Dynamic Monitoring of Water During Lithographic Printing

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Abstract

A portable near-infrared moisture meter has been utilized to track water during the lithographic printing process. The absorbance at 1.94 um is used to monitor water without interference. An angular dependence was found for aligning the meter a few degrees off perpendicular when monitoring various substrates. Water was measured in newsprint at various stages of a press run before and during printing. It was also monitored in ink on both the image and non-image areas of the plate as the water settings were changed on press. Differences in the equilibrium distribution of water on plate for a spraybar and Molleten dampening system were followed. The relevance to ink/water balance during lithographic printing is discussed. The sensitivity of this approach for non-contact measurement is demonstrated for various applications.

Introduction

The applications of near-Infrared (NIR) spectroscopy for monitoring of industrial processes has rapidly accelerated in recent years. The NIR spectrum (0.75 – 2.5 um) is made up of weak, broad, overtone, combination and harmonic bands, distinguishing NIR from the traditional mid-IR (MIR) region (2.5 – 25 um), composed of strong, distinct, fundamental bands. Advantages of NIR are a low absorption coefficient, which allows for a longer path length, the ability to handle condense phases well, and rapid, non-destructive sampling of on-line processes. Disadvantages include sensitivity to the local environment (e.g. hydrogen bonding), calibration difficulties for applying Beer's Law, and, again, a low absorption coefficient. In addition, the interference of other –OH functionalities in the MIR region is a possibility. Water has four absorption

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wavelengths in the NIR: 1.2, 1.45, 1.94, and 2.94 um, with the 1.94 um wavelength (a combination band) distinct from interference with other species.

The KJT-100 Moisture Meter (Kett), developed by Kagaku Electric and Japan Tobacco, takes advantage of the 1.94 um distinction and is, in essence, a single wavelength spectrophotometer. The KJT-100 is a hand-held, battery powered meter that operates on the diffuse reflectance principle. Light from the source is passed through the optical system to interact with the surface of interest. Light that is reflected back from the surface is collected by the optics and passed through a narrow-band interference filter, which singles out the 1.94 um band specific to water. The KJT-100 then ratios the amount of light received at 1.94 um to the amount from nearby wavelengths to determine how much absorption there is due to water in the sample. Because the measurement is based on ratios, the device essentially stays in calibration indefinitely, immune to drifts due to aging of the lamp, detector, or electronics. The meter, with a focal length of about 150 mm and measurement diameter of 25 mm, can be powered by battery or an AC adapter and connected to a PC via an RS-232C for extended remote control operation. The meter is simply aimed at the material of interest and focused with the aid of the optical guide. The KJT-100 then automatically makes the measurement and computes the absorption value or % moisture.

As for printing applications, Rosenberg (1986, 1992) has applied MIR to track water on the plate during the printing process using 2.83 um absorbance. This wavelength represents a broad MIR absorption of –OH, which can give rise to a convoluted response in the presence of ink and fountain solution components bearing this functionality. The potential utility for examination of water in ink on moving rollers was, however, clearly demonstrated. Lindholm and Strom (1997) have reported on the use of NIR at 1.94 um as a way to make on-line measurements of ink film thickness on a flexographic press.

Specular And Diffuse Reflectance

The angular dependence of the meter with respect to the surface being measured was investigated for several different types of printing substrates. The KJT-100 meter was held in place on the benchtop while different materials were focussed at a 90° angle to the optical axis. The materials were then rotated off axis while the absorbance values were recorded. As can be seen in Figure 1, different paper substrates that produce diffuse reflectance had only small changes in their recorded absorbance values as they rotated a few degrees from a 90° angle. The plastic and coated cardboard produced specular reflectance and a few degrees off-axis orientation produced large changes in their recorded absorbance values. For most of our applications, the meter was mounted to ensure reproducibility of substrate alignment to the optical beam.

