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A Comparison between waterless lithography and conventional lithography

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A Comparison Between Waterless Lithography and Conventional Lithography

by

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Abstract

Waterless lithography is one of the printing processes that was developed around 1968. It has a strong impact in the current printing industry. Like other printing processes, waterless lithography has both advantages and disadvantages. It is said that waterless lithography can print with more consistency and less dot gain than conventional lithography. However, it has one significant disadvantage, currently there is only one waterless lithographic plate supplier in the industry.

There is very little quantitative data describing the waterless lithographic process to support the arguments that waterless lithography prints with more consistency and less dot gain. There is even a report that conflicts with such arguments. Consequently, this research investigates waterless lithography to provide more quantitative data and a better understanding with its conventional counterpart.

The purpose of this research was to compare a process capability index (consistency) in terms of solid ink density and the magnitude of dot gain between waterless lithography and conventional lithography. This research performed a series of test runs in an academic environment. The densities of the sample press sheets were measured and used to calculate dot gain. Several statistical methods were used to analyze data and compute process capability indices. From the data analysis, it was found that waterless lithography is only as good as, but not better than, conventional lithography in terms of process capability of solid ink density. Also, waterless lithography does not produce significantly less dot gain than conventional lithography.

Chapter 1

Introduction

Lithography is a very popular printing process. It has many advantages. For example, it offers high printing quality and the plate is easy to make. However, it has many disadvantages such as high paper waste, the use of alcohol or alcohol substitute, and maintenance of the ink/water balance. Waterless lithography is an alternate way of printing that uses a silicone rubber layer on the plate surface to repel ink in the non-image area. Therefore, a fountain solution is not needed.

Waterless lithography is not a new idea. It was first developed by 3M in the late 1960s under the name "Driography." However, 3M gave it up because of the problems in the development of suitable ink for this process and the durability of the waterless plate.[1] Consequently, the patent was sold to Toray Industries, a large Japanese company. In 1977, waterless lithography was reintroduced by Toray at Drupa.[2] Waterless printing is now receiving adequate development investment to cause optimism within the industry.[3]

Although many people have claimed that waterless lithography is the preferred process over conventional lithography, there are very few quantitative data to support such arguments. Therefore, it is useful to conduct an experiment so that the two processes can be compared. This research compares the process capability of waterless lithography and conventional lithography in terms of solid ink density and the magnitude of dot gain.

Major Components of Waterless Lithography

The three major components of waterless lithography that distinguish it from conventional lithography are a waterless plate, specialized ink, and a temperature control system.[4] The following is a brief description about those components.

Waterless Plate

The Toray waterless plate consists of an aluminum base coated with a silicone rubber layer. The silicone rubber layer has very low surface energy which repels printing ink in the non-image area. It works the same way as water in conventional lithography. The image areas, which are made of photopolymer, are recessed slightly allowing the plate to carry more ink than a conventional plate and to print more sharply. Moreover, this plate helps to minimize dot gain.

Special Ink

Ink for waterless lithography is formulated similar to conventional ink in terms of basic raw material constituents.[5] The main difference is that waterless ink uses a special resin. Thus, the waterless ink has higher viscosity and stiffer body than conventional ink.[6]

Temperature Control System

Temperature control is the third major component of waterless lithography. In conventional lithography, a dampening solution is not only used to separate image area from the non-image area, but it also helps to cool the press. In waterless lithography, no dampening solution is used; therefore, a temperature control system is necessary to reduce the heat that is generated by the mechanical actions in the printing unit such as ink splitting between the ink form roller and the plate cylinder. The temperature control

system keeps the ink viscosity within 10 °F range of optimum printing temperature.[7] Each printing unit has its own vibrator rollers, chilled water and circulation system because each color (cyan, magenta, yellow and black) may have a different temperature range.[8]

Advantages and Disadvantages

Waterless lithography has many advantages. Firstly, waterless lithography eliminates the need of water, thus the need for ink-waterless balance.[9] Secondly, it makes less paper stretch which results in better registration.[10] Thirdly, it is environmentally friendly because neither alcohol nor alcohol substitute is used in the process.[11] Finally, waterless lithography simplifies the lithographic operation.[12]

On the other hand, waterless lithography also has disadvantages. A waterless plate is not as durable as a conventional pre-sensitized plate.[13] Moreover, there is only one plate manufacturer in the industry.[14] Waterless lithography costs more than conventional lithography due to the higher price of plate and ink.[15] In addition, waterless lithography requires paper stock that possesses a high surface strength.[16]

Terminology

Accuracy: Accuracy refers to how close the process is coming to a target value. It is expressed as the difference between the process average (x) and the target value of the specification.[17]

Control chart: A control chart is a graphic comparison of process performance data to statistical control limits, not specification limits.[18] The control limit is defined as "the mean $\pm$ 3 standard variations."[19]

Mean (x): Mean is a measure of central location of a data set.[20]

Precision: Precision refers to the repeatability of the process. It is the inverse of variation and is expressed as the 6 standard deviations spread of the process.[21]

Standard variation (s): Standard variation is a measurement of the variation in a process.[22]

Process capability: Process capability is a standardized evaluation of the inherent ability of a process to perform under operation conditions.[23]

Dot gain: Dot gain is the increase in the size of a halftone dot from the time it is created on the halftone film until it is finally printed on paper.[24]

Stable process: A process which does not have a special caused variation, but random variation.

Formula

$$\text{Mean}(x) = \frac{\Sigma x}{n}$$

$$\text{Standard variation (s)} = \sqrt{\frac{(x-x)^2}{n-1}}$$

$$CP = \frac{USL - LSL}{6s}$$

USL = Upper specification limit
LSL = Lower specification limit

$$\%\text{Dot gain} = \left[\left(\frac{1-10^{-Dt}}{1-10^{-Ds}}\right)\right] x\ 100 - \%\ FDA$$

D^t = The density of the tint-paper density.
D^s = The density of the solid-paper density.
FDA = Film dot area.

Endnotes for Chapter 1

[1] John O'Rourke, Waterless Printing U.S. Marketing Considerations and Applications, pp. 1-2.

[2] Ibid., p. 2.

[3] Lawrence J. Bain, "The Influence of Technology on Lithographic Pressroom Productivity," Critical Trends Graphic Communications Industry, (January 1994), pp. 34-36.

[4] John O'Rourke, Waterless Printing U.S. Marketing Considerations and Applications, p. 3.

[5] "Running on Empty," American Printer, (August 1992), p. 47.

[6] Lisa Cross, "Watershed Year for Waterless." Graphic Arts Monthly, (February 1993), p. 52.

[7] George J. Whalen, "Waterless Offset Update II — Essential Ingredients of Sheetfed Waterless Offset," High Volume Printing, (August 1992), p. 114.

[8] Ibid., p.115.

[9] John O'Rourke, "Waterless Plate Technology Make a Splash." FormsMfg, p. 29.

[10] Lisa Cross, "Watershed Year for Waterless," Graphic Arts Monthly, (February 1993), p. 52.

[11] Ibid.

[12] Clifton Frazier, November, 1993.

[13] Richard Drong, "Waterless Printing An Overview," American Ink Maker, (October 1992), p.53.

[14] Mark T. Michelson, "Waterless Offset Generates Flood of Renewed Interest." Printing Impressions.

[15] George J. Whalen, "Waterless Offset Update," High Volume Printing, (June 1992), p. 57.

[16] Mark T. Michelson, "Waterless Offset Generates Flood of Renewed Interest." Printing Impressions.

[17] Charles Layne, Inference Statistics Class, Winter, 1992.

[18] Joseph M. Juran, Juran's Quality Control Handbook 4th ed, (New York: McGraw-Hill, 1988), p.16.25.

[19] Michael J. Apfelberg, "How to Do a Process Capability Study," GATFWORLD, (January-December 1991), p. 27.

[20] Charles Layne, November 1993.

[21] Charles Layne, Inference Statistics Class, Winter, 1992.

[22] Apfelberg, p. 26.

[23] Joseph M. Juran, Juran on Planning for Quality, (New York: The Free Press, 1988), p.331.

[24] Mile Southworth, Quality and Productivity in the Graphic Arts, (New York: Graphic Art Publishing, 1990), pp. 14-13.

Chapter 2

Theoretical Base of the Study

Waterless lithography composes of three major components. They are a waterless plate, special ink, and a temperature control system.

Waterless Plate

The first component of waterless lithography is the plate. It cosists of an aluminum base with a straight grain, non anodized aluminum, coated with a primer and then a light photosensitive material.[1] A two microns coating of silicone rubber layer is applied to the photopolymer. A transparent cover film is affixed to the surface of the plate to protect the plate surface from any physical damage. The plate is exposed by UV radiation in a standard vacuum frame, then developed either by hand or in a special automatic processor using specific chemicals.[2]

In the negative-working system, the bond between the photopolymer layer and the silicone rubber layer is, when exposed through a negative, weakened in exposed areas.[3] On the other hand, in the positive-working system, the silicone rubber layer bonds itself firmly to the photopolymer layer. Either in the negative or positive working system, the protective cover film is stripped away after the plate is exposed. The plate is transported to a special processor that has three tanks using two specialized chemistries and ordinary tap water as the developer.[4]

When the plate passes through the first tank which is a pre-treatment–di-ethylene glycol type–solution, the pre-treatment solution performs two functions, softening the

silicone surface of the entire plate and creating the cross link between the silicone and the photopolymer layer in the non-image areas only. The pre-treatment solution is then squeezed off and the plate is transported to the developing solution. Here the silicone rubber layer in the image area of the plate is brushed off using tap water and a rotating and oscillating brush. Then the plate is transported through the last solution, which is a dye solution. This chemistry has three main functions. One is to give the plate a visual contrast in the image and non-image areas. The second function is to slightly etch the photopolymer in the image areas to make it more ink receptive. The third function is to harden the non-image areas of the plate. There is no need to apply gum arabic.[5] The waterless plate is not oxidized because it consists of a photosensitive layer and a silicone rubber layer.

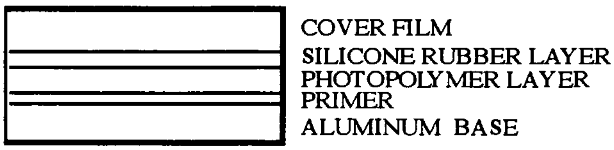

Figure 1. The cross section of waterless plate.

