgb*'*} = *lab*^{*}_{*ol**v*'*} (elementary hue output) is within the file

<http://idisk.me.com/klaus.richter-Public/HE67/HE67L0FP.PDF>

Both *FP*-files include the CIELAB measurement data of the start output (*NA*-file) for the 1080 colours and the transfer.

On the output page 8 of the file GE67L0NP.PDF a 9x9x9 grid of *rgb*-input data (rows 01 to 27 and columns A to a) is given. On the output page 15 of the file GE67L0FP.PDF a 9x9x9 grid of transferred *rgb'*_{*ol**v*'*}-input data is given. On the output page 15 of the file HE67L0FP.PDF a 9x9x9 grid of transferred *rgb'*_{*rgb*'*}-input data is given.

The *PS*-files (*FA*.PS) which include this transfer in source code are *not* given at the Web-site.

For the definition of the many other coordinates used in the files see DIN 33872-1 and (41 pages, 1,5 Mbyte)

<http://www.ps.bam.de/D33872-AE.PDF>

If the CIELAB data of the eight device colours OYLCVMNW are given, then equations between *relative* and *adapted* CIELAB coordinates are defined in DIN 33872-1, for example between *ol**v*'* = *lab*^{*}_{*ol**v*'*} and *LAB*^{*}_{*a*}

*ol**v*'* → *LAB*^{*}_{*a*} (CIELAB star data)

If a start output of a 9x9x9 grid of regular *ol**v*'*-input data is produced, then there is a deviation compared to the intended *LAB*^{*}_{*a*} data. This is described by the relation

*ol**v*'* → *LAB*^{*}_{*a*}' (CIELAB star-dash data)

For the output of the intended *LAB*^{*}_{*a*} data the *ol**v*'*-input data shall be changed to *ol**v*'*(dash-star)

*ol**v*'* → *LAB*^{*}_{*a*} (CIELAB star data)

For *device hue* output the data of the 9x9x9 grid *ol**v*'* and *rgb* are identical. Instead of the notation *ol**v*'*(dash-star data) according to DIN 33872 one may use in this case *rgb'*(dash data).

For the *elementary* hue output there is an additional transfer from *ol**v*'* to *rgb'**. For *device* and *elementary* hue output the two transfers may be described as *rgb* → *rgb'*_{*ol**v*'*} and *rgb* → *rgb'*_{*rgb*'*}.