On-Press Control of Metallic Inks

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Abstract

Investigations have been made to find practical measurement methods for metallic offset inks. Laboratory-based tests and on-press tests were conducted utilizing a variety of metallic colors based on the Pantone® metallic book. The inks were tested in regard to polarized and non-polarized density measurements, gloss and color measurements using spherical and non-spherical spectrophotometers.

Results showed that cyan density readings done with a polarized densitometer represented best changes in ink film thickness regardless of the tested color. Gloss measurements done at three different gloss angles showed that the 60° angle proved the most reliable.

From the three colorimetric values L* indicated change in ink film thickness. L* measurements were conducted with a spherical spectrophotometer.

These three parameters were used to evaluate press sheets which were also analyzed for a visual match to the Pantone® book. From the three measurements, cyan density, gloss, and L*, the L* value was in direct relation to the printed color in the Pantone book. L* measurements done with 0/45 geometry-based spectrophotometer gave a wider range in values but were not as accurate as the spherical measurements in relation to a visual match.

Introduction

Metallic inks have been available for some time to enhance the appeal of printed pieces. Time and time again it has been shown that the use of metallic inks enhances a printed product and can add a perceived value. The printing of metallic inks presents its own challenge since the pigment in metallic inks is either aluminum-based for silver colors or bronze-based for gold colors. Bronze is made from copper and zinc, and through varying ratios of copper and zinc a certain shade of gold is achievable (Mannig and Verderber, 2002). The metallic pigments come in the form of flakes and are provided in paste form to ink

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manufacturers who incorporate them into their offset printing inks. Metallic inks tend to have different ink/water-balance characteristics than regular organic pigment based printing inks. This characteristic is only one of the challenges posed to the press operator.

The on-press control of metallic inks happens mostly on a visual basis. It is either the press operator or the client who determines if the metallic color looks right. Pantone® has provided a color fan with 301 metallic inks. This color fan can be used, again, for the visual evaluation of the printed Pantone® metallic ink. The Pantone® metallic color fan provides ink formulations for the colors in the fan based on Pantone 877 (P 877) silver and Pantone 874 (P 874) gold. These base metallic inks are then mixed with base colors from the original 1137 color Pantone® book.

Many attempts have been made to find a practical method to measure printed metallic ink films. Attempts have been made in the past to measure printed metallic inks with 0º/45º geometry based densitometer or spectrophotometer, but it resulted in unreliable measurements. Mannig and Verderber (2002) described the use of a polarized densitometer to monitor the printed ink film thickness of silver metallic inks.

Breede and Sharma (2008) showed that it was possible to monitor the printed ink film of silver metallic ink using a standard densitometer and a spectrodensitometer. Their investigations used only silver metallic ink. In 2006 Ploumidis proved that a polarized densitometer is more sensitive to changes in the printed ink film thickness than a non-polarized densitometer. Ploumidis (2006) also used polarized measurements to obtain spectral data from the printed samples for further analysis. Spectral data and densitometric values were derived from instruments with 0º/45º geometry. Although these results were encouraging it needs to be said that only bronze-colored and silver metallic inks were investigated.

Measurement devices based on 0º/45º type geometry are commonly used as quality control tools in the pressroom, yet these tools are usually not equipped to perform polarized measurements. Polarized measurements of metallic inks are beneficial, since the specular effect of the metallic inks is minimized. A study done by Mouw showed that the use of a sphere geometry type instrument, also known as d/8º, is beneficial in regard to the colorimetric evaluation of metallic inks.

The studies done in the past were either concerned with the measurement geometry that should be used for the evaluation of printed metallic inks or looked at either basic silver or gold metallic inks. This shows the need for a study that builds on the results of the previous studies but expands into metallic colors that also contain regular color giving components. It is the goal of this study to find a common, or more than one common, measurement parameter for metallic inks regardless of their composition.

Experimental

This study encompassed several parts. In the first stage, a representative number of colors from the Pantone® book were chosen to represent a variety of metallic base color content and basic Pantone® mixing colors. From these metallic inks two were chosen for a pressrun to validate the findings from the laboratory study. The findings from the first pressrun required a second pressrun. The printed sheets from the second pressrun were not only be evaluated through measurements but will also be visually assessed in order to determine the validity of the measurements used.

Lab mixes and Prüfbau prints

In the first part of the study 25 metallic inks from the Pantone® metallic book were chosen and lab size color samples were mixed. These colors are a representation of metallic inks based on P 877 silver and P 874 gold with a varying degree of metallic content. These colors are listed in Table 1.

Pantone number	Components
8002	877 (50%) + 874 (50%)
8020	877 (76%) + P021 (19.2%) + P032 (4.8%)
8060	877 (76%) + P032 (24%)
8082	877 (52%) + Rhodamine (48%)
8122	877 (64%) + Purple (36%)
8140	877 (76%) + P072 (4.8%) + Purple (19.2%)
8200	877 (76%) + P072 (4.8%) + Process Blue (19.2%)
8221	877 (64%) + Process Blue (24%)
8282	877 (52%) + Green (48%)
8401	877 (76%) + Black (24%)
8440	877 (76%) + P021 (4.8%) + P032 (19.2%)
8541	874 (64%) + Purple (25.2%) + Black (10.8%)
8560	874 (64%) + P032 (25.2%) + Black (10.8%)
8561	874 (64%) + Rhodamine (25.2%) + Black (10.8%)
8600	874 (76%) + P072 (19.2%) + Process Blue (4.8%)
8622	874 (64%) + Black (36%)
8723	874 (40%) + Green (60%)
8742	874 (52%) + Process Blue (33.6%) + Green (14.4%)
8761	874 (40%) + Process Blue (60%)
8781	874 (52%) + P072 (48%)
8800	874 (52%) + Violet (48%)
8821	874 (52%) + Purple (48%)
8862	874 (52%) + Rubine (48%)
8900	874 (64%) + P021 (7.2%) + P032 (28.8%)
8940	874 (76%) + P021 (24%)

Table 1. *List of tested metallic colors.*

Before the metallic inks were mixed and printed, the silver and gold base colors were printed with varying ink film thicknesses and measured with a regular and a polarized densitometer. This was done to determine which densitometer is more sensitive to changes in the printed ink film thickness. The measurements were made with two Ihara R710 densitometers. One of them had been upgraded for polarized measurements.

