A STUDY OF CONVENTIONAL VS. WATERLESS LITHOGRAPHY

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Keywords: Comparison, Litho, Offset, Statistics, Waterless

Abstract

Waterless printing has received much attention in recent trade journals and printing equipment exhibitions [1,2,3,4]. Numerous reasons have been cited as to why it is a preferred printing process over its conventional counterpart. However, little quantitative data is available that describes the capability of waterless printing. In order to gain a deeper understanding of the waterless printing process, a four-color sheet-fed press capable of printing with and without water was used in this experiment. This research compares the process capabilities of waterless lithography and conventional lithography in terms of solid ink density through press sheet sampling, densitometric measurement, and data analysis. Several statistical methods are used to analyze the data, and initial findings are reported in terms of printing consistency of both processes.

Introduction

In major league sports competition such as the World Series, it takes not just one, but seven games to determine who wins the professional baseball championship. Given the fact that valid decisions are data-based, what would constitute a valid comparison between two competing printing technologies such as waterless printing and conventional offset lithography? This paper attempts to answer this research question with the premise that the comparison should not only be data-based, but also conducted with a well-designed experiment and the application of appropriate statistical analysis techniques.

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The objective of the study is to compare two offset press runs, one printed with water and one printed without water, with regard to printing consistency over time. While test elements such as resolution targets, halftone scales and pictorial images at various screen rulings, were included in the test form, only solid ink densities of cyan, magenta, yellow, and black are measured, analyzed, and discussed in this paper. There are two reasons for this approach: (1) We want to keep a rather complicated matter simple, and (2) Variation in solid ink densities contributes to tone and color variation during printing. Thus, understanding how consistently each of the two printing processes performs is an important first step.

Experimental Procedures

The experiment was conducted on May 22, 1993 in Chicago using an Akiyama 40" sheetfed press. Table 1 summarizes the equipment and materials used.

Table 1. Equipment and materials used in the experiment.

	Waterless	Conventional
Press	Akiyama 40" sheetfed	(same)
Paper	Warren Recycled Lustro	(same)
Plates	Toray (neg. working)	Kodak KNA (neg. working)
Inks	Sun Chemical	DPI America
Fountain	---	Rycoline + 8% Alcohol

There were five press runs conducted on that day. A coin toss determined the run sequence. Conventional and waterless printing alternated. The purpose of the first press run was to warm up the press, and to allow press operators to gain familiarity with the job. The first press run also helped establish aim points for solid ink densities. For calculation of the process capability indices, tolerances were determined to be +/- 5% of solid ink densities. The purpose of the 2nd and 3rd press runs was to study press makeready efficiency (not covered in this paper). The study of printing consistency was based on the 4th and 5th press runs.

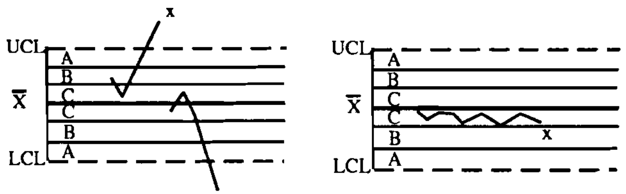
An ink-down sequence of KCMY was used for both press runs. The makeready and the running speed of the press were both 8,000 iph. A quantity of 1,500 sheets was allocated for press makeready, and a quantity of 4,000 sheets for each of the production runs. Press sheets were pulled every minute for 30 minutes of running time.

Densities of the press sheets were measured with an X-Rite X-Scan scanning densitometer. For each press sheet, density measurements were collected from multiple ink zones over a width of 30". The average of solid ink densities across the sheet was analyzed.

Data Analyses & Decision-making

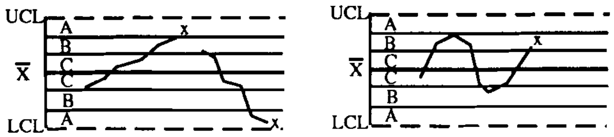
Several statistics were used to test the stability of the printing process. Initially, histograms of solid ink densities were used to see whether the distribution was normal. The Shapiro-Wilk W Test was used to test for the normality of distribution [1].

Individual and moving range charts were also used to detect any special cause variation. Here, a subgroup of 5 was used for the moving range chart. Stability of the process was judged by observing individual and moving range charts for patterns of special cause variation. There are eight tests for special cause variation. Figure 1 illustrates four of them .



