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INFLUENCE OF THE RENDERING METHODS ON DEVIATIONS IN PROOF PRINTING

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Abstract: *The aim of the work is the testing of the quality of proof printing in Piezo Ink Jet technique and consideration of the influence of the rendering methods on the reproduction quality of the proof printing. Analyzed rendering methods are: perceptual, saturation, relative colorimetric and absolute colorimetric. Overall, absolute colorimetric rendering method is the most efficient.*

Generally, there is no most inefficient method of rendering. Specific quality of the used dyes and ink coverage is the reason for this. The proof printing of full tone of primary and secondary colors with absolute perceptual rendering method gave the biggest average deviation. The relative colorimetric rendering method is inappropriate for printing the full tone of dark brown.

Key words: *Proof printing, product printing, ICC profiles, rendering methods.*

1. INTRODUCTION

Fast technological development contributes to changes in printing, design and graphic communications. One of the most important problems is accuracy of original and reproduction.
Proof printing is inevitably the semi-phase which is necessary for user and engineer to conciliate wishes and technological possibilities. Because of high production prices, printing one proof on production machines is almost impossible. However, the development of high quality Ink Jet printing provided proof printing and printing the small editions.

With digital printing original the digital information is translated in different color modes, which results in hue error. It makes it necessarily to implement ICC profiles so as to complete the color management. It takes in consideration all factors which have influence on obtaining final production proof (type of printing ink, type of printing substrate, printing technique, construction of printing machine…).

Their quantitative analyzes provides successful results in proof printing, specially mottled colors (CMYK, RGB), but also oftener achromatic colors (black and gray). It makes the base for future quality production printing.

2. EXPERIMENTAL

The aim of this paper is to review precision of proof printing. The reproduction of the full tone (100% ink drift) so as 50% of tone value is examined independently. ''Production prints'' have been generated, for the purpose of this experiment, on lithography offset printing machine Heidelberg Speedmaster GTO 4/0 (paper for art printing and paste offset ink), while proof printing has been done on Piezo Ink Jet printer Epson R2400 Photo (K3 pigmented inks and photo mat paper).

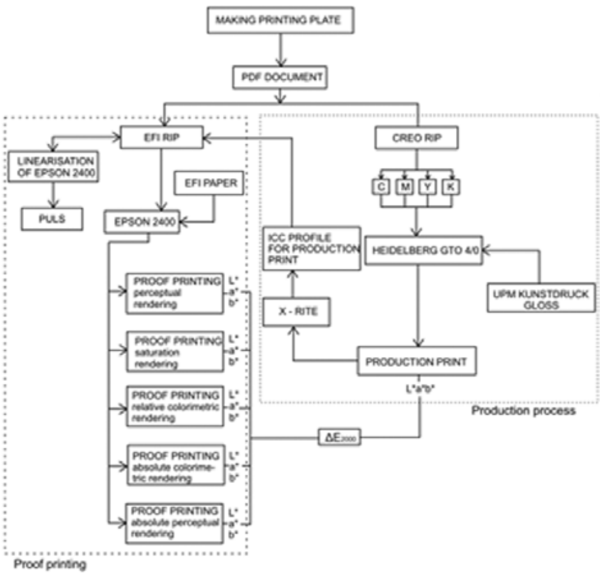

Figure 1. Scheme of the research process

2.1. Overall problem

Because of higher color saturation, the tone values printed in Ink Jet are necessary to be translated (compressed) into lower offset tone values. With EFI software RIP 4 standard methods of tone value translations are possible (perceptual rendering, saturation

rendering, absolute colorimetric rendering and relative colorimetric rendering) which have direct impact on final quality of reproduction.
Calculating differences of tone values in CIE L*a*b* ΔE enable quantitative assess of quality concrete proof printing. Primary colors (CMYK), secondary colors (RGB) and tertiary brown color have been researched.

