RYETAGA

MAKE YOUR
IMPRESSION
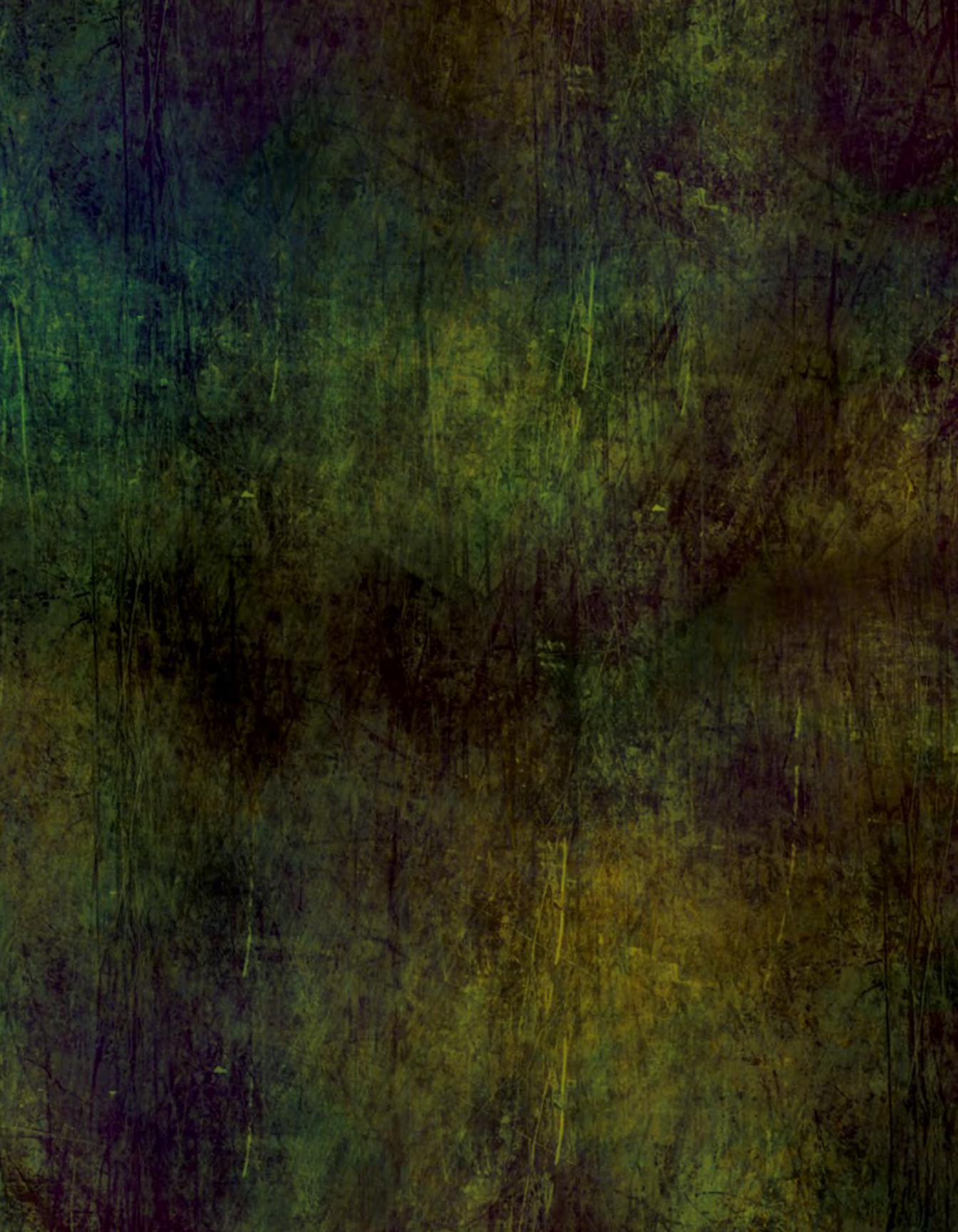2015

TABLE OF CONTENTS

RYETAGA

This journal was created with the environment in mind. The text pages are made from 30% post consumer recycled fibres. The creation of this journal saved:

| 30% | 4 Trees | 12,783L of water | 157 kg of waste | 1,435 kg CO2 | 3 GJ | 1 kg NOX |

WATCH THIS JOURNAL COME TO LIFE WITH AURASMA

Hear directly from the authors and take a look at the presses, inks, paper, and processes used to create this journal.

1. Download Aurasma

Go to the app store and download the free Aurasma App on your device. Compatible with Apple or Android Devices.

2. Follow the RyeTAGA Channel

In order to see the videos, you need to follow our channel.

Click the Aurasma icon on the bottom of the screen, search 'RyeTAGA', click on our channel and then click 'Follow' in the top right corner.

3. Scan

Scan the entire page with your device on the title page of each report to experience augmented reality.

The following pages can be used with Aurasma:

Page 10   Page 40   Page 58

Page 78   Page 100

Viewing the Digital version of this journal

To experience this digital journal's interactive features, it is best viewed on Adobe Reader.
This allows you to click to isolate magnified graphs for evaluation.
In addition, if you do not have a device to use Aurasma, Adobe Reader will allow you to view the augmented reality videos without the use of Aurasma app.
Just click on the ▷ button on each title page to see the videos.
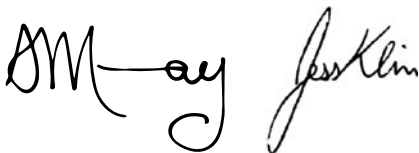
THE PRESIDENTIAL ADDRESS

Dear TAGA,

It is our pleasure to present the 2015 Ryerson University Student Chapter Journal: a collection of best practices and unique printing applications. For the ninth consecutive year, RyeTAGA is pleased to be attending the TAGA conference and is excited to be surrounded by brilliant minds of the graphic arts in Albuquerque, New Mexico.

All efforts put into the successful completion and delivery of this journal have been an immensely constructive and valuable learning experience for all involved. The twelve RyeTAGA members in attendance at the conference worked tirelessly to make this journal a success.

This would not have been possible without the generous support we receive. We would like to extend thanks to our hardworking executive team and helpful general members, the School of Graphic Communications Management, and our many generous sponsors. Without the support of Martin Habekost, our faculty advisor, we could not have achieved the level of success that we did. Thank you.

It has been another successful year and we are very proud to share the RyeTAGA journal with you. This journal showcases the fantastic work the students of RyeTAGA and GCM can accomplish!

Stephanie Murray & Jessica Klein
RyeTAGA Co-Presidents

A LETTER FROM THE FACULTY ADVISOR

Dear RyeTAGA students,

Another year has passed and it is time to attend the TAGA conference in March 2015. You have worked hard in regards to all aspects of this journal. Starting from the selection of the research papers that are in this journal, to the design and layout, to the print production and finally the finishing touches. The multimedia team worked hard on the e-version of this journal that is accessible independent of the digital platform that is being used.

We had successful and not so successful fundraising events, but in the end it all came together so the group could travel to Albuquerque, New Mexico. You were successful in securing monetary and material sponsors for this journal.

Those of you who attend their second or third TAGA conference, meet up with friends you made in Fort Worth or Portland and enjoy the not so official part of the conference. Make new friends and don't be shy to talk to all the conference attendees. Connect with them in person. You'll never know when and where these connections might be useful.

Enjoy the conference and may the best journal win.

Martin Habekost, Dr. rer. nat.
Ryerson TAGA student chapter advisor

1
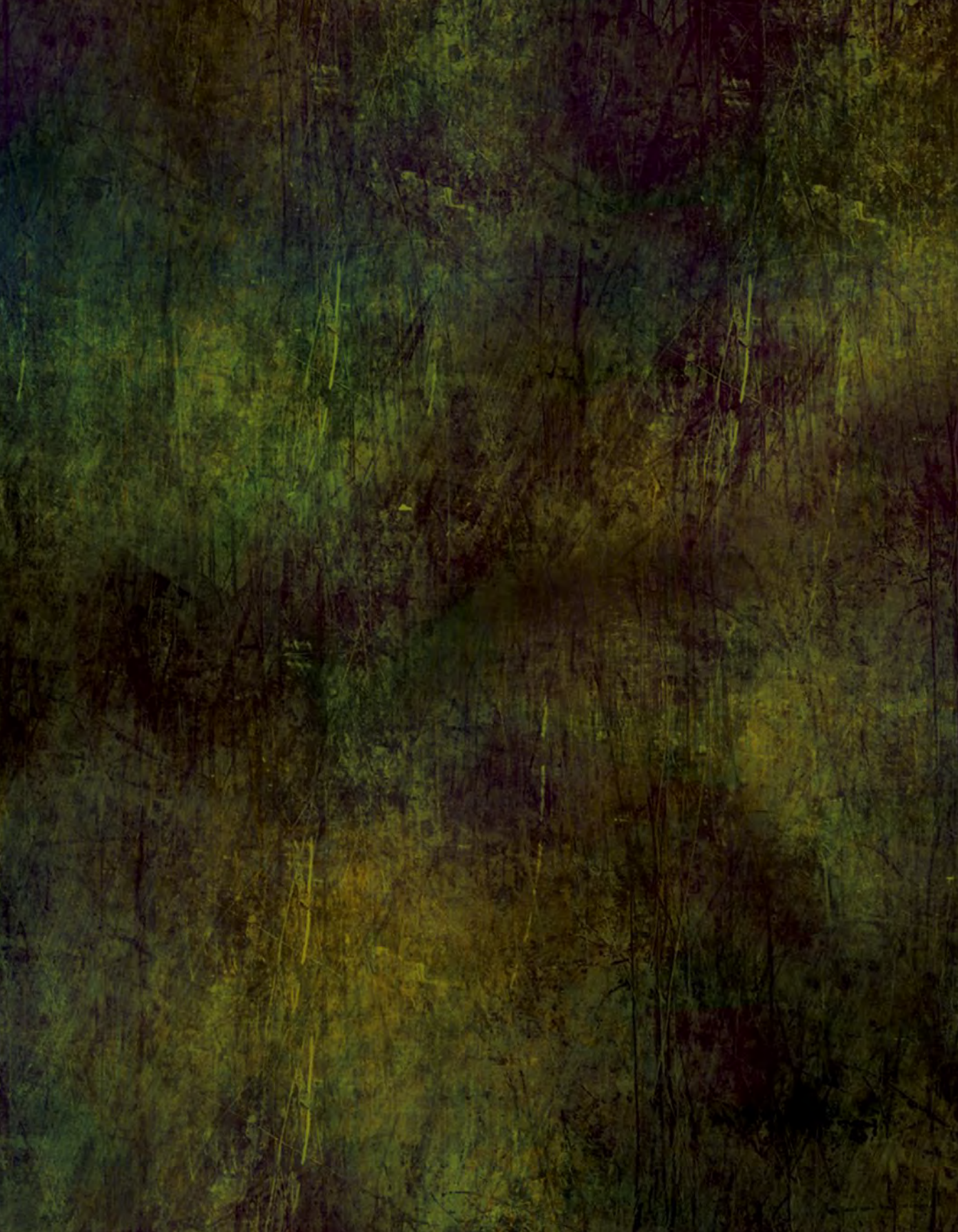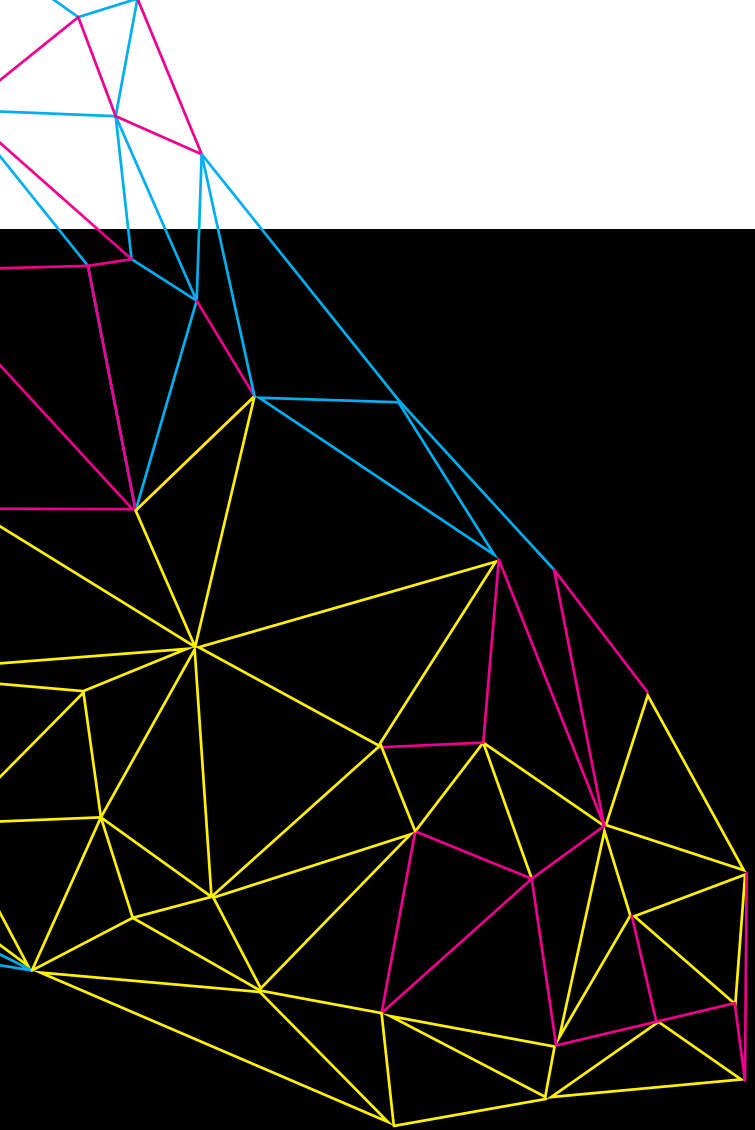
1 Consistency of the Xerox 700 Across Mid to Long Press Runs

By: Alex Chheun & Amy Nguyen

Abstract

The digital printing sector is becoming more and more prominent in the printing industry and yet there is no defined standard to evaluate the quality of the printed work provided by digital presses. The IDEAlliance Digital Press System Certification Program aims to provide certification to presses which have consistently demonstrated the ability to meet certain printing tolerances as outlined by certification. A test has been designed using test procedures and tolerances from this certification program in combination with custom ones to evaluate the Xerox 700, a press which is considered to be certified. This test aims to see if certain aspects of its certification can be repeated and to evaluate the overall consistency the press by comparing printed characteristics to tolerances outlined by IDEAlliance, GRACoL printing tolerences, and the manufacturer's specifications. The main parameters evaluated were solid ink densities, color difference using the CIEDE2000 equation, front-to-back registration, and color-to-color registration. In the end, the data showed that the Xerox 700 was able to reproduce and meet IDEAlliance and GRACoL's tolerances in regards to color difference, color-to-color registration, and solid ink densities respectively. The press's front-to-back registration varied drastically throughout the press run and often bypassed the tolerance that the manufacturer had set for its own printer.
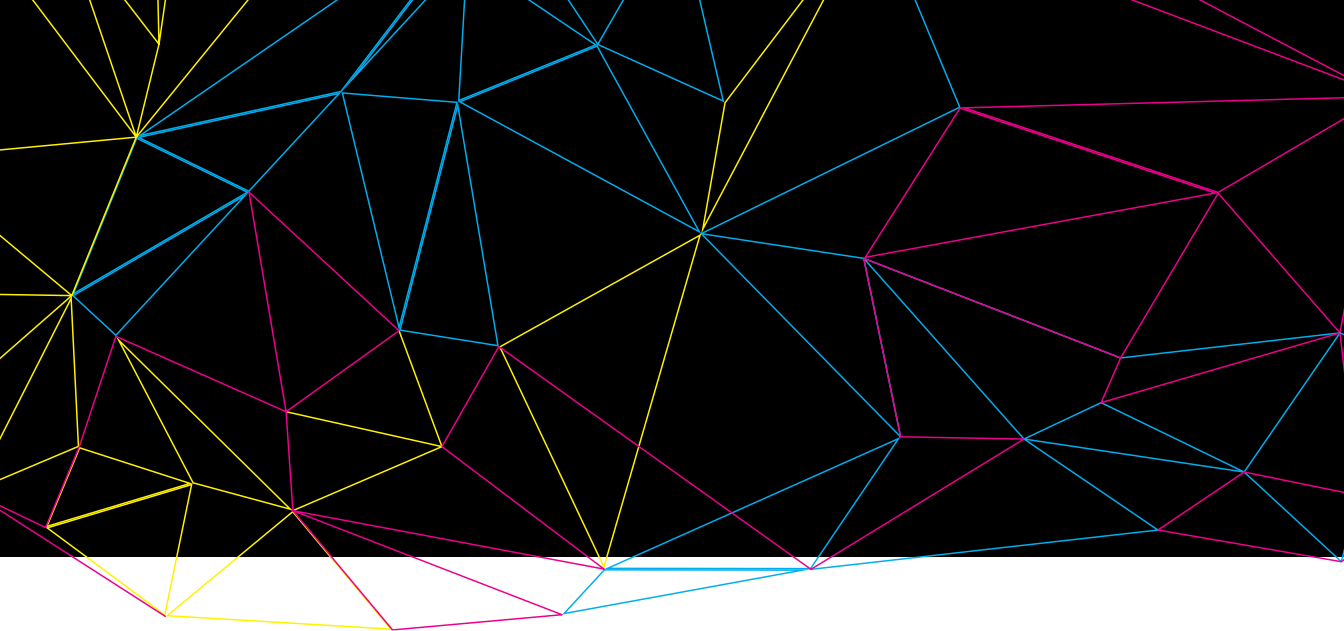
Introduction

Consistency is valued and recognized with the use of international standards in the graphic arts industry; however, the development of a standard for the digital print sector has yet to exist despite its many technological advances. The digital print sector has begun to stabilize and mature; thus, the lack of standardization brings to question as to how viable digital printing is as an alternative to conventional printing. Because of this, it is important to determine the competencies of digital printers. The absence of a printing plate in digital printers means frequent variations in the overall print, especially in regards to properties such as color, registration, and overall image quality. Although there is no established standard, IDEAlliance provides a Digital Press Certification Program containing color specifications that can be used as an indication for color reproduction and registration on a digital press.

This paper aims to evaluate a Xerox 700 (xerographic) Digital Color Press in determination of how well it is able to maintain a quality print over a medium-to-long press run. A test has been designed to assess the different print characteristics of numerous sheets printed on the press through a medium-to-long press run. It will determine how consistent these properties are relative to the other sheets printed within the same press run, in comparison to values outlined by the IDEAlliance Digital Press Certification program, and specifications of other printing processes. Based on the IDEAlliance Digital Press Certification Program, there are already many digital presses that are considered certified and able to consistently produce high quality work and meet printing standards. IDEAlliance has certified several Xerox presses, and the Xerox 700 is one of them (IDEAlliance, 2013). This means that the Xerox 700 should be able to meet the
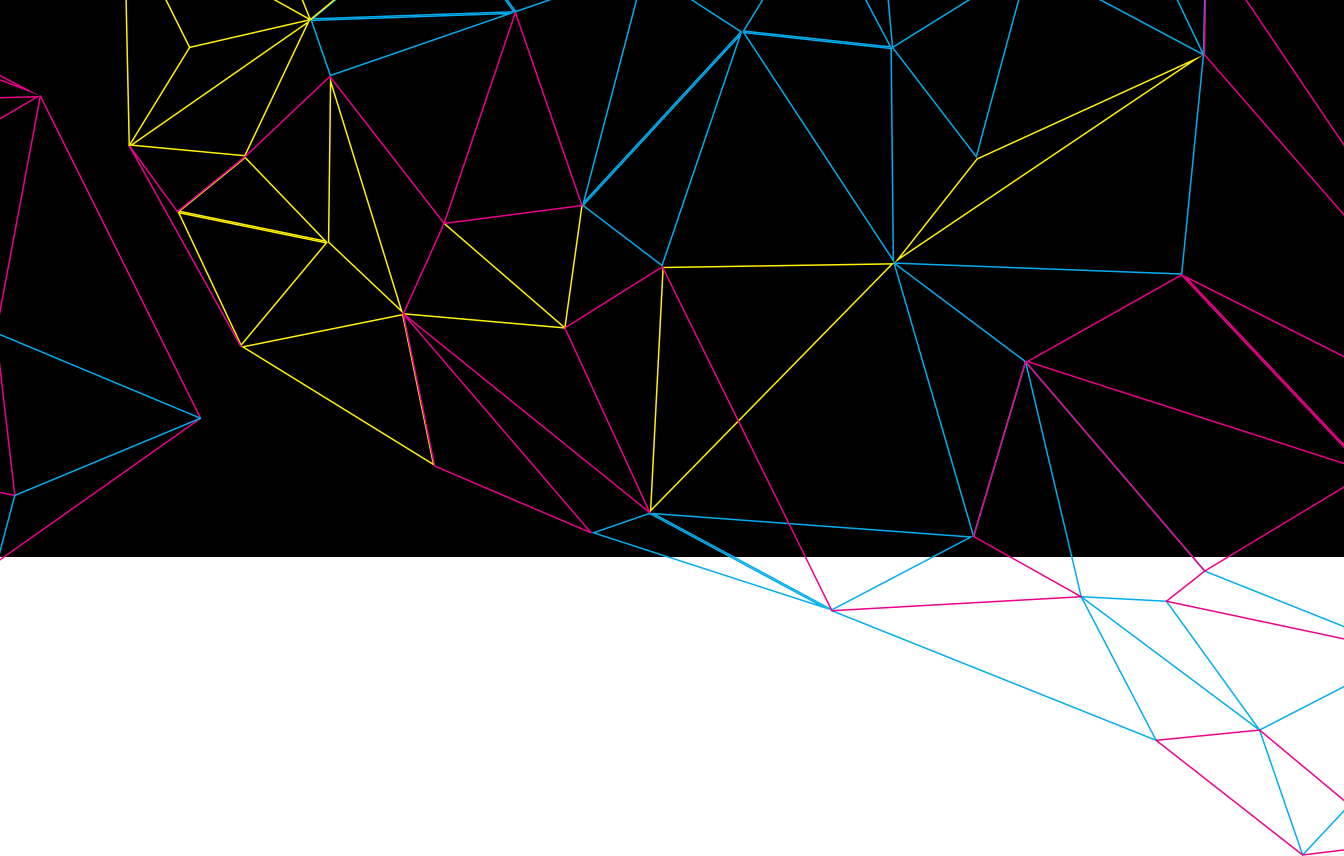
standards outlined in the certification program; however, the certification was awarded to the Xerox 700 using a Fiery DFE. The Xerox 700 that is being tested uses a FreeFlow DFE; therefore, it is possible that there will be some deviations from the certification program.

The predicted outcome is that there will be a fair amount of variation across all of the measured properties. However, it is likely that the variations may be greater for some properties than others. This is mainly attributed to the fact that there are no printing plates or fine-tuning adjustments. The image is produced through digital means, being cached and re-used by the Raster Image Processor (RIP) with every copy printed. This allows for variations, as digital information is very dynamic and not static compared to a physical printing plate. Because so many different parameters are being evaluated

for this test, it is difficult to say whether the press, overall, is consistent or not. Instead, each parameter will be addressed individually based on the results. If a parameter is generally unable to meet tolerances outlined by the IDEAlliance Digital Press Certification Program or other specifications, that specific parameter will be considered inconsistent. However, if the parameter consistently conforms to tolerances outlined by the certification program or another specified printing specification, then that parameter will be considered consistent.

Definitions

■ **CIELAB Color Space:** "The 1976 CIE color space transformation with the dimensions L*, a*, and b*, in which equal distances in the space represent approximately equal color differences" (Field, 2004, p.346).

■ **Delta E (ΔE):** The overall measured difference between two colors in the CIELAB color space represented as ΔE (efi, n.d). Several variants of the ΔE equation exist and each consider different variables of color difference.

■ **Solid Ink Density (SID):** The measure of perceived darkness based on the light absorption or reflectance of a solid ink patch on the printed sheet, as well as the paper underneath. (Breede, 2006, p.107).

■ **Front-to-Back Registration:** The alignment of graphics on one side of the sheet relative to the graphics on the other side of the sheet (Kipphan, 2001, p.309).

■ **Color-to-Color Registration:** The alignment of overlapping colors in multi-color printing (Kipphan, 2001, p.278).

Testing and Evaluation Principles

The design of this test is to measure color consistency using the specifications in the IDEAlliance Certification as a benchmark for colorimetric measurements. Consistency in registration will also be evaluated on a visual approach and compared to the capabilities of the press as outlined by the manufacturer. In order to accomplish this task, a test form was specially created so that all elements that we intend to measure are present. This included some color measurement tools and elements as outlined by the IDEAlliance Digital Press System Certification. This will ensure that we have the means to compare to this certification, as well as others we deemed necessary based on our intention to evaluate registration and overall consistency. To ensure validity in our colorimetric test results, the press was calibrated before the press run using the i1 Spectrophotometer and a printed test chart generated from the Xerox 700. Calibrating the press beforehand is important in creating a consistent printing environment (IDEAlliance, 2011).

This test was completed by printing 500 test forms on the Xerox 700. Whilst the amount of sheets printed is half the amount that was used in the IDEAlliance Digital Press Certification Program, a larger number of the sheets were evaluated. In the certification program, 1000 sheets were printed, but only 10 sheets were measured (IDEAlliance, 2011). With such a
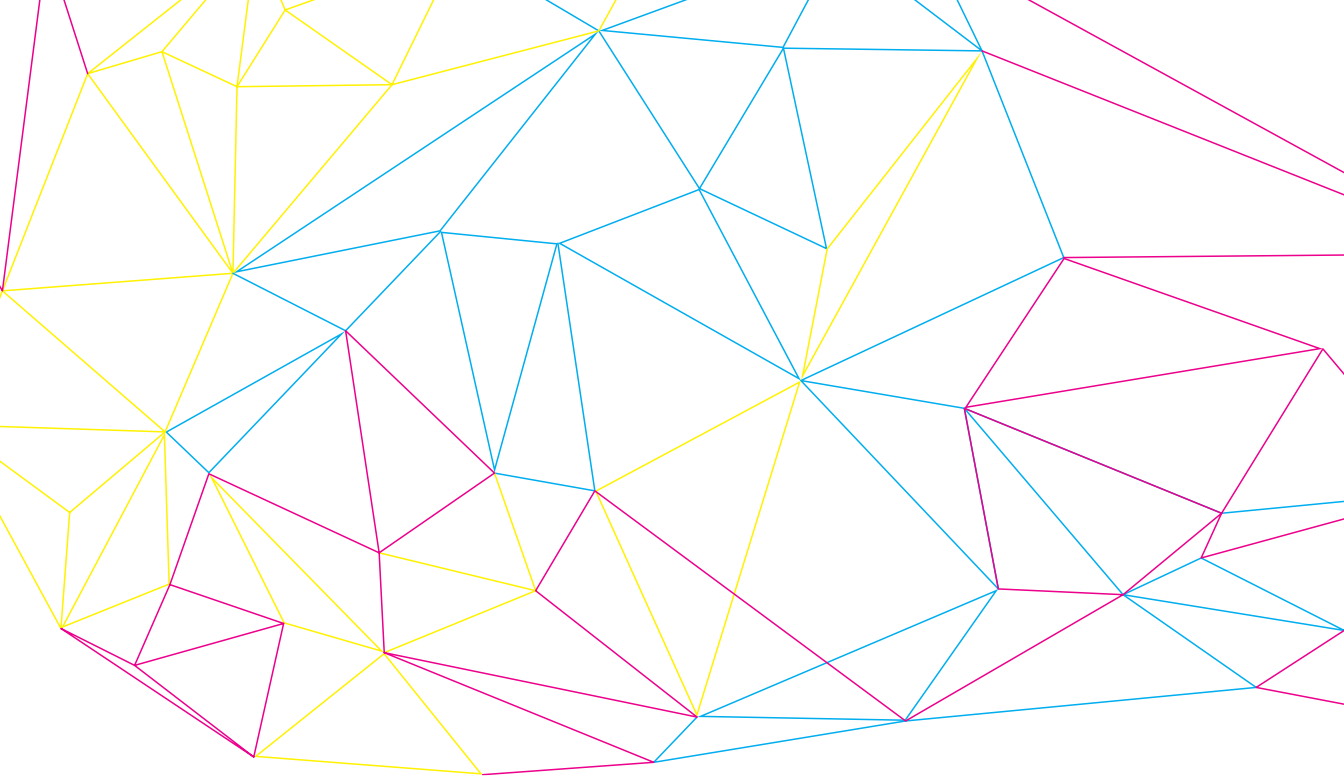
small sample size compared to total number of sheets printed, a lot of changes in the variables could be missed. In order to more accurately evaluate the consistency of the Xerox 700, we decided to measure 50 of the 500 sheets printed instead. The larger sample size allows us to see more differences and changes in the variables throughout the entire run. Also, the certification program only measures 5 sequential sheets (IDEAlliance, 2011). The problem with the small sample size is once again present, making it an unviable representation of such a large press run. In order to counteract these issues, a larger sample size within our 500 printed sheets was evaluated. Out of those 500 sheets, 50 random and 20 sequential sheets were quantified for color consistency, and evaluated for registration. The purpose of conducting measurements for these two sets of sheets is to observe how the variables change over the entire production

of the 500 sheets in comparison to smaller consecutive portion of the press run. The 50 sheets that were pulled for evaluation were randomly generated in Microsoft Excel. The range of consecutive sheets, which were to be evaluated, was also randomly generated in Microsoft Excel. With regards to registration, 10 sheets were pulled from the 500-sheet pile in random but somewhat consistent intervals in order to measure the change or consistency along the entire press run.

