Digital Proofing of Spot Color Printing

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Abstract

In commercial, product or packaging printing, specific color inks are often used to meet specific requirements of customers. Recent developments in digital printing made this technique attractive for possible implementation in commercial, product or packaging printing. While digital printing is not expected to completely replace the conventional printing techniques, digital printing can be used for product proofing, replacing conventional procedures for product verification. To use digital printing for proofing and short run production, proper reproduction of spot colors with digital printers is essential. Digital color reproduction is closely related to color management, since a properly managed digital workflow is essential for accurate digital color reproduction.

The overall objective of this investigation is to establish a digital proofing system for spot color printing. Color management with ICC profiles is used to investigate the reproduction of specific spot colors. Selected digital printers combined with its print driver and a commercially available RIP are tested and characterized by generating ICC profiles. These profiles are used to compare the device gamut and to investigate reproduction of specific spot colors. The reproduction of the spot colors on optimal (manufacture recommended Epson Premium Semimatte Photo Paper) and actual production substrates are compared. The quality of reproduction is evaluated in terms of the usual ΔE in L*a*b* color space.

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1. Introduction

Color affects the subconscious and influences people – especially when it comes to business. A colorful printing production can grab customer's attention instantly. Spot color, providing attractive color imaging, is wildly used in commercial, product and packaging printing (Hrehorova, 2005). Today, when printing workflow enters the digital era, a suitable digital color-proofing solution should be investigated to meet the needs of spot color printing. Indeed, the saturated Pantone Matching System (PMS) colors not well reproduced with digital printing (Suchy, 2005).

The most important feature in a proof printer is color control, which helps ensure consistency from the proof to the final output. Digital proofers have advantages of high speed, wide color gamut, and affordable prices for a device, therefore, providing significant time and cost savings compared to analog film-based proof. Moreover, some digital printers combine with advanced color-matching software to offer a better color match (Stewart, 2004; Fenton, 2000). Functionally, there are two kinds of software to control a printer. The first one is the print driver (inkjet printer manufacturer's software); the other one is the third-party raster imaging processor (RIP) software (Hrehorova, 2006). Print driver software drives printer to print data files in RGB mode. A RGB printer can be controlled by three channels. A user sends an RGB image and the print driver performs the conversion from RGB to CMYK. A third-party raster imaging processor (RIP) software interprets raster and vector data files for a specific postscript printer in either RGB or CMYK mode. By controlling CMYK inks directly, RIP software can provide better control for accurate digital color reproduction. The application of an RGB or CMYK device will depend on the user's workflow (Sharma, 2004; Rich, 2004).

Paper is a significant variable in predicting and reproducing color. The interaction between paper and ink, together with paper properties like whiteness, light scattering, and gloss (Lee, 2004, 2005) must be considered in the digital proofing process. Proofing on the actual production stock more closely predicts print outcome. However, working with different inks and devices, the actual production printing substrate can have a very different color gamut and behave differently in the digital proofing process. Therefore, optimum digital proofing must factor the paper into the color reproduction process (Wales, 2004; Norberg & Andersson, 2003; Bandyopadhyay, 2001).

The key to achieving the best quality spot color reproduction is to combine the right equipment, software, and media. This study was conducted to establish a digital proofing system for spot color printing. An Epson Stylus Pro 4000 ink jet printer was used with UltraChrome pigmented ink. These inks have been shown to produce good color gamut and Lightfastness (Chovancova, 2004, 2005, Rasmusson, 2005). Both RGB and CMYK print models are discussed and compared. Two kinds of substrates - actual production printing substrate and optimum paper (manufacture recommended Epson Premium Semimatte Photo Paper) were tested.

2. Methodology

The objective of this investigation was to establish a digital proofing system for spot color printing. Color management with ICC profiles was used to investigate the reproduction of specific spot colors. The digital printer, an Epson Stylus Pro 4000, was tested for digital proofing with optimum paper and actual production substrates. Two examples of printer control software- Epson Stylus Pro 4000 print driver and GMG ColorProof RIP- were tested and compared.

2.1 Spot Color Test Chart

Four spot colors were selected for evaluation: blue, black, red, and yellow. Each chart consisted of 66 patches of different gray levels, generating a chart with a variety of shades for the color (as shown in **Figure 1**). The colors were printed on the actual production printing substrate by a drum cylinder gravure proofing press. Each specific measured area on the individual chart was measured for $L^*a^*b^*$ values five times to reduce the measuring error and the average value was computed as original data. According to these original data, the spot color test charts in digital form were generated by using Adobe Photoshop CS2, so that these charts could be used for actual digital printing reproduction.

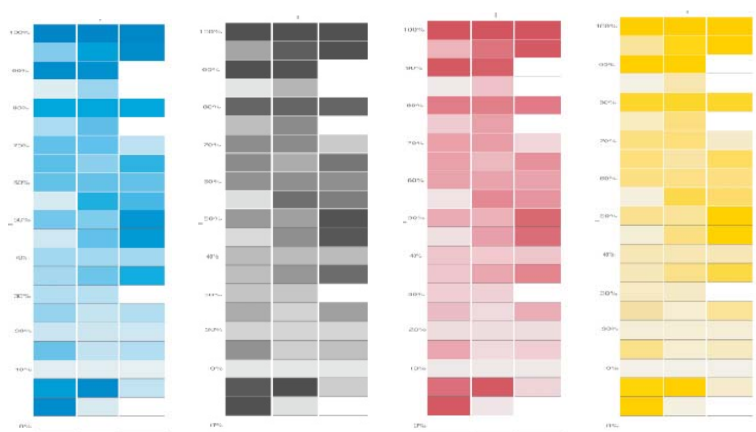

Figure 1: Spot Color Test Chart

2.2 Equipment and Materials

In this study an Epson Stylus Pro 4000 printer was used with pigmented ink. Printing was controlled by either print driver (RGB mode) or a commercially available RIP (CMYK mode). Two substrates were used: actual production printing substrate and manufacture recommended proofing paper.

