INK/PAPER/FOUNTAIN SOLUTION INTERACTIONS

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Abstract: The S. D. Warren Paper Company and the Flint Ink Corporation conducted a joint project to study the effects of the water pick-up of inks, the ink set time of papers, and acid versus alkaline fountain solutions on printability. The project used experimental design techniques. The effects of ink, paper, and fountain solution were examined for gloss, percent trap, print quality, and effect on water setting on the press for optimum performance.

Introduction

The lithographic printing process is most complex involving many different forces and components. The components ink, paper, and fountain solution are most often blamed for printing problems yet little is understood how they actually affect the final print.

When printing problems arise, it is the physical properties of an ink that are usually altered to suit customer demands as opposed to switching paper supplies. In addition to tack adjustment, one of the physical properties of ink to be altered often is the water pick-up rate although this property is one of the least understood. Fountain solutions also play an important role in the printing process. They can affect the emulsification rate of an ink and their transfer properties can determine how much fountain solution transfers onto the plate. Paper can also affect the final output by its ability to receive

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the ink. The optical characteristics of the paper will also contribute to the quality of the final print. However, there have been few, if any, studies on how the fountain solution interacts with the paper and ink to affect the final print quality.

A joint project was conducted between the S. D. Warren Paper Company and the Flint Ink Corporation to gain a better understanding of the effect of the interactions of ink, paper, and fountain solutions during printing. It was decided to incorporate three major variables - ink's emulsification rate, acid versus alkaline fountain solution, and paper with varying "ink set time" (IST). An indirect part of this project was to study the effectiveness of experimental design techniques. This technique allows for optimization in order to obtain the maximum amount of information in a minimal number of experiments. To our knowledge, use of these techniques under pressroom conditions has never before been attempted.

Experimental Approach

This project was set up as a three factor, two level factorial design (2^3) (Dupont, 1974). The three factors were ink, paper, and fountain solution. The two levels were low and high water pick-up (LWPU and HWPU) of the inks, low and high ink set time of the papers, a commercial acid fountain solution and an experimental alkaline fountain solution.

Every possible combination of the three factors at the two levels results in eight experiments. This can be represented graphically as a cube as shown in Figure 1. Every point on the cube represents one of the eight possible combinations. For example, the lower front left point would represent a combination of an ink with low water pick-up, low IST paper, and the fountain solution assigned the negative sign (acid fountain solution). The design was set up to use the bottom units of the press as repeats of the top units. This would permit the calculation of the experimental errors associated with the various tests.

The testing was done at a commercial printer chosen because it had a web press equipped with a non-Dahlgren dampener so that isopropanol need not be used. The use of isopropanol was avoided because it causes all or the majority of water pick-up curves to be equal and have the same water pick-up rate. Also, the press, a Harris M-110, was capable of running one fountain solution on the top four units and a second solution on the bottom four.

The 60 pound coated papers (supplied by S. D. Warren) differed with respect to coating formulation, giving rise to high and low "ink set time" (IST). The ink set time is defined as the amount of time required to prevent set-off from occurring. IST of 30-200 seconds is considered fast. Anything greater than 1000 seconds is slow and generally set-off problems occur. The high IST paper used in this test had a value greater than 2000 seconds and the low IST paper had a value of approximately 100 seconds. The gloss of the several rolls of the low IST paper ranged from 45 to 65.

Two series of lithographic heatset inks were used. The series had different emulsification rates. The emulsification rates were adjusted with additives. The tack of the inks was adjusted so that the tack would not be considered a factor. Table I lists the inkometer values of the test inks. The tack of the inks were stepped so that the printing sequence would be black, cyan, magenta, and yellow.

The fountain solutions used in this test were an acid etch (Rosos G-7A-"V" Comb) and an experimental alkaline etch from Flint. The physical properties for the fountain solution are also listed on Table I. Emulsification rate curves for the inks were completed using these fountain solutions and are shown in Figures 2-4. The method described by Surland (1980) was used to obtain the ink emulsification curves.

