Metallic Ink Measurement Using the M3 Mode

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Abstract

In the past it has been quite difficult to measure and control metallic inks on press. Since 2002, various research projects have been carried out to find a way to control these inks on press. The main challenge is that the 0/45º or 45/0º measurement geometry commonly used in press rooms, does not necessarily lend itself to measure the density or the color of metallic inks accurately. The metallic flakes inside a metallic ink have different orientations and reflect the light in different directions resulting in different colors and different amounts of light send back to the instrument. Incorporating polarization filters into densitometers helped to minimize the effect of different amounts of light being reflected back to the sensor inside a densitometer. A 0/45º spectrophotometer can not be used to measure the color of a metallic ink. Metallic inks are commonly used in the automotive industry, which uses either a multi-angle goniometer to measure and control metallic inks. Another measurement device that can be used for measuring the color of a metallic ink is a sphere-geometry based spectrophotometer, also known as an instrument with a d/8º measurement geometry. This device uses indirect lighting vs. direct lighting used in common press room color measurement tools. The indirect lighting and the ability to exclude the gloss of a sample from the color measurements allows one to measure and control metallic inks. The only problem is that there is probably no d/8º spectrophotometer in a press room.

In 2009, ISO 13655 was released which specified different measurement modes. These modes, labelled M0, M1, M2 and M3, define measurement conditions. ISO 13655:2009 - Graphic technology — Spectral measurement and colorimetric computation for graphic arts images, now specifies four measurement modes - M0, M1, M2 and M3. The M0 is a legacy mode and covers previously built instruments (i.e. X-Rite 428, 530 etc). The M1 mode specifies the amount of UV light in a D50 light source. The M2 mode is D50 without and UV light below 400 nm. The M3 mode describes the use of two polarization filters. The light source is the same as in the M2 mode. One polarization filter is in front of the light source and the

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grating of the second polarization filter is orthogonal to the first filter and sits in front of the measurement sensor. The M3 mode was originally designed to measure the dry-back effect of inks and also to control special effect inks. The M3 minimizes surface reflections that could influence any color measurements.

The Pantone metallic book contains 301 metallic colour that use either P877 silver or P874 as the basic metallic colors. These metallic base colors are mixed with the Pantone basic colors to create the various metallic inks. In this study, 9 metallic inks with various amounts of metallic silver and metallic gold were printed first on the Prüfbau printability tester and then on a 2-color offset press. Two M3-mode capable spectrodensitometers and one sphere-geometry based spectrophotometer were used to measure the printed colors. Both M3-mode instruments were capable of not only measuring the colors, but also giving quite similar L*a*b*-values and density values, outperforming the sphere-geometry based instrument.

Instruments capable of using the M3 measurement mode can be used to measure and control metallic inks on press.

Introduction

Metallic inks add visual appeal to a printed package and suggest value and exclusivity to the consumer that can influence the customer's buying decision, perhaps into paying more for the perceived extra value. Until the implementation of ISO 13655 in regards to well-defined measurement modes, metallic inks were mainly evaluated visually during print production. The inherent properties of metallic inks—adding a sheen that reflects light and changes colour appearance according to the viewing angle—rendered any form of controlled color management ineffective, making visual evaluation the only effective way to match colour. However, visual evaluation is not an accurate, reliable, or efficient way to match colour since it is subjective to the viewer, which is why colour management techniques were originally developed. Fortunately, with the introduction of defined measurement modes to the graphic arts industry, dependency on visual evaluation is eliminated. In particular, the M3 mode has been specified for the measurement of special effect inks such as metallics. Having well-defined control metrics for metallic inks is necessary and this research paper will establish or control these control metrics. This will take the guesswork out of the print production of special effect inks, effectively saving time and resources in the form of reprints.

In a research project in 2010 "On Press Control of Metallic Inks", M. Habekost & R. Dykopf, (Habekost & Dykopf, 2010) it was proven that a sphere geometry based color measurement device (X-Rite SP64) can be used to control the printing of metallic inks on press. Also a polarized densitometer was used in that research project to monitor the printed ink density of the tested metallic inks. Unfortunately, a sphere-geometry based measurement device is quite uncommon in the Graphic

Arts industry. It is more used in the automotive industry, where colour control of metallic inks has been practiced for years. The graphic arts industry faced obstacles in adopting the more efficient methods used in the automotive industry, mainly that the measurement devices used apertures far too large for any standard colour bar.

