BLAŽ BAROMIĆ 07
11TH INTERNATIONAL
CONFERENCE ON PRINTING, DESIGN AND GRAPHIC COMMUNICATIONS
26th-29 th September 2007, Zadar, Croatia

Original scientific paper

THE INFLUENCE OF ELECTROINK PIGMENTATION ON THE QUALITY OF INDIRECT DIGITAL PRINTING

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Abstract: *Indirect electrophotographic printing with the liquid toner is based on specially constructed ElectroInk. Somewhat better quality of prints is attributed to the tiny pigment particles which, when exposed to the visible light, result in expressive chromaticity. The star like shape ensures good bonding of the pigment and the printing substrate which results in a small and even ink coating.*

Prints with different pigmentation of ElectroInk were made for this work (inking density from 1,20 to 2,00). Different printing substrates were used in printing (Symbol = fine art paper, Arcoprint = natural paper, Splendogel = specially prepared paper for electrophotographic printing). Different concentrations of pigment quantity in ElectroInk influence differently the quality of the final print. Achieving of optimum, i.e. the high quality print on such printing substrates is possible to determine by electrophotographic measurements (CIE LAB ΔE and space gamut) and by densitometric measurement (inking density and the value of the dot gain).

The results show that the deviation of the space volume is the greatest on natural paper (Arcoprint = 11, 12%), fine art paper (Symbol = 7,9%) and on specially coated paper (Splendogel = 5,98%). The greatest space gamut is formed with the thickest ink (D=2,0), where the expected increase of colour reproduction is not achieved. Gradual increase of inking density (from D = 1.20 to D=1.60) on Splendogel paper results in modest gamut increase of 9,29%, while the other printing substrates react better (Arcoprint 40,41%, Symbol 31,29%).

The average inking deviations of basic inks (ΔEMAX - ΔEMIN) are great (Symbol =12,6, Splendogel =10,6 and Arcoprint =10,26). The screened and unscreened printing elements have identical changes.

Key words: *indirect electrophotography, ElectroInk Mark 3.1, reproduction gamut*

1. INTRODUCTION

70 years have passed from the revolutionary Chester Carlson`s "dry" printing to the recent electrophotography. During this time the process of electrophotographic printing has been greatly improved. Although the electrophotographic printing on the principle of Xerography (printing with the powder toner) is still dominant, electrophotographic system for printing which applies special ink of dual aggregate states has been developed in the last 10 years. Such inks contain smaller inking carriers which results in thinner ink coating, higher output resolution and better print quality (according to the characteristics the Indigo prints are similar to the prints obtained in standard lithographic offset) (http:/en wikipedia. org, 16.11. 2005).

2. THEORETICAL PART

The pioneer in the development of electrophotographic ElectroInk is the company Indigo Electronic Printing Systems Ltd. From Rehovot (Israel).The company Indigo works at the same time in indirect satellite construction of printing machines which use only one OPC (Organic Photo Conductor), which enables multicolour variable printing. The unique transfer dressing (placed on offset cylinder) which enables 100% ink transfer on the printing substrate is very important for such construction. (Kiphan H, 1997).

The basic characteristic of the special ElectroInk is that it changes its viscosity during the printing process (during warming, the viscosity of ink is quickly changed, from the liquid aggregate state it passes into the paste-like aggregate state). The composition of ElectroInk is very complex. It is characterized by three components: pure pigment, liquid pigment carrier and additive for increasing the electric conductivity. (Drennan B, 1998).

The manufacturer of the original ElectroInk is the Japanese company Toyo Ink which produces pigments for the leading world producers of offset inks. The original paste-like pigment mixture (pigments and resins) is characterized by the specific star like shape of very uniform sizes (from 1 to 2 µm). For cyan, magenta and black, the quantity of pigment mixture in liquid ElectroInk is very small (about 10%). Only in yellow (because of low chromaticity) greater pigment concentration (of about 15%) is added. For high quality HIFI printing, Indigo has developed 6-colour Indicrom printing system (except CMYK the violet-blue and orange are also printed) and the possibility of printing per choice is also possible (128 PANTONE color tones).

The most dominating substance in the prepared ElectroInk is the liquid pigment carrier. The function of the liquid carrier is to disperse the pigment mixture in the ink fountain, creating the necessary fluidity for the future printing process. The total share of the liquid carrier is very great (from 75% to 88%). According to the chemical composition, the liquid carriers are high molecular hydrocarbon compounds with a very low volatility temperature (they change their aggregate state from the liquid into the gaseous state very quickly while being warmed). Such compounds belong to the group of petroleum spirits which are known under the factory name ISOPAR.

