Brand Color Reproduction Using Expanded Gamut Technology with Offset Printing

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Abstract

Expanded gamut printing is a very interesting and exciting concept for printing Pantone® colors without having to use a dedicated printing unit for that color. Expanded gamut printing increases the color gamut of CMYK through the addition of Orange, Green and Violet or OGV to expand the color space gamut of a printing press beyond standard color spaces such as GRACoL and FOGRA for the goal of increasing efficiency and printing quality and reduced expenses.

Many brand owners and packaging buyers depend on Pantone® colors to increase the aesthetic of their products. Also, maintaining the consistency and the accuracy of the reproduced colors are considered to be an essential step for brand owners as it would affect their brand's identity. With the existence of various digital workflow solutions, the accuracy of Pantone® color reproduction might be affected and thus, the main goal of this project is to investigate how color accurate these different workflow solutions are when a Pantone® brand color is reproduced with expanded gamut technology.

In this project 10–15 brand colors that use a Pantone® color were chosen. The selected colors cover all aspects of the color wheel. A test form was created and printed with an offset printing process. The test form was then processed for expanded gamut printing with the two different expanded gamut premedia workflow solutions that are available for this project. There will be at least four press runs needed for this project. Since the School of Graphic Communications Management only has a four-color offset press the press sheet has to be sent twice through the press. The color sequence that was used for printing the seven colors was selected based on the recommendation of the providers of the premedia workflow solutions.

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Once the test sheets have been printed the selected colors will be measured for the L*a*b* color coordinates and compared to the L*a*b* values of those Pantone® colors provided by Pantone® itself.

A pilot project was conducted previously testing one digital workflow that showed some inconsistencies with the accuracy of the color reproduction. After consulting with the workflow solution provider changes were made in the initial setup of the workflow solution. Also, a second digital workflow will be used, and a similar evaluation will be conducted. The composition of the tested Pantone® colors will also be compared to see if the two digital workflows "create" the same Pantone® color differently.

Some of the chosen colors resulted in a lower DE-value than the same color build from CMYK and some resulted in larger DE-values. It was also seen that some of the chosen test colors were outside of the gamut of the printing inks used in this study. Overall this was a very interesting project to conduct and increased the knowledge about expanded gamut printing.

Introduction

Brand color consistency is integral to a brand's identity. Consumers identify a brand by its brand color. With each new brand color, a new printing unit needs to be used creating the need for 8 to 12 color presses. Traditional printing methods include the four-color process plus spot colors which take up a lot of inventory space and create longer makeready times.

Expanded Gamut removes the need for extra inventory space by focusing only on Cyan, Magenta, Black, Yellow, Orange, Green and Violet. This combination of colors can achieve up to 90-95% of the Pantone® Plus book while reducing makeready time, costs and ink waste.

Many offset print companies have maybe a five or six color press and some have an eight-color perfecting press. An offset press cannot be extended by one or two more print units like an in-line flexographic printing press. An offset printing company wanting to venture into expanded gamut printing would have to invest in a new printing press with seven printing units. This a decision that needs to be weighed carefully. In flexography having a press with 7 or more print units is more common and therefore a switch to expanded gamut printing is easier in that regard.

Historic development of expanded gamut printing

A more detailed overview of the historic development of expanded gamut printing was giving in a publication by Habekost & Grusecki (Habekost 2019). A few highlights from this overview are that the first instance of expanded gamut printing was in 1960 when Hallmark Cards added extra colors to the standard set of printing ink for their greeting cards. From then on, many different approaches were taken to expand the gamut of the printing press. The most known systems were the Opaltone and Hexachrome, but these were not widely used since most print companies had a four and maybe a five-color press at the time.

Expanded gamut as it is understood today goes beyond CMYK printing by adding Orange, Green and Violet (OGV) colors.

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 savings)

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 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.

At the 2019 TAGA conference, Hargrove (Hargrove, 2019) demonstrated with data from a print company that printed the same job(s) conventional and later with expanded gamut technology that there was a cost reduction of $845. The company needed half the makeready time and half the press time. There were fewer wash-ups, less ink waste and the job had less of an environmental impact.

At the same conference, O'Hara et al. (O'Hara, 2019) presented their research into expanded gamut printing by reducing the chroma of Orange, Green and Violet (OGV) from 100% to 80% in 10% increments. The main points from the study were:

- The greatest chroma of the OGV inks does not mean the largest gamut volume
- The greatest chroma does not mean the most Pantone colors. Low chroma inks can often make more Pantone colors
- The greatest gamut volume doesn't mean the most Pantone colors and
- The ink film thickness appears to influence the gamut size beyond its influence on the chroma of solids.

Since expanded gamut printing is a hot topic in the industry at the moment many premedia software solutions are available to implement seven color printing. All these software solutions require that characterization charts need to be printed on the press together with the inks and substrate that will be used for expanded gamut printing, so the software knows what the gamut of the process is. The number of test patches on these characterization charts is also a topic of discussion.

At the same conference, Hoffstadt (Hoffstadt, 2019) gave a presentation on the ideal number of test patches for expanded gamut printing. If the same 9-step resolution from CMYK would be applied to CMYKOGV about 5 million test patches would be needed and "…even with only 4 steps per ink, we have 4^7 = 16384 patches at a rather poor grid resolution…" (Hoffstadt, 2019). Then the question was what can be done to reduce the number of test patches to a number between 1,000 – 5,000. At the time the number of patches used by GMG OpenColor is 4200 (35x30 patches on 4 pages).

In the summer of 2019 Sharma (Sharma, 2019A) conducted an evaluation of spot color reproduction in multicolor printing. Several software vendors participated in the study. A test chart was created and processed through various software solutions. The aim of this study was not to determine which solution was the best, but how each software handled expanded gamut printing. One of the tests conducted in this study looked also how a spot color was built using 3, 4 or more colors. The study output the test charts on an Epson P9000 inkjet proofer and also an HP Indigo 7900. There was no output of the test chart on a flexographic or offset press which is commonly used in the production of packaging using spot colors. According to the author of the study, this will be done in the second part of the study (Sharma, 2019B).

In Europe, Fogra has also been active in the evaluation of expanded gamut solutions. In the Color Management Symposium in February 2019 and 2020 solutions for expanded gamut will be shown. Participants in the Fogra study also had to process a test chart and the color accuracy of the rendered Pantone colors will be compared.