(a) Out of control limits

(c) Nine consecstive points in zone C



(b) Trends

(d) Cyclic

Figure 1. Four of the eight patterns of special cause variation [2].

In this study, a stable process is said to have (1) a normal distribution as tested by the Shapiro-Wilk W test, and (2) no pattern of special cause variation detected in its individual and moving range charts. An unstable process would be one when either or both of the two conditions are violated. It has been our experience that an unstable printing process tends to have more variation than a stable one.

CP stands for *capability of process*. It describes how consistent a process can be when it's running with only common cause variation present. The formula for CP is tolerance divided by 6 sigma, where the tolerance is +/- 5% of the aim solid ink densities. And sigma is the standard deviation of the distribution, estimated from the sigma hat [3]. As shown in Figure 2, CP indicates how capable the process is in meeting the specification. The larger the CP index, the more capable is the process. As a rule of thumb, a process is considered to be capable when the CP index is equal to or greater than the value of 1.33.

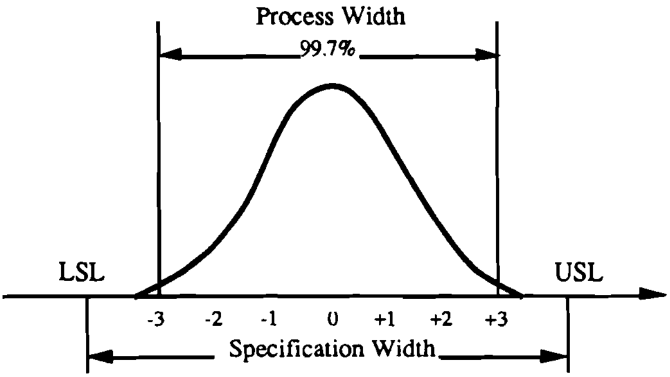


Figure 2. Concept of process capability index.

CP is invalid when the process is not stable. In this study, we decided to compute process capability indices regardless of the stability of the process, but apply a decision table to determine whether the comparison of printing consistency between the two processes can be done with validity. As shown in Table 2, there are four possibilities: (1) when both processes are stable, we can compare their stability; (2) when the conventional process is unstable, but having a greater CP value, we can interpret that the conventional process has a greater potential to be a more stable process; otherwise, we cannot compare their stability; (3) when the waterless process is unstable, but having a greater CP value, we can interpret that the waterless process has a greater potential to be a more stable process; otherwise, we cannot compare their stability; (4) when both processes are not stable, we cannot compare their stability.

Table 2. Decision-making table.

Case	Is the process stable?		Validity of comparison
	Waterless	Conventional	
1	Yes	Yes	Yes
2	Yes	No	Yes, If CPconv. > CPwl, else No.
3	No	Yes	Yes, If CPwl > CPconv., else No.
4	No	No	No

Experimental Findings

Figure 3 provides a quick look at time plots for both printing processes. Trends are observed when all 30 samples were included. In order to increase the chance of accepting the process for being stable, it was felt that early trends, e.g., the black printer of the conventional process, should be excluded since it is a sign of premature sampling. Consequently, all statistics were computed with the first 20% of the samples excluded.

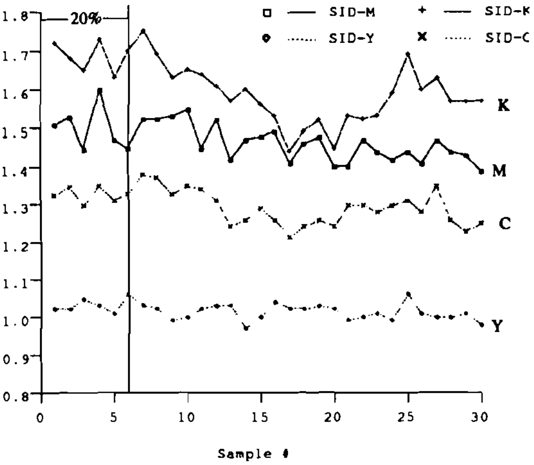


Figure 3(a). Time plots of the waterless press run.