Special Ink

The second component is special ink. Ink for waterless lithography is formulated similar to conventional ink in terms of basic raw material constituents.[6] Pigments, waxes and oils used in waterless ink are similar to those used in conventional inks. The major difference between waterless and conventional inks is that waterless ink uses a special resin.[7] Waterless ink has higher viscosity and stiffer body than conventional ink.[8]

A theory behind waterless lithography is that the silicone rubber layer which makes up the non-image areas of the plate has a very low surface energy and very oleophobic nature. When an ink of a specific viscosity is applied to the waterless plate, the silicone rubber layer will resist the ink provided the ink's viscosity is such that it has a greater affinity for itself than it does for the silicone.[9]

Temperature Control System

The third component in waterless lithography is a temperature control system. In conventional lithography, a dampening system is not only used to distinguished image and non-image areas, but it also helps to cool the press. On the contrary, in waterless lithography, image and non-image areas are distinguished by ink/temperature balance; therefore, a temperature control system is necessary to reduce the heat.

The temperature control system is designed to maintain the temperature at a constant throughout the press run.[10] At a constant temperature, the viscosity of the ink can be maintained within a narrow range of optimum printing temperature.[11] The essential objective in waterless lithography is to keep the ink within a narrow band of optimum printing temperature. A typical range would be 80-88 °F.[12] The range may vary depending on the ink formulation.

There are some ideas of cooling the press[13], but the most effective system is to cool the vibrator rollers in the inking systm with chilled water. Another method is to cool the plate cylinder with chilled air[14]. The temperature control system incorporates a closed loop controller. The sensor, which is an infrared pyrometer mounted on each printing unit, reads the temperature at the surface of the plate cylinder and sends the information to the controller.[15] Moreover, the press operator can monitor a temperature by inputting a desired temperature to the controller. However, the temperature cannot

exceed the critical toning temperature (C.T.T.) otherwise it will result in background toning.[16]

Precise control of temperature is critical to the success of the waterless printing.[17] The temperature control system effects ink rheology. Ink that is too cold will result in poor ink transfer[18]. On the other hand, ink that is too warm will result in increased dot gain and break down and begin to adhere to the non-image area.[19]

Endnotes for Chapter 2

[1] John O'Rourke, Waterless Printing U.S. Marketing Considerations and Applications, p. 3.

[2] Lisa Cross, "Waterless Ignites Renewed Interest," Graphic Arts Monthly, (April 1992), p. 39.

[3] George J. Whalen, "Waterless Offset Update II: Essential Ingredients of Sheetfed Waterless Offset," High Volume Printing, (August 1992), p. 114.

[4] O'Rourke, p. 4.

[5] George J. Whalen, "Waterless Offset Update II: Essential Ingredients of Sheetfed Waterless Offset," High Volume Printing, (August 1992), p. 118.

[6] "Running on Empty," American Printer, (August 1992), p. 47.

[7] O'Rourke, p. 4.

[8] Lisa Cross, "Waterless Ignites Renewed Interest," Graphic Arts Monthly, (April 1992), p. 39.

[9] O'Rourke, p. 5.

[10] Ibid., p. 6

[11] George J Whalen, "Waterless Offset Update II: Essential Ingredients of Sheetfed Waterless Offset," High Volume Printing, (August 1992), p. 114.

[12] Ibid.

[13] "The Toray Waterless Plates and Its Printing System," Japan Graphic Arts, (1990 issue), p. 108.

[14] Catherine M. Stanulism, "The Toray Waterless Offset Plate System," High Volume

Printing, (February 1990), p. 50.

[15] O'Rourke, p. 6.

[16] "The Toray Waterless Plates and Its Printing System," Japan Graphic Arts, (1990 issue), p. 109.

[17] O'Rourke, p. 6.

[18] Richard Drong, "Waterless Printing: An Overview," American Ink Maker, (October 1992), p. 56.

[19] Ibid.

Chapter 3

Review of the Literature

In the printing industry, it is widely stated that waterless lithography provides a high quality reproduction, prints with less dot gain and has more consistency than conventional lithography. According to the article, "Waterless offset Generates Flood of Renewed Interest," it is said that without the emulsifying effects of water on press, dot gain is said to be only 7% to 9% in comparison to the 17% to 21% dot gain found in traditional dampened offset printing.[1] The article, "Waterless Printing: An Overview," quoted that the structure of the Toray plate allows the printer to carry almost twice the ink film thickness normally carried and yet get about half the dot gain of the regular wet conventional litho application.[2] From the article, "A Printing Process That's "Run Dry"," Daniel Dejan said that, with waterless, the dot gain is reported to be held to a maximum of 8% in the midtone range.[3]

The article, "Watershed Year For Waterless," quoted that waterless offers the printers the ability to print high quality, consistent work while increasing productivity, decreasing waste, and protecting the environment.[4] Richard Stein, president of National Printing & Packaging, the first printer in North America to use the Toray system, said "With higher quality you get more gloss and consistency, less dot gain".[5]

Although many people believe that waterless lithography provides a more consistent reproduction than conventional lithography, there are no quantitative data to support it. Some companies and researchers have conducted experiments; however, quantitative data has not been provided.

According to the article, "Waterless Offset Update III — Worldwide developments in Web," Anderson Litho, Los Angeles, CA, ran a waterless test in 1989. Test results showed that midtone dot gain of waterless lithography was one-half of the conventional ltihgraphy.[6] However, no quantitative data wase ever published.

There are M.S. theses done by RIT graduate students related to waterless lithography. The first one is "A study of the effect of ink tack, printing pressure and printing speed on toning in the driographic system." The research found that there is a relationship between the tack of the ink selected and toning.[7] It was done by Thomas C. Rigg in 1974. The second one is "A study of Toray's negative working driographic printing plate and the effect ink tack has on toning in the non-image area." It investigated that ink tack has an effect on the degree of toning on a driographic plate and it was concluded that the amount of oil content in an ink has more influence on the degree of toning than tack did.[8] The study was done by Larry M. Capitano in 1987. The third one is "A study of the effect of oil added to Toray driography ink on toning in the non-image areas of Toray company's negative working driographic plates." This research found that a strong positive relationship exists between the amount of oil contained in the driographic ink and the amount of toning in the non-image areas of negative Toray plates.[9] It was done by Joseph A. El-Yabroudi in 1989. All of them focus on testing the ink aspect of the process without the attention in temperature variation.

In the article "GATF Technology Alert '94"[10], the author quoted that waterless lithography has a major impact on the printing industry. Richard Warner, GATF Research Director, and Llyod DeJidas, GATF Business Manager, summarized the result from their research that waterless lithography produced lower dot gain with a higher screen ruling. They also said that the ink temperature in the process should be controlled. However, there is no procedure specified in the article as how data were analyzed. Glenn Thore,

L&E Packaging, reported his findings that color is more consistent and better in waterless lithography. In "1994 Technology Forecast",[11] it was stated that eliminating water from the lithographic process can increase the consistency of the color reproduction because water is the greatest variable in the process.

Quantitative analysis and documentation of waterless printing began when Professor Robert Chung of School of Printing Management and Sciences at RIT did a research project that compared waterless and conventional lithography.[12,13] This is the first research that provides the quantitative information. The research was conducted to verify the claims from the industry that waterless makeready is faster than conventional makeready and that waterless prints more consistent. The results of the experiment did not support those claims. The waterless makereadies took several minutes longer than conventional makereadies and the waterless process did not print more consistent than the conventional process.[14] In terms of dot gain, he noticed that the difference in plate exposure had caused an unfair comparison. Furthermore, he observed that both plates showed increased dot gain as the screen ruling increased. However, the study did not completely answer the question of what process is consistent. Professor Robert Chung concluded that "Clearly, more testing—and more refine testing—is needed." He suggested several changes in methodology. Specifically, (1)the normal variation of the process must be determined before setting the specification limits; (2)plate exposures must be standardized, and (3)the pictorial images in the test form should be given different screening curves in order to achieve the same tone reproduction.

"A study of conventional vs. waterless lithography" by Professor Robert Chung and Chanassa Pichitgarnda of RIT[15] compared conventional and waterless lithography in terms of solid ink density. Average densities and individual and moving range charts were used to analyze data in the research. Moreover, it was found that the conventional

process is more consistent than waterless lithography. There was no temperature monitoring in the experiment and no comparison of dot gain in this research. The authors suggested that the tolerance of solid ink density for the future experiment be +/-10% of the aim point in stead of +/-5% of the aim point because +/-5% of the aim point was a very tight tolerance. Moreover, the measurements should be read only as a single repeat of the test target. In addition, the sample size should be 100 printed sheets instead of 30 printed sheets which was too small a sample size.

Two Types of Variation

Every manufacturing process has variations which can be divided into two types. The first is chance-cause or random variation, which cannot be completely eliminated.[16] The second is assignable-cause variation or special caused variation, which can be identified through statistical analysis and then eliminated from the process.[17] When only random variation occurs in a process, the process is said to be stable and is in a state of control.

Process Capability

The term process capability is widely used to designate the inherent reproducibility of a process and the ability to repeat results during multiple cycles of operation.[18] It is also used to determine whether the process meets or exceeds specifications. Before determining the process capability, the process has to be stable. A stable process is a process which has no special caused variation although it may have a random variation. The stability of the process does not depend on a shape of the histogram because even though a process has a normal shape distribution, there can be a special caused variation in the process. On the other hand, the process that does not have

a normal shape histogram may be considered stable if it does not have a special caused variation. An R chart is a statistic tool that is used to detect a special caused variation. Consequently, the stability of a process can be determined by using an R chart[19].

An R chart that has a pattern as shown below reveals that there is a sign of special caused variation. All points of special caused variations need to be removed which will, in turn, result in a stable process.

