

PRESS INK/WATER EQUILIBRIUM  
AND THE CORRELATION TO LABORATORY  
METHODS FOR ITS PREDICTION

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Abstract: One of the most troublesome ink performance characteristics, water balance, is also one of the most difficult properties to determine off press. Several methods have been proposed to accurately predict this property, but their accuracy has been questioned. Most of the tests were developed from historical data, i.e. physical properties of inks that performed poorly were compared to the same properties for inks that performed well.

Results of studies characterizing inks for printing properties and water balance utilizing a highly instrumented printing press are presented. These results are then compared to results obtained using a generally accepted laboratory method. Inks were also evaluated using a laboratory method developed in Europe and the results are compared to the findings from the press.

A theory is presented which explains the differences observed between laboratory and press results.

INTRODUCTION

Currently the leading process in the field of commercial printing is lithography. This process is unique in that the image to be printed lies on the same plane of the printing plate as the non-image area. The method by which ink is attracted to only the image area utilizes the physical principle that oil and water are immiscible. In order to affect this preferential attraction of ink to the image area of the plate, water (dampener solution) is applied to the total plate surface where it is adsorbed onto the non-image (hydrophilic) area of the plate. Oil based ink is then applied to the total plate surface where it is attracted to

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the image (oleophilic) area of the plate and is repelled from the previously wetted non-image (hydrophilic) area. The printing plate carrying the inked image is then either applied directly or indirectly (offset) to the substrate producing the printed image.

In actual practice, at the time water (dampener solution) is applied to the total surface of the plate, a certain amount applied to the image (oleophilic) area is weakly bound there and must be removed by the ink in order for the ink to come into intimate contact with the image area and adhere to it. This water (dampener solution) must be absorbed by the ink for this to occur. Further, the ink must be able to absorb a part of the water applied to the non-image area or the plate would become flooded with water in a short time. The ability of the ink to absorb this water yet retain its physical properties is one of the most troublesome ink performance characteristics and is commonly referred to as water balance. A laboratory method to accurately predict the water balance characteristics of an ink would be of benefit to those supplying and to those using lithographic ink.

Surland, in his 1980 paper presented at TAGA, outlined refinements to a test method originally presented by him in 1967 that would relate emulsification capacity of an ink to water balance, and accurately predict this critical press performance characteristic of an ink.

Many inkmakers have adopted this method, or variations of this method, for formulation development and for quality control testing. Printers have also included this type testing in their system as a basis for accepting or rejecting ink. Some inkmakers have questioned the validity of this method since inks which do not display the correct theoretical emulsification capacity run efficiently on the press.

The following report is a summary of an attempt to determine the degree of correlation between the results obtained by the aforementioned laboratory method for determining emulsification capacity/water balance and results obtained using an operating press.

## PRESS TEST METHOD DEVELOPMENT

The press used for the testing was a Heidelberg GTO 12 X 18 inch single color unit which had been retrofitted with a Smith Dampener<sup>1</sup> in place of the Heidelberg dampening system. In addition, modifications had been made so that the temperature of the noncomposition ink rollers could be controlled as could the temperature of the ink fountain roller, thereby controlling the press temperature. Also fitted to the press were infrared water gauge, ink film thickness meter, and ink tack meter developed by FOGRA<sup>2</sup> and manufactured by Grapho Metronics<sup>3</sup>. The pressroom was controlled for ambient temperature from 72 to 76 degrees fahrenheit and for relative humidity from 48 to 52 percent.

The press was operated with the ink distribution rollers and ink fountain roller controlled to a temperature of 90 degrees fahrenheit. The dampener solution was prepared by adding Varn Total<sup>4</sup> fountain concentrate to water in a quantity sufficient to achieve a pH of 4.5. S. D. Warren 70 pound L.O.E. dull coated stock<sup>5</sup> was the standard.

It had been previously determined that conventional sheet-fed inks manufactured by a nationally recognized ink company performed well on the press which led to their being selected as standard.

