REAL-TIME RATES OF WATER PICKUP BY LITHOGRAPHIC INKS

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Abstract: A set of newsinks differing in lab-tested, water-pickup character, were press-tested using a scraped-form-vibrator, laboratory keyless inker. The ink was collected rather than recycled, allowing determination of single-revolution water-pickup rates.

Within a few revolutions (milliseconds), the inks picked up 6 to 12% water, inferring that obtaining ink/water balance (first acceptable copy) in lithography is not limited by the rate of water/ink mixing on-press. More likely, the limiting condition is the rate of wetting the printing plate, an inherently-slower phenomenon.

The initial water-pickup rates are in the range of about 300 to 500 percent per minute, which is many times higher than that generally predicted from bench-scale water pickup tests. Nevertheless, the water-pickup rates for this set of inks ranked similarly whether using the press-derived, millisecond-water-content values or the laboratory values derived from minutes of mixing.

BACKGROUND

In conventional lithographic printing, essentially all of the ink and water being fed to the press ends up on or in the paper (or inadvertently in the surroundings). Since most of the on-press ink exists in very thin films, few convenient ways exist to analyze the water content of the ink during printing.

Keyless inker configurations, with an ink-scraping doctor blade located close to the inking form-rollers, offer unique opportunities to study, for instance, the on-press rate of water pickup by the ink. When arranged to not recirculate the unused, scraped ink, which volume typically is about 8 to 12 times the volume of that going

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to the paper, it can be collected and studied as representative of one, two, or multiple passes (revolutions) through the inking system. Heretofore, one had to accept sampling the ink at an up-and-running or steady-state situation on-press, or else rely on laboratory tests, both of which involve long ink/water interaction times (minutes).

Accordingly, a set of black inks differing in water pick-up behavior were evaluated on a keyless lithographic configuration appropriate to this analysis concept.

EXPERIMENTAL APPROACH

Five inks were supplied by a major newsink manufacturer. These varied in laboratory-measured water-pickup properties but were based on a typical injector newslitho ink formulation. A standard injector newsink, from a second supplier, was used as a comparative control. Observations were made and recorded during press operation. Water contents, Laray flow-times, and printed optical densities were measured subsequently.

Test Press - The 10 side of an Urbanite press was used, equipped with injector ink feed and direct-to-plate sock dampening. The copper ink-vibrator drum nearest the printing plate was fitted at 30° angle with a reverse doctoring blade of 0.008 inch steel. The configuration is diagrammed schematically in Figure 1. The unit was run slowly, 15,000 iph, to allow time for viewing ink and water responses. The ANPA test pattern of Appendix I was used as the test format.

Press rollers, blankets, and cylinders were set according to standard procedures and not varied for the duration of the test. Dampening solution was Flint V2020 at 1-1/2 oz. per gallon of deionized water. The ink identities are given in Table I.

Ink was fed to the injector unit from a pressurized canister. The injector was set to deliver equal ink quantities across the press at about 1.05 printed optical density. This requires several times the feed rate called for with conventional lithography. The scraped ink was collected in a cross-press catch-pan and scraped by hand into a container from which it was pumped back into the canister prior to starting the next cycle. The dampener setting was maintained at the just-above-scum condition.

FIGURE 1

SCHEMATIC OF 10 SIDE OF LAB URBANITE KEYLESS INKER COUPLE

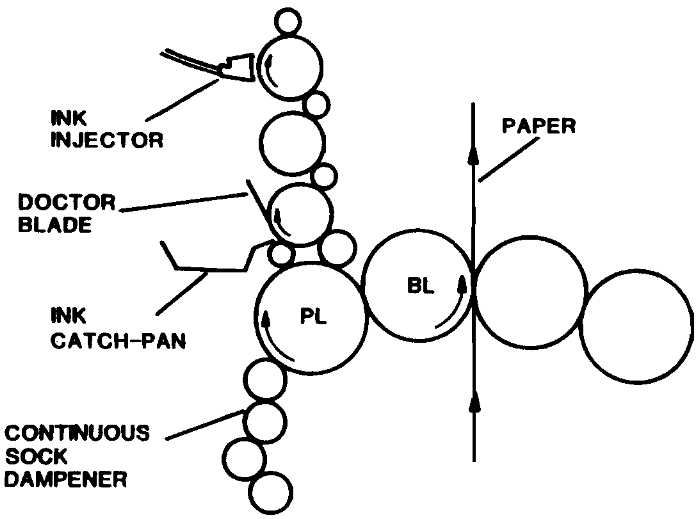


TABLE I. BLACK NEWSINK IDENTITIES

Ink Test Code	Manufacturer's Identification	
A	R-164-7-12-1)	
B	R-164-7-12-2)	
C	R-164-7-12-3)	Supplier I
D	R-164-7-12-4)	
E	R-164-7-12-5)	
F	CKK330-T6	Supplier II