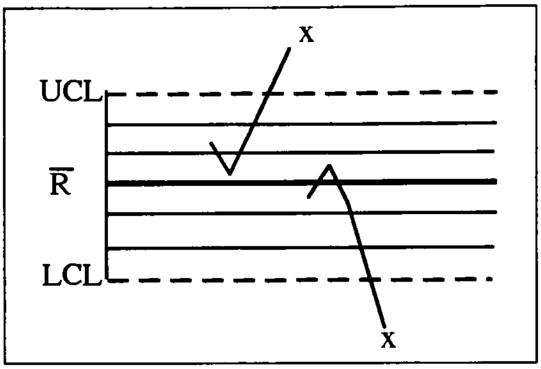

Figure 2. An unusual pattern using an R chart

According to Juran's Quality Control Handbook,[20] the following steps are necessary to construct x-bar and R charts. Firstly, twenty five subgroups of four or five individual data each are taken. Secondly, $\bar{x}$ and R are calculated from each subgroup. Thirdly, the average of all subgroups, $\bar{\bar{x}}$ and the average range, $\bar{R}$ are calculated. Fourthly, a control chart for average is constructed by using $\bar{\bar{x}}$ as central line, $\bar{\bar{x}}+ A_2\bar{R}$ as an upper control limit, and $\bar{\bar{x}}-A_2\bar{R}$ as a lower limit. Finally, a control chart for range is also constructed by using $\bar{R}$ as a central line, $D_4\bar{R}$ as an upper control limit, and $D_3\bar{R}$ as a lower control limit. The value of A_2, D_3, and D_4 factors depend on subgroup size and are given in Table A in Appendix A.

Process capability index

Process capability index (CP index) mathematically shows the relationship of the specification and the variability of the process.[21] CP index is the ratio of tolerance of the process to 6 standard deviations. The formula is[22]

$$CP = \frac{USL - LSL}{6s};$$

USL = Upper specification limit
LSL = Lower specification limit

The greater the number, the more precise the process.

Interpretation of CP

When comparing process 1, which has CP1 as process capability index, and process 2, which has CP2 as process capability index, if CP1 > CP2, process 1 is more precise than process 2. CP shows only the dispersion of a process which means it shows precision and not accuracy. CP only looks at total variation.

Endnotes for Chapter 3

[1] Mark T. Michelson, "Waterless Offset Generates Flood of Renewed Interest," Printing Impressions.

[2] Richard Drong, "Waterless Printing: An Overview ," American Ink Maker, (October 1992), p. 55.

[3] Daniel Dejan and Kurt Klein, "A Printing Process That's 'Run Dry'."

[4] Lisa Cross, "Watershed Year for Waterless," Graphic Arts Monthly, (February 1993), p. 51.

[5] "Running on Empty," American Printer, (August 1991), p. 47.

[6] John O'Rourke, "Waterless Offset Update III —Worldwide Developments in Web," High Volume Printing, (October 1992), p. 62.

[7] Thomas C. Rigg, "A Study of the Effect of Ink Tack, Printing Speed on Toning in the Driographic System," M.S. Thesis, RIT, 1974.

[8] Larry M. Capitano, "A Study of Toray's Negative Working Driographic Printing Plate and the Effect Ink Tack has on Toning in the Non-Image Area," M.S. Thesis, RIT, 1987.

[9] Joseph A. El-Yabroudi, "A Study of the Effect of Oil Added to Toray Driographic Ink on Toning in the Non-Image Areas of Toray company's Negative Working Driographic Plates," M.S. Thesis, RIT, 1989.

[10] Miles Southworth, "GATF Technology Alert '94," The Quality Control Scanner, vol. 14, no. 2, pp. 1-2.

[11] 1994 Technology Forecast, p. 17.

[12] Robert Chung, A Study of Conventional vs. Waterless Lithography, (Unpublished).

[13] Robert Chung, "Showdown in the Pressroom," T & E News, (Special Edition: Print Quality ' 93), pp. 10, 16.

[14] Ibid.

[15] Robert Chung and Chanassa Pichitgarnka, " A Study of Conventional vs. Waterless Lithography", TAGA Proceeding, (1994), pp. 276-285.

[16] Robert Chung, Richard Adams, and Tom Petronio, "Anatomy of a Web Press Run," Graphic Arts Monthly, (March 1990), p. 101.

[17] Ibid.

[18] Joseph M. Juran, Juran on Quality by Design, (New York: Macmillan, Inc., 1992), p.242.

[19] Edward E. Schilling, Private conversation (July 13, 1994).

[20] Joseph M. Juran, Juran's Quality Control Handbook 4th ed, (New York: McGraw-Hill, 1988), p.24.7.

[21] Michael J. Apfelberg, "How to Do a Process Capability Study," GATFWORLD, (January-December 1991), p. 27.

[22] Ibid.

Chapter 4

Hypotheses

Hypotheses

Many people have claimed that waterless lithography is a better process than conventional lithography. Yet,there is no quantitative data to substantiate the claims when comparing waterless lithography and conventional lithography. For example, "Is the color gamut of the waterless lithography larger than the color gamut in conventional lithography?"."Is the dot gain less?", and "Is it more precise in color uniformity?". This research was aimed at answering these questions.

Specifically, this research investigated the area of dot gain and process capability. The two hypotheses were:

1. Waterless lithography has larger process capability index in terms of solid ink density than conventional lithography. More specifically:
    1.1 Waterless lithography has larger process capability index in terms of black solid ink density than conventional lithography.
    1.2 Waterless lithography has larger process capability index in terms of cyan solid ink density than conventional lithography.
    1.3 Waterless lithography has larger process capability index in terms of magenta solid ink density than conventional lithography.
    1.4 Waterless lithography has larger process capability index in terms of yellow solid ink density than conventional lithography.
2. Waterless lithography produces significantly less dot gain than conventional lithography. More specifically:
    2.1 Waterless lithography produces significantly less black dot gain than conventional lithography.

2.2 Waterless lithography produces significantly less cyan dot gain than conventional lithography.
2.3 Waterless lithography produces significantly less magenta dot gain than conventional lithography.
2.4 Waterless lithography produces significantly less yellow dot gain than conventional lithography.

Decision making table for hypothesis testing.

It was possible that experimental errors may prevent meaningful conclusions. One such error is when either or both of the process is behaves unstable. The abnormality was determined based on the unusual pattern of R chart which is when one point is beyond 3s zone. The unusual pattern of the R chart is shown in Figure 2. in Chapter 3, Literature Review.

The decision making table (Table 1.) is used to determine whether the hypothesis can be tested. In the first condition, if both processes (waterless lithography and conventional lithography) are stable, the hypothesis can definitely be tested. The hypothesis can also be tested if one of the processes is not stable, but the CP of the unstable process is shown to be larger than that of the stable process. On the other hand, if the CP of the stable process is smaller than that of the unstable process, the hypothesis cannot be tested. If both processes are not stable after removing 20% of the data, the hypothesis cannot be tested.

Table 1. Decision making table for hypothesis testing.

	Is the process is stable?		Test for hypothesis
	Waterless	Conventional	
1	Stable	Stable	Yes.
2	Stable	Not stable	Yes, If CPconv. > CPwl, else No.
3	Not stable	Stable	Yes, If CPwl > CPconv., else No.
4	Not stable	Not stable	No.

Since there was no assurance that the process would be stable, using a 4 color process would yield four opportunities as opposed to just one with a monochrome single impression press run.

Chapter 5

Methodology

The objective of this research was to compare the process capability (consistency) in terms of solid ink density and magnitude of dot gain between waterless lithography and conventional lithography. The null hypotheses stated that waterless lithography produced significantly more process capability indices and less dot gain than conventional lithography. To obtain the quantitative data, a series of press runs were performed. The densities of the press sheets were measured and used to calculate percent dot gain and process capability indices.

Equipment and Materials

1. Printing press: Heidelberg Speedmaster 4 colors which can print with or without water.

   1.1 Temperature regulation for both waterless and conventional process was 75 °F.

2. Paper: Uncoated No.1 premium opaque paper, 17.5" x 22.5," basis weight 60 lbs., 44,000 sheets.
3. Test form: GATF Digital Test Form.
4. Plate: Both plates are to be exposed to the same degree, i.e., solid step #4

   4.1 Waterless plates: Toray negative working plates

   4.2 Conventional plates: G.M.X. Viking 3M negative working plates

5. Inks

   5.1 Waterless inks: Dainippon DRI-O-COLOR

   5.2 Conventional inks: G.P.I. Natural Lith ink

6. Fountain solution: Rosos KSP10 ASM3, pH = 3.8 and conductivity = 1500
7. One press operator: The press operator was allowed to adjust the printing conditions as necessary since the adjustment was considered part of the process regulation. However, it was necessary to record every adjustment the press operator made.
8. Densitometer: X-Rite X-Scan scanning densitometer.

Experimental Procedure

This research conducted four press runs. Two press runs were designated for waterless lithography and the others were designated for conventional lithography. These four press runs took place in two days. The first day of the press run was for allowing the press operator to become familiar with printing the test form. The second day of the press run was for the real experiment. On the first day of the test, the first sets of prints of waterless lithography and conventional lithography were run, and given a code: "waterless press run 2" and "conventional press run 2." The second sets of prints were run on the second day and given a code: "waterless press run 1" and "conventional press run 1." The press run began with the conventional lithography to set references. When the two Thesis Committee members (Professor Clifton Frazier and Professor Robert Chung) signed the OK sheet (the press sheet that visually matched the proof), the solid ink densities of the OK sheet were recognized as the aim points. On the second day, the press run began with the waterless run. The aim points were set in the same way as on the first day. The tolerance is +/-10% of the aim points of solid ink density. The aim points and tolerance were also used for the second run on each day.

All of the tests were printed by Heidelberg Speedmaster 4 colors on uncoated No.1 premium opaque paper 17.5" x 22.5", basis weight 60 lbs. The makeready speed and running speed were both at 8,000 iph. The ink-down sequence for both processes

was black, cyan, magenta, and yellow.

To minimize the random cause of variations due to the press operator, all of the press runs were operated (inking, registration and adjustments) by only one operator (Professor Clifton Frazier). Adjustments were allowed during the runs. Assistants were available for paper handling, plate mounting, ink fountain change over, and press sheet sampling.

