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A Study of Water Pick-up Rates and their Effects on Ink Rheology, Ink Strength, Ink Dryback and Ink Rub-off

by

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Abstract

It has been thought that the water pick-up rate and capacity of an ink may have a profound affect on the press performance of an ink. As the water content of ink changes so do the rheological characteristics of the ink and this effects ink performance attributes such as ink transfer, drying , rub resistance, set-off and strength.

An emulsification curve can shed some light on how ink might perform on a press but this alone is not enough. The objective of this thesis research was to study the interaction of fountain solution and ink as used in the printing of newspapers, in terms of ink water pick-up rates and capacity. Further, this is a study of the effect of the fountain solution and ink interaction on ink transfer, drying, rub resistance, set-off and strength.

In this study, three different black news inks and three different fountain solutions have been used to make a total of nine different ink and fountain solution combinations. One set was a specific black news ink and fountain solution combination, Flint Low Rub Black and Anchor Neutral Fountain Solution, used in the printing of *USA Today* at Boston Offset in Norwood, MA. The paper, a 30# newsprint, was the only newsprint used throughout the testing. Water pick up rates have been determined and emulsification curves have been developed with the use of a Duke Tester for all nine ink and fountain solution combinations. The effect of these water pick-up rates on the rheological characteristics has been studied with the use of a Brookfield Rotational Viscometer. With the use of a motorized Little Joe printability tester, ink was laid down on the newsprint at

a constant volume and any changes in ink strength were measured with a densitometer. Rub resistance was examined with a Rub Tester and a densitometer.

The experimental data from this study show a direct correlation between the water pick-up capacity of an ink and the affect this has on the ink rheology and ink performance. The tests and data revealed that each ink had a tendency to pick-up more of the alkaline fountain solution than the neutral solution. The least was picked up with the acid fountain solution. The more fountain solution the inks picked up, the greater the changes in viscosity, strength, dryback and rub-off.

With the low-rub premium and the dense black, the viscosity rose higher as the ink picked-up more fountain solution. The soy low-rub ink reacted differently. The soy ink had an initial drop in viscosity then, as the ink began to pick up more fountain solution, the viscosity seemed to stabilize. The more fountain solution the ink picked-up the weaker the strength became. At the same time, the more fountain solution that was picked-up, the less density was lost due to dryback and rub-off.

Chapter 1

Introduction and Statement of the Problem

Traditionally, the research on "water pick-up" characteristics of ink concerned how much the rheology of the ink is affected rather than how the ink's performance is affected. Offset lithography depends upon the ability of an ink to emulsify the fountain solution. We know that when an ink takes on fountain solution it has many affects on the ink rheology and ink performance. Rheological characteristics such as tack and viscosity are altered. This then affects ink transfer and other performance attributes such as ink drying, rub resistance and ink strength.

Knowing how these ink performance attributes will be affected during a pressrun can be very useful in many different ways. Quality and productivity will both be affected by any changes in ink transfer and ink strength. If the ink strength is significantly reduced then solid ink densities will decline. When this happens, it becomes increasingly more difficult to maintain the target solid ink densities and obtain ink and water balance. At the same time, as the ink strength is weakened, adjustments are made to hold the target solid ink densities. This might, in turn, create the need for adding more fountain solution to keep the plate clean. The ink strength can become so low that the target solid ink density can not be met. The decline of ink mileage is a significant concern. If solid ink densities can be controlled better – without any major impact on the quality – then this can

translate into cost savings attributable to less make-ready time, less waste and improved ink mileage while maintaining the same quality standard or even improving it.

Ink Rub-off and ink set-off have become much more of a quality issue for the newspaper industry. If an ink has low rub resistance and poor set-off tendencies, it will set-off to adjacent pages, come off on delivery belts, conveyers, stackers, strappers and on human fingers. It has been, and still is, a big problem for the reader when the ink on the paper they are reading turns their fingers black. If a newspaper is using a low rub or no rub black ink, this should not be a profound problem.

The water pick-up characteristic of an ink has a significant effect on the inks' performance characteristics. Understanding how different combinations of ink and fountain solution relate to water pick-up can be very useful to the Newspaper industry by helping to predict how a particular ink and fountain solution combination may perform on press.

Statement of the Problem

The problem addressed in this thesis research is to bring some insight into how an ink's water pick-up rate and water capacity change with the use of an alkaline, neutral or acid fountain solution. What affect do the three different types of fountain solutions have on the ink's rheological characteristics such as ink viscosity? Finally, how do the rheological changes affect the ink's performance? More specifically, how is ink strength, dryback and rub resistance affected as the percent of water in the ink increases?

Ink strength and dryback can have significant implications on both quality and production aspects of an ink. If the ink strength has been weakened, then the solid ink densities will be affected. This will then require an increase in ink to maintain the target solid ink densities which, in turn, lowers the ink mileage and raises production costs. Ink dryback is a major concern if the target density reached during printing falls way off as the ink dries. Rub resistance is also a very important factor. Low rub resistance suggests a problem in ink drying and setting.

Chapter 2

Background Theory and Literature Review

Discussion on Lithography

The leading process in the field of commercial printing is lithography. This process is unique because the image to be printed lies on the same plane as the non-image area. During this process, the dampening solution is applied to the entire plate surface where it adheres to the non-image (hydrophilic) area of the plate. Oil based ink is then applied to the total plate surface where it is attracted to the image (oleophilic) area of the plate and is repelled from the previously wetted non-image area. The printing plate carrying the inked image is then either applied directly or indirectly (offset) to the substrate which carries the final printed image.[1]

In actuality, when fountain solution is applied to the plate's surface, a certain amount is applied to the image (oleophilic) area where it is weakly bound. It must be removed by the ink in order for the ink to come in intimate contact with the image area and perform proper ink transfer. Therefore, the fountain solution needs to be absorbed by the ink for this to occur. Furthermore, the ink may absorb part of the fountain solution during the contact between the ink form roller and dampened non-image areas. The ability of the ink to absorb this water while retaining its physical properties is one of the

most critical ink performance characteristics and is commonly referred to as “ink and water balance.” A laboratory method to accurately predict the ink and water balance characteristics of an ink would be of benefit to those supplying and those using lithographic ink.[2]

Discussion on Emulsions

When two phases are present, ink and fountain solution, they will either mix together to form one single new phase (a solution), or else remain separate. In the latter case, the two phases are said to be insoluble; however, if one can be finely divided and suspended in the other, a dispersion is formed and the two phases are said to be miscible. Typical dispersions are foams (vapor bubble dispersed in a liquid), aerosols (liquid drops dispersed in a vapor), and emulsions (drops of one liquid dispersed in another).[3] An emulsion is created when fountain solution droplets are dispersed in an ink.

Discussion on Ink Chemistry

Printing ink is made up of two primary components, a pigment and a vehicle. The purpose of the pigment is to provide the image contrast on the substrate plus other desirable properties, i.e., light resistance, soap resistance, gloss, etc. Some common pigments used in today’s inks are Red Iron Oxide, Magenta Iron Oxide, Bronze Blue, Diarylide Yellows and Carbon Blacks.[4]

The purpose of the vehicle is to carry the pigment to the substrate, hold it there and provide other desirable properties, e.g. drying mechanism, transfer properties, rub

resistance, gloss and setting. There are several different kinds of oils that can be used as ink vehicles. The oils used in printing inks come from a variety of sources: mineral oils, vegetable oils, and sometimes animal oils.[5]

Mineral oils are extracted from the ground or from beneath the seabed. At the time of extraction, the oil is referred to as crude oil and is of no use in printing inks until it has undergone fractional distillation where it is split up into many separate oil fractions. Mineral oils are used in the majority of lithographic inks and letterpress inks that dry by oxidation polymerization.[6]

The use of vegetable oils in ink manufacture has been on the rise over the past decade due to environmental concerns. Soybean oil is the most commonly used among vegetable oils. Other popular vegetable oils are linseed oil, tung oil, safflower oil, sunflower oil and castor oil.[7]

Other oils, such as from fish and whales, have been used for special purposes in inks in the past. However, their use has declined over recent years mainly because of pressures on conservation and also because of the strong odor associated with some fish oils.[8]

Although there are many classifications of printing inks, web offset printing principally employs three: news, nonheatset, and heatset. News inks consist of a pigments and hydrocarbon or soy bean oils. On normal printed sheets some ink films stay on the sheet surface and others travel through the sheet structure. Because there are no drying oils used in the formulation of newsinks these inks are unable to form a hard dry ink film and, therefore, these inks never really dry, and the ink is easily rubbed from the printed

sheet. Adding a modified drying oil to these *low-rub* news inks improves their rub resistance by forming a film that retains the pigment.[9]

News inks are composed of pigment (usually carbon black), mineral or vegetable oil, resin, and sometimes a drying oil. News inks may contain a solvent, but they contain no dryer, because they dry by absorption, which requires no heat.[10]

Discussion on Fountain Solution Chemistry

Fountain solutions are water-based solutions used on lithographic presses to prevent the nonimage area of the printing plate from taking on ink. Fountain solutions may contain many additives which improve their working properties. These are additives such as alcohols, inorganic salts, phosphoric acid, gum Arabic, mould inhibitors, and surfactants.[11] Fountain solution composition varies for a number of reasons. The type of dampening system that is on the press, environmental concerns, the type of ink being used, the type of plates being used, and the substrate being printed on are all factors that will affect the fountain solution formulation.

In general, a dampening solution will consist of the following ingredients:

- **Water,** with minimal impurities.
- **Acid** or **base,** depending to a large extent on the ink being used. Acids used include phosphoric acid, acid phosphate compounds, citric acid, or lactic acid.
- **Gum,** either natural (gum Arabic) or synthetic, to desensitize nonimage areas, i.e. to make them prefer water instead of ink.

- **Corrosion inhibitors,** to prevent the dampening solution from reacting with the plate. Magnesium nitrate is sometimes used; it also acts as a scratch desensitizer.
- **Buffer,** a substance capable of neutralizing acids and bases in solutions and, thereby, maintaining the acidity or alkalinity level of the solution.
- **Wetting agents,** such as isopropanol or an alcohol substitute, which decreases the surface tension of water and water-based solutions.
- **Drying stimulator,** a substance–e.g., cobalt chloride–that compliments the drier in the ink. Drying stimulator is an additive that is used only if the ink is not drying fast enough.
- **Fungicide,** to prevent the formation of mildew and the growth of fungus and bacteria in the dampening solution.
- **Antifoaming agent,** to prevent the buildup of foam. Foam can interfere with the even distribution of dampening solution on the dampening rollers.[12]

Discussion on Ink and Fountain Solution Interaction

There is more chemistry and chemical interactions involved in offset lithography than in any other printing process. Paper, ink and printing plates are brought together in the pressroom. When these items come together on a printing press – along with fountain solution – a number of chemical and physical changes occur.[13]

A particular reaction may involve several materials. For example, when ink dries on paper, the rate of drying depends on the formulation of the ink, and often on the

properties of the paper, the pH of the fountain solution, the amount of fountain solution emulsified in the ink, and the temperature of the pressroom.[14]

There are two central mechanisms which lead to water-in-ink emulsification. The first mechanism occurs at the inker form-roller/plate nips in the image areas. A thin ink film (left in the image areas at the plate/blanket nip) is covered with fountain solution at the dampener/plate nips and then comes in the ink/plate nip against a thick ink layer and some surface water. Water is pressed between these two unequally thick ink layers and, thus, the emulsified water tends to remain in the image areas. The same happens in every form roller nip, but there the surface water films are probably thinner and their emulsification effect remains smaller than that at the first nip. In the latter form roller nips, the ink films are more equal in thickness. This may cause surface water formation of the already emulsified water which is now closer to the central line of the splitting ink film.[15]

The second mechanism occurs at the inker form-roller/drum nips in the non-image areas. The ink films on the form-rollers pick up water from the well dampened non-image areas and come against the ink film on the inker drum and its surface water (probably a very thin water film). Because there is much more of the non-image area on the plate, this second mechanism may dominate. This is also the mechanism that transfers water into the inker.[16]

Discussion of Polarity

There are many different factors that can influence the ink and fountain solution interaction and the ability to achieve and maintain proper ink and water balance. In 1981,

Van Esch conducted a study on the interaction between fountain solution and ink raw materials.[17] Many parameters such as pigment wetting, rheology, binders and additives were studied. Van Esch came to several conclusions. First, he found that the choice of pigment in offset inks is a very important factor in ink and water balance. He discovered that inks with higher oil absorption numbers produced better ink and water balance. Van Esch also studied the influence of the polarity on the ink and water balance and concluded that the lower the polarity the better the ink and water balance.

Several studies found that the polarities of the fountain solution and ink significantly influence the emulsification characteristics of the ink and fountain solution combinations. Densmore[18] argued that, during orientation, molecules align themselves such that their non-polar ends are facing the ink and their polar ends face the fountain solution. It is this alignment that reduces the surface energy, facilitating the incorporation of the fountain solution into the ink. Karttunen and Manninen concluded that the low surface tension (low polarity) is not only beneficial for the elimination of scumming but can also be used to avoid the low emulsification tendency of less polar inks.[19]

Background Theory on Water Pick-up Tests

Since the late 1950's there have been many testing methods developed to determine water pick-up rates. In 1959 Bowles & Reich used a custom made bar mill to mix ink and fountain solution. Many other tests, utilizing various mixers and roller devices such as the Pope & Gray Litho Break Tester and various tackmeters with water sprayed on the rollers or equipped with water pans, have also been investigated. The

problem with all of these test methods is that nearly all of them emphasized a single point emulsification result –i.e., a certain amount of ink and dampening solution were agitated for a period of time and the total amount of dampening solution taken up was determined gravimetrically or chemically, or a change in apparent tack reading recorded.[20]

In 1967, Surland used a simple mixer with specially shaped agitator blades to mix the ink and dampening solution. The rate of emulsification of a dampening solution was then measured and plotted over a ten minute period.[21] In 1980, Surland further refined this testing method to help better predict an ink's performance on press. Surland also plotted the amount of fountain solution emulsified against time and found that, essentially, all inks could be classified into six curves. The particular curve type corresponds to a characteristic performance on the press and thus predicts the efficiency of the ink.[22] These curves are fairly accurate at predicting an ink's press performance.

In 1981, The Asscociation of Standarized Testing Methods (ASTM), in response to concerned printing ink manufacturers, appointed a task force to investigate and develop a standardized test procedure for measuring water pickup. This study used a combination of consensus and interlaboratory round-robin findings in which 20 laboratories participated in one or all six of the round robins conducted by the Task Force. The task force concluded its work in 1990 with the publication of ASTM Standard Test Method D4942 "Water Pickup of Lithographic Printing Inks and Vehicles in a Laboratory Mixer".

ASTM recommends two testing methods. Test Method D4942A is a single-point five minute test. The mixing period of five minutes was selected because that is the

leveling-off time for Surland's ideal ink. Test Method D4942B differs only in minor details and is based on Surland's ten minute test method.[23]

Over the years, there have been many other test methods designed which have been conducted on running presses as well as in the laboratory. In 1983, Tasker, Cygan, Fang, Lachcik and Nakamura developed three new test methods –all utilizing the Litho-break tester. Test 1, called "Delta PV", is performed with the use of the Litho-break tester to emulsify the solution into the ink and a falling rod to measure the plastic viscosity. A large difference in plastic viscosity between the non-emulsified ink and the emulsified ink indicates difficulty in color control across the sheet and throughout the run. Test 2, called The "a-k Fit", again utilizes the Litho-break tester to create the emulsion and the resulting emulsion is analyzed for water with the Karl Fisher method. Test 3, called Emulsified Water Particle Size, analyzes the emulsified ink water particles through a microscope. This test operates on the theory that the smaller the particle size the better the emulsion and, therefore, the better the ink will perform.[24]

In 1985, Fritz Braun studied water pickup with the use of a Lithomat Emulsifying Tester and a Graphometronic instrument to measure tack and ink film thickness. He used the Lithomat because he thought it best simulated the conditions of an offset press.[25] Braun concluded that the amount of water absorbed was not the only deciding factor governing the formation of an emulsion. The manner in which the emulsion is formed as well as any fountain solution additives that influence the nature and shape of the droplets is important.

In 1991, Durand and Wasilewski developed a new technique for measuring water pickup. They devised the "titration" test that measures water pickup by measuring changes in torque on a mixing blade as fountain solution is flowed into mixing ink. The torque profile is characterized by two parameters, Emulsification Capacity (EC) and Change in Torque (ΔT). The design of this technique arose from observations that a distinct endpoint could be reached when titrating an ink with water or fountain solution. The endpoint is characterized by an excessive turbulence and slippage on the mixing blade when the ink sample no longer accepts additional water.[26] The results of water pick-up tests using the "titration" method correlate well with test results from the Surland method.

The most important research relevant to this thesis are two papers by Aage Surland: "The Effects of Alcohol on Inks" (published in 1967) and "A Laboratory Test Method for Prediction of Lithographic Ink Performance" (published in 1980). In these studies, Surland changed the way water pick-up tests are conducted and showed how the results could be used to predict accurately how an ink and fountain solution combination would perform on press.

Another study showing the significance of Surland's work was the previously discussed method developed by ASTM–Method D4942.

In 1991, Fuchs, Lindqvist, and Wallstrom published "Vegetable Oil Based Newsinks and their Printability Properties and Deinkability", a study in which everything from emulsification rates to rub-off and set-off were compared between different types of

vegetable based inks – including soy and mineral based newsinks.[27] This study concluded that vegetable oil newsinks had a slower emulsification rate and a lower emulsification capacity. These inks also had less rub-off and set-off than the mineral newsinks. The study concluded that vegetable oil newsinks were at least equal to or surpassed the mineral oil newsinks in printability properties.

Footnotes for Chapter 2

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[3] John MacPhee, "An Engineers Analysis of the Lithographic Printing Process," Technical Association of the Graphic Arts, (1979): 237.

[4] Ronald E. Todd, Printing Inks: Formulation principles, manufacture and quality control testing procedures (Leatherhead, UK: PIRA International, 1994) , 71.

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[7] Ibid., 84.

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[10] Ibid., 217.

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[17] C. Van Esch, "The Interaction Between Damping Solution and the Ink Raw Materials," Paper presented at the 15th FATIPEC Congress, June 8th-June 13th, 1980: 469.

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[23] ASTM Standard Test Method D4942, " Water Pickup of Lithographic Printing Inks and Vehicles in laboratory Mixer," ASTM Annual Book of Standards, (1997) Vol. 06.02: 396.

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[26] R. R. Durand, Jr. and O. Wasilewski, "A new Technique for Measuring Water Uptake of Lithographic Inks," Technical Association of the Graphic Arts Proceedings (1991) : 339

[27] Boris Fuchs, Ulf Lindqvist, Eva Wallstrom, "Vegetable Oil Based Newsinks and their Printability Properties and Deinkability," Technical Association of the Graphic Arts Proceedings (1991) : 433.

Chapter 3

Hypotheses

The following hypotheses will be examined by this thesis:

Using three different black news inks (Flint 100% Soy Low Rub Black, Flint Low Rub Black and Flint Dense Black) and three different fountain solutions (Anchor alkaline, Anchor neutral and Anchor acid), a total of nine different water pick-up curves was generated. These curves were then used to determine the relationship between the water pick-up rates of an ink, ink rheology and ink performance in the following ways:

1. Water Pick-up:

A three-factor factorial model was used to test the main effects and the interaction effects.

Main Effects	Interactions
Ink (α_i)	Ink/F.S. $(\alpha\beta)_{ij}$
Fountain Solution (β_j)	Ink/Time $(\alpha\gamma)_{it}$
Time (γ_t)	F.S./Time $(\beta\gamma)_{jt}$
	Ink/F.S./Time $(\alpha\beta\gamma)_{ijt}$

Y_{ijt} = weight from ink i, fountain solution j, time t

$E[Y_{ijt}] = F_{ij}(t)$ where $F_{ij}(t)$ is an unspecified response curve for ink i = 1,2,3, and

solution j = a,b,c.

$$E[Y_{ijt}] = \mu + \alpha_i + \beta_j + \gamma_t + (\alpha\beta)_{ij} + (\alpha\gamma)_{it} + (\beta\gamma)_{jt} + (\alpha\beta\gamma)_{ijt}$$

Hypotheses	Hypothesis Proven	P-Value
1A	Ha	na
	Test for Interactions	
1B.1 (ink/f.s)	Ha	0
1B.2 (ink/time)	Ha	0
1B.3 (f.s./time)	Ha	0
1B.4 (ink/f.s./time)	Ha	0
	Test for Main Affects	
1C (ink)	Ha	0
1D (f.s.)	Ha	0
1E (time)	Ha	0

Table 1. Water pick-up.
A P-value under .05 indicates statistical significance.

1A. Ho: $F_{1a}(t) = F_{1b}(t) = F_{1c}(t) = F_{2a}(t)\ F_{2b}(t) = F_{2c}(t) = F_{3a}(t) = F_{3b}(t) = F_{3c}(t)$

Ha: not Ho (at least two of the curves will differ)

1B.1. Ho: No interaction $(\alpha\beta)_{ij} = 0$ for all $_{i,j}$

Ha: At least one of the $(\alpha\beta)_{ij}$ terms is non-zero: $(\alpha\beta)_{ij} \neq 0$

1B.2. Ho: No interaction $(\alpha\gamma)_{it} = 0$ for all $_{i,t}$

Ha: At least one of the $(\alpha\gamma)_{it}$ terms is non-zero: $(\alpha\gamma)_{it} \neq 0$

1B.3. Ho: No interaction $(\beta\gamma)_{jt} = 0$ for all $_{j,t}$

Ha: At least one of the $(\beta\gamma)_{jt}$ terms is non-zero: $(\beta\gamma)_{jt} \neq 0$

1B.4. Ho: No interaction $(\alpha\beta\gamma)_{ijt} = 0$ for all $_{i,j,t}$

Ha: At least one of the $(\alpha\beta\gamma)_{ijt}$ terms is non-zero: $(\alpha\beta\gamma)_{ijt} \neq 0$

1C. Ho: No difference in ink $\alpha_1 = \alpha_2 = \alpha_3 = 0$

Ha: At least one of the alpha terms is non-zero: $\alpha_i \neq 0$ for some i.