ISOPAR is a liquid carrier which has a good electric conductivity (42 pmho/cm^2). However, in order to achieve qualitative acceptance of the star-like pigments for photoconductor (offset dressing) greater starting electric conductivity is necessary. Greater electric conductivity is achieved with the addition of the liquid for increasing the electric conductivity, which is according to its structure a chain-like polar molecule. In the prepared ElectroInk, the share of the chain-like polar molecules varies from 2-5%, by which the working electric conductivity of 100 pmho/cm^2 is set. The chain-like polar molecules, with their negative pole, are bonded to the positive star-like pigment particles. The positive pole is turned in the direction of the surrounding liquid ISOPAR (Larson J. P., et al, 2002).

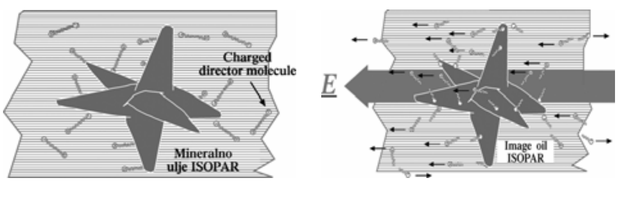

Figure 1. Schematic presentation of the prepared ElectroInk

The activity of the outer electrostatic field influences the structural change of the liquid ElectroInk. The weak intermolecular forces within the polar chain-like molecules break (the liquids for increasing the electric conductivity) and the pigment particles become negative. It results in the possibility of selectively acceptance of pigments for smaller electropositive photoconductor surfaces, i.e. on the electronegative parts of the developing printing system (figure 1).

During printing, the liquid ElectroInk passes from the photoconductor onto the hot, positively charged transfer medium. ISOPAR changes its aggregate state at high temperature (from the liquid phase into the gaseous phase) which results in increasing the share of the star-like pigments (i.e. in the change of ink viscosity). By heating, the monomer star-like pigments are mutually easily bonded into greater groups creating one homogeneous layer. By stopping the activity of the positive electric field, the pigment particles (paste-like ElectroInk) are squeezed into the printing substrate and by cooling it they become stiff. The pressing force is considerable (Majnarić I., Brozinčević M., Bolanča S, 2005).

Homogeneously printed layer of ElectroInk is difficult to break. In the paper recycling process it causes additional problems, i.e. in the deinking process the ElectroInk particles are grouped into greater accumulations which cannot be removed. This is a great problem for the paper industry which uses the old paper as the raw material (Bolanča Z., Bolanča I., Majnarić I, 2005).

3. EXPERIMENTAL PART

The influence of the concentration of ElectroInk pigments on the final multi-colour reproduction has been analyzed in this investigation, i.e. what is the influence of the pigmentation of ink on the quality of the final HP Indigo print. In the preparatory part of the experiment the digital printing form was created (in PDF form) which was used for the densitometric and spectrophotometric analysis.

Such special test form contains 378 ECI patches for the production of ICC profiles (space gamut), step like wedge from 10% to 100% screen values in the steps of 10%, textual and line microelements (negative and positive) and the standard chromatic ISO illustrations.

The printing part of the experiment is done on the production electrophotographic machine HP Indigo TurboStream. 3 characteristic printing substrates are used in printing: Arcoprint (natural offset paper) Symbol (fine art paper printing gloss) and Splendogel (coated natural paper for HP Indigo printing machines). During the experimental printing the composition of ink varied, i.e. the prints with 5 different pigmentation of the liquid ElectroInk (for the basic process colours from 1.20 to 2.00) were made (figure 4).

Measuring of the chromatic (Lab, DE) and the densitometric values (D, SV) of prints was performed by spectrophotometers X-rite DTP 41 and X-rite Swatch Book. The software (Monaco Platinum and ColorShop X) is necessary for their functioning, by means of which the results were obtained which were presented in the two dimensional and the three dimensional form (Majnarić I., Bolanča I., Bolanča Z., Milković M, 2005).