ICC profiles were generated for two substrates. For the print driver, a TC 918 chart was printed without color management. For the GMG ColorProof RIP, the ECI2002R CMYK chart was printed without any ink limitation, because a specific full gamut color profile is needed to reproduce spot colors. Printed charts were then measured with a GretagMacbeth SpectroScanT, operated by GretagMacbeth Measure Tool 5.0.4 software. The measurement files were used to generate profiles using GretagMacbeth ProfileMaker Pro 5.0.4. The detailed information of different print combinations used in the study is listed in **Table 1**.

Table 1: Print combinations used in the study

	Combination 1	Combination 2	Combination 3	Combination 4
Printer	Epson Stylus Pro 4000	Epson Stylus Pro 4000	Epson Stylus Pro 4000	Epson Stylus Pro 4000
Substrate (Media)	Actual production printing substrate	Actual production printing substrate	Premium Semimatte Photo Paper	Premium Semimatte Photo Paper
Printer control software	Epson Stylus Pro 4000 print driver	GMG ColorProof RIP	Epson Stylus Pro 4000 print driver	GMG ColorProof RIP

2.3 Evaluation of Spot Color Reproduction

The four selected spot color test charts were printed via the print driver and the GMG ColorProof RIP, whereas the ICC profiles were assigned in relevant functions. L*a*b* values for each color patch of the chart were measured using the GretagMacbeth SpectroScanT. The quality of spot color reproduction was evaluated in terms of the ΔE in L*a*b* color space. The color gamuts of four print combinations were compared using ColorThink 2.1.2 software, while X-Rite Monaco GamutWorks 1.1.2 software was used for gamut volume comparison.

3. Results and Discussion

In this study, RGB and CMYK Workflows were employed to establish digital proofing systems for spot color printing. The Epson Stylus Pro 4000 printer was profiled using its own print driver and GMG Color Proof RIP on the actual production printing substrate and manufacturer recommended proofing paper (Premium Semimatte Photo Paper). Selected spot color test charts were then printed via print driver and RIP. The color gamuts of different print combinations were tested and compared by using ColorThink 2.1.2 and X-Rite Monaco GamutWorks 1.1.2 software. The quality of spot color reproduction was evaluated in terms of ΔE.

3.1 Gamut Comparison

The color gamut is the range of colors that a particular combination of printer, ink, media, and RIP can achieve. **Figure 2** illustrates the color gamut comparison for Epson Pro 4000 print driver and GMG ColorProof RIP on the actual production printing substrate. As shown in **Figure 2**, there are some saturated colors that the GMG ColorProof RIP can achieve that the print driver cannot. The gamut comparison on Premium Semimatte Photo Paper for the Epson Pro 4000 print driver and GMG ColorProof RIP are shown in **Figure 3.** The color gamut of Epson Pro 4000 print driver is similar to the color gamut of GMG ColorProof RIP. Epson Pro 4000 print driver yield wider gamut in yellow area.

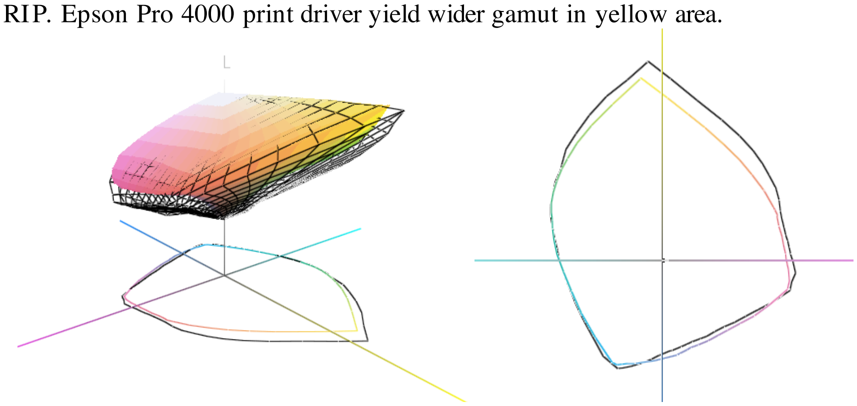

Figure 2: Gamut comparison for actual production printing substrate: Epson 4000 Print driver (true color) vs. GMG RIP (wireframe)

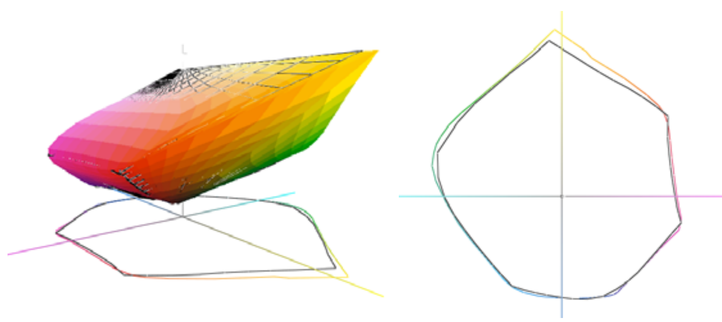

Figure 3: Gamut comparison for Premium Semimatte Photo Paper: Epson 4000 Print driver (true color) vs. GMG RIP (wireframe)