The solid CMYK and overprints were measured with a spectrophotometer for L*a*b* and density values. Both density and L*a*b* values are measured due to the relationship between the two. A change in density will often also result in a change in L*a*b* values. It should also be noted that a single spectrophotometer, the X-Rite 530 Series Spectrophotometer (Serial Num-

ber - 051480), was used to conduct all measurements. This is because of inter-instrument agreement and instrument repeatability. Despite the accuracy of an instrument, there will always be some variation between measurements made by 2 separate instruments of the same model. The variation for consecutive measurements by the same instrument is always a lot lower than the variation between 2 different instruments (X-Rite, 2012). In order to minimize the amount of variation in our measurements, the same device was used for the entire process.

Registration will be measured through use of a digital microscope called the Dino-Lite Digital Microscope. For front-to-back registration, a light source would be put under elements that are supposed to back up to each other perfectly and the amount of offset or deviation will be captured and measured with the digital microscope. For color-to-color registration, 4 registration marks, 1 from each corner of the test form, will be viewed and measured with the digital microscope. The 4 values will then be averaged to be representative of the color-to-color registration of the page. However, if any of these registration marks breaks past IDEAlliance's tolerance of 0.1 mm, then that value will be used as the representation for that sheet (IDEAlliance, 2011).

Figure 1

Custom test form with indications of where the colour and registration measurements were taken for test.

To determine how consistent the Xerox 700 is, the data we collected will be compared to the IDEAlliance Digital Press Certification program as well as standards and specifications outlined for other printing processes in the graphic arts industry. As actual standards or specifications do not exist for digital presses, the certification program acts as the main measure or benchmark of the press's performance. For parameters that are not outlined in certification program, specifications from other printing processes will be used as a benchmark. Also, in regards to registration, the data will be compared to the capabilities of the press as outlined by the manufacturer. In accordance to these premises, our parameters will be compared to the following benchmarks:

■ Density will be compared to GRACoL specifications in which the solid ink densities are outlined as follows with an allowable ± 0.1 tolerance (IDEAlliance, 2007):

   ■ K: 1.60

   ■ C: 1.30

   ■ M: 1.40

   ■ Y: 1.00

■ Color consistency will be compared to the IDEAlliance Digital Press Certification Program in which it states that the maximum E^*_{oo} between any solid patch and the average $L^*a^*b^*$ of that patch throughout the entire press run should not exceed 2.0 (IDEAlliance, 2011).

■ Registration will also be compared to the IDEAlliance Digital Press Certification Program in which it is indicated that color-to-color registration should be within 0.1 mm (IDEAlliance, 2011). Front-to-back registration will also
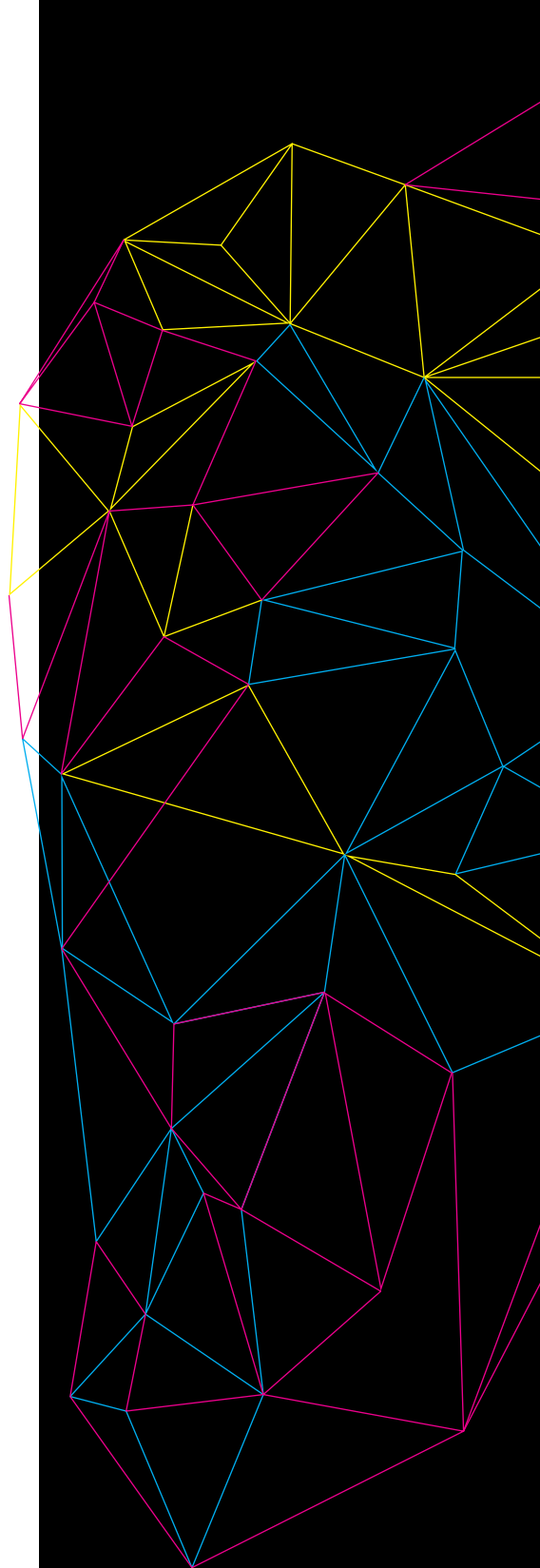
be evaluated and compared to the Xerox 700's manufacturer's specifications in which it is said that the press can achieve registration of 1mm or less in front-to-back applications (Xerox, 2009).

There are some considerations when collecting the data for evaluation. The use of E^*_{oo} is vital when comparing the color data to the certification program, as there are many versions of the E formula. The values in the certification program are based on the E^*_{oo} equation. Each equation has different considerations and will result in a different value, so if the E^*_{oo} equation is not used, then the press would not be evaluated properly. E^*_{oo} is the most

recently formulated equation which is considered to be most accurate due to its utilization of variables that address shortcomings in the human eye, making it the most accurate representation of the human eye's perception of color difference (Habekost, 2013). When evaluating the registration of the printed sheets under a microscopic camera, a scale should be present because it provides a basis of measurement in the enlarged image, as one cannot accurately measure the distance between objects viewed under a microscope due to the change in proportions. This ensures that whatever is being viewed can be perceived in an aspect that allows for proper measurement.

Equipment

- Xerox 700 Digital Color Press

- X-Rite 530 Series Spectrophotometer (Serial No. - 051480)

- X-Rite i1 Spectrophotometer (Serial No. - 3.278-611601-2)

- Dino-Lite Digital Microscope

Materials

- Domtar Opaque - Plainfield 11" x 17" 50 lbs, 20M, 74 g/m^2, 96 brightness, 150 whiteness

Equation

CIE94 Equation used

$$\Delta E^*_{00} = \sqrt{\left(\frac{\Delta L'}{k_L S_L}\right)^2 + \left(\frac{\Delta C'}{k_C S_C}\right)^2 + \left(\frac{\Delta H'}{k_H S_H}\right)^2 + R_T \frac{\Delta C'}{k_C S_C} \frac{\Delta H'}{k_H S_H}}$$

Procedures

Part 1: Creating the Test Form

1. Create a new 11" by 17" (tabloid) landscape file on Adobe Illustrator.

2. Place all required testing elements such as: a color bar on the artboard containing solid and tint color patches; grays patches made from CMY and from K; small and large text; a graphic image; and registration marks along the border of the artboard.

3. Export the test form as a PDF file.

Part 2: Warming up & calibrating the Xerox 700

1. Send the PDF of the test form to the Xerox 700's Freeflow DFE.

2. On the DFE, adjust the properties of the job to the following:

- 50 sheets
- printed on 11" x 17" tabloid stock
- printed in color
- duplex

3. Apply the changes and release the job.

4. After the press has finished printing the 50 sheets and has warmed up, select the calibration option from the DFE and follow the steps as outlined by the DFE to calibrate the press, making sure to use the X-Rite i1 Pro Spectrophotometer calibration method as opposed to the Xerox scanner method.

Part 3: Printing the Test Form

1. Adjust the properties of the test form job to print 1 sheet and release the job.

2. Visually evaluate the front-to-back registration of the printed sheet and make positioning adjustments through the DFE to achieve the best registration possible.

3. Print another copy of the testform to evaluate the results of the adjustments.

4. Repeat steps 1 to 3 until adequate front-to-back registration is achieved.

5. Adjust the properties of the test form job to print 500 sheets and release the job.

Part 4: Measuring the Test Form

1. Measure the all L*a*b* values of the solid colours using the X-Rite 530 series spectrodensitometer.

2. Record all values in Microsoft Excel. Average the L*a*b* values of each colour.

3. Calculate the E^*_{oo} of each solid colour using the averaged L*a*b* values as the reference/second colour.

4. Graph the results with indication of the averages, aimpoints, tolerances, and trend lines.

5. Visually inspect the registration and front-to-back registration under a microscope over a light table.

Results

Solid Ink Densities of CMYK
(50 Random vs. 20 Sequential)

In comparison of the density data for the 50 random sheets and the 20 sequential sheets, some general trends are seen consistently between the two; however, there are some properties which are unique to each set of measurements as well. In both instances, the cyan SID lies within the tolerances around the 1.30 density target aimpoint. The data points for the 50 random sheets appear to fluctuate around the aimpoint and to quite a large degree. The data points for the 20 sequential sheets, however, tend to lie below the 1.40 density aimpoint. There is less fluctuation present in the 20 sequential sheets as well, as indicated by range of data points compared to the 50 random sheets. Both sets of cyan solid ink density data also have a very subtle negative trendline. For the magenta SID in both sets of data, almost all data points lie below the 1.40 density target aimpoint. There are also several points in both instances that lie either on the minimum tolerance or below it. There is also a much greater amount of fluctuation present in the 20 sequential sheets than the 50 random sheets. While the trendline for both sets of magenta SID data are negative, the trendline for the 20 sequential sheets are a lot more drastic and noticeable than that of the 50 random sheets. In terms of the yellow SID, all data points lie below the 1.00 density target aimpoint. Most points are around the minimum tolerance, with

several lying right on it or even below it. Both sets of data have approximately the same level of fluctuation and both contain a very subtle negative trendline. The black SID data points for the 50 random sheets are generally within the tolerances with a few points that lie above the maximum tolerance. In both the 50 random sheet and 20 sequential sheet data, most black SID data points are between the 1.60 density target aimpoint and the maximum tolerance, although there are a few that lie below the target aimpoint. The data points also seem to progressively get closer to the target aim point as the press run goes on. The highest amounts of fluctuation between all colors are present in the black SID. Both black SID trend lines are negative, although the trendline for the 50 random sheets is slightly more drastic. Overall, the SID of all the toners tends to be decreasing throughout the press run, although this trend is most noticeable in the data for magenta in the 20 sequential sheets and for black in the 50 random sheets. Fluctuation also exists in all colors to varying degrees. Additionally, the overall average of the densities is higher in the 50 random sheets compared to the 20 sequential sheets. Finally, the cyan SID appear to be the color that is closest to meeting the GRACoL specifications, while yellow SID deviated greatly from the GRACoL target aim point.

Solid Ink Density — Minimum Tolerance — Maximum Tolerance

Sold Ink Density — Target Aimpoint — Linear (Solid Ink Density)

Solid Ink Density   ▬ Minimum Tolerance   ▬ Maximum Tolerance

⬤ Sold Ink Density   ▬ Target Aimpoint   ▪▪▪ Linear (Solid Ink Density)

Table 1

SID averages, aimpoints, and range of 50 random sheets printed on the Xerox 700.

SID	Cyan	Magenta	Yellow	Black
Aimpoint	1.30	1.40	1.00	1.60
Average	1.31	1.33	0.93	1.63
Minimum	1.25	1.28	0.90	1.58
Maximum	1.38	1.37	0.96	1.73
Range	0.13	0.09	0.06	0.15

Table 2

SID averages, aimpoints, and range of 20 sequential between pages 429 to 448 printed on the Xerox 700.

SID	Cyan	Magenta	Yellow	Black
Aimpoint	1.30	1.40	1.00	1.60
Average	1.27	1.32	0.91	1.63
Minimum	1.23	1.29	0.89	1.57
Maximum	1.34	1.45	0.94	1.68
Range	0.11	0.16	0.05	0.11
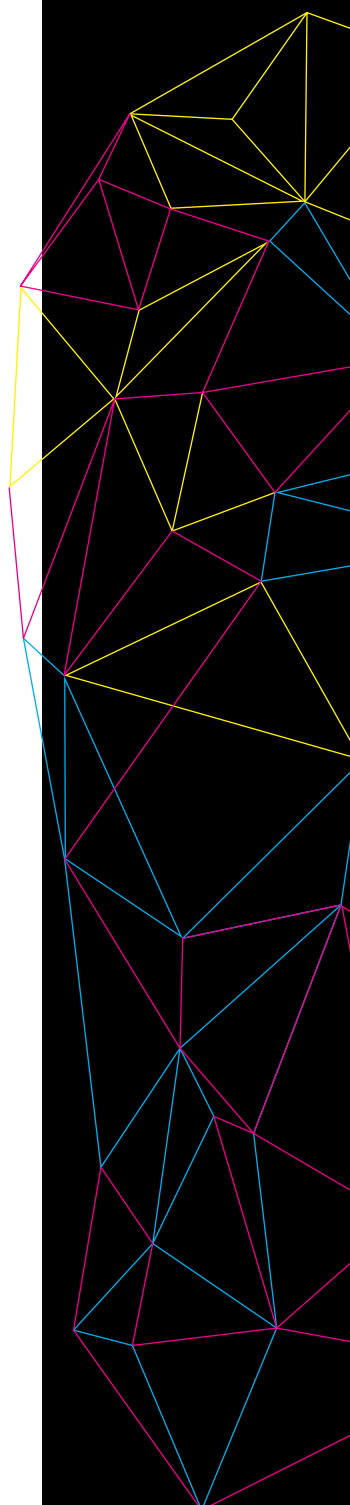
CIELAB values of CMYK
(50 Random vs. 20 Sequential)

Color appears to be rather consistent throughout the press run, although there are some differences in fluctuations as well as some outliers. All of the cyan, yellow, and black E^*_{00} data points for the 50 random sheets and 20 sequential are within well within the 2.0 E^*_{00} tolerance. Cyan's data points for the 20 sequentials sheets have less color difference with an average of 0.52 E^*_{00} and a more narrow range than the 50 random sheets measured. Out of all solid colors measured, yellow shows the least fluctuation. Black on the other hand, has the most drastic amount of fluctuation out of all the colors. The trend lines for these three colors in the 50 random sheets are all negative, however they have a very shallow slope. For the 20 sequential sheets though, yellow retains its shallow negative trend line while cyan and black change to a subtle positive trendline. Magenta, on the other hand, has one point that is outside of the 2.00 E^*_{00} tolerance in the 20 sequential sheets, whilst all points in the 50 random sheets are within the tolerance. The single point outside of the tolerances appears to be an outlier due to its drastic difference from the rest of the data points in its set of measurements; however, without a justified assignable cause, its inclusion in the data is required. There is also a negative trend line throughout both the 50 random sheets and 20 sequential sheets. Overall, it seems to be that the trend for color accuracy in CMYK is that as the press run progresses, color accuracy improves. This is most noticeable in the graphs for cyan and black for the 50 random sheets in which the trend lines have a slightly steeper negative slope. These graphs show a pattern similar to that of the density graphs. The density values decrease throughout the press run and so does the amount of color difference.

E^*_{00} Maximum Tolerance   Linear E^*_{00}
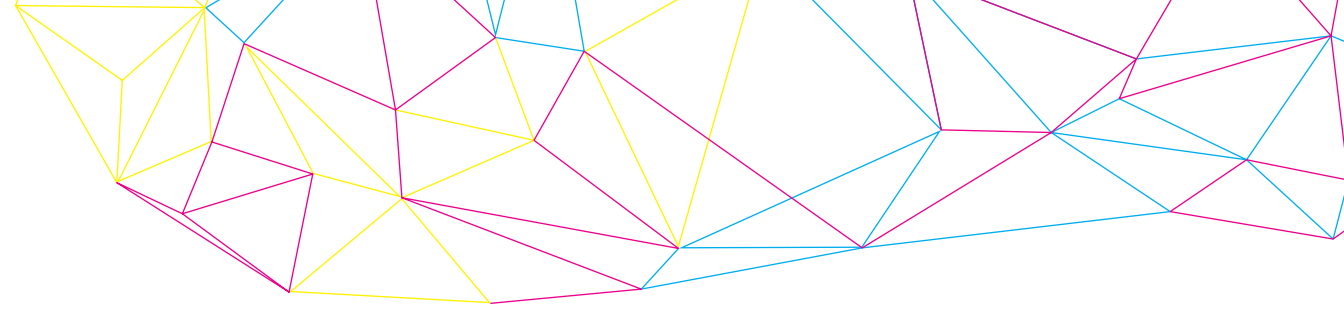
E*$_{00}$ Maximum Tolerance   Linear E*$_{00}$
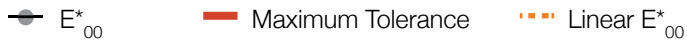
E*$_{00}$ Maximum Tolerance   Linear E*$_{00}$
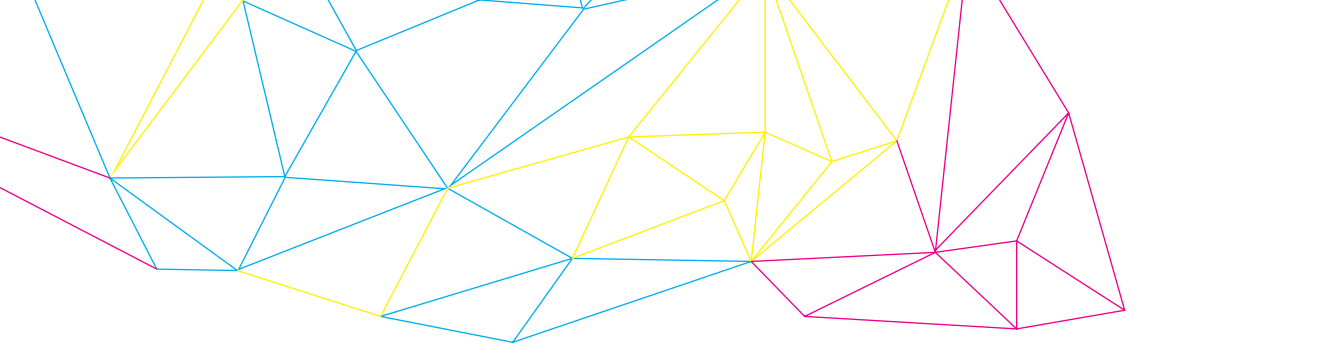
Table 3

ΔE^*_{00} of Solid CMYK for 50 random sheets printed on the Xerox 700.

ΔE^*_{00}	Cyan	Magenta	Yellow	Black
Average	0.77	0.58	0.70	0.45
Minimum	0.25	1.30	0.37	0.04
Maximum	1.39	1.10	1.41	1.45
Range	1.14	0.97	1.12	1.41

Table 4

ΔE^*_{00} of Solid CMYK for 20 sequential sheets between pages 429 to 448 printed on the Xerox 700.

ΔE^*_{00}	Cyan	Magenta	Yellow	Black
Average	0.53	0.69	0.51	0.42
Minimum	0.19	0.23	0.20	0.09
Maximum	1.00	3.09	1.05	1.05
Range	0.81	2.89	0.85	0.96

CIELAB values of RGB
(50 Random vs. 20 Sequential)

The RGB overprints generally appear to be able to meet the tolerances outlined by the IDEAlliance Digital Press Certification Program with the exception of some sheets, but there is a lot of fluctuation within the data points. The red overprints between the 2 sets of sheets resulted in an average E^*_{oo} of approximately 0.70. However, in the 20 sequential sheets there is one point which resulted in a E^*_{oo} of 4.82. The drastic difference between this point and the rest suggest that this point may possibly be an outlier, however, an assignable cause cannot be determined, so it is included in the final data. The green overprints averaged around 0.75 E^*_{oo} between the 2 sets of sheets. Like the red overprints, there appears to be 1 point which is drastically different from the others that it should be deemed an outlier, but with no assignable cause, it is a data point that has to be considered. Additionally, in the 50 random sheets, there is a single point at the start which lies right above the maximum tolerance. The level of fluctuation in the green overprints is quite high. Green is also the only overprint with a positive trend line. The blue overprints averaged around 0.80 E^*_{oo} between the two sets of sheets. One point lies above the maximum tolerance in the 50 random sheets, however, the difference is not drastic enough to be thought of as an outlier. High levels of fluctuation exist for the blue overprints as well. Overall, most overprint data points are within the tolerance level of 2.00 E^*_{oo}. There is a small amount of points that lie outside the tolerance and even some evident outliers present in the data, but the lack of an assignable cause makes them permissible. There are also significant amounts of fluctuation among all of the overprints, as shown by many dramatic peaks and valleys in all of the overprint graphs in both the 50 random and 20 sequential sheets. In these set of colors, it is difficult to determine whether there is a recurring pattern between the red, blue, and green throughout the press run. The graphs show no indication of a clear trend such as a recurring pattern for the solid CMYK color data points; the steadily decreasing E^*_{oo} values.

E^*_{00} Maximum Tolerance   Linear E^*_{00}

E^*_{00} Maximum Tolerance   Linear E^*_{00}

$\bullet$ E^*_{00} ▬ Maximum Tolerance   ▪▪▪ Linear E^*_{00}

Table 5

$\triangle E^*_{00}$ of Solid RGB for 50 random sheets printed on the Xerox 700.

$\triangle E^*_{00}$	Red	Green	Blue
Average	0.64	0.85	1.04
Minimum	0.18	0.15	0.25
Maximum	1.34	4.71	2.77
Range	1.16	4.56	2.52

Table 6

$\triangle E^*_{00}$ of Solid RGB for 20 sequential sheets between pages 429 to 448 printed on the Xerox 700.

$\triangle E^*_{00}$	Red	Green	Blue
Average	0.82	0.66	0.71
Minimum	0.11	0.14	0.16
Maximum	4.82	1.60	1.82
Range	4.71	1.46	1.66

Front-to-Back & Color-to-Color Registration

In terms of front-to-back registration, the pages near the beginning of the press run had tighter front-to-back registration than the ones near the end. There were a few instances of the registration breaking past the 1mm tolerance that was indicated by the manufacturer. The unconformity to this tolerance starts relatively early in pages at the end of the 100s. Although there was some fluctuation in the measurements, the general trend line shows that the registration was progressively getting worse. For color-to-color registration, all measured sheets were well within the tolerances set by IDEAlliance. There was a small amount of fluctuation, but the steady trend line shows that color-to-color registration may likely never break through the tolerances.

Figure 2

Front-to-back registration on page 48 with a very small deviation of 0.14 mm.
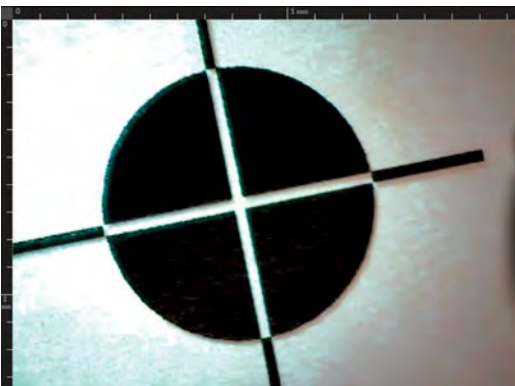

Figure 3

Front-to-back registration on page 134 deviates to the left and downwards by 0.46 mm. This deviation is within tolerances.
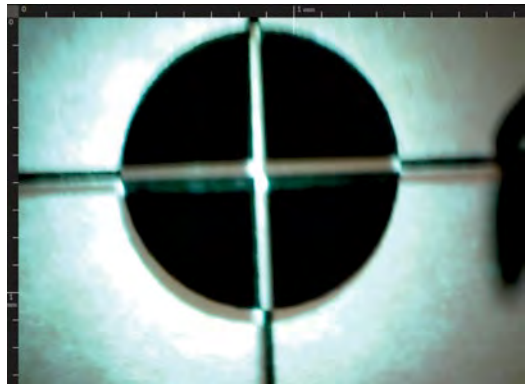
Figure 4

Front-to-back registration on page 331 deviates to the right by 1.09 mm, which is outside of the 1 mm tolerance in the IDEAlliance Certification.
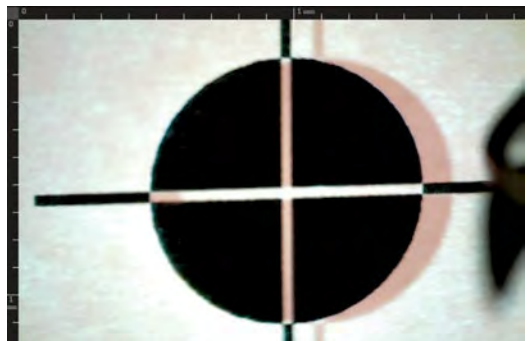
Figures 5 to 8 shows the four registration marks evaluated at each corner of one test form. All sheets measured had perfect registration similar to the registration marks depicted in the figures.

Figure 5

Color-to-color registration mark at the top left corner of the test form.