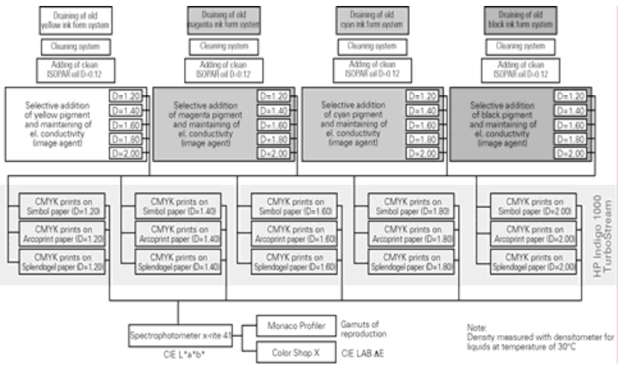

Figure 4. Schematically presented plan of the experimental printing

4. RESULTS AND DISCUSSION

The influence of the liquid toner pigmentation on CIE LAB colour results (obtained by measuring 378 ECI patches on 3 kinds of paper) are presented in figures 5,6,and 7.

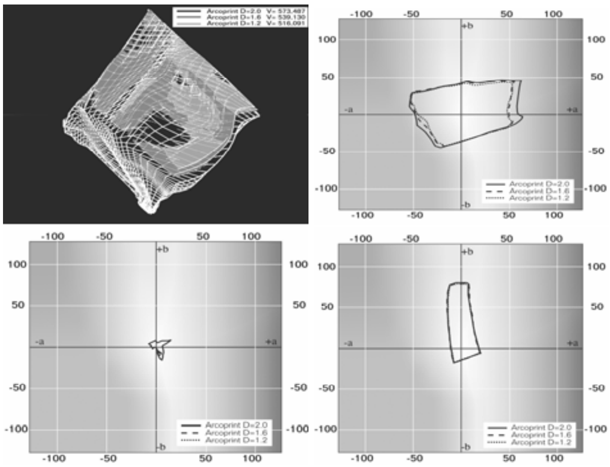

Figure 5. Presentation of Indigo gamut which was caused by the variation of ElectroInk concentration on Arcoprint paper

The greatest reproduction gamut on Arcoprint paper (figure 5) was achieved with the ink density D=2,00 (V=573,487) while the smallest gamut was achieved with the ink density D=1.20 (V=516,091). The total gamut increase was 57,396 space units. The change of the liquid ink density from D=1,20 to D=1,60 will result in the increase of the gamut size for 23,039 space units. Further ink density increase for 0,40 (from the ink density 1,60 to 2,00) will result in further gamut increase for 34,357 space units. Observing the characteristic cross sections, it is visible that the tones underwent the greatest changes in the central and the lower part of the gamut. The greatest change appeared in magenta, red and cyan area. It is characteristic that yellow was the least changed. It can be explained by low viscosity of ink (too low pigment concentration) which insufficiently covers the surface of the printing substrate. Reflection from the printing substrate in this case is great, which results in lowering the chromatic saturation of the printed ink. The dark tones are well reproduced only with the thickest ink (D=2,00), while they appear only in outlines.

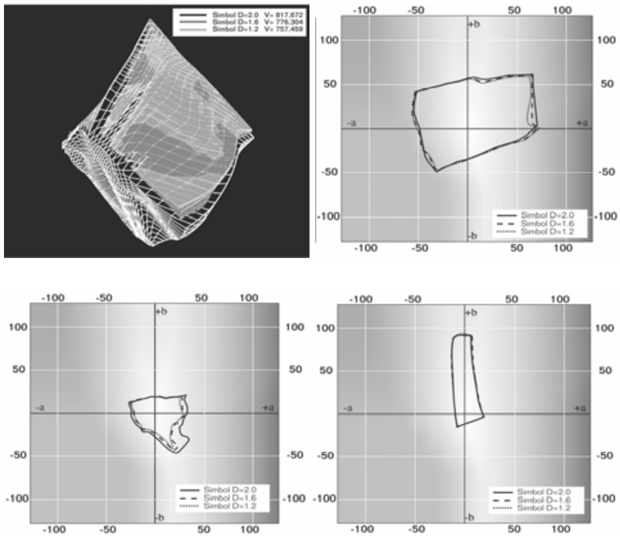

Figure 6. Presentation of gamut which was caused by the variation of ElectroInk concentration on Symbol paper.

