Practical Application of Experimental Design Techniques in the Pressroom

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Abstract: Experimental design procedures are widely used in the laboratory. Application of these techniques to commercial printing plants presents special problems due to the need to fit the experiments in with production schedules. Under certain circumstances it may be possible to conduct the experiments as part of the routine production process.

In this paper we describe the results of a series of print trials conducted over a seven week period in a newspaper pressroom. Major variables examined were ink-related: vehicle chemistry, pigmentation level, and emulsification characteristics. All three process inks were varied according to the experimental design requirements. In all cases, results were normalized to a pseudo-control, the standard ink formulation, in order to minimize week-to-week variations. Operating characteristics of the inks (scum point, washout point) were determined. In addition to objective measures of print quality such as ink trap and dot gain, subjective evaluations of key properties were undertaken using the printers as judges.

Results were not consistent over the range of colorants studied, i.e., whereas vehicle type might influence the scum point of the magenta it did not influence the performance of the cyan and yellow inks. In addition several interaction effects were noted. The use of the printers as quality judges was particularly beneficial.

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Introduction

It is well known that many North American newspapers have experienced declines in circulation and advertising revenue over the past two decades. This is due in part to new electronic and other forms of printed products, which now compete against newspapers for a growing share of their customer base. Additionally, many newspapers were slow to change away from letterpress to modern offset and flexographic printing processes. Upgrading newspaper presses allows widespread use of high quality color inks, which readers and advertisers now demand.

The St. Petersburg Times was one of the first newspapers in the United States to begin using the offset process for printing newspapers, and has a long standing reputation for leading quality improvements in this industry. As changes in reader and advertiser expectations became apparent, a project was initiated to identify the relationship certain color offset ink formulation variables had on quality of the printed newspaper reproduction.

Initial project planning activities focused on four areas: 1) identification of the ink formulation variables to be examined, 2) use of experimental design techniques for planning the experiment and analyzing test data, 3) long term, full scale press testing procedures, and 4) a subjective survey as an additional step to assess print quality, which complemented data from traditional instrumental print analysis techniques. Individually, each of these techniques has been used. However, we believed this combination of evaluation techniques was novel, and allowed data to be examined to determine if subjective quality changes, over a period of time, were of a magnitude perceivable to a panel of readers.

Experimental

Ink Variables

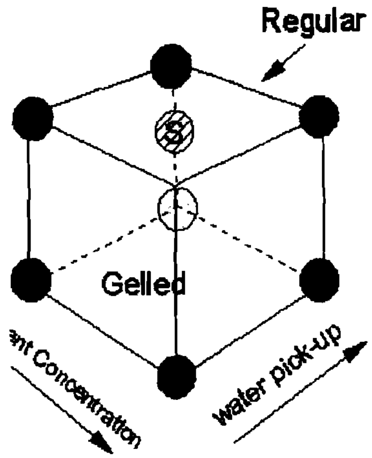
Three ink formulation variables were identified for evaluation as follows: 1) use of a regular or a gelled news ink varnish, 2) altering fountain solution emulsification properties of the inks, and 3) changing pigment content of the inks, which impacts ink film thickness used on the press. Gelled vehicles differ from their normal hydrocarbon counterparts in that the former create a more structured ink. Eight sets of test inks were prepared having the following characteristics:

Test Ink Set #	*Vehicle*	*WPU*	*Pigment Content*
1	G	+	+
2	G	+	-
3	G	-	+
4	G	-	-
5	S	+	+
6	S	+	-
7	S	-	+
8	S	-	-

Vehicle	*Water pick-up (WPU)*	*Pigment Content*
G = gelled vehicle	+ = high level	+ = high level
S = standard vehicle	- = low level	- = low level

As shown in the following figure, the experimental design utilized the standard inks as a center point on the "face" of the cube representing the experimental design space.

Pigmentation level and water pickup are continuous variables and vehicle composition (regular or gelled) is a categorical variable. We used the standard ink, labeled "S" in the drawing, as a benchmark - all results are relative to the performance of the standard ink on that particular day, enabling us to minimize press variations over the seven-week trial period. The design is, therefore, a "screening" design, intended to pick up what are called main effects. Linear mathematical models were used to fit the data.