Figure 6

Color-to-color registration mark at the top right of the test form.

Figure 7

Color-to-color registration mark at the bottom left of the test form.

Figure 8

Color-to-color registration mark at the bottom right of the test form.
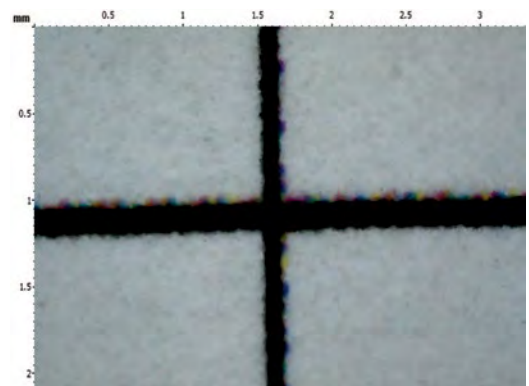
Deviation   Maximum Tolerance   Linear (Deviation)

Conclusion

The sporadic fluctuations in the cyan SIDs as well as its overall ability to consistently meet the GRACoL SID target aimpoint might be a result of Optical Brightening Agents (OBA) within the paper. The substrate that this test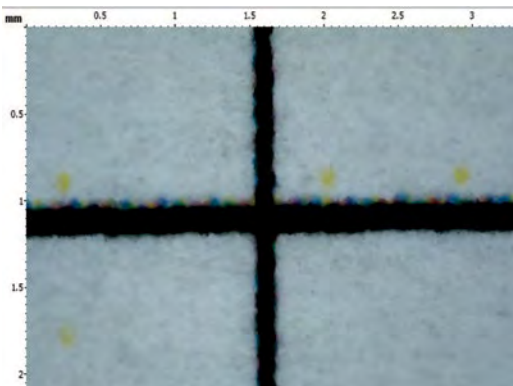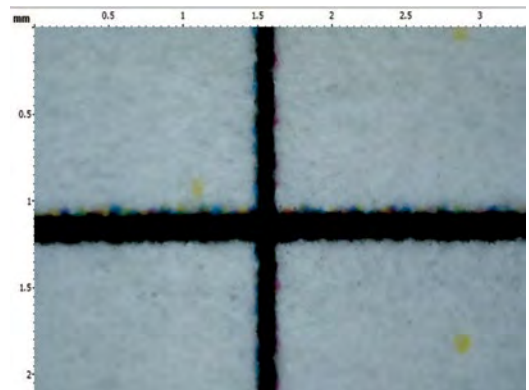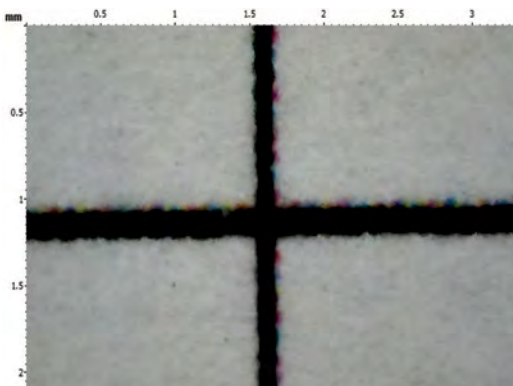 was performed with is categorized as "Britewhite," with brightness and whiteness readings of 96 and 150 respectively. These 2 properties are generally measured on 100 scale, so values at the higher end of the spectrum and even beyond it are indicative of OBAs being within the substrate (Xerox, 2005). Based on this, it is likely that the tested substrate has OBAs present within it, thus affecting how printed colors are perceived by spectrophotometers. The presence of OBAs makes substrates appear whiter and a blue tint, especially when viewed under UV light settings. Spectrophotometers do not take the reflectance of UV light into account when taking measurements, and in turn, just interprets it as blue light being reflected; thus, resulting in higher readings for colors such as cyan (Chaikovsky & Garrison, 2012).

The use or lack of color management during the press run could have also contributed to the results we acquired. Use of color management on a DFE tends to prioritize an accurate reproduction of color through the use of multiple colors without considerations for things such as density or grey balance (A. Sharma, personal communication, April 2, 2014). Without
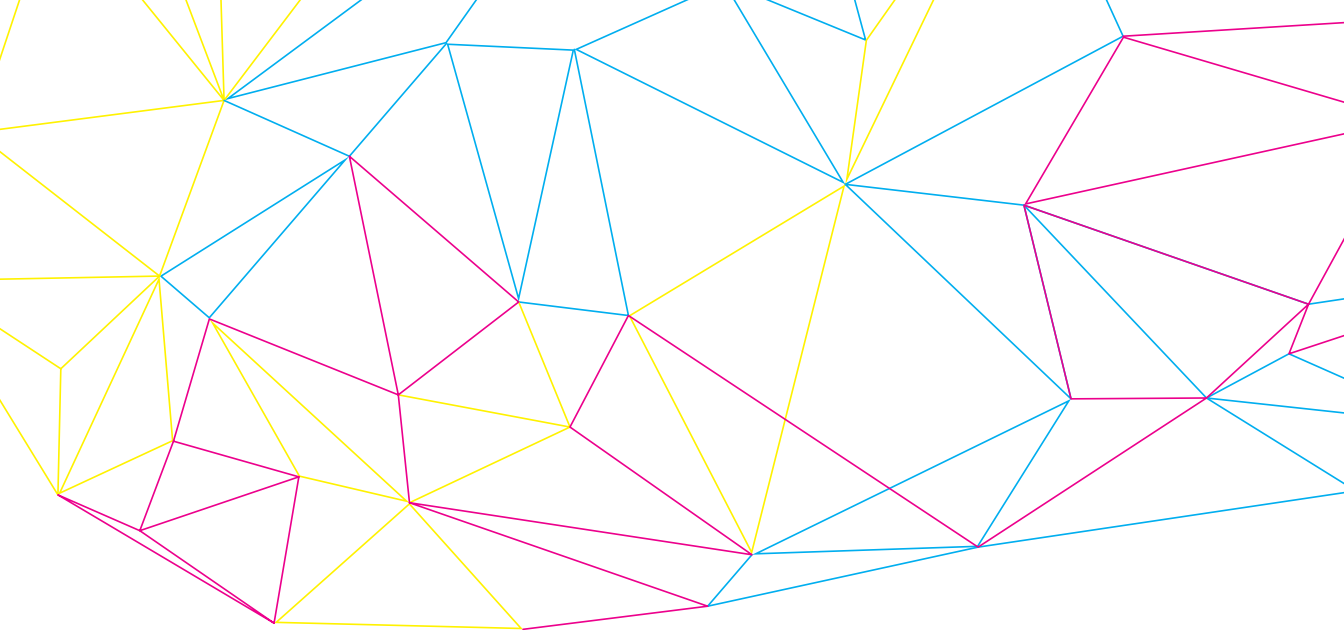
color management, colors are printed with more purity, using only the respective color to print (A. Sharma, personal communication, April 2, 2014). Color management was not used in our press run and as such, colors remained pure but the accuracy is questionable. Despite this, color consistency was relatively good overall. The press was capable of mostly achieving E^*_{00} values of under 2.00. Using color management may have resulted in even better E^*00 values; however, the additional mixture of colors may have consequently affected the densities, thus causing more fluctuation and inaccuracies.

The large amount of fluctuation could also be the result of the paper being uncoated. Uncoated paper is believed to have low ink holdout and can negatively affect the toner adherence to the paper and the way light reflects off the color (MacMillianGraphics, 2003). Considering the level of accuracy of a spectrophotometer, small variations could affect the results, including the particle size of the toner and its distribution when printed. Toner is uneven and angular particles of various shapes;

thus, when printed, the distribution would not be completely uniform (Xerox, 2013).

While the SID of the process colors were all within the GRACoL tolerances, they did not necessarily meet the target aim points. This may be due to the pigments/colorants that were used to produce the toners. The different composition between offset lithography inks and toner affect how color is reproduced and whether or not certain density values can be achieved by each of the compositions. This provides some explanation as to why the yellow and magenta SIDs were generally lying closer to the minimum tolerance liit, as the difference between toner and ink for these colors could be drastically different. This makes it difficult for the toner to meet GRACoL tolerances.

A general trend that was observed was that as density decreased, the E^*_{00} decreased as well. This indicates that even though most densities at the start and end of the pressrun were within the GRACoL tolerances, they were still too high; thus, resulting in larger color differences.
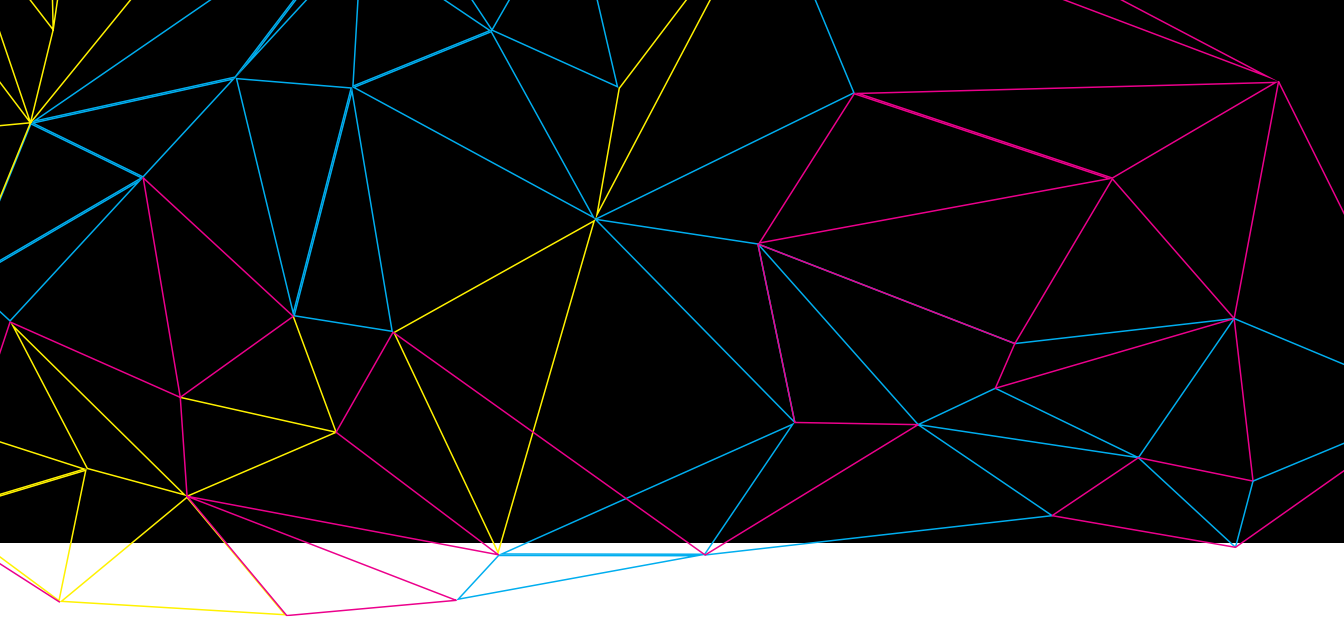
As the press run continued, density started to subtly decline. This could be attributed to the strain put on the press due to the continuous run length. At the same time, this pattern shows how tolerances from 2 different specifications do not integrate into the same test effectively (Vogl, n.d.). In this test, lower densities are required to minimize color differences, however, most density values are not even meeting the GRACoL specification aimpoints. A compromise or balance of these two parameters will then need to be made. One can either ignore the density aimpoints in order to achieve optimal color consistency or try to achieve the density aimpoints at the expense of some color consistency.

A lot of our results are in accordance with published information. The GRACoL specification outlines a set of densities that should be met for offset lithographic printing and these aim points and tolerances were used to evaluate the Xerox 700's ability to remain consistent in relation to these values. Although

these are 2 completely different printing processes, the values represent a level of quality within a printed piece and comparison to these values not only gives a benchmark to measure consistency from, but also indicates, to some degree, the amount of quality that the Xerox 700 can produce. Given that the SIDs of all the colors, with the exception of only a few data points, fall within the tolerances outlined by GRACoL specifications, it can be said that in terms of SID, the Xerox 700 was able to meet GRACoL specifications.

According to the IDEAlliance Digital Press Certification Program, the maximum E^*_{00} between any solid patch and the average $L^*a^*b^*$ of that patch throughout the entire press run should not exceed 2.0 (IDEAlliance, 2011). Most of our data is within this indicated tolerance, with the exception of a small number of points which might be outliers, thus indicating that the press was generally able to meet IDEAlliance's tolerances. IDEAlliance also indicates that the
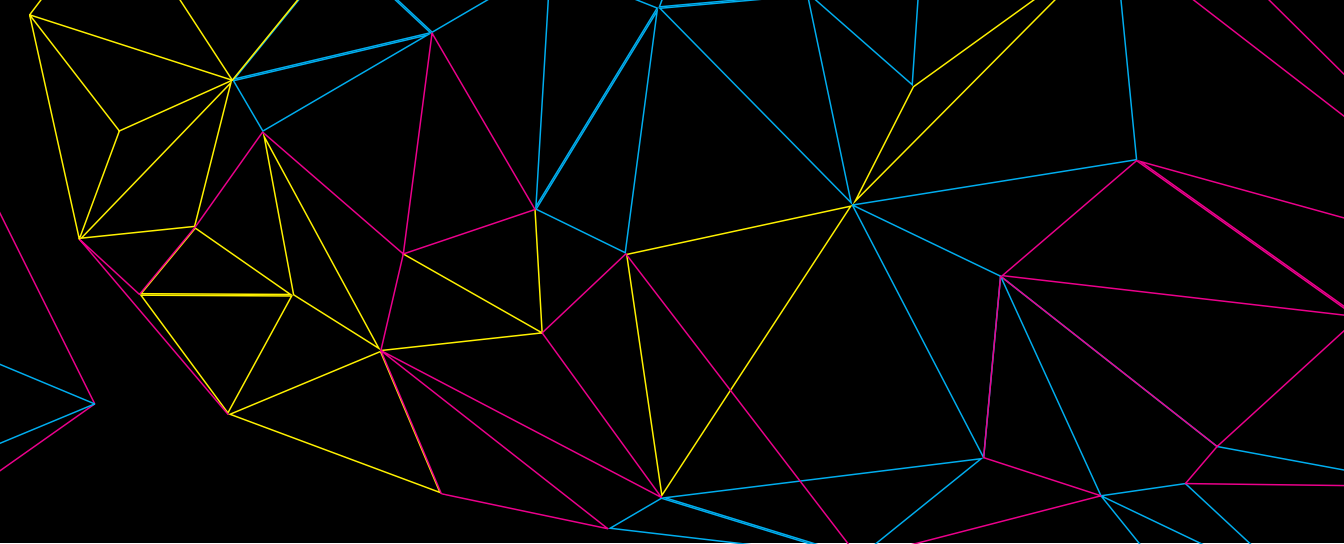
maximum tolerance for color-to-color registration should be 0.1mm and all of our data was able to meet this tolerance.

The manufacturer of the Xerox 700 states in one of its specification brochures that the Xerox 700 is able to achieve front-to-back registration of 1mm (Xerox, 2009). Our data indicates that while this is achievable, there is absolutely no consistency in the press's ability to stay within this tolerance. After having optimally adjusting the front-to-back registration on the DFE, the front-to-back registration on the prints was nearly perfect. However, after approximately 190 sheets, fluctuation in this parameter became really sporadic and drastic. The amount of deviation started to gradually increase at this point and never returned to registration that was as optimal as when it had been freshly adjusted. Out of the 10 sheets that were measured for front-to-back registration, 4 of the sheets were unable to meet the 1 mm tolerance. If the same ratio was applied to the

entire press run, then there would be 200 sheets that do not back up to each other adequately. So whilst the press is technically able to achieve a front-to-back registration of 1mm, this may only be applicable to shorter runs, as this parameter starts to deviate greatly after a certain number of sheets.

The results contradicted our preconceived assumptions on the Xerox 700's color and registration consistency throughout a medium-to-long press run. Our data shows that while there is some fluctuation in the data for density, color consistency, and color-to-color registration, all 3 of these parameters were able to meet tolerances outlined by IDEAlliance and GRACoL, with only some minor exceptions. It is inevitable that there will always be some data points that do not meet the tolerances, as no printing process is absolutely perfect. That means that the data points that slightly breakthrough tolerances are attributed to this while those that drastically break tolerances are due
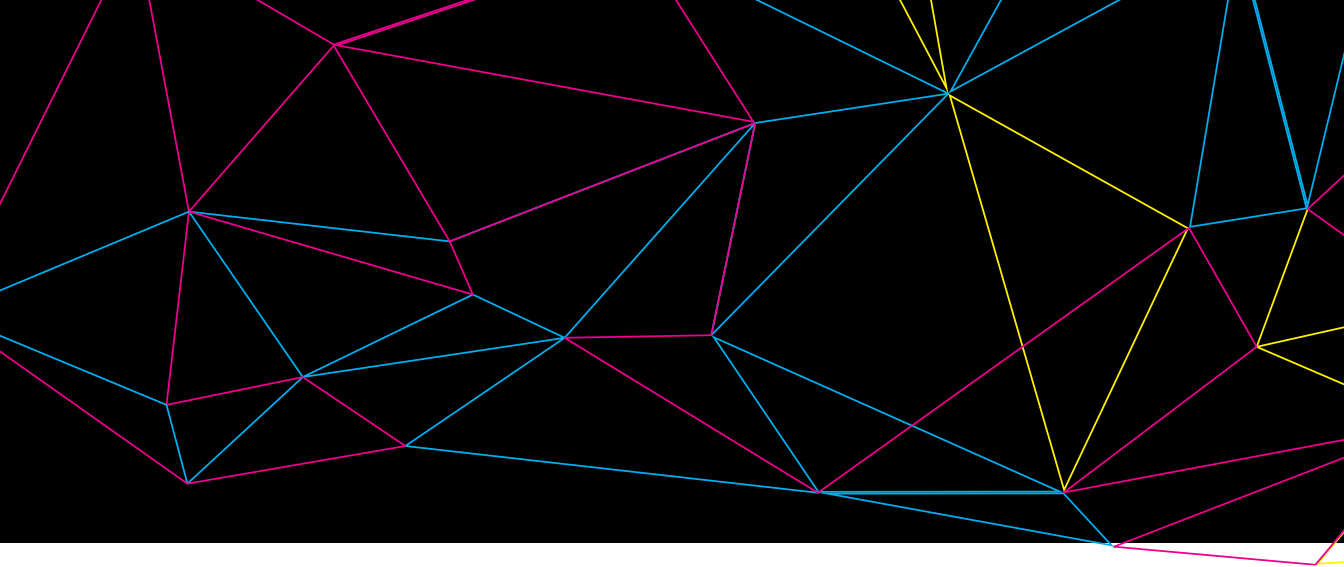
to the high possibility of them being outliers. Additionally, we measured a much bigger sample size in comparison to the certification program, so the odds of finding data that do not meet the tolerances are a lot greater. Despite this, the number of points we found that do not meet the tolerances is really small. Had all testing been done in accordance to the certification program, it could have been possible that no data points that are out of tolerance been discovered at all. Under such presumptions, it was concluded that by being more lenient with the requirements set up for the test, it would hold true that the Xerox 700 is consistent in terms of density, color, and color-to-color consistency.

The same cannot be said about front-to-back registration, as this is the sole parameter in which our hypothesis was confirmed. The data shows that out of only 10 sheets, almost half of the sheets did not meet the front-to-back registration values outlined by the manufacturer. The registration started out really well, but then it began to drastically drift out of the tolerances with no signs of returning back to its initial position. This parameter's overall inconsistency and inability to reproduce values meets our requirements in support of the hypothesis.

Weaknesses exist in every experimental test and the same holds true for this test. Calibrating the equipment and instruments to collect our data, along with the use of Excel functions and equations helped minimize validity issues; however, there are still a number of factors which could have influenced our results. The test forms were printed duplex; thus, colorimetric measurements could have been affected by the show-through of the second form on the other side of the sheets. It was also difficult to quantify the deviation of color registration and front-to-back registration accurately using the ruler on the DPM program. Front-to-back registration was particularly difficult to capture using the microscope because a light table was needed to see the registration marks on the second form to compare to ones on first form. Moreover, the 500 sheets were not measured the same day they were printed. It's unsure whether the pressroom was properly conditioned and whether it affected the sheets while
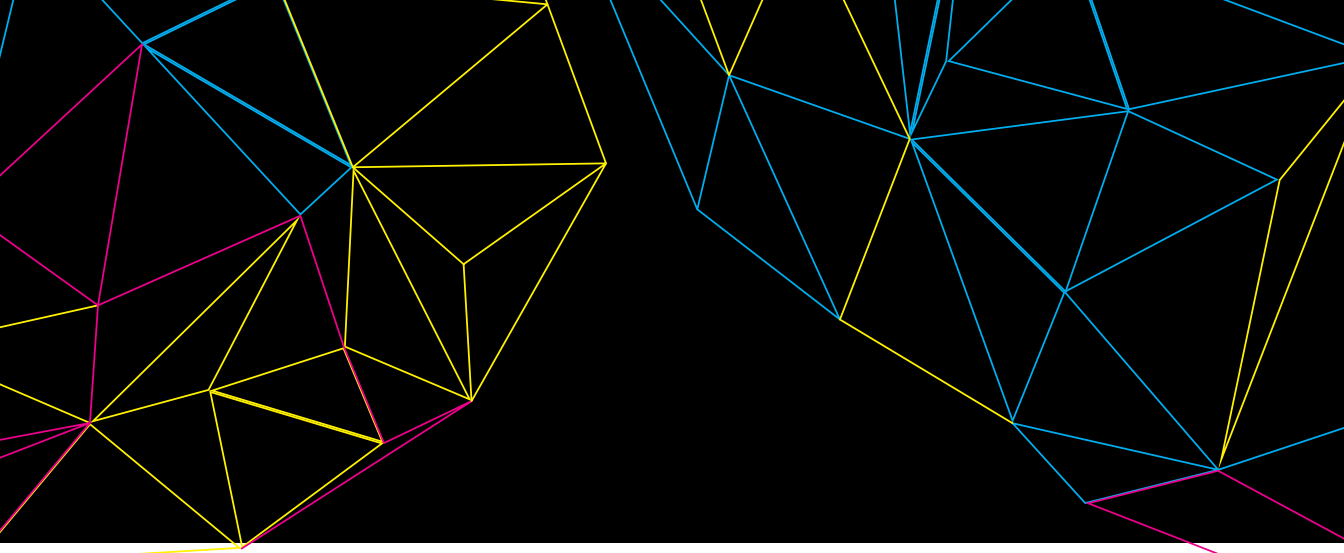
they were stored there. In addition to this, repeatability of the X-Rite 530 Series Spectrophotometer (Serial No. - 051480) is best on a short-term basis. Even though the same device was used for all the measurements, the sheets were measured days apart, which to some degree, affects the repeatability of the instrument. For this test, only 500 sheets were printed instead of 1000 sheets, which is specified in the IDEAlliance Digital Press Certification. 1000 sheets would have given a more accurate representation of consistency throughout a long press run. Also, a lot more sheets were measured in our test than IDEAlliance's certification program. These 2 factors could have both positive and negative implications for the test. Measuring a smaller sample of a larger population means that the odds of detecting errors or anomalies is lower. This could falsely indicate that a press is more consistent than it actually is. By measuring a large sample in a smaller population, a better reprsentation of the press run is being recorded. Although this means better detection of changes, it could actually affect whether or not the press is able to meet certification requirements.

Overall, the intended purpose of this paper is to evaluate how viable digital printing is without an official standard. This viability is evaluated based on a press's consistency and ability to meet existing tolerances or specifications even though they may not be intended for digital presses. It also specially evaluates certain aspects of the Xerox 700 in greater detail than the IDEAlliance Digital Press Certification Program. We intended to discover trends and patterns in regards to consistency for the Xerox 700 to see if its ability to meet IDEAlliance's certification requirements can be repeated. Repeatability of a press's abilities to meet the certification requirements indicates the overall consistency of the press, thus suggesting that standards could be met if they were available.

References

Breede, M.H. (2006). *Handbook of graphic arts equations* (2nd ed.). Sewickley, PA: Graphic Arts Technical Foundation.

Chaikovsky, S. & Garrison, J. (2012). Effects of Optical Brightening Agents on Color Reproduction in Digital Printing. Retrieved April 4, 2014 from http://digitalcommons.calpoly.edu/cgi/viewcontent.cgi?article=1076&context=grcsp

EFI (n.d). *Delta E, delta H, delta T: what does it mean?* Retrieved March 28, 2014 from http://w3.efi.com/en/services/fiery-wide-format-services/~/media/Files/EFI/COM/Services/Delta%20E_H_T.pdf

Field, G. G. (2004). *Color and its reproduction: fundamentals for the digital imaging and printing industry* (3rd ed.). Pittsburgh, PA: Graphic Arts Technical Foundation.

Habekost, M. (2013). *Which color differencing equation should be used?* Retrieved March 30, 2014 from http://www.hdm-stuttgart.de/international_circle/circular/issues/13_01/ICJ_06_2013_02_069.pdf

IDEAlliance (2007). *GRACoL 2007 specifications.* Retrieved April 7, 2014 from http://www.idealliance.org/sites/default/files/GRACoLSpec2007errata.pdf

IDEAlliance (2011). *IDEAlliance digital press certification program.* Retrieved March 31, 2014 from http://files.idealliance.org/Certifications/DigitalPressCert/Digital_Press_Cert_Program_V2.2.pdf

Kipphan, H. (2001). *Handbook of print media* (1st ed.). Germany: Springer-Verlag Berlin Heidelberg.

MacMillan Graphics Ltd. (2003). *Getting it onto the paper: how ink and toner work.* Retrieved April 1, 2014 from http://www.macgra.com/0311Printips.pdf

Vogl, H. (n.d). *Measuring the variation of a digital printer.* Retrieved April 2, 2014 from http://cias.rit.edu/~gravure/tt/pdf/pc/TT4_Vogl01.pdf

X-Rite, Inc. (2012). i1 Publish Pro 2. Retrieved March 28, 2014 from http://www.xrite.com/product_overview.aspx?ID=1914&Action=support&SupportID=5586

Xerox Corporation (2005). *Demystifying three key paper properties.* Retrieved April 3, 2014 from http://www.xerox.com/downloads/usa/en/t/ThreeKeyPaperPropertiesWhitePaper.pdf

Xerox Corporation (2009). *Xerox 700 digital color press.* Retrieved April 2, 2014 from http://www.dahill.com/products/pdfs/Xerox_700_brochure_Specs.pdf

Xerox Corporation (2013). *Xerox emulsion aggregation.* Retrieved April 7, 2014 from http://www.office.xerox.com/latest/SUPWP-01.pdf

2
Measurement & Analysis of
Braille Printing
on Emprint SpotDot

By: Sarah Aspler & Melissa Binsted

Abstract

The world population is changing rapidly, as blindness and sight disabilities become more and more prevalent. In addition, the topic of accessibility to all is one that is finding its way into more conversations. Due to this change, printed products are increasingly requiring tactile applications such as braille. The importance of including braille on printed products, like packaging, and the ability of printers to be able to provide braille-printing services is increasing in relevance, in order to establish a higher level of accessibility on a wide variety of products. Braille is a sequence of raised dots that act as a code by which languages can be read by individuals who are blind or have sight disabilities. Provincial standards for Ontario and European standards for packaging have been formed, as well as the ISO 11156:2011, an international standard implemented which states that packaging should be produced for the accessibility of all users in mind.