Test Procedure - The plan was to run Ink F as an internal comparative control both before and after running the test set of five inks. However, we were able to run this ink subsequent to the test set only, about one week later. The actual times and sequence of the various runs are summarized in Table II.

TABLE II. PRINT TESTING SEQUENCE

Date/Time		Ink Number
8/9	AM	A
8/9	PM	C
8/10	AM	E
8/10	PM	B
8/11	AM	D
8/17	AM	F

The printing-test procedure is given in Appendix II. The first print cycle in each case involved about 6,000 impressions; the second cycle 4,000 to 5,000 impressions; the third cycle 3,000 to 4,000 impressions. More of Ink F was available in the pressroom, consequently, the print cycles are somewhat longer.

RESULTS AND OBSERVATIONS

Ink-performance observations are ranked in Table III.

TABLE III. QUALITATIVE OBSERVATIONS DURING PRINT TESTS[a]

Solid Print Area Optical Density	Appearance[b]	Free Water In Catch Pan	Dampener Setting
F	Smooth	E	B (44)
A	Some streaks		E (42-44)
D	Smooth	C, B, D	C (42)
B	Smooth		D, F (40)
C	Smoother than A	A	
E	Smooth, washed-out	F	A (38)

a. All ranked qualities are listed in descending order from highest or most to lowest or least.
b. Not a ranked quality.

Ink Analyses - Water contents of the ink before printing and at each printing cycle were determined using the Dean-Starke toluene co-distillation procedure. The results are summarized in Table IV. These data are considered accurate to about 0.5 ml, provided that our press-side ink sampling procedure is that accurate.

TABLE IV. WATER CONTENTS OF TEST INKS DURING KEYLESS PRINTING

	Measured Water Contents of Ink (ml/100gm)					
	A	B	C	D	E	F
Before Test	2	2.5	2	2.5	3	0
After Cycle 1	6	8	7	9.5	9	6
After Cycle 2	7	10	9	13	11	8
After Cycle 3	8	14	11	14	15	10

If interested in water pickup rates for each cycle, one must subtract the starting water contents, as summarized in Table V.

TABLE V. APPARENT WATER PICKUP RATES OF TEST INKS DURING KEYLESS PRINTING CYCLES

	Water Pickup (ml/100gm)					
	A	B	C	D	E	F
Cycle 1	4	5.5	5	7	6	6
Cycle 2	1	2	2	3.5	2	2
Cycle 3	1	4	2	1	2	2

The data can also be viewed as the total press-added water content at the end of each printing cycle, Table VI.

TABLE VI. APPARENT WATER PICKUP BY TEST INKS AFTER 1, 2, and 3 CYCLES OF KEYLESS PRINTING

	Water Pickup (ml/100gm)					
	A	B	C	D	E	F
Cycle 1	4	5.5	5	7	6	6
Cycle 2	5	7.5	7	10.	8	8
Cycle 3	6	11.5	9	11.5	12	10

Dwell time within two 5/32 inch form-roller stripes, for 3 1/4 inch diameter form-vibrator rollers running at 15,000 iph is about 0.008 sec per impression, or 0.015 sec per revolution, therefore 0.015 sec per cycle.

$$\frac{2 \text{ stripes} \times 5/32 \text{ in}}{3.25 \text{ in} \times 3.14} \times \frac{3600 \text{ sec/hr}}{15{,}000 \text{ iph}} \times \frac{2 \text{ imp}}{\text{revolution}}$$

Observations from the Tables IV through VI data are:

1. Despite the short dwell-times at the two form-roller stripes, during which water and ink transfer take place, three cycles (three press revolutions) allowed apparent water contents as high as 15%.

