Colour Accuracy of Corporate Colours in Expanded Gamut Print Reproduction

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Abstract

Expanded gamut printing, as the name implies, expands the gamut of printable colors that can be achieved through a combination of CMYK by adding Orange, Green and Violet (OGV). Through the addition of these additional three colors it is possible to cover almost 95% of the colors that are in the Pantone® color guide for printing. The benefit of using expanded gamut printing is, that the same inks can stay in the ink fountains of a printing press and only the printing plates need to be changed from job to job. No time-consuming ink changes are necessary if a printing press uses the expanded gamut ink set.

The exact reproduction of brand identity colors is very important to brand owners. Brand owners allow minimal color discrepancies of their brand color(s). Therefore, it is important to achieve the best possible color reproduction when printing brand colors using the expanded gamut technology. It is the goal of this project to find out how much color deviation there is when a Pantone® color is reproduced with expanded gamut technology.

In this project 14 brand colors that use a Pantone® color were investigated. These brand colors should cover all aspects of the color wheel. The first part of the project was the characterization of the press followed by a press run of the 14 selected brand colors. The accuracy of the color reproduction was checked against the digital color values for the selected Pantone® colors from the Pantone Expanded Gamut guide.

From the 14 selected colors 10 colors showed a more accurate color reproduction. The average DE2000 value for the tested colors was 3.24 vs. 6.24 for the four-color version.

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The main challenges in this project were running a seven-color job on a four-color press and controlling the ink/water balance for the Orange, Green and Violet inks on press.

Introduction

Expanded gamut printing is not new. It has gained more traction in the last couple of years. Expanded gamut printing is mainly used in packaging, where corporate colors need to be printed with color accuracy. Printing packaging in the traditional way could mean four-color process plus spot colors in print units 5, 6 and 7. In flexographic packaging printing it could mean that each print unit contains a spot color. After the press run the print units with the spot color need to be cleaned and prepared for the next print run. This is time consuming and material intensive. Any leftover ink needs to be stored for possible reuse in the future.

Expanded gamut printing does away with this. One of the main things needed for printing with expanded gamut is a 7-color printing press. The colors in the ink fountain stay the same and only the printing plates for the next job are put on, substrate might be changed, and the next job gets printed. Through the combination of Black, Cyan, Magenta, Yellow, Orange, Green and Violet/Blue many of the Pantone® colors can be achieved without the need of having the actual spot color in the printing unit. As the name of the process implies the addition of three extra colors expands the gamut of the standard four-color printing process to cover about 90 - 95% of the Pantone® Plus book.

A brief history of expanded gamut printing and benefits of this process

The history of expanded gamut printing has been well described by John Seymour in two articles (Seymour, 2018) (Seymour, 2019). A brief synopsis of the two articles will be given here.

The earliest instance of expanded gamut printing happened in 1960 when Hallmark Cards added extra colors to the standard set of printing inks for their greeting cards. These extra colors included fluorescent pink, yellow and magenta. In 1968 Shoichi Shimada came up with a system for Dainippon Screen. He used the three primary colors CMY and three secondary colors OGV plus black to expand the gamut. This sounds a lot already of what is being done today in regard to expanded gamut printing.

In 1985 Harald Küppers came up with a system using six chromatic inks. These inks were Yellow, Magenta-Red, Violet-blue, Cyan Blue, Green and Black. He converted a color into a mosaic of these six inks to achieve the look of the color from afar, but one can see that this was not a very practical approach to printed on a printing press, since any color registration problems would lead to color variations.