1D. Ho: No difference in F.S. $\beta_1 = \beta_2 = \beta_3 = 0$

Ha: At least one of the beta terms is non-zero: $\beta_j \neq 0$ for some j.

1E. Ho: No difference due to the amount of time

$$\gamma_1 = \gamma_2 = \gamma_3 = \gamma_4 = \gamma_5 = \gamma_6 = \gamma_7 = \gamma_8 = \gamma_9 = \gamma_{10} = 0$$

Ha: At least one of the gamma terms is non-zero: $\gamma_t \neq 0$ for some t.

2. Viscosity:

A three-factor factorial model was used to test the main effects and the interaction effects.

Main Effects	Interactions
Ink (α_i)	Ink/F.S. $(\alpha\beta)_{ij}$
Fountain Solution (β_j)	Ink/Time $(\alpha\gamma)_{it}$
Time (γ_t)	F.S./Time $(\beta\gamma)_{jt}$
	Ink/F.S./Time $(\alpha\beta\gamma)_{ijt}$

Y_{ijt} = viscosity from ink i, fountain solution j, time t

$E[Y_{ijt}] = F_{ij}(t)$ where $F_{ij}(t)$ is an unspecified response curve for ink i = 1,2,3, and solution j = a,b,c.

$$E[Y_{ijt}] = \mu + \alpha_i + \beta_j + \gamma_t + (\alpha\beta)_{ij} + (\alpha\gamma)_{it} + (\beta\gamma)_{jt} + (\alpha\beta\gamma)_{ijt}$$

Hypotheses	Hypothesis Proven	P-Value
2A	Ha	na
	Test for Interactions	
2B.1 (ink/f.s.)	Ha	0
2B.2 (ink/time)	Ha	0
2B.3 (f.s./time)	Ha	0
2B.4 (ink/f.s./time)	Ha	0
	Test for Main Affects	
2C (ink)	Ha	0
2D (f.s.)	Ha	0
2E (time)	Ha	0

Table 2. Viscosity.
A P-value under .05 indicates statistical significance.

2A. Ho: $F_{1a}(t) = F_{1b}(t) = F_{1c}(t) = F_{2a}(t)\ F_{2b}(t) = F_{2c}(t) = F_{3a}(t) = F_{3b}(t) = F_{3c}(t)$

Ha: not Ho (at least two of the curves will differ)

2B.1. Ho: No interaction $(\alpha\,\beta)_{ij} = 0$ for all $_{i,j}$

Ha: At least one of the $(\alpha\,\beta)_{ij}$ terms is non-zero: $(\alpha\,\beta)_{ij} \neq 0$

2B.2. Ho: No interaction $(\alpha\gamma)_{it} = 0$ for all $_{i,t}$

Ha: At least one of the $(\alpha\,\gamma)_{it}$ terms is non-zero: $(\alpha\,\gamma)_{it} \neq 0$

2B.3. Ho: No interaction $(\beta\gamma)_{jt} = 0$ for all $_{j,t}$

Ha: At least one of the $(\beta\,\gamma)_{jt}$ terms is non-zero: $(\beta\,\gamma)_{jt} \neq 0$

2B.4. Ho: No interaction $(\alpha\,\beta\,\gamma)_{ijt} = 0$ for all $_{i,j,t}$

Ha: At least one of the $(\alpha\,\beta\,\gamma)_{ijt}$ terms is non-zero: $(\alpha\,\beta\,\gamma)_{ijt} \neq 0$

2C. Ho: No difference in ink $\alpha_1 = \alpha_2 = \alpha_3 = 0$

Ha: At least one of the alpha terms is non-zero: $\alpha_i \neq 0$ for some i.

2D. Ho: No difference in F.S. $\beta_1 = \beta_2 = \beta_3 = 0$

Ha: At least one of the beta terms is non-zero: $\beta_j \neq 0$ for some j.

2E. Ho: No difference due to the amount of time

$$\gamma_1 = \gamma_2 = \gamma_3 = \gamma_4 = \gamma_5 = \gamma_6 = \gamma_7 = \gamma_8 = \gamma_9 = \gamma_{10} = 0$$

Ha: At least one of the gamma terms is non-zero: $\gamma_t \neq 0$ for some t.

3. Ink Strength:

A three-factor factorial model was used to test the main effects and the interaction effects.

Main Effects	Interactions
Ink (α_i)	Ink/F.S. $(\alpha\beta)_{ij}$
Fountain Solution (β_j)	Ink/Amount of Ink $(\alpha\gamma)_{ik}$
Amount of Ink (γ_k)	F.S./ Amount of Ink $(\beta\gamma)_{jk}$
	Ink/F.S./ Amount of Ink $(\alpha\beta\gamma)_{ijk}$

Y_{ijk} = strength from ink i, fountain solution j, amount of ink k

$$E[Y_{ijk}] = \mu + \alpha_i + \beta_j + \gamma_k + (\alpha\beta)_{ij} + (\alpha\gamma)_{ik} + (\beta\gamma)_{jk} + (\alpha\beta\gamma)_{ijk}$$

Hypotheses	Hypothesis Proven	P-Value
3A	Ha	na
	Test for Interactions	
3B.1 (ink/f.s.)	Ha	0
3B.2 (ink/amount of ink)	Ho	0.151
3B.3 (f.s./amount of ink)	Ho	0.664
3B.4 (ink/f.s./amount of ink)	Ho	0.378
	Test for Main Affects	
3C (ink)	Ha	0
3D (f.s.)	Ha	0
3E (amount of ink)	Ha	0

Table 3. Ink strength.
A P-value under .05 indicates statistical significance.

3A. Ho: Ink strength will not differ due the ink, f.s. or the amount of ink used.

$$\alpha_i = 0,\ \beta_j = 0,\ \gamma_k = 0,\ (\alpha\beta)_{ij} = 0,\ (\alpha\gamma)_{ik} = 0,\ (\beta\gamma)_{jk} = 0,\ (\alpha\beta\gamma)_{ijk} = 0$$

Ha: Ink strength will differ due the ink, f.s. or the amount of ink used.

$$\alpha_i \neq 0,\ \beta_j \neq 0,\ \gamma_k \neq 0,\ (\alpha\beta)_{ij} \neq 0,\ (\alpha\gamma)_{ik} \neq 0,\ (\beta\gamma)_{jk} \neq 0,\ (\alpha\beta\gamma)_{ijk} \neq 0$$

3B.1. Ho: No interaction between the ink and f.s. $(\alpha\beta)_{ij} = 0$ for all $_{i,j}$

Ha: At least one of the $(\alpha\beta)_{ij}$ terms is non-zero: $(\alpha\beta)_{ij} \neq 0$

3B.2. Ho: No interaction between the ink and the amount of ink $(\alpha\gamma)_{ik} = 0$ for all $_{i,k}$

Ha: At least one of the $(\alpha\gamma)_{ik}$ terms is non-zero: $(\alpha\gamma)_{ik} \neq 0$

3B.3. Ho: No interaction between the f.s. and the amount of ink $(\beta\gamma)_{jk} = 0$ for all $_{j,k}$

Ha: At least one of the $(\beta\ \gamma)_{j\,k}$ terms is non-zero: $(\beta\ \gamma)_{j\,k} \neq 0$

3B.4. Ho: No interaction between the ink, f.s. and the amount of ink $(\alpha\ \beta\ \gamma)_{i\,j\,k} = 0$

for all $_{i,\,j,\,k}$

Ha: At least one of the $(\alpha\ \beta\ \gamma)_{i\,j\,k}$ terms is non-zero: $(\alpha\ \beta\ \gamma)_{i\,j\,k} \neq 0$

3C. Ho: No change in ink strength due to the ink $\alpha_1 = \alpha_2 = \alpha_3 = 0$

Ha: At least one of the alpha terms is non-zero: $\alpha_i \neq 0$ for some i.

3D. Ho: No change in ink strength due to the f.s. $\beta_1 = \beta_2 = \beta_3 = 0$

Ha: At least one of the beta terms is non-zero: $\beta_j \neq 0$ for some j.

3E. Ho: No change in ink strength due to the amount of ink $\gamma_1 = \gamma_2 = \gamma_3 = 0$

Ha: At least one of the gamma terms is non-zero: $\gamma_k \neq 0$ for some k.

4. Ink Rub-off:

A four-factor factorial model was used to test the main effects and the interaction effects.

<u>Main Effects</u>	<u>Interactions</u>
Ink (α_i)	Ink/F.S. $(\alpha\beta)_{i\,j}$
Fountain Solution (β_j)	Ink/Amount of Ink $(\alpha\gamma)_{i\,k}$
Amount of Ink (γ_k)	Ink/ Material $(\alpha\delta)_{i\,m}$
Material (δm)	F.S./ Amount of Ink $(\beta\gamma)_{j\,k}$
	F.S./ Material $(\beta\delta)_{j\,m}$
	Amount of Ink/ Material $(\gamma\delta)_{k\,m}$
	Ink/ F.S. / Amount of Ink $(\alpha\beta\gamma)_{i\,j\,k}$
	Ink/ F.S. / Material $(\alpha\beta\delta)_{i\,j\,m}$
	Ink/ Material/ Amount of Ink $(\alpha\delta\gamma)_{i\,m\,k}$
	F.S./ Amount of Ink/ Material $(\beta\gamma\delta)_{j\,k\,m}$
	Ink/F.S./Amount of Ink/Material $(\alpha\beta\gamma\delta)_{i\,j\,k\,m}$

Y_{ijkm} = rub-off from ink i, fountain solution j, amount of ink k, rub-off material m

$E[Y_{ijkm}] = \alpha_i + \beta_j + \gamma_k + \delta_m + (\alpha\beta)_{ij} + (\alpha\gamma)_{ik} + (\alpha\delta)_{im} + (\beta\gamma)_{jk} + (\beta\delta)_{jm} + (\gamma\delta)_{km} + (\alpha\beta\gamma)_{ijk}$

$+ (\alpha\beta\delta)_{ijm} + (\beta\gamma\delta)_{jkm} + (\alpha\delta\gamma)_{imk} + (\alpha\beta\gamma\delta)_{ijkm}$

Hypotheses	Hypothesis Proven	P-Value
4A	Ha	na
	Test for Interactions	
4B.1 (ink/f.s.)	Ha	0
4B.2 (ink/amount of ink)	Ha	0
4B.3 (ink/material)	Ha	0
4B.4 (f.s./amount of ink)	Ha	0.004
4B.5 (f.s./material)	Ha	0
4B.6 (amount of ink/material)	Ho	0.858
4B.7 (ink/f.s./amount of ink)	Ha	0.004
4B.8 (ink/f.s/material)	Ho	0.06
4B.9 (ink/amount of ink/material)	Ho	0.215
4B.10 (f.s./amount of ink/material)	Ho	0.471
4B.11 (ink/f.s./amount of ink/material)	Ho	0.292
	Test for Main Affects	
4C (ink)	Ha	0
4D (f.s.)	Ha	0
4E (amount of ink)	Ha	0
4F (material)	Ha	0

Table 4. Ink rub-off.
A P-value under .05 indicates statistical significance.

4A. Ho: $\alpha_i = \beta_j = \gamma_k = \delta_m = (\alpha\beta)_{ij} = (\alpha\gamma)_{ik} = (\alpha\delta)_{im} = (\beta\gamma)_{jk} = (\beta\delta)_{jm} = (\gamma\delta)_{km} = (\alpha\beta\gamma)_{ijk} =$

$(\alpha\beta\delta)_{ijm} = (\beta\gamma\delta)_{jkm} = (\alpha\delta\gamma)_{imk} = (\alpha\beta\gamma\delta)_{ijkm} = 0$

Ha: $\alpha_i \neq \beta_j \neq \gamma_k \neq \delta_m \neq (\alpha\beta)_{ij} \neq (\alpha\gamma)_{ik} \neq (\alpha\delta)_{im} \neq (\beta\gamma)_{jk} \neq (\beta\delta)_{jm} \neq (\gamma\delta)_{km} \neq (\alpha\beta\gamma)_{ijk} \neq$

$(\alpha\beta\delta)_{ijm} \neq (\beta\gamma\delta)_{jkm} \neq (\alpha\delta\gamma)_{imk} \neq (\alpha\beta\gamma\delta)_{ijkm} \neq 0$

4B.1. Ho: No interaction between the ink and the f.s. $(\alpha\beta)_{ij} = 0$ for all $_{i,j}$

Ha: At least one of the $(\alpha\beta)_{ij}$ terms is non-zero: $(\alpha\beta)_{ij} \neq 0$

4B.2. Ho: No interaction between the ink and the amount of ink $(\alpha\gamma)_{i,k} = 0$ for all $_{i,k}$

Ha: At least one of the $(\alpha\gamma)_{i,k}$ terms is non-zero: $(\alpha\gamma)_{i,k} \neq 0$

4B.3. Ho: No interaction between the ink and the rub-off material $(\alpha\delta)_{im} = 0$ for all $_{i,m}$

Ha: At least one of the $(\alpha\delta)_{im}$ terms is non-zero: $(\alpha\delta)_{im} \neq 0$

4B.4. Ho: No interaction between the f.s. and the amount of ink $(\beta\gamma)_{jk} = 0$ for all $_{j,k}$

Ha: At least one of the $(\beta\gamma)_{jk}$ terms is non-zero: $(\beta\gamma)_{jk} \neq 0$

4B.5. Ho: No interaction between the f.s. and the rub-off material $(\beta\delta)_{jm} = 0$ for all $_{j,m}$

Ha: At least one of the $(\beta\delta)_{jm}$ terms is non-zero: $(\beta\delta)_{jm} \neq 0$

4B.6. Ho: No interaction between the amount of ink and rub-off material

$(\gamma\delta)_{km} = 0$ for all $_{k,m}$

Ha: At least one of the $(\gamma\delta)_{km}$ terms is non-zero: $(\gamma\delta)_{km} \neq 0$

4B.7. Ho: No interaction between the ink, f.s. and the amount of ink

$(\alpha\beta\gamma)_{ijk} = 0$ for all $_{i,j,k}$

Ha: At least one of the $(\alpha\beta\gamma)_{ijk}$ terms is non-zero: $(\alpha\beta\gamma)_{ijk} \neq 0$

4B.8. Ho: No interaction between the ink, f.s. and the rub-off material

$(\alpha\beta\delta)_{ijm} = 0$ for all $_{i,j,m}$

Ha: At least one of the $(\alpha\beta\delta)_{ijm}$ terms is non-zero: $(\alpha\beta\delta)_{ijm} \neq 0$

4B.9. Ho: No interaction between the ink, amount of ink and the rub-off material

$(\alpha\gamma\delta)_{ikm} = 0$ for all $_{i,k,m}$

Ha: At least one of the $(\alpha\gamma\delta)_{ikm}$ terms is non-zero: $(\alpha\gamma\delta)_{ikm} \neq 0$

4B.10. Ho: No interaction between the f.s., amount of ink and the rub-off material

$(\beta\gamma\delta)_{jkm} = 0$ for all $_{j,k,m}$

Ha: At least one of the $(\beta\gamma\delta)_{jkm}$ terms is non-zero: $(\beta\gamma\delta)_{jkm} \neq 0$

4B.11. Ho: No interaction between the ink, f.s., amount of ink and rub-off material

$(\alpha\beta\gamma\delta)_{ijkm} = 0$ for all $_{i,j,k,m}$

Ha: At least one of the $(\alpha\beta\gamma\delta)_{ijkm}$ terms is non-zero: $(\alpha\beta\gamma\delta)_{ijkm} \neq 0$ for all $_{i,j,k,}$

$_{m}$

4C. Ho: No difference in rub-off due to the ink $\alpha_1 = \alpha_2 = \alpha_3 = 0$

Ha: At least one of the alpha terms is non-zero: $\alpha_i \neq 0$ for some i

4D. Ho: No difference in rub-off due to the f.s. $\beta_1 = \beta_2 = \beta_3 = 0$

Ha: At least one of the beta terms is non-zero: $\beta_j \neq 0$ for some j.

4E. Ho: No difference in rub-off due to the amount of ink $\gamma_1 = \gamma_2 = \gamma_3 = \gamma_4 = 0$

Ha: At least one of the gamma terms is non-zero: $\gamma_k \neq 0$ for some k.

4F. Ho: No difference in rub-off due to the rub-off material $\delta_1 = \delta_2 = \delta_3 = \delta_4 = 0$

Ha: At least one of the delta terms is non-zero: $\delta_m \neq 0$ for some m.

5. Ink Dryback:

A three-factor factorial model was used to test the main effects and the interaction effects.

Main Effects	Interactions
Ink (α_i)	Ink/F.S. $(\alpha\beta)_{ij}$
Fountain Solution (β_j)	Ink/Amount of Ink $(\alpha\gamma)_{ik}$
Amount of Ink (γ_k)	F.S./ Amount of Ink $(\beta\gamma)_{jk}$
	Ink/F.S./ Amount of Ink $(\alpha\beta\gamma)_{ijk}$

Y_{ijk} = strength from ink i, fountain solution j, amount of ink k

$E[Y_{ijk}] = \mu + \alpha_i + \beta_j + \gamma_k + (\alpha\beta)_{ij} + (\alpha\gamma)_{ik} + (\beta\gamma)_{jk} + (\alpha\beta\gamma)_{ijk}$

Hypotheses	Hypothesis Proven	P-Value
5A	Ha	na
	Test for Interactions	
5B.1 (ink/f.s.)	Ho	0.561
5B.2 (ink/amount of ink)	Ha	0.047
5B.3 (f.s./amount of ink)	Ha	0.012
5B.4(ink/f.s./amount of ink)	Ho	0.39
	Test for Main Affects	
5C (ink)	Ha	0
5D (f.s.)	Ha	0
5E (amount of ink)	Ha	0

Table 5. Ink dryback.
A P-value under .05 indicates statistical significance.

5A. Ho: The ink dryback is not affected due to the ink, f.s. or the amount of ink

$\alpha_i = \beta_j = \gamma_k = (\alpha\beta)_{ij} = (\alpha\gamma)_{ik} = (\beta\gamma)_{jk} = (\alpha\beta\gamma)_{ijk}$

Ha: There is an difference in ink dryback due to the ink, f.s. or the amount of ink

$\alpha_i \neq \beta_j \neq \gamma_k \neq (\alpha\beta)_{ij} \neq (\alpha\gamma)_{ik} \neq (\beta\gamma)_{jk} \neq (\alpha\beta\gamma)_{ijk}$

5B.1. Ho: No interaction between the ink and f.s. $(\alpha \beta)_{ij} = 0$ for all $_{i,j}$

Ha: At least one of the $(\alpha \beta)_{ij}$ terms is non-zero: $(\alpha \beta)_{ij} \neq 0$

5B.2. Ho: No interaction between the ink and the amount of ink $(\alpha\gamma)_{ik} = 0$ for all $_{i,k}$

Ha: At least one of the $(\alpha\gamma)_{ik}$ terms is non-zero: $(\alpha\gamma)_{ik} \neq 0$

5B.3. Ho: No interaction between the f.s. and the amount of ink $(\beta \gamma)_{jk} = 0$ for all $_j$

Ha: At least one of the $(\beta \gamma)_{jk}$ terms is non-zero: $(\beta \gamma)_{jk} \neq 0$

5B.4. Ho: No interaction between the ink, f.s. and the amount of ink

$(\alpha \beta \gamma)_{ijk} = 0$ for all $_{i, j, k}$

Ha: At least one of the $(\alpha \beta \gamma)_{ijk}$ terms is non-zero: $(\alpha \beta \gamma)_{ijk} \neq 0$

5C. Ho: No difference in ink dryback due to the ink $\alpha_1 = \alpha_2 = \alpha_3 = 0$

Ha: At least one of the alpha terms is non-zero: $\alpha_i \neq 0$ for some i

5D. Ho: No difference in ink dryback due to the f.s. $\beta_1 = \beta_2 = \beta_3 = 0$

Ha: At least one of the beta terms is non-zero: $\beta_j \neq 0$ for some j.

5E. Ho: No difference in ink dryback due to the amount of ink used $\gamma_1 = \gamma_2 = \gamma_3$

Ha: At least one of the gamma terms is non-zero: $\gamma_k \neq 0$ for some k.

6. pH

A two-factor factorial model was used to test the main effects and the interaction effects.

Main Effects	Interactions
Ink (α_i)	Ink/Time $(\alpha\gamma)_{it}$
Time (γ_t)	

Y_{it} = pH of ink i, time t

$E[Y_{it}] = F_i(T)$ where $F_i(T)$ is an unspecified response curve for ink i = 1,2,3, time t =0,10

$E[Y_{it}] = \mu + \alpha_i + \gamma_t + (\alpha\gamma)_{it}$

Hypotheses	Hypothesis Proven	P-Value
6A	Ha	na
	Test for main Affects	
6B (ink)	Ha	0.01
6C (time)	Ha	0
	Test for Interactions	
6D (ink/time)	Ha	0.01

Table 6. Ink pH.
A P-value under .05 indicates statistical significance.