The colors were printed using a Prüfbau printability tester on #1 coated paper and checked for a visual match. After this was achieved, consecutive prints with declining ink film thickness were produced. These prints were then measured with the polarized and the non-polarized densitometer. The L*a*b* coordinates of these colors were measured with a Hunter ColorQuest spectrophotometer which uses sphere geometry for its measurements. The gloss of the printed samples was measured at 20º, 60º, and 75º using a Novo-Gloss glossmeter.

First pressrun

Based on the results from the prints done on the Prüfbau printability tester the colors P 8401 metallic silver and P 8862 metallic pink were chosen for the first pressrun. A duotone image was placed on the press form to ensure sufficient ink take-off, and patches of the two test colors were printed for measurement. The inks were donated from a reputable ink manufacturer. For this pressrun the densities of the printed inks were monitored with the polarized densitometer. The printed ink density was increased to the limit of the ink/water balance, after which the ink fountain rollers were shut off and the ink stored on the ink train rollers was depleted. In total 200 sheets were printed on the same stock as was used for the samples printed on the Prüfbau.

Every 5th sheet was analyzed for gloss, density and color. The test image can be seen in Figure 1.

Figure 1. *Test form for the first pressrun; the square patches above the image will be analyzed.*

Second pressrun (incl. visual assessment)

After analyzing the results of the first pressrun and the Prüfbau prints, a different set of colors was chosen for the second pressrun. The reasons for choosing a different set of metallic colors was that we wanted to include inks with a high and a low amount of metallic base color into the mix as well as colors which used gold and silver as their metallic base. The following list shows the metallic colors:

- P 8401 Silver (76% P877 + 24% Black)
- P 8581 Gold (76% P874 + 16.8% P021 + 7.2% Black)
- P 8203 Blue (40% P877 + 48% ProBlue +12% P072)
- P 8723 Green (40% P874 + 60% Green)

This list shows that two inks have a high amount of metallic base color in them (P 8401 and P 8581) and two have a low amount of metallic base color in them (P 8203 and P 8723). Based on the results from the first pressrun and the results from the analysis of the lab prints the second press sheets were evaluated in regard to:

- Cyan density (Status T, polarized) of the printed colors
- The gloss at 60º
- The L*a*b* values
- Visual evaluation of the printed colors

The test form can be seen in the Figure 2.

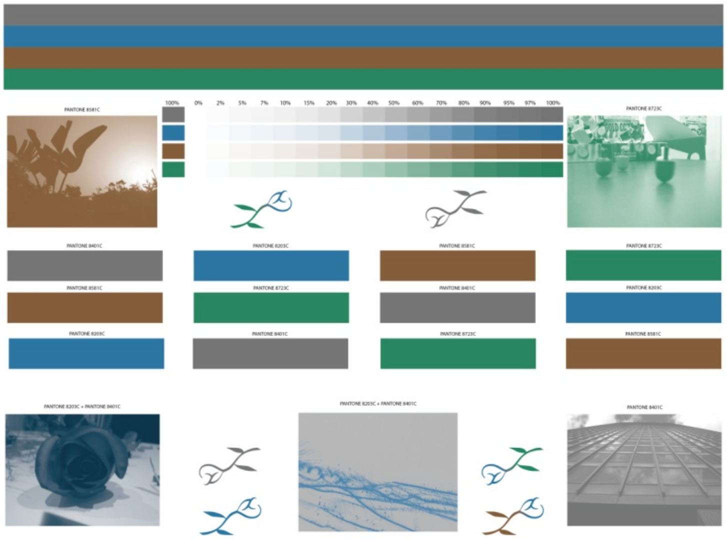

Figure 2. *Test form for the second pressrun.*

Like in the first pressrun the printed ink densities were monitored to see if the target density can be achieved. The target density was determined by measuring the Pantone® metallic book. For some of the colours this was achievable, but for others, no matter how much the inking was increased, the density of the Pantone book could not be reached. Once this had been confirmed the printed ink density was increased until the inks started to scum on press. After this the ink ductor rollers were shut off and 500 consecutive sheets were printed. From these 500 sheets every 10th sheet was analyzed to the above listed criteria.

As a final evaluation a visual comparison between the printed press sheets and the Pantone® metallic book was done. A male and a female observer observed the colors. This was done to determine which sheets would be deemed visually acceptable and to establish a certain tolerance in regard to one or more of the above listed criteria.

Results

The results from this study have been split up into various stages that reflect the development of this project over time.

Results from Prüfbau prints

In the first part of this study the metallic base colors P 877 silver and P 874 gold were printed with declining density and measured with two densitometers. One densitometer was capable of taking polarized measurements. The results from this initial test can be seen in Tables 2 and 3.

Color	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Silver: Pantone 877 (polarized)	K: 0.90 C: 0.91 M: 0.91 Y: 0.73	K: 0.93 C: 0.94 M: 0.94 Y: 0.75	K: 0.92 C: 0.93 M: 0.93 Y: 0.75	K: 0.84 C: 0.86 M: 0.85 Y: 0.70	K: 0.81 C: 0.83 M: 0.82 Y: 0.68
Silver: Pantone 877 (regular)	K: 0.59 C: 0.61 M: 0.59 Y: 0.57	K: 0.57 C: 0.59 M: 0.57 Y: 0.55	K: 0.57 C: 0.59 M: 0.57 Y: 0.54	K: 0.56 C: 0.58 M: 0.56 Y: 0.53	K: 0.54 C: 0.56 M: 0.55 Y: 0.52

Table 2. *Density measurements of P 877 silver.*

The visual presentation of some of these density measurements can be seen in Figure 3.