In relation to other tested papers, the Symbol prints (figure 6) have the greatest increase of gamut caused by ink density variations (ΔV=60,213). The greatest space volume was realized with the ink density 2,00 (V=817,672) while the smallest was obtained by the ink density of D=1,20 (V=757,459). In this case the gamut increase of 7,94% was obtained. The change of the ink density from D=1,20 to D=1,60 will result in the gamut size increase for 18,845 space units. Further increase of the pigment concentration in ink (from D=1,60 to D=2,00) will result in greater gamut change of 41,368 space units. By the variations of ink the gamut in the central part will not have greater changes. But there are some small differences. They are visible in magenta and yellow. Gamut increase on Symbol paper is more visible in darker areas of gamut and it is dominant in violet blue area.

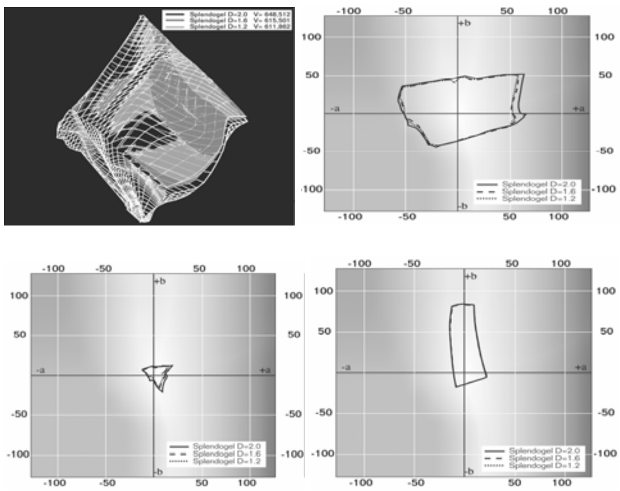

Figure 7 Presentation of Indigo gamut caused by variation of ElectroInk concentration on Splendogel paper

On Splendogel paper, the greatest reproduction gamut (figure 7) was achieved by the ink density of D=2,00 (V=648,512). Gamut of the smallest size (V=611,862) was achieved by the ink density D=1,20. The total gamut increase was 36,65 space units. Change of the ink density from D=1,20 to D=1,60 will result in gamut increase for 3,639 space units. Further ink density increase for 0,40 units (from D=1,60 to D=2,00) will result in a great gamut increase of 33,011 space units. Gamut values on Splendogel prints have similar shape as gamut values on Arcoprint prints (their cross-sections coincide). The only difference is visible in darker tones because the coating of the printing substrate (Splendogel) attracts ElectroInk better.

For the precise analyzes of the influence of the pure pigment concentration on the reproduction, it is necessary to print and to measure the characteristic patches with 100% and 50% screen. Their deviation in relation to the calibration is presented in figures 9 and 10.

