Some Insight Into the Relevance of Off-press Measurements of Fountain Solution Take-up by Ink

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Abstract: A printing problem of excessive blanket piling in the image areas on a web press was investigated by conducting off-press measurements of fountain solution taken up by ink. The ink-fountain solution combinations tested included those that performed badly and those that eliminated the problem. Three different type measurements were made. The first, originally suggested by Surland, utilized a Duke tester, while the second, utilizing a litho break tester, was one suggested by Tasker, et al. The third, observing the effect of mixing some of the combinations in a laboratory ultrasonic cleaner, was suggested by Blom. Data is presented to show to what extent the three types of measurements correlate with each other and with the on-press problem of excessive image area piling. The data is also analyzed to determine whether ink or fountain solution was the controlling factor vis-à-vis the problem encountered.

Introduction

A long-sought objective of lithographic researchers has been to perfect a laboratory test of the interaction of ink and fountain solution that would correlate and thus predict on-press performance. The very limited success achieved to date in this regard can be attributed to a number of reasons. While perhaps not the most important, one such reason is the paucity of well-documented side-by-side on-press failures and successes, together with samples of the materials causing them.

Early in 1996, a printing problem was encountered with a heatset web book press, newly installed in a pressroom that included several existing web

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presses. The problem, one of excessive blanket piling in the non-image areas, was unique to the new press. In the course of assisting the printer to solve this problem, the writer was able to obtain samples of the two different combinations of ink and fountain solution that were used during the period when the problem was experienced, and the two different combinations that resulted in the elimination of the problem.

The purpose of this paper is to present the results of various laboratory tests run on twelve different combinations of these samples, and to show the degree to which the results correlate with each other and with on-press performance.

Background Information

Three different types of laboratory tests have been advanced for assessing the interaction of ink and fountain solution. The first type, proposed by Surland, involves stirring ink and fountain solution together in a mechanical mixer and measuring the amount of fountain solution emulsified into the ink versus time (Surland, 1967). This water take-up test is sometimes referred to as the Duke test, after the manufacturer of the mixer in current use. According to Surland's teaching, the important parameter is "a"; what he called the water balance time, and appeared to define as the time at which saturation is reached, as shown in Figure 1 (Surland, 1980). In one series of press tests he was able to correlate the margin between maximum and minimum allowable water settings to "a", for values of "a" up to 6 minutes. Currently, the figure of merit, or indicator of performance, is generally taken as grams of water take-up per 100 grams of ink (in percent) after five or ten minutes of mixing (ASTM, 1989).

During the 1980s, numerous investigators lent support to Surland's method by reporting some correlation between its results and on-press performance (Cuzner, 1984; Bassemir and Shubert, 1985; Fadner, 1987; Dawley, 1988; and Peters, et al, 1990). The widespread use of this test led to the preparation of the previously referenced ASTM procedure for conducting it.

There were also criticisms of the test on the grounds that correlation with on-press performance was, in fact, very poor or non-existent (Flint, 1985). This difference of opinion appears to have been resolved in favor of the critics, because today there is little support in the industry for the Surland type test.

Another objection to the Surland test not raised previously, is that the time of the test, five to ten minutes, is long compared to actual ink residence time on the rollers of a press, except for conditions of extremely light ink coverage. That is, from calculated curves of ink residence time versus ink coverage, for typical presses (MacPhee, 1995), it is seen that on-press ink residence times are about 200 plate cylinder revolutions for an ink coverage of 6 percent, and less for higher coverages. The 200 plate cylinder revolutions are equal to a one minute residence time at a speed of 12,000 impressions per hour,