Idealliance has also been quite active over the past two years and formed a committee to create a seven-color characterization target similar to the IT8.7/4 target used for four-color print characterization (Idealliance, 2020). This test target is available for free to anyone interested in expanded gamut printing. This project has a small 400 patch target and a large four-page target with 4340 patches (35x31 patches on 4 pages).

Equipment and Materials

The study conducted by Habekost & Grusecki (Habekost, 2019) used only OpenColor from GMG and no other software solution to evaluate how expanded gamut can be used. In this study, Esko's Equinox solution was also used. The same colors from the 2019 study were also used in this study. Before these colors could be printed on press both software solutions needed a calibration test chart print on press. This calibration test chart is then read into the respective software and is used

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*

to calculate how to build the Pantone colors.
Below is a table of all the brand colors that were used in this project:
The following equipment was used in this study:

- Equipment:
  - Heidelberg PM74-4P
  - X-Rite Intellitrax
  - X-Rite iSis XL (M1)
  - X-Rite eXact (M1)
  - GMG OpenColor V2.2
  - GMG ProfileEditor 5.10.1.121
  - Epson SureColor P9000
  - Kodak Prinergy & Preps
  - Pantone Color Manager
  - Esko Equinox Profile Creator (v14)
  - Esko ColorPilot V14
  - Esko PackEdge V14
  - ColorThink Pro 3.0.7

- Materials:
    - Offset inks from Hubergroup Canada
        - Black: 49 RL 2501
        - Cyan: 43 F 10 PX
        - Magenta: 42 F 10 PX
        - Yellow: 41 F 11 PX
        - Orange 2 ONX 51500
        - Green 4 ONX 51502
        - Violet 3 ONX 51501

- Substrate: Caroline 8pt C1S

Procedure

Since two different software solutions were used two calibration press runs needed to be done. The main challenge was that the School of Graphic Communications Management has only a four-color offset press. This means that the press sheets had to be sent twice through the press until all seven colors were printed. This also meant that some time passed between the first and the second pass due to the changeover of the inks and bringing the remaining colors up to density. This gave

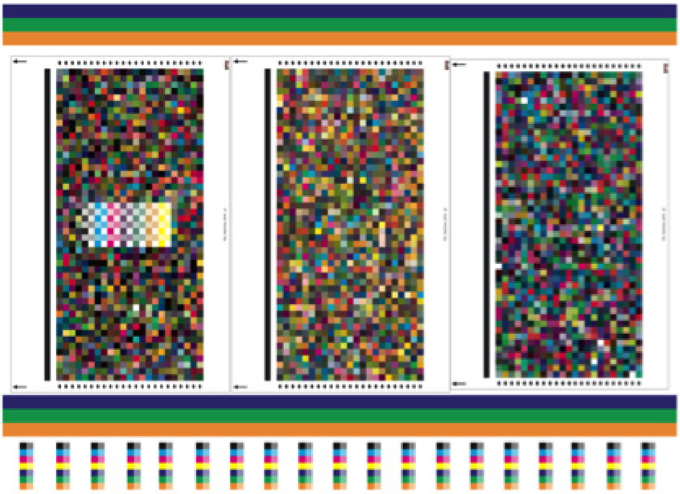

Figure 1: *GMG OpenColor test charts need to characterize the press*

the inks from the first pass time to set into the substrate.

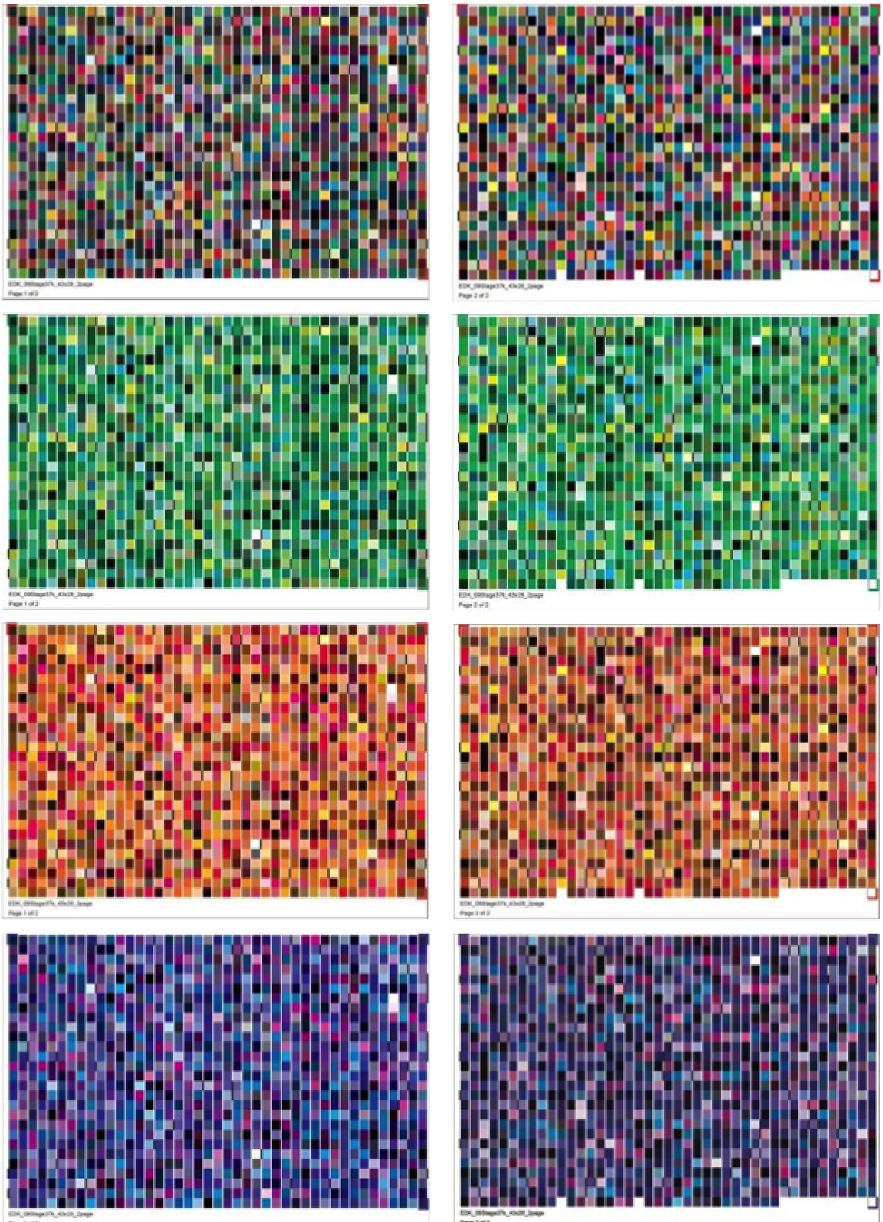

Figure 2: *Esko Equinox test charts need to characterize the press*

The test charts from both software solutions can be seen in the images below. The test charts for Equinox had a much different layout as can be seen below. It is visible that there is a great difference not only in the layout of the test charts but also in the number of test patches that each software requires to create a multicolor press profile.