The European Committee for Standardization (CEN) states that braille height should be 0.20 mm. This height can be reduced as a result of handling methods. The purpose of this research and test conducted is to focus on the durability of braille height, printed with the Emprint SpotDot, when it is exposed to two different factors, friction and compression. In addition, this experiment was designed to test the Emprint SpotDot's ability to print braille to meet established standards consistently as part of a stable process. To complete this test, a total of 60 braille samples were printed using the Emprint SpotDot on 70 lb coated and uncoated offset stocks and two tests were performed. Firstly, 30 samples of braille on each stock were tested using the Sutherland Ink Rub Tester with a 4 lb weight to simulate the effect of friction on braille height durability. Secondly, 30 samples of braille on each stock were compressed by a 5 lb weight for 24 hours to study the influence that weighted compression had on braille height durability. All braille heights were measured using a digital micrometer

Following data collection, it was concluded that the Emprint SpotDot is a stable process that can print braille on both 70 lb uncoated offset stock and 70 lb coated offset stock that meets and exceeds the braille height standard for pharmaceutical packaging. It was also found that coated paper has a higher resistance to external factors (friction and compression), therefore decreasing less in height than uncoated stock. In all experiments, except testing friction's effect on 70 lb uncoated offset paper, the braille height remained above standard, thus ensuring legibility. It has been determined in our research that braille on coated stock is more durable than braille on uncoated stock.

These tests were designed to replicate the external forces that packaging is exposed to during production and transportation. Despite meet-

ing standards when initially produced, it is critical that the braille height on a product also continues to meet this requirement when it reaches its final end-use application to ensure legibility. Thus, decreases in braille dot height due to external factors must be anticipated for before the production of Braille.

As a raised surface, Braille is vulnerable and always at risk of falling below required standards. Therefore, steps should be taken to reduce the effect these forces have on braille height, such as utilizing coated paper over uncoated, producing a significantly higher than standard braille height or to decrease the braille's exposure to such forces.

Introduction

Braille is a sequence of raised dots that act as a code by which languages can be read by individuals who are blind or have insufficient eyesight for reading (American Foundation for the Blind, 2013). Researching braille is critical because the world's population is changing and the print industry must be flexible in order to conform and meet their needs, in particular accessibility needs. The World Health Organization estimates that there are 285 million people worldwide who are visually impaired (WHO, 2013). Therefore, printing that engages different senses including touch are required to convey information to these people. As a result of these changes in the needs of the end-user, standards must be met.

Braille has become a hot topic in the print industry due to regulations in Ontario and legislation put forth in Europe. Under the Accessibility for Ontarians with Disabilities Act of 2005 (AODA), the provincial government has set the goal to create a barrier-free and accessible province by the year 2025. One of the methods of producing this accessible environment is the use of braille printing (Queen's Printer of Ontario, 2013). As a result from these changes in Ontario,

will be required to combine braille services into their repertoire to abide by this act. The key parameters of braille include height (which is the focus of this report), distance between the braille dots, and the diameter of the dots (Kibirkstis, Ventye, Mayik, & Vakulich, 2011). All braille printing must produce braille with a standard height. The European Committee for Standardization (CEN) states that braille height should be 0.20 mm on pharmaceutical packaging (PharaBraille, n.d.). The research will primarily focus on pharmaceutical packaging braille applications that display information such as dosage, ingredients and expiration dates. If braille does not meet this standard, it is therefore identified as inaccessible and illegible, which may be a dangerous situation for any user who may be visually impaired.

Braille applications in the print industry have been slowly increasing in popularity since 2011 (Hurt, 2011). Not only were provincial (AODA) and European regulations and legislation (CEN) put forth, but the International Organization for Standardization (ISO) implemented a new standard titled ISO 11156:2011. This standard is applicable internationally and states that "packaging must be designed for the accessi-

bility of all users, manufacturers must consider the varying physical and sensory capabilities of users to ensure that the package can be used by all consumers, whether they are elderly, blind, deaf, or have no disability at all" (ISO, 2011). Companies have the opportunity to become certified in accessible design, therefore adding another service, which meets international standards and adds value to their company's brand and overall image (ISO, 2011).

In order to provide some insight into the current use of braille in the pharmaceutical packaging industry, multiple European medicine packages were collected, measured and evaluated.

It was expected that the Emprint SpotDot would consistently produce braille that would meet the industry standard height of 0.20mm, as well as the fact that braille height will decrease when influenced by external factors of friction and weighted compression. When exposed to these factors, it is further hypothesized that the braille height will fall below standard requirements.

Production errors such as missing dots could change the entire meaning of a message (Hurt, 2011). However, this research will focus on the durability of braille height when it is exposed to two different factors, friction and compression. By simulating friction and compression upon samples printed on the Emprint SpotDot wprinter, durability can be evaluated. Braille itself is a raised surface treatment that can be left exposed and vulnerable to external factors (American Foundation for the Blind, 2013). For example, abrasive shipping or the pressure of multiple packages stacked on top of another

may cause damage to the braille embossing. The problem is that this damage could decrease the height of the braille under the standard, and potentially could render the product illegible or change the intended message. A solution for this problem could be selecting a certain substrate by anticipating and regulating, shipping and delivery methods (with regards to both weight and motion).

The Sutherland Ink Rub Tester was selected to simulate a rough delivery process resulting in friction and possible damage to the braille. This was the first test conducted on the braille samples produced. This machine's intentional purpose is not for this test. This machine is designed to evaluate the rubbing resistance or scuffing of a printed surface against another surface; similar to the events which occurs at the delivery section of the press, a palette drying in a pressroom, or during transportation of a printed product (ChemInstruments, Inc., 2014). This equipment was not designed for the intended purpose, however it was the only equipment available which could would make it possible to obtain some insight into the effects of external motion and pressure upon a raised braille surface.

A total of 60 braille samples were printed using the Emprint SpotDot on 70 lb, coated and uncoated offset stock. 30 samples of each paper type was tested using the Sutherland Ink Rub Tester with a 4 lb weight, and the other 30 samples compressed by a 5 lb weight for 24 hours. This was done to study the influence that friction and compression have on braille height durability.

Equipment

■ Emprint SpotDot Braille Printer

■ Digital Micrometer, Model PK-0505CPX, Mitutoyo Corporation (Code No. 700-118-20; Serial No. 003444)

■ Sutherland Ink Rub Tester

■ 4 lb Ink Rub Tester weight

■ 5 lb weight

Materials

■ 30 samples of braille printed on 70 lb uncoated offset stock

■ 30 samples of braille printed on 70 lb coated offset stock

Procedures

1. Print 30 samples of the alphabet in braille on both the 70 lb uncoated and coated stocks (total 60 samples) on the Emprint SpotDot.

2. Measure the flat paper caliper with the digital micrometer.

3. Using a digital micrometer, measure and record 5 readings for each braille sample. Ensure that all measurements are of the same braille letters (B, D, F, H and J). Also, record 5 readings with the digital micrometer of the paper caliper of each sample.

4. Calculate the average braille height of each sample, as well as the average of the average braille height (X-Bar) and standard deviation for the uncoated and coated stocks. Use the standard deviation to calculate the upper and lower control limits (multiply the standard

deviation by 3 and add it to, or subtract it from the X-Bar, respectively). In addition, calculate the average paper caliper of each sample.

5. Graph the results including average paper caliper, average braille height, X-Bar braille height, and standard braille height lines in Excel.

6. For each type of paper, divide the samples in two groups. Each group of 15 samples will be tested using different methods (total of 4 groups of 15 samples each).

7. The first method (Test A: Ink Rub Tester) will be used on Group 1 and Group 2, using the 4 lb weight. The braille will be placed under two sets of 125 strokes (250 strokes in total). Record braille heights after each set of 125 strokes. For each set, measure and record 5 readings for each braille sample with a digital micrometer.

8. Calculate the new average braille height of each sample and the X-Bar.

9. Graph the results including average braille height, X-Bar braille height, and standard braille height lines in Excel.

10. The second method (Test B: Compression) will be used on Group 3 and Group 4 of samples. The 5 lb weight will rest on top of the braille for 24 hours. Measure and record the braille heights of each sample 5 times after the designated time with a digital micrometer.

11. Calculate the new average braille height of each sample after each set and the X-Bars.

12. Graph the results including average braille height after each set, X-Bar braille height of each set, and standard braille height lines in Excel.

Table 1

Designation of number of samples used for each test.

Group 1	15 uncoated samples (Test A: Ink Rub Tester)
Group 2	15 coated samples (Test A: Ink Rub Tester)
Group 3	15 uncoated samples (Test B: Compression)
Group 4	15 coated samples (Test B: Compression)

Note: All samples printed on 70lb uncoated or coated offset stock.

All 60 samples of the braille alphabet (30 samples on 70 lb uncoated stock and 30 on 70 lb coated stock) using the Emprint SpotDot. Each set of samples was measured with the digital micrometer five times to determine an average braille height for each sample produced. This made it possible to calculate the standard deviation, upper control limit (UCL), and lower control limit (LCL) of the data, and determine the capabilities and consistency of the Emprint SpotDot. The readings collected also allowed us to observe if the Emprint SpotDot was capable of printing to the European Committee for Standardization (CEN) braille height standards of 0.20 mm (PharaBraille, n.d.).

Two series of tests were conducted that consisted of the effect of friction caused through agitation and pressure caused by the Sutherland Ink Rub Tester on braille (Test A) and the effect of weighted compression on braille over a prolonged period of time (Test B). A comparison between the results collected for the coated and uncoated stocks are completed to determine what substrates possess the greatest resistance to exterior forces (friction and weighted compression) and if the braille samples still meet standard height requirements.

Results

Figure 1

Average braille height of 30 samples printed on the Emprint SpotDot on 70 lb offset uncoated paper
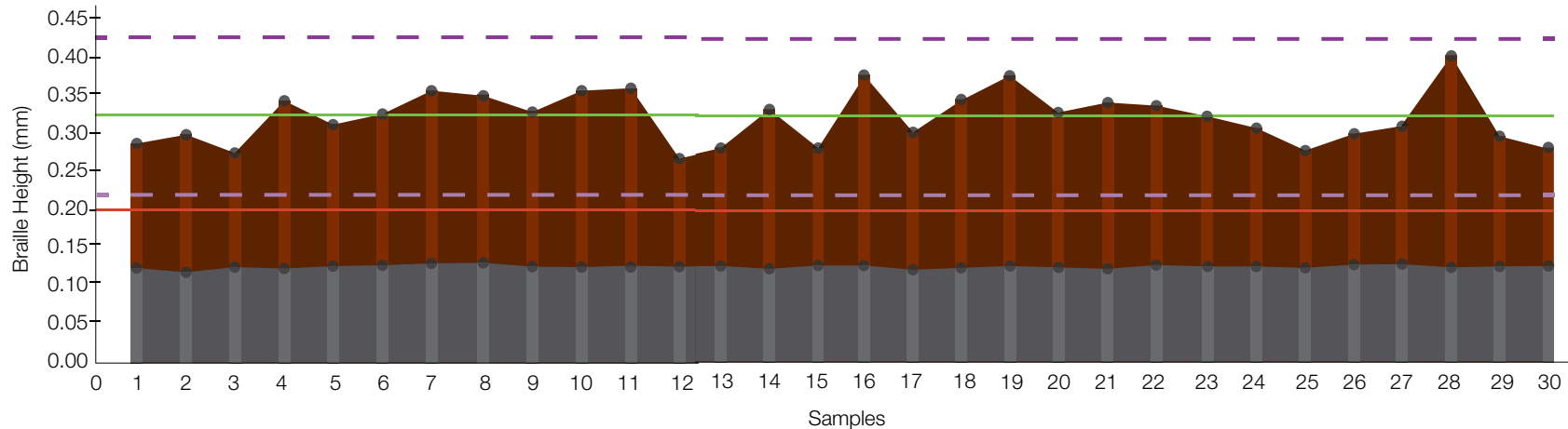
Legend:
- Average Paper Caliper
- Average Braille Height
- Standard Braille Height
- X Bar of Average Braille Height
- UCL
- LCL

Table 2: Collected measurements of 30 samples of braille printed on the Emprint SpotDot on 70 lb offset uncoated paper read five times each (measurements taken at letter B, D, F, H, and J), with calculations for average braille height for each set of data, X-Bar, standard deviation, upper control limit (UCL), and lower control limit (LCL).

Figure 2

Average braille height of 30 samples printed on the Emprint SpotDot on 70 lb offset coated paper

Legend:
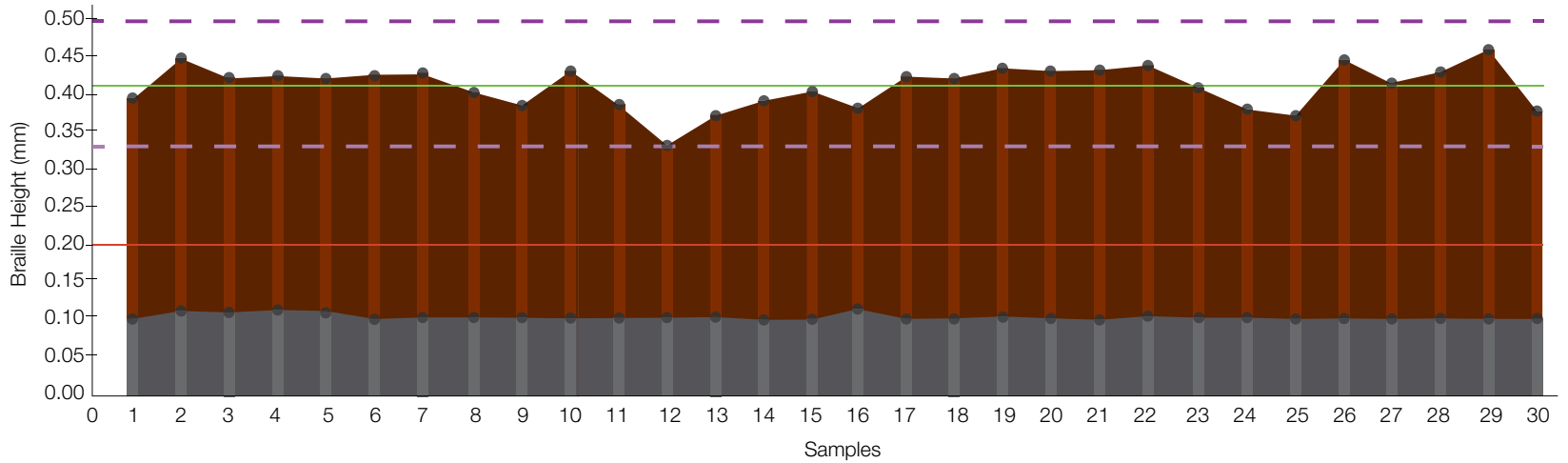- Average Paper Caliper
- Average Braille Height
- Standard Braille Height
- X Bar of Average Braille Height
- UCL
- LCL

Figure 3

Figure 4

Average Braille Height (125 Strokes)	X Bar of Average Braille Height (125 Strokes)
Average Braille Height (250 Strokes)	X Bar of Average Braille Height (250 Strokes)
Standard Braille Height	

Figure 5

Figure 6

Average Braille Height   X Bar of Average Braille Height   Standard Braille Height

49

Conclusion

From the completion of this experiment, it can be concluded that the Emprint SpotDot can print braille on both 70 lb uncoated offset stock and 70 lb coated offset stock, and exceed the braille height standard of 0.20 mm for pharmaceutical packaging (PharaBraille, n.d.). The X-Bar (average of the average) braille height produced by the Emprint SpotDot on 70 lb uncoated offset paper was approximately 0.323 mm, which is 0.123 mm above standard. The X-Bar braille height produced by the same device on 70 lb coated offset paper was 0.410 mm and 0.210 mm above standard or in other words approximately double the standard value.

It was expected that the Emprint SpotDot would produce braille that was to standard height, however it was not expected that the braille height of both sets of 30 samples would be significantly higher than the standard as found. It is important to produce braille that meets the standard value, as this ensures the braille will be legible. Similar to a font that is too small, braille that is not tall enough cannot be read. For example, small faults in the production of braille on pharmaceutical packages, such as insufficient height can cause confusing or incorrect medicine and dosage information, which can have dangerous consequences (Steel, 2011). As on both the 70 lb offset uncoated and coated stocks, the braille heights were above standard, this compensates for exposure to external forces, such as friction and compression. In other words, it will ensure that the braille meets standard height requirements despite being exposed to a certain limit of friction or compression.

When exposed to the force of friction through the use of the Sutherland Ink Rub Tester, the 70 lb coated offset stock retained the braille height of the samples better than the 70 lb uncoated offset stock. For the coated stock, the X-Bar braille height dropped from 0.410 mm to approximately 0.325 mm after 125 strokes of a 4 lb weight and further to 0.294 mm after a total of 250 strokes. Thus, in total and on average, the braille height of the coated samples dropped 0.116 mm. However, the braille height did not fall below standard.

On the other hand, for the uncoated samples, the X-Bar braille height dropped from 0.323 mm to approximately 0.207 mm after 125 strokes and finally to 0.185 mm after a total of 250 strokes with the 4 lb weight. It decreased a total of 0.138 mm in height. In this case, the average braille height no longer meets standard, which could produce legibility issues. As well, while the braille height on the coated paper fell 0.116 mm, the braille height on the uncoated paper fell 0.138 mm (an additional 0.022 mm). It was assumed that both sets of samples would decrease in braille height (as occurred) and fall below standard after being exposed to friction. However, it was found that only the 70 lb uncoated offset paper possessed braille height that no longer met standard. The

70 lb coated offset paper therefore continued to possess braille height that was greater than the standard of 0.20 mm by approximately 0.94 mm.

When testing braille height under weighted compression of 5 lb over the course of 24 hours, it was again found that the braille samples printed on the 70 lb coated offset stock, retained their braille height better than those printed on the 70 lb uncoated offset stock. For the coated stock, the X-Bar braille height fell from 0.410 mm to about 0.378 mm or by 0.032 mm. This still exceeds the standard braille height for pharmaceutical packaging.

The X-Bar braille height for the uncoated paper reduced from 0.323 mm to approximately 0.257 mm, or by 0.066 mm. This is still greater than the standard braille height, but the quantity of the drop in height is greater than demonstrated by the coated stock. It was assumed that the braille height of both sets of samples would reduce under weighted compression, proved by these results. It was also expected that the braille height would fall below standard, which has been proven through the results collected to be false.

By measuring the braille prior to any testing, it was determined that the X-Bar braille height printed on 70 lb coated offset paper was 0.410 mm, while on 70 lb uncoated offset paper was about 0.323 mm. It can be concluded that a greater braille height is produced using the Emprint SpotDot on coated paper. As discussed above, from further tests (Test A and B), it is evident that coated paper retains braille height better than uncoated paper when exposed to

external forces. This is likely due to the fact that differences in the paper manufacturing process occur between the creation of each paper type, such as between uncoated and coated stocks. These variances include the type of fibres used, the amount of refining, as well as the type and amount of additives. The basic properties and quality characteristics of paper are substantially determined by material preparation including preparation of pulp, additives, and auxiliary agents, as well as pulp grinding treatment and the supply of fillers and additives (Kipphan, 2001). In addition, packaging will wear differently depending on the variety of paperboard, its composition, and the surface properties of the paperboard (Kibirkstis et al., 2010).

To narrow the reasoning for the resiliency of the coated paper in contrast to that of the uncoated paper, the main difference between the two paper types will be the primary focus. It is a fact that coated paper possesses extra layers in the form of coating. The rigidity and structure possessed by coated paper is often provided by the clay that is typically used in making coating (Chris Kular, Personal Communication, April 8, 2014). Through applying clays or pigments the coating fills the tiny pits between the base paper's fibres (Lewis Paper, 2012). Coated stocks are more resilient to wear and consistently have a high-quality stiffness and bulk (Caliper Media, Inc., n.d.; Macon Printing, 2013). Uncoated paper does not go through this extra step in the paper manufacturing process and therefore might not have the same structure and rigidity as the coated paper. Thus, when exposed to

external factors, uncoated paper is less likely to hold the braille heights.

It was also determined that the Emprint SpotDot is a stable braille embossing process because it printed within the upper control limit (UCL) and lower control limit (LCL) calculated for each type of stock. The UCL and LCL for the 70 lb uncoated offset stock were 0.424 mm and 0.221 mm respectively. For the 70 lb coated offset stock the UCL was 0.500 mm, while the LCL was 0.330 mm. From the average readings taken from the 60 samples printed, no outliers existed (no averages were greater than the UCL or lower than the LCL). Therefore, it can be concluded that the Emprint SpotDot is in a state of control, as all averages remain within the control limits. Further, no higher degree of uniformity could be achieved with the existing braille printing process of the Emprint SpotDot, which means the samples produced will be more uniform (Besterfield, 2009). Moreover, a natural pattern of variation is present, with only chance causes of variation occurring. These occur due to small variations in machine performance and material characteristics, which are expected and considered as part of a stable process, such as that of the Emprint SpotDot (Besterfield, 2009). As a result of the process being stable, the chance of experimental errors is reduced. This can be observed by the fact that samples exist within an accepted range of values before being tested.

As proper braille testing equipment was not available, other devices were used to measure and test the braille applications. The braille heights of all samples were measured with a digital micrometer. Although this is an appropriate instrument to use to measure braille height, there is a more suitable device called the DOMAS Braille Tester, which is specifically designed to measure the dot size, dot spacing, and dot height of the braille alphabet on pharmaceutical packaging (Tendering pacific, 2014). This instrument is designed to quickly and consistently test embossed braille, as well as store embossing guidelines in PDF files. It detects if there are embossed dots missing or lacking in raised height (Tendering pacific, 2014). The DotScan by in-situ GmbH, has also been designed as an non-contact, optical inspection system to reliably recognize and evaluate the tactile quality of braille dots (Steel, 2014). It utilizes an industrial camera based vision system and implements a shape-form-standing algorithm to calculate braille height (Steel, 2014).

Although measuring the braille height was easily done with the digital micrometer, experimental errors may have occurred if the measurement was not taken directly on the braille dot, causing incorrect readings. As well, despite a fine micrometer being used as a quality control procedure for measuring braille height, it can damage the dots and cause inaccurate measurements (Steel, 2011). If access to the DOMAS Braille Tester or DotScan could have been achieved, using this instrument instead could have prevented this possible error. To counter this possible human error of misplacing the micrometer, five readings were taken of each

sample and averaged. As well, for consistency, through the entire experiment the exact same micrometer was used for all measurements (by verifying the serial number). This was done to avoid inconsistencies between instruments and further experimental errors.

In addition, as discussed, the Sutherland Ink Rub Tester is not meant to be used for the purposes described here, but rather to test the rub resistance of a printed piece after production. As no instrument was available to test the effect of friction on braille (nor did our research discover any instruments designed for this purpose), the Sutherland Ink Rub Tester was selected as a substitute to replicate this external force. As the Sutherland Ink Rub Tester applies a consistent pressure and movement, it reduced the chance of variations between results due to inconsistencies in these two areas being applied to the 30 samples used for this test.

Exterior forces caused by improper handling could have unintentionally reduced the braille height before initial measurements, as well as between initial braille heights and the braille heights existing after exposure to friction or weighted compression. To avoid the least amount of exterior force placed on our braille samples outside of the chosen tests discussed in Table 1 under Procedure, all tests were completed immediately after printing. This included taking the initial braille height

measurements of the samples the same day as producing the samples.

The purpose of this report is to examine the effect of the external forces of friction and weighted compression on the height of embossed braille dots. International requirements surrounding braille are increasing, such as those set by the Accessibility for Ontarians with Disabilities Act of 2005 (AODA) and the European regulations and legislation (CEN) put forth, as well as the International Organization for Standardization's (ISO) new standard of ISO 11156:2011A (American Foundation for the Blind, 2013; Queen's Printer of Ontario, 2013; PharmaBraille, n.d.). With braille becoming a legislated requirement in many places around the world, research not only into the production of braille is required, but also into the durability of braille, as conducted in this experiment.

Abrasive shipping or the pressure of multiple packages stacked on top of one another may cause damage to braille dots by decreasing the height. Pharmaceutical packaging goes through rigorous transportation and handling processes, like other packaging (Kibirkstis et al., 2011). This decrease in dot height must be anticipated for before the production of braille. These tests were designed to replicate the external forces that packaging is exposed to during production and transportation. Despite meeting standards when initially produced, it is

critical that the braille height on a product also continues to meet this requirement when it reaches its final end-use application to ensure durability and legibility. This will not only help those who are blind or have insufficient eyesight for reading, but will also help printers and package manufacturers ensure that their products are useful and helpful for end users.

In assessment of the results collected, it has been found that as braille is exposed to friction and weighted compression, its height reduces and creates a risk of falling below regulated standards. Therefore, steps should be taken to reduce the effect these forces have on braille height, such as utilizing coated paper over uncoated, producing a significantly higher than standard braille height or to reduce the braille's exposure to such forces.

Acknowledgements

Chris Kular - Professor at Ryerson University, Graphic Communications Management

Chris Kular was extremely helpful in regards to this braille analysis project. He assisted with the use the Emprint SpotDot printer in his office located in the Heidelberg Centre - School of Graphic Communications Management, at Ryerson University. Chris Kular allowed us to borrow and measure samples of pharmaceutical packaging containing braille that he has collected (images of these samples can be seen in the Appendix). He also provided industry resources, other samples, and participated in general discussions that helped develop the focus this special project.

Dr. Abhay Sharma - Professor at Ryerson University, Graphic Communications Management

Abhay Sharma was a valuable resource throughout the project. He acted as supervisor during the majority of tests that were completed during lab hours. He also provided us with recommendations for our methodology and constructive feedback about our Interim Report, which helped complete this final report.

References

American Foundation for the Blind (2013). Braille: living with vision loss. Retrieved April 6, 2014 from http://www.afb.org/info/living-with-vision-loss/braille/12

Besterfield, D.H. (2009). *Quality control: custom edition for Ryerson University*. Boston, MA: Pearson Learning Solutions.

Caliper Media, Inc. (n.d.). Choosing paper - coated vs uncoated. Retrieved April 8, 2014 from http://calipermedia.com/choosing-paper-coated-vs-uncoated/

ChemInstruments, Inc. (2014). Sutherland ink rub tester. Retrieved April 6, 2014 from http://www.chemsultants.com/testing-equipment-products/testing-devices/sutherland-rub.aspx

Hunt, B. (2011). Raising the image. *Labels and Labeling.* Retrieved April 6, 2014 from http://www.labelsandlabeling.com/news/features/raising-image

International Organization for Standardization (2011). *ISO 11156:2011(en) packaging — accessible design — general requirements.* Retrieved April 7, 2014 from https://www.iso.org/obp/ui/

Kibirkstis, E., Ventye, I., Mayik, V., & Vakulich, D. (2011). Investigation of geometrical and physical - mechanical parameters of Braille by assessing the different types of cardboard material. *Scientific Journal "Mechanika," 17(6),* 656-660. Retrieved April 8, 2014 from http://zurnalas.mechanika.ktu.lt

Kipphan, H. (2001). *Handbook of print media* (1st ed.). Germany: Springer-Verlag Berlin Heidelberg.