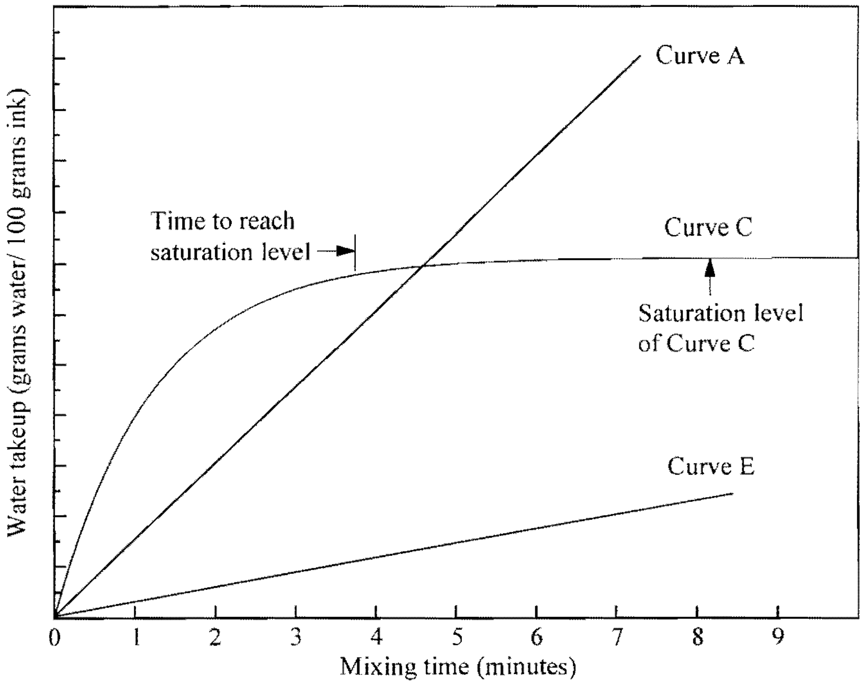

Figure 1 Examples of water take-up curves (Surland, 1980). Curves A and E invariably indicate poor performance on press according to Surland. Inks with curves like C exhibit wide water balance on press and are easy to run. Important parameter of Curve C is "a", time to reach saturation, rather than water take-up at that time, i.e. saturation level.

and a 24 second residence time at 30,000 impressions per hour.

The second type of test, advanced by Tasker, involves preparing a water-in-ink emulsion on a litho break tester and assessing the change produced in the plastic viscosity and yield value of the ink by emulsification (Tasker et al, 1983). The underlying premise is that a properly formulated ink will perform well on press if its flow characteristics, represented by plastic viscosity and yield value, are not changed drastically by water take-up. The litho break tester was selected to produce the emulsion on the rationale that it better simulates the emulsifying action produced on press. Despite the sound reasoning behind it, and a demonstration by the originator of its ability to predict on-press performance, this test method has received very little attention from the industry.

A third type of laboratory test for assessing ink and fountain solution interaction was proposed recently in connection with the investigation of a printing problem that also involved blanket piling in non-image areas (Blom, 1996). This test involved mixing small amounts of ink (0.2 grams) with 10 cc of fountain solution in a laboratory ultrasonic cleaning bath and observing the degree to which ink became dispersed in fountain solution. It was based on the rationale that the source of the non-image area piling was ink dispersed or emulsified in fountain solution. Unfortunately, the on-press performance data available to Blom was insufficient for assessing correlation with this test.

Description of the Problem and Its Resolution

The problem in question, excessive non-image area piling on a newly installed press, was well-defined because blankets had to be washed every 7-8000 impressions, versus 60,000 or more impressions on the existing presses that used the same inks, papers, plates, and fountain solution. The piling appeared to be ink, but analysis indicated it contained components from both ink and paper. Other details on the problem were as follows:

1. Inks from two different suppliers, referred to here as inks A and B, were in routine use, and no differences were noted in the problem when running one ink versus the other. The viscosities and yield values of these inks are given in Table I.

Table I Properties of heatset inks tested. Bad performance on press indicates excessive non-image area blanket piling.

Ink	Performance on press	Plastic viscosity	Yield
A	Bad	149 poise	2,374 dynes/cm^2
B	Bad	152 poise	2,355 dynes/cm^2
C	Good	62 poise	3,344 dynes/cm^2
D	Good	67 poise	2,537 dynes/cm^2

2. The fountain solution used, referred to here as Fountain Solution 1, was identical to that used on the older presses. It consisted of a one part concentrate mixed in a proportion of 2.5 ounces per gallon of water.

3. When piling built up, the tops of letters in printed text tended to disappear, especially with coated stocks.

4. Piling was the same on both upper and lower blanket cylinders.

5. There was no apparent relationship to time-of-day, season, or operating personnel.

6. When running uncoated stock, a snaky pattern through screens was sometimes observed.

7. Piling extended to blanket areas not contacted by the web.

8. The snapping noise, due to blanket release, was much louder than on other presses, and loudest when running coated stock.

The problem existed for several months, and during that time, all of the pertinent press settings were checked, such as roller stripes and cylinder packings, to insure that they were within specifications.