2.2. Methodology

In this paper the process of proof printing in digital Ink Jet has been analyzed (Kipphan H., 2001.) The aim is to accomplish identical appearance of original proof (printed in offset printing) and proof printed in Ink Jet.
Five methods of rendering have been used and analyzed: perceptual rendering, saturation rendering, absolute colorimetric rendering, relative colorimetric rendering and absolute perceptual rendering. Experimental procedure starts with making specific printing plate which is in PDF digital format. Printing plate consists of standard printing elements for quality control of reproduction and 378 precisely defined elements which enable construction of ICC profile. (Majnaric I., Golubović K., Donevski D., 2007.)

From the obtained PDF file the standard printing plates are made through Creo RIP and they have been printed on the production machine Heidelberg GTO 4/0. The coated paper substrate UPM gloss 135 g/m^2 has been used in edition of 50 proofs. From printed edition, 3 samples have been chosen (from the beginning, from the middle and the end of edition) and they have been analyzed and statistically elaborated. For the analysis the spectrophotometrical method is used which, as the result, describes tone values gained during printing. In so doing the measuring equipment and software used are: X-Rite DTP41 (Monaco Profiler), X-Rite PULSE (PULSE ColorElite). X-Rite DTP41 is a spectrofotometer, the device which measures light through the standardized filters. Spectrofotometry especially standardizes two factors: light source (D_{50}, D_{55}, D_{65} and D_{75} with their color temperatures of 5000 K, 5500 K, 6500 K and 7500 K) and standard observer (it is usual to use observing angle of 2^0). (Sharma A., 2004.)

After the production printing the construction of ICC profile is done which is characterized by: the printing technique (offset), printing machine (Heidelberg GTO 4/0), printing substrate (paper UPM gloss 135 g/m^2) and printing ink (offset ink Huber rapid).
For proof printing in Ink Jet technique the printer Epson Photo R2400 is used which applies K3 permanent inks and EFI 9200 photo mat paper. (Sugiyama K., 2008.)
After initial linearization, in EFI RIP the activation of production ICC profile is made, through which 5 proof prints with different rendering methods are obtained.
For optimal use of color management and for achieving the desired color the printer has to print continuously all color values. Linearization of printer is a form of its optimization and represents a mode of printer calibration. During printing dot gain of tone value always occurs, so the wanted and the real values are not always the same. (Hsu F., 2005.)

Linearization of printer is performed trough printing test forms and measuring the same ones with spectrophotometer. The measured results are used for modifying strength of nozzle trough printing software. Process of linearization is conducted trough the test forms for: measuring the total color drift, drift of particular inks (per canal), for linearization and quality control. Final proof analysis use characteristic elements (full tone and 50% of tone value for primary, secondary and tertiary inks). Final results are shown in CIE L*a*b* color system and from them the color differences ΔE are calculated. (Luo M. R., Cui G., Rigg B., 2001.)

$$\Delta E^*_{ab} = \sqrt{\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2}} \quad (1.1)$$

where

$$\begin{aligned} \Delta L^{*2} &= L^*_r - L^*_{or} \\ \Delta a^{*2} &= a^*_r - a^*_{or} \\ \Delta b^{*2} &= b^*_r - b^*_{or} \end{aligned} \quad (1.2)$$

Year 2000. The formula ΔE has been modified and today it has the following shape:

$$\Delta E^*_{2000} = \sqrt{\left(\frac{\Delta L^*}{S_L k_L}\right)^2 + \left(\frac{\Delta C^*}{S_C k_C}\right)^2 + \left(\frac{\Delta H^*}{S_H k_H}\right)^2 + R_T \left(\frac{\Delta C^*}{S_C k_C}\right)\left(\frac{\Delta H^*}{S_H k_H}\right)} \quad (1.3)$$

where ΔL*, ΔC* and ΔH* represent differences in brightness, saturation and tone between production and proof printing. Other parameters of the above mentioned formula ΔE_{2000} are defined as:

$$\begin{aligned} S_L &= 1 + \frac{0{,}015\left(\overline{L'} - 50\right)^2}{\sqrt{20 + \left(\overline{L'} - 50\right)^2}} \\ S_C &= 1 + 0{,}045\overline{C'} \\ S_H &= 1 + 0{,}015\overline{C'}T \end{aligned} \quad (1.4)$$

