2019

RYETAGA

RYERSON UNIVERSITY STUDENT CHAPTER

RYETAGA

TECHNICAL ASSOCIATION OF THE GRAPHIC ARTS

RYERSON UNIVERSITY STUDENT CHAPTER

2019

RYETAGA

Technical Association of the Graphic Arts

Published by RyeTAGA
www.ryetaga.com

School of Graphic Communications Management
Ryerson University
125 Bond Street
Toronto, Ontario
M5B 2K3 Canada
www.ryerson.ca/gcm

“The care of the Earth is our most ancient and most worthy, and after all, our most pleasing responsibility.”

- Wendell Berry -

table of

NFC Feature | 8

Our Inspiration | 10

Letter from our Faculty Advisor | 13

Letter from our President | 14

Exploration of Conductive Ink Properties | 16

Amanda Whyte
Carman Fan
Katie Campbell
Mia Cyrwus

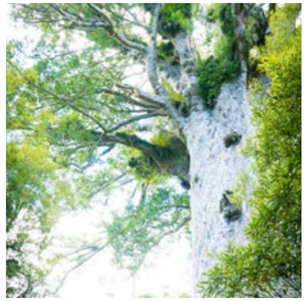
Colour Accuracy of Expanded Gamut Printing | 43

Julia Forrester

contents

77 | **Holography in Print**

Arundhuthi Ghosh



87 | **Evaluation of FM Screening**

Samantha Stante

104 | Meet our Executive Directors

112 | Meet our Associates

113 | Colophon

114 | Image Sources

115 | Meet our Sponsors

TRY OUT OUR

NFC

FEATURE

QR Code for Online Version

- INSTRUCTIONS FOR USE -

on both Apple & Android devices

1. Connect to the internet or nearest wifi network on your mobile device

2. Simply tap your device on the sticker above to view the following;

1st Tap	Watch our Student Chapter 2019 authors speak about their reports
2nd Tap	Meet this year's RyeTAGA Team
3rd Tap	Meet our 2019 Sponsors

OUR INSPIRATION

From the beginning of time, nature and humankind have had a special relationship. It is this very relationship that has inspired the design of the 2019 RyeTAGA journal. We as humans have become accustomed to the beauty of nature, and as such we have taken for granted the many resources we use to fuel our industries today. As we work as a united, global community to adopt sustainable practices, we hope that the design of this journal will serve as a reminder of how beautiful our planet is and how it is our duty to preserve it.

A LETTER FROM

MARTIN HABEKOST

Dear RyeTAGA Student Chapter,

After taking a break from being the faculty advisor for a few years, I am now your advisor again, together with the Chair of School, Jason Lisi.

I did not know how much I missed being involved with the chapter. It is always a pleasure to meet with you once a week and see how the journal starts to form over time. Creative has many design ideas. Production tries to keep creative in check, so the ideas do not get too crazy. Editorial team is always looking for research articles. Corporate relations' constant fundraising solicits support from industry and the university. In the end, many, many people are needed to create the journal that is now in your hands.

The RyeTAGA student chapter has been very successful over the years, winning the Kipphan Cup multiple times.

I look forward to the 2019 TAGA conference in Minneapolis. Enjoy the conference and may the best journal win (hopefully ours)!

Martin Habekost, Dr. rer. nat.
RyeTAGA Co-faculty Advisor

- OUR PRESIDENT -

AIDAN KAHANE

Dear TAGA,

It comes with great pleasure to present to you our 2018/2019 Ryerson University Student Publication Journal. This journal is the culmination of a year's worth of hard work and dedication from an amazing executive team of eight individuals hand chosen from the best and brightest students in the Graphic Communications Management program at Ryerson University. This year's journal would not have been possible without the continuous support of our faculty, staff, and sponsors. This year, we wanted to focus on the environmental impact the printing industry has on the world by including various innovations and design elements inspired by this topic within our journal.

We believe that our journal truly represents the Canadian printing industry proudly through constant innovation and adaptability that we have incorporated into our journal. We hope you enjoy reading the amazing reports within our journal as we have worked many hours putting them together. This year has had some hiccups that both pushed us forward and educated us on dealing with untimely issues. Our team has worked day and night to produce this journal in front of you today and we are proud of all that we have accomplished this past year.

We would like to send our thanks to those who have helped in producing the 2018/2019 RyeTAGA journal. Without our team, sponsors, friends, and family, none of this would have been possible. We are so grateful for their generosity and dedication and the donations and sacrifices they have made for our success. To our Faculty Advisors, Jason Lisi and Martin Habekost, we could not have done this without your constant support and believing in us through each and every step along the way.

We understand that the bar is set high this year, but we are here to rise to the challenge. Regardless of the outcome, we are proud and excited about what we have accomplished and feel grateful for the knowledge we gained and the experiences we overcame to be where we are today. We feel honoured to be among some of the top student minds of this industry and look forward to another eventful conference. This year's journey has allowed us to become more knowledgeable, understanding and inspired and we would not ask for any other way. This experience has been that of a lifetime, and it is our pleasure to share this experience with you.

Sincerely,

Aidan Kahane,
President, RyeTAGA

01

EXPLORATION OF CONDUCTIVE INK PROPERTIES

Amanda Whyte | Carman Fan | Katie Campbell | Mia Cyrwus

SCOPE & SUMMARY

The main focus of this test is the printed surface area and its properties on conductive ink, specifically how well it transfers electricity from one point to the next. Using a voltmeter, this test measures the effectiveness of Bare Conductive ink to hold a consistent charge across various line widths and lengths. Printed on various substrates, it will resemble those potentially used in the packaging industry. The lines will be printed on a Vandercook letterpress, using photopolymer plates. The plate consists of two lines for each line length and width so that positive and negative charges can run through the line, and ultimately create a closed circuit. From an application standpoint, a 9-volt battery will be used to ensure that the circuit is able to provide energy to the LED light.

This test hopes to discover the uses and capabilities of conductive ink across the supplied substrates and to understand its limitations. Graphical methods will be used to analyze the trends within the conductivity meter readings to provide recommendations for printability and runability. From the results, the lower quality prints appear to have poor receptivity (i.e. are not able to transfer the full 9 volts from the battery). This was most evident in most of the coated or smooth samples. Uncoated or matte samples have better receptivity due to their ability to absorb more ink (in which dot gain may have assisted in connecting the printed lines). The results will ultimately help companies that wish to enter the printed electronics market and to help determine the minimum line thickness and maximum line length that can be used for a variety of substrates.

INTRODUCTION

The exploration of circuit technician/consumer-based carbon conductive inks will help printers looking to enter the printed electronic markets understand the important aspects that will affect the ink's conductivity. This test involves using the traditional method of printing: letterpress printing. The imaging plate will consist of various line lengths and line widths to be tested to find the relationship between total ink coverage area and conductivity (which will be measured by the voltage each image is able to transfer from one end to the other); substrate properties will also be considered. The main idea of this topic is to find out the common printing variables that affect the conductive nature of these specialty inks.

The significance of this test is to determine the possible applications, based on the results collected through these experimentations. As mentioned, "it is important that the solvents evaporate leaving behind sufficient binder for good adhesion and sufficient particle packing to conduct electrons after drying. The conductive fillers are what provide the conductive properties" (Bhore, 2013). Therefore, the objective of this test is to determine if conductivity will increase in correlation with higher ink, i.e. covering more area on the substrate. Additionally, different substrates will be tested to determine whether their respective properties will affect the ink's conductivity.

The expected educational gains include understanding which specific ink coverage area and substrates are appropriate for certain applications. Printed electronics have been exploring multiple different substrates, such as plastic films and textiles. By learning about the behaviours of conductive inks, it will allow printers or technicians to determine whether to use the conductive ink as a conductor, a resistor, or to combine with other metal-based conductive inks.

DEFINITIONS

| CONDUCTIVITY |

The ability of a type of energy to move from one medium to another. (Merriam-Webster, n.d).

| VOLTAGE |

The electric potential expressed in volt measurements (Merriam-Webster, n.d).

| ELECTROMIGRATOIN |

An electrical field influencing the movement of metallic material on a non-metallic medium (Bhore, 2013).

TESTING PRINCIPLES

| CONDUCTIVITY ON DIFFERENT SUBSTRATES |

To get a sense of how commercially viable this product is, tests will be done on various substrates, with some limitations due to the Vandercook letterpress' need for flexible materials. Many characteristics of typical inks can be altered by which paper they are paired with, so this test will include an assessment of the substrate in relation to the conductivity of ink. The use of the Yupo plastic paper will give insight into the commercial viability of the ink, as many types of packagings are printed on plastic materials. The different textures, weights, and compositions of the substrates will presumably affect the adhesion of ink, appearance of print, as well as the ability to conduct an electrical current.

Though done manually and in a very short run, the tasks performed are very much like those that would be done commercially on-press. Steps are taken to standardize and improve the process of letterpress printing, such as frequent washups and continual quality checks of the printed material. The use of different substrates will give insight to how different industries might make use of the ink, and how appropriate each one would be based on the print quality. Alternatively, using a different printing method, such as on the flexographic press or the Quickmaster offset press, will assist in analyzing the ink characteristics on label substrates and thicker materials.

| CONDUCTIVITY DEPENDENCE ON SURFACE AREA |

The performance characteristics for this testing principle are defined as the strength of electricity relative to line length and width, in comparison to its source voltage amount (in this case, 9 volts). By printing lines of different lengths and thicknesses, the ink's ability to carry an electrical current based on the surface area will be tested. For example, this test should confirm if a relationship between a line's length and conductivity exists. Either the larger distance between start and end of the current will mean it is weaker, or adversely, the increased surface area means that it can more effectively carry the current. The testing equipment is used to systematically record the capabilities of the printed material, in this case, its conductivity. The LED lights, along with the battery, give an initial look at whether or not the printed line can carry a current and the voltmeter is then able to give quantitative data on its conductive efficiency.

Currently on the market, there is a small variety of conductive inks being sold. The same procedures could be done with the other varieties, such as a flexographic conductive ink. Adjustments should be considered for the difference in the printing processes. In this particular test, other media applications could have been used to test if the ink film was conducting electricity effectively; therefore, instead of LED lights, other electronic outputs (ex. speakers) could have been used.

MATERIALS TESTED

Bare Conductive Electric Paint

Bare Conductive Ltd.

Substrates tested:

- Canson Opalux Transparent Paper, 110lb. (19" x 24")
- Yupo Plastic Watercolour Paper, 86lb. (20" x 26")
- Euroart Silk Coated, 80lb. 100M
- Supreme Gloss, 80lb. 182M
- Crayola Fingerpaint Paper (16" x 12")

EQUIPMENT USED

Vandercook SP15 Test Proofer
Metal 0.918" Packing Slate
Custom Photopolymer Plate
Little Joe hand roller
Digital Microscope
VoltMeter Fluke 337; True RMS Clamp Meter
ATC Green 9V Battery
Alligator clips
Battery Snap 9V (BFA-3306YY-2)
LED Lights

PROCEDURES

| CREATING THE PHOTOPOLYMER PLATES |

1. Output photopolymer plates (image in Appendix A)

(a) Include various line widths and line lengths. Print two lines of each side by side to account for both the positive and negative currents when measuring the print.

(b) Send PDF file through the CtP using Kodak Prinergy to the imagesetter. Expose as if it were a flexographic plate. Handwash the uncrosslinked area. Let dry.

| PRINTING SAMPLES ON THE VANDERCOOK PRESS |

1. Mount the photopolymer plate onto the metal 0.918" packing slate of the Vandercook letterpress, using double sided hard tape (solids)

2. Position the slate and secure it with quoins and furniture.

3. Using the plastic boards (used for ink mixing),; manually even out the ink using the Little Joe proofer hand roller until a tacky consistency is achieved.

4. Once ink is even on the roller, manually ink the clean plate while ensuring no dried ink is present on the plate.

5. Ensure the Vandercook is positioned appropriately to print and use flexible substrates that can easily wrap around the paper cylinder.

(a) Step on the foot pedal that opens the gripper and slip the substrate in. Remove foot from the foot pedal to close the clamps.

(b) Make sure the paper rolls with the cylinder as it is slowly rolled across the plate; lightly hold the paper in place as it rolls.

6. Pull out the substrate when printed.

7. Repeat steps 4 - 10 for each new substrate.

(a) Re-ink each time so the ink does not dry on the plate (every print), clean the rollers, and re-ink the Little Joe Proofer in a clean area. The ink dries quickly and may cause the substrate to stick to the plate and the letterpress. This may also cause inconsistent results.

| MEASURING SAMPLES: TESTING FOR CONDUCTIVITY WITH VARIOUS LINE LENGTHS AND LINE WIDTHS |

1. Use the Direct Current (DC) option on the voltmeter to measure the conductivity of each line.

(a) This is because we are measuring from a 9 volt battery, which is a direct current, as opposed to a plug in a wall which would be an alternating current.

2. Attach a 9 volt battery to the lines using alligator clips on both the positive and negative sides. Attach the positive and negative voltmeter pins to the corresponding positive/negative line and record the value that appearsed.

(a) This value records the output voltage, which should theoretically match the voltage of the battery. If it does not match, this means there is resistance within the line.

(b) Measure all of the line lengths and widths on each sheet. Take note if any lines are not able to reproduce (e.g. 0.25pt line width could not be printed) and reduce the number of measurements per sheet (with a total of 20 measurements per sheet).

(c) Record any inconsistencies and variances within the printed product (e.g. line break, faded print) to take into account when analyzing the results.

3. Record the results of line length and line width in a table across various substrates and create a scatter plot and/or a line graph of the results in relation to one another, to determine if there are any trends.

RESULTS

SUBSTRATE	Line Length (inches)	DC VOLTAGE Mean	Median	Range	Standard Deviation	Line Thickness (inches)	DC VOLTAGE Mean	Median	Range	Standard Deviation
SUPREME GLOSS	**9**	**7.25**	**7.25**	**1.9**	**1.34**	8	8.02	7.9	1	0.42
	8	**6.13**	**7.95**	**5.8**	**0.49**	7	8.18	8.4	1	0.43
	7	8.1	8.15	0.5	0.22	6	7.84	7.9	1.7	0.68
	6	8.275	8.3	0.3	0.13	5	7.96	7.9	1.1	0.44
	5	**6.66**	**8.3**	**0.3**	**2.70**	**4**	**6.46**	**7.8**	**8.6**	**3.63**
	4	8.14	8.3	1.5	0.60	3	7.22	8	4.7	1.89
	3	8.42	8.6	0.7	0.30	2	6.74	6.8	2.9	1.16
	2	8.48	8.6	0.8	0.33	1	6.625	6.5	2.3	0.98
	1	8.58	8.6	0.6	0.25	0.75	5.9	6	2.5	1.25
	0.5	8.64	8.8	0.7	0.30	0.5	4.6	4.1	4.9	2.49
EUROART SILK COATED (MATTE)	9	7.8	7.8	0.6	0.42	8	8.35	8.35	0.1	0.06
	8	8.04	7.9	0.4	0.19	7	8.275	8.3	0.5	0.21
	7	8.08	8.2	0.9	0.36	**6**	**6.975**	**8.2**	**5.5**	**2.66**
	6	8.08	8	0.6	0.26	5	7.26	8.2	3.9	1.68
	5	8.08	8.1	0.6	0.22	4	7.78	8.3	2.5	1.06
	4	8.22	8.3	0.5	0.22	3	8.05	8.05	0.7	0.29
	3	8.32	8.4	0.6	0.25	2	7.26	8.1	3.4	1.43
	2	8.48	8.5	0.2	0.08	1	7.1	7	1.8	0.73
	1	8.54	8.5	0.1	0.05	0.75	7.275	7.3	1.9	0.81
	0.5	8.56	8.6	0.1	0.05	0.5	7.7	7.7	0.6	0.42
OPALUX	9	–	–	0	–	8	0	0	0	–
	8	–	–	0	–	**7**	**1.7**	**1.7**	**3.4**	**2.40**
	7	0.3	0.3	0	–	6	2.3	2.3	1.4	0.99
	6	0.9	0.9	1.8	1.27	5	–	–	–	–
	5	1.7	1.7	1	0.71	4	–	–	–	–
	4	0.95	0.95	0.9	0.64	3	–	–	–	–
	3	0.75	0.75	0.7	0.49	2	–	–	–	–
	2	1.35	1.35	2.3	1.63	1	–	–	–	–
	1	3.55	3.55	1.7	1.20	0.75	–	–	–	–
	0.5	2.3	2.3	2.2	1.56	0.5	–	–	–	–

Fig 1. Data of the conductivity of various substrates

- Results continued on next page -

SUBSTRATE	Line Length (inches)	DC VOLTAGE				Line Thickness (inches)	DC VOLTAGE			
		Mean	Median	Range	Standard Deviation		Mean	Median	Range	Standard Deviation
FINGER PAINT (KRAFT)	9	7.55	7.55	0.1	0.07	8	8.4	8.4	0	0
	8	7.75	7.75	0.5	0.35	7	8.35	8.35	0.1	0.07
	7	7.9	7.9	0	0	6	8.4	8.4	0.2	0.14
	6	8.2	8.2	0.2	0.14	5	8.3	8.3	0.2	0.14
	5	8.35	8.35	0.1	0.07	4	8.25	8.25	0.1	0.07
	4	8.35	8.35	0.1	0.07	3	8.15	8.15	0.3	0.21
	3	8.45	8.45	0.1	0.07	2	7.95	7.95	0.1	0.07
	2	8.6	8.6	0	0	1	8	8	0.2	0.14
	1	8.6	8.6	0	0	0.75	–	–	0	–
	0.5	8.6	8.6	0.2	0.14	0.5	7.6	7.6	0	–
YUPO PLASTIC	9	2.6	2.6	0	–	8	5.5	5.5	1	0.71
	8	3.70	3.7	0	–	7	5.8	5.8	–	–
	7	4.65	4.65	1.3	0.92	6	5.4	5.4	–	–
	6	5.05	5.05	0.5	0.35	5	4.1	4.1	–	–
	5	5.6	5.6	0.6	0.42	4	4.5	4.5	–	–
	4	5.8	5.8	1.2	0.85	3	4.2	4.2	–	–
	3	5.85	5.85	1.5	1.06	2	2.8	2.8	–	–
	2	6.7	6.7	0.6	0.42	1	0.8	0.8	–	–
	1	8	8	0.2	0.14	0.75	0.2	0.2	–	–
	0.5	8	8	0.4	0.28	0.5	–	–	–	–