Lewis Paper (2012). Coated vs. uncoated paper. Retrieved April 9, 2014 from http://www.lewispapernews.com/coated-vs-uncoated-paper/

Macon Printing (2013). Coated vs. uncoated. Retrieved April 9, 2014 from http://maconprinting.com/coated-and-uncoated-paper

PharmaBraille. (n.d.). Procedures for pharmaceutical Braille artwork. Retrieved February 10, 2014 from http://www.pharmabraille.com/pharmaceutical-braille/pharmaceutical-braille-procedures.htm

Queen's Print for Ontario (2014). Ontario public service accessibility plans and policies. Retrieved February 10, 2014 from http://www.ontario.ca/government/accessibility

Steel, G. (2011). Optical inspection of Braille font height and shape. *PharmaBraille.* Retrieved April 8, 2014 from http://www.pharmabraille.com/pharmaceutical-braille-news/braille_font_height_and_shape_inspection

Tendering pacific (2014). Braille Tester. Retrieved April 7, 2014 from http://www.tendringpacific.com/instrument/braille-tester/

World Health Organization (2014). Visual impairment and blindness. Retrieved April 6, 2014 from http://www.who.int/mediacentre/factsheets/fs282/en/
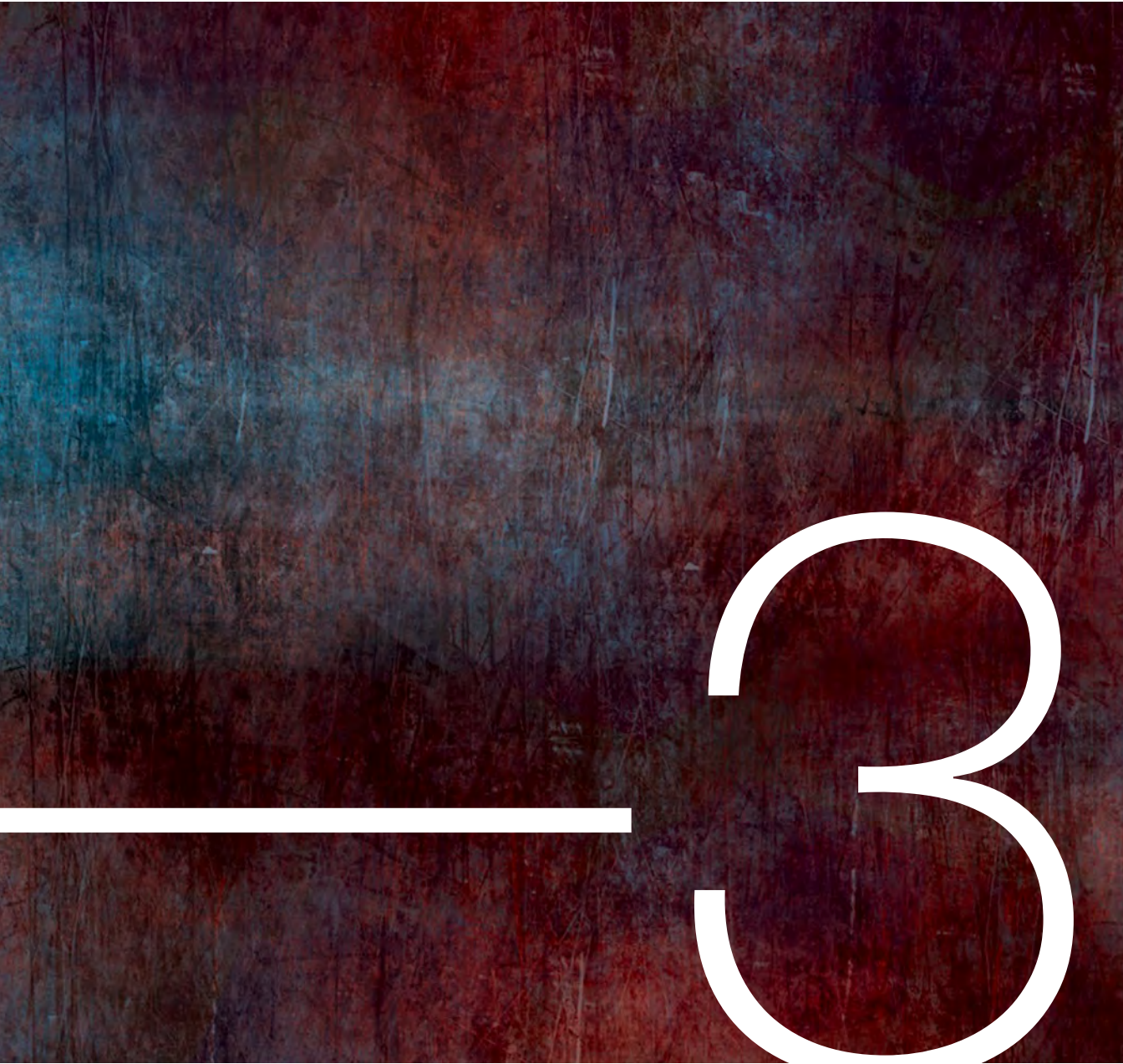
—3

3

Creating Metallic
Special Effects with the Color-Logic System
using CS plug-ins, FX-Viewer & Roland white ink

By: Tak-Po Chu & Harleen Singh

Abstract

The Color Logic Design Suite is a system which allows designers to easily design metallic effects for end use applications. Metallic effects are just one of the few methods which improve the visual appearance of a product. The Color Logic Design Suite includes a set of plug-ins, which are used with software part of the Adobe Creative Suite including: Photoshop, Illustrator and InDesign in order to achieve various metallic effects.

This experiment places the Color Logic software into a simple workflow, with regards to the necessary software and steps needed in order to fully produce a design with metallic effects. A metallic design is efficiently done through the Color Logic Design Suite, saving time and money. Within the Design Suite, software such as the plug-in system and the FX-Viewer are crucial to construct and evaluate of the print product.

By using the plug-in system, a design was created and evaluated on the FX-Viewer, and then printed on the Roland XR-640 using a metallic substrate. Despite the design coming out as anticipated, there were many mishaps in the steps taken in order to appropriately print the design. While the software proved to be very efficient at printing, it is difficult to output on a metallic substrate because it requires a more complex RIP software to render the design appropriately. This experiment proves that the Color Logic Software is very useful for designers who wish to create metallic effects in their designs. However, careful consideration should be taken for how the metallic effect will be produced.

Introduction

One of the rising methods of finishing is the use of a process ink and silver ink to create metallic effects, invented by Richad Wilen (US Patent No, 6,691,610, 2004). This allows printers to print a wide range of metallic colors without the need to actually purchase any metallic colors. With this method, a separate plate, silver, is created in addition to the traditional CMYK plates. Printing a thin layer of the ink on top of the silver layer will achieve the metallic properties.
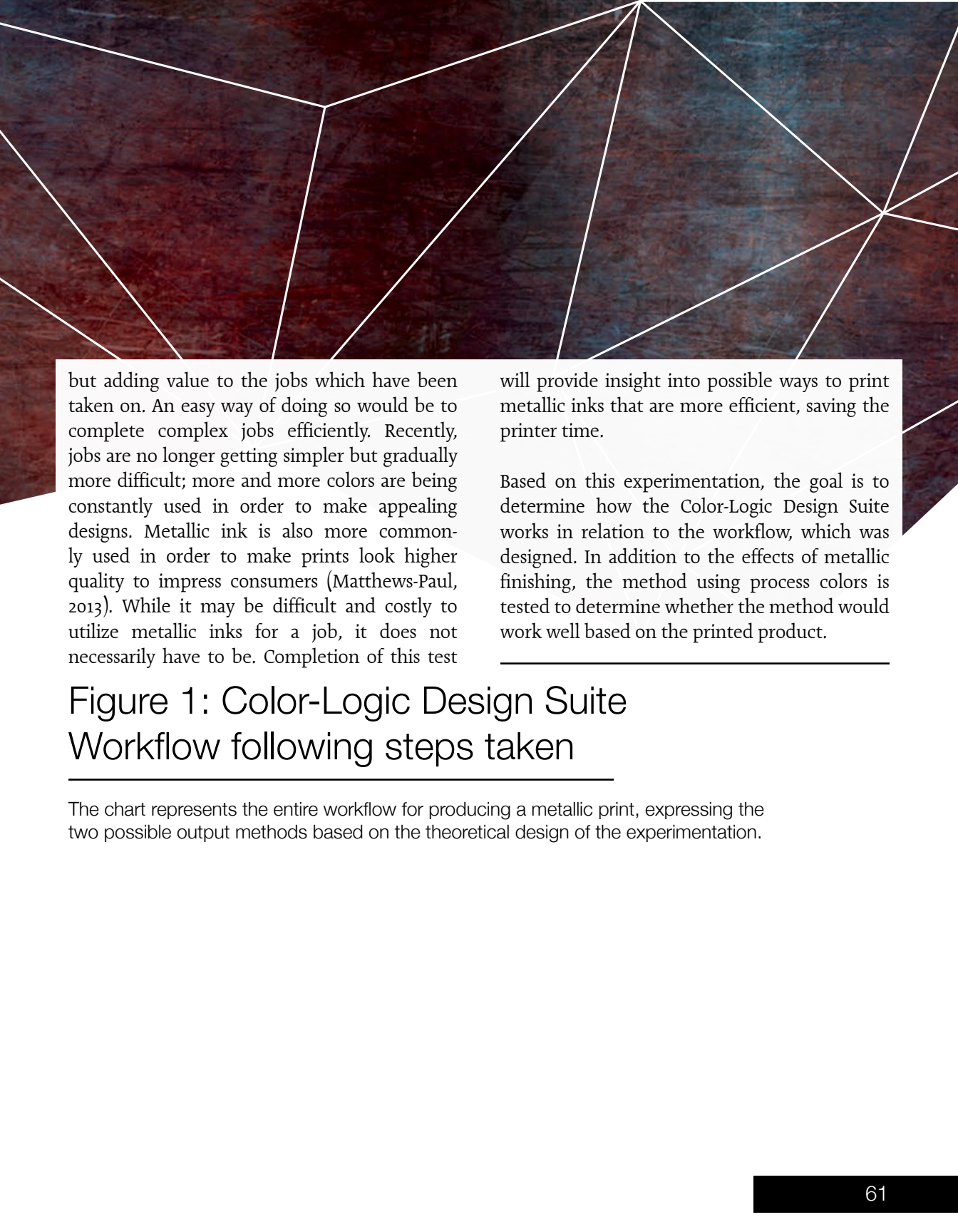
In the past, it was relatively difficult to utilize metallic inks for a design. Some of the problems included the inability to replicate the metallic color based on the color matching swatch books, as metallic inks often appear differently with different substrates or coating (Brown, 2012). As a result, metallic colors were usually difficult to replicate on press.

In recent years, many companies have created products, with the concept that Wilen invented, applying it to digital inkjet printers in addition to offset lithography. Through simplifying the design process and print production process, companies are now able to create metallic effects that reflect and capture the attention of the consumer (Color-Logic, 2011).

A fairly new market software, Color-Logic Design Suite has been introduced to the printing industry. The Color-Logic Design Suite is one of the many types of software that has been made available to the industry as an alternative to printing with metallic inks. Creating a printed product with plug-ins for Adobe Illustrator CS6 and Adobe Photoshop CS6 will test the effectiveness of the Color-Logic system. This new market has been introduced as a way to differentiate from other printed products.

While this is a relatively new software in the industry, the purpose of this test is to understand how to apply such a software to the workflow and to understand how the system works. Completion of this project will assist in determining if the software would serve as an asset to any print company. In addition, this experimentation will provide a thorough understanding of the skills needed to utilize and set up similar programs as well as the end results by printing a design with the Color-Logic plug-ins.

In the Graphic Arts Industry, timing is paramount as it is necessary to get jobs completed on time in order to utilize all the equipment effectively. However, it is not just about providing the clientele an adequate print,

but adding value to the jobs which have been taken on. An easy way of doing so would be to complete complex jobs efficiently. Recently, jobs are no longer getting simpler but gradually more difficult; more and more colors are being constantly used in order to make appealing designs. Metallic ink is also more commonly used in order to make prints look higher quality to impress consumers (Matthews-Paul, 2013). While it may be difficult and costly to utilize metallic inks for a job, it does not necessarily have to be. Completion of this test will provide insight into possible ways to print metallic inks that are more efficient, saving the printer time.

Based on this experimentation, the goal is to determine how the Color-Logic Design Suite works in relation to the workflow, which was designed. In addition to the effects of metallic finishing, the method using process colors is tested to determine whether the method would work well based on the printed product.

Figure 1: Color-Logic Design Suite Workflow following steps taken

The chart represents the entire workflow for producing a metallic print, expressing the two possible output methods based on the theoretical design of the experimentation.

The experiment will determine whether the software is effective, relative to traditional methods. If this proves to be true, then the software can be said to serve as a more cost effective and efficient solution to the application of metallic effects.

Wilen's invention in 2002 was the use of a separate layer in addition to the four standard process colors in order to create metallic effects (US Patent No, 6,691,610, 2004). This was considered a more cost effective manner for offset lithography in comparison to purchasing inks from the suppliers. The current test is to identify whether this same principle is effective for digital inkjets such as the Roland XR-640, utilizing an alternative method to produce metallic finishing.

With the Color-Logic Design Suite, two methods have been intrduced in order to create the metallic effects. The first method is similar to that of Wilen, which involves printing a layer of silver before applying a thin layer of the process color on top. The thin layer will be slightly transparent, allowing the silver ink to show through, creating the effect. The alternative method is to print on a substrate that has metallic properties (such as foil). Instead of printing a layer of silver, a layer of white ink is applied on top of the substrate in all areas which will not have the metallic effect. The process colors will be applied onto the substrate on top of the white ink. That way, only the parts with the substrate exposed will produce the metallic effect. For this experiment, a metallic substrate will be used.

Equipment

- Macbook Pro OSX Version 10.7.5

- Mac OSX Version 10.8.5

- Color-Logic Design Suite™ Software
  - *Color- Logic Plug-in license for*
  - *Adobe Illustrator CS6*
  - *Color-w Logic Plug-in license for*
  - *Adobe Photoshop CS6*
  - *FX-Viewer 1.0*

- Adobe Creative Suite 6 Software
  - *Adobe Photoshop*
  - *Adobe Illustrator*

- SM-1210 Reflective self-adhesive vinyl from TG Graphics

- Orajet transparent vinyl

- Metal Mylar Silver/Gold; 20" x 25" 0.002mL from Aboveground

- Chrome Silver Polyester; 0.002mm 27" x 40" TPM220 from DeSerres

- VersaWorks Advanced 4.8 RIP Software

- Roland SOLJET PRO 4 XR-640

Procedure

To test the new methods of applying metallic colors to a design, a plug-in system for Adobe Illustrator and Photoshop called Dimensional-FX, Watermark-FX, and Gradation-FX will be licensed. The photo shown below in Figure A will be used. Adjustments will be made to the image to present various metallic effects achievable with the Color-Logic Design Suite. The following are the steps that will be taken to conduct this test:

The experiment will involve creating visually pleasing design through the use of metallic inks utilizing Color-Logic's plug-in system in Adobe Illustrator and Photoshop.

Design - Illustrator

1. Create a new document that is 25" x 30" and place image_1.jpg as shown below into the document with the dimensions of 13.8" x 20.7"

Click File and then place "Image_1" to input into Illustrator and create outlines around the fence, background and peak holes under the dome figure using the pen tool. Take the outlined "Image_1" and place this behind the background of this this vector template.

2. Take the outlined "Image_1" and place this behind the background of this this vector template.
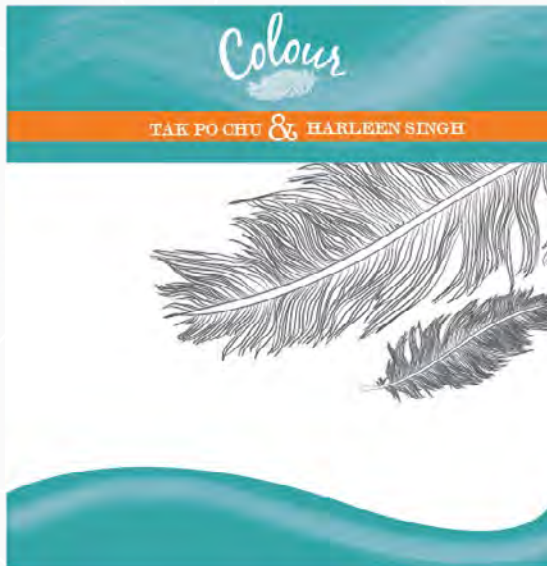

3. Click File and then place "Image_1" to input into Illustrator and create outlines around the fence, background and peak holes under the dome figure using the pen tool. Take the outlined "Image_1" and place this behind the background of this this vector template.

4. Add any solid colour of choice from the COLOR-LOGIC Metallic Silver Graphic Styles panel to the top and bottom of the vector file. In this example we choose CL097-S.

5. To create a watermark effect, click the feather under the word "Color" and click CL097-S Watermark-FX. Make sure it's the same color code otherwise the effect would not work.

6. Go to Windows > Swatch libraries > COLOR-LOGIC Metallic Silver Swatches. COLOR-LOGIC Metallic Silver Swatches are all

the metallic colors in CMYK format that can be used to create the gradient for the background (colorlogic, 2013). Click CL 4713 SILVER as this allows you to overprint the silver ink which you can later invert the effect during the RIP when printing with white ink as the fifth channel.
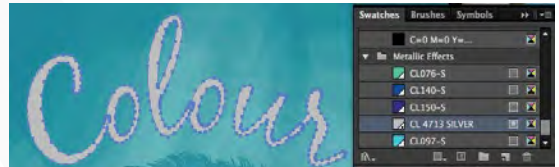

7. A gradient effect will be created for the outlined "image_1" by choosing two metallic colours from the COLOR-LOGIC Metallic Silver Swatches. To open the gradient panel, click Windows > Gradient. Slight adjusts can be made using the gradient slider to give a smooth blend between the two colors.

8. An Action script must be loaded onto Illustrator to allow the Color-Logic plug-ins to work (colorlogic, 2013). To do this open the Actions panel, which is located in the windows tab. Click the options dropdown located in the Actions panel and click Load Actions (colorlogic, 2013). Open "COLOR LOGIC-Metallic Silver.aia" located in the Actions folder. An .aia is an action file format (colorlogic, 2013).

9. Click the Direct Selection Tool and go to the Actions panel to select "Make " fill" metallic", and click the icon in the Actions panel called "play the correction selection." This allows you to play the script as well as make the selected elements metallic (colorlogic, 2013).

10. Click the Direct Selection Tool and go to the Actions panel to select "Make " fill" metallic", and click the icon in the Actions

panel called "play the correction selection." This allows you to play the script as well as make the selected elements metallic (colorlogic, 2013).
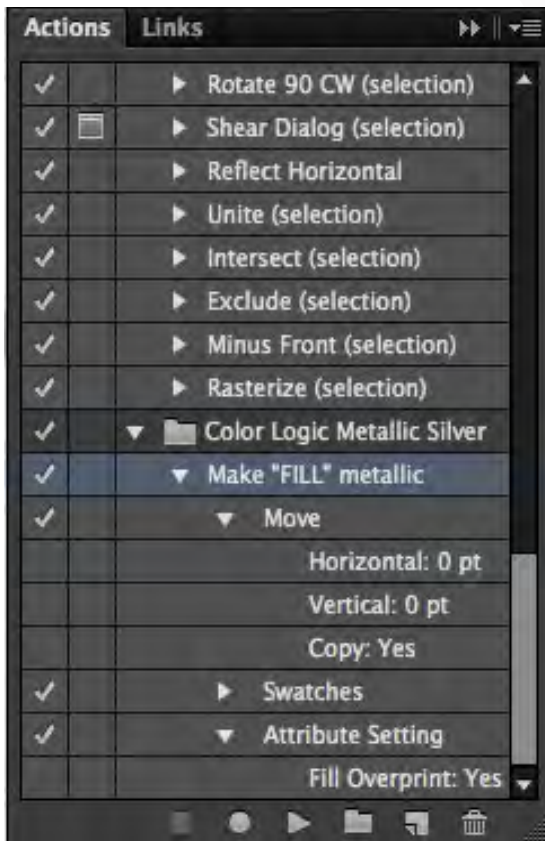
11. To create a watermark: Click File > Place > "image 2" and place the image on top of the duplicated "image 1" photo. Select the design and change the fill of the design to Color-Logic separation–Silver (Colorlogic, 2013). Change the opacity down to 80% (Colorlogic, 2013). Turn on Overprint Fill in the Attributes panel (Colorlogic, 2013). This effect can be seen when reflected in light, and disappears when there is no light (Colorlogic, 2013).

12. Step 12: Save file in .Ai format and PDF format. No other specifications are needed to save this file.

13. Step 13: Drag and drop the PDF file in FX-Viewer to view different angles of the metallic effects.

14.

The following steps were taken in reference to Color-Logic Design User Manual in consideration of the designed workflow:

1. Print the file as a PostScript file: output as separations. Select the necessary printer profile driver (PPD).

2. Take the PostScript file and use Adobe Distiller to convert the files into PDF, this will create five separate PDF files, each representing a different color channel.

3. Open all the images of the PDF in Adobe Photoshop in grayscale mode, with cropping to art box.

4. Flatten the image of each channel and select the merge channel function (Channel > Merge Channel) on one of the images. Select Multichannel as the mode. If done correctly, the there should be the number "5" highlighted in the Merge Channels tab.

5. Assign each channel accordingly based on the name, which was given to the image, corresponding with the channel number. If done correctly, the end result will be a single file with five channels.

6. Colorize the first four channels as CMYK, leaving the last channel with no color: Select Image > Mode > CMYK Color

7. As the last channel will be metallic effects, change the properties into a spot color channel. In order to get the Roland XR-640 to output white ink, the spot color channel must be named RDG_WHITE with color value of Y= 20% and K = 10% (Roland DGA Corporation, 2010). Select OK.

8. With the spot color channel selected, go to Image > Adjustments > Invert. This will reverse the colors on the silver channel. With this action, the areas covered are now designated areas where the designer does not want any silver ink to appear (application of white ink).

9. Save the file as a PDF with the spot color channel option selected.

1. Open "bracelet_ps" in Photoshop. Click the Windows tab then click extensions to open the Color-Logic plug-in. Use the English script (Colorlogic, 2013). This will generate the fifth silver channel for "bracelet_ps". Under the Channels Panel, the user will see 5 different channels (C, M, Y, K, CL 4713 SILVER) (Colorlogic, 2013).

2. Use the wand tool to select parts of the snake bracelet that you want to make metallic. Go to Windows and open Paths and click the icon at the bottom to "make work path from selection"

3. To make the selection have smooth edges to avoid sharp unrealistic effects do the following: Select>Modify> Contract> insert 2 pixel> OK Select>Modify>Feather> insert 5 pixels> OK

4. The area selected is where the metallic effect will be shown when printed .To do this go to the channels panel and deselect CMYK. Make sure you have the CL 4713 SILVER channel selected. Make sure the foreground/background color pickers are reset to black/white with black being the foreground color.

Note*: If you were to print with silver ink, select the area you do not want to make metallic (white areas of the image) and then go under "Select" and click "Inverse" to invert the selected area. This will allow metallic ink to be printed.

Then you would follow the same procedure as stated above.

5. Clicking the delete button on the keyboard will replace the selected area with white. Areas that are white are where the metallic substrate will be more apparent.

6. Select the Silver channel. Using the brush tool you can erase parts of the background and change the curves for that channel to increase the contrast (colorlogic, 2013).

7. Save this file as a TIFF .JPEG, PDF, DCS2.0 or .PSD file and make sure to check "Spot Colors" in the save dialog panel (User Manual, 2011). This allows the user to insert the image within a page layout along with the spot metallic channel (User Manual, 2011).

Output RIP - Utilizing CMYK Inks + White Ink + Metallic Paper

1. Change the fifth channels name in Photoshop from CL 4713 SILVER to RDG_WHITE.

2. Double click the RDG_WHITE channel and

have the following colour values: Y=20% K=10%.

3. Save the file as Photoshop PDF.

Output on Roland XR 640 - Printing with White Ink

1. Open Versaworks and drag the design file into Versaworks. Double click on the image to bring up the print properties

2. Select Layout and get the media width. Position the image where desired.

3. Under Quality, select SP-CLT: PET Clear Film, Adhesive and select W > CMYKLcLmLK

(v) as the mode. This mode allows the printer to print a layer of white ink before printing the process colors on top. Only a few substrates will be allowed to have white printed on them. The designation listed is one of them.

4. Select OK, right click on the image name under job list and select print.

Figure 2: Color-Logic Design Suite Workflow of Steps Taken

The chart illustrates the workflow and the steps taken from design to output for the experimentation.

Set-up

The initial set-up of the software was relatively straightforward. There were no technical difficulties, which were faced during the installation of the software. However, logistics-wise, the procedure to install and activate the program could have been much more efficient. When installing the Color-Logic Design Suite plug-in and the FX-Viewer onto the computer, the disc required the user to first apply for the activation code online by giving a request number. While it is uncertain how the problem occurred, registration of the software resulted in delayed installation, as the access codes provided were not valid. Upon requesting and receiving an email for the activation code the following day, the code did not match the request number that was given. To fully get the software installed and activated took an extra two days. As a result, customer service had to be contacted in order to obtain a new set of codes in order to register and install each piece of software.

The plug-ins offers efficiency in order to create designs specific for utilizing the process metallic colors. While one can design without the software, it would take a significantly longer time to create the desired effects. With the Color-Logic Design Suite, the swatches have been designed to produce the desired color. The swatch stores data, which is used to indicate the density needed in the silver channel as well as the standard amount of ink coverage for the necessary process color.

During the design process it is important to consider how the effects are constructed. The following two images show an example of the watermark effect in FX-Viewer. The feather on the left is a watermark created using the same code for CL097-S and works when the light reflects off the foil substrate at different angles. The image on the right is also a watermark created using the color code CL037-S which does not work because the feather does not appear and disappear. The different code names have their own dimensional-FX and watermark-FX built in for that specific metallic swatch color to create the effect.

Figure 3

Demonstration of CL097-S (Right side of image) and CL037-S(Left side of image)
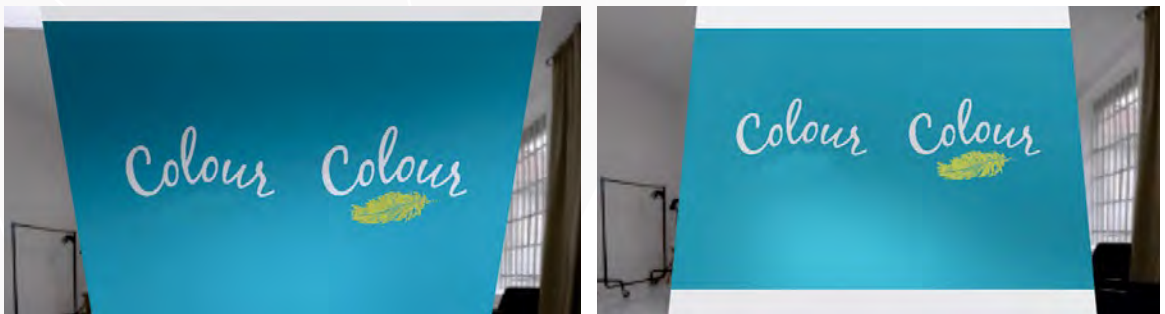
The experiment led to greater understanding that during the design stages, it is fundamental to take into consideration the type of substrate the product is to be printed on, whether it is a clear white substrate or a metallic reflective substrate. For this project the background acts as a reflecting metallic and the dimensional effect as a process color, thus when they are put together, it creates a contrasting effect as shown in the samples provided (Colorlogic, 2013).