$$\begin{aligned} T = {} & 1 - 0{,}17\cos\left(h' - 30^0\right) + 0{,}24\cos\left(2h'\right) \\ & + 0{,}32\cos\left(3h' + 6^0\right) - 0{,}20\cos\left(4h' - 63^0\right) \end{aligned} \quad (1.5)$$

$$\begin{aligned} R_C &= 2\sqrt{\frac{\overline{C'}^7}{\overline{C'}^7 + 25^7}} \\ R_T &= -\sin\left(2\Delta\Theta\right)R_C \\ \Delta\Theta &= 30\exp\left\{-\left[\left(h' - 275^0\right)/25\right]^2\right\} \end{aligned} \quad (1.6)$$

For visual valorization of the obtained ΔE results table 1 is used. (Zjakić I., 2007.)

Table 1. Rate of visual perception and color difference.

ΔE	Visual perception
Between 0 i 1	Average human eye can not see the difference
Between 1 i 2	Very small difference
Between 2 i 3,5	Moderately difference
Between 3,5 i 5	Difference
Between 5	High difference

Color difference ΔE shows reproduction quality and deviation of reproduction and original. Indirectly, this value represents loss and deviation of three stimulus values which correspond to perception of color in human eye.

3. RESULTS AND DISCUSSION

Impacts of rendering on proofing are shown in figure 2, 3, 4, 5, 6, 7, 8 and 9. Separate process, the secondary and tertiary colors are graphically reported.

The reproduction of CMYK full tones created perceptual rendering, saturation rendering, absolute colorimetric rendering and absolute perceptual rendering is shown in figure 2 and 3.

The biggest difference between the proof and the production cyan print was created by absolute perceptual rendering method and it amount is $\Delta E_{100\%C}$=3,4383, the difference that is visible to the naked eye. The nearest proof sheet is reached with absolute colorimetric rendering, the difference is visually very small ($\Delta E_{100\%C}$ =1,7041). Other types of rendering give the following results: $\Delta E_{100\%C}$ =2,4138 (perceptual rendering), $\Delta E_{100\%C}$ =3,3967 (saturation rendering) $\Delta E_{100\%C}$ =2,2819 (relative colorimetric rendering).

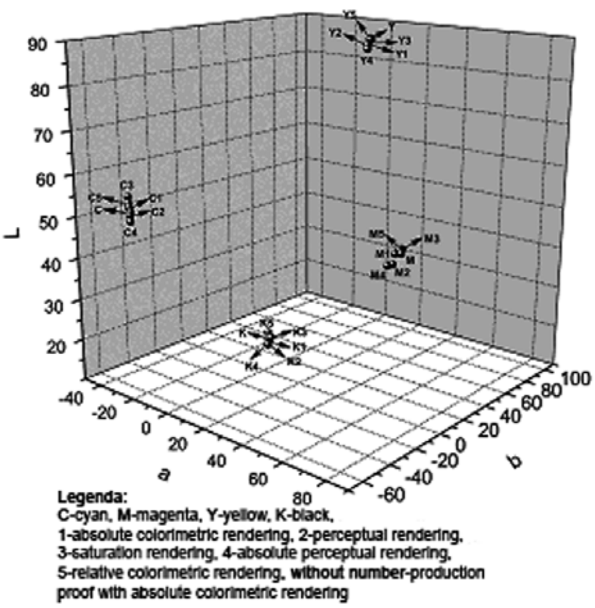

Figure 2 Display of L*a*b* values from proof prints with different rendering methods and production print (100% tone value for CMYK)

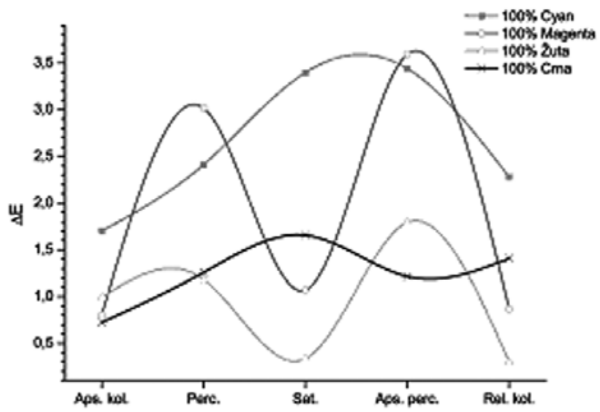

Figure 3 Display of ΔE production print and proof prints with different rendering methods (100% tone value for CMYK)