The new ISO 13655 defines a measurement mode called "M3" for use in the graphic arts, which uses two polarization filters during color measurement. These polarization filters eliminate the influence of the metallic glare on the color measurement. One of the polarization filter is in front of the light source and the second polarization filter is in front of the light sensor. The orientation of the polarization filters is orthogonal to each other.

For this project, three measurement devices were used. One measurement device was a sphere-geometry based color measurement device (X-Rite SP64) with diffuse lighting. The two other measurement devices have a 45/0º measurement geometry, but are capable of switching to the M3 measurement mode, which can be used for the measurement of special effect inks (ISO 13655).

Before going into detail in this research project, I would quickly like to list the three "M" measurement modes:

- M0 – legacy mode (any illumination source, tungsten lamp commonly assumed);
- M1 – D50, UV-included mode (devices can use two different methods to achieve this mode);
- M2 – UV-cut mode (removes all UV light from the measurement system, below 400 nm);
- M3 – polarizing mode, same as M2 but with two orthogonal polarization filters. One filter is in front of the light source and one filter is in front of the measuring sensor. This mode can be used for the measurement of wet offset press sheets and effect inks.

Cheydleur and O'Connor (Cheydleur & O'Connor, 2015) wrote a white paper, that gives a very good overview of the various M-measurement conditions.

Theory

The measurement of metallic inks has always been a challenge in the graphic arts industry due to the nature of the measurement instruments that are used. In a white paper Mouw (Mouw, 2008) describes that the 45º angle is the best angle for color assessment. The best instrument to use for measuring metallic inks would be a multi-angle instrument, since the metallic print changes its appearance based on the observation angle. Thus, the use of an instrument with 45º- measurement geometry poses its challenges. In a literature review Muehlemann and Myers (Muehlemann

& Myers, 2012) came to the conclusion that densitometers with a 45º/0º geometry work better with metallics when a polarization filter is in the densitometer. Mannig and Verderber (Mannig & Verderber, 2002) and Ploumidis (Ploumidis, 2006) evaluated polarization filters for the on-press control of metallic inks. Both studies said that a polarization filter made the densitometer more sensitive to changes in the ink film thickness. It was also found that switching from status T to status I on the polarized densitometer increased the sensitivity of the density readings.

In 2008, Breede and Sharma (Breede & Sharma, 2008) evaluated the use of a multi-angle gloss meter, a densitometer and a spectrophotometer for the evaluation of printed metallic inks. They came to the conclusion that a gloss meter did not work well for the evaluation of printed metallic inks. They did find, that with the L*-readings of the spectrophotometer they could track the printed ink film thickness. Both authors also said that any of the density channels of the densitometer worked well for keeping track of the printed ink film thickness. This study used only silver metallic ink.

In 2010 Habekost and Dykopf (Habekost & Dykopf, 2010) studied 25 metallic inks and three instruments for the evaluation of metallic inks on press. In their study, a gloss meter, a polarized densitometer, and sphere-geometry based spectrophotometer was used. The main results from this study were, that gloss measurements taken at a 60º angle gave relevant results and the metallic inks needed to have more than 50% metallic ink content for the gloss measurements to be meaningful. From the polarized densitometer readings the cyan density values proved to be useful in tracking the printed ink film thickness. Discrepancies were found between the printed ink densities that were visually acceptable, but different from the measured ink densities in the Pantone® book. This can be seen in Figure 1. Also, the L*-readings taken with sphere-geometry spectrophotometer gave a good indication of the printed ink film.