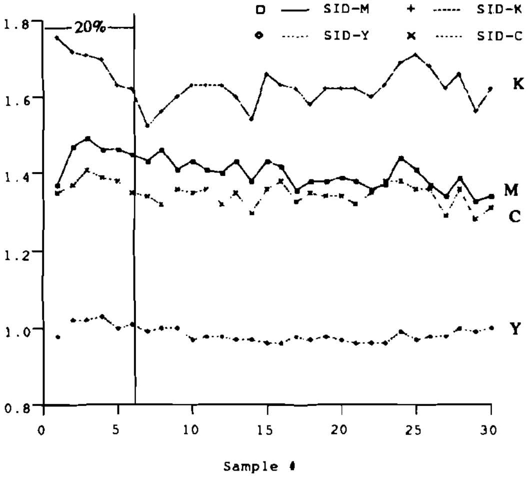


Figure 3(b). Time plots of the conventional press run.

Solid ink densities of the waterless process by individual and moving range charts are shown in Figure 4. Analyses of special caused variation were carried out using JMP software. The sigma hat was computed from the average of ranges and a constant, d_2. Its process performance is summarized in Table 3.

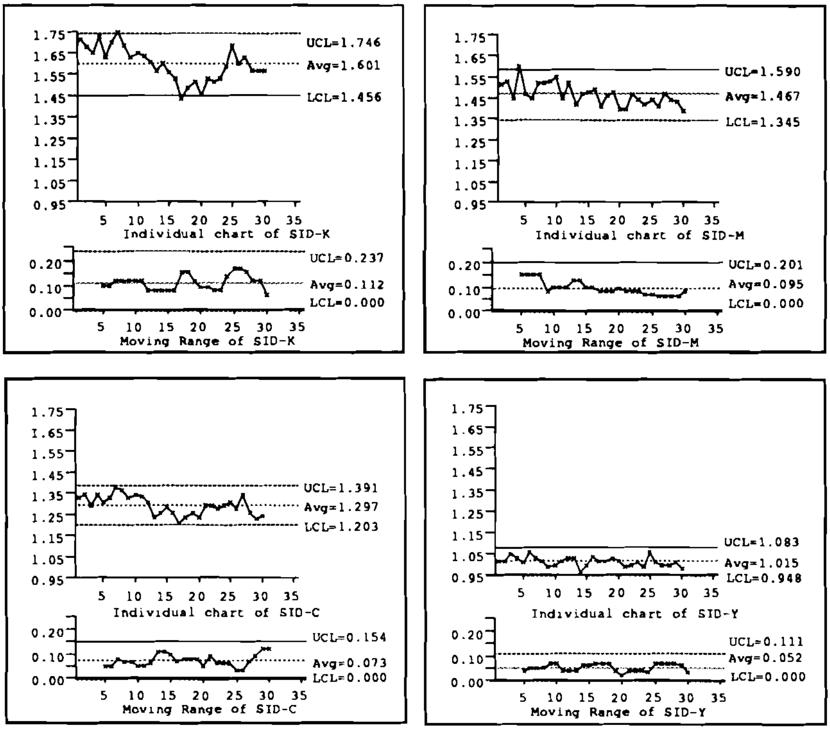


Figure 4. Individual and moving range charts of the waterless process.

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

	Waterless SID (first 20% of samples excluded)			
Ink color	K	C	M	Y
Sample size	24	24	24	24
Mean	1.58	1.289	1.456	1.011
Sigma hat	0.048	0.033	0.036	0.022
Distrib. normal (0.05)?	Yes	Yes	Yes	Yes
LCL (x bar – 3 sigma hat)	1.436	1.191	1.35	0.945
UCL (x bar+ 3 sigma hat)	1.725	1.387	1.568	1.078
6 sigma hat	0.288	0.198	0.216	0.132
Data trend random?	No-Down/up	No-down	No-down	Yes
Process stable?	No	No	No	Yes
Aim point	1.61	1.28	1.41	1.03
LSL (5% of SID)	1.53	1.21	1.34	0.98
USL (5% of SID)	1.69	1.35	1.48	1.08
CP	0.357	0.502	0.509	0.813
Process capable (1.33)?	No	No	No	No

Base on the Shapiro-Wilk W test for distribution normality, all four printing units of the waterless process were found to be normal. By examining individual and moving range charts, the yellow printer was the only printing unit found to be stable. In addition, CP values of all four printing units are less than the value of 1.33. Therefore, we conclude that the waterless process is not capable of meeting specifications.