During each of the eight press runs the water settings were adjusted until the best printing conditions were obtained. This was done for all inks. The water range from wash-out to scum was

Table 1

PROPERTIES OF INK AND FOUNTAIN SOLUTIONS

INKOMETER VALUE OF INKS	
CYANS	12.0 ± .5
MAGENTAS	11.0 ± .5
YELLOWS	9.5 ± .5

FOUNTAIN SOLUTION CONDITIONS

WATER
pH = 6.6
CONDUCTIVITY = 150 micromhos/centimeter

FOUNTAIN SOLUTION
ROSOS (G-7A-V comb) at 1.0 oz./gal.
pH = 3.45
CONDUCTIVITY = 800 micromhos/centimeter

FLINT EXPERIMENTAL ALKALINE at 1.0 oz./gal.
pH = 9.2
CONDUCTIVITY = 800 micromhos/centimeter

determined for the cyan, magenta, and black inks. The range was not determined for the yellow inks because of limited time on the press. The settings for best printing conditions were recorded for the study of how each factor affects the water setting. After press conditions stabilized, approximately 10-15 prints were pulled at each setting for the evaluation of density, gloss, and percent trap.

Density readings of the prints were taken on a Cosar 61 Smart densitometer. Readings were taken on each of the 10-15 prints and averaged to give the final density value. These readings were relative to the stock. Gloss readings were taken on a Hunterlab D-48D glossmeter at a 75^{o} angle. Again, readings were averaged for the final gloss value. Percent trap values were obtained on a Cosar 61 Smart densitometer. The densitometer gives direct reading for percent trap. Laboratory prints were made on a Prufbau printability tester.

Results

The top and bottom units of the press were to have been adjusted by the printer prior to testing in order that we could make the assumption that the top and bottom units were equal. This was to have been determined by the top and bottom units printing to the same optical density when using the same paper, ink, and fountain solution. Analysis of the signatures following the test revealed that some of the densities differed by more than 0.10 densitometer units. We did not feel that we could make the assumption that the bottom and top units were equal. Since the top and bottom units were no longer considered equal, this prevented any statistical evaluation of the results.

In the tests conducted, the high water pick-up inks required a higher water setting for the best performance. Examination of the cubes in Figures 5 through 8 clearly indicate that the high water pick-up inks required a higher water setting. This effect is consistent throughout all tests and is not dependent on the type of fountain solution or the paper used. The top face of the cubes represent the experimental alkaline etch while the bottom face is the acid etch. The front face represents the low IST paper and the back face the high IST paper. The cube is examined for water pick-up by comparing the left face of the cube (low water pick-up) to the right face of the cube (high water pick-up). All other factors are kept constant by comparing only corners connected by one of the front or back edges of the cube. The high water pick-up inks required a higher water setting in all cases but the print quality as determined by visual observation and, as shown below, percent trap was the same as that obtained with the low water pick-up inks although the HWPU inks printed at a slightly higher gloss.

The effect of the two fountain solutions on water pick-up can be noted by going from top to bottom along an edge. As shown in Figures 5 through 8 there is a decrease in water setting in all cases going from the experimental alkaline etch to the acid etch.

The IST of the papers also had an effect on the water setting. This can be noted by going from front to back of the cubes in Figures 5 through 8 along the side edges. In all cases, the high IST paper resulted in a lower water setting. The experimental design was drafted with the assumption that all prints collected would be acceptable prints. However, it was not always possible to obtain acceptable prints when using the high IST paper. The rules of experimental design suggest the use of extremes for the levels chosen. The ink set time of the high IST paper would definitely place the paper in the high level of the experimental design. However, the paper used is not one that would be sold commerically. Since we could not get acceptable prints for all combinations of the high IST paper, we decided to look only at the prints of low IST paper for visual assessment of print quality, gloss, and percent trap. This, coupled with the decision not to consider the top and bottom units as equal, lead us to evaluate the results in a traditional manner. Only the paper of low IST was examined hereafter.

It should be noted that the water setting range from wash-out to scum was the same for all of the above conditions ($\pm$ 5), regardless of the ink, paper, or fountain solution used.

Table 2 lists the optical densities of the inks. The HWPU inks printed at the same density or at a slightly greater density (within 0.10 densitometer units) than the LWPU inks except for the magenta inks on the bottom units. In these two cases, the HWPU inks printed at a significantly higher density. Overall, the HWPU inks had little or no significant effect on density.