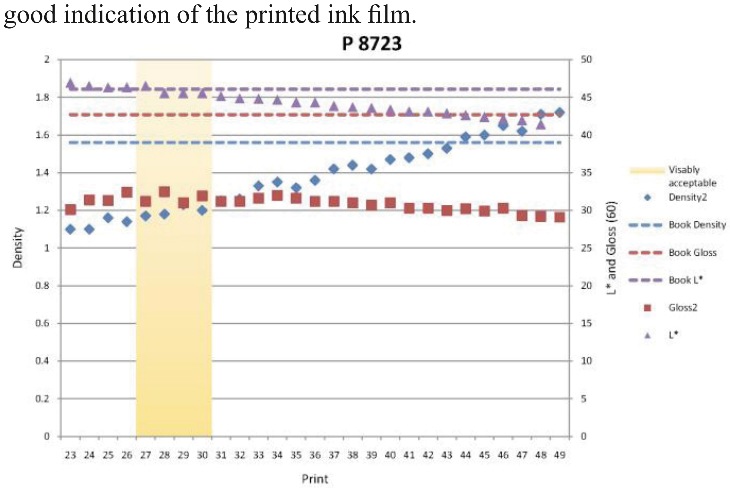

Figure 1: *Example of a Pantone colour with visually acceptable colour on the left side, while the same printed ink density as the Pantone book gets achieved on the right side of the graph*

All the research done in the past shows that it was somewhat possible to conduct measurements of printed metallic inks using a polarized densitometer either in Status I mode or using the cyan densities in Status T mode.

With the newly defined M-measurement modes, the M3 mode will be evaluated for color control of metallic inks on press. Two measurement instruments supporting the M3 mode will be used in this study. Based on previously done research and articles found in the literature, a sphere-geometry based spectrophotometer will also be part of this study.

Experimental & Results

Before the experimental procedures will be introduced and results analyzed, a list of the equipment and materials are shown.

List of equipment:

- Prüfbau Printability Tester
- X-Rite eXact
- X-Rite SP64
- Techkon SpectroDens
- Heidelberg QM46-2

List of materials:

- Paper for prints:
    - Supreme Gloss Offset 24 x 36 182M, 100lb, 148g/m2
- Background measurement paper:
    - Kromekote Offset 23 x 35 102M, 60lb, 89g/m2
- Inks:
    - P8203 Blue from Wikoff
    - P8682 Green from Wikoff
    - P8063 Pink from Wikoff
    - P877 Silver from ColorLogic
    - P874 Gold from Hostmann-Steinberg*
    - P8283 (hand-mixed using P877 Silver and PANTONE Green from Hostmann-Steinberg*)
    - P8083 (hand-mixed using P877 Silver and PANTONE Rhodamine Red from Saphira)
    - P8783 (hand-mixed using P874 Gold and P072 Blue from Saphira)
    - P8863 (hand-mixed using P874 Gold and PANTONE Rubine Red from Colmar)
- Pantone® Metallic Ink Book
- * = Hostmann-Steinberg is now known as hubergroup

List of software:
- X-Rite ColorMaster (Version 8.9.3)
- X-Rite eXact DataCatcher
- Techkon SpectroConnect (Version 2.5.2)
- MS-Excel for PC/Mac
- Keyspan USB-to-serial port adapter
- PC with Windows 7

In this project, three color measurement devices—the Techkon SpectroDens, the X-Rite eXact, and the X-Rite SP64—are used for the color measurement of metallic inks. These devices will allow for comparison between them using the M3 measurement mode (SpectroDens and eXact) and the gloss excluded sphere-based measurement mode (SP64). Prints with varying ink film thickness were first made using the Prüfbau printability tester to see which of the three color coordinates L*a*b* can be used for control purposes. It will also be determined if the ink density, measured under the M3 measurement conditions with the SpectroDens and eXact, can be used to track the metallic inks during print production. The Pantone® metallic ink book will be used as the reference guide for the achievable color. After a series of test prints on the Prüfbau printability tester, press runs were conducted on the Heidelberg QM46-2 to verify the found control metric(s) for metallic inks.

First, the nine different colors tested were measured from the Pantone® metallic ink book by density using the eXact. These colours (5 direct from a supplier and 4 manually mixed) were tested on the Prüfbau Printability Tester by achieving the same ink density as the one recorded from the Pantone Metallic book and were then printed consecutively 14 times for a total of 15 prints for each colour. As a result, the ink film thickness of each consecutive print decreased. After the inks had dried, each print was measured using the X-Rite eXact, X-Rite SP64, and Techkon SpectroDens to capture both the L*a*b* and density values. The prints were measured upon a stack of Kromekote offset paper as it is closest to the ideal paper white: L* 95, a* 0, b* -2 (ISO 12647-2, 2013). These values were then graphed to examine the relationship(s) between these variables and ink film thickness.