The standard vehicle system was comprised of a medium melt-point hydrocarbon resin dissolved in petroleum oil. The gelled vehicle system utilized a modified hydrocarbon resin, which allowed reactivity with cross-linking agents to increase structure and molecular weight.

Laboratory Ink Testing Procedures

A series of laboratory tests were used during the ink formulating process to ensure relevant attributes of the formulations were maintained, while the aforementioned targeted ink variables were altered. The laboratory tests utilized were as follows:

Water pick-up - 50 grams of ink were mixed on a Duke emulsification tester with 50 grams of press ready fountain solution for 3 minutes. The excess fountain solution was decanted to determine the amount of solution emulsified into the ink. The decanted solution was then replaced in the mixing vessel, along with additional fresh solution, so that the total amount was again 50 grams. This process was repeated after total mixing times of 6 and 9 minutes. The targeted water pick-up value was measured by the 9 minute reading. The 3 and 6 minute readings were used to ensure a "B" type rate of emulsification occurred, which is a diminished rate of fountain solution absorption into the ink after each mixing period . (1)

High shear viscosity - A Laray falling rod viscometer was used to measure high shear viscosity with a series of two rod drops at weights of 400 and 100 grams (30°C). Small changes in the amount of clay fillers, activated organoclay, and ink solvent (petroleum distillate) were made to ensure that high shear viscosity remained constant.

Low shear viscosity - A RVT Brookfield viscometer was used to measure low shear viscosity at 2.5, 5, 10, and 20 rpm. Small changes in the amount of clay fillers, activated organoclay, and ink solvent were made to ensure that the low shear viscosity remained constant.

Apparent tack - A Thwing-Albert electronic inkometer was used to measure ink tack at 90°F. The tack reading was taken after distributing the ink on the rollers for one minute at low speed (400 rpm), then increasing speed to 1200 rpm for an additional one minute period, at which time the apparent tack was recorded. Ink tack was adjusted, if necessary, by small additions of ink solvent.

High water pick-up formulations were designed to emulsify 40% more fountain solution in comparison to the standard formulation. Low water pick-up formulations emulsified 40% less.

Pigment content was altered based on the weight percent in the formulation. Experimental inks having high pigment levels contained 30% more pigment than the standard. Inks having low levels contained 30% less.

Press Testing Procedure

Press tests were conducted at the St. Petersburg Times on a double wide GOSS Metro newspaper press. It was equipped with a conventional (as opposed to ink train) dampening system, and utilized standard lithographic plates.

Press testing was conducted every Tuesday morning on an advance "Food" section press run, which was distributed to readers at a later time. The editorial staff permitted print evaluation test targets (color bars) as part of the printed subject matter, which allowed us to make instrumental print quality (density, dot gain, % trap) evaluations. We were very pleased with the decision (and the investment) the St. Petersburg editorial staff made in allowing this, as many newspapers hesitate doing so as it may detract from the editorial content of the issue.

Press test runs always began with the standard inks, after careful evaluation of the physical condition of the press. This allowed a performance baseline to be established, measuring reproducibility of the press and standard ink performance. Ink densities were carefully set, and the press was brought up to operating speed and allowed to come to equilibrium. Evaluation of the range of dampening latitude was then conducted, and print samples were collected for testing. The advance press run was long enough on each testing day so that two additional sets of test colors could be evaluated after completion of the standard ink test run. Each test run lasted for approximately 30-40 thousand impressions, for a total of about 120,000 impressions per day's run.

Color sequence was atypical: magenta, yellow, cyan and black. This particular sequence is one St. Petersburg was evaluating during the time we conducted our tests.