By reproduction of magenta the worst result was also achieved with absolute perceptual rendering ($\Delta E_{100\%M}$=3,5925), while the best result incurs with absolute colorimetric rendering ($\Delta E_{100\%M}$=0,8066). This difference the average human eye can not perceive. Other rendering methods results in next differences in tone values: $\Delta E_{100\%M}$=3,0150 (perceptual rendering), $\Delta E_{100\%M}$=1,0690 (saturation rendering) and $\Delta E_{100\%M}$=0,8719 (relative colorimetric rendering).

The method of absolute perceptual rendering gives the highest differences in yellow ($\Delta E_{100\%Y}$=1,7933). The closest print to the production print is the proof print with relative colorimetric rendering method ($\Delta E_{100\%Y}$ =0,3014). Perceptual rendering gives the difference in tone value $\Delta E_{100\%Y}$ =1,1823, saturation rendering $\Delta E_{100\%Y}$ =0,3345 and absolute colorimetric rendering $\Delta E_{100\%Y}$ =0,9948. Full tone reproduction of black color saturation rendering reveals as the worst choice ($\Delta E_{100\%K}$=1,6548). The lowest deviation is generated with absolute colorimetric rendering ($\Delta E_{100\%K}$=0,7233). Other rendering methods give the following results: $\Delta E_{100\%K}$=1,2580 (perceptual rendering), $\Delta E_{100\%K}$=1,2147 (absolute perceptual rendering) and $\Delta E_{100\%K}$=1,4074 (relative colorimetric rendering).

Reason of this deviation for CMK lays in fact that the absolute colorimetric rendering method depicts the colors of the origin gamut and transforms them so that there is no colorimetric differences between the original and the reproduction. The white point in destination profile is not taken into consideration, yet the white point of source profile is being copied. The colors that cannot be reproduced in target space simple disappear. Color reproduction is precise, but its visual rate is disarranged. Colors out of the gamut are being "cut". It is being mapped in the closest colors of different saturation which are on the edge of the output gamut. (Sharma A., 2004.)

The Absolute Perceptual rendering method are non-standard but provide improved results over the standard intents. Standard intents would produce regions of images that are whiter than the paper color of the input.

For brighter chromatic color (yellow) the relative colorimetric method gives the smallest difference because it uses the fact that human eye always accommodates to observe white substrate. Thereby it comes to the mapping source white in the white color of the destination, so that white color of reproduction is the white color of paper, and not the white color of original. All colors inside gamut are precisely reproduced, but “tilted” for certain angle. Colors out of the gamut are depicted in color that has the smallest colorimetric difference regarding original color, and that has the same lightness. It might happen that it is impossible to recognize two colors on the reproductions that are in the original space two different colors. It is called color “cutting”. In figure 4 and 5 the influence of rendering methods on 50% tone value for process colors (CMYK) is shown. For 50% of screen value the biggest difference is generated in reproduction of cyan and yellow color with perceptual rendering method. It numbers $\Delta E_{50\%C}$=1,7962, while for yellow $\Delta E_{50\%Y}$=2,1130. The absolute colorimetric method gives the smallest difference for cyan ($\Delta E_{50\%C}$=0,8434) and black ($\Delta E_{50\%C}$=0,8434).