Both test charts were processed through the Kodak Prinergy Workflow that is used to image plates for the Heidelberg PrintMaster PM74-4P. The following screen angles were used:

- 0 degrees for yellow and violet,
- 105 degrees for Magenta and Green,
- 165 for Orange and Cyan and
- 45 for Black.

Using these angles helped avoid moiré by using the same screen angles for opposing

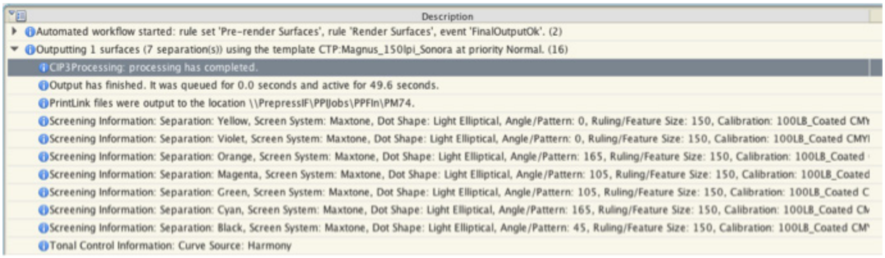

Figure 3: *Screen angles used in Kodak Prinergy*

colors. This can also be seen at the screenshot taken from Prinergy. After the test charts with 3358 test patches for GMG OpenColor had been printed on press the press sheets were allowed to dry and then three random press sheets were selected, the test charts cut out and read into OpenColor with an X-Rite iSis XL and a press profile created. 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 test chart in Adobe Illustrator with the Pantone® colors listed in Table 1. The resulting PDF file was then processed through Kodak Prinergy to created offset printing plates for use on the Heidelberg PrintMaster PM74-4P press.

The procedure for Esko Equinox is a little bit different. After the eight test charts had been created in Equinox Profile Creator using the combinations of CMYK, OCMK, CGYK, CMVK with 2,408 test patches each resulting in a total of 9632 patches. After printing the test charts multiple charts were selected and measured using the i1iO. The measurements were averaged in Equinox Profile Creator and smoothed for better results. After this step, a profile was created. ColorPilot was then used to create and Equinox color strategy which contains color management settings to be used in Equinox conversions. This was done with the help of the color profile previously created. In the next step, a test form was created in Adobe Illustrator with the Pantone test colors selected for this project. In the final step, Esko PackEdge was used to perform the spot color reproduction to expanded gamut using the generated color strategy created previously. The converted file was then saved as a normalized PDF and processed through Kodak Prinergy to create offset printing plates for use on the Heidelberg PrintMaster PM74-4P press.

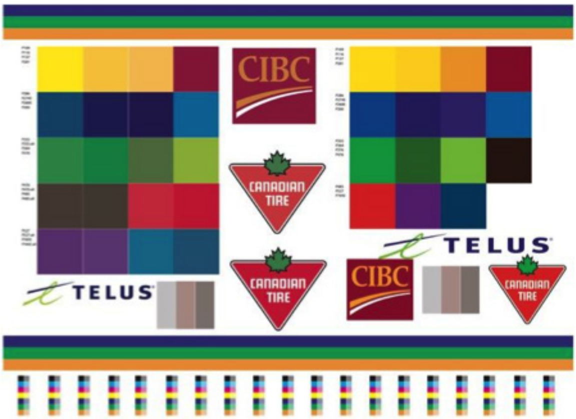

Figure 4: *Test chart to test the Pantone color used in this study. The left side of the chart is the expanded gamut version and the right side is the four-color process version of the same Pantone colors.*

The layout of the test chart can be seen in the following image.

Results

Ink dry-back observations

During the previous project by Habekost & Grusecki (Habekost, 2019) it was observed that the black ink and the expanded color gamut inks orange, green and violet showed some dry back after a fresh press sheet had been pulled. This was just an observation but was not quantified. During this project, observations were done

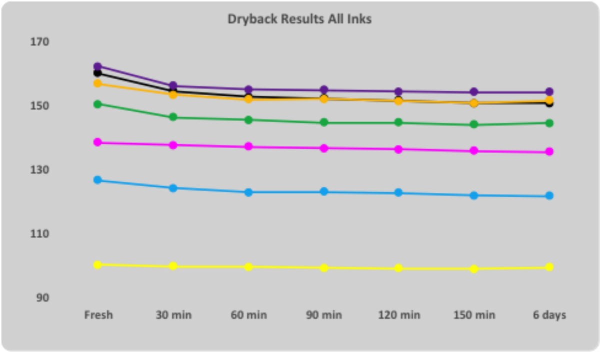

***Figure 5:** Observed ink density dry-back for all seven colors*

to quantify the empirical evidence from before.

Initial observations were done every 30 minutes up to 150 minutes (2.5 hours) and one final measurement was done after 6 days. From figure 5 it is visible that some inks showed dry-back and some not so much. Therefore, the graph was split up into observations about CMY and KOGV. These graphs can be seen in

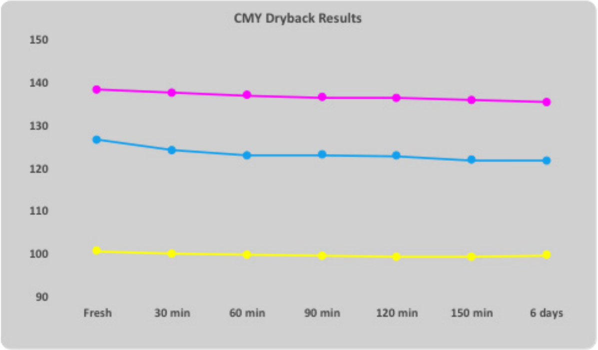

***Figure 6:** Observed dry-back results for CMY only*

the following images.