Print density values were requested and received from GATF<sup>6</sup> and were used in the testing. Density was determined using a Cosar 61<sup>7</sup> densitometer. Determination of print quality

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<sup>2</sup>Deutsche Forschungsgesellschaft für Druck und Reproduktionstechnik, Munich, West Germany

<sup>3</sup>Grapho Metronics, Munich, West Germany

<sup>4</sup>Varn Products, Oakland, MI

<sup>5</sup>S. D. Warren Co., Div. of Scott Paper Co., Westbrook, ME

<sup>6</sup>Graphic Arts Technical Foundation, Pittsburgh, PA

<sup>7</sup>Cosar Corporation, Garland, TX

was made using the method outlined by GATF in their bulletin #113 entitled "Control of Ink-Water Balance" and by evaluation of dot sharpness and solid evenness.

Standard press speed was 5000 impressions/hour. Standard press run was 8000 impressions.

In order to determine the amount of dampener solution contained in the ink on an operating press, it was necessary to safely remove a sample of ink from the ink form rollers (the rollers which apply ink to the plate) then to quickly and accurately measure the moisture content.

A guard was designed and fabricated which, when attached to the press, allowed a sample to be safely taken directly from the portion of the fourth form roller corresponding to the image area on the plate.

The size of the sample thus collected was between 50 and 70 milligrams and as such was too small for accurate, reproducible moisture content determinations by conventional methods. It was determined that the Mitsubishi Moisture Meter with the Water Vaporizer<sup>8</sup> attachment accurately analyzed samples smaller in weight than those collected from the press and was therefore chosen for this work. The Mitsubishi instrument is fully automatic and uses a combination of coulometry and Karl Fischer titration as the principle of operation.

#### PRESS TESTING AND RESULTS

Before running the inks on press, a moisture content determination was made on each ink. The results indicated total moisture to be less than 0.1% for each of the four colors.

Each ink was given a press run of 8000 impressions and followed in two weeks with an additional run of 8000 impressions. Each press run was made starting with a clean press.

When each press run was started, the inking system and dampening system were adjusted to give the best print quality at the standard density for that color. Ink

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<sup>8</sup> Mitsubishi Chemical Industries, Limited, New Enterprises Division, Tokyo, Japan

samples were taken from the image area of the fourth form roller every 1000 impressions and a moisture content determination was made using the Mitsubishi Moisture Analyzer. Figure 1 summarizes the data obtained from each press run of each color. The results have been transformed from total moisture to moisture added which is the scale usually obtained in laboratory test methods. A total moisture content of 50 percent (1:1 ink/water) as determined by the Mitsubishi would be 100 percent (moisture added equal to original ink volume) by most laboratory methods.

The amount of dampener solution carried by an ink on an operating press has been reported to be at least as high as 15 percent (18 percent of the scale used in this presentation) in two independent studies (Rosted and Madsen, 1966; and Bock, 1969). These previous findings were supported by this study.

Print quality using the cyan, magenta, and yellow inks was good and could be considered commercially acceptable. Marginally acceptable prints were obtained with black ink as wash marks were difficult to eliminate and sharp dots were hard to achieve.

In addition, one press run of 8000 impressions was made with S. D. Warren 70# Gloss coated paper stock to determine if any differences could be observed with a different paper stock. No significant differences were observed in moisture content of the ink or print quality.