All Chart Values have been rounded at least to the nearest hundredth
** Opalux: 0.5" – 5": unable to get a reading, therefore no data to analyze**
Outliers were taken out from calculations

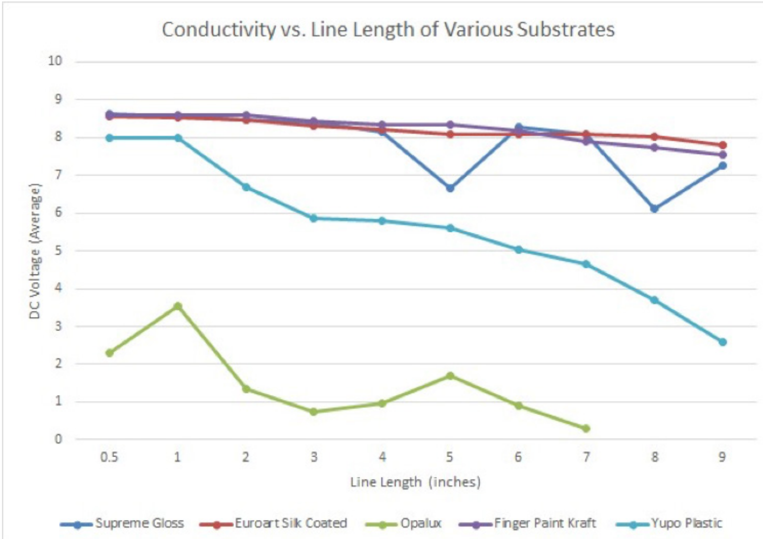


Fig 2. Conductivity in relation to line lengths of various substrates

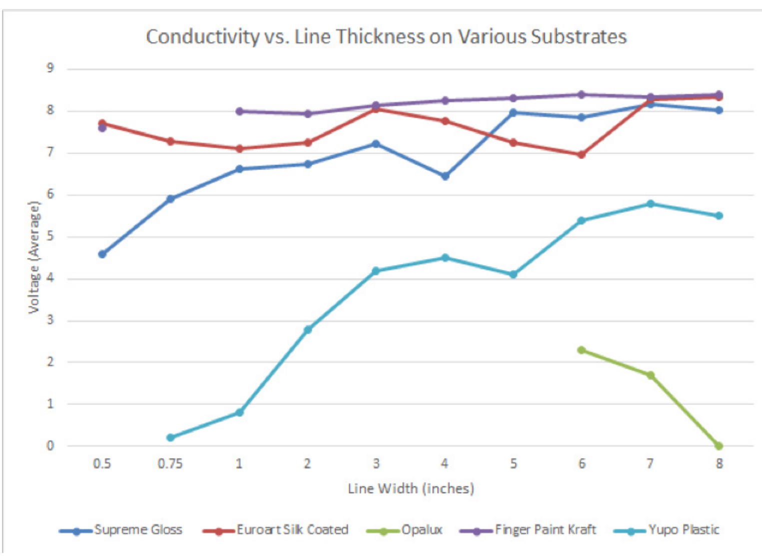


Fig 3. Conductivity in relation to line thickness on various substrates

DISCUSSION

It is important to note that the conductive ink used has a texture and tackiness that almost mimics offset inks and screen printing inks. The results were mainly affected by the quality of print, how well the ink adheres to the substrate and how visually connected the print was in terms of its surface area. Generally, most of the tested line lengths had relatively small ranges and standard deviations in correspondence to their respective mean and medians. There are some that stood out (which are bolded in the chart). Out of the five substrates tested, Supreme Gloss appears to be the most unstable in terms of the longer line lengths; however, this is mostly due to the broken and inconsistent print (As shown in Fig. 4).

Fig 4. Microscopic Image of the Supreme Gloss Coated Sample 2 with a line thickness of 0.75"

For the 5” long line (Supreme Gloss sample), the standard deviation is 2.7, which indicates the relative distance from the average in terms of volts received. According to the raw data, there was one outlier in which only 2.2 volts was received (this number was taken out as the print was not sufficient); also, there was one sample that only received 6 volts, which resulted in a fairly large difference compared to the median of 8.3. It is likely that the 6 volts had heavily skewed the average. As for line thickness, there are only a couple of standard deviations and ranges that are significantly larger than most of the others. For example, Supreme Gloss for 4” thickness has a range of 8.6 and a standard deviation of 3.63. According to the raw data, one sample of the five was unable to receive a voltage reading, which explains the large difference. The Euro Art Silk sample for 6” line thickness was slightly broken, which affects the conductivity as less electrical energy was able to transfer from one point to the other.

The first graph illustrates the relationship between conductivity (average) and line lengths; in addition, tested substrates were plotted onto this graph for better comparison purposes. In terms of line lengths, the Opalux sample was the poorest in receiving energy. The strongest and most stable appears to be the Euro Art and Crayola Finger Painting sample. This could be due to its ability to better absorb ink and thus, it has better surface area and connectivity (not broken like in fig. 4). Supreme Gloss Coated paper appears to be very unstable, while Yupo Plastic is rather consistent. Although both mediums are smooth, Yupo Plastic was able to demonstrate that the farther away from the source, the less energy output. Overall, the graph depicts that the shorter the line, the more energy it will be able to receive. The second graph illustrates the relationship between conductivity and line thickness. It is important to note that there were a number of missing readings, as the conductivity meter was unable to measure the voltage; this could be due to the very thin lines and the halo around the lines. As in the first graph, the Opalux sample was the poorest in terms of conductivity. Yupo Plastic was able to clearly illustrate the relationship between line thickness and voltages received. To conclude, the graph (Fig. 3) generally describes that the thicker the line the better the receptivity.

The results are in agreement with published information, more specifically, the datasheet of the ink states “a wider sample will have less resistance than a thin one” (Bare Conductive, n.d). As well as in Bhore’s paper (2013, p. 7), it mentions that the more filler or particles in the ink, the more conductive it is. Although, it is uncertain how the ink tested is formulated, the surface area can differentiate the number of particles used to print; thus, if a larger printed surface area is printed, then there would be less resistance. Therefore, with less resistance equates to more energy transferring from one point to the other (which is also shown in Fig. 3).

Initial assumptions were that the input voltage would be reduced when measuring at the end of a line of printed ink in accordance to line length and width. It was originally assumed that the shorter the lines, the higher the output voltage, resulting in less resistance. According to the results, this was true because it was found that the shorter the measured line, the higher the transfer of voltage. Alternatively, the thicker the line width the higher the voltage receptivity, because thinner lines were broken and not connected according to the printing process. This contradicted the assumptions made because it was assumed that the thinner the line the less resistance. This was negated through the printing process since thinner lines could not be easily replicated, therefore a wider uninterrupted surface area of conductive ink provided a higher, more accurate reading.

Various hurdles were encountered while conducting this test, some could be written off as part of the learning curve and were resolved throughout the process. Other issues had more to do with the materials being used and would require larger adjustments to be made either to the test or to the actual materials in order to achieve the best results. The Vandercook double-sided tape was substituted with 3M hard tape (used in flexography) to mount the plate due to availability. If the tape had a greater/lesser thickness than the intended tape, it would have either increased/ decreased the pressure between the plate, paper, and cylinder. An altered printing pressure could lead to varied or undesired ink film thicknesses and halos around the printed image. The quick drying time of the Bare Conductive Ink had not been accounted for going into the test and led to a few complications on press. On a preliminary print on Euro Art stock, the paper stuck to the plate while the roller passed, and ripped as it was removed from the plate. This was due to a buildup of dried ink on the actual plate. In this case, a new protocol was set early on in the testing to wipe down and clean the plate after every 1-2 passes, as to avoid the buildup of dried ink that initially ripped one of the prints. The 0.25pt line thickness got damaged during the printing process, leading to a change in texture, as well as altering the appearance of the prints. The damage was most likely due to a dried ink build-up, which was caused by long exposures to open air.

RECOMMENDATIONS

| PRINTABILITY |

Depending on the type of conductive ink (flexographic or offset), from the samples and testing, it is evident that the printed image must be solid and adhere to industry standards. Despite the fact that the ink is often only used for solid objects (i.e. one colour objects, such as a square), the printed image should be of density standards; this is because a solid and continuous printed image is required in order to maximize the transfer of energy from one point to the other. This is evident on the Opalux print sample (where the ink had trouble adhering to the substrate and the overall printed quality was not solid enough). It is also probable that if too much ink is used, too many volts may transfer, which causes the media to not work altogether. Therefore, the ink film thickness should be considered, as with more conductive filler, the higher its ability to transfer energy (Bhore, 2013, p. 7). It is also important to note that conductivity increases after the ink dries, according to Bare Conductive Ltd (n.d).

| RUNABILITY |

During the test, it was documented that the ink can be extremely tacky. With this specific ink, it is important to wash the plate every time before it is re-inked. For printers who are looking to use conductive inks for their products, they should consider testing tackiness of ink since "a great problem with [conductive] ink is its adherence and resistance to mechanical stress on the surface of the electrodes" (Volf, et al, 2015). Thus, adjusting pressure and gaps on rollers would be important as to prevent potential paper jams due to the tackiness of the ink. Roller pressures may also contribute to excessive ink film thicknesses, which, as mentioned before, can cause the media to not work as it would be exposed to high voltage levels.

| END USE |

Finding the optimal ratio between performance characteristics of a line of conductive ink and its ink film surface area could ideally be used to develop RFID printing technology to increase a package's functionality (Merilampi et. al., 2010). Additive processes are becoming more popular to increase the value of a product and minimize the need for additional substrate materials. BARE Conductive Inks have a carbon base, which is made for commercial use, and its primary characteristic is its ability to formulate different inks at varying resistive properties. From this, the inks can be categorized according to their resistive properties, type of resin and type of carbon. Carbon does not have compatibility issues with gas or liquid, which makes it more applicable than silver conductive inks as overprinting is less of a concern. In addition, carbon "doesn't have a tendency of electromigration," which means it is chemically resistive and more stable than a silver base (Bhore, 2013). This can be highly adaptable to consumer products such as RFID tags and other printed circuit technology. It should be noted that this specific type of ink is great for simple circuit work.

REFERENCES

Bare Conductive. (n.d). Bare Paint Technical Data Sheet [PDF]. Retrieved March 17, 2017 from http://www.canadarobotix.com/prototyping/bare-conductive-electric-paint-jar-50ml

Behavior of Ink-Jet Conductive Inks. Department of Materials Science and Engineering, Yonsei University. Seoul, Republic of Korea.

Bhore, S. S. (2013). "Formulation and Evaluation of Resistive Inks for Applications in Printed Electronics." Master's Theses.

Merilampi, S. L., et al. (2010). The Effect of Conductive Ink Layer Thickness on the Functioning of Printed UHF RFID Antennas. Tampere University of Technology, Vol. 98, No. 9.

Merriam-Webster. (n.d). Conductivity. Retrieved March 26, 2017 from https://www.merriam- webster.com/dictionary/conductivity

Merriam-Webster. (n.d). Voltage. Retrieved March 26, 2017 from https://www.merriam- webster.com/dictionary/voltage
Side´n, J., Fein, M.K., Koptyug A., and Nilsson H.-E. (2007).

Printed Antenna with Variable Conductive Ink Layer Thickness.The Institution of Engineering and Technology, Sweden.

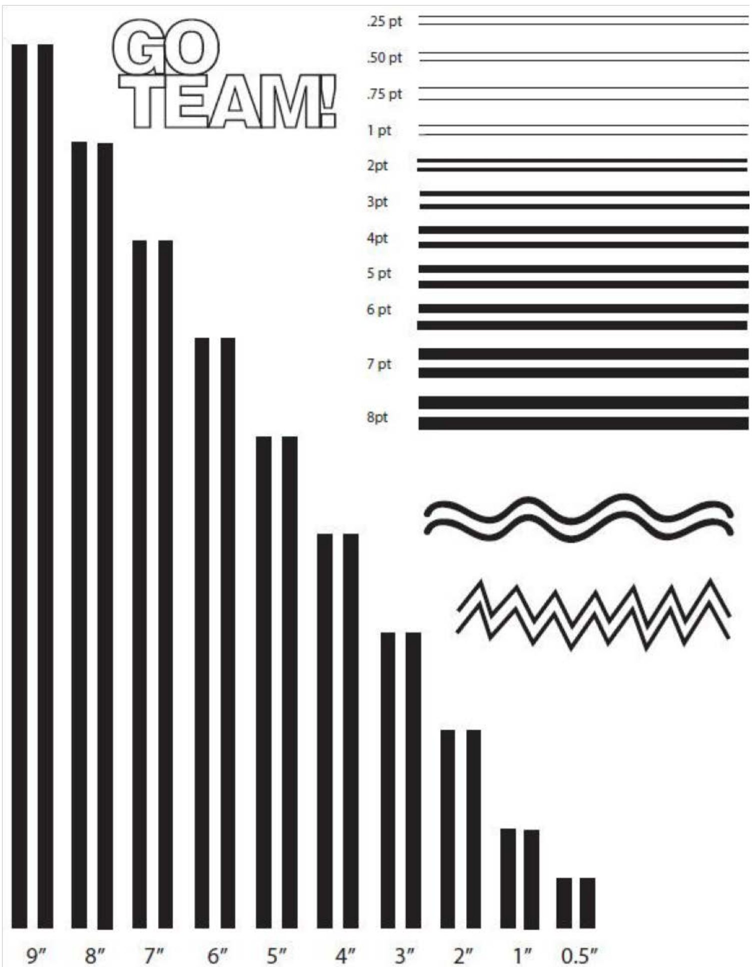
Volf, J., et al. (2015). "Effect of conductive ink properties of tactile sensors" [PDF]. Procedia Engineering. Retrieved March 17,2017 from https://doi.org/10.1016/j.proeng.2015.08.610

Woo, K., Jang, D., Kim, Y., Moon, J. (2013). RelationshipBetween Printability and Rheological

APPENDIX

| APPENDIX A |

Plate Image



| APPENDIX B |

Raw Data

SUPREME GLOSS SAMPLE RAW DATA

Sample	Line Length	DC Voltage	Notes	Thickness Line Length	DC Voltage	Notes
1	9	8.2		8	8.4	
	8	8.3	–	7	8.4	–
	7	8.2	–	6	7.9	–
	6	8.3	–	5	7.7	–
	5	8.3	–	4	7.7	–
	4	8.3	–	3	8	–
	3	8.4	–	2	7.2	–
	2	8.5	–	1	6.8	–
	1	8.6	–	0.75	6	–
	0.5	8.7	–	0.5	2.4	–
2	9		Really Broken	8	7.8	Faded
	8	7.6	Slightly Broken	7	8.5	–
	7	8.1	–	6	8.4	–
	6	8.1	–	5	8.5	–
	5	8.5	–	4	8.6	–
	4	8.6	–	3	8.6	–
	3	8.6	–	2	8.4	Slightly Broken
	2	8.6	Faded	1	–	Broken
	1	8.5	Faded	0.75	–	Broken
	0.5	8.8	–	0.5	7.3	Broken
3	9		Broken	8	7.5	
	8	–	Broken	7	7.5	–
	7	7.8	–	6	6.7	Faded
	6	8.3	–	5	7.4	Faded
	5	2.2	Faded	4	0	Faded
	4	8.2	–	3	3.9	Faded
	3	8.6	–	2	5.5	–
	2	8.7	–	1	6.2	–
	1	8.8	–	0.75	4.6	Faded
	0.5	8.8	Faded	0.5	–	Faded

- Results continued on next page -

Sample	Line Length	DC Voltage	Notes	Thickness Line Length	DC Voltage	Notes
4	9	6.3	Broken	8	8.5	
	8	2.5	Broken	7	8.5	–
	7	8.3	–	6	8.3	–
	6	8.4	–	5	8.3	–
	5	8.3	–	4	8.2	–
	4	8.5	–	3	8	–
	3	8.6	–	2	5.8	–
	2	8.7	–	1	7.9	–
	1	8.8	–	0.75	7.1	–
	0.5	8.8	–	0.5		Faded
5	9		Broken	8	7.9	
	8	–	Broken	7	8	–
	7	–	Broken	6	7.9	–
	6	–	Broken	5	7.9	–
	5	6	–	4	7.8	–
	4	7.1	–	3	7.6	–
	3	7.9	–	2	6.8	–
	2	7.9	–	1	5.6	–
	1	8.2	–	0.75	–	Faded
	0.5	8.1	Really Broken	0.5	4.1	Faded

EUROART SILK COATED (MATTE) SAMPLE RAW DATA

Sample	Line Length	DC Voltage	Notes	Thickness Line Length	DC Voltage	Notes
1	9		Broken	8	8.4	Faded
	8	8.3	–	7	8.5	–
	7	8.4	–	6	8.5	–
	6	8.4	–	5	8.5	–
	5	8.4	–	4	8.4	–
	4	8.4	–	3	8.4	–
	3	8.5	–	2	8.3	–
	2	8.5	–	1	8.2	–
	1	8.5	–	0.75	8.2	–
	0.5	8.5	Broken	0.5	8	–