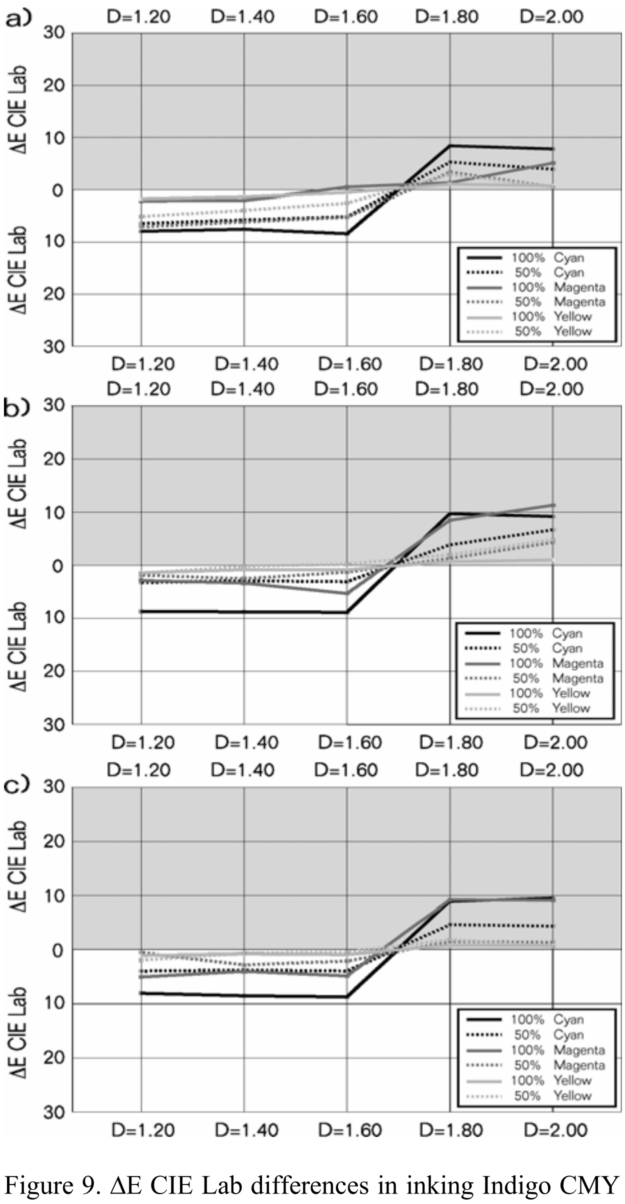

Figure 9. ΔE CIE Lab differences in inking Indigo CMY prints caused by the variations of ElectroInk concentration on Arcoprint paper, Symbol paper and Splendogel paper

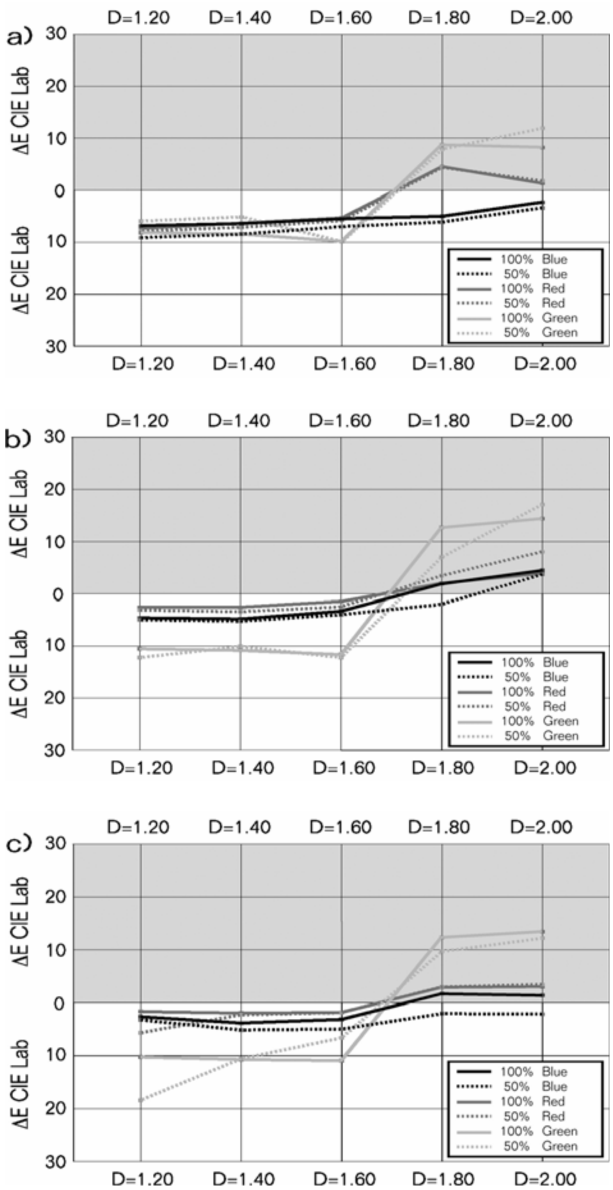

Figure 10. ΔE CIE Lab differences in inking Indigo RGB prints caused by the variations of ElectroInk concentration on Acoprint paper, Symbol paper and Splendogel paper

On Arcoprint prints (figures 9a and 10a) by changing the ink composition, the total deviation in print ΔE_{MAX} - ΔE_{MIN} of 10,94 is achieved. The total deviations of full tones are great ΔE_{MAX} - ΔE_{MIN}; they are 10,26). The greatest deviation is in cyan ($\Delta E_{100\%}$=16,8) and green ($\Delta E_{100\%}$=18,5). In relation to the full tones the screened prints change more intense (ΔE_{MAX} - ΔE_{MIN} is 11,61). Among the basic process inks, the greatest deviation has cyan ($\Delta E_{50\%}$=11.7) and magenta ($\Delta E_{50\%}$=7.4). Among the secondary inks, the ink red ($\Delta E_{50\%}$=12.2), green ($\Delta E_{50\%}$=21.7) and violet blue ($\Delta E_{50\%}$=5.7) are separated. It can be concluded from these results that the greatest oscillations have the densitometric darkest inks (cyan, magenta and yellow), i.e. the subtractive inks in which they are represented..