2. All of the inks increase in apparent water content as the number of printing cycles increase.

3. All of the inks pick up the largest amount of water during the initial printing cycle (first revolution on press). Subsequent water pickup rates are always lower than for the first cycle. However, the third-cycle rate may or may not be less than that for the second cycle.

4. Three of the inks pick up water fastest and essentially equally, within three revolutions, Inks B, D, and E; two have slightly lower rates, Inks C and F; one, Ink A, has a clearly lower water pickup rate.

Viscosities of the inks were run at laboratory temperature both before and after printing, using a modified Laray viscometry procedure. Results are given in Table VII in terms of fall time for the Laray rod at two different shear rates (loads) for each ink. Although this shortened, two-value procedure cannot be used to calculate the usual yield value and high-shear-viscosity parameters, these data are useable for general comparisons within the set. It should be noted that the before and after sets were run on different days with the ambient temperature being significantly different (2 to 5°C) on those two days. Accordingly, the Table VII results must be viewed with caution.

TABLE VII. RELATIVE VISCOSITY NUMBERS FOR TEST INKS

Ink	Before Print Tests		After Print Tests	
No.	130g*	230g*	130g*	230g*
F	6.4 $\pm$0.4	2.9 $\pm$0.2	9.4 $\pm$0.5	4.4 $\pm$0.5
D	5.5 $\pm$0.3	2.6 $\pm$0.1	5.0 $\pm$0.1	2.6 $\pm$0.2
C	4.2 $\pm$0.2	2.2 $\pm$0.1	4.8 $\pm$0.3	2.3 $\pm$0.3
E	4.1 $\pm$0.3	1.7 $\pm$0.2	3.6 $\pm$0.3	1.7 $\pm$0.3
A	3.3 $\pm$0.4	2.7 $\pm$0.1	3.6 $\pm$0.5	2 $\pm$0
B	3.1 $\pm$0.7	1.0 $\pm$0.1	3.8 $\pm$0.2	1.7 $\pm$0.3
Temperature	26 to 27°C		22 to 25°C	

*Rod Loading

The rheology data indicate the following:

1. Viscosity ranks for the as-received inks, highest to lowest are:

1.	Ink F
2.	Ink D
3, 4.	Ink C, E
5, 6.	Inks A, B

2. Only Ink F exhibits significant change due to pickup of water, that being an increase in resistance to flow. The rest of the inks show little or no effect, within our experimental error.

3. The different response of the Ink F from that of the Supplier I inks (Inks A through E) is consistent with, if not related to, the fact that Ink F from Supplier II ink has no water in it initially. All of the Supplier I inks have 2 to 4% water, as-received.

Printed Optical Densities - Densitometer readings were made in triplicate within the large solid circle on each printed page, using three consecutive sheets to obtain an average optical density value. The average OD values varied little as a function of copy count during a given printing cycle, excepting during the first 500 to 1,000 copies (Appendix III). This variation probably corresponds to the printing system adjusting for an ink change and were not included in the OD analysis.

TABLE VIII. PRINTED SOLID BLACK OPTICAL DENSITIES AS FUNCTIONS OF NUMBER OF PRINTING CYCLES

Ink	Cycle 1	Cycle 2	Cycle 3	Cycle 1 to Cycle 3 Change
F	1.12 ±.01	1.07 ±.01	1.05 ±.01	-0.07
D	1.07 ±.00	1.02 ±.01	1.01 ±.00	-0.06
A	1.04 ±.01	1.02 ±.01	1.01 ±.01	-0.03
B	1.01 ±.01	0.97 ±.00	0.95 ±.01	-0.05
C	0.96 ±.01	0.95 ±.00	0.91 ±.01	-0.05
E	0.95 ±.00	0.84 ±.03	0.77 ±.02	-0.18

These data, summarized as Table VIII, exhibit the following characteristics.

1. First-cycle printed optical densities varied with ink type. In order of highest to lowest OD are F, D, A, B, C, E. The most dense prints were made by the most viscous inks, F and D.

2. The printed optical densities declined in successive cycles for all inks. This is coincident with successively increasing water content.

3. Ink E is significantly different from the rest in that its optical density change due to recycling is more than twice that of the others. As noted in Table III, this ink also had the largest amount of observed free water in the catch pan while running on-press. It also required the highest dampener setting to print scum-free.