From these three colors it clear that Magenta and Yellow are the most stable colors and show very little dry-back, while Cyan shows a dry-back of about 5 points from

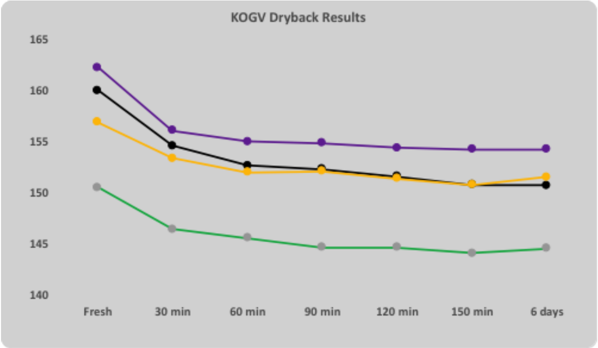

***Figure 7:** Observed dry-back results for KOGV*

1.27 to 1.22. For KOGV the chart looks a bit different.
These four inks show some significant dry-back of about 8 points. This is quite some dry-back considering that the press run was carried out on a coated substrate that is used for the manufacturing of folding cartons. For any future press run with these inks, the target densities should be set 10 points higher than previously, meaning if the target ink density is 1.60 the ink should be printed wet 1.70 so that after the ink dry-back the ink density is at the desired level.

Since this dry-back was observed the measured printed ink densities of the different press sheets for the press run of the test charts and the swatches were measured. From figures 1 and 4 it can be seen that solid and 50% test patches were placed in every ink zone of the press sheet. The solid ink densities were measured across the sheet and averaged, and the standard error of these measurements were calculated. This was done for the press run of the test charts and the press run of the chosen test

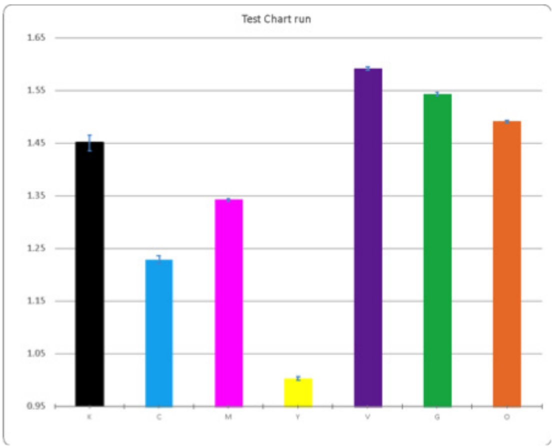

Figure 8: *Average solid ink densities of the expanded gamut inks with the standard error bar during the press run of the test charts*

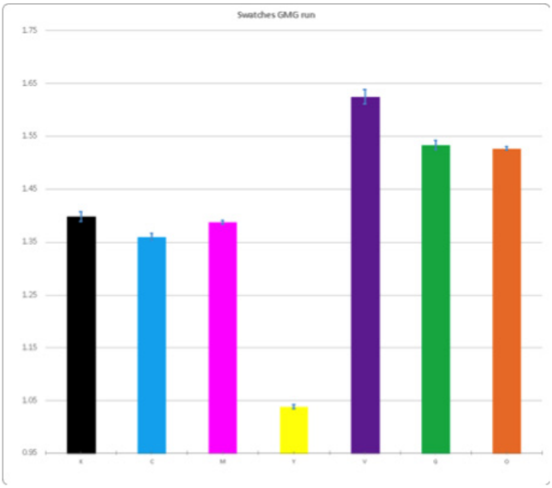

Figure 9: *Average solid ink densities of the expanded gamut inks with the standard error bar during the press run of the swatch test (figure 4)*

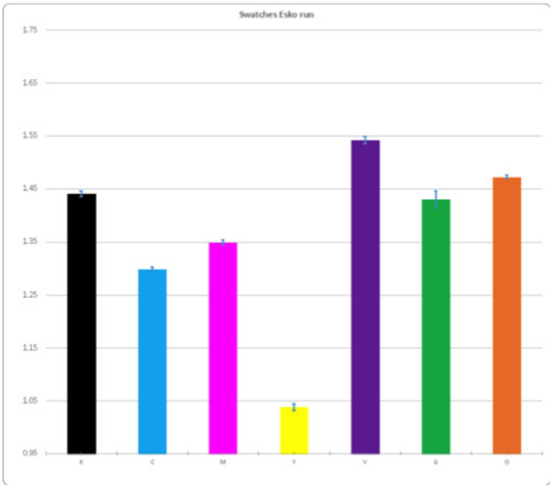

Figure 10: *Average solid ink densities of the expanded gamut inks with the standard error bar during the press run of the swatch test (figure 4)*

swatches. The results can be seen in the figures below.
From figure 8 to 10 it can be seen that the standard error of the solid ink densities is quite small. During the press run of the test swatches, the standard error bar is even smaller than during the press run of the test charts. There are some fluctuations for the ink densities of Black, Cyan and Magenta, but this was not done intentionally. During both press runs the black ink was always difficult to control. The ink density was either too high or too low when the color bar was measured with the Intellitrax system. The ink densities for Orange, Green and Violet were quite similar during the press runs.

Color composition results

One of the goals of this project was to see how accurate the chosen spot colors can be reproduced using GMG OpenColor and Esko Equinox. The accuracy was determined using the DE2000 value of the expanded gamut colors compared to the L*a*b* values of the Pantone color obtained from Pantone Color Manager. This test was not done to see which software does a better job, but to see what kind of work has to be done beforehand, so expanded gamut can be used on press.

Overall results

Overall quite good DE2000 color difference could be achieved with Esko Equinox even though an older version of Equinox was used (version 14 as opposed to current available version 18). Good to acceptable results were achieved. Some of the ECG color formulations outperformed the CMYK renditions of the chosen Pantone® colors. These results can be seen in the image below.