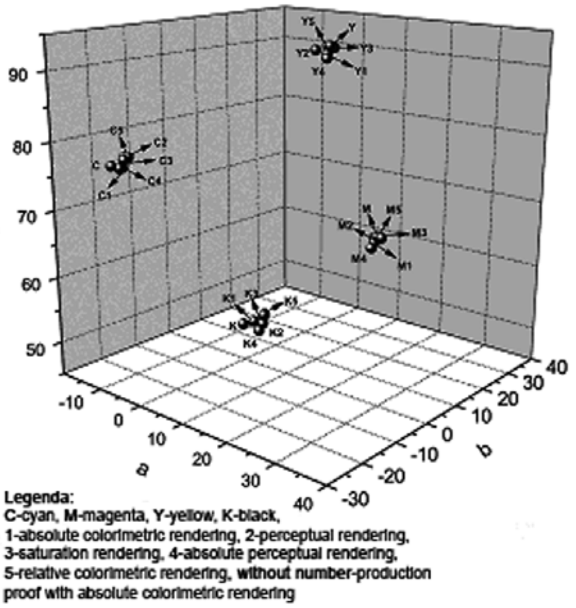

Figure 4. Display of L*a*b* values from proof prints and production prints (50% tone value for CMYK)

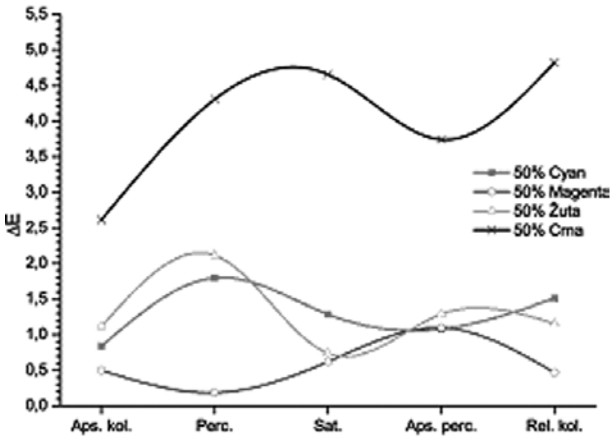

Figure 5. Display of ΔE from production prints and proof prints generated with different rendering methods (50% tone value for CMYK)

Other rendering methods for cyan give the following results: $\Delta E_{50\%C}$=1,2877 (saturation rendering), $\Delta E_{50\%C}$=1,0798 (absolute perceptual rendering) and $\Delta E_{50\%C}$=1,5089 (colorimetric rendering).

For the reproduction of 50% yellow, the saturation rendering enables the best results and it results with difference that is not visible by average human eye ($\Delta E_{50\%Y}$=0,7362). Other rendering methods give the following results: $\Delta E_{50\%Y}$=1,1146 (absolute colorimetric rendering), $\Delta E_{50\%Y}$=1,2861 (absolute perceptual rendering) and $\Delta E_{50\%Y}$=1,1536 (relative colorimetric rendering).

For proof printing of black, the relative colorimetric rendering reveals as the worst choice. It generated considerable difference in tone value and it amounts $\Delta E_{50\%K}$=4,8238. Other methods of rendering also give large differences in tone value, and they are for perceptual rendering $\Delta E_{50\%K}$=4,3031, for saturation rendering $\Delta E_{50\%K}$=4,6556 and for absolute perceptual rendering $\Delta E_{50\%K}$=3,7395.

By the reproduction 50% magenta, the perceptual rendering is showed as the best one ($\Delta E_{50\%M}$=0,1846). Absolute perceptual rendering resulted with the biggest difference in tone value $\Delta E_{50\%M}$=1,0992. Other rendering methods give the differences that are not visible to human eye: $\Delta E_{50\%M}$=0,4987 (absolute colorimetric rendering), $\Delta E_{50\%M}$=0,6185 (saturation rendering) and $\Delta E_{50\%M}$=0,4683 (relative colorimetric rendering).

Reproduction of screen tones does not give the identical results as reproduction of full tones. The usage of saturation method will achieve the lowest deviation in reproduction of yellow. At the same time the colors out of gamut of the reproduction are translated into his edge, by translating saturated colors of the original into the saturated colors of reproduction, not keeping relative rate between colors. Colors which are out of gamut are translated in the closest colors of the same saturation, and the saturation is being increased by moving the colors inside the gamut toward its edge. Assets of this method are not the cutting off colors out of gamut, but expanding colors near inside gamut edge. Expanding colors increases its saturation. (Sharma A., 2004.)

