2012
RYETAGA

RYERSON UNIVERSITY STUDENT
CHAPTER OF THE TECHNICAL
ASSOCIATION OF THE GRAPHIC ARTS


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FACULTY ADVISOR ADDRESS

DR. MARTIN HABEKOST

The date of the upcoming annual technical conference is coming very quickly. Many of us look forward to escape the winter weather in Toronto for some sunshine and warmer temperatures in Florida.

It takes the efforts of many people to put this publication together. You really have to use all the skills that you have learned to make this journal possible. Many ideas were put on the table, and only the best ones made it into the journal. I liked how we all made decisions in regards to layout and typography. The journal has a wide spread of topics. I am happy to see that print technologies other than offset (flexography and silk-screen) were used in the research reports. This shows the diversity of interests that you, the students, have.

Your fundraising efforts helped offsetting some of the costs for travel, conference and journal production. Thank you to everyone at the School of Graphic Communications Management (GCM) at Ryerson University for all their help and support.

Let's see if we keep the two-year rhythm of winning the cup. I would really like to see it back in our school. This journal is the product of many and not of a few. So either we win it all, or hopefully we get one of the consolation prizes. Besides the competition, a really important part of the conference is to listen to all the interesting research presentations. Meeting students from other chapters and exchanging information on how they run their chapter and how they overcame any challenges with the journal production is also important.

Good luck with the competition, all the best to you and enjoy your time in Jacksonville,

Martin Habekost, Dr. rer. nat.
Ryerson TAGA Student Chapter Advisor

PRESIDENTIAL ADDRESS

SARA D'ARCEY AND ANNA WHATMAN

Another year of RyeTAGA has come to a close, providing us with time to reflect back on all that has been accomplished, all of the opportunities provided, and all of the valuable experiences gained throughout the production of our 2011/2012 journal. The RyeTAGA team has worked hard throughout the school year to produce a wonderful and thought out journal. The entire team has been incredibly dedicated throughout the process and we truly appreciate every individual who helped to contribute to this year's journal.

This year RyeTAGA was able to experiment with thermochromic inks and revisited the method of sheetfed offset printing to produce the cover of our journal. For the content of our journal we printed digitally. By choosing these printing processes, members were given the chance to assist in the printing of the journal as well as see another side of production compared to previous years. Through editing, design, fundraising, typesetting, printing, and finishing, each member played a key part in the production of the journal.

These pages represent the hard work of our brilliant students and the dedication of our executive team. We would be remised if we did not also thank every member for their support and help with the creation of this journal. Finally, we truly could not have succeeded without the support and generosity of the GCM faculty and sponsors. We sincerely hope you will enjoy this journal as much as we have enjoyed creating it.

Cheers to another great year, team!

Sara D'Arcey and Anna Whatman

ABOUT THERMOCHROMIC INKS

Thermochromic inks have been an important part in the 2012 RyeTAGA Journal since the initial brainstorming stages. Yet, it still amazes us how versatile it is, and how much it can add to a finished product. Thermochromic ink has been used quite sparingly in the past—for gimmick clothing of advertising. However, more recently it has begun to grow in popularity. It is being used on food and beverages, authenticity applications for checks, business forms, RX pads, and promotional print media. Many people have begun to use thermochromic inks to help their product stand out, and to increase ease of use for the costumer.

Thermochromic inks are available for offset printing, screen-printing, flexo printing, gravure printing and metal decal printing. Each ink must be specially formulated for that specific process, but it is clear that thermochromic inks are quite versatile. However, when using these inks, the printing process must be monitored carefully. Thermochromic inks have the ability to return to their original colour, this is called "thermal memory". When the ink is exposed to, too great a temperature, this memory will be damaged. Despite this, thermochromic inks are quickly becoming more widely used.

There are two variants of thermochromic inks. The most common of the two is called Leucodye. Leucodye inks allow for ink to change from one colour when cool to a different colour when heated. This is achieved through mixing a permanent colour ink with Leucodye ink. The second variant of thermochromic ink is Liquid Crystals. They are more sensitive to temperature change than Leucodye inks. However, they are very difficult to work with and more expensive.

VIEW THE 2012 RYETAGA JOURNAL ONLINE

This year's RyeTAGA journal includes an electronic version with additional multimedia content, including the appendices. This online journal was designed for touch-based devices*, using an app framework called Sencha Touch. To access the online journal, scan the QR code below, or point your smartphone or tablet's web browser to: http://2012.ryetaga.com

ABOUT SENCHA TOUCH

"Sencha Touch is the world's first app framework built specifically to leverage HTML5, CSS3, and Javascript for the highest level of power, flexibility, and optimization."
(Source: Sencha Touch Website)

For us, Sencha offered a way to create a touch-based electronic publication that is accessible from any device with a webkit browser—using web-based programming languages that the team was already familiar with. Sencha's unique leveraging of web languages enables a one size fits all layout that automatically reflows across different screen sizes.

ABOUT THE MULTIMEDIA TEAM

Thanks to the multimedia team for dedicating their own time to learn Sencha Touch. Three months of student directed training through online tutorials, collaborative experimentation, and digital elbow grease; an electronic book, created for the internet, from the internet.

* Compatible with Apple iOS 3+, Android 2.1+, BlackBerry 6+ devices, and any webkit enabled web browser

CAROL FUNG

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THERMOCHROMIC INKS: EFFECTS OF INK FILM THICKNESS ON FABRIC

ABSTRACT

The purpose of this test is to determine the effect of different substrates and ink film thicknesses on the colour strength of a screen-printed thermochromic ink. Comparing substrates is vital, as different materials will have a different level of absorption that will result in varying appearance of the ink. Testing the difference between white and black substrates is also essential as the surrounding colour will affect the visual appearance of another colour. Furthermore, this test specifically compares the differences between one, two, and three layers of thermochromic ink at both cold and room temperatures. The data gathered from these tests and comparisons will allow for a greater understanding and knowledge of screen printing on fabrics with thermochromic inks.

SUMMARY

This test has determined that the intensity and colour changing properties of thermochromic inks on fabrics are at their strongest on light coloured, less absorptive fabrics, with a thicker ink film. It was also determined that with darker thermochromic inks on dark fabric, it is very difficult for the naked eye to see changes in colour. We also determined that white fabrics showed greater ink colour difference between ink film thickness levels at colder temperatures compared to the black fabrics at room temperature.

From these results, it is recommended that printers looking for the greatest colour intensity and largest colour change from thermochromic inks use lighter coloured fabrics with low absorbency, using the thickest ink film and using an ink that changes colour at a lower temperature. When using dark fabrics, it is recommended to choose cotton, with a thick ink film, and using an ink that changes at higher temperatures. Printers are reminded that consistent ink film thickness is essential for obtaining the proper colour change in thermochromic inks and that this can be achieved through proper drying techniques and refraining from printing inks wet-on-wet.

INTRODUCTION

The objective of this test is to explore and examine the variables that affect thermochromic ink when printed on fabric. Exploring these variables will elaborate on which conditions produce optimal results. The test is an accurate and valid means of determining the effect of these variables due to the standards that have been set for comparison. The test will compare white and black fabrics in cotton, linen, and polyester to see their effect on the colour and difference in change within the colour. Furthermore, this test compares the effects of different thicknesses of ink. Our test replicates common screen-printing practices, which allows the information gathered from this test to be applied to screen-printing within the industry.

THEORY

Screen-printing has been used for printing on fabrics since 700 A.D. in China as well as in Egypt (Eldred & Scarlett, 1995). Initially the screens were made of silk but through the passing of time, nylon, polyester, steel and other metals have come to commonly replace silk screens within the industry. Commonly, screen-printing is used for small runs or single products; however it can be mass-produced using a web screen press (Eldred & Scarlett, 1995). For the purpose of this test, we used a silk screen-printing kit as recommended by an ink company representative.

Due to the differing printing process, inks created for the purpose of screen-printing are different from those made for offset or flexography. Offset inks are much longer and must have a tack to properly print. If they were to be used for screen-printing, they would likely ruin the printed piece due to the strings they would leave when the screen was pulled from the substrate (Eldred & Scarlett, 1995). Screen inks are often much shorter and referred to as "buttery" or as paint (Eldred & Scarlett, 1995). The shorter ink prevents strings from forming when the ink is lifted. Thermochromic inks are slightly different than common screen-printing inks due to the different chemicals and particle size required for the colour change. The average particle size for thermochromic inks is between three and five microns (Homola, 2003). This means that these inks require a much coarser screen mesh with a heavier ink laydown to compensate due to the particle size being nearly ten times larger than normal. Furthermore, the temperatures the ink is exposed to must be monitored extremely closely. Thermochromic inks that are able to reverse back to their original colour have what is referred to as "thermal memory" (CTI Inks, 2010). When the ink is exposed to extreme temperatures, the ink will no longer be able to achieve its full colour as the exposure has harmed its thermal memory.

Like the vast majority of inks, thermochromic inks may be either organic or inorganic. The most common of the two used today is inorganic due to the wider range of substrates it can print on as well as cost and several other factors (Kunjappu, 2000). One factor is that inorganic inks allow for a specific type of thermochromic ink called Leucodye. Leucodye inks allow for ink to change from one colour when cool to a different colour when heated (Homola, 2003). This is achieved through mixing a permanent colour ink with leucodye ink. It is likely that the ink used in this test was created in this manner. More specifically, a base colour of yellow was selected and blue leucodye was added to the yellow. When the ink is cooled the printed layer is green and when warmed, it reverts to yellow as the leucodye becomes clear (Johansson, N.D.). Due to the nature of our ink, changing from "green" bellow 0°C to "yellow" above 0°C it can be assumed we are dealing with Leucodye ink. However, the second variant of thermochromic ink is Liquid Crystals. They are much more sensitive to temperature change than leucodye inks and are very difficult to work with and manufacture (Johansson, N.D.). This difficulty means that liquid crystals are much more expensive and less suited for one off or small runs than leucodye.

As previously mentioned the fabrics being used are linen, cotton and polyester. The different absorptivity, porosity, coarseness and general attributes of each fabric will have a large affect on the end-use as well as the thermochromic inks ability to adhere and maintain colour. The more absorptive a substrate is, the lower is its ink holdout and the colour density of printed images are strongly influenced by the ink holdout of the substrate. For example, because uncoated papers are more absorptive than coated papers, the colour intensity on the coated paper will be much greater on the coated paper compared to the uncoated paper (Wilson, 2007). We plan to apply this theory to fabrics and believe that the more absorptive the fabric is, the less intense its colours will appear.

EXPECTED EDUCATIONAL GAINS

By completing this test, a greater knowledge will be gained on the affects of different fabrics and layers of ink on colour change in regards to thermochromic ink. Proper recommendations were made for the appropriate end use required. It was easily identifiable which fabric is best for printing thermochromic ink effectively as well as which fabric and amount of layers have the greatest colour change and most vibrant colour overall. This knowledge may be used to better plan the production of fabric products that are implementing thermochromic inks. Furthermore, it will bring further insight into screen-printing and its practical applications.

DEFINITIONS

ABSORPTION: Soaking in or penetration of liquid components of the ink into the pores of an absorbent substrate (Kipphan, 2001).

COLOUR STRENGTH: An ink's colour power as determined by its pigment concentration (Sheetfed Offset Press Operating).

INK HOLDOUT: The extent to which a substrate retards the inward penetration of a freshly printed ink film (Wilson, 2007).

SCREEN-PRINTING: A printing process in which ink is forced through a porous open mesh screen that has non-image areas blocked out in some manner and image areas left open to permit the flow of ink through the screen (Ingram, 1999).

SPECTRODENSITOMETER: An extremely accurate color measurement device using a diffraction grating to split light into its component wavelengths, which are then measured by numerous light sensors. (Global Imaging , n.d).

THERMOCHROMIC INK: This particular kind of ink changes between two different colours or shades depending on what temperature it is exposed to. Usually the ink changes colour when exposed to a high temperature and returns to its original colour when cooled (MyPrintGuide, 2010).

EQUATIONS

Delta (Δ)E: $\Delta E_{ab} = \sqrt{(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2}$

$\Delta L = L_2 - L_1$

$\Delta a = a_2 - a_1$

$\Delta b = b_2 - b_1$

TESTING PRINCIPLES

The methods used in this test are similar to those used by fabric printers, as well as craftsmen. Therefore, the information gathered by our test can be applied to others who wish to print using thermochromic inks on fabrics.

Key equipment that we used was our screen printing kit and the X-Rite Spectrodensitometer. A spectrodensitometer combines the capabilities of a densitometer and spectrophotometer into one machine. It allows you to check dot gain, density, L*a*b* values and much more. For the purpose of this test, we used the spectrodensitometer to measure the L*a*b* values of our substrate as well as the ink printed on it. The spectrodensitometer uses CIE illuminant, such as D50, as well as reflectance of the item being measured to accurately determine any value required. As mentioned previously, the second tool we used for this test was the Speedball STENCIL Printing Kit. Screen-printing, our kit included, is a stencil process where ink is forced through a mesh or a screen onto a substrate, which in the case of this test is linen, cotton or polyester (Eldred & Scarlett, 1995). When the ink is forced through the mesh with a squeegee, even pressure must be applied to distribute the ink evenly onto fabric. However, before the printing can occur a stencil must be created. As previously stated screen printing relies on stencils, this gives the ink direction and shapes it when being transferred onto the substrate. In the case of this test, we chose to use a simple square keep the test as simple as possible.

We chose to conduct the test in this way so as to get the most accurate results possible. By measuring the L*a*b* values, we are able to gain further insight, such as the ΔE of the product when compared to different fabrics as well as different layers. There are many different ways a test can be conducted to see the affects of different fabrics on thermochromic inks. It is possible to do a rub test to see how well the ink adheres to different fabrics. It is also possible for different fabrics to be chosen or a different type of thermochromic ink. It is quite simple to replicate what was tested during this experiment by simply following the laid out procedure. Furthermore, due to the similarity between how items are printed within the industry in comparison with how the fabric is printed in this experiment it is also quite simple to replicate the printing conditions.

MATERIALS USED

- CTI Thermochromic UV Screen Ink 3 micron grind Batch #00181801
    - Part Number: 5GY00XXD130401
    - Colorado Springs, CO
- Fortune Gloss Offset 24 x 36 182M 100 lb 148 g/m2 Grain Long
- 100% Polyester Black & White
- 100% Cotton Twill Black & White
- 100% Linen Black & White

EQUIPMENT USED

- X-Rite Spectrodensitometer 500 Series #011828 Granville, MI
- Micrometer The L.S. Starrett Co. LTD
    - Great Britain
    - No. 436-1 in
- Speedball STENCIL Printing Kit
    - 8 x 10 printing screen
    - Red Baron Squeegee
    - Transparency Film
    - X-ACTO Knife
- Scissors
- Duct Tape
- Writing Utensils
- Ink Knife

PROCEDURE

1. Using the spectrodensitometer, the L*a*b* values were read in four different places on the Fortune Gloss paper that was used as a backing when measuring the fabric. The results were averaged and recorded.

2. Using the spectrodensitometer, each of the fabric samples were measured in four different places, average and record results.
3. Using the micrometer, the caliper of each of the fabric samples was measured in four different places, average and record results.
4. The white polyester fabric was taken and cut into 3 squares of relatively even size (large enough for at least a square that measures 1.5"x1.5") and labelled 1, 2, and 3. This was repeated for each colour and type of fabric.
5. The X-ACTO knife was used to cut out a 1.5" x 1.5" square in the transparency film.
6. A fabric sample taken and taped to a hard surface, ensuring that it would stay in place. The printing screen was then placed over the fabric and the transparency film was put into the printing screen.
7. An appropriate amount of ink was placed onto the transparency film. The squeegee was use to squeeze the ink through the 1.5" x 1.5" square on the film onto the fabric and left to dry The was repeated for every fabric sample.
8. On all the samples labelled 2 or 3, steps 7 and 8 were repeated so each would have a second layer of ink.
9. On all samples labelled 3, steps 7 and 8 were repeated so each have a third layer of ink.
10. Using the spectrodensitometer, the L*a*b* values of all the samples were read at room temperature where the ink has been printed, and again while using the Fortune Gloss paper as a backing. Values were recorded.
11. Step 10 was repeated after cooling the fabrics to sub-zero temperatures.
12. Using the micrometer, the caliper of the printed areas was measured on each of the fabrics. Results were recorded.

RESULTS

These results revealed that the white fabrics showed a much greater colour change as ink layers were added when compared to the black fabrics. The greatest colour change appeared to occur when going from one layer of ink to two layers compared to going from two layers to three layers. This means that the colour intensity changes when added a third layer of ink is less effective than when adding a second layer. The greatest colour change was observed on the white cotton between the first and third ink layers (ΔE of 18.75). The smallest colour change was seen on the black polyester between the second and third layers of ink (ΔE of 1.44).

Fabric	ΔE (1-2 layers)	ΔE (2-3 layers)	ΔE (1-3 layers)
White Cotton	9.59	9.25	18.75
Black Cotton	10.65	5.15	16.35
White Polyester	5.79	4.35	10.04
Black Polyester	5.12	1.44	3.76
White Linen	6.44	7.85	14.15
Black Linen	2.47	5.73	7.80

TABLE 1: At room temperature using ΔE_{ab}

Fabric	ΔE (1-2 layers)	ΔE (2-3 layers)	ΔE (1-3 layers)
White Cotton	18.29	18.14	35.82
Black Cotton	5.51	4.03	9.50
White Polyester	5.23	8.62	13.56
Black Polyester	4.67	0.96	3.81
White Linen	16.54	4.93	21.34
Black Linen	2.58	1.72	1.96

TABLE 2: At below freezing temperatures using CIE 1976 to calculate ΔE_{ab}

Below freezing temperature, the ink colour has changed to green and the white fabrics show a much greater colour change as more ink is added compared to the black fabrics. It is also clear that the colour difference between one layer of ink and two layers of ink is greater than that between two layers and three layers. This means that the added colour benefit is greater going from one to two layers than going from two to three layers of ink. This was also observed in the fabrics measured at room temperature. The greatest colour change was seen on the white cotton between the first and third ink layers (ΔE of 35.82) and the smallest colour difference was seen in the black polyester fabric between the second and third ink layers (ΔE of 0.96). This was also observed in the spectrodensitometer readings for the fabrics at room temperature.

The results clearly show that the colour difference from one layer to three layers below freezing temperature was greater in the white fabrics while the colour difference from one layer to three layers at room temperature was greater in the black fabrics.