Data Collection

The samples were taken after the makeready was finished and the density reached the aim points. A sample sheet was pulled out every 80 impressions. The press run lasted 1 hour; consequently, the total of 100 sample sheets were collected. The densities of the press sheet were measured by CPC for press regulation and by X-Rite X-Scan scanning densitometer for data collection and data analysis. The density of each color was measured at the lower left corner control bar of page 2 of the GATF Digital Test Form as shown in Appendix C. The reason why the single repeat of the test target was measured was to eliminate the across the sheet variation which was influenced by the press operator, not by the process itself. From the collected data, x-bar and R charts with subgroup of 4 were constructed to see if there were special caused variations in the process. All special caused variations found in the R chart were then removed which gave a stable process. The mean and standard deviation of solid ink density were computed to derive the process capability indices. Afterwards, the CP values from the two processes were compared.The mean of dot gain (at 50% dot area) was also calculated and then compared.

Chapter 6

The Results

Several assumptions were made in this research. First, the sample press sheets taken during the press run were representative of the entire population. Second, both waterless and conventional press runs in this research were typical and can be repeated elsewhere in the industry. Third, a stable process does not have to have normally distributed data.

Solid Ink Density

The density data which were collected by X–Rite X-Scan scanning densitometer are shown in Table B1 in Appendix B. The x-bar and R charts of solid ink density of waterless and conventional processes are shown in Figure 3 and 4. All special caused variation were already removed from R charts.

According to the decision making table, all processes can be compared because both are stable. From the process performance summary tables (Table 2 and 3), solid ink densities of black and cyan waterless lithography have better CP indices than those of conventional lithography. On the other hand, solid ink densities of magenta and yellow conventional lithography have better CP indices than those of the waterless process. However, all printers of both processes were capable of producing solid ink density at the tolerance of +/- 10% aim point because all CP indices are bigger than 1.33.

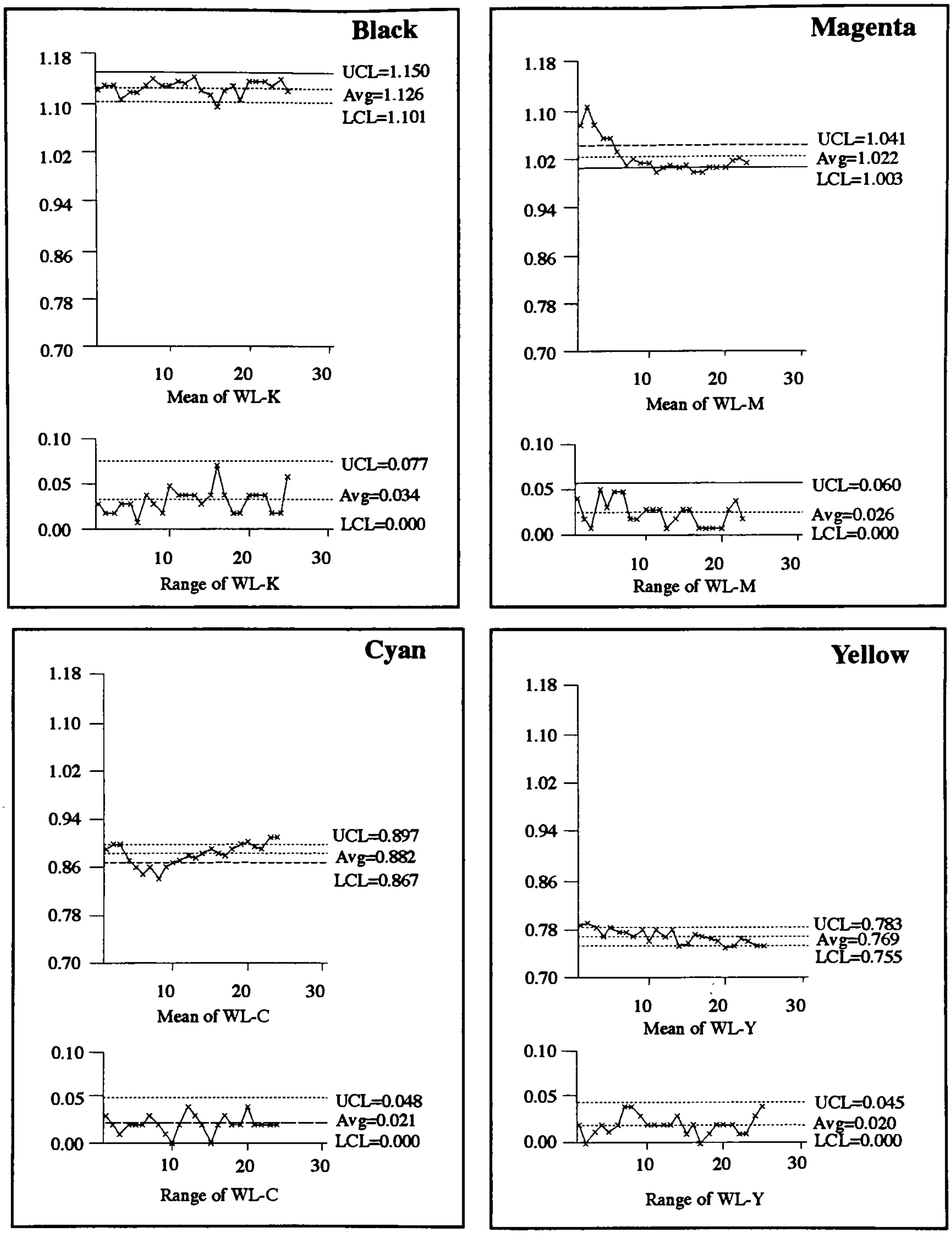

Figure 3. X-bar and R charts of waterless solid ink density (subgroup = 4).

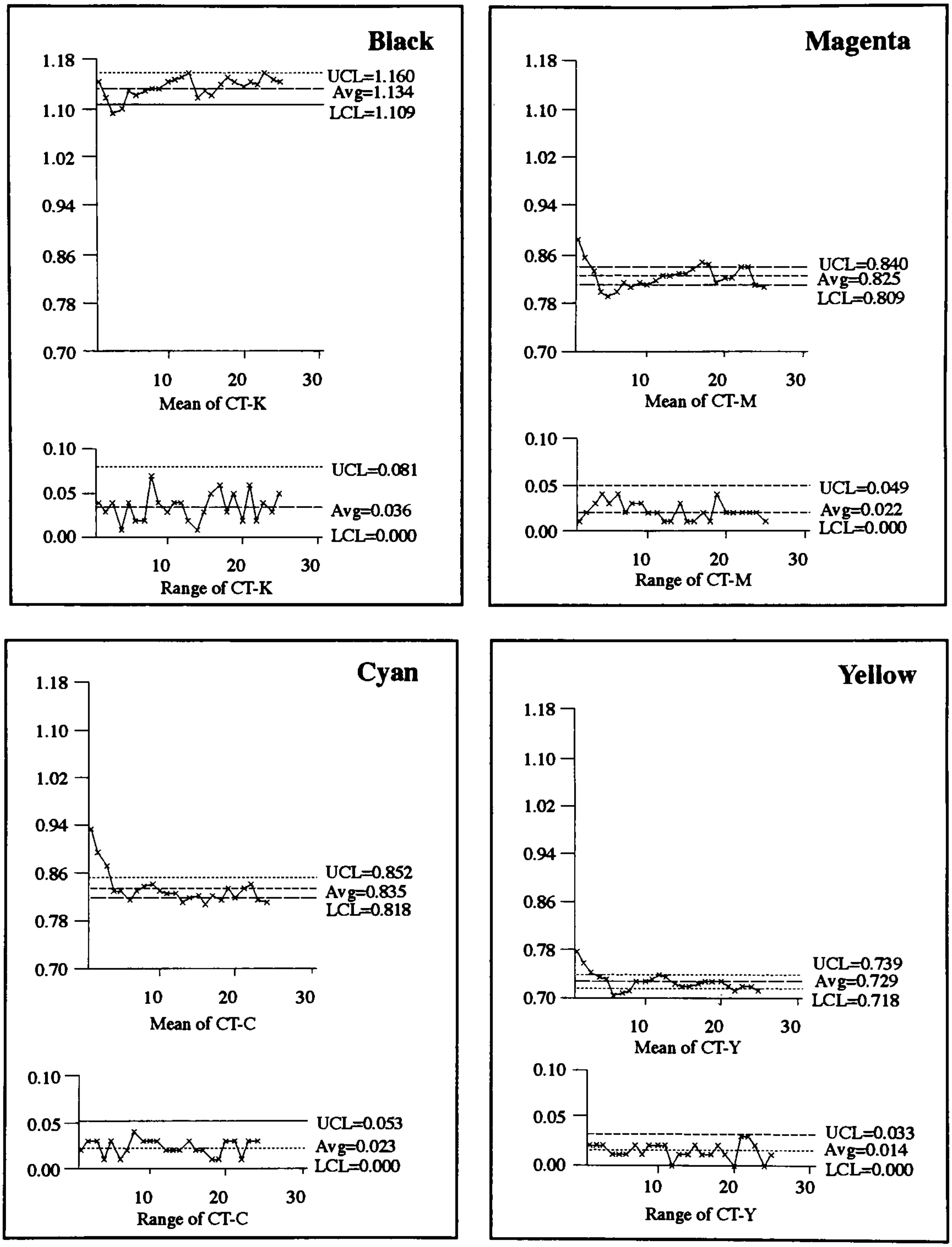

Figure 4. X-bar and R charts of conventional solid ink density (subgroup = 4).

The tables below are the process performance summary tables of waterless and conventional solid ink density.

Table 2. Process performance summary—Waterless solid ink density.

	Waterless solid ink density			
Ink Color	K	C	M	Y
Sample size	100	96	92	100
# of data points removed	0	4	8	0
Subgroup size	4	4	4	4
x-bar-bar	1.126	0.882	1.022	0.769
UCL (x bar+ 3sigma hat)	1.150	0.897	1.041	0.783
LCL (x bar- 3sigma hat)	1.101	0.867	1.003	0.755
sigma hat	0.017	0.010	0.013	0.010
6 sigma hat	0.099	0.061	0.076	0.058
R-bar	0.034	0.021	0.026	0.020
Special caused variations	No	No	No	No
Aim point	1.10	0.89	1.10	0.79
USL (+10% of aim point)	1.210	0.979	1.210	0.869
LSL (-10% of aim point)	0.990	0.801	0.990	0.711
Tolerance	0.220	0.178	0.220	0.158
CP	2.22	2.91	2.90	2.71
Process capable (1.33)?	Yes	Yes	Yes	Yes

Table 3. Process performance summary—Conventional solid ink density.