Magenta in 50% drift will minimally oscillate with perceptual rendering method. In the method the complete experience of colors is being conserved, while the colors of the original are changing, respectively their three-stimulus values, so that they can desist in color gamut of reproduction preserving the rate between colors. Visual rates are being stored, so as the contrast between colors. By translation all the colors are changed, regardless their place in color space. Relative rate is the most preserved in brightness and tone.

The reason of this deviation lays in the fact that in Ink Jet technique with continuously print screen tone they were not printed identically as the production prints, yet through 8 inks: cyan (C), light cyan (LC), magenta (M), light magenta (LM), black (K), light black (LC), light, light black (LLC) and yellow (Y).

Deviation of the secondary and the tertiary colors for full tone depending on rendering method is shown in figure 6 and 7.

Applying the absolute perceptual rendering method the secondary full tones (RGB) will have the highest differences in tone value ($\Delta E_{100\%R}$=3,2765, $\Delta E_{100\%G}$=3,2554 and $\Delta E_{100\%B}$=1,4566). Although those differences are moderately and very small, the method is not recommended for usage in proof printing. Saturation rendering has shown as the most convenient for reproduction of red and blue with differences not visible for human eye ($\Delta E_{100\%R}$=0,6602, $\Delta E_{100\%B}$=0,6852). Other rendering methods in red prints give the following results: $\Delta E_{100\%R}$=1,3604 (absolute colorimetric rendering), $\Delta E_{100\%R}$=2,3828 (perceptual rendering) and $\Delta E_{100\%R}$=1,9079 (relative colorimetric rendering). Other methods applied for rendering blue enable following differences in tone value: $\Delta E_{100\%B}$=1,0150 (absolute colorimetric rendering), $\Delta E_{100\%B}$=1,2752 (perceptual rendering) $\Delta E_{100\%B}$=1,0322 (relative colorimetric rendering).

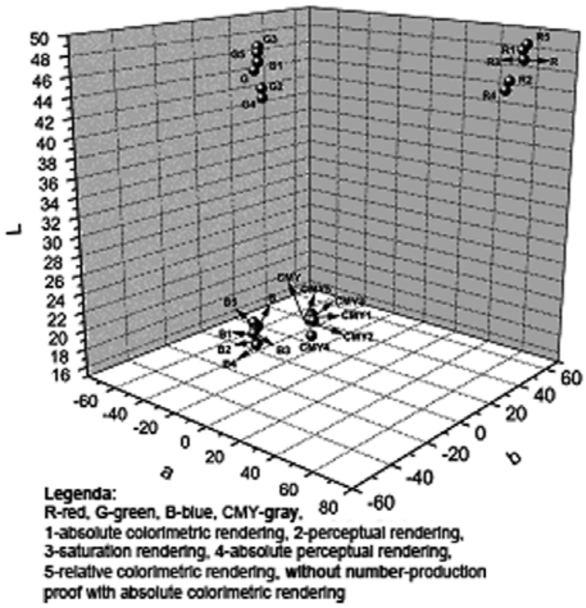

Figure 6. Display of L*a*b* values from proof prints with different rendering methods and production print (100% tone value for RGB and CMY)

For realization of accurate green as the best method showed is the absolute colorimetric rendering ($\Delta E_{100\%G}$=1,8542). Other rendering methods give the following differences in tone value: $\Delta E_{100\%G}$=2,5918 (perceptual rendering), $\Delta E_{100\%G}$=3,1714 (saturation rendering) and $\Delta E_{100\%G}$=2,7312 (relative colorimetric rendering).

Absolute perceptual rendering method gives the closest proof print of tertiary brown to production print ($\Delta E_{100\%CMY}$=2,0364). That is not standardized method, but the combination of absolute colorimetric rendering method and perceptual method of rendering. It is proved as the best because in tertiary brown color the drift is high (100% C, 100% M and 100% Y).