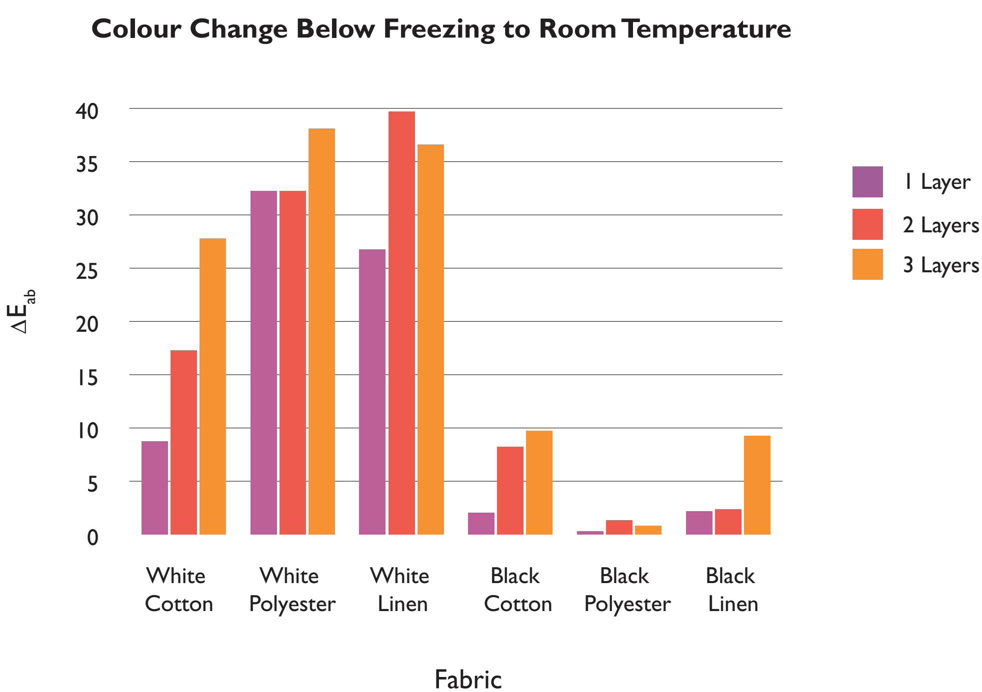

FIGURE 1: Colour change below freezing to room temperature

Fabric	ΔE 1 Layer	ΔE 2 Layers	ΔE 3 Layers	
White Cotton	8.73	17.27	27.78	
White Polyester	32.23	32.26	38.13	
White Linen	26.77	39.72	36.60	
	22.58	29.75	34.17	28.83 Avg
Black Cotton	2.06	8.23	9.71	
Black Polyester	0.30	1.33	0.81	
Black Linen	2.17	2.37	9.26	
	1.51	3.98	6.59	4.03 Avg

TABLE 3: ΔE between room temperature and below freezing.

The ΔE was highest for both black and white fabrics at three layers of ink with an average of 34.17 ΔE for the white fabrics and 6.59 ΔE for the black fabrics. The black polyester and white linen were anomalous in this aspect, showing a lesser colour change in the third ink application. However, the ΔE at three layers was still considerably higher than the ΔE at one layer. The results also showed that there was a greater colour change in the white fabrics compared to the black fabrics as the white fabrics had an average ΔE of 28.83 while the black fabrics had only a ΔE of 4.03. The white linen had the highest colour change (ΔE of 39.72) at two layers of ink and the white polyester had the highest colour change at one and three layers of ink (ΔE of 32.23 and 38.13 respectively). The black polyester had the lowest colour change at all layers of ink for all the fabric types. Out of the black fabrics, the black cotton showed the most colour change between the temperatures.

Fabric	1 layer	2 layers	3 layers
White Cotton (R)			
White Cotton (F)			
Black Cotton (R)			
Black Cotton (F)			
White Polyester (R)			
White Polyester (F)			
Black Polyester (R)			
Black Polyester (F)			
White Linen (R)			
White Linen (F)			
Black Linen (R)			
Black Linen (F)			

TABLE 4: Colours of ink (R= Room temperature, F= Below freezing temperature)

In a visual evaluation of the results, the colour changes were much more noticeable in the white fabrics. In all of the white fabrics, the ink film thickness increases, as does the darkness of the colour intensity. Overall, the white fabric measured below freezing temperature had the greatest level of colour change intensity between layers was the white cotton which showed the greatest darkening (-33.81 ΔL), shift towards green (9.98 Δa), and shift towards blue (-30.12 Δb). At room temperature, the white cotton also showed the most darkening (-18.24 ΔL), a shift towards green only slightly smaller than that of the white polyester (-0.26 Δa), and the largest shift towards blue (-12.28 Δb). The white fabric measured below freezing temperature that had the least intensifying of colours between layers was the white polyester with the least amount of darkening (-11.75 ΔL), shift towards green (6.69 Δa), and shift towards blue (-12.20 Δb). At room temperature, the white polyester had the least amount of darkening (-9.89 ΔL), smallest shift towards green (-0.30 Δa), and smallest shift towards blue (-4.84 Δb).

With the black fabrics, it was much more difficult to tell if there is a colour change at all when increasing the ink film thickness. The ink seemed to lighten as more ink layers are added. This effect was especially noticeable in the black cotton fabric. As the ink film thickness increased for each black fabric, the L* value also increased meaning that the colour of the ink was getting lighter as detailed on Table 11 (See Appendix online). This may be due to the fact that the colour of the fabric was too overpowering at thinner ink layers, causing it to appear darker. Overall, the black fabric measured below freezing temperature that had the greatest level of colour change intensity between layers was the black cotton which measured the greatest brightening (7.12 ΔL), shift towards green (-7.50 Δa), and was the only black fabric to show a shift towards yellow (0.20 Δb). At room temperature, the black cotton had the greatest amount of brightening (11.84 ΔL), the largest shift towards green (-11.35 Δa), and the largest shift towards yellow (7.63 Δb). The black fabric measured below freezing temperature that had the least level of colour change intensity between layers was the black linen which measured the least amount of brightening (0.81 ΔL), shift towards green (-1.70 Δb), but had a slightly larger shift towards blue than the black polyester (-1.38 Δb). At room temperature, the black polyester had the least amount of brightening (3.01 ΔL), the smallest shift towards green (-2.33 Δa), and the smallest shift towards yellow (0.50 Δb).

The results show that at both room and below freezing temperature, the cotton fabrics showed the largest amount of intensifying colour, compared to similarly coloured fabrics as more ink layers were added. The white polyester fabric showed the least amount of intensifying colour compared to similar coloured fabrics, at both room and below freezing temperatures and the black polyester showed the least amount of intensifying colour at room temperature compared to the other black fabrics. Below freezing temperature, the black linen showed the least amount of intensifying colour of the black fabrics. Overall, the white cotton at freezing temperature experienced the most amount of intensifying colours as the ink film thickness increased and the black linen at freezing temperature experienced the least.

In general, there was a more visible colour change between ink film thicknesses in white fabrics when exposed below freezing temperature compared to the colour of the ink at room temperature. On the other hand, the black inks had a more visible colour change between ink film thicknesses when measured at room temperature than below freezing temperature.

Fabric		1 layer	2 layers	3 layers
White Cotton	ΔL	-6.55	-14.53	-21.82
	Δa	-4.78	0.35	5.45
	Δb	-11.85	-20.32	-29.7
Black Cotton	ΔL	-1.83	-6.92	-6.55
	Δa	0.77	3.55	4.62
	Δb	-0.73	-5.72	-8.15
White Polyester	ΔL	-27.22	-25.75	-29.08
	Δa	-0.09	1.61	6.91
	Δb	-33.32	-36.36	-40.68
Black Polyester	ΔL	-0.28	-1.05	-0.07
	Δa	0.06	-0.41	0.24
	Δb	-0.07	-0.8	-0.81
White Linen	ΔL	-20.81	-29.53	-26.82
	Δa	1.22	7.17	9.13
	Δb	-32.01	-42.98	-38.05
Black Linen	ΔL	-1.83	-1.91	-6.9
	Δa	0.47	-0.08	4.48
	Δb	-1.25	-1.57	-3.59

TABLE 5: Difference between colour at room temperature compared to below freezing temperature

We can conclude that as ink film thickness increases, the colour intensity increases as well. Our data also shows that the colour change between warm and cold is more pronounced with a higher ink film thickness as seen in Table 5. When looking at the difference in colour change from warm to cold temperatures, it is more pronounced in the white fabrics. That said, it is still possible to see the colour change in the black fabrics.

All the white fabrics below freezing temperature saw a shift towards red while all other fabrics exhibited a shift towards green. The greatest shifts towards green were seen in the black fabrics at room temperature.

After observing the bleeding of the ink and the thickness of the fabric, it was determined that the linen was the most absorbent, followed by cotton, and the polyester was the least absorbent. The white polyester also demonstrated the greatest colour change of the three white fabrics while the black polyester had the smallest colour change overall. The white linen had the greatest colour change of the white fabrics after polyester and the black cotton had the greatest colour change of the black fabrics.

DISCUSSION

All measurements were taken with the Fortune Gloss paper behind the fabric to act as a constant background. This way the transparency of the fabric did not have a great affect on the spectrodensitometer readings. As the ink is being applied on the fabric, the fabric absorbs the ink which can have an influence on the colour intensity. The relationship between these two factors, fabric absorbency and colour intensity, was that the higher the absorbency of the fabric, the lower the colour intensity. The white polyester may have had the greatest colour change as a result of the fabric having the lowest absorbency. This means that the ink remains on the surface. The other fabrics and their relationship to colour change were seemingly unaffected by absorbency because a limited sample size was used and/or there was a miscalculation due to human error or improper readings. This is proven to be true in the black fabrics as the colour of the ink is mostly lost when it is absorbed into the substrate.

At room temperature, the more absorbent fabrics (cotton and polyester) had a reduced ΔE when comparing the second and third ink layers to the first and second layers. Of the white fabrics, the colour difference of polyester from one layer to the second layer was exponentially larger than the difference between the second and third layer. This may have been the result of the fabric not holding as much ink as the other fabrics. This means that when a third layer of ink was applied, less of it was able to transfer to the substrate, hindering its colour intensity. The layers of ink applied on the fabric contributed to the visibility and the intensity of the colour. It is possible that the fabric was completely saturated and could not hold any more ink, which leads to a thinner ink film in the third layer. In addition if the second layer was not completely dry, then the third layer would not have dried properly on top, also resulting in a thinner ink film. This was proven for polyester, which bled significantly more than other fabrics.

The ink showed up much better on the white fabrics than on the black fabrics because the colour of the fabric has an impact on the colour of the ink, as the ink is not completely opaque and is absorbed into the substrate. When visually inspecting the samples, it was also true that the colour surrounding the ink had an effect on what we perceived that colour to be (Habekost, 2009). The greatest colour change of the ink from room temperature to freezing temperature occurred when the fabric had three layers of ink. This could be a result of thicker ink films that lead to greater colour intensity. According to Eldred and Scarlett (1995), thicker ink films have greater colour intensities in comparison to a thin film of ink because of a higher level of pigmentation.

The fact that the black fabrics showed a smaller change in colour between one and three layers of ink below freezing temperatures than at room temperature could be due to the fact that as the ink became darker it became harder to see on the dark fabric. This colour change was more pronounced in the white fabrics as the light colouring of the substrate did not hinder or blend into the dark ink colour. A large ΔE in this context means that the added layers of ink contributed to the appearance of the ink in a larger way than those with a smaller ΔE. Every ink on every fabric had a slight change in appearance as ink layers were added.

The results of this test were in agreement with published information because according to DeJidas and Destree (2005), thicker ink films have higher colour strength and colour intensity compared to thinner ink films. This is reflected in the results as the colour of the ink intensifies as more layers of ink are added. Colour difference between the inks at room temperature and below freezing is also greater as the ink film thickness increases (Eldred, 1995). According to Wilson (2007), more absorptive substrates will reduce the colour intensity of the ink as it is absorbed deeper into the material. In one sense, this information did agree with the results as the least absorptive substrate demonstrated the greatest range of colour. However, this information did not completely agree with our results as the most absorptive substrate did not have the lowest ink appearance and displayed the second highest ink colour change. It was assumed that each layer of ink would increase the colour's appearance and saturation, thereby showing a colour difference (ΔE).

After measuring all the samples and looking at each of the colours at each layer of ink, it is clear that as the ink film thickness increased, the colour saturation and vibrancy increased as well. It was also assumed that the inks would appear stronger and have a greater colour change on the white fabrics compared to the black fabrics.

This was proven in our results as many of the colour changes in the black fabric are not visible to the naked eye and the white fabric had very large colour changes after being exposed to freezing temperatures.

It was expected that the least absorbent fabric would have the greatest ink colour change, which proved to be the white polyester. Since it was determined that it was the least absorbent, it had the largest colour change but the black polyester had the lowest colour change of all the fabrics. It was also expected that linen, the most absorbent fabric, would have the smallest colour change but it actually had the second highest. The cotton, which possessed absorbency in between the linen and polyester, was expected to have a colour change somewhere in between the other fabrics but it had the lowest colour change of the white fabrics and the highest of the black fabrics.

A weakness of this test is that in order to activate the ink's colour changing properties, it had to be cooled to -1°C. This proved to be difficult, as the spectrodensitometer could not be moved from its location on the print console of the facility. In order to cool the fabrics to the proper temperature, ice was applied directly to the samples. As a result, the colour changed very quickly and many times. In order to reduce the margin of error on the test, ice was applied to the fabric until the last possible moment before readings were taken. Another problem that was experienced during this test was the range in fabric absorptivities. It was difficult to apply more ink layers, as the previous layer was still wet. Allowing for ample drying time between the applications of ink layers helped, and also ensured that the ink would not smudge.

RECOMMENDATIONS

PRINTABILITY

A solution to avoid slow drying screen ink is ultraviolet drying systems (Eldred & Scarlett, 1995). Since this would cure the ink, it would protect it from being rubbed off and be not sticky. However, it is important not to over-cure the ink or it would affect the colours in the warm state (CTI Inks, 2010). It is recommended that when looking for consistent thermochromic ink, ensure that the first layer of ink is dry or use a thicker ink film. This way the decrease in inconsistency for ink film thickness could lead to fewer colour differences in different areas of the print.

The greatest benefit of colour intensity is at two layers of ink, which could reduce cost and usage of ink. This could also reduce the amount of ink that would get clogged in the screen. By decreasing the amount of ink, the fabric would have a lower chance of becoming saturated with ink and would increase the drying time and productivity. Alternatively, if the fabric had a higher absorptivity, it could reduce the chance of being saturated. According to Eldred and Scarlett (1995), ink drying too slowly could be a cause of ink that is too thick, which would require a change of screen fabric or reducing ink viscosity.

Consistency in the ink film thickness, and therefore the ink colour and colour change is essential for promotional items that bear the corporate colours of a business. If the ink film thickness is not correct then the corporate colour will be incorrect which will reduce recognition of the brand.

END-USE

The end-use applications for this test mostly concern the identification of colour at a certain range. Since this type of ink reacts with temperature, this can easily be applied to products that can use this technology to monitoring body temperature. This could provide a visual gauge for maintaining temperature at a certain level. In a case where a severe colour change is needed, it is recommended that a light coloured fabric with the thickest ink film possible is used. The light coloured fabric allows for the ink to be more visible and the thick ink film increases colour intensity, which makes the ink more vibrant. If the temperature change needs to be more apparent, providing intermediate colours to account for temperatures in between the two extremes could be a solution.

Since a clear indication of colour is an important factor, it is advised that multiple layers of ink are used, especially on darker fabrics where they will not show up as well. When looking for the greatest colour change in thermochromic inks, it is suggested that the printer use a light coloured fabric and use multiple layers of ink. Specifically, it is recommended that white linen is used, which results in the greatest colour intensity because of the multiple layers of ink. However, if the printer wishes to use a darker coloured fabric with thermochromic inks, cotton should be used because it provided the greatest colour intensity as well as greatest colour change as the ink film increased. The printer is advised to refrain from using polyester as a fabric when wishing to use darker thermochromic inks as the results indicated that the change in the colour of the ink from warm to cold temperatures would not be noticeable by the naked human eye. When working with dark fabrics, the printer should ensure that the ink has very high colour strength, is very opaque and is a lighter colour so that it will show on the dark fabric. It is also recommended that they choose a fabric that is less absorptive so that the ink holdout is increased to ensure that the ink will sit on the top of the substrate and appear the most vibrant (Wilson, 2007). It is essential for the printer to test all of the substrates for its ink absorbency and hold out to determine the proper ink film thickness required to attain a certain colour for the design. If the printer wishes to use an absorptive, dark substrate, they should use a thick ink film with high colour strength and opacity in order to ensure the greatest colour change in the thermochromic ink. It is also suggested that they use a thermochromic ink that changes colour at higher (preferably body or room temperature) as it was seen that the inks on the dark fabrics had more colour intensity at room temperature. For lighter fabrics, they should use thermochromic inks that are suited for colour change at colder temperatures (-5°C to 10°C) as the inks on the white fabrics showed more colour intensity at below freezing temperatures.

Thermochromic inks have been used as a fashion trend. However, thermochromic inks could also be used to serve as a visual aid for medical patients who need to be kept at certain temperatures. Also, it could be used for infants who are unable to communicate whether or not their temperature level is uncomfortable or even lethal. It could also be applied to outdoor apparel to possibly warn wearers when their body temperature has dropped to unsafe levels on the inside of their clothing. It could also be used in workout clothing to tell wearers if they are not pushing themselves enough by their cooler temperature, proper pace or are working out too hard by the hotter temperature. Additionally, it could be applied to textiles used to create tea cozies to indicate if the tea is too hot or if it has cooled to a certain temperature.

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FLEXOGRAPHIC DOT GAIN: PLATE COMPRESSIBILITY AND MOUNTING TAPE THICKNESS

ABSTRACT

The main property being tested for our special project is the dot gain achieved on flexographic presses. The special project will test the correlation between plate hardness and mounting tape thickness and to see how it affects dot gain during a flexographic press run. Dot gain can be controlled and altered during many steps of the process, whether in press or the viscosity of ink, there are many influencing factors in dot gain. It is believed plate hardness and mounting tape thickness work parallel with each other, therefore it was decided to test the correlation between the two and try to keep all other factors such as ink and impression at a constant to keep the results as consistent as possible. The purpose of our test is to find out how much of an impact plate hardness and mounting tape thickness have on dot gain and what the best ratio of hardness and compressibility is to achieve the least dot gain.

SUMMARY

This report covers the dot gain experienced while printing on the Comco Cadet 700 using two plates with two different hardness readings, one set at 51A and the other at 57.5A. It is important to note that it was decided to use three different Sticky Back densities for this test, as it was believed this might make a difference in dot gain from one plate to the other. This information is covered in further detail in the results section.

It is vital for the flexographic industry to better process and increase its image quality output capabilities in order to become the most dominant printing process for the packaging industry. Companies worldwide are realizing the true potential of well-executed marketing campaigns that include interesting and intricate packaging, thus flexography must be able to meet customer demands. At its current stage, flexography lacks the high image quality necessary to print some of the packages that make-up companies or designer clothing companies require of them simply because the process is not up to par to offset. By solving issues such as dot gain, a large player in high image quality especially for packaging, flexography's dominance can be further increased in the packaging sector of the print industry.

INTRODUCTION

In the printing industry, when one thinks of flexography one thinks of packaging right away. While flexography is the dominant printing process for packaging, it often lacks the high quality image reproduction capabilities used by companies that are mostly concerned with the image quality of their package. Companies such as make-up distributors, designer clothing wear, and up-scale food distributors are often very concerned with the accuracy of colours and registration, and demand that the package be printed perfectly because they are willing to pay for the quality. These companies understand the importance of an appealing package and how much of an impact it plays on consumers, meaning the printing process must match their high expectations. There are an increasing number of companies who are appealing to consumers with their innovative packaging designs, and flexography must look to capture this growing market before another printing process does.

By focusing on the correlation between plate thicknesses and mounting tape thickness and its effects on dot gain, the goal was to lower the amount of dot gain achieved in flexographic printing through our research. Research included both hands-on press runs and secondary sources. By combining our expertise in flexography and our innovative thinking we hoped to provide a solution on how to lower dot gain even more. This in turn will mean increased image quality for flexography and its furthering as the go-to process for all packaging print applications in the future.