	Conventional solid ink density			
Ink Color	K	C	M	Y
Sample size	100	96	100	100
# of data points removed	0	4	0	0
Subgroup size	4	4	4	4
x-bar-bar	1.134	0.835	0.825	0.739
UCL (x-bar + 3sigma hat)	1.160	0.852	0.840	0.729
LCL (x-bar - 3sigma hat)	1.109	0.818	0.809	0.718
sigma hat	0.017	0.011	0.011	0.007
6 sigma hat	0.105	0.067	0.064	0.041
R-bar	0.036	0.023	0.022	0.014
Special caused variations	No	No	No	No
Aim point	1.10	0.89	1.10	0.79
USL (+10% of aim point)	1.210	0.979	1.210	0.869
LSL (-10% of aim point)	0.990	0.801	0.990	0.711
Tolerance	0.220	0.178	0.220	0.158
CP	2.10	2.66	3.43	3.87
Process capable (1.33)?	Yes	Yes	Yes	Yes

Dot gain

The density data which were collected by the X–Rite X-Scan scanning densitometer are shown in Table B2 in Appendix B. Data are from the 2nd day press runs because analysis will be done on this set of data only. The x-bar and R charts of dot gain of waterless and conventional processes are shown in Figure 5 and 6. All special caused variations detected in R charts were already removed from R charts.

According to the process performance summary tables of dot gain (Table 5 and 6), all printers of waterless lithography have CP indices that are bigger than 1.33 except a black printer which has CP index of only 1.29. For conventional lithography, only magenta and yellow printers have bigger CP indices than 1.33. Moreover, black and magenta printers of conventional lithography produced less dot gain than those of waterless lithography. On the other hand, cyan and yellow printers of conventional lithography produced more dot gain than those of waterless lithography.

The student t-test[1] was applied to test for the significant differences of dot gain. The variances (s^2) in t-test were calculated from individual data. The results of t-test are shown in Table 4 below. Only one pair that had significant difference in producing dot gain was the black printers.

Table 4. t-test of dot gain.

	K	C	M	Y
t-calculated	7.99	-3.81	1.93	-8.86
t-critical	1.97	1.97	1.97	1.97
Significantly different	Yes	No	No	No

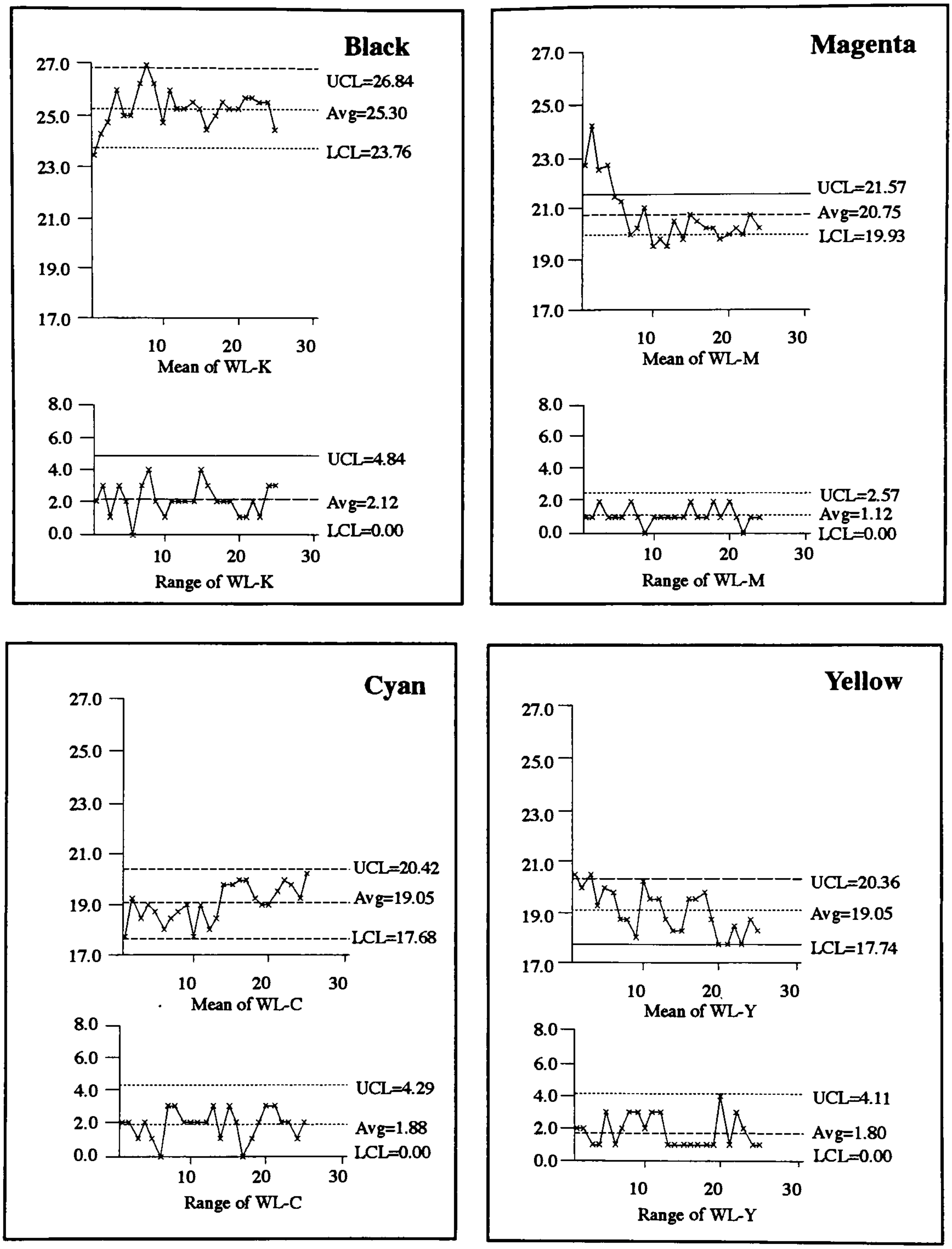

Figure 5. X-bar and R charts of waterless dot gain (subgroup = 4).

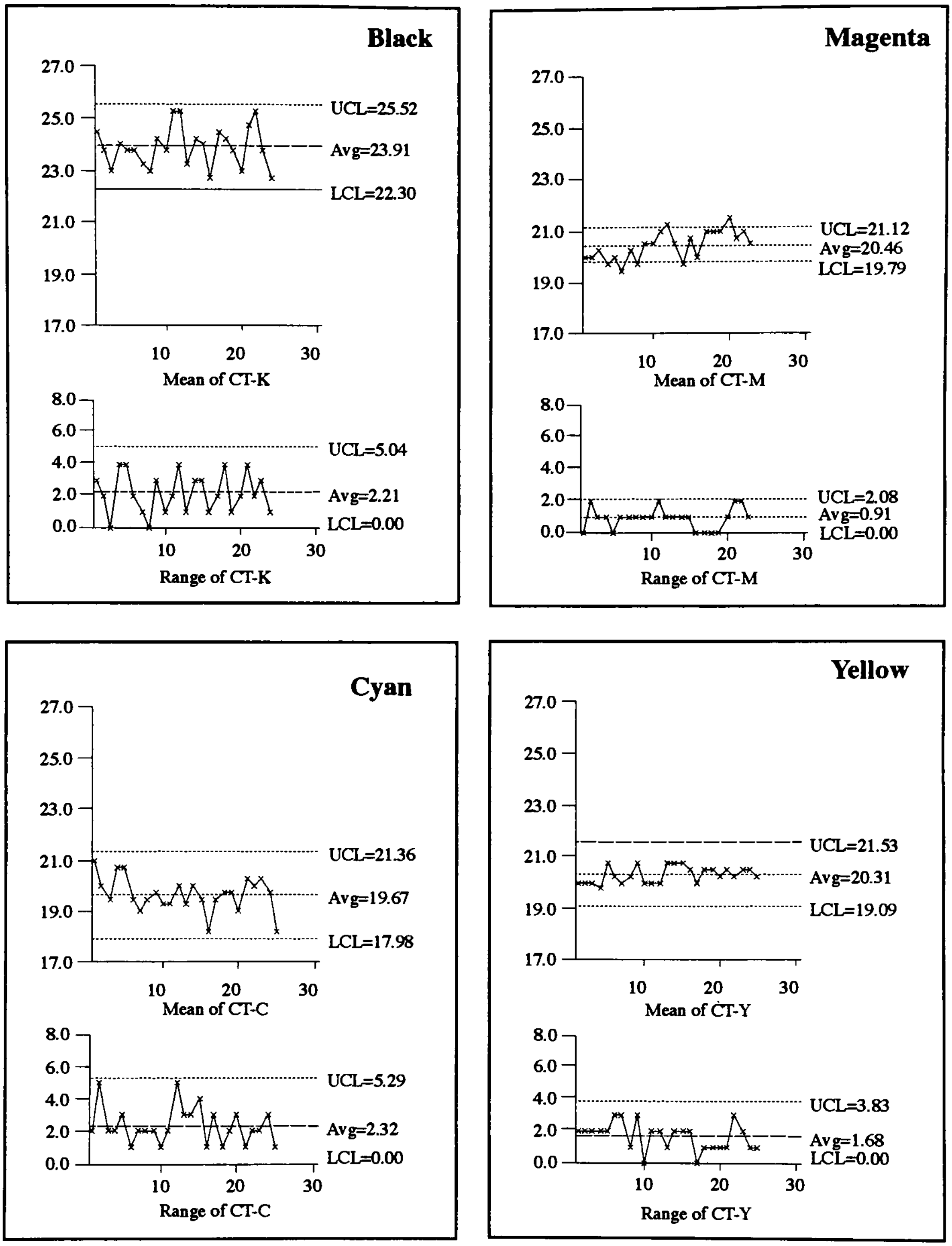

Figure 6. X-bar and R charts of conventional dot gain (subgroup = 4).

The tables below are the summary tables of waterless and conventional dot gain.

Table 5. Process performance summary—Waterless dot gain.

