RYETAGA

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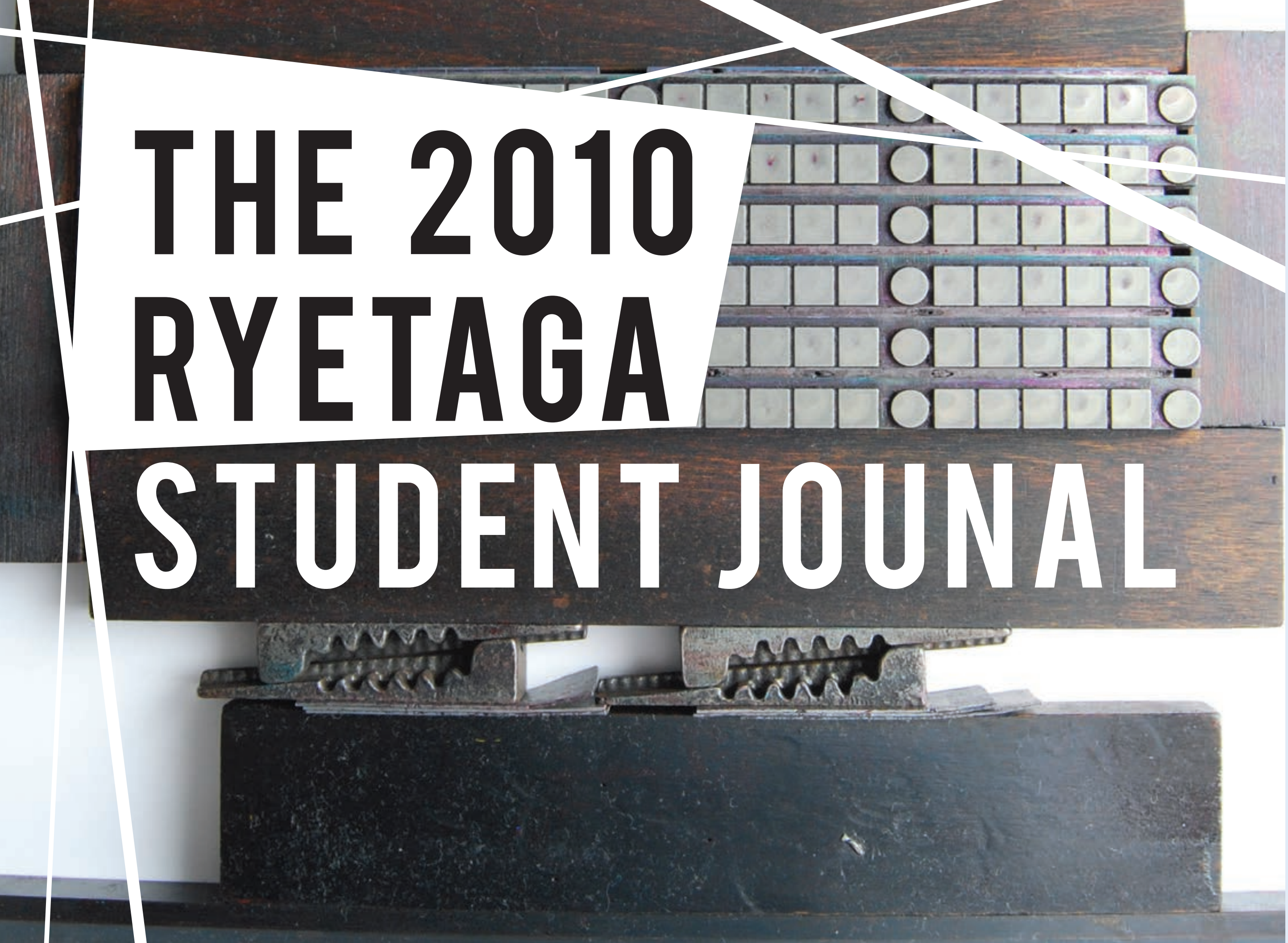
THE 2010 RYETAGA STUDENT JOUNAL



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LETTER FROM DR. MARTIN HABEKOST

Dear ryeTAGA students,

It is unbelievable that another year has passed and the next TAGA conference is about to take place in San Diego in sunny California. This is now my 4th year as the faculty advisor and it is always fascinating to see all of the ideas that you, the students, have in regards to the publication of the student journal.

Over the last few years the ryeTAGA student chapter has grown from a few devoted students from mainly one year of the Graphic Communications Management program to a group of students that encompasses every year. This also enables some to attend more than one conference. You have the chance to meet some students from other TAGA student chapters again and of course make new friends.

The last year saw many activities of the ryeTAGA student chapter. They span from arranging to get quite some paper donated for the journal production to silk screening T-shirts used for fundraising; and earmarking some events to having an industry professional come twice to the school to give a talk on how to network, how to talk to people from the industry and lose the fear on how to do so.

You were also quite successful in securing funds for this year's conference to the point that the flight costs for all students were covered. All these activities show that the nature of the ryeTAGA student chapter has changed a lot, and you all know what it takes to get a good student journal together and have a successful conference.

Good luck with the competition and all the best to you,

Martin Habekost, Dr. rer. nat.
ryeTAGA student chapter advisor
www.ryetaga.com

LETTER FROM THE CO-PRESIDENTS

As another year closes we are provided with a moment of reflection that reminds us of the opportunities and experiences that this journal production has brought forward. The ryeTAGA team of 2010 has been more than wonderful throughout this process and we truly appreciate every individual who has contributed.

The planning of this journal began in the summer of 2009 when we first started brainstorming the general theme. The theme was developed to represent a technical idea with a creative flare. By incorporating symbols and elements from around the press room, we took an artistic approach to printing and fully displaying all that was involved in the journal production process. Through these activities, our whole team worked hard all year to ensure that the spirit of TAGA was shared within our Ryerson community.

These pages represent the hard work of our most brilliant students, our wonderful creative team and the dedication of our executive team who were all crucial parts to putting this successful journal together. Please enjoy the following pages and make sure to check out our multimedia DVD. We look forward to attending the 2010 TAGA Conference in San Diego, California!

Great job team!

Marta Wajda & Holley Chiborak
ryeTAGA Co-presidents 2009-2010

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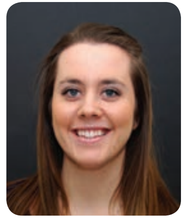

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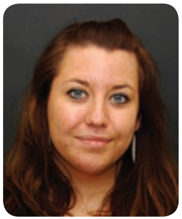

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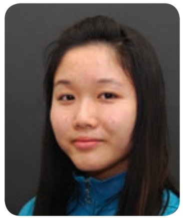

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EXAMINING MICROPRINTING SECURITY

MICHELLE AN
JAMIE MACE
MARTA WAJDA

ABSTRACT

The purpose of this test is to determine which printing method, traditional offset or newer digital, is ultimate for reproducing microprint lines and text, such as that used for security printing purposes. To accomplish this several variables were considered, including printing methods (Heidelberg offset and Xerox digital) and coated versus uncoated substrates.

Our findings indicate that both printing methods have advantages as well as disadvantages. We discovered that digital printing was able to produce smaller text sizes (0.20 pt). However, offset printing better produced smaller curved lines (0.01 pt), straight lines (0.03 pt) and clearer

starbursts. Both coated and uncoated papers produced similar results using the digital method. Nevertheless, our offset coated proofs were able to produce finer curved lines than uncoated paper (0.01 pt versus 0.10 pt). The starbursts were also produced with more pronounced detail on coated paper.

INTRODUCTION

This test is significant because it investigates the ability of most offset and digital presses to reproduce the microprinting features seen on genuine and authentic products, such as currency, pharmaceutical packaging, personal identifications, certificates, cheques and more. Today, "the level of counterfeiting is approximately 5-10% of world trade, which represents a direct revenue loss of 400-1,000 billion dollars world wide" (Dispoto, 2009). In addition, recent advancements in the quality of digital printing have endangered product authenticity and brand image.

Our objective is to discover the anti-counterfeiting properties of microprinting, a commonly used technique that has many physical limitations. We will do this by running a specially designed test form on accessible digital and offset presses to see the limitations encountered using the various methods and materials.

We aim to find out how well microprinting holds up as an anti-counterfeiting technique in today's community as we attempt to reproduce fine lines and texts of varying sizes and styles.

DEFINITION

Micropringting: “Type printed so small that it appears to be a solid line and can be read under magnification. When copied or scanned, the microprint message becomes unreadable” (MicroPrinting, n.d.).

TEST PRINCIPLE

The principle of this test is to discover how different printing methods affect the reproducibility of line matter and text. We accomplished this by creating a 12 x 18 in. test form with a variety of different line forms (straight, curved, diagonal) and widths (0.001 pt to 9.00 pt), text sizes (9.00 pt to 0.001 pt), and different sized starbursts. We printed these test forms first on coated paper using an offset method, then on uncoated paper using the same offset method. We then printed the test forms on the same papers using a digital method. We compared the results and drew conclusions regarding which method would be most suitable for microprinting purposes.

This test was designed to simulate practices involved in microprinting for security purposes. We tried to ensure accuracy by using the same papers on both presses, having a trained professional with us while operating the presses, and by creating a test form with a variety of different line and text variables present.

There are many weaknesses in this test's design that will be further discussed in detail.

MATERIALS TESTED

- Substrates:
  - Supreme Gloss Text (19 x 25 in.), 100 M, 100 lb, 148 g/m^2
  - Roland Opaque 30 (19 x 25 in.), 80 M, 80 lb, 118 g/m^2
- Hostmann-Steinberg HIT Process Black, Batch #5100761, 8 QK 1765-V
- Xerox DocuColor black dry ink/toner

EQUIPMENT USED

- Adobe Illustrator CS3
- Adobe Distiller 7.0
- AGFA ApogeeX 3.5
- AGFA Sherpa 24 Proofer, SN. G843FLJQPQ
- Fiery EXP8000 RIP
  - (Used with Xerox DocuColor)
  - Server: 4BQCI3HT
  - System version: 3.0
- Kodak CTP Magnus 400, Serial #M412141
- Heidelberg Printmaster 74
  - Power supply: 200 Amps, 200 Volts
  - Max sheet size: 53 x 74 cm
  - Min sheet size: 21 x 28 cm
  - Max sheet thickness: 0.60 mm
- Xerox DocuColor 7000 AP
  - Power supply: 240 Amps
  - 208/220/230/240 Volts
  - Max sheet size: 12 x 18 in.

PROCEDURES

1. Create a test form in Adobe Illustrator investigating various microprinting features and techniques such as line and text size, serif and sans-serif fonts, etc., and using one solid process colour. Make sure the design fits both press sizes (i.e. 12 x 18 in.).
2. Save the file as a PostScript file, then use Distiller to create a high resolution PDF.
3. Send the PDF to the AGFA Apogee X workflow, including a path to the AGFA Sherpa 24 Proofer and the Kodak CTP Magnus 400.
4. Obtain the proof and plate, and run the job on the Heidelberg Printmaster 74 using a coated and uncoated paper stock, and only one ink (black).
5. Run the same PDF job file on the Xerox DocuColor 7000 AP using the same coated and uncoated papers.
6. Compare the printed samples from both presses and both paper stocks.

LIMITATIONS TO EXPERIMENT

When conducting this experiment, we were faced with many variables, which affected the final outcome. Firstly, neither the papers nor the inks that we used would have been the same used for microprinting purposes.

The capabilities of our M400 platesetter were inadequate for engraving fine hairlines and small type; more sophisticated equipment is used when microprinting.

Software limitations were also a factor. For instance, when making our test form (*Figure 1.1*) in Adobe Illustrator CS3, the smallest line stroke that Illustrator was capable of rendering was 0.001 pt, and the smallest text was 0.10 pt. However, when the file was distilled and turned into a PDF, all type smaller than 0.90 pt was dropped, and the straight line strokes smaller than 0.10 pt seemed to have been bumped up to 0.30 pt upon visual inspection. Also, when using AGFA Apogee X, the finest LPI we could set for platesetting purposes was 250. A more sophisticated workflow program in situations involving microprint, again, would surpass this. In Distiller, the many options available would also have an effect on PDF output. We ensured that "Compress Text and Line Art" was always unchecked and that "Do Not Downsample" was checked.

Also, since we did not include every possible option for text and line sizes, it may be that our smallest line size of 0.03 pt may actually be able to be printed even smaller; 0.02 pt may be possible, for instance.

Among some of the techniques tested in our form were starbursts, lines at an angle of 62 degrees, serif versus sans-serif fonts and curved lines. None of the objects were obtained from industry experts as our test is experimenting the limitations people encounter when attempting to counterfeit a microprinting feature. For example, the starbursts

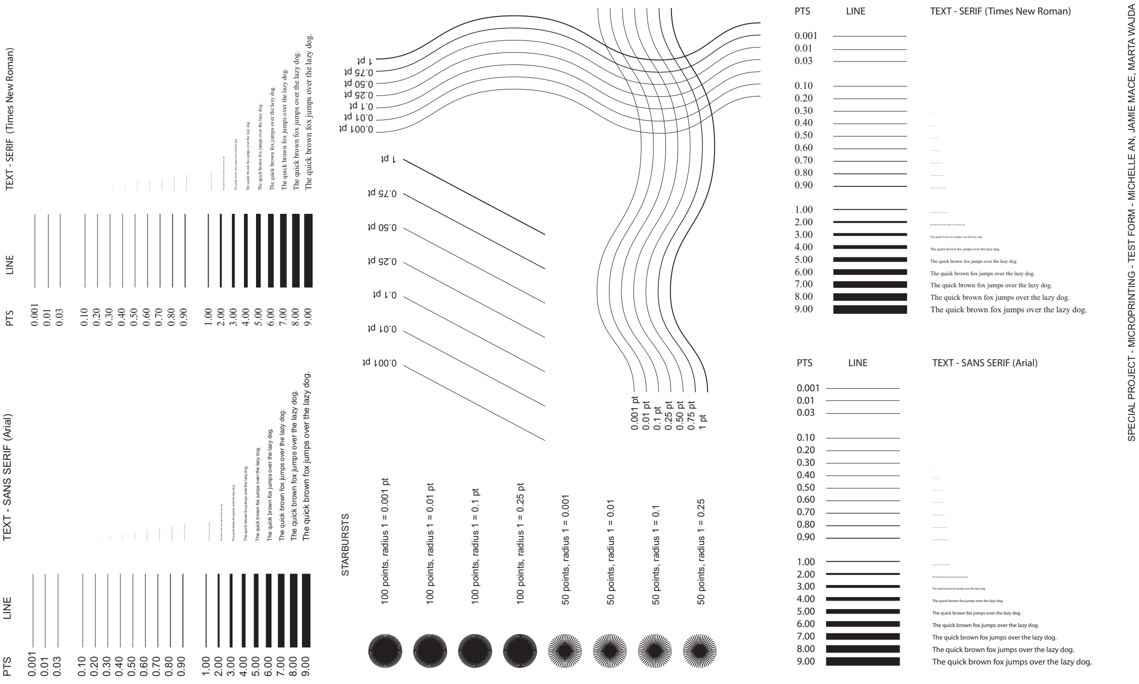

Figure 1.1 — Sample test form.

were created by hand using varying strokes and sizes to discover the potential accuracy and fineness of our printed samples.

RESULTS

When studying our two offset proofs, we noticed some obvious differences between our coated and uncoated samples. To begin, our coated paper was able to produce finer curved lines than uncoated paper (0.01 pt versus 0.10 pt). The starbursts also were produced with more pronounced detail on coated paper.

However, there were also many similarities between the two prints. Both papers were able to produce fine hairlines (0.03 pt). This was expected due to the resolution the RIP employed: 1/2400 dpi x 72 pt/in. = 0.03 in. Our uncoated paper's 0.03 pt hairlines were slightly harder to see. The curved lines proved difficult to reproduce on both samples; being easiest to see on the more vertical and horizontal line sections, and more difficult to see on the diagonal sections. Both samples also were able to produce text (both serif and sans-serif) at a size of 1.00 pt, although this text was only visible with a loupe.

When comparing our offset proofs with our digital proofs, we noticed that our text samples could be reproduced at much smaller sizes (0.20 pt for both coated and uncoated) using the digital method. However, our curved line samples could only be reproduced at 0.10 pt for both coated and uncoated, as opposed to offset's 0.01 pt. Also, the digital method was only able to reproduce horizontal lines at 0.10

pt, as opposed to offset's 0.03 pt. With regards to the starbursts, we feel that they reproduced best using the offset method as offset yielded the most even lines with the smallest inner core.

DISCUSSION

According to our results and research, there are many factors involved in various security methods, including microprinting. One must consider the various variables involved in each technique. For example, printing processes and other factors, such as ink, influence the outcome of a printed product and its end-use.

Many security-printing techniques are implemented as good deterrent methods for anti-counterfeiting. Authorities are often encouraged to use a minimum of three different methods and devices for each security document (Adams & Warner, 2005). However, security features are not only limited to printed attributes as a means of security (National Research Council of the National Academics [NRCNA], 2007). There are many other techniques that are utilized as different forms of security tactics that make it even more difficult for counterfeiters to reproduce these documents at an adequate quality. Specific security techniques can include other features, such as: durable or special substrates, security strips, or watermarks (only visible by transmitted light that prevents photocopying efforts) (NRCNA, 2007). The implementation of printed features also includes characteristics such as: colour-shifting inks, enlarged, off-centered portraits, extensive and elaborate patterns, as well as fine lines and microprint (NRCNA, 2007) that are difficult to reproduce on typical printing technology and equipment. For this particular test, microprint was the main, along with detailed tests.

Microprint is essentially microscopic letters that possess characteristics, which include character heights that range between values of 15-150**μ** or 0.5-6.0 mils (Adams & Warner, 2005). When observed at a normal viewing distance, a line of microtext can easily give the illusion of a simple rule or frame (Adams & Warner, 2005). It is especially difficult to reproduce microprint through photocopying methods because of the miniscule and miniature size of microtext (Adams & Warner, 2005). For instance, cheques often consist of a signature line that is actually used as a strategic security tactic. This particular line is a line of microprinted text (Adams & Warner, 2005). For other documents, microprint can also be incorporated within images and patterns (Adams & Warner, 2005). Many people do not know that microprint is present or even existent, nor do they know where to find it. Typically microprint is invisible to the untrained eye. However, it is not impossible to see. Microprint can be seen with the use of a magnification tool and sometimes may be viewable by the naked eye (Adams & Warner, 2005).

Microprint is an incorporation of text, images or various patterns that must be printed with exact specifications and dimensions. These measurements and specifications must fall within the exact micron and submicron measurements; possibly even tens of nanometers, which result in extremely smooth and sleek surfaces (Adams & Warner, 2005).

Nanoprinting is a segment of microprint that requires extremely high resolution (Adams & Warner, 2005). These levels are so high that even the best and more sophisticated commercial technologies are unable to simulate true microprint. It also incorporates many types of ink that can include organic molecular materials, hybrid organic/inorganic nano particles, biomaterials and polymers (Adams & Warner, 2005). The combination of these inks and extreme levels of resolution allow for increased security and can be produced inexpensively (Adams & Warner, 2005).

For more skillful counterfeiters, it is possible to simply scan and reproduce bank notes and achieve correct colour matches, thus posing a significant threat in illegal duplications (NRCNA, 2007). Typically, digital counterfeiting involves three crucial steps, 1) Capturing the image; 2) Processing the image; and 3) Printing the image. Oftentimes, scanning bank notes on a 3,000 pixel per inch scanning bed, requires approximately 7,500 x 18,000 pixels (NRCNA, 2007).

There are several quality control procedures that are followed before any superior reproduction is created. However, the skill level of the counterfeiter affects all this. The procedures are as follows (NRCNA, 2007):

- Removing artifacts that are scanned
- Brightness/contrast adjustments
- Colour adjustments
- Filters for sharper and enhanced images (USM)
- Rotating images if required

Quality programs, such as Adobe's Creative Suites are extremely accessible, therefore posing as a larger threat. As well, as technology continues to evolve, issues such as "contrast adjustments, USM, line width control and smoothing" can be adjusted with ease (NRCNA, 2007).

Historically, offset printing methods are viewed as a superior printing process in comparison with digital print. However, digital printing processes have greatly improved, and as a result the quality differences between the two methods are quite similar (Offset Printing vs. Digital Printing, n.d.).

RECOMMENDATIONS

PRINTABILITY

In order to have text reproduce properly for everyday printing purposes and optical readability, it is recommended by many companies, such as NC Label, that font size be no smaller than 4 pt (6 pt for reverse text). In addition, minimum line thickness should be no less than 0.5 pt (NC Label: Prepress Requirements, 2008). Care should be taken to ensure that if printing using an offset method, the type size selected does not exceed the platesetter's capabilities. If it does, these lines of type may be dropped from the plate and thus not reproduce.

If using an offset method, we recommend using coated paper to achieve finer lines in the printed result. Should the need arise for finer, smaller printing, as such for security purposes, microprinting is suggested. To ensure a proper printing environment, all variables mentioned in our limitations need to be considered in the workflow process of the product.

RUNABILITY

Depending on the printing method used, it is recommended to ensure proper substrates, inks, and other variables are considered for proper runability. For example, our digital run used offset paper which is not recommended on digital presses, possibly creating static electricity, which may interfere with the final printed result and running capabilities.

END USE APPLICATION

In all, microprinting should only be used in situations requiring high security, due to the extreme expense of proper microprinting technology, the techniques involved, and legal issues that may arise.

We recommend that if microprinting is desired for text, it may be best to use a digital printing method. However, if hairlines are desired, an offset method may yield better results for both curved as well as straight lines. In addition, the run length of the job may influence the printing method used. Evidently, products such as currency are not suitable for digital runs. In fact, intaglio is the preferred printing method (Pivotal Resources, 2004).

Finally, for end use purposes, substrate caliper needs to be considered when using different printing methods, as some presses have specific structural limitations.

IMPORTANCE OF SECURITY PRINTING

Due to the rapid and ever-changing innovation of advanced digital printing and photographic technologies, it has provided greater opportunities and easier ability to replicate any dimensional image (NRCNA, 2007). Counterfeiting has existed since the creation of money, however it requires both technical and artistic skills along with access to the proper resources (NRCNA, 2007). The ability to duplicate images can be accomplished effortlessly by "low-skilled amateurs" (NRCNA, 2007). Consequently, this has provided counterfeiters with the right set of circumstances to forge or imitate banknotes and other legal or high-security documents. Therefore, as a result, it is extremely crucial to maintain confidentiality in implemented techniques, possess special equipment (only available to the government and their partnering organizations), as well as continuously applying research and development activities to update security technologies and techniques. Furthermore, these practices should be far more advanced than commercial purposes in order to overcome or reduce possible chances of threat. Therefore, the effectiveness of security features must last as long as the document's complete life cycle, if not, more (NRCNA, 2007).

