# Experimentally Derived Criteria for Assessing Calculations of Ink/Water Interactions on Press

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Interaction, Water, Ink, Emulsification, Evaporation, Model, Pickup

Abstract: The measurements of lithographic press performance reported on in this paper all relate to behavior that is governed by the interactions that take place between ink and water on press. In addition to providing a means for verifying calculations of ink/water interactions on press, this experimental data provides insight into the manner in which water is consumed on press. Five groups of both new and existing experimental data are summarized as follows: (1) water consumption versus ink coverage on presses with integrated dampeners, and presses with segregated dampeners, (2) water consumption versus printed ink film thickness, (3) water consumption as a function of the number of ink form rollers, (4) the effect on water consumption of adding a rider roller to the dampening form roller, and (5) the amount of water lost by transfer to paper.

## Introduction

In developing an analytical model for calculating how ink and water interact on the rollers of a lithographic press, three different types of water release from ink must be taken into account and quantified. The first two types of release occur at the exit of the nips formed between two ink-receptive rollers. If water is present at the nip entrance, it is emulsified into the ink as the ink and water pass through the nip. Due to the film splitting action that takes place at the nip exit, some of the emulsified water is released from the ink. Because of the large negative pressures that are developed in splitting, some of the water is released in the form of vapor, and hence is lost from the system. Some of the emulsified water is also released as surface water, and hence is retained by the system. These two forms of water release are illustrated in Figure 1(a).

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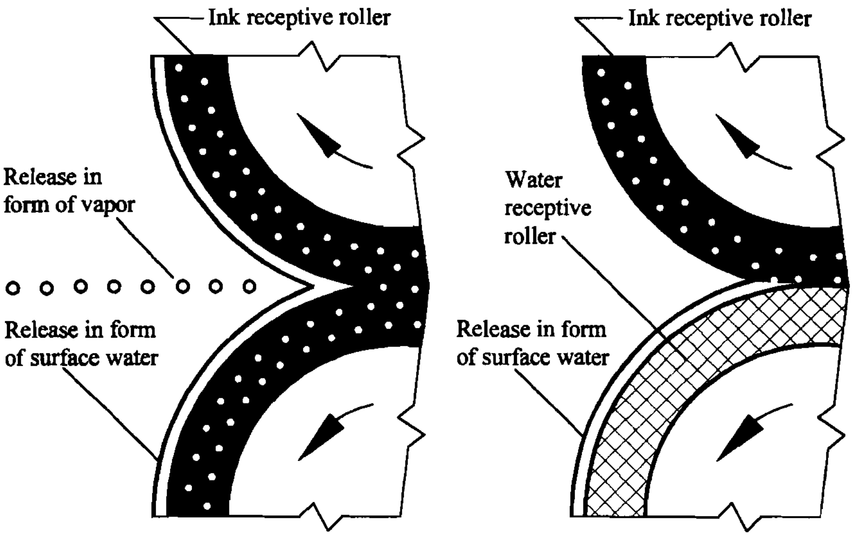


(a) Nip formed by pair of ink-receptive rollers, one rigid and one resilient.

(b) Nip formed by resilient ink-receptive roller and rigid water-receptive roller.

Figure 1 Diagrams that illustrate the three types of water release that occur in the roller train of a lithographic press.

The third type of water release from ink, illustrated in Figure 1(b), occurs in nips between an ink-receptive and water-receptive roller—provided, of course, that the ink film at the nip entrance contains emulsified water. Under these conditions, some of the emulsified water is released to the surface of the water-receptive roller in the form of surface water during passage through the nip.

For the purpose of modeling, the character of these three types of water release can be quantified in terms of the following factors:

$f$ = fraction of emulsified water, passing through a nip formed between two ink-receptive rollers, that is released from the ink at the nip exit.

$s$ = fraction of total water release, $f$, that is released as surface water.

$z$ = fraction of emulsified water, passing through a nip formed between an ink-receptive and water-receptive roller, that is released to the water-receptive roller during passage through the nip.

From the first two definitions it can be seen that $sf$ is the fraction of emulsified water that is released in the form of surface water, and hence retained by the system. Similarly, $f(1-s)$ is the fraction released as vapor, and hence lost from the system.