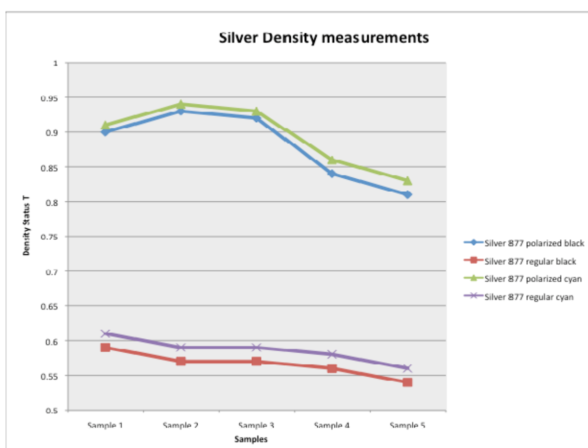

Figure 3. *Polarized and unpolarized cyan and black density measurements (Status T) of P 877 silver.*

From Figure 3 it can clearly be seen that the cyan and black densities follow the same pattern and clearly show the declining densities of the printed lab samples.

The same procedure was also repeated for declining density prints of P 874 gold. The measurement data for these prints can be seen in the Table 3.

Color	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Gold: Pantone 874 (polarized)	Y: 1.00 K: 0.88 C: 0.80 M: 0.91	Y: 0.98 K: 0.86 C: 0.78 M: 0.89	Y: 0.97 K: 0.84 C: 0.77 M: 0.87	Y: 0.92 K: 0.79 C: 0.73 M: 0.82	Y: 0.88 K: 0.76 C: 0.70 M: 0.79
Gold: Pantone 874 (regular)	Y: 0.88 K: 0.69 C: 0.60 M: 0.73	Y: 0.84 K: 0.65 C: 0.56 M: 0.69	Y: 0.84 K: 0.65 C: 0.56 M: 0.68	Y: 0.80 K: 0.62 C: 0.54 M: 0.65	Y: 0.79 K: 0.62 C: 0.54 M: 0.65

Table 3. *Density measurements of P 874 gold.*

One of the goals of this study was to find measurement characteristics for metallic inks regardless of the color these inks have. Therefore, the same density readings (black and cyan) that were used for P 877 silver will also be used for P 874 gold to see if they show a similar trend.

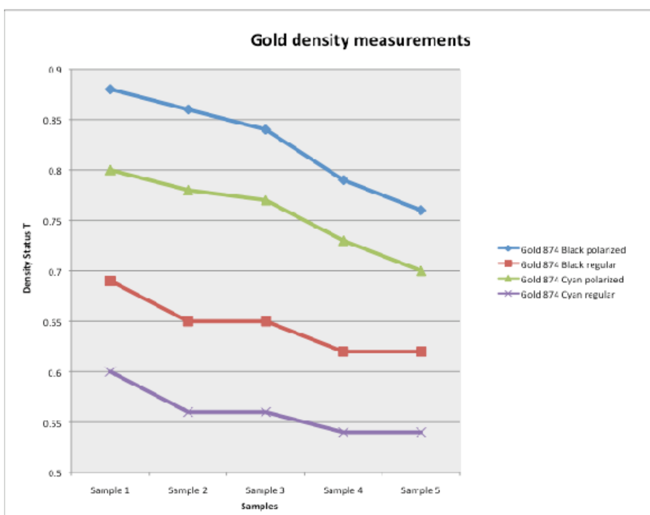

Figure 4. *Polarized and unpolarized cyan and black density measurements (Status T) of P 874 gold.*

From Figure 4 it can be seen that the results are not as clear as they were for P 877 silver, but it is still visible that the polarized density readings for cyan and black are more sensitive to changes in the ink film thickness. From these initial tests it needs to be seen if the polarized density measurements for cyan and black can also be used for other metallic colors.

As an example the color P 8200 consisting of P 877 silver, P 072, and Process Blue and P 8742 made from P 874 gold, Process Blue, and Green were chosen. The visual representation of density readings from these two colors can be seen in Figure 5.

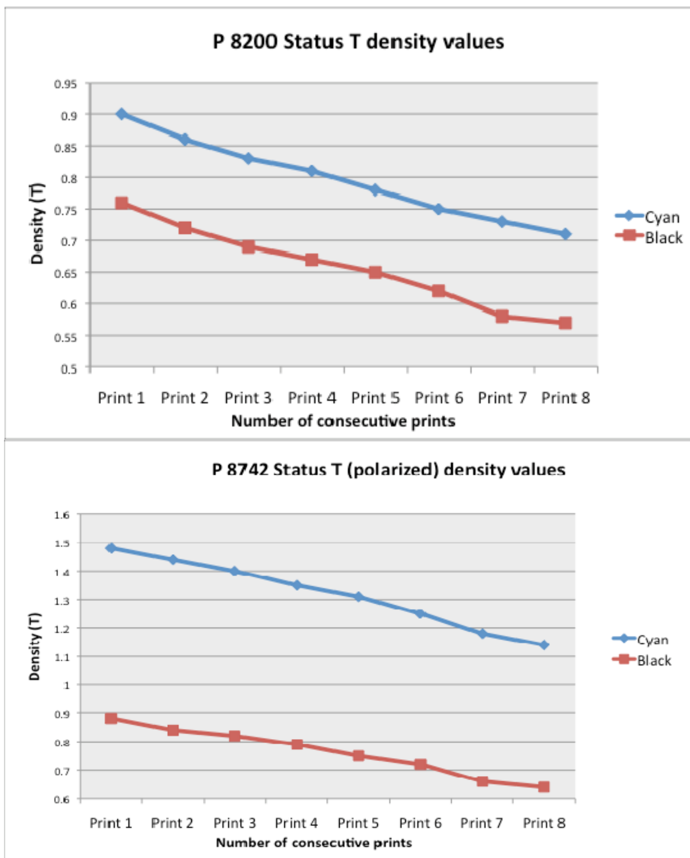

Figure 5. *Polarized density measurements of P 8200 and P 8742.*

From Figure 5 it is clearly visible that cyan and black polarized density readings can be used to monitor the printed ink film thickness. One could argue that the cyan density readings show a more linear decline than the black density readings. This was also the case for P 874 gold. From these initial tests it seems that the polarized cyan density can be used to monitor the printed ink film thickness of metallic inks.