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THE EFFECT OF INK TACK IN FOUR-COLOUR PRINTING

REBECCA DYKOPF
GLORIA LEUNG
PAULINE WUT

ABSTRACT

In this test, tack graded inks have been tested for their ability to trap overprint colours. A set of inks with ascending and descending tack values were tested to compare the different results on coated and uncoated substrates. Tack-reduced inks were created by mixing the regular inks with linseed oil. This allowed both samples to be printed using a CMY colour sequence but with opposite tack order.

The purpose of this test was to discover how much of an influence tack has on multicolour printing, specifically colour reproduction. Preucil's trap equation and colour hexagons were used to determine the outcome of this experiment.

The results of this test showed that the descending tack order inks resulted in slightly better trap values on both coated and uncoated paper. The colour gamut produced by the colour hexagons also showed a slightly larger gamut for the descending tack inks.

It was found that there are many factors which influence tack and trap. Resins and additives in ink influence its original tack value. On press, tack increases as speed increases, and tack increases as ink film thickness is lowered. As temperature increases, tack decreases and press design will influence how well colours trap.

There are also many factors which influence colour sequence other than tack values, such as colour reproduction, moiré, and transparency. When trying to solve these problems tack should still be taken into consideration when moving colours on press. One solution which allows for colours to be rearranged without changing tack sequence is to use quickset inks.

A possible source of error for this test was machine malfunction or inaccuracy as well as human error such as measuring or cleaning the equipment between uses.

INTRODUCTION

For this research report, we conducted an experiment testing the difference between printing inks in an ascending and descending tack order. Tack is the resistance of an ink to splitting between two surfaces, or the "stickiness" of an ink (Eldred & Scarlett, 1990). On a printing press, tack is most important at the printing nip where the ink is being transferred from the blanket cylinder to the substrate. Tack most directly influences the printing process colours by affecting trapping, whether or not paper will pick, and is partially responsible for how sharp the printed image will be (DeJidas & Destree, 1995).

When a layer of ink is printed on top of previously printed ink it will not be transferred as completely as if it were being printed directly onto the substrate. This is the inevitable problem of trapping, which is acknowledged and accepted within certain tolerances. Trap is measured as the ratio of the second-down ink film on a previously printed ink film to the second-down ink film on white paper alone. This measurement is taken by measuring the density of an overprint colour (i.e. red), subtracting any portion of the second-down colour which may be present in the first-down colour (yellow within magenta), and dividing it by the measurement of the second-down colour on its own (yellow) to get a percentage (Breede, 1999). Ideally the result should be 100%, but as stated above this is not possible (see *Figure 2.1*). Normally acceptable values for wet-on-wet trapping are between 75%-95% (Field, 1999). The lower this number, the more the overprint colour will tint towards the colour of the first-down ink.

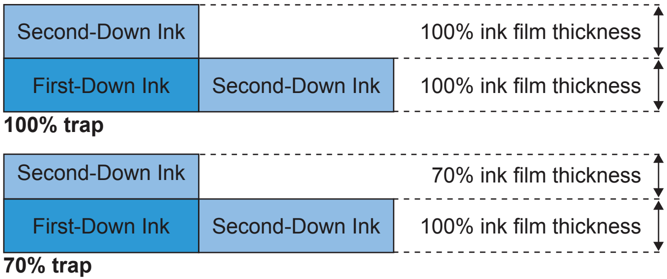


Figure 2.1 - Measuring trap
(Breede, 1999)

Tack of inks must be taken into consideration to produce the best trapping results in multicolour printing and therefore the best colour. Is it commonly stated that trapping will be best when the first-down ink has the highest tack value and the succeeding colours have progressively lower tack values (Eldred, 2001). This is printing with a descending tack order.

The purpose of this test is to compare trapping inks which have a descending tack order and a set with an ascending tack order. Expected educational gains from this test include determining how much of a difference will be produced from printing in the non-recommended tack order compared to the regular inks, as well as a study on the various influences on tack and trapping. This test is significant because printers sometimes try to switch the order or tacks of their inks to produce better colour quality and solve printing problems. How important tack order is to good print quality and how to properly change colour sequence should be determined before this is attempted.

Some of the topics which will be discussed in this paper include the printing process' effect on tack, printing problems linked to tack, and the impact of colour sequence on print quality.

DEFINITIONS AND EQUATIONS

Crystallization: The ability to print one ink film on top of a dried ink film that has hardened, repelling ink (PrintWiki, 2008).

Dry Trapping: Describes the adhesion abilities of a wet ink film over a dried ink film (Lawler, 1995).

Picking: The force of the printed ink film exceeding the paper's resistance, causing rupturing or deformation of the surface of a substrate (PrintWiki, 2008).

Trap:

$$Trap = \frac{(Density\ of\ two\text{-}colour\ overprint - Density\ of\ first\text{-}down\ ink)}{Density\ of\ second\text{-}down\ ink}$$

Where density is measured through the complementary filter of the second-down colour (Breed, 1999).

Wet Trapping: Describes the adhesion abilities of the overprint ink when it is printed wet-on-wet (Lawler, 1995).

TESTING PRINCIPLE

Both tack and trap were measured in this test. Tack was measured using an inkometer and a defined volume of ink. The inkometer measures the force required to split an ink film at the roller nip while running at a specified speed, replicating printing conditions. The inkometer is a three-roller model of an inking unit of a press. One brass and two rubber rollers are used. The brass roller is set to a specific temperature, keeping the ink temperature constant. One rubber roller acts as the vibrator, distributing ink evenly, and the other is a rider roller. A counterweight is attached to a bar connected to the rider roller, which measures the force needed to keep the rider roller steady. This roller with the lever is attached to a sensor that is pressed as the pressure increases (Eldred and Scarlett, 1990). This process replicates the tack value at a printing nip.

In order to measure trap, three process colours were printed using the Universal Testprinter. Special blanket cylinders were created so that all three overprint colours (RGB) and primary colours (CMY) could be printed on one strip of paper. The blanket cylinders were inked using the Universal Inking Unit and then moved to their positions on the Testprinter. The Testprinter simulates blanket-to-blanket printing. The Testprinter was used because it has the ability to print all three colours in one pass with precise settings.

Ink film thicknesses were determined for each substrate based on GRACoL standard target densities. Once a sample was printed, a densitometer was used to read the densities of the primary and overprint colours. These were used with Preucil's equation to find trap values as well as used to produce colour hexagons for each print. More than one print was produced for each set of inks on the same substrate so that any possible problems or outliers would be identifiable and not cause a skew in our results.

MATERIALS TESTED

PAPER

- **Coated:** Domtar Luna Gloss Book 100#, 8.5 x 11 in., 20 M, 100508001
- **Uncoated:** Cougar Opaque 70/28#, 8.5 x 11 in., 14 M

OTHER

- Recochem: Boiled Linseed Oil

INK

- See *Table 2.1*.

EQUIPMENT USED

- Inkometer Pipette
- Electronic Inkometer, Thwing-Albert Instrument Co., Serial #3716, Model #101-A
- R710 Colour Reflection Densitometer, IHARA Electronic Co. Ltd, Serial #57313
- Testprinter Universal Testprinter
- Universal Inking Unit
- Three blanket cylinders with overprint patterns cut out

	Cyan	Magenta	Yellow
Hostmann-Steinberg-Huber Group Sheetfed Offset + High Gloss 1 Stay Open 42 F 10 RL-V	Reflecta Cyan 5.5 lb, 2.5 kg. SAP: 29 3583-0101 Batch #8ON17808 PRODN: 102955263	Reflecta Magenta 5.5 lb, 2.5 kg. SAP: 29 3581-0101 Batch #8ON17604 PRODN: 102951956	Reflecta Yellow 5.5 lb, 2.5 kg. SAP: 29 3529-0101 Batch #8ON18024 PRODN: 102957237
Sun Chemical Tack Altered Inks	Batch #7100PC1076 AAOSF5222704: FCLT Stay Open Process: C229	Batch #7100PD1846 NWNSF4220369: Stay Open Low Tack MA: C229	Batch #7100PD2444 NWNSF2220370: Stay Open Low Tack YE: C229
Sapphira SF Advance	Process cyan C 2000 Batch #21F08020	Process magenta M 2001 Batch #21F128062	Process yellow Y 1000 Batch #21F108013
Sun Chemical Vegetable Inks	B6815 (90805712) Offset Ecolith Vegetable Process Cyan Batch #48547028, 1 kg	P6815 (90805631) Offset Ecolith Vegetable Process Magenta Batch #48512027, 1 kg	G6815 (90805633) Offset Ecolith Vegetable Process Yellow Batch #39975222, 1 kg

Table 2.1 — Inks tested.

PROCEDURES

There were two main components to completing this test. The first was attaining the tack values of the inks being used and creating inks with different tack values. The second was printing the overprints. The procedure has been divided into these two sections.

TO ATTAIN TACK VALUES

1. Switch on the Inkometer, start at low speed, then switch to high.
2. With the speed at 400 RPM and the temperature at 90˚F, zero the machine by turning the black dial.
3. Switch back to low speed and turn 'drive' off.
4. Place 1.2 cc of ink (cyan, magenta, or yellow) on the center of the rollers.
5. Turn the rollers by hand to avoid misting.
6. Press the 'drive' button to restart the machine.
7. Record the gram-meters after the first minute and every 30 seconds until 10 minutes has been reached.
8. Switch back to low speed and stop the machine by pressing the 'drive' button.
9. Repeat steps 1 through 8 with the other two inks from the same set.

   Note: It must be ensured that the machine has been thoroughly cleaned with all solvent removed when measuring a new ink.
10. Once a set of inks has been obtained which has a CMY descending tack order, alter the tack of the magenta ink by mixing 15 g of ink with

approximately 0.25-0.75 mL of linseed oil.

11. Test this ink as described in steps 1 through 8.
12. If the tack is not lower than that of the original yellow ink, add slightly more linseed oil to a new 15 g of ink and test it again to receive a lower tack value.
13. Once the magenta is found with a tack value which is less than the yellow ink, mix more of it using the same ink to linseed oil ratio.
14. Repeat steps 10 through 13 trying to get the tack of the cyan ink to be lower than the tack reduced magenta ink starting with about 0.5-1.25 mL of linseed oil.

    Note: Never fully turn off the machine unless you are done working with it; turn the machine *On/Off* using the 'drive' button.

TO PRINT OVERPRINTS USING THE UNIVERSAL TESTPRINTER

15. Measure one of the unaltered inks using a Prüfbau pipette and place it on the metering roller of the Universal inking unit.
16. Turn on the machine at 100 m/min and place the blanket roller in contact with the black metering roller.
17. Let it run for 2 minutes to ensure uniform ink coverage before stopping.
18. Tape a strip of uncoated paper onto the blanket section of the carrier on the Universal Testprinter.
19. Place the blanket roller onto the appropriate station of the Universal Testprinter (Station 2: cyan, Station 3: magenta, Station 4: yellow).

20. Set the Testprinter to the following settings:
    - Liquifeed, Printack, and Continuous Printing: *Off*
    - Station 1: *Off*
    - Stations 2, 3, and 4: *On*
        - Accelerated and Multiple Offset: *Off*
        - Start offset: 40
        - Printlength: 240
        - Pressure: 110
        - Speed: 0.5
        - Number of prints: 1
        - Printing interval: 0
        - Pre-delay: 0
21. Run the Testprinter.
22. Allow the sample to dry for 5 minutes.
23. Use a densitometer to check the density.

    Note: Ensure the same densitometer is used each time to reduce variations.
24. If the density does not fall within the specified aim-points repeat steps 1-9 with more or less ink as required.
25. Repeat steps 1-10 for the other two inks in the set, recording the amount of ink needed to produce the correct density.
26. Repeat steps 1-8 with all 3 inks using the amount of ink needed to produce the correct densities.
27. Use the densitometer to obtain all of the density readings for CMY, RGB, and overprint patches.
28. Repeat steps 1-13, replacing the cyan and magenta with the tack-reduced cyan and magenta, running it on coated and uncoated paper.

RESULTS

INKOMETER RESULTS

- Please see *Table 2.2*.

TESTPRINTER RESULTS

- Please see *Tables 2.3* and *2.4*.
- Please see *Figures 2.3* to *2.12*.

DISCUSSION

The results show that slightly better trap was produced using the descending set of inks than the set with ascending trap. This can be determined from the average trap values, including a comparison of the colour hexagons. One important value which can be seen when comparing the colour hexagons is that the cyan, magenta, and yellow values produced by the tack-reduced inks had very similar placements compared to the regular inks. This shows that it truly was the trapping which caused the different colour gamuts and not the different inks. In all samples both blue and green were closer to cyan. As well, red had nearly perfect hue even while magenta was very far off. When visually analyzing the results no obvious difference was noticed between the ascending and descending tack order samples. This is not surprising since the trap average did not show a very large difference between the ascending and descending samples. In general, the coated samples showed much more vivid colours, which is supported by the larger gamuts produced in their colour hexagons.

Sun Chemical Offset Ecolith Vegetable Pro Cyan		Sun Chemical Offset Ecolith Vegetable Pro Magenta		Sun Chemical Offset Ecolith Vegetable Pro Yellow		Sun Chemical Offset Ecolith Vegetable Pro Cyan With Linseed Oil		Sun Chemical Offset Ecolith Vegetable Pro Magenta With Linseed Oil	
Time	Tack	Time	Tack	Time	Tack	Time	Tack	Time	Tack
1	10.4	1	7.4	1	8.2	1	6.0	1	6.2
1.5	10.6	1.5	7.6	1.5	8.0	1.5	6.0	1.5	6.3
2	10.3	2	7.7	2	7.9	2	6.1	2	6.4
2.5	10.1	2.5	7.5	2.5	7.9	2.5	6.1	2.5	6.5
3	10.1	3	7.7	3	7.9	3	6.2	3	6.5
3.5	10.0	3.5	7.6	3.5	7.8	3.5	6.2	3.5	6.6
4	9.9	4	7.8	4	7.9	4	6.3	4	6.8
4.5	9.9	4.5	8.1	4.5	7.9	4.5	6.5	4.5	6.9
5	10.0	5	8.1	5	8.0	5	6.5	5	7.0
5.5	10.0	5.5	8.0	5.5	8.0	5.5	6.5	5.5	7.0
6	10.1	6	8.1	6	8.0	6	6.6	6	7.1
6.5	10.1	6.5	8.2	6.5	8.1	6.5	6.7	6.5	7.2
7	10.2	7	8.3	7	8.1	7	6.8	7	7.3
7.5	10.1	7.5	8.4	7.5	8.1	7.5	7.0	7.5	7.4
8	10.2	8	8.4	8	8.2	8	7.1	8	7.5
8.5	10.3	8.5	8.5	8.5	8.2	8.5	7.3	8.5	7.5
9	10.3	9	8.7	9	8.2	9	7.1	9	7.6
9.5	10.5	9.5	8.4	9.5	8.2	9.5	7.3	9.5	7.7
10	10.5	10	8.5	10	8.3	10	7.3	10	7.7

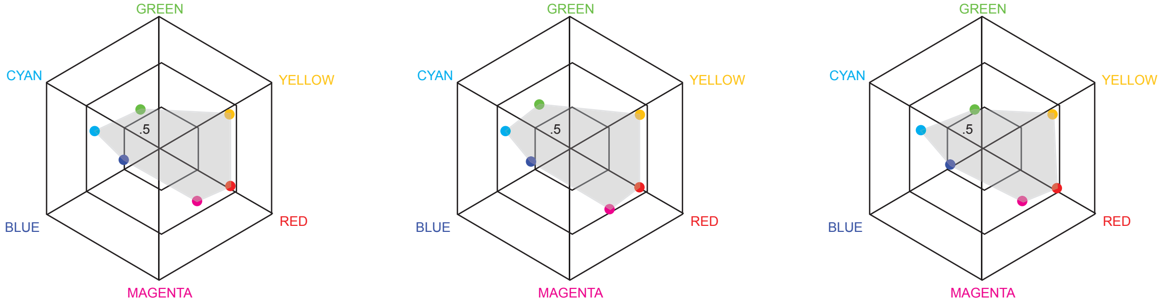
Table 2.2 — Inkometer results; Sun Chemical Ecolith Vegetable Pro Ink
Note: Time is recorded in minutes, and tack is recorded in gram-metres at 400 RPM and 90°F.
Note: 1 mL and 0.6 mL of linseed oil were added to 15 g of the Cyan and Magenta inks respectively.

	Descending Tack Order			Ascending Tack Order		
	R	G	B	R	G	B
Sample 1	50.54%	75.27%	53.27%	46.81%	73.40%	58.25%
Sample 2	46.74%	68.48%	48.78%	47.83%	71.74%	57.01%
Sample 3	50.00%	83.70%	71.30%	42.11%	74.74%	56.25%
Average	49.09%	75.81%	57.79%	45.58%	73.29%	57.17%

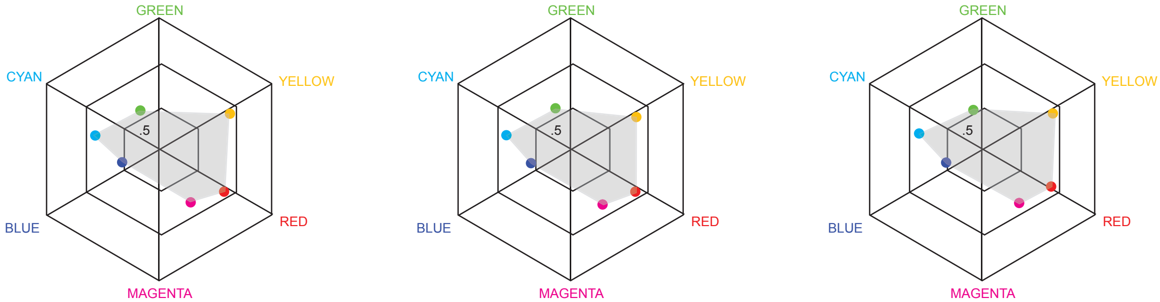
Table 2.3 — Overprint traps on uncoated paper.

	Descending Tack Order			Ascending Tack Order		
	R	G	B	R	G	B
Sample 1	49.55%	79.28%	74.15%	47.06%	69.61%	68.35%
Sample 2	58.18%	82.73%	72.73%	48.57%	72.38%	70.50%
Average	53.87%	81.00%	73.44%	47.82%	70.99%	69.42%

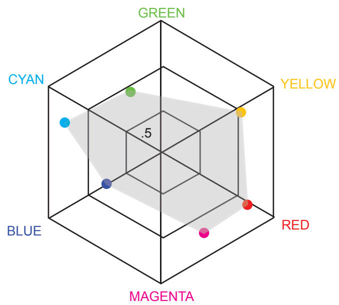
Table 2.4 — Overprint traps on coated paper.



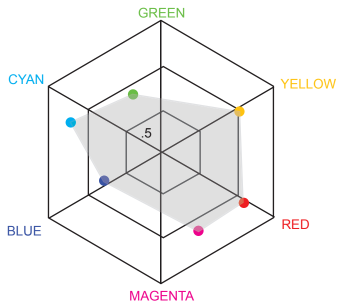
Figures 2.3, 2.4, and 2.5 — Samples 1, 2, and 3 of descending tack order on uncoated paper.

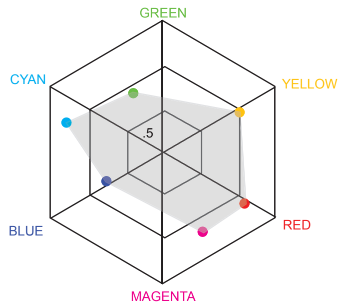


Figures 2.6, 2.7, and 2.8 — Samples 4, 5, and 6 of ascending tack order on uncoated paper.

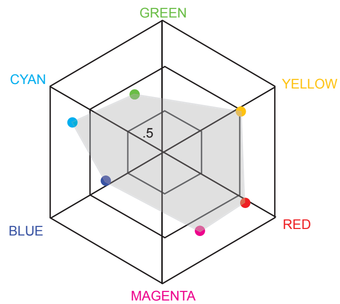


Figures 2.9 and 2.10 — Samples 7 and 8 of descending tack order on coated paper





Figures 2.11 and 2.12 — Samples 9 and 10 of ascending tack order on coated paper



Linseed oil was used to reduce the tack of the magenta and cyan Sun Chemical inks. More linseed oil than expected was needed to get the tack to the desired values with 1 mL for cyan and 0.6 mL for magenta, for 15 g of ink. The original inks were printed in usual descending tack order (CMY). Cyan was 10.5, magenta 8.5, and yellow 8.3 gram-meters. Although the small difference between the magenta and yellow was not ideal, out of all the ink sets tested, the Sun Chemical inks produced the best results. We lowered the tacks of the magenta and cyan until the yellow had the highest tack value (8.3), followed by magenta (7.7) and then cyan (7.3). We chose to use the 10-minute reading from the inkometer to compare the tack values of the different samples to simulate what the tack values would be after running on press.

The tack of the magenta and cyan were lowered instead of simply running the inks in YMC order so that the exact same overprint traps would be measured. For example, had the inks been run in reverse, the descending overprint of red would be magenta over yellow while the ascending overprint of red would have been yellow over magenta, resulting in a different shade of red (Mortimer, 1998). By reducing the tack of the magenta and cyan it was possible to use the same inks in the same order but the reverse tack order.

There are four main components of ink: pigments, solvents, vehicles, and additives. The two components that affect the tack of an ink are vehicles and additives.

The vehicle of an ink carries the pigments to the substrate and binds the ink film to the substrate. The resins in the vehicle promote tack. A common additive to inks are reducers which include varnishes, solvents, oils, or waxy or greasy compounds. These are added to reduce the tack of the ink (International Paper, 2008, and Eldred & Scarlett, 1990).

There are many sections of the printing process which influence tack. The ones which may have impacted the results of this test are described below. Tack increases as speed increases on press. In the case of this experiment, the speed of the inkometer (400 rpm) was set to match the speed of the Universal inking unit (100 m/min). Ink film thickness has an impact on tack because a thinner ink film will resist splitting a lot more than a thick ink film. For this test, the ink film thickness for each ink was determined by trying to reach target densities. This may have caused skewed results as the regular instructions for measuring tack using an inkometer require the use of the same amount of ink for each ink, whereas different volumes are used when printing samples. Temperature also has an effect on the tack of an ink, as ink gets warmer its tack will decrease. In this test, the tack of all the inks were measured at a consistent temperature, but this could not be controlled on the inking unit or the Testprinter as there was no temperature control. The design of the printing press will also affect tack and trapping. As the paper passes from one unit to another it will start to set and the tack will increase. This variable was kept consistent during the test as there is equal distance between the units on the Testprinter (DeJidas & Destree, 1995, and Field, 1999).