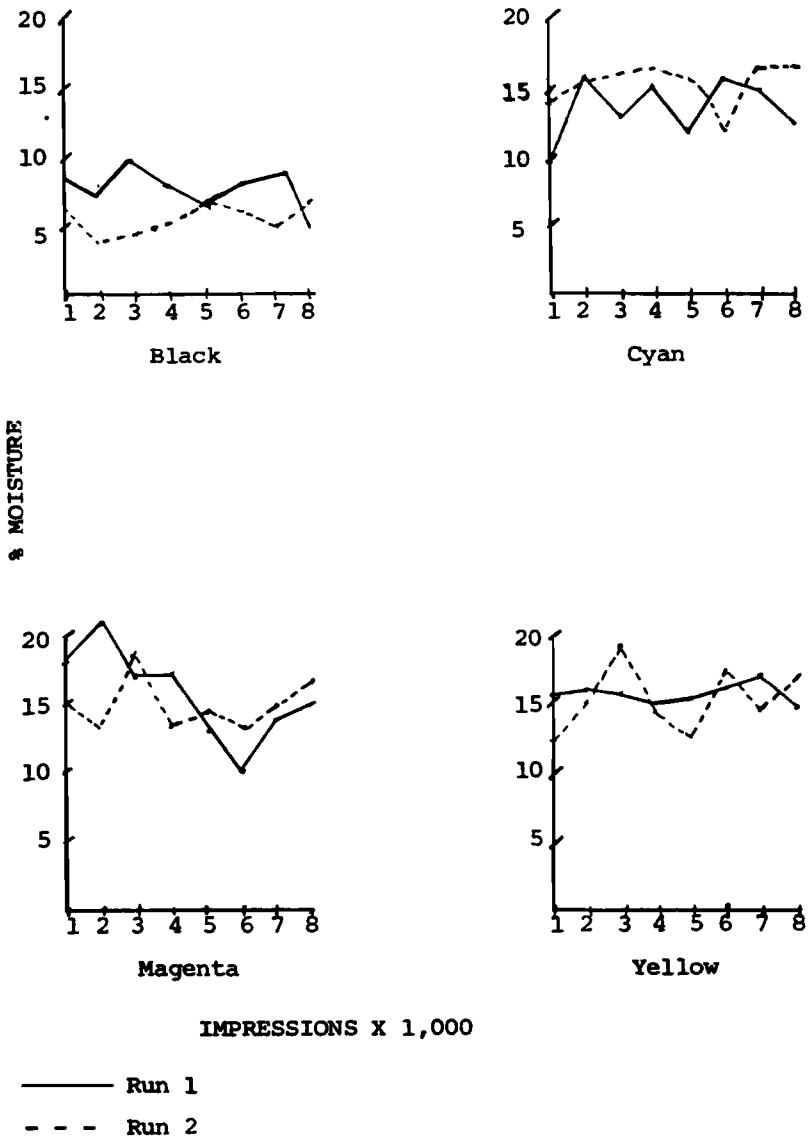


Figure 1. Moisture content of inks during press runs.

A press run of 12,000 impressions was made to determine the effect of a longer run on moisture content and print quality. No significant differences were observed.

During one press run, ink samples were taken high in the ink train (near the ink ductor). Although there was some migration of dampening solution up the ink train, the moisture content at that point was less than 2 percent.

After the press runs were made, it was felt that the degree of latitude for dampener settings would be a desirable piece of information, therefore the inks were run to determine this latitude. Table 1 represents the range from the normal settings to produce print fill-in (low water) and edge wash marks (high water).

TABLE 1

DAMPENER SETTING LATITUDE

<u>COLOR</u>	<u>LOW WATER</u>	<u>HIGH WATER</u>
Black	-2 Units	+1 Units
Cyan	-4 Units	+4 Units
Magenta	-6 Units	+4 Units
Yellow	-6 Units	+6 Units

With these data in hand, the performance characterization of the test inks using the press was complete.

DUKE TESTER METHOD AND RESULTS

The Surland (1980) method for determining water balance/emulsification capacity of inks utilized a modified Sunbeam Mixmaster which needed constant attention to operate at a uniform speed of 90 RPM. A much more reliable device to perform the same test was developed by Duke Custom Systems<sup>9</sup> and was named the Duke Ink-Water Emulsification Tester. The results obtained from the Duke have been shown to be the same as those from the Mixmaster but with much better reproducibility. For these reasons the Duke was used in this investigation.