Density, gloss, and colorimetric values (L*a*b* and LCh) were analyzed in-depth from 11 of the Prüfbau prints representing a variety of colors. This resulted in 12 variables being analyzed and graphed for each color. By comparing these colors to each other, 4 variables were determined to have significance and were analyzed in greater detail. For each metallic color cyan polarized density, 60° gloss, L*, and chroma values were analyzed to determine a trend. Figure 6 shows an example of the resulting graphs. In this example it can be seen that as ink film thickness decreased gloss and cyan density decrease and lightness and chroma show a slight increase. Unfortunately not all the graph showed similar trends. We attempted to find trends in regard to the ratio of metallic ink content or in the base metallic color used, but none were found. It was determined that the main reason these variables did not show usable trends was because of the small number of prints analyzed.

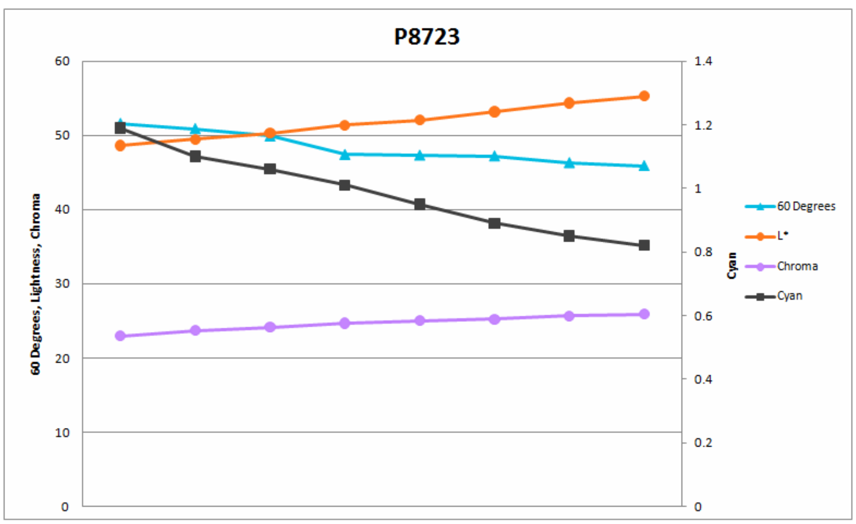

Figure 6. *Results of P8723 Prüfbau prints.*

Results from first pressrun

Many different factors were measured from the 2-color press form resulting from the first pressrun, including gloss, density, L* a* b* values, and LCh values. It was believed that there should be at least one other measure which can help accurately determine change in ink film thickness and color. The first factor analyzed was gloss to determine which of the 3 angles measured (20°, 60°, and 75°) showed the best correlation to change in ink density. Three patches of each color were measured. Figures 7 and 8 show the results for the two colors printed when the results for the three patches measured is averaged.

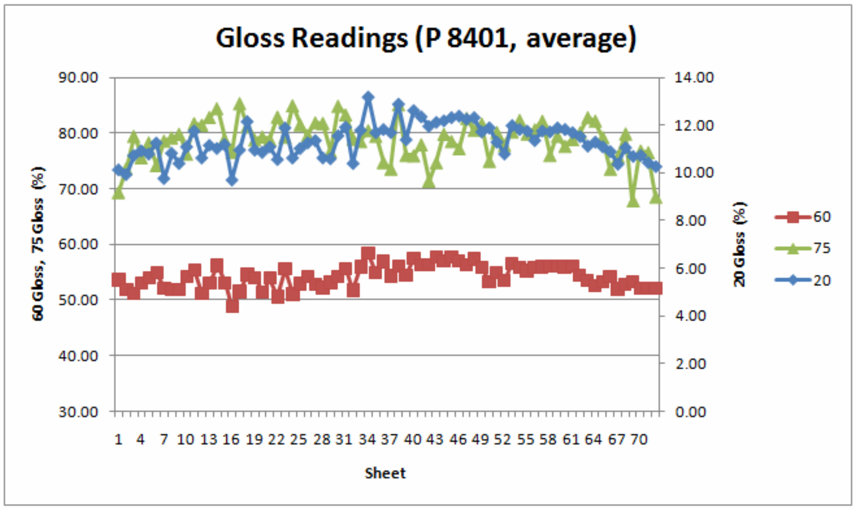

Figure 7. *A comparison of gloss readings at 3 different angles from P 8401, metallic silver. Ink density increases with the sheet number.*

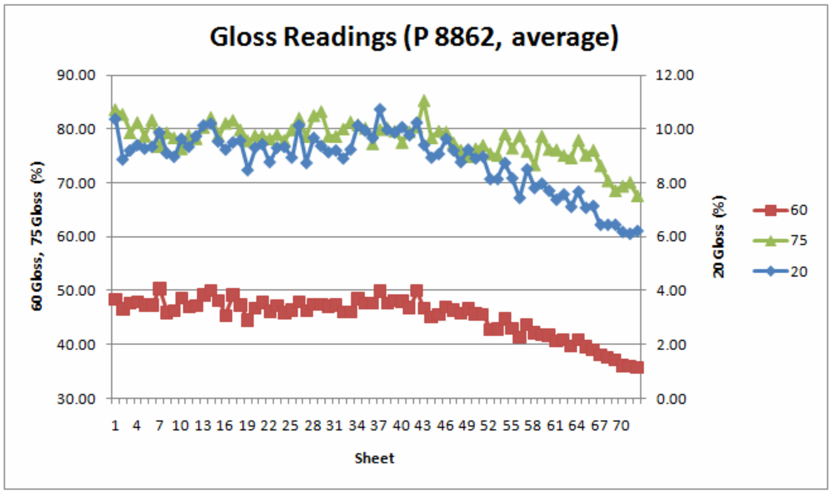

Figure 8. *A comparison of gloss readings at 3 different angles from P 8862, metallic pink. Ink density increases with the sheet number.*

From the this analysis it was determined that 60° was the best angle at which to measure gloss because the other two angles showed much more haphazard readings throughout the run, specifically with lower densities.