From these graphs, it was observed that there is a reliable relationship between ink film thickness and both the L* and density value of the prints when measuring using the M3 mode. However, when measuring using the sphere-based spectrophotometer in gloss excluded-mode (SPEX = specular excluded) the results were sometimes erratic. The most problematic color to measure with the SP64 was P877 silver.

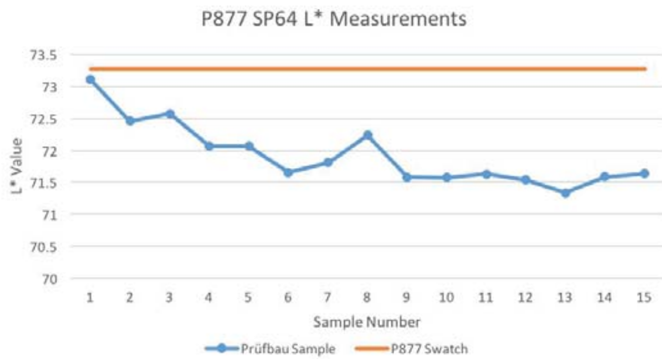

Figure 2: *L* values retrieved from the X-Rite SP64 with samples printing Pantone 877 Silver on the Prüfbau Printability Tester as ink film thickness decreases*

Metallic inks pose a unique challenge for color measurement, because the metallic flakes in the ink can be oriented in different ways. The following figure illustrates this well.

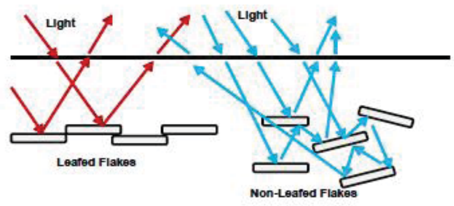

Figure 3: *Light reflection of leafed and non-leafed metallic ink flakes (Muehlemann & Meyers, 2012)*

The way that metallic inks achieve this effect is the inclusion of metallic flakes dispersed throughout the ink in either a leafed or non-leafed pattern (Muehlemann, 2012). Regardless of the pattern, the fact that the flakes are oriented in different ways, means that light can bounce off these flakes at different angles resulting in different parts of the visible spectrum being reflected back to the measuring sensor.

In contrast, the M3 mode uses UV-cut measurement methods (the same as the M2 mode) combined with a polarization filter to "remove or minimize reflections" (Cheydleur & O'Connor, 2011). This mode is ideal for metallic inks since reflections are the very characteristic that make them difficult to accurately measure with other measurement devices.

When measuring Pantone® 874 Gold with the sphere-geometry based X-Rite SP64, the first sample printed on the Prüfbau printability tester measured an L*-value difference of almost 5 compared to the L*-value measured from the Pantone swatch book despite the fact that the sample matched the density of the swatch book (see Figure 4). The rest of the samples measured with the SP64 did not result in a predictable trend line, instead forming an almost parabolic line as the samples decreased in ink film thickness, none of which matched the swatch book reading.

In contrast, the samples measured with the X-Rite eXact and the Techkon SpectroDens using the M3 mode showed similar, very logical trend lines across both devices as the samples decreased in ink film thickness (see Figures 5 and 6). Both devices also measured an almost exact match between the first sample and the swatch book.

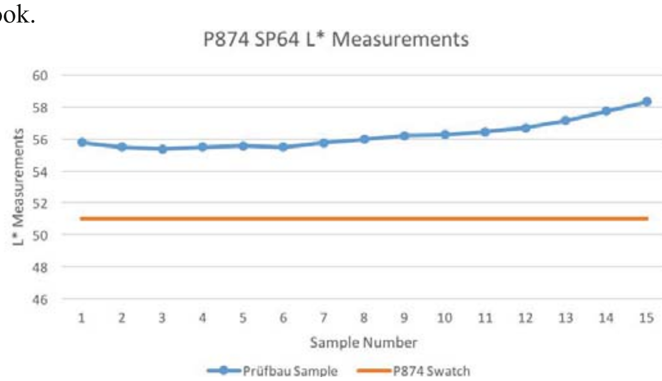

Figure 4: *L* values retrieved from the X-Rite SP64 with samples printing Pantone 874 Gold on the Prüfbau Printability Tester as ink film thickness decreases*