As can be seen in the results, the type of substrate used will affect trapping and colour reproduction. The absorbency of the substrate being printed on affects trap. If the substrate is absorbent, the ink vehicles within the ink will penetrate much more quickly into the substrate. This increases the tack of the surface ink, improving the trapping to the next ink (Eldred & Scarlett, 1990).

The results received from this experiment were in agreement to the general accepted printing principle, found specifically in GATF textbooks, that printing with descending tack values produces better colour as measured by trap. Before conducting this test we were aware of this standard so we were expecting our results to show higher trap values when printing with the descending set of inks. We were surprised to see how small the difference was; expecting a much larger gap in the trap values. One of the reasons for this may be that neither the ascending nor descending sets of ink had the recommended one to two tack-units difference between each of the inks. Also, in general, low tack values, such as the ones of the inks we were using, can cause poor trapping (Wilson, 2003). Although the trap values of the descending set were higher than the ascending set, very few of our values reached the industry standard for trapping which for sheetfed printing are at least 75% (Wilson, 2003).

There were a number of opportunities during this test for machine and human error. A general concern was machine malfunction or inaccuracy from the aging inkometer. Another issue with the inkometer and the Universal Testprinter was that if the rollers were not cleaned properly, or if any solvent was left on the them, it could cause skewed results. This may explain why three sets of inks were tested for tack values with only one resulting in the expected tack order. This may have also been caused by contamination in the inks, another possible source of error. It was also discovered that some of the densitometers in our lab consistently produced conflicting results. Another source of error was found when printing the overprints. It was ideal that all three overprints and all three primary colours be printed in the middle section of each strip but this did not occur for every sample. As a result some readings had to be taken from the sides of the print where printing pressure would be different and the print more inaccurate.

A final possible source of error is that the densitometric method of trap evaluation does not produce perfectly accurate results. This is a result of first-surface reduction and gloss, multiple internal reflections, opacity of the second-down ink, back transfer, and the spectral response of the densitometer. Specifically the use of narrow-band compared to wide-band densitometer filters will effect trap calculations.

RECOMMENDATIONS

WET TRAPPING VS. DRY TRAPPING

The above experiment dealt exclusively with wet trapping. Wet trapping is the result of the second-down colour printing while the first-down colour is not completely dry. Wet trapping is dependent on the tack of the ink and ink film thickness.

When the first-down ink has dried completely before the second colour is printed it is called *dry trapping*. This could be the case when printing a job on a press that does not have enough units to print all of the colours required in one pass. One problem which can occur during dry trapping is *crystallization*. Trapping is impaired when crystallization happens because the dried ink causes an extremely hard ink film (Eldred & Scarlett, 1990). The most likely cause of crystallization is when there is too much grease or wax component in the dried ink film (GATF Staff, 1994). For this reason, linseed oil must be used with caution as it is a drying oil (Ultrachem, 2009) and encourages dry trapping and crystallization to form. In general, wet trapping is encouraged whenever possible, leaving only enough time between the application of colours to allow for optimal trapping.

PROBLEMS CAUSED BY EXTREME TACK

Tack values which are too high or too low will cause printing problems aside from trapping. Low tack causes dot gain, poor image sharpness, drying problems, and low gloss (Eldred & Scarlett, 1990). Dot gain and poor image sharpness are caused because an ink with low tack will spread out when transferred from the blanket cylinder to paper.

If tack is too high picking may occur where fibres of a paper are pulled from the surface. This occurs during ink transfer when the tack of an ink is greater than the force required to break away portions of the paper's surface. Picking is typically less common with coated paper because of the presence of a coating. However, if tack is too high when printing on coated paper, the coating can be pulled off the paper causing a more noticeable problem and possibly causing the coating of the paper to wrap around the blanket cylinder.

Other problems caused by paper which cannot resist the tack of an ink film include piling, linting, or curling. Slowing the press or increasing ink film thickness are ways in which these problems might be remedied without changing the composition of the ink (Eldred & Scarlett, 1990).

PRESS FACTORS

The printing press design can influence trap because it determines the printing nips and impression points. If there is a large space or dryers between printing units, the ink which has been printed will have time to dry causing an increase in its tack. In combination with the printing speed this will determine the tack of the first-down ink at the point when the second-down ink is printed. Press speed will determine how quickly the paper passes between units, while the press design will determine the physical space which the paper needs to travel to get from one impression unit to another. If there is not sufficient time between impressions the preceding ink film may not have enough time to set sufficiently to produce good trap (Field, 1999).

For this reason different printing processes call for different tack requirements. Web printing requires lower tack inks because the press is running at a higher speed compared to sheetfed printing (Wilson, 2003). When printing on a common impression cylinder the tack difference between successive inks may need to be higher since there may not be sufficient time for the inks' tack to rise from setting.

Temperature while printing should be kept in mind because it has a direct influence on trapping performance. It is important to understand that an increase in temperature lowers the tack of ink. Temperature needs to be maintained and kept constant at all times to obtain optimal colour (Field, 1999). In multicolour printing it is important to keep temperature consistent between units. If one unit is warmer or colder than the other, the other ink's tack may increase or decrease. This could negatively affect the set tack order and resulting trapping variations.

Solvent absorption and evaporation during the printing process affects the tack of an ink. Since the printing plate is kept moist with water, the water can become emulsified in the ink. GATF tests show that the tack of ink on press decreases by about half of the original value once dampening rollers are turned on (Eldred, 2001). Depending on the press design the solvent may evaporate from the ink as it travels through the press causing an increase in tack. The tack will also increase if any solvent which is in the ink absorbs into the rollers or blankets.

QUICKSET INKS

Quickset inks or unitack inks are preferred by ink manufacturers because they allow the setting of an ink, increasing the tack from unit-to-unit, and the inks' tacks do not need to be altered in the manufacturing process. Unitack inks are not tack-rated but instead all have the same tack values. They are also referred to as quickset inks because they are formulated with a quickset varnish which is absorbed quickly into the substrate during printing, causing the ink to set quickly. An ink may have the same tack value as the next ink to be printed but it will set sufficiently between printing units that the tack will increase and proper trapping will occur (DeJidas & Destree, 1995).

The main advantage to this is that it allows one set of process colours to be used in any sequence (Eldred & Scarlett, 1990). This is a good solution for any printing problems that are remedied by changing the colour sequence being printed without changing the tack order being printed.

OPTICAL PROPERTIES

When printing with four colour process, there are 24 possible colour sequences; the three most common sequences are YMCK, CMYK, and KCMY. It is interesting to note that regardless of the sequence selected, black would be printed either first or last because its placement influences the quality of jobs requiring a heavy coverage of black (Field, 1999). Colour reproduction is affected by the order of colours regardless of their tack values. If a colour sequence is changed but still uses a descending tack order (using a new set of inks), this will have an effect on colour reproduction but not on trap. For example, consider trapping magenta over yellow. Since the trapping of the magenta cannot possibly be perfect, the result would be more towards a slight orange instead of a true red. If the colours were reversed the imperfect trapping of yellow over magenta would make the red overprint less orange and more magenta (Mortimer, 1998). One way to determine the colour sequence may be to determine which secondary overprint colours are most important in the printed product and run a colour sequence that best runs that overprint (Mortimer, 1998).

Moiré patterns occur as a result of the different halftone patterns overlapping. When a moiré pattern occurs it is suggested that the colour sequence be switched, separating the two colours causing the problem (Field, 1999). This should be done with care because switching the printing sequence may influence trapping. If switching the colours is the only option then the tacks should be altered with a reducer to keep a descending tack order. Another option is to use a new set of inks which will print in a descending order in the new colour sequence. Mechanical problems such as slur or misregistration may also be a reason for colour change. To fix these problems it is recommended that the yellow be printed on the defective unit because yellow is the least visually discernible colour (Field, 1999). The same suggestions listed above in regards to switching colour sequence should be taken into consideration.

If a process ink does not have the proper transparency properties then trap will not be ideal. As determined earlier, the colour of an overprint usually shifts towards the first-down colour. However, if the second-down colour is too opaque then the colour of the first-down ink would not show through. As a result the overprint produced would shift towards the colour of the second-down ink (Field, 1999).

PRACTICAL APPLICATIONS

There are many instances when colour reproduction must be accurate and have perfect trapping. Trapping is pertinent for high quality jobs where colour accuracy is important. Accurate colour reproduction is necessary for company logos, such as "Telus green" and "Tim Hortons red", because it influences the image of the company and corporate identity. If the company is extremly concerned about a corporate colour, spot colours should be selected and used instead. If a spot colour is used, issues noted above, such as tack, optical properties, and total ink coverage, should be taken into consideration when placing the ink within the colour sequence.

Depending on the ink coverage, the quality of certain jobs would suffer if printed in the regularly used colour sequence. For example, when printing a job with a solid cyan background, cyan would need to be placed on the last printing unit in order to retain the density needed and to improve the quality of the print (Field, 1999).

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APPENDIX

- Please see *Tables 2.6* to *2.15* for original densitometer readings.

	R	G	B	
C	1.04	0.42	0.15	
M	0.24	1.07	0.68	
Y	0.02	0.11	0.93	
R	0.24	1.13	1.15	Trap = 50.54%
G	1.12	0.53	0.85	Trap = 75.27%
B	1.09	0.99	0.60	Trap = 53.27%

Table 2.6 — Sample 1: Regular tack order of Sun Chemical Vegetable Inks on uncoated paper

	R	G	B	
C	1.17	0.56	0.29	
M	0.26	1.23	0.71	
Y	0.03	0.10	0.92	
R	0.26	1.14	1.14	Trap = 46.74%
G	1.37	0.64	0.92	Trap = 68.48%
B	1.28	1.16	0.73	Trap = 48.78%

Table 2.7 — Sample 2: Regular tack order of Sun Chemical Vegetable Inks on uncoated paper

	R	G	B	
C	1.00	0.39	0.15	
M	0.28	1.15	0.79	
Y	0.03	0.11	0.92	
R	0.28	1.25	1.25	Trap = 50.00%
G	1.04	0.50	0.92	Trap = 83.70%
B	1.23	1.21	0.76	Trap = 71.30%

Table 2.8 — Sample 3: Regular tack order of Sun Chemical Vegetable Inks on uncoated paper

	R	G	B	
C	0.99	0.36	0.11	
M	0.22	1.03	0.63	
Y	0.02	0.09	0.94	
R	0.23	1.15	1.07	Trap = 46.81%
G	1.03	0.47	0.80	Trap = 73.40%
B	1.09	0.96	0.56	Trap = 58.25%

Table 2.9 — Sample 4: Reverse tack order of Sun Chemical Vegetable Inks on uncoated paper

	R	G	B	
C	1.06	0.39	0.13	
M	0.21	1.07	0.65	
Y	0.01	0.08	0.92	
R	0.23	1.16	1.09	Trap = 47.83%
G	1.07	0.48	0.79	Trap = 71.74%
B	1.14	1.00	0.59	Trap = 57.01%

Table 2.10 — Sample 5: Reverse tack order of Sun Chemical Vegetable Inks on uncoated paper

	R	G	B	
C	1.02	0.38	0.13	
M	0.24	1.12	0.70	
Y	0.02	0.09	0.95	
R	0.22	1.07	1.10	Trap = 42.11%
G	1.02	0.47	0.84	Trap = 74.74%
B	1.11	1.01	0.62	Trap = 56.25%

Table 2.11 — Sample 6: Reverse tack order of Sun Chemical Vegetable Inks on uncoated paper

	R	G	B	
C	1.42	0.43	0.13	
M	0.25	1.47	0.81	
Y	0.02	0.09	1.11	
R	0.21	1.39	1.36	Trap = 49.55%
G	1.45	0.53	1.01	Trap = 79.28%
B	1.52	1.52	0.77	Trap = 74.15%

Table 2.12 — Sample 7: Regular tack order of Sun Chemical Vegetable Inks on coated paper

	R	G	B	
C	1.40	0.42	0.13	
M	0.24	1.39	0.76	
Y	0.01	0.07	1.02	
R	0.22	1.32	1.24	Trap = 47.06%
G	1.37	0.48	0.84	Trap = 69.61%
B	1.42	1.37	0.68	Trap = 68.35%

Table 2.14 – Sample 9: Reverse tack order of Sun Chemical Vegetable Inks on coated paper

	R	G	B	
C	1.34	0.41	0.12	
M	0.24	1.43	0.78	
Y	0.02	0.09	1.10	
R	0.22	1.39	1.42	Trap = 58.18%
G	1.31	0.50	1.03	Trap = 82.73%
B	1.45	1.45	0.74	Trap = 72.73%

Table 2.13 — Sample 8: Regular tack order of Sun Chemical Vegetable Inks on coated paper

	R	G	B	
C	1.35	0.41	0.13	
M	0.24	1.39	0.76	
Y	0.01	0.08	1.05	
R	0.21	1.33	1.27	Trap = 48.57%
G	1.32	0.49	0.89	Trap = 72.38%
B	1.44	1.39	0.70	Trap = 70.50%

Table 2.15 – Sample 10: Reverse Tack Order of Sun Chemical Vegetable Inks on coated paper

MODERN MARBLIZATION

KIMBERLY FONG
DIANE FORD
ANGELA KONG
AMANDA REHAL

ABSTRACT

The scope of this report encompasses the many properties as they relate to marblization. This includes the subsequent properties for analysis, including paper curl and ink absorption as measured by ink density. Several other properties that were subjectively analyzed include warp, bleed, and visual appearance. Additional properties that would have been tested, time permitting, include rub-off and drying time. The purpose of this test is to explore the various properties and how they are interrelated to producing a finished marblization.

To summarize the experiments, thirty variables were explored in relation to the process of marblization. The basic techniques of the process

were easy to master, but the greater intricacies required much more time to perfect. Not all variables were successful. Substrates provided the most dramatic results, ranking Plainfield uncoated the best, followed by acetate, fountain solution bases, and gum arabic ink dilutions. It is recommended that the quantity of ink be increased, the ink/chemical balance be thoroughly analyzed, and proper marbling techniques be adhered to regardless of ink, base, chemicals, or substrates. It is nearly impossible to incorporate marblization into an automated printing press situation. Rather than take the effort to create a process, it is wiser to print digitally. Marblization should remain a process which adds value to a product, as its value is in the uniqueness and originality of the finished piece.

INTRODUCTION

Paper marblization dates back to 986 CE in East Asia, where a compilation called *Four Treasures of the Scholar's Study* was found referencing a type of decorative paper and how it was made. This process has been used to decorate substrates for many centuries in many different countries, such as Turkey, Europe, Japan, and China (Easton, 1983). There are few materials required to marble paper. The real challenge is in understanding the interactions of various chemicals and liquids and possessing an overall technical knowledge of items, such as surfactants that keep the colours from sinking or blending.

Japan has the most documented form of marblization called *suminagashi*, which was assigned its own birthday of February 1, 1151. It differs from current Western methods in that it uses water as a base instead of a size to support the inks. This is similar to the method used in these experiments. Another trait to note about suminagashi is that handmade paper is used, contributing to the unique look of the final product (Easton, 1983).

The traditional Western method uses a marbling base of gum tragacanth and water, though the current preferred base is carragheen (Irish) moss and water. Inks are then dropped on and worked if desired by things such as brushes or combs to create appealing patterns. Slightly dampened substrates are then placed in the ink, removed, rinsed, and hung to dry.

The Egyptian method of paper marbling uses vegetable dyes, which are transferred to the paper with a sponge instead of dipping the paper into the dyes (Easton, 1983). There was even an attempt to mechanize the process and make a press that could create marblized paper, surviving today as collotype (Merriam-Webster, 2008). The end result, while appealing, did not have the same look as hand made marblizations, nor were they as distinct, even though they were imitating a popular marbling pattern.

The process of marblization has not been extensively tested or modified in over a century. When this art form settled in, the base was comprised of water with carragheen moss, and the substrates for marblization were coated with alum. The patterning from these marblizations was categorized in groups. The following are some examples: American (crosswise comb), antique spot, bouquet, British, combed patterns (German), curl (French curl, snail), drag patterns, drawn patterns, German (cocoa), gloster, gold vein patterns Italian (hair vein, vein, light Italian), Japanese, morris, and nonpareil (comb) (Easton, 1983). Though the patterns, colours, and method to create them were documented, no two patterns look exactly the same. This method grew ever popular as a recreational craft, peaking around the 1970's (Easton, 1983).

The main purpose and significance of this test is to observe properties of marblizations with readily available chemicals, substrates, and inks and their effect on the marbling process. This requires a base understanding of the properties as relating to these three categories and how they interact with one another. The objective of this test is to explore the properties in hopes of producing a better, easily reproducible result; specifically with good ink transfer, less warping and curl of the substrate, less ink bleeding, and better absorption. These qualities would provide a better final product that could be used for endpapers and enhanced documents.

Educational gains are attained from a new insight into an old process that is seldom given a second thought, and a deeper understanding of how various inks, oils, chemicals, and substrates behave when creating a final product. There is also merit in the exploration of historical data concerning the importance of this process in cultures worldwide.

DEFINITIONS AND EQUATIONS

Alum (Potassium Aluminium Sulphate): Also known as potash, alum assists the chemical bond of ink and substrate (Wolfe, 1989).

Bleed: For the purposes of this report, it is defined as the process of the ink spreading out on the substrate after transfer to the substrate.

Carragheen (Irish) Moss: Extracted from dry seaweed, it is a thickening agent that provides an ideal medium to manipulate inks (Wolfe, 1989).

Collotype: A photomechanical process for making prints directly from a hardened film of gelatin or other colloid that has ink-receptive and ink-repellent parts (Merriam-Webster, 2008).

Curl Test: A test to measure the water resistance of paper (Romano & Romano, 1998).

Density Range: The gamut difference between the maximum and minimum density of a printed substrate (Romano & Romano, 1998).

Ebru: A Turkish form of marblizing on fine paper (Cohen & Cohen, 1990).

Likert Scale: A rating scale format that requires respondents to indicate the extent to which they agree or disagree on a cognitive-based scale (Hair, Wolfinbarger, Ortinau & Bush, 2008).

Linseed Oil: A thinning agent used to reduce viscosity and tack of oil based inks and paints. It is also used as a component in many printing driers (Romano & Romano, 1998).

Marblization: A method to create a design through ink on water resembling marble (Easton, 1983).

Ox Gall (Ox Spit): A thinning agent for water based pigment compounds (Cohen & Cohen, 1990).

Safflower Oil: A common substitution for linseed oil; it increases gloss and transparency, however it is slow drying (Winsor & Newton, 2008).

Sizing: Various materials used to increase surface strength (Romano & Romano, 1998). Also known as the European form of marblization (Easton, 1983).

Stand Oil: A refined version of linseed oil used as a slow-drying thickener/extender for oil based inks and paints (Winsor & Newton, 2008).

Suminagashi: Japanese marbling utilizing plain water and floating inks, with little manipulation or interference only by gentle movements (Cohen & Cohen, 1990).

Thixotropy: The characteristic of ink to lose viscosity when being stirred or otherwise worked (Eldred & Scarlett, 1990).

MATERIALS TESTED

SUBSTRATES

- Vellum, 8 M, 65 g/m^2, 24 lb
- Rice paper, 30 g/m^2
- Euroart coated, 91 M, 148 g/m^2, 100 lb
- Plainfield uncoated, 88 M, 103 g/m^2, 70 lb
- Acetate, 60 g/m^2
- Canson Mi-Teintes, 120 M, 907 g/m^2, 335 lb
- Yupo (Polypropylene), 30 M, 197 g/m^2, 73 lb
- Strathmore canvas card, 9 M, 187 g/m^2, 85 lb

LIQUID BASES

- Powdered alum by Club House
- Carragheen (Irish) moss by Angel Brand
- Mild soap by Jergens
- Fountain solution by Varn Products Company Inc., Total Plus ~ar~ D0F74519

INKS

- Hit Process Magenta by Hostmann-Steinberg, 2Qk 176555-V
- Hit Process Yellow by Hostmann-Steinberg, 1QK 1765-V
- Flexographic Process Yellow by Hostmann-Steinberg, 1-A 100068-JS
- Flexographic Process Magenta by Hydrotop Pro, 2 A 100069-JS
- PMS Silver by Colmar, PS527606
- PMS Transparent White by Colmar, PS232789
- Metallic Pigment by Pearl EX, JAC663

OIL/THINNER

- Safflower oil by Winsor & Newton: Artisan Water
- Linseed oil by Winsor & Newton: Artisan Water
- Stand oil by Winsor & Newton: Artisan Water
- Ox Gall Liquid by Winsor & Newton: Water Colour
- Granulation medium by Winsor & Newton: Water Colour
- Gum Arabic by Winsor & Newton: Water Colour
- Baby Care Baby Oil by Percara
- Drier by Hostmann-Steinberg

EQUIPMENT USED

- Curl Tester by Testing Machines Inc., Model #78-7 RPI 005440
- R170 Colour Reflection Densitometer, IHARA, R Series, Serial #074843
- Microprocessor ATC pH Meter by Hanna Instruments, Model #HI8417W
- Prüfbau pipette
- Metal pan/basin (11 3/4 in. by 13 3/4 in. by 2 in.)
- 1 mL graduated syringe

TEST PRINCIPLE

The purpose of this test is to explore the variables that affect the marblization process. The series of tests are a valid means of determining the properties being tested due to the establishment of a standard for comparison. The standard procedure also provides stability, in that it provides a starting point where variables can easily be swapped out while the other factors remain reasonably controlled.

This test is carried out in this method for ease of not only comparison but also consistency. A part of this project's endeavor was to establish a consistent, reproducible marblization, and to discover the factors that would lead to the most visually desirable result. (See *Table 3.1* for the full list of variables tested.) The establishment of a standard also achieves this, as it is a benchmark for which subsequent tests can be measured both objectively and subjectively on Likert scales for each property observed (Hair et al., 2008).

The method used for marblization in these tests more closely resembles the Japanese method of suminagashi (Easton, 1983). The Egyptians utilized a method of sponging vegetable dyes on to the substrates. This method does not resemble the definition of marblization as used in this report. Other than this method, possible alternatives to this test are rather difficult to design. Instead of alternative methods, there are multiple properties to be experimented with, such as additional materials and combinations of multiple variables. Ultimately, it is a combination of variables that will yield the best result. This would be a direction to investigate for possible further pursuit.