- Results continued on next page -

Sample	Line Length	DC Voltage	Notes	Thickness Line Length	DC Voltage	Notes
2	9		Broken	8	8.3	
	8	7.9	Faded	7	8	–
	7	8	–	6	8.1	–
	6	8	–	5	8.2	–
	5	8.1	–	4	8	–
	4	8.1	–	3	8.1	–
	3	7.9	Faded	2	8.1	–
	2	8.4	–	1	6.4	–
	1	8.6	–	0.75	7	–
	0.5	8.6	–	0.5	–	Broken
3	9		Broken	8	8.3	Faded
	8	7.9	–	7	8.3	–
	7	8.3	–	6	8.3	–
	6	8.3	–	5	8.4	–
	5	8.1	–	4	8.3	–
	4	8.3	–	3	–	–
	3	8.4	–	2	6.9	–
	2	8.5	–	1	7.4	–
	1	8.5	–	0.75	7.6	–
	0.5	8.5	–	0.5	7.4	–
4	9	7.5	Slightly Broken	8		Broken
	8	7.9	–	7	–	Broken
	7	7.5	–	6	3	Slightly Broken
	6	7.8	–	5	4.6	Slightly Broken
	5	7.8	–	4	5.9	Faded
	4	7.9	–	3	7.7	–
	3	8.3	–	2	4.9	Slightly Broken
	2	8.4	–	1	6.5	–
	1	8.5	–	0.75	–	Broken
	0.5	8.6	–	0.5	–	Broken
5	9	8.1		8	8.4	
	8	8.2	–	7	8.3	–
	7	8.2	–	6	–	Faded
	6	7.9	–	5	6.6	–
	5	8	Faded	4	8.3	–
	4	8.4	–	3	8	–
	3	8.5	–	2	8.1	–
	2	8.6	–	1	7	–
	1	8.6	–	0.75	6.3	–
	0.5	8.6	–	0.5	–	Faded

FINGER PAINTING KRAFT PAPER SAMPLE RAW DATA

Sample	Line Length	DC Voltage	Notes	Thickness Line Length	DC Voltage	Notes
1	9	7.6		8	8.4	
	8	8	-	7	8.3	-
	7	7.9	-	6	8.3	-
	6	8.1	-	5	8.2	-
	5	8.3	-	4	8.2	-
	4	8.3	-	3	8	-
	3	8.5	-	2	8	-
	2	8.6	-	1	7.9	-
	1	8.6	-	0.75	-	Broken
	0.5	8.5	-	0.5	7.6	Faded
2	9	7.5		8	8.4	
	8	7.5	Faded	7	8.4	-
	7	7.9	-	6	8.5	-
	6	8.3	-	5	8.4	-
	5	8.4	-	4	8.3	-
	4	8.4	-	3	8.3	-
	3	8.4	-	2	7.9	-
	2	8.6	-	1	8.1	-
	1	8.6	-	0.75	-	Faded
	0.5	8.7	-	0.5	-	Faded

FINGER PAINTING KRAFT PAPER SAMPLE RAW DATA

Sample	Line Length	DC Voltage	Notes	Thickness Line Length	DC Voltage	Notes
1	9	7.6		8	8.4	
	8	8	-	7	8.3	-
	7	7.9	-	6	8.3	-
	6	8.1	-	5	8.2	-
	5	8.3	-	4	8.2	-
	4	8.3	-	3	8	-
	3	8.5	-	2	8	-
	2	8.6	-	1	7.9	-
	1	8.6	-	0.75	-	Broken
	0.5	8.5	-	0.5	7.6	Faded

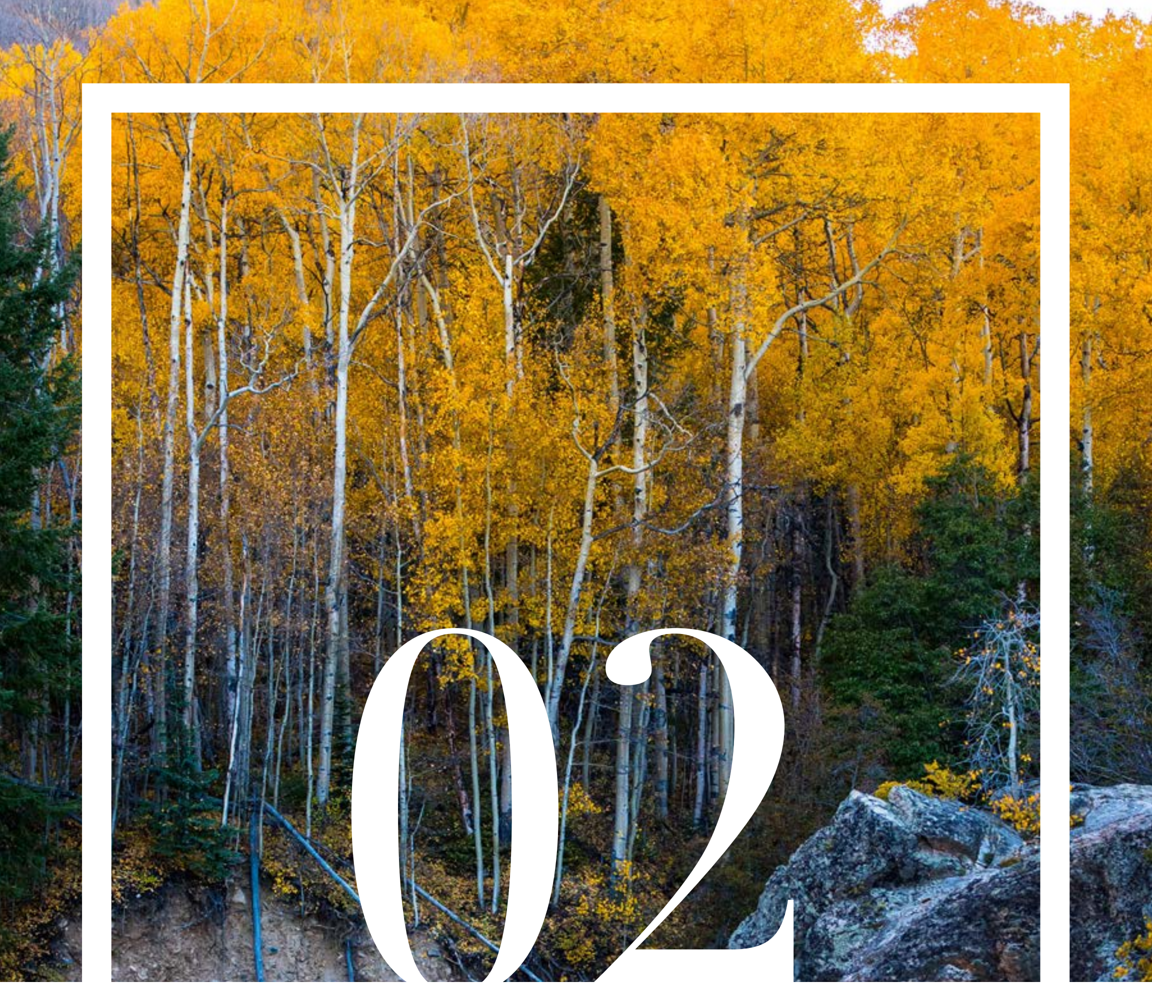
- Results continued on next page -

FINGER PAINTING KRAFT PAPER SAMPLE RAW DATA

Sample	Line Length	DC Voltage	Notes	Thickness Line Length	DC Voltage	Notes
2	9	7.5		8	8.4	
	8	7.5	Faded	7	8.4	–
	7	7.9	–	6	8.5	–
	6	8.3	–	5	8.4	–
	5	8.4	–	4	8.3	–
	4	8.4	–	3	8.3	–
	3	8.4	–	2	7.9	–
	2	8.6	–	1	8.1	–
	1	8.6	–	0.75	–	Faded
	0.5	8.7	–	0.5	–	Faded

YUPO PLASTIC WATER COLOUR PAPER SAMPLE RAW DATA

Sample	Line Length	DC Voltage	Notes	Thickness Line Length	DC Voltage	Notes
1	9		Broken	8	5	
	8	–	Broken	7	–	Broken
	7	4	Faded	6	–	Broken
	6	4.8	Faded	5	–	Broken
	5	5.3	–	4	–	Broken
	4	5.2	–	3	–	Broken
	3	5.1	Faded	2	–	Broken
	2	6.4	–	1	–	Broken
	1	7.9	–	0.75	–	Broken
	0.5	7.8	–	0.5	–	Broken
2	9	2.6	Faded	8	6	
	8	3.7	Faded	7	5.8	–
	7	5.3	–	6	5.4	–
	6	5.3	–	5	4.1	–
	5	5.9	–	4	4.5	–
	4	6.4	–	3	4.2	–
	3	6.6	–	2	2.8	–
	2	7	–	1	0.8	Faded
	1	8.1	–	0.75	0.2	Faded
	0.5	8.2	–	0.5	–	Faded



02

THE COLOUR ACCURACY OF EXPANDED GAMUT PRINTING

Julia Forrester

SCOPE & SUMMARY

The purpose of this project is to determine whether using spot colours or seven colour (7/C) process colours will result in a more accurate colour reproduction. To do so, the L*a*b* values of twelve (12) spot colours from the Pantone Formula Guide and twelve (12) corresponding expanded gamut colours from the Pantone Extended Gamut Guide will be measured and compared to their appropriate reference L*a*b* values in Photoshop to determine the difference in colour (Delta E) between samples and references. The resulting CIEDE2000 values will then be compared and analyzed to determine which printing method creates the most colour accurate reproductions. Using the results of this testing, this report will provide a greater understanding of the abilities and limitations of each of these two printing methods as it relates to colour management and will make recommendations regarding the application of each going forward.

It is widely recognized within the graphic arts industry that Pantone colour books are meant solely as reference guides for spot colours, not as completely accurate reproductions of the Pantone colour libraries available in Photoshop and Illustrator. Pantone itself stated, when announcing their newest colour guides, that while "none of the printed formulas in previous guides are known to be inaccurate...it is possible that a few select colo[u]rs in some guides visually appeared differently due to wider process variation based on variables in the printing process such as paper stock, base pigments, finished inks, press conditions and environmental conditions – all of which can contribute to inconsistency" (Color Alignment FAQ, 2018). With this potential for inconsistency acknowledged, this testing will be used to determine whether 7/C printing is able to more accurately reproduce colours than printing with spot colours.

The best way to determine colour accuracy is to compare the measured L*a*b* values of a printed colour sample to its reference L*a*b* values (listed in Photoshop) to determine the difference in colour (Delta E) between the two. The lower the Delta E value, the closer the printed colour is to its reference. This test will be conducted for twelve spot colours and their corresponding expanded gamut colours to determine, overall, which method of printing is able to achieve more accurate colour reproductions.

INTRODUCTION

Spot colours are colours created without screens or dots (Color Intelligence, 2018). The most famous and widely-used set of spot colours are those found in the Pantone Matching System. Each of these spot colours is created by precisely mixing a combination of base inks (of which there are 18) according to a specified formula (Color Intelligence, 2018). Spot colours appear brighter than four colour process colours due to the gamut of the 18 base inks, and as such are commonly used for corporate logos and branding (Color Intelligence, 2018).

Expanded gamut (EG) printing, on the other hand, is the process of adding supplementary ink colours to a conventional four colour process (Smyth, 2017). While the additional inks can be a variety of different colours, the most common combination for expanded gamut printing currently is Cyan, Magenta, Yellow, Black + Orange, Green, and Violet (CMYK + OGV) (Smyth, 2017). This is the combination used by Pantone in their Extended Gamut Guide. Although this is a seven colour process, only three colourants (maximum) are ever used to create a colour (Sharma, 2018). For example, using a four colour process, a combination of cyan, magenta, and yellow would be used to create an orange colour. However, the same target colour in a seven colour process would be made from only the three nearest colourants - yellow, orange, and magenta (see Figure 1). Because the three adjacent colourants are of similar hues (as opposed to cyan, magenta, and yellow) the printing process is much easier to control, and slight misregistration of inks on press has a less jarring effect on the final colour (Sharma, 2018).

Fig 1. Pantone 150 XGC (left), a seven-colour process colour, is composed only of two adjacent colourants - Yellow and Orange.

The process as it is known today dates back to the late-1980s/ early-1990s, when Harald Küppers introduced Color-Atlas a seven colour process designed to use red, green, and blue in addition to CMYK, and Davis Mills and Don Carli, sponsored by industry vendors, established the HiFi Color Project (Kasdorf, 2003). At the time, however, widespread adoption of the process was limited due to high licensing and material costs, “combined with the complexity of creating separations and process control” (Smyth, 2017).

In recent years though, expanded gamut printing has become more accessible than ever, as the costs and complexity associated with the process have decreased (Smyth, 2017). In an interview with Chris Smyth for Graphic Arts Magazine, Matthew Serwin, Graphic Arts Sales Specialist at Spicers Canada explains that “‘the continuing development of digital workflows and enabling technologies [have blended] together to create renewed interest [in the expanded gamut process]’” (2017). Pantone’s response to this increased interest was the creation of the Extended Gamut Guide in 2015. Meant to allow printers to reproduce a wider range of colours and accurately simulate Pantone spot colours (Pantone Extended Gamut, n.d.), the Extended Gamut Guide has undoubtedly contributed to the popularity of expanded gamut printing today.

DEFINITIONS

| COLOUR GAMUT |

The range or extent of colours a device can produce; most print processes use CMYK inks in a subtractive colour imaging process, and therefore in general, printers and presses have a smaller colour gamut than additive RGB colour devices such as digital cameras and flat-panel displays (Sharma, 2018).

| COLOUR MANAGEMENT |

A way of controlling colour in digital imaging software, hardware, and systematic procedures (Sharma, 2018).

| DELTA E (ΔE) |

A metric used to calculate a numerical measure between two colours. The larger the ΔE, the more distinct the difference between the two colours (Sharma, 2018)[1].

| EXPANDED GAMUT (EG) PRINTING |

The process of adding more colours (usually, but not always, orange, green, and violet) to a conventional four colour process setup; also referred to as extended gamut or extended/expanded colour gamut (Smyth, 2017)[2].

| HUE ANGLE |

The angle of the dominant wavelength of a hue (h) in the CIE colour space (Hue Angle, n.d.); starts at the +a* axis and is expressed in degrees. Hue angle is calculated using the equation:
$hab = \tan^{-1}(b^*/a^*)$ ("Precise Color Communication", 2007).

| MEASURING MODES |

Defined by ISO 13655 (Graphic technology - Spectral measurement and colorimetric computation for graphic arts images), the UV component in measuring instruments is now clearly defined using four modes: M0, M1, M2, and M3 (Sharma, 2018).

M0 - legacy mode (any illumination source)
M1 - D50, UV-included mode (recommended for colour management)
M2 - UV-cut mode (removes all UV light below 400 nm from the measurement system)
M3 - polarizing mode

[1] *The CIEDE2000 equation was used to calculate the Delta E values for this testing.*

[2] *For the purpose of this report, expanded gamut (EG) printing will refer to a seven colour (7/C) process using orange, green, and violet inks in addition to the traditional cyan, magenta, yellow, and black (CMYK) process inks.*

TESTING PRINCIPLES

The testing for this report will consist of twelve spot colour samples and twelve equivalent seven colour process colour samples being measured and compared to their respective reference L*a*b* values listed in Photoshop. The twelve colours tested will be mid-tone colours, with hue angles roughly 30o from each other in the CIELAB 1976 colour space (see Figure 2). Each sample will be measured ten (10) times, with its L*a*b* values and the measurement mode of the spectrophotometer being populated automatically in an Excel spreadsheet. These L*a*b* values will then be averaged and compared to the reference values in Photoshop (see Figure 3) to determine the difference in colour (CIEDE2000) between them.

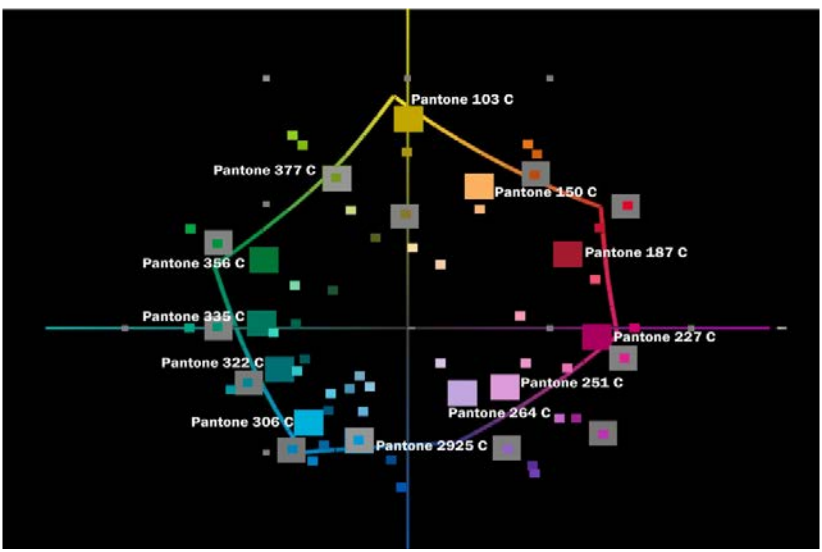
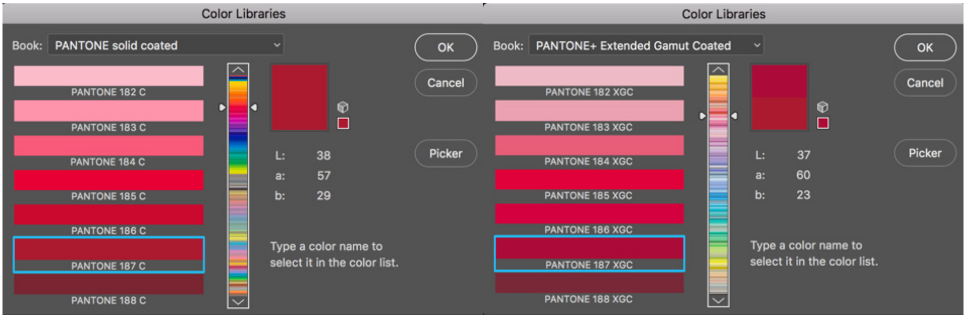


Fig 2. The twelve spot colours used (labelled in the diagram) compared to the GRACoL 2006 gamut in CHROMiX ColorThink, shown in a 2D colour space.