4. Ink A had the smallest OD change during the three cycles and also had the lowest dampener setting (Table III).

ANALYSIS OF PRINTED SAMPLES

Printed copy when using inks B, C, and E have streaks that are indicative of excess water. Inks A, D, and F had no water streaks, had the highest print density (Table VIII), and had generally-acceptable print quality.

Inks B, C, and E have the lowest laboratory-measured water pickup capability; inks A, D, and F had the highest, Figure 2. A tentative conclusion from this apparent correlation is that a successful ink in this particular keyless inking configuration must have an ultimate lab-value water pickup of about 80% or higher--otherwise excess water will appear in the printed result.

One would expect a similar correlation to appear during the three-cycle-printing reported here. Reference to Figure 3 will verify this is not the case. However, the initial rates of water pickup by the inks on-press are not necessarily directly related to the inks' ultimate water pickup value as measured in the laboratory. Possibly initial rates are controlled by wetting and diffusion phenomena rather than by the exact chemical nature and concentration of added wetting agents, that is, by kinetic rather than thermodynamic factors.

FIGURE 2

LABORATORY-MEASURED WATER PICKUP RATES OF INKS A THROUGH F

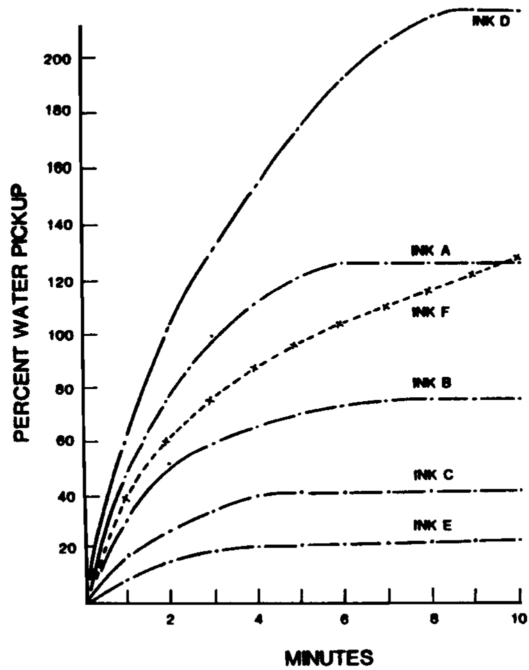
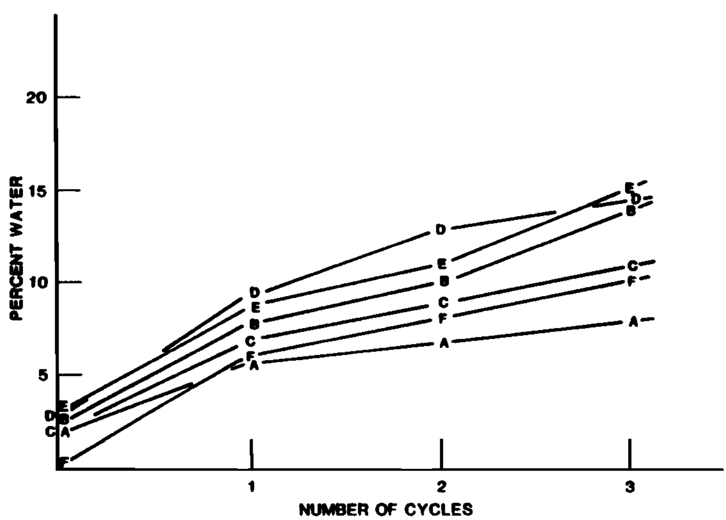