The gloss results of the signatures of low IST paper are presented in Table 3. The results are presented as relative gloss where the gloss of the stock has been subtracted from the gloss of the print. (Studies in our laboratories and elsewhere (Borchers, 1963) have shown that for papers of the same absorbency, print gloss varies linearly with paper gloss.) The optical densities of the signatures have not been included. Laboratory prints of these inks and papers, plus laboratory

Table 2

DENSITY VALUES

WATER PICK UP	ACID F.S.	ALKALINE F.S.
TOP UNITS		
	MAGENTA	
LOW	1.10	1.10
HIGH	1.06	1.16
	CYAN	
LOW	1.13	1.20
HIGH	1.16	1.27
	YELLOW	
LOW	0.79	0.72
HIGH	0.79	0.79
BOTTOM UNITS		
	MAGENTA	
LOW	0.84	0.79
HIGH	0.95	0.96
	CYAN	
LOW	1.03	1.04
HIGH	1.09	1.13
	YELLOW	
LOW	0.74	0.72
HIGH	0.76	0.77

Table 3

PRINT GLOSS RELATIVE
TO PAPER GLOSS

WATER PICK UP	ACID F.S.	ALKALINE F.S.
TOP UNITS		
	MAGENTA	
LOW	6	8
HIGH	12	14
	CYAN	
LOW	3	7
HIGH	8	10
	YELLOW	
LOW	-5	2
HIGH	8	11
BOTTOM UNITS		
	MAGENTA	
LOW	9	4
HIGH	10	8
	CYAN	
LOW	11	6
HIGH	9	6
	YELLOW	
LOW	5	0
HIGH	11	9

prints of other inks and papers, have resulted in an increase of no more than 10 gloss units per 1.0 densitometer units. Since the density of a given ink did not vary more than 0.40 (Table 2) from top to bottom units or from acid to alkaline fountain solutions, we would not expect the differences in density to account for more than 4 gloss units for the magenta, 2 units for the cyan, or 1 unit for the yellow.

We would consider two prints to be of equal gloss if they were within 6 gloss units (at 75^{o}). The results show that there is no significant change in gloss going from acid to alkaline fountain solution. The difference in gloss was never more than 6 units except for the lone case of the LWPU yellow on the top unit where there was a difference of 7 relative gloss units going from acid to alkaline fountain solution.

There is a trend with a slight increase in gloss going from low to high water pick-up inks although the only difference that could be considered significant is the yellows on the top unit using acid fountain solution and the yellows on the bottom unit using alkaline fountain solution. Table 4 lists the percent trap values. Two trap values were considered equal if they were within 5 percentages or less. The first item to note is that the fountain solutions had no effect on the percent trap values. For example, the percent traps of the low WPU inks were within 4 percentages of one another whether printed with acid or alkaline fountain solution.

The WPU of the inks had no effect on the traps when comparing high versus low WPU inks. The traps are equal except for the yellow/magenta trap on the top unit with the acid fountain solution; the magenta/cyan trap with the alkaline fountain solution; and the three traps on the bottom units with the alkaline fountain solution.

However, differences can be explained by the differences in the densities at which the traps were printed. Laboratory studies with these inks and papers have shown that when the density of the first down color is kept constant, the percent trap is relatively insensitive to any change in

Table 4

PERCENT TRAP RESULTS

WATER PICK UP	ACID F.S.	ALKALINE F.S.
TOP UNITS		
	YELLOW/MAGENTA	
LOW	52	52
HIGH	61	57
	YELLOW/CYAN	
LOW	77	80
HIGH	82	81
	MAGENTA/CYAN	
LOW	70	69
HIGH	71	77
BOTTOM UNITS		
	YELLOW/MAGENTA	
LOW	68	72
HIGH	63	61
	YELLOW/CYAN	
LOW	83	84
HIGH	78	77
	MAGENTA/CYAN	
LOW	69	72
HIGH	68	62

density of the second down color. For example, for a yellow/magenta trap, with the magenta kept constant at a density of 0.80, a trap with yellow printed to 0.61 has a percent trap of 85%, but a trap printed with yellow at 1.00 has a percent trap of 94%.

However, percent trap values are sensitive to changes in the density of the first down color when the density of the second down color is kept constant. For example, using the yellow/magenta trap with the density of the yellow kept constant at 0.70, a print with the magenta printed to 1.17 will have a percent trap of 13% whereas a print with the magenta printed to 0.68 will have a percent trap of 94% on the low IST paper.