Polarized and non-polarized densities were compared at this point to confirm what had been observed with the Prüfbau prints. As Figures 9 and 10 show, it was confirmed by the pressrun that polarized cyan density is a good indicator of change in metallic ink film thickness. This can be seen by the greater change measured through polarized density when compared to non-polarized density. For P 8401 the range of measured densities was .39 for polarized readings and .28 for non-polarized readings. For P 8862 the range of the measured densities was .49 for polarized readings and .45 for non-polarized readings

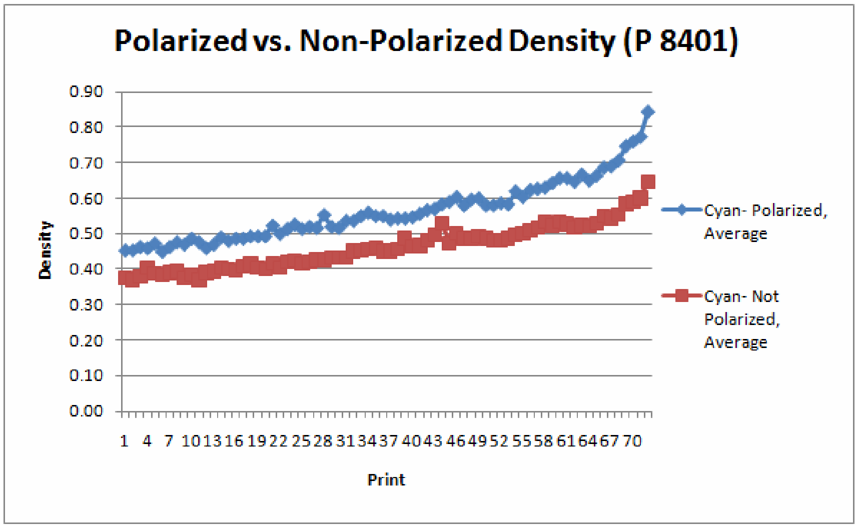

Figure 9. *A comparison of polarized and non-polarized density from P 8401, metallic silver. Ink density increases with the sheet number.*

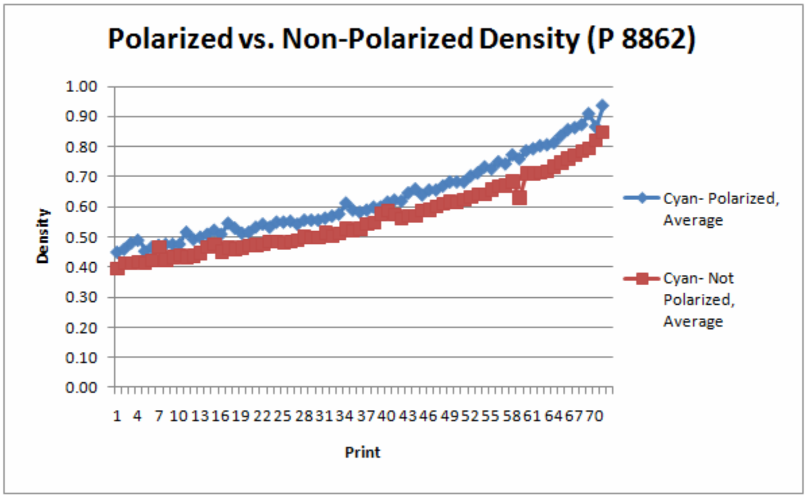

Figure 10. *A comparison of polarized and non-polarized density from P 8862, metallic pink. Ink density increases with the sheet number.*

Although it was determined that 60° gloss readings was the most telling of the three measured, a strong correlation between 60° gloss readings and change in density was not very clear after this pressrun. Figures 11 and 12 show a comparison of 60° gloss to polarized and non-polarized cyan densities. The second patch measured has been used as an example in this case.

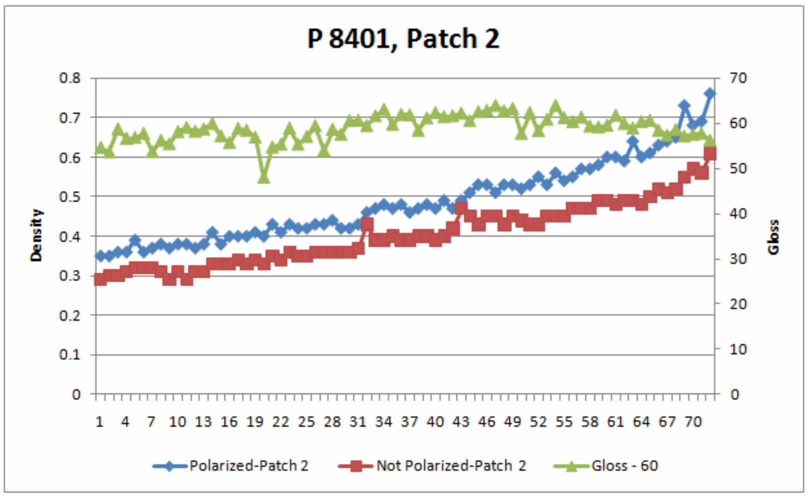

Figure 11. *A comparison of polarized and non-polarized density as well as 60° gloss from P 8401, metallic silver.*

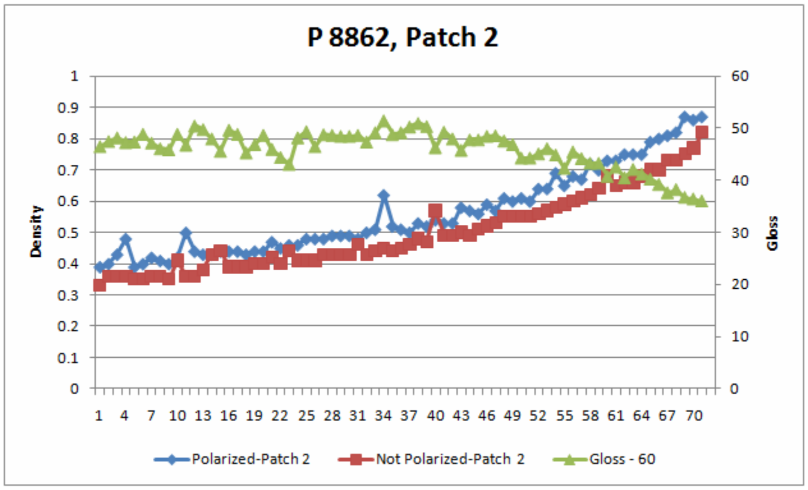

Figure 12. *A comparison of polarized and non-polarized density as well as 60° gloss from P 8862, metallic pink.*

As can be seen from Figures 11 and 12 there is an increase in gloss as less ink is printed onto the sheets. This trend was much more dominant in the metallic pink color than in the metallic silver. Figure 13 includes a comparison of L*, chroma, and gloss to density and show similar results. The density measurement used for these graphs is polarized cyan density. P 8862, the metallic pink, shows clear increases in chroma and decrease in lightness and gloss as density. P 8401, the metallic silver color, shows a clear decrease in lightness, but not as clear of a trend in regard to chroma and gloss.