The gamut comparisons on the actual production printing substrate and Premium Semimatte Photo Paper, for the Epson 4000 Print driver and GMG ColorProof RIP are shown in **Figure 4** and **Table 2** (with L*a*b* values of original spot color data for reference). **Figure 4** and **Table 2** indicate that the color gamut of Premium Semimatte Photo Paper is larger than that of actual production printing substrate. The largest gamut volume was found in Epson Pro 4000 print driver with Premium Semimatte Photo Paper print combination (with a gamut volume of 1,397,665, similar to that seen for this paper with other RIPs, Hrehorova, 2006), followed by the GMG ColorProof RIP with Premium Semimatte Photo Paper, GMG ColorProof RIP with the actual production printing substrate, and Epson 4000 print driver with the actual production printing substrate print combination.

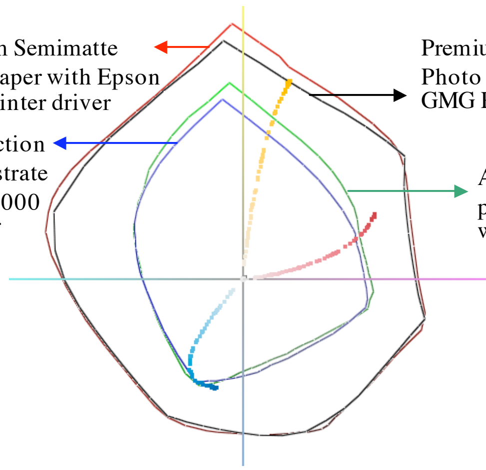

Figure 4: 2D gamut comparison for different print combinations.

Table 2: Numerical comparison of gamut volume for each print combination

	Print combinations	Gamut Volume
■ (blue)	Actual production printing substrate with print driver	361,821
■ (green)	Actual production printing substrate with GMG RIP	446,586
■ (red)	Premium Semimatte Photo Paper with print driver	1,397,665
■ (black)	Premium Semimatte Photo Paper with GMG RIP	1,276,358

3.2 Original and Digitally Printed $L^*a^*b^*$ Values Comparison

The ΔE values calculated for original and actual printed $L^*a^*b^*$ values for each color (print combination of actual production printing substrate with Epson 4000 print driver) are shown in **Table 3** and **Figure 5**. **Table 3** indicates that the average ΔE values for yellow are higher than 8. The black colors, in contrast, have smaller average ΔE values, which are lower than 4. The comparisons in the **Figure 5** demonstrate that the ΔE values of the yellow test chart are significantly larger than the others, especially in shadow areas. For the yellow color test chart, the ΔE values are over 4 from 30% tint to solid tints, whereas the ΔE values of black color test chart are over 4 from mid-tone to solid tints. The ΔE values of blue and red color test charts increase significantly in shadow areas.

Table 3: ΔE comparison of original and printed $L^*a^*b^*$ values for actual production printing substrate with Epson 4000 print driver

Blue			Black			Red			Yellow		
18.8	19.3	19.8	7.4	6.9	7.4	23.7	23.5	22.7	24.3	25.7	25.8
3.3	10.9	17.6	5.1	1.6	6.9	3.1	7.5	20.8	8.5	11.1	23.8
17.3	15.4	1.2	5.8	6.1	1.2	20.1	18.3	1.1	22.5	19.6	1.4
0.9	2.1	1.1	1.9	2.9	1.1	2.0	4.1	1.0	1.2	6.8	1.1
7.7	7.6	7.5	1.0	1.1	1.0	8.3	8.3	8.8	8.8	8.7	9.3
1.7	4.6	0.8	2.8	6.9	1.0	2.8	3.2	1.5	6.9	10.6	1.1
3.6	2.9	1.7	6.8	6.3	2.4	3.0	2.9	3.0	9.9	9.7	3.9
3.4	3.6	4.7	6.7	4.8	6.4	4.0	2.4	2.6	10.0	6.9	10.9
4.5	4.5	4.4	5.5	6.6	6.5	3.0	2.3	2.6	9.1	9.1	8.6
0.4	4.5	2.5	2.0	4.4	6.9	2.9	3.8	3.0	2.0	9.7	9.8
3.6	3.1	14.3	5.2	6.0	5.8	3.9	2.8	13.8	9.3	8.3	16.9
1.7	3.6	12.4	1.5	6.7	4.0	3.6	2.6	11.8	2.3	8.9	13.8
2.0	1.4	1.5	2.5	2.9	2.7	2.8	2.8	1.6	7.0	5.3	6.7
1.9	3.6	4.9	2.6	4.3	3.2	3.1	2.0	4.8	6.2	8.3	7.9
1.8	1.3	1.2	2.6	3.2	1.0	3.2	2.9	1.0	5.3	5.7	1.2
2.1	1.6	19.4	4.1	2.3	4.4	4.2	3.7	3.0	7.3	4.3	9.4
1.8	1.7	1.2	2.2	1.9	1.9	3.0	3.1	3.0	3.8	3.4	3.4
4.9	1.3	2.1	3.2	3.7	2.2	3.0	3.9	2.7	8.2	3.8	5.3
0.5	0.4	0.5	1.4	1.2	2.0	1.7	1.7	1.5	1.5	1.4	1.1
11.3	17.4	1.3	4.4	7.7	2.8	10.0	20.7	3.2	14.2	24.0	3.9
18.2	0.4	1.0	8.3	1.8	0.9	19.6	1.9	1.6	20.3	1.8	1.4
18.8	19.3	19.8	7.4	6.9	7.4	23.7	23.5	22.7	24.3	25.7	25.8
Average: 5.5			Average: 3.9			Average: 5.9			Average: 8.7		

Note: Gray field represents ΔE value larger than 4.