FIGURE 3

WATER CONTENTS DURING THREE KEYLESS INKING CYCLES. INKS A THROUGH F

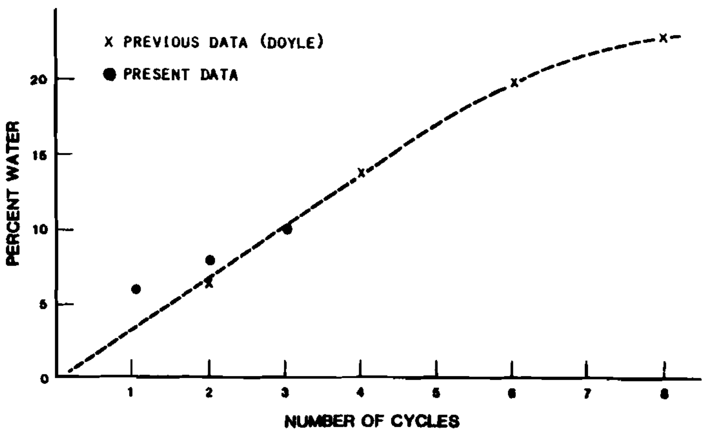


DISCUSSION OF RESULTS

The Ink F water pickup data can be compared with previous, more-extensive data that was obtained similarly, but at at 20,000 iph. Figure 4 is a plot of measured percent water-pickup on press versus number of times the ink was recycled. The first-cycle value from this work is high compared with the extrapolated value from the previous work, 6% versus about 3%. However, the correspondence between these two independent data sets is quite good. The straight-line portion of Figure 4 (first four cycles) corresponds to a water pickup rate of about 500 percent per minute (20,000 imp/hr press speed is 333 imp/min; 3% water pickup in one cycle, two impressions, is 3 x 333/2 percent per minute).

FIGURE 4

WATER CONTENTS OF INK F DURING KEYLESS INKING



Another way of evaluating these data is to compare the laboratory-measured water-pickup rates with those obtained here. The former were obtained from Supplier I and are shown in Figure 2. Using Ink F as an example, the <u>initial</u> water-pickup rate is about 39 percent per minute (Figure 2 first value is 39%) versus the Figure 4 value of about 500 percent. It should be noted that the Figure 2 Ink F data involved Rycoline alkaline dampening solution rather than Flint alkaline.

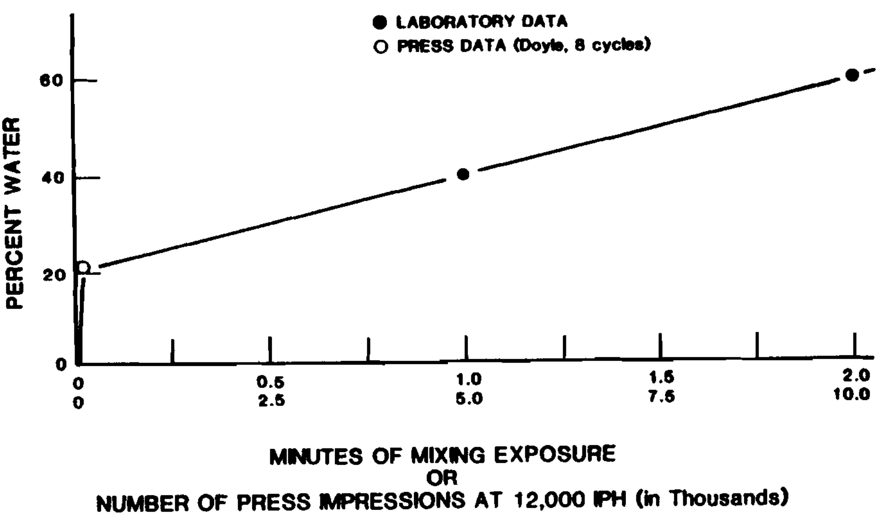
The Table IV water-pickup results, plotted in Figure 3, illustrate minor differences among the six inks but also illustrate that initial water pickup rates for all these inks are in the same range as the Ink F, about 300 to 500 percent per minute.

There are at least two possible explanations for the high water-pickup rates observed here, compared with typical laboratory measurement of the same inks.

1. If the initial (milliseconds) high water-pickup capability is real, typical laboratory water-pickup curves below about two minutes would be similar to the Figure 5 schematic, rather than to Figure 2. If this is the case, standard laboratory procedure values are meaningless when applied to a keyless inking operation, where ink dwell times on-press may be considerably shorter than that for conventional lithography.

FIGURE 5

FITTING OF ON-PRESS AND OFF-PRESS INK/WATER MIXING DATA



Despite this conclusion, the fit of our millisecond data to the Supplier I one-minute and longer data is remarkably good, as demonstrated in Figure 5. Our initial water-pickup rates correspond, essentially, to a linear extrapolation of the short-time laboratory mixing data to zero time .

2. The press system forces dampening solution onto the scraped drum of the Figure 1 configuration by way of the printing plate and form rollers. If the ink on this form vibrator (the scraped roller), cannot pick up water as fast as our nominal values indicate, it follows that we were actually scraping-off ink at lower water content than our measurements infer, along with free water that was present on the ink film.