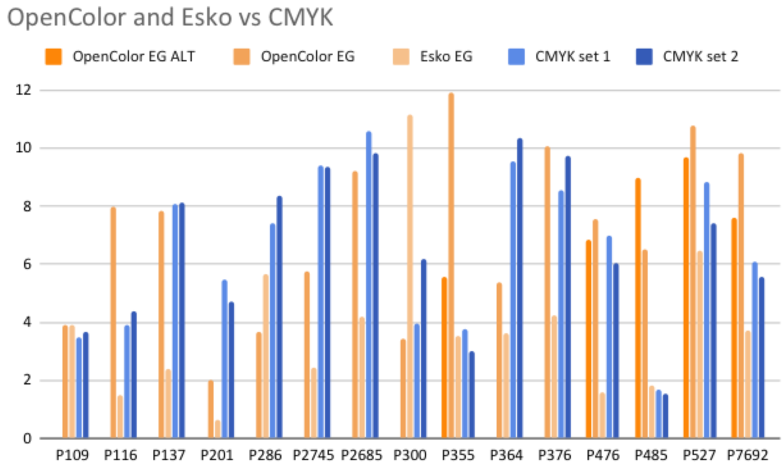

Figure 11: *Color difference values (DE2000) of the expanded gamut rendition of the Pantone® colors used in this project versus the CMYK builds from the press run shown in figure 4*

In the figure above the expanded gamut DE2000 values for both OpenColor and Esko are represented in orange, while the two sets of CMYK versions of the Pantone® colors are shown in blue. Some of the best results can be seen in P137, P201, P2745, P2685 and P364. It is also interesting to see that for some inks the CMYK build gives a lower DE2000 value than the expanded gamut version of the same color. A prime example of this is P485.

The color composition of some test colors is shown below. It is interesting to see how the two software solutions build the expanded gamut version of a Pantone® color based on the information they have from the test chart press run.

The first color that gets compared is Pantone 109. The build from both software solutions has a similar DE2000 value but their composition is slightly different.

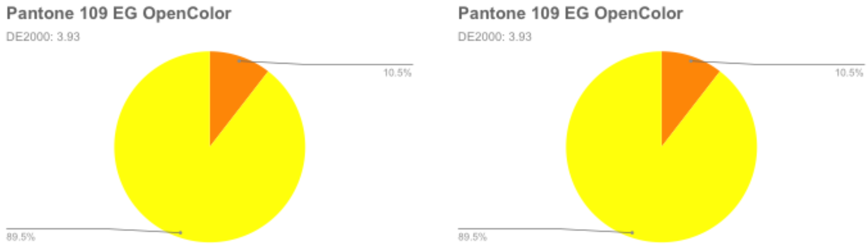

Figure 12: *Ink build of P109*

The ink composition and the DE2000 values can be seen in the figure below.
It is interesting to see that the OpenColor version of P109 has almost three times as much orange in its composition, yet the DE2000 value is very similar to the ink build by the Esko software.

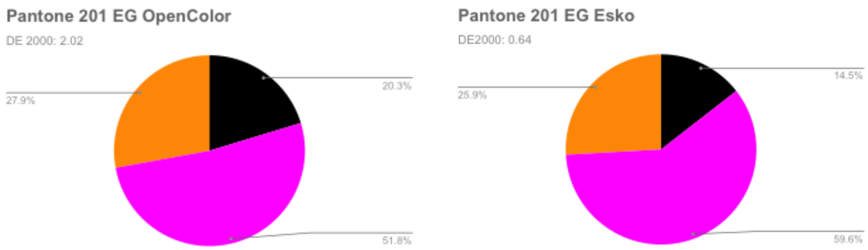

Figure 13: *Ink build of P201*

The next color is Pantone 201.
The composition of P201 between the two software solutions is quite similar, yet the DE2000 value is quite different, yet still quite a good DE value.

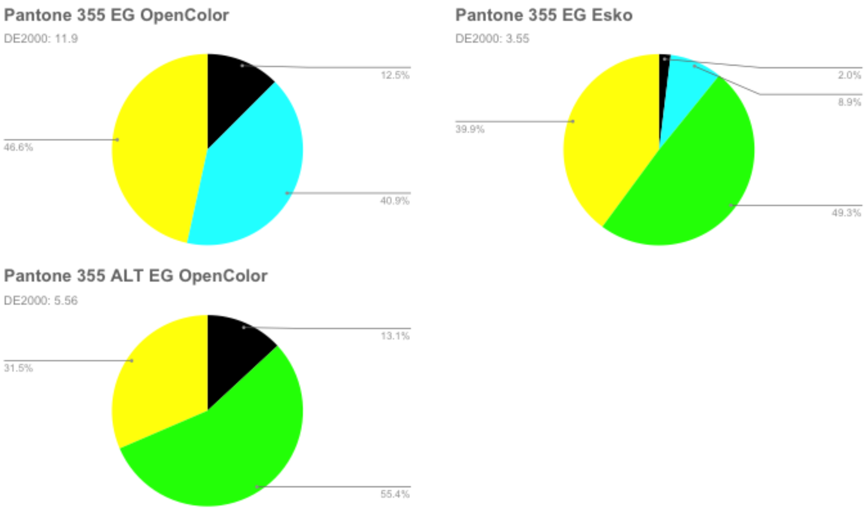

Figure 14: *Ink build of P355. For this color, OpenColor was asked to make an alternate build.*

The next color that gets analyzed closer is Pantone 355.
For this color, it was interesting to see that Esko Equinox used a four-color build while in OpenColor was set up to use only three colors. OpenColor gives the user the option to exclude one or more of the seven colors from an ink build. Since Pantone 355 is a green color why not use the green from the expanded ink set and use yellow and black to change the color, so the resulting green is closer to the desired color. It can be seen from figure 13 that the alternate ink build resulted in lower DE than the ink build originally suggest by OpenColor.

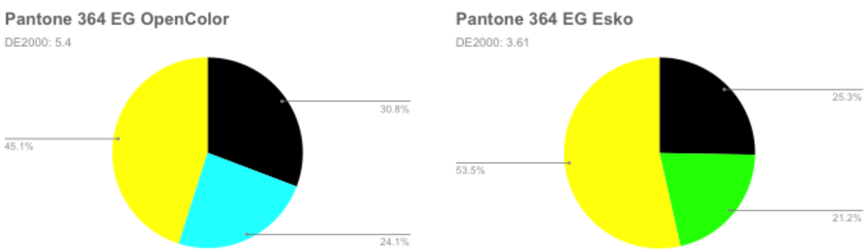

Figure 15: *Ink build of P364*

The next color that gets analyzed closer is Pantone 364.
For this color, OpenColor was not asked to provide an alternative build since the ink composition suggested by the system made sense to the operator.