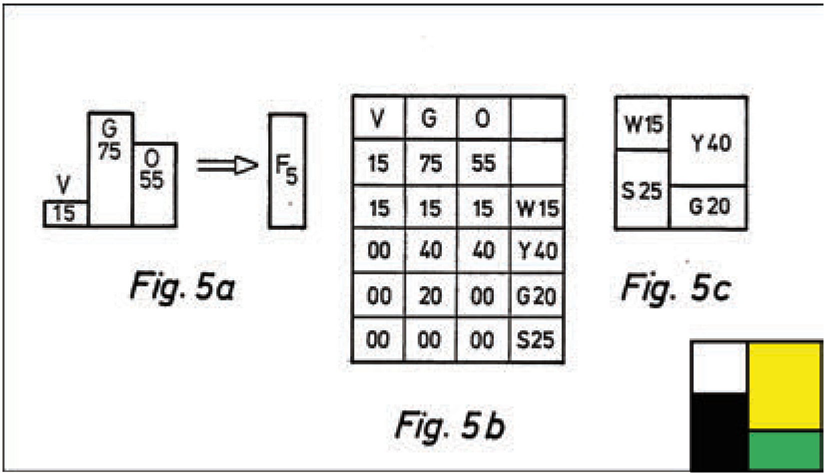

Figure 1. *Küppers approach to simulate a color through a mix of colored tiles to simulate that color (figure from Seymour 2018)*

Between 1994 and 1995 seven patents were filed for expanded gamut printing. In 1994 Don Hutcheson came up with the idea to print a double hit of CMYK to expand the gamut of four-color offset printing. This idea is now pursued in a modified version through IDEAlliance called XCMYK. The idea behind XCMYK is to expand the gamut of four-color offset printing by printing the process colors at higher densities than currently recommended by GRACoL. This also expands the gamut of four-color offset printing, but not as much as 7-color printing.

In 1994 the Eder MCS (Multi-Color Separation) was brought to the market which uses CMYK plus x-colors. This software was later on also sold by Linotype-Hell. In the same year Pantone® released its Hexachrome system which replaced the process yellow and magenta with fluorescent yellow and magenta and added orange and green. This solution found some uptake in the industry but not a lot.

In 1995 the Opaltone system came to market. It used CMYK plus RGB to expand the gamut of four-color offset printing. The purpose of this invention was to print:" ... saturated colors such as deep reds, greens and blues cannot be reproduced satisfactorily due to the limited print range of four-color process." (Seymour 2019).

The invention of FM screening in the mid-1970's helped also with concept of expanded gamut printing. FM screening eliminates the problem of having only 4 screen angles available but seven colors in the mix. FM screening eliminates the problem of having possibly Moiré on the press sheet. It took some years until FM screening became usable for high quality work. This was in 1993 with the introduction of Agfa CristalRaster technology.

The benefits of expanded gamut printing have been nicely summed up by Baldwin (Baldwin, 2016). The benefits are as follows:

- Ink savings (only seven colors are needed, no spot colors)
- Reduced press characterizations
- Reduced wash-ups
- Ganging jobs
- Material savings (inks and substrates)

Ink savings are realized because only the seven colors need to be kept in the press room. The need for keeping all those special colors on shelves that might get used later on in time is not there anymore. The press gets characterized for printing with the seven colors on the most common substrates used in a print company. The need for wash-ups is also reduced since always the same seven colors are kept in the ink fountains. No time-consuming wash-up is needed between jobs when compared to running a spot color and that color needs to be changed for the next press run. The wash-up for one print unit can easily take up to 30 minutes to clean out the ink fountain and clean all the rollers, put the new ink into the fountain and setting up the next job. Since the spot colors are simulated through the seven-color process different sized jobs with different spot colors can be put on one press sheet if the jobs are specified to run on the same substrate. This increases efficiency within the print company. As previously pointed out the need to keep hundreds and hundreds of spot colors on shelves in the press room is not there anymore when the vast majority of the print jobs can be run using the expanded gamut technology.

Equipment and Materials

The aim of this project was to find out how well selected corporate colors can be reproduced using expanded gamut printing. Since expanded gamut printing is mainly used in flexographic printing for packaging the authors of this paper also wanted to see how well this works in offset lithography on a folding carton type application.