The problem was solved as a result of contacting another printer who had experienced a similar problem on the same model press. He discovered that the problem was related to the choice of ink and fountain solution, and solved it by switching to a combination referred to here as Ink C and Fountain Solution 2R. This fountain solution comprised two parts: a gum and etch mixed in a proportion of 4 ounces per gallon of water, and an alcohol replacement mixed in a proportion of 2 ounces per gallon.

When this same combination was tried on the press in question, the problem of excessive non-image area piling immediately went away. Specifically, the allowable interval between blanket washes rose to 60-70,000 impressions.

At some later date, a fourth ink, referred to here as Ink D, was tried with Fountain Solution 2A, and this ran successfully as well. The viscosities and yield values of Inks C and D are also given in Table I for comparison.

Laboratory Test Results

The three types of laboratory tests described earlier were carried out on twelve combinations of the inks and fountain solutions in question. Eight combinations were derived from the four inks and two fountain solutions used on press. The balance of four combinations comprised the four inks and the gum and etch part of Fountain Solution 2R, i.e. Fountain Solution 2R without the alcohol replacement part. This is referred to here as Fountain Solution 2, and was included to enable an assessment to be made of the effect of the alcohol replacement component in Fountain Solution 2R.

The Duke water take-up measurements were made at GATF's ink laboratory under the direction of Brad Evans. The tests utilizing the litho break tester were performed in the R & D laboratory of INX International Ink Co. under the direction of Bill Tasker, and the ultrasonic mixing tests were done in the Central Research laboratory of Mead Corporation under the direction of Bruce Blom.

Table II presents a summary of the various measurements made during laboratory tests aimed at providing an assessment of the effects of water on ink performance. A review of these results shows the following:

1. For three of the inks, A, B, and D, Duke water pickup decreased in going from Fountain Solution 1 to 2, and from 2 to 2R. (Duke water pickup for Ink C is judged to have been the same for all three fountain solutions.) This is illustrated in Figure 2, and suggests that a relationship exists between Duke water take-up and non-image area piling.

Table II Summary of measurements, made during laboratory tests, aimed at assessing the effects of water on ink. Bad performance on press indicates excessive non-image area blanket piling, while NR indicates the given combination was not run.

Ink	Variable		Fountain solution		
			1	2	2R
A	Performance on press		**Bad**	NR	NR
	Duke:	water pick-up per 100 grams ink	60.0	49.0	36.0
	Litho break:	water content, percent	12.7	6.1	3.2
		viscosity ratio, after/before	0.8	0.9	0.8
		yield ratio, after/before	1.0	0.8	0.6
B	Performance on press		**Bad**	NR	NR
	Duke:	water pick-up per 100 grams ink	67.0	50.0	38.0
	Litho break:	water content, percent	12.1	4.2	3.4
		viscosity ratio, after/before	1.0	0.9	0.9
		yield ratio, after/before	1.0	0.9	0.6
C	Performance on press		NR	NR	**Good**
	Duke:	water pick-up per 100 grams ink	40.0	44.0	41.0
	Litho break:	water content, percent	16.1	5.1	3.4
		viscosity ratio, after/before	0.9	0.7	0.6
		yield ratio, after/before	0.6	0.5	0.4
D	Performance on press		NR	NR	**Good**
	Duke:	water pick-up per 100 grams ink	61.0	35.0	28.0
	Litho break:	water content, percent	6.1	4.3	3.2
		viscosity ratio, after/before	1.0	0.8	0.7
		yield ratio, after/before	0.9	1.1	1.1

2. The water content in the litho break test decreased in all inks in going from Fountain Solution 1 to 2, and from 2 to 2R. This is illustrated in Figure 3, and suggests two relationships: one between water take-up and type of fountain solution, and one between water take-up and non-image area piling, as in 1.

3. The effect of water take-up on ink viscosity was mixed. For the two combinations that performed badly on press, the viscosity of Ink A decreased 20 percent and that of Ink B not at all as a result of water pickup. For the two combinations that had good on-press performance, the viscosity of Ink C decreased 40 percent and that of Ink D 30 percent. These effects do not suggest any relation between viscosity degradation and non-image area piling.

4. The effect of water take-up on ink yield was also mixed: no effect on Inks A, B, and D, and a 60 percent reduction in that of Ink C, in those combinations run on press. Here again, no relation to non-image area piling is suggested.