(a) (b)

Fig 3.
*(a) The Photoshop reference L*a*b* values for Pantone 187 C.*
*(b) The Photoshop reference L*a*b* values for Pantone 187 XGC.*

With Pantone colour books being the de facto colour reference for designers and printers around the world, each colour will be measured directly from its respective colour book: the Formula Guide for the spot colours and the Extended Gamut Guide for the 7-colour process colours. Using the Pantone colour books themselves, which are held to a high standard of accuracy by the company (Falconer, 2018), will ensure print consistency between the samples.

MATERIALS TESTED

Pantone Colour Books[3]

- Pantone Formula Guide, Solid Coated (© 2016)
- Pantone Extended Gamut Guide, Coated (© 2015)

EQUIPMENT USED

Software

- Adobe Photoshop (CC 2018)
- Microsoft Excel
- PANTONE Color Manager
- TECHKON SpectroConnect

Materials

- Coated Photo Paper
- TECHKON SpectroDens (Spectro-Densitometer)

[3] *Pantone recommends replacing colour guides every 12-18 months as age and usage can cause fading and yellowing that affect the colour of swatches (Did you know?, 2018). Although these colour books are due to be replaced according to Pantone's guidelines, they have been stored appropriately in a dark cabinet and been handled with care when used, minimizing the negative aging effects they may have experienced.*

PROCEDURE

| PREPARATION |

1. Export the Extended Gamut Guide colour book for Photoshop from Pantone Colour Manager.

2. Choose twelve (12) midtone Pantone colours with hue angles roughly 30o from each other in the CIELAB 1976 colour space.

(a) Use a colour difference calculator (e.g. brucelindbloom.com) and/or Excel to calculate/verify the hue angles[4].

3. Gather the Pantone Formula Guide (Solid Coated) and Pantone Extended Gamut Guide (Coated) that will be used for testing.

4. Create an Excel spreadsheet to record the L*a*b* values and measurement mode used for testing.

5. Ensure TECHKON SpecroDens is connected to the TECHKON SpectroConnect software.

(a)Ensure the spectrophotometer measurements automatically populate in the Excel spreadsheet.

4 After verifying the hue angles, the colours were also compared to both the GRACoL 2006 and Epson SureColor P9000 (a proofer with 7/C capabilities) gamuts using CHROMiX ColorThink for reference. However, because spot colours and expanded gamut colours are able to reproduce colours outside the conventional CMYK gamut, this step is not necessary to conduct this testing (which is why it is not listed as a step in the Procedure). If the samples being tested had been printed internally, however, this step of comparing the gamuts in ColorThink would be crucial to ensuring that the device being used for printing would be able to accurately reproduce the colours.

| MEASURING SAMPLES |

1. Find the swatch for the first colour in the Formula Guide and place it on top of the coated photo paper on a hard surface (e.g. a desk).

2. Using the TECHKON SpectroDens (set to M2 mode and D50 lighting condition), measure the L*a*b* values of the sample.

3.Ensure the measurements are recorded in Excel.

4.Measure the sample an additional nine (9) times, then average the sample's L*a*b* values in Excel.

5. Using the reference L*a*b* values for that colour from Photoshop and the averaged L*a*b* values of the sample, calculate the CIEDE2000 for the colour.

6. Repeat steps #1-5 for the equivalent swatch of the first chosen colour in the Extended Gamut Guide.

7. Repeat steps #1-6 for the remaining eleven (11) colours.

RESULTS

For all twelve spot colours and all twelve expanded gamut colours, the L*a*b* values measured and the measurement mode used by the TECHKON SpecroDens were automatically populated in an Excel spreadsheet using the SpectroConnect software.

See the Appendix for the full results of the conducted testing.

The consolidated results of the testing conducted are shown in the chart below (see Figure 4).

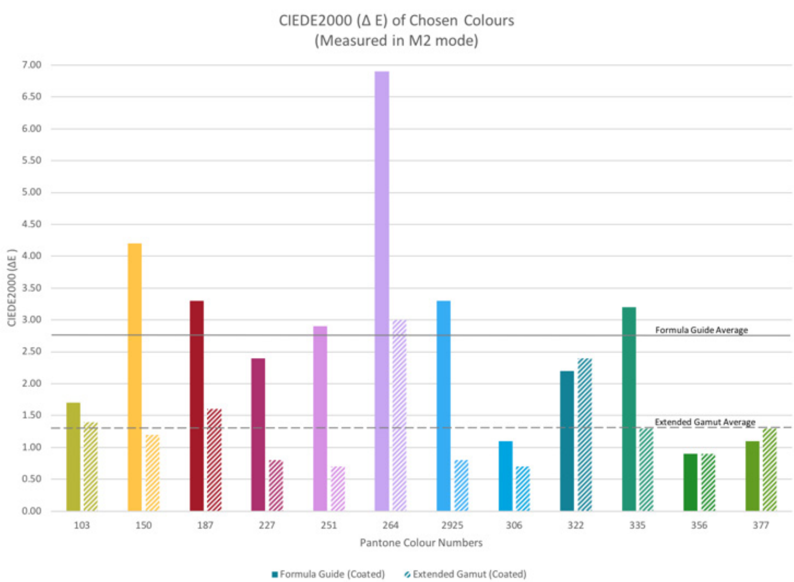


Fig 3. Consolidated results of the colour accuracy testing[5].

5 For a variety of reasons, including (but not limited to) hue, chromacity, and saturation, the colour purple is often difficult to reproduce accurately on press (Prakhya, 2014). This may be the reason for the higher CIEDE2000 values of Pantone 264 C/XGC.

For every colour sample tested (except Pantone 322 C/XGC, Pantone 356 C/XGC, and Pantone 377 C/XGC) the samples from the Extended Gamut Guide colour book had lower Delta E values when compared to their appropriate reference values[6] than the samples from the Formula Guide colour book. The Pantone 356 XGC sample had the exact same Delta E as that of Pantone 356 C, with a value of 0.9. In the case of Pantone 322 XGC and Pantone 377 XGC, their Delta E values of 2.4 and 1.3 (respectively) are only 0.2 greater than that of their spot colour counterparts. All three of these Delta E values are still acceptable for colour reproduction commercial printing (Sharma, 2018), and two of the three meet the tighter tolerance of 2ΔE2000 that Pantone holds for 90% of its spot colours in the Formula Guide (Color Alignment, 2018). Overall, the lower Delta E values of the 7/C samples demonstrate that printing with three adjacent colours in an expanded gamut process (specifically, CMYK + OGV) results in more accurate colour reproduction than printing with a single spot colour does.

Pantone and X-Rite (Pantone's parent company) claim that while Extended Gamut is better than CMYK at reproducing Pantone spot colours (X-Rite states that it can match 90% of spot colours compared to CMYK, which can match 55%), Pantone spot colours "are still the ideal choice for consistent, accurate colour reproduction" (Gundlach, 2018). However, if the results of this testing hold true for the majority of spot colours in the Pantone Matching System, this statement by X-Rite would be disproved, as the Extended Gamut colours have proven, thus far, to be more colour accurate than spot colours. This conclusion would have major implications not only throughout the graphic arts industry but also for companies that rely on spot colours to keep their logos and branding consistent.

6 In Photoshop, the twelve colours have different reference values listed in the Formula Guide and Extended Gamut Guide. The twelve spot colour samples were compared to the reference values listed in the Formula Guide and the twelve expanded gamut samples were compared to the reference values listed in the Extended Gamut Guide. For comparison, the difference in colour between each set of references is listed in the Appendix.

DISCUSSION

| PRINTABILITY |

Printability is an important consideration when printing with a seven colour process. Traditionally, four colour process inks are screened on press (AM screening), although stochastic printing (FM screening) has gained popularity in recent years (Jayaraman, 2015). Utilizing different screen angles for each ink allows printers to avoid moiré, an undesirable print artifact that occurs in halftone reproductions as a result of an interference pattern caused by incorrect screen angles (Moiré, n.d.). FM screening, which uses a random dot pattern instead of screen angles, can also be used to avoid this problem (Hershey, 2006). The inks used in a seven colour process are generally screened similarly to those in the four colour process. However, opposite colours (e.g. magenta and green), which will not overlap due to the three nearest-colourant system used in expanded gamut printing, are often printed at the same screen angle to avoid moiré (Politis et al., 2015). As with 4/C printing, FM screening is often used in expanded gamut printing for the same reason (Politis et al., 2015).

| RUNABILITY |

There are several factors that contribute to the ease with which the expanded gamut printing process can be executed. The first (seemingly obvious) factor associated with the runnability of expanded gamut printing is having the capacity to print seven colours. For smaller printers who may only have a 4 or 5/C press, printing a seven colour process in one pass is impossible. As such, these smaller printers will not be able to compete in the expanded gamut market until the demand for the process becomes great enough to warrant upgrading to a larger press that is better suited to the process (should they have the resources and physical space available to do so).

For printers with the capacity to print seven colours, specialized software and workflows are required for re-separating files intended for expanded gamut printing (unlike conventional process files with spot colours) and proofing before jobs go to print (The Printer's Guide, 2017). The software required for expanded gamut printing can be both expensive for printers to purchase and difficult to learn, requiring extra training for those directly working with it (The Printer's Guide, 2017). As a result, while offering expanded gamut printing may have long-term benefits for shops, especially as the demand for the process grows, these barriers to entry can discourage printers from initially adopting the process.

Additionally, maintaining registration on press becomes more of an issue when printing three process inks than it is when printing with just one spot colour (Smyth, 2017). As stated previously, slight misregistration on press is less of an issue when printing with three adjacent colourants (as done in expanded gamut printing) than it is when printing with CMYK. Although this misregistration may seem negligible in comparison to that of conventional printing, it remains an ongoing issue that printers could avoid by utilizing a single spot colour. For example, "smaller knockout copy that would have conventionally run as a single colour spot can pose a registration challenge for printers when it is made of screens of three different colours" (Smyth, 2017). As a result, printers looking to replace spot colours in jobs by printing with a seven colour process need to have good control of their press registration to ensure quality work is produced.

Finally, printing with expanded gamut requires greater process control than conventional printing (with or without spot colours). Conventional printing has established standards that can be followed, such as G7 calibration and GRACoL or SWOP profiles, to ensure accurate and consistent work is produced on press. Expanded gamut printing, however, has yet to have standards developed to the same extent as conventional printing (The Printer's

Guide, 2017). Standardization has begun to expand as the process gains popularity within the graphic arts industry and among clients. To address the additional challenges presented by the expanded gamut process, “new ISO standards are being developed and released which help support a more open workflow for ECG ... includ[ing] ISO 17972 CxF/X-4 Spot colour characterization data for exchanging colour information as spectral data, ISO 20654 – Spot Colour Tone Value for calculating tone value increase for spot colours, and ISO 20677-1 iccMAX a new format for ICC profiles that better supports tints and overprints” (Smyth, 2017). As adoption rates increase, establishing standards to guide the expanded gamut process will become critical to the ability to successfully produce jobs according to customer specification.

| END USE |

Expanded gamut printing, as the name suggests, increases the range of colours a device can produce. As such, many colours that are out of gamut for conventional CMYK printing can be produced with the addition of colourants such as orange, green, and violet. As a result, EG printing can produce more vibrant, eye-catching colours than 4/C printing can (Baldwin, 2016). The ability to produce colours more vibrant than those of a 4/C process and more accurate than spot colours provides expanded gamut printing with a unique and competitive advantage in the print market.

Pantone estimates that 15-20% of packaging is printed using EG, and that number “is expected to increase more than 50% within the next decade” (Smyth, 2017). Being able to produce brighter, more vivid colours is of great benefit to brand owners, with “90% of snap judgments [being] made about products are based on colour alone” (Smyth, 2017). However, the rise of EG printing in packaging may be driven more by printers than by brand owners (Smyth, 2017). As a process, expanded gamut printing is more time and resource efficient than conventional printing. It saves money on ink and materials, as ink inventories can be reduced and less substrate is wasted on proofing (Baldwin, 2016). As well, printing all jobs using the same seven colours means that jobs can be ganged and fewer wash-ups are required between them (Baldwin, 2016). The efficiency and savings associated with EG printing will contribute to its growth in packaging in the coming years.

While it has many applications for packaging, the main end use for expanded gamut printing, based on the testing conducted for this report, is for brand colours and logos. Colour is used by brands to differentiate themselves from their competitors and increase recognition in the minds of consumers (Odgis, 2017). Coca Cola red and Starbucks green are just two of the many brand colours consumers instantly associate with the companies they represent. Janet Odgis, President and Creative Director of Odgis + Co., an award-winning branding firm, states that "given how colo[u]r so radically increases brand identification (which, in turn, can boost sales and engagement), [it is] crucial that colo[ur remain consistent across all expressions of the brand, whether online or in print" (2017). To maintain this key level of consistency, brands have long turned to Pantone spot colours to reproduce their brand colours in print. However, the testing conducted for the twelve colour samples, as discussed previously, concluded that printing using expanded gamut offers comparable or superior colour accuracy than printing with spot colours does. Should these results hold true for the majority of Pantone spot colours, brands that currently use spot colours for their identity can switch to an EG process, producing more accurate colours at a reduced cost. As well, smaller companies that may not be able to afford the use of spot colours for branding purposes can be provided with a more accurate solution than the four colour process at a fraction of the price of printing with spot colours. Either way, expanded gamut printing makes maintaining colour accuracy and consistency more affordable than ever before for brand owners, both big and small.

REFERENCES

Baldwin, C. (2016, May). Expanded gamut printing 101. Retrieved December 20, 2018, from https://www.nilpeter.com/ref.aspx?id=1279

Color Alignment FAQ. (2018, May 15). Retrieved December 21, 2018, from https://www.pantone.com/color-intelligence/articles/technical/print-enhancements

Color Intelligence: Spot vs. Process Color. (2018). Retrieved December 21, 2018, from https://www.pantone.com/color-intelligence/articles/technical/spot-vs-process-color

Did you know? Updating Your Pantone Guides Can Save You Valuable Production Time And Money! (2018, October 10). Retrieved December 22, 2018, from https://store.pantone.com/hk/en/articles/did-you-know-updating-your-pantone-guides-can-save-you-valuable-production-time-and-money.html

Falconer, B. (2018, February 28). What Is the Perfect Colour Worth? The New York Times. Retrieved December 20, 2018, from https://www.nytimes.com/2018/02/28/magazine/what-is-the-perfect-color-worth.html

Gundlach, M. (2018, February 9). 5 Tools You Need to Print Extended Gamut. Retrieved December 19, 2018, from https://www.xrite.com/blog/5-tools-to-print-extended-gamut

Hershey, J. (2006, June 1). The Dish on Dots. PackagePrinting. Retrieved December 22, 2018, from https://www.packageprinting.com/article/industry-experts-weigh-am-fm-transitional-hybrid-screening-methods-31116/all/

Hue Angle. (n.d.). Retrieved December 21, 2018, from http://printwiki.org/Hue_Angle

Jayaraman, N. R. (2015, February 8). AM / FM Screening process. Retrieved December 19, 2018, from https://printing.santhipriya.com/2015/02/am-fm-screening-process/

Kasdorf, W. E. (Ed.). (2003). The Columbia Guide to Digital Publishing. New York, NY: Columbia University Press.

Moiré. (n.d.). Retrieved December 22, 2018, from http://printwiki.org/Moiré

Odgis, J. (2017, December 06). Keeping Color Consistent Is a Vital Element of Branding. Retrieved December 22, 2018, from https://www.huffingtonpost.com/janet-odgis/keeping-color-consistent-_b_8749334.html

Pantone Extended Gamut Coated Frequently Asked Questions. (n.d.). Retrieved December 21, 2018, from https://www.pantone.com/downloads/support/FAQ/Pantone-FAQ-Extended-Gamut-Coated-Guide-20150910.pdf?ver=2

Politis, Anastasios, Tsigonias, Antonios, Tsigonias, Marios, Gamprellis, Georgios, Tsimis, Diana & Trochoutsos, Christos. (2015). Extended Gamut Printing: A review on developments and trends. (Rep). Retrieved December 21, 2018, from https://www.researchgate.net/publication/285582518_Extended_Gamut_Printing_A_review_on_developments_and_trends

Prakhya, S. H. (2014, January 17). Why is purple considered the most difficult colour to print? Retrieved December 23, 2018, from https://www.quora.com/Why-is-purple-considered-the-most-difficult-color-to-print

Precise Color Communication. (2007). Retrieved December 20, 2018, from https://www.konicaminolta.com/instruments/knowledge/color/pdf/color_communication.pdf

The Printer's Guide to Expanded Gamut. (2017, February). Retrieved December 21, 2018, from http://www.techkonusa.com/wp-content/uploads/2017/02/Techkon-Expanded-Gamut-Whitepaper-Final.pdf

Sharma, A. (2018). Understanding Color Management (2nd ed.). Hoboken, NJ: John Wiley & Sons.