As it can be seen that the build is different between the two software solutions. The DE2000 values achieved by these two ink builds is still better than the DE values

of the CMYK build of this color (see figure 4).
From the range of the chosen Pantone colors, the following expanded gamut builds achieved better DE2000 values than the corresponding four-color process build. These colors are:

- P201
- P286
- P2745
- P2685
- P364

The four-color process builds of the following colors resulted in lower DE2000 values than the expanded gamut build:

- P116
- P300
- P485
- P527
- P7692

From these results, it can be seen that testing needs to be done to find out which colors are better made from a CMYK build or which ones should be build using the seven colors from the expanded gamut ink set.

Color gamut of the test forms

Another interesting aspect of this project is to look at the color gamut that is created by measuring the test forms from both software packages involved in this project.

The first color gamut that can be seen in the figure below includes the measurements

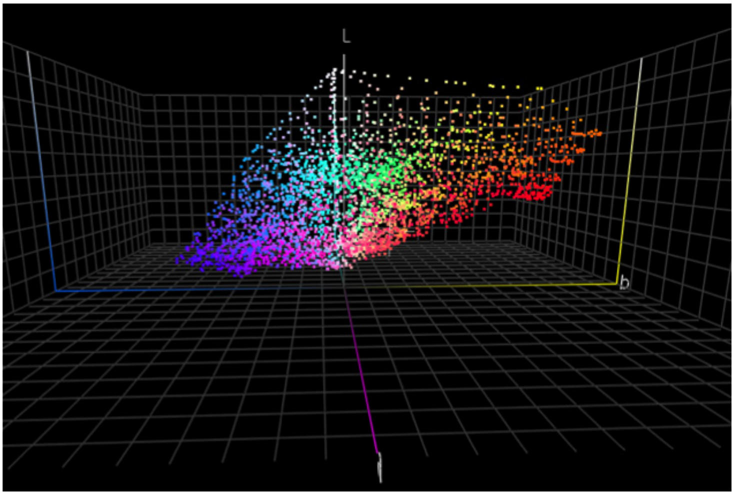

Figure 16: *Color gamut of GMG test charts*

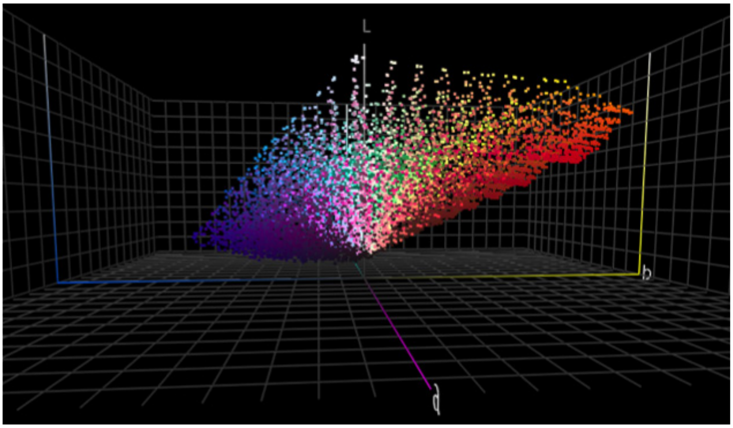

Figure 17: *Color gamut of Esko Equinox test charts*

of the test chart used by OpenColor using ColorThink for visualization.
Because the Esko workflow used more test charts with more test patches the gamut is more densely populated than the gamut from OpenColor. In the following figures, the same color gamut is shown together with the test colors that were used in this

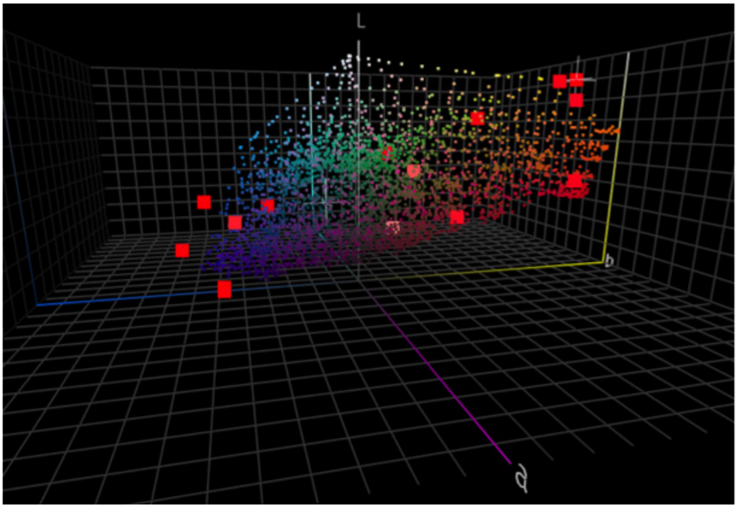

Figure 18: *Color gamut of GMG test charts with the Pantone color used in this study shown in red squares*

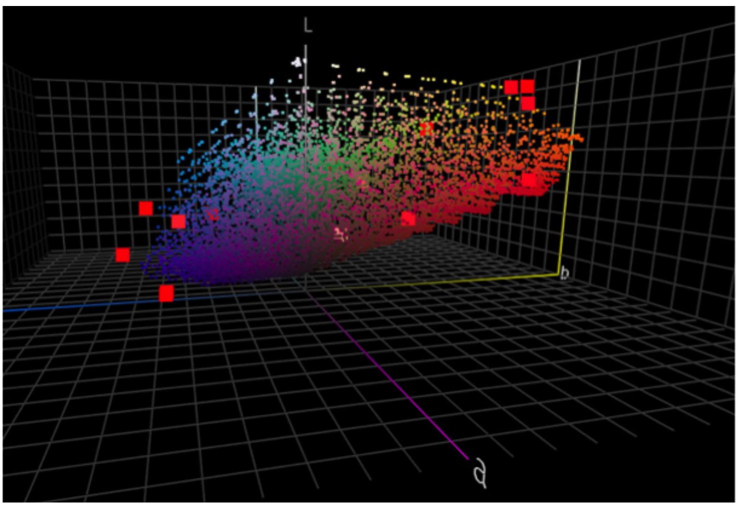

Figure 19: *Color gamut of Esko test charts with the Pantone color used in this study shown in red squares*

study using ColorThink for visualization.