6A. Ho: The pH is not affected by ink or time $\alpha_i = \gamma_t = (\alpha\gamma)_{i\,t}$

Ha: The pH is affected by ink and time $\alpha_i \neq \gamma_t \neq (\alpha\gamma)_{i\,t}$

6B. Ho: No change in pH due to the ink $\alpha_1 = \alpha_2 = \alpha_3 = 0$

Ha: At least one of the alpha terms is non-zero: $\alpha_i \neq 0$ for some i.

6C. Ho: No change in pH due to time $\gamma_0 = \gamma_{10} = 0$

Ha: At least one of the gamma terms is non-zero: $\gamma_t \neq 0$ for some t.

6D. Ho: There is no interaction between the ink and time $(\alpha\,\gamma)_{i\,t} = 0$ for all $_{i,\,t}$

Ha: At least one of the $(\alpha\,\gamma)_{i\,t}$ terms is non-zero: $(\alpha\,\gamma)_{i\,t} \neq 0$

Conductivity

A two-factor factorial model was used to test the main effects and the interaction effects.

Main Effects	Interactions
Ink (α_i)	Ink/Time $(\alpha\gamma)_{i\,t}$
Time (γ_t)	

$Y_{i\,t}$ = pH of ink i, time t

$E[Y_{it}] = F_i(T)$ where $F_i(T)$ is an unspecified response curve for ink i =1,2,3, time t = 0, 10

$E[Y_{it}] = \mu + \alpha_i + \gamma_t + (\alpha\gamma)_{i\,t}$

Hypotheses	Hypothesis Proven	P-Value
7A	Ha	na
	Test for Main Effects	
7B (ink)	Ha	0
7C (time)	Ha	0
	Test for Interactions	
7D (ink/time)	Ha	0

Table 7. Ink conductivity.
A P-value under .05 indicates statistical significance.

7A. Ho: The conductivity is not affected by ink or time $\alpha_i = \gamma_t = (\alpha\gamma)_{it}$

Ha: The conductivity is affected by ink and time $\alpha_i \neq \gamma_t \neq (\alpha\gamma)_{it}$

7B. Ho: No change in conductivity due to the ink $\alpha_1 = \alpha_2 = \alpha_3 = 0$

Ha: At least one of the alpha terms is non-zero: $\alpha_i \neq 0$ for some i

7C. Ho: No change in conductivity due to time $\gamma_0 = \gamma_{10} = 0$

Ha: At least one of the gamma terms is non-zero: $\gamma_t \neq 0$ for some t.

7D. Ho: There is no interaction between the ink and time $(\alpha\,\gamma)_{it} = 0$ for all $_{i,t}$

Ha: At least one of the $(\alpha\,\gamma)_{it}$ terms is non-zero: $(\alpha\,\gamma)_{it} \neq 0$

8. Tack

A two-factor factorial model was used to test the main effects and the interaction effects.

Main Effects	Interactions
Ink (α_i)	Ink/Time $(\alpha\gamma)_{it}$
Time (γ_t)	

Y_{it} = tack of ink i, time t

$E[Y_{it}] = F_{it}(k)$ where $F_{it}(k)$ is an unspecified response curve for ink i =1,2,3, time t = 0, 10

$E[Y_{it}] = \mu + \alpha_i + \gamma_t + (\alpha\gamma)_{it}$

Hypotheses	Hypothesis Proven	P-Value
8A	Ha	na
	Test for Main Effects	
8B (ink)	Ha	0
8C (time)	Ha	0
	Test for Interactions	
8D(ink/time)	Ha	0

Table 8. Ink tack.
A P-value under .05 indicates statistical significance.

8A. Ho: The tack is not affected by ink or time $\alpha_i = \gamma_t = (\alpha\gamma)_{i\,t}$

Ha: The tack is affected by ink and time $\alpha_i \neq \gamma_t \neq (\alpha\gamma)_{i\,t}$

8B. Ho: No change in tack due to the ink $\alpha_1 = \alpha_2 = \alpha_3 = 0$

Ha: At least one of the alpha terms is non-zero: $\alpha_i \neq 0$ for some i

8C. Ho: No change in tack due to time

$$\gamma_0 = \gamma_1 = \gamma_2 = \gamma_3 = \gamma_4 = \gamma_5 = \gamma_6 = \gamma_7 = \gamma_8 = \gamma_8 = \gamma_{10} = 0$$

Ha: At least one of the gamma terms is non-zero: $\gamma_t \neq 0$ for some t.

8D. Ho: There is no interaction between the ink and time $(\alpha\,\gamma)_{i\,t} = 0$ for all $_{i,\,t}$

Ha: At least one of the $(\alpha\,\gamma)_{i\,t}$ terms is non-zero: $(\alpha\,\gamma)_{i\,t} \neq 0$

Chapter 4

Methodology

Experimental Objective

The objective of this experiment was to create nine different water pickup curves using nine different inks and fountain solution combinations. The water pickup curves were created using the Surland method of plotting amount of fountain solution emulsified against time. The amount of fountain solution emulsified was determined gravimetrically. The nine different inks and fountain solution combinations were then tested for rheological changes and ink performance characteristics.

Instrumentation

Duke Ink-Water Emulsification Tester Model D-10

Brookfield Synchro-lectric Viscometer Model RVT

Little Joe Offset Proofing Press Model HM96

Thwing-Albert Inkometer

Rub Tester

X-Rite 418 Densitometer

OHAUS Triple Beam Balance

The instruments used to conduct these tests was a Duke Ink-Water Emulsification Tester, a motorized Little Joe Offset Proofing Press, a Brookfield Viscometer, an

Inkometer, a Rub Tester and a Densitometer. The Duke Tester was used to determine the rate of emulsification of the nine different ink and fountain solution combinations and to create the water pickup curves. The Brookfield Viscometer was used to study the rheological changes in the emulsified inks at different stages of percent water pick-up. The Little Joe Offset Proofing Press is a small mechanical device that simulates the action of a rotary printing press. The inking device for the Little Joe makes it possible to measure the amount of ink to be laid down as controlled by the operator. The printing device lays the ink down on a thin strip of paper. With the inking amount being held at a constant, a densitometer was then used to determine the ink strength by measuring the densities of the nine different ink and fountain solution combinations after ten minutes of mixing. These densities were then compared to the densities of the straight inks. A Rub Tester and densitometer was used to determine the rub resistance. The Inkometer was used to determine the tack of each ink with no emulsified fountain solution.

Materials Used

Flint Arrowlith Low-Rub Premium Black

Flint Arrowlith Dense Black

Flint Arrowlith Rub-Free Soy Black

Anchor Aqua Magic KO Neutral Fountain Solution

Anchor Fast Start II Alkaline Fountain Solution

Anchor News Etch 505 Acid Fountain Solution

Newsprint

At the beginning stages of this project I decided to use all of the materials that USA Today uses at the Gannett Offset, Boston printing plant – including the newsprint. At the beginning stages of the ink strength and rub-off tests utilizing the Little Joe Offset Proofing Press several problems were encountered that made it necessary to make some changes in materials and the methods used to apply the ink to the paper.

The problem was that there was too much variation in densities across the printed sheet and from sheet to sheet. Two changes were made to correct this problem. The first change that was made was the newsprint. The Bowater newsprint that was acquired from Gannett Offset in Boston had large density variations within the paper itself. This also didn't seem to be very representative of the Bowater paper used by Gannett Offset. It was not possible to hold the densities within the very tight .03 range that was set with the Bowater paper. The problem with the paper was resolved by switching paper. It was decided to switch to the newsprint that another Gannett newspaper, The Democrat and Chronicle in Rochester, NY, uses. A 30# newsprint was acquired from The Democrat and Chronicle and was used for the ink strength and rub-off tests.

The second part of the problem was operator variation in applying the ink to the Little Joe Offset Proof Press. This problem was resolved and the procedure used is described below.

Discussion of Experimental Procedure

The experimental procedure described here was repeated at least twice to generate data for the nine different combinations involved in this experiment.

Treatment	Flint Ink	Anchor Fountain Solution
1	1(low rub)	A (neutral)
2	1(low rub)	B (alkaline)
3	1(low rub)	C (acid)
4	2(dense black)	A (neutral)
5	2(dense black)	B (alkaline)
6	2(dense black)	C (acid)
7	3(soy low rub)	A (neutral)
8	3(soy low rub)	B (alkaline)
9	3(soy low rub)	C (acid)

Ink and Fountain solution Index

Step I. Using the Duke Tester, all nine ink and fountain solution combinations were tested for rate of emulsification and water capacity. This data was recorded and used to create the water pick-up curves by plotting amount of water emulsified against time. All tests were run at a constant temperature of 21°C. The Duke Tester bowl and mixing blades were weighed together to give a combined tare weight. The Duke Tester was set at 90rpm. Fountain Solution pH, conductivity and temperature were measured and recorded before and after each ten minute testing period. These tests were repeated four times.

Below is the procedure used:

A. Measure out 50gm of ink 1 into Duke Tester bowl.

B. Pour 100ml of fountain solution A into a beaker. Meter out 20ml and add to the bowl.

C. Add 20ml of fountain solution A to bowl and begin mixing. Observe for 1 minute. If all of the fountain solution disappears before the minute is up add more to maintain an excess.

D. When the mixer stops, detach the mixing blades and add blades to the bowl. Holding the blades at the side of the bowl, decant the free fountain solution to the beaker containing the unused fountain solution Run the blades very slowly through the ink in the bowl and decant additional free water into the beaker.

E. Weigh the mixing bowl and contents, including the blades and record data.

F. Repeat steps C through E for a total of ten minutes and record data.

This procedure was repeated for all nine ink and fountain solution combinations.

Step II. Using a Brookfield Viscometer, step I was repeated to measure ink viscosity. In order to have a sample size large enough to measure the viscosity, the ink amount used was increased to 75gm and the fountain solution amount was increased to 150ml. Measure out 30ml of fountain solution per minute of mixing time and:

A. At every one minute interval, the viscosity was determined using the appropriate spindle size at speed 1.0, and the data were recorded.

B. Step A was repeated at speed 2.5 and the data were recorded.

This procedure was repeated for all nine ink and fountain solution combinations.

Step III. The ink tack was determined using a Thwing-Albert Inkometer.

A. The initial ink tack was determined for each of the three inks and the data was recorded.

Step IV. The ink strength of straight ink and ink at the maximum emulsification capacity was determined with the Little Joe Offset Proof Press and a densitometer. Newsprint was cut into strips suitable for mounting on the Little Joe device and marked so that the same side of the paper (felt or wire) was used throughout the experiment. Densities for this testing were held to within .03 variation across the sheet, and from sheet to sheet when repeating the tests. After a week of testing, results suggested that, due to the tight .03 variation limit, the procedure used to apply the ink to the Little Joe Offset Proof Press needed modification. After another week of testing and experimenting, a method was developed that made it possible to hold to the .03 variation range. The revised procedure used was:

A. Measure out 0.4 cc's of straight ink 1 onto Little Joe and print onto newsprint.

B. Measure density at eight random data points with densitometer and record data.

C. Repeat steps A and B for inks 2 and ink 3 and record data..

D. Repeat steps A, B and C for each of the three inks using 0.6 cc's and 0.8 cc's of ink and record data.

E. Repeat steps A through D using ink that has gone through the ten minutes of mixing described in Step I.

F. Repeat steps A through E for each of the nine ink and fountain solution combinations.

Step V. Using a Rub Tester and a densitometer, the rub resistance was tested using the

following procedures:

A. Using the very same printed strips of paper from step IV with straight ink, the rub-resistance was measured after eight hours of drying time with the use of the rub-tester and the densitometer. The cut strips of paper were placed in the rub-tester and were rubbed back and forth across the printed sheet three times.

B. The densities across the printed strip were measured at three points and recorded both prior to and after the rub test.

C. Repeat steps A through B for each of the three straight ink strips printed with 0.4 cc's, 0.6 cc's and at 0.8 cc's of ink.

D. Repeat steps A through C for all of the nine ink and fountain solution combinations.

E. Repeat steps A through D using Kleenex 3-ply tissue paper, Kleenex 3-ply Tissue paper with Aloe, and your finger.

Step VI. The dry-back tests were conducted with a densitometer using the following procedures:.

A. Density measurements were taken at eight hours after printing and at eight random points across the printed sheet. The data were recorded.

B. Step A was repeated for the three straight inks and the nine ink and fountain solution combinations and for 0.4 cc's, 0.6 cc's, and 0.8 cc's of ink.

Step VII. Data Analysis: All tests were conducted at least twice to minimize error. All tests were also conducted in a random order. The recorded data was analyzed using the following statistical methods:

A. Water pick-up was analyzed by a three factor factorial with four replications. Emulsification curves for each of the nine different treatment combinations were created by running the tests four times and then averaging the results. The first factor is the ink, the second factor is the fountain solution, and the third factor is time. The data was analyzed using a standard analysis of variance to compare the main affects and interactions. The averaged data was then used to create the curves.

B. Repeated step A for creating the curves for ink viscosity.

C. Ink strength and dryback was analyzed by a three factor factorial with two replications. The first factor is the ink, the second factor is the fountain solution, and the third factor is the percent fountain solution emulsified. The data was analyzed using a standard analysis of variance to compare the main affects and interactions.

D. Rub-off was analyzed by a four factor factorial with two replications. The first factor is the ink, the second factor is the fountain solution, and the third factor is the amount of ink used and the fourth factor is the rub-off material used. The data was analyzed using a standard analysis of variance to compare the main affects and interactions.

E. Conductivity, pH and Tack were analyzed by a two factor factorial with two replications. The first factor being the ink and the second factor being time. The data was analyzed using a standard analysis of variance to compare the main affects and interactions.

Chapter 5

Statistical Analysis of the Data

Categories of Experimental Data

There were eight categories of experimental data which were analyzed in this research:

A. Water Pick-up: nine ink and fountain solution combinations (Hypothesis 1A – 1E)

B. Viscosity: nine ink and fountain solution combinations (Hypotheses 2A 2E)

C. Ink Strength: three straight inks plus nine ink and fountain solution combinations with three different amounts of ink being used. (Hypotheses 3A – 3E)

D. Ink Rub-off: three straight inks plus nine ink and fountain solution combinations with three different amounts of ink being used and four different rub-off materials being used. (Hypotheses 4A – 4F)

E. Ink Dryback: three straight inks plus nine ink and fountain solution combinations with three different amounts of ink being used being used. (Hypotheses 5A – 5E)

F. Ink pH: the three straight inks were mixed with deionized water to determine the affect the ink had on the pH. (Hypotheses 6A – 6D)

G. Ink conductivity, the three straight inks were mixed with deionized water to determine the affect the ink had on the conductivity. (Hypotheses 7A – 7D)

H. Ink Tack, the three straight inks were used and the ink tack for each was determined. (Hypotheses 8A – 8D)

Discussion of Results

Treatment	Flint Ink	Anchor Fountain Solution
1	1(low rub)	A (neutral)
2	1(low rub)	B (alkaline)
3	1(low rub)	C (acid)
4	2(dense black)	A (neutral)
5	2(dense black)	B (alkaline)
6	2(dense black)	C (acid)
7	3(soy low rub)	A (neutral)
8	3(soy low rub)	B (alkaline)
9	3(soy low rub)	C (acid)

Table 9. Ink and Fountain solution Index

Water Pick-up

General Linear Model

Factor	Levels	Values										
Ink	3	1	2	3								
F.S.	3	1	2	3								
Time	11	0	1	2	3	4	5	6	7	8	9	10

Analysis of Variance for Water Pick-up

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Ink	2	2445.79	2445.79	1222.90	446.28	0.000
F.S.	2	24940.64	24940.64	12470.32	4550.85	0.000
Time	10	45411.93	45411.93	4541.19	1657.24	0.000
Ink*F.S.	4	1258.91	1258.91	314.73	114.85	0.000
Ink*Time	20	1360.94	1360.94	68.05	24.83	0.000
F.S.*Time	20	7943.35	7943.35	397.17	144.94	0.000
Ink*F.S.*Time	40	633.14	633.14	15.83	5.78	0.000
Error	297	813.84	813.84	2.74		
Total	395	84808.55				

Table 10. Analysis of Variance model for Water pick-up.

The statistical analysis of the water pick-up data shows that all of the factors – the ink, fountain solution and time – have an affect on the amount of fountain solution picked up by each ink. P- values of zero for all of the interaction tests and all of the main affects

show that everything is significant. The ink, fountain solution and time are all significant factors as well as the interaction between all of these factors.

In addition, the water pick-up data and curves also show that fountain solution B had the most weight picked-up by all three inks, followed by fountain solution A, then fountain solution C, respectively. Furthermore, ink 1 picked-up the most fountain solution followed by ink 2 then ink 3, respectively.

Viscosity

General Linear Model

Factor	Levels	Values										
ink	3	1	2	3								
f.s.	3	1	2	3								
time	11	0	1	2	3	4	5	6	7	8	9	10

Analysis of Variance for Viscosity

Source	DF	Seq SS	Adj SS	Adj MS	F	P
ink	2	2251485	2251485	1125742	32.73	0.000
f.s.	2	120011776	120011776	60005888	1744.66	0.000
time	10	56510208	56510208	5651021	164.30	0.000
ink*f.s.	4	35729800	35729800	8932450	259.71	0.000
ink*time	20	81860056	81860056	4093003	119.00	0.000
f.s.*time	20	49693520	49693520	2484676	72.24	0.000
ink*f.s.*time	40	15865965	15865965	396649	11.53	0.000
Error	99	3405006	3405006	34394		
Total	197	365327808				

Table 11. Analysis of Variance model for Viscosity.

The statistical analysis of the viscosity data shows, with p-values of zero for all of the interactions and all of the main affects, that all of the factors are significant and do have an affect on the viscosity. The ink, fountain solution and time as well as all of the interactions between each of these factors has a significant affect on the ink's viscosity.

In addition, the viscosity data and curves also show that ink 1 had the largest increase in viscosity, followed by ink 2 and then ink 3. Fountain solution B had the largest effect on viscosity, followed fountain solution A and then solution C. It is important to point out that ink 3 reacted very differently from ink 1 and ink 2. Ink 3 started at a very high viscosity and, when fountain solution was added to the ink, the viscosity abruptly dropped before beginning to stabilize. Inks 1 and 2 started at a low viscosity and slowly became more viscous as fountain solution was added.

Ink Strength

General Linear Model

Factor	Levels	Values			
ink	3	1	2	3	
f.s.	4	0	1	2	3
c.c.s	3	4	6	8	

Analysis of Variance for Strength

Source	DF	Seq SS	Adj SS	Adj MS	F	P
ink	2	0.48935	0.48935	0.24468	93.19	0.000
f.s.	3	1.35088	1.35088	0.45029	171.50	0.000
c.c.s	2	1.85203	1.85203	0.92601	352.69	0.000
ink*f.s.	6	0.09682	0.09682	0.01614	6.15	0.000
ink*c.c.s	4	0.01885	0.01885	0.00471	1.79	0.151
f.s.*c.c.s	6	0.01077	0.01077	0.00179	0.68	0.664
ink*f.s.*c.c.s	12	0.03515	0.03515	0.00293	1.12	0.378
Error	36	0.09452	0.09452	0.00263		
Total	71	3.94837				

Table 12. Analysis of Variance model for Strength.

The statistical analysis of the ink strength data shows that with a p-value of zero each of the main effects-- ink, fountain solution, time-- has a significant affect on the ink strength. With a p-value of zero, the statistical analysis also shows that the interaction between the ink and fountain solution is a significant factor in contributing to the ink

between ink and time (3B.2), fountain solution and time (3B.3) and the interaction between the ink, fountain solution and time (3B.4) has no statistical significance on the affect upon the ink strength.

In addition, the ink strength data and curves also show that, with no fountain solution, ink 3 had the highest density at all amounts, followed by ink 2 and then ink 1. Ink 3 had the highest density at 0.4 cc's. and 0.6 cc's, followed by ink 1 and then ink 2. At 0.8 cc's. ink 3 had the highest density, followed by ink 2 and then ink 1. Fountain solution C had the smallest effect on ink strength, followed fountain solution A and then solution B.

Rub-off

General Linear Model

Factor	Levels	Values			
material	4	1	2	3	4
ink1	3	1	2	3	
fs	4	0	1	2	3
ccs1	3	4	6	8	

Analysis of Variance for Rub-off

Source	DF	Seq SS	Adj SS	Adj MS	F	P
material	3	0.0149574	0.0149574	0.0049858	17.41	0.000
ink	2	0.1175497	0.1175497	0.0587749	205.19	0.000
fs	3	0.1403531	0.1403531	0.0467844	163.33	0.000
ccs	2	0.2096701	0.2096701	0.1048350	365.99	0.000
material*ink	6	0.0164260	0.0164260	0.0027377	9.56	0.000
material*fs	9	0.0093439	0.0093439	0.0010382	3.62	0.000
material*ccs	6	0.0007384	0.0007384	0.0001231	0.43	0.858
ink*fs	6	0.0138330	0.0138330	0.0023055	8.05	0.000
ink*ccs	4	0.0617585	0.0617585	0.0154396	53.90	0.000
fs*ccs	6	0.0057220	0.0057220	0.0009537	3.33	0.004
material*ink*fs	18	0.0083989	0.0083989	0.0004666	1.63	0.060
material*ink*ccs	12	0.0045269	0.0045269	0.0003772	1.32	0.215
material*fs*ccs	18	0.0051194	0.0051194	0.0002844	0.99	0.471
ink*fs*ccs	12	0.0089610	0.0089610	0.0007468	2.61	0.004
mater*ink*fs*ccs	36	0.0117325	0.0117325	0.0003259	1.14	0.292
Error	144	0.0412480	0.0412480	0.0002864		
Total	287	0.6703387				

Table 13. Analysis of Variance model for Rub-off.