This test does not replicate conditions of printing as conventionally described. Marblization in itself is a printing form seldom used compared to the bulk of other printing processes. Thus, it replicates actual printing/end use situations quite accurately for one-colour marbling situations (Chambers, 1995). If there is one thing that has been discovered from these tests, it is that marblizing is a relatively easy process to execute, as the techniques are rather simple, but doing so competently is another challenge entirely.

PROCEDURE

1. Obtain a 4" x 6" *substrate* (refer to *Table 3.1*).
2. Measure 500mm^3 of an *ink* with the pipette and mix in 2 ¼ mL of an *oil*.
3. Fill basin with 1000 mL of a *base* and combine it with 50mm^3 of the mixture above.
4. Name substrate and place in basin momentarily.
5. Remove substrate, dry flat for 24 hours, then measure curl and density.

NOTES

- Only one variable was changed for each subsequent test to compare to standard (coated paper, process magenta, linseed oil, and water).
- Linseed oil and process magenta were used for all tests, unless it was the variable under experimentation.
- Metallic pigment is mixed with 500mm^3 of transparent white.

Oils	Papers	Inks	Bases
Safflower	Vellum	Metallic Pigment: 10 g	Fountain Solution: 30 mL, 970 mL H_20
Linseed	Rice Paper	Colmar Silver	Hot Water: 50˚C
Stand	Coated Paper	Colmar Green	Cold Water: 20ºC
Baby	Uncoated Paper	Colmar Orange	Soap: 5.8 g
Ox Gall	Acetate	Process Yellow	Carragheen Moss: 9.20g
Granulation Medium	Canvas	Flexographic Yellow	Alum: 0.75 g, 1000 mL, 1000 mL H_20
Gum Arabic	Yupo	Flexographic Magenta	

Table 3.1 — Variables tested

- Acetate: A drop of drier was placed into the ink mixture to decrease dry time.
- Carragheen Moss: 9.20 g boiled into 525 mL of water, added to 475 mL water.

RESULTS AND DISCUSSION

It is a simple fact that oil and water do not mix. Marblization takes full advantage of this fact. There are many other variables that must be controlled not only in the preparation of inks, but also the liquid base and the substrates' properties. Even weather can be an influencing factor (Easton, 1983). Common variations that prove effective are changes in oils and chemicals added to the liquid base, such as soap. These changes are not necessarily for the better. The variations selected were based not only on the common materials noted in texts, but also upon available chemicals that were easily substitutable in the marblization process.

While it seems as though the measurements yielded inconclusive results, there are a series of smaller characteristics that, though seeming inconsequential at first, presented themselves as items for further consideration. However, due to time constraints and the limited scope of the proposed project, all of these avenues could not be pursued.

The results are not easily explained and can be interpreted in many ways. The following section will be broken into three main areas for discussion. The first section will cover the performance by observed characteristic, and the second will outline the average performance of each variable within their respective categories. The final section will discuss all samples based on their average performance over all observed characteristics. All means for comparison are based on the ratings found in *Table 3.2*. This table provides the ratings as decided by group consensus for each variable. External sampling was intended at the project's conception but was deemed too cumbersome for the scope of this project. *Table 3.3* shows a series of variables and their subsequent rating based on the average of the above process.

CURL

The first reading in *Table 3.2* is curl. The values show that the readings may have been skewed, which can be attributed to drying situations elaborated further on. Curl ranking was calculated by determining the inverted percentage value for each curl from 90º. For example, a curl of 15º would result in a rounded table value of 8 (i.e. (1-(15/90))*10=8.3). By far, the vellum was the worst performer concerning curl, which can largely be attributed to its fine-grain composition (Wilson, 1998). Rice paper is composed of loose fibres, however it did not perform as poorly. The specimens that performed the best with regards to curl were mostly of the plastic variety, such as acetate and yupo (polypropylene). These substances have relatively little give in terms of their ability to curl. As a fabric, canvas was a top performer, which was expected from research (Chambers, 1995).

ABSORPTION

Many of the recorded density results were skewed due to the inconsistent surface marblization creates. The density data was placed on a scale using the same method as curl, with the exception of the high being a 1.0 average density. Gum arabic and ox gall were used to thin the ink for the best results. Research indicates that ox gall is preferable to thin ink, much like gum arabic, however it did not indicate the effect it has on oils (Wolfe, 1989). This may account for the surprising results. Further testing would be ideal to determine if using both variables simultaneously would provide similar, if not a better outcome. It was expected that adding ox gall to the oil would thin it and encourage it to float on the surface so finely it could not be absorbed into the substrate. The metallic silver (premixed ink and pigment alike) bared dismal products, as did most spot colours. The metallic inks were quite heavy and sunk to the bottom, whereas the spot colours may not have had the correct thixotropic properties (Eldred & Scarlett, 1990).

WARP

Warp, while similar to curl, was based more on the condition of the substrate in the center, as opposed to along the edges on a scale of zero to ten, ten being the best. As indicated in *Table 3.3*, and similar to curl, the least warp occurred in the plastics (acetate and yupo), with canvas and rice paper close behind, as expected. Vellum, again, seemed the worse for the wear. Warp and curl are very interrelated and the same factors that contribute to a substrate's

	Curl	Absorption	Warp	Bleed	Appearance	Average
Linseed Standard	9	2	7	2	5	5
			Variations of Oils and Chemicals			
All Oils	8	2	7	5	9	6
Baby Oil	9	1	6	4	2	4
Granulation Medium	9	1	5	6	8	6
Ox Gall	10	1	8	4	2	5
Stand Oil	9	1	6	6	6	6
			Variations of Substrates			
Acetate	10	4	10	8	3	7
Acetate + Drier	10	2	9	4	7	6
Canvas	10	2	9	4	7	6
Mi-Teintes	9	1	7	5	4	5
Plainfield Uncoated	9	4	8	8	9	8
Rice Paper	9	1	9	2	6	5
Vellum	0	3	2	4	1	2
Yupo	10	1	10	7	3	6
			Variations of Ink			
Flexo Magenta	9	2	8	2	9	6
Flexo Magenta + Yellow	9	2	8	3	10	6
Flexo Yellow	9	2	7	2	7	5
Green	9	0	6	6	3	5
Orange	10	2	5	6	2	5
Silver	9	0	4	2	0	3
Silver Pigment	9	0	4	2	0	3
Yellow	9	1	6	4	2	4

Table 3.2 — Sample evaluation. Note: Values are indicated by a scale of 0 to 10, where 0 is the worst and 10 is the best.

curl will most likely exhibit the same behaviours concerning warping.

BLEED

The bleed rating, on a scale from zero to ten, was based on the visual indications of bleed on the samples. Bleed, as defined for this report, is the run of water or oil once it had been transferred to the substrate. It presented itself as both halos and large smeared areas of ink, as well as water stains on the substrates. The findings for bleed were over a large spread, however fountain solution provided the least amount of bleed. This is favourable, considering how much contact a substrate and ink have with fountain solution. Flexographic inks were the worst offenders, despite their behaviour when placed in the water. The flexographic inks behaved ideally, but perhaps spread a little too widely across the surface of the water.

When the substrates were placed in the basin the inks were not absorbed immediately. Thus, when the substrates were removed, the ink slid off the pages as well, smearing together. The finished marblization was attractive, but considering the evaluation of the variable, it was the least desirable.

APPEARANCE

The appearance of the final marblization was rated on an identical scale as the others, from zero to ten. The most visually appealing marble pattern was given the highest rating (see *Figures 3.1–3.4* in the Appendix). The results came in two major categories; either a semi-smooth grainy appearance

	0	1	2	3	4	5	6
Curl							
Absorption					Ox gall (oil), Green, Silver, Silver pigment	Baby oil, Granulation medium, Stand oil, Mi-Teintes, Rice paper, Yupo, Process Y, Carragheen moss boiled, Soap	Linseed standard, All oils, Canvas, Acetate + Drier, Flexographic M + Y, Flexographic M, Flexographic Y, Orange
Warp			Vellum	Silver	Silver pigment	Granulation medium, Orange, Ox gall (base)	Baby oil, Ox gall (oil), Stand oil, Green, Process Y, Alum, Carragheen moss boiled, Gum arabic, Soap
Bleed				Linseed standard, Rice paper, Flexographic M, Flexographic Y, Silver pigment	Flexographic M + Y, Silver	Baby oil, Safflower oil, Canvas, Vellum, Process Y, Hot water	All oils, Soap, Ox gall (oil), Mi-Teintes, Carragheen moss hot
Appearance	Silver pigment	Acetate + Drier, Vellum, Silver	Baby oil, Safflower oil, Orange, Process Y, Soap	Acetate, Yupo, Green	Carragheen moss hot, Ox gall (base)	Linseed standard, Ox gall (oil), Gum arabic, Hot water	Stand oil, Rice paper, Alum, Carragheen moss boiled

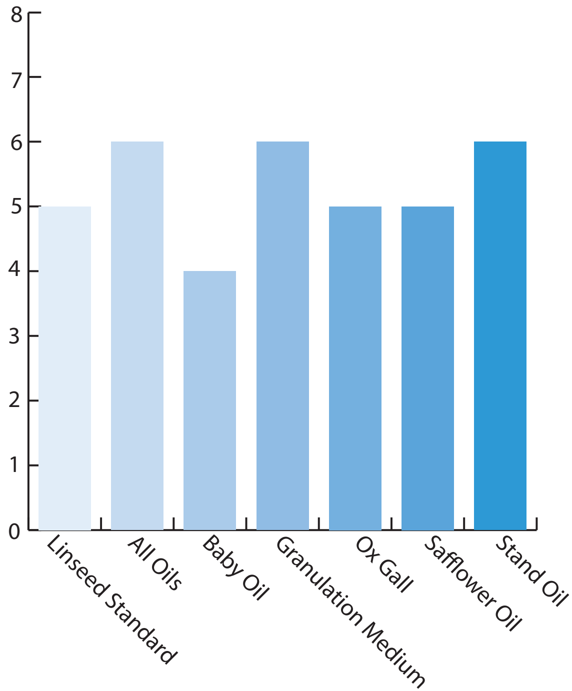
Table 3.3 — Performance per variable. See Table 3.2 for original settings. Note: M is short for Magenta, and Y is short for Yellow.

7	8	9	10	
Vellum	All oils, Gum arabic, Soap	Linseed standard, Baby oil, Granulation medium, Ox gall (oil), Stand oil, Mi-Teintes, Plainfield uncoated, Rice paper, Flexographic M + Y, Flexographic M, Flexographic Y, Green, Silver, Silver pigment, Process Y, Alum, Carragheen moss boiled, Fountain solution, Ox gall (base)	Safflower oil, Acetate, Acetate + Drier, Canvas, Yupo, Orange, Carragheen moss hot, hot water	Curl
Alum, Vellum, Hot water	Acetate, Plainfield uncoated, Carragheen moss hot, Fountain solution	Ox gall (base)	Gum arabic	Absorption
Linseed standard, All oils, Flexographic Y, Mi-Teintes, Carragheen moss hot, Fountain solution	Safflower oil, Hot water, Plainfield uncoated, Flexographic M, Flexographic M + Y	Canvas, Rice paper	Acetate, Acetate + Drier, Yupo	Warp
Granulation medium, Stand oil, Green, Acetate + Drier, Orange, Alum, Ox gall (base)	Yupo, Gum arabic, Carragheen moss boiled	Acetate, Plainfield uncoated	Fountain solution	Bleed
Mi-Teintes, Canvas, Flexographic Y	Granulation medium, Fountain solution	All oils, Plainfield uncoated, Flexographic M	Flexographic M + Y	Appearance

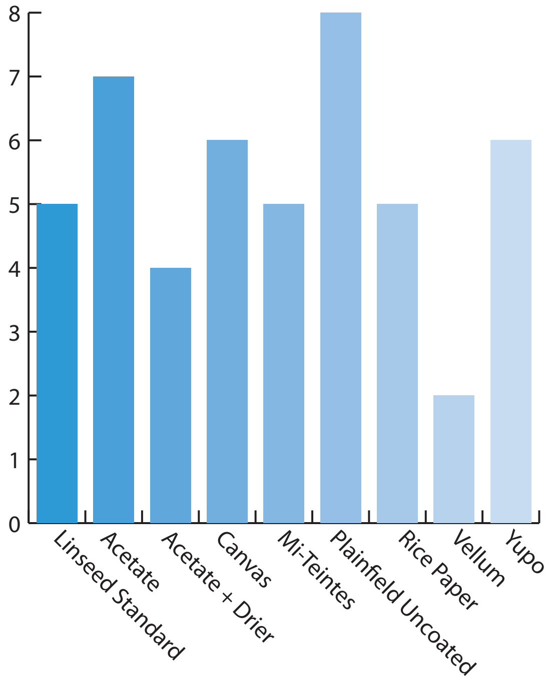
or a speckled pattern. The most pleasing marblization resulted from the Flexographic Magenta + Yellow tests. This was due to the increased ink spread caused by a significantly lower viscosity. While it was appealing, it was not exemplary of the kind of bleed that marblization should exhibit. The tests containing all oils, as well as the tests with Plainfield uncoated paper tied for a close second. While technically demonstrating an ideal one-colour marblization pattern, they lacked the same draw that the two-colour test provided. The least visually appealing test was the silver pigment. Barely any ink was transferred to the substrate, as the ink lacked the ideal thixotropic properties, sinking like a stone to the bottom of the basin.

VARIABLE CATEGORIES
OILS AND CHEMICALS

To view samples for the variations of oils and chemicals, please refer to *Figure 3.1* in the Appendix. The oils and chemicals that were added to the ink had a wide variety of effects on the final printed appearance. The majority of the oils added to the ink resulted in a spotted pattern, as they decreased the viscosity of the ink. This caused it to seep into the pipette, which required shaking into the base liquid to provide any ink for transfer. The only oil that showed a smooth wave pattern instead of spots was the stand oil with an increased overall viscosity of this oil. Stand oil is a refined linseed oil that can be used as an extender. It kept the thixotropic properties of the ink higher and allowed it to be dropped into the base instead of shaken, resulting in a more pleasing pattern. Granulation medium, while providing a pleasing pattern, had a very low density and gave the appearance of a patterned wash. While appealing and usable in some circumstances, it did not fall within the desired density. Of all the oils tested, the stand oil, granulation medium and the combination of all oils came closest to the visually desired result, although they did not resemble the standard. Overall, on a scale of one to ten, the oils and chemicals produced generally mediocre results as seen in see *Graph 3.1*. To maximize the effects of the oils and chemicals on the process, further testing is required in this area to determine the optimum ratio of ink to oils and chemicals.



Graph 3.1 — Variations of oils and chemicals and their ranking



Graph 3.2 — Variations of substrates and their ranking

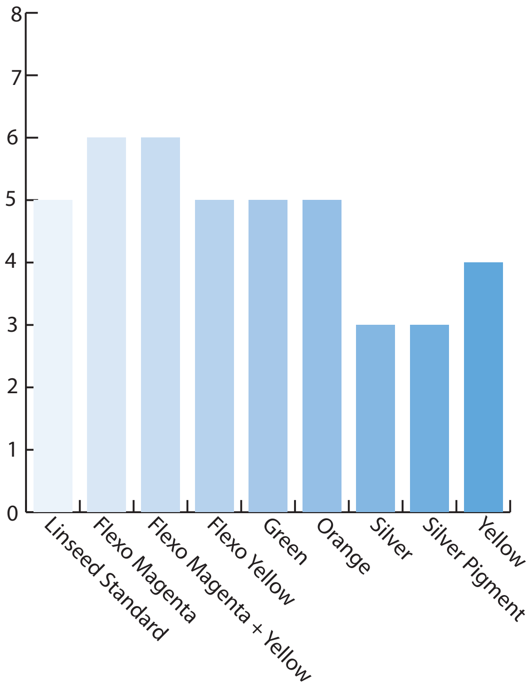
SUBSTRATES

Technically speaking all types of absorbent material can be used as a substrate, but curl and absorption need to be taken into account. Of all the substrates tested, vellum had the poorest result, as some corners curled more than 180° (see *Graph 3.2*). The absorption, on the other hand, was a little better, with an average of 3. *Figure 3.2* in the Appendix contains visual samples for the variations of substrates.

All of the other substrates tested had very little curl. Acetate was ranked the highest, along with Plainfield, purely because acetate had major ink blotches that skewed the results and Plainfield is porous. Rice paper ranked the lowest despite its porosity compared to Plainfield, only because there was insufficient ink to transfer properly. However, not as part of the formal experimentation, large amounts of ink were used to test the rice paper, and it resulted in transferring a lot more of the ink than expected. The best substrates for preventing warp were the plastics: acetate and yupo, as no warp was evident. Once again, vellum ranked the lowest, because it has a lot of pronounced waves and bumps. The acetate and Plainfield paper had the best ink holdout, meaning it bled the least. This is mainly due to the ink bonding with the acetate once they came into contact with each other and Plainfield, once again, absorbed most of the ink into its fibres. For the second time, rice paper ranked last, because it was too porous. The ink went through the sheet without really being absorbed, and there was little ink for a proper transfer. The best appearance would be Plainfield uncoated. It had good ink spread and was relatively dark in colour, with an average density of 0.42. With no surprise, vellum placed last for appearance, mainly due to the effects of curl and warp, which greatly decreases its visual appeal. Overall, Plainfield uncoated had the best characteristic average in all four variable categories, with acetate following closely behind.

INK

Flexographic inks provided a very drastic result in comparison to the other tests as it displayed the most marblized characteristics. *Figure 3.3* in the Appendix contains the visual samples for the variations of



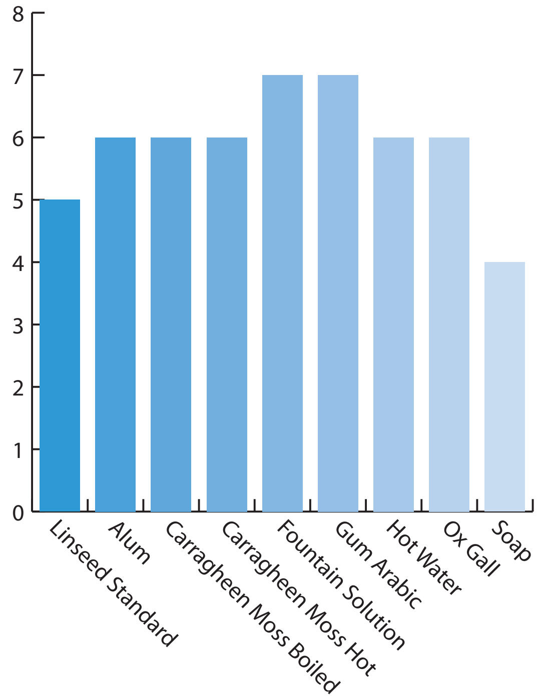
Graph 3.3 — Variations of ink

ink. Others however, such as the silver pigments tested resulted in very faded or unnoticeable prints. Flexographic magenta and yellow inks fared the best results in appearance, although they did not adhere to the paper as well as other inks causing the ink to bleed profusely. Green and orange spot colours did above average for bleeding, but that could be due to the small quantity of ink used. This makes it more difficult to judge based on bleed characteristics. Curling was not an issue with the various inks, since it is mainly the substrate that affects curling. Ink absorption was poor, ranging around rankings of 1-2. Changing the substrate could help the absorptions of the ink. The variable inks displayed average results in the warp attribute, with Flexographic magenta and Flexographic magenta + yellow ranking 8 and silver pigment rating the lowest with 4. To have the best ink fidelity and condition with the paper, it is recommended to use ink with characteristics similar to flexographic inks (see *Graph 3.3*).

BASE

Alterations to the base while using a common mixture of magenta ink and linseed oil produced the most dramatic results of the experiments and some of the most interesting patterns. *Figure 3.4* in the Appendix contains the visual samples for the variations of base.

Other than the soap base, which failed to transfer any significant amount of ink to the paper, all of the other methods transferred patterns with an acceptable density and minimal bleed (see *Graph 3.4*).



Graph 3.4 — Variations of bases

When visually evaluating the samples over the five categories to determine which results were the best, Gum Arabic and fountain solution tied for the best options. It was not a surprising result, as both are used on press to aid and control the transference of ink to substrate. The densities were heavier on both Gum Arabic and fountain solution samples. This method also created appealing patterns on the substrate.

THE BIG PICTURE

It is one thing to look at all of the specific details, and in some ways, it is more rewarding to do so, however the bigger picture cannot be ignored. It is very easy to get lost in the many things that can go right, and very wrong. Plainfield uncoated was the top performer after averaging all categories. This leans to the idea that all tests should have been done on uncoated stock instead of coated. The results (especially absorption) may have been drastically better. Acetate, fountain solution, and gum arabic overall have the best scoring averages in the five analyzed attributes.

EXTERNAL RETROSPECTION

The published information available in no way provides adequate means for comparison. As far as research has indicated, the information concerning the procedure of these tests has never been published in this manner. The cold-water base was used as means for a standard, due to accessibility and ease of preparation. However, a number of resources indicated that the use of carragheen moss to create a liquid "size" ideal for floating the ink was best for modern applications. The traditional recipe called for 50 g of moss to be boiled in 5 litres of water for 30 minutes, then left overnight. Then a further 2 litres of water was to be added and the resulting mixture is strained and used (Charnwood Books, 2009). A modified version of these instructions were used (approximately 10 g of moss boiled in 1 litre of water for 20 minutes). The resulting mixture contained significantly less water than was needed and was supplemented with cold water. The mixture was not permitted to sit overnight, but was cooled for a period of time before testing. The difference was very visible in the process but not in the visual results.

The carragheen was also placed in hot water for a time and used as a base, but it was not as effective as boiling. Sodium alginate, a seaweed derivative, can be used in place of carragheen (Cohen & Cohen, 1990). A substance called borax is a common additive to carragheen solutions to soften the water (Chambers, 1986). Another popular base mentioned is methylcellulose paste, also used as wallpaper paste, for a smoother appearance. Common household starch is capable of the same result (Chambers, 1995).

This is not to say water is not a suitable size for this project. The Japanese made use exclusively of water. Today's texts suggest that using distilled or soft water is best if another appropriate size is unavailable (Cohen & Cohen, 1990).

Many fabric marbling texts commonly reference use of acrylic (water) based paints (interpreted in this experiment as flexographic inks) instead of oil-based inks (Cohen & Cohen, 1990). However, one source insists that by using oil-based paints (which can be loosely interpreted as inks) is somewhat advantageous, as marblized materials do not have to be soaked in alum to assist absorption or any other such preparations. Oils are recommended for beginners, however by using them, a considerable amount of control is lost over the patterning (Wolfe, 1989). The oils do have to be diluted, for which the text suggests turpentine or other such agent to increase viscosity, not unlike the linseed oil that was used for testing (Chambers, 1995). The alum was not used as typically described, such as preparing the substrates before hand for colour acceptance. Instead, a small quantity was dissolved into the water in hopes of achieving the same results. There was no published information concerning this use of alum, but in comparison to the linseed standard, it performed better, though not as well as some alternate substances.