	Waterless dot gain			
Ink Color	K	C	M	Y
Sample size	100	100	96	100
# of data points removed	0	0	4	0
Subgroup size	4	4	4	4
x-bar-bar	25.30	19.05	20.75	19.05
UCL (x bar+ 3sigma hat)	26.84	20.42	21.75	20.36
LCL (x bar- 3sigma hat)	23.76	17.68	19.93	17.74
sigma hat	1.03	0.91	0.54	0.87
6 sigma hat	6.18	5.48	3.26	5.25
R-bar	2.12	1.88	1.12	1.80
Special caused variations	No	No	No	No
Aim point	22	17	23	20
USL (+4 of aim point)	26	21	27	24
LSL (-4 of aim point)	18	13	19	16
Tolerance	8	8	8	8
CP	1.29	1.46	2.45	1.53
Process capable (1.33)?	No	Yes	Yes	Yes

Table 6. Process performance summary—Conventional dot gain.

	Conventional dot gain			
Ink Color	K	C	M	Y
Sample size	96	100	92	100
# of data points removed	4	0	8	0
Subgroup size	4	4	4	4
x-bar-bar	23.91	19.67	20.46	20.31
UCL (x bar+ 3sigma hat)	25.52	21.36	21.12	21.53
LCL (x bar- 3sigma hat)	22.30	17.98	19.79	19.09
sigma hat	1.07	1.13	0.44	0.82
6 sigma hat	6.44	6.76	2.65	4.90
R-bar	2.21	2.32	0.91	1.68
Special caused variations	No	No	No	No
Aim point	22	17	23	20
USL (+4 of aim point)	26	21	27	24
LSL (-4 of aim point)	18	13	19	16
Tolerance	8	8	8	8
CP	1.24	1.18	3.02	1.63
Process capable (1.33)?	No	No	Yes	Yes

Plate/press curves

The plate/press curves is another way of comparing dot gain. The graphs below show the plate/press curves of thesample sheet from the middle of the press run of both waterless and conventional lithography. In this research, both waterless and conventional plates were exposed at the same solid step (step #4). The graphs show that only black printers have different dot gain. The other printers produce almost the same dot gain. Theses graphs support the statistical findings.

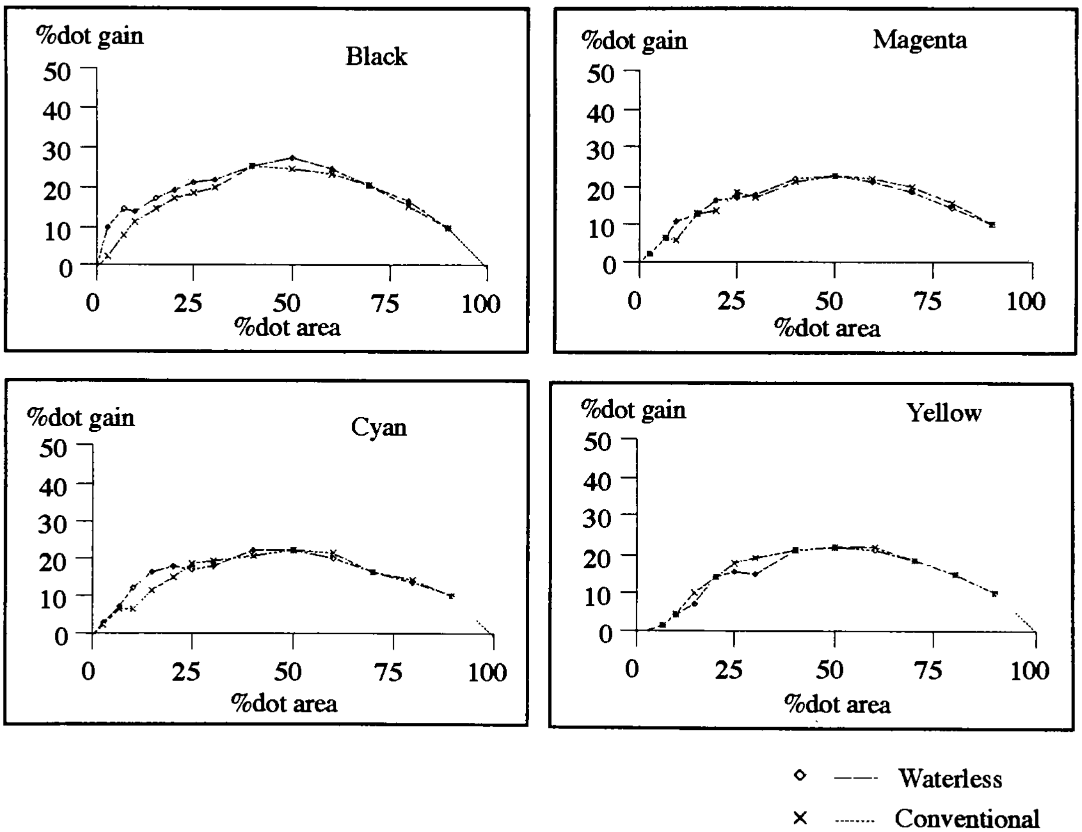

Figure 7. Plate/press curves of waterless and conventional lithography.

Endnotes for Chapter 6

[1] Allen G. Bluman, Elementary Statistics, (Iowa: Wm.C. Brown, 1992), p. 326.

Chapter 7

Summary and Conclusion

Conclusion on solid ink density

It can be concluded that black and cyan printers of waterless lithography have better process capability than black and cyan conventional lithography because the waterless process have better CP indices than the conventional process. Therefore, hypotheses 1.1, which said that waterless lithography produces larger process capability index in terms of solid ink density in black than conventional lithography, and 1.2, which said that waterless lithography produces larger process capability index in terms of solid ink density in cyan than conventional lithography, are accepted.

On the other hand, hypotheses 1.3, which said that waterless lithography produces larger process capability index in terms of solid ink density in magenta than conventional lithography, and 1.4, which said that waterless lithography produces larger process capability index in terms of solid ink density in yellow than conventional lithography, are rejected because magenta and yellow conventional lithography have larger CP indices than those of waterless lithography.

Conclusion on dot gain

Contrary to the industry's belief that waterless lithography produces less dot gain, it can be concluded that only the black printer has statistically significant difference in producing dot gain. The black printer of conventional lithography produced less dot gain than the black printer of waterless lithography. Therefore, the

hypothesis 2.1, which stated that waterless lithography produces less black dot gain than conventional lithography, should be rejected. Hypotheses 2.2, which stated that waterless lithography produces less cyan dot gain than conventional lithography, 2.3, which stated that waterless lithography produces less magenta dot gain than conventional lithography, and 2.4, which stated that waterless lithography produces less yellow dot gain than conventional lithography, can neither be accepted because there are no statistically significant difference in producing dot gain.

According to the CP indices, black and cyan waterless lithography are the better processes than those of conventional lithography. On the other hand magenta and yellow conventional lithography are the better processes than those of waterless lithography.

Summary

From the experimental finding, it cannot be accepted that waterless lithography is the better process. In studying process capability indices in the solid ink density area, even though there are differences between the two processes in some printers, both processes are capable of producing good results. In considering dot gain, black and cyan printers of conventional lithography have less CP indices than black and cyan printers of waterless lithography and are not capable of producing acceptable results. However, the black printer of waterless lithography is neither capable. In addition, only black printer of conventional lithography has significantly less dot gain than black printers of waterless lithography. In conclusion, waterless lithography is only as good as, but not better than conventional lithography.

Discussion

Even though it cannot be statistically accepted that waterless lithography is better than conventional lithography, some differences between the two processes are

significant. However, those differences are still visually not noticeable. In other words, the results of both processes are not noticiablly different to the human eye.

This research has many improvements over the previous research. The press run of each process lasted approximately 1 hour which was considered practical in the industry. Moreover, the sample size of 100 better represented the entire population and left room for removal of any point of special caused variation when it occurred. In addition, this research used a different way of determining the stability of the process. Using an R chart helped in assuring that stability of the process would not be mistakenly judged by only the shape of the histogram of the process. Another improvement was in dot gain comparison. This research controlled plate exposure of both processes at the same step. This resulted in a fair comparison and made the research more valid.

Further research

The future research may investigate the correlation between ink temperature and the consistency of solid ink density between the two processes.

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Appendix A

Appendix A

Formula for x-bar and R charts

Central line = $\bar{\bar{x}}$

Upper control limit for $\bar{x} = \bar{\bar{x}} + A_2\bar{R}$

Lower control limit for $\bar{x} = \bar{\bar{x}} - A_2\bar{R}$

Centrol line = $\bar{R}$

Upper control limit for $R = D_4\bar{R}$

Lower control limit for $R = D_3\bar{R}$

$$\sigma = \frac{\bar{R}}{d_2}$$

Table A. X-bar & R control chart factors

X-bar & R control chart factors				
n	D3	D4	A2	d2
2	0	3.267	1.88	1.128
3	0	2.574	1.023	1.693
4	0	2.282	0.729	2.059
5	0	2.114	0.577	2.326
6	0	2.004	0.483	2.534
7	0.076	1.924	0.419	2.704
8	0.136	1.864	0.373	2.847
9	0.184	1.816	0.337	2.97
10	0.223	1.777	0.308	3.078

Appendix B

Appendix B

Table B1. Waterless and conventional solid ink density data.