To the author's knowledge, there is no information in the literature on either the values of $f$, $s$, and $z$, or on how they are affected by variables such as ink film thickness. Thus, one can only guess at what values to use in constructing an analytical model for simulating how ink and water react on press. However, in developing such a model, the author discovered that certain aspects of simulated press behavior are very sensitive to the values of $f$, $s$, and $z$ used in the calculation. In particular, the following behavior was identified as being very sensitive to the values of $s$ and $z$ used:

1. Water consumption versus ink coverage on presses with integrated dampeners versus presses with segregated dampeners.
2. Water consumption as a function of the number of ink form rollers. This behavior of the model was also found to be very sensitive to the minimum amount of water on the plate that is necessary to run clean, i.e., without scumming, as a function of ink film thickness.
3. The effect on water consumption of adding a rider roller to the dampening form roller.
4. The amount of water lost by transfer to paper.

It was also found that the amount of emulsified water in ink, at various locations on the press, predicted by the model, was sensitive primarily to the value of $f$.

This suggests that realistic values of the release rates can be arrived at by employing the iterative process shown in Figure 2. That is, different sets of

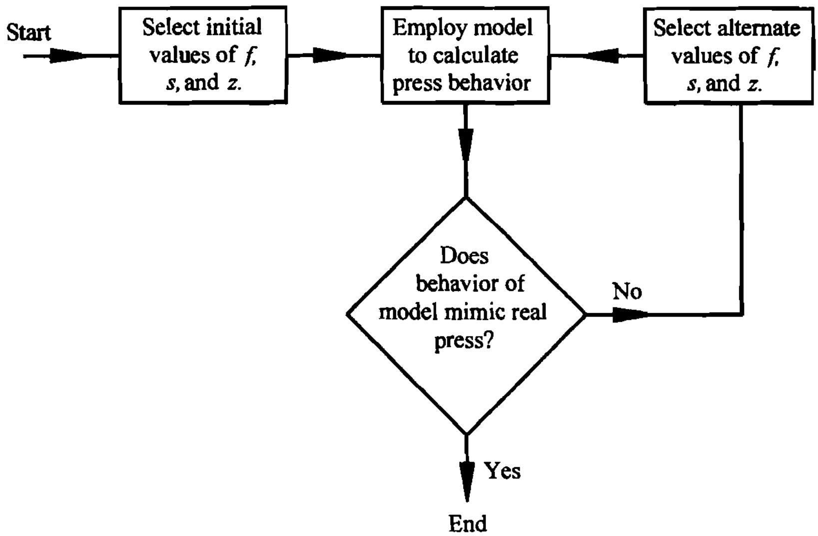


Figure 2 Flow diagram of iterative process used to determine values of water release factors $f$, $s$, and $z$. Model refers to analytical model for calculating ink/water interactions on press.

values of $f$, $s$, and $z$ are substituted into the model until the behavior of the model corresponds to the behavior of a real press in all of the respects given above. When this occurs, it can be concluded that realistic values of $f$, $s$, and $z$ have been arrived at, and that the model has been verified.

The purpose of this paper is to summarize the available experimental data on press behavior that is appropriate for use in this manner for verifying behavior of the analytical model. It is to be followed by a future paper that will describe the model itself and the results obtained in applying it.

## Water Consumption Versus Ink Coverage

It is rather surprising that there is so little published information on how water consumption is affected by ink coverage on the plate. Furthermore, a good