Small amounts of free water was observed in the catch pan during these runs, the amounts depending upon which ink was being run. We have no way of knowing whether the water existed as free water on the vibrator roller before it reached the scraping blade.

Comparing the qualitative free-water observations, Table III, with the limiting extents of water-pickup from Figure 2, one finds a reasonably good correlation, Table IX. In fact, if inks A and D values (or labels) had been inadvertantly reversed (by the ink supplier or by us), the correlation would be excellent. Ink F has no limiting-water-pickup value and in these tests showed little or no free water in the catch pan.

All of these factors indicate that water-pickup using the first few cycles in scraped, keyless inking systems qualitatively correlates with laboratory-derived rates represented by curves such as Figure 2. Obviously, the absolute values differ markedly.

Optical densities of the prints were remarkably sensitive to increasing water contents accompanying successive cycles (Table VIII). Although the rheology data is minimal, the very small viscosity changes due to increasing water in the Supplier I inks, infers that these optical density decreases are due to dilution effects of water, rather than to rheologically-controlled ink-transfer effects (Ink E is a possible exception because of the larger amount of free water observed at the catch pan).

TABLE IX. OBSERVED FREE WATER VERSUS MEASURED WATER PICKUP CAPABILITY

Free Water In Catch Pan[a]	Water Pickup Tendency[b]
E	E
	C
C, B, D	B
	A
A	D
F	F

a. Relative rank, most to least.
b. Relative rank, least to most.

There is a general correlation between optical density loss over three cycles and the water content increases of the inks, Table X. With the exception of Ink F, which had no initial water content, the printed optical density changes also correlate qualitatively with total water content.

TABLE X. OPTICAL DENSITY LOSS VERSUS WATER GAIN

Ink No.	Printed Optical Density Change[a]	% Water Picked Up[b]	% Water Content[c]
E	-0.18	12	15
F	-0.07	10	10
D	-0.06	11.5	14
B	-0.05	11.5	14
C	-0.05	9	11
A	-0.03	6	8

a. From Table VIII for 3 cycles.
b. From Table VI at 3 cycles.
c. From Table IV at 3 cycles.

These general optical density/water-pickup correlations infer that the free water observed in the ink catch-pan came from shear-separation of water from the ink rather than from existence of a separate, temporary water film on the vibrator just prior to the scraping blade.

TENTATIVE CONCLUSIONS

1. Sampling of scraped ink in keyless lithographic configurations is an effective technique for comparing real-time water-pickup rates of inks. We need yet to accurately differentiate between water that has been press-mixed into the ink and free water carried by the ink.