In addition, the rub-off data and curves also show the following:

	Tissue		Tissue w/ Aloe		Finger		Paper	
C.C.S.	Ink	FS	Ink	FS	Ink	FS	Ink	FS
	1	no fs	3	no fs	3	no fs	3	no fs
.4ccs	3	C	1	C	1	A	1	C
	2	A	2	A	2	C	2	A
		B		B		B		B
	3	no fs	3	no fs	3	no fs	3	no fs
.6ccc	1	C	1	C	1	A	1	A
	2	A	2	A	2	C	2	C
		B		B		B		B
	3	no fs	3	no fs	3	no fs	3	no fs
.8ccs	1	A	1	C	1	A	1	C
	2	C	2	A	2	C	2	A
		B		B		B		B

Table 14. Ink Rub-off chart going in order from least resistant to the most resistant.

The statistical analysis of the rub-off data shows that, with a p-value of zero all of the main affects-- ink (4C), f.s. (4D), amount of ink (4E) and the material (4F)--all have a significant affect on the rub-off. The tests for interactions show that the interaction between ink and fountain solution (4B.1), ink and amount of ink (4B.2), ink and material (4B.3), fountain solution and amount of ink (4B.4), fountain solution and material (4B.5) and the interaction between ink, fountain solution and the amount of ink (4B.7) all have a significant affect on rub-off. The p-value of 0.06 shows that the interaction between ink, fountain solution and material (4B.8) is not significant by the slimmest of margins--0.01--but, nonetheless, is still deemed as an insignificant interaction and therefore has no affect on the rub-off. The interactions between amount of ink and material (4B.6), ink and

amount of ink and material (4B.9), fountain solution and amount of ink and material (4B.10), and the interaction between ink, fountain solution, amount of ink and material (4B.11) all have p-values over .05 and therefore are all considered insignificant interactions and have no affect on the rub-off.

This chart shows that with all materials and with all amounts of ink, each ink with no fountain solution had the of lowest rub-off resistance. Fountain solution B had the highest rub-off resistance. Fountain solution A, for 7 out of 12 treatments, had the second best results for least rub-off resistance followed by fountain solution C. With each fountain solution and each rub-off material used ink 3 had the lowest rub-off resistance followed ink 1 and then ink 2. One exception was fountain solution B and rub-off by paper. In this case ink 3 had the lowest rub-off resistance, followed ink 2 and then ink 1.

Ink Dryback

General Linear Model

Factor	Levels	Values			
ink	3	1	2	3	
f.s.	4	0	1	2	3
c.c.s	3	4	6	8	

Analysis of Variance for Dryback

Source	DF	Seq SS	Adj SS	Adj MS	F	P
ink	2	0.127907	0.127907	0.063953	24.59	0.000
f.s.	3	0.070871	0.070871	0.023624	9.08	0.000
c.c.s	2	0.078861	0.078861	0.039430	15.16	0.000
ink*f.s.	6	0.012816	0.012816	0.002136	0.82	0.561
ink*c.c.s	4	0.027957	0.027957	0.006989	2.69	0.047
f.s.*c.c.s	6	0.050858	0.050858	0.008476	3.26	0.012
ink*f.s.*c.c.s	12	0.034294	0.034294	0.002858	1.10	0.390
Error	36	0.093627	0.093627	0.002601		
Total	71	0.497190				

Table 15. Analysis of Variance model for Dryback.

The statistical analysis of the ink dryback data shows that, with p-values of zero, all of the main affects, ink (5C), fountain solution (5D) and the amount of ink (5E) are all significant factors in affecting the ink dryback. With p-values also under 0.05, the interactions between ink and the amount of ink (5B.2) and the interactions between fountain solution and the amount of ink (5B.3) also have a significant affect on the ink dryback. With p-values over 0.05 the interaction between ink and fountain solution (5B.1) and the interactions between ink, fountain solution and the amount of ink (5B.4) have no significant affect on the ink dryback.

In addition, the ink dryback data and curves also show that, with no fountain solution, ink 3 had the highest density at all amounts, followed by ink 2 and then ink 1. Ink 3 had the highest density at 0.4 cc's. and 0.6 cc's, followed by ink 1 and then ink 2. At 0.8 cc's, ink 3 had the highest density, followed by ink 2 and then ink 3. Fountain solution C had the smallest effect on the ink strength, followed fountain solution A and then solution B.

pH

General Linear Model

Factor	Levels	Values		
ink	3	1	2	3
time	2	0	10	

Analysis of Variance for pH

Source	DF	Seq SS	Adj SS	Adj MS	F	P
ink	2	0.74555	0.74555	0.37277	24.42	0.001
time	1	2.88120	2.88120	2.88120	188.72	0.000
ink*time	2	0.74555	0.74555	0.37277	24.42	0.001
Error	6	0.09160	0.09160	0.01527		
Total	11	4.46390				

Table 16. Analysis of Variance model for pH.

The statistical analysis of the pH data shows, with p-values under 0.05, the main affects-- ink (6B) and time (6C) as well as the interaction between the ink and time (6D)-- are all significant and do have an affect on the pH.

In addition, the deionized water, with all three inks, showed a significant drop in pH. The deionized water reacts almost identically to inks 1 and 2 with the pH dropping from about 7.68 to a pH of about 7.02 and 7.04, respectively. Ink 3 on the other hand caused the deionized water to drop from a pH of about 7.68 to a pH of about 6.21.

Conductivity

General Linear Model

Factor	Levels	Values		
ink	3	1	2	3
time	2	0	10	

Analysis of Variance for Conductivity

Source	DF	Seq SS	Adj SS	Adj MS	F	P
ink	2	3263.7	3263.7	1631.9	161.62	0.000
time	1	10220.0	10220.0	10220.0	1012.22	0.000
ink*time	2	3263.7	3263.7	1631.9	161.62	0.000
Error	6	60.6	60.6	10.1		
Total	11	16808.0				

Table 17. Analysis of Variance model for Conductivity.

The statistical analysis of the conductivity data shows, with p-values of zero, the main affects-- ink (7B) and time (7C), as well as the interaction between the ink and time (7D)-- are all significant and do have an affect on the pH.

In addition, the deionized water, with all three inks, showed a significant rise in conductivity. The conductivity rose the most with ink 1 from 154.8 to 256, followed by ink 3 with a rise from 154.8 to about 212. Ink 2 increased from 14.8 to about 169.4.

Tack

General Linear Model

Factor	Levels	Values										
time	11	0	1	2	3	4	5	6	7	8	9	10
ink	3	1	2	3								

Analysis of Variance for Tack

Source	DF	Seq SS	Adj SS	Adj MS	F	P
time	10	10.3908	10.3908	1.0391	36.98	0.000
ink	2	2.6214	2.6214	1.3107	46.65	0.000
Error	20	0.5620	0.5620	0.0281		
Total	32	13.5741				

Table 18. Analysis of Variance model for Tack.

The statistical analysis of the tack data shows, with p-values of zero, the main affects-- ink (8B) and time (8C), as well as the interaction between the ink and time (8D-- are all significant and do have an affect on the ink tack.

In addition, ink 1 has the largest drop in tack from 6 gm-meters to 3.6 followed by ink 2 which went from 5 gram meters to 3 gram meters. Ink 3 fell from 4.75 gram meters to 3.4 gram meters.

Chapter 6

Data Analysis and Conclusions

Data Analysis

The focus of this thesis project was to determine the significance of water pick-up tests and to determine what happens to the ink rheology and ink performance attributes when the ink is mixed with fountain solution. Using nine different ink and fountain solution combinations, the water pick-up tests were performed. Then changes in rheology were tested by determining viscosity changes as well as changes in ink tack. The ink performance characteristics were analyzed by testing the affects on ink strength, dryback and rub-off. The affect that the ink may have on the fountain solution was investigated by testing for pH and conductivity changes.

The results of all of these tests have been broken down by ink into three separate sections. All data results have been averaged over the number of times each test was performed.

Treatment	Flint Ink	Anchor Fountain Solution
1	1(low rub)	A (neutral)
2	1(low rub)	B (alkaline)
3	1(low rub)	C (acid)
4	2(dense black)	A (neutral)
5	2(dense black)	B (alkaline)
6	2(dense black)	C (acid)
7	3(soy low rub)	A (neutral)
8	3(soy low rub)	B (alkaline)
9	3(soy low rub)	C (acid)

Ink and Fountain solution Index

Surland Discussion

P	Water Balance Range	Damp. Sol'n. Effect	Image Area: Print/Plate	Ink Lay On Print	Rel. Print Density
A	zero		∞		
B	narrow	flota-tion	> 1	∼∼∼	< 1
C	wide		= 1	═══	= 1
D	narrow	tint	< 1	ΛΛΛΛ	< 1
E	zero		= 0		= 0
F	narrow	tint	< 1	→ΛΛΛΛ	→ < 1

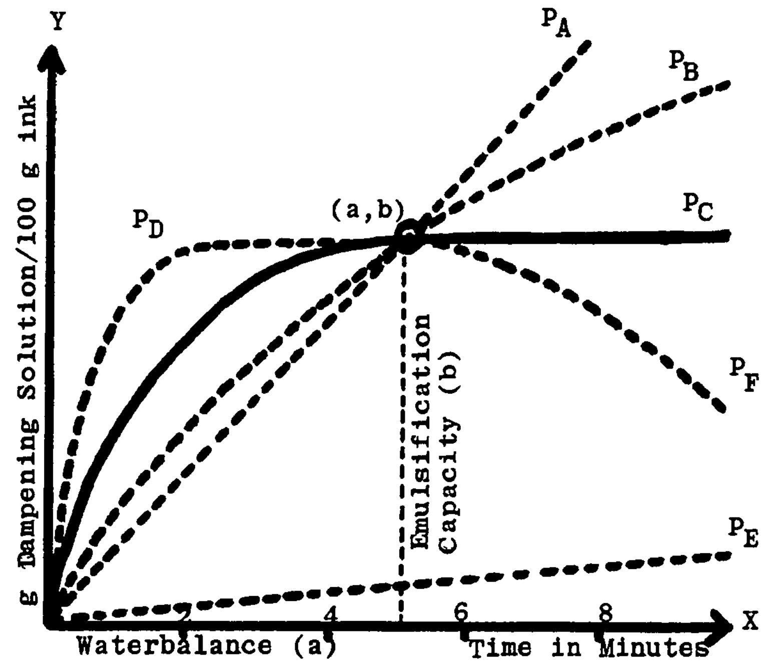

Figure 1.0. Surland P Curves vs. Press Performance[1]

Surland believed that all inks could be classified into six different water pick-up curves. Figure 1.0 shows the six different typical curve shapes and expected performance wise of inks that fall into each curve classification. The Y axis represents full miscibility

between the two phases, (ink and fountain solution) and the X axis represents absolute repellency between the two phases. Therefore, it is no surprise that the P_A ink scums (transfers to image and non-image areas indiscriminately) under all conditions and that the P_E ink will not produce an image at all. Transfer is prevented by heavy water film over the ink form roller and plate image. All of the curves (except P_E) were drawn to pass through the same point (a,b) only to demonstrate that a single end point test could be satisfied by all the curves.[2]

It is Surland's conclusion that an ink that exhibits a water pick-up curve such as P_C type inks is the easiest and best performing ink to run on press. According to Surland, P_C type inks exhibit a wide water balance, a high degree of print fidelity and a solid ink density that can be easily monitored within a wide latitude. Inks that exhibit curves other than the P_C type exhibit no water balance or a very narrow water balance and are very difficult to control on press. An ink that reaches its water balance and levels off at around five minutes seems to perform the best on press.[3]

Note: Throughout the rest of this chapter cubic centimeters will be referred to as "cc's" and fountain solution will be referred to as "f.s."

Ink 1 – Flint Arrowlith Low-Rub Premium Black

Water Pick-up	F.S. A	F.S. B	F.S. C	
Water Pick-up (gms f.s. picked up)	42.2	59.625	23.525	
Viscosity @speed 1.0(avg. change)	6215+	11825+	375+	
Viscosity @speed 2.5(avg. change)	3090+	5320+	240+	
Strength/Dryback/Rub-off				
0.4 cc's	**No f.s.**	**F.S. A**	**F.S. B**	**F.S. C**
Ink Strength (ink density)	0.872	0.55	0.5015	0.662
Dryback (density loss)	0.018	0.013	0.0075	0.0005
Rub-off (density loss by material used)				
finger	0.10995	0.0615	0.03665	0.0348
paper	0.0568	0.0155	0.02515	0.0518
kleenex	0.0853	0.0538	0.0166	0.07395
kleenex w/aloe	0.0782	0.05035	0.0317	0.0723
0.6 cc's	**No f.s.**	**F.S. A**	**F.S. B**	**F.S. C**
Ink Strength (ink density)	1.0705	0.7265	0.7245	0.862
Dryback (density loss)	0.06	0.0085	0.014	0.026
Rub-off (density loss by material used)				
finger	0.137	0.0865	0.06565	0.0768
paper	0.075	0.0615	0.06365	0.0383
kleenex	0.12	0.07215	0.0803	0.986
kleenex w/aloe	0.1202	0.06	0.0655	0.08845
0.8 cc's	**No f.s.**	**F.S. A**	**F.S. B**	**F.S. C**
Ink Strength (ink density)	1.1865	0.905	0.8335	1.02
Dryback (density loss)	0.096	0.0295	0.0185	0.0445
Rub-off (density loss by material used)				
finger	0.1685	0.1165	0.06515	0.10165
paper	0.1	0.0683	0.0368	0.073
kleenex	0.1485	0.09665	0.08695	0.0885
kleenex w/aloe	0.123	0.0765	0.08015	0.1
Tack	2.4-			
pH	.63-			
Conductivity	97.6+			

Table 19. Ink 1 test results.

Figure 1.1 clearly shows how differently ink 1 reacted with each of the three fountain solutions. The shape of the curves, according to Surland, should be a good predictor to how the ink will perform on press.

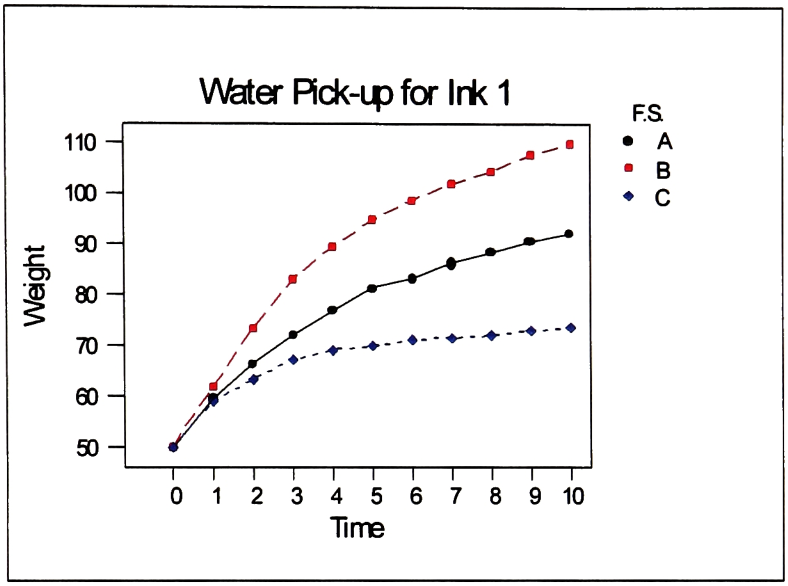

Figure 1.1. Ink 1 water pick-up.

In Figure 1.1 it appears that curve C has a very close resemblance to the P_C curve shown in Figure 1.0. This would suggest that this ink and fountain solution would perform best on press. The problem is that this is an acid fountain solution which is a much less forgiving solution to the surface of the plate. Extended exposure eventually etches the surface of the plate, causing the non-image area to become sensitized and susceptible to scumming.

Curve A and curve B seem to more closely resemble the P_B curve shown in Figure 1.0. According to Surland, these ink and fountain solution combinations will exhibit a narrow water balance and will not perform as well as the P_C type ink. According

to Figure 1.0, although the P_B type ink does not perform as well as the P_C type ink, it does perform better than the other curve types.

The water pick-up data shows that ink 1 picked up more of fountain solution B (alkaline), an average of 59.625 over four runs. This is followed by fountain solution A (neutral) with an average of 42.2 grams being picked-up. Fountain solution C (acid) had the least amount picked-up with an average of only 23.525 grams. There does seem to be a direct correlation between the amount of water taken up and the affect this has on the ink rheology and ink performance.

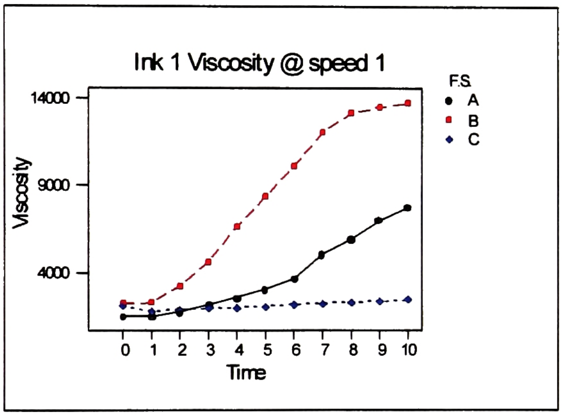

Figure 1.2. Ink 1 viscosity at speed 1.0.

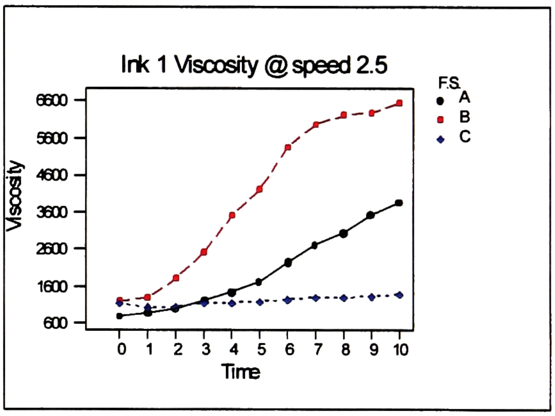

Figure 1.3. Ink 1 viscosity at speed 2.5.

Figure 1.2 and Figure 1.3 show that, at both speeds, the more fountain solution that is picked up by the ink the higher the viscosity rises. Ink 1 with fountain solution A and fountain solution B, at both speeds, has a significant rise in viscosity. The acid fountain solution (C) didn't have a significant effect on the viscosity because ink 1 picked up the least amount of the acid fountain solution.

The shear thinning affect can be seen by comparing Figure 1.2 and Figure 1.3. This means that, at a higher speed or a higher shear rate, the viscosity does not rise as

high. By comparison, the shape of the curves of Figure 1.2 and Figure 1.3 is similar at both speeds.

It has been observed that the more water the ink picked-up the higher the viscosity increased, but there are other factors that can affect viscosity. The droplet size and the consistency of the droplet sizes also can have an impact on viscosity. Large water droplets will show a bigger rise in viscosity. Also, droplets that all have a consistent size will show a steep rise in viscosity. On the other hand, an ink with smaller droplets or droplets that vary in size will tend to have a lower viscosity.[4]

The water pick-up rates also seem to have a direct impact on the ink strength and ink dryback. As can be seen in Figure 1.4 the ink strength or ink density is the highest with no fountain solution at all amounts. You can also see that the density naturally rose, with all fountain solutions, as the amount of ink was increased.

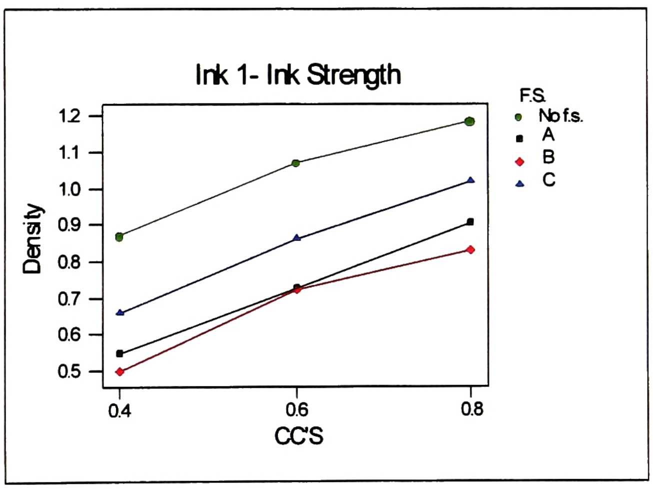

Figure 1.4. Ink 1 strength.

Figure 1.4 demonstrates that the ink density is higher when the ink has lower amounts of fountain solution as with fountain solution C. As the ink picks up more of a fountain solution, the ink strength is weakened and the density is lowered. Ink 1 picked

up the highest amount of fountain solution B, and the density is clearly lowest with fountain solution B.

Ink strength or ink density is a reflection of how much pigment is on the sheet. As the ink picks up more fountain solution it becomes diluted and, therefore, does not carry as much pigment to the sheet. Ink strength is also a direct reflection on how much carbon content the ink has to begin with.[5] The data suggest that ink 3 has the highest carbon content followed by ink 1 then ink 2.

Figure 1.5 illustrates that there are several crossovers by the different fountain solutions. Ink 1, with no fountain solution, shows a much higher loss of density (due to dryback) then the same ink with fountain solution. Furthermore, the density loss due to dryback is very close with each of the fountain solutions as can be seen in Figure 1.5. Also, as the amount of ink increases so does the density loss due to dryback. This is true for the ink with no fountain solution as well as the ink with fountain solution.