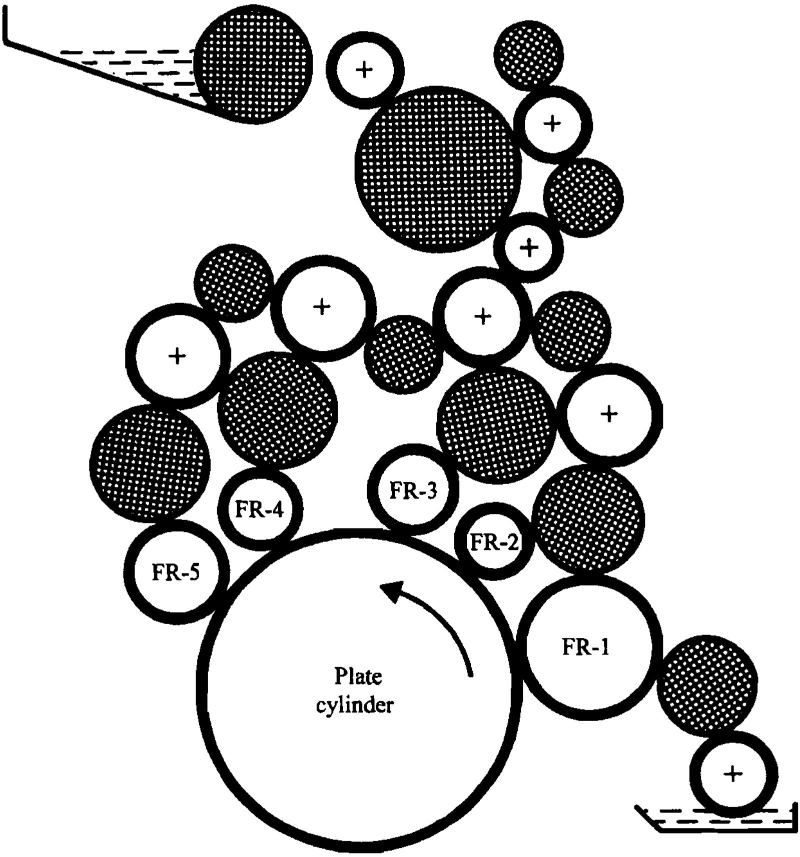


Figure 3 Roller diagram of press equipped with an integrated type dampening system. FR refers to ink form roller.

fraction of what has been published is not considered reliable because it is based on the use of tracers in the fountain solution. Thus, in the end, there are only three published sources: Bassemir and Krishnan, 1988; MacPhee, 1985; and MacPhee, 1997. To these is added a fourth set of data, published here for the first time.

A review of these four sources discloses that in two cases, consumption increases with coverage, whereas it is relatively flat in the other two. Apparently, this is explained by the fact that in the former, the dampening systems were of the integrated type, whereas in the latter they were not. The behavior in each case will be reviewed now in detail.