Another aspect that was learned was using the action script. The action file is received with the license of the Color-Logic system

(Colorlogic, 2013). This downloads a simple script, which allows users to add Color-Logic metallic effects more easily to the process colors of their choice, by searching for the closest match to the metallic silver (Colorlogic, 2013). When creating effects on a gradient background, a few aspects are needed to be taken care of. When creating effects for gradients, the user cannot have the design embedded in the gradient as a solid dimensional effect because the effect would not work. (Colorlogic, 2013).

The FX-Viewer software allows the user to see if the effects under different light settings work (Colorlogic, 2013). If they do not work according to the specifications, this can be taken back to Illustrator and be adjusted. The FX-Viewer can only visualize metallic colors of the Color-Logic library; thus metallic pantones would not work in this program (Colorlogic, 2013). The FX-Viewer reads the PDF file format and runs it through a RIP (Colorlogic, 2013). There are two ways to view the file: the first is in the spherical environment which acts as a 3D graphics studio and shows how light and shadow bounces off the design elements (Colorlogic, 2013); the second way to view the file is called 3D light box, which has a single light source and shows how the file goes from light to dark (Colorlogic, 2013).

Output

In order to output a design using white ink, it takes significantly more steps than it does to output with silver ink. The Color-Logic Design Suite focuses greatly on the desire for printing with silver inks. The initial plug-ins are designed so that the creation of metallic effects is through the use of a silver channel. This is created with the use of the CL 4713 SILVER swatch from the COLOR-LOGIC – Metallic Silver Swatches panel located in the swatches library. To input the silver channel into the CMYK separations and print with metallic ink is simple because all the necessary channels have been implemented once one of the color swatches in the Color-Logic Library has been selected. Thus, all that the printer has to do is RIP the file and proceed to output on the device. Whereas, it is difficult to print on a metallic substrate as there are multiple steps to approach this.

The structuring of the white inks file for output from Adobe Illustrator proved to be a difficult challenge as there is a lack of appropriate resources, specifically the RIP software. The version of VersaWorks, which is currently used, is a free version, therefore, limiting the amount of adjustments which can be performed on the file. As the experiment used the most basic necessities in order to create and output a metallic design, additional steps, which might not have been necessary, were required. There were various steps taken in order to achieve the metallic effects by printing the file with white ink. A PostScript file was needed to be generated in order to complete one of the steps to alter the silver ink channel to a white ink channel. This required the use of a designated PPD. While there was not one available for the Roland XR-640, the PPD designed for a

Xerox Phaser 7800GX was used instead. Color-Logic indicates that for this process, the appropriate PPD for use is AdobePDF8.0. However, the desired PPD was not available, and an alternative PPD was used.

Output with a file designed on Adobe Photoshop allows for more flexible alterations between output with methods 1 or 2. Unlike Adobe Illustrator, Photoshop allows one to invert the channels. Since the Color-Logic plug-in immediately creates the CL 4713 SILVER channel, all one needs to do is to invert this channel for the appropriate application of white inks when printing on the Roland XR-640.

The output results of the file on the Roland XR-640 were not desirable. On the first output, a metallic substrate called Metal Mylar Silver/Gold was used to output the image. However, the image came out mottled and distorted [Figure 4]. The inks did not adhere to the substrate used because the temperature of the dryer caused the ink to melt away. One factor unaccounted for was the substrate compatibility with the printer.

Figure 4

The Metal Mylar used to output the design. The ink does not adhere properly to the substrate resulting in the distortion.

The Roland XR-640 is only useable with specific substrates, which have been certified for companies to partake and sell their material for this large format printer, certifying that there will be no damages to the device at the same time. The Metal Mylar was not one of them. As a result, different methods were attempted in order to create a print with the metallic effect. One of the ideal substrates was a Reflective Self-Adhesive Vinyl produced and sold by TG Graphics. This particular material has metallic foil applied during the creation of the substrate. Printing on it with the design would provide

the desired metallic effects. The company was contacted for the desired substrate. During this time, alternative methods of output were tested in order to achieve the metallic effects.

One of the alternative methods was to print the design on the adhesive Orajet transparent vinyl and apply it onto the metallic substrate, Chrome Silver Polyester. While the print would not be applied directly onto the substrate, it created the same effect, as it would have [Figure 5]. The problem with this method was applying the adhesive vinyl onto the Chrome Silver Polyes-

ter substrate. Ripples and air pockets formed during the application process and were very difficult to remove, even when trying to apply the vinyl slowly. While the alternative method works in achieving the desired effects, this did not produce a quality piece because of the number of defects.

Figure 5

Design printed on OraJet Transparent Vinyl and applied to Chrome Silver Polyester. The alternative method provides better metallic effect, but many defects such as air pockets and ripples.

When the desired substrate arrived and the image was printed, the results were not as desirable as expected. The metallic effect was dull compared to the alternative method, which was conducted during the available time. The metallic substrate that was used had a significant impact on the overall appearance of the image [Figure 6]. The glossier the metallic substrate, the greater the metallic effects appeared.

Figure 6

Image printed on SM1210 Reflective self-adhesive vinyl.

Conclusion
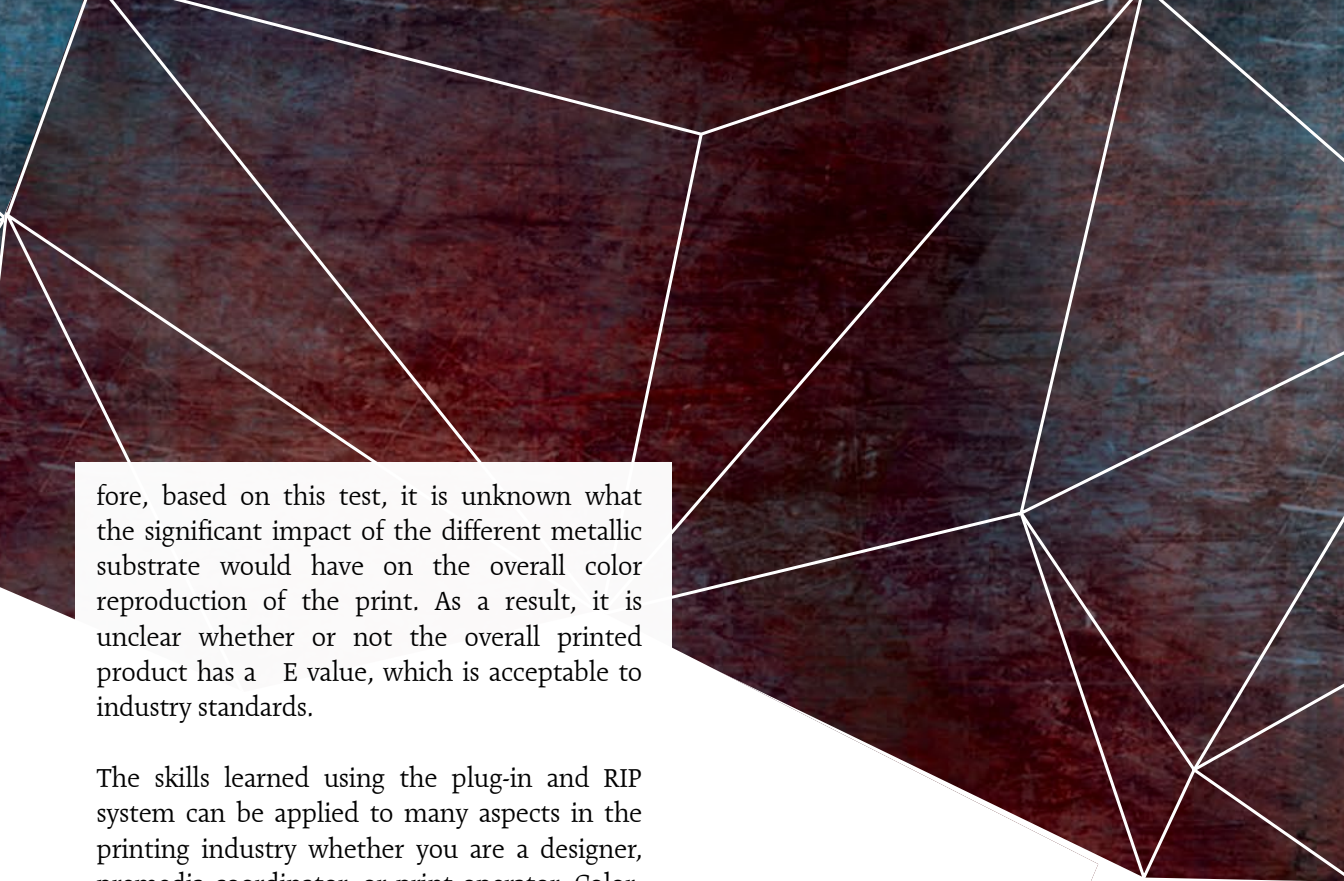
The Color-Logic Design software is a very effective tool for both designers and printers who are looking to create various print products with metallic effects. While using the software during the design phase is relatively straightforward, setting up the print for output is slightly more challenging. Based on the experimentation, the software proves to be effective for the purposes of design with method 1 output (CMYK inks + Silver ink + White paper). While this method is popular for creating small areas with metallic visual effects, the software does not provide the same amount of support for output with method 2 (CMYK inks + White inks + Metallic paper) when creating the design in Adobe Illustrator. Utilizing Adobe Photoshop to create the design allows for better interchange between methods 1 and 2.

The metallic effects overall are very effective. With method 2, the metallic substrate, which the image is printed on, becomes a crucial factor on the overall appearance and effectiveness of the metallic finishing. Method 1 would not produce similar results as the silver ink which is used to produce the metallic finishing

is a constant variable; there is low expectation in the visual appearance of the ink.

In addition, through the process of the experiment, it is noticed that method 2 is not only viable to application on a metallic substrate but a transparent vinyl as well. If that is the case, then the vinyl can be applied to a surface with metallic properties to achieve the same metallic effects.

During the test, one of the aspects that were not considered was the use of a more complex RIP processor. For the experimentation, a free version of VersaWorks was utilized to output the file, restricting efficient construction of the white ink channel. It is not identified in this experiment whether the method 2 process would be easier to construct, had there been a fully installed RIP processor been used. The color accuracy of the metallic process colors, which were printed, is also an unknown factor of this test. Since method 2, which required the use of a metallic substrate, was used, the type of metallic substrate in relation to the color reproduction was also not considered. There-

fore, based on this test, it is unknown what the significant impact of the different metallic substrate would have on the overall color reproduction of the print. As a result, it is unclear whether or not the overall printed product has a E value, which is acceptable to industry standards.

The skills learned using the plug-in and RIP system can be applied to many aspects in the printing industry whether you are a designer, premedia coordinator, or print operator. Color-Logic is a valuable piece of software for any designer who wishes to increase the variety of designs possible, or printers who are looking to providing metallic finishing effects for their current or potential clients.

As printing process metallic colors is one of the alternatives to purchasing a metallic spot color, this process can prove to be very cost effective and efficient. The use of software such as the Color-Logic Design Suite not only provides an efficient method in creating and constructing the design, which a RIP program can easily inter-pret, but ensures adequate color reproduction.

Acknowledgements

References

Brown, D. (2012). About metallic inks. *Graphic Arts Magazine.* Retrieved February 13, 2014 from http://graphicartsmag.com/articles/2012/03/about-metallic-inks/

Color-Logic, Inc. (2011). *Process metallic color system.* Retrieved February 7, 2014 from http://www.color-logic.com/

Colorlogic (2013, August 14). *Color-Logic: label printing for metallics* [Video File]. Retrieved February 13, 2014 from http://www.youtube.com/embed/n31vO3lwLYI?rel=0

Matthews-Paul, S. (2013). A shiny challenge: metallic inks for wide-format print. *Output.* Retrieved February 13, 2014 from http://www.outputmagazine.com/wide-format-print/equipment/inks/a-shiny-challenge-metallic-inks-for-wide-format-print/

Roland DGA Corporation (2010). *Advanced file preparation and printing techniques for Versa UV printer/cutters.* Retrieved April 8, 2014 from http://support.rolanddga.com/docs/Documents/departments/Technical%20Services/Manuals%20and%20Guides/LEC_AdvancedFilePreparation.pdf

Wilen, R. (2004). *US. Patent No. 6,691,610.* Deerfield Beach, FL: U.S. Patent and Trademark Office.

4

Technical Comparison of
Old & New
Canadian Bank Notes

By: Jeff Jones & Sarah Stanley

Abstract

In this report a technical comparison was performed between the old and new Canadian bank notes. Five tests were chosen in order to determine and examine various print and substrate characteristics between the two notes. Those tests included curl tendency, observable print quality, color consistency, braille height examination and tensile strength and elongation. In the curling tendency test, each bank note was dampened and the curl was measured in intervals of 60 seconds. Testing for observable print quality involved taking pictures of both bank notes in similar areas and comparing which note demonstrated itself to be a higher quality print. The third test, color consistency, involved calculating $\triangle E_{76}$ and observing individual differences in $L^*a^*b^*$ values. In the braille analysis, the height of the braille was measured using a micrometer and compared to the international standard. Determining tensile strength and elongation in the final test involved measuring how much force in pounds (lbs) each bank note could bear before fracturing. After performing all five tests and analyzing the results, it was found that the quality and durability of both bank notes differed significantly. The question of which bank note is better is discussed further in this report.

Introduction

In 2011, the Bank of Canada unveiled new Canadian polymer bank notes. The Bank of Canada claimed that these new and improved polymer bank notes were better in terms of toughness, resilience, durability and lifespan (Bank of Canada, 2014). The disadvantage to the new notes however was that they cost almost double the amount taken to produce the old ones. Each polymer note costs 19 cents to print, whereas the old bills cost only 10 cents (Robertson, 2014). The question remains whether or not it was it was beneficial to switch at all.

For this report it was to be determined if the move to polymer bank notes was the right decision made by the Bank of Canada. In order to find out, a technical comparison of the old and new Canadian bank notes was performed. Five tests were conducted to determine which bank note is better in terms of print quality, runnability and end use. Each test performed examined a certain characteristic of the bank notes and the results helped in determining whether the Bank of Canada was right to make the switch to polymer. Such characteristics included functionality, overall print quality, and durability. The five tests conducted included curling tendency, observable overall print quality, color consistency, braille height examination and tensile strength & elongation.

Prior to starting any testing, it was hypothesized that because the older bank notes are made from uncoated, cotton based paper, they would result in a higher curling tendency, and overall poorer print quality. Furthermore, the older bank notes were also suspected to yield poorer results with regards to tensile strength, braille height and the consistency of color between various denominations. The new polymer bank notes however were expected to provide more promising results in that they will have very little curling tendency, yield a higher print quality because of their less absorptive nature, meet braille standards, maintain a higher consistency in color and also retain a higher tensile strength.

Equipment

- Ten new $5 Canadian bank notes

- Ten old $5 Canadian bank notes

- Microscope by Carl Zeiss, made in Germany & Pentax K-200 DSLR Camera

- Testing Machines Inc. Curl Tester No 78-8

- X-Rite Densitometer, 500 series #011828

- Tensile strength tester, Thwing-Albert Instrument Company, Model QC II electronic tensile tester

- Mitutoyo Micrometer, Mitutoyo Corporation, model PK-0505CPX, Serial No. 700-118-20

Procedures

1.1 Curling Tendency

1. Take one old and one new Canadian bank note and place it under weight until completely flattened.

2. Place and submerge both notes in a tray of water and sit for 1 minute.

3. Place notes on flat dry surface and use a sponge to remove excess water.

4. Move notes to another flat dry surface.

5. Using the Testing Machines Inc. Curl Tester No 78-8, measure the curl of each note on the foil end in 1 minute intervals. Take 10 measurements.

6. Using Excel create a graph that illustrates the curl each note experienced.

7. Repeat steps 5 and 6 using the opposite end of the bank notes.

1.2 Observable Print Quality

1. Setup the camera microscope and computer.

2. Take one old and one new bank note and place under the microscope.

3. Take pictures of various spots on the first bill, then take pictures in the same spots on the second bill.

4. Export pictures onto computer and convert to PDFs.

1.3 Color Consistency

1. Using twenty bank notes, ten new and ten old, identity two solid ink locations on each in which to measure, and mark them on the note.

2. Using the X-Rite Spectrophotometer, 500 series #011828, measure the first location for each note. This will be used as the original/standard to compare the other measurements to.

3. Record the results.

4. Repeat steps 2 and 3 until 10 measurements have been made.

5. Repeat steps 2 to 4 for the second location

6. Use the formula $\triangle E = \sqrt{(L_1-L_2)^2 + (A_1-A_2)^2 + (B_1-B_2)^2}$ to manually determine $\triangle E_{76}$.

7. Using Excel, create a graph that illustrates the $\triangle E$ calculations.

8. Using Excel, create another graph that illustrates the differences of each L*A*B* value for each test area.

1.4 Braille Height Examination

1. Using 20 bank notes, ten new and ten old, identity the locations where braille is present.

2. Using the micrometer (Serial No. 700-118-20), first zero, then measure the thickness of the braille. Record results.

3. Repeat steps 2 and 3 until all bank notes have been tested.

1.5 Tensile Strength

1. Measure both a new and old banknote into ten 0.125'' strips.

2. Cut out the measured strips.

3. Using the Tensile Strength Tester, place one strip into the clamps.

4. Zero the device and press Start.

5. After the strip breaks, record the results.

6. Repeat steps 3 - 5 until 20 strips have been tested in total.

7. Using Excel create graphs that illustrates the strength (load) and elongation of each bank note.

Results

Figure 1a: Curl Tendency of Bank Notes on Side A

The curl tendency of both bank notes on the foil side.

Figure 1b: Foil side of bank notes

The curl tendency of both bank notes on the foil side.

Figure 1c: Curl Tendency of Bank Notes on Side B

The curl tendency of both bank notes on the opposite side

Figure 1d: Opposite side of bank notes

As shown in Figure 1a, it was found that there was greater curling tendency on the side of the note with the foil band (see Figure 1b). On the opposite side to the foil band, there was significantly less curl in both notes. Overall, as was expected, the old bank note had a much higher paper curl due to the substrate that was used. In both cases the new bank note had a much lower curl tendency, not even reaching half of curl the old note experienced.

Figure 2a:

A zoomed in view of the new old bank notes taken at 6.2 x 7.7 mm magnification.
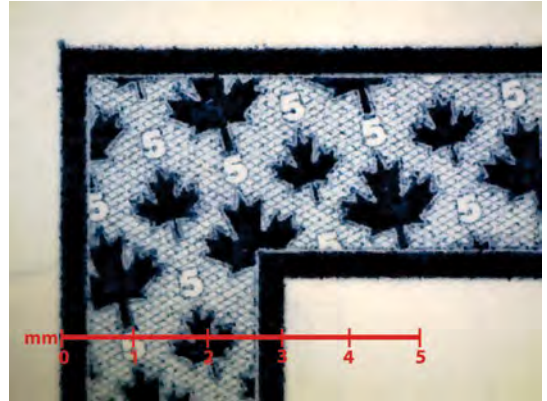
Figure 2b:

A zoomed in view of the new new bank notes taken at 6.2 x 7.7 mm magnification.
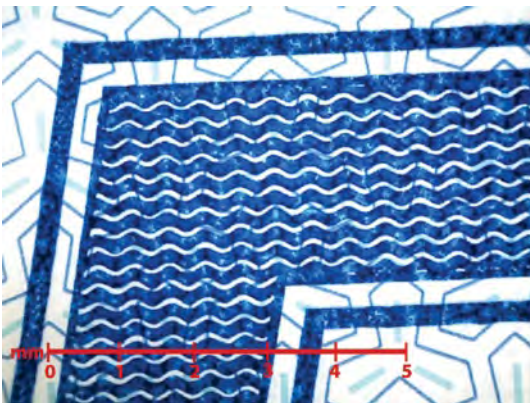
Figure 3a: Delta E for Old Bank Note

The $\triangle E_{76}$ of both areas tested for the old bank notes.

Figure 3b:Test Area 1 for old bank note.

Figure 3c: Test Area 2 for old bank note.

Figure 3d:

Graphs showing individual differences in L*a* b* values for each test area in the old bank notes.

Difference in L*a*b Values for Old Note Test Area 1

Difference in L*a*b Values for Old Note Test Area 2

Figure 3e: Delta E for New Bank Note

The $\triangle E_{76}$ of both areas tested for the new bank notes.

Figure 3f: Test Area 1 for new bank note

Figure 3g: Test Area 2 for new bank note

Figure 3h:

Graphs showing individual differences in L*a*b* values for each test area in the new bank notes.

Difference in L*a*b* Values for New Note Test Area 1

Difference in L*a*b* Values for New Note Test Area 2

Figure 4a: Braille Height Comparison

The height of the braille on both bank notes compared to the international standard.

As shown in figure 4a above, it was found that the braille on the new bank note is much closer to the standard in comparison to the old bank note. However, neither met the current standard.

1.5 Tensile Strength and Elongation

Figure 5a: Strength (Load) Comparision

The measured strength (load) for both the old and new bank notes.

Figure 5b:

A more detailed look at the old and new bank notes' strength -- showing their mean, and upper and lower control limits.

Strength (Load)
of Old Note

Strength (Load)
of New Note

Figure 5c: Elongation Comparison

The measured elongation for both the old and new bank notes.

The results on the right show that the new bank note has a significantly higher load and elongation in comparison to the old bank note. For the elongation, the old bank note has an average of 1.5 mm of elongation, whereas the new bank note had an average of 22.8 mm. For the load, the average was 4.1 lbs for the old bank note and 9.4 lbs for the new one.

Figure 5d:

A more detailed look at the old and new bank note's elongation -- showing their mean, and upper and lower control limits.

Elongation
of Old Note

Elongation
of New Note

Conclusion

The five tests which have been conducted and observed have yielded interesting results. In regards to the curling tendency of both bank notes, it was found that the new polymer bank note had a much higher resistance to curl, having only a max curl of 20° before receding back to its initial form. This was because plastic and coated paper substrates prevent a lot of absorption from moisture by creating a barrier that causes the moisture to sit on top of the substrate (Mohawk, 2006). The old paper bank note curled much more, reaching a max curl of 42°. It was interesting to discover that both notes reached a much higher curl on the side with the foil strip. This was determined to be because the foil was acting as an extra layer on the old and new bank note. After thorough investigation, the old bank note was discovered to be most likely curling more on the foil side due to the strip being more repellant to moisture, and instead the foil strip would act as a force that pulls and contracts, causing the paper before and after it to curl more. These results confirm earlier predictions that the old paper bank notes would in fact retain moisture and curl more than the new polymer ones.

Curling tendency is an important factor to consider when deciding on a substrate to use for print and end use. If taken lightly, it can result in serious problems such as paper jams, print register problems, and a lower end quality (TAPPI, 2011). Furthermore, regarding end use, bank notes must also be resilient to external factors such as moisture in order to retain their shape. For example, if dampened, the bank note should be able to retain its original form. Regarding only curling tendency and these issues, the Bank of Canada made a good decision by going with a polymer bank note.

The second test conducted was the observable print quality test. In this test a microscope was used with a DSLR camera to take close up, detailed images of both the new and old Canadian bank note. Looking at the images there was a clear distinction between the two. The new bank note appeared to be of much higher quality, having much cleaner, sharper, and defined lines, whereas the quality of the old bank note appeared to be significantly lower with the majority of the image and text bleed-ing and poorly defined. Based on research provided by the Bank of Canada, the new polymer notes are printed using a fine-line and intaglio process, which produces sharper images on polymer than on paper (Bank of Canada, 2011). These results confirmed prior predictions that the new bank notes held a higher, sharper level of quality. As for the old bank notes, the fact that they were printed on a cotton-based paper substrate meant that the absorption rate for them would be much higher and therefore most likely result in messier lines and bleeding.

In real life situations, the main benefit of the new notes higher quality is that it brings more advanced security features. The fact that the note has much sharper and cleaner lines makes counterfeiting much more difficult. Counterfeiters would most likely try to use commercial processes to reproduce notes, such as inkjet, in which they would encounter great difficulty, as printing on polymer requires a more unique and advanced printing process (Allen, 2013).

In regards to the braille test, results displayed that neither the new or the old bank note meets the current standard of North American braille. The average height of the braille on the old bank notes was found to be 0.145 mm, while the average height for the new notes was 0.234 mm. The standard height for braille is 0.48 mm according to the National Library Service for the Blind and Physically Handicapped of the Library of Congress, which is used by all North American braille producers (Braille Authority, n.d.). A proposed reason as to why both bank notes do not reach the standard is that the characters used on the bank notes are technically not considered official braille, it is more so considered a tactile feature. This system consists of symbols of six raised dots and the numbering and positioning of the dots reflects the denomination (Samuel, 2010). Furthermore,

the reason why the dots are less legible on the old bank note is because of the substrate used. The cotton-based uncoated paper the old notes use has a much lower durability than the new notes and so cannot hold up over time. Over the span of a year or two, the height of the dots is greatly reduced. While the new bank notes do not use actual braille, the tactile features they do use provide much greater accessibility to those who are visually impaired.

The fourth test conducted was the color consistency test. Two areas on each note were selected to be measured, one on the front and one on the back. Areas that appeared to be the most solid were chosen as they would yield the most promising results. These areas are displayed in Figures 3b, 3c, 3f and 3g. Using the equation: $\triangle E = \sqrt{(L_1 - L_2)_2 + (A_1 - A_2)_2 + (B_1 - B_2)_2}$, the $\triangle E$ for each test area was determined (Sharma, 2004, pg 100). Looking at Figure 3a and 3e shown above, the $\triangle E_{76}$ results for the old bank note were found to be more erratic. Values ranged from a $\triangle E_{76}$ of 5.34 to 1.11, while the new bank note $\triangle E_{76}$ values ranged from 3.16 to 0.33. This not only revealed that the new bank notes are better in regards to color reproduction, but they also retained a better consistency in color over the old bank notes. Furthermore, individual differences in L*a*b* values were also dis-

played as shown in figures 3d and 3h, in order to gain a better understanding of the color consistency of both bank notes. In figure 3d, both test areas for the old bank notes were found to yield much higher differences in L*a*b* versus the new bank notes, that were found to have much more consistent values. While there was a high fluctuation in the L* value in test area one for the new bank note, this was believed to be due to the various reflective areas on the note. There was also found to be a high fluctuation in the L* value for the old bank notes, primarily in test area two. This was discovered to be most likely due to the several embossed areas on the note, which would have possibly caused light to be reflected back at different times when measuring.

The final test that was performed was the tensile strength test. The results for this test were also found to be highly in favour of the new bank note, especially in terms of elongation. As shown in Figure 5a above, the new bank note had a much higher load, ranging from 6.7 to 10.7 lbs. The old bank note was much weaker, having only a load that ranged from 3.5 to 5 lbs. This is likely due to the polymer substrate the new bank note is printed on, which is much more durable than the cotton-based, old bank note. With regards to elonga-

tion, the new bank note was also superior by being able to retain a much longer length of stretch before fracturing. Looking at Figure 5c, the new bank note was able to stretch upwards to 21 times more than the old bank note before finally tearing. Because polymer is within the same family as plastic, it is able to withhold its form during, and after, enduring stress more effectively. The fact that the old bank notes are made of cotton means that they have little to no resistance to tearing. Overall, these results show that the new bank note is much more durable and capable of withstanding tremendous change in length in comparison to the old bank note.