Results

Press Variables

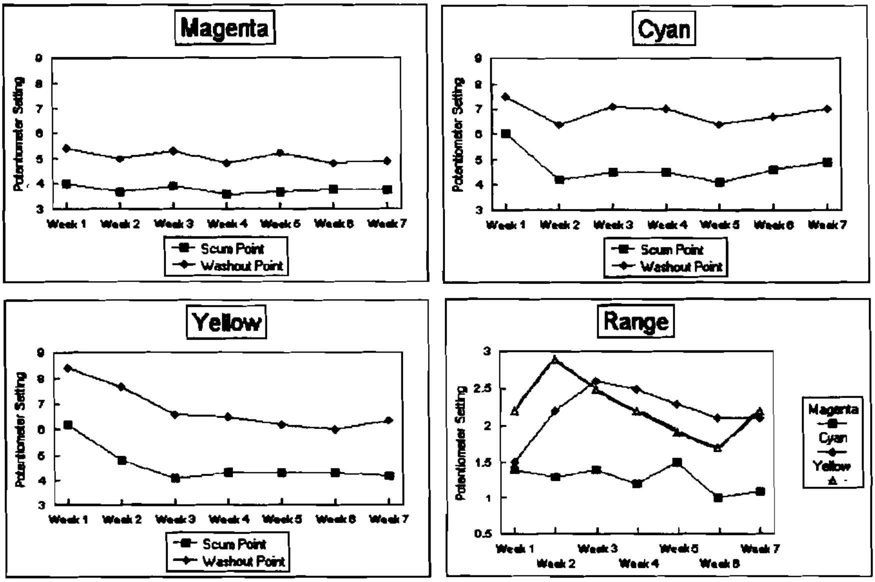
Before looking at the effects of our major variables on print quality we should look at the stability of the press over the seven-week duration of the testing program. Figure 1 shows the variations in the measured print properties of the standards inks.

Table 1. Summary Statistics for data shown in Figure 1									
	Density			Dot Gain			%Trap		
	Cyan	Mag	Yell	Cyan	Mag	Yell	Red-y/m	Blue-c/m	Green - y/c
Avg.	0.92	0.99	0.97	38	41	40	56	81	88
COV	6%	5%	4%	11%	14%	17%	15%	5%	3%

Densities were fairly consistent, see Table 1, generally within the acceptable range of ± 0.05 density units and fairly close to the NAA [(2)] standards (cyan, magenta = 0.90, yellow = 0.85). NAA calls for dot gain to be in the 28-34% range so we are somewhat higher in that regard. St. Petersburg has historically "fingerprinted" their presses and adjusted their color separations accordingly. Why the percent trap for the yellow/magenta combination increased noticeably during week 4 is not known but could simply be a consequence of the magenta density being lower than the yellow density for that one week (yellow is trapped on the magenta).

Figure 2 shows the variations in the controllable press variables. Standard procedure was to set the ink to the target densities and adjust the water to the optimum point for each color. Wash-out and scum points were then determined by respectively raising and lowering the dampener potentiometer settings. This was done for each ink during the press run. The data in Figure 2 represents the variations in the potentiometer when using the standard ink. The "scum" point was the setting at which the ink was seen to begin printing in the non-image area, the "washout point" was the setting at which the image density noticeably dropped, and "range" is simply the difference between the two settings.

Figure 2. Variations in dampener settings for standard inks.



As seen in Figure 2, after the first week the ranges became remarkably consistent, with perhaps some long term variations for the yellow. Table 2 summarizes the statistical analysis of the data shown in the figure.

Table 2. Summary Statistics for data shown in Figure 2 (potentiometer settings)									
	Scum			Washout			Range		
	Cyan	Mag	Yell	Cyan	Mag	Yell	Cyan	Mag	Yell
Avg	4.7	3.8	4.6	6.9	5.1	6.8	2.2	1.3	2.2
COV,	13%	3%	15%	3%	7%	12%	15%	13%	16%

Noteworthy is that the range of the magenta is significantly less than that of the cyan and yellow inks. Magentas have historically been considered the most sensitive to dampener levels of the colors and our data supports this perception. One of our goals in this work was to see if we could improve on this performance.

To minimize the influence of these variations we elected to use the <u>difference</u> between the values obtained for the standard ink and each test ink run on the same day, as a measure of whether any of our ink variables influenced the dampener settings.

Table 3 shows the results of the statistical analysis of the data for the dampener variables. All analyses were conducted using E-Chip software. [3] The arrows (↑ ↓) in the chart indicate the direction of the change, i.e., as the water pick-up of the yellow ink increases the scum point (potentiometer setting) decreases; less water can be run.