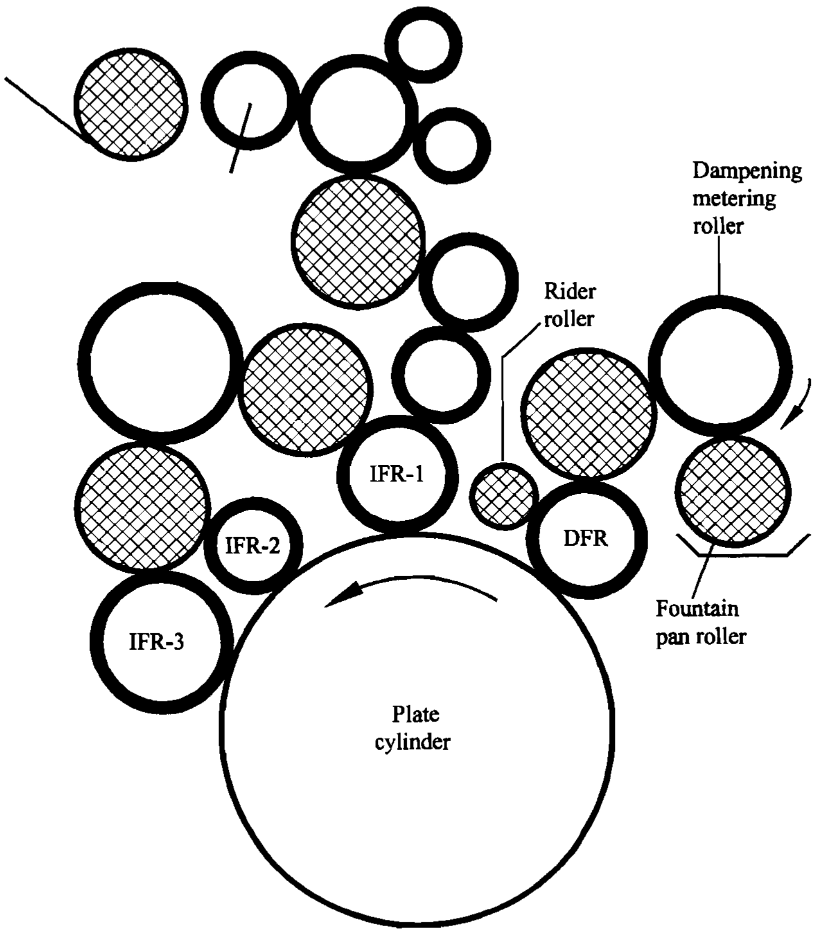


Figure 4 Roller diagram of a sheetfed press equipped with a non-integrated type dampener. DFR refers to dampening form roller and IFR to ink form roller. During most runs to measure water consumption, rider roller was removed.

Behavior of Integrated Dampeners

This type of dampener is one in which dampening solution is fed to a roller in the inking system, usually the first ink form roller. Such an arrangement is shown in Figure 3, which is a diagram of the press used in the tests reported on in MacPhee, 1985. In those tests, ink coverage ranged from 8.3 to 55.6 percent, and water consumption was found to be independent of it, i.e., flat. Confirmation that water consumption is essentially independent of ink coverage for presses equipped with integrated dampeners is given by Bassemir and Krishnan, 1988. They based their conclusion on the fact that fountain solution feedrate, as represented by the setting of the dial on the Dahlgren controller, was essentially the same over a range of coverages from five to sixty percent.

Behavior of Non-Integrated Dampeners

This type of dampener is one in which water is fed to a separate dampening form roller with no bridge to the inker, as shown in Figure 4. The first evidence of a different type of behavior was obtained during an experiment (MacPhee, 1997) run on a web press. The dampeners on this press were similar to the one in Figure 4, except that rider rollers were not used. One dampener was equipped with a manifold opposite the flooded nip. Flow from the manifold to the nip was

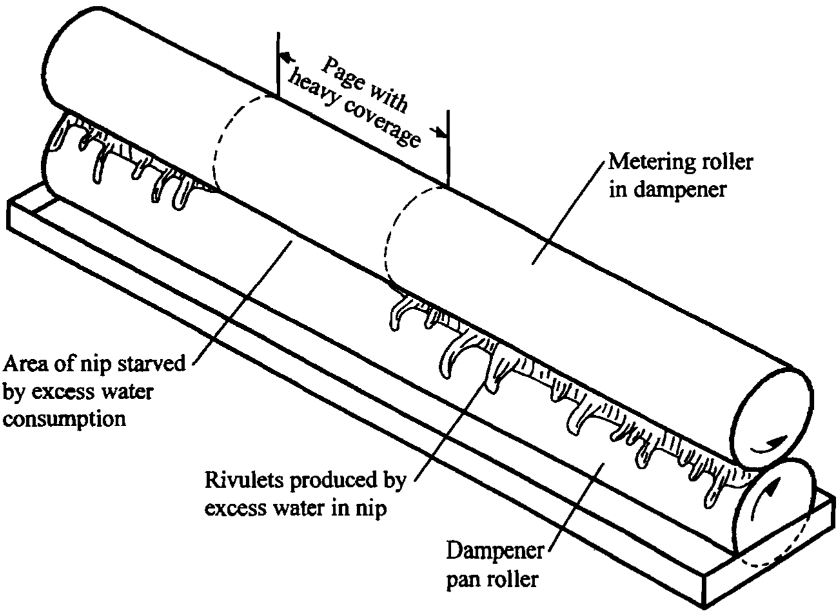


Figure 5 Diagram (MacPhee, 1997) showing results of experiment run on a press, similar to the one shown in Figure 4, equipped with a non-integrated dampener. A unique water supply system was used that fed only enough water to keep metering nip filled.

controlled in a manner to maintain just enough water to keep the metering nip filled. When running a plate with uniform coverage, the pattern of rivulets draining away from the nip was uniform. However, when running a four-page-wide plate having heavy coverage on one page, the rivulet pattern was as shown in Figure 5, indicating a higher rate of water consumption in the area occupied by the page with heavy coverage.