The above explains why the three low WPU inks trapped better on the bottom units when one notices the differences in densities that the low and high WPU inks were printed (see Table 2). The difference in densities also explains why the high

WPU ink has a higher yellow/magenta trap on the top unit with the acid fountain solution. Overall, we can see no effect of the WPU or fountain solution on percent trap.

Conclusions

The joint research program by the S. D. Warren Paper Company and the Flint Ink Corporation has shown that:

A. Water setting for best performance on a press is increased with increased WPU of inks, with a decrease in IST of paper, and when using an alkaline fountain solution was opposed to an acid fountain solution.

B. The high WPU inks printed at an equal or slightly greater density than the low WPU inks.

C. The range from wash-out to scum was the same for low or high WPU inks when using either acid or alkaline fountain solutions (range of ± 5) although the setting for best performance was higher for the high WPU inks and the alkaline fountain solutions.

D. The fountain solutions had no effect on gloss, percent trap, or print quality as determined by visual observations.

E. The WPU of the inks had no effect on percent trap although the high WPU inks printed at a slightly higher gloss and slightly higher density.

F. Experimental design is applicable to commercial print trials. In future trials, we would recommend the use of commercially available materials for the high and low levels of the design as opposed to what can be made experimentally. Also, a design should be constructed in which the top and bottom units are not equal.

Literature Cited

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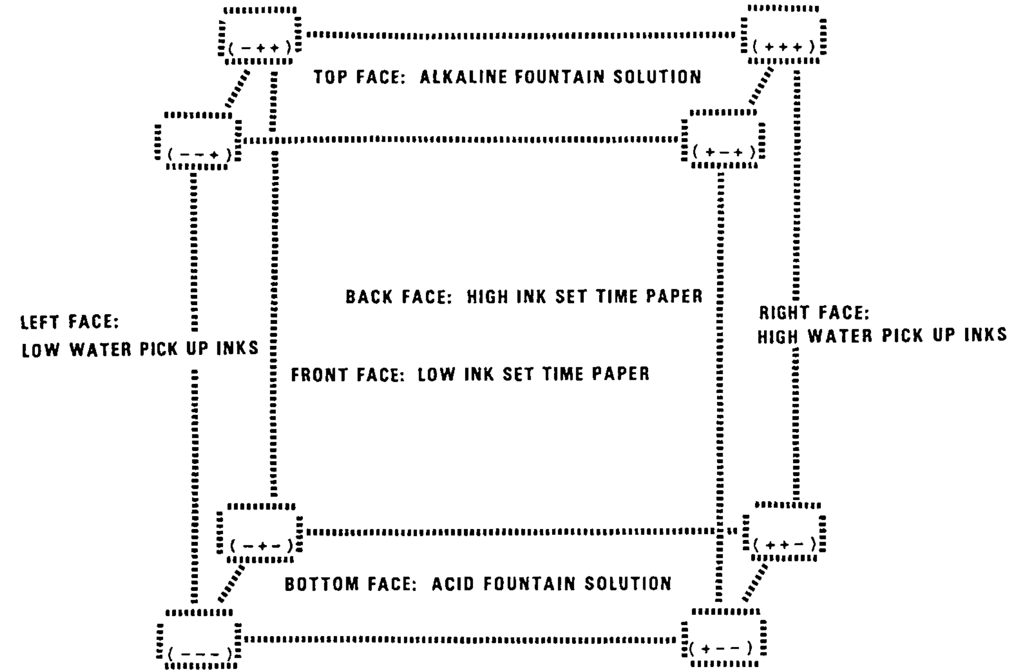

Figure 1. Graphic Representation of Experimental Design.