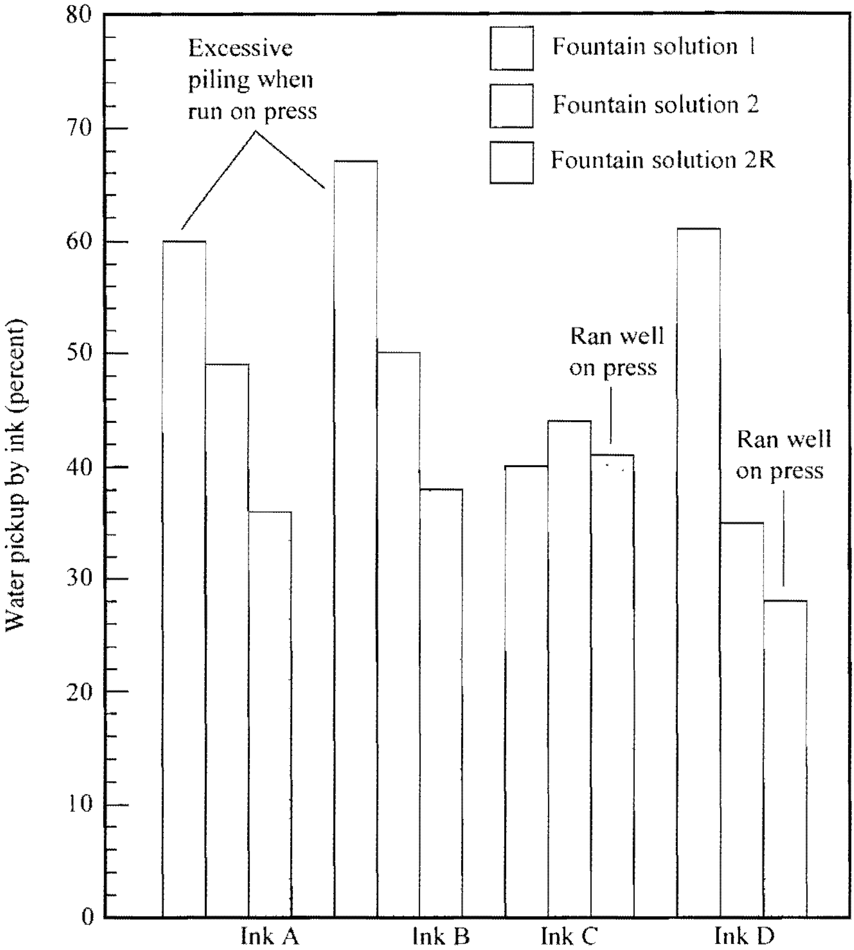

Figure 2 Duke water pick-up as a function of ink and fountain solution.

5. There was no observable trend in the effect of the take-up of the different fountain solutions on ink viscosity or yield.

Table III presents a summary of various observations aimed at assessing the effects of ink on water made during laboratory tests. None of the observations given here appear to provide an indicator of on-press performance.

Analytical Model

It has been proposed that the water pickup by ink, as a function of time, can be described by a first order differential equation (Tasker et al, 1983). For

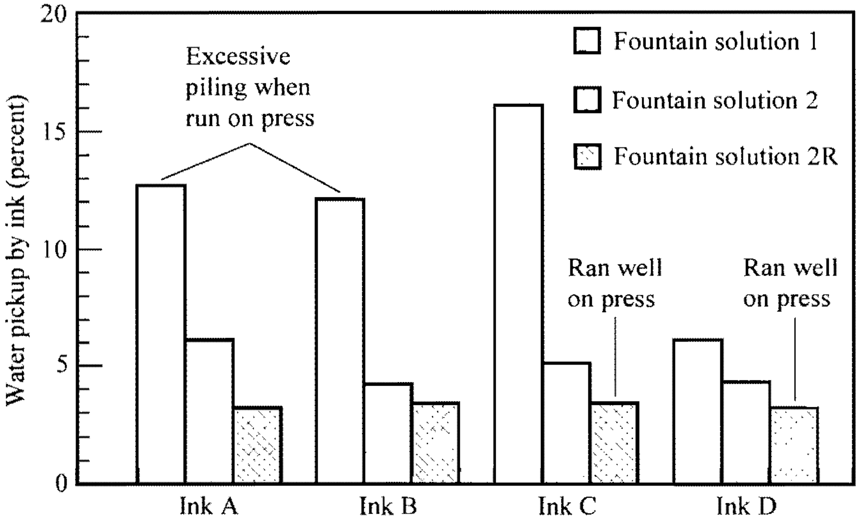

Figure 3 Litho break water pick-up as a function of ink and fountain solution.