From the figures 18 and 19, it can be seen that quite a few of the test colors are outside of the gamut of both systems. Due to this fact it is clear that sometimes quite large color differences have been observed. The color difference between the L*a*b* values of the tested Pantone colors obtained from Pantone ColorManager and the L*a*b* values measured of the press sheets can be seen in

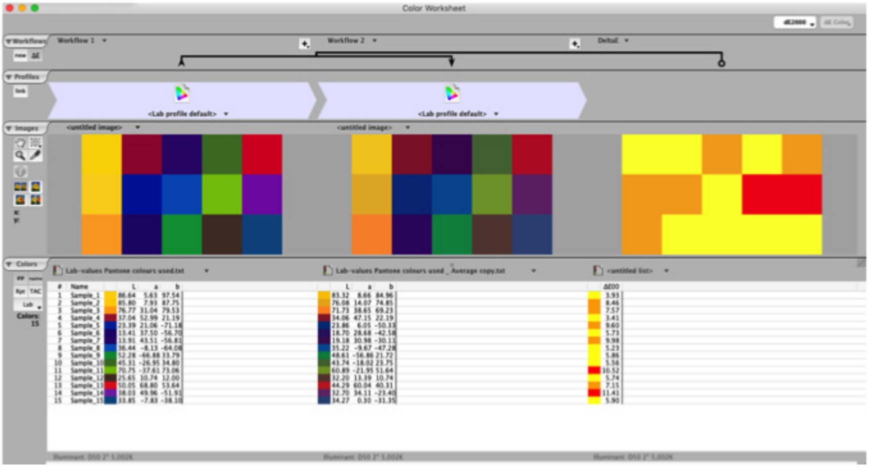

Figure 20: *Color differences between the Pantone color values from Pantone ColorManager and the GMG press sheets using ColorThink for visualization*

the following figures.

The color differences range from DE2000 value of 3.41 to 11.41. These differences also explain the color differences that were seen in figure 11. The average DE2000

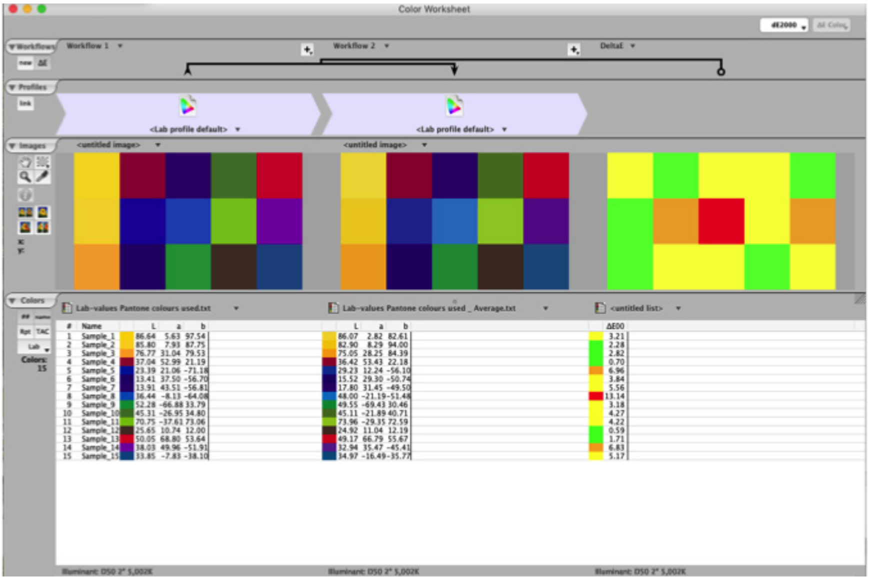

Figure 21: *Color differences between the Pantone color values from Pantone ColorManager and the Esko press sheets using ColorThink for visualization*

value is 7.07.
The color differences range from a DE2000 value of 0.59 to 13.14. The average DE2000 value for colors printed on press is 4.30.

From these last two charts, it can be seen that there is still room for improvement. Newer versions of the two software solutions used in this study most likely will show improvements in the algorithms used to calculate the ink compositions.

Possible reasons for the observed color differences

Newer versions of the two software solutions used in this study will most likely result in more accurate ink formulations, but other factors play a role as well. A list of possible factors could be:

- Solid ink density differences between the press run of the calibration patches (figure 1) and the press run of the test form (figure 4)
- Color differences in the process colors between the two press runs (figure 1 and 4)
- Tone value increase differences between the same press run

The average solid ink densities for the two press runs mentioned above are shown

Color	Ink density difference
K	-0.06
C	0.08
M	0.03
Y	0.05
V	0.07
G	0.00
O	0.04

Table 2: *Ink density differences between the press run of the calibration patches (figure 1) and the test form (figure 4)*

in figures 8 and 9. The numerical differences are in the table below:
From this table, it can be there was a significant ink density difference (positive or negative) in black, cyan and violet on the second press run which was used to determine the color difference between the Pantone color from the Pantone Color

Ink	Black	Cyan	Magenta	Violet	Green	Orange	Yellow	DE 2000 measured
P 109	0	0	0	0	0	11.09	94.71	3.93
P 116	0	0	20.88	0	0	0	85.29	7.97
P 137	0	0	0	0	0	55.94	53.67	7.82
P 201	35.39	0	90.3	0	0	48.59	0	2.02
P 286	0	100	0	76.36	33.06	0	0	3.67
P 2745	28.05	30	0	100	0	0	0	5.78
P 2685	28.29	0	43.54	100	0	0	0	9.22
P 300	14.21	98.81	0	30.93	0	0	0	3.43
P 355	21.97	71.89	0	0	0	0	81.8	11.9
P 355 alternate	20.85	-	0	0	88.14	0	50.04	5.56
P 364	49.37	38.74	0	0	0	0	72.38	5.4
P 376	13.12	35.77	0	0	0	0	92.88	10.07
P 476	75.02	0	18.12	0	0	39.18	0	7.54
P 476 alternate	71.81	-	-	15.95	0	49.62	0	6.83
P 485	7.89	0	84.42	0	0	77.24	0	6.51
P 485 alternate	7.89	0	97.11	0	0	-	75.28	8.98
P 527	12.9	59.63	83.93	0	0	0	0	10.8
P 527 alternate	11.16	-	57.21	65.31	0	0	0	9.71
P 7692	39.91	79.79	33.79	0	0	0	0	9.85
P 7692 alternate	39.71	63.41	-	39.19	0	0	0	7.61

Table 3: *Pantone color compositions determined by OpenColor and the corresponding DE2000 value*

Manager and what was printed on the press sheet. The table below shows the composition of the Pantone colors used in this study as determined by OpenColor. The colors that show large color differences like P355, P376, P527, P527 alternate, P 7692 and P7692 contain significant amounts of cyan, violet and/or black. This is a good indication that the ink density differences have an impact on the measured color differences.