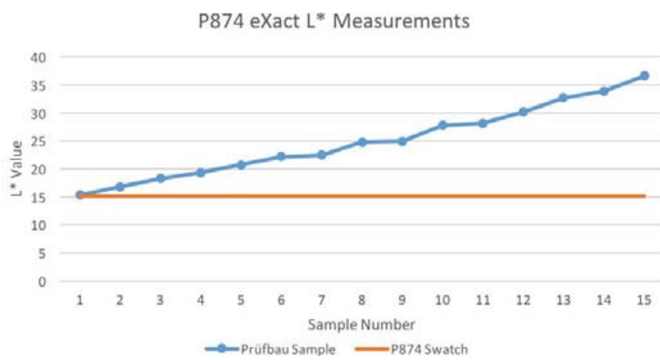

Figure 5: *L* values retrieved from the X-Rite eXact with samples printing Pantone 874 Gold on the Prüfbau Printability Tester as ink film thickness decreases*

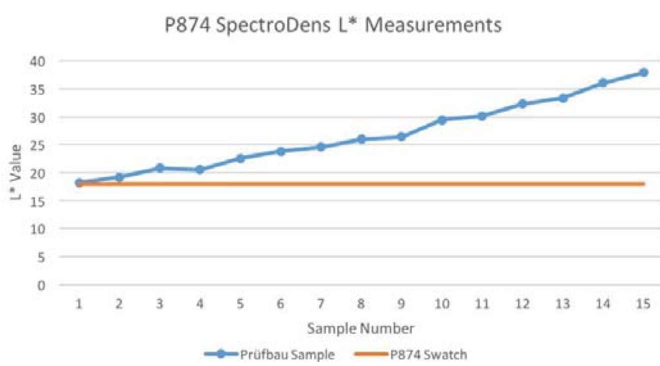

Figure 6: *L* values retrieved from the Techkon SpectroDens with samples printing Pantone 874 Gold on the Prüfbau Printability Tester as ink film thickness decreases*

A press run was also conducted on the Heidelberg QM46-2 to verify that the same results from the samples printed on the Prüfbau printability tester would carry on to real-life scenarios. A test form was created with a single-color image and tint patches including a 100% solid match intended for measurement purposes. Like the samples on the Prüfbau Printability Tester, the initial print was matched for the same density measured in the Pantone swatch book and once matched, the press was allowed to continue to run until 200 sheets were printed. The ink ductor was shut off once target density was achieved. Every 10th print was retrieved from the press run as the sample for measurement, resulting in 20 total samples per ink color.

Just as the measurements taken using the X-Rite SP64 on the Prüfbau printability tester samples were sometimes erratic, this continued to prove true during the press run. In fact, the L* value measurements taken using X-Rite SP64 for the same swatch (Pantone® 874 Gold), showed a different trend line during the press run than it showed for the samples printed on the Prüfbau printability tester (see Figures 7 - 9).

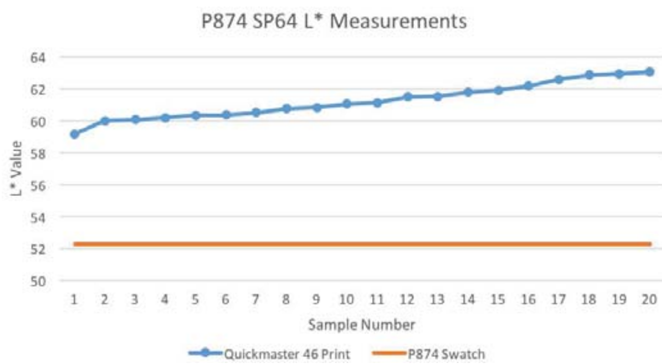

Figure 7: *L* values retrieved from the X-Rite SP64 with samples printing Pantone 874 Gold on the Heidelberg QM46-2 as ink film thickness decreases*

However, the devices measuring using the M3 mode continued to consistently correlate with each other and reliably show a distinct trend line during the press run (see Figures 8 and 9). This is important as it confirms that L* continues to be a reliable control metric for measuring metallic inks.