	WL-K	WL-C	WL-M	WL-Y	CT-K	CT-C	CT-M	CT-Y
1	1.11	0.89	1.06	0.78	1.17	0.94	0.89	0.79
2	1.14	0.90	1.10	0.80	1.15	0.94	0.89	0.78
3	1.12	0.87	1.07	0.78	1.13	0.92	0.88	0.77
4	1.12	0.90	1.08	0.79	1.13	0.93	0.89	0.77
5	1.14	0.91	1.11	0.79	1.13	0.90	0.87	0.77
6	1.12	0.89	1.11	0.79	1.12	0.90	0.86	0.75
7	1.14	0.91	1.11	0.79	1.12	0.91	0.85	0.76
8	1.12	0.89	1.09	0.79	1.10	0.88	0.85	0.75
9	1.13	0.90	1.08	0.79	1.09	0.86	0.83	0.74
10	1.12	0.90	1.07	0.78	1.11	0.89	0.85	0.74
11	1.13	0.90	1.08	0.79	1.07	0.88	0.83	0.74
12	1.14	0.89	1.07	0.78	1.10	0.87	0.82	0.76
13	1.09	0.86	1.03	0.76	1.10	0.88	0.82	0.74
14	1.12	0.87	1.05	0.76	1.10	0.86	0.81	0.74
15	1.11	0.88	1.08	0.78	1.09	0.82	0.79	0.73
16	1.10	0.88	1.05	0.77	1.10	0.83	0.78	0.74
17	1.12	0.87	1.07	0.78	1.14	0.83	0.80	0.73
18	1.12	0.87	1.04	0.79	1.12	0.84	0.80	0.73
19	1.10	0.85	1.05	0.78	1.11	0.83	0.80	0.73
20	1.13	0.86	1.05	0.78	1.15	0.83	0.77	0.74
21	1.11	0.85	1.05	0.77	1.12	0.83	0.78	0.71
22	1.12	0.85	1.04	0.79	1.11	0.84	0.80	0.70
23	1.12	0.84	1.00	0.78	1.12	0.84	0.80	0.71
24	1.12	0.86	1.04	0.77	1.13	0.81	0.82	0.71
25	1.12	0.88	1.01	0.78	1.13	0.82	0.81	0.72
26	1.15	0.86	1.03	0.80	1.13	0.82	0.82	0.70
27	1.11	0.85	1.01	0.76	1.14	0.81	0.82	0.71
28	1.14	0.85	0.98	0.77	1.12	0.82	0.80	0.71
29	1.16	0.83	1.03	0.78	1.09	0.82	0.81	0.71
30	1.13	0.85	1.01	0.79	1.16	0.83	0.81	0.72
31	1.14	0.84	1.02	0.76	1.14	0.84	0.82	0.71
32	1.13	0.84	1.02	0.75	1.14	0.83	0.79	0.72
33	1.12	0.86	1.01	0.77	1.12	0.84	0.83	0.74

Table B1. Waterless and conventional solid ink density data (continue).

	WL-K	WL-C	WL-M	WL-Y	CT-K	CT-C	CT-M	CT-Y
34	1.13	0.86	1.02	0.77	1.12	0.81	0.80	0.72
35	1.14	0.87	1.02	0.80	1.13	0.85	0.80	0.72
36	1.12	0.86	1.00	0.78	1.16	0.85	0.83	0.73
37	1.13	0.86	1.03	0.77	1.16	0.84	0.81	0.72
38	1.10	0.83	0.96	0.75	1.14	0.86	0.82	0.73
39	1.15	0.87	1.01	0.75	1.13	0.84	0.81	0.74
40	1.14	0.89	0.99	0.77	1.14	0.83	0.80	0.73
41	1.16	0.87	1.03	0.77	1.13	0.85	0.81	0.72
42	1.13	0.87	1.01	0.78	1.15	0.82	0.81	0.73
43	1.13	0.87	1.00	0.79	1.14	0.83	0.82	0.74
44	1.12	0.87	1.01	0.78	1.17	0.83	0.83	0.74
45	1.13	0.88	1.01	0.78	1.14	0.81	0.83	0.74
46	1.15	0.87	0.99	0.77	1.15	0.84	0.82	0.74
47	1.11	0.86	0.98	0.76	1.18	0.83	0.83	0.74
48	1.14	0.88	1.01	0.77	1.14	0.83	0.82	0.74
49	1.16	0.88	1.00	0.79	1.15	0.83	0.82	0.73
50	1.15	0.88	1.00	0.77	1.16	0.84	0.83	0.74
51	1.14	0.90	1.02	0.79	1.15	0.82	0.82	0.74
52	1.12	0.86	0.99	0.77	1.17	0.82	0.83	0.74
53	1.14	0.86	1.00	0.76	1.12	0.80	0.83	0.73
54	1.11	0.88	1.01	0.77	1.12	0.82	0.84	0.72
55	1.12	0.89	1.01	0.74	1.11	0.82	0.81	0.72
56	1.12	0.88	1.01	0.74	1.12	0.81	0.83	0.73
57	1.12	0.88	1.01	0.75	1.12	0.83	0.82	0.73
58	1.13	0.88	0.99	0.76	1.12	0.81	0.83	0.72
59	1.12	0.90	1.01	0.76	1.12	0.81	0.83	0.73
60	1.09	0.88	1.00	0.76	1.15	0.83	0.83	0.71
61	1.05	0.89	0.99	0.76	1.15	0.81	0.83	0.72
62	1.11	0.89	1.02	0.78	1.11	0.83	0.84	0.73
63	1.10	0.89	1.00	0.78	1.12	0.84	0.84	0.72
64	1.12	0.89	1.02	0.77	1.10	0.81	0.83	0.72
65	1.11	0.87	1.01	0.77	1.15	0.82	0.85	0.72
66	1.15	0.89	0.98	0.77	1.11	0.82	0.84	0.72
67	1.11	0.89	0.99	0.77	1.13	0.80	0.86	0.73
68	1.11	0.88	1.00	0.77	1.17	0.80	0.84	0.73
69	1.13	0.90	0.99	0.77	1.16	0.83	0.85	0.74
70	1.14	0.87	1.00	0.76	1.15	0.83	0.85	0.73
71	1.12	0.88	1.00	0.76	1.13	0.81	0.84	0.73
72	1.13	0.87	1.00	0.77	1.16	0.82	0.84	0.72
73	1.11	0.88	1.00	0.77	1.13	0.81	0.81	0.72
74	1.11	0.90	1.00	0.76	1.15	0.82	0.81	0.73

Table B1. Waterless and conventional solid ink density data (continue).

	WL-K	WL-C	WL-M	WL-Y	CT-K	CT-C	CT-M	CT-Y
75	1.11	0.90	1.01	0.76	1.17	0.82	0.84	0.73
76	1.09	0.89	1.00	0.75	1.12	0.82	0.80	0.73
77	1.12	0.89	1.01	0.76	1.14	0.84	0.82	0.73
78	1.13	0.90	1.00	0.75	1.14	0.83	0.81	0.73
79	1.13	0.91	1.00	0.74	1.12	0.84	0.83	0.73
80	1.16	0.90	1.01	0.75	1.14	0.83	0.82	0.73
81	1.15	0.92	1.02	0.75	1.12	0.82	0.83	0.73
82	1.16	0.92	1.00	0.77	1.12	0.83	0.82	0.73
83	1.12	0.88	0.96	0.75	1.15	0.83	0.81	0.73
84	1.12	0.89	1.03	0.75	1.18	0.80	0.82	0.70
85	1.15	0.90	1.00	0.77	1.13	0.82	0.84	0.70
86	1.13	0.90	1.00	0.76	1.15	0.84	0.84	0.72
87	1.11	0.88	1.01	0.77	1.15	0.83	0.83	0.70
88	1.15	0.90	1.01	0.76	1.13	0.85	0.85	0.73
89	1.13	0.88	1.02	0.76	1.13	0.85	0.83	0.73
90	1.12	0.89	1.01	0.77	1.16	0.84	0.85	0.72
91	1.13	0.89	1.00	0.76	1.17	0.84	0.85	0.72
92	1.14	0.90	1.03	0.76	1.17	0.84	0.83	0.71
93	1.13	0.91	1.04	0.76	1.16	0.83	0.81	0.72
94	1.15	0.91	1.01	0.77	1.14	0.82	0.82	0.72
95	1.15	0.92	1.02	0.75	1.16	0.80	0.80	0.72
96	1.13	0.90	1.00	0.74	1.13	0.82	0.81	0.72
97	1.13	0.90	1.00	0.73	1.12	0.81	0.80	0.71
98	1.16	0.92	1.02	0.77	1.15	0.83	0.81	0.72
99	1.10	0.91	1.01	0.76	1.14	0.81	0.81	0.71
100	1.10	0.91	1.02	0.76	1.17	0.80	0.80	0.72

Table B2. Waterless and conventional dot gain data.

	WL-K	WL-C	WL-M	WL-Y	CT-K	CT-C	CT-M	CT-Y
1	23	19	22	21	25	21	20	20
2	23	18	23	21	24	22	20	21
3	25	17	23	19	26	21	20	20
4	23	17	23	21	23	20	20	19
5	24	18	25	21	25	23	21	19
6	23	20	24	19	24	20	20	21
7	24	19	24	20	23	18	20	20
8	26	20	24	20	23	19	19	20
9	25	19	24	20	23	20	21	20
10	25	18	25	21	23	20	20	21
11	25	19	23	21	23	18	20	20
12	24	18	22	20	23	20	20	19
13	27	20	22	19	26	21	20	19
14	24	18	22	19	22	20	20	19
15	26	19	22	19	24	20	19	20
16	27	19	24	20	24	22	20	21
17	25	18	23	19	22	21	20	21
18	26	19	23	20	23	19	20	20
19	24	19	22	19	26	22	20	20
20	25	19	23	22	24	21	20	22
21	25	18	22	20	25	20	19	20
22	25	18	22	20	23	19	19	20
23	25	18	21	19	23	19	20	19
24	25	18	21	20	24	20	20	22
25	27	18	21	18	23	19	19	19
26	27	20	22	20	23	18	20	22
27	24	17	21	19	24	19	20	19
28	27	19	21	18	23	20	22	20
29	26	20	20	19	23	19	20	20
30	26	17	21	20	23	19	20	20
31	30	20	19	19	23	21	21	21
32	26	18	20	17	23	19	20	20
33	27	20	20	18	24	19	19	22
34	27	19	20	17	24	20	20	21
35	25	18	20	20	23	19	20	19
36	26	19	21	17	26	21	20	21
37	25	17	21	21	24	20	21	20
38	25	19	21	21	24	19	20	20
39	24	18	21	20	24	19	20	20
40	25	17	21	19	23	19	21	20
41	25	20	20	19	26	20	20	20

Table B2. Waterless and conventional dot gain data (continue).