While it seems strange for ox gall to have been the top performer, the inks did not mix well with the liquid. The ox gall has not been specified for use with oil-based inks. Ox gall makes it possible to break the surface tension of the size and allow inks to spread. Not enough means that inks will not spread, and too much means inks will spread widely and become less dense on substrates. Linseed oil was suggested as ideal for decorative uses (such as endpapers) over ox gall (Wolfe, 1989). Olive oil was also considered acceptable for use (Chambers, 1986). On another note, research also indicates that yellow requires less gall, which can be extrapolated to linseed oil, than the others, because of the mineral content of the colour (Wolfe, 1989). This does lend some explanation to the results of the yellow sample, as the same amount of linseed oil was used for yellow as magenta, but the results did not match.

ASSUMPTIONS

Preconceived assumptions about the marblization process came from the limited experience of the end-paper design done in class labs. The subject was presented with very imprecise directions with only the expectation that the final results would have to be ironed. There was no exact ratio of linseed oil to ink, or roughly how much to place in the pan. From this prior experience with the process it was expected that the ink coverage would be heavier than the majority of the results showed. The curls were expected to be considerably less dramatic. The expected wavy patterns of colour were not achieved, but instead more speckled patterns were generated from testing.

It was difficult to resist "playing" with the ink when it was placed in the water base, but only for those tests that did not disperse or speckle in contact with the water. Temptation to add additional ink in those cases was overbearing. Combing out the ink helped to distribute it more evenly but excessively causes the ink to become spotted and too separated, pulling away from its marbling pattern. It is not hard to set up the tests, but it also is not hard to skew them, either from contamination of equipment and materials, varying base temperature or the quantity of ink from the pipette.

It was unexpected to see that Plainfield uncoated, acetate, fountain solution, and gum arabic overall have the best scoring averages in the five analyzed attributes. It was also expected that rice paper would perform a little better than it did during testing. The paper all but drowned, and the ink seemed to seep straight through it, though it was quite easy to remove from the water if proper care was taken to avoid ripping the corners. Other porous papers may prove interesting to test in the future.

WEAKNESSES

The weaknesses of this test lie heavily in the number of times the materials were prepared for testing. While measurements were done as accurately as possible, the testing occurred over several weeks, and inconsistencies may have influenced the results. This error could be minimized in subsequent tests if they were all done at once instead of over multiple lab sessions.

The ink did not always have constant viscosity. This was to be expected, since all inks have their own unique set of properties. The problem with this lay not in the ink itself, but in the mode for measuring and depositing it into the basin. The seal on the pipette was not always adequate, and so the ink occasionally seeped deeper into the pipette, unable to be dropped from a slight distance above into the pan. This led to the shaking of the pipette in the water, instead of the gentle drop as prescribed by the Japanese method.

This may have affected the results in a manner of ways. First, and foremost, it means that erratic quantities of ink were deposited into the basin for absorption. Secondly, it also means that the shaking, while it dislodged the ink that may have seeped in through submersion, released the ink below water, sometimes causing it to sink and also causing it to interfere with any marbling patterns that would have formed naturally. This error could have been rectified by the use of a dropper. The use of a dropper would require considerably more observance when controlling quantity of ink, however it would lean better to the overall composition of the marblizations.

Along with the inconsistencies of the ink is the quantity. The quantity used for each test was a meager $50mm^3$, to ensure there was enough for each test from the mixed ink prepared. This influenced the results, because at times there was not enough ink for the substrate to absorb in order to create a pattern. This was also due to the composition of the mixture as well, not solely the quantity. Some compositions did sink when placed in the water (such as the silver pigment). This error was quite difficult to remove, as the problem lay in the very exploration of sample properties. It was very difficult to predict what would sink to the bottom, and what the ideal quantity of ink was without trial and error.

The composition of the inks themselves may have contaminated the tests. For example, the tests that utilized the soap base may have left residue in the basin, despite best efforts to clean thoroughly. This contamination may have skewed the results, as whatever the effect the residue had on the inks may also have occured in the successive tests. There was also the potential for the residue to react with whatever current variable was being tested, such as oil. Unfortunately, the basin was also used by other groups for testing, and was not left in the same condition. This lack of cleaning may have done more damage than originally thought, as although undocumented, there was a noticeable increase in cyan densities when collecting data. These errors are relatively easy to fix in subsequent tests, however it is not cost effective. By lining the pan with aluminum foil or another similar disposable material, the lining could be removed after every test, thus eliminating the chance for residue or sunken ink to stick to the bottom of the basin in addition to the contamination from other persons using the equipment.

A consistent drying time and a method of drying was not established. Drying time was previously a factor that seemed a likely candidate to measure, however due to erratic scheduling it proved to be very difficult to monitor. This may have altered the results in the measurements of curl (warp) and in the measurements of density, as inks and substrates may not have dried completely at time of measurement. In repeated tests, it would be wise to establish a consistent time frame (such as 24 or 48 hours), and then measure the drying time with use of the print ink drying tester equipment. It would also be wise to create a mounting frame to suspend substrates on to control the warp. This would ensure the warp exhibited could not be attributed to inconsistent drying methods, but to the natural warp of the substrates as they absorbed ink.

The number of variables that were substituted into the process could be considered excessive. On the other hand, it can be considered quite limited. The problem arises from having too many materials to explore, and the inability to place sufficient focus on each one's individual merits. That said, there are some materials that there was no opportunity to test, such as poppy oil, liquin, turpentine, etc. This limits the usefulness of the findings, as there are potentially infinite easily accessible chemicals that could be explored. There are two solutions to this; firstly, experimentation could be limited to one chemical at a time where multiple tests on performance are executed or additional chemicals can be experimented with at a later time after analyzing the first set of experiments.

These tests analyze only the performance of the materials, and not the techniques utilized to create the atypical patterning associated with marblization. This has limited the test results, as it makes it difficult to describe the merit of the designs produced with little intervention. In the future, this could be rectified by running a different set of tests to identify the recreation of popular patterns, such as cascade, feather and comb designs (Chambers, 1986).

As previously mentioned weather was an influencing factor. This was not taken into consideration, as the pre-cut substrates were brought back and forth between the lab and home, which could have easily affected the results. The relative humidity changed constantly between the environments, and the substrate was not allowed to acclimatize, affecting curl, brittleness, and the potential for cracking in extreme cases.

RECOMMENDATIONS
PRINTABILITY

Each liquid base affected the viscosity of the ink and how it flowed in the water in different ways. Some chemicals were able to transfer nicely and in full colour on the coated paper like fountain solution, gum arabic, and Flexographic inks. However, other samples, like soap water and silver ink either dripped off the substrate or were completely dispersed into the water. This made it almost completely invisible on the paper, or produced a speckle pattern. When putting ink into the base liquid, it is best to use a dropper so ink can be distributed into the liquid in even quantities. Using larger amounts of inks as well as multiple colours can increase the colour fidelity, density, thickness, and brilliance (Wolfe, 1999). For the water base, it is best to keep the water no deeper than an inch and a half and no shallower than half an inch, for either end can make it more difficult to remove the substrate from the pan, since there is a possibility the substrate will sink into the base when placing it in initially.

When using different types of substrates some worked better than others in terms of curling, transferring, and density. For any sheet of paper, when placing it into water it is best to bend the paper into a 'U' shape to let the center touch the water first and then gently drop the sides of the paper down (Chambers, 1995). Lightly pressing down and tapping the substrate can achieve maximum transfer and remove of any bubbles trapped between the water surface and substrate. If there is a bubble or gap in the pattern, it is possible to re-dip the paper placing the area back in the pattern and it will pick up ink without adding much to the rest of the pattern. Larger pieces of substrate are easier to handle and control because of their firmness and can be cut down to an appropriate size after the marblizing process and after they are allowed to dry. The size of the substrate has an influence on how it will curl once in contact with the base. It is thus recommended to use a substrate size that is 10-30% larger than the final size, so the best area of the pattern can be chosen for use and the curled edges can be trimmed off and discarded.

RUNABILITY

It is almost impossible to incorporate marblization into a printing process, because it will not be unique. It is essentially printing wallpaper via gravure printing. However, there is the possibility to digitize the process, somewhat like Variable Data Printing, where each printed substrate is unique. For this to be made digital, a program would need to be created to generate random marblized patterns via an algorithm to be printed. Even if marblization could be used on press, many types of substrates could not be used that are available via traditional methods. Some examples include rice paper and acetate.

There are many issues for running a marblized paper in a printing press due to the condition of the substrate. When paper has been marblized, it has a tendency to warp and curl, so it is important to flatten the substrate as much as possible so there is no distortion during the printing process. A possibility to prevent as much warping and curling as possible would be to hang the marblization vertical with a weighted end to hold it taunt or stretch and clamp the substrate over a frame until it is dry. If not, it could lead to blanket or cylinder damage on the press, and tearing, folding or more curling to the substrate, damaging the printed area. One way to help flatten the substrates is to run them through the press without printing. Some substrates like rice paper are too delicate to run through a press. They become fragile when wet and will rip when going through a press and drenched by dampening solution. Rice paper also has a caliper that is too fine for most presses and it is too lightweight to run through without numerous problems. The only way to avoid this problem is to slow down the press considerably so the paper can run through without any tearing. For a plastic based substance, it will cause tacking on the printing cylinders, and will require a longer time to dry unless processed with a drier that will not effect the plastic with excess heat, or the addition of avoiding heavy ink coverage to prevent sticking and offsetting in the delivery. For example, acetate does not have porous pockets to help the ink adhere onto the substrate by having the ink seep into it, but it has a smooth surface without texture.

However, marblized paper would never be used on a printing press, because proper registry cannot be achieved. Efficiency will also be a major factor, because each sheet will need to be marblized by hand and at least a 24-hour dry time will be needed. If for some reason marblized paper needs to be printed on, perhaps a digital process will work to give the appearance of print on a marblized sheet.

END USE APPLICATIONS

It is important for the paper to be durable and thick enough to be used as end pages for bookbinding and not damage during the tipping process or being handled by a customer. Marbled paper adds value to the end product and gives an embellished, expensive feel to the product. With the right combination of inks, base, tools, chemicals, and substrates, marblization can create a work of art that can be used outside of bookbinding for things such as art pieces (posters or postcards), wrapping paper, clothing, or any absorbent surface. By using tape or an etching, marbling can be used as patterns for silhouettes or large cap drop text. However not only paper can be marbled. It can be done on wood, canvas and ceramics to create decorative pieces. Substrates that were of a thicker caliper such as canvas, coated paper, or materials other than wood pulp, showed a tendency towards less curling or warping and are a better option if the binding 19 method can handle it. It is recommended to use marbled cloth like cotton instead of pulp products for end papers as it does not curl or warp, and has better ink holdout, but it will require more ink as most will be absorbed into the cloth. It will give a more authentic feel when complimented with a leatherback hardcover book. Vellum and acetate can be used, but it has no particular outstanding result and vellum would require a lot of flattening. When rice paper is marblized, the side that is placed into the base loses the slight coated feeling it has and this may be due to the water penetrating the coating and ruining it. This causes a two-sidedness for the product it is used to create.

Depending on the desired pattern, different substrates and ink mixtures should be used to achieve it. A smooth and consistent texture can be achieved via three methods tested; the type of substrate, ink, and oil. The flexographic inks produced the best, consistent appearance, but with a little haze. It also gives a semi-grainy look and if two or more inks are mixed, like coloured sand. The combination of multiple inks creates large variations of patterns in the ink, giving the grainy effect, smooth and consistent texture and random darker spots all on one page. The smoothest result is with the individual oils. Granulation medium produced a better result when compared to ox gall, because it transferred more ink and did not have dark specs on it, due to the ink not spreading out fully. However, if more white space were desired, ox gall would be the better choice. Although these two appear to be the smoothest, it may not be because the colour is very light in contrast to the other samples. An optical illusion may play a part, because the colour blends in with the white substrate, reducing the grainy look. If perhaps more ink was added, the colour would be darker and the grainy look would be more evident.

A dotted or specked pattern can be achieved via all four methods tested. In order to get better colour in hexachrome and opaque inks such as orange or green, more ink is needed. The reason is due to ink tack, as those colours will be printed last on a press, causing it to be more viscous. Therefore, less linseed oil should be added so it is not as diluted (Wolfe, 1989). The closest resemblance to a printed sheet is the use of baby oil, because the speckles look like halftone dots of various sizes. By using linseed oil, soap, or boiled carragheen, a soft halo effect can be accomplished. If a series of small "lines" or fibre effect is required, stand oil should be used. It should be noted that the ink and oil separates on the ink blotches on the paper if something is added to the base, for example fountain solution or ox gall, after it has finished drying. As for the different substrates, acetate and vellum is not recommended. Uncoated paper or rice paper is able to absorb more ink than others once it comes into contact with the water, resulting in an instant capture of the ink pattern. It would be one of the best methods to achieve a darker density, although if a darker density is desired, more ink can be added to increase it. This also means, depending on the ink pattern, it can be a speckled pattern or a smooth texture.

It is essential for the printed pattern to last as long as the product, such as a book, or a minimum of five years if it is the product itself, such as a postcard. Certain problems will decrease the value of the product and the visual appearance will also decrease due to rub-off or fading. Normally, there are no chemicals or oils in the ink to help prevent these problems, but they can be added, or a coating can be applied. Oils such as linseed oil will help increase abrasion resistance and safflower oil can help increase gloss, which in turn increases readability (Romano & Romano, 1998).

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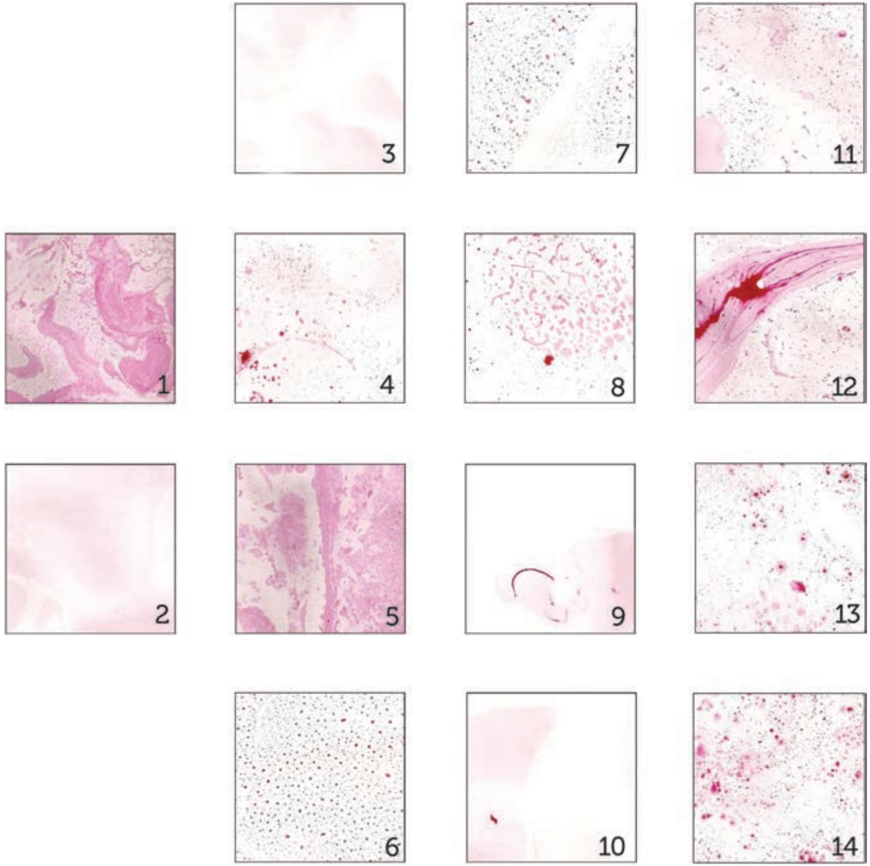
APPENDIX

- Please see Figures *3.1* to *3.4* for test specimen.

Figure 3.1
Variations of Oils/Chemicals

1. All Oils (T1)
2. Granulation Medium (T1)
3. Granulation Medium (T2)
4. Safflower Oil (T1)
5. All Oils (T2)
6. Baby Oil (T1)
7. Baby Oil (T2)
8. Safflower Oil (T2)
9. Ox Gall (T1)
10. Ox Gall (T2)
11. Stand Oil (T2)
12. Stand Oil (T1)
13. Linseed Standard (T2)
14. Linseed Standard (T1)



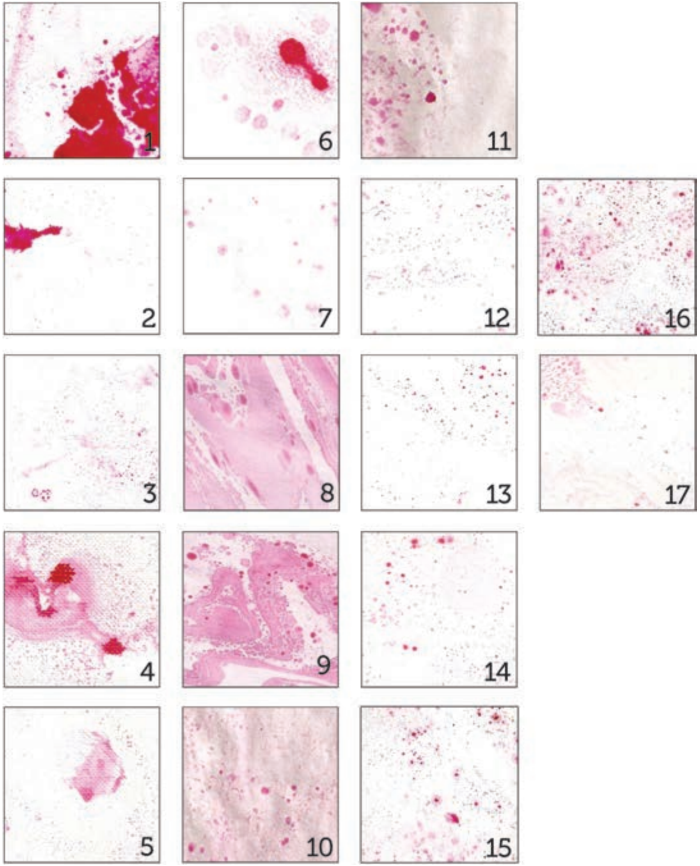
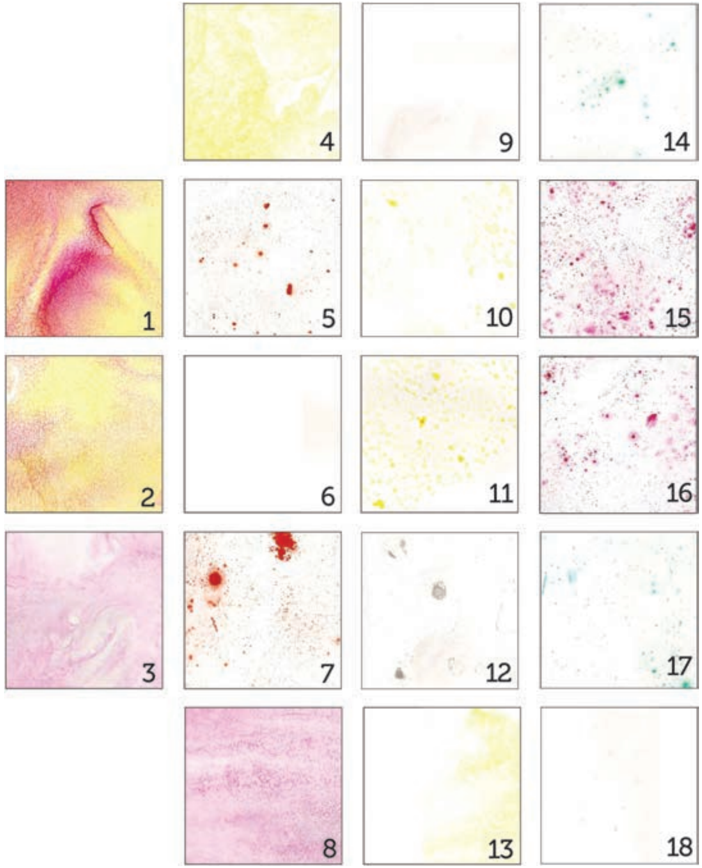


Figure 3.2
Variations of Substrates

1. Acetate (T1)
2. Acetate (T2)
3. Acetate + Drier (T2)
4. Canvas (T1)
5. Canvas (T2)
6. Rice Paper (T1)
7. Rice Paper (T2)
8. Plainfield (T1)
9. Plainfield (T2)
10. Vellum (T1)
11. Vellum (T2)
12. Yupo (T1)
13. Yupo (T2)
14. Mi-Teintes (T2)
15. Linseed Standard (T2)
16. Linseed Standard (T1)
17. Mi-Teintes (T1)

Figure 3.3
Variations of Ink

1. Flexo M + Y (T2)
2. Flexo M + Y (T1)
3. Flexo Magenta (T2)
4. Flexo Yellow (T1)
5. Orange (T2)
6. Silver Pigment (T1)
7. Orange (T1)
8. Flexo Magenta (T1)
9. Silver Pigmet (T2)
10. Yellow (T2)
11. Yellow (T1)
12. Silver (T2)
13. Flexo Yellow (T2)
14. Green (T2)
15. Linseed Standard (T1)
16. Linseed Standard (T2)
17. Green (T1)
18. Silver (T1)



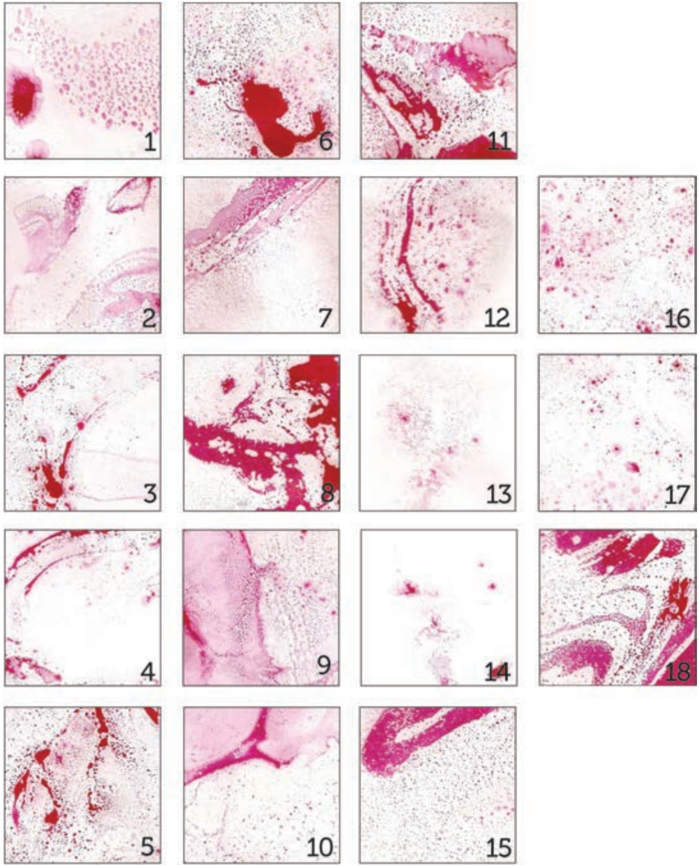


Figure 3.4
Variation of Base

1. Alum (T1)
2. Alum (T2)
3. Carragheen Moss Boiled (T1)
4. Carragheen Moss Boiled (T2)
5. Carragheen Moss Hot (T1)
6. Carragheen Moss Hot (T2)
7. Gum Arabic (T1)
8. Gum Arabic (T2)
9. Hot Water (T1)
10. Hot Water (T2)
11. Ox Gall (T1)
12. Ox Gall (T2)
13. Soap (T1)
14. Soap (T2)
15. Fountain Solution (T2)
16. Linseed Standard (T1)
17. Linseed Standard (T2)
18. Fountain Solution (T1)

VISUAL SIMILARITY BETWEEN COATED AND UNCOATED PAPERS

ANDREA GLAESER
SHARON LANGLOTZ
LENNA PANOU

ABSTRACT

The purpose of this analysis is to determine how to achieve visual similarity of the same colour on both coated and uncoated papers. Various factors can influence the reproduction of colour on diverse substrates such as gloss, absorptivity, and density. Properties tested were the density values of CMYK and their respective L*a*b* values on both coated and uncoated paper.