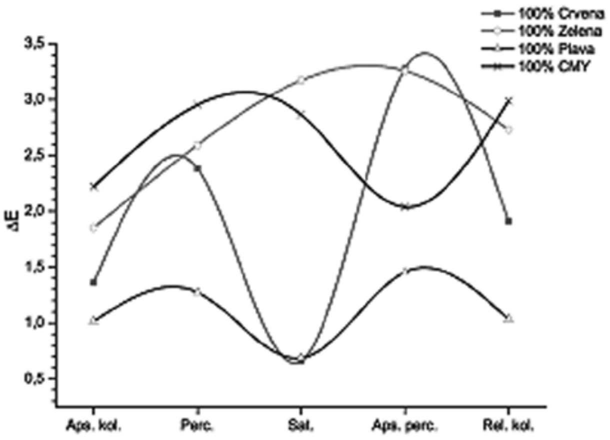

Figure 7. Display of ΔE production print and proof prints with different rendering methods (100% tone value for RGB and CMY)

For creation triple color drift (100% C, 100% M and 100% Y) the highest difference in tone value between production print and proof print is generated by relative colorimetric rendering ($\Delta E_{100\%CMY}$=2,9876). Other differences in tone value are: $\Delta E_{100\%CMY}$=2,2204 (absolute colorimetric rendering), $\Delta E_{100\%CMY}$=2,9512 (perceptual rendering) and $\Delta E_{100\%CMY}$=2,8647 (saturation rendering).

Reproduction of the secondary and the tertiary colors gives higher deviation in printing full tone. Tertiary brown color and secondary green in full tone have more quality reproduced obtained by absolute colorimetric rendering. Printing red and blue by saturation rendering gave the smallest deviation.

Influence of rendering methods on secondary and tertiary color in screen field (50% tone value) is shown in figures 8 and 9.

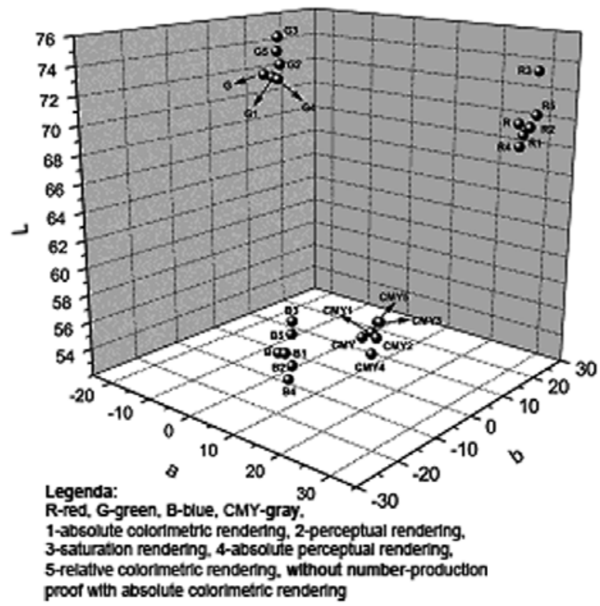

Figure 8 Display of L*a*b* values from proof prints with different rendering methods and production print (50% tone value for RGB and CMY)

In the reproduction of 50% secondary and tertiary screen tones the saturation method resulted with the worst proof prints ($\Delta E_{50\%R}$=3,0212, $\Delta E_{50\%G}$=3,1998, $\Delta E_{50\%B}$=2,8384, $\Delta E_{50\%CMY}$ 2,6910). Proof print closest to the production print, in secondary and tertiary color, is generated with the method of absolute colorimetric rendering ($\Delta E_{50\%R}$=0,7190, $\Delta E_{50\%G}$=1,8343, ΔE_{B}=0,8615, $\Delta E_{50\%CMY}$ =1,8495).