In addition, the difference in reliability between the sphere-based and M3 mode instruments were visibly apparent as well. The L*-values retrieved from the X-Rite SP64 only had a range of 4 (59 to 64) whereas the X-Rite eXact had a range of 26 (18 to 44) and the Techkon SpectroDens had a range of 24 (20 to 44). The range of the SP64 did not correlate with the visible difference in lightness apparent in the samples, since there was a very clear progression in the increase in lightness as the ink film thickness decreased. The results from the M3 devices made more sense in terms of what could visibly be seen on paper.

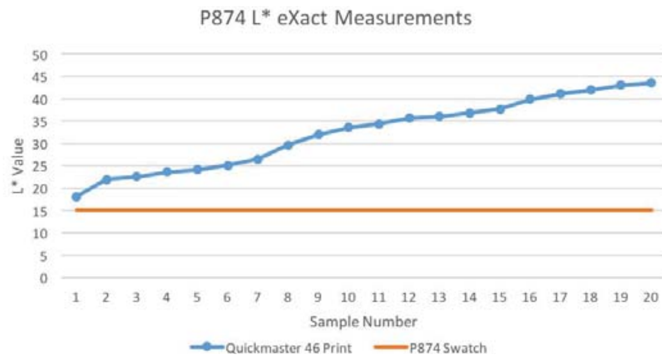

Figure 8: *L* values retrieved from the X-Rite eXact with samples printing Pantone 874 Gold on the Heidelberg QM46-2 as ink film thickness decreases*

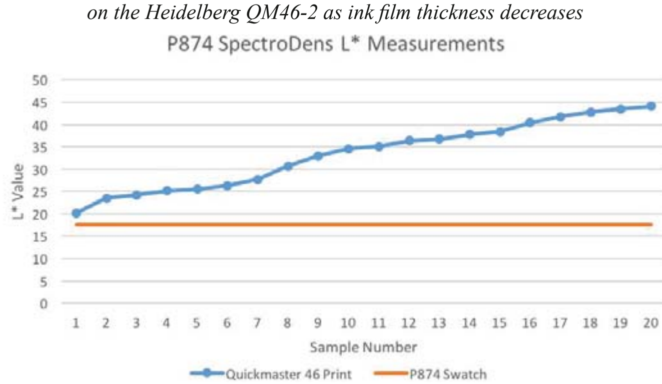

Figure 9: *L* values retrieved from the Techkon SpectroDens with samples printing Pantone 874 Gold on the Heidelberg QM46-2 as ink film thickness decreases*

While there was a slight difference between the values measured from the samples printed on the Prüfbau printability tester and the Heidelberg QM 46-2 (see Figure 10 and 11), there are a number of factors attributed to this variance. For one, the environment printing the samples on the Prüfbau was much more controlled than on the press as the Prüfbau is a direct blanket-to-paper machine. Another reason for this difference is the introduction of fountain solution during the press run which may cause slight variation in the printed ink appearance compared to a pure ink. Despite these small differences, the overall trend lines of both the Prüfbau and the QM46 for L*-values are still similar in shape, confirming the reliability of this particular control metric when measuring with M3 devices.

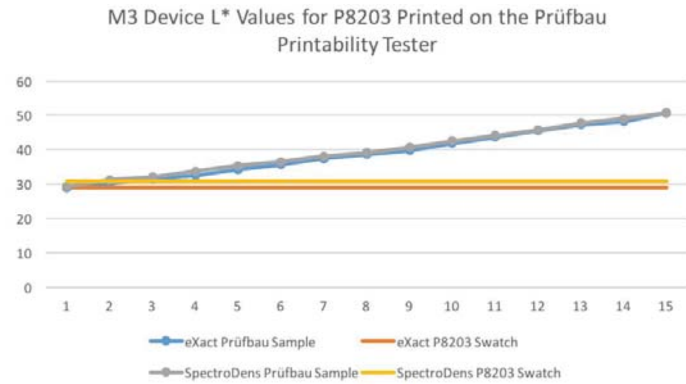

Figure 10: *L* values retrieved from the X-Rite eXact and Techkon SpectroDens with samples printing Pantone 8203 Blue on the Prüfbau Printability Tester as ink film thickness decreases*