Similarly, analyses of solid ink densities of the conventional process by individual and moving range charts are shown in Figure 5. Its process performance is summarized in Table 4.

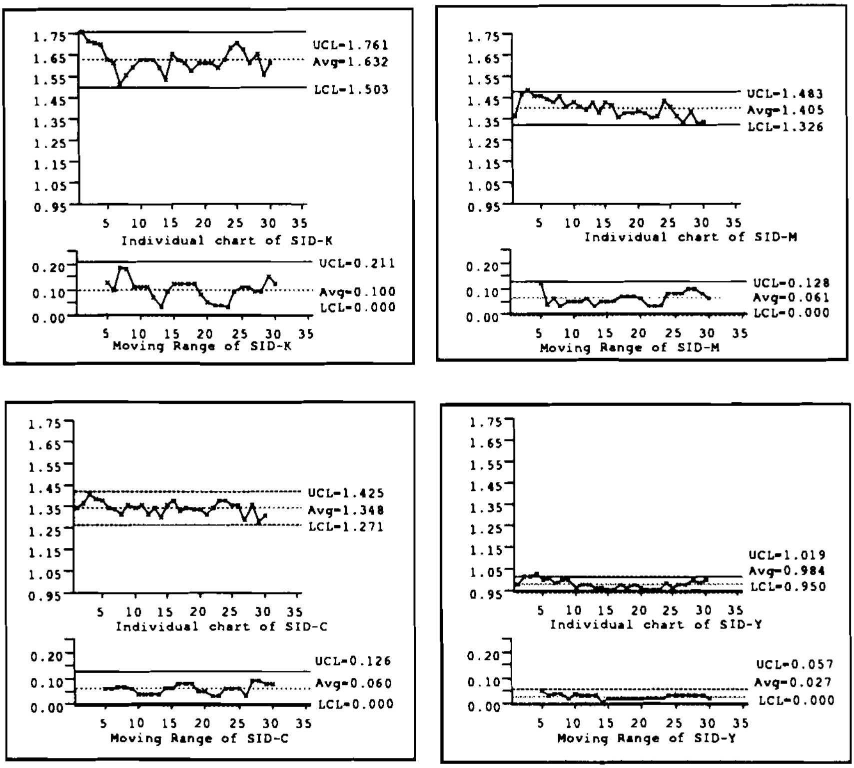


Figure 5. Individual & moving range charts for the conventional process.

Notice that the scaling is common for all individual and moving range charts. At a glance, we can see that the black printer exhibits more fluctuations than the yellow printer. Further we observe out-of-control situations at the beginning of the press run, and this would not be evident in Figure 3(a) and 3(b).

Table 4. Process performance summary—conventional process.

	Conventional SID (first 20% of samples excl.)			
Ink color	K	C	M	Y
Sample size	24	24	24	24
Mean	1.618	1.341	1.393	0.978
Sigma hat	0.038	0.026	0.027	0.01
Distrib. normal (0.05)?	Yes	Yes	Yes	No
LCL (x bar- 3 sigma hat)	1.503	1.265	1.314	0.947
UCL (x bar+ 3 sigma hat)	1.733	1.418	1.473	1.009
6 sigma hat	0.228	0.156	0.162	0.06
Data trend random?	No-down	Yes	No-down	Down/up
Process stable?	No	Yes	No	No
Aim point	1.61	1.28	1.41	1.03
LSL (5% of SID)	1.53	1.21	1.34	0.98
USL (5% of SID)	1.69	1.35	1.48	1.08
CP	0.592	0.847	0.677	1.206
Process capable (1.33)?	No	No	No	No

Base on the Shapiro-Wilk W test for distribution normality, three printing units of the conventional process were found to have normal distribution with the exception of yellow printer being abnormal. However, by examining individual and moving range charts, the cyan printer was the only printing unit found to be stable. In addition, CP values of all four printing units are less than the value of 1.33. Therefore, we conclude that the conventional process is not capable of meeting the specifications.