In obtaining the standard prints, it is necessary to standardize the inking of 50%SV and 100%SV. It is visible in the histogram, that all the process inks with the density of D=1,70 have the inking difference of ΔE=0, i.e. they have the print identical to calibration. Very similar situation is noticed in printing with the secondary colours red and green. The only exception is violet blue colour which does not come nearer to ideal calibration, i.e. the adherence of cyan to magenta should be better for its forming.

On Symbol prints (figures 90b and 91b) by the variation of the pigment concentration the average inking deviation ΔE_{MAX} - ΔE_{MIN} of 12,65 is achieved. In relation to Arcoprint, the full tones of Symbol prints, have somewhat greater average tone deviation (ΔE_{MAX} - ΔE_{MIN} is 13,21). It is characteristic that, by the changes of the ink densities, the greatest deviation of 100% is achieved in green ($\Delta E_{100\%}$= 26,0) and 100% in cyan ($\Delta E_{100\%}$=18,6), while the smallest is achieved at 100% yellow ($\Delta E_{100\%}$=2,4). The screened prints have somewhat smaller medium deviation of inking ΔE_{MAX} - ΔE_{MIN} which is 12,1). From the processed screened inks the greatest change is in green ($\Delta E_{50\%}$=29.3), red ($\Delta E_{50\%}$= 11.4) and cyan ($\Delta E_{50\%}$= 9,9). For achieving the optimal print it is recommended to use the unique inking density of D=1,70.

On Splendogel paper (figure 90 and 91c) by varying the ink density, the prints are obtained which have medium inking deviation of all tones ΔE_{MAX} - ΔE_{MIN} of 10,65. Solid tones have changes which are smaller than on Symbol prints, but greater than on Arcoprint prints (medium deviation of full tones ΔE_{MAX} - ΔE_{MIN} is 11,46). The changes are most visible in green (ΔE_{100}=24,3), cyan ($\Delta E_{100\%}$=18,2), and magenta ($\Delta E_{100\%}$=14,1). In printing with different thickness of ink the screen prints have smaller changes (medium deviation of the screened tones ΔE_{MAX} - ΔE_{MIN} is 9,85). The greatest change is in green ($\Delta E_{50\%}$=30.6), red ($\Delta E_{50\%}$=9,0), and cyan ($\Delta E_{50\%}$=8,5). For the prints of the most similar calibration the inking density D=1,70 is also recommended.

Yellow colour presents the greatest problem in calibration of the printing machine. It is specially emphasized in the realization of 50% yellow. Because of its great brightness it is difficult to keep the pureness of ink, i.e. its constant value during printing. It was noticed that even during the printing process the electric conductivity of the yellow ElectroInk grows. During the working temperature of 30°C the particles of the pure pigment slowly overtake the additional electro negative characteristic from its surrounding, which finally results in too thick ink layer on prints. Because of that the manufacturer of HP Indigo machines often changes the composition of ElectroInk pigments in order to solve this problem (up to now there are 4 types of ElectroInks developed for the market).

It is characteristic for all results, that the maximal viscosity of ink does not mean the greatest inking density on prints (they are in histogram between D=1,80 and D= 2,00 as the horizontal line). This appearance can be explained by too big viscosity of the liquid ink. The greater the concentration of pigment is the smaller fluidity of the ink will be. During printing, the liquid ink is distributed on photoconductor through the slit 0,5 mm wide (Slit Injector).Because of the too small fluidity, the smaller quantity of ink will pass in the determined time which will finally result in smaller quantity of ink on prints.

5. CONCLUSION

Deviation of the space volume caused by the change of pigmentation was the greatest on Arcoprint paper (11,12%) Symbol paper (7,9%) and Splendogel paper (5,98%).

The greatest space gamut is formed by the thickest ink D=2,0 (Arcoprint V= 573, 487 Symbol V= 817,672 Splendogel V= 648,512) which is the increase in relation to calibration: Arcoprint ΔV=57,3 Symbol ΔV=60,2 Splendogel ΔV = 36,6 gamut units.

Gradual increase of inking density (from D=1,20 to D=1,60) will result on Splendogel paper in modest gamut increase of 9,29%. Other printing substrates react better (Arcoprint 40,14% and Symbol 31,29%).

The average deviations which appeared in the inking ($\Delta V\ E_{MAX}$ -$\Delta V\ E_{MIN}$) are great (Symbol 12,6, Splendogel 10,6 and Arcoprint 10,26). The screened and the non screened elements have almost identical changes.

The printing on Splendogel paper with the pigmentation of 1.70 is recommended because it gives the uniform printing quality for the basic process colours.

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