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<sup>9</sup>Duke Custom System, Nashville, TN

The test method employed called for 50 grams of the ink under test to be charged in the vessel, then 50 milliliters of the dampener solution used in press testing to be added. The device was then activated for 5 cycles of 90 revolutions (1 minute) each. At the end of each 90 revolution cycle (minute), the unabsorbed dampener solution was decanted into a graduate and the percent absorbed by the ink was calculated. Each ink was tested three times with dampener solution and three times with distilled water. No significant differences were observed in the results from the three tests for each ink either with dampener solution or with distilled water. (Note: Some workers have advocated the use of distilled water instead of dampener solution as proposed by Surland (1967).) During one test for each ink, a small ink sample was taken at the end of each 90 revolution cycle and the actual moisture content of the ink/dampener solution formed was determined using the Mitsubishi equipment.

Figure 2 summarizes the results of testing each ink with dampener solution and analyzed by decanting unabsorbed dampener solution and also by using the Mitsubishi. The results for the distilled water tests have not been included for the aforementioned lack of significant differences.

It should be pointed out that the generally accepted range of emulsification capacity for this type ink is 30 percent to 60 percent using a Surland type test. The majority of the solution should be absorbed within 360 to 450 revolutions (4 to 5 minutes). Water balance is this point of no further significant absorption.