the Duke mixer, such an equation can be derived by assuming that, given a long enough mixing time, water take-up will reach some saturation level, W_∞. Thus, the rate of pickup can be assumed proportional to the difference between the saturation value of the take-up and the take-up at any instant of time. Based on these two assumptions, equation (1) can be written:

$$M_m \frac{dW}{dt} = M_m R_e (W_\infty - W) \tag{1}$$

where:

M_m = mass of ink in mixer in grams
R_e = fractional rate of emulsification in minutes^{-1}
t = time in minutes
W = water take-up at time t, in grams of water per grams of ink
W_∞ = water take-up at saturation

The solution to equation (1) yields the response of water take-up over time, given by equation (2):

$$W = W_\infty \left(1 - e^{-t/\tau_e}\right) \tag{2}$$

where:

Table III Summary of observations, made during laboratory tests, aimed at assessing the effects of ink on fountain solution. Bad performance on press indicates excessive non-image area blanket piling, while NR indicates the given combination was not run.

Ink	Variable	Fountain solution		
		1	2	2R
A	Performance on press	**Bad**	NR	NR
	Duke ink bleed in water	Slight	Slight	None
	Litho break scumming	None	None	None
	Ultrasonic ink bleed in water	Slight	NR	Severe
B	Performance on press	**Bad**	NR	NR
	Duke ink bleed in water	Slight	Slight	None
	Litho break scumming	None	None	None
	Ultrasonic ink bleed in water	Slight	NR	None
C	Performance on press	NR	NR	**Good**
	Duke ink bleed in water	Slight	None	None
	Litho break scumming	None	Severe	Slight
	Ultrasonic ink bleed in water	Severe	NR	Severe
D	Performance on press	NR	NR	**Good**
	Duke ink bleed in water	Slight	None	Slight
	Litho break scumming	None	None	Slight
	Ultrasonic ink bleed in water	NR	NR	NR

$\tau_e = 1/R_e =$ emulsification time constant in minutes

The time constant, τ_e, provides a measure of how long a mixing time is required to reach the saturation level. For example, W will reach 63 percent of the value of W_∞ in a mixing time equal to τ_e and 95 percent in a time equal to $3\tau_e$. Thus the value of $3\tau_e$ is equivalent to Surland's parameter "a" defined above and illustrated in Figure 1.

These equations do not apply to a system of rollers, as on the litho break tester or the inking rollers on a press. This is because emulsified water is removed continuously from such systems, by evaporation in the former, and by both evaporation and transport to the plate in the later. The appropriate form of equation (1) for these systems is given by equation (3) and the response by equation (4).

$$M_r\left(\frac{dW}{dt}\right) = M_r R_e\left(W_\infty - W\right) - M_r R_o W \qquad (3)$$

Table IV Values of water pick-up at saturation and emulsification time constant obtained from fits of Duke water take-up data to analytical model.

Ink	Variable	Fountain solution		
		1	2	2R
A	Performance on press	**Bad**	NR	NR
	W_∞, water pick-up at saturation, percent	56.3	46.7	35.6
	τ_e, emulsification time constant, minutes	2.2	1.9	1.2
B	Performance on press	**Bad**	NR	NR
	W_∞, water pick-up at saturation, percent	65.6	45.8	36.9
	τ_e, emulsification time constant, minutes	2.8	1.8	1.2
C	Performance on press	NR	NR	**Good**
	W_∞, water pick-up at saturation, percent	39.6	45.3	41.7
	τ_e, emulsification time constant, minutes	2.6	2.0	1.7
D	Performance on press	NR	NR	**Good**
	W_∞, water pick-up at saturation, percent	57.4	34.7	29.3
	τ_e, emulsification time constant, minutes	2.0	0.6	0.4

$$W = f\,W_\infty\left(1 - e^{-t/\tau_r}\right) \tag{4}$$

where:

M_r = mass of ink on rollers that is involved in the emulsification process

$$f = \left(\frac{R_e}{R_e + R_o}\right)$$

R_o = rate of outflow of emulsified water, in terms of grams of water per water take-up per minute

$$\tau_r = \left(\frac{1}{R_e + R_o}\right)$$

Equation (4) predicts that, on a roller system, where there is outflow of water, the water take-up at saturation will be lower than in a batch system by the fraction, f. (On a press, R_o, and hence the fraction f, will also vary with ink coverage on the plate.) The time constant will also be less than in the batch system. This is on condition that the emulsification rate, R_e, remains unchanged, which it may not. Even so, this model is in accordance with the data obtained in this project that show water pickup is far less in the litho break tester than it is in the Duke mixer for comparable mixing times. This model is also in accordance with measured data that show water pickup in batch type laboratory testers is far greater than that occurring on a press (Fetsko, 1986).