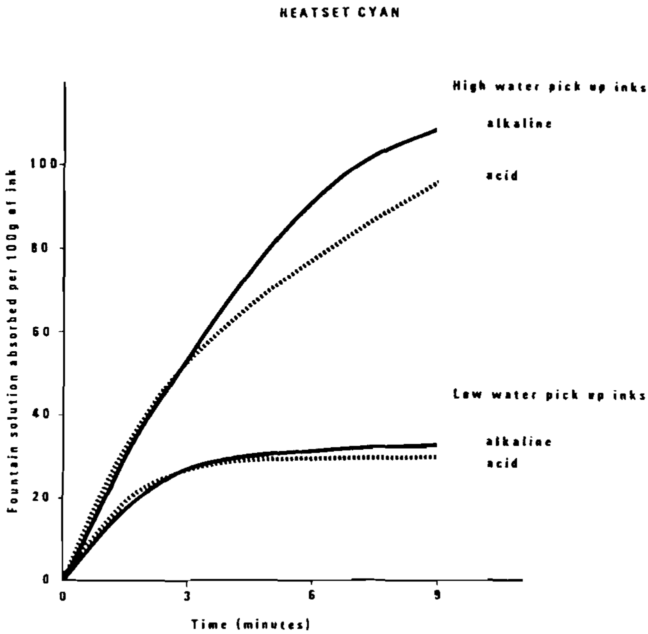

Figure 2
Emulsification Rates for the Cyans

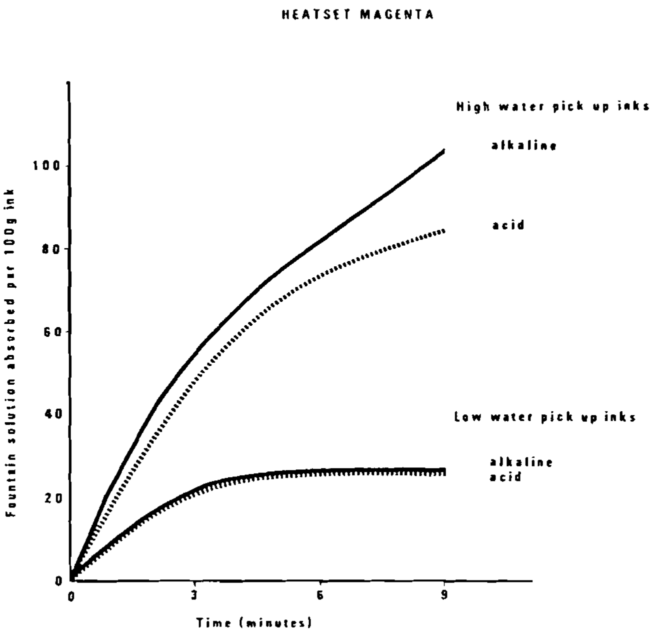

Figure 3
Emulsification Rates for the Magentas

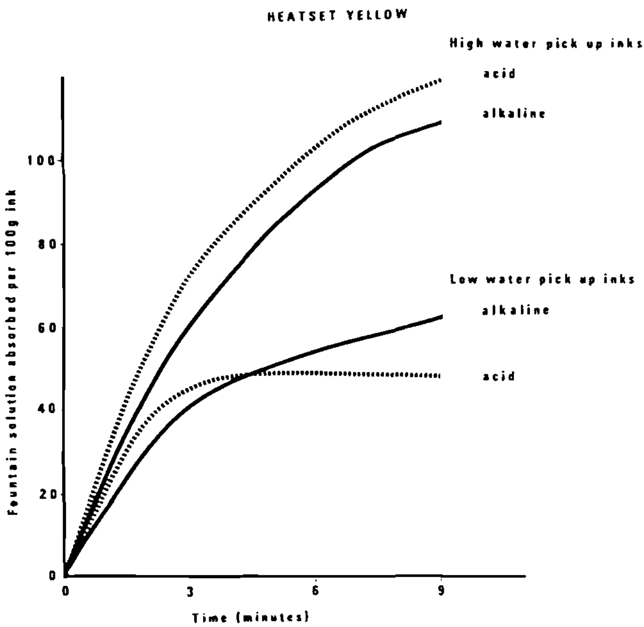

Figure 4
Emulsification Rates for the Yellows

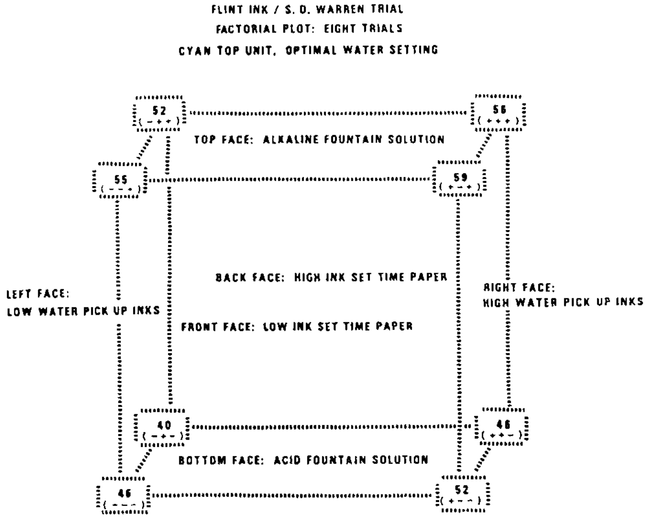

Figure 5
Water Settings for Optimum Performance,