We concluded that to reach visual similarity, more ink was required on uncoated paper compared to coated paper due to its absorptivity factor. We also determined that as the paper dried, density values of CMYK decreased while L*a*b* values increased.

INTRODUCTION

Various types of papers reproduce colour differently due to their surface's capacity to absorb a printed ink film. This variability in colour has since been controlled with the introduction of ISO 12647-2 as the standard to follow when printing with offset lithography. SWOP (Specifications for Web Offset Printing) and GRACoL (General Requirements and Applications for Commercial Offset Lithography) were engineered to raise the quality of specific printing processes, commercial and publications. However, these are simply guidelines that base their values on those imposed by ISO 12647-2 and provide the foundation for controlling their respective process. It should therefore be noted that throughout our testing process, SWOP and GRACoL were not employed, as they are specifications and not considered standards. As of current, ISO 12647-2 is the only standard for offset printing (Radenic et al, 2007) and therefore was implemented into our test and how we examined our results.

The objective of our test is to determine at which density printed inks achieve similar colour when comparing coated and uncoated paper surfaces. The specific amount of ink required to achieve these colours was only taken into consideration when testing on the Prüfbau, as we were able to accurately measure quantities applied using the pipette tool.

Expected educational gains include understanding the relationship L*a*b* and CMYK values have on interpreting the visual similarity of colours. Also, we expect to grasp a concept of how much ink is necessary to achieve colour accurately in terms of spectrophotometric and densitometric values.

All ink values (CIE LAB and CMYK densities) are provided for wet and dry readings. Wet inks usually read higher in density (lower L*) and "dry-back" to a lighter value. Printing on aqueous coatings usually reduces or even eliminates the difference between wet and dry readings and can considerably shorten the calibration process (IDEAlliance, 2007)

EQUATIONS

$$\Delta E = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}$$

Where:

- $\Delta L^* = L^{*act} - L^{*ref}$
- $\Delta a^* = a^{*act} - a^{*ref}$
- $\Delta b^* = b^{*act} - b^{*ref}$

DEFINITIONS

CIE LAB: A 3-D Colour space mathematically derived from CIE XYZ. Chromaticity coordinates resulting in greater perceptual uniformity, L* (neutral light-dark axis), a* (red/green axis), b* (blue/yellow axis). *Figure 4.1* shows a cross section (IDEAlliance, 2007).

Dryback: The decrease in the gloss of an ink that occurs during the drying of sheetfed offset inks (Wilson, 1998).

Solid Ink Lab Values: Colour information that is used to specifically map a colour gamut. These measurements are extremely useful for colour management experts (IDEAlliance, 2007).

ISO 12647-2 (2004): Specifies a number of process parameters and their values to be applied when preparing colour separations for 4-colour offset printing, or when producing 4-colour prints by one of the following methods: heatset-web, sheetfed or continuous forms process printing or proofing one of those processes (ISO, 2009).

SID (Solid Ink Density): A numerical measure of how much complimentary (major filter) light is absorbed by a solid patch in a colour control bar as measured and reported by a reflection densitometer, measured dry with instrument calibrated to status-T (IDEAlliance, 2007).

Optimum Colour Reproduction: Colour accuracy that occurs when the printed colour matches the observer's perception of the compromised appearance of the original colour (Field, 2004).

TEST PRINCIPLE

The principle behind this test is to display how variable substrates can affect the visual similarity of a printed ink film. Ink density is an important factor when reproducing colour on coated and uncoated papers. It is advised to follow ISO 12647-2 specifications, as it is currently the only official standard for offset printing (IDEAlliance, 2007). Using these specifications as guidelines only, we can more closely attain the optimum densities required to prevent a noticeable shift in colour.

The process of our findings simulates actual press conditions as we conducted a short pressrun on the 4-Colour Heidelberg Printmaster, whereby we printed on ISO certified papers and process inks. As the press was running the ink zones were gradually shut off, applying less ink to the paper and, therefore, resulting in lower densities. Press sheets were pulled at random throughout the duration of the pressrun to allow for variable density readings. This allowed us to define the moment at which density plateaus for each printed ink and also states the amount of ink required to achieve visual similarity.

A related test was conducted using the Prüfbau machine by gradually adding uniform quantities of ink (100 mm^3) to the rollers then printing the ink films. L*a*b* and CMYK values were recorded for each sample to determine the result of increasing the amounts of ink applied to both coated and uncoated papers. These findings were also used to conclude how much ink is required of both to achieve the desired result. If the exact instruments are not used throughout the analysis of the samples our results may appear skewed as values can differ between devices. When lowering ink keys or applying ink to the rollers, one must be careful that the same amount is reduced/applied each time to ensure consistency. Also, when following ISO specifications, one must ensure that ISO is applied into all aspects of the printing process; from paper to plates, they must all correspond with the standards, otherwise improper results will arise.

MATERIALS TESTED

INK

- Hostmann Steinberg Reflecta Black 5.5 lb, 2.5 kg
- Hostmann Steinberg Reflecta Cyan 5.5 lb, 2.5 kg
- Hostmann Steinberg Reflecta Magenta 5.5 lb, 2.5 kg
- Hostmann Steinberg Reflecta Yellow 5.5 lb, 2.5 kg

PAPER

- Roland Opaque 19 x 25 in., 80 M, 119 g/m^2
- Supreme Gloss Text 19 x 25 in, 100 M, 148 g/m^2

EQUIPMENT USED

- Densitometer
  - Model: R710 Ihara Colour Reflection Densitomer #2
  - Manufacturer: Ihara Electronic Industries
  - SIN #: 661.257.577
- Press
  - Heidelberg Printmaster 4-Colour
- Prüfbau
  - Dr. Ing. H. Drüner
  - 82380 Peißenberg, München
- Ink Knives
- L*a*b* spectrophotometer
- Ink Pipette

PROCEDURE
PRÜFBAU

1. Cut strips of both coated and uncoated paper to 2 x 10 in.
2. Using a pipette, measure 100 mm^3 (2 rotations) of black ink.
3. Place ink on large rubber roller of the Prüfbau and allow the instrument to run for 1 minute.
4. Lower smaller steel roller to transfer the ink from the rubber roller and let run for 1 minute.
5. Turn off Prüfbau and place steel transfer roller on first section to print.
6. Tape an uncoated strip of paper on the carrier and place in correct position.
7. Run the Prüfbau to print an ink film on the strip of paper.
8. Take density readings of CMYK as well as L*a*b* readings of the wet ink film. Ensure a white piece of paper is under the sample during these readings.
9. Record results and let dry.
10. Repeat steps 2-9 increasing the amount of ink by 100 mm^3 to reach a maximum of 1000 mm^3. Conduct this test on both uncoated and coated paper samples.
11. Take density and L*a*b* readings from the dry strips and record results.
12. Input results in an Excel worksheet to create necessary charts/graphs and compare.

PRESSRUN

13. Turn ink keys off to gradually decrease the ink film thickness during the pressrun.
14. Gather press sheets from the beginning, middle and end of the pressrun.
15. Select 10 press sheet samples from both coated and uncoated papers.
16. Take the dry density and L*a*b* readings of CMYK, and an additional K (for consistency purposes) from the colour bar. Also, measure the same values of the coated and uncoated.
17. Record results.
18. Place results in an Excel worksheet and create necessary graphs/charts and compare.

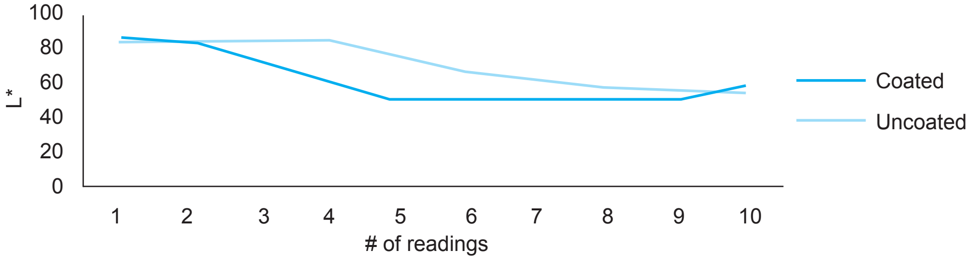
RESULTS AND DISCUSSION

- Please see *Graphs 4.1* to *4.15* for results

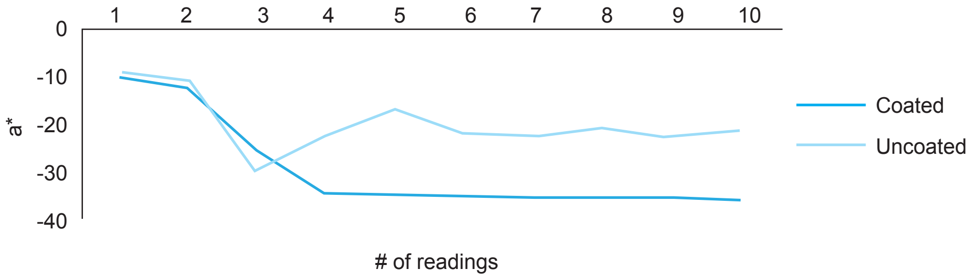
VISUAL COMPARISON OF THE PRÜFBAU PRINTED SAMPLES

When comparing the printed samples from our Prüfbau printouts, it is apparent that the visual similarity cannot be achieved for KCMY. However, the closest match between papers would be the yellow printed samples. This is due to the lightness of the colour and the darkness of the other three inks when they adhere to the substrate. Coated papers produce richer colour that cannot be matched by uncoated papers, no matter the amount of ink that is added to the paper (Wilson, 1998).

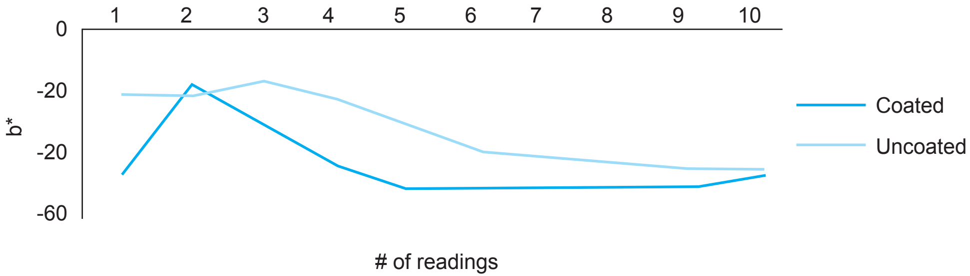
Graph 4.1
L*: Cyan coated
versus uncoated.

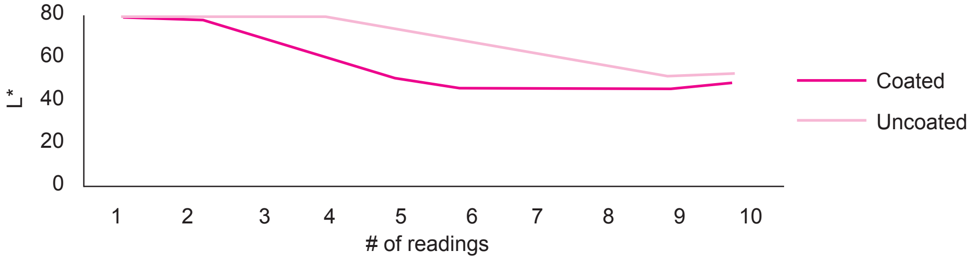


Graph 4.2
a*: Cyan coated
versus uncoated.

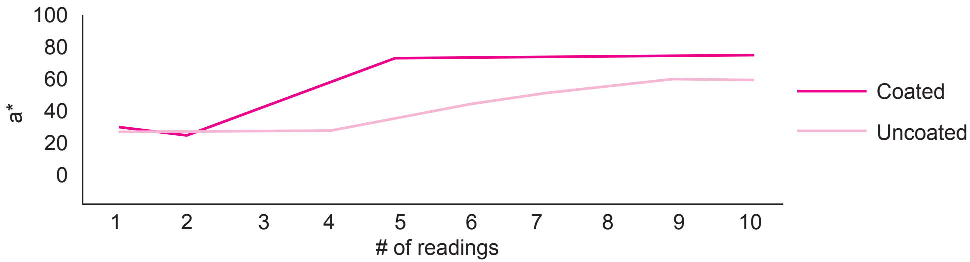


Graph 4.3
b*: Cyan coated
versus uncoated.

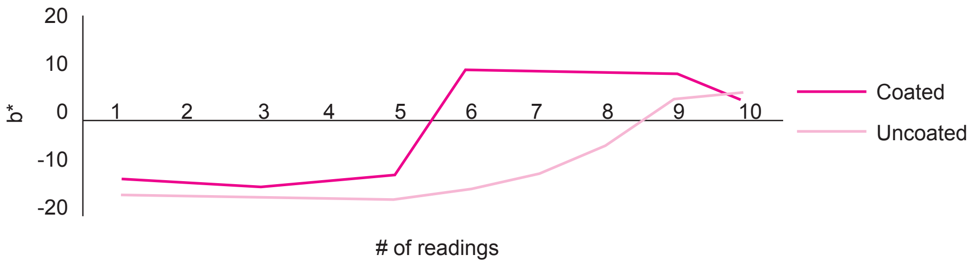




Graph 4.4
L*: Magenta
coated versus
uncoated.

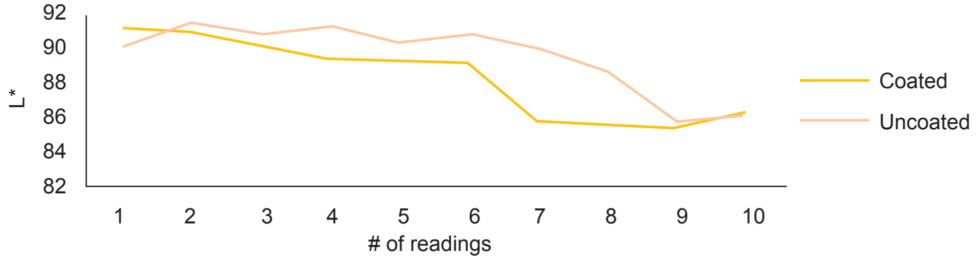


Graph 4.5
a*: Magenta
coated versus
uncoated.

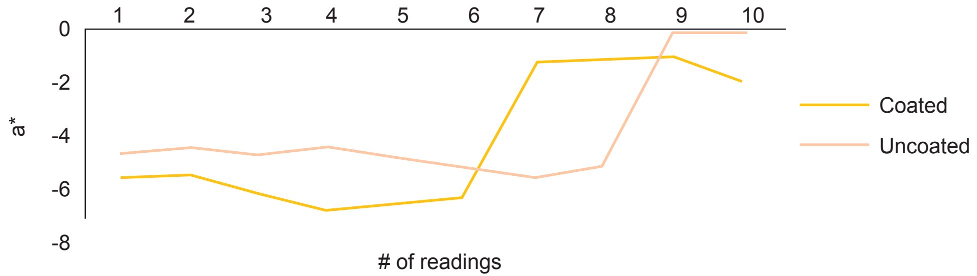


Graph 4.6
b*: Magenta
coated versus
uncoated.

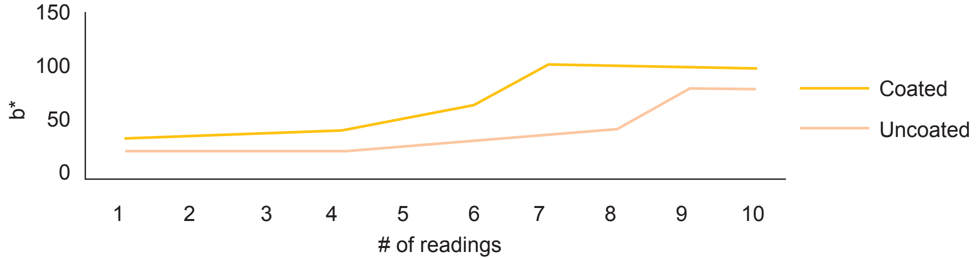
Graph 4.7
L*: Yellow coated
versus uncoated.

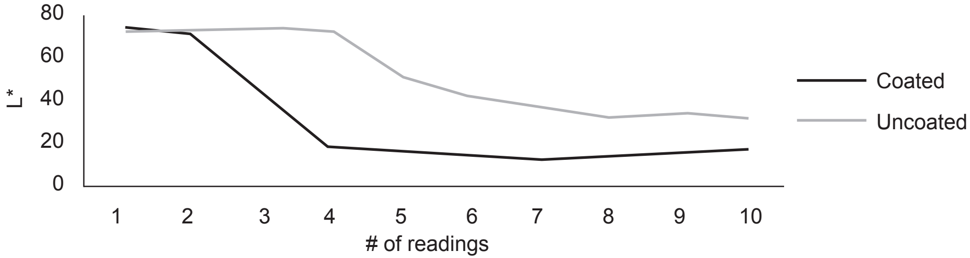


Graph 4.8
a*: Yellow coated
versus uncoated.

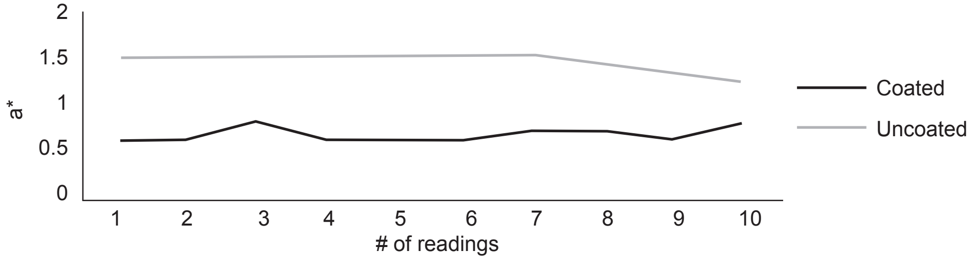


Graph 4.9
b*: Yellow coated
versus uncoated.

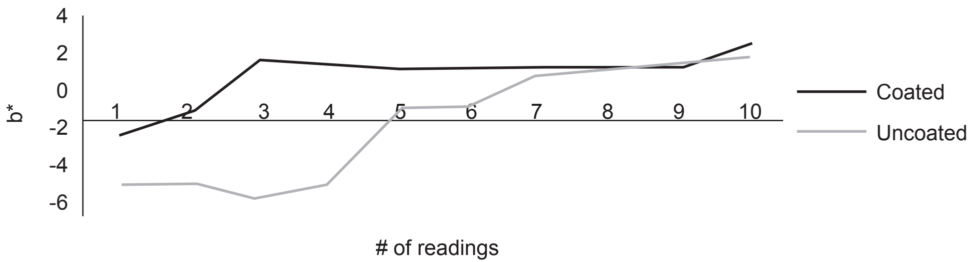




Graph 4.10
L*: Black 1
coated versus
uncoated.

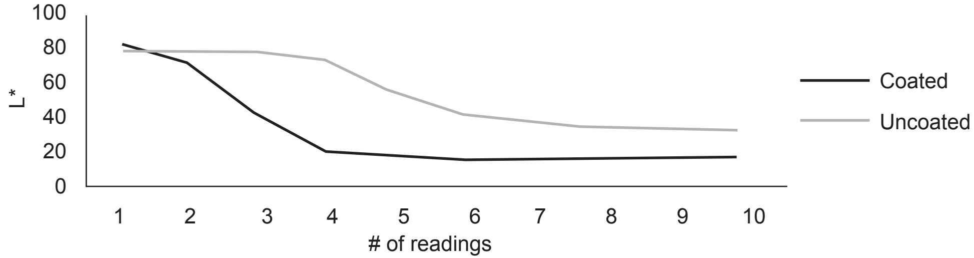


Graph 4.11
a*: Black 1
coated versus
uncoated.

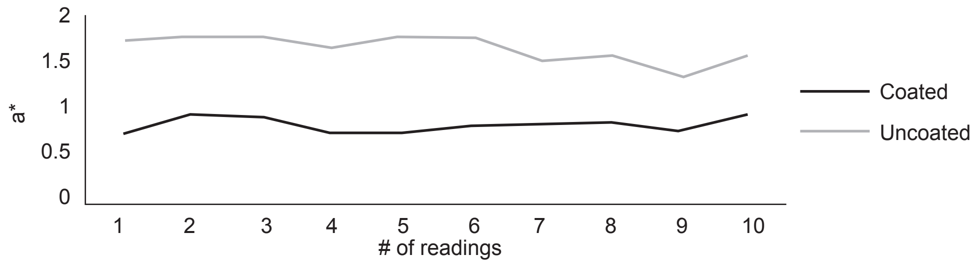


Graph 4.12
b*: Black 1
coated versus
uncoated.