DEFINITIONS AND EQUATIONS

COMPRESSIBILITY: The term compressibility refers to the extent to which a press blanket will reduce in thickness under the pressures generated during printing (Print Wiki, 2011).

DUROMETER: A device (also called a type-A durometer) used to measure the hardness of the surface of an offset printing ink roller, offset blanket, or gravure impression roller, and the term for the roller or blanket's hardness itself. Durometer is measured on a scale of 0 to 100, where 0 is an extremely flexible surface, and 100 is an extremely inflexible surface, such as cast iron. A roller's surface (i.e., the compound—such as rubber—that comprises its surface) must maintain a certain degree of flexibility and resilience in order to affect proper ink transfer (Print Wiki, 2011).

DOT GAIN: Dot gain refers to a characteristic of halftone printing whereby reflectance of the printed material is less than would be expected from the percentage area coverage of the dots set on film by the imagesetter, or the percentage area coverage expected from a digital code value in the digital representation of the image.

The major component of dot gain is optical dot gain, by which light scatters in the printing substrate. Dot gain may also be contributed by dot spreading, press gain, slurring, or doubling. Dot gain is dependent upon many factors associated with the ink, the press, and the substrate being printed (Print Wiki, 2011).

PRINTING PRESSURE: Any force or pressure required to transfer an inked impression from the image carrier to the substrate. Printing pressure is determined by the amount of pressure that exists between either the plate cylinder and the impression cylinder (in flexography) (Print Wiki, 2011).

STICKY BACK (MOUNTING TAPE): A double-sided adhesive used on some presses to mount flexographic plates on the plate cylinder. Other types of presses use clamps, magnetic plate backing, and other mounting devices (Print Wiki, 2011).

STOCK (SUBSTRATE): Term for any surface to be printed to which ink will adhere. The stock, also called substrate, is typically paper, but can also be plastics, foil, metal, cloth, or any other surface to which printing ink will be applied (Print Wiki, 2011).

$$\text{Total dot area} = 100 \times \frac{1-10^{-\text{tint}}}{1-10^{-\text{solid}}}$$ (Breede, 2006)

Tint = the colour density measured with a densitometer at the 25%, 50%, 75% patch
Solid = the colour density measured with a densitometer at the 100% patch

TESTING PRINCIPLE

This test was a great way of determining which type of plate is better with which Sticky Back density, as two different materials were tested with different and yet extremely similar hardness. By adding the dimension of the Sticky Back density, all the controllable variables in the flexographic process were taken into consideration. It should be noted that due to the nature of the equipment available to us, it was not possible to control a major variable in this experiment: printing pressure. This was due to the fact that the Comco Cadet does not have an automatic printing pressure adjustment, or any way of it showing the current pressure used. We hoped that our experience in running this kind of flexographic press would allow us to run a constant printing pressure throughout the entire press run.

We would like to have used a more modern press, with which we could closely measure all of the variables included in this test. However, this was not possible at the time due to the equipment available to us at the school and the current economic conditions, which did not allow for expensive press time in industry. In the future we hope we will be able to redo this test on a better press in order to properly investigate our theories.

MATERIALS TESTED

- Lohman 0.015", 0.017", 0.021" Sticky Back
- Dupont thermal-developed plates
- Water-washed plates
- Self-adhesive label stock

EQUIPMENT USED

- Ihara Electronic INDCO LTD, Model R densitometer, Serial no. : 074836
- Rex Model 1700 Durometer, Type A scale
- Comco Cadet 700 Flexographic Press
- #2 Zahn Cup
- 66T Plate Cylinder
- 600 LPI Anilox rolls

PROCEDURE

1. Plates were obtained or created that included 25%, 50% and 100% ink patches.
2. Plates with different hardness were used.
3. Aqua Verse Dense Black ink was obtained from SunChemical.
4. The flexographic press was set up:
    a. The ink pan, ink roller, and doctor blade were mounted.
    b. The plates were mounted onto plate rollers using the 0.015" Sticky Back.
    c. The ink viscosity was checked using a #2 Zahn cup;.
    d. Viscosity was adjusted as needed.

   e. Ink was poured into ink pan.
   f. The plate roller was mounted onto the press.
5. Impression and proper colour were obtained.
6. Up to 100 were run and monitored for any changes in colour.
7. The plate cylinder was taken out.
8. The plate was dismounted and given a quick rinse.
9. The plate was remounted using the 0.017" Sticky Back.
10. Steps 5 through 9 were repeated, remounting the plate using the 0.021" Sticky Back.

RESULTS AND DISCUSSION

Note: The results are colour coded so that anything with a green background refers to the 0.015" Sticky Back, anything with a yellow background refers to the 0.017" Sticky Back, while the red background refers to the 0.021" Sticky Back.

The results are divided into two parts: raw results referring to the colour density measured with the (model) densitometer, and the calculated dot gain results, which were calculated using the Murray/Davies Total Dot Area Equation (Breede, 2006). This formula was chosen as opposed to the Yule/Nielson Physical Dot Area Equation because the n factor information for the two types of plates used was not obtained/available in this test.

0.015" Sticky Back	**Thermal Developed Plate Compressibility = 51 (mm)**			**Water Washed Plate Compressibility = 57.5 (mm)**		
% Patch Tested	25	50	100	25	50	100
Start of Press Run	0.39	0.51	0.94	0.39	0.49	0.93
Middle of Press Run	0.37	0.58	1.3	0.51	0.67	1.32
End of Press Run	0.32	0.47	1.05	0.41	0.53	1.01
Average	0.36	0.52	1.10	0.44	0.56	1.09

TABLE 1: Measurements taken at the 25%, 50%, 100% patch on both plates using the 0.015" Sticky Back

The first part that will be analysed is the colour density. Colour density was measured using an Ihara model R densitometer over three different points in all three different press runs. We ran measurements at the beginning of the run, the middle, and towards the end of the run.

Table 1 shows the measurements taken of both plates when using the 0.015" Sticky Back. These measurements were then averaged to obtain an average measurement that was used for the main dot gain calculations.

Most notably in this table are the variations between the different stages in which the measurements were taken. The water-washed plate colour density in the middle of the run seems much higher than the density of the thermal-developed plate. This is disturbing as the densities measured at the 100% patch are extremely close to each other.

0.017" Sticky Back	**Thermal Developed Plate Compressibility = 51 (mm)**			**Water Washed Plate Compressibility = 57.5 (mm)**		
% Patch Tested	25	50	100	25	50	100
Start of Press Run	0.24	0.34	0.98	0.37	0.49	0.95
Middle of Press Run	0.63	0.78	1.04	0.55	0.69	1.02
End of Press Run	0.53	0.73	1.16	0.55	0.72	1.16
Average	0.47	0.62	1.06	0.49	0.63	1.04

TABLE 2: Measurements taken at the 25%, 50%, 100% patch on both plates using the 0.017" Sticky Back

Table 2 shows the measurements taken of both plates when using the 0.017" Sticky Back. These measurements were then averaged to obtain an average measurement that was used for the main dot gain calculations.

The most noticeable facts about these measurements are the extremely low densities measured in the 25% patch at the start of the press run. These considerably lowered the average for the 25% patches and thus possibly skewed the end results.

0.021" Sticky Back	Thermal Developed Plate Compressibility = 51 (mm)			Water Washed Plate Compressibility = 57.5 (mm)		
% Patch Tested	25	50	100	25	50	100
Start of Press Run	0.34	0.57	0.99	0.41	0.5	0.95
Middle of Press Run	0.37	0.56	1.1	0.45	0.57	1.07
End of Press Run	0.35	0.53	0.99	0.4	0.48	0.94
Average	0.35	0.55	1.03	0.42	0.52	0.99

TABLE 3: Measurements taken at the 25%, 50%, 100% patch on both plates using the 0.021" Sticky Back

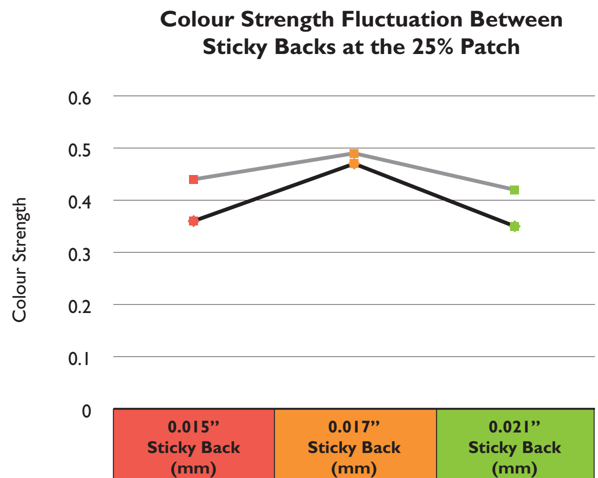
Table 3 shows the measurements taken of both plates when using the 0.021" Sticky Back. These measurements were then averaged to obtain an average measurement that will be used for the main dot gain calculations.

Unlike the previous two measurements, the measurements using the 0.021" Sticky Back were consistent throughout the press run, except for a spike in the 100% patch in the middle of the run. However, it is necessary to deduce if this is due to the difference in the Sticky Back, or if it was due to other factors that could occur during a press run.

0.015" Sticky Back	Thermal Developed Plate Compressibility = 51 (mm)			Water Washed Plate Compressibility = 57.5 (mm)		
% Patch Tested	25	50	100	25	50	100
0.021" Sticky Back	0.39	0.51	0.94	0.39	0.49	0.93
0.017" Sticky Back	0.32	0.47	1.05	0.41	0.53	1.01
0.015" Sticky Back	0.37	0.58	1.3	0.51	0.67	1.32

TABLE 4: Average of the colour density tests measured at the 25%, 50%, and 100% patches

Table 4 summarizes the average measurements from the previous three tables, and allows an analysis of how the different Sticky Backs measure up against each other. With a quick look at this table it can be seen that the colour density of both plates, when using the 0.017" Sticky Back, is much higher compared to the other two Sticky Backs, with the exception of the 100% patch measurement. The differences seen in this table are illustrated in the graphs below.

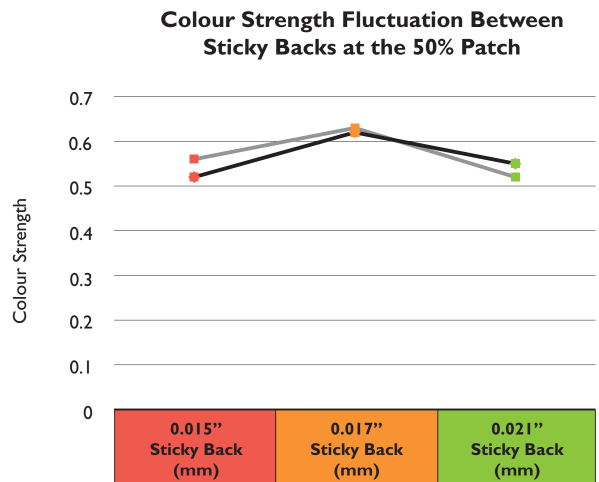


	0.015" Sticky Back (mm)	0.017" Sticky Back (mm)	0.021" Sticky Back (mm)
Water	0.36	0.47	0.35
Thermal	0.44	0.49	0.42

FIGURE 1: Colour strength fluctuation between Sticky Backs at the 25% patch

Figure 1 illustrates the differences between the measurements at the 25% patch of each plate. The trend noticed in this graph will significantly affect our final dot gain results, if the trend does not match with the 100% patch trend.

As seen above, the average colour density at the 25% patch is stronger when using the 0.017" Sticky Back. The colour density difference between the other two Sticky Back densities is negligible, as it is only a 0.01- 0.02 difference. The colour density is extremely close between the two plates, when using the 0.017" Sticky Back, however when the other two Sticky Backs were used, there were noticeable colour density differences between the two plates. This could deeply affect the dot gain calculations as the calculations are based on the colour density.

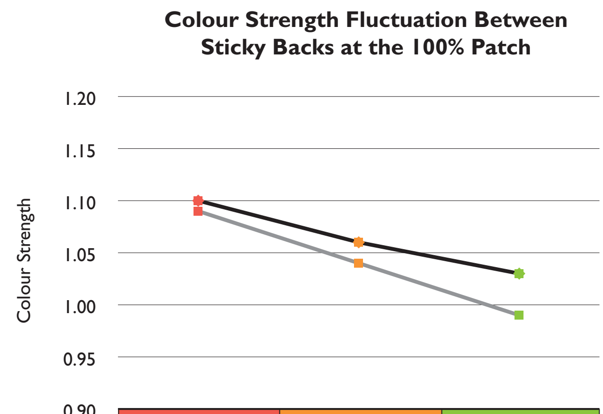


	0.015" Sticky Back (mm)	0.017" Sticky Back (mm)	0.021" Sticky Back (mm)
Water	0.52	0.62	0.55
Thermal	0.56	0.63	0.52

FIGURE 2: Colour strength fluctuation between Sticky Backs at the 50% patch

Figure 2 illustrates the differences between the measurements at the 50% patch of each plate. The trend noticed in this graph will significantly affect the final dot gain results, if the trend does not correlate with the 100% patch trend.

Compared to the 25% patch graph, the trend at the 50% patch seems to be a smaller colour density between the two plates at either Sticky Back density. It is, however, important to note that the trend of the higher density at the 0.017" Sticky Back continues in this graph as well. It will be important that this trend continues in the 100% patch measurement.



	0.015" Sticky Back (mm)	0.017" Sticky Back (mm)	0.021" Sticky Back (mm)
Water	1.1	1.06	1.03
Thermal	1.09	1.04	0.99

FIGURE 3: Colour strength fluctuation between Sticky Backs at the 100% patch

Figure 3 illustrates the trend at the 100% patch. The trend noticed in this graph greatly affects the end result of our test as it does not match with the other two graphs.

Contrary to the past trends at the 25% and 50% patches, the 100% patch has a constant drop in colour density from the 0.015" Sticky Back all the way to the 0.021" Sticky Back. This greatly affected the measurements as the highest density measurement in the other graphs was the measurement at the 0.017" Sticky Back. We used the Murray/Davies Total Dot Area Equation to calculate all the dot gain based on the colour densities presented above.

Thermal-Developed Plate Compressibility = 51 (mm)			
Tint 25%	Solid	Dot Area	Dot Gain
0.39	0.94	66.95	41.95
0.37	1.3	60.37	35.37
0.32	1.05	57.24	32.24
0.36	1.10	61.25	36.25
0.24	0.98	47.42	22.42
0.63	1.04	84.24	59.24
0.53	1.16	75.73	50.73
0.47	1.06	72.14	47.14
0.34	0.99	60.48	35.48
0.37	1.1	62.29	37.29
0.35	0.99	61.64	36.64
0.35	1.03	61.45	36.45

TABLE 5: Dot gain at the 25% patch for the thermal-developed plates

Table 5 illustrates the results obtained for the 25% patch with the thermal-developed plates. The most striking feature in this case is the high difference in dot gain registered between the start and middle measurement at the 0.017” Sticky Back. The dot gain in the middle measurement is double that of the start. The average dot gain was extremely close when using the 0.015” and 0.021” Sticky Back, and extremely high when using the 0.017” Sticky Back.

Thermal-Developed Plate Compressibility = 51 (mm)			
Tint 50%	Solid	Dot Area	Dot Gain
0.51	0.94	78.06	28.06
0.58	1.3	77.59	27.59
0.47	1.05	72.58	22.58
0.52	1.10	75.87	25.87
0.34	0.98	60.64	10.64
0.78	1.04	91.77	41.77
0.73	1.16	87.43	37.43
0.62	1.06	83.06	33.06
0.57	0.99	81.42	31.42
0.56	1.1	78.71	28.71
0.53	0.99	78.52	28.52
0.55	1.03	79.51	29.51

TABLE 6: Dot gain at the 50% patch for the thermal-developed plates

Table 6 illustrates the results obtained for the 50% patch with the thermal-developed plates. The trend noticed in Table 5 with the values at the 0.017" sticky continues in this table as well. It is important to note that the data at the 0.021" Sticky Back has a low variation between the different testing times. Overall, the highest average dot gain is noticed again at the 0.017" Sticky Back, while the lowest is registered by the 0.015" Sticky Back.

Water-Developed Plate Compressibility = 57.5 (mm)			
Tint 25%	Solid	Dot Area	Dot Gain
0.39	0.93	67.15	42.15
0.51	1.32	72.57	47.57
0.41	1.01	67.71	42.71
0.44	1.09	69.07	44.07
0.37	0.95	64.59	39.59
0.55	1.02	79.40	54.40
0.55	1.16	77.15	52.15
0.49	1.04	74.37	49.37
0.41	0.95	68.82	43.82
0.45	1.07	70.52	45.52
0.4	0.94	68.00	43.00
0.42	0.99	69.11	44.11

TABLE 7: Dot gain at the 25% patch for the water washed plates

Table 7 illustrates the results obtained for the 25% patch with the water washed plates. These measurements reflect the past trend at the 0.017" Sticky Back; however the average dot gain is larger than the dot gain registered with the thermal-developed plates. Figure 4 (see page 47) illustrates the results obtained for the 50% patch with the water washed plates.

The trend noticed in the past dot gain tables still holds true for the 0.017" Sticky Back. The results using the 0.021" are not as constant as they were when printed with the thermal plates. Once again the average dot gain is higher than the dot gain obtained with the thermal plates, except when using the 0.021" Sticky Back. This could be due to the lower dot gain measurement at the end of the run, which will have significantly lowered the average of the dot gain using the water washed plate.

The results obtained put the dot area at the 25% patch at approximately 60%, while the area at the 50% patch is between 75-85%. It is believed that these results are extremely accurate as they place the results near the standard for dot area at these patches in flexographic printing. These standards were obtained from real life flexography experience from the professionals at the Flexo-exchange forum (Burgos, 2009).

The main purpose of our test was to note the difference in dot gain between the two plates with different hardness. According to Greg Platt from GMF Flexo, less dot gain should occur on a softer plate, and more dot gain should occur on a harder plate. This test is conclusive then, as the average dot gain registered by the water washed plate, which had a hardness of 57.5A is consistently higher than the average dot gain registered by the thermal-developed plate, which had a hardness of 51A only.

There were no resources found on the correlation between dot gain and Sticky Back density. It is known, however, that every plate cylinder has a certain undercut that means it can be used only with a certain type of Sticky Back in order to keep the right repeat length. If a Sticky Back that was thicker than the standard Sticky Back were to be used, then the repeat length of the image would be longer, due to the overall diameter of the plate being larger. This would affect the registration of the image with the die cutter, which would affect end user quality. It is unknown what happens to dot gain when the wrong Sticky Back is used. The thicker the Sticky Back, the more room the plate has to compress, and thus not needing to be forced onto the substrate. This is the same idea behind softer plates having a smaller dot gain than harder plates. It is for this purpose that this test compared the dot gain obtained from the thermal plate while using the 0.015" Sticky Back and compared it with the dot gain obtained from the water washed plate while using the 0.021" Sticky Back. When the averages between the two at the 25% patch are compared, the thermal plate yields significantly better results, however the thermal plate dot gain is similar when using the 0.015" and 0.021" sticky with only a 0.20 difference in dot gain, with the dot gain obtained from the sample using the 0.021" Sticky Back being higher. This disproves our initial theory that dot gain could be affected by Sticky Back for any other reasons but the total thickness of the plate.