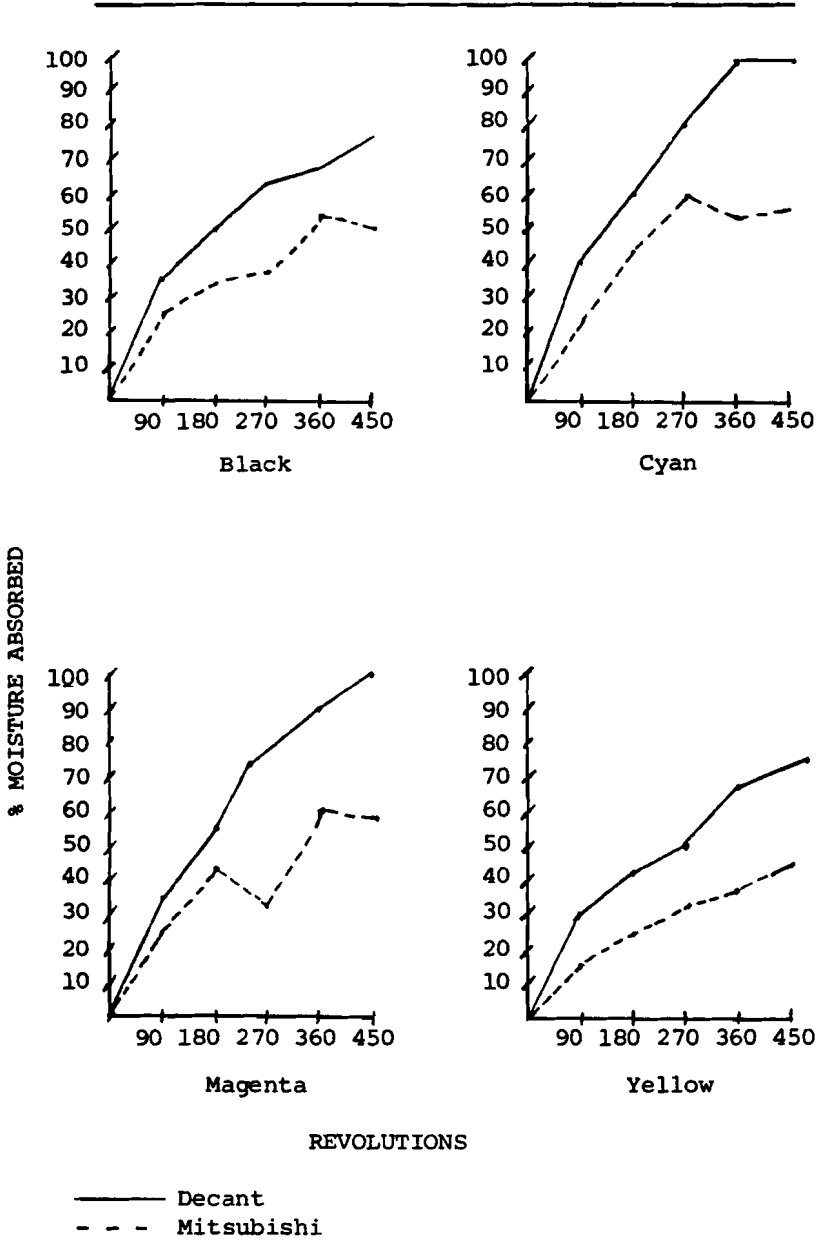


Figure 2. Duke tester method summary.

## CORRELATION BETWEEN METHODS

The results from the press tests indicated that the amount of moisture found in the ink cycled between upper and lower limits. By statistically analyzing the data from each press run for each ink, it was found that the observed differences were not significant. The observations from each press run for each ink were then pooled and a moisture content range was calculated. This range was then related to the amount of water taken up by the ink using the Duke Tester method. Table 2 is a compilation of this data. The percentages for the press test moisture ranges have been transformed to reflect the scale of the percentages obtained by the Duke Tester method.

TABLE 2

	Press Test Percent Moisture Content Range	Duke Tester Method Percent Absorbed				
		Revolutions				
		90	180	270	360	450
Black	4.3 to 8.1	35	51	63	76	81
Cyan	12.0 to 16.4	38	60	83	98	100
Magenta	11.4 to 18.6	33	57	75	91	97
Yellow	13.5 to 17.9	27	41	51	64	75

Between the Duke Tester method for emulsification capacity and the press test, there was no correlation when the conventional method for obtaining results was used. When the Mitsubishi equipment was used for obtaining results, the cycling of moisture content observed in the press test was seen in all inks except yellow, although the Duke Tester method displayed much higher moisture percentages.

Results from the press indicated that water balance was not a point, but a range achieved within the first 1000 impressions. Moisture content of the ink then cycled between the upper and lower values for that particular ink during the press run.

Water balance was never achieved with these inks using the Surland type test and obtaining results by decanting and measuring unabsorbed dampener solution. When actual moisture content of the ink was determined using the Mitsubishi equipment, an indication of water balance, evidenced by

moisture content cycling, was seen in all inks except yellow.

It was believed that the higher ink moisture content seen using the decanting method for analysis was due to the inability to totally remove the unabsorbed dampener solution from the ink/water mass formed by the test.

Although the Duke Tester method results for the black ink indicated a tendency toward excess emulsification, it was very intolerant of excess dampener solution and gave poor print quality with this condition. It was also very slow to recover from dampener settings high enough to cause wash marks.

The other colors had wider water balance latitude although the Duke Tester method indicated a tendency toward excess emulsification and no water balance.

It was believed that the lack of correlation observed was due to the differences between shear rates developed by the Duke Tester (or Mixmaster) and those developed in the roller nips of the press (or any press). Further, the Duke Tester method is static, i.e. no replenishment of ink or dampener solution, whereas an operating press is a dynamic system with ink and water being constantly removed and replaced.

#### ALTERNATE TESTING AND RESULTS

It was believed that a test that more closely approximated the shear rates found in the roller nips of a printing press would characterize the emulsification capacity of an ink. A test method used by a major ink manufacturer in Europe utilized a device similar to the Thwing-Albert Litho-Break Tester<sup>10</sup>. This device operates at much higher shear rates than the Duke Tester but not as high as those found in the roller nips of an operating press.

Preliminary testing determined that the most reproducible results were obtained with the roller pressure set at 15 pounds per square inch and with the machine being operated at low speed.