In conclusion, having performed these five tests regarding characteristics of the old and new bank notes, the Bank of Canada has made the right decision in switching to the new polymer substrate. The new polymer bank note is not only of a higher quality visually, but it also has a higher resilience to moisture and curl, making things such as security printing much more effective. It addition, it is also superior in regards to tensile strength and elongation, color consistency and durability in maintaining tactile features. Overall, the new polymer bank note has much greater end use capabilities and will likely remain as Canada's new currency for many years to come.

Acknowledgements

References

Allen, K. (2013). Plastic banknotes: the implications for security, dealers and magicians. *The Guardian.* Retrieved February 10, 2014 from http://www.theguardian.com/business/2013/dec/17/plastic-banknotes-security-dealers-magicians

Bank of Canada (2014). Features for the blind and partially sighted. Retrieved April 6, 2014 from http://www.bankofcanada.ca/banknotes/materials-download-order/blind-and-partially-sighted/

Bank of Canada (2014). *What you should know about your Canadian polymer bank notes.* Retrieved February 10, 2014 from http://www.bankofcanada.ca/wp-content/uploads/2013/02/polymer_leaflet_what_should_know.pdf

Braille Authority (n.d.). *Size and spacing of Braille characters.* Retrieved April 5, 2014, from http://www.brailleauthority.org/sizespacingofbraille/sizespacingofbraille.pdf

Green, C., & Atkins, J. (2011). *The problem of paper curl. Tappi, 7*(10), 1-6. Retrieved February 10, 2014 from http://www.tappi.org/Bookstore/Technical-Papers/Journal-Articles/Archive/Frontline-Focus/NovemberDecember-2011.aspx

Mohawk Fine Papers, Inc. (2014). Paper, Print and Digital. Retrieved October 19, 2014 from http://www.mohawkconnects.com/

Robertson, I. (2014). Polymer banknotes thwarting counterfeiters... so far. *Toronto Sun.* Retrieved February 12, 2014 from http://www.torontosun.com/2014/02/08/polymer-banknotes-thwarting-counterfeiters--so-far

Samuel, C. (2010). Making bank notes accessible for Canadians living with blindness or low vision. *Bank of Canada.* Retrieved April 7, 2014 from http://www.bankofcanada.ca/wp-content/uploads/2011/08/samuel.pdf

Sharma, A. (2004). *Understanding color management.* Clifton Park, NY: Thomson/Delmar Learning.

—5

5

Evaluation of the
Inter-instrument
Agreement

Between the i1Pro, i1Pro 2,
& i1iSis XL

By: Arnold Chan & Jacqueline Chan

Abstract

This experiment uses the i1Pro, i1Pro 2, and i1iSis XL spectrophotometers to determine the inter-instrument agreement. The three instruments would be used to measure a universally readable test target in 3 different ways to have their measured L*a*b* compared based on the $\triangle E^*94$ equation.

Before conducting the experiment, we predicted that the highest inter-instrument agreement would be between i1Pro 2 vs. i1iSis XL, and the lowest would be between i1Pro vs. i1iSis XL. Three different methods of measurement were tested for this experiment: the first method was to print a TC3.5 Patch on three separate sheets; the second method was to put one of each measuring target onto one sheet for a total of three targets; the last method was to create a custom and universally accepted test target.

Upon analysing our results for all three methods, we concluded that the best method is to have one universally accepted test target, as it could eliminate printing variations and allow for consistency and measurement of the same patch. As a result, it reduces the amount of external factors such as printer repeatability and consistency, allowing a higher inter-instrument agreement between devices. There will be 24 test patches in the chart. This custom chart was created in X-Rite ColorPort to have a variety of highlights, shadows, and solid color patches.

The inter-instrument agreement between i1iSis XL and i1Pro 2 showed to have the lowest difference in $\triangle E^*94$, maximum $\triangle E^*94$ of 0.69; which meant the instrument had the greatest inter-instrument agreement. The i1Pro and i1Pro 2 on the other hand, shows the highest difference in $\triangle E^*94$, maximum $\triangle E^*94$ of 1.91. These results confirm our expected outcomes and support our hypothesis. The i1iSis XL vs. i1Pro 2 showed the least difference between measurements as the scanning process reduces human error as well as providing precise measurements through consistent and automated scanning.

Introduction

For this test, the i1Pro, i1Pro 2 and i1iSis XL are evaluated on the inter-instrument agreement between the three devices. The purpose of this test is to determine which device is most accurate and has the highest inter-instrument agreement between the other devices. Inter-instrument agreement can be defined as the level of compatibility of two or more different color measuring instruments when reading the same color (Becker, 2011). Each device is different because different technology is used in each to measure. We are doing this experiment because color and the description of color are subjective, instruments are needed in order to give us numerical and comparable data. However, if the readings are different from instrument to instrument when measuring, it is impossible to accurately measure, analyze, and perform color management.

For example, if the devices have a low inter-instrument agreement, the L*a*b* values would be different to each other, but the color would visually look the same. In this situation, if the client wants to reproduce a specific set of L*a*b* values, the operator would never be able to reproduce that color consistently. Having a high inter-instrument agreement between devices will solve this problem and ensure consistency between devices (Datacolor, 2013).

Although color management and spectrophotometry are not new topics, they are the fundamental and essential aspects of production and quality control regardless of the printing method and technology used. It is impossible to bypass the need for accurate color measurement when producing in an industry environment. The concern of using different measuring devices is often overlooked in industry and lecture environments. If the specific model and serial number of an instrument is not documented, it can be difficult to replicate the same values with a different

instrument. This is especially important in large companies where multiple spectrophotometers and other measuring devices are used daily (International Color Consortium, n.d.).

According to the specifications on the X-Rite website, the i1Pro, i1Pro 2, and i1iSis XL, all supposedly have the same average and maximum $\triangle E^*94$, 0.4 and 01.0, respectively. Therefore, they should have a high inter-instrument agreement with each other. However, X-Rite claims that i1Pro 2 is "the most accurate and forward thinking profiling device available today" by compensating for optical brightening agents" and "built-in wavelength calibration technology" (X-Rite, Inc., n.d.).

Based on our research and manufacturer specifications, we hypothesize that the inter-instrument agreement between i1iSis XL vs. i1Pro 2 will be the highest. This is because X-Rite claims i1Pro 2 is the most accurate device, and the i1iSis XL is fully automated, which eliminates most of the human errors (Rich, 2004). On the other hand, the i1Pro and i1Pro 2 would have the lowest inter-instrument agreement because the i1Pro 2 is an upgraded version of i1Pro. Thus each line of the test target needs to be measured multiple times to record the data. Measuring the target manually multiple times can easily cause skew results and measurements as human error becomes incorporated with the measurements.

To determine the inter-instrument agreement between i1Pro, i1Pro 2, and i1iSisiXL, test targets are made on ColorPort. These targets are then printed using the Epson Stylus Pro 4800 as a control for each of the devices. ColorPort will be used to collect all the CIE L*a*b* values. These values will then be imported into Colorthink Pro and graphed in Microsoft Excel to calculate and observe the maximum, minimum and average of $\triangle E^*94$.

Equipment

Printer

- Epson Stylus Pro 4800

Substrate

- Matchprint Pro Coated SM240P 17" Wide roll, Type 1: Kodak, Serial: 084-0060B

Software

- i1Profiler:X-Rite, v1.5.0 - XRD Version: 2.3.1.4

- i1Profiler Copyright License Dongle: X-Rite

- ColorBurst Raster Image Processor, v7.4

- X-Rite ColorPort, v1.5.4

- Chromix Colorthink Pro, v3.0.3

- Microsoft Excel 2011

Materials

(Numbering refers to physical label on the device)

- i1iSis XL #1: X-Rite, Serial: 005165

- i1Pro:X-Rite #1: Gretag Macbeth, Serial:3.278-815139-9

- i1Pro 2 #1: X-Rite, Serial:1015516

Equation

CIE94 Equation Used

$$\Delta E_{94}^{*} = \sqrt{\left(\frac{\Delta L^{*}}{k_L S_L}\right)^2 + \left(\frac{\Delta C_{ab}^{*}}{k_C S_C}\right)^2 + \left(\frac{\Delta H_{ab}^{*}}{k_H S_H}\right)^2}$$

$$\Delta L^{*} = L_1^{*} - L_2^{*}$$

$$C_1^{*} = \sqrt{a_1^{*\,2} + b_1^{*\,2}}$$

$$C_2^{*} = \sqrt{a_2^{*\,2} + b_2^{*\,2}}$$

$$\Delta C_{ab}^{*} = C_1^{*} - C_2^{*}$$

$$\Delta H_{ab}^{*} = \sqrt{\Delta E_{ab}^{*\,2} - \Delta L^{*2} - \Delta C_{ab}^{*\,2}} = \sqrt{\Delta a^{*2} + \Delta b^{*2} - \Delta C_{ab}^{*\,2}}$$

$$\Delta a^{*} = a_1^{*} - a_2^{*}$$

$$\Delta b^{*} = b_1^{*} - b_2^{*}$$

$$S_L = 1$$

$$S_C = 1 + K_1 C_1^{*}$$

$$S_H = 1 + K_2 C_1^{*}$$

Procedures

A problem in this experiment is that each device required a different test target to successfully measure a color patch. To overcome this issue, three methods were developed and applied in our research to collect a variety of data to determine the most appropriate method of measuring targets with all three spectrophotometers. After collecting and measuring data using each method, the data was plotted into Microsoft Excel and graphed to visualize the data. To accurately compare our results to X-Rite's specifications, the same equation of ΔE^*94 was used with UV included (Gay, Melo, & Hirscheler, 2004). All targets were printed with "color management" turned off, to ensure consistent reproduction of color without interference from the RIP software.

Method 1: TC3.5 Patch on three different sheets

Figure 1

The TC3.5 patch set containing over 432 patches with the layout for the i1iSis XL, i1Pro 2, and i1Pro respectively.
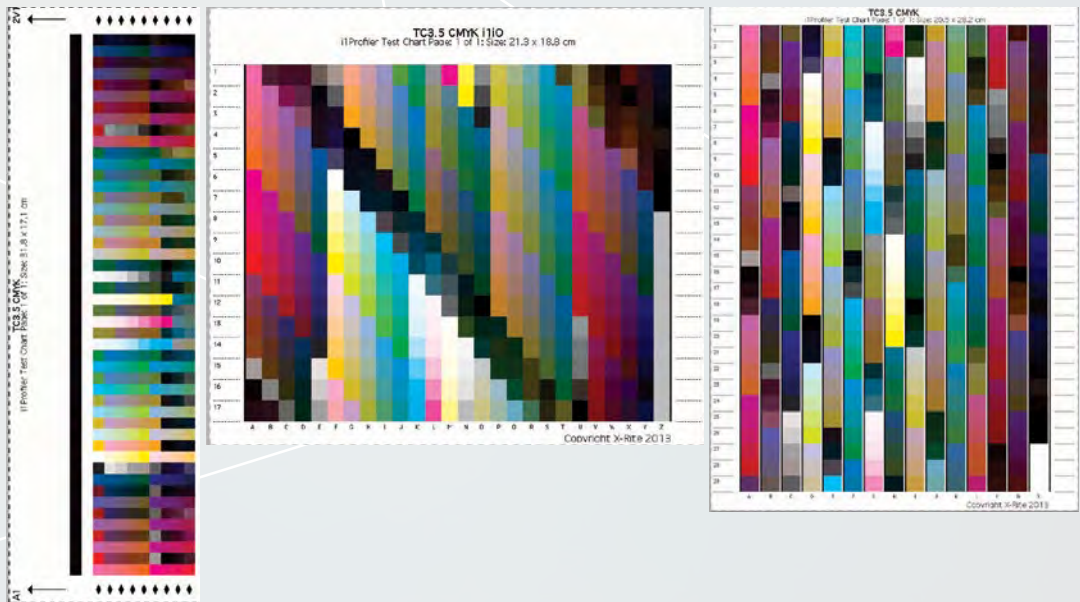
The first method will use the i1Profiler to create a TC3.5 Patch Set with 3 different test charts (i1Pro, i1Pro 2, i1iSis XL). Each test chart was printed individually on the Epson Stylus Pro 4800 using ColorBurst. The test charts were measured using i1Profiler with a single scan under the same condition to minimize external factors. The measured results were then placed into ColorThink Pro to get the L*a*b* values for each individual patch.

1. Open i1Profiler, select TC3.5 Patch and save it as a TIF file.

2. Save the test target on three different TIF files for the following devices: i1Pro, i1Pro 2 and i1iSis XL.

3. Open the TIF files using ColorBurst, print them using Epson Stylus Pro 4800.

4. Measure the test target using with i1Pro, i1Pro 2 and i1iSis XL with i1Profiler, change the setting to "single scan".

5. Save the data as txt files.

6. Drag the .txt files to ColorThink Pro to compare the L*a*b* values between devices, the maximum, minimum, and the average of $\triangle E^*94$.

7. Use Excel to plot a graph and visualize the data.

Method 2: Three targets on one sheet

Figure 2

i1Sis XL, i1Pro, and i1Pro 2 readable targets.
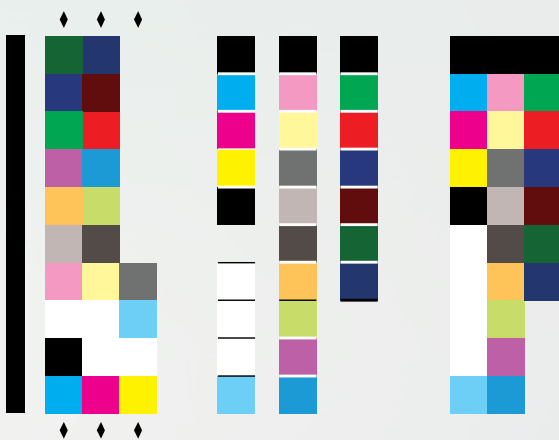
The second method required three custom test targets, which contain individual targets for i1Pro, i1Pro 2 and i1iSis XL, all on the same sheet. The sheet will be measured using ColorPort with each device's respective measuring process. The collected L*a*b* values would be exported into Excel and the $\triangle E^*94$ will be calculated for each of the three color patches.

1. Open ColorPort and create custom test target for i1iSis XL, i1Pro and i1Pro 2.

2. Save the test targets as TIF files and merge them together using Photoshop onto one sheet.

3. Print the merged targets using ColorBurst using the Epson 4800.

4. Open ColorPort, select the appropriate test target and measure the test target using with i1iSis XL, i1Pro and i1Pro 2 respectively.

5. Save the data as csv files.

6. Open the csv files in Excel, calculate the $\triangle E^*94$, plot a graph to visualize the data.

Method 3: One universally recognizable target

Figure 3

The universal target can be read normally with the i1iSis XL or in spot mode by both the i1Pro and i1Pro 2.

The last method was to create a custom test target specifically for i1iSis XL using ColorPort. This patch is essentially an i1iSis XL test target but with enlarged patches to allow for manual spot measurements with the two handheld spectrophotometers. The target was printed with the Epson Stylus Pro 4800 using ColorBurst RIP. The test chart was measured under identical conditions consecutively using ColorPort on "spot mode" with i1Pro and i1Pro 2, with the regular scan for i1iSis XL included. The collected L*a*b* values would be exported into Excel and calculated for each color patch.

1. Open ColorPort, create custom test target that is for i1iSis XL on one sheet of paper.

2. Save the test target as TIF file and print using ColorBurst as a RIP on the Epson 4800.

3. Open ColorPort, select the test target and measure the test target using i1Pro and i1Pro 2, with the settings changed to "spot mode".

4. As per the previous procedures, measure target using i1iSis XL. Ensure the setting is "UV included".

5. Save the data as .csv files.

6. Open the .csv files in Excel, calculate the $\triangle E^*94$, plot a graph and visualize the data.

Results

Figure 4: TC3.5 Patch on
Three Different Sheets

The TC3.5 patch set containing over 432 patches with the layout for the i1iSis XL, i1Pro 2, and i1Pro respectively.

Method 1

i1iSis XL vs. i1Pro 2	ΔE*94	i1iSis XL vs. i1Pro	ΔE*94	i1Pro 2 vs. i1Pro	ΔE*94
Average	0.65	Average	0.62	Average	0.89
Maximum	2.32	Maximum	2.30	Maximum	3.01
Minimum	0.058	Minimum	0.061	Minimum	0.109

Figure 5: Three Targets on One Sheet

The inter-instrument agreement graphed for all three devices using method 2.

Method 1

- ▇ Average
- ▇ Maximum
- ▇ Minimum
- ▇ Quoted Average
- ▇ Quoted Maximum

i1iSis XL vs. i1Pro 2	ΔE*94
Average	0.65
Maximum	1.53
Minimum	0.12

i1iSis XL vs. i1Pro	ΔE*94
Average	0.81
Maximum	2.77
Minimum	0.27

i1Pro 2 vs. i1Pro	ΔE*94
Average	0.88
Maximum	1.74
Minimum	0.04

Figure 6: One Universally Recognizable Target

The inter-instrument agreement graphed for all three devices using method 3.
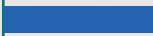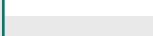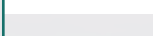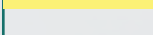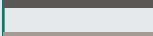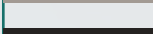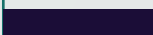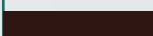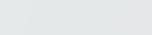
Method 3

- Average
- Maximum
- Minimum
- Quoted Average
- Quoted Maximum

i1iSis XL vs. i1Pro 2	ΔE*94	i1iSis XL vs. i1Pro	ΔE*94	i1Pro 2 vs. i1Pro	ΔE*94
Average	0.37	Average	0.60	Average	0.76
Maximum	0.69	Maximum	1.34	Maximum	1.91
Minimum	0.06	Minimum	0.06	Minimum	0.14

Figure 7

The CMYK values of each patch and the color created used in the custom target.

No.	Cyan	Magenta	Yellow	Black	Reference
1	100	0	0	0	
2	0	100	0	0	
3	0	0	100	0	
4	0	0	0	100	
5	3	0	0	0	
6	0	3	0	0	
7	0	0	3	0	
8	0	0	0	3	
9	50	0	0	0	
10	0	50	0	0	
11	0	0	50	0	
12	0	0	0	50	
13	25	25	25	0	
14	50	50	50	50	
15	0	25	75	0	
16	25	0	75	0	
17	25	75	0	0	
18	75	25	0	0	
19	100	0	100	0	
20	0	100	100	0	
21	100	100	0	0	
22	34	98	95	54	
23	88	35	100	29	
24	100	96	21	32	

When using method 1, the results from our experiment demonstrated that there is a higher inter-instrument agreement between i1iSis XL and i1Pro 2 compared to others. Our data showed that i1iSis XL and i1Pro 2 have the smallest variation and $\triangle E^*94$ between all comparisons of the three devices. The largest discrepancies between measurements occur when comparing the i1Pro and i1Pro 2 spectrophotometers.

The second method used shows similar results of the first method with a tighter grouping of the range and still supports the stated hypothesis. The overall minimum and maximum $\triangle E^*94$ values for each measurement went down, indicating a smaller difference in measurement and higher instrument agreement.

The third and final method shows the greatest agreement between instruments out of all the methods because the average $\triangle E^*94$ values are lowest. The maximum $\triangle E^*94$ value is also lower, meaning that the overall measurements are more accurate and consistent between instruments with less outliers.

Overall, our data shows that the i1iSis XL and i1Pro 2 have the greatest inter-instrument agreement between the three devices with all three methods. The lowest agreement between measurements occurs between the i1Pro and i1Pro 2 spectrophotometers. The methods used shows the tightening of the range of $\triangle E^*94$ as the methods tested further increase the consistency of our measurements; with method 1 having the largest range in values and method 3 having the smallest range of $\triangle E^*94$ values.

One thing we observed consistently through these measurements is that the largest $\triangle E$ came from patch 14 every time (Grey with 50% of every process color), which raised the overall average of all readings. Regardless of the setting or method of measurement, this patch was the most problematic out of all 24 patches.

Conclusion

The i1iSis XL is the device with the highest accuracy out of all three devices. One explanation is because it greatly reduces the need for human interaction when scanning the test targets, which reduces the variations in measurement, caused by human error (X-Rite, Inc., 2012). Scanning manually with the two handheld devices proves to be less accurate as using the measuring rail, as it does not ensure that the measuring time and distance is exactly the same for each patch. Comparing this scenario to the other two inter-instrument agreements, i1iSis XL vs. i1Pro and i1Pro 2 vs. i1Pro, it has the highest maximum of $\triangle E^*94$, an average minimum of $\triangle E^*94$, and the lowest average $\triangle E^*94$ out of the three scenarios. While having the lowest average of $\triangle E^*94$, it indicates that the consistency between i1iSis XL and i1Pro 2 is very high. However, having the highest maximum $\triangle E^*94$ suggested that there is an outlier.

As expected, the inter-instrumentation agreement between i1Pro and i1Pro 2 is the lowest. This was represented with the highest $\triangle E^*94$ average of the instruments, indicating low consistency. The i1Pro2 has many new improvements and features relative to the original revision of the i1Pro, which can explain why the i1Pro is the most inconsistent. For instance, the i1Pro 2 has a smaller minimal patch size for scan measurements, 7mm, compared to the original i1Pro's 10mm. Additionally, the i1Pro 2 has a position detection sensor and a build-in wavelength calibration system to compensate for small but noticeable shifts in the measuring environment (X-Rite, Inc., 2012). The results of inter-instrument agreement between i1iSis XL and i1Pro supports our hypothesis as well; it is between those two scenarios (HunterLab, 2008).

Method 2 further supported the theory that the i1iSis XL and i1Pro 2 had the highest inter-instrument accuracy, while the i1Pro 2 and i1Pro, on the other hand, would have the lowest. In general, the three scenarios using method 2 had a higher average of $\triangle E^*94$, a lower maximum of $\triangle E^*94$ and a higher minimum of $\triangle E^*94$ compared to method 1. This could be explained by the variations of L*a*b* values in method 1. Each time

the target is being printed, there will be slight variations in ink and paper. These variations create a bigger range, thus a higher maximum and a lower minimum. Since method 2 does limited these variations by putting the file through a RIP, it has a lower range, resulting in a lower maximum, and a higher minimum of $\triangle E^*94$.

The results from method 3 also proved that the inter-instrument accuracy between i1iSis XL and i1Pro 2 is the highest, i1Pro and i1Pro 2 is the lowest. However, the results from the three scenarios differ between the average, maximum, minimum. In general, the average of $\triangle E^*94$ is lower, the maximum of $\triangle E^*94$ is lower, but the minimum of $\triangle E^*94$ is higher compared to the method 1. This could be due to the same reasoning provided for method 2. Since method 3 had utilized one universal test target, it eliminated printing variations. Therefore the $L^*a^*b^*$ values of each patch would remain constant, the only difference would be the instrument used to determine the values.

Based on X-Rite specifications of i1iSis XL, i1Pro 2 and i1Pro, it states that the inter-instrument agreement should have an average of $\triangle E^*94$ of 0.4 and maximum of 1.0 (X-Rite, Inc., 2011). Comparing the results of method 1 and 2 to the specifications, none of these values meet the specifications set by X-Rite. All of them have an average of $\triangle E^*94$ higher than 0.4 and maximum $\triangle E^*94$ of higher than 1.0. However, the inter-instrument agreement between i1iSis XL and i1Pro 2 using method 3 qualified, obtaining an average $\triangle E$ under 0.4 and a maximum under 1.0. The scenario between i1iSis XL and i1Pro is very close to the specifications. This indicates method 3 is a better way to test the inter-instrument agreement between devices, as external factors such as paper and ink will affect the results.

The reason to test inter-instrument accuracy with three different methods is because each method has unique pros and cons. In method 1, although it is true that the printing variations will cause the results to have a higher maximum and

lower minimum of $\triangle E$, the smallest standard test target has 442 patches. The large amount of patches can average out the $\triangle E^*94$. Additionally, each test target has a pre-designed layout for the specific instruments. Each instrument needs a specific test target layout to allow automatic measuring. This is a more efficient way to test the inter-instrument agreement between devices.

In method 2, instead of having the test targets going through a RIP three separate times (printing one target out per sheet), this was only done once by having all test targets printed on the same sheet of paper to eliminate some of the printing variations. This allows all three devices to take measurements automatically, instead of using spot mode for i1Pro and i1Pro 2 as mentioned for method 3. Using method 2 can eliminate more printing variations compared to method 1, however, this method utilizes fewer patches. Therefore, even one outlier will skew the average. Compared to method 3, it is less time consuming because it is only one test sheet, but has more printing variations since the test target are printed on three different section of the paper, with each target being utilized for a different device.

Method 3 eliminates printing variations in order to achieve a more consistent value of maximum and minimum $\triangle E^*94$. However, it is more time consuming because a custom test target needs to be created. In addition, i1iSis XL, i1Pro and i1Pro 2 require a specific layout in order to make appropriate measurements. This can be solved by preparing an i1iSis XL test target, and using spot mode functionality on the i1Pro and i1Pro 2 to make the appropriate measurements. Using spot mode is more time consuming than scanning the whole strip; hence, only 24 patches were created. If one of the patches is an outlier, it could skew the average of $\triangle E^*94$.