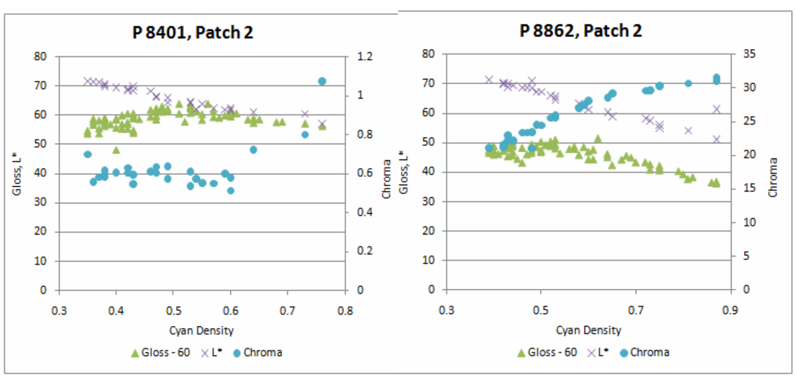

Figure 13. *Comparison of 60° gloss, L* , chroma, to Cyan density for P 8401 and P 8862.*

Overall, the second pressrun did confirm some of our expectations about density measurement but left more questions regarding gloss readings and other colorimetric evaluations. We could not make any general conclusion about gloss or colorimetric measurements from the pressrun because it was limited to only two colors, or the Prüfbau prints, because there were not enough samples of each color, although some trends were starting to emerge. It was therefore decided that another pressrun would be prepared.

Results from second pressrun

For this pressrun four colors were chosen to compare many measurement factors. It was hoped that some of the inconclusive results from the Prüfbau prints and previous pressrun could be attributed to the amount of metallic content in the inks or the base metallic color chosen. Therefore, of the four colors chosen, two contained silver as their metallic base and two contained gold. Of these, one of each set was a color where more than half of the mixed ink was metallic ink and one consisted of less than half metallic ink.

Gloss measurements were analyzed first to try to clarify and substantiate the results obtained from the first pressrun. Figure 14 shows a comparison of 60° gloss measurement and polarized cyan density for all 4 colors measured. The gloss and density measurements presented are an average of each of the 3 patches measured from 49 press sheets.

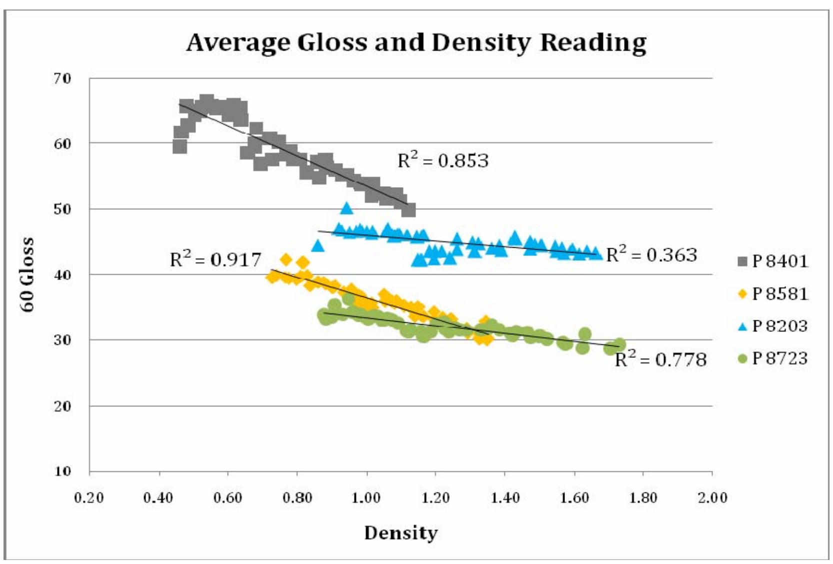

Figure 14. *60° gloss readings compared to polarized cyan density, an average of 3 patches measured for each colour.*

Figure 14 shows a very telling pattern. For all four colors as density increases gloss decreases, but the rate of change is different for the different types of ink. P 8041, the metallic silver, and P 8581, the metallic gold, both show a greater decrease in gloss than P 8203, the metallic blue, and P 8723, the metallic green. This is significant because P 8401 and P 8581 were the colors used which contain more than 50% metallic ink while P 8203 and P8723 have less than 50% metallic ink used when they are mixed. It therefore appears as though gloss is a better indicator of change in colors which have more than 50% metallic ink content.

After density and gloss measurements were taken, L*a*b* measurements were taken with a spherical spectrophotometer. It was found that as ink film thickness decreased L* increased across all four colors. What was known at this point was that polarized cyan density, 60° gloss, and L* all indicate change in printed metallic ink films. The next step taken was to compare all the measurements to a visual analysis of the printed samples compared to a Pantone book and measurements of the Pantone book.

Figures 15 through 17 show the results of this comparison for one of the patches measured for each color. In these graphs the dashed lines represent the measurements of the Pantone book. The color of the dashed lines is the same as the measurements from the press sheets, density, gloss, and L*. The highlighted section of the graph is the sheets which were determined to have an acceptable visual match to the Pantone book. Only P 8401, P 8581, and P 8723 were used for this analysis. P 8203 could not be used because the hue of the ink used was dissimilar to the Pantone book; there were therefore no printed samples which could be considered a visually acceptable match to the Pantone book.