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<sup>10</sup> Thwing-Albert Instrument Co., Philadelphia, PA

With the test method employed, 1.32 cc of ink was applied to each lower oscillating roller. The machine was then activated and the ink was allowed to distribute 3 minutes. The machine was then deactivated and the pans containing 25 milliliters of the standard press dampener solution were set in place on the machine. The machine was then re-activated and samples of ink were taken at 5 seconds, 5 minutes, and 10 minutes directly from the machine while operating. These samples were then analyzed for moisture content using the Mitsubishi Moisture Meter.

Since the litho break tester has two sets of rollers, samples were taken from each set of rollers two times. No significant differences were observed from either set of rollers or from either test session. Moisture content was converted to the same scale as that for the Duke Tester method.

Results of this testing are summarized in Figure 3. All colors, except black, displayed a higher moisture content at the 5 minute interval than at the 10 minute interval. This test displayed a difference between the black ink and all other colors as did the press.

These results did not suggest that an ink under these test conditions which had a higher moisture content at 10 minutes than at 5 minutes would perform poorly on the press. The important observation was that this test method did show a difference in the moisture content of the black ink when compared to the other colors.

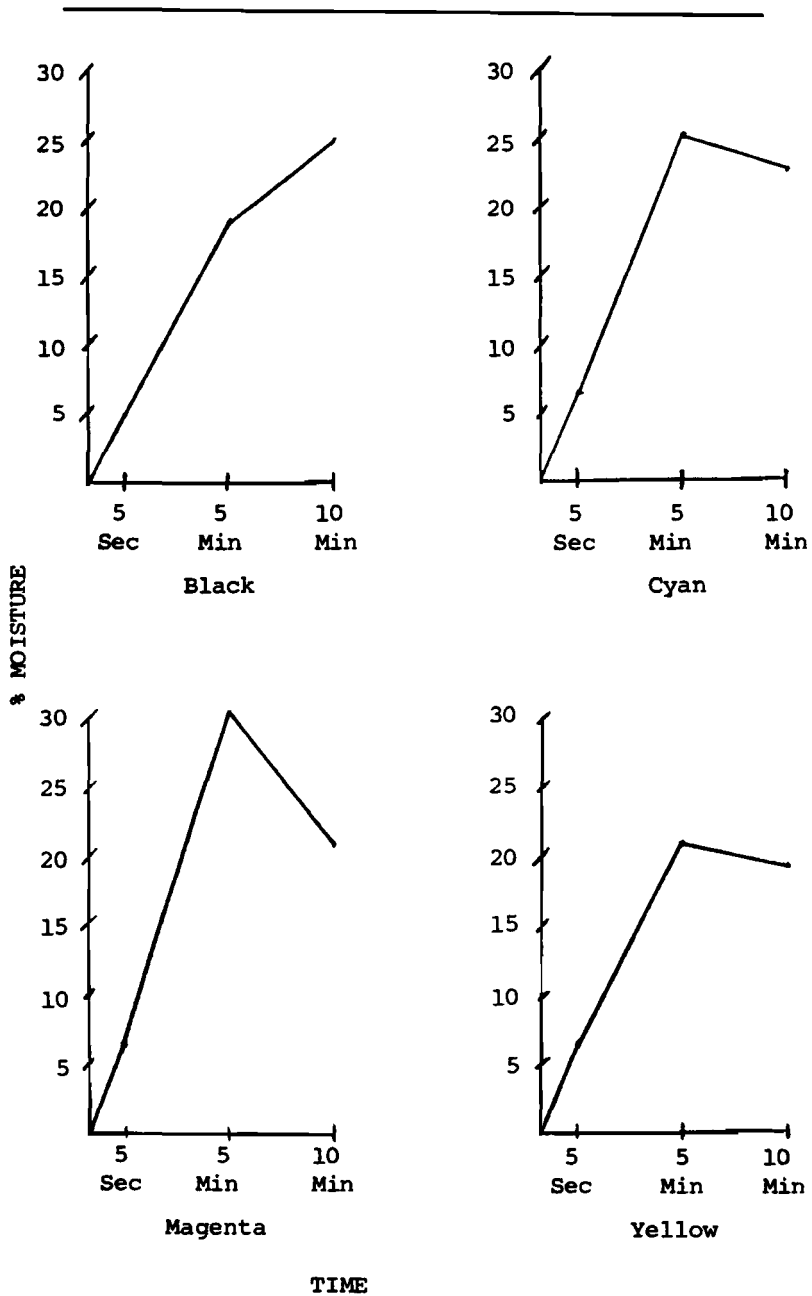


Figure 3. Litho break test summary.