Confirming quantitative evidence of this behavior was obtained in the past year during tests run on a press with the exact roller figuration shown in Figure 4.

The fountain roller on one of the dampeners was fitted with a semicircular pan having a 1/8-inch clearance with the roller —so as to make water level in the pan, as measured with a sight glass, very sensitive to changes in water volume. Water consumption over a given period of operation (time to print 1000 sheets) was measured by determining the volume of makeup water needed to maintain a constant water level, as indicated by a line on the sight glass. This resulted in an estimated accuracy of 5 percent in the measurements, since a change in sight glass level of 1/32 inch was equivalent to a volume change of 2.3 cc.

Table I Summary of water consumption measurements made on press shown in Figure 4, equipped with non-integrated dampener. Ink coverage on plate was 19.7 percent except where noted. Different fountain solution was used during Runs 1 and 2.

| Run | Rider roller in place? | Number of ink form rollers | Printed ink film thickness (microns) | Water consumption | | |
|---|---|---|---|---|---|---|
| | | | | Measured value (cc/1000) | Correction factor | Corrected value (cc/1000) |
| 1 | Yes | 3 | 0.85 | 42.3 | 1.048 | 44.3 |
| 2 | No | 3 | 0.89 | 38.8 | 1.035 | 40.1 |
| 5 | No | 3 | 0.89 | 45.6 | 1.035 | 47.2 |
| 6 | Yes | 3 | 0.94 | 44.5 | 1.019 | 45.3 |
| 8a | No | 3 | 0.96 | 47.6 | 1.012 | 48.2 |
| 8b | No | 1 | 0.93 | 39.6 | 1.022 | 40.5 |
| 9* | No | 3 | 0.96 | 34.2 | 1.012 | 34.6 |
| 10** | No | 3 | 0.85 | 46.7 | 1.048 | 48.9 |

* 4.5 percent coverage.

** 50.4 percent coverage.

During each run, every one hundredth sheet was saved. Subsequently, solid ink density was measured in four locations across the sheet and averaged. The average densities were converted to printed ink film thicknesses using a plot of ink film thickness versus solid ink density data obtained with a printability tester.

The results of the water consumption measurements for plate coverages of 4.5, 19.7, and 50.4 percent are listed in Table I. All of the measured values were corrected to a printed ink film thickness of 1.0 micron using a correction factor of 0.3 percent increase in water/1.0 increase in ink, derived from the best linear fit of the data in Figure 7. The corrected data, plotted in Figure 6, shows that water consumption increased with coverage in the range of 4.5 to 19.7 percent, and then leveled off between 19.7 and 50.4 percent.

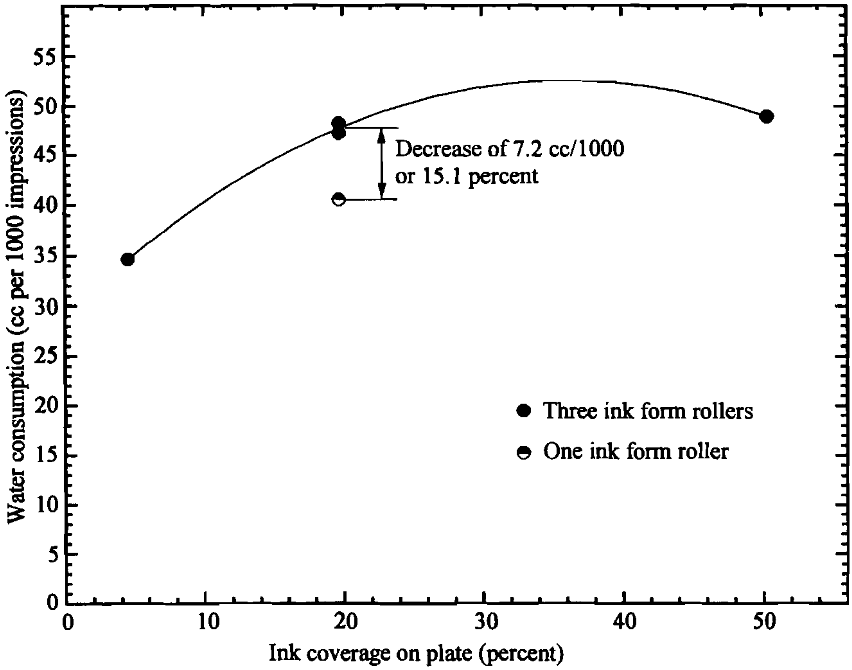


Figure 6 Plot of water consumption measurements made on sheetfed press shown in Figure 4.