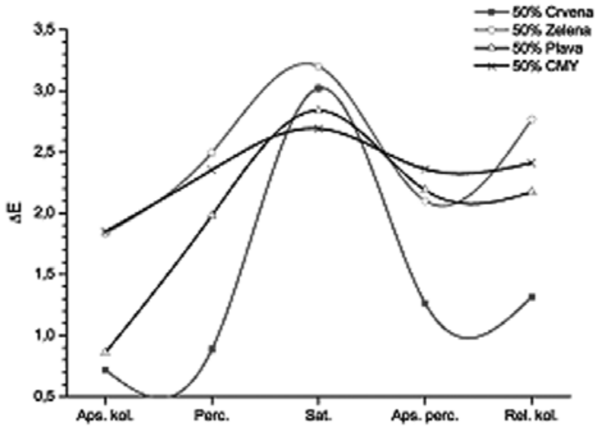

Figure 9 Display of ΔE production print and proof prints with different rendering methods (50% tone value for RGB and CMY)

Other rendering methods by 50% tone value of red gives the following differences in tone value: $\Delta E_{50\%R}$=0,8871 (perceptual rendering), $\Delta E_{50\%R}$=1,2642 (absolute perceptual rendering) and $\Delta E_{50\%R}$=1,3170 (relative colorimetric rendering).

By reproduction of green, the following differences are gained: $\Delta E_{50\%G}$=2,4958 (perceptual rendering), $\Delta E_{50\%G}$=2,1022 (absolute perceptual rendering) and $\Delta E_{50\%G}$=2,7655 (relative colorimetric rendering).
In blue print with perceptual rendering the difference $\Delta E_{50\%B}$=1,9817 is generated, with absolute perceptual rendering $\Delta E_{50\%B}$=2,1890 and with relative colorimetric rendering $\Delta E_{50\%B}$=2,1717.

Reproduction of 50% tertiary with rendering methods for CMY generated the differences in tone value: $\Delta E_{50\%CMY}$=2,3534 (perceptual rendering), $\Delta E_{50\%CMY}$=2,3607 (absolute perceptual rendering) and $\Delta E_{50\%CMY}$ =2,4104 (relative colorimetric rendering).
In printing the tertiary colors, regardless the screen value, the oscillations in tone value have not been perceived, the difference is constant and amounts around ΔE_{CMY} =2,3.

4. CONSLUSION

Generally speaking, the method of *absolute colorimetric rendering* showed to be the most convenient one for all the examined inks (for full tone and screen tones), but resulting in minimum average of the tone value difference for primary colors (CMYK) which are printed in single drift ($\Delta E_{100\%CMYK}$=1,0572 and $\Delta E_{50\%CMYK}$=1,2672). Secondary colors (RGB) made with double printing will give the smallest average deviation by proof printing $\Delta E_{100\%RGB}$=1,4099 and $\Delta E_{50\%RGB}$=1,1383, while for tertiary colors (made with 300% printing) it will be $\Delta E_{50\%CMY}$ =1,8495. In the reproduction of the tertiary full tone the *absolute perceptual rendering* ($\Delta E_{100\%CMY}$=2,0364) is proved as the best method.

The worst results are generated with different rendering methods, and they depend on type of pigment, but also on surface coverage of halftones.

Perceptual method of rendering has showed to be the worst choice in the reproduction of screen values of primary colors ($\Delta E_{50\%CMY}$=2,0992) while in reproduction of the screen values of secondary and tertiary colors the *saturation method of rendering* ($\Delta E_{50\%RGB}$=3,0198 and $\Delta E_{50\%CMY}$=2,6910) showed itself as the worst one. *Absolute perceptual rendering method* gives the highest average deviation in proof printing of primary and secondary full tones ($\Delta E_{100\%CMYK}$=2,5097 and $\Delta E_{100\%RGB}$=2,6628).

Relative colorimetric rendering method showed as unfavorable in printing dark brown full tones ($\Delta E_{100\%CMY}$ =2,9876).

* * *

Based on the research we come to conclusion that for Piezo Ink Jet proof printing of full tones *absolute colorimetric rendering method* for CMK, and *relative colorimetric* for Y were applied. For halftones printed with process inks *absolute colorimetric rendering* (C+K), *perceptual rendering* (M), and *saturation rendering* (Y) are recommended.

In order to achieve the ideal secondary and tertiary tones it is recommended *saturation rendering* (R+B), *absolute colorimetric rendering* (G), and *absolute perceptual rendering* (CMY) are recommended. For secondary color halftones only *absolute colorimetric rendering* is recommended

5. LITERATURE

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