## DISCUSSION

A method patterned after that proposed by Surland (1967, 1980, 1983) for determining emulsification capacity and water balance may give a printer or inkmaker an indication of what can be expected on the press but the results obtained in this study did not correlate to press performance. Although the generally accepted ranges for emulsification capacity were exceeded and water balance was not attained, the cyan, magenta, and yellow inks performed well on the press. The black ink was very intolerant to slight adjustments in dampener control settings and was judged to have had poor water balance latitude.

MacPhee (1979) pointed out that emulsified ink taken from a press contained dampener solution droplets less than 1 micron in diameter as was evidenced by the inability to see them with an optical microscope. It was further stated that emulsified ink taken from a Mixmaster contained dampener solution droplets on the order of tens of microns.

The probable reason for this observed difference is the difference in shear rates between a Mixmaster or Duke Tester and the roller nips on a press. The Mixmaster and Duke Tester are low shear devices which do not adequately distinguish between dampener solution emulsified and dampener solution encapsulated by an ink during the test. It is believed that in this type test, emulsification capacity and water balance are interrelated and both are evident when an equilibrium is reached at the point (percent absorbed and time) where encapsulation of dampener solution due to mixing action is balanced by deencapsulation at the areas of highest shear rates in the devices, i.e. the area under the rotating blades and the area where the rotating blades pass close by the sides of the bowl.

The Litho Break Tester more closely approximates the high shear conditions present on an operating press and negates the encapsulation of dampener solution evident in the Mixmaster or Duke Tester. Tasker (1983) pointed out the importance of shear rates on emulsification capacity and used a Litho Break Tester in his work which highlighted the lack of correlation between the method according to Surland and actual press performance.

It is postulated that the ideal lithographic ink must have the ability to emulsify approximately 21 percent by weight dampener solution under high shear conditions without being drastically affected in its physical properties. If the ink emulsifies a greater amount than this it will then begin to take on the character of the dampener solution and will start to fill the non-image area of the plate. If the ink does not have the ability to emulsify this amount of dampener solution, it will be repelled from the image area of the plate producing poor print quality early in the press run and will fail to transfer down the ink train later in the press run. If the emulsification potential of the ink is either too high or too low, poor print quality and poor press performance will result. Although the ink may not be called upon to carry its full potential of dampener solution, that potential must be available in order to give the press operator latitude to adjust dampener controls as needed to produce smooth solids and sharp dots.

It is further postulated that the emulsification rate of an ideal lithographic ink is inversely proportional to the amount emulsified by that ink. When ink initially encounters dampener solution, it will readily incorporate that dampener solution by emulsification. As the ink continues to emulsify dampener solution, that rate steadily decreases as the total percent of emulsified dampener solution approaches the ideal 21 percent. If the ink encounters more dampener solution at the zero emulsification rate, that dampener solution will ride on the surface of the ink-ink rollers preventing smooth deposition of ink on the image area.

This reasoning is consistent with the models presented by MacPhee (1979) and the results of this study.

Although the scope of this study did not allow for the development of a test method for predicting the emulsification capacity of a lithographic ink, it is believed that such a method could be developed using some type of high shear device and a quantitative method for determining moisture content of the emulsified ink.

## CONCLUSIONS

1. A method which uses a low shear rate device such as the Mixmaster or Duke Tester to accurately predict the emulsification capacity and water balance of a lithographic ink does not always correlate to press performance.
2. In order for any method to accurately predict press performance of a lithographic ink, it must take into account the shear rates encountered in the roller nips of a printing press.

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