Unfortunately for us, the Comco Cadet 700 is not a computerized press. This means that it was not possible to monitor and sustain a constant print pressure between the three press runs, as it was necessary to release impression in order to replace the plates. We believe that since impression is just a matter of touch, the test results could be skewed. In the future it would be ideal to have access to a press where the impression can be monitored when performing this test again.

RECOMMENDATIONS

PRINTABILITY

The flexographic process is often looked at like the work horse of the different printing processes; it achieves very high speeds but at some of the lowest quality often on substrate such as corrugated board which goes to further worsen the quality of the final image. The only reason these perceptions about flexography have been built is because they are true. Flexography does produce lower quality images than offset but that is quickly changing as more research gets done about the flexographic process and which factors are influencing print quality. Once more R&D has been invested in flexography it will be competing with other printing processes in the areas that hold it back such as image quality, thus opening more doors for the capabilities of flexography in the printing industry.

Dot gain highly influences the ability to reproduce accurate, high-quality printed images through the spreading of dots around the image area. The two factors discussed in this research paper, mounting tape thickness and plate hardness, are highly influential on the amount of dot gain achieved on press because they deal with the amount of compressibility achieved for printing the image on the substrate. While a lot of the dot gain issues experienced on press can be reduced in prepress (Millward, 2010), the nature of the flexographic printing process and its use of a rubber photopolymer plate leave it exposed to high dot-gain, especially when printing on substrates such as corrugated that has low ink holdout (Belanger, 2007).

It is vital to note the importance of a foam layer in the construction of flexographic mounting tapes due to its ability to compensate for thickness variations in both the plate and substrate. The foam allows for better control of impression force, all while absorbing vibration allowing for faster press speeds and delivering a high quality printed product. (Kilhenny, 2008). Without the use of foam in mounting tape, achieving acceptable print quality would be next to impossible due to the low levels of compressibility when using only photopolymer plates VS photopolymer plates with mounting tape that has foam, as exhibited in Figure 4 (Kilhenny, 2008).

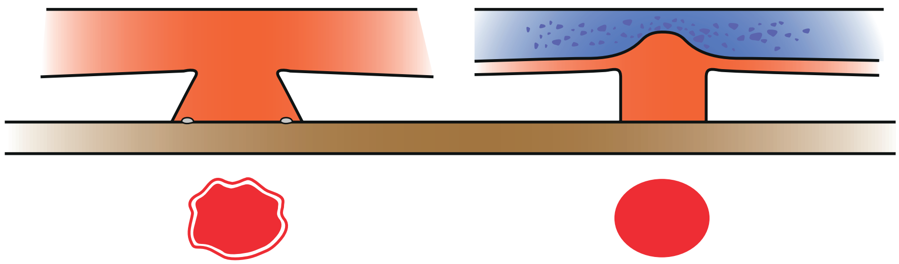
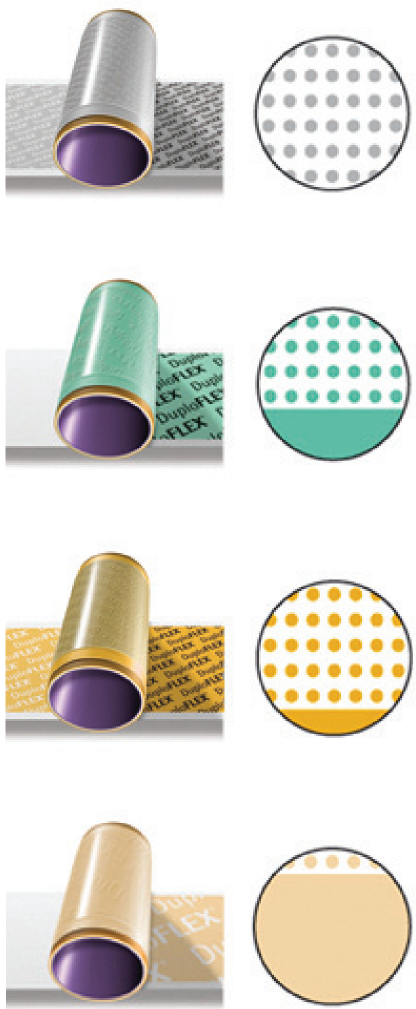


FIGURE 4: Plate only vs. Plate with cushion in Sticky Back

The decision of which mounting tape to use ultimately comes down to the type of job being printed. Much like the trend of customization and tailoring projects for our clients is taking over in the print industry (Kular, 2011), the flexographic process has different mounting tapes that are more suited for a specific type of job. The varying foam hardness in these different mounting tapes is what makes one better for process work while another excels at solids. This again comes back to compressibility and how it affects a process that uses a rubber photopolymer plate, the main focus of this research paper. An example of 4 different types of mounting tapes offered by Lohman Tapes shows that they offer unique mounting tape for specific applications (Figure 5, see page 48).



fine process work, highlights, very fine lines (minimized dot gain)

process work, brilliant half-tones, fine lines

half-tone and lines, combination of solid, line work and screen

solids, lines and large fonts (dense ink coverage)

FIGURE 5: Lohman's options of different tapes for specific types of jobs (Lohmann Tapes, n.d.)

RUNABILITY

The plate thickness and mounting tape thickness have a significant impact on the performance of the press run. While dot gain is in direct correlation with plate and mounting tape thickness, it affects printability and end-use applications more, however these two factors also impact runability when examined more closely.

The first defect that will likely be noticed when using improper mounting tape or plate thickness is that the repeat length of the image will be incorrect (FPI, 2009). This is why it is vital to use the standards chart provided by the FTA that list what the plate and mounting tape thickness should add up to for your desired repeat length. While this research focused on the ratio of thicknesses achieves the best quality, the specifications regarding total thickness to ensure proper repeat length were still followed.

Another defect quickly noticed, if the plate is too soft and mounting tape too hard and vice-versa, will be the missing of small fonts and small images or lack of impression for them (FPI, 2009). Due to the nature of rubber photopolymer plates and their need to touch the substrate, the plates compress onto the substrate to make their impression. This means that if the mounting tape and plate thickness combo is too soft it will impress too much, filling the image or copy area with ink, or if too hard it will not impress onto the substrate enough, thus leaving a poorly impressed image or copy area.

Lastly, while this defect is not fully concerned with the correlation between plate thickness and mounting tape thickness, it is vital to mention because of its high impact on the endurance levels of the flexographic process. Edge lifting is a common problem in flexography and has some very easy and simple remedies that should be used to lower the chance of a problem on press especially during a long pressrun where downtime is costly. Some suggested remedies include: plate edge sealing using an adhesive, plate edge sealing using single coated industrial tape, and using an adhesion promoter for rubber plates (3M, 1999).

END-USE

The ultimate impact of dot gain is most profound in the end-use applications of the printed products. Whether they are narrow web label stock or corrugated stock products, dot gain has its biggest impact at the final stage. While the flexographic process is very well suited for printing single colours at a very fast rate on a multitude of different substrates, it is only able to do this because the dot gain achieved is virtually unimportant and the image usually is only there for labelling/branding purposes; an example can be seen in Appendix entry 2.3 (GAM, 2010). The area left for improvement is solidifying flexography as a means to reproduce high-quality images on the large array of substrates it can already print on. By increasing quality, flexography will gain the edge over other printing processes in terms of being the go-to printing process for multi-color, accurate, and high-quality packaging needs.

Appendix entry 2.1 shows a high-quality printed package that was not printed using flexography because this level of image reproduction quality would not be possible. Inspection with a loupe reveals that registration is near perfect and dot gain is very low. This package utilized 4 colours and showed no visible signs of being printed poorly. When compared to Appendix entry 2.2, we can see that this image exhibits a lower quality package that when inspected is not concerned with perfect registration or dot gain. The package only utilizes two colors, the company's brand colours, and aims to get acceptable registration only as we can see. The branding of the box is the main concern for this company, thus perfect registration is not needed, just the logo to maintain a consistent look for branding reasons. It is important to keep in mind the job that these companies wanted their packages to perform. The Muesli Company wanted to promote a high-class sophisticated health cereal and thus use a very graphically appealing and attention-grabbing box. Canada West, on the other hand, wanted to promote their low price, high-quality boots by giving the impression that they care about the boots and giving you a lower price rather than a fancy box. It is vital for printers to understand the wants and needs of their customers when selecting printing processes for them to use, as both have their time and place.

This comparison opens up the floor for the area of opportunity for flexography. By removing this need for printers to use different processes for certain jobs, flexography can single handedly dominate the packaging sector of the print industry by resolving some of its quality issues. As the packaging sector of the print industry shows the most promise as far as survivability and not being driven out by digital technology, it is vital for flexography's quality to increase and secure its name as the best printing processes for all packaging.

Companies are constantly creating more elaborate and more colourful packages for their products in order to set themselves apart from competitors. Flexographic printers must keep up with their client needs in order to keep getting repeat business and not make their clients look to other printing processes. By staying on top of the corrugated and narrow/

wide web label market while increasing quality in reproducing accurate, high-quality four-color images, the flexographic printing process could be the one and only printing process for packaging in the future.

SPECIAL RECOGNITION

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VEGETABLE INKS AND PACKAGING: MORE HARM THAN GOOD?

ABSTRACT

The purpose of this research project was to analyze and make a qualitative comparison between three different types of vegetable-based inks: a waterless soy ink (Taniguchi), a vegetable process ink (Sun Chemical), and a high-strength low VOC ink (Flint). These inks were evaluated on the basis of ink setting and rub resistance to determine a level of safety based on the outcomes. Related properties, which were not part of the test but could be tested to evaluate the safety of a low migration food grade ink, are its level of migration and how organoleptically neutral the ink is on the senses.

SUMMARY

The focus of our instrumentation test was based on a fictional scenario of a local restaurant's desire to "green" their consumer packaging. This restaurant, referred to as Mercatto's, wanted to add a logo made purely from vegetable-oil-based inks, which would declare that they are an environmentally-friendly company. This logo would appear on two of their packaging substrates: a wax paper used to wrap various food items, and a cast-coated box substrate used to hold items such as desserts. The management at Mercatto's contacted the students of Ryerson University to determine whether or not this move would be safe for their customers and a viable solution for the company.

In order to make a well-informed recommendation for the company, we conducted two instrumentation tests to evaluate the rub resistance and ink setting of three different inks against these two substrates. The three inks tested were all vegetable based; the first was a waterless black from Taniguchi Ink, the second was a magenta ink from the Sun Chemical Ecolith line, and the third was a low VOC high strength vegetable oil- based ink from Flint.

At the end of our instrumentation testing we concluded that the Sun Chemical ink was the best in terms of rub resistance and set-off. Although a cost-effective solution for the company, further research determined that using vegetable-based ink would pose a health risk for consumers because the ink was not organoleptically neutral to the senses and, moreover, was prone to migration. In order for the product to meet its ultimate end use goal of consumer safety the restaurant would have to use a low migration food grade ink, such as the Corona MGA series from the Huber Group.

We wanted to further explore why vegetable inks are harmful for food packaging and determine if there are any viable solutions to printing with vegetable-based inks in the food industry. We found that there were no realistic approaches to incorporate vegetable based ink in food packaging due to government regulations, health and safety concerns and the overall chemistry of the ink.

INTRODUCTION

As consumers become more environmentally aware, they are starting to demand the same of the companies they buy from, urging them to implement green initiatives into their daily practices. Established businesses such as Hewlett Packard, IBM and Sony have responded to their customers growing concerns for environmental responsibility by "Going Green"—a term in the business world that can range from using more post consumer recyclable materials in your packaging to reducing your annual carbon emissions to protect the ozone layer (Newsweek, 2010).

For the purpose of this test, we will be using the central theme of a restaurant and their desire to "Go Green" as the basis of our research and format our findings and conclusions as a recommendation to their upper management.

The restaurant's initial findings showed that using vegetable inks posed a risk if they came into direct contact with food and served as the primary package, such as a burger wrap (Waxman, 2006). This was due to the presence of trace amounts of petroleum oils within the ink. Although they are vegetable oil-based inks, petroleum oils are added to accelerate the drying time of the ink. Moreover, petroleum oils contain Volatile Organic Compounds (VOCs), which can emit hazardous air pollutants into the air and would taint a customer's meal. A vegetable ink with minimal or no petroleum oil would be needed to achieve the end-use goal.

To assess the validity of the restaurant's initial findings and either refute or accept its legitimacy, two tests (Rub Resistance and Ink Setting) will be performed. The objectives of these tests are further defined in the Testing Principles section of this report. The largest educational gain from this instrumentation was deciphering the properties of different brands of vegetable inks. From this we learned more about alternative inks for packaging, and by doing external research we were able to come to a conclusion on which ink was the most beneficial.

DEFINITIONS

VEGETABLE INKS: Contain vegetable oils as a replacement for some or all of the petroleum oil (Massachusetts Toxics Use Reduction Institute, 1994).

LOW MIGRATING INKS: An ink that sets through absorption. Low migration inks are engineered to be organoleptically neutral, meaning they will not negatively impact the senses such as taste and scent (Huber Group, 2008a).

LOW MIGRATING UV INKS: A low migration UV ink is one that does not contain solvent and cures through polymerization (Huber Group, 2008b).

OVERALL MIGRATION LIMIT: A measurement of the inertness of the material and prevents an unacceptable change in the composition of the foodstuffs, and, moreover, reduces the need for a large number of specific migration limits or other restrictions, thus giving effective control (The Commission of the European Communities, 2002).

TESTING PRINCIPLE

For this research paper, we tested the printed inks on the principle of how they resist abrasion, which simulates moving of the product inside its packaging and whether this affects the printed image. Another reason for testing rub resistance was to see how the ink reacted once it came into contact with food or other surrounding packaging substrates. The objectives of the two tests we performed were to find out how rub resistant different brands of vegetable inks were on two different substrates. We also determined the setting time of these inks and evaluated their corresponding amounts of ink pick up based on how much set-off was produced. Alternative tests could be performed on specialty food grade inks to determine its effectiveness in achieving its end-use goal. These tests, which test the organoleptic properties, migration, and migration modeling, are explored in more detail in the recommendations portion of this report.

We originally hypothesized that the results from our study would show us that vegetable inks were superior to the pure vegetable inks in terms of ink hold out, rub resistance and drying time, because the added petroleum oils in these vegetable inks would accelerate the drying process. However, as the basis of our instrumentation changed, we had to create a secondary hypothesis based on which of our three vegetable oil based inks were superior in terms of ink setting and rub resistance. We hypothesized that the Arrowstar low VOC ink from Flint was the best ink out of our tested materials. The logic behind our hypothesis was influenced by its price in addition to claims made by the company on the ink's performance in a technical document.

MATERIALS TESTED

INKS:

- Taniguchi Ink Co. Ltd - Enviro-Soy Waterless Series Printing Ink – Black
- Sun Chemical - Offset Ecolith Vegetable Process Magenta P6815 (90805631)
- Flint - Arrowstar High Strength 4001 Vegetable Oil Based Offset Ink – Magenta

SUBSTRATES:

- Lumiart Gloss Book 17.5 x 23 - 59M - 70lbs - 104g/m2
- Cast-coated Recycled Card Stock
- Wax Paper

EQUIPMENT USED

- Prüfbau Dr.-Ing. H. Dürner 82380 Peißenberg/ München Sutherland Ink Rub Tester us. Pat. 2,734,375 Canadian pat. 532 864
- Brown Company - Kalanazoo, Michigan serial no. 1714 Ihara R710 Color Reflection Densitometer - R Series serial no. 074836

PROCEDURE

SET-OFF TEST

1. Card stock and wax paper were cut into individual one-inch strips (four of each).
2. A strip of card stock was attached to the plastic carrier with tape and positioned for print.
3. 100 mm^3 of the Sun Chemical magenta ink sample was measured using the pipette.

4. The ink was transferred onto the rubber roller of the Prufbau Test Printer. Rollers were run for a minimum of 30 seconds to allow the ink to evenly distribute.
5. The blanket cylinder was lowered onto the rubber roller and left for at least 30 seconds for the ink to fully transfer.
6. The blanket cylinder was moved into the first print position and the impression cylinder onto the second print position.
7. The Prufbau was run and the test strip passed through the first impression where ink was applied.
8. Immediately after, the Lumiart Gloss Book strip was positioned to overlap the substrate and move it under the impression cylinder.
9. Using the handle located at the right of the machine, the test strip was inched past the impression cylinder; and moved once after a 30 second interval, a 60 second interval, a 120 second interval, and a 240 second interval.
10. The test strip was removed from the carrier and set aside to dry.
11. Step 2 was repeated using the wax paper instead, mounted in front of a Lumiart Gloss Book strip.
12. Step 3 to 10 were repeated using 50 mm^3 instead.
13. Steps 2 to 12 were repeated to obtain two set-off test strips of the card stock and two for the wax paper. The rollers were cleaned and allowed adequate time to dry.
14. Steps 2 to 12 were repeated using the black Taniguchi ink sample.
15. Steps 2 to 12 were repeated using the magenta Flint Arrowstar ink sample.

From this procedure, the following was obtained for analysis:

Card stock
- 2 set-off test strips printed with the magenta Sun Chemical Ink
- 1 set-off test strip printed with the black Taniguchi Ink
- 1 set-off test strip printed with the magenta Flint Arrowstar Ink

Wax paper
- 2 set-off test strips printed with the magenta Sun Chemical Ink
- 1 set-off test strip printed with the black Taniguchi Ink
- 1 set-off test strip printed with the magenta Flint Arrowstar Ink

RUB RESISTANCE TEST PART A

1. The card stock and wax paper were cut into individual one-inch strips (six of each).
2. A strip of card stock was attached to the plastic carrier with tape and positioned ready for print.
3. 1 micron of the magenta Sun Chemical ink sample was measured out in the pipette.
4. The ink was transferred onto the rubber roller of the Prufbau Test Printer and the rollers were run for a minimum of 30 seconds to allow the ink to evenly distribute.
5. The blanket cylinder was lowered onto the rubber roller and left for at least 30 seconds for the ink to fully transfer.
6. The blanket cylinder was moved into the first print position and the Prufbau was run to pass the test strip through the first impression and ink was applied.
7. The test strip was removed from the carrier and set aside to dry.
8. Step 2 was repeated using the wax paper instead, with a strip of Lumiart Gloss Book mounted behind it.
9. Step 3 was repeated using 50 mm^3 instead.
10. Steps 4 to 8 were repeated.
11. Steps 2 to 11 were repeated to obtain two printed test strips of the card stock and two for the wax paper. The rollers were cleaned and allowed adequate time to dry.
12. Steps 2 to 12 were repeated using the black Taniguchi Waterless ink sample.
13. Steps 2 to 12 were repeated using the magenta Flint Arrowstar ink sample.

From this procedure, the following was obtained for analysis:

Card stock

- 2 printed test strips printed with the magenta Sun Chemical Ink
- 2 printed test strip printed with the black Taniguchi Ink
- 2 printed test strip printed with the magenta Flint Arrowstar Ink

Wax paper

- 2 printed test strips printed with the magenta Sun Chemical Ink
- 2 printed test strip printed with the black Taniguchi Ink
- 2 printed test strip printed with the magenta Flint Arrowstar Ink

Note: A minimum of one day was allowed for all printed test strips to dry before proceeding to Part B.