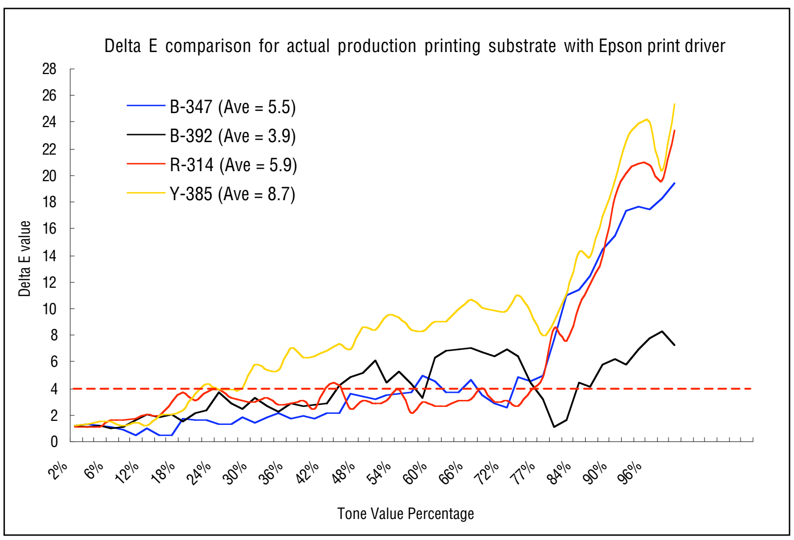

Figure 5: ΔE comparison of original and printed $L^*a^*b^*$ values for actual production printing substrate with the Epson 4000 print driver.

The ΔE comparisons of original and printed $L^*a^*b^*$ values for each color on actual production printing substrate printing via GMG RIP are shown in **Table 4** and **Figure 6**. **Table 4** indicates that the averages ΔE for blue, black, and red color are less than 2. Conversely, the yellow spot color has the highest ΔE value of 4.5. In the **Figure 6**, the comparisons clearly demonstrate that the ΔE values of the yellow spot color are significantly larger than those of others. The ΔE values of blue, black and red color test charts increase significantly in shadow areas.

Table 4: ΔE comparison of original and printed $L^*a^*b^*$ values for actual production printing substrate with GMG RIP.

Blue			**Black**			**Red**			**Yellow**		
8.4	8.2	8.2	7.2	7.5	5.9	8.4	7.1	8.0	16.0	16.3	17.0
0.5	1.9	6.2	0.4	2.2	5.9	1.1	2.0	6.0	4.7	5.8	14.5
6.0	5.1	0.3	6.4	5.3	0.2	6.0	4.5	0.3	13.7	12.3	0.4
0.3	0.6	0.4	0.2	0.7	0.3	0.3	0.6	0.3	1.1	3.6	0.2
0.8	1.0	0.2	0.3	0.9	2.7	2.2	1.7	1.8	4.8	4.9	4.6
0.5	1.0	0.2	0.4	0.9	0.6	0.4	0.9	0.6	2.9	4.5	0.2
1.1	0.4	0.1	0.2	0.5	0.8	1.2	0.9	0.7	4.6	4.5	2.5
0.8	0.5	0.4	0.2	0.9	0.4	1.2	0.5	1.3	4.5	3.6	4.7
0.4	0.9	0.4	0.4	0.7	0.4	1.0	0.7	1.0	4.6	4.2	4.1
0.4	1.2	0.8	0.6	1.6	0.7	0.5	1.3	1.1	1.4	4.8	4.7
0.8	1.1	3.3	0.9	0.7	3.8	1.0	0.7	2.8	4.6	4.1	10.5
0.5	0.9	1.9	0.3	1.4	3.1	0.8	1.1	2.8	1.6	4.4	7.9
0.6	0.6	0.2	0.7	0.6	0.6	0.4	0.3	0.5	3.2	2.8	3.1
0.6	0.4	0.8	0.3	1.3	2.2	0.4	0.6	1.2	2.9	4.1	4.8
0.4	0.4	0.1	1.0	0.5	0.4	0.5	0.3	0.3	2.5	2.3	0.4
0.3	0.2	0.4	1.1	0.2	0.2	0.6	0.4	1.2	3.7	1.9	4.1
0.6	0.4	0.5	0.8	0.6	0.3	0.5	0.3	0.4	1.5	1.4	1.6
0.4	0.1	0.1	0.5	0.3	0.6	1.1	0.4	0.6	4.1	1.7	2.7
0.5	0.3	0.3	0.4	0.4	0.7	0.6	0.5	0.6	1.1	1.2	1.1
1.0	6.5	0.4	3.6	6.7	0.4	2.6	4.5	0.5	7.3	15.2	2.0
7.9	0.5	0.4	5.5	0.5	0.6	4.8	0.5	0.6	11.2	1.9	0.8
Average: 1.4			Average: 1.5			Average: 1.5			Average: 4.5		

Note: Gray field represents ΔE value larger than 4

For the actual production printing substrate, the GMG ColorProof RIP improves the color difference and delivers better color reproduction for the four selected spot colors. However, the actual production printing substrate has poor color reproduction in highly saturated colors, no matter which printer control software is used. Those spot colors trajectories traversing out of the color gamut of the test printer, as shown in **Figure 4**, contribute to the higher ΔE values. Effort must be taken to improve the color reproduction of shadow areas.