## Water Consumption Versus Number of Form Rollers

In the tests just described, the effect on water consumption of running with only one ink form roller (the first one) in contact with the plate cylinder was also measured. As shown in Figure 6, this resulted in a reduction in water usage of 15.1 percent. A similar test was run during tests on the press with an integrated dampener, shown in Figure 4 and previously referenced (MacPhee, 1985). The result, plotted in Figure 7, was a reduction in water usage of 17.3 percent, which is comparable to the reduction of 15.1 percent for the press with an integrated dampener.

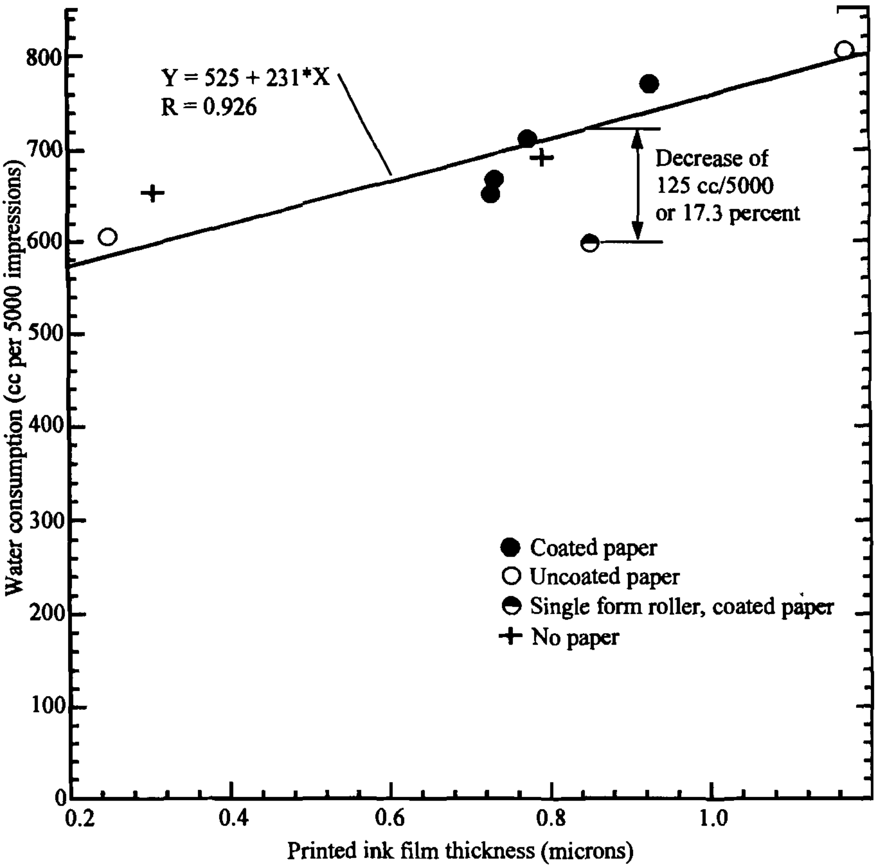


Figure 7 Measurements of water consumption versus printed ink film thickness made on the press shown in Figure 3 (MacPhee, 1985).

## Effect of Rider Roller on Water Consumption

Tests were run on the press shown in Figure 4 to determine the effect of adding a rider roller to the dampening form roller. One set of results (Runs 5, 6, and 8a in Table I) indicated that the rider roller caused water consumption to decrease by five percent. An earlier set of runs, using a different fountain solution that had proved unsatisfactory, (Runs 1 and 2 in Table I) had just the opposite effect, an increase of 11 percent. It is difficult to believe that adding the rider roller results in a decrease in water consumption because there is no physical explanation for it. In contrast, an increase can be explained by the addition of a nip of the type shown in Figure 1 (a), which would result in additional water release. Thus, it is assumed that the correct effect of adding the rider roller is to increase water consumption by an amount ranging from zero to ten percent.