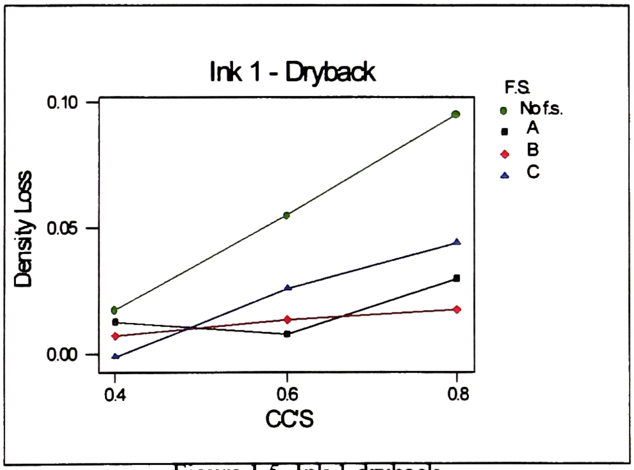

Figure 1.5. Ink 1 dryback.

Figure 1.5 shows the interactions between the various fountain solutions and ink 1. With fountain solution B and C, the density loss is higher as the ink amount is increased. Fountain solution A , for an unknown reason, reacted differently by producing

a lower density loss at 0.6 cc's then at 0.4 cc's. One explanation could be due to the testing procedures. During these tests the density measurements were taken randomly. This is due to the fact that there was no way to measure the exact point before and after the dryback period.

Generally, an ink with lower water content and lower viscosity will be absorbed more by the paper, and this increases the dryback and lowers the density of the ink. An ink with a higher water content will swell the paper fibers more, and thus, it will not allow as much of the ink to be absorbed into the paper. The result is less density loss due to dryback.[6] At 0.8 cc's you can see this trend. Another factor, again, is the carbon content and the amount of pigment that is carried to the sheet.

The ink rub-off data also do not show the clearest picture in respect to the rub-off material used relative to water content, but it is very clear that a correlation exists between the water content of the ink and the density loss due to rub-off.

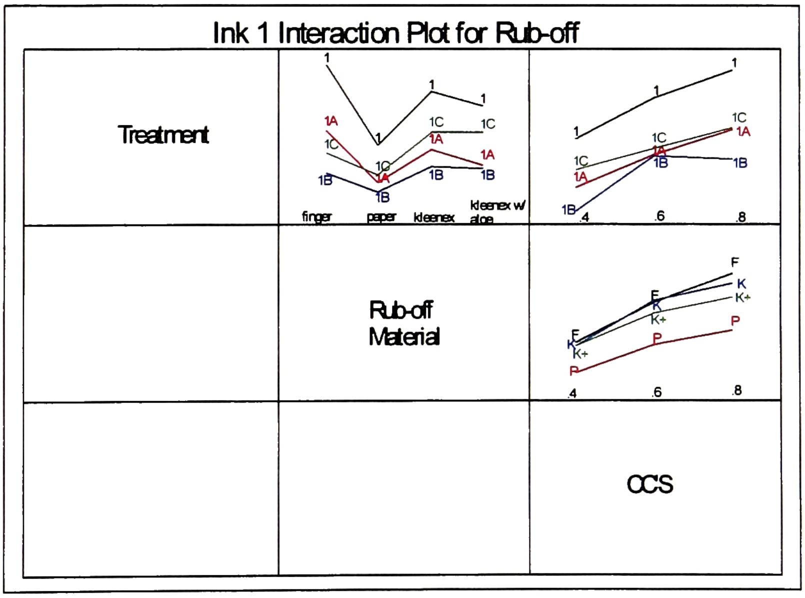

Figure 1.6. Ink 1 rub-off.

Figure 1.6, ink 1 with no fountain solution, has the lowest rub-off resistance. The more fountain solution this ink picks-up the better the rub-off resistance. This appears to be true for all ink amounts. For rub-off materials, Figure 1.6 shows the finger caused the largest drop in density the Kleenex the second largest drop, and the Kleenex with aloe caused the third largest decline. The paper had a significantly lower affect on the rub-off.

Tests were run to see how each ink might have an affect on the pH and conductivity. I did not found a clear correlation between any of the other test results and the pH and conductivity results. Figures 1.7 and 1.8 show the pH and conductivity test results respectively.

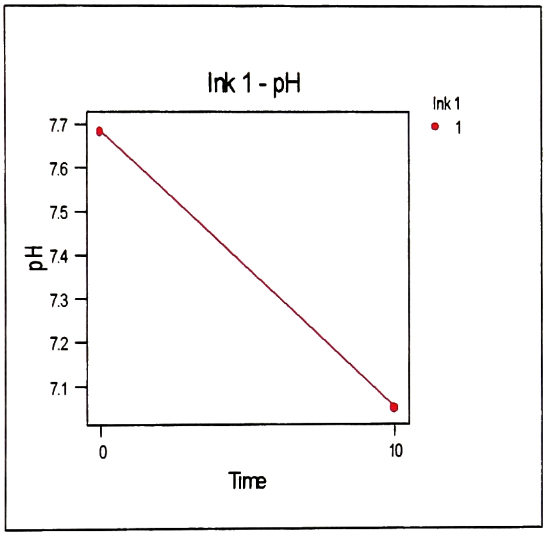

Figure 1.7. Ink 1 pH.

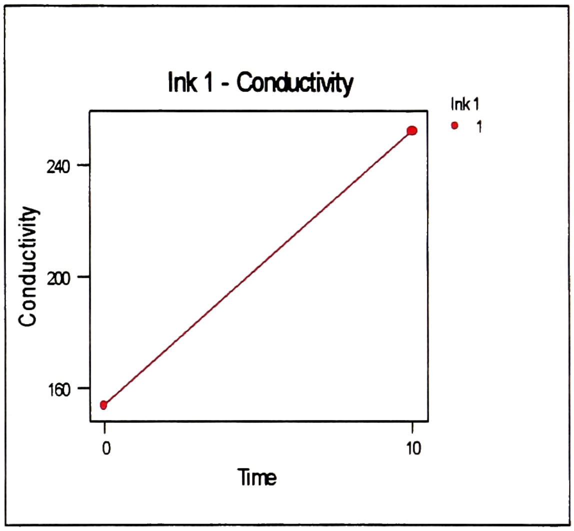

Figure 1.8. Ink 1 conductivity.

A drop in pH and/or a rise in conductivity do not appear to be significant factors in affecting ink rheology or performance. The rise in conductivity for ink 1 is the largest of the three inks. The rise in conductivity is due to the release of ions into the solution. This may be caused by salts in the ink being dissolved into the

solution.[7] Further study is suggested to determine exactly what is causing the drop in pH and the rise in conductivity.

A tack test was also run on each ink produced no clear direction or pattern.. Figure 1.9 shows the results of the tack test on ink 1. Ink 1 had a drop in tack of 2.4 gm-meters.

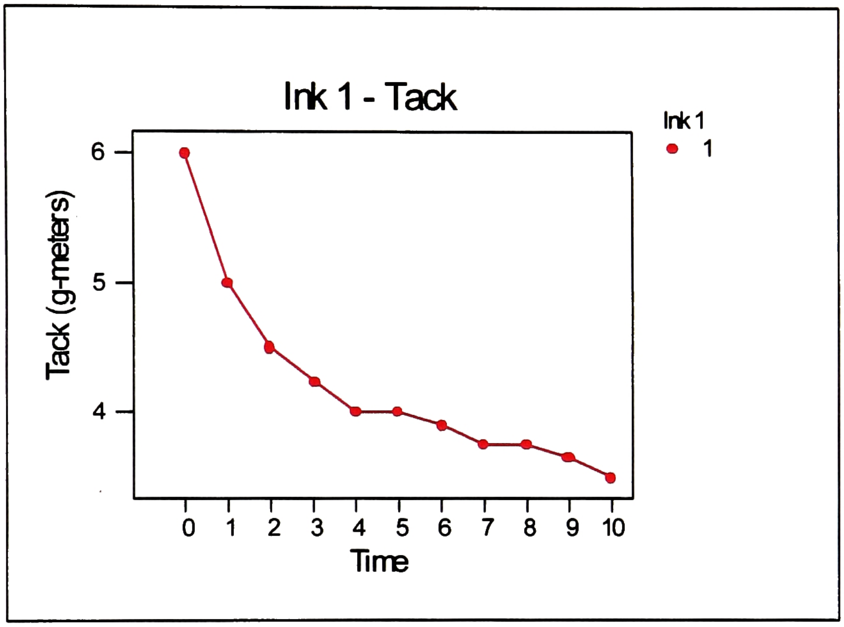

Figure 1.9. Ink 1 tack.

The tack tests were run on a Thwing-Albert Inkometer. These tests were only run on the straight ink, ink with no fountain solution. I was not able to run tack tests on ink that had been mixed with fountain solution because the inkometer would break the emulsion. Therefore, since I was not able to test the ink with fountain solution in it, I was not able to establish a relationship between water pick-up, tack and the ink performance.

Ink 2 – Flint Arrowlith Dense Black

Water Pick-up	F.S. A	F.S. B	F.S. C	
Water Pick-up (gms f.s. picked up)	33.975	56.525	19.45	
Viscosity @speed 1.0(avg. change)	4450+	8075+	175+	
Viscosity @speed 2.5(avg. change)	2200+	4220+	190+	
Strength/Dryback/Rub-off				
0.4 cc's	**No f.s.**	**F.S. A**	**F.S. B**	**F.S. C**
Ink Strength (ink density)	0.797	0.5595	0.4315	0.6045
Dryback (density loss)	0.0005	0.0075	0.006	0.0005
Rub-off (density loss by material used)				
finger	0.076	0.02135	0.023	0.0815
paper	0.0465	0.03185	0.022	0.042
kleenex	0.0715	0.0563	0.035	0.05
kleenex w/aloe	0.058	0.035	0.385	0.035
0.6 cc's	**No f.s.**	**F.S. A**	**F.S. B**	**F.S. C**
Ink Strength (ink density)	1.023	0.77	0.62	0.8445
Dryback (density loss)	0.0235	0.005	0.002	0.01
Rub-off (density loss by material used)				
finger	0.1065	0.077	0.0435	0.048
paper	0.065	0.0615	0.0395	0.0355
kleenex	0.108	0.0767	0.05185	0.067
kleenex w/aloe	0.0935	0.0633	0.045	0.078
0.8 cc's	**No f.s.**	**F.S. A**	**F.S. B**	**F.S. C**
Ink Strength (ink density)	1.154	0.914	0.781	1.018
Dryback (density loss)	0.0525	0.0105	0.0045	0.026
Rub-off (density loss by material used)				
finger	0.12	0.08695	0.0465	0.077
paper	0.06	0.03195	0.0815	0.055
kleenex	0.1285	0.0867	0.063	0.095
kleenex w/aloe	0.1115	0.07365	0.053	0.133
Tack	2.00-			
pH	.625-			
Conductivity	16.9+			

Table 20. Ink 2 Test results.

The water pick-up data for ink 2 shows very similar looking curves to ink 1. Ink 2 picked up slightly smaller amounts of all three fountain solutions but still reacted differently to each fountain solution. See Figure 2.1 below.

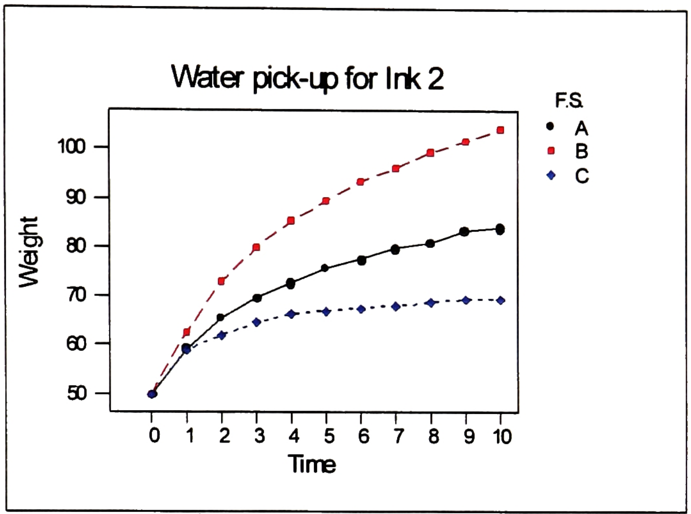

Figure 2.1. Ink 2 water pick-up.

Figure 2.1 shows how ink 2 reacted with each of the three fountain solutions. The same comparisons can be made of this ink to the Surland model. As with ink 1, curve C for ink 2 closely resembles the P_C curve shown in Figure 1.0. This would suggest that this ink and fountain solution would also perform best on press. But again, this is the acid fountain solution which is not the ideal type of solution to run as was explained earlier.

Curve A and curve B for ink 2 are also very similar to that of ink 1 in that they seem to more closely resemble the P_B curve shown in Figure 1.0. According to Surland, these ink and fountain solution combinations will exhibit a narrow water balance and will not perform as well as the P_C type ink. According to Figure 1.0, although the P_B type ink does not perform as well as the P_C type ink, it does perform better than the other curve types.

The water pick-up data shows that ink 2 picked up more of fountain solution B (alkaline), an average of 56.525 grams over four runs. This is followed by fountain solution A (neutral) with an average of 33.975 grams. Fountain solution C (acid) had the least amount picked-up with an average of only 19.45 grams. There does seem to be a direct correlation between the amount of water taken up and the affect this has on the ink rheology and ink performance.

The change in viscosity follows the same pattern as ink 1. The more fountain solution the ink picks up the more viscous the ink becomes. Figures 2.2 and 2.3 it can be demonstrate the affect the amount of water picked-up amount has on the viscosity of the ink.

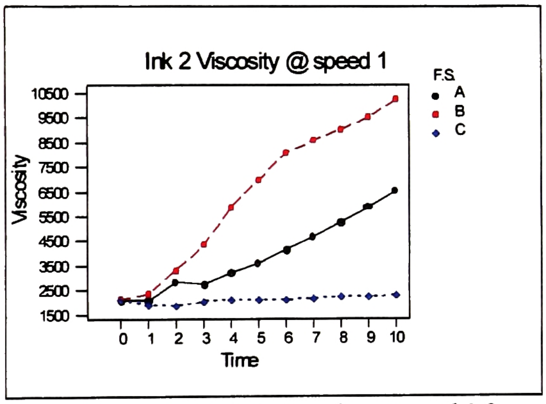

Figure 2.2. Ink 2 viscosity at speed 1.0.

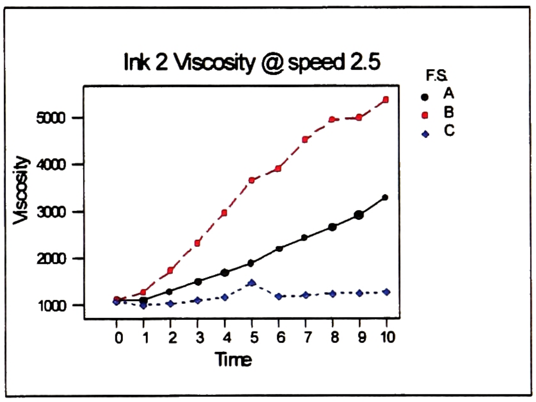

Figure 2.3. Ink 2 viscosity at speed 2.5.

The ink 2 viscosity curves are very similar to the curves for ink 1. Although the viscosity change is not quite as high with each fountain solution as it was with ink 1, ink 2 reacted very similarly to each fountain solution. Fountain solution B, which had the highest amount picked-up by ink 2, exhibits the highest increase in viscosity. This is followed by fountain solution A then fountain solution C. Fountain solution C (acid),

which had the least amount of solution picked-up by ink 2, shows no real significant change in the viscosity.

A conclusion supported by Figures 2.2 and 2.3 is that while the curves look very similar, see that the viscosity does not rise as high at the higher speed as it does the lower speed (Figure 2.2).

As with ink 1, the ink strength data shows a very clear correlation with the water content of the ink. The ink with no fountain solution has the highest densities at all ink amounts tested. The more water content in the ink the lower the density becomes. This is clearly seen in Figure 2.4.

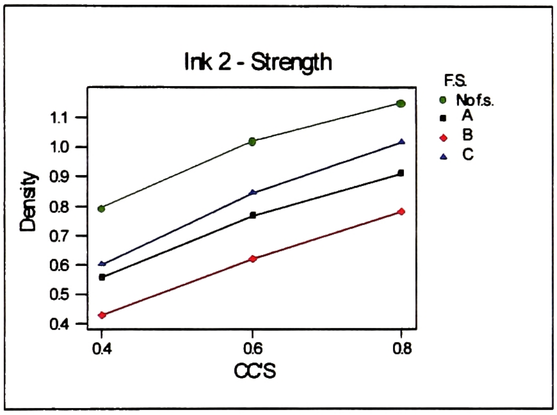

Figure 2.4. Ink 2 strength.

Figure 2.4 shows that the ink with no fountain solution maintains the highest density at all amounts. As the water content in the ink rises, the density drops. The density pattern of ink 2 is very similar to that of ink 1. The densities are slightly lower than that of ink 1 but this is most likely due to a lower carbon content.

The relationships of dryback with ink 2 to no fountain solution has a much higher density loss due to dryback then when it is mixed with fountain solution. The difference

in dryback between the different solutions is very small. Ink 2 with fountain solution A and fountain solution C react very similar to ink 1. When the ink has less fountain Solution, it tends to have a greater density loss due to dryback. Figure 2.5 depicts this very well.

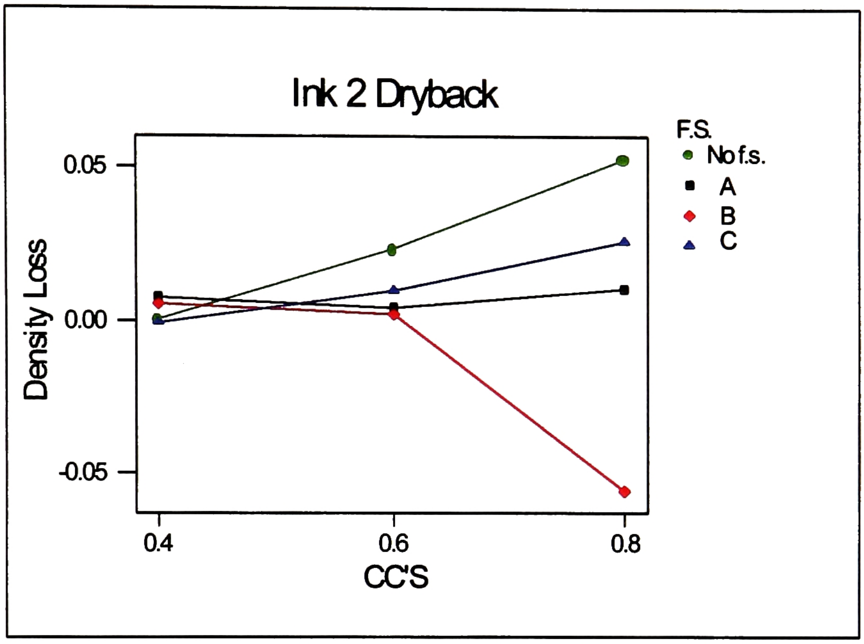

Figure 2.5. Ink 2 dryback.

Figure 2.5 demonstrates that there is something different going on between ink 2 and fountain solution B. Fountain solution B appears to cause ink 2 to react quite a bit differently in terms of density loss due to dryback. As the ink amount increases the density loss is reduced, especially between 0.6 cc's and 0.8 cc's. Up to 0.6 cc's fountain solution B reacts very similarly to fountain solution A and fountain solution C. This is explained by the fact that ink 2 has the highest content of fountain solution B. As the amount of ink is increased, the dryback was decreased. In fact, at 0.8 cc's, the dryback was eliminated.

The rub-off data for ink 2 does not show a clear correlation between the water content and the density loss due to rub-off.

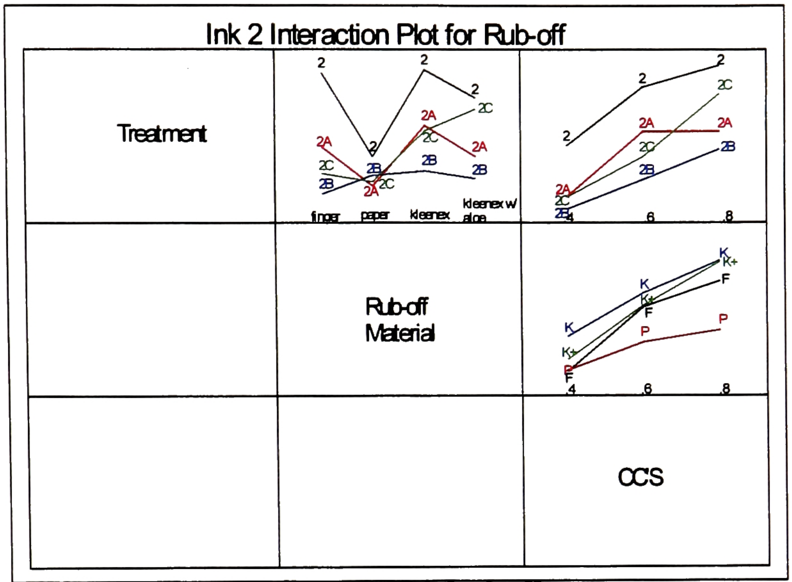

Figure 2.6. Ink 2 rub-off.

Figure 2.6 shows the rub-off pattern of ink 2. Ink 2 with no fountain solution, at all amounts of ink, has the highest density loss. Furthermore, as the ink amount rises so does the density loss. Fountain solution B had the highest amount picked up by ink 2. Treatment 2B shows the lowest density loss due to rub-off. Treatment 2A and 2C crossover several times within the interaction between treatment and rub-off material as well as the interaction between treatment and the amount of ink.