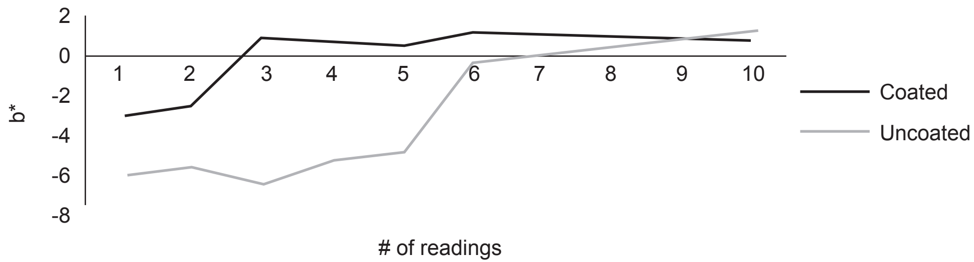
Graph 4.13
L*: Black 2
coated versus
uncoated.



Graph 4.14
a*: Black 2
coated versus
uncoated.



Graph 4.15
b*: Black 2
coated versus
uncoated.



VISUAL COMPARISON OF THE PRESSRUN SAMPLES

The pressrun results showed that the uncoated prints appeared grainy and lighter in colour when compared to the coated prints, which are smoother and richer in colour. Images printed on coated papers appear more crisp and vibrant, whereas images on uncoated papers appear dull and dry. Coated paper also produces finer detail within the images while uncoated paper lacks this ability, resulting in images that appear to be of lower quality.

Gradients within the prints on coated papers are evidently softer and banding is not as obvious. Uncoated papers produce gradients with harsh breaks that affect the visual appeal of the overall print.

COMPARISON OF PRÜFBAU'S WET VS. DRY INKS

L*a*b* values and CMYK densities were measured

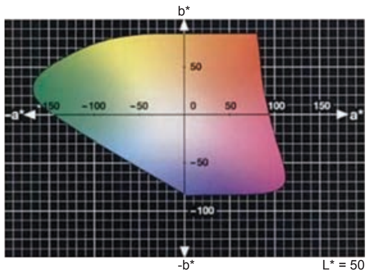


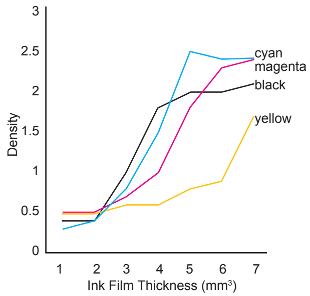
Figure 4.1 — CIELAB colour space (cross section of the colour solid). (Kipphan, 2001)

for all printed samples when wet, as well as dry, after sufficient drying time was provided (approximately 48 hours). This process was conducted to determine if any discrepancies or variances were apparent in printed ink films effecting visual similarity. Our results for CMYK densities determined that there was minimal difference between the two ink films (wet and dry). While CMYK differed slightly between wet and dry ink films, we found that the L*a*b* values had a significant variation caused by dryback (GRACoL, 1999). The a* and b* values altered considerably due to the drying of the inks, which may or may not have affected visual similarity but is required for reference for anticipated press re-runs (GRACoL, 1999).

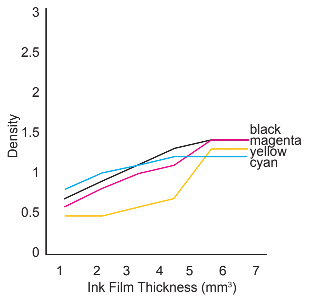
PRÜFBAU AND PRESSRUN L*A*B* RESULTS

There are vast differences in results regarding the L*a*b* values of an ink film between coated and uncoated papers. It is apparent that with both substrates, lightness decreases as ink density increases. If you refer to the CIE L*a*b* colour space, you will notice the placement of the colours reflects the values of our results in relation to location (Kipphan, 2001).

For example, cyan's coated a* values are negative meaning that the ink is more green. The b* values are also in the negative region, resulting in a bluer colour. Comparing these results to cyan's uncoated L*a*b* values, the values are not identical in negative value, however still portray the same curve demonstrating similar placement on the colour space.



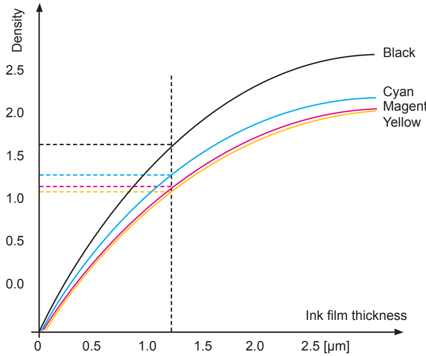
Graph 4.16 — Density of ink film on coated substrate.



Graph 4.17 — Density of ink film on uncoated substrate.

PRÜFBAU AND PRESSRUN CMYK RESULTS

While adding equal increments of ink in the Prüfbau test, it showed that the density values for coated papers was higher than those read from the uncoated papers. This could be due to the fibrous surfaces of the uncoated paper tested (Karg et al, 2005). Gradually increasing the amount of ink provided a visual means of understanding ink film thickness and its effect on colour. It appeared that coated papers required lesser amounts of ink to achieve optimum colour reproduction compared to uncoated papers, which are comprised of a more porous surface, resulting in higher absorptivity levels. Using cyan as an example, our results indicate that when the paper has reached maximum absorptivity, the density of the coated values level out at 2.5 while the uncoated values plateau at 1.4. The following values of coated and uncoated ink films (*Graphs 4.16* and *4.17*) are compared to the standard ISO density specifications (*Graph 4.18*).



Graph 4.18 — The optical densities of inks with different ink film thicknesses. (Kipphan, 2001)

COMPARISON OF DELTA E TO ISO STANDARDS

The Delta E equation was used to compare the pressrun's L*a*b* values to ISO standards. We chose to only apply the Delta E equation to our pressrun findings, as the printing process was more consistent and controlled. This Delta E difference determines the amount of deviance that is acceptable for printing to ISO specifications. In the case of our tests, we wanted to follow ISO's standard deviance of 5 units to maintain consistency (Radencic et al, 2007).

DELTA E EVALUATION/PERCEPTION (KIPPHAN, 2001)

- ΔE between 0 and 1
  - No visual deviation
- ΔE between 1 and 2,
  - Very minor deviation
  - Experienced eye
- ΔE between 2 and 3.5
  - Medium deviation
  - Common perception
- ΔE between 3.5 and 5
  - Large deviation
- ΔE exceeding 5
  - Major deviation

ISO L*A*B* VALUES AND ALLOWABLE TOLERANCES

	Black	Cyan	Magenta	Yellow
L	16	54	46	88
A	0	-36	72	-6
B	0	-49	-5	90
ΔE	5	5	5	5

(Radencic et al, 2007)

CYAN

Coated press sheets were able to achieve a delta E within ISO standards of 4.8, while uncoated press sheets were unable to derive a delta E within 5. Instead, the delta E reading was 14.2, a value considered to be of major deviance and therefore inappropriate to apply during pressruns which require ISO standard papers.

MAGENTA

While the coated papers were close to the delta E requirement, they differed by 2.9 resulting in a reading of 7.9. Therefore, printing magenta on these coated papers results in colours that are not acceptable. This also applies to uncoated papers, where an even larger deviance was discovered of 13.7.

YELLOW

Upon close evaluation of the coated and uncoated delta E results, it was concluded that both samples produced a delta E much greater than 5.

Coated had a reading of 10.3 and uncoated generated a reading of 9.0. This result indicates that like magenta, they are unacceptable for printing in an ISO standardized environment.

BLACK #1 AND #2

Coated results were similar to those of cyan where their delta E was within ISO tolerance of 5, producing a delta of 3.4 for black #1 and a delta of 2.7. Uncoated however, produced a larger delta E value of 17.7 for black #1 and 16.6 for black #2. These values are intolerable when compared to ISO 12647-2 specifications.

COMPARISON OF L*A*B* VALUES BETWEEN COATED AND UNCOATED

CYAN

Evaluating the cyan swatches on both coated and uncoated press sheets, found that the first three L* values are similar. The subsequent press sheets (samples 3 - 8) began to show a visible difference in lightness. The 9th samples shared similar L* values, therefore these two samples are the closest match in terms of lightness. By comparing the a* values, we can conclude as to why cyan appears differently on the two different stocks. On the L*a*b* axis, a* describes the amount of red-green tones present in the particular colour, negative values being green and positive values being red (Field, 2004). We can see that coated samples have a larger negative number than those of uncoated, therefore appearing more green. The b* value represents the yellow-blue tones present in the colour; similarity in b* values between the two samples are noticeable on the 10th sheets, enabling us to conclude that coated papers have more of a blue tone than that of their uncoated counterparts.

MAGENTA

Magenta has similar results as our cyan values, where coated papers appear to have a more red tone than uncoated. Also, we found that our uncoated papers appear to have a blue tone.

YELLOW

L* value results of the yellow samples were skewed due to the general lightness of the colour. Both samples are similar in appearance, although coated seem to have more of a yellow undertone than that of uncoated. Samples 1 to 3 show similar results, while samples 4 to 8 show a greater difference in values. Both samples then plateau for the 9th and 10th readings. The a* coated values show a drastic increase in yellow tone earlier in the pressrun when compared to uncoated a* values. Although both papers show similar patterns in terms of areas of increases and decreases their values were consistently different. Due to this result, a valid conclusion cannot be drawn about the a*, red-green tonal variation. When viewing the yellow-blue values (b*), it is apparent that the same findings for a* apply to these results as well.

BLACK

The measurement of two black samples was applied to each press sheet to ensure that consistent colour was produced throughout the pressrun. The L* and a* values for both black 1 and 2 on coated and uncoated samples meet only at the end of the run. The b* values are closest in relation to each other at the end of the pressrun. Although the values for both black 1 and 2 are consistent throughout the pressrun, this consistency involves a deviance between papers great enough to prevent a viable conclusion.

RECOMMENDATIONS

The two major factors of achieving proper visual similarity of a printed ink film are the source of lighting (ie. fluorescent vs. D65) and the individual's ability to distinguish colour accurately. This form of visual colour difference is known as metamerism (Kleerdex Company, 2008). Customers should be aware of the effect different light sources have on colour appearance, and print managers should be advised to display the printed proof under appropriate D65 lighting (Kleerdex Company, 2008). To diminish discrepancies between visual appeal CIE L*a*b* colour space was created to produce standards and determine how a colour should be measured (Kleerdex Company, 2008).

Different types of fillers and chemicals used in the manufacturing process of paper play a significant role in how a colour appears when printed. Typically coated papers are available in a variety of shades of white, ranging from blue-white to yellow, which can affect readability, legibility and how the printed piece is perceived (GRACoL, 1999). It is recommended that coated papers be used for reproducing high quality images to prevent variance from proof to printed result. Correspondingly, it is recommended that uncoated papers be used for reading purposes. Papers that are matted, uncoated natural whites or slightly yellowish in colour are more pleasant to read and should therefore be used when printing text (Itkonen, 2009).

The coatings applied to paper provide a smoother and more ink receptive surface ensuring appropriate printing and handling characteristics (Karg et al, 2005). It is suggested that coated papers are to be used for high quality reproduction due to their ability to reproduce finer detail and heavier ink films (Karg et al, 2005).

By increasing density on uncoated papers to better match the quality and outcome of coated papers, the pressrun may be hindered by the picking of fibres onto the impression cylinder (Karg et al, 2005). Fibres will create hickeys on subsequent prints, thereby effecting image quality (Eldred, 1990).

To ensure consistency among pressruns, printers should employ the use of a standard such as ISO 12647-2 to provide specifications throughout the entire printing process. These standards should all follow the same densitometric parameters to maintain control (Radencic et al, 2007). As previously stated, specifications such as SWOP and GRACoL are simply guidelines used to ensure repetition of process within their print environment. Print manufacturers have the choice of which standard they want to employ, however it should be noted that specific standards are unique to their corresponding printing method (Radencic et al, 2007).

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HALFTONE DOTS: A COMPARISON OF STOCHASTIC AND CONVENTIONAL PRINTING

JOEL MCCURDY
AMALIA POLSINELLI
MAREK SKOWRON
BRITTANI WILCOX

ABSTRACT

The purpose of this project is to create a comparison between conventional and stochastic screening processes. Is one better than the other? We will also determine the common misconceptions related to stochastic screening. To accomplish this, information from books, articles and websites were compiled and compared to the opinions of current industry leaders who print both Stochastic and Conventional.

Our results indicate that, due to the limited documentation of relevant information regarding first and second order stochastic printing, there are negative connotations tied to FM screens. However, this relatively new

process can be very beneficial to companies as well as customers. FM screens rely heavily on consistency and quality control but often result in exceptional print quality.

The type of work a print company typically outputs should be considered when a decision to implement a stochastic screening process is being made. In some cases, such as a when a company generally produces large amounts of one-colour, text-heavy jobs, conventional printing will still be the most efficient way to print.

From this research, we hope to gain a higher level of knowledge of the different types of screening processes available in today's industry. This will allow us to understand the appropriateness and benefits of each screening process.

INTRODUCTION

This report is significant because the documentation of evolving technology needs to be kept up to date to ensure accuracy in our information-based world. Dated articles and books are misleading and hinder the implementation of beneficial new technology.

The objective of this report is to learn of the abilities and inabilities of stochastic screens, in comparison to conventional screens. Thus, we will create a report that updates the available information of this relatively new process. This is important because up-to-date information affects a company's decision to implement new technologies in their workplace that may be beneficial not only to their customers, but also to their business and quality of work.

EXECUTIVE SUMMARY

In today's fast paced world, technology is ever evolving and updating, improving and outshining old ways of doing things. Stochastic printing has been evolving for the past 50 years, and seems to have developed within the last decade and improved on some of the common issues related to conventional printing. Why have companies not adopted this new process then?

After an in depth investigation into the world of stochastic halftones, it becomes clear that past generations of stochastic printing continue to haunt the second order stochastic screening process today. There is a lack of recent documentation in existence, allowing misconceptions of this screening process to fester. Even reports written as recently as 10 years ago are no longer relevant. These original reports are based on a film-to-plate workflow and first order technology, which was released in 1994 (Whitcher, 2004). There were many inherent problems with first-order stochastic screening (Whitcher, 2004). These reports create misunderstanding for individuals interested in learning about and possibly implementing a stochastic screening process. Now, with second-order stochastic, this technology is free of the traditional problems associated with earlier versions (Whitcher, 2004). Yet it fails to be properly documented.

This paper is being written to report on the reality of today's printing technologies. It will begin with an introduction and brief explanation of what AM and FM screening is. Through the report, there will be a comparison between the two screening methods, while discussing (and correcting) the common misconceptions related to stochastic printing. In essence, this report will provide an updated documentation of what stochastic and conventional printing really is and really means for the printing industry.

This paper will outline conventional and stochastic related topics such as effect CTP has had on stochastic, hardware and software requirements and process control. This report will also including print quality issues such as moiré, the size of colour gamut, dot gain and registration.

AM AND FM SCREENING

In the realm of halftone screening, the chronological timeline of screening methods is as follows: Amplitude Modulation (AM screening), Frequency Modulation (FM screening) and AM-FM hybrid screening. FM screening made its official debut over a decade ago, while hybrid screening has surfaced within the past five years (RIT Homage, 2007).

Conventional AM screening is the process that is characterized by dots that are equally spaced apart from the center, but vary in diameter (Hershey, 2006). Refer to *Figure 5.1* for an example of AM screening. Each dot is formed in a halftone cell, which is usually based on a grid of 16 x 16 pixels. To form the dot shape, the pixels within the cell are 'turned on', as seen in *Figure 5.2*, in order to form the dot shape (Pritchard, 2009). This means that the diameter of the dot determines the shade of the region of the image. Therefore, a larger dot results in a darker shade of the region. AM screening is always measured in lines per inch (lpi).

When employing AM screening, the printer must choose which shape dot will be best suited for the job. This is important because the shape can impact the look of the final presswork. These dot shapes include the Round, Euclidean, Elliptical, Square and Line dot, and specialty dots such as the Pepper and Novelty dot (Pritchard, 2009).

The most common issue associated with conventional screens is the issue of moiré. Moiré is caused by misaligned and overlapping screens (RIT Homage, 2007). To minimize moiré, each colour separation (CMYK) is set to a specific screen angle. This topic will be covered further, later in the report.

Frequency-modulated (FM) screening, otherwise known as Stochastic, is characterized by the variation in the frequency of the dots in a given region but not a variation in dot diameter (*Figure 5.3*) (Zarwan, 2003). Where the dots are dense, there is more colour and where the dots are sparse, there is less colour (Ferriolo, 2002). Due to the size of the dots, this screening method is measured in microns instead of lines per inch.

Similar to an AM screen, an FM screen dot is formed in a halftone cell, based on a 16 x 16 pixel grid. They differ because cells are turned on in a 'random' fashion in order to form the FM dot shape (Pritchard, 2009). Refer to *Figure 5.4* for a visual example.

The main difference between AM and FM lies within FM's ability to eliminate moiré patterns and provide a more continuous tone for the human eye (RIT Homage, 2007). Images printed using stochastic more closely represent the original photography (Ferriolo,

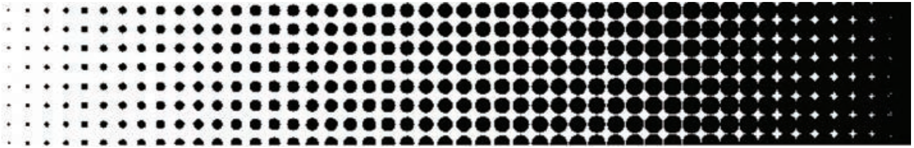

Figure 5.1 — AM screening
(Pritchard, 2009)

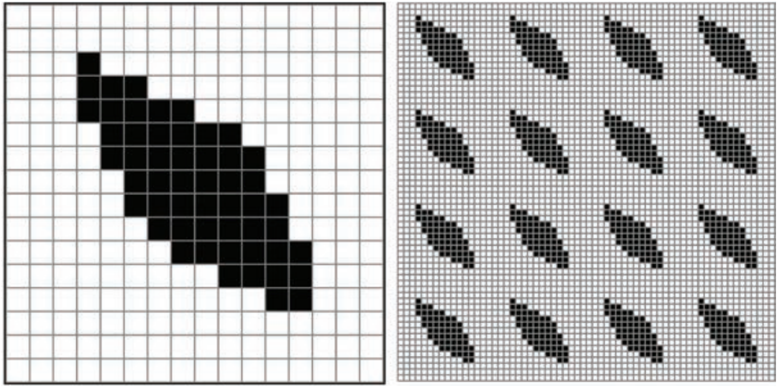

Figure 5.2 — AM 16 by 16 cell: enlarged (left) and reduced (right)
(Pritchard, 2009)

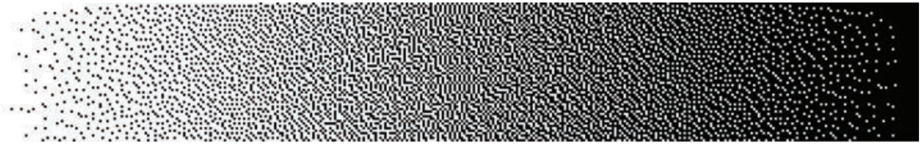

Figure 5.3 — FM screening
(Pritchard, 2009)

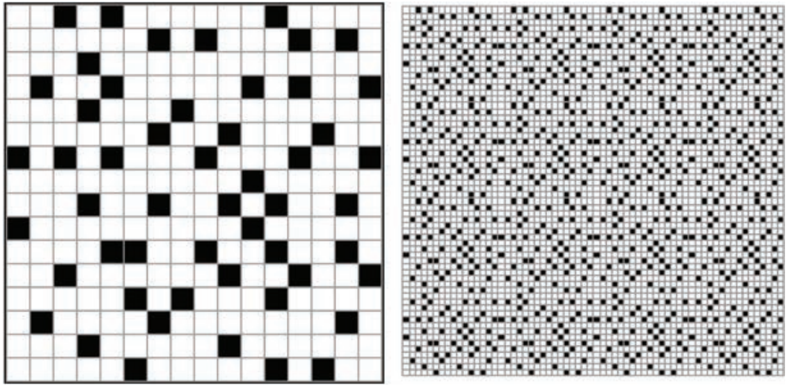

Figure 5.4 — FM 16 by 16 cell: enlarged (left) and reduced (right)
(Pritchard, 2009)

2002). However, when FM Screening was introduced in 1994, it was part of a film-based workflow. This dot shape/pattern is referred to as First Order FM, where the dots were consistent in size. While it provided a photographic-like quality, the reproductions were often grainy and mottled in the flat tone areas (Pritchard, 2009). Second Order Stochastic technology is the second coming of FM screening, meaning that both dot sizes and spacing are not fixed (Whitcher, 2004). This results in extremely smooth renditions, ultra detail, sharpness and the complete absence of moiré (Whitcher, 2004). As previously mentioned, FM was first a film-based workflow, but has since evolved to a Computer-To-Plate (CTP). This allows printers to take full advantage of the benefits that come with stochastic printing. This will also be further discussed within the report.

DISCUSSION

COMPUTER-TO-PLATE

When printers think of stochastic printing, their mind often goes to how difficult it is to implement this type of halftone screening. With Computer-to-Plate technology becoming the standard, FM screening is gaining traction within the industry.

When stochastic printing was released in 1994, it was to be used in conjunction with a film-based workflow. This caused many issues with calibration, contacting, and proofing, resulting in a screening technique that was difficult and time consuming during the pre-press stage (Witcher, 2004). CJ Graphics reports that when film was still being used, quality control was next to impossible; there were a lot of wasted plates due to microscopic dust particles (Personal Communication, 2009). Dust particles were common for conventional plates as well, but unlike AM, stochastic plates could only be struck once (Ferriolo, 2002). At the time, the advantages were offset by the drawbacks that a film-based workflow had. Fortunately, these issues have been virtually eliminated with Computer-to-Plate technology. CTP produces a first generation dot, rather than one created on film, allowing printers to take advantage of its benefits to quality, without having to waste materials (Hershey, 2006). CTP technology has revolutionized plate making for both stochastic and conventional printing.

Tom Menard from Acuity stated that stochastic plates can produce a higher resolution, and therefore, conventional halftones can be produced on them and be used for AM printing. However, since not all conventional plates have the ability to produce 300 LPI, it cannot be said that stochastic can be printed using conventional plates.

Ryburn Goodyear, from Ryerson University, explains that this is "generally a limitation with traditional plate exposure and not CTP plates". Since CTP plates are exposed using a laser, they have the "resolution to image the 10 to 20 micron spots of stochastic" (Personal Communication, 2009).