Smyth, C. (2018, March 27). Expanded colour gamut. Graphic Arts Magazine. Retrieved December 20, 2018, from https://graphicartsmag.com/articles/2017/03/expanded-colour-gamut/

APPENDIX

| APPENDIX A |

Results of Conducted Tests

Pantone 103 C	L*	a*	b*	Mode[7]	CIEDE2000
Reference	71	-1	87	N/A	N/A
1	69.22	1.17	86.36	D50/2°/M2/ABS	N/A
2	69.61	1.13	86.43	D50/2°/M2/ABS	N/A
3	69.39	1.21	86.36	D50/2°/M2/ABS	N/A
4	69.41	1.15	86.32	D50/2°/M2/ABS	N/A
5	69.5	1.26	86.77	D50/2°/M2/ABS	N/A
6	69.68	1.09	86.45	D50/2°/M2/ABS	N/A
7	69.75	1.17	86.54	D50/2°/M2/ABS	N/A
8	69.15	1.2	86.05	D50/2°/M2/ABS	N/A
9	69.45	1.26	86.6	D50/2°/M2/ABS	N/A
10	69.5	1.24	86.65	D50/2°/M2/ABS	N/A
Avg.	69.47	1.19	86.45	N/A	1.7

Pantone 103 XGC	L*	a*	b*	Mode	CIEDE2000
Reference	72	-2	76	N/A	N/A
1	73.25	0.18	76.27	D50/2°/M2/ABS	N/A
2	73.33	0.18	76.31	D50/2°/M2/ABS	N/A
3	73.2	0.2	76.13	D50/2°/M2/ABS	N/A
4	72.96	0.18	75.52	D50/2°/M2/ABS	N/A
5	73.01	0.2	76.1	D50/2°/M2/ABS	N/A
6	72.49	-0.07	75.31	D50/2°/M2/ABS	N/A
7	72.69	0.03	75.51	D50/2°/M2/ABS	N/A
8	72.68	0.24	75.92	D50/2°/M2/ABS	N/A
9	72.96	0.22	75.82	D50/2°/M2/ABS	N/A
10	72.53	0.16	75.68	D50/2°/M2/ABS	N/A
Avg.	72.91	0.15	75.86	N/A	1.4

7 M2 measurement mode was used as the lowest common denominator between the two Pantone colour books and Photoshop.

Pantone 150 C	L*	a*	b*	Mode	CIEDE2000
Reference	78	29	58	N/A	N/A
1	80.05	24.07	61.9	D50/2°/M2/ABS	N/A
2	80.41	24.09	61.72	D50/2°/M2/ABS	N/A
3	79.92	23.8	61.4	D50/2°/M2/ABS	N/A
4	80.07	24.23	62.09	D50/2°/M2/ABS	N/A
5	80.44	23.18	60.41	D50/2°/M2/ABS	N/A
6	80.16	23.36	60.79	D50/2°/M2/ABS	N/A
7	80.26	23.44	60.89	D50/2°/M2/ABS	N/A
8	80.4	23.71	61.3	D50/2°/M2/ABS	N/A
9	80.41	23.7	61.3	D50/2°/M2/ABS	N/A
10	80.43	23.88	61.41	D50/2°/M2/ABS	N/A
Avg.	80.26	23.75	61.32	N/A	4.2

Pantone 150 XGC	L*	a*	b*	Mode	CIEDE2000
Reference	81	21	54	N/A	N/A
1	81.37	21.41	51.2	D50/2°/M2/ABS	N/A
2	81.21	21.82	51.33	D50/2°/M2/ABS	N/A
3	81.36	21.28	51.04	D50/2°/M2/ABS	N/A
4	80.98	21.87	51.75	D50/2°/M2/ABS	N/A
5	80.85	21.8	51.95	D50/2°/M2/ABS	N/A
6	80.73	21.9	51.88	D50/2°/M2/ABS	N/A
7	81.31	21.61	51.11	D50/2°/M2/ABS	N/A
8	81.29	21.51	51.27	D50/2°/M2/ABS	N/A
9	81.31	21.72	51.4	D50/2°/M2/ABS	N/A
10	80.95	21.77	51.97	D50/2°/M2/ABS	N/A
Avg.	81.14	21.67	51.49	N/A	1.2

Pantone 187 C	L*	a*	b*	Mode	CIEDE2000
Reference	38	57	29	N/A	N/A
1	33.93	53.68	30.36	D50/2°/M2/ABS	N/A
2	34.42	53.97	30.27	D50/2°/M2/ABS	N/A
3	35.64	54.53	29.46	D50/2°/M2/ABS	N/A
4	34.48	53.75	29.92	D50/2°/M2/ABS	N/A
5	33.49	53.24	30.41	D50/2°/M2/ABS	N/A
6	34.61	53.93	29.92	D50/2°/M2/ABS	N/A
7	34.69	54.25	30.5	D50/2°/M2/ABS	N/A
8	34.02	53.7	30.51	D50/2°/M2/ABS	N/A
9	33.87	53.53	30.31	D50/2°/M2/ABS	N/A
10	35.46	54.36	29.46	D50/2°/M2/ABS	N/A
Avg.	34.46	53.89	30.11	N/A	3.3

Pantone 187 XGC	L*	a*	b*	Mode	CIEDE2000
Reference	37	60	23	N/A	N/A
1	37.58	59.8	25.47	D50/2°/M2/ABS	N/A
2	38.25	60.33	25.79	D50/2°/M2/ABS	N/A
3	37.26	59.93	26.43	D50/2°/M2/ABS	N/A
4	37.65	59.85	25.73	D50/2°/M2/ABS	N/A
5	38.26	60.46	25.54	D50/2°/M2/ABS	N/A
6	38.06	60.25	26.39	D50/2°/M2/ABS	N/A
7	38.25	60.26	25.63	D50/2°/M2/ABS	N/A
8	38.03	60.14	25.72	D50/2°/M2/ABS	N/A
9	37.62	59.78	25.55	D50/2°/M2/ABS	N/A
10	37.75	59.95	25.41	D50/2°/M2/ABS	N/A
Avg.	37.87	60.08	25.77	N/A	1.6

Pantone 227 C	L*	a*	b*	Mode	CIEDE2000
Reference	36	68	-4	N/A	N/A
1	37.53	68.18	0.85	D50/2°/M2/ABS	N/A
2	37.58	68.7	0.51	D50/2°/M2/ABS	N/A
3	38.15	68.17	-0.39	D50/2°/M2/ABS	N/A
4	37.25	68.27	0.96	D50/2°/M2/ABS	N/A
5	38.31	68.65	-0.49	D50/2°/M2/ABS	N/A
6	37.42	68.32	1.42	D50/2°/M2/ABS	N/A
7	37.27	67.97	0.96	D50/2°/M2/ABS	N/A
8	37.9	68.1	-0.16	D50/2°/M2/ABS	N/A
9	37.69	68.59	0.71	D50/2°/M2/ABS	N/A
10	37.67	68.35	0.3	D50/2°/M2/ABS	N/A
Avg.	37.68	68.33	0.47	N/A	2.4

Pantone 227 XGC	L*	a*	b*	Mode	CIEDE2000
Reference	38	63	-4	N/A	N/A
1	38.36	63.16	-2.2	D50/2°/M2/ABS	N/A
2	38.14	62.79	-2.26	D50/2°/M2/ABS	N/A
3	38.39	63.03	-2.31	D50/2°/M2/ABS	N/A
4	38.42	63.09	-2.19	D50/2°/M2/ABS	N/A
5	37.99	62.61	-2.21	D50/2°/M2/ABS	N/A
6	37.9	62.5	-2.51	D50/2°/M2/ABS	N/A
7	38.76	63.1	-2.43	D50/2°/M2/ABS	N/A
8	38.29	63.17	-2.17	D50/2°/M2/ABS	N/A
9	38.23	63	-2.16	D50/2°/M2/ABS	N/A
10	38.68	63.15	-2.41	D50/2°/M2/ABS	N/A
Avg.	38.32	62.96	-2.29	N/A	0.8

Pantone 251 C	L*	a*	b*	Mode	CIEDE2000
Reference	73	33	-22	N/A	N/A
1	73.32	38.78	-19.75	D50/2°/M2/ABS	N/A
2	72.9	39.04	-19.61	D50/2°/M2/ABS	N/A
3	72.77	38.83	-19.79	D50/2°/M2/ABS	N/A
4	74.4	36.07	-18.96	D50/2°/M2/ABS	N/A
5	72.96	38.83	-19.69	D50/2°/M2/ABS	N/A
6	72.75	38.99	-19.59	D50/2°/M2/ABS	N/A
7	72.92	38.87	-19.78	D50/2°/M2/ABS	N/A
8	72.42	38.62	-19.67	D50/2°/M2/ABS	N/A
9	74.01	36.93	-18.97	D50/2°/M2/ABS	N/A
10	73.08	38.46	-19.67	D50/2°/M2/ABS	N/A
Avg.	73.15	38.34	-19.55	N/A	2.9

Pantone 251 XGC	L*	a*	b*	Mode	CIEDE2000
Reference	72	20	-12	N/A	N/A
1	72.52	19.47	-12.44	D50/2°/M2/ABS	N/A
2	72.46	20.03	-12.69	D50/2°/M2/ABS	N/A
3	72.66	19.93	-12.8	D50/2°/M2/ABS	N/A
4	72.17	19.93	-13	D50/2°/M2/ABS	N/A
5	73.03	19.16	-12.63	D50/2°/M2/ABS	N/A
6	72.3	19.93	-13.13	D50/2°/M2/ABS	N/A
7	71.96	19.98	-12.92	D50/2°/M2/ABS	N/A
8	72.9	19.58	-12.68	D50/2°/M2/ABS	N/A
9	72.28	19.6	-12.62	D50/2°/M2/ABS	N/A
10	72.59	19.39	-12.81	D50/2°/M2/ABS	N/A
Avg.	72.49	19.70	-12.77	N/A	0.7

Pantone 264 C	L*	a*	b*	Mode	CIEDE2000
Reference	75	15	-25	N/A	N/A
1	72.55	24.72	-23.47	D50/2°/M2/ABS	N/A
2	72.63	25.1	-23.32	D50/2°/M2/ABS	N/A
3	72.8	24.9	-23.61	D50/2°/M2/ABS	N/A
4	73.42	24.38	-23.22	D50/2°/M2/ABS	N/A
5	73.17	24.75	-23.4	D50/2°/M2/ABS	N/A
6	72.91	24.63	-23.2	D50/2°/M2/ABS	N/A
7	72.6	25.23	-23.71	D50/2°/M2/ABS	N/A
8	72.85	25.14	-23.68	D50/2°/M2/ABS	N/A
9	73.21	24.6	-23.23	D50/2°/M2/ABS	N/A
10	72.67	24.68	-23.01	D50/2°/M2/ABS	N/A
Avg.	72.88	24.81	-23.39	N/A	6.9

Pantone 264 XGC	L*	a*	b*	Mode	CIEDE2000
Reference	74	1	-17	N/A	N/A
1	71.73	13.74	-20.72	D50/2°/M2/ABS	N/A
2	71.87	13.79	-20.83	D50/2°/M2/ABS	N/A
3	71.28	13.89	-20.86	D50/2°/M2/ABS	N/A
4	71.08	13.85	-20.75	D50/2°/M2/ABS	N/A
5	72.06	13.71	-20.59	D50/2°/M2/ABS	N/A
6	71.5	13.69	-20.69	D50/2°/M2/ABS	N/A
7	71.61	13.69	-20.7	D50/2°/M2/ABS	N/A
8	71.27	13.84	-20.77	D50/2°/M2/ABS	N/A
9	71.32	13.66	-20.51	D50/2°/M2/ABS	N/A
10	71.56	13.59	-20.57	D50/2°/M2/ABS	N/A
Avg.	71.53	13.75	-20.70	N/A	3.0

Pantone 2925 C	L*	a*	b*	Mode	CIEDE2000
Reference	58	-18	-46	N/A	N/A
1	59.42	-23.5	-42.7	D50/2°/M2/ABS	N/A
2	60.18	-23.47	-42.61	D50/2°/M2/ABS	N/A
3	59.56	-23.49	-42.7	D50/2°/M2/ABS	N/A
4	59.87	-23.56	-42.72	D50/2°/M2/ABS	N/A
5	59.61	-23.54	-42.88	D50/2°/M2/ABS	N/A
6	59.66	-23.5	-42.7	D50/2°/M2/ABS	N/A
7	59.71	-23.67	-43.06	D50/2°/M2/ABS	N/A
8	59.53	-23.59	-42.79	D50/2°/M2/ABS	N/A
9	59.29	-23.55	-42.61	D50/2°/M2/ABS	N/A
10	59.2	-23.57	-42.85	D50/2°/M2/ABS	N/A
Avg.	59.60	-23.54	-42.76	N/A	3.3

Pantone 2925 XGC	L*	a*	b*	Mode	CIEDE2000
Reference[8]	60	-15	-41	N/A	N/A
1	59.94	-16.45	-41.42	D50/2°/M2/ABS	N/A
2	59.93	-16.43	-41.25	D50/2°/M2/ABS	N/A
3	59.98	-16.43	-41.31	D50/2°/M2/ABS	N/A
4	59.7	-16.45	-41.32	D50/2°/M2/ABS	N/A
5	59.72	-16.41	-41.15	D50/2°/M2/ABS	N/A
6	59.59	-16.49	-41.12	D50/2°/M2/ABS	N/A
7	59.77	-16.44	-40.96	D50/2°/M2/ABS	N/A
8	59.47	-16.31	-41.33	D50/2°/M2/ABS	N/A
9	59.64	-16.35	-41.24	D50/2°/M2/ABS	N/A
10	60.03	-16.47	-41.1	D50/2°/M2/ABS	N/A
Avg.	59.78	-16.42	-41.22	N/A	0.8

*8 As stated previously, the L*a*b* values listed in Photoshop were used as the reference values for the printed samples tested. However, for Pantone 2925 XGC, Pantone 356 XGC, and Pantone 377 XGC, there was a glitch in Photoshop that resulted in it displaying incorrect L*a*b* values for these three colours. For examples, Pantone 2925 XGC, a bluish colour which should have an L*a*b* of 60, -15, -41, was listed in Photoshop as 47, 76, 19, a reddish colour instead. To get around this problem, a .cxt file of the Extended Gamut Guide, which lists the L*a*b* values of all the colours in the colour book, was exported from PANTONE Color Manager and used for those three samples instead. To verify that the L*a*b* values listed in the .cxt file were consistent with those listed in Photoshop, the values of several colours listed accurately in Photoshop were compared to those listed in the .cxt file. This comparison confirmed that the values matched and the .cxt file values could be used for the missing three colours without inconsistency in the Delta E calculations.*

Pantone 306 C	L*	a*	b*	Mode	CIEDE2000
Reference	67	-36	-36	N/A	N/A
1	65.39	-36.65	-36.79	D50/2°/M2/ABS	N/A
2	65.8	-36.89	-37.09	D50/2°/M2/ABS	N/A
3	65.93	-36.55	-36.83	D50/2°/M2/ABS	N/A
4	65.42	-36.73	-36.71	D50/2°/M2/ABS	N/A
5	65.39	-36.62	-36.87	D50/2°/M2/ABS	N/A
6	66.06	-36.2	-36.47	D50/2°/M2/ABS	N/A
7	66.49	-36.26	-36.45	D50/2°/M2/ABS	N/A
8	65.74	-36.9	-37.19	D50/2°/M2/ABS	N/A
9	65.23	-36.64	-37.04	D50/2°/M2/ABS	N/A
10	65.48	-36.69	-36.8	D50/2°/M2/ABS	N/A
Avg.	65.69	-36.61	-36.82	N/A	1.1

Pantone 306 XGC	L*	a*	b*	Mode	CIEDE2000
Reference	65	-31	-35	N/A	N/A
1	64.71	-32.25	-34.26	D50/2°/M2/ABS	N/A
2	65.03	-32.5	-34.43	D50/2°/M2/ABS	N/A
3	65.16	-32.37	-34.34	D50/2°/M2/ABS	N/A
4	64.78	-32.3	-34.43	D50/2°/M2/ABS	N/A
5	64.83	-32.23	-34.22	D50/2°/M2/ABS	N/A
6	64.83	-32.17	-34.32	D50/2°/M2/ABS	N/A
7	65.05	-32.44	-34.42	D50/2°/M2/ABS	N/A
8	65.09	-32.34	-34.38	D50/2°/M2/ABS	N/A
9	65.02	-32.32	-34.24	D50/2°/M2/ABS	N/A
10	64.82	-32.26	-34.26	D50/2°/M2/ABS	N/A
Avg.	64.93	-32.32	-34.33	N/A	0.7

Pantone 322 C	L*	a*	b*	Mode	CIEDE2000
Reference	41	-44	-18	N/A	N/A
1	38.28	-43.06	-18.39	D50/2°/M2/ABS	N/A
2	38.67	-43.27	-18.55	D50/2°/M2/ABS	N/A
3	39.14	-43.22	-18.67	D50/2°/M2/ABS	N/A
4	38.04	-42.83	-18.32	D50/2°/M2/ABS	N/A
5	39.52	-43.72	-18.69	D50/2°/M2/ABS	N/A
6	38.06	-43.21	-18.31	D50/2°/M2/ABS	N/A
7	38.03	-43.09	-18.37	D50/2°/M2/ABS	N/A
8	38.68	-43.16	-18.53	D50/2°/M2/ABS	N/A
9	38.98	-43.61	-18.59	D50/2°/M2/ABS	N/A
10	38.36	-43.06	-18.36	D50/2°/M2/ABS	N/A
Avg.	38.58	-43.22	-18.48	N/A	2.2