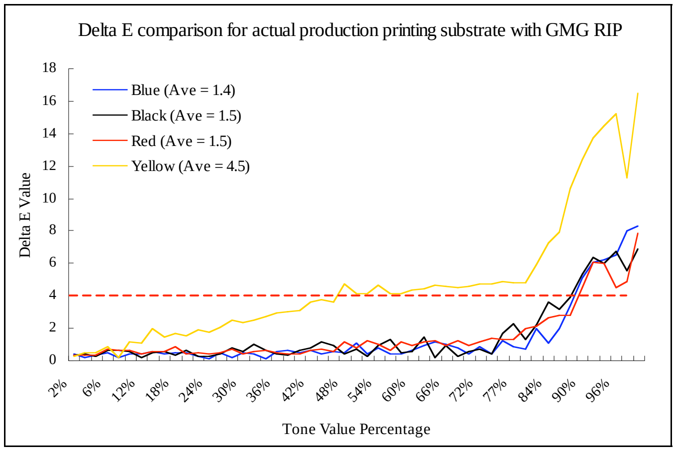

Figure 6: ΔE comparison of original and printed $L^*a^*b^*$ values for the actual production printing substrate with GMG RIP

Table 5 and **Figure 7** show the ΔE comparisons of original and printed $L^*a^*b^*$ values for Premium Semimatte Photo Paper with print driver print combination. **Table 5** indicates that the yellow spot color has the highest average E value of 4.9, followed by blue (1.8), red (1.6), and black colors (1.3).

Table 5: ΔE comparison of original and printed $L^*a^*b^*$ values for Premium Semimatte Photo Paper with the print driver.

Blue			Black			Red			Yellow		
2.2	1.7	2.2	1.7	1.8	1.6	0.9	1.2	1.8	12.9	12.3	12.3
1.4	1.7	3.0	1.5	1.4	1.9	0.3	1.3	1.2	3.4	9.4	11.4
3.4	2.8	1.4	1.8	1.5	1.3	1.3	1.9	1.4	12.2	12.5	1.6
1.6	0.9	1.3	1.9	0.9	1.3	2.2	1.5	1.2	1.4	3.6	1.4
2.1	2.8	2.5	1.0	0.9	0.9	1.0	0.8	2.6	9.3	8.3	7.9
1.6	1.8	1.0	1.2	0.5	1.2	2.1	0.6	1.6	2.2	4.8	1.3
1.9	2.0	1.2	1.1	0.9	1.0	1.0	1.8	2.7	4.5	4.3	2.8
1.7	1.0	1.5	0.8	1.3	0.5	1.4	0.8	0.4	4.8	3.9	5.3
1.6	1.6	1.7	1.1	1.4	1.1	1.0	1.2	0.8	4.6	4.3	3.8
0.6	0.8	1.0	2.2	0.7	0.7	2.0	0.9	1.1	2.4	6.3	4.4
1.7	1.6	2.8	1.0	1.8	2.1	2.3	0.8	1.3	4.5	3.3	11.0
1.0	1.8	1.9	1.6	1.3	2.0	2.3	1.8	1.0	2.8	4.3	10.2
1.1	0.9	1.1	0.7	0.8	0.8	2.3	2.4	1.7	2.6	3.1	3.2
1.6	1.6	1.8	0.8	1.1	0.8	2.6	1.8	0.7	2.6	3.9	5.6
1.4	0.6	1.3	1.0	1.2	1.2	3.2	2.7	1.3	2.3	2.4	1.4
1.5	1.3	1.7	1.2	1.6	1.0	1.2	2.4	0.8	4.6	2.8	3.5
0.6	0.8	0.7	1.2	1.2	1.7	2.3	1.9	2.1	1.7	1.9	2.1
1.8	1.0	1.0	2.3	1.3	0.9	1.7	2.4	2.9	4.2	2.9	2.6
0.7	1.0	0.9	2.0	2.0	2.4	1.9	1.9	1.7	1.4	0.9	1.4
2.6	2.9	1.4	1.8	1.7	1.2	1.5	1.3	2.6	11.3	11.5	3.1
3.9	0.4	1.2	1.8	2.3	1.0	0.6	1.8	1.4	7.8	1.7	1.2
Average: 1.8			Average: 1.3			Average: 1.6			Average: 4.9		

Note: Gray field represents ΔE value larger than 4

Figure 7 shows that the ΔE values of the yellow spot color are significantly larger than those of others from mid-tone to shadow areas. In contract, ΔE values of red and black spot color are controlled and have range of 0.5-4.