Although there are some obvious interactions here, treatments 2A and 2B still follow the basic pattern of increasing levels of rub-off as levels of fountain solution in the ink decline. Figure 2.6 shows that the Kleenex has the biggest affect on the rub-off followed by the Kleenex with aloe and then the finger, respectively. The paper had the smallest affect on the rub-off. There is no clear picture as to what affect, if any, the water content may have on the rub-off material.

The tack test for ink 2 didn't reveal any surprising information. Ink 2 had a drop of 2.0 gram meters.

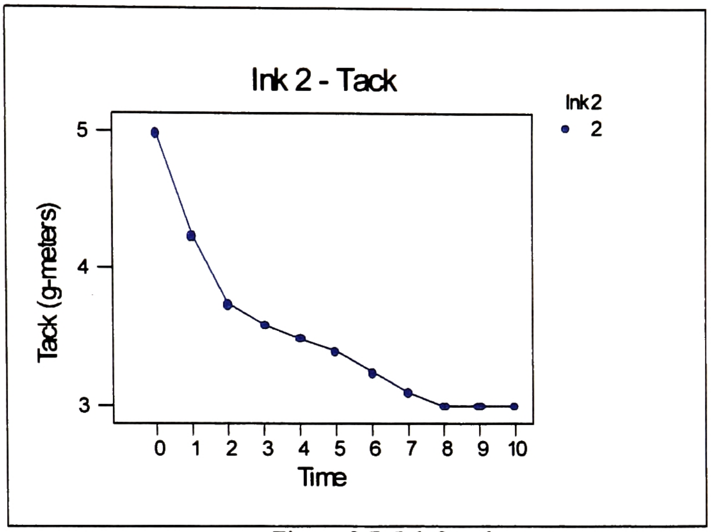

Figure 2.7. Ink 2 tack.

Figure 2.7 shows the drop in viscosity over the ten minute test. Ink 2 reacted similarly to ink 1 in this respect.

The ink 2 pH tests also revealed a very similar pattern to ink 1. Ink 1 had a drop in pH of 0.63 as compared to the drop in pH of ink 2 of 0.625. Figure 2.8 shows the drop in pH over the ten minute testing period.

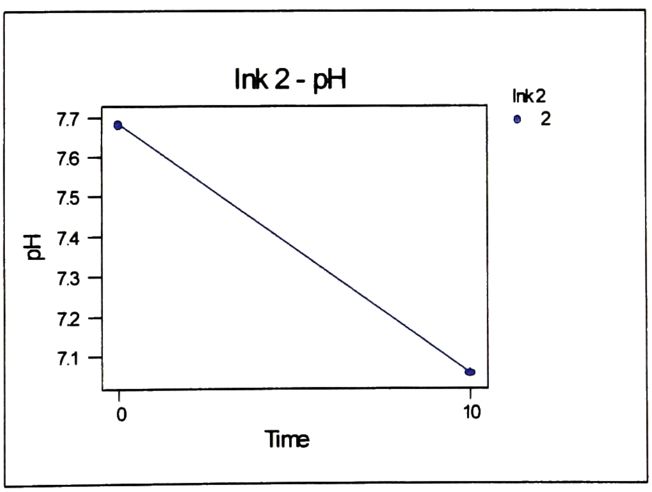

Figure 2.8. Ink 2 pH.

Although the drop in pH is very similar between ink 1 and ink 2, the conductivity tests are very different. Ink 1 showed a rise in conductivity of 97.6. Figure 2.9, for ink 2, shows a rise in conductivity of only 16.9.

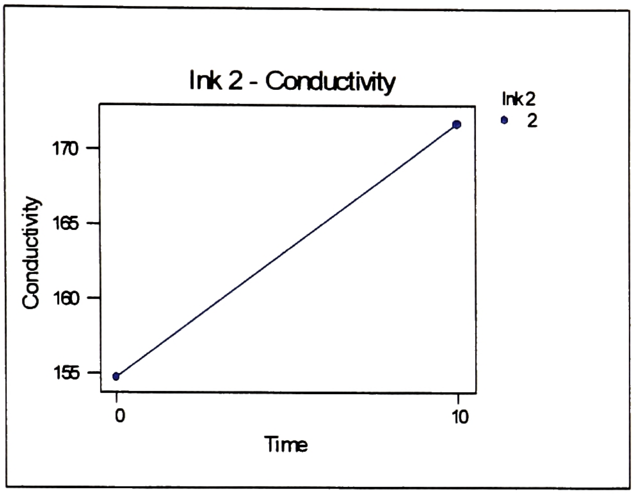

Figure 2.9. Ink 2 conductivity.

As stated earlier, the large rise in conductivity for ink one is most likely due to the release of ions into the solution. The ions most likely came from salts in the ink. The fact that ink 2 did not have a similar dramatic rise in conductivity suggests there is a significant difference in formulation of the two inks. Ink 2 did not have a breakdown of its salts in the solution.

Ink 3 – Flint Arrowlith Rub-Free Soy

Water Pick-up	F.S. A	F.S. B	F.S. C	
Water Pick-up (gms f.s. picked up)	21.025	49.75	21.6	
Viscosity @speed 1.0(avg. change)	5950-	3150-	5000-	
Viscosity @speed 2.5(avg. change)	3200-	1640-	2520-	
Strength/Dryback/Rub-off				
0.4 cc's	No f.s.	F.S. A	F.S. B	F.S. C
Ink Strength (ink density)	0.9195	0.784	0.5975	0.7935
Dryback (density loss)	0.0615	0.0405	0.021	0.0525
Rub-off (density loss by material used)				
finger	0.1215	0.045	0.042	0.058
paper	0.078	0.058	0.017	0.0469
kleenex	0.0765	0.062	0.0235	0.0635
kleenex w/aloe	0.0685	0.048	0.0245	0.05365
0.6 cc's	No f.s.	F.S. A	F.S. B	F.S. C
Ink Strength (ink density)	1.17365	1.0415	0.8405	1.007
Dryback (density loss)	0.16665	0.1165	0.055	0.1085
Rub-off (density loss by material used)				
finger	0.172	0.117	0.08	0.1166
paper	0.1635	0.11	0.07	0.1165
kleenex	0.142	0.113	0.0685	0.0995
kleenex w/aloe	0.143	0.1005	0.0665	0.09
0.8 cc's	No f.s.	F.S. A	F.S. B	F.S. C
Ink Strength (ink density)	1.3405	1.246	0.987	1.182
Dryback (density loss)	0.2685	0.2135	0.103	0.1765
Rub-off (density loss by material used)				
finger	0.233	0.172	0.137	0.1735
paper	0.255	0.1885	0.106	0.176
kleenex	0.215	0.184	0.1	0.155
kleenex w/aloe	0.21	0.1785	0.0983	0.157
Tack	1.35-			
pH	1.685-			
Conductivity	60.6+			

Table 21. Ink 3 test results.

The soy ink, ink 3, reacted differently than inks 1 and ink 2. The main factor, of course, is that this is a vegetable oil based ink and not a mineral oil based ink. The soy oil is an alkali refined oil with a lower viscosity than mineral oils. Because the soy oil is less viscous, additives are added to raise the viscosity. Soy oil is also more polar than mineral

oils, and it is for this reason that different resins are used. All of these factors change how the soy ink will react to the fountain solution.[8]

The water pick-up data shows that ink 3 picked up significantly lower amounts of fountain solution A and fountain solution B but picked up just about the same amount of fountain solution C.

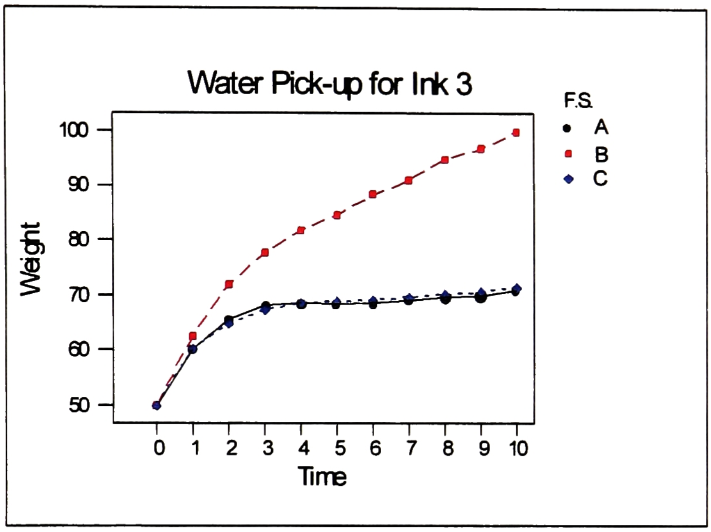

Figure 3.1. Ink 3 water pick-up.

Figure 3.1. shows that ink 3 picked up nearly identical amounts of fountain solutions A and C. The soy based ink has an obvious affinity for the alkaline fountain solution (curve B). The curves for fountain solution A and C closely resemble the Surland curve P_C in Figure 1.0. The curve for fountain solution B more closely resembles the P_B curve from Figure 1.0. This suggests that the soy ink would perform best with the neutral fountain solution (curve A). Although fountain solution C also exhibits a P_C-like curve, fountain solution C is an acid solution, and, for reasons already discussed, would not be the best choice.

Ink 3 picked-up almost 30 grams more of fountain solution B than fountain solutions A or C. Even though this ink is showing very different properties, one can still see a direct correlation between the water pick-up rates and capacity of the ink and the affect this has on ink rheology and the ink performance.

The soy ink was much more viscous than the other inks. This ink, when it takes up water, becomes less viscous. This is a totally different reaction from ink 1 and ink 2. This may suggest that soy ink may not show the same tendency of producing a true water in oil emulsion. If soy inks do not emulsify with fountain solution, then the water picked up by the ink in this test also suggests that surface water may be formed, resulting in a drop in viscosity.[9] The difference with ink 3 is that, during the first minute of mixing, there was a very dramatic drop in viscosity. Then, after the initial drop, the viscosity stabilized.

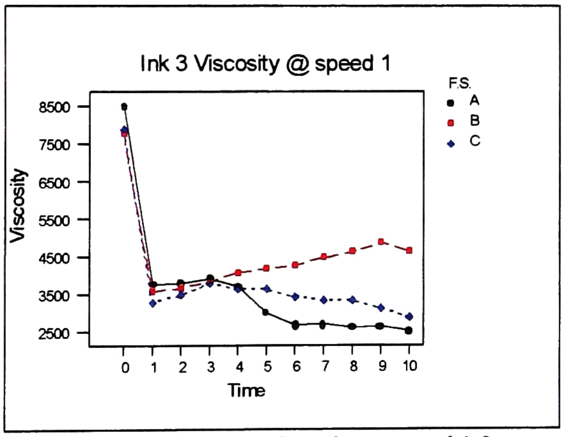

Figure 3.2. Ink 3 viscosity at speed 1.0.

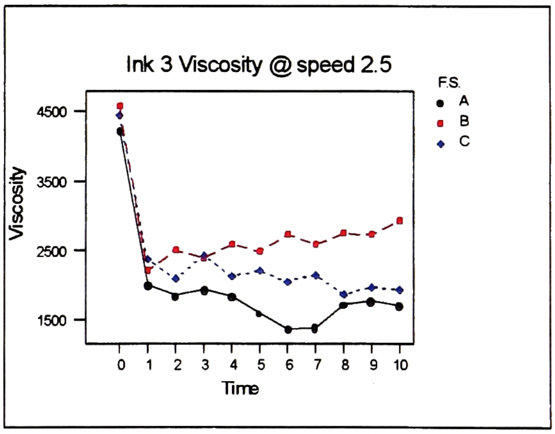

Figure 3.3. Ink 3 viscosity at speed 2.5.

Figure 3.2 and 3.3 show what happened to the viscosity as the ink picked up water. At both speeds, similar curves can be seen. The illustrations show that there was a very dramatic drop in viscosity in the first minute of mixing for all three fountain solutions. As the mixing time continues you can see that, in the case of the ink with

fountain solutions A and C there is not much more viscosity loss because the ink does not take up to much more fountain solution. In the case of the same ink with fountain solution B (alkaline), the viscosity begins to slowly rise after the initial drop because this ink continued to pick-up the fountain solution.

The abrupt drop in viscosity of the soy ink may be explained in a few ways. It may be that the two phases, ink and fountain solution, may clash so much because the viscosity of each phase is quite different. The fountain solution dilutes the ink until the ink begins to emulsify. Another reason for the abrupt drop in viscosity may be that a small amount of fountain solution may break down the ink structure, but—over a long period of time-- the structure builds back up.[10]

Comparing Figures 3.2 and 3.3, one can also see the shear thinning affect of this ink. When the speed of the Brookfield is raised, the ink shows a very similar pattern to an ink at a lower speed and lower viscosity

The ink strength data for ink 3 show a correlation between the amount of water the ink picked-up and the ink density. The more water ink 3 picked up the weaker the strength became. This is true at all ink amounts. This is just as ink 1 and ink 2 reacted.

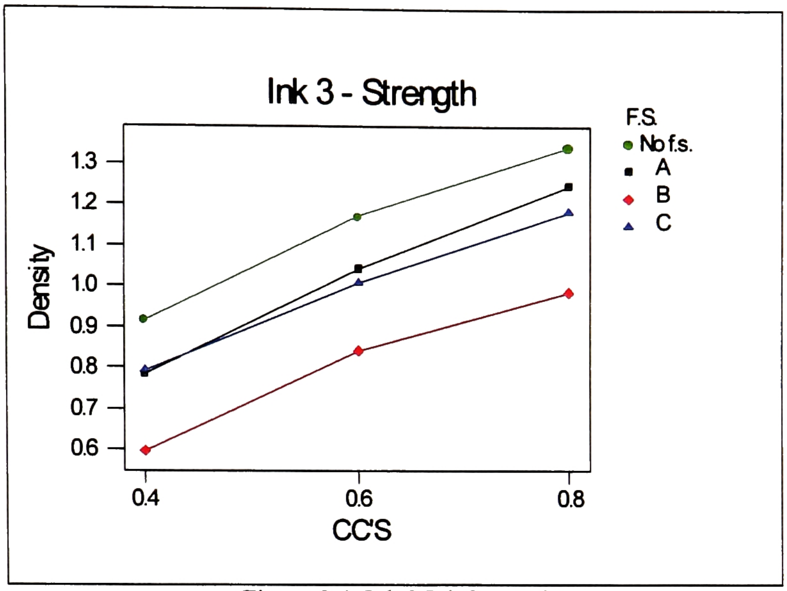

Figure 3.4. Ink 3 Ink Strength

Figure 3.4 shows that with no fountain solution, ink 3 has the highest density at all amounts. Ink 3 picked-up smaller amounts of fountain solutions A and B and, therefore, the densities remain high. This ink picked up more of fountain solution B and therefore has the lowest density with this fountain solution.

Test results indicate ink 3 (soy) has the highest carbon content of the three inks. The ink strength is a direct reflection upon the carbon content and the amount of pigment available on the sheet.

There are a few explanations as to why this ink may have a higher carbon content. Soy oil is a less viscous oil than mineral oil. To make up the difference in viscosity, more carbon may have been added along with more resin and binder.[11] A higher carbon content will increase ink density. Therefore, it will take less ink to reach a target ink density. This can have a significant impact on ink mileage.

The ink dryback data also shows a direct link to the water pick-up. The more fountain solution picked up by the ink the less density loss is incurred due to dryback. Ink 3 (soy) shows a significant increase in dryback as compared to ink 1 and ink 2. This is most likely due to the lower viscosity of the ink. An ink with a lower viscosity will be absorbed into the paper more, thus reducing the density.

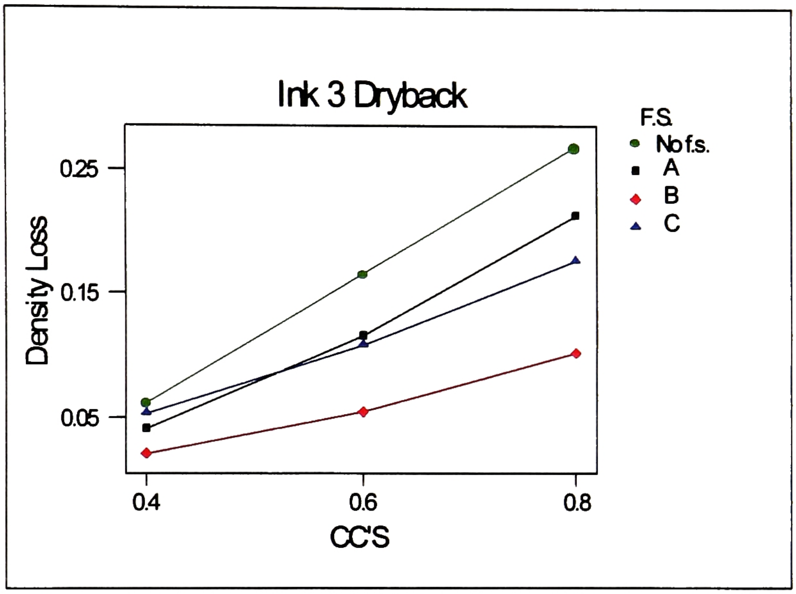

Figure 3.5. Ink 3 dryback.

Figure 3.5 depicts very well how more fountain solution in the ink reduces the amount of dryback. You can see that the ink with no fountain solution has the highest density loss at all amounts. This can be seen with each of the fountain solutions. Fountain solutions A and C follow the pattern except for a slight variation at 0.4 cc's. Fountain solution B, which had the highest amount picked-up by ink 3, had the lowest density loss due to dryback.

The rub-off data for ink 3 follows the pattern of ink 1 and ink 2. The more fountain solution the ink has the less rub-off will occur.

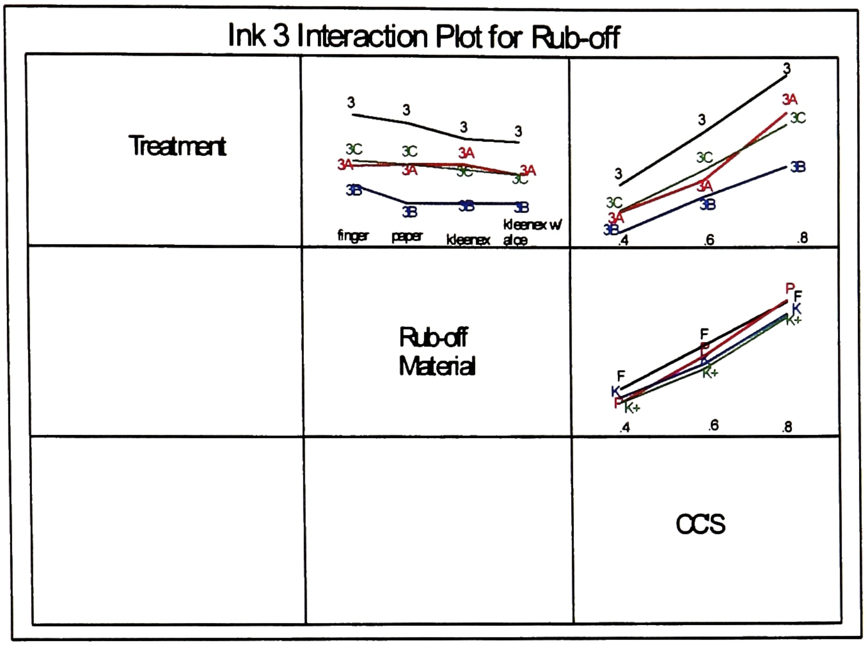

Figure 3.6. Ink 3 rub-off.

Ink 3 picked up almost identical amounts of fountain solutions A and C. In Figure 3.6 you can see how close the two curves are. Fountain solution B had the highest amount picked-up and it had the lowest density loss. In respect to the rub-off material, all have very similar curves. But you can see that the finger had a slightly higher density loss, followed very closely by the paper. The Kleenex and the Kleenex with aloe show very similar curves. There does not seem to be any correlation between the water pick-up and the rub-off material used. Furthermore, each rub-off material has reacted slightly differently to each ink.

During the tack test, ink 3 had a drop in tack of 1.35 gram meters. This is the lowest drop in tack out of the three inks. Ink 3 began at a tack lower than that of ink 1 and ink 2. One explanation for the lower tack is because of the soy oil used in this ink. Soy oil reduces the tack of the ink.[12]

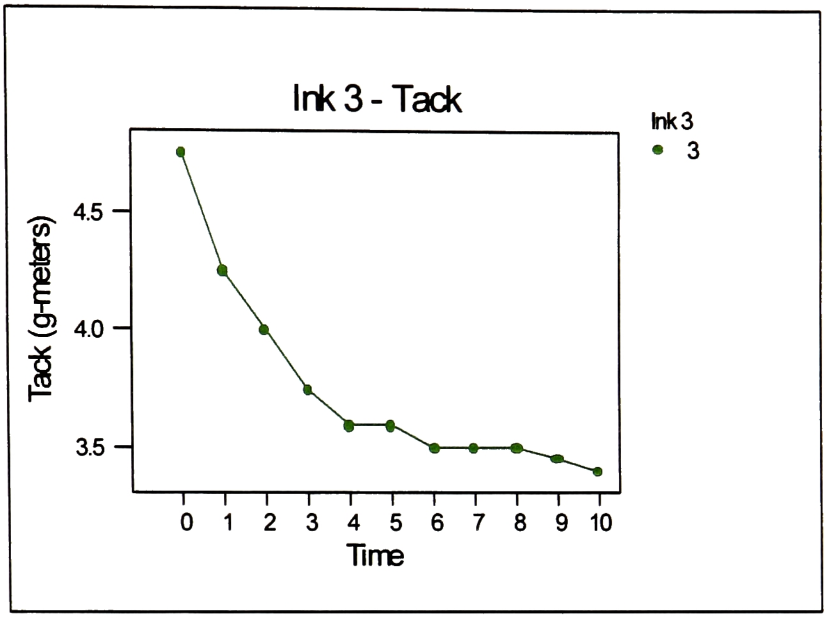

Figure 3.7. Ink 3 tack.