RUB RESISTANCE TEST PART B

1. The Sun Chemical card stock test strip was laid printed side up on the platform area of the Sutherland Ink Rub Tester.
2. A strip of Lumiart Gloss Book was secured onto the 40lb weight with two pieces of tape.
3. The rub tester was set to 80 rubs and the weight was attached to the machine.
4. The machine was turned on and the weight was allowed to move back and forth across the printed substrate. It was ensured that the strip remained in place for the duration of the test.
5. As the machine reset, both the test strip and the Lumiart strip were removed, labelled, and examined.
6. Steps 1 to 5 were repeated with the Taniguchi cardstock test strip.
7. Steps 1 to 5 were repeated with the Flint cardstock test strip.
8. Steps 1 to 5 were repeated with the Sun Chemical wax paper test strip.
9. Steps 1 to 5 were repeated with the Taniguchi wax paper test strip.
10. Steps 1 to 5 were repeated with the Flint wax paper test strip.
11. The test was repeated with the remaining test strips using the 20lb weight and setting the tester to 60 rubs.

RESULTS & DISCUSSION

RUB RESISTANCE	CARD STOCK	WAX PAPER
TANIGUCHI – 2lb 60 RUBS	• Almost as dark as the 4 lb sample but the rub off remains to the edges	• Barely noticeable • More of a smudge
TANIGUCHI – 4lb 80 RUBS	• A lot of black ink came off • More than the 2lb which is expected • The most out of all the samples	• More noticeable than the magenta sample • Some darker spots but mostly light
SUN CHEMICAL – 2lb 60 RUBS	• Darker than the 4lb 80 rub sample • Darkest magenta sample	• Darker than the 4lb magenta • Mainly on the edges • Darker than the black 2lb 60 rubs
SUN CHEMICAL – 4lb 80 RUBS	• Not as much came off as the black ink • Fairly light, but darker than the wax paper sample	• Barely noticeable • The lightest rub there is out of all the samples
FLINT – 2lb 60 RUBS	• Very light • Lighter than 4lb	• Very dark • The most rub off of all samples
FLINT – 4lb 80 RUBS	• Darker than 2lb • Very consistent • One of the darkest samples	• Lighter than 2lb • Barely noticeable

TABLE 1: Observations for rub resistance test

After completing the rub resistance test, we noticed some inconsistencies and patterns to our results. We tested both of our substrates, card stock and wax paper, with three different inks on two rub settings. Also, the two inks were applied with two different amounts, either at 100 mm^3 or 50 mm^3. The reasoning behind testing the substrates at two different rubbing conditions was for our printability and end-use capabilities. As the substrate was printed on, we needed to consider the amount of rub-off directly after printing, as well as throughout the life of the package as it travelled through different environments. Our qualitative observations are recorded in Table 1, and the results further discussed in this section.

When the three inks were compared, Sun Chemical's Magenta had the best rub resistance overall. When looking at the substrates tested, the weight applied, and the number of rubs for each individual ink, the results varied. Especially when looking at Sun Chemical's Magenta results, we noticed a pattern that we did not predict. The two best samples for this magenta ink were the card stock and wax paper, both rubbed at 4lbs and 80 rubs. On the contrary, the two worst samples were rubbed at 2lbs and only 60 rubs. Even though the same amount of ink was applied to each substrate (50 mm^3 for wax paper and 100 mm^3 for card stock), the samples still showed opposite results to our hypothesis. Our prediction was that the lighter the pressure used and less number of rubs, the better the rub resistance would be.

There are a few factors that may have caused these results. The first reason could have been human error. When putting the specific amount of ink on the roller by using the pipette, the measurements could have been imprecise, causing the ink film thickness to be altered. The ink film thickness may also have been altered if the ink was not distributed evenly on the large rollers, causing it to be inconsistent on the small roller that made the impression on the substrate. If the ink film was thicker it would have caused the ink to rub off because thinner ink films yield better rub resistance (Paine & Paine, 1992).

The second reason could have been due to the different weight used. The 4lb weight had a solid piece of black material that rubbed against the paper, but the 2lb weight had two separate pieces of black material that only rubbed the paper in those two spots. Even though it was only a 2lb weight, it could have rubbed the sample differently, causing the results to vary.

The third reason that the 2lb rubbed samples produced more rub off than the 4lb rubbed samples was the drying time. Vegetable inks generally take longer to set into the paper, thus the drying time was increased (Massachusetts Toxics Use Reduction Institute, 1994). If the

4lb samples were created before the 2lb samples, this extra drying time would have been advantageous to the rub resistance. Though unlikely, the extra time was still considered as a potential reason for the erratic results.

The results differ when what happened with Taniguchi's black waterless ink was examined. Although the black ink had a worse overall rub resistance than the magenta ink, the best rub resistance occurred with the lighter weight and less rubs. This makes sense because fewer pounds were put against the paper, creating less friction. Waterless ink has a higher viscosity, which means it may not have absorbed fully into the substrate, making it more prone to rub off (Kipphan, 2001).

We believed our Flint ink would yield the best results for rub resistance because we were told that it had excellent rub resistance for vegetable ink. Although, looking at our results, we can see that this is not the case. Our results proved to be reversed, again, for the wax paper. The 2lb-60 rubs sample had a very dark rub off, but the 4lb-80 rubs sample had a lighter result. Our samples for the coated card stock had better results. The 4lb-80 rubs sample produced a darker rub off than the 2lb-60 rubs sample. Just like Taniguchi's ink, this is what we predicted, due to the weight and number of rubs applied.

The varying outcome seen with the wax paper could have been because of the paper sample rather than the ink sample. The paper used seemed to have a thicker wax coating than the 4lb/80 rubs sample, which may have caused this inconsistency. Even though we acquired the substrates from the same place, there is a chance the wax paper had inconsistent amounts of wax applied to the paper.

Our overall result of which ink had the best rub resistance did not match our predictions. We believed Flint's vegetable ink would have a better rub resistance than Taniguchi's waterless vegetable ink and Sun Chemical's vegetable ink. In fact, it was quite the opposite. Flint had the worst rub resistance, followed by Taniguchi, therefore making Sun Chemical's magenta the best, in terms of rub resistance, out of the three inks tested on the two substrates.

SET-OFF	CARD STOCK	WAX PAPER
SUN CHEMICAL 50 mm^3	• Had less set-off overall than magenta #2 • The 120 and 240 points were about equal for set-off amounts	• Not as much set-off as the 100 mm^3 but still a lot • No decrease as the time went on • The substrate was not absorbing much
SUN CHEMICAL 100 mm^3	• Had a lot of set-off for the first 30 seconds and each time frame from then on decreased by about half	• A lot of set-off • No noticeable decrease in set-off • More set-off than the 5 microns but still too much
TANIGUCHI	• Barely any set-off • The first 30 seconds had the most but equals about the same amount of set-off as Sun Chemical in their last time frame	• Same as the magenta results; a lot of set-off • Although the wrap sample still maintained most of the ink • No decrease as time went on
FLINT	• Dried consistently • Not as much set-off as wax paper	• Went through the wax paper • Too much ink applied • More set-off on the paper than was left • No decrease in darkness

TABLE 2: Observations for set-off test

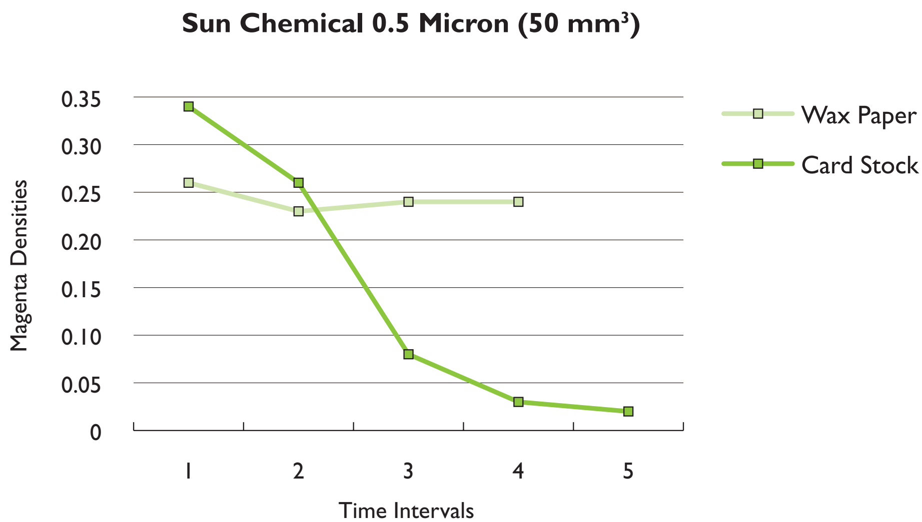

FIGURE 1: Density of Sun Chemical 0.5 micron ink measured throughout rub resistance test

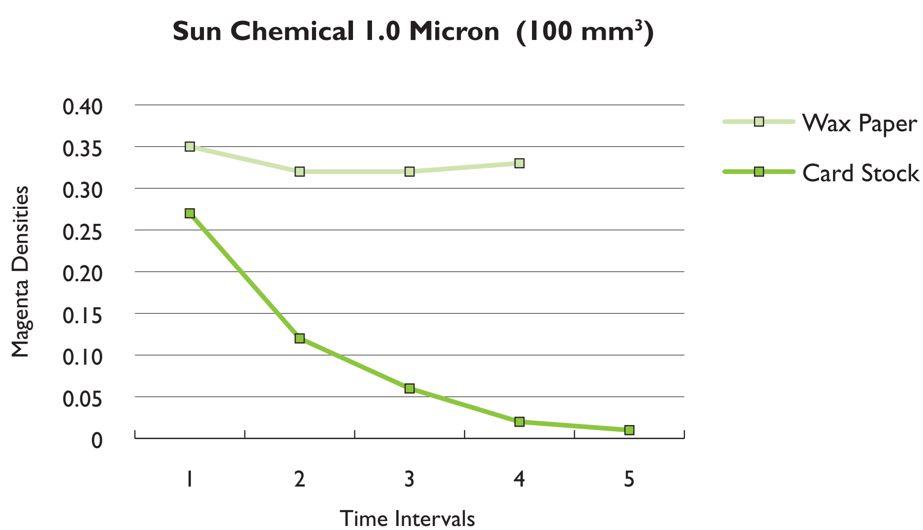

FIGURE 2: Density of Sun Chemical 1.0 micron ink measured throughout rub resistance test

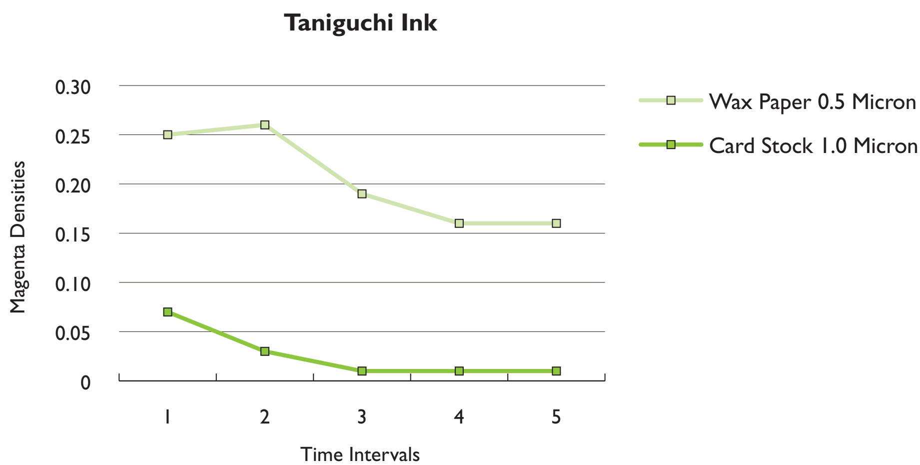

FIGURE 3: Density of Taniguchi ink measured throughout rub resistance test

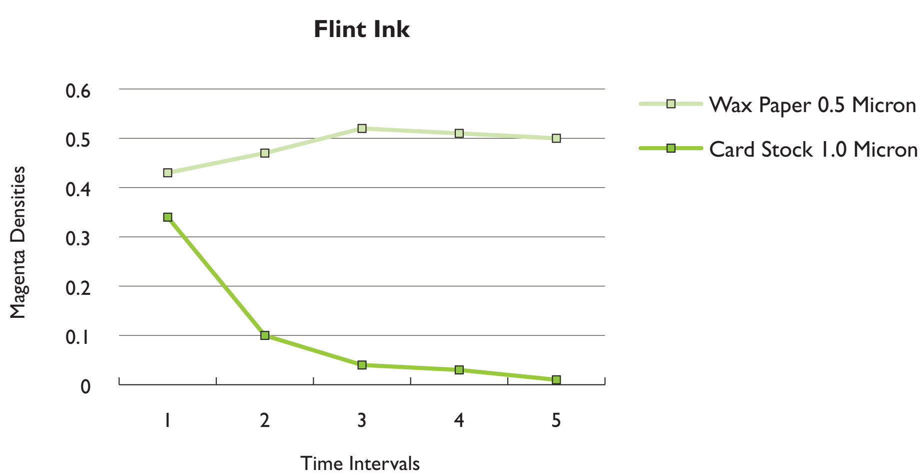

FIGURE 4: Density of Flint ink measured throughout rub resistance test

When observing the amount of set-off produced by each ink overall, we found that across all three inks, those printed on the thin wax substrate resulted in a heavier set-off in comparison to the thicker card stock. Figures 1, 2, 3, and 4 above illustrate the results of how each of the inks set-off for both card stock and the wax paper. The vertical axes represent the densities recorded and the horizontal axes represent the measurements at each time interval (0, 30, 60, 120, and 240 seconds).

There was little variance between the amounts of set-off at each progressing interval. Ink set-off from the card stock, however, was substantially less and decreased with each passing interval giving indication to a faster drying rate. The combination of absorptivity and ink drying time were related to how much set-off appeared on another substrate. We knew that vegetable inks would have a slower drying time because of the small amount of petroleum oil used, so from there we gauged that the differences were due to the substrate. Our reasoning behind this was that the card stock was more porous than the wax substrate. There is a fine line between a substrate being too absorbent, or not absorbent enough. When working with coated papers, less ink is required because of a higher ink hold out. If the environmental inks have less petroleum, they will take longer to dry; therefore the substrate's absorptivity must be taken into consideration.

The high level of ink set-off from the thin wax paper made it difficult to gauge its level of set-off. This meant the amount of ink applied to the wax paper was too much, not allowing it to fully absorb. The wax coating on the paper is applied to keep moisture away from food products (Robertson, 1993). The substrate we used to test did not have heavy wax coating but still had a light enough coating to prevent this moisture from breaking down the fibers of the paper. Therefore, this coating was likely to block out a portion of the ink applied, which increased its chances of setting off. In order to reduce the amount of set-off, we should have applied a smaller amount (less than 50 mm^3) to the rollers to complete the test. This way, we might have been able to track how long it took for the ink to dry before setting off.

A weakness to testing the set-off of the thin wax paper substrate is that we used a coated paper to show the amount of set-off. We did not acquire enough of this substrate to take in account that we would have to test it against itself, so we had to improvise. It is hard to say whether this affected the amount of set-off, as we feel it had more to do with the ink and the substrate we applied it on. However, every detail was considered when analyzing our results.

After analyzing our results we came to the conclusion that the Taniguchi ink dried the quickest on the card stock making it the ink with the least amount of set-off. The results matched our predictions, as well as published material. The slow drying times of vegetable based inks due to the amounts of vegetable oil replacing petroleum did indeed yield more set-off (Massachusetts Toxics Use Reduction Institute, 1994). Water has a slow evaporation rate, so the absence of this in waterless inks allowed for a quicker drying time (Eldred, 2001).

In regards to which ink produced the best results for both substrates, this was extremely hard to gauge. It is difficult to tell which ink had the least amount of set-off on the wax paper because of the heavy set-off for each. Therefore, we based our conclusion on the way they reacted on the card stock. That said, the Taniguchi ink produced the least amount of set-off, giving it an advantage over the other two inks, in terms of drying time.

RECOMMENDATIONS

PRINTABILITY

The substrate type was a factor in determining the best ink to use for our packaging application. Our results indicated that, when compared to the thin wax paper, the card stock substrate was more receptive to the tested inks. The comparatively rougher surface of the card stock allowed the substrate to absorb more of the ink pigment, resulting in a lesser amount being set-off. The smooth coating on the wax paper meant less absorption, and therefore it was only able to bind a small portion of the pigments to itself; the remainder was set-off (HP 920XL Cartridge, 2010). Although the wax paper tended to yield a glossier printed image, its ability to effectively receive ink was hindered.

Based on the level of printability of each ink sample onto the two test substrates, the card stock was a more ideal surface for accepting the inks used in food packaging. This option also met the required environmental benefit, as the use of a glossy or waxed paper causes the product to be non-recyclable and requires a longer period to biodegrade (Jones, 2010). To minimize the environmental impact while still maintaining the quality of how the ink sat on the substrate, it is recommended that a non-wax coated substrate be selected for printing. Also, since the coating on the card stock allowed the paper to be printed without significant ink absorption, it assured the ink would not run or spread, which might subsequently have caused blurriness or lack of contrast (Paper N' Inc, 2001).

The ink that best printed onto the substrate was Sun Chemical Vegetable Ink. It is not recommended that any of these inks be used for food packaging purposes, due to their overall poor ink absorption, high levels of ink set-offs, and vulnerability to rub off. Should the printing process be done on a coated cardboard stock, the greatest results would be achieved with the use of Sun Chemical ink.

A negative printability factor we encountered while testing the inks was the ink seeping through the wax paper when printing with the Flint ink. This may have been the result of contamination, or the sheet of wax paper being too porous. Regardless, this would have caused issues with printability while on press. It would therefore require that the amount of ink be reduced or to substitute the wax paper with one of a thicker stock.

The other concern we faced was the high amount of ink set-off, which we believe to be linked to slow drying rates and poor adhesion of ink to paper. Ink to paper adhesion is important, as poor adhesion may lead to print failures (Kamal, Strom, Schoelkopf, & Gane, 2010). High amounts of set-off may affect the printability of a substrate. As the absorbency of the substrates lowers, the ink does not set and will remain on the surface of the paper, causing set-off to occur as it is printed (Torraspapel, 2008). High amounts of set-off create problems with printability, since it becomes harder to control the amount of ink being printed.

END-USE

A green company is more than just a selling point used on customers or an FSC logo that is printed on a finished piece. Although the idea of a restaurant being 100% green is a wonderful environmentally progressive thought, it is simply not a viable solution. Incorporating vegetable inks into food packaging is not an achievable solution for Mercatto's, or any company in the food industry for that matter as these inks are prone to migrating. These inks did not meet government guidelines in place that stipulated the requirements for inks used in food-based packaging. Although the Sun Chemical ink proved to be the better choice in terms of rub resistance and Taniguchi ink was the best for setting, in order for the restaurant to meet the primary end-use requirement of consumer safety, they would need to use a low migrating ink instead of the tested vegetable inks.

In this section, we provide recommendations to Mercatto's concerning the next steps with incorporating a food-grade ink into their consumer packaging. We also discuss more about low migration inks in addition to the government guidelines that are currently in place to protect consumer safety and the testing methods used to evaluate the stability of these low migration inks that determine its appropriateness in achieving its end-use goal of consumer safety.