	WL-K	WL-C	WL-M	WL-Y	CT-K	CT-C	CT-M	CT-Y
42	25	18	19	20	24	18	21	20
43	27	19	19	21	25	19	21	21
44	27	19	20	18	26	20	20	19
45	24	17	19	18	25	20	21	20
46	26	18	20	20	28	23	22	19
47	25	18	20	21	24	19	21	21
48	26	19	20	19	24	18	20	20
49	25	19	19	19	23	18	21	21
50	24	17	20	19	23	19	22	21
51	26	18	19	19	23	19	21	21
52	26	20	20	18	24	21	21	20
53	26	20	21	19	24	19	19	21
54	26	20	20	18	24	19	19	20
55	24	20	21	18	23	20	21	20
56	26	19	20	18	26	22	23	22
57	24	19	20	18	23	18	20	21
58	28	22	20	19	26	22	21	20
59	25	19	20	18	24	20	21	20
60	24	19	19	18	23	18	20	22
61	26	20	22	19	23	19	20	22
62	23	20	21	20	22	18	20	20
63	25	21	20	19	23	18	19	20
64	24	19	20	20	23	18	20	20
65	24	20	20	19	24	18	20	20
66	26	20	21	20	24	19	21	20
67	25	20	20	20	26	21	21	20
68	25	20	21	19	24	20	21	20
69	25	19	20	20	23	20	20	20
70	25	19	20	19	24	20	20	21
71	27	19	21	20	27	20	20	21
72	25	20	20	20	23	19	20	20
73	24	19	20	18	24	21	21	21
74	25	18	19	19	24	19	21	20
75	26	19	21	19	24	20	21	20
76	26	20	21	19	23	19	21	21
77	26	21	20	20	24	18	21	20
78	25	19	20	18	25	18	21	20
79	25	18	20	16	23	19	21	21
80	25	18	19	17	31	21	21	20
81	26	21	20	18	23	20	21	20
82	26	20	20	17	23	21	21	20

Table B2. Waterless and conventional dot gain data (continue).

	WL-K	WL-C	WL-M	WL-Y	CT-K	CT-C	CT-M	CT-Y
83	25	19	21	18	22	20	21	21
84	26	18	19	18	24	20	21	21
85	25	20	20	17	24	19	21	20
86	27	21	21	19	23	20	22	19
87	26	20	20	18	25	20	21	22
88	25	19	20	20	27	21	22	20
89	25	20	20	18	25	21	21	20
90	25	19	20	19	26	21	20	20
91	26	19	20	17	26	20	20	20
92	26	21	20	17	24	19	22	22
93	25	19	20	19	23	19	21	20
94	26	20	21	19	23	19	20	21
95	24	19	21	19	26	22	22	21
96	27	19	21	18	23	19	21	20
97	25	19	20	18	22	18	21	20
98	26	21	20	18	23	18	20	21
99	24	21	20	19	23	18	21	20
100	23	20	21	18	23	19	20	20

Appendix C

PAGE 1

GATF *Digital Test Form*

Chanassa Pichitgarnka's Thesis: A comparison between waterless and conventional lithography.

Waterless Press Run 1 1994

	C	M	Y	K	B	G	R	3-C
10								
20								
30								
40								
50								
60								
70								
80								
90								
100								

GATF 24pt
GATF 20pt
GATF 16pt
GATF 12pt
GATF 8pt
GATF 6pt
GATF 4pt
GATF 3pt
GATF 2pt

400 375 350 325 300 275

0.25 0.50 0.75 1.00 1.25 1.50 1.75 2.00 2.25 2.50 2.75 3.00 3.25 3.50 3.75 4.00

1 2 3 4 5 6 7 8 9 10 11 12 13

0.15 0.30 0.45 0.60 0.75 0.90 1.05 1.20 1.35 1.50 1.65 1.80 1.95

Cyan	Yellow						
	10	9	8	7	6	5	4
Magenta	9						
	8						
	7						
	6						
	5						
	4						

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1														
2														
3														
4														
5														
6														
7														
8														
9														
10														
11														
12														
13														

25	24	22	20	18	16	14	12
24							
22							
20							
18							
16							
14							
12							

50	46	44	42	40	38	36	34
46							
44							
42							
40							
38							
36							
34							

75	71	69	67	65	63	61	59
71							
69							
67							
65							
63							
61							
59							

GATF IMAGING RESOLUTION TARGET

100 C+M M M+Y Y C+Y C

25C+16M+16Y 50C+39M+39Y 75C+63M+63Y

25K 50K 75K

GCA/GATF Digital Proof Comparator Cyan Magenta Yellow Black

Test form: GATF Digital Test Form
Imagesetter: Agfa SelectSet 5000, 2400 dpi.
Uncoated paper No.1 premium opaque
Press: Heidelberg Speedmaster 4 colors
Ink-down sequence: KCMY

PAGE 2

GATF *Digital Test Form*

Chanassa Pichitgarnka's Thesis:
A comparison between waterless and conventional lithography.

Waterless Press Run 1 1994

5K	10K	15K	20K	25K	30K	35K	40K	50K	60K	70K	75K	80K	90K	100K
5C+3M+3Y	10C+6M+6Y	15C+10M+10Y	20C+14M+14Y	25C+17M+17Y	30C+21M+21Y	35C+25M+25Y	40C+30M+30Y	50C+40M+40Y	60C+50M+50Y	70C+60M+60Y	75C+65M+65Y	80C+72M+72Y	90C+82M+82Y	100C+93M+93Y

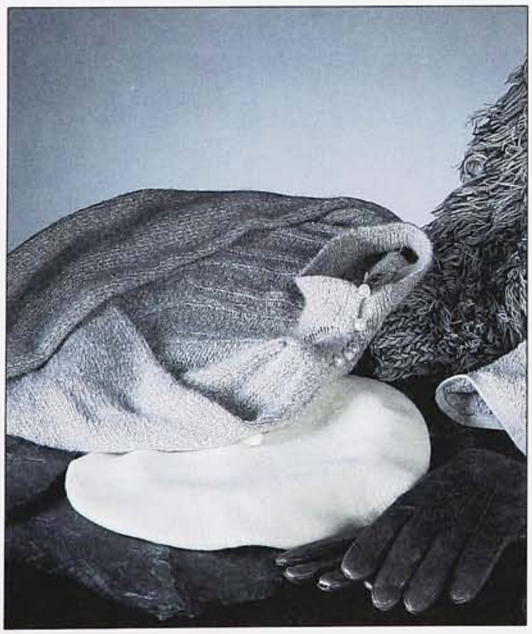
600 dpi	1200 dpi
2400 dpi	3600 dpi

PAGE 3

GATF *Digital Test Form*

Chanassa Pichitgarnka's Thesis:
A comparison between waterless and conventional lithography.

Waterless Press Run 1 1994



GATF *Digital Test Form*

Chanassa Pichitgarnka's Thesis:
A comparison between waterless
and conventional lithography.

Waterless Press Run 1 1994

Inks: Dainippon DRI-O-COLOR
Printing plate: Toray waterless
Blanket: DayInternational 9500
Printing date: April 1994

25C

25M

25Y

25K

25C + 16M + 16Y

PAGE 1

GATF *Digital Test Form*

Chanassa Pichitgarnka's Thesis:
A comparison between waterless and conventional lithography.

Conventional Press Run 1 1994

	C	M	Y	K	B	G	R	3-C
10								
20								
30								
40								
50								
60								
70								
80								
90								
100								

GATF 24pt
GATF 20pt
GATF 16pt
GATF 12pt
GATF 8pt
GATF 6pt
GATF 4pt
GATF 3pt
GATF 2pt

1 2 3 4 5 6 7 8 9 10 11 12 13

0.15 0.30 0.45 0.60 0.75 0.90 1.05 1.20 1.35 1.50 1.65 1.80 1.95

400 375 350 325 300 275

0.25 0.50 0.75 1.00 1.25 1.50 1.75 2.00 2.25 2.50 2.75 3.00 3.25 3.50 3.75 4.00

Cyan / Magenta	10	9	8	7	6	5	4
9							
8							
7							
6							
5							
4							

(Cyan; Yellow across; Magenta down)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1														
2														
3														
4														
5														
6														
7														
8														
9														
10														
11														
12														
13														

25	24	22	20	18	16	14	12
24							
22							
20							
18							
16							
14							
12							

50	46	44	42	40	38	36	34
46							
44							
42							
40							
38							
36							
34							

75	71	69	67	65	63	61	59
71							
69							
67							
65							
63							
61							
59							

GATF IMAGING RESOLUTION TARGET

4000 3800 3600 3400 3200 3000 2800 2600 2400 2200 2000 1800
1600 1400 1200 1000 800 600 400 300 200 100 75 50

100 C+M+Y K 75 50 25

100 C+M M M+Y Y C+Y C 75 50 25

25C+16M+16Y 50C+38M+38Y 75C+63M+63Y
25K 50K 75K

GCA/GATF Digital Proof Comparator Cyan Magenta Yellow Black

Test form: GATF Digital Test Form
Imagesetter: Agfa SelectSet 5000, 2400 dpi.
Uncoated paper No.1 premium opaque
Press: Heidelberg Speedmaster 4 colors
Ink-down sequence: KCMY

PAGE 2

GATF *Digital Test Form*

Chanassa Pichitgarnka's Thesis:
A comparison between waterless
and conventional lithography.

Conventional Press Run 1 1994

5K	10K	15K	20K	25K	30K	35K	40K	50K	60K	70K	75K	80K	90K	100K
5C+3M+3Y	10C+6M+6Y	15C+10M+10Y	20C+14M+14Y	25C+17M+17Y	30C+21M+21Y	35C+25M+25Y	40C+30M+30Y	50C+40M+40Y	60C+50M+50Y	70C+60M+60Y	75C+65M+65Y	80C+72M+72Y	90C+82M+82Y	100C+93M+93Y

600 dpi | 1200 dpi | 2400 dpi | 3600 dpi

GATF *Digital Test Form*

Chanassa Pichitgarnka's Thesis: A comparison between waterless and conventional lithography.

Conventional Press Run 1 1994

SURPRINT

KNOCKOUT

PAGE 4

GATF *Digital Test Form*

Chanassa Pichitgarnka's Thesis:
A comparison between waterless
and conventional lithography.

Conventional Press Run 1 1994

Inks: G.P.I. Natural Lith
Printing plate: 3M G.M.X. Viking
Blanket: DayInternational 9500
Fountain solution: Rosos KSP10 ASM3
Printing date: April 1994

25C

25M

25Y

25K

25C + 16M + 16Y