Below is a table of all the brand colors that were used in this project:

Brand	Color	Color	Pantone#	Pantone #
Telus	Green	Purple	376	2745
CIBC	Red	Yellow	201	137
RBC	Blue	Yellow	286	116
BMO		Blue		300
Bell	Blue		7692	
Canadian Tire	Red	Green	485	355
Cadbury	Purple		2685	
UPS	Brown		476	
Yahoo	Purple		527	
John Deere	Green	Yellow	364	109

Table 1. *Brand colors used in this project*

The following equipment was used in this study:

- Heidelberg PM74-4P
- X-Rite Intellitrax
- X-Rite iSis XL (M1)
- X-Rite eXact (M1)
- GMG OpenColor
- GMG ProfileEditor
- Epson SureColor P9000
- Kodak Prinergy & Preps
- Pantone Color Manager

The substrate Carolina 8pt C1S was used for this study to test a material that would be used for the manufacturing of folding cartons.

Procedure

The challenge for this study was also that only a four-color printing press was available to conduct the study. This means that the press sheets had to pass twice through the press. The first pass printed KCM and the second pass printed VGOY. This ink sequence was also used in GMG OpenColor to generate the test charts. The image of the test charts can be seen in the figure below.

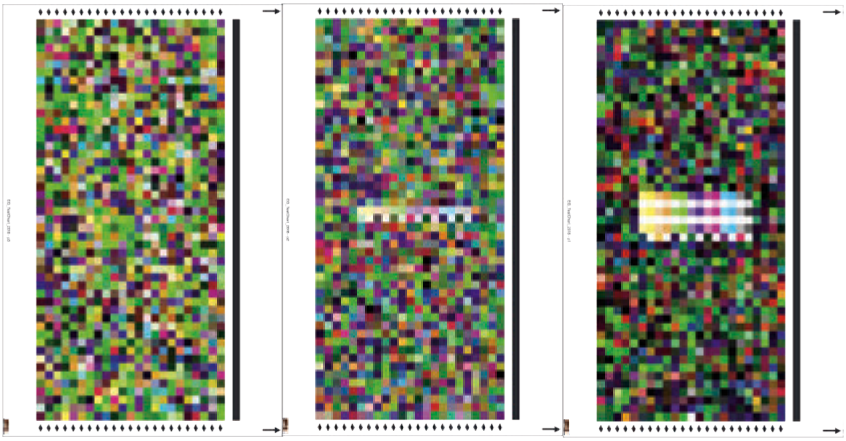

Figure 2. *Test chart need to characterize the press*

The test charts were processed through the Kodak Prinergy workflow at the School of Graphic Communications Management.

The following inks were used on press during this project:

Print unit	Ink number	Ink name	Target ink density
		1st pass	
1	49 RL 2501	Inkredible Reflecta CoFree Black	1.65
2	43 F 10 PX	Perfexion Eco Cyan	1.40
3	42 F 10 PX	Perfexion Eco Magenta	1.46
		2nd pass	
1	3 ONX 51501	Esko Violet	1.93*
2	4 ONX 51502	Esko Green	1.76*
3	2 ONX 51500	Esko Orange	2.00*
4	41 F 11 PX	Perfexion Eco Yellow	1.04
*Printed ink densities measured from the Pantone Plus book			

Table 2. *List of inks used in this project*

The following table shows the actual densities on the press run of the test chart shown in figure 2.

Print unit	Ink number	Ink name	Target ink density	Actual ink densities 1st run
		1st pass		
1	49 RL 2501	Inkredible Reflecta CoFree Black	1.65	1.52
2	43 F 10 PX	Perfexion Eco Cyan	1.40	1.31
3	42 F 10 PX	Perfexion Eco Magenta	1.46	1.41
		2nd pass		
1	3 ONX 51501	Esko Violet	1.93*	1.66
2	4 ONX 51502	Esko Green	1.76*	1.53
3	2 ONX 51500	Esko Orange	2.00*	1.62
4	41 F 11 PX	Perfexion Eco Yellow	1.04	0.97
*Printed ink densities measured from the Pantone Plus book				

Table 3. *Actual ink densities from the press run of the test charts.*

It needs to be said that the target densities are wet ink densities and the actual densities are dry ink densities that were measured once the press sheets had dried. From this press run three press sheets were randomly selected and read in three times each to minimize any measurement errors. The measurement condition used on the iSis was M1. From these measurements the press characterization was made and OpenColor calculated a press profile.