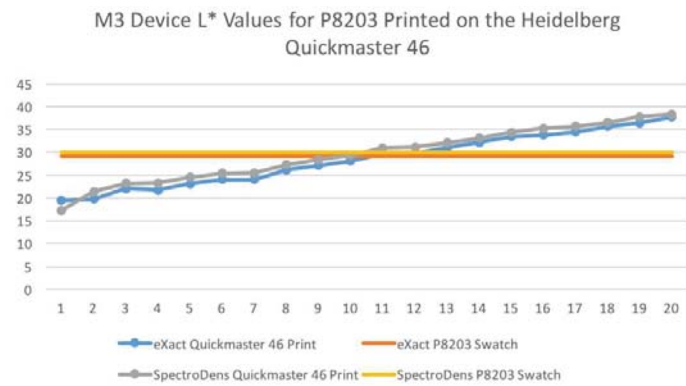

Figure 11: *L* values retrieved from the X-Rite eXact and Techkon SpectroDens with samples printing Pantone 8203 Blue on the Heidelberg QM46-2 as ink film thickness decreases*

After measurements were taken and recorded using both the sphere-geometry based and M3-capable devices, the Delta E00 was calculated between the original swatch in the Pantone® swatch book and the samples printed on the Prüfbau printability tester. These calculations showed that the devices measuring the M3 mode were consistently correlated, again resulting in predictable trend lines. However, the calculations resulting from the sphere geometry-based X-Rite SP64 only correlated in some instances and were drastically different in others (see Figures 12 and 13). These results are further evidence that measuring metallic inks using a sphere geometry-based spectrophotometer is not as reliable as those using the M3 mode.

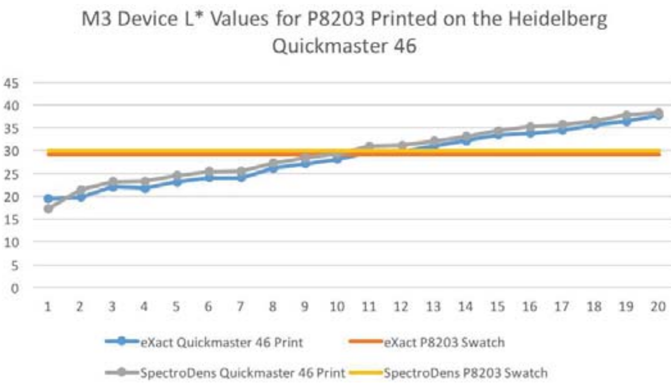

Figure 12: *Comparison of Delta E00 values measured from the X-Rite eXact, X-Rite SP64, and Techkon SpectroDens calculated between the Pantone Swatch Book and Prüfbau samples' L*a*b* values for Pantone 8863*

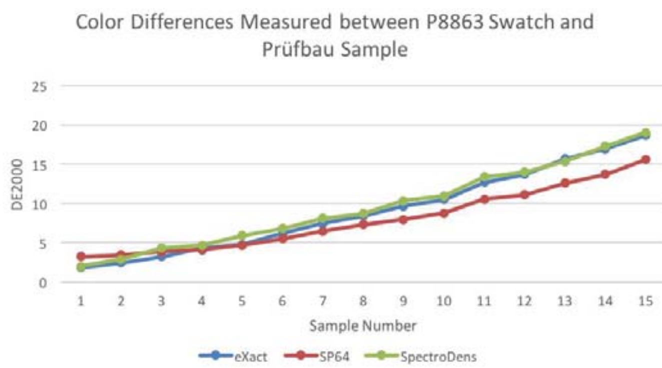

Figure 13: *Comparison of Delta E00 values measured from the X-Rite eXact, X-Rite SP64, and Techkon SpectroDens calculated between the Pantone Swatch Book and Prüfbau samples' L*a*b* values for Pantone 8203*

Conclusions

This project has proven that the M3 measurement mode works very well for measuring and controlling metallic inks on press. Both M3-capable measurement devices gave very similar density readings. One needs to keep in mind that these instruments do not measure density in the way a densitometer does. They both measure the spectrum of the light reflected back from the sample and convert the spectral data mathematically into a density value. The calculated density values were quite close to each other. Slight differences started to occur at very high ink film thicknesses and therefore high ink densities. At high ink film thicknesses the amount of light that gets reflected back to the measuring sensor is quite little. This could be the reason for the recorded differences in ink density values between the SpectroDens and the eXact.

The main outcome for this study is that the M3 measurement mode is suited very well for measuring and controlling metallic inks on press.

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