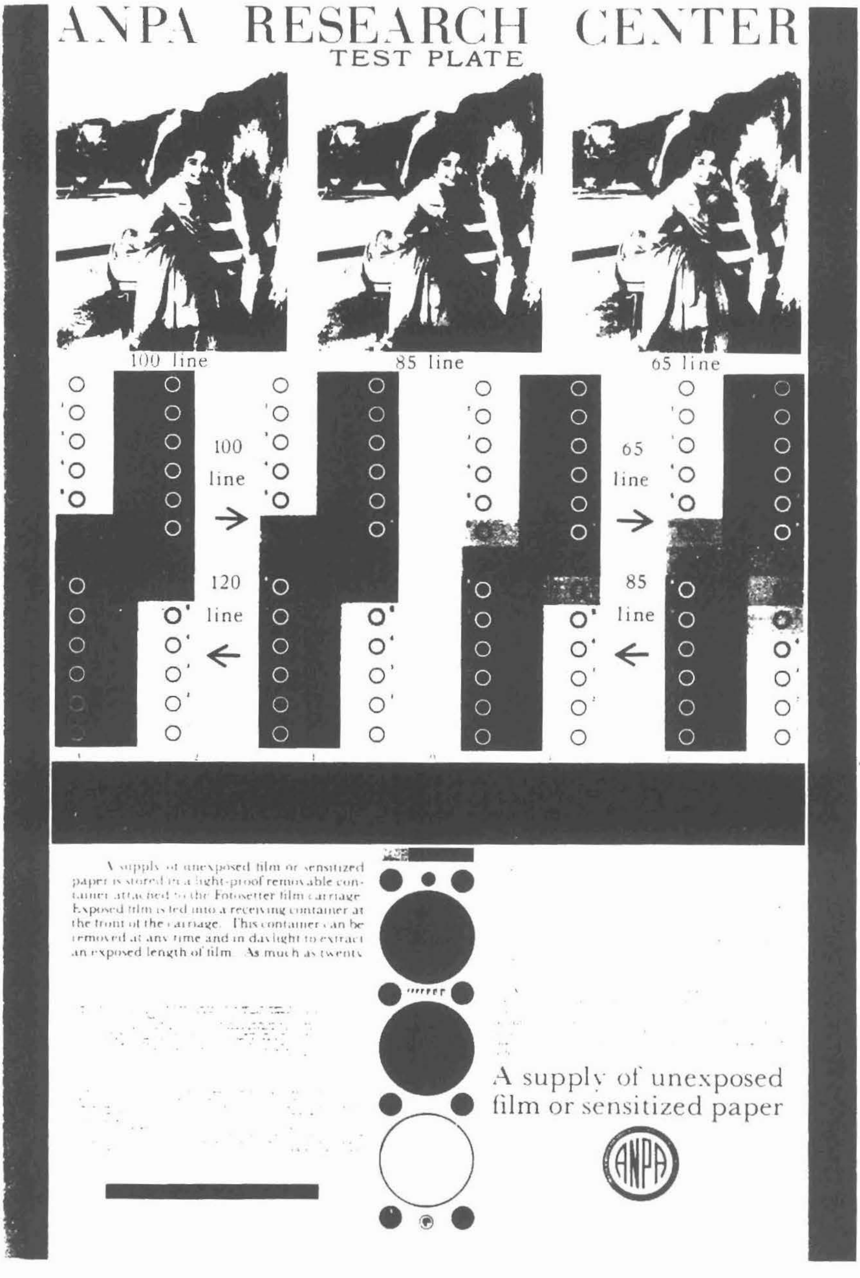
2. Inks can pick up about 6 to 12% water within several press revolutions. This corresponds to 300 to 500% per minute water-pickup rates.

3. The water-pickup rates observed here are many times greater than that inferred by laboratory mixing tests; but for ranking this series of differing inks the two methods correlate well.

4. The high water-pickup rates infer that obtaining ink/water balance on press is not limited by the rate of ink/water mixing, rather, the limitation may be the time required to differentially wet the printing plate.

5. Further research of this kind is needed. We expect that optimum requirements for keyless lithographic inks will be different than those for conventional lithography. And, the keyless inker configuration allows insights into lithography not readily available using conventional press configurations.

APPENDIX I
ANPA TEST PATTERN



APPENDIX II
PRINTING TEST PROCEDURE

1. The ink in the shipping container (25 lb.) was mixed with a motorized stirrer. A c 2 lb. reference sample was retained for analysis.

2. About one pound of ink was run through the recycle pump to purge it of previous ink.

3. The ink was transferred to a clean ink-injector pressure canister. It was noted that 22 lb. of ink corresponded to about 3/4 full.

4. The injector pumps were set using the first ink by setting to a printed solid value of 1.05 ±0.05 ODU cross-press. The injectors were not varied during the balance of testing all six inks.

5. Dampening for each ink was set and retained at the minimum dial setting that resulted in a clean non-image area, just above the scumming condition.

6. The first 750 prints during a print cycle were used to purge the previously used ink from the ink-feed system. The counter was then reset to zero.

7. Printed samples were pulled at 300 and 1,000 impressions, and every thousand thereafter during each cycle.

8. Cycle 1 for each ink corresponds to running to a near-empty canister (22 lb.). Some ink was left in the canister to avoid air in the feed lines.

   At the end of cycle 1, the scraped-ink catch pan was drained into the pumping reservoir, where the scraped ink and free water, if any, were remixed using a motorized mixer. A small sample was removed for subsequent water-content measurement.