Comparison of Printing Consistency

Based on the above data analyses and the decision table, we conclude that (a) No comparison can be made for black and magenta printers because both processes were not stable (case 4); (b) No comparison can be made for the cyan printer either (case 3); (c) Since the CP value of the yellow printer (not stable) of the conventional process is greater than that of the waterless printer (stable), we conclude that the conventional process is more consistent than the waterless lithography (case 2).

Discussion & Further Research

This study marked a significant beginning where quantitative data were used to compare process performance between conventional and waterless lithography. Out of the four process ink units compared, we only found the yellow printing unit of the conventional process to be more stable than its waterless counterpart. With such limited findings, we intend to refine and repeat the experiment in the future.

We can not underscore the importance of a well-designed experiment. While every effort was made to ensure that the "playing field" being leveled, we believe that there are still rooms for improvement. We want to take the following comments and recommendations into consideration as we go about the second round of the experiment.

1. Basically, we decided that no comparison should be made unless either one process or both processes perform under steady state. The steady state of the process must be evidenced by the test of distribution normality and the analyses of special cause variation. The reality is that printing processes are seldom treated as a science. It is too easy to find anomalies in them. To increase the odds of having valid comparison, it's only reasonable that we determine if part of the data should be excluded (the 20% rule) from the analyses. Given that being the case, we almost could not draw any definite conclusion from the experiment. In the future, we intend to devise a more sensitive method of excluding data that produce special cause variation so that true capabilities of the printing processes can be assessed.

2. The experimental design allows intervention between press operators and the press. There are two good reasons for it: (1) A press operator is always part of a printing process—have you seen a press run that is unmanned? We believe that having a press operator regulate the process for printing consistency is the rule, not the exception; (2) As with the same paper stock used for both press runs, the effect of the press operator would not influence the differences of the two printing processes.

3. The tolerance determines the specification width. Consequently, there are two points regarding the tolerances for solid ink density: (1) Tolerances, expressed as the same percentage of aim solid ink densities, are more appropriate than tolerances expressed in same density ranges. This offers more density range which is needed for a stronger ink such as black; (2) Tolerances of +/- 5% of solid ink densities are too tight for printing on coated stock. This has caused small CP values that render the process not capable. Until the consistency of the process is improved, tolerances of +/- 10% of solid ink densities are desirable.

4. The experimental design was concerned with both across-the-sheet variation and variation over time. Across-the-sheet variation was assessed from measurements of multiple repeats of the test target (30" in width), and variation over time was assessed from press sheet pulls over the duration of the press run. As a result, the process variation was pulled from both sources. Since across-the-sheet variation is primarily

influenced by press operators, and not the process itself, it is desirable to monitor only the variation over time by measuring a single repeat of the test target (5" in width).

5. Additionally, the next round of comparison between conventional and waterless printing calls for the following improvements: (1) Increase the number of press sheets sampled from 30 to 100 so that x-bar and range charts can be used in lieu of individual and moving range charts, (2) Monitor dot gain variations in addition to solid ink density variations; (3) Monitor temperature variations so that its correlation with solid ink density and dot gain can be studied.

References

1. O'Rourke, John, "Waterless Printing U. S. Market Considerations and Applications," TAPPI Proceedings, 1992.

2. Bain, Lawrence J., "The Influence of Technology on Lithographic Pressroom Productivity," Critical Trends in Graphic Communications Industry, R&E Council of the Graphic Arts Industry, Chadds Ford, PA, pp. 34-36, 1994.

3. Cross, Lisa, "Watershed Year for Waterless," Graphic Arts Monthly, February 1993, pp. 51-53.

4. JMP User's Guide, SAS Institute Inc., Cary, NC, 1989.

5. Wheeler, Donald J. and David S. Chambers, Understanding Statistical Process Control, Statistical Process Control, Inc., 1986.

6. Juran, Joseph M., Juran's Quality Control Handbook, 4th ed., McGraw-Hill, NY, NY, 1988.

Acknowledgments

We wish to extend our sincere thanks to the following individuals and their companies for their support in this project: Arthur LeFebvre, LeFebvre Intergraphics; Joe Mater, S. D. Warren; John O'Rourke, Toray; Iain Pike, X-Rite; Tony Stanton, GATF; Glen Thore, L&E Packaging; John Compton and Mark DuPré, RIT T&E Center & LQPGA. Without their support, we could not have completed this study.