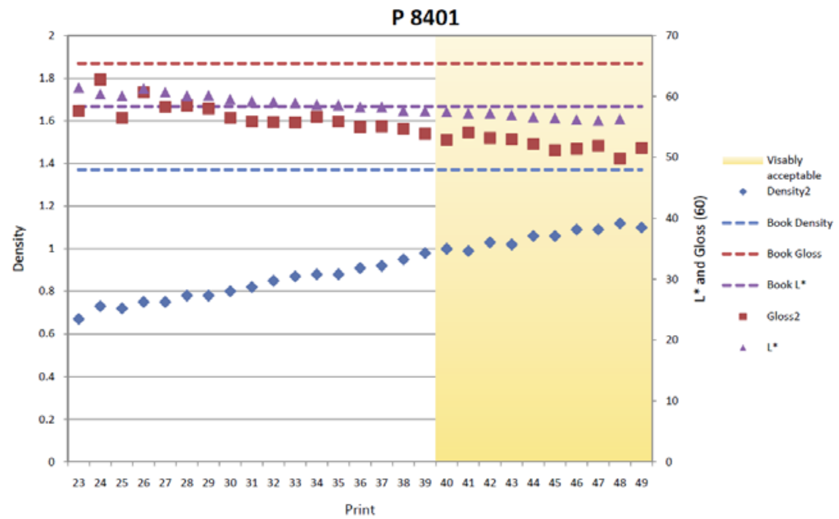

Figure 15. *Density, gloss, and L* compared to their respective readings from the Pantone book (the dashed straight lines) for P 8401. The yellow area represents the sheets deemed a visually acceptable match to the pantone book.*

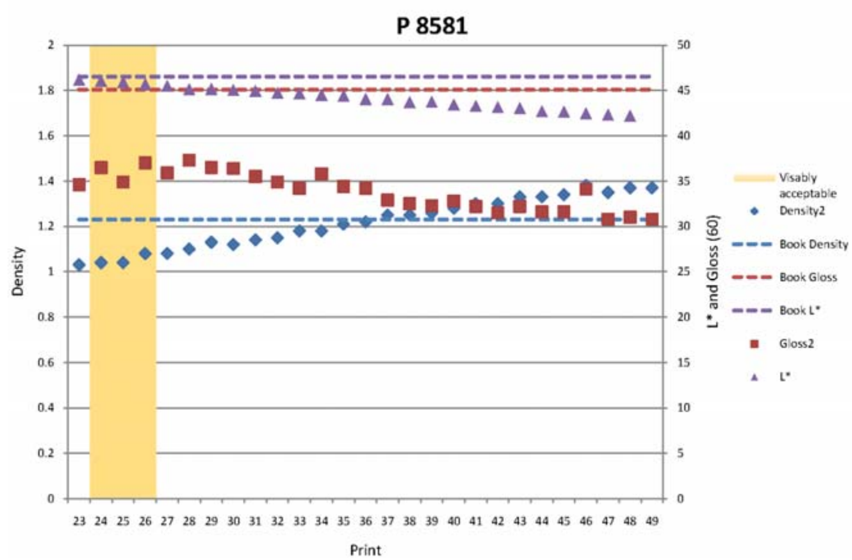

Figure 16. *Density, gloss, and L* compared to their respective readings from the Pantone book (the dashed straight lines) for P 8581. The yellow area represents the sheets deemed a visually acceptable match to the pantone book.*

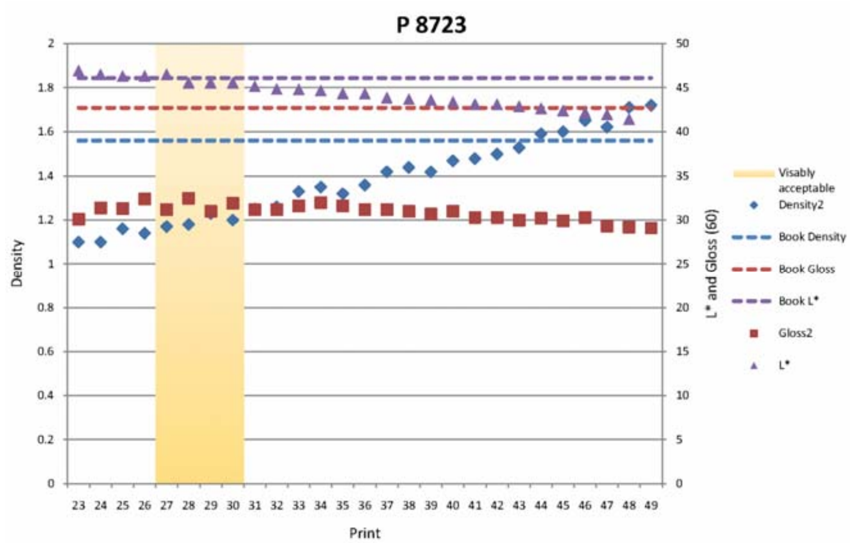

Figure 17. *Density, gloss, and L* compared to their respective readings from the Pantone book (the dashed straight lines) for P 8723. The yellow area represents the sheets deemed a visually acceptable match to the Pantone book.*

The results of the comparison were slightly surprising. Even though all three factors charted are good indicators of change, only one reached the same measurement values as the Pantone book within the visually acceptable sheets. With all three colors the gloss and density measurements of the visually acceptable sheets do not come close to those of the Pantone book. In P 8401, the metallic silver, the L* values reach the same as the Pantone book when the ink film is slightly less thin than the sheets which were deemed visually acceptable. In P 8581, metallic gold, and P 8723, metallic green, the L* values are extremely close. These results show that the measurement which gives the best indication of visual match when compared to the Pantone book is L*.

Once this was discovered all of the patches were measured with a non-spherical spectrophotometer to determine if the same would be true with the L* reading from a non-spherical spectrophotometer. The results are summarized in Figures 18 through 20. Again, only three colors were analyzed because a visually acceptable match could not be obtained for P 8203.