After the press profile had been created the whole Pantone® Plus coated library was loaded into the project in OpenColor and the press profile was used to calculate how OpenColor would "mix" the seven colors to achieve the Pantone® colors listed in table 1. The percentages calculated by OpenColor were then used to build the next test chart as can be seen in the following figure.

Figure 3: *Test chart to test the Pantone color used in this study. The left side of the chart is the expanded gamut version and the right side is the four-color process version of the same Pantone colors.*

The test chart shown in figure 3 was created in Adobe Illustrator. The patches on the left side of the test chart were created using the "Appearance tool" and the second and third colors were added as fills according to the separations calculated by OpenColor.

Print unit	Ink number	Ink name	Target ink density	Actual ink densities 1st run	Actual densities 2nd run
			1st pass		
1	49 RL 2501	Inkredible Reflecta CoFree Black	1.65	1.52	1.40
2	43 F 10 PX	Perfexion Eco Cyan	1.40	1.31	1.23
3	42 F 10 PX	Perfexion Eco Magenta	1.46	1.41	1.38
			2nd pass		
1	3 ONX 51501	Esko Violet	1.93*	1.66	1.58
2	4 ONX 51502	Esko Green	1.76*	1.53	1.45
3	2 ONX 51500	Esko Orange	2.00*	1.62	1.46
4	41 F 11 PX	Perfexion Eco Yellow	1.04	0.97	0.99

*Printed ink densities measured from the Pantone Plus book

Table 4. *Actual ink densities from the press run of the second test form (figure 2)*

The print ink densities in table 4 are also dry densities. It is clear that the ink densities of the first run were not achieved. This is mainly due to severe ink scumming observed especially for the orange, green and violet inks. A visual representation of these numbers can be seen in figure 4.

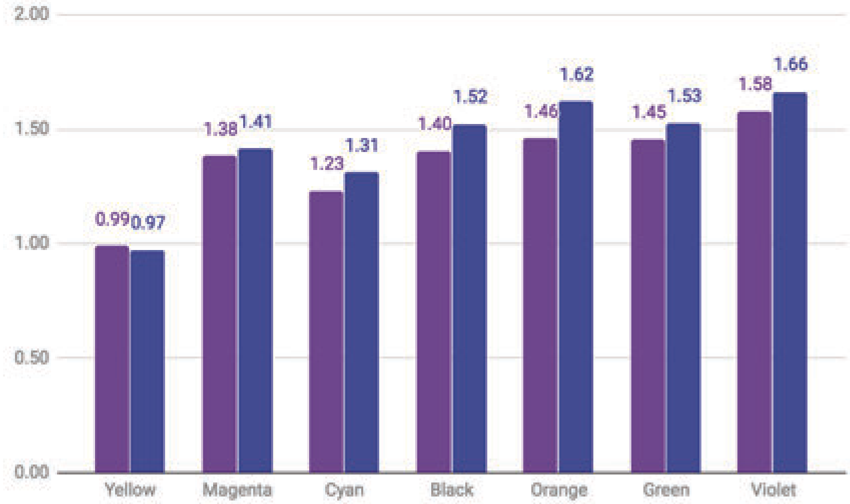

Figure 4. *Printed ink densities (dry) of the seven inks used for the press run of the test chart shown in figure 2*

The difference between both press runs can clearly be seen.

Results

The most important part of this project was to find out how the seven-color version of the Pantone® colors selected for this project compare to the L*a*b*-values of the same color from the Pantone® Expanded Gamut guide. These reference L*a*b* values were obtained from the Pantone Color Manager software. For the four-color version of the test chart in figure 2 the reference L*a*b*-values were obtained from the Pantone® Plus guide. The color patches on the test chart were read in three different spots and the obtained L*a*b*-values were averaged and then used for the calculation of the DE200 values. One could ask why two different reference L*a*b were* libraries used in this study. The reason for this was that the L*a*b*-values in the two Pantone® guides for the tested colors are not the same. This can be seen in figure 5.