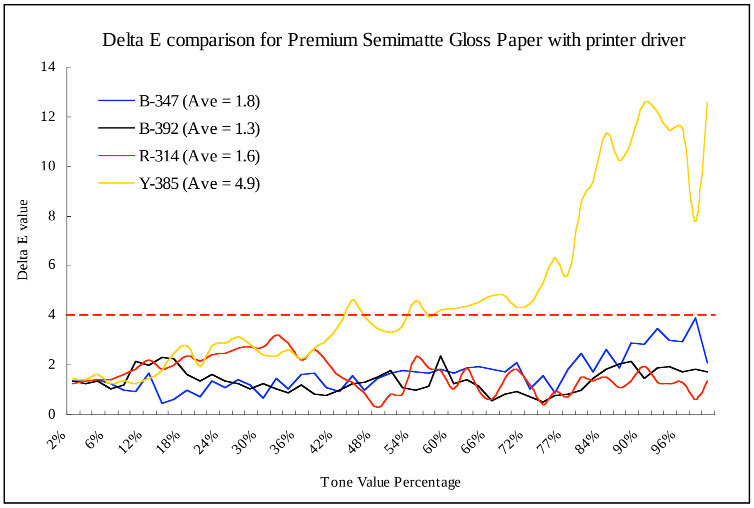

Figure 7: ΔE comparison of original and printed $L^*a^*b^*$ values for the Premium Semimatte Photo Paper with print driver

Table 6 and **Figure 8** show the ΔE comparisons of original and printed $L^*a^*b^*$ values for Premium Semimatte Photo Paper with the GMG RIP print combination. **Table 6** shows that the average ΔE values of four selected spot colors are all lower than 4. The yellow spot color has the highest ΔE value of 3.4. The average ΔE values for blue, black, and red color are lower than 1. **Figure 8** represents that the ΔE values of selected spot colors are lower than 2, with the exception of the yellow color. For the yellow test chart, the ΔE values are over 4 from 60% to solid tint.

For Premium Semimatte Photo Paper, the print driver provides good color reproduction in black and red spot color. Conversely, the ΔE values of the blue and yellow color test chart are over 4 and increase significantly from 70% tint to solid tints. Overall, GMG ColorProof RIP offer better color reproduction for the four selected spot colors.

Table 6: ΔE comparison of original and printed L*a*b* values for Premium Semimatte Photo Paper with GMG RIP

Blue			**Black**			**Red**			**Yellow**		
0.4	0.6	0.6	0.4	0.6	0.5	2.9	2.0	1.6	6.4	6.2	6.3
0.3	0.5	0.5	0.9	0.2	0.3	0.7	1.1	1.8	3.6	5.8	6.5
0.4	0.7	0.5	0.2	0.4	1.5	1.6	1.3	1.4	6.4	6.1	1.5
0.3	0.3	0.7	0.5	0.9	1.6	0.3	0.9	1.4	1.5	2.6	1.6
0.8	0.5	0.4	0.7	0.4	0.7	2.0	1.9	2.4	5.8	5.4	5.5
0.4	0.4	0.3	0.5	0.5	1.4	0.7	1.0	1.3	2.6	4.2	1.8
1.2	0.6	0.1	0.5	1.1	0.8	0.4	0.8	0.2	4.4	4.2	1.5
0.8	0.4	1.0	0.6	0.8	0.5	0.7	1.0	1.0	4.4	2.9	4.8
0.7	0.6	0.7	0.3	0.4	0.4	0.4	0.7	0.6	4.1	3.9	4.0
0.4	0.6	1.4	0.6	0.4	1.0	0.6	1.1	0.8	1.1	5.4	4.8
0.8	0.5	0.5	0.4	0.2	0.6	0.5	1.0	1.0	3.9	3.4	5.9
0.7	0.6	0.7	0.9	0.6	0.3	0.4	1.1	0.8	0.7	4.1	5.7
0.9	0.2	0.2	0.6	0.5	0.6	0.7	0.7	0.8	2.2	2.3	2.2
1.1	0.5	0.5	0.4	0.2	0.5	0.8	0.8	1.4	2.3	3.9	5.4
0.2	0.1	0.6	0.4	0.8	1.6	0.8	0.5	1.6	2.2	1.6	1.6
1.4	0.5	0.4	0.5	0.9	0.6	1.2	0.3	0.8	2.9	1.0	3.6
0.6	0.2	0.2	0.5	0.3	0.4	0.5	0.1	0.3	1.1	0.8	1.2
1.3	0.1	0.3	0.5	1.0	0.6	0.7	0.2	0.5	3.8	0.8	2.3
0.5	0.7	0.3	0.6	0.5	0.3	0.5	0.3	0.3	1.4	1.1	1.4
1.1	2.0	0.2	0.7	0.2	1.1	0.6	1.8	0.1	5.8	5.9	1.1
0.9	0.6	0.3	0.5	0.6	1.7	2.1	0.7	1.0	4.6	0.4	0.9
Average: 0.6			Average: 0.6			Average: 0.9			Average: 3.4		