Pantone 322 XGC	L*	a*	b*	Mode	CIEDE2000
Reference	40	-47	-17	N/A	N/A
1	43.03	-47.04	-15.41	D50/2°/M2/ABS	N/A
2	42.49	-46.63	-15.51	D50/2°/M2/ABS	N/A
3	42.47	-46.4	-15.63	D50/2°/M2/ABS	N/A
4	42.32	-46.84	-15.32	D50/2°/M2/ABS	N/A
5	42.46	-46.64	-15.16	D50/2°/M2/ABS	N/A
6	42.63	-46.79	-15.2	D50/2°/M2/ABS	N/A
7	42.62	-46.48	-15.47	D50/2°/M2/ABS	N/A
8	42.19	-46.6	-15.53	D50/2°/M2/ABS	N/A
9	42.45	-46.6	-15.54	D50/2°/M2/ABS	N/A
10	42.59	-46.72	-15.35	D50/2°/M2/ABS	N/A
Avg.	42.53	-46.67	-15.41	N/A	2.4

Pantone 335 C	L*	a*	b*	Mode	CIEDE2000
Reference	45	-51	1	N/A	N/A
1	41.22	-49.54	1.17	D50/2°/M2/ABS	N/A
2	41.82	-49.55	1.09	D50/2°/M2/ABS	N/A
3	41.57	-49.73	1.12	D50/2°/M2/ABS	N/A
4	40.62	-48.65	1.05	D50/2°/M2/ABS	N/A
5	42.32	-49.23	0.91	D50/2°/M2/ABS	N/A
6	41.29	-49.57	1.25	D50/2°/M2/ABS	N/A
7	42.4	-49.62	1.13	D50/2°/M2/ABS	N/A
8	41.45	-49.24	1.22	D50/2°/M2/ABS	N/A
9	41.33	-49.02	1.11	D50/2°/M2/ABS	N/A
10	41.53	-49.55	1.15	D50/2°/M2/ABS	N/A
Avg.	41.56	-49.37	1.12	N/A	3.2

Pantone 335 XGC	L*	a*	b*	Mode	CIEDE2000
Reference	44	-54	1	N/A	N/A
1	44.53	-52.28	2.9	D50/2°/M2/ABS	N/A
2	44.56	-52.6	2.97	D50/2°/M2/ABS	N/A
3	44.74	-52.53	2.87	D50/2°/M2/ABS	N/A
4	44.86	-52.63	2.95	D50/2°/M2/ABS	N/A
5	44.64	-52.47	2.89	D50/2°/M2/ABS	N/A
6	44.93	-52.8	2.95	D50/2°/M2/ABS	N/A
7	44.21	-52.08	2.88	D50/2°/M2/ABS	N/A
8	44.67	-52.47	2.94	D50/2°/M2/ABS	N/A
9	44.61	-52.53	2.91	D50/2°/M2/ABS	N/A
10	44.26	-51.92	2.86	D50/2°/M2/ABS	N/A
Avg.	44.60	-52.43	2.91	N/A	1.3

Pantone 356 C	L*	a*	b*	Mode	CIEDE2000
Reference	43	-50	26	N/A	N/A
1	42.41	-48.89	27.44	D50/2°/M2/ABS	N/A
2	42.68	-48.71	27.26	D50/2°/M2/ABS	N/A
3	42.98	-48.64	27.2	D50/2°/M2/ABS	N/A
4	43.39	-48.89	27.38	D50/2°/M2/ABS	N/A
5	42.26	-49.00	27.45	D50/2°/M2/ABS	N/A
6	42.52	-48.99	27.4	D50/2°/M2/ABS	N/A
7	42.52	-48.58	27.21	D50/2°/M2/ABS	N/A
8	41.91	-49.13	27.65	D50/2°/M2/ABS	N/A
9	42.86	-48.81	27.31	D50/2°/M2/ABS	N/A
10	42.15	-49.12	27.59	D50/2°/M2/ABS	N/A
Avg.	42.57	-48.88	27.39	N/A	0.9

Pantone 356 XGC	L*	a*	b*	Mode	CIEDE2000
Reference	45	-51	28	N/A	N/A
1	46.1	-49.86	28.62	D50/2°/M2/ABS	N/A
2	46.27	-49.99	28.6	D50/2°/M2/ABS	N/A
3	46.00	-49.90	28.73	D50/2°/M2/ABS	N/A
4	46.10	-49.76	28.92	D50/2°/M2/ABS	N/A
5	46.00	-49.93	29.01	D50/2°/M2/ABS	N/A
6	45.59	-49.81	28.32	D50/2°/M2/ABS	N/A
7	45.41	-49.54	28.5	D50/2°/M2/ABS	N/A
8	45.39	-49.67	28.74	D50/2°/M2/ABS	N/A
9	45.57	-50.00	28.35	D50/2°/M2/ABS	N/A
10	45.62	-50.09	28.84	D50/2°/M2/ABS	N/A
Avg.	45.81	-49.86	28.66	N/A	0.9

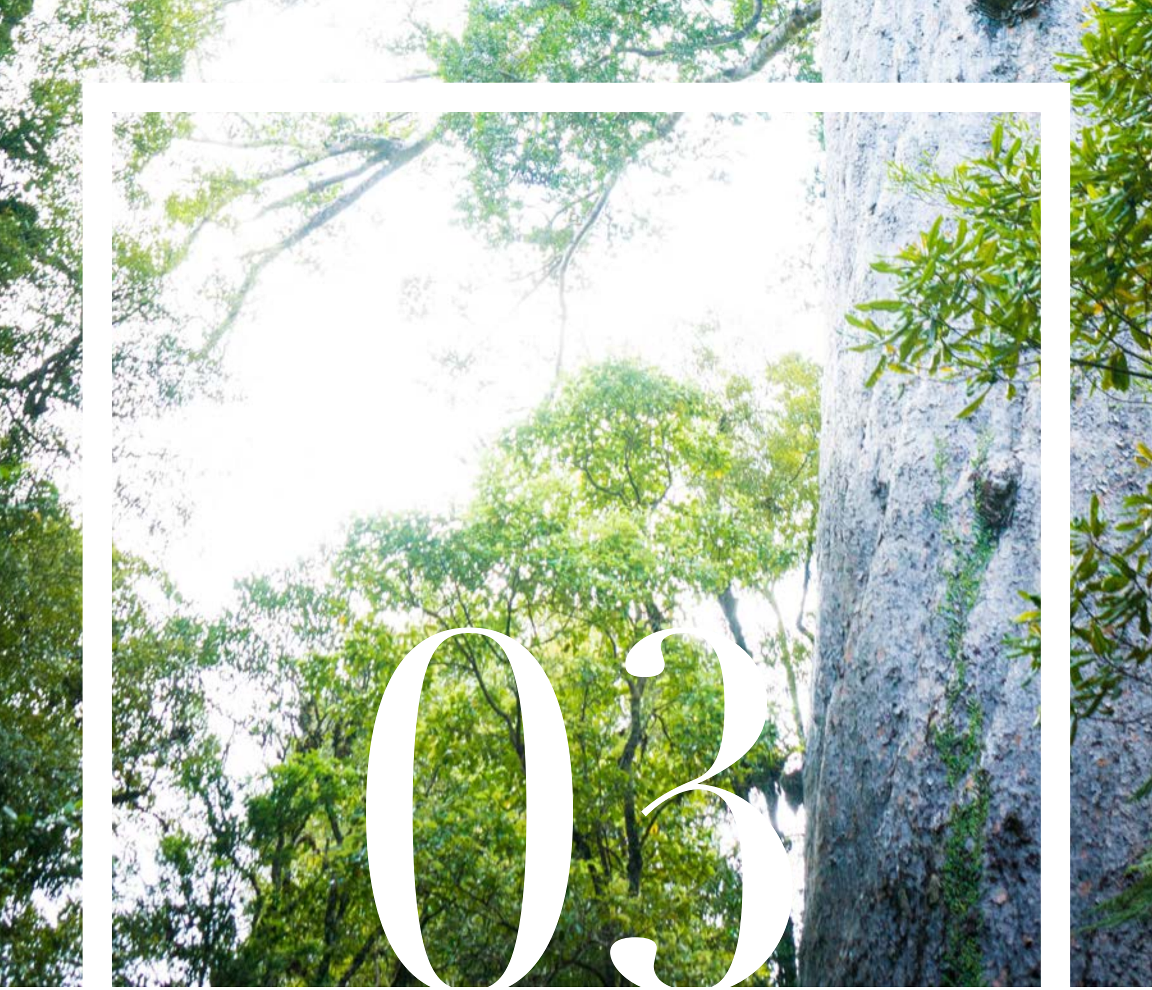
Pantone 377 C	L*	a*	b*	Mode	CIEDE2000
Reference	57	-26	59	N/A	N/A
1	56.88	-24.09	59.71	D50/2°/M2/ABS	N/A
2	56.98	-24.28	60.29	D50/2°/M2/ABS	N/A
3	57.11	-24.24	60.14	D50/2°/M2/ABS	N/A
4	56.96	-23.98	59.97	D50/2°/M2/ABS	N/A
5	57.28	-24.22	60.43	D50/2°/M2/ABS	N/A
6	57.06	-24.26	60.1	D50/2°/M2/ABS	N/A
7	57.45	-24.51	60.87	D50/2°/M2/ABS	N/A
8	57.43	-24.28	60.02	D50/2°/M2/ABS	N/A
9	57.25	-24.21	60.35	D50/2°/M2/ABS	N/A
10	57.29	-24.26	60.57	D50/2°/M2/ABS	N/A
Avg.	57.17	-24.23	60.25	N/A	1.1

Pantone 377 XGC	L*	a*	b*	Mode	CIEDE2000
Reference	63	-25	60	N/A	N/A
1	62.74	-23.27	60.7	D50/2°/M2/ABS	N/A
2	62.14	-23.12	60.69	D50/2°/M2/ABS	N/A
3	62.07	-23.11	60.19	D50/2°/M2/ABS	N/A
4	62.06	-22.98	60.24	D50/2°/M2/ABS	N/A
5	62.22	-23.22	60.34	D50/2°/M2/ABS	N/A
6	61.55	-23.37	59.66	D50/2°/M2/ABS	N/A
7	61.34	-23.26	59.14	D50/2°/M2/ABS	N/A
8	61.97	-23.09	60.18	D50/2°/M2/ABS	N/A
9	61.94	-23.18	59.62	D50/2°/M2/ABS	N/A
10	61.93	-23.15	60.16	D50/2°/M2/ABS	N/A
Avg.	62.00	-23.18	60.09	N/A	1.3

| APPENDIX A |

CIEDE2000 of Reference Values

Reference Values	L*	a*	b*	CIEDE2000
Pantone 103 C	71	-1	87	
Pantone 103 XGC	72	-2	76	2.6
Pantone 150 C	78	29	58	
Pantone 150 XGC	81	21	54	4.6
Pantone 187 C	38	57	29	
Pantone 187 XGC	37	60	23	3.7
Pantone 227 C	36	68	-4	
Pantone 227 XGC	38	63	-4	2.1
Pantone 251 C	73	33	-22	
Pantone 251 XGC	72	20	-12	6.9
Pantone 264 C	75	15	-25	
Pantone 264 XGC	74	1	-17	10.1
Pantone 2925 C	58	-18	-46	
Pantone 2925 XGC	60	-15	-41	2.8
Pantone 306 C	67	-36	-36	
Pantone 306 XGC	65	-31	-35	2.5
Pantone 322 C	41	-44	-18	
Pantone 322 XGC	40	-47	-17	1.6
Pantone 335 C	45	-51	1	
Pantone 335 XGC	44	-54	1	1.3
Pantone 356 C	43	-50	26	
Pantone 356 XGC	45	-51	28	2.0
Pantone 377 C	57	-26	59	
Pantone 377 XGC	63	-25	60	5.3



03

HOLOGRAPHY IN PRINT

Arundhuti Ghosh

SCOPE & SUMMARY

The purpose of this research paper is to examine the use of holography within printing. It will not focus on the analysis of physical holograms created by light sources, but rather define and analyze how holographic print has grown within both the graphic arts industry and allied industries.

Holograms are three-dimensional images created by the interference of light from a laser, or any other coherent light sources. The concept of a hologram itself dates back to 1947, developed by scientist Dennis Gabor. Since their inception, holograms have been incorporated into various industries for many services. Holographic printing, however, is the rendition of a hologram on a flat surface, creating three-dimensional images on the substrate. The process has grown in recent decades and spans multiple industries, including biomedical, security, and graphic communications.

INTRODUCTION

For a long time, holograms were widely regarded as being fictional. However, technology has expanded within the last century. Holograms are now able to be captured on flat surfaces, providing new appeal. This new technology has fascinated many, showing usefulness in a number of industries worldwide.

This paper aims to provide an in-depth look at holographic printing, its roots, enhancement, and future trends. Through thorough analysis of history, industries, and market reports, this report will provide various conclusions on the effectiveness of holographic printing and its future place within the graphic communications industry.

HISTORY & BACKGROUND

Holography was first developed by Hungarian-British physicist Dennis Gabor in 1947 while working for the British Thomson-Houston (BTH) Company (Milestones: Invention of Holography, 2016). The term holography, coined by Gabor himself, originates from the Greek word “holos”, meaning “whole”, and “gramma”, meaning “message” (Sergey, n.d.). According to Sean F. Johnston, Gabor had used his new principle of “wave-front reconstruction” to develop a diffraction microscope (2006). An electron photograph (hologram) is taken, bearing no visual resemblance to the image subject. Then, through a synthesis carried out with light waves, the similarity is restored (Johnston, 2006). At the time however, developments were lagging as the light sources available were not sufficient.

In 1983, Mastercard International Inc. began looking for a new security feature for credit cards, one that was cost-effective and easy to use for both merchants and consumers (Mastercard’s Goal, 1983). The outcome was a printed foil hologram, reflecting a rainbow-like shine with the changing reflections of light. This new technology and design made credit card thievery and counterfeiting extremely difficult. The following year “National Geographic” printed a holographic image of an eagle on the cover of its March issue. A few years later, they debuted yet another holographic cover with their centennial issue in December of 1988 (National Geographic Milestones, 2014).

CURRENT APPLICATION

Holographic printing has experienced commendable growth in recent times. What was once a difficult and expensive technique has now become innovative and cost-efficient. The use of holographic printing currently spans multiple industries, providing a variety of services. The printing process has enabled these industries to further explore and build upon current technology and ideas for an innovative future.

According to Wired, recent developments in the biomedical industry have made it possible to produce three-dimensional holographic scans (Patel, 2015). While traditional biomedical imaging uses CT scanners, MRI, and many more, holographic imaging provides a quick and much more accurate scan (Patel, 2015). Developed by the start-up company called EchoPixel, this method allows doctors to move around, zoom in on, and manipulate the body part and/or organ in the image. In addition, it can further assist with surgical planning as well as conducting diagnostics. Recently approved by the Food and Drug Administration (FDA), the interactive features of this new means of holographic print enables a better approach to patient diagnosis and improves the ability of healthcare providers to deliver proper treatment to patients.

In addition to their biomedical uses, holograms have greatly advanced the standards within the security printing industry. As mentioned earlier, in 1983, Mastercard International Inc. unveiled a hologram on their credit cards in response to the excessive levels of counterfeiting (Mastercard's Goal: Security Plus Flair, 1983). However, the security feature has made its way onto more than simply credit cards. In 2012, the Bank of Canada released new five, ten, twenty, fifty, and one hundred dollar bills featuring a variety of security features, accompanied by more sophisticated holograms than those on the previous designs (Carletti, 2011). Due to this new addition, the amount of counterfeit bills in Canada dropped from 470 per million to 35 per million, according to CBC (2011).

FUTURE APPLICATIONS

Holographic printing is a relatively new technology, having been introduced within the last few decades. The technology will continue to increase and push boundaries as further research is conducted and implementation is executed. The sector is expected to grow at a Compound Annual Growth Rate (CAGR) of 30.23% from 2014 to 2020 due to the increased use in various industries (Holographic Display Market by Technology, 2015). Specifically, the push for security in printing, as well as packaging, is currently driving the growing need for holographic print.

Canada's change to polymer banknotes featuring holographic images mimics many other nations' strategies to avoid fraud, such as England, Switzerland, and Israel (Hologram association details opportunities, 2016). With holograms now on credit cards, passports, and official documents, duplication has become difficult. Alongside Canada, international efforts have been made to study detection methods for counterfeit bills featuring holographic print. A report published by the Optical Society of Korea discusses their experiment using Full-field Optical Coherence Tomography (FF-OCT) to spot fake Korean banknotes (Choi, Min, Lee, Eom, & Kim, 2010). FF-OCT utilizes full-field illumination with an extended light source, where laser beams are guided with bulk optics. After measuring various holographic prints on banknotes, they found that some printed holograms had varying levels of thickness and order of printing, thus detecting a counterfeit banknote (Choi et al., 2010). Despite the technology not being widely used for fraud detection, the technique falls in tandem with security in printing, as well as how utilizing FF-OCT in holographic printing can create tougher and more sophisticated counterfeit barriers.

In addition, hologravure has become a growing process within the printing industry, though it has yet to hit the standards for widespread use. The process of gravure itself is an intaglio method, where the image areas are engraved in the impression cylinder (Pocket Pal, 2007). Hologravure, however, is an interference by moiré along with line density. It is capable of creating three-dimensional images through solid dots and lines, according to Jachin Wang in his book "Hologravure" (2016). It is predicted that the process will soon be appearing in newspapers, magazines, photographs, and amongst other mediums of print (Wang, 2016). Using the concepts of holography, this up and coming printing process has encouraged the exploration of new methods to print in the graphic communications industry.