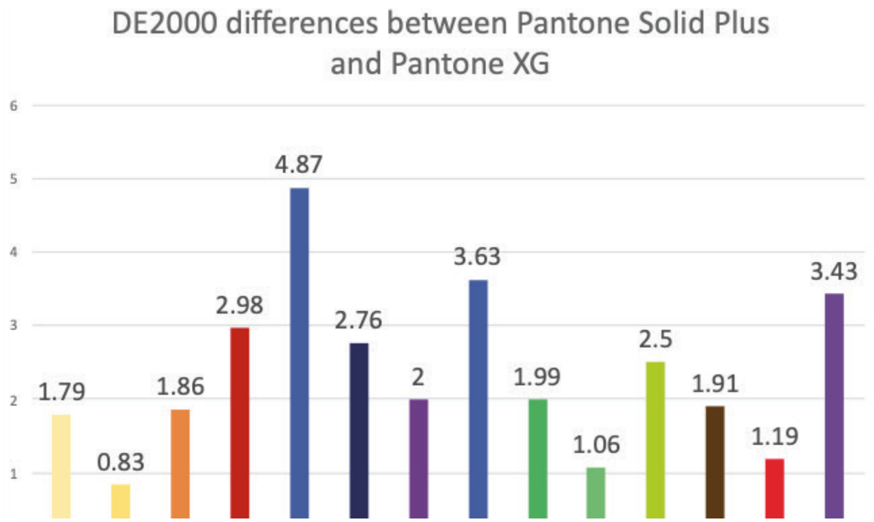

Figure 5. *Color differences between the Pantone Plus and Pantone Expanded Gamut library.*

The different reference values from both Pantone libraries can also be seen in the ColorThink plot below.

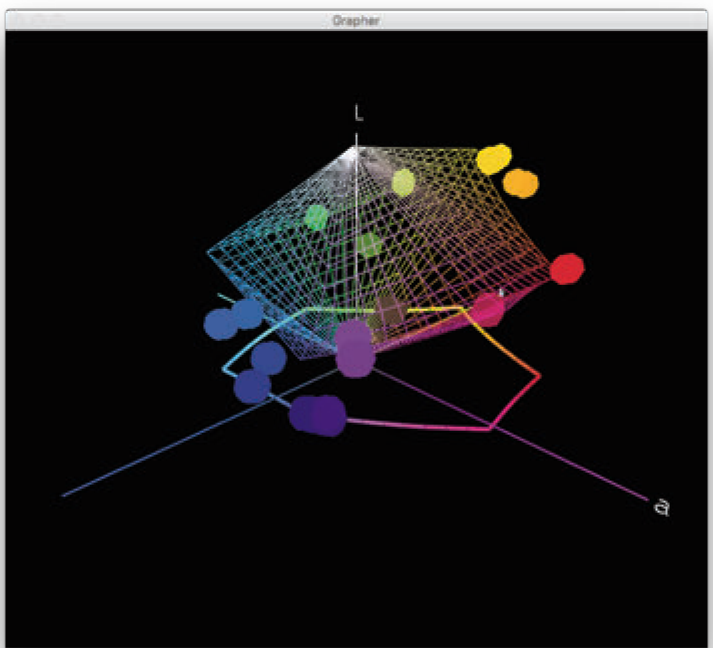

Figure 6. *Difference in the L*a*b*-values of the two Pantone color libraries in comparison to the GRACoL color space shown as a wireframe*

The visual representation of the color differences between the L*a*b*-values of the tested colors from the two Pantone libraries in comparison to the color patches from the test form shown in figure 3.