Note: Gray field represents ΔE value larger than 4

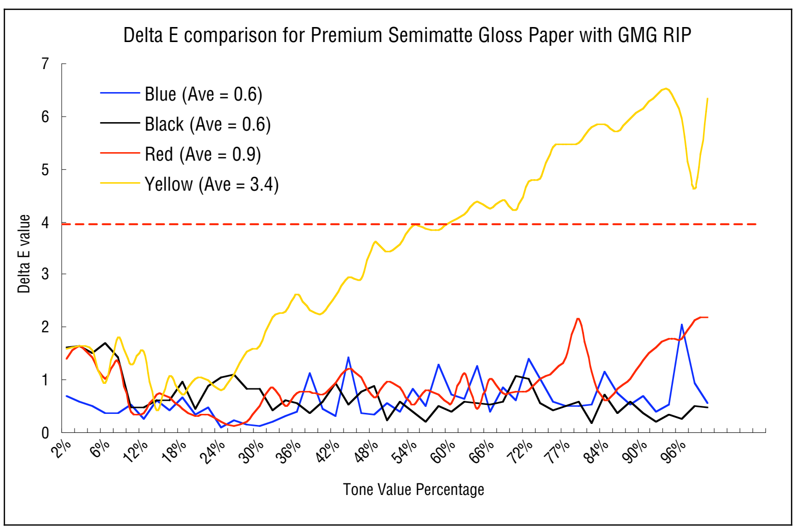

Figure 8: ΔE comparison of original and printed $L^*a^*b^*$ values for the Premium Semimatte Photo Paper with print driver.

3.3 ΔE comparison of original and printed $L^*a^*b^*$ values for Spot Color Test Charts

Figures 9 to **Figures 12** present ΔE comparisons of original and printed $L^*a^*b^*$ values for blue, black, red, and yellow spot color charts, respectively. For the blue spot color test chart, the ΔE values of the actual production printing substrate with the print driver combination (black line) are significantly larger than those of others. Conversely, the print combination of Premium Semimatte Photo Paper with GMG RIP (blue dash-line) has lower ΔE values. The actual production printing substrate with GMG RIP combination (blue line) also has better reproduction capabilities in blue spot color except for highly saturated areas. Premium Semimatte Photo Paper has lower ΔE values compared to the actual production printing substrate and its ΔE values are controlled in the range of 0-4.

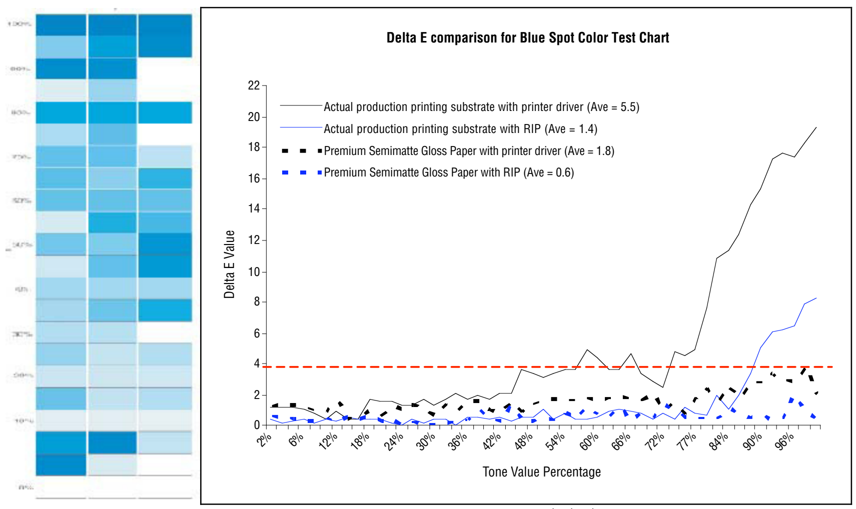

Figure 9: ΔE comparison of original and printed $L^*a^*b^*$ values for blue color.

As shown in **Figures 10** and **11**, printing via either print driver or GMG RIP, the actual production printing substrate tends to have larger ΔE values for black and red spot color in shadow areas. Premium Semimatte Photo Paper has better reproduction capability in black and red spot color in terms of lower ΔE values. The yellow spot color chart, compared to other spot color charts, has relatively high ΔE values. The ΔE values of the actual production printing substrate with the print driver combination (black line) increase significantly from the tint of 30% to solid area, whereas the ΔE values of the other three print combinations increase significantly from the tint of 50% to solid area. Printing via either print driver or GMG RIP, Premium Semimatte Photo Paper has lower ΔE values compared to the actual production printing substrate.

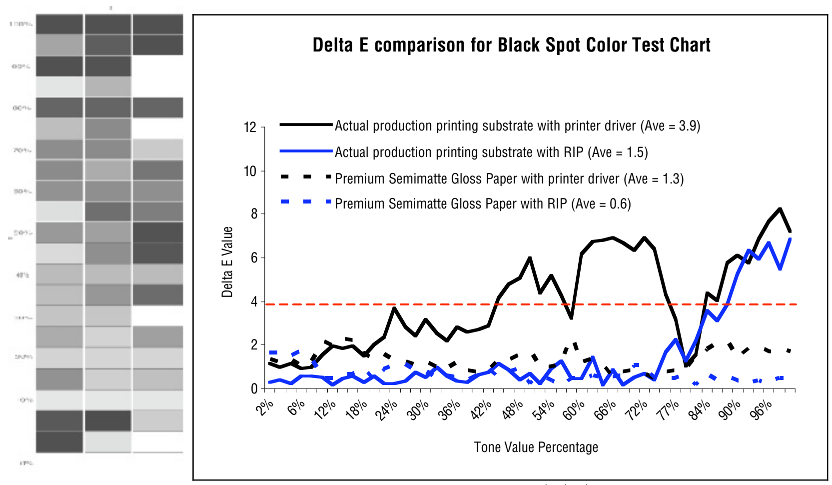

Figure 10: ΔE comparison of original and printed $L^*a^*b^*$ values for black color.