Holographic print has begun to see an increase in packaging, as competition for consumer loyalty increases in package aesthetics. Holograms on packaging and labels have provided a visually appealing design, heightened security and safety, and a higher market share, according to Packaging Digest (Bellm, 2014). Hasbro Games took advantage of these benefits with Vacumet Corporations' HoloPRISM technology for their packaging design of MONOPOLY: The Disney Edition (Bellm, 2014). One of the very few game companies to do so, Hasbro managed to use holographic print as a means to set a competitive advantage in their market. Holographic printing has been steadily growing in packaging with processes such as gloss UV and holographic hot and cold printing (Print Effects, 2017). UV gloss can give packages a sleek and shiny appeal, while hot and cold printing methods can stamp holographic polymers into a variety of substrates. Its wide scale use in packaging has yet to see a certain growth as processes become affordable and accessible to the graphic communications industry.

CONCLUSION

Holograms have undoubtedly witnessed a mass expansion and modernization within the last century. With its ties to print, holographic printing has enhanced and become a valuable asset in a multitude of industries. This has encouraged many to further explore and test the limits of printing holograms on flat surfaces, often yielding positive results. Overall, this innovative process is set to grow extensively in the coming decades. Providing an array of beneficial services to many as well as introducing new technologies, holographic printing will soon become a frontline process in the graphic communications industry.

REFERENCES

Bellm, D. (2014, January 29). Holograms offer added dimensions in packaging security. Retrieved March 14, 2017, from http://www.packagingdigest.com/holograms-offer-added-dimensions-packaging-security

Carletti, F. (2011, November 14). Canada's first polymer money has enhanced security features. Retrieved March 14, 2017, from http://www.cbc.ca/news/business/canada-s-first-polymer-money-has-enhanced-security-features-1.1004467

Choi, W., Min, G., Lee, B., Eom, J., & Kim, J. (2010). Counterfeit Detection Using Characterization of Safety Feature on Banknote with Full-field Optical Coherence Tomography. Journal of the Optical Society of Korea, 14(4), 316-320. doi:10.3807/josk.2010.14.4.316

Hologram association details opportunities for market growth in 2017. (2016, November 16). Retrieved March 14, 2017, from http://www.labelsandlabeling.com/news/latest/hologram-association-details-opportunities-market-growth-2017

Holographic Display Market by Technology (Electro holographic, Touchable, Laser), Product (Camera, Digital Signage, Medical scanners, Smart TV), Application (Consumer, Commercial, Medical, Industrial), Geography - Global Forecast to 2013 - 2020. (2015, January). Retrieved March 14, 2017, from http://www.marketsandmarkets.com/Market-Reports/holographic-market-144316799.html

Johnston, S. F. (2006). Retrieved February 29, 2017, from https://books.google.ca/books?hl=en&lr=&id=iPfU_powAgAC&oi=fnd&pg=PR13&dq=holography history dennis gabor&ots=UZOSTqIVFN&sig=WaqhzCcPNNEUd19RhPqyY-XGuOE#v=snippet&q=history&f=false

Mastercard's Goal: Security Plus Flair. (1983, March 21). Retrieved March 5, 2017, from http://www.nytimes.com/1983/03/22/business/mastercard-s-goal-security-plus-flair.html

Milestones: Invention of Holography, 1947. (2016, January 27). Retrieved February 25, 2017, from http://ethw.org/Milestones:Invention_of_Holography,_1947

National Geographic Milestones. (2014, September 04). Retrieved March 6, 2017, from http://press.nationalgeographic.com/about-national-geographic/milestones/

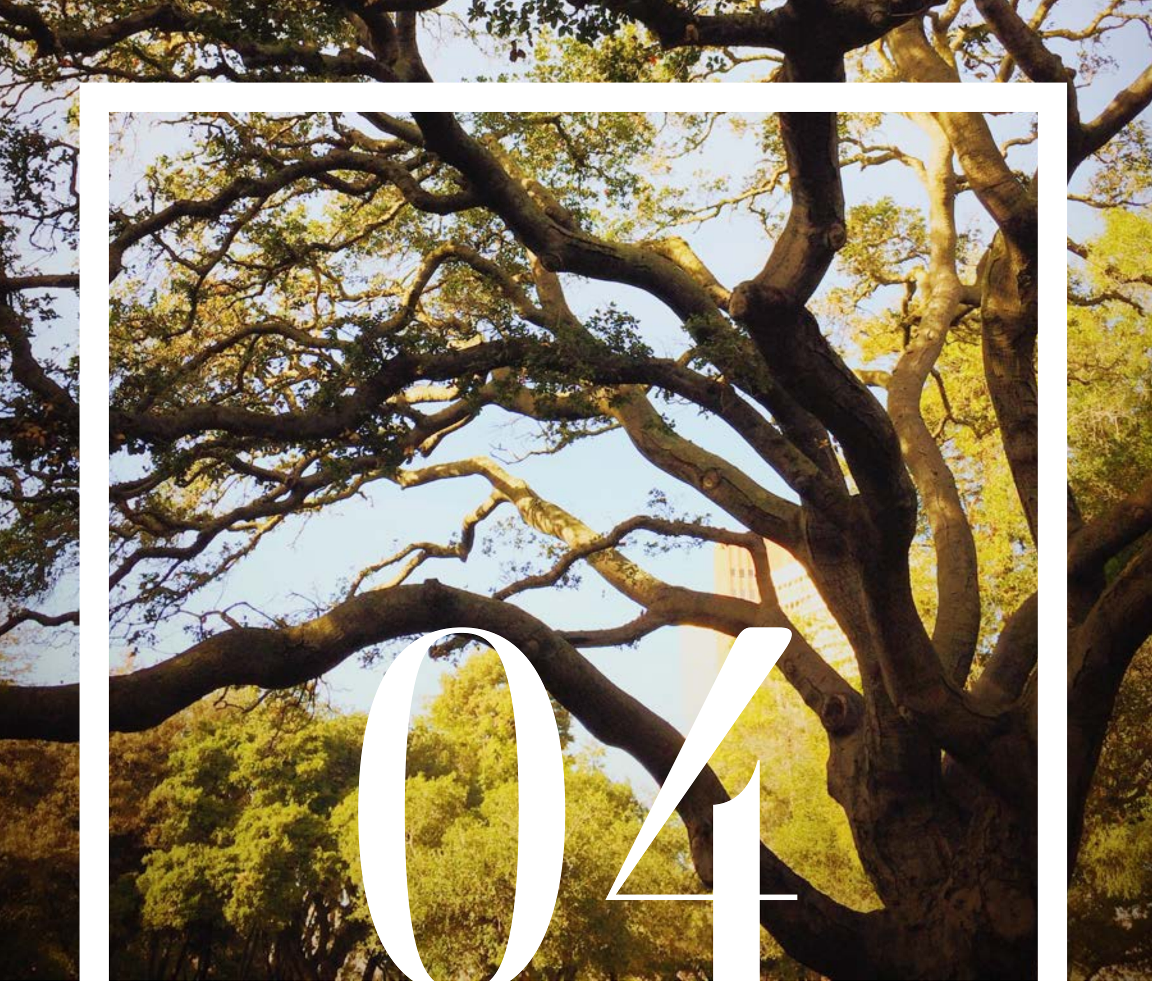
Patel, N. V. (2015, April 06). Holograms Will Let Doctors See 3-D Views of Our Insides. Retrieved March 14, 2017, from https://www.wired.com/2015/04/holograms-will-let-doctors-see-3-d-views-insides/

Pocket Pal (20th ed.). (2007). Memphis, TN: International Paper Company.

Print Effects, Special Features & New Materials Blends Key in 2017. (2017, February 28). Retrieved March 15, 2017, from http://www.packagingeurope.com/Packaging-Europe-News/70953/Print-Effects-Special-Features--New-Materials-Blends-Key-in-2017.html

Sergey, Z. (n.d.). History of the holography. Retrieved February 27, 2017, from http://www.holography.ru/histeng.htm

Wang, J. (2016). Hologravure. Retrieved March 14, 2017, from https://books.google.ca/books?id=d8dzC wAAQBAJ&pg=PT244&lpg=PT244&dq=hologramsandgraphiccommunication&source=bl&ots=sDvWkH3pbs&sig=IeprOftApmBHElm



04

AN EVALUATION OF FM SCREENING

Samantha Stante

SCOPE & SUMMARY

The purpose of this report is to analyze the effect FM screening has on the graphic communications industry today. Though highly recognized in the industry already, this research examines how the process has developed since its creation and its current uses within the graphic communications industry. Also identified are the various ways in which FM screening has the potential to expand and make future enhancements within different sectors of the industry. These divisions have the ability to use this revolutionary technology to innovate their practices.

This research paper will examine the correlation that FM (stochastic) screening has to the graphic communications industry. There will be a discussion of four main aspects of FM screening: the history and background of stochastic technology, how this technology enhances the graphic communications industry, industries other than graphic communications that FM screening benefits and future advancements of or uses for FM screening. Finally, the technology will be critically analyzed and an outlook on whether it is suitable to believe that FM screening will continue to grow and advance will be provided.

Throughout this report, there will be references made to Robert Engal, a print operator for Cober Printing Solutions in Kitchener, Ontario. Engal, an industry expert with over twenty years of experience, who works directly with the FM screening process. He was also an employee of the company before they made the transition from AM to FM screening. As such, he is able to provide valuable insight into the application of FM screening, and the benefits it possesses over its AM counterpart.

INTRODUCTION

FM screening, also known as stochastic screening, is an alteration to the conventional AM screening method. The main difference between the two is that FM screening is comprised of same-sized dots that are randomly spaced apart, whereas AM screening is comprised of dots that are equally spaced apart but vary in size. Many advancements have been made in the use of FM screening because of its efficiency and low cost compared to other types of screening. As well, this method is able to produce high-resolution images, proving to enhance printing throughout the graphic communications industry. The quality printing of stochastic screening has not only had a great impact on the graphic communications industry but also on several allied industries, as its use has become more widespread.

This new type of alternative screening was revolutionary compared to AM screening for the following reasons: it helps printers produce high-stability images with quality detail, it does not create the effect of halftone rosettes, ensuring no chance that a pattern can turn into a moiré and, lastly, there is no impact on RIP time. Stochastic screening provides something for which printers have long strived: for printed images to look like a continuous tone, the way humans see the world.

DEFINITIONS

| AM (AMPLITUDE MODULATED) SCREENING |

Conventional printing where dots are distributed with equal space, but vary in size, forming a line screen, denoted by lines per inch (LPI).

| CHROMA |

The quantity of colourant present within a colour, relating to its saturation and strength. Chroma is mostly tested to the Munsell Color Space model.

| CONTINUOUS TONE |

An image that is not comprised of halftone dots, but creates a smooth tone transition from light to dark.

| FM (FREQUENCY MODULATED) SCREENING |

Also known as stochastic screening, it is a type of printing where inks comprised of same sized dots are distributed at random spaces, denoted according to the size of FM dots in microns (μ).

| GREY COMPONENT REMOVAL (GCR) |

A mechanism that involves reducing the cyan, magenta, and yellow process colour inks, by supplementing them with an equivalent amount of black ink.

HISTORY & BACKGROUND

Before FM screening, only halftone dots were used in printing. Creating tones with variable-sized dots was technology that Frederic Ives, a scholar at Cornell University, expanded. In 1878, his method of ruled glass halftone screening took over the industry and continued to for the next hundred years (Elton, 2013). The crucial modification to halftone resulted in AM screening, which consisted of layering and angling cyan, magenta, yellow, and black (CMYK) on top of each other when printing, causing a rosette pattern. However, this screening process came with two main drawbacks. First, if the specified screen angle rules were not followed it would cause moiré, a printing defect. Secondly, a "staircasing" effect would occur when printing lines.

FM screening is an image reproduction process first envisioned by Karl Scheuter in 1965, at the Technical University of Darmstadt. Since then, it has created a significant change in the printing process. Scheuter designed FM screening to be comprised of same-sized dots erratically spaced apart in different concentrations, resulting in a randomized pattern creating an image. Shadows in printed images would have a higher concentration of dots, and highlight areas would have a lower concentration. Sometimes called stochastic screening, the process gets its name from "a mathematical term meaning 'being or having a random variable.' It [is] derived from the Greek stochastikos, or 'skilled at aiming'" (Elton, 2013). Its name is meant to represent the random pattern of dots that are produced by the technology to form a desired printed product.

Scheuter, the process' inventor, wrote a technical paper about FM screening in 1984, entitled Frequency Modulated Picture Recording with Random Distribution. The publication encompasses all aspects of stochastic screening, or, as he put it, "stochastic tonal distribution" (Elton, 2013). The FM screening process, as it is known today, originated from this text, and is still referenced on many occasions.

| CAPABILITIES OF FM SCREENING|

The application of FM screening has many benefits in the graphic communications industry. First, it is widely regarded as more efficient than the conventional (AM screening) processes. Robert Engal, a print operator at Cober Printing Solutions, stated in an interview that "stochastic screening doesn't enhance the industry, it enhances the product" (2017). However, in an industry that relies on the quality of the products it produces, the two are almost one and the same. FM screening produces higher quality products due to the intricate detail (in the highlights and the lowlights of a print) caused by using very small dots; it does so more efficiently than conventional or AM screening. When printed products are improved, customer satisfaction is improved, which leads to more business and increased sales. Additionally, FM screening has furthered LPI integrity in print and has found rising popularity being used in conjunction with expanded gamut printing.

Compared to conventional screening, FM screening produces a larger gamut volume (the range of colours that a printer can produce in print). In other words, it has more chroma, or intensity of a specific colour, than its conventional counterpart. Having the ability to create colours with a greater amount of chroma corresponds with having a larger colour gamut because there are more tone values available for each colour produced.

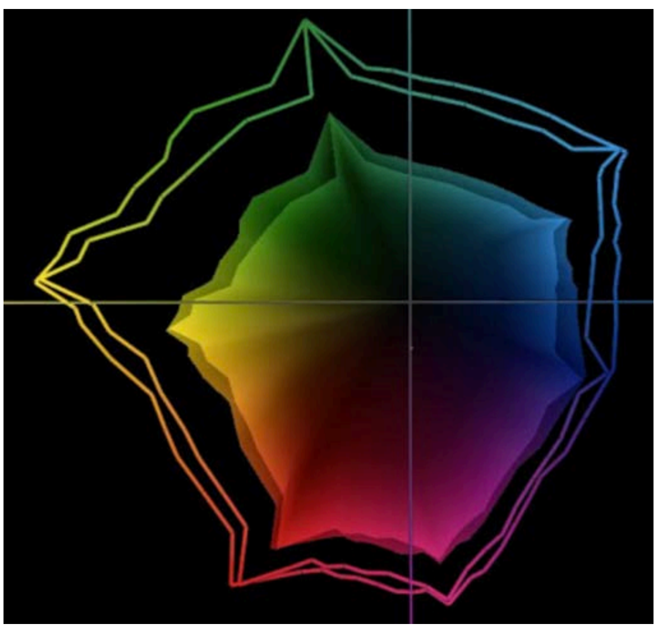


Fig 1. FM screening colour gamut shown as the opaque volume, and AM screening colour gamut shown as the solid volume (Pritchard, 2009).

The difference in gamuts between AM and FM is not always noticeable in image reproduction. However, differences in chroma at varied tone settings can affect the hue of screened, spot, or Pantone colours. In his article, “AM and FM Gamuts Compared,” Gordon Pritchard explains that “technically speaking, FM screening does not actually increase the gamut. Instead, it is more accurate to say that FM reduces the potential gamut less than the larger dots of an AM screen does. The function of ink in printing is to filter light, [and] when that happens you see colo[u]r according to what part of the spectrum is filtered by the ink” (Pritchard, 2009). Through reducing the possible gamut less than the larger dots of AM screening, printers can make better use of the gamut available for reproduction in print, and can more accurately present the continuous tone colours that the human eye can see.

FM screening can also accomplish a high LPI integrity. In comparison, the rosette pattern created with AM screening can often present a “high frequency moiré,” which is what makes conventional screening unreliable (Pritchard, 2010). If one colour in the rosette pattern has a misregistered angle or has shifted a little too much, the image will result in a moiré. This conflict is completely avoided with FM screening due to the fact that there are no screening angles used for the dots. Pritchard states that “FM screens do not produce rosettes. As a result, they maintain their lpi image integrity when slight misregistration naturally occurs” (2010). This greater tolerance for misregistration reduces the number of products that need to be reprinted due to errors such as moiré. Avoiding this saves not only time but money for printers.

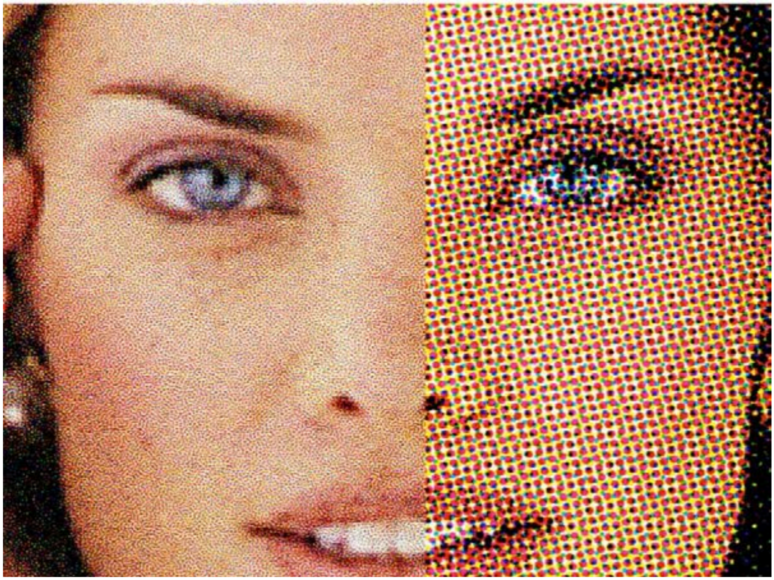


Fig 2. FM screening, left, compared to rosette pattern in AM screening, right (FM screening on left side, 2012).