INK MIGRATION AND LOW MIGRATING INKS

Ink migration can occur in one of three ways: penetration migration, set-off and evaporation (gas phase transfer). The first, migration, is simply the transfer of a substance from the printed substrate (outside) through the unprinted side (inside) and then to the food (Commision Directive, 2002). The second is by set-off which is simply direct contact of the printed surface to that of the non printed surface and then to the packaged food content (Huber Group, 2008a). This phenomenon of transfer between the printed and non printed surfaces is a condition we attempted to simulate in our ink setting test. The third and final method of migration is through gas phase transfer or "flash off". This type of migration may occur through an air gap between two substances or the surrounding airspace within the package (Huber Group, 2008a). An example of gaseous transfer through an air gap would be through two cups stacked inside of each other. A small air gap between the two would allow for gaseous migration; the transfer of such volatile compounds through the air can negatively affect both the odour and taste of the package contents (Huber Group, 2008a).

A low migration ink or MGA ink is one that is organoleptically neutral, meaning it will not negatively impact the senses such as taste and scent and furthermore does not migrate (Huber Group, 2008a). These inks dry through setting and are therefore prone to having poor rub resistance. For added protection against this, a printer can use a specially formulated water-based coating that is also organoleptically neutral to prevent or reduce rub off (Huber Group, 2008a).

A low migration UV ink is one that does not contain solvent and cures through polymerization. As there are virtually no solvents within the ink, these inks have an extremely low VOC content (PNEAC, n.d.). Like the MGA Inks, specially formulated food grade UV inks are also being used in food packaging. These low migrating UV inks can be used in a lithographic, letterpress or continuous forms setting (Huber Group, 2008b) and can be run on substrates such as paper or card stocks. One must keep in mind, however, that when using nonabsorbent substrates (i.e. cast-coated, film or foil), scratch resistance tests must be carried out prior to production. This is why we used the rub resistance test, as a means of simulating this precaution. Low migration UV inks are very similar to the MGA inks as they do not migrate; the only main difference between the two are their drying methods. MGA inks set while food grade UV inks dry through a chemical reaction. During the reaction, "the UV reactive, low molecular photo initiator and vehicle molecules are cross linked to build a polymeric, solid film (Huber Group, 2008b)". The curing process of this ink, however, is prone to potential migration due to:

> "...decomposition products of photoinitiators and non-reacted photo initiators residual monomers that remain in the ink film or are absorbed into the substrate - incomplete reaction by the ink components due to inadequate curing (Huber Group, 2008b)."

These disadvantages weaken the effectiveness of the food grade UV ink and were most notably displayed during the 2005 Italian Nestle Milk health scare when traces of UV photoinitiator ITX (Isopropyl thioxanthone) were discovered in some infant Nestle milk products (Byrne, 2009).

Sun Chemical has developed a special polymeric proprietary photoinitiator which does not migrate but rather stays within the ink's core matrix (Milmo, 2006) to help prevent such scares from ever reoccurring. But with most new technological advances, research and development for this photoinitiator is still going on.

REGULATIONS AND SAFETY

There are many different government guidelines in place concerning packaging and the use of food grade inks. The fact that must be stressed is that these regulations are simply guidelines and have yet to be established as a governing law. Article 3 of the 1935/2004 directive on food packaging safety states that:

> "Food packaging shall be manufactured in compliance with good manufacturing practice so that, under normal or foreseeable conditions of use, they do not transfer their constituents to food in quantities which could: endanger human health, bring about an unacceptable change in the composition of the food or bring about a deterioration in the organoleptic characteristics thereof (Huber 2008a)."

Moreover, the Commission Regulation (EC) No 2023/2006 of 22 December 2006 on good manufacturing practice for materials and articles intended to come into contact with food goes onto state that:

> "There shall not be any direct contact of the printed surface with the food and that migration & set-off of components of printing inks shall not exceed the limits (Huber 2008a)."

Specific migration limits have been established by EU Commission Directives and vary by substrates and package content. For example, the specific migration limit for plastics, as established by the Commission Directive 2002/72 EC is 60mg of substances/kg. If no toxicological evaluation has or can be made or for non evaluated substances, the EuPIA (European Printing Ink Association) has declared that the migration limit must not exceed 10 ppb or 10 µg (micrograms)/kg (Polster, 2011). With most substances, this number is close to the analytical detection limit, the amount before a trace can be detected and deemed as unsafe (Huber Group, 2008a).

This migration limit only applies for the parts of the package that come into direct contact with the food item (primary package) and are waived on the secondary packaging (Huber Group, 2008a).

Moreover, one must take into consideration incorporating a packaging barrier when using food grade inks to enhance its safety. Examples of effective barriers include glass, silica or a virgin resin such as Polyethylene terephthalate (PET), Polyvinylidene chloride (PVDC), and Ethylene Vinyl Alcohol (EVOH) (The Commission of the European Companies, 2002)

NECESSARY TESTING

To test the appropriateness of a low migrating ink, tests in accordance with the guidelines listed in the European Union Commission Directive 97/48/CE in addition to those listed in 82/711/EEC may be performed. These tests will evaluate the organoleptic properties, will help establish migration limits and assist with migration modeling. Due to the complexity of these tests and our limited resources, we were not able to perform them in this instrumentation.

Migration analysis is the most common test that can be performed. To perform this test, food stimulants are used in lieu of the actual food item as testing the exact item is not always possible. Choosing the proper stimulant is dependent on the type of food that is being tested. For example, acidic foods with a pH less than 4.5 would use acetic acid 3% as its stimulant whilst fatty foods would use a rectified Olive Oil (The Council of the European Communities, 1982).

To establish the proper testing conditions, one would use the outlined contact and test times in Table 3 (See page 71) below that "correspond with the worst foreseeable conditions of contact for the plastic material or article being studied (The Council of the European Communities, 1982)."

From COUNCIL DIRECTIVE of 18 October 1982: Laying down the basic rules necessary for testing migration of the constituents of plastic materials and articles intended to come into contact with foodstuff p.8, by The European Council Directive 1982.

For the full testing procedures on how to conduct a migration analysis, Mercatto's may refer to the 1982 European Council Directive as seen in Table 3.

From a financial standpoint, however, we concluded that progressing further with the initiative to integrate food grade inks into Mercatto's packaging would be an extremely expensive endeavour due to the relatively high cost of these specialty inks. Furthermore, Mercatto would have to hire a company that specializes in the testing and analysis of food contact packaging to perform the tests that are in compliance with the European Union Commission Directive 97/48/CE in addition to those listed in 82/711/EEC. As an alternative, Mercatto can look into using substrates that are more environmentally friendly and easier to recycle rather than using the substrates they currently have in place.

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CONDITIONS OF CONTACT IN WORST FORSEEABLE USE	TEST CONDITIONS
Contact Time	Test Time
t ≤ 5 min	See the conditions in point 4.4
5 min < t ≤ 0,5 hours	0.5 hours
0,5 h < t ≤ 1 hour	1 hours
1 h < t ≤ 2 hour	2 hours
2 h < t ≤ 4 hour	4 hours
5 h < t ≤ 24 hour	24 hours
t > 24	10 days
Contact Temperature	Test Temperature
T ≤5 °C	5 °C
5 °C < T ≤ 20 °C	20 °C
20 °C < T ≤ 40 °C	40 °C
40 °C < T ≤ 70 °C	70 °C
70 °C < T ≤ 100 °C	100 °C or reflux temperature
100 °C < T ≤ 121 °C	121 °C
121 °C < T ≤ 130 °C	130 °C

TABLE 3: Conventional conditions for migration tests with food simulants

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LENTICULAR PRINTING: EXPLORATION AND APPLICATIONS TO INDUSTRY TRENDS

ABSTRACT

Lenticular printing is one of the least recognized printing applications with the greatest potential to add value to print. The purpose of this report is to provide a clear understanding of the methodology behind lenticular printing and to gain insight about this specialized printing process. Furthermore, this report brings to light the demand for lenticular products and the many applications it is currently used for. The information given will further develop the growing market of lenticular printing.

SUMMARY

Lenticular printing has always been considered a specialized niche market. By delivering sufficient knowledge about this particular topic, this report can be used as a guideline for those who are interested in entering the market and/or simply learning the general procedure of lenticular printing. One of the most important components when printing lenticular pieces is completing an accurate pitch test.

A digest-sized lenticular cover was printed on a Heidelberg Speedmaster CD 74. In order to print this product, an optical and mechanical pitch was determined so that the press could be calibrated to match the output LPI. For this test, the optical pitch was determined to be 99.635 LPI and the mechanical pitch was 99.673 LPI. Determining the pitch is based on visual perception and requires skill and experience. We consulted with a lenticular prepress specialist in order to correctly and successfully output this job.

To further understand the potential of lenticular printing, research was conducted to determine recent market trends and industry applications that revolve around the lenticular market. The additional information revealed that consumers prefer motion displays rather than static displays and that motion displays are capable of creating a 51% sales increase (Softmotion, 2011). Furthermore, lenticular has grown into markets such as packaging, labels, variable data printing and entertainment. The increasing growth of lenticular print has sparked many printers' interests and printing companies are contemplating investing in this specialized printing process. Presidents from Big3D and Matrix Imaging provided insightful recommendations about lenticular printing.

INTRODUCTION

Lenticular in the printing industry is being used more widely for businesses who want to be creative and unique within their marketing strategy. To fully understand the lenticular process, we have provided detailed information about the history and theoretical concepts related to this topic. This research report is to be read as an informative analysis to educate the processes of lenticular printing and how it is applicable in many fields of the printing industry.

The discovery and exploration of lenticular printing began in the early 1900's. Throughout the years the original formula has been explored and tested by using barrier screens and camera lenses. As of today, the concept of lenticular is ever-changing, but understanding the original science behind this process is of great importance. Every year, new technology continues to bring new advancements in design capabilities, software, printing possibilities, and the lenticular lenses (Linking Solutions, 2004). This all started with the "barrier method", which was an autostereoscopic display that presents a three-dimensional image to a viewer without the need for special glasses or other impediments (Roberts, 2003).

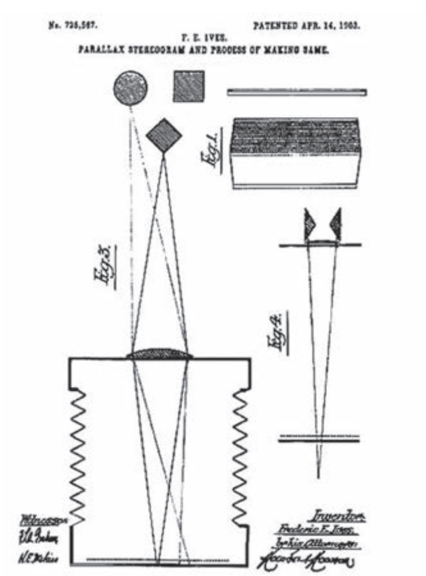

FIGURE 1: The Parallax Stereogram

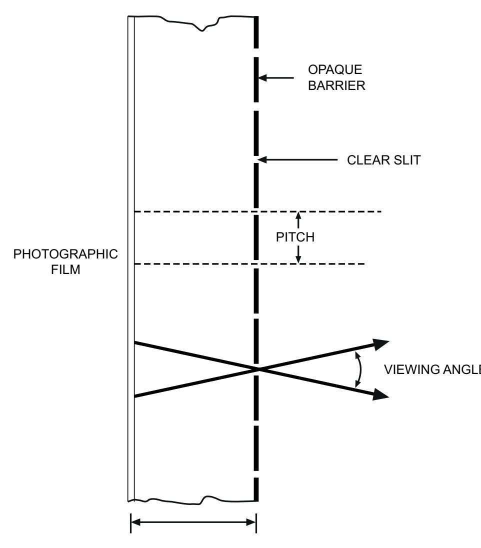

FIGURE 2: The anatomy of a Parallax Barrier (Roberts, 2003)

The autostereoscopic concept involved dividing two or more pictures into "stripes" and aligning them behind a series of vertically aligned "opaque bars" of the same frequency (Roberts, 2003). This concept was first proposed and demonstrated by a French painter, G.A. Bois-Clair, in 1962 and he proved that he could create 3D effects when viewers would walk by his paintings. In 1896, Jacobson and Berthier proposed the barrier technique using photographic methods. Frederick E. Ives first applied photographic methods in 1903 within the United States and 1906 in France. Instead of viewing the effect with our eyes, Frederick Ives created and patented the "Parallax Stereogram" which is a stereo viewing aid (See Figure 1 and 2).

The parallax stereogram consists of three elements: a barrier-masking screen, a transparent glass plate behind the barrier screen, and a photographic emulsion. The barrier-masking screen consists of vertical opaque lines, which are separated by clear slits. The glass plate is used to create space between the screen and the image. The photographic emulsion consists of pictures that are divided into fine mosaic image stripes aligned behind each clear aperture (Roberts, 2003). How it worked depended on precise viewing angles of the eye through the barrier screen. When a photographic plate is behind the barrier screen, the viewer's left-eye would see only the left mosaic stripes and the right eye would see only the right stripes (See Figure 3). Using a fine-pitched barrier, the screen becomes nearly transparent and, as such, each eye would see its own corresponding image stripes as a composite image. The eye will then perceive the two dissimilar views as a three-dimensional impression (Roberts, 2003).

A fundamental drawback of parallax stereograms is the fact that the stereo image could only be viewed correctly from a narrow viewing "zone". When the head excessively moves side-to-side outside of the viewing zone then the left and right eye views will be switched and therefore be seen by the inappropriate eye (Roberts, 2003). The result is a pseudoscopic image where the depth is inverted (foreground appears to the background and vice versa). Adding multiple views beyond the two stereo views to widen the viewing range resolved this problem. This creates a "look around" capability, where the pictures moves through a sequence of stereo views as the viewer moves from side to side, which reveals different aspects of the scene.

In 1915, the first method to allow multiple views behind a barrier screen was proposed. In 1918, Clarence W. Kanolt was issued his U.S. Patent 1,260,682, which incorporated a large format camera (See Figure 4) that included movable barrier screens between exposures. He called it the "Parallax Panoramagram" and suggested that the camera could be used to create animation. Fredrick E. Ives' son, Herbert E. Ives, made great advancements with this technique. He was the first to create images using a large aperture camera lens (a lens with a diameter wider than the interocular distance). This permitted an "infinite" set of views, which allowed moving objects to be photographed "instantly". This advancement in lenticular techniques also gave rise to a variety of "scanning" camera systems and early television applications (Roberts, 2003).

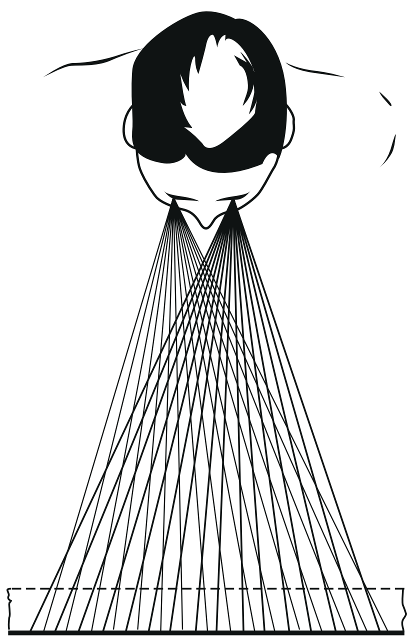

FIGURE 3: Sight lines through a Parallax Barrier Screen (Roberts, 2003)

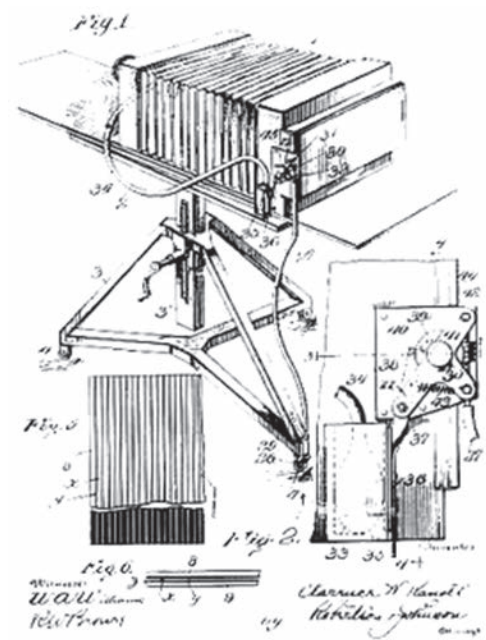

FIGURE 4: C.W. Kanolt's Parallax Panoramagram Camera (patented)

As further progress was made by Herbert Ives, parallax barriers became a dramatic tool for advertisers in the 1990's. However, with the new technology of lenticular displays, parallax barrier methods have disappeared. In 1908, physicist Professor Gabriel M. Lippmann proposed to use a series of lenses as the picture surface instead of opaque barrier lines. This led to the creation of integral methods that utilized an array of small spherical lenses to both record and play back the image (See Figure 5). Yutaka Igarashi made another advancement in 1978 by digitally interlacing a multiplicity of computer generated two-dimensional views. However, integral methods did not achieve commercial success and thus lenticular methods were developed.

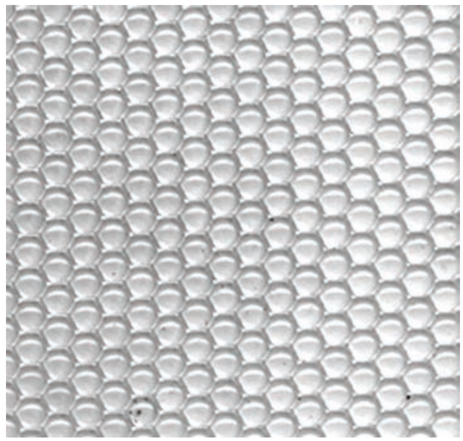

FIGURE 5: An Integral "Fly's-eye" lens array greatly enlarged (Roberts, 2003).

In the late 1920s, several scientists simplified Lippmann's proposition and incorporated a lenticular lens array. The lens sheet was optically analogous to the parallax barrier screen and more research advancements in the technology occurred into 1930s. There was the British "lenticulated screen" process, the French method of Josse, and the German "Diacor" method (Roberts, 2003). When a lenticular array is coated with a film emulsion at its focal plane and exposed to light rays from a particular angle, the light rays redirect in the same approximate direction as the recording angle once it is developed. This unique property found success in commercial applications as a means for producing colour motion picture film. Instead of individual stereo images being exposed behind the lenticular screen, individual stripe images relating to red, green, and blue aspects are recorded and re-combined through a special projection system into a full colour image using only black and white emulsion (See Figure 6). This 3D lenticular photography was later greatly advanced by Professor Maurice Bonnet of France, and Victor Anderson and Doug Winnek of the U.S. (Roberts, 2003).

Since the 1960's, lenticular techniques showed rapid progress as large corporations recognized its advertising potential. The manufacturing process involved printing the image

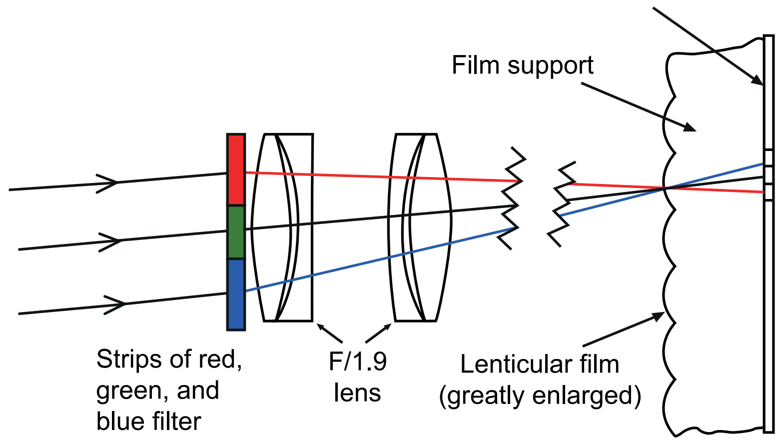

FIGURE 6: The Kodak Kodacolor Process (R.W.G. Hunt, 1947)

using a 300 line offset press and a special technique for coating and lenticulating a thin layer of plastic on the image at a high speed (Roberts, 2003). At that time, the process was known as "Xograph" and was developed at Eastman Kodak in Tennessee and was credited to Arthur Rothstein and Marvin Whatmore. Few companies produced lenticular products during that time and used proprietary methods with lenticular screens manufactured only for their internal use. Most of the screens used for lithographic reproduction were heat embossed in PVC (polyvinyl chloride). In the early eighties, consumer multi-lens cameras were introduced and the negatives could be processed into lenticular prints. This created a higher demand for the fine-line lenticular material, which was then mass-produced at Rexham in North Carolina for the process. Ken Conley, the key engineer for this project, was credited for developing methods to form effective lenticular lenses. These lenticular materials were then coated with a photographic emulsion by 3M in Italy and later by Kodak in Toronto (Roberts, 2003).