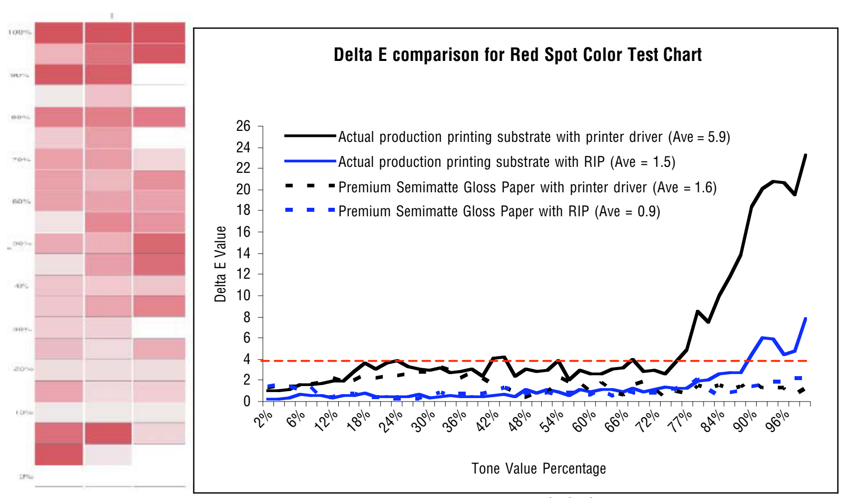

Figure 11: ΔE comparison of original and printed $L^*a^*b^*$ values for red color.

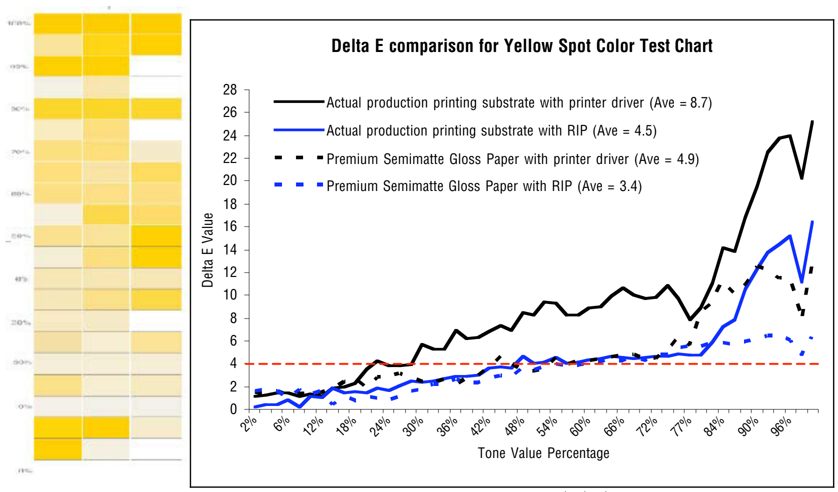

Figure 12: ΔE comparison of original and printed $L^*a^*b^*$ values for yellow color

4. Conclusions

In terms of color gamut comparison for substrates, the color gamut of Premium Semimatte Photo Paper is significantly larger than that of actual production printing substrate. As for printing control software, the color gamut of GMG ColorProof RIP is similar to the color gamut of Epson Stylus Pro 4000 print driver. The largest gamut volume was found in print combination of Premium Semimatte Photo Paper with Epson Stylus Pro 4000 print driver, whereas the combination of actual production printing substrate with print driver yields the smallest color gamut volume.

Overall, the manufacture recommended proofing paper printing via GMG RIP results in better spot color reproduction. Actual production printing substrate has poor color reproduction in highly saturated colors, no matter which printer control software are used. It also found that the actual production printing substrate cannot accept such large amount of ink at solid areas for blue and black color and causes ink smearing. Effort must be taken to improve the color reproduction of shadow areas. For Premium Semimatte Photo Paper, two print control softwares provide good color reproduction for the four selected spot colors except for yellow color. Users can proof spot colors on Premium Semimatte Photo Paper printing via print driver if a third party RIP is not available. **Table 7** shows the summary of ΔE comparison for different output combinations.

Among the four selected spot colors, yellow is the hardest one to reproduce, due to some spot colors in the test charts that are out of color gamut of the test printer. Further investigation will include possible testing on a Hexachrome printer to pursue a wider color gamut.

Table 7: Summary of ΔE comparison for different print combinations

ΔE / Chart	Actual production printing substrate/ print Driver			Actual production printing substrate/ GMG RIP			Premium Semimatte Photo Paper/ print Driver			Premium Semimatte Photo Paper/ GMG RIP		
	Max	Min	Ave	Max	Min	Ave	Max	Min	Ave	Max	Min	Ave
Blue	19.3	0.4	5.5	8.3	0.1	1.4	3.9	0.4	1.8	2.0	0.1	0.6
Black	8.3	0.9	3.9	6.9	0.2	1.5	2.3	0.5	1.3	1.7	0.2	0.6
Red	23.3	1.0	5.9	7.8	0.3	1.5	3.2	0.3	1.6	2.2	0.1	0.9
Yellow	25.4	1.1	8.7	16.4	0.2	4.5	12.5	1.2	4.9	6.5	0.4	3.4

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