10. The mixed cycle-1 ink was pumped back into the injector supply canister to begin cycle 2.

11. Cycle 2 was run in a manner similar to cycle 1.

12. A third cycle was run and the remaining ink discarded.

APPENDIX III. PRINTED OPTICAL DENSITIES[a,b]

Ink A	Cycle 1	Cycle 2	Cycle 3
300 imp.	-	1.05 ±0.03	0.99 ±0.03
1,000	-	1.06 ±0.05	1.02 ±0.03
2,000	1.03 ±0.02	1.01 ±0.04	1.00 ±0.02
3,000	1.04 ±0.04	1.03 ±0.03	1.02 ±0.03
4,000	1.06 ±0.02	1.03 ±0.03	
5,000	1.06 ±0.03		
6,000	1.05 ±0.04		
6,500	1.04 ±0.03		
Ave.	1.04 ±0.01	1.02 ±0.01	1.01 ±0.01

Ink B	Cycle 1	Cycle 2	Cycle 3
300 imp.	0.81 ±0.05	1.01 ±0.02	0.96 ±0.02
1,000	0.97 ±0.02	0.99 ±0.03	0.96 ±0.02
2,000	1.00 ±0.02	0.97 ±0.04	0.94 ±0.03
3,000	1.00 ±0.02	0.98 ±0.03	0.95 ±0.03
3,700	-	-	0.97 ±0.03
4,000	1.01 ±0.03	0.97 ±0.02	
5,000	1.02 ±0.03	0.97 ±0.03	
6,000	1.03 ±0.03		
Ave.	1.01 ±0.01	0.97 ±0.00	0.95 ±0.01

a. Averages exlude the data at less than 2,000 imp.
b. Each value represents 18 data points.

APPENDIX III. PRINTED OPTICAL DENSITIES (continued)

Ink C	Cycle 1	Cycle 2	Cycle 3
300 imp.	0.99 ±0.03	0.96 ±0.03	0.94 ±0.03
1,000	0.95 ±0.03	0.94 ±0.02	0.95 ±0.03
2,000	0.95 ±0.03	0.94 ±0.02	0.91 ±0.03
3,000	0.97 ±0.03	0.95 ±0.03	0.92 ±0.04
4,000	0.95 ±0.02	0.95 ±0.02	
5,000	0.96 ±0.03		
6,000	0.95 ±0.03		
Ave.	0.96 ±0.01	0.95 ±0.00	0.91 ±0.01

Ink D	Cycle 1	Cycle 2	Cycle 3
300 imp.	0.95 ±0.02	1.07 ±0.02	1.00 ±0.02
1,000	1.05 ±0.03	1.05 ±0.04	1.02 ±0.02
2,000	1.07 ±0.03	1.01 ±0.03	1.01 ±0.02
3,000	1.06 ±0.02	1.01 ±0.03	1.01 ±0.02
4,000	1.07 ±0.03	1.01 ±0.03	
5,000	1.07 ±0.02	1.05 ±0.02	
6,000	1.09 ±0.01		
6,800	1.07 ±0.03		
Ave.	1.07 ±0.00	1.02 ±0.01	1.01 ±0.00

APPENDIX III. PRINTED OPTICAL DENSITIES (continued)

Ink E	Cycle 1	Cycle 2	Cycle 3
300 imp.	0.82 ±0.08	0.98 ±0.05	0.93 ±0.04
1,000	0.92 ±0.03	0.90 ±0.03	0.82 ±0.07
2,000	0.95 ±0.02	0.90 ±0.04	0.81 ±0.02
3,000	0.95 ±0.03	0.85 ±0.04	0.76 ±0.04
3,700	-	-	0.75 ±0.15
4,000	0.95 ±0.02	0.81 ±0.05	
5,000	0.94 ±0.02	0.83 ±0.06	
6,000	0.95 ±0.02		
Ave.	0.95 ±0.00	0.84 ±0.03	0.77 ±0.02

Ink F	Cycle 1	Cycle 2	Cycle 3
300 imp.	0.86 ±0.03	1.11 ±0.03	1.03 ±0.03
1,000	0.94 ±0.12	1.10 ±0.01	1.06 ±0.03
2,000	1.10 ±0.04	1.07 ±0.02	1.05 ±0.01
3,000	1.10 ±0.02	1.06 ±0.00	1.06 ±0.02
4,000	1.13 ±0.00	1.06 ±0.02	1.04 ±0.04
5,000	1.11 ±0.02	1.06 ±0.05	
6,000	1.10 ±0.04	1.09 ±0.03	
7,000	1.13 ±0.01		
8,000	1.12 ±0.02		
8,600	1.13 ±0.01		
Ave.	1.12 ±0.01	1.07 ±0.00	1.05 ±0.01