## Water Consumption Versus Ink Film Thickness

It is known from experience that when the water feed setting is at just above the scumming level, an increase in ink feedrate will produce scumming, and that therefore water feed must also be increased. To the author's knowledge, there is only one set of data in the literature that provides information on the proportionality constant of this relationship—Figure 5 in MacPhee, 1985. This is reproduced here as Figure 7, and shows that, at a printed ink film thickness of 1.0 micron, the required increase in water federate is 0.3 percent for every 1.0 percent increase in ink feedrate. For thicker printed ink films, the proportionality constant, expressed in these units, is somewhat higher.

Table II Summary of measurements of moisture added to paper during printing. Minimum required water film thickness is assumed to be 0.3 microns.

| Source | Paper | | Number of colors printed | Total moisture change (percent) | Equivalent water film thickness/color | |
|---|---|---|---|---|---|---|
| | Type | Basis weight (grams/ meter$^2$) | | | (microns) | (percent minimum required) |
| Krech, Durand, 1998 | Unctd | 36—38 | 8 | +3.1 | 0.14 | 47 |
| | Unctd | 36—38 | 8 | +2.7 | 0.12 | 40 |
| | Unctd | 36—38 | 8 | +2.8 | 0.13 | 43 |
| MacPhee, Thompson, 1999 | Ctd | 118 | 4 | +0.6 | 0.18 | 60 |
| | Ctd | 148 | 8 | +0.3 | 0.06 | 20 |
| | Ctd | 148 | 10 | 0 | 0 | 0 |
| MacPhee, et al, 2000 | Ctd | 118 | 2 | +0.09 | 0.05 | 17 |
| | Ctd | 89 | 2 | +0.19 | 0.08 | 27 |
| | Ctd | 89 | 2 | +0.12 | 0.05 | 17 |
| | Ctd | 89 | 2 | +0.04 | 0.02 | 7 |
| | Unctd | 52 | 8 | +0.75* | 0.05 | 17 |
| | Unctd | 52 | 8 | +1.36** | 0.09 | 30 |

* Average of two runs.

** Average of three runs.

## Water Lost to Paper

Within the past few years, three different sets of data on the amount of water transferred to paper, and hence lost, have been published. Two of these sets were obtained on web presses using an on-line type of instrument for measuring moisture content in paper (Krech and Durand, 1998, and MacPhee, et al, 2000). The third set was obtained on four different sheetfed presses using an off-line type of instrument (MacPhee and Thompson, 1999). In all three instances, moisture transfer to paper was obtained by measuring moisture content in the paper before and after printing. Table II is a summary of the three sets of measurements just referenced. When the measured water loss is expressed in absolute terms, as the thickness of an equivalent uniform film of water transferred to the paper, it ranges from zero to 0.18 microns. If it is assumed that the minimum required amount of water feed to press (i.e. the amount just to prevent scumming) is 0.3 microns (MacPhee, 1998), then the measured losses can be expressed in terms of a percent of this minimum. (The value of 0.3 is the average of the minimum of 0.2 and the maximum of 0.4 microns of the measured values given in the reference.) As shown in Table II, these values range from zero to 60 percent, with a mean of 27 percent.

Although some of the variance in the measured values given in Table II may be due to experimental error, some, no doubt, is also due to the fact that all of the presses involved were not being run at the just above scumming level. Even if both of these causes are accepted as being plausible, an inexplicably large spread in water transfer would still remain. For example, suppose that the two largest (0.18 and 0.14microns) and the two smallest measurements (0 and 0.02 microns) were attributed to experimental errors, and hence ignored. The range remaining, 0.05 to 0.13 microns, is difficult to explain. That is, if the lower value is assumed to correspond to the just above scumming level, then the higher level would correspond to feeding more water than required by a factor