From Ken Conley's work, many regained interest in lenticular and thus a number of plastic manufacturers wanted to produce the material. As technology advancements increased in the graphic arts industry, the lenticular creation process moved rapidly from the proprietary in-house photomechanical domain into the hands of printers. During that time, it was seen as an effective advertising tool and any ambitious printer had the means to sell this unique product. The reverse ink printed lenticular sheet market doubled every year and so many large reputable companies propelled into this industry such as Kodak and Quad Graphics. By 1996, lenticular technologies and materials became widely available in the printing industry. Today, lenticular advertising is relatively well-known, which is fueled by a hundred year old industry that continues to captivate, develop and grow (Roberts, 2003).

THEORETICAL CONCEPTS

Lenticular printing is a printing process that combines interlaced static images, which are fused on a lenticular lens to create illusions of depth, motion, and other effects. Through a complex printing process, the end result is a dramatic and eye catching printed piece that instantly captures the audience's attention. This optical illusion is created by a plastic sheet, which is made up of many rows of tiny lenses that are commonly called "lenticules" (Linking Solutions, 2011). In order to create this sophisticated marketing material, you will need a set of images that must be specially prepared to match the lens. These images are interlaced together and sliced up into strips, which are then blended together into one image. The size of the printed product is based on the lenticular lens and the resolution is based on the printing device (Linking Solutions, 2011).

When viewing the lenticular piece, you will see that each lens on the lenticular sheet will magnify a small portion of the interlaced image beneath it. Therefore, when changing the viewing angle, a different portion of the image is magnified, which creates the overall animated effect. The lenticules are precisely aligned with the interlaced image underneath it in order for the special effect to work properly (Hershey, 2007). This is the main reason why the image appears to change as the viewing angle changes. There are different types of animations that can be done with lenticular printing such as a simple flip between two images or multiple images consisting of several frames of motion. Lenticular print can also appear to be three-dimensional (3D). With the increasing development of print technologies, today's offset lithography and digital flatbed presses can now print directly on the smooth backside of the lens to produce eye-catching 3D, morphing, flipping, animation and zooming effects (Hershey, 2007).

DEFINITIONS

LENTICULE: This is a small convex lens on a lenticular sheet. It is a single row of cylindrical shaped lens on top of the sheet. Without lenticules, the lenticular sheet is basically a sheet of flat plastic (KNT 3-D, 2009).

LPI (LENSES PER INCH OR LINES PER INCH): Different thicknesses (LPI) of lenses are suitable for different applications and printing methods. In general, thick (lower LPI) lenses are more suitable for printing large posters. Thin (Higher LPI) lenses are more suitable for small, handheld pictures. The type of lenticular effect is also relevant: thick (narrow angle) lenses are more suitable for 3D, while thinner (wide angle) lenses are better for flip and animation effects (3D Lenticular, 2010).

VIEWING ANGLE: This is the refractive measure, pitch and curvature of lenticules in a v-shaped region in which lenticular image effects can be seen clearly. This angle of a specific region is the viewing angle of lenticular sheet (KNT 3-D, 2009).

TESTING PRINCIPLE

Lenticular printing is a high-resolution process that requires the interlaced data behind the lens to be very precise to create a great lenticular image. The interlace data needs to be fine enough so that it sits between the lenticules. Lenticular can be produced through a variety of printing processes from digital inkjet, flexography, web offset, and most commonly offset lithography. Regardless of output device it is critical that a pitch test is conducted. The pitch test is a calibration tool that determines the specific output LPI that matches your output device, taking the media and lenticular sheet into consideration for a particular job (Microlens, 2009). Different output devices will yield a slight difference in output LPI for a specific lens, which is why it is important that the pitch test is conducted on the device that you intend to output a lenticular job with.

We consulted with a lenticular prepress specialist, Dale Waldron, who guided us through this testing process. For this test, a 100 LPI lenticular lens was used for output on the Heidelberg Speedmaster CD 74. The 100 LPI lenticular lens is most commonly used for a variety of end-use applications. It can be used for large lenticular projects such as signage or smaller dimension lenticular pieces such as postcards. This test was conducted to show how the lenticular printing process is performed and the mandatory procedures required to produce a good lenticular image. We used the lenticular software HumanEyes Creative 3D for design and the HumanEyes Producer 3D to produce the pitch test and interlacing of the design file. The HumanEyes Suite is a series of powerful programs built for printing lenticular. It is industry-recognized for its user-friendly interface and performance.

Prior to printing any lenticular application, proper calibration of the output device must be performed to accurately print a good lenticular image. Through Human Eyes Producer 3D a pitch test target was generated based on the specifications of the lens and the end use application variables such as viewing distance. The pitch test target consisted of a range of values that are typically user defined.

For this test we chose a range of ± 1 LPI from 100 LPI. This test target ranged from 99 LPI to 101.019 LPI with 105 steps in between. The test target was made up of rows of black lines interlaced at all 105 LPI values. With this pitch test target printed on the back of the lenticular lens, we can determine two crucial measurements for this test: the optical pitch and the mechanical pitch. The optical pitch is determined based on a visual observation of how clean the flip transitions are across the length of the lenticular press sheet (Waldron, 2011). The mechanical pitch is the LPI value that best represents where the black line is printed on the lenticular sheet. These black lines should be printed consistently across the length of the press sheet maintaining its position between two lenticules. HumanEyes will take the corresponding LPI for the mechanical pitch into consideration when interlacing the lenticular design file to the LPI value of the optical pitch.

We chose HumanEyes 3D because it is compatible with Apple OS X, user friendly and it is widely used by the industry. Besides from HumanEyes 3D, there are other lenticular software options available on the market. The process for outputting any lenticular project uses software that would use similar steps to those listed in the procedure. Regardless of software, the optical and mechanical pitches are two variables that are critical to producing a good lenticular image and they are strictly dependent on the lens LPI and the output device used. Without the use of lenticular software there are other alternatives to printing lenticular. It is possible to interlace a lenticular file using Adobe Photoshop. However, the process of doing this can be extremely time-consuming and completely inaccurate if the design is interlaced incorrectly.

EQUIPMENT USED

- Heidelberg Speedmaster CD 74: 23” x 29” 6 colour + AQ runs up to 32 pt board
- CTP-Creo/Kodak Trendsetter 800 Quantum
- HumanEyes Producer 3D
- HumanEyes Creative 3D V3.0.014

MATERIALS TESTED

- Lenticular sheets (100 LPI lens) 42 degrees, 355µ nominal gauge
    - PITCH 101.25 - 101.75 ISO 9002 Certified

PROCEDURES

PART A: CREATING THE PITCH TEST TARGET IN HUMANEYES PRODUCER 3D

1. A 28 x 20 inch 100 LPI lenticular lens was used to determine the output LPI or pitch value for Heidelberg Speedmaster CD 74.
2. The pitch test was created starting by opening HumanEyes Producer 3D and selecting the menu Tools > Pitch Measurement. Under Output Settings, Landscape was selected. The Width was set to 28” and Height to 20”, according to the dimension of the lenticular lens.
3. Printer Resolution was set to 2400 DPI.
4. Under Pitch, the estimated pitch was set to 101.25 LPI, and Pitch step 0.1 LPI. The pitch range stated: from 99 to 101.019.
5. Under Strip Height, 0.16 inches was entered. ”Mirrored” was selected so that the pitch test would be printed on the back of the lens.
6. Continue was selected and the test was saved as a TIFF file named pitchtest100LPI.tif.
7. Under output data, the number of strips was 105 and the net width was 19.25 inches.

PART B: PRINTING THE PITCH TEST IN HUMANEYES PRODUCER 3D

1. The pitch test was output to plate using the CTP-Creo/Kodak Trendsetter 800 Quantum.
2. The single black plate was mounted on to the black unit of the Heidelberg Speedmaster CD 74.
3. The 100 LPI lenticular lens material was positioned into the feeder with the lens facing downward and lens direction perpendicular to the direction of travel.
4. Ran 25 lenticular lenses for make-ready.
5. A press sheet was retrieved and checked for consistency.

PART C: DETERMINING THE OPTICAL PITCH FOR THE LENS

1. The lenticular sheet (portrait) was oriented so that the lenticules ran vertically and the LPI pitch values ran down the left hand side of the lens.
2. The press sheet appeared to show a moiré pattern converging towards the middle of the sheet. They may also appear as black and clear bars. Under a loupe these bars are actually a series of black lines that are interlaced at different values that will help determine your final output LPI.
3. The lenticular pitch test target was held at arm's-length distance away and the viewing angle of the lenticular sheet tilted left and right to see the rows and to determine which row transitioned the cleanest from a solid black to clear across the length of the lenticular press sheet.
4. Once the row that best transitions was identified, the corresponding LPI value was found on the left hand side of the press sheet. This was the output LPI for the device. This LPI value is the optical pitch used to interlace any lenticular job that uses this 100 LPI lenticular lens on this press.

PART D: DETERMINING MECHANICAL PITCH FOR THE LENS

1. The lenticular sheet was oriented landscape with the LPI pitch values running along the bottom of the sheet, and reversed so that the lenses were facing downwards.
2. A loupe was used to look closely at the strip that corresponded with the output LPI of the optical pitch and the other columns beside it.
3. The black lines printed at the bottom and top of the same strip were inspected to ensure that they were in between two lenticules and were printed in the same place across the length of the sheet.

4. The column with the most consistently printed lines was found and the corresponding LPI noted from the bottom of the lenticular sheet. This LPI value is the mechanical pitch used in conjunction with the optical pitch to interlace any lenticular job intended for output using this 100 LPI lens on this Heidelberg Speedmaster CD 74.

PART E: USING THE OPTICAL AND MECHANICAL PITCH VALUES TO OUTPUT A LENTICULAR JOB

1. After a design was created and imported into HumanEyes Creative 3D, the project was saved as "project.ldoc" and the imposition for the press was set up.
2. Under Output Settings, the width was set to 28" and height to 20". Printer resolution was set to 2400 DPI.
3. Under Lenticular Lens, the lens orientation was set to horizontal, the optical pitch to the result from Part C and the mechanical pitch to the result from Part D.
4. Four-cornered alignment marks were added by dragging the third icon from the left at the bottom of the window to the border of the imposition layout.
5. Centre marks were added by double-clicking the fifth icon from the left at the bottom of the window. The mark width was indicated to be 0.25" and mark height 1". The icon was clicked and dragged to the centre, left and right of the imposition layout.
6. Alignment marks were added to the bottom of the imposition layout by clicking and dragging the second icon from the left at the bottom.
7. Side guides were added by clicking and dragging the eleventh icon to all four corners of the imposition layout.
8. This imposition layout was saved by clicking Create Template under the Layout Info palette, then Save New.
9. The project.ldoc file on the computer was dragged into the imposition layout.
10. In the bottom right hand side of the window, the interlace button was used to render this file. Color Space was set to CMYK and Color Profile to Generic CMYK profile.
11. This file was saved as project.tif was then ready to be printed on press. To print the final project, Part B was followed.

RESULTS AND DISCUSSION

Optical Pitch:	99.635 LPI
Mechanical Pitch:	99.673 LPI

TABLE 1: 100 LPI lenticular lens output on a Heidelberg Speedmaster CD 74

It was critical to understand the process of how to conduct a pitch test because the optical and mechanical pitches are two numbers that are crucial to outputting any lenticular job. The optical and mechanical pitches are strictly device-dependent and vary depending on the output device and the lens used. For this test, the optical pitch was 99.635 LPI and the mechanical pitch was 99.673 LPI.

Identifying pitch values was a very subjective process. Even though it was known what exactly to look for, it was based on the visual perception of the particular person. The optical pitch was determined by looking at the test target and identifying which row of black lines transitioned the cleanest from black to clear across the length of the press sheet. There may have been several rows above and below this line that also appeared to transition just as well and some people may have perceived those other lines to be the optical pitch. A possible solution for this subjectivity would have been to take this refined LPI range and output another pitch test target with 100 steps. From this new test target, an even more accurate optical pitch LPI can be found. Depending on the lenticular job and the lens used, accuracy may need to be as close as 1/1000ths of an inch (LPC World, 2007).

Determining the mechanical pitch was just as subjective, because the visual perception from person to person is different. For the mechanical pitch, it was necessary to determine the consistency of the black lines printed in between the lenticules, across the length of the press sheet. It was extremely difficult to visually identify where and how much the black lines shifted in between the lenticules. Experience is required to be able to accurately identify the optical and mechanical pitch values to properly output lenticular images. Under the guidance of Dale Waldron, it was confirmed whether the pitch values chosen were correct for output and would yield the best result. The success of this test can be observed by looking at the final printed product – the RyeTAGA 2011 lenticular journal cover.

Producing the pitch test for lower or higher LPI lenticular lenses will yield different results. The process would be similar to the series of steps in the procedure. With lower LPI lenses, accuracy is even more important because the slightest miscalculation will be more evident in comparison to a higher LPI lens.

Lenticular is not, however, applicable for all printing processes. It is possible as long as the output device is capable of printing interlaced lines thin enough to fit behind a lenticular lens. The only printing process that cannot print lenticular is screen-printing. Lenticular printing is a very precise process and it may at times require accurate readings up to 1/1000ths of an inch in order to output a good lenticular image. The more accurate the process and the measurements, the finer and more effective the final printed product will be (LPC World, 2007).

MARKET TRENDS AND LENTICULAR APPLICATIONS IN THE INDUSTRY

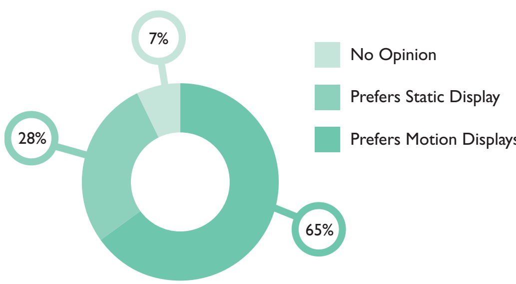

FIGURE 7: Motion vs. Static Display Survey (Softmotion, 2011)

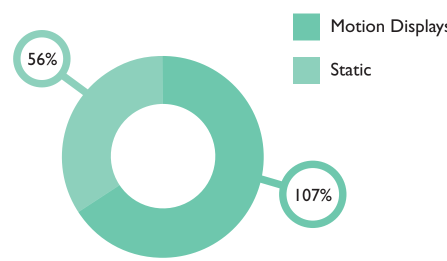

FIGURE 8: Sales increase with Motion and Static Displays (Softmotion, 2011)

The extremely wide diversification of the consumer market calls for value-added features to influence and satisfy customers. With varying marketing trends and diversified marketing campaigns, static print is becoming less effective. Also, lenticular posters are being used to replace static printed posters to advertise for 3D movies. Lenticular itself creates a whole new value-added printed piece in marketing because it is a great eye-catcher (Pierret, 2010).

Furthermore, for successful advertising campaigns, professionals must consider the marketing benefits of using lenticular products. For example, lenticular posters are available in large quantities and at affordable prices. Unique in their appeal, a lenticular advertising piece has proven to be one of the most effective marketing materials in history. It is perfect for any occasion and provides a competitive edge in any marketing campaign. The personalization of lenticular print gears to be the standard for promotional items in the fast-paced and ever changing world of business and e-commerce. Business cards, bookmarks, key tags, mouse pads, luggage tags and wallet cards are just a few personal features that are now printed on lenticular stock (3D Lenticular Printing, 2010).

With the advancement of technology (computer hardware and digital imaging software), photo labs and designers have the ability to create lenticular images more quickly (DDA Vista Lenticular Products, 2000). Dominating new markets whilst maintaining significant business relationships with existing customers is every company's goal. New ideas are always emerging to capture the ever-changing marketing trends by turning these ideas into reality. Lenticular printing and advertising is penetrating the market and slowly increasing the demand. Independent studies and tests that were conducted to measure sales using a static display versus a motion display reveal that motion displays were much more effective. The sales volume in stores where static displays were used increased by an average of 56%, but when stores that had motion displays reported that, sales increased up to 107%. The study showed that motion displays created a 51% increase of sales over static displays. Another fact is that retailers prefer motion displays because they believe that it will increase sales. A three-year marketing study showed that 65% of retailers wanted advertisers to provide motion displays (Softmotion, 2011).

PACKAGING

Depending on the shape and size of the die line, the packaging design has limited amount of space to place information, but this is only true with traditional static print. However, lenticular imaging allows for double or even up to triple the amount of information that can be covered over the same amount of surface area. This is due to the amount of effects that can be embedded into the lenticular piece. Additionally, lenticular can show how a product works or the various outcomes of using the product. For example, a hair colouring product can use a 'flip effect' to change the hair colour from brown to blonde, and vice versa, or to another designated colour offered by the company (Swientek, 2002). National Graphics, a lenticular company located in Wisconson, was able to create a much thinner, higher-definition lens that can be specifically used for packaging. This new material, called Crystal lens, is a 200 line material capable of delivering enough detail to accurately convey bar code information when scanned at the point of purchase. It is only 0.007 inches thick making it practical for packaging (Giuseffi, 2011).

One of the most critical fundamentals related to packaging is security, and printing on lenticular addresses product protection for both tampering and copyright. Lenticular is a great asset for holographic printing because it is very difficult to imitate (Sellex 3D, 2010). Consider direct mailing for example, the lenticular substrate and printing seal guarantees that the package has not been tampered or opened. Another example of lenticular used for security is with pharmaceutical packaging.

Lenticular printing protects against:

- Intellectual theft
- Imitations
- Counterfeit
- Tampering

Lenticular is dominating the packaging mainstream because of its thinner lens structure to fit on cylindrical objects and plastics. For cartons and other packaging substrates, the lenticular label can be laminated with thin lenticular materials. Also, new computer-to-plate technologies will capture more detailed images to the rear of the lens, resulting in much sharper visual effects. A lenticular lens with two hundred lenticules per inch (also called the 'crystal') tolerates finer serif typefaces and smaller point sizes on substrates. The 'crystal lens' allows bilingual messages that can 'flip' from one language to another (Swientek, 2002).

LABELS

Printing labels on lenticular stock, requires a continuous roll with the lenticules oriented parallel to the continuous feed. The lenticular web is applied to a transfer tape on a release liner or a carrier web. The lens sticks fast, and then the tape is die-cut to create a web of pressure sensitive labels. The resulting product is a continuous web of lenticular labels with the lenticules running parallel to one another and its length, which is the longitudinal axis of the web. For products like bottles, the process is difficult because the labels have to be affixed circumferentially rather than flat. This makes the labels perpendicular to the object so visual effects only occur when the object is moved vertically relative to one another. The reason is that the continuous lenticules run parallel to the direction of travel and therefore the characteristics under which the visual effects occur are limited.