Equation (2) was fitted to the twelve sets of data obtained on the Duke tester. The parameters, W_{∞} and τ_e, obtained from these fits, are given in Table IV. The trends in the values of W_{∞} vis-à-vis fountain solution are similar to those of water pickup values, obtained in both the Duke and litho break tests, discussed above. Although the values of τ_e follow the same trends, these are not in accordance with Surland's teachings insofar as on-press performance is concerned. That is, good press performance should be accompanied by larger values of τ_e and that is not the case here.

Conclusions

1. There were not enough samples in this study to determine with confidence whether a correlation exists between on-press performance and laboratory test results. Nevertheless, some significant conclusions can be drawn as set forth in the following paragraphs.

2. Except for one measurement (Ink C in combination with Fountain Solution 1) all of the measurements of pickup , regardless of form, indicate that it is the properties of the fountain solution, and not the ink, that were the factors controlling water pickup by ink.

3. The limited data on on-press performance strongly suggest that pickup was a variable controlling non-image area piling.

4. In view of 2 and 3, it is concluded that, for the combinations tested, fountain solution, not ink, was the factor controlling non-image area piling.

5. None of the other figures of merit exhibited a trend that would suggest a relationship with non-image area piling. These included change in ink viscosity, change in ink yield, emulsion time constant (Surland's parameter "a"), tinting in the Duke mixer, scumming on the litho break tester, and ink take-up in the ultrasonic cleaner.

6. Aside from the piling problem, the four combinations tried on press appeared to have had about the same on-press performance. A conclusion to be drawn from this is that other characteristics of lithographic performance, such as stripping, tinting, and scumming, were not affected by water pickup, at least to the extent that they came to the attention of the press operators. (It was observed, however, that "everything ran better" after switching to Ink C and Fountain Solution 2R.)

7. Except for three outliers, there was a fair correlation (R = 0.8) between the Duke and litho break water take-up measurements, as shown in Figure 4.

8. The lower water pickups measured on both litho break testers and press rollers, vis-à-vis the mixers used in the Surland test, can be explained by the analytical model given in this paper.

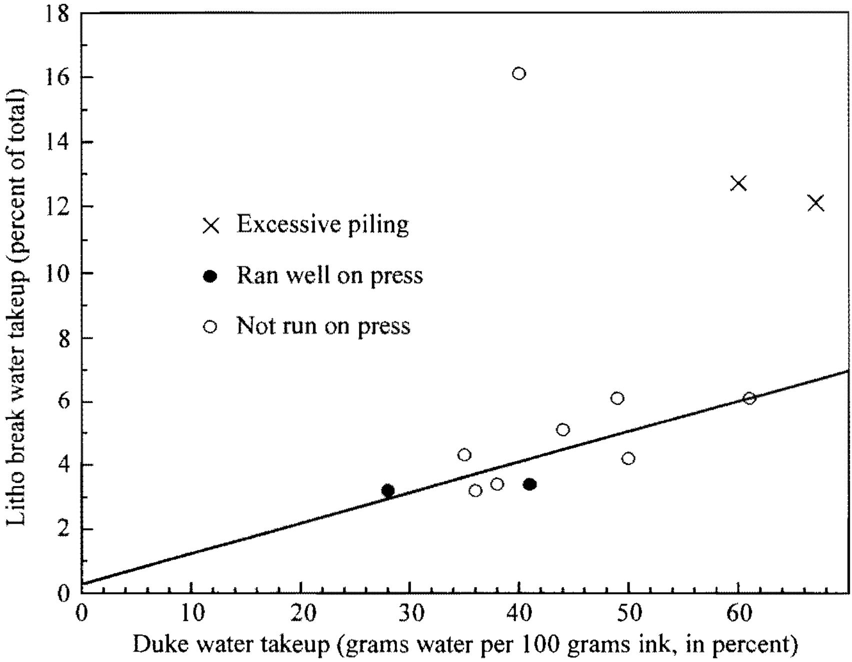

Figure 4 Relationship between water pick-up as measured on the Duke mixer and litho break tester. Curve is best straight line fit (R=0.8) of nine pairs of measurements that do not include the three outliers.

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