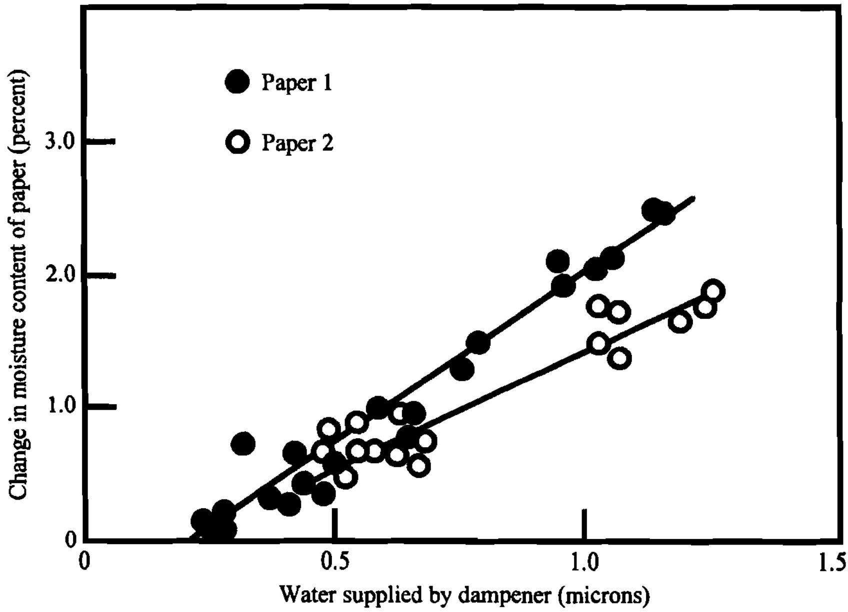


Figure 8 Measurement of moisture increase in web versus amount of water fed by the dampening system (Trollsas, Eriksson, and Malmqvist, 1992). Basis weights of papers were calculated by this author (MacPhee) to be 39 grams/meter$^2$ for paper one and 56 grams/meter$^2$ for paper 2, based on slopes of best linear fits.

of 2.6, which is hardly plausible. Therefore, if the data in Table II is to be believed, it can only be explained in terms of some nonlinear effect.

Just such a nonlinear effect was observed in an experiment that was run to measure the effect of water transfer on paper expansion (Trollsas, Eriksson, and Malmqvist, 1992). In this experiment, water was transferred to a moving unprinted web of newsprint using a ductor type dampening system. The amount of water fed by the dampener was measured together with the change in moisture content of the web. The results, given in Figure 8, show that the gain in moisture remained at zero as water feedrate was increased from 0 to 0.2 microns. Above 0.2 microns, moisture change increased linearly with feedrate. This suggests that at supply rates below 0.2 microns, all of the water supplied was being evaporated from the surface of the four dampening system rollers and large rubber roller used to transfer water to the web. A similar effect could be occurring during printing such that below some threshold, no water is transferred to the paper, while above it, water transfer occurs disproportionately, as in Figure 8.

## Summary


An analytical model for calculating ink/water interaction on press, to be described in a future paper, has been found to be very sensitive to the values of three different water release rates. The only way in which the correct values of these rates can be established is to vary the values used in the model until the calculated behavior of the model corresponds to the behavior of a real press. Based on experimental evidence presented in this paper, five different types of real press behavior can be used in this regard as follows:

1. On a press equipped with an integrated dampener, water consumption does not vary with ink coverage on the plate. In contrast, water consumption increases with coverage on a press equipped with a non-integrated dampener.
2. When printing with a single ink form roller, water consumption is 15—17 percent less, compared to printing with three to five ink form rollers. This is independent of the type of dampener.
3. The effect on water consumption of adding a rider roller to the dampening form roller on a press with a non-integrated dampener is to increase consumption somewhere between zero and ten percent.
4. When printing a 1.0 micron thick ink film and with water feedrate set at the just above scumming level, water feedrate must be increased by 0.3 percent for every 1.0 percent increase in ink feedrate.
5. The amount of water transferred to paper varies nonlinearly with water feedrate. At the just above scumming level, water transfer to paper may be as small as zero. At higher water feedrates, the water transferred to paper may amount to 25—30 percent of total consumption.

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