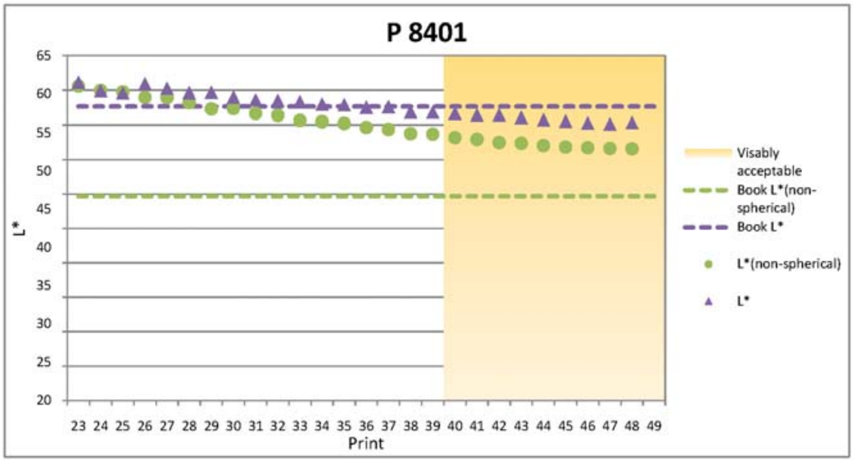

Figure 18. *L* measured through a spherical spectrophotometer and a non-spherical spectrophotometer compared to their respective readings from the Pantone book (the dashed straight lines) for P 8401. The yellow area represents the sheets deemed a visually acceptable match to the Pantone book*

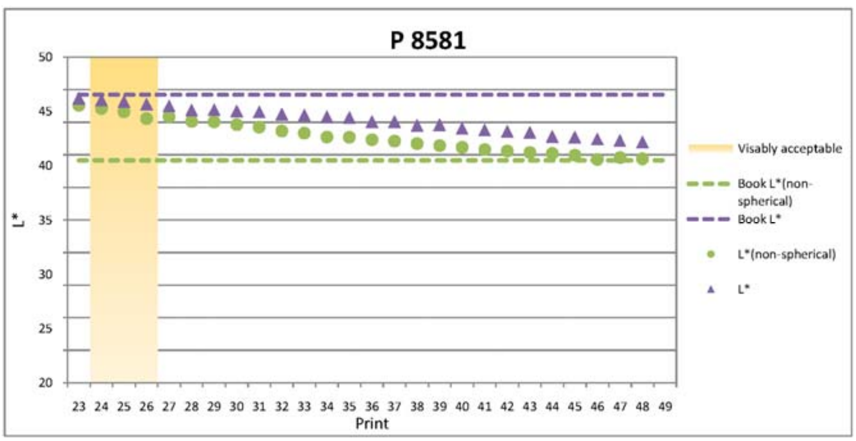

Figure 19. L measured through a spherical spectrophotometer and a non-spherical spectrophotometer compared to their respective readings from the Pantone book (the dashed straight lines) for P 8581. The yellow area represents the sheets deemed a visually acceptable.*

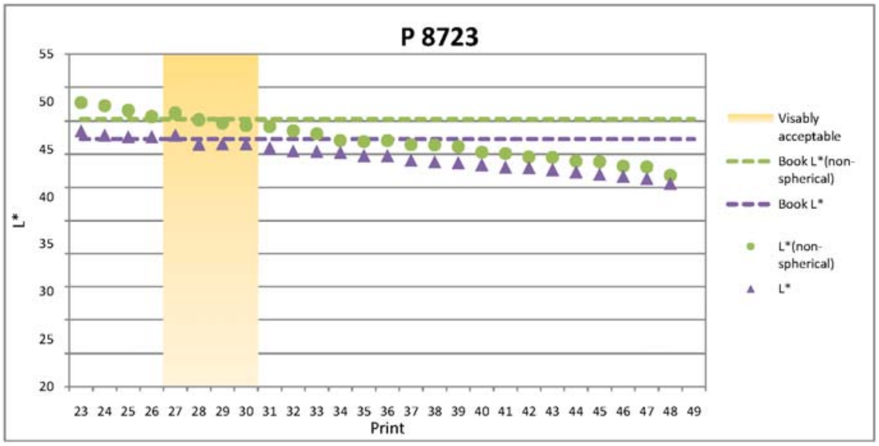

Figure 20. *L* measured through a spherical spectrophotometer and a non-spherical spectrophotometer compared to their respective readings from the Pantone book (the dashed straight lines) for P 8401. The yellow area represents the sheets deemed a visually acceptable.*

Figures 18 through 20 show that for 2 of the 3 colors tested the spherical spectrophotometer produced more accurate results by about 5 L*. The third color, P 8723 showed almost the exact same degree of accuracy from the spherical and non-spherical spectrophotometers.

One other comparison was made between these possible measurements. The amount of change which each device and measurement gave over sheets 23 to 49 is displayed in Table 4. For the three colors tested, the change percentage of each measurement was analyzed to see which measurement method best showed change. It can be seen that for all three colors polarized density showed a greater percentage change compared to the other measures.

Colour	**Density**		**Gloss**		**L* (spherical)**		**L* (non-spherical)**	
P 8401	.45	40.18%	13	20.7%	5.42	8.81%	8.11	13.29%
P 8581	.35	25.36%	6.5	17.43%	4.02	8.7%	4.97	10.91%
P 8723	.62	36.05%	3.4	10.46%	5.53	11.78%	7.59	15.22%

Table 4. *Absolute and percentage change values for density, gloss, and L*.*

Conclusions

From the variety of tests conducted for the evaluation of printed metallic inks three results proved to be usable regardless of the actual color of the printed ink. One of the first measurements was ink density. Density measurements done with a polarized densitometer, using the cyan density values, reflected well the changes of the printed ink film thickness. Gloss measurements proved only to be relevant when measured at a 60° angle. Gloss was more telling for inks that contained more than 50% of one of the metallic base colors. L* readings showed similar results to the density readings but were found to be more accurate at representing a visual match when compared to the Pantone book. The L* measurements were done with a spherical spectrophotometer. A non-spherical spectrophotometer was used to see if the results would be similar, but it did not match up as well to a visual assessment of the printed sheets and the Pantone book. This being said, the cyan density readings still showed a more exact representation of change in percentage when compared to L* and gloss readings.

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