PROCESS CONTROL

Stochastic screening is a relatively new technology and the process control has not had as much time to be mastered as conventional screening. Most companies started printing conventionally and have had time to develop quality standards that have become the status quo in the industry. Each screening technique requires three basic steps of process control: selection of screening attributes, press characterization and a monitored press run. Each step is tailored to the individual process (Hershey, 2006). The selection of screening attributes differs from printer to printer. Therefore, a company printing stochastic screens would determine the spot size (e.g. 10μ, 20μ, 30μ, etc) and for conventional, the screen ruling of lines per inch, would be determined. Press characterizing and monitoring are both essential parts of a successful run, regardless of the technology, but since stochastic is new it requires more effort (Hershey, 2006). Both methods also require an efficient press operator who understands the technology and process.

With stochastic screens, it is essential to have high process control and the ability to measure your process in order to achieve the quality that it is known for (Fenton, 2005). It requires regular press calibration that includes running the press at normal densities, finding the smallest dot that is being held on the press and reading each target to build separate curves for individual colors. According to CJ Graphics, for both stochastic and conventional screening, each paper, dot and press must also have an individual curve (Fenton, 2005). Checking fountain solution, chemistry and maintaining a controlled process are all important when implementing this technique. There is an increase of approximately 5-10 minutes per job for quality control and like all new technologies, it can require multiple attempts in order to find the process that works for each individual company (Fenton, 2005). Quality procedures do make it harder to print. However the advantages of quality can outweigh the initial learning curve (Ferriolo, 2002).

It is the opinion of Blayne Jensen, Systems Manager at Lorraine Press, that some succeed with FM while other fail due to their process control. "In my experience with advising print firms, companies that focus on process control and understand testing are more successful. We believe that process control and the ability to measure your process is essential in making stochastic work (Fenton, 2005). Tom Menard of Acuity insists that if stochastic is adopted as the standard, it is no more difficult than printing conventional.

HARDWARE AND SOFTWARE

At first, stochastic printing did not take off because RIP's "simply had not been powerful enough to provide a reasonable production throughput" and a lot of computer power was necessary in order to handle stochastic screening algorithms (Campbell, 2003). With the advancement of RIP software, these kinds of issues are no longer as relevant, but the ability to print with stochastic screens comes at a price. When purchasing an imagesetter or platesetter, the ability to produce stochastic screens is not a standard feature, however "most vendors offer it as an option and the cost can vary anywhere from $30,000 upward" according to Premedia professor, Ryburn Goodyear. There are some imagesetters and platesetters that are unable to produce stochastic because the feature has not been added on. For example, "our previous Agfa Phoenix Imagesetter was not" Goodyear explains.

Creo's 10-micron Staccato software runs in second-order stochastic and prides itself on having consistent printing throughout the entire run, which Stanley Rosen from Creo says results in "less paper waste and quicker make-readies" and has won great response from its users. The software can help to reduce variations in colour, dot gain, trapping and increases tonal and colour stability (Whitcher, 2004).

FILE SIZE

Information from five years ago states that enormous file size was also a factor with earlier versions of stochastic (Yule, 2004). Ryburn Goodyear provided insight on the file size differences between stochastic and conventional screening. He explained that FM file sizes can actually be smaller for the original scanned image, but have larger files in the RIP because of the large algorithms used to program the imagesetter (Personal Communications, 2009). The normal ratio for scanned images to conventional halftone dots is 2:1, which results in a 300 DPI file for 150 LPI. With stochastic, files can be scanned as low as 150 DPI (Goodyear, personal communication, 2009). Goodyear explains that the reason this is possible is because "the higher resolution for traditional screening is necessary to avoid moiré with the traditional angles and this is unnecessary with stochastic". The RIPped files for stochastic printing are larger because "the screening algorithm for stochastic is more complex" and the information that is used to drive the imagesetter or laser is "one that must randomize the laser position opposed to exposing on a set grid", therefore producing a larger file than conventional screening (Goodyear, Personal Communications, 2009).

MOIRÉ

There are many factors that cause moiré. These causes include interference between patterns in the original image and the scan, interference between patterns in the original image and the halftone screening and interference between the different colour screens in a conventional separation (Shaw, 1995).

The conventional screening process employs the use of various screen angles to eliminate the moiré patterns that are created when the four process colours are overprinted. When the angles applied to the halftone dots are set at improperly aligned screen angles, the problem of colour moiré occurs (Monaco, 2002). Subject moiré can also occur when pattern in a photo, such as plaid, interfaces with a halftone dot pattern (Monaco, 2002). By staggering the four process colours at different angles, the distortion is kept to a minimum. However, if the angels are not appropriate for the given application, moiré will continue to occur. Generally, conventional screen angles are set to 0° for yellow, 15° for magenta, 45° for black and 75° for cyan. These values are adjusted in prepress to apply to the job that is being processed. Though the angles can be changed for various job applications, moiré can still be seen in some images when produced with conventional

AM screening techniques.

Proponents of stochastic printing often claim that the FM screening process results in the elimination of moiré (Campbell, 2003). It is the lack of ordered dot patterns and the absence of screen angles that eliminates screen moiré patterns (Braden Sutphin Ink Company). While FM screening does eliminates this undesirable pattern between the original artwork and the halftones, it should be noted that if there are moiré patterns created by interference of the scan pixels in the artwork, stochastic screening will accurately reproduce this pattern. The angles used in conventional printing are all relative to the fixed spacing between dots on the horizontal axis (Campbell, 2003). Considering that the stochastic screening process places the halftone dots at 'random', the application of angles would serve no functional benefit.

In essence, FM screens are eliminating moiré patterns between each colour that is being printed. Because stochastic removes this interference between ink colours, there is no longer a limit to the number of colours that a printer can use in a screen build or separation, an important advantage over conventional (Shaw, 1995).

COLOUR GAMUT

Colour gamut is the range of colours that a device such as a monitor or printer can produce (Eldred, 2001). It is a common misconception that an FM screen can reproduce a wider colour gamut compared to an AM screen (T. Menard, personal communication, 2009).

Below in *Figure 5.5*, both images are representing the colour gamut of an AM and FM screen. The FM colour gamut (translucent) with 20 micron raster has a curve applied to it to allow it to align with the tones of the AM screen. The Conventional screen is 175 lpi. Upon first glance, the FM colour gamut appears to be significantly larger compared to the AM colour gamut. However, FM screening does not actually increase the gamut of colour (Pritchard, 2009). Instead, it is accurate to say that AM screens typically restrict the gamut at lower lpi's, while FM screens allow for the potential of a larger gamut (Pritchard, 2009).

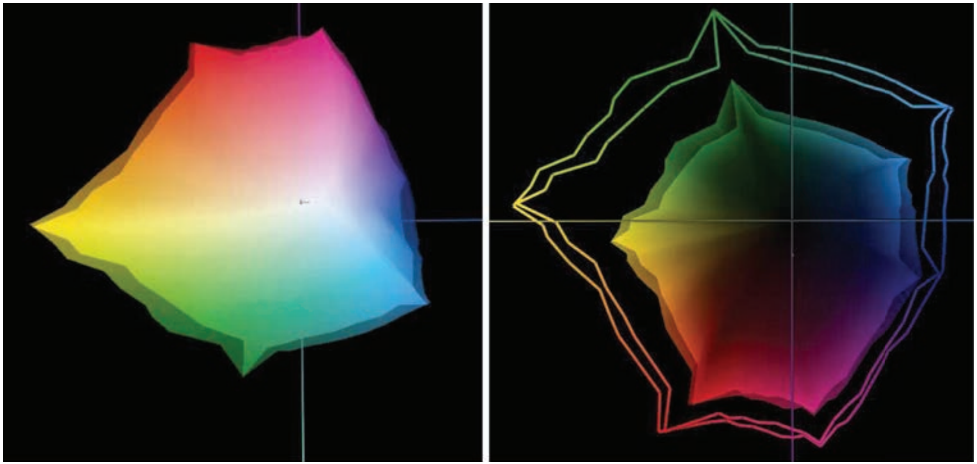

Figure 5.5 — AM versus FM colour gamut.
(Pritchard, 2009)

In printing, the function of ink on paper is so that the light is filtered, and when this occurs, you can see colour according to what part of the spectrum is filtered by the ink (Pritchard, 2009).

Stochastic's ability to make it appear as though it provides a larger colour gamut is centered around the filtering of light. Light is filtered in several different ways. Refer to *Figure 5.6* for a visual reference. First, light can pass through the film of ink and is then filtered by it as it is reflected off the substrate (Pritchard, 2009). Some light is also scattered in the substrate under the dot of ink, which is referred to as optical dot gain, and a coloured shadow appears around the dot of ink (Lawler, 1997). Light can also pass between the dots and comes back through the film of ink (Pritchard, 2009). Next, some light can simply be reflected off the surface of the dot rather than actually passing through it (Eldred, 2001). And lastly, some light is not filtered at all through the ink. Rather, it goes between the dots of ink and is directly reflected off the surface of the substrate (Pritchard, 2009). When this occurs, the unfiltered light mixes with the light that has been filtered by the ink and contaminates/grays it (Pritchard, 2009).

Since FM screens use such small dots, there are more dots in a given area and they allow for more dot gain due to the greater amount of perimeter to area ratio. The dots of ink are smaller and closer together, resulting in less space between the dots for light to be filtered (T. Menard, Personal Communication, 2009). The majority of light is being filtered by ink, not by paper. This means less contamination and less of a loss of gamut (Pritchard, 2009).

As ink thickness increases it becomes a less efficient filter of light (Eldred, 2001). So as ink thickness increases, the light tends to reflect off the surface of the dot, instead of penetrating it. This is where FM screens have an advantage. FM screen dots tend to be thinner, more uniform and more consistent (Hershey, 2006). For example, an FM screen dots of 20µ halftone can carry only 2µ thick of ink, even if more ink is applied (Hershey, 2006). This increases their ability to filter the light. AM screen dots are typically thicker and can be inconsistent (Ferriolo, 2002).

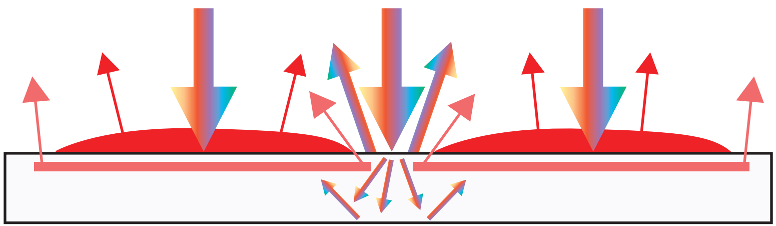

Figure 5.6 — Light filtering through substrate and ink.
(Pritchard, 2009)

DOT GAIN

There are two types of dot gain; mechanical (or physical) and optical dot gain. Mechanical dot gain is caused by the spreading of ink on the substrate. Optical dot gain takes place when light striking a page is refracted through the ink film and a shadow is created on the substrate making the dots appear larger (Cheeseman, 1998). Mechanical dot gain, which is also commonly referred to as Tone Value Increase (TVI), is typically positive since the blanket enlarges the dot upon transfer to the substrate (Kipphan, 2001). Dot gain is a common problem that every printer encounters during production. Regardless of the printing method, compensation for the growth of halftones must be applied prior to the production phase of the job and also through appropriate press adjustments (Kipphan, 2001).

Due to the size of the dots and the number of dots, there is a greater amount of total perimeter of dots in an FM screen, compared to an AM screen. Because mechanical dot gain occurs at the border where the dot ends and the unprinted substrate begins, FM screening exhibits more dot gain than AM screening (Janjomsuke, 2003). Based on *Figure 5.7*, it can be seen that the maximum physical dot gain is lower for AM screening than for FM screening. Specifically, at the 50% dot area, the maximum AM dot gain is approximately 20%, while the maximum for FM screening is 32%. The minuscule size of the dots also makes changes in size more pronounced considering that any growth is typically a significant portion of the dots total size.

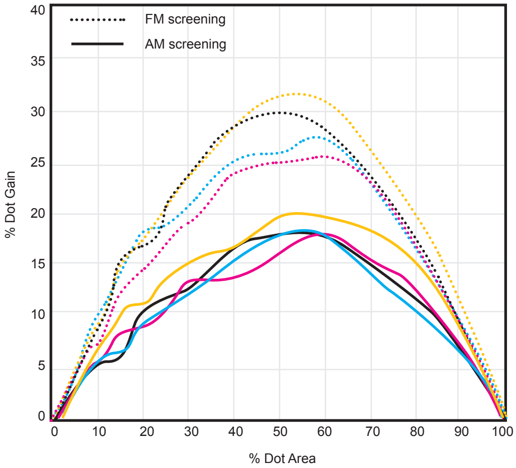

Figure 5.7 — Maximum dot gain of AM and FM screening.
(Janjomsuke, 2003)

For example, a 21µm stochastic dot has 20% more dot gain than a conventional 150 lpi halftone at 50% (Rundel, 2002). While this may seem like a large obstacle to overcome, when the proper tone curves are applied during the pre-press phase, the majority of stochastic dot gain can be compensated for before it hits the press (Romano, 1995). This means that accurate finger printing of the press must be done in order to correctly compensate for FM screenings high dot values (Campbell, 2003).

In addition to the mechanical dot gain that stochastic screening produces on press, high levels of optical dot gain also occur but should not always be viewed as a negative factor. Considering FM screening uses more halftone dots and the overall ink coverage is much higher than that of AM, more of the substrate is covered with ink. This causes more refraction and less paper to show through. The results are a cleaner and more authentic chroma then that of the conventional process because less distortion from the paper colour is present (Braden Sutphin Ink Company, n.d.).

REGISTRATION

Good color registration is the ability to print each of the colors in a multicolor printing job consecutively in the same position on the substrate (Kipphan, 2001). Register should be within the range of a few hundredths of a millimeter. To ensure proper registration, marks are imaged onto the plates of each separate color and should be monitored during the press run to guarantee each colour is overlapping the previously printed colour in the same position on the substrate. (Kipphan, 2001).

There is a common misconception that misregister is eliminated when employing stochastic screening. This, however, is untrue, since misregister is a problem that occurs because of many factors on press, stochastic printing not being impervious to any of these. Both techniques of printing, conventional and stochastic, are affected by registration issues, which are most commonly caused by a change in the papers dimensions due to mechanical stretching, excessive moisture or lack of or press configurations not being synchronized from unit to unit (Kipphan, 2001). Stochastic printing, however, decreases the visual effect of misregistration because it does not use screen angles like the conventional method does (Transcontinental Magazine and Catalog Group).

When there is misregistration in conventional screening, the eye can see the separate colours, which are not meant to be visible; with proper registration, they should be overprinted. These areas of the image will become contaminated with the out-of-register colour and can cause a "rainbow" affect (Romano, 1995). "Due to the 'ordered' distribution of dots in a conventional screen, if one colour is not 'registered' with the others it shows up very clearly" (Braden Sutphin, n.d.). The color shift from the misregister can be seen in *Figure 5.8*.

Frank Romano explains, "Stochastic relaxes the need for critical registration. Poor registration will not cause color shifts or rainbows in the neutrals as AM screens cause due to an out-of-register rosette pattern. Out-of-register FM screens still will appear out of register, but color will not be affected" (1995). *Figure 5.9* illustrates this.

In the past, there were problems with first order stochastic and producing plates for stochastic printing "because dots in an FM screen are also very small, requiring precise plate production. This poses a challenge for anyone in an analog-plate-making workflow, where register issues and dust can wreak havoc with the ability to produce fine dots" (Campbell, 2003). With today's CTP technology, producing plates can be significantly more accurate which insures less misregister between plates (Campbell, 2003).

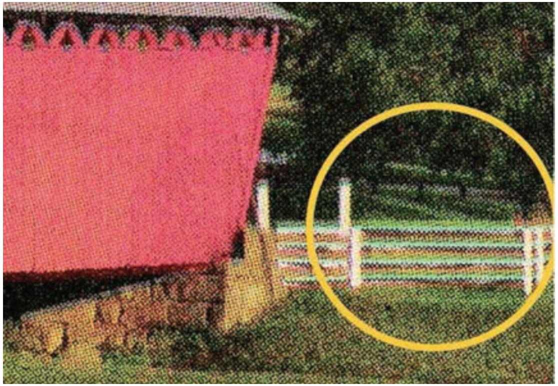

Figure 5.8 — Misregister in AM screening.
(Creo, n.d.)

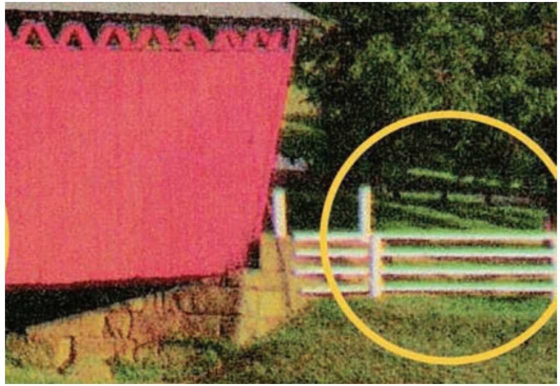

Figure 5.9 — Misregister in FM screening.
(Creo, n.d.)

RECOMMENDATIONS
RUNABILITY

Presses need to be stopped frequently for blanket washes due to the thinner ink layer of FM screens, which lead to more contamination (Fenton, 2005). Close monitoring of the blanket is important. Often, ink levels are increased to achieve more fullness in shadow areas, which resulted in heavier buildup on the blanket. The ink then begins to solidify on the blanket, leading to cracks, swelling and eventually even blanket replacement (Fenton, 2005).

Heavy piling occurs due to the small size of dots in

FM screening and the thin, uniform ink film, which uses less water. It is recommended that changing the ink or fountain solution to more forgiving formulations will allow the operators to run more water, in turn, reducing the piling problem (Fenton, 2005).

Strong inks should be avoided because they require heavier amounts of fountain solution, which does not work well with the thin layer of ink created with the stochastic screening process. It is recommended that inks with a lower water pickup be used (Fenton, 2005).

PRINTABILITY

Specific dot gain compensation curves must be employed, as well as different inks, when printing with FM (Fenton, 2005). This will compensate for the dot gain that occurs due to the small halftones being produced.

When a substrate is being selected for an FM job, it is critical to consider how the micron-sized dots will lay on the paper. The small sized dots are an advantage in regards to the absorption of the ink, and printing with FM on lower quality paper, such as newsprint, typically result in better quality compared to conventional prints. However, textured paper should be avoided since the small dots will be easily lost in the crevices of the paper (Mohawk Paper Mills, n.d.).

END USE APPLICATIONS

Stochastic screening has come a long way in the last decade, but is not a perfect process and is not suited for all companies and all printers. The type of print work a company most often prints should be taken into consideration when consideringthe implementation of the stochastic screening process.

A suitable candidate for employing FM screening may be a company that reproduces images of high quality and vivid colour. FM tends to render finedetails and produces a more saturated colour, compared to AM. For example, a company that produces a lot of work with fabrics, jewelry, etc, will benefit from using an FM screening process (Shaw, 1995).

Using FM screens on lower quality substrates, such as newsprint, can be highly beneficial. FM effectively increases the quality of the printed work without the high cost of switching to a better quality substrate.

A company that frequently outputs work with a lot of heavy text and minimal images will not profit from switching from a conventional screening process to a stochastic one. This is due to the fact that AM still dominates FM's ability to produce flat tones (RIT Homage, 2007).

CONCLUSION

The process of stochastic screening has made significant improvements over the last 50 years since the conception of first order FM screening. With the introduction of Computer-to-Plate technology, many of the processes largest downfalls have been overcome. The introduction of the CTP process has allowed many of the original issues concerning FM's small dot size to be eliminated. The digital file is immediately exposed to the plate, creating a first generation dot for printing and reducing waste in the process.

Just like any new technology, the initial implementation of stochastic printing can be difficult. However, with consistent process control and a dedication to quality, stochastic's benefits can outweigh the beginning challenges. The elimination of colour moiré due to the absence of screen angles saves valuable prepress time when processing a job. FM screen's greater overall ink coverage and improved filtering of light also allows for a potentially larger colour gamut to be seen. This also allows for greater optical dot gain, which presents colours free of distortion from substrate show through. The more forgiving nature of the FM process for registration problems can also be considered a benefit over the conventional process.

In terms of runability, the FM process may require more attention than the conventional method of screening. Special attention to blankets, ink-water levels and fountain solution types must be considered for the benefits of stochastic to be properly attained. Compensation for higher dot gain must also be made in the pre-production phases for the advantages of stochastic to be seen on press and at end-use.

The stochastic process continues to minimize its weaknesses and improve upon its strengths. With new and relevant documentation, much of the original misconceptions of the FM process can be clarified and the benefits of stochastic can be better understood. More recent documentation of second generation stochastic screening's benefits must also be made in order to properly demonstrate how the screening method has improved since film-to-plate. A clear distinction between first and second order stochastic screening must be understood in order to further the adoption of FM screening in the printing industry.

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ABOUT RYETAGA

RyeTAGA is the *Ryerson University Student Chapter of the Technical Association of the Graphic Arts*. Our membership consists of enthusiastic students from the School of Graphic Communications Management, who help prepare for our participation in the annual TAGA Conference. There are many activities involved in our preparations, including the designing, planning and production of this student journal, as well as, the organization and fundraising for our attendance at the conference. To help raise awareness and support we took part in many industry events, including a golf tournament hosted by the IAPHC and the Graphics Canada Tradeshow. In our own school community, we held bake sales, pub events, printed and sold print-themed calendars, and hosted networking seminars with the generous help of Tony Karg from FujiFilm. Together, our outstanding ryeTAGA team has accomplished an impressive amount of work through their constant dedication and effort. We look forward to greeting the other participating student chapters at the 2010 TAGA Conference in San Diego, California!


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FINAL NOTES

Creative Production
- Fonts: Adobe Caslon Pro, Arial, Bebas, Museo, Unit
- Programs: Adobe Creative Suites 3 and 4 with XMPie Plug-In
- EngView Package Designer

Journal Stocks
- Text: Domtar Solutions Text, Super Smooth, 80 lb. , FSC Certified
- Cover: Wassau Paper Royal Metallics: Chalice Silver Cover, 86lb., FSC Certified
- Sleeve: Wassau Paper Royal Compliments: Eclipse Black Vellum Cover, 80lb., FSC Certified

In-House Equipment
- Xerox DocuColor 7000
- Heidelberg Polar 76 Guillotine
- Pakready Cutter
- Stahlfolder 1220E

Professional Assistance
- Webcom: Printing on sleeve
- York Bindery: Perfect binding