Table 3. Statistically Significant Responses for Dampener Settings (significant at - * = @ 95%, ** = @ 99%)

	S_M	W_M	L_M	S_c	W_c	L_c	S_Y	W_Y	L_Y
Water Pick-up							* ↓		
Pigment Level						* ↑		* ↑	
Ink Vehicle									
Vehicle/Pick-up		* ↓				** ↓			
Vehicle/Pigment level									

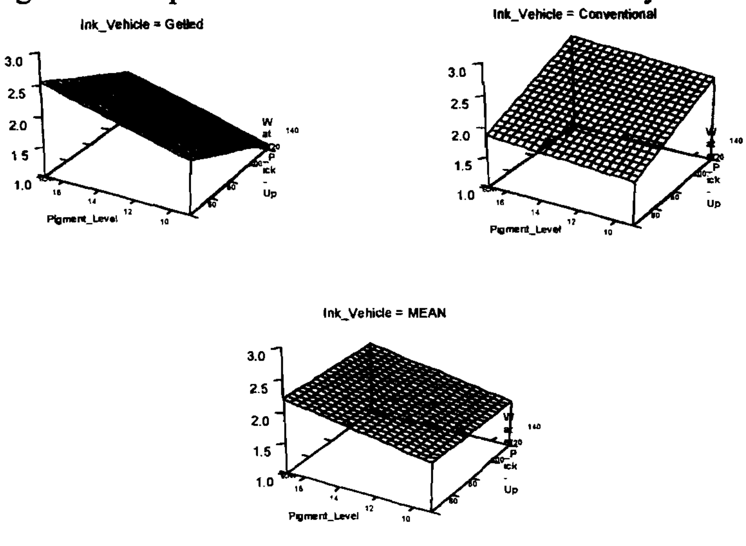
S_M, W_M, L_M, ... etc. are the scum point, washout point, and latitude (range of dampener setting) of the magenta, cyan and yellow, respectively

The ability to reduce the dampener setting is always desirable; we can see from the table that increasing the water pickup of the yellow had a beneficial effect. Raising pigment level enhanced the latitude of the cyan and raised the washout point of the yellow; all desireable effects. The extent of the change, about 0.25 units on the potentiometer [4], in the case of the yellow, may or may not be a change that could be maintained in the pressroom. Unfortunately, the latitude of the magenta, normally being very narrow (Table 2) was not widened by any of the changes we made.

Our experimental design allowed us to test for two interactions; ink vehicle/water pickup and ink vehicle/pigment level. Figure 3, taken directly from the E-Chip output, shows how the latitude of the cyan was affected by the ink formulation changes.

Maximum latitude is desirable and, depending on vehicle choice, the results suggest that two significantly different water-pickup levels would be necessary. Figure 3 also shows the results for the "mean" of the vehicles (mathematically speaking only; no mixtures containing both vehicles were tested); a small (but significant, see Table 2) effect of pigmentation level on the latitude response is apparent (higher is better).

Figure 3. Response surfaces for water latitude of cyan



Print Variables

Table 4 shows the results of the experimental design analysis. There was only one significant effect - pigment level - on dot gain and that was in the "wrong" direction. Conventional wisdom suggests that higher pigmentation levels will allow thinner ink films, which will be less likely to contribute to dot gain. Since viscosity was held at a fairly constant level, this may explain the lack of positive effects.

Table 4. Statistically Significant Responses for Print Attributes (significant at - * = @ 95%, ** = @ 99%)

	Density			% Trap			% Dot Gain		
	cyan	mag	yell	cyan	mag	yell	cyan	mag	yell
Water Pick-up									
Pigment Level								* ↑	
Ink Vehicle									
Vehicle/ Pick-up									
Vehicle/ Pigment Level									

Visual Print Quality

The procedure for assessing print quality was to take the front page from the experimental runs and compare them to the standard run the same day. Judges, who included the press crew, examined the full-color food pictorial for the following attributes: general overall appearance, ink lay in solid areas (mottle, smoothness), general color brightness, halftone sharpness, gloss, ink rub, color cleanliness, and ink-print-through.

Judges were asked to make their assessment for each attribute by checking the box that most closely described their assessment. [5]

Attribute -

Preference Judgment

____ ____ ____ ____ ____ ____ ____

Prefer A — No Preference — Prefer B

Unbeknown to the judges was that, irrespective of labeling, Sample A was always the standard ink. If a judge preferred Sample A a numerical rating of -3 was assigned; if they preferred Sample B, a rating of +3 was assigned, no preference then a "0" was assigned, and so on. The preferences were then averaged over all judges for each attribute. There were from 5-8 judges every week, but not always the same judges. Keep in mind that for each of pair of samples judged, one was always the standard ink run that same day.