Figure 3.7 shows the path that the tack of ink 3 took over the ten-minute test. Starting at a tack of 4.75 gram meters and ending at 3.4 gram meters ink, 3 had a loss in tack of only 1.35 gram meters.

Ink 3 caused a drop in pH of 1.685. This is a significant drop. The soy oil used to formulate this ink is most likely a refined oil that is basically neutral in nature. So there must be something acidic in the ink that was dissolved or released into the water during the test, possibly a resin or a binder, which caused the drop in pH.[13] Figure 3.8 illustrates the drop in pH very well.

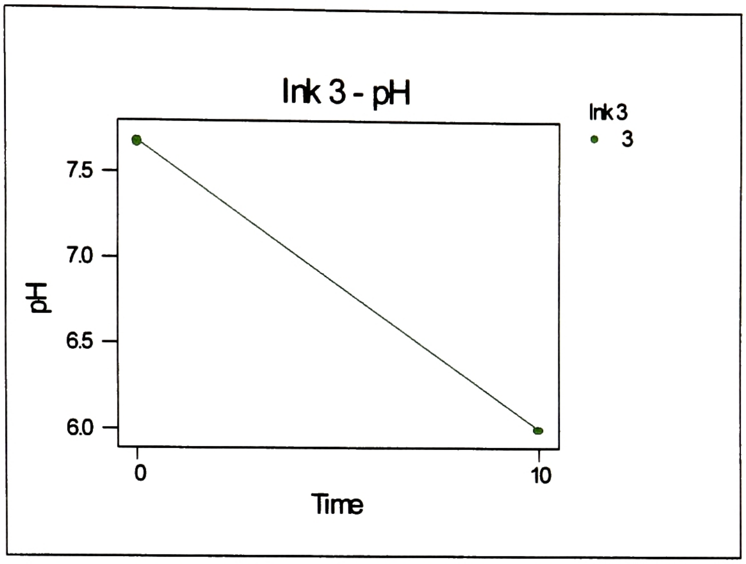

Figure 3.8. Ink 3 pH.

The conductivity test for ink 3 revealed a rise in conductivity of 60.6. This rise in conductivity falls right in between the conductivity increases in ink 1 and ink 2, 37 points lower than ink 1 and 43.7 points higher than ink 2. Figure 3.9 illustrates the rise in conductivity for ink 3. Again, it is most likely an additive that caused the rise in conductivity, rather than the soy oil itself.[14]

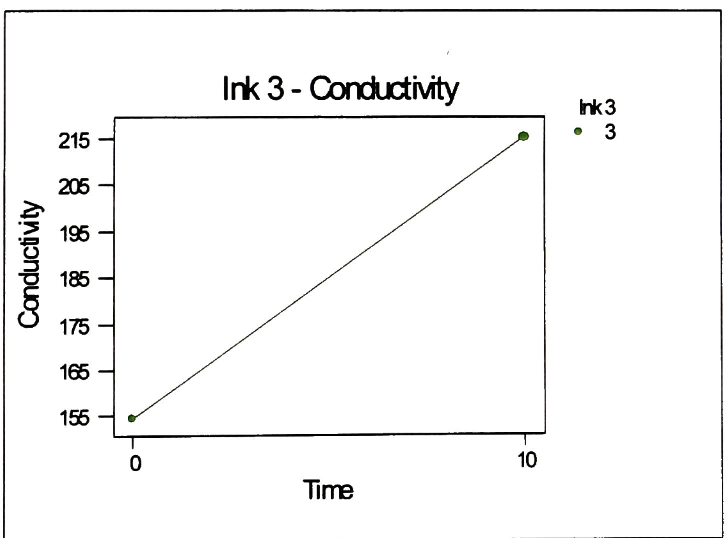

Figure 3.9. Ink 3 conductivity.

Discussion on Soy Ink

Soy inks were first introduced in response to environmental concerns caused by mineral oil inks. And the environmental issue has been a big selling point of soy inks, but soy inks can also offer more in the way of quality and productivity.

The soy ink used in this thesis project has out performed the other two inks in several ways. The soy ink with the neutral fountain solution displayed a water pick-up curve that very closely resembled the Pc curve from the Surland model. This ink and fountain solution combination reached an ink and water balance after about five minutes of mixing. This would suggest that this ink and fountain solution combination would perform very well on press.

The soy ink also maintained the highest densities throughout the ink strength tests. This ink did have a higher density loss due to dryback and rub-off then the other two inks, but this is most likely due to the fact that this ink had the highest densities and, apparently, the highest carbon content of the three inks.

The ink strength results for the soy ink are very significant. The strength data indicates that it would take less of the soy ink to reach the target solid ink density than the other two inks. This would then suggest an increase in ink mileage with the soy ink. This does not necessarily translate to cost savings. Right now, soy ink costs two to three times mores than comparable mineral oil ink. It is very unlikely that the added cost of using the soy ink can be made up by improved ink mileage alone. Perhaps, with improved make-ready time, less start up waste, an increase in quality, and the improved mileage, the cost difference can become more insignificant.

Even though soy inks are more environmentally friendly and may have a positive impact on quality and productivity, for a production director, it still comes down to a question of cost effectiveness. It is the cost of the soy inks that is the biggest reason for why more newspaper operations do not use more soy inks today.

Significance to Today's Pressroom

Now that we have all of the data compiled and all of our conclusions are drawn we need to ask ourselves what all of this mean to the modern newspaper operation. This information can have an impact on all aspects of a pressroom operation. Ink and fountain solution combination has an affect on the quality and productivity of the operation, not to mention the financial aspects.

It is important to mention that all of this data was collected in a laboratory and not in a working pressroom. There are many other factors that come into play in a pressroom that we were not able to duplicate in the lab. Factors that can have a significant affect on the water pick-up, viscosity, tack, strength, rub-off and dryback. On the press, for example, the ink and fountain solutions go through several nips, which is one of the ways the ink picks up the fountain solution. This is different than the ink and fountain solution being mixed in a Duke tester. Other factors such as temperature changes as well as speed and speed changes on press can also have an effect on how the ink picks up the fountain solution. Interactions with press washes and the type of plates and blankets being used also need to be taken into consideration.

Publishers and pressroom managers must treat ink as a commodity. The ink is a staple product in the printing industry that should be bought at the lowest price, but also

offer the best performance. Performance is typically measured in ink mileage that can be easily calculated by the pounds of ink used per ton of newsprint consumed in the same period. Density has a direct and easily demonstrated relationship to ink mileage. Water pick-up's relationship to performance is less clear.[15]

To try to find out what significance this study may have on today's pressroom, I have spoken to a few people working as either press managers or production managers. Bruce Meissner, Press Manager at the Sacramento Bee, relayed an experience that he had in evaluating ink performance by water pick-up tests. At the Sacramento Bee, water pick-up tests are run regularly on new batches of ink. This is done as a quality control tool. One batch of ink showed a very different water pick-up rate. The ink took in much more water than it had previously. This suggested a change in formulation. The concern was that, since the ink took up more water, the strength would be weakened and the mileage would suffer. The ink mileage actually improved. Water pick-up tests, by themselves, are difficult to correlate to actual ink performance.[16]

Bruce Meissner has found through real world experience that there is not a direct relationship between the % water that an ink picks up, and the final mileage of the product. What has been found is inks that reach a steady-state in pick-up after about four minutes in the Duke tester will generally perform better than inks that continue to pick-up greater amounts of water during the length of the test.[17] It is possible that inks that fail to reach a stability point become incapable of releasing sufficient water to the plate surface at the final nipping point. As more water is added, the viscosity and tack changes within

the ink train, until eventually (and quickly) over-emulsification occurs. Steady state inks both pick up and release water very efficiently.[18]

Looking at the water pick-up graph, Figure 4.1, you can see that the only inks that reach this “steady-state” by about 4 minutes are each ink in combination with the acid fountain solution as well as treatment 3A (soy ink with neutral f.s.). However, the aggressive nature of the acid is less forgiving to the gum surfaces of the plate. Extended exposure eventually etches the surface of the plate, causing the non-image area to become sensitized –an event that leads to scumming. Acid solutions must also contain gum arabic solutions, and plates left on the cylinders must be coated with gum solutions to keep them from oxidizing even between short runs. Over presentation of acid solutions can cause plate blinding, or the desensitizing of image areas on the plate.[19]

Alkaline solutions are more forgiving than acids, and have gained favor due to fast clean-up, lack of stripping problems on rollers, and the wider range of sensitivity in application.[20]

Neutral solutions are even more forgiving, and are even easier to measure and control.[21] Ink 3 shows steady states similar to acid performance when using the neutral solution. The neutral solutions are easier to control on press than alkaline when using soy inks.[22] This research supports that finding.

Footnotes for Chapter 6

[1] Aage Surland, "A Laboratory Test Method for Prediction of Lithographic Ink Performance," Technical Association of the Graphic Arts Proceedings (1980) : 222.

[2] Ibid

[3] Ibid

[4] Richard R. Durand Jr PhD, Technical Manager, Sun Chemical, interview by author, Questionnaire and telephone conversations, Rochester, NY and Carlstadt, NJ, September 22, 1998.

[5] Ibid.

[6] Ibid.

[7] Ibid.

[8] Ibid

[9] Ching Chen, Technical Director, T& E Center, Rochester Institute of Technology

[10] Richard R. Durand Jr. PhD, Technical Manager, Sun Chemical, interview by author, Questionnaire and telephone conversations, Rochester, NY and Carlstadt, NJ, September 22, 1998.

[11] Ibid.

[12] Ibid.

[13] Ibid.

[14] Ibid

[15] Bruce Meissner, Press Manager, Sacramento Bee, interview by author, Questionnaire and telephone conversations, Rochester, NY and Sacramento, CA, September 22, 1998.

[16] Ibid.

[17] Ibid.

[18] Ibid.

[19] Ibid.

[20] Ibid.

[21] Ibid.

[22] Ibid.

Chapter 7

Recommendations for Further Study

All of this data was collected in a laboratory on equipment that is supposed to simulate pressroom conditions. The problem is that the lab equipment used doesn't really simulate pressroom conditions very well. There are so many variables within the printing process, especially on the press, that can have significant affects on the water pick-up attributes of the ink, ink rheology and ink performance characteristics.

It is for these reasons that this author would like to see these tests conducted under conditions that more closely resemble press conditions. I recommend future research be directed toward tests that more closely simulate the rigors of what a press does to the ink and fountain solution.

- Measuring the viscosity changes over an entire run at higher shear rates and at higher speeds.
- Measuring affects on ink strength over an entire run.
- Testing dryback and rub-off on an actual Newspaper.

This type of testing may not be financially practical or even logistically possible but it still remains the next logical step.

This author would also like to see testing performed on a variety of soy inks to compare water pick-up rates against the Surland model.

Appendix A

Data

Table 22.

Water Pick-up Run#1

						TIME	(min)					Cond.		pH		Temp.		ml
ink/fs	0	1	2	3	4	5	6	7	8	9	10	start	stop	start	stop	start	stop	left
1/A	50	59.8	66.8	71.7	76.8	80.4	81.6	86.4	87.7	89.9	91.4	1319	1371	6.70	8.65	21.2	21.5	48.0
1/B	50	61.0	71.8	81.8	89.6	94.3	98.6	101.5	103.6	106.5	109.9	1433	1465	9.42	8.92	20.8	21.1	31.5
1/C	50	59.5	64.4	67.0	68.7	89.0	69.9	70.5	70.8	71.8	72.4	1365	1427	5.55	5.44	21.5	20.5	70.5
2/A	50	80.2	66.2	70.7	74.0	77.3	78.8	81.2	81.4	84.7	85.2	1344	1363	6.78	6.65	20.5	19.7	58.0
2/B	50	62.8	74.6	79.6	86.5	93.3	97.6	101.1	104.5	106.1	107.3	1440	1473	9.50	8.75	20.5	20.5	32.5
2/C	50	59.3	61.2	63.7	66.4	65.7	67.7	88.2	67.5	69.0	68.0	1487	1421	5.35	5.20	21.4	22.0	72.0
3/A	50	60.2	65.7	68.6	69.8	69.9	70.5	71.0	71.0	71.0	72.0	1325	1411	6.80	6.34	20.7	20.5	72.0
3/B	50	62.2	72.5	79.0	84.3	86.8	90.9	94.4	97.8	100.0	103.7	1430	1425	9.54	8.66	21.0	21.0	39.0
3/C	50	60.6	86.1	88.3	70.0	70.3	70.7	71.0	71.5	72.7	73.8	1341	1443	5.67	5.53	21.1	21.3	68.0

Table 23.

Water Pick-up Run#2

						TIME	(min)					Cond.		pH		Temp.		ml
ink/fs	0	1	2	3	4	5	6	7	8	9	10	start	stop	start	stop	start	stop	left
1/A	50	58.8	65.6	71.4	76.2	81.7	83.1	85.2	88.7	91.7	93.1	1318	1370	6.7	6.6	21.7	22.7	50.0
1/B	50	62.6	73.6	83.9	90.9	96.7	101	105	108	111	112	1418	1470	9.4	8.9	21.8	22.7	28.0
1/C	50	58.7	63.9	67.8	89.5	69.7	70.8	70.9	71.6	71.9	72.2	1358	1418	5.5	4.9	21.5	22.2	69.0
2/A	50	59.2	85.5	69.3	73.3	75.9	78	78.9	80.3	82.2	83.5	1310	1340	6.8	6.5	21.5	21.9	56.0
2/B	50	62.5	72	80	86.3	90.6	98.4	98.2	103	104	107	1420	1443	9.4	8.9	21.6	22.8	32.5
2/C	50	58.2	61.1	64	65	67	67	67.9	68.5	69.2	69.4	1453	1401	5.6	5.2	21.6	22.6	75.0
3/A	50	60.5	68.6	68.8	70	69.3	68.7	70	69.5	70	70.8	1325	1415	6.8	8.7	20.6	20.1	71.0
3/B	50	63.6	73.4	79	83.1	86.9	90.4	92.8	97	99.2	101	1436	1415	9.6	8.35	20.5	20.1	41.0
3/C	50	60.3	64.6	67.5	69	69.3	69.7	69.7	70.3	70.5	71.2	1328	1418	5.9	5.8	20.9	20.3	89.0

INK	F.S.
1= Flint Low Rub	A= Anchor Neutral
2= Flint Dense Black	B= Anchor Alkaline
3= Flint Soy	C= Anchor Acid
50 gms	100 ml

Table 24.
Water Pick-up Run#3

						TIME	(min)					Cond.		pH		Temp.		ml
ink/fs	0	1	2	3	4	5	6	7	8	9	10	start	stop	start	stop	start	stop	left
1/A	50	59.7	66.9	72.9	77.4	81.4	84.0	86.5	88.7	90.7	92.4	1302	1348	6.97	6.63	21.3	21.3	46.5
1/B	50	61.8	74.2	84.3	89.3	94.9	97.8	101.2	103.2	106.9	108.8	1434	1480	9.55	9.05	21.1	21.2	30.5
1/C	50	59.6	64.6	68.0	69.4	70.6	71.9	72.5	73.0	73.7	74.5	1345	1400	5.77	5.49	21.0	21.3	67.5
2/A	50	59.7	65.5	69.4	72.5	75.0	76.5	79.5	81.4	83.2	84.2	1309	1316	7.01	6.87	21.2	21.2	55.0
2/B	50	62.6	73.0	80.6	65.3	88.5	91.8	95.3	97.9	101.0	102.5	1430	1440	9.50	8.98	21.1	21.2	36.0
2/C	50	60.0	63.7	66.3	67.7	68.0	68.3	68.7	69.9	70.3	70.7	1342	1399	5.79	5.40	21.1	21.1	71.5
3/A	50	59.7	65.2	68.5	68.9	68.5	68.8	68.9	70.0	70.4	71.5	1315	1405	7.05	6.65	20.6	19.8	67.5
3/B	50	63.1	72.1	78.0	80.4	83.8	88.3	90.0	93.8	96.2	98.9	1441	1425	9.55	6.38	20.3	20.3	44.0
3/C	50	80.0	64.4	67.3	68.1	68.4	68.6	69.9	70.3	70.3	71.4	1332	1422	5.78	5.62	20.3	20.1	68.5

Table 25.
Water Pick-up Run#4

						TIME	(min)					Cond.		pH		Temp.		ml
ink/fs	0	1	2	3	4	5	6	7	8	9	10	start	stop	start	stop	start	stop	left
1/A	50	59.9	67.3	72.3	77.2	82.1	84.5	87.3	89.2	90.7	92.2	1306	1350	7.01	6.85	21.5	21.7	52.0
1/B	50	61.9	73.4	82.2	88.2	93.1	96.8	100.6	103.1	106.1	107.8	1444	1488	9.54	9.16	21.8	22.2	33.0
1/C	50	58.5	60.7	66.0	69.0	70.0	72.1	72.2	72.8	74.3	75.0	1355	1409	5.85	5.74	22.0	23.4	68.0
2/A	50	58.5	65.2	69.5	71.2	75.4	77.9	80.0	81.6	83.5	83.0	1310	1318	7.05	6.91	22.0	22.9	64.0
2/B	50	62.6	72.1	79.7	83.2	86.2	88.2	90.3	93.3	96.5	99.3	1457	1445	9.47	9.01	21.2	22.0	41.0
2/C	50	58.4	62.1	64.8	66.3	67.6	67.6	66.0	69.3	69.5	69.7	1325	1348	5.91	5.84	21.9	22.2	74.0
3/A	50	60.4	65.3	66.4	66.4	66.4	66.9	66.9	68.0	68.5	69.8	1293	1371	7.00	6.62	21.9	22.3	71.0
3/B	50	61.6	70.0	75.4	80.2	81.4	84.0	87.0	90.8	92.4	95.4	1435	1460	9.44	8.35	21.5	21.1	46.0
3/C	50	60.7	64.6	67.0	67.6	67.6	68.0	66.2	69.0	69.0	70.0	1335	1410	5.73	5.65	21.4	21.3	70.0

INK	**F.S.**
1= Flint Low Rub	A= Anchor Neutral
2= Flint Dense Black	B= Anchor Alkaline
3= Flint Soy	C= Anchor Acid
50 gms	100ml

Table 26.

				Viscosity- Speed 1 - Run # 1							
	start					TIME					
Ink/f.s.	viscosity	1	2	3	4	5	6	7	8	9	10
1/A	1520	1400	1700	2020	2420	2940	3380	5300	5850	7100	7950
1/B	1850	2100	3000	4550	6250	8050	9350	12100	12800	13300	13500
1/C	2150	1850	1900	2050	2050	2050	2200	2250	2250	2350	2400
2/A	2150	2075	2250	2750	3250	3600	4150	4650	5300	5850	6550
2/B	2150	2300	3300	4250	5600	6700	7900	8200	8700	8975	9600
2/C	2150	2000	1950	2100	2150	2150	2150	2150	2200	2250	2300
3/A	9500	3750	4250	4250	4250	2750	2500	2750	2750	2500	2500
3/B	8100	3400	3500	3600	3800	4000	4100	4400	4700	5000	4900
3/C	8000	3100	3300	3600	3500	3800	3500	3400	3300	3200	2800

Table 27.

				Viscosity- Speed 1- Run #2							
	start					TIME					
Ink/f.s.	viscosity	1	2	3	4	5	6	7	8	9	10
1/A	1550	1650	1900	2350	2850	3350	4000	4950	6050	6900	7550
1/B	1900	2500	3500	4700	7000	8700	10900	12000	13500	13700	13900
1/C	2050	1800	1850	1950	2000	2100	2200	2300	2350	2400	2550
2/A	2050	2150	2400	2800	3250	3650	4250	4700	5300	5900	6550
2/B	2200	2500	3400	4500	6200	7300	8300	9000	9600	10100	10900
2/C	2100	1900	1850	2050	2150	2150	2150	2250	2300	2300	2300
3/A	7500	3800	3400	3600	3200	3300	2900	2700	2500	2800	2600
3/B	7500	3800	3900	4100	4400	4400	4500	4600	4600	4800	4400
3/C	7800	3500	3700	4000	3800	3500	3400	3300	3400	3100	3000

INK	F.S.
1= Flint Low Rub	A= Anchor Neutral
2= Flint Dense Black	B= Anchor Alkaline
3= Flint Soy	C= Anchor Acid
75 gms	150 ml

Table 28.

				Viscosity - Speed 2.5 - Run #1							
	start					TIME					
Ink/f.s.	viscosity	1	2	3	4	5	6	7	8	9	10
1/A	720	832	952	1128	1400	1560	2300	2820	3040	3600	3980
1/B	1080	1180	1740	2460	3300	3980	5280	5920	6200	6240	6360
1/C	1140	1080	1060	1180	1180	1160	1280	1280	1280	1320	1380
2/A	1100	1100	1280	1520	1720	1900	2200	2380	2640	2840	3280
2/B	1080	1230	1700	2330	2920	3560	3740	4720	5000	5000	5400
2/C	1080	1010	1040	1120	1180	1800	1200	1200	1240	1260	1300
3/A	5200	2800	2400	2600	2500	2200	2000	2100	1900	1900	1800
3/B	4560	2160	2400	2280	2480	2400	2560	2560	2720	2800	2960
3/C	4560	2360	2040	2400	2080	2120	2120	2120	1840	1960	1960

Table 29.