Another possibility for the observed color difference between the Pantone colors could also be any color differences between the seven process colors used in the

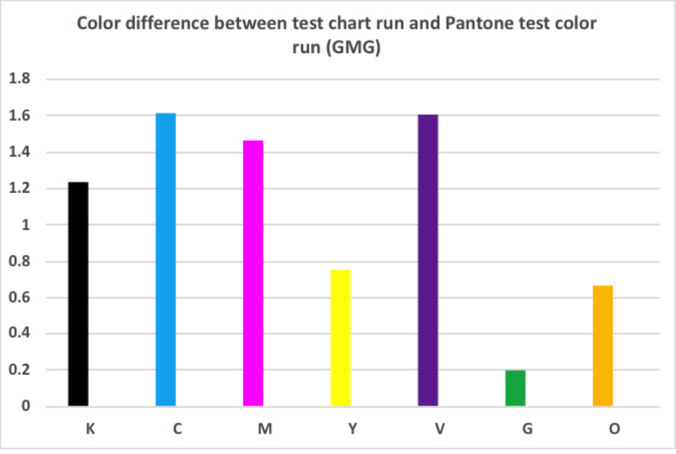

Figure 22: *Color differences between the seven process colors for the press runs associated with the ink formulations used with GMG OpenColor*

press sheets shown in figure 1 and figure 4. The measured color differences are shown in the figure below.
From figure 22 it can be seen that black, cyan, magenta and violet show color differences of more than 1 DE. These color differences could also have contributed to the large color difference measured between the printed Pantone colors and the reference color values from the Pantone Color Manager.

Another possible source for color differences is the TVI from both press runs. The measurements for orange, green and violet were done switching to SCTV on the

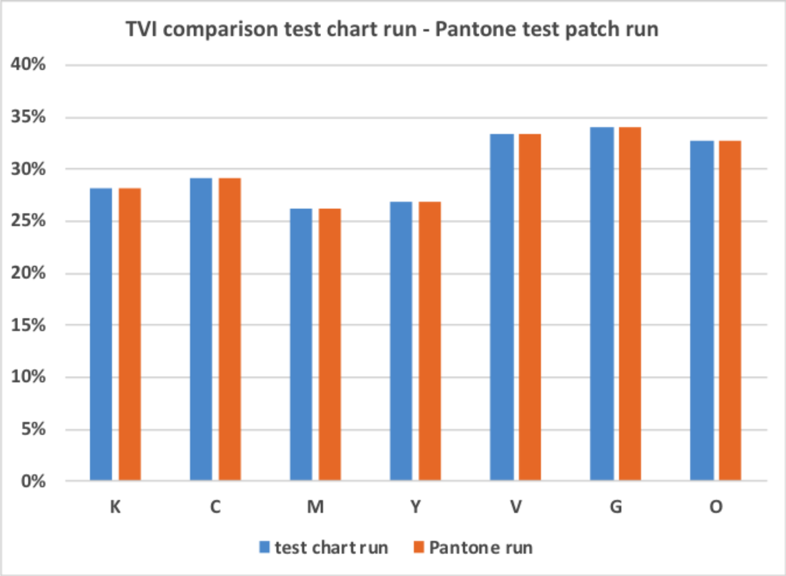

Figure 23: *TVI values for test chart press run (figure 1) and the Pantone test patch run (figure 4) for use with GMG OpenColor*

X-Rite eXact used for this study. The TVI values for the seven inks can be seen in the figure below.
The figure shows clearly that the TVI values were identical for both press runs, so this influence can be ruled out.

Unfortunately, these comparisons could only be done with the press runs conducted for testing the GMG software solution. The calibration test sheets for use with Esko had been discarded before the measurements could be done.

Conclusions

The route to use expanded gamut printing requires, like venturing into any new technology, testing, trial and retesting until the best results are achievable. Unknowingly we chose colors that are on the edge of the color gamut that is achievable with ink set used in this study. Logically the color management applied "moves" the test colors to the closest colors on the edge of the gamut. It can also be seen that having ink density differences between the calibration and the test color press run influenced the DE values of resulting Pantone colors. The ink density differences also contributed to color differences in the seven process colors which in turn influenced the color accuracy of the tested Pantone colors.

Overall it was interesting to venture into this area and work with this technology.

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References

Baldwin, C., Expanded gamut printing 101, http://www.labelsandlabeling.com/sites/labelsandlabeling/files/magazine/labels-vol38-issue2-2016/html5forpc.html?page=50, May 2016, accessed January 25, 2020

Habekost, M. and Grusecki, I., Color Accuracy of Corporate Colors in Expanded Gamut Reproduction, TAGA 2019 conference proceedings, p. 97 – 108

Hargrove, K. The Rise of Expanded Gamut, Presentation at the 71st Annual Technical Conference, Minneapolis, MN, http://efiles.printing.org/eweb/docs/

taga/2019/ppt/TAGA19-Session8B-Hargrove-1spp.pdf, March 2019, accessed January 25, 2019
Hoffstadt, H., Characterization of Multicolor Printing: Challenges and Solutions, TAGA 2019 conference proceedings, p. xxx – xxx

Idealliance, Expanded Color Gamut (ECG) Project, https://www.idealliance.org/ecg, accessed January 25, 2020

O'Hara, L., Congdon, B., Lindsay, K., Optimizing Chroma for Expanded Color Gamut, A Cautionary Tale, TAGA 2019 conference proceedings, p. xxx – xxx

Sharma, A. Ryerson University Expanded Gamut Study 2019, August 2019 (A) http://www.tinyurl/expandedgamut

Sharma, A, Personal communication, November 2019 (B)