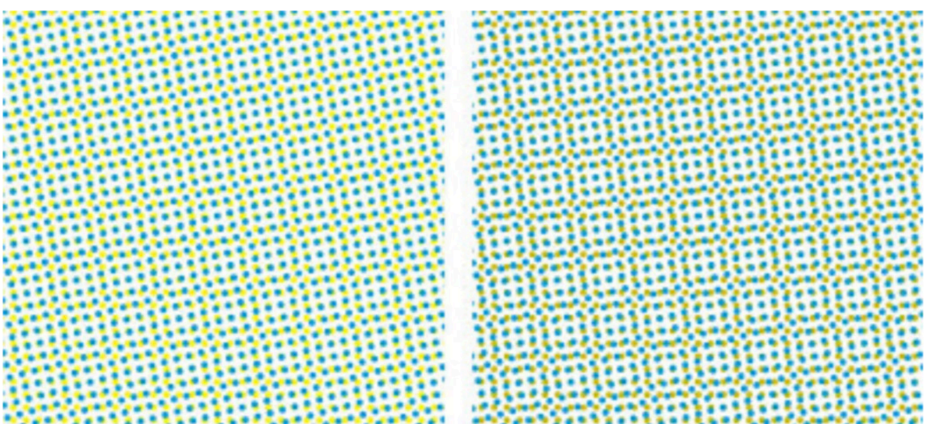


Fig 3. Normal AM screening, left; moiré pattern in AM screening, right (Pritchard, 2009).

Another advantage of FM screening is its ability to print square dots. AM screening is also capable of this technology, but not on the same scale as stochastic. Square dot technology, which can be seen in FM screening, does not allow for any variation in power from the center to the edge (Elton, 2013). Square dots create minimal dot gain, which eliminates the effect of the printed image looking different than originally intended. The differentiation caused by dot gain is perceived as the shadow areas of an image appearing much darker than intended. This can have a negative effect on small text, making it hard to read due to a blurry appearance. "The primary difference [between traditional dots and square dots] is that square spot imaging technology uses a 5000-dpi laser spot as compared to flat-bed violet solutions that use 800 dpi lasers. This produces a dot on the plate that is 5 times less susceptible to tonal variation due to typical daily fluctuations in processing conditions" (Elton, 2013). The ability to better manage dot gain on press results in more accurately reproduced prints, which is extremely valuable to printers.

There are many benefits that FM screening has, and continues to prove, to the graphic communication industry. Larger gamut volume, a high LPI integrity and minimal dot gain are just some of the many elements which are used every day to more efficiently produce products. FM screening is also just as fast in rendering, or RIPing time as AM screening. Therefore, the efficiency that FM screening allows is highly advantageous for printers.

CURRENT APPLICATIONS

The newspaper industry largely uses FM screening, primarily due to its ability to print a smaller linescreen than the newspaper print standard. “Although even at that time it was accepted that newspaper printing did not require a 12-micron dot, the entire concept of holding very small dots on lithographic plates from film imaged on newspaper image setters was a huge challenge. With the advent of fast computer to plate, FM screening for newspapers becomes a more attractable proposition” (Elton 2013). Newspaper substrate is uncoated and extremely porous, which causes the paper to absorb more ink (than coated paper would), increasing dot gain. This has limited the abilities of newspaper printing because there cannot be high-quality photos printed, colour-accurate branding can be changed, and the drying time for the ink is very long. FM screening has been found to be a better option than AM screening for newsprint, because of its large line screen size capabilities, resulting in less dot gain, which is less than conventional printing. This type of screening has also been found to save ink because of its different uses of colour separation. “The other aspect of ink savings or ‘ink optimization’ is to use this technology in conjunction with achromatic separations or Grey Component Removal (GCR)” (Elton 2013). GCR is used to reduce the quantity of the expensive inks (yellow, magenta, cyan) that are used in highly concentrated areas, like shadows. This decreases the cost of the print job because less ink is needed.

FM screening is also used is the fashion industry. It proves to give printed patterns higher quality and colour compared to AM screening, due to its larger gamut range. It also allows for finer detail within designs. Since the dots are randomly spaced apart, there is no worry for the effect of staircasing, or moiré. Albert Fields, writer for PrintWiki, describes the advantage of using FM screening, stating: “It is particularly suitable for the color printing of complicated images involving complex textures such as that of woven fabrics like tweeds and silks, repeating backgrounds, and other geometric shapes that tend to cause interference/moiré problems when printed using conventional screens” (2010). Detail for apparel, textiles, and fabrics needs to be precise, or else the design or pattern risks being ruined. When a pattern is printed conventionally, there is an increased possibility of deviance of screen angles, resulting in moiré within the piece. If this occurs, the piece will need to be discarded and reprinted, costing the printer time and money. With FM screening, however, this potential problem is bypassed, leaving no reason for concern regarding moiré.

Stochastic screening is also widely used in the interior design industry for wallpaper, tapestry, bedding, and other printed textiles. Interior designers mostly use FM screening for the same reasons the fashion industry uses this type of printing: creating more intricate designs with less room for error. For example, when a designer has an image in their head of what they want their product to look like, effects like staircasing, that virtually distort the design, are not desired. Robert Engal states that “FM screening is a way of distributing dots in a certain area so you don’t end up with stair casing on certain designs or images where there is a straight line, for example a vertical line. Conventional screening would create a jagged effect, where stochastic screening eliminates it” (Engal, 2017). As demonstrated in the fashion industry, having a print not turn out the way it was planned can be avoided using FM screening.

Hybrid screening, which combines FM and AM screening, is another form of printing that is used for expanded gamut purposes. Steven Waxman, printing consultant and writer for the Printing Industry Exchange, explains this process as follows: “Hybrid screening (also known as “cross modulated screening” and by many other names) places the miniscule FM dots on a regularly spaced AM grid...The good news is that hybrid screening will hold a dot pattern in highlights, then it will allow for a smooth transition in the mid-tones, and finally it will continue to maintain detail in the shadows" (2007). Waxman exemplifies the key benefit to hybrid screening: having the conversion between tones of colours transition uniformly. This expands the colour gamut of hybrid printing, since more tones are being created. Using hybrid screening can produce more colour-pleasing images and tones than FM or AM screening alone, which will increase colour accuracy.

FUTURE APPLICATIONS

Given the capabilities of FM screening, its use in the graphic communications industry will almost definitely continue to increase in the coming years. As its popularity increases, so to will the advancements made to the technology and its applications. The closer to continuous tone that FM screening gets, the more it will improve production quality in all industries that utilize it. In an interview with Package Printing called The Dish on Dots, Fuji and Enovation stated that "print buyers want a reproduction as close to continuous tone as possible" (Hershey, 2006). This technology is growing as more people are realizing its capabilities and benefits it has toward printing. Kodak also commented the advances FM screening is taking towards offset printing, stating: "what drives the further adoption of FM screening in offset is the printer's desire to meet customer expectations, lower manufacturing costs, and differentiate themselves from their competition" (Hershey, 2006). The efficiency and productiveness of stochastic screening is what keeps this technology developing.

CONCLUSION

Stochastic screening has increasingly improved since it was invented. Still, there are areas in which it can expand and develop so that the technology can be more widely used. It is evident that the efficiency of FM screening is greater than that of AM screening. It provides many more attributes to the graphic communications industry, along with various other industries. It is important that users of this technology look for extended uses for it. Using randomized patterns instead of evenly spaced out dots allows viewers to look at an image or design as if it were a continuous tone, which is a key goal for not only FM screening but printers around the world.

REFERENCES

Waxman, S. (2007). Printing Industry
Exchange. HybridScreening. Retrieved fromElton. A. (2013). Colour Splash. Benefits of FM Screening. Retrieved from http://www.coloursplash.eu/Benefits%20of%20FM%20 screening.pdfngal, R. Personal Communication. (March 17, 2017).

Fields, A. (2010). PrintWiki. Stochastic Screening. Retrieved from http://printwiki.org/Stochastic_Screening

[FM screening on left side and AM screening on right side]. (2012, September 13). Retrieved November 31, 2018, from http://printcolormanagement.weebly.com/articles-gallery/what-is-the-difference-between-fm-and-am-screening

Hershey, J. (2006). Package Printing. The Dish on Dots. Retrieved from https://www.packageprinting.com/article/industry-experts-weigh-am-fm-transitional-hybrid-screening-methods-31116/
Janischewski, C. (2009). WAN-IFRA Magazine. Color Quality Symposium: Screening Processes; The Benefits of FM Screening. Retrieved from www.wan-ifra.org/system/files/field_ifra_mag_file/E_p26_27_jan.pdf

Pritchard, G. (2009). The Print Guide. AM and FM Gamuts Compared. Retrieved fromhttp://the-print-guide.blogspot.ca/2009/03/am-and-fm-gamuts-compared.html

Pritchard, G. (2010). The Print Guide. FM/Stochastic Screening. Retrieved from http://the-print-guide.blogspot.ca/2010/01/fmstochastic-screening.html

Pritchard, G. (Photographer). (2009). FM screening colour gamut shown as the opaque volume, and AM screening colour gamut shown as the solid volume [Digital Image]. Retrieved from http://the-print-guide.blogspot.com/2009/03/am-and-fm-gamuts-compared.html

Pritchard, G. (Photographer). (2009). Normal AM screening, left; moiré pattern in AM screening, right. [Digital Image] Retrieved from http://the-print-guide.blogspot.com/2009/12/moire.html

MEET OUR

TEAM

AIDAN KAHANE

My name is Aidan Kahane and I have been a member of RyeTAGA for the past four years. My experience has been filled with highs and lows from which I have learned so much. This student group presents an opportunity for students to explore innovations in the graphic arts industry today and provide their own insight with fresh eyes. Discovering technologies to incorporate in these journals to change the way we perceive print has always been a passion of mine. This year, I was fortunate enough to work with a passionate and hard-working group of individuals who have blown me away with their skills and talent poured into this year's journal. I am honored to have worked alongside these individuals and know that the industry has a bright future ahead. Thank you, TAGA, for this amazing experience and for many unforgettable moments.

- OUR EDITORIAL DIRECTOR -

JULIA FORRESTER

It has been my privilege to work with the RyeTAGA team again this year. Both the executive team and associate members have dedicated many hours to the production of this year's publication, and I extremely proud of the work we have done together. As the Editorial Director for the second consecutive year, I have truly been able to grow in this position and further develop my copyediting and leadership skills. Having reviewed and edited the work of others for several years, this year has been particularly exciting for me as I was able to have my own research paper published in the RyeTAGA journal and submitted for consideration for the Harvey Levenson Undergraduate Student Paper Award. I hope you enjoy all the papers included in this year's journal and look forward to presenting our publication at the TAGA conference.

- OUR CREATIVE DIRECTOR -

ELEESA JACOB

Being a part of something as unifying and hands-on as the 2019 RyeTAGA team in my fourth year of Graphic Communications Management has certainly been a privilege. As I reflect on my journey as Creative Director, I cannot help but feel thankful for the opportunity to work with such an ambitious and hard-working group of individuals. From conception to completion, we have worked tirelessly to produce a journal that is timeless and reflects our passion for the industry - a passion that will translate as we progress through our careers. RyeTAGA has served as the real-world application of my education at Ryerson and supplemented my knowledge regarding design, marketing, leadership and management. A huge thank you goes out to all those involved in the production of this journal: namely, our faculty advisors, industry sponsors and TAGA!

- OUR CORPORATE RELATIONS DIRECTOR -

MINA OUT

After being a part of RyeTAGA previously as a general member, I am glad that I took the leap to work with RyeTAGA as part of the executive team. Working as the bridge between RyeTAGA and the industry sponsors that enable us to make our journals, I have been able to improve and develop on my business communication skills. I am grateful that RyeTAGA has provided me the opportunity to get hands-on experience with creating a publication and that I have been able to do this alongside a truly wonderful team. Our team has done a lot over this year in order to coordinate the many working parts that goes into producing our journal, and all of our members have done an exception job. Lastly, thank you to our industry partners to providing us sponsorship and guidance so we can do what we do best, making beautifully produced journals. We are looking forward to being able to present our journal at the TAGA conference this year.

- OUR TREASURY AND ADMINISTRATIONS DIRECTOR -

LOREN AMARAL

As this was my first year participating in RyeTAGA, I was both nervous and honoured to be trusted with the responsibility of Treasury and Administration Director. Luckily, with the support of faculty, executives, associates and past members, I had a wonderful time assisting in financial matters and administrative work. RyeTAGA has given me the opportunity to work collaboratively with others and learn plenty about managing, planning and communicating with industry professionals. I would like to personally thank all our sponsors who made our journal possible by supporting and believing in us young professionals. I am pleased to present this year's journal, with confidence that it is one of our most innovative, creative and well-evolved journals yet! We are truly proud of all the hard work and dedication that has gone into this year's journal and I am honoured to have been a part of this brilliant project. Thanks TAGA!

- OUR MULTIMEDIA DIRECTOR -

VICTORIA SALLESE

It has been a great experience taking on the Multimedia Director position for RyeTAGA this year. I have not stopped learning since our very first meeting. I cannot thank my fellow executives and my associates enough for sharing their skills and showing their support for one another while producing our journal. Being a part of RyeTAGA gave me a hands-on experience of what it takes to make ideas become a reality, and has been a true test of applying what I have been learning during my studies at Ryerson University. RyeTAGA has also given me the opportunity to become a TAGA Social Media Ambassador. Since then, I have been able to network with and get to know amazing people from the graphic arts industry who I could potentially work alongside in the future. I am looking forward to attending my very first TAGA Conference with this incredible team, and cannot wait to share what we have been working on with all of you!

- OUR PRODUCTION DIRECTOR -

CINDY TRENH

This year marks my third year as a member of RyeTAGA, and I am extremely grateful for all the knowledge I have gained from being a part of this student chapter. As the Production Director this year, I was able to learn more about the print industry through plant tours and sponsors, and was able to apply the skills I have learned from my program to complete this journal. I would like to thank RyeTAGA's sponsors this year and our faculty at GCM for making it possible to create another beautiful journal. I would also like to thank the executive team, as well as our associates, for working so hard this year to ensure RyeTAGA succeeds! It has been a pleasure working with this year's team and I am excited to see the amazing journals RyeTAGA will continue to produce in the future.

- OUR MARKETING AND EVENTS DIRECTOR -

EMILIJA BIGA

This year has been an amazing journey with the RyeTAGA team. I have learned many new skills, from networking with industry professionals to leading a team of highly talented people. We had a lot of fun hosting events such as our Make-Ready Week and our Button/Sticker Sale while also creating the journal. My associates and I worked tirelessly this year to ensure that everyone in the Graphic Communications Management stayed informed with what RyeTAGA is doing next by creating posters, posting on social media and actively engaging with the student body. I am very thankful to have had the opportunity to be this year's Marketing and Events Director and am grateful to have been able to meet so many great people along the way.

OUR

ASSOCIATES

THANK YOU FOR ALL YOUR HELP, INITIATIVE AND DEDICATION!

PRODUCTION

-

Edwin Bang
Elyssa Tibbo
Samantha Stante
Vincent Tran
Amanda Arone
Cecilia Leung

MARKETING AND EVENTS

-

Camille Llena
Princess Rannia Manabat
Angelica Gaitan

CREATIVE

-

Krupa Mistry
Christopher Chai-Tang

TREASURY & ADMIN

-

Natalie Hague
Andrea Mendoza

MULTIMEDIA

-

Linda Nguyen
Catherine Di Luca
Sabrina Alaimo

EDITORIAL

-

Samantha Nunziano
Pauline Reyes
Tate Kamps
Izabella Halonska
Jamera Dacosta

THE COLOPHON

TYPEFACES, EQUIPMENT, SOFTWARE & STOCKS

TYPEFACES

-

Futura PT
Didot LT Pro

SOFTWARE & EQUIPMENT

-

Adobe InDesign CC, Illustrator & Photoshop
Canon ImagePRESS C10000VP

FINISHING EQUIPMENT

-

Scodix Ultra2 Pro with Foil

STOCKS

-

Neenah Touché Bright White 13pt
Mohawk Via Smooth Pure White 100 Text

mohawk

IMAGE

SOURCES

PHOTOGRAPHERS FEATURED IN THIS JOURNAL

Photo by Cristina Gottardi
https://unsplash.com/photos/wVTGdIGdojc

Photo by Casey Horner
https://unsplash.com/photos/4rDCa5hBlCs

Photo by Nathan Anderson
https://unsplash.com/photos/cgO39sAIXpc

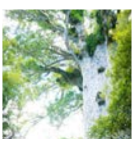


Photo by Sheldon Nunes
(link removed by photographer)

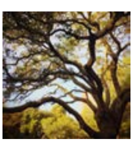


Photo by Victor Zambrano
https://unsplash.com/photos/naQdcC4nVgA

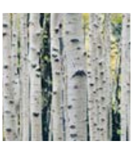


Photo by Peng Chen
https://unsplash.com/photos/qd-dvtbS45Q

Photo by Ivan Ho
https://unsplash.com/photos/EHkPaxA0hAk

MEET OUR SPONSORS

We would like to take this opportunity to thank our sponsors for their help in producing this year's journal. It is because of your generous donation of expertise, money, and materials that we are able to compete at the TAGA conference every year. The RyeTAGA team truly appreciates all that you do to ensure that our student chapter is able to put forward the best publication possible, and hope to continue doing so for many years to come.

HEIDELBERG

mohawk

Ryerson University

GRAPHIC COMMUNICATIONS MANAGEMENT

NOTES