When the lenticular labels are applied with conventional continuous labeling equipment to a vertically standing object, for example, a bottle, a viewer perceives the desired visual effect either:

1. As the object rotates about on its longitudinal axis or,
2. As the viewer walks past the vertically standing object (Kiraly, 2011).

VDP

The market for variable data printing (VDP) in relation to lenticular is growing at the moment. The concept behind VDP is to personalize using print on-demand technologies. Thus, enabling printers to customize to their capabilities. With VDP features, lenticular capable devices can input digital images on lenticular products to create different versions that accommodate the individualized data (National Graphics Inc, 2011).

ENTERTAINMENT AND ADVERTISING:

Lenticular advertisements have become sophisticated enough to attract today's audience that is swamped in digital entertainment. Lenticular advertising is all about differentiating reality and fantasy, which is able to intrigue today's generation of consumers. Overall, lenticular printed materials are eye-catching and are extremely effective advertising pieces for virtually any market (Dickinson, 2010). Lenticular advertisements have a lot of advantages over other types of printed promotions. The most obvious advantage is the ability to give three-dimensional life and movement to images. Big3D's founder and president, Tom Saville, says, "We are seeing more people looking to stand out in their advertising, particularly with direct mail where they want to send fewer pieces and get more bang for their buck. It's a growing part of our business" (Dickinson, 2010).

Big3D is one of the biggest lenticular print shops in the United States and they have seen the increasing demand for lenticular advertising. Examples of lenticular advertising can be seen on store signage, retail displays, movie posters, DVD covers and direct mail. Another advantage is that lenticular prints cannot be copied and thus can reduce counterfeit products (e.g. concert tickets and NASCAR pit passes). A disadvantage is that large-format lenticulars are far more expensive than small-format lenticulars. Although end-use customers would love to include large-format lenticulars in their advertising mix, they might not be able to afford it. The extra cost is due to the lenticular lenses used to create the morphing effects because they are so desirable. Added to the extra material cost is the additional prepress work that needs to be completed in order to get the animation perfect. Lenticular is considered as a great product and if you can catch someone's attention in three or five seconds, the piece has done its sales job (Dickinson, 2010).

RECOMMENDATIONS

Based on the information above and the market trends, entering into the lenticular market requires change within the company. With the high quality materials and printing presses available today, it is easier than ever to integrate lenticular printing into the company's current processes. However, the company must be committed to take the time and energy to perfect this specialized printing process. Printing companies who are contemplating lenticular would be well-advised to make sure they have the market for it as well as lenticular specialists on staff who know how to sell it (Hershey, 2007).

As described by Brian Freije, president of Matrix Imaging, printing lenticular is an art and not a science. "If you don't lay it down on the lens just right, you can get travelling where the image doesn't line up properly," says Brian Freije (Dickinson, 2010). He also says that if you do not pitch it right, it can flip too quickly and ruin the animation. From his experience, you always ask the client about the viewing distance, because depending on the distance it can look great or look terrible. Brian suggests that knowing the viewing distance is very important because you can set up the lenticular to flip faster or slower depending on the viewing distance (Dickinson, 2010). Printers should also be very well aware of colour registration. Colour registration must be maintained within a 1/1,000th of an inch tolerance. It is important that image alignment be maintained within this tolerance for the best possible results (LPC World, 2007).

Printers who would like to start providing lenticular products to their clients must have the sufficient knowledge of the printing process and understand the type of equipment needed. For example, large printing companies who sell lenticulars such as Big3D and Matrix Imaging use an Océ LightJet photo image for the majority of their large-format lenticular printing. However, inkjet is another viable solution. Printers would have to consider setup costs, because it is more cost effective for longer runs. A preferred solution by the presidents of these two companies is using continuous tone photographic printing (Dickinson, 2010).

Since lenticular printing is a niche market, customers are very picky, therefore choosing your processes is very important. Another recommendation made by Brian Freije is to consider investing in the latest Inca Onset S20 press because it can be used as an alternative for larger and more outdoor-durable lenticular projects. The S20 does full-bed array printing, which reduces banding and can print at high volumes (50 full-bed boards an hour). Big3D uses a custom-engineered Lüscher flatbed inkjet printer for their larger outdoor projects. This printing press is recommended because it is capable of producing displays that need to last multiple years in any weather condition (Dickinson, 2010).

Printers should also consider the capabilities of UV-cure printing because it allows you to print in reverse, directly onto the lens, which effectively takes two steps and eliminates the cost of extra material during the process. However, this type of printing lacks continuous tone. Printers should also be aware of precision, clarity and brilliance because they are crucial elements in lenticular printing.

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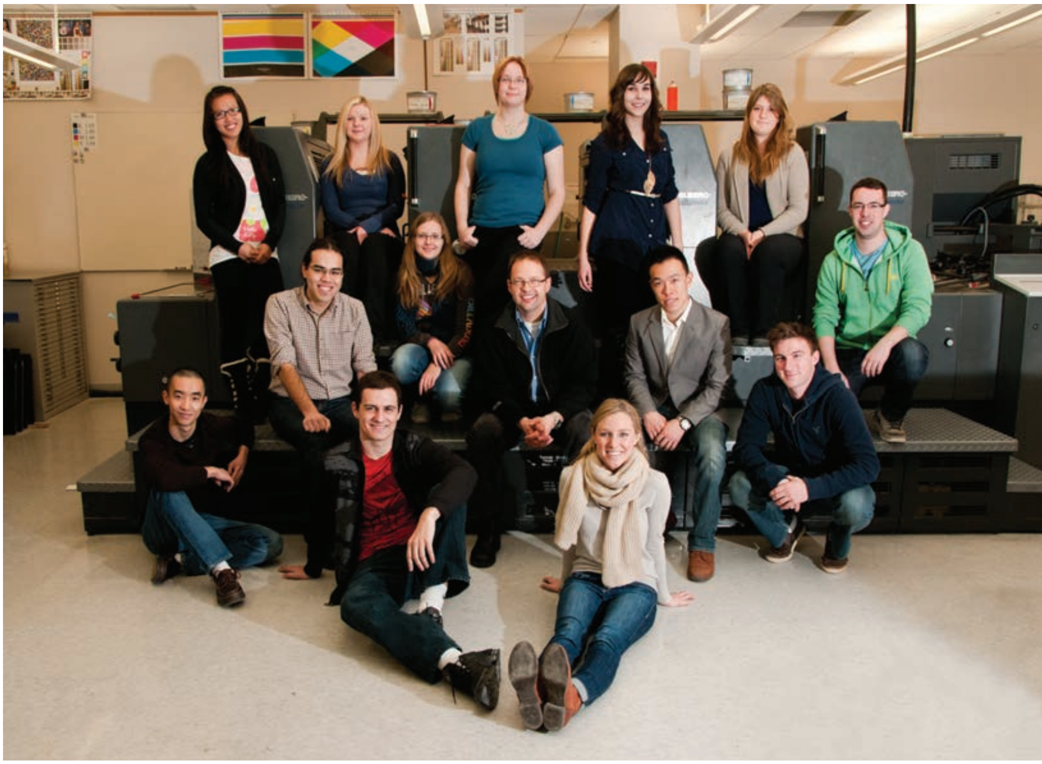
CREDITS



THE GENERAL MEMBERS

The 2011 – 2012 general members were involved and supported RyeTAGA in the following areas: creative, multimedia, fundraising, marketing, editorial and production. We would like to acknowledge all of their hard work and dedications throughout the year. On behalf of the entire executive team, thank you! It has truly been a pleasure working with you all.

FIRST YEAR STUDENTS

Veronica Annis, Sarah Aspler, Anna Avitsian, Damiano Banaj, Mike Beneteau, Melissa Binstead, Krista Brown, Jacqueline Chan, Arnold Chan, Angela Chau, Leslie Choi, Tak Po Chu, Angelique Coetzee, Nancy Condori, Alex Downey-Gin, Alina Esmatyar, Elizabeth Faria, Batool Fatima, Ali Fattahi, Michaela Fraser, Sim Lall, Emily House, Kristen kelava, Holly Lam, Deborah Lewis, Joel Loyol, Christina Maccallum, Shanley Maguire, Zuan Mao, Jannis Morgan, Stephanie Murray, Keerthinka Naganathy, Anil Parcha, Traci Phillips, Ashleigh Russell, Harleen Singh, Nicole Thornburrow, Frances Tsesler, Asra Tunio, Michael Vander Eyken, Jessica Wong, Thomas Woo.

SECOND YEAR STUDENTS

Faris Abu-Kweik, Rhonda Atkinson, Natalia Bagan, Martyna Benisz, Mark Brejnik, Alysha Eggett, Niki Fereidooni, Kristina Fritz, Brian Hui, Logan Keith, Nikita Kuzmin, Tabea Lemcke, Ashley Lombardo, Sinead Moran, Ryan O'Donoghue, Catherine Palumbo, Anna Salazar-Tello, Alyssa Szeto, Tracy Ta, Veronica Torres, Emily Wong, Alex Wong, Mike Wu.

THIRD YEAR STUDENTS

Babak Amoozgar, Yvonne Chan, Mark Corrigan, Cora-Lynn Hazelwood, Trung Nguyen, Jean-Luc Quesnel, Rakhi Ray, Paul Tarascio, Julie Tran, Roza Zahedifar.

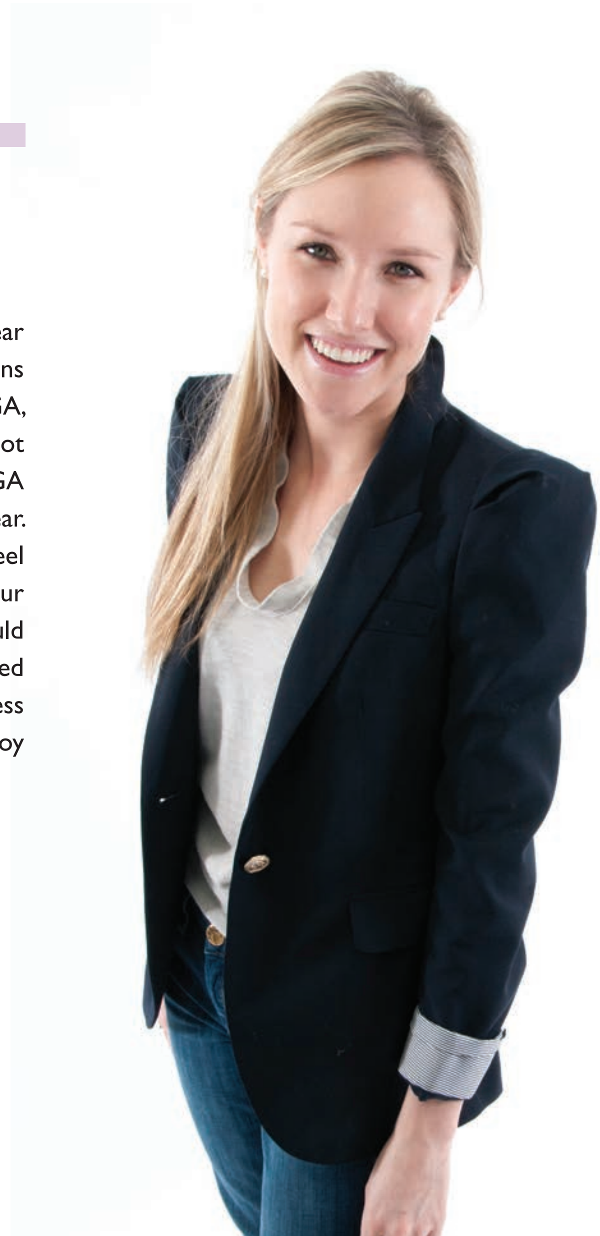
FOURTH YEAR STUDENTS

Ovidiu Bradu, Erika Elsner, Carol Fung, Kimio Hatashita, Kaitlyn Matheson, Cindy Thai.

SARA D'ARCEY

CO-PRESIDENT

As I complete my fourth and final year of both the Graphic Communications Management Program and RyeTAGA, I would be remissed if I did not acknowledge how hard all of RyeTAGA has worked throughout the year. Nobody said it would be easy, but I feel this publication is a reflection of our entire chapter's commitment. I would like to thank everyone that has helped and supported us during this process and I sincerely hope that you will enjoy reading our journal.



ANNA WHATMAN

CO-PRESIDENT

Being involved in RyeTAGA has been something that I enjoyed throughout each year at GCM. It takes a great deal of hard work from multiple individuals to create our journal each year—from fundraising, to design, to production. Everyone must have a hand and must be dedicated to create something that we can all be proud of. This position has required a great deal of work but I am proud of myself, and everyone involved for what we have accomplished.

JACKY MAO

CREATIVE DIRECTOR

Being involved with RyeTAGA was a rewarding experience that put my four years of skills and knowledge to the test. I had the opportunity to establish the creative direction for this year's journal. It was an honour working with a team of dedicated and talented individuals who put a lot time and hard work into making this journal possible. I would also like to express my thanks to the faculty and our sponsors who provided us with the support, resources and funding for this project.

ANDREW WONG

MULTIMEDIA DIRECTOR

Traditionally, the Multimedia Director's main responsibilities were the RyeTAGA website and the filming/editing of a production video to showcase the work behind this journal. With the proliferation of e-readers and tablets, I felt it was important to also explore the creation of a digital publication optimized for touch-based devices. None of this would have been possible without a dedicated team. Thank you to the multimedia team for all your hard work on the e-journal.

EILEEN CHIANG

EDITORIAL/PRODUCTION DIRECTOR

Going into my fourth and final year of both GCM and RyeTAGA, I wanted to accomplish something special. The editorial/production role was a new executive position this year so I had no idea what to expect. Fortunately, I had plenty of help in editing and reviewing student research papers and marketing material, as well as planning and producing the journal. This was a great learning experience that I know will result in an outstanding journal.

EMILY KUCHTA

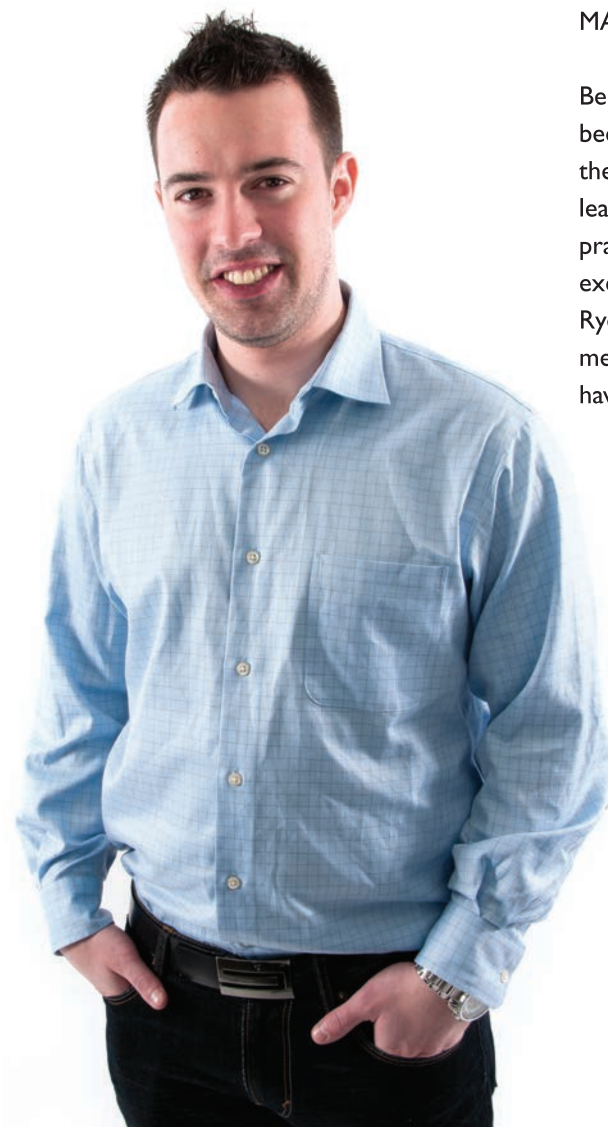
FINANCE DIRECTOR

This is my last year at Ryerson, and though the work has been tough, the time has flown by. Working as the financial director for RyeTAGA, I keep a close eye on monetary matters and completed any secretarial work. I'm looking forward to entering our journal into this year's competition. A lot of hard work and dedication has been put into our entry, and the final outcome is something I, along with my team members, are truly proud of.

KANEESHA SERJUE

FUNDRAISING DIRECTOR

This year, my responsibilities were to come up with creative ideas to obtain funding for this years journal. Working with a team of students we were able to host three successful bake sales, a student pub night as well as providing pancake breakfast for the students. I applied for this specific position because I enjoy coordinating events and I am very thankful to be apart of this experience.



BRIAN BAKO
MARKETING DIRECTOR

Being a part of the RyeTAGA team has been a great opportunity for me to take the theory and concepts that I have learned in class and use them within a practical setting. This year has been very exciting to follow the direction where RyeTAGA is going and I hope that the members involved within RyeTAGA have learned as much as I have.

MARTIN HABEKOST, DR. RER. NAT.

RYERSON TAGA STUDENT CHAPTER ADVISOR

COLOPHON

This journal was created by the students of Ryerson University Student Chapter of the Technical Association of the Graphic Arts. RyeTAGA team members were an active part of every step of production. Industry assistance, facilities and equipment were employed during production where indicated below.

COVER

- Bebas Neue Typeface
- Kromekote C1S 12pt Cover Stock
- Base artwork printed with Heidelberg PM74 Offset Press at Ryerson University, Toronto, Canada.
- CTI Black 29°C Thermochromic Ink printed with Sias Simple screen press at Flash Reproductions, Mississauga, Canada.

TEXT

- Gill Sans Typeface
- Supreme Silk 80lb Text Stock
- Printed with Xerox DocuColor 7000 Digital Press at Ryerson University, Toronto, Canada.

BINDING & FINISHING

- 30" Stahl Folder at RP Graphics, Mississauga, Canada.
- Polar 78 Cutter, Heidelberg 137XT & 76 Cutter
- Perfect-bound with Heidelberg Perfect Binder at RP Graphics, Mississauga, Canada.

ADDITIONAL SOFTWARE & EQUIPMENT USED

- Microsoft Word 2011
- Adobe Creative Suite 5
- Kodak Preps 5
- Kodak Prinergy
- EFI Fiery
- Nikon D300 & D90
- Kodak Magnus 400 Platemaker

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FUJIFILM CANADA

RSU STUDENTS' UNION

FINAL ACKNOWLEDGEMENT

The RyeTAGA team would like to thank everyone that has helped and supported us during this entire process. Without the generosity, guidance, time and gracious support of these individuals our team would not have been able to produce this year's journal. We would like to especially thank our faculty advisor Dr. Martin Habekost as well as Ian Baitz, Peter Roehrig, Mohammed Khaled, Scott Millward, Jason Lisi, Dr. Richard Adams, Taras Karpiuk, Marietta Canlas, Rich Pauptit, David Gallant, Randy Irving, Elias Saswirsky, George Mazzaferro, Melanie Edwards, Burl Mathias, Ralph Pike, Lou Bekyarovich, Geoff Barker, Mary Tran, Meg Matera, …. and all those whom we may have missed.