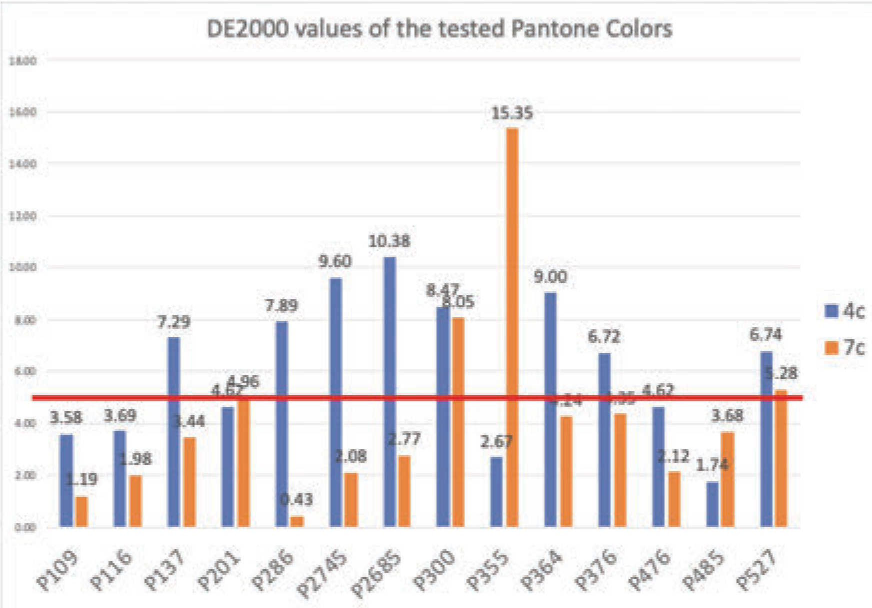

Figure 7. *DE2000 values of the tested Pantone colors in comparison to their respective reference values in Pantone Expanded Gamut guide and the Pantone Plus guide*

From figure 7 it can clearly be seen out of the 14 tested colors 10 colors had a lower DE value in their 7-color version compared to their 4-color version. The DE value for Pantone 355 stands out and the reason for this anomaly will be discussed later. The average DE2000 value for the expanded gamut colors without the two outliers (8.05 and 15.35) is 3.24. The average DE2000 value for the 4-color versions of the tested colors is 6.22. This means that the color differences were almost cut in half.

In order to find a source for this anomaly the hue angles for orange green and violet were measured and compared against recommendations from FIRST (FIRST, 2017) The suggested values for orange, green and violet were as follows:

- 54º, 181º and 307º

The measured values were:

- 54º, 172º and 310º

The biggest discrepancy in the hue angles can be observed for the green ink used in this project. This could contribute to the large DE2000 value of 15.35.

Another reason could also be the tendency of the orange, green and violet inks to scum on press resulting in more dampening solution being applied to the printing plate resulting in a lower printed ink density. The lower ink densities of the second press run were shown in table 4 and figure 4.

During the press run of the test chart shown in figure 3 it was noticed that some form of Moiré was happening in some of the red and blue colors. A closer examination of the screen angles used in the press run revealed the reason for this. The screen angles for the seven colors were as follows:

- Black: 45º
- Cyan and Green: 165º
- Magenta and Orange: 105º
- Violet and Yellow: 0º

The screen angles were automatically assigned by the workflow used for making the printing plates and not manually selected. Similar colors like cyan and green and magenta and orange were on similar screen angles resulting in the observed Moiré.

Outlook for future work

For future work a few things need to be improved upon. First of all, the press characterization needs to be repeated to ensure that that step was done correctly. When the second press run will be repeated it has to be ensured that opposing colors are on the same screen angle. This means that cyan and orange will be on the same angle, as well as Magenta and Green will be on the same screen angle. These opposing colors are very unlikely be used for simulating one of the Pantone® colors.

A study done by Zeleznik in 2011 (Zeleznik, 2011) using the flexographic print process suggest the following screen angles:

- Black & Violet: 52.50º
- Orange & Cyan: 22.50º
- Green & Magenta: 82.50º
- Yellow: 7.50º

The dryback of the inks used in this project needs to be evaluated to ensure that the dry ink density is the desired ink density as outlined in table 2. The following target ink densities for violet, green and orange are suggested:

- Violet: 1.75
- Green: 1.65
- Orange: 1.70

Another option to avoid any Moiré is to use FM screening as was described earlier. Using FM screening poses another set of challenges. Printing with FM screening on the printing plate requires two calibration press runs to adjust the TVI curves from the FM plates to those of the AM plates.

Future projects in this area will also test different Pantone colors for their color accuracy when they are reproduced using the Expanded Gamut process.

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