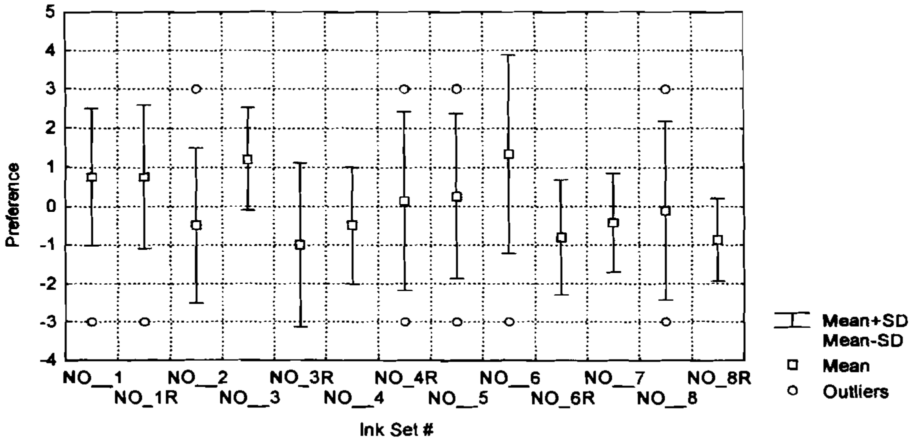
E-Chip analysis showed there were no significant effects of ink properties on perceived quality.

What this says is that over the 7-week period none of the experimental inks performed any better than the standard inks, with respect to perceived print quality. One possible cause of this observation is that the experimental "noise", which includes uncontrolled variables, was too large. Figure 4 shows, for the attribute "general overall assessment", how each sample set rated. As can be seen the variation within a sample set (among judges) is large, and there is variation between replicate sample sets, for example Set #6 and Set #6R; #3 and #3R. The conclusion is that on any given day an experimental ink may outperform a reference ink, at least slightly, but that over a prolonged period it may not. In no case did any experimental ink demonstrably outperform the standard.

Figure 4. "General Quality Assessment"

Does the experimental ink set look better (+) than the standard ink set

All judges; pooled variance



Conclusions:

Full scale printing tests are often involved and, because of costs, of limited duration. As such they can often result in misleading conclusions because they do not take long term variations of uncontrolled variables into account.

We have been able to conduct a series of carefully planned tests over a seven-week period in an actual newspaper pressroom running "live" copy. By running over such a long period of time, the experimental data contains the "noise" that would otherwise go unnoticed in a short duration test. In short term testing this noise might bias the results and lead to erroneous conclusions.

By randomizing the testing of our controlled variables and making "blind" comparisons of the printed results, we were able to clearly demonstrate that major changes in ink properties (± 30% changes in pigmentation levels, ±40% changes in water pickup levels, vehicle changes) had no significant impact on perceived print quality. Only one measured print quality attribute was found to be significantly affected by the controlled variables. Some runnability issues were detected and suggest opportunities for future product development.

Finally, we need to reiterate that our conclusions are valid for the range of the experimental variables covered as well as the nature of the press. Different types of inking/dampening systems might respond differently to these inks. Inks whose properties are outside the bounds we set might also give different results. The ranges we chose, however, represented the practical limits of pigmentation levels and ink-water interactions achievable with the materials used. Newer vehicles and pigment dispersions can now allow for wider ranges of pigment loading and consequently the possibility of different results.

(1) Surland, A. TAGA Proceedings, 1980, pp. 222-247. See also ASTM Test Method D-4942.

(2) Newspaper Association of America Color Book, v. 8 (January 1993). The actual specifications are slightly higher since a "wet" ink density is specified. Our targets/reading were based on "dry" ink density.

(3) ECHIP, Inc.; 7640 Lancaster Pike, Suite 6, Hockessin, DE 19707 USA.

(4) Unfortunately, we are not able to translate the potentiometer settings into actual volumes of applied dampening solution.

(5) Lyne, M.: TAPPI 62(11), p. 103(1979).