Cyan Inks, Top Units

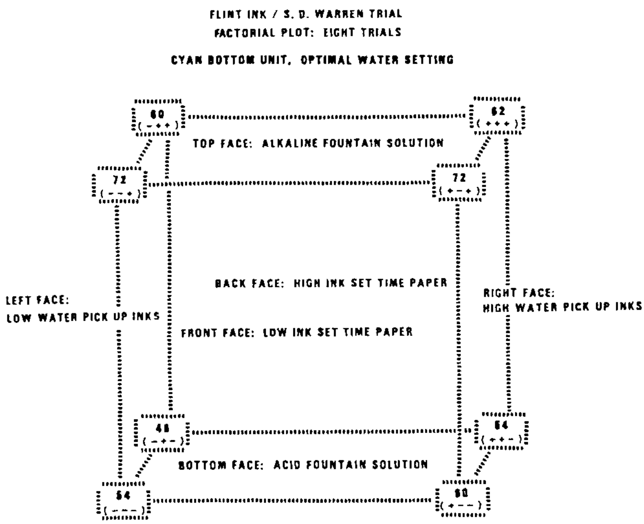

Figure 6
Water Settings for Optimum Performance,
Cyan Inks, Bottom Units

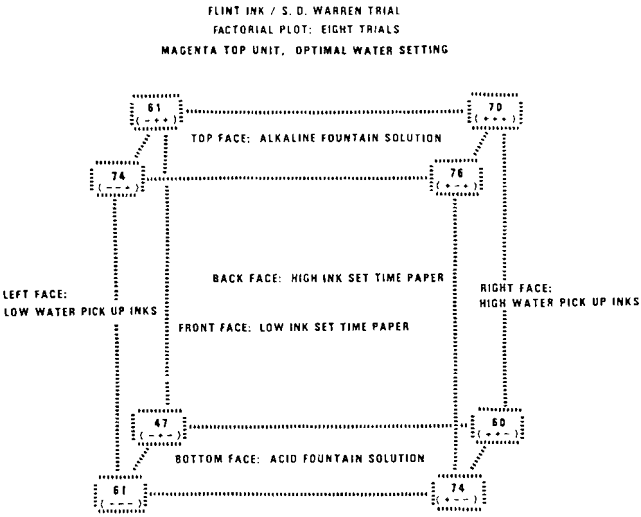

Figure 7
Water Settings for Optimum Performance,
Magenta Inks, Top Units

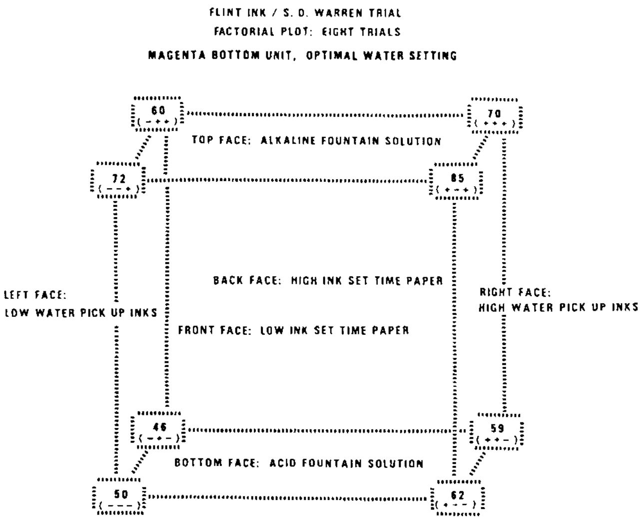

Figure 8
Water Settings for Optimum Performance,
Magenta Inks, Bottom Units