Acknowledgements

References

Becker, E. (2011). Tip #4 inter-instrument agreement. *Cyberchrome, Inc.* Retrieved March 24, 2014 from http://www.cyberchromeusa.com/Color-QC-and-Matching-Blog/bid/76644/Tip-4-Inter-Instrument-Agreement

Datacolor (2009). *Inter-instrument agreement.* Retrieved February 9, 2014 from http://industrial.datacolor.com/support/wp-content/uploads/2013/01/Inter-Instrument-Agreement.pdf

Gay, J., Melo, C., & Hirscheler, R. (2011). Instrumental whiteness evaluation: practical results of inter-instrument agreement tests. *Fibre2fashion.* Retrieved March 24, 2014 from http://www.fibre2fashion.com/industry-article/9/879/instrumental-whiteness-evaluation1.asp

Hunterlab. (2008). *Maximizing inter-instrument agreement.* Retrieved March 21, 2014 from http://www.hunterlab.se/wp-content/uploads/2012/11/Maximizing-Inter-Instrument-Agreement.pdf

International Color Consortium (n.d.). *Precision and bias of spectrocoloimeters.* Retrieved March 14, 2014 from http://www.color.org/icc_white_paper_22_precision_and_bias_in_measurement.pdf

Rich, D. (2004). Graphic technology — improving the inter-instrument agreement of spectrocolorimeters. *NPES.* Retrieved March 19, 2014 from http://www.npes.org/LinkClick.aspx?fileticket=OOI6mzsA8Rs%3D&tabid=156

X-Rite, Inc. (n.d.). i1Basic Pro 2. Retrieved February 12, 2014 from http://www.xrite.com/product_overview.aspx?ID=1912&Action=Specifications

X-Rite, Inc. (2011). *i1iSis.* Retrieved February 13, 2014 from http://www.xrite.com/documents/literature/en/L11-213_iSis_Brochure_en.pdf

X-Rite, Inc. (2012). *i1Pro spectrophotometers.* Retrieved March 24, 2014 from https://www.xrite.com/documents/literature/en/L7-518_i1PRO-i1PRO2_en.pdf

X-Rite, Inc. (2013). *The new X-Rite standard for graphic arts.* Retrieved February 9, 2014 from http://www.xrite.com/documents/literature/en/L7-462_XRGA_WhitePaper_en.pdf

—6
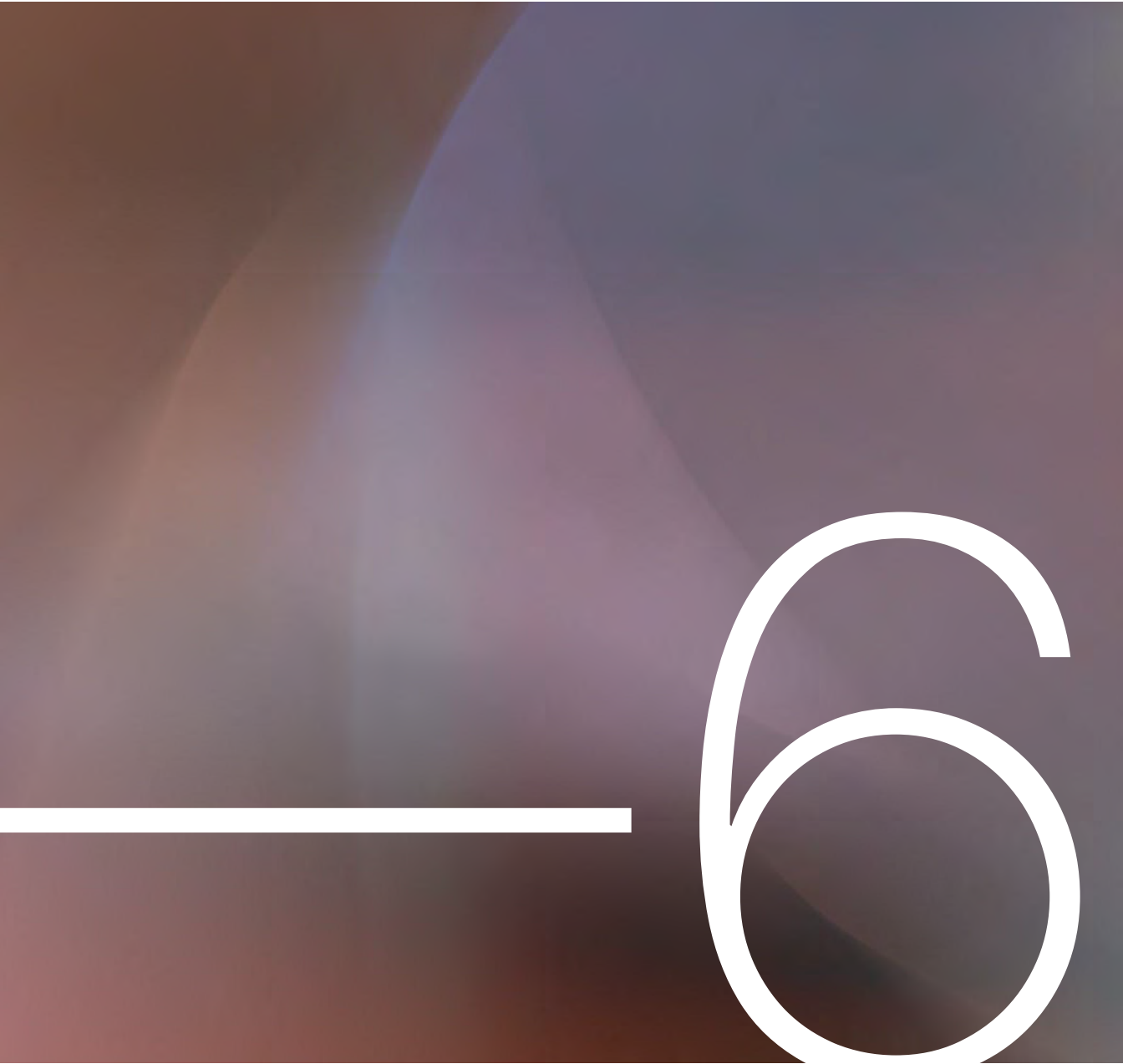
6

Evaluation of Different

Delta E Equations

for Saturated Colors,
Pastels, Neutrals,
& Skin Tones

By: Jessica Wong

Abstract

Color is a subjective topic when conversed, however it can be measured and described using CIE color difference formulas: $\triangle$E76, $\triangle$E94, $\triangle$E2000, and CMC. Each of the formulas has corrections in adjusting the previous formula's shortcomings by introducing the weighting to be more accurate. However, the formulas do not describe the appearance of color since the appearance of color has many factors affecting it, such as the surrounding elements and lighting. Differences in color reproduction may not appear to match when visually assessed, but match when assessed colormetrically. The human visual system is very sensitive towards slight changes in color in certain areas of the L*a*b* color space, such as pastels, neutrals, and skin tones while being less sensitive in saturated colors. The formulas of $\triangle$E76, $\triangle$E94, $\triangle$E2000, and CMC all have different formulas for calculating the color difference from L*a*b* values, which yield different values for each of the equations. Due to the wide range of values of the results from the four equations, it must be necessary to specifically indicate which formula was used to calculate the color difference.

Introduction

Describing and defining color is a very subjective topic. Color spaces aid this process by describing the color between people and machines. Color is a reaction in the brain to visual stimulus. We could describe color in measuring its spectral power distribution however it can lead to redundancy since the retina in the human eye uses only three broad bands corresponding to red, green, and blue light (Ford and Roberts, 1998). The experiment will be about evaluating the effectiveness of the four formulas used in calculating color differences to determine which formula is best when calculating saturated colors, pastels, neutrals, and skin tones by using the X-Rite 530 Spectrodensitometer to measure the L*a*b values for each group. The equations of △E76, △E94, △E2000, and CMC all have different formulas in calculating color difference. For the results, it was predicted that there would be a larger color difference within the light pastels when calculated with △E76. △E94 would lack accuracy within the blue-violet regions, △E2000 would have better performance when measuring neutrals and CMC would give the same color difference in all the regions in the color wheel (Habekost, 2013).

CIE (International Commission on Illumination) is a body that is responsible for international recommendations for colorimetry and photometry. CIELAB transforms CIE XYZ, an early CIE color space, to a uniform and circular space that is useful for measurement (Adams, Sharma and Suffoletto, 2008). Figure 1 shows the L*a*b* system, which separates color into luminance (L*), red-green (a*), and blue-yellow (b*) (Sharma, 2004).

Figure 1

The L*a*b* color space system, specifies color via its position in a uniform 3D color space

L*=100
White

+b*
Yellow

-a*
Green

+a*
Red

-b*
Blue

L*=0
Black
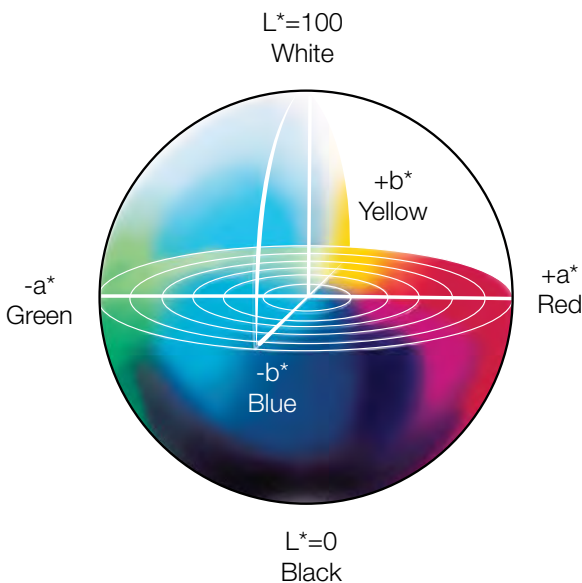
Delta E

Delta E ($\triangle E$) is the mathematical difference between two color samples. It calculates how far apart the two colors are in the L*a*b* color space (Adams et al. 2008). Differences between the two samples are calculated with their respective L*, a*, and b* values. The "original" equation, $\triangle E76$ or $\triangle E^*_{ab}$ is:

$$\Delta E^*_{ab} = \sqrt{\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2}}$$

A $\triangle E$ of 0 means there is no difference between the two colors, as they are the same. A $\triangle E$ of 1.0 means the difference between the two colors would be undetectable to the human eye, while a large $\triangle E$ indicates the two samples are distinctly different colors (Sharma, 2004). $\triangle E76$ is used in many ISO procedures in process control of halftone color separations, proof, and production prints however the formula is not the most perceptually uniform. Different formulas in calculating $\triangle E$ were later derived in order to measure color differences that is more approximate to the human visual system (Adams et al., 2008).

ΔE94 (E^{*}_{94})

CIE revised the original formula which corrects the visual non-uniformity of L*a*b* through weightings of lightness (L*), chroma (C*), and hue (h*) to calculate color differences. The K-coefficients affect factors influencing col- or difference judgment and the S-coefficients adjust CIELAB's visual non-uniformity, which represents a better visual difference (Habekost, 2007). The formula for △E94 is:

$$\Delta E^{*}_{00} = \sqrt{\left(\frac{\Delta L^{*}}{k_{L}S_{L}}\right)^{2} + \left(\frac{\Delta C^{*}}{k_{C}S_{C}}\right)^{2} + \left(\frac{\Delta h^{*}}{k_{H}S_{H}}\right)^{2}}$$

ΔE2000 (E^{*}_{00})

△E$_{oo}$ improves the shortcomings of the △E94 formula by adding weighting factors depending on the hue angle of color in an attempt to correlate more closely to human vision. A rotational factor was applied since CIE 94 has deficiency in the blue-violet region of the spectrum by inputting lightness weighing functions ($k_{L}S_{L}$), a chroma weighting function ($k_{C}S_{C}$), a hue weighting function ($k_{H}S_{H}$), which improves the performance of blues, and a factor R_{T} improving the performance of grey colors (Habekost, 2013). The formula for △E2000 is:

$$\Delta E^{*}_{00} = \sqrt{\left(\frac{\Delta L'}{k_{L}S_{L}}\right)^{2} + \left(\frac{\Delta C'_{ab}}{k_{C}S_{C}}\right)^{2} + \left(\frac{\Delta h'_{ab}}{k_{H}S_{H}}\right)^{2} + R_{T}\left(\frac{\Delta C'_{ab}}{k_{C}S_{C}}\right)\left(\frac{\Delta H'_{ab}}{k_{H}S_{H}}\right)}$$

Color Measurement Committee (E^{*}_{CMC})

The equation was not created by the CIE but instead by the Color Measurement Committee (of the Society of Dyers and Colourists of Great Britain) (Millward, 2010). This formula recognizes the various color sensitivities of the human visual system where a △E of 1.0 gives the same visual differences within all regions of the color wheel (Adams et al. 2008). S_{L}, S_{C}, and S_{H} are the weighting factors for lightness, chroma, and hue respectively. The l and c factors are constant, which are defined by the user weighing the importance of chroma and lightness relative to the color's hue (Habekost, 2013). The formula for this equation is:

$$\Delta E^{*}_{CMC} = \sqrt{\left(\frac{\Delta L^{*}}{lS_{L}}\right)^{2} + \left(\frac{\Delta C^{*}}{cS_{C}}\right)^{2} + \left(\frac{\Delta h^{*}}{S_{H}}\right)^{2}}$$

Equipment

- X-Rite 530 Series Spectrophotometer (Serial No. - 051480)

- Pantone Solid Coated Formula Guide, fourth edition, second printing

- CHROMiX ColorThink Pro 3.0

Procedures

1. Obtain the X-Rite 530 Spectrodensitometer and the Pantone Solid Coated Formula Guide.

2. Measure 3 sets of L*a*b* values for saturated colors, pastels, neutrals and skin tones.

3. Calculate the ΔE values for each set using the four color difference formulas (ΔE76, ΔE94, ΔE2000, and CMC) and plot the L*a*b* values into CHROMiX ColorThink Pro.

4. The testing conditions for this test utilized fluorescent lighting under room temperature conditions. First an X-Rite 530 Spectrodensitometer and Pantone Solid Coated Formula Guide was obtained in the press lab. The next step was to measure and record the L*a*b* values of three sets of patches pertaining to saturated color, pastels, neutrals, and skin tones in the Pantone book (Figure 2). Finally, the color difference between the patches was calculated using the four known color difference formulas and the L*a*b* values were plotted in CHROMiX ColorThink Pro to determine which formula was the best choice in measuring for each of the differing color patches.

Figure 2

The color patches chosen to be tested consisting of saturated colors, pastels, neutrals, and skin tones.
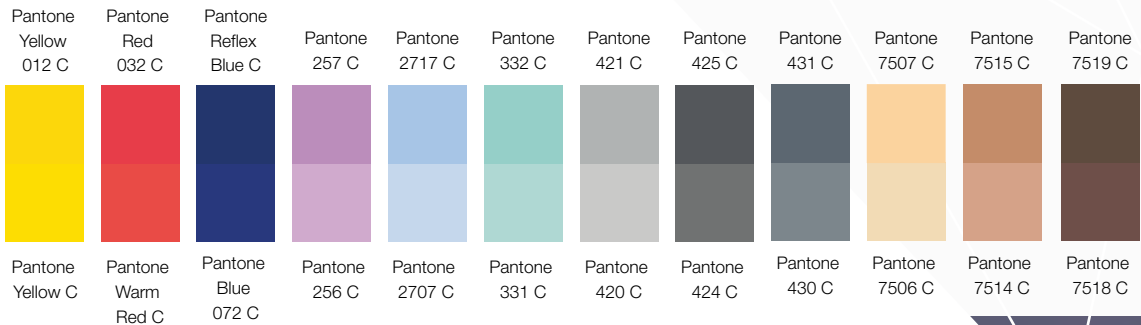
Results

The table below presents the L*a*b

Color	L*	a*	b*
Saturated			
Yellow C	88.61	-3.07	109.89
Yellow 012 C	86.10	4.55	113.82
Warm Red	57.68	69.31	52.33
Red 032 C	55.29	71.12	41.50
Blue 072 C	15.96	40.09	-74.36
Reflex Blue C	17.11	26.49	41.50
Pastels			
256 C	79.85	14.75	-13.95
257 C	70.37	22.22	-20.01
2707 C	84.20	-2.11	-17.47
2717 C	78.14	-2.48	-26.32
331 C	86.63	-21.72	-2.34
332 C	84.92	-26.62	-2.01

Color	L*	a*	b*
Neutrals			
420 C	78.99	-0.51	-0.61
421 C	72.46	-0.37	-1.89
424 C	47.04	-0.58	-3.08
425 C	35.62	-0.51	-3.48
430 C	54.41	-2.07	-7.04
431 C	39.71	-2.42	-8.73
Skin Tones			
7506 C	87.35	5.09	18.17
7507 C	86.92	9.22	28.00
7514 C	70.74	15.97	21.83
7515 C	64.04	20.23	25.25
7518 C	36.45	11.79	10.39
7519 C	32.80	7.24	10.03

NOTE: values taken from the color patches in Figure 2.

The next table shows the L*a*b* values calculated using the four color difference equations (ΔE76, ΔE94, ΔE2000, and CMC) and later were graphed in ColorThink Pro.

Saturated	ΔE76	ΔE94	ΔE2000	CMC
Yellow C/ Yellow 012C	8.933611	3.868855	4.122044	4.180747
Warm Red C/ Red 032 C	11.23519	5.041694	5.61302	6.872639
Blue 072 C/ Reflex Blue C	15.66094	4.928043	5.385874	6.483365
Pastels				
256 C/ 257 C	13.50537	10.73554	8.371684	9.078581
2707 C/ 2717 C	10.73233	7.826921	5.936035	7.205234
331 C/ 332 C	5.200288	3.040347	2.78814	3.125448
Neutrals				
420 C/ 421 C	6.655742	6.648549	4.889066	5.18068
424 C/ 425 C	11.42722	11.42566	10.24338	10.8553
430 C/ 431 C	14.80097	14.75728	14.40909	13.02723
Skin Tones				
7506 C/ 7507 C	10.67102	5.812727	5.272694	6.757211
7514 C/ 7515 C	8.644883	7.174306	5.924423	6.171741
7518 C/ 7519 C	5.844194	4.845324	5.272446	6.495869

Figure 3: Saturated

A visual depiction of saturated colors regarding the color differencing equations used.

Figure 4

The saturated L*a*b* samples graphed in ColorThink Pro.

Figure 5:
Pastel

A visual depiction of
pastel colors regarding
the color differencing
equations used.

Figure 6

The pastel L*a*b* samples
graphed in ColorThink Pro.

Figure 7: Saturated

A visual depiction of neutral colors regarding the color differencing equations used.

Figure 8

The neutral L*a*b* samples graphed in ColorThink Pro.

Figure 9: Pastel

A visual depiction of
skin tone colors regarding
the color differencing
equations used.

Figure 10

The skin tone L*a*b*
samples graphed in
ColorThink Pro.

In the saturated group, the color differencing equations had the $\triangle E$ values going from very high values ($\triangle E76$), to low values ($\triangle E2000$ and CMC) (Figure 3). For the pastels, neutrals, and skin tone group, the $\triangle E$ retains high values throughout the four differencing equations (Figures 5, 7, and 9). In ColorThink Pro, the saturated samples are found around the edges of the graph (Figure 4) while the samples for pastels, neutrals, and skin tone are found near the central region of the graph (Figures 6, 8, and 10).

Conclusion

In the saturated sample, there was a large shift in the $\triangle E$ values from $\triangle E76$ to the low values of $\triangle E2000$ and CMC. This is due to the revisions of the formulas in calculating $\triangle E$, as the more recent formulas are derived in order to measure color, which is a better representation to the human visual system (Adams et al., 2008). For the pastels, neutrals, and skin tone group, the $\triangle E$ retains its high values throughout the four differencing equations. This indicates that the human visual system is very sensitive towards slight changes in color in these sample groups. The values remain high so the samples are more visually relatable (Sharma, 2004). In ColorThink Pro, the saturated samples are found around the edges of the graph while the samples for pastels, neutrals, and skin tone are found near the central region. That is because the L*a*b* system separates color into lightness (L*) and color information into a red-green axis (a*), and a yellow-blue axis (b*). The position of a color indicates how saturated it is. As the position moves from the central region towards the edges, the saturation increases (Sharma, 2004).

Although the results for $\triangle E2000$ and CMC in the saturated colors have lower values, there was very few differences. This indicates that the human visual system is less sensitive to the color difference in very saturated colors, meaning $\triangle E76$ is more accurate for some colors and being less accurate in others (Sharma, 2004). The colors located around the near neutral L* axis of the L*a*b* system would be more noticeable to changes in color in our eyes, while colors further away, being more saturated, would be less noticeable in changes to color. Therefore human eyes are more sensitive to the magnitude of certain color differences than others.

The CIE system measures colors according to human vision characteristics. This enables a color to be made and matched to another and it can also be used to predict the visual differences between two colors. However the CIE system doesn't describe the appearance of color. The appearance of color has many factors influencing it, such as the lighting, the characteristics of the surrounding colors in the visual field, and

the geometry of the color surface. When an image is printed, the type of lighting and the surrounding elements on the page will have differing effects on its appearance. Therefore the differences concerning color reproduction may not appear to match when visually assessed, but match when they are measured colorimetrically (Ford and Roberts, 1998).

In summary, there is no right or wrong equation to use; the method of choice depends on what the scenario. The newer formulas of $\triangle E$ relate better to human perception since it calculates a more elliptical than spherical distance in the $L^*a^*b^*$ color space (Berns, 2000). Colors have different tolerances and $\triangle E_{94}$, $\triangle E_{2000}$, and CMC all calculate color differences in an elliptical method. The shape and size of the ellipses change dramatically throughout the $L^*a^*b^*$ color space (Sharma, 2004). Due to the simplicity of $\triangle E_{76}$, the equation has the same tolerance distance around the sample color and the original (Berns, 2000). This means a color may be within the $\triangle E_{76}$ tolerance, having no difference between the two color samples, but the same may not hold true for other colors where there may be a significant difference. It is essential to indicate which of the four-color differencing formulas was used to calculate the $\triangle E$ values to maintain consistency. Each formula has different ways in calculating the color difference, so there will be a wide range of values from using the varying color differencing equations.

References

Adams, R., Sharma, A., & Suffoletto, J. (2008). *Color management handbook: a practical guide.* Pennsylvania: PIA/GATF.

Berns, R. (2000). *Billmayer and Saltzman's principles of color technology* (3rd ed.). Canada: John Wiley & Sons.

CIELAB Colour Space Model [Image]. (2014). Retrieved March 30, 2014 from http://ww.colorcodehex.com/cie-lab.jpeg

Ford, A., & Roberts, A. (1998). *Colour space conversions.* Retrieved March 30, 2014 from http://www.poynton.com/PDFs/coloureq.pdf

Habekost M. (2013). *Which color differencing equation should be used?* Retrieved March 30, 2014 from http://www.hdm-stuttgart.de/international_circle/circular/issues/13_01/ICJ_06_2013_02_069.pdf

Millward, S. (2010). *Color difference equations and their assessment.* Retrieved March 30, 2014 from http://cias.rit.edu/~gravure/tt/pdf/pc/TT9_color_difference_equations.pdf

Sharma, A. (2004). *Understanding color management.* New York: Thomson Delmar.

Credits

First Year Students

- Chris Cho
- Carmen Fan
- Susan Hanna
- Parastoo H.
- Susan Hanna
- Joanna Kozij
- Jessica Lewis
- Xin Lin
- Jasmine Ooi
- Jeremy Page
- Jenny Park
- Jihyun Park
- Denia Parkin
- Jasmine Ragual
- Sabrina San
- Kara Sidoruk
- Jessica Tam
- Anastassia T.
- Amanda Whyte
- Melissa Williams

Second Year Students

- Rubab Ashraf
- Victoria Campoli
- Maisha Chowdhury
- Jessica Rocha-Da
- Silva
- Yael Feldman
- Elizabeth Finlay
- Janna Guyatt
- Daniel Langsford
- Maria Manila
- Laura Ozaeta
- Christina Phan
- Tricia Sadac
- Maya Seto
- Paolo Sulay
- Vinh Tran

Third Year Students

- Shanfar Balsara
- Beverly Bourke
- Kenesha Campbell
- Sabihat
- Chowdhury
- Marija Dikova
- Jennifer Huynh
- Melissa Karjanmaa
- Jasmine Keo
- Fitz Morales
- Jessica Luong
- Jim Phan
- Caitlin Saberon
- Anna Tang
- Fionni Tsang

Fourth Year Students

- Christopher Ambedkar
- Jeff Bezbrozh
- Arnold Chan
- Jacqueline Chan
- Angela Chau
- Madison Ditullio
- Emily House
- Traci Phillips
- Ellie Voutsinas

CO-PRESIDENT
STEPHANIE MURRAY

Being a part of RyeTAGA the past three years has really enhanced my university experience and opened my eyes to the many facets of the printing industry. I love seeing our initial ideas develop into a cohesive and polished finished product that we are proud to present at the Annual TAGA Conference. Now finishing my fourth year at GCM, I'm really excited to have been a leader of this innovative, exciting team and to have brought everyone together to create another potentially award-winning journal.

CO-PRESIDENT
JESSICA KLEIN

RyeTAGA gave me the opportunity to expand my knowledge, excel at my strengths, and to help foster an amazing team to do the best they possibly can. I am honoured to have co-leaded this year's RyeTAGA executive team and I am very proud of what we have collectively created.

CREATIVE DIRECTOR
HARLEEN SINGH

For this year's student chapter, I wanted to emphasize and creatively show the uniqueness of each technical report. Taking on the role as the Creative Director has taught me that time management and communication is key to being successful in everything that I do. From planning to composing the design of the journal I am thankful for the great feedback and assistance I received from the RyeTAGA executives and the general members.

I have had the privilege of working with motivated members that are very supportive and encouraging with the ideas I have brought to the table. Without them, this journal would have not been complete!

MULTIMEDIA DIRECTOR
ANJELICA TIZON

Taking the lead of this year's RyeTAGA Multimedia team has been an experience to remember. I learned so much this year, not only from the production process of the journal, but from all the people I had the chance to meet. I was so fortunate to be a part of such a great executive team with equally great general members.

RyeTAGA enabled me to use the skills I learned in class to create an actual product, and expand my knowledge even more on our evolving industry. I'm very excited to see how we, as an industry, continue to adapt and challenge a world that thinks print is dying.

Here's to everyone who worked so hard to bring this journal to life, and to hoping that we bring home the Kipphan Cup for the second year in a row!

PRODUCTION DIRECTOR
TAK PO CHU

It has been a phenomenal year for RyeTAGA. Setting higher standards, we tackled on some more ambitious goals, thinking of different creative methods for this year's journal. The executive team has worked effortlessly, dedicating much of their own personal time to ensure that everything, down to the smallest detail, was near perfect.

Being Production Director for a second and final year has been an immense experience. It has been a great run, having the privilege to work with such an amazing team of brilliant minded people. RyeTAGA has truly defined my university career. My utmost respect to the 2015 team, the executives before us, and my best regards to our successors in the years to come.

MARKETING DIRECTOR
RAMAGE ZAKI

My involvement with RyeTAGA for the second consecutive year has allowed me to grow personally as I collaborated with an outstanding team. Becoming the marketing director has given me a chance to pursue what I love and prepare for the professionally for the industry. RyeTAGA continues to provide opportunities for my colleagues and I, executives and general members alike, to network with industry professionals, exposing us early on to the graphic arts industry.

CORPORATE RELATIONS DIRECTOR
ALINA ESMATYAR

I have been a part of RyeTAGA twice in my four years in GCM, the experience this year has been incredible. My position as Corporate Relations Director has allowed me to interact with companies throughout Toronto and pitch RyeTAGA's outgoing experiences, awards and successes. With a strong professional team it has become a memorable year!

FINANCIAL DIRECTOR
ANDRÉ VALLE

Joining the RyeTAGA executive team for this past year has been remarkably rewarding. Between the challenges we faced, the projects we worked on, and the people we met, every moment made me a better person, providing me with valuable experience. I am very proud of the work we have done this past year, and I cannot think of a better group to have done it with.

FACULTY ADVISOR

MARTIN HABEKOST

Quite a few things have been achieved since the last TAGA conference. A new team has been assembled and a lot of work went into the creation and production of the journal. Our fundraising efforts were successful and enables us to go with 12 students to Albuquerque. I am looking forward to the conference to hear about the latest research in the Graphic Arts Industry and meet old friends again. The student competition for the best journal will show some interesting techniques that were used in creating a student journal. Enjoy the conference!

2014 – 2015 Executive Team

Colophon

Typefaces

BigNoodleTitling
Cartier Book
Helvetica Neue
Lucida Sans Unicode

Inks

Probite Process Cyan, Magenta, Yellow, Black by Mi5 Print and Digital Communcations
HP Indigo Metallic and Process Inks

Stocks

Rolland Opaque50 Bright White Smooth 80 lb Cover – 215 g/m^2
Supreme Silk 80 lb Text – 120 g/m^2
Cougar Super Smooth Double Thick Cover 130 lb – 352 g/m^2

Software & Equipment

Adobe Creative Suite 5.5 and 6
Xerox FreeFlow
Heidelberg SpeedMaster CD 102 at Mi5 Print and Digital Communications
Xerox 700 at Ryerson University
Emprint SpotDot at Ryerson University
Kodak Prinergy at Mi5 Print and Digital Communications

Bindery & Finishing Equipment

Stahl Folder 1220E at Ryerson University
Polar 78 Cutter at Ryerson University
Muller Martini Amigo Perfect Binder at Ryerson University

Final Acknowledgements

It's the little things that make one big thing great. Sometimes it's just one or two little things, and sometimes it's a multitude of little things, but here we are at the end of the 2015 RyeTAGA journal with one big thing that is so great because of a handful of people.