				Viscosity -Speed 2.5 -Run #2							
	start					TIME					
Ink/f.s.	viscosity	1	2	3	4	5	6	7	8	9	10
1/A	900	960	1060	1320	1560	1900	2200	2700	3100	3500	3820
1/B	1360	1400	1880	2560	3720	4440	5440	6040	6240	6360	6720
1/C	1140	1000	1020	1100	1140	1200	1220	1320	1320	1360	1380
2/A	1140	1180	1360	1520	1720	1920	2240	2500	2700	3040	3360
2/B	1200	1380	1800	2360	3040	3760	4080	4320	4880	4960	5320
2/C	1120	1020	1060	1100	1180	1180	1200	1240	1280	1280	1280
3/A	4640	2520	2040	2200	2000	2120	1760	1680	1560	1680	1640
3/B	4600	2280	2640	2520	2720	2600	2920	2640	2800	2680	2920
3/C	4360	2400	2160	2480	2200	2320	2000	2200	1920	2000	1920

INK	F.S.
1= Flint Low Rub	A= Anchor Neutral
2= Flint Dense Black	B= Anchor Alkaline
3= Flint Soy	C= Anchor Acid
75 gms	150 ml

Table 30.

Ink Strength

	Run 1		Run 2		Run 1		Run 2		Run 1		Run 2	
	0.4 cc's		0.4 cc's		0.6 cc's		0.6 cc's		0.8 cc's		0.8 cc's	
	Avg.	Dry	Avg.	Dry	Avg.	Dry	Avg.	Dry	Avg.	Dry	Avg.	Dry
Ink	Dens.	Back	Dens.	Back	Dens.	Back	Dens.	Back	Dens.	Back	Dens.	Back
1	0.868	0.859	0.876	0.849	1.071	1.015	1.07	1.015	1.185	1.095	1.188	1.086
2	0.793	0.795	0.801	0.798	1.026	0.998	1.02	1.001	1.158	1.108	1.15	1.095
3	0.925	0.863	0.914	0.853	1.166	1.013	1.181	1.001	1.348	1.071	1.333	1.073

Ink	Avg.	Dry	Avg.	Dry	Avg.	Dry	Avg.	Dry	Avg.	Dry	Avg.	Dry
F.S	Dens.	Back	Dens.	Back	Dens.	Back	Dens.	Back	Dens.	Back	Dens.	Back
1/A	0.541	0.526	0.559	0.548	0.729	0.72	0.724	0.716	0.914	0.878	0.896	0.873
1/B	0.51	0.493	0.493	0.495	0.726	0.716	0.723	0.705	0.843	0.819	0.824	0.811
1/C	0.659	0.665	0.665	0.66	0.851	0.823	0.873	0.849	1.015	0.971	1.025	0.98
2/A	0.574	0.563	0.545	0.541	0.769	0.766	0.771	0.765	0.913	0.909	0.915	0.898
2/B	0.424	0.42	0.439	0.431	0.616	0.606	0.624	0.63	0.778	0.778	0.786	0.793
2/C	0.615	0.615	0.594	0.595	0.843	0.825	0.846	0.844	1.027	1.005	1.009	0.979
3/A	0.763	0.723	0.805	0.764	1.05	0.935	1.033	0.915	1.258	1.036	1.234	1.029
3/B	0.594	0.58	0.601	0.573	0.845	0.785	0.836	0.786	0.981	0.888	0.993	0.88
3/C	0.801	0.744	0.786	0.738	1.004	0.904	1.01	0.893	1.17	0.998	1.194	1.013

INK	**F.S.**
1= Flint Low Rub	A= Anchor Neutral
2= Flint Dense Black	B= Anchor Alkaline
3= Flint Soy	C= Anchor Acid

Table 31.

Rub-Off - 0.4cc's - Run # 1

INK 1

Rub-off Material	Paper Density Before	After
Finger	0.8866	0.7833
Paper	0.8966	0.8633
Kleenex	0.8766	0.7866
Kleenex w/ Aloe	0.88	0.7966

INK 1A

Rub-off Material	Paper Density Before	After
Finger	0.536	0.483
Paper	0.54	0.523
Kleenex	0.5533	0.493
Kleenex w/ Aloe	0.5333	0.4766

INK 1B

Rub-off Material	Paper Density Before	After
Finger	0.52	0.47
Paper	0.5333	0.4933
Kleenex	0.5066	0.5
Kleenex w/ Aloe	0.5166	0.4766

INK 1C

Rub-off Material	Paper Density Before	After
Finger	0.6666	0.66
Paper	0.6766	0.64
Kleenex	0.6733	0.586
Kleenex w/ Aloe	0.68	0.606

Ink 2

Rub-off Material	Paper Density Before	After
Finger	0.806	0.736
Paper	0.813	0.773
Kleenex	0.793	0.73
Kleenex w/ Aloe	0.776	0.723

Ink 2A

Rub-off Material	Paper Density Before	After
Finger	0.583	0.5633
Paper	0.58	0.5633
Kleenex	0.5666	0.52
Kleenex w/ Aloe	0.5733	0.5433

Ink 2B

Rub-off Material	Paper Density Before	After
Finger	0.436	0.41
Paper	0.433	0.416
Kleenex	0.426	0.396
Kleenex w/ Aloe	0.42	0.38

Ink 2C

Rub-off Material	Paper Density Before	After
Finger	0.623	0.613
Paper	0.626	0.606
Kleenex	0.633	0.573
Kleenex w/ Aloe	0.62	0.58

Ink 3

Rub-off Material	Paper Density Before	After
Finger	0.92	0.82
Paper	0.923	0.85
Kleenex	0.913	0.84
Kleenex w/ Aloe	0.913	0.856

Ink 3A

Rub-off Material	Paper Density Before	After
Finger	0.76	0.723
Paper	0.793	0.743
Kleenex	0.77	0.72
Kleenex w/ Aloe	0.756	0.71

Ink 3B

Rub-off Material	Paper Density Before	After
Finger	0.603	0.563
Paper	0.603	0.593
Kleenex	0.6	0.596
Kleenex w/ Aloe	0.596	0.563

Ink 3C

Rub-off Material	Paper Density Before	After
Finger	0.79	0.73
Paper	0.803	0.753
Kleenex	0.796	0.733
Kleenex w/ Aloe	0.793	0.733

INK
1= Flint Low Rub
2= Flint Dense Black
3= Flint Soy

F.S.
A= Anchor Neutral
B= Anchor Alkaline
C= Anchor Acid

Table 32.

Rub-Off - 0.4cc's - Run # 2

INK 1

Rub-off Material	Paper Density Before	Paper Density After
Finger	0.8766	0.76
Paper	0.8733	0.793
Kleenex	0.8466	0.766
Kleenex w/ Aloe	0.853	0.78

INK 1A

Rub-off Material	Paper Density Before	Paper Density After
Finger	0.56	0.49
Paper	0.57	0.556
Kleenex	0.5333	0.486
Kleenex w/ Aloe	0.53	0.486

INK 1B

Rub-off Material	Paper Density Before	Paper Density After
Finger	0.5066	0.4833
Paper	0.5033	0.493
Kleenex	0.4966	0.47
Kleenex w/ Aloe	0.48	0.4566

INK 1C

Rub-off Material	Paper Density Before	Paper Density After
Finger	0.663	0.6
Paper	0.67	0.603
Kleenex	0.6766	0.616
Kleenex w/ Aloe	0.6566	0.586

Ink 2

Rub-off Material	Paper Density Before	Paper Density After
Finger	0.835	0.753
Paper	0.816	0.763
Kleenex	0.786	0.706
Kleenex w/ Aloe	0.756	0.693

Ink 2A

Rub-off Material	Paper Density Before	Paper Density After
Finger	0.553	0.53
Paper	0.543	0.496
Kleenex	0.536	0.47
Kleenex w/ Aloe	0.543	0.503

Ink 2B

Rub-off Material	Paper Density Before	Paper Density After
Finger	0.46	0.44
Paper	0.443	0.416
Kleenex	0.446	0.406
Kleenex w/ Aloe	0.433	0.396

Ink 2C

Rub-off Material	Paper Density Before	Paper Density After
Finger	0.603	0.576
Paper	0.6	0.536
Kleenex	0.596	0.556
Kleenex w/ Aloe	0.59	0.56

Ink 3

Rub-off Material	Paper Density Before	Paper Density After
Finger	0.926	0.783
Paper	0.936	0.853
Kleenex	0.936	0.856
Kleenex w/ Aloe	0.92	0.84

Ink 3A

Rub-off Material	Paper Density Before	Paper Density After
Finger	0.773	0.72
Paper	0.816	0.75
Kleenex	0.8	0.726
Kleenex w/ Aloe	0.79	74

Ink 3B

Rub-off Material	Paper Density Before	Paper Density After
Finger	0.6	0.556
Paper	0.61	0.586
Kleenex	0.606	0.563
Kleenex w/ Aloe	0.606	0.59

Ink 3C

Rub-off Material	Paper Density Before	Paper Density After
Finger	0.776	0.72
Paper	0.786	0.743
Kleenex	0.79	0.726
Kleenex w/ Aloe	0.7933	0.746

INK

1= Flint Low Rub

2= Flint Dense Black

3= Flint Soy

F.S.

A= Anchor Neutral

B= Anchor Alkaline

C= Anchor Acid

Table 33.

Rub-Off - 0.6cc's - Run # 1

INK 1

Rub-off Material	Paper Density	
	Before	After
Finger	1.07	0.92
Paper	1.066	0.983
Kleenex	1.05	0.923
Kleenex w/ Aloe	1.073	0.9466

INK 1A

Rub-off Material	Paper Density	
	Before	After
Finger	0.726	0.63
Paper	0.746	0.673
Kleenex	0.7333	0.666
Kleenex w/ Aloe	0.713	0.663

INK 1B

Rub-off Material	Paper Density	
	Before	After
Finger	0.7533	0.686
Paper	0.733	0.666
Kleenex	0.7433	0.67
Kleenex w/ Aloe	0.72	0.656

INK 1C

Rub-off Material	Paper Density	
	Before	After
Finger	0.8566	0.78
Paper	0.85	0.81
Kleenex	0.8566	0.756
Kleenex w/ Aloe	0.8633	0.763

Ink 2

Rub-off Material	Paper Density	
	Before	After
Finger	1.066	0.946
Paper	1.043	0.973
Kleenex	1.013	0.903
Kleenex w/ Aloe	1	0.913

Ink 2A

Rub-off Material	Paper Density	
	Before	After
Finger	0.79	0.686
Paper	0.776	0.69
Kleenex	0.76	0.6866
Kleenex w/ Aloe	0.77	0.7

Ink 2B

Rub-off Material	Paper Density	
	Before	After
Finger	0.643	0.596
Paper	0.636	0.6
Kleenex	0.623	0.5733
Kleenex w/ Aloe	0.6	0.56

Ink 2C

Rub-off Material	Paper Density	
	Before	After
Finger	0.843	0.79
Paper	0.823	0.776
Kleenex	0.833	0.763
Kleenex w/ Aloe	0.833	0.773

Ink 3

Rub-off Material	Paper Density	
	Before	After
Finger	1.15	0.983
Paper	1.143	0.996
Kleenex	1.13	1
Kleenex w/ Aloe	1.146	1.01

Ink 3A

Rub-off Material	Paper Density	
	Before	After
Finger	1.03	0.92
Paper	1.05	0.93
Kleenex	1.046	0.93
Kleenex w/ Aloe	1.033	0.936

Ink 3B

Rub-off Material	Paper Density	
	Before	After
Finger	0.853	0.773
Paper	0.863	0.793
Kleenex	0.84	0.77
Kleenex w/ Aloe	0.853	0.773

Ink 3C

Rub-off Material	Paper Density	
	Before	After
Finger	1.006	0.896
Paper	1.016	0.9
Kleenex	0.996	0.9
Kleenex w/ Aloe	0.98	0.896

INK

1= Flint Low Rub
2= Flint Dense Black
3= Flint Soy

F.S.

A= Anchor Neutral
B= Anchor Alkaline
C= Anchor Acid

Table 34.

Rub-Off - 0.6cc's - Run # 2

INK 1

Rub-off Material	Paper Density	
	Before	After
Finger	1.06	0.936
Paper	1.05	0.983
Kleenex	1.043	0.93
Kleenex w/ Aloe	1.05	0.936

INK 1A

Rub-off Material	Paper Density	
	Before	After
Finger	0.73	0.653
Paper	0.72	0.67
Kleenex	0.73	0.653
Kleenex w/ Aloe	0.716	0.646

INK 1B

Rub-off Material	Paper Density	
	Before	After
Finger	0.72	0.656
Paper	0.7233	0.663
Kleenex	0.7233	0.636
Kleenex w/ Aloe	0.7	0.633

INK 1C

Rub-off Material	Paper Density	
	Before	After
Finger	0.85	0.773
Paper	0.8666	0.83
Kleenex	0.8766	0.78
Kleenex w/ Aloe	0.8666	0.79

Ink 2

Rub-off Material	Paper Density	
	Before	After
Finger	1.026	0.933
Paper	1.033	0.973
Kleenex	1.006	0.9
Kleenex w/ Aloe	1.023	0.923

Ink 2A

Rub-off Material	Paper Density	
	Before	After
Finger	0.776	0.726
Paper	0.76	0.723
Kleenex	0.77	0.69
Kleenex w/ Aloe	0.7666	0.71

Ink 2B

Rub-off Material	Paper Density	
	Before	After
Finger	0.65	0.61
Paper	0.643	0.6
Kleenex	0.63	0.576
Kleenex w/ Aloe	0.603	0.553

Ink 2C

Rub-off Material	Paper Density	
	Before	After
Finger	0.856	0.813
Paper	0.85	0.826
Kleenex	0.84	0.776
Kleenex w/ Aloe	0.856	0.76

Ink 3

Rub-off Material	Paper Density	
	Before	After
Finger	1.18	1.003
Paper	1.17	0.99
Kleenex	1.15	0.996
Kleenex w/ Aloe	1.13	0.98

Ink 3A

Rub-off Material	Paper Density	
	Before	After
Finger	1.01	0.886
Paper	1.02	0.92
Kleenex	1.013	0.903
Kleenex w/ Aloe	1.02	0.916

Ink 3B

Rub-off Material	Paper Density	
	Before	After
Finger	0.836	0.756
Paper	0.843	0.776
Kleenex	0.843	0.776
Kleenex w/ Aloe	0.836	0.783

Ink 3C

Rub-off Material	Paper Density	
	Before	After
Finger	1	0.87
Paper	1.01	0.893
Kleenex	1.006	0.903
Kleenex w/ Aloe	0.996	0.9

INK

1= Flint Low Rub
2= Flint Dense Black
3= Flint Soy

F.S.

A= Anchor Neutral
B= Anchor Alkaline
C= Anchor Acid

Table 35.

Rub-Off - 0.8cc's - Run # 1

INK 1

Rub-off Material	Paper Density	
	Before	After
Finger	1.176	0.986
Paper	1.176	1.076
Kleenex	1.163	1.01
Kleenex w/ Aloe	1.143	1.023

INK 1A

Rub-off Material	Paper Density	
	Before	After
Finger	0.926	0.823
Paper	0.9166	0.85
Kleenex	0.886	0.803
Kleenex w/ Aloe	0.896	0.83

INK 1B

Rub-off Material	Paper Density	
	Before	After
Finger	0.833	0.77
Paper	0.8433	0.82
Kleenex	0.8366	0.75
Kleenex w/ Aloe	0.8533	0.783

INK 1C

Rub-off Material	Paper Density	
	Before	After
Finger	0.9933	0.9
Paper	0.97	0.92
Kleenex	0.98	0.893
Kleenex w/ Aloe	1	0.89

Ink 2

Rub-off Material	Paper Density	
	Before	After
Finger	1.143	1.01
Paper	1.163	1.1
Kleenex	1.14	1
Kleenex w/ Aloe	1.13	1.01

Ink 2A

Rub-off Material	Paper Density	
	Before	After
Finger	0.9166	0.836
Paper	0.9033	0.88
Kleenex	0.91	0.84
Kleenex w/ Aloe	0.91	0.836

Ink 2B

Rub-off Material	Paper Density	
	Before	After
Finger	0.803	0.713
Paper	0.786	0.716
Kleenex	0.766	0.703
Kleenex w/ Aloe	0.78	0.72

Ink 2C

Rub-off Material	Paper Density	
	Before	After
Finger	1.01	0.946
Paper	1.02	0.976
Kleenex	1.02	0.92
Kleenex w/ Aloe	1.116	0.93

Ink 3

Rub-off Material	Paper Density	
	Before	After
Finger	1.326	1.07
Paper	1.323	1.07
Kleenex	1.34	1.12
Kleenex w/ Aloe	1.313	1.113

Ink 3A

Rub-off Material	Paper Density	
	Before	After
Finger	1.22	1.046
Paper	1.23	1.043
Kleenex	1.23	1.046
Kleenex w/ Aloe	1.23	1.06

Ink 3B

Rub-off Material	Paper Density	
	Before	After
Finger	0.973	0.856
Paper	0.976	0.87
Kleenex	0.97	0.873
Kleenex w/ Aloe	0.9766	0.883

Ink 3C

Rub-off Material	Paper Density	
	Before	After
Finger	1.146	0.986
Paper	1.156	0.98
Kleenex	1.15	1.006
Kleenex w/ Aloe	1.16	1.016

INK

1= Flint Low Rub
2= Flint Dense Black
3= Flint Soy

F.S.

A= Anchor Neutral
B= Anchor Alkaline
C= Anchor Acid

Table 36.

Rub-Off - 0.8cc's - Run # 2

INK 1

Rub-off Material	Paper Density Before	Paper Density After
Finger	1.17	1.023
Paper	1.153	1.053
Kleenex	1.15	1.006
Kleenex w/ Aloe	1.146	1.02

INK 1A

Rub-off Material	Paper Density Before	Paper Density After
Finger	0.9	0.77
Paper	0.883	0.813
Kleenex	0.8933	0.783
Kleenex w/ Aloe	0.9	0.813

INK 1B

Rub-off Material	Paper Density Before	Paper Density After
Finger	0.8233	0.756
Paper	0.8433	0.793
Kleenex	0.8433	0.756
Kleenex w/ Aloe	0.813	0.723

INK 1C

Rub-off Material	Paper Density Before	Paper Density After
Finger	1.016	0.906
Paper	1.016	0.92
Kleenex	1	0.91
Kleenex w/ Aloe	1	0.91

Ink 2

Rub-off Material	Paper Density Before	Paper Density After
Finger	1.143	1.036
Paper	1.13	1.073
Kleenex	1.12	1.003
Kleenex w/ Aloe	1.116	1.013

Ink 2A

Rub-off Material	Paper Density Before	Paper Density After
Finger	0.9033	0.81
Paper	0.9066	0.866
Kleenex	0.92	0.8166
Kleenex w/ Aloe	0.9133	0.84

Ink 2B

Rub-off Material	Paper Density Before	Paper Density After
Finger	0.796	0.793
Paper	0.803	0.71
Kleenex	0.796	0.733
Kleenex w/ Aloe	0.776	0.73

Ink 2C

Rub-off Material	Paper Density Before	Paper Density After
Finger	1	0.91
Paper	1.016	0.95
Kleenex	0.99	0.9
Kleenex w/ Aloe	1.01	0.93

Ink 3

Rub-off Material	Paper Density Before	Paper Density After
Finger	1.3	1.09
Paper	1.34	1.083
Kleenex	1.3	1.09
Kleenex w/ Aloe	1.32	1.1

Ink 3A

Rub-off Material	Paper Density Before	Paper Density After
Finger	1.22	1.05
Paper	1.22	1.03
Kleenex	1.22	1.036
Kleenex w/ Aloe	1.23	1.043

Ink 3B

Rub-off Material	Paper Density Before	Paper Density After
Finger	0.993	0.836
Paper	0.996	0.89
Kleenex	0.973	0.87
Kleenex w/ Aloe	0.993	0.89

Ink 3C

Rub-off Material	Paper Density Before	Paper Density After
Finger	1.18	0.993
Paper	1.206	1.03
Kleenex	1.186	1.02
Kleenex w/ Aloe	1.19	1.02

INK

1= Flint Low Rub

2= Flint Dense Black

3= Flint Soy

F.S.

A= Anchor Neutral

B= Anchor Alkaline

C= Anchor Acid

Table 37.

Tack Readings

						minutes					
Ink	20sec.	1	2	3	4	5	6	7	8	9	10
1	6	5	4.5	4.25	4	4	3.9	3.75	3.75	3.65	3.6
2	5	4.25	3.75	3.6	3.5	3.4	3.25	3.1	3	3	3
3	4.75	4.25	4	3.75	3.6	3.6	3.5	3.5	3.5	3.45	3.4

Table 38.

pH and Conductivity Changes

				Test 1				
	pH		Conductivity		Temperature		Weight	ML
Ink	start	stop	start	stop	start	stop	gained	Left
1	7.68	7.02	155	249	20.5	20.7	25gm	24
2	7.68	7.04	155	174.2	20.5	20.5	22gm	28
3	7.68	6.21	155	219	20.5	20.5	34.1gm	11

				Test 2				
	pH		Conductivity		Temperature		Weight	ML
Ink	start	stop	start	stop	start	stop	gained	Left
1	7.69	7.09	154.8	256	20.3	20.2	25.5gm	23
2	7.69	7.08	154.8	169.4	20.3	20.5	26gm	26
3	7.69	5.79	154.8	212	20.3	20.3	37.7gm	11

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