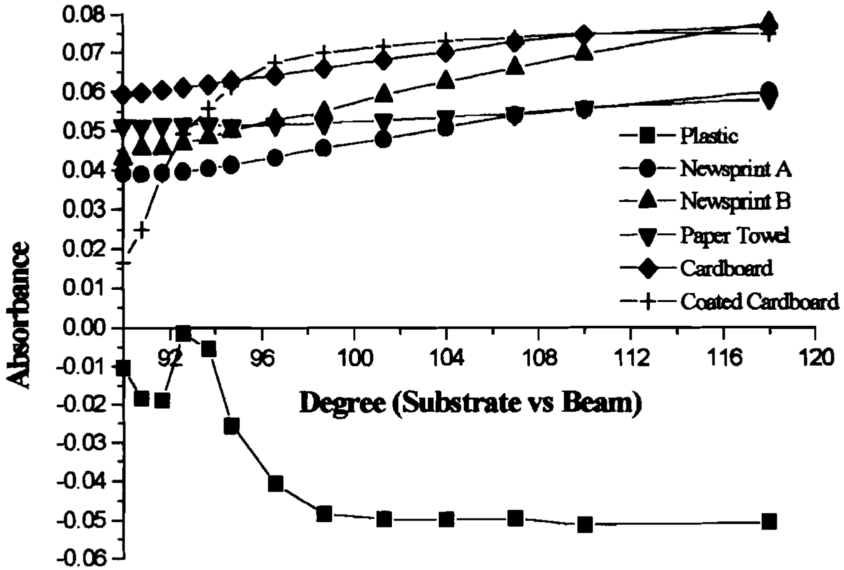

Figure 1. Comparison of angular dependence of KJT-100 Moisture Meter for specular and diffuse reflectance.

For remote, hand-held usage, the same operator was employed to keep variations in holding the meter to a minimum, with an emphasis on maintaining the same angular orientation (slightly off a 90° angle).

Moisture Changes In Paper During Printing

The first step in examining water in paper was to develop calibration curves for different newsprint papers. The absorbance of a single sheet of paper (no backing) was recorded under various conditions. Sheets were left in sealed chambers with saturated salt solutions that equilibrated the % relative humidity (%RH) in the chamber at different levels. For example, potassium sulfate (98 %RH), calcium chloride (60 %RH), and magnesium chloride (33 %RH) salt solutions would cause the paper samples to have 3 different moisture levels. Following the ASTM-644-89 oven drying method of measuring the weight loss or gain of the paper at 0 %RH and at the above chamber %RH levels, the % moisture of each paper sample can be determined. Plotting the recorded absorbance values for each paper sample vs. % moisture yields a calibration curve for that particular paper.

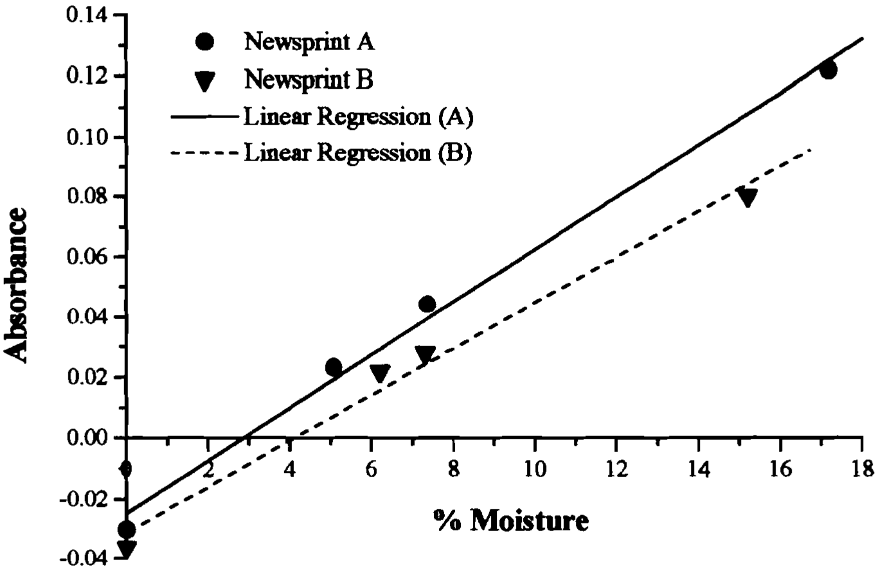

Figure 2. Calibration curves of two newsprint samples.

After calibrating a newsprint paper, the calibration points were entered into the KJT-100 and an analytical curve was computed. The changes in the moisture content of the newsprint during a production run at a major newspaper printer were determined. Measurements were taken during the four-color printing process (printing four color on one side and only black on the other) at 5 different locations on the press, from the reel before printing through to beyond the last printing unit. Figure 3 shows the changes in moisture content for 4 different pages at various stages of the printing process (some data is missing due to the inaccessibility of some areas of the press). Increases from 8% to 14%, (a 75% increase) were found to occur in the paper in a matter of seconds. The results obtained here are consistent with the physical testing of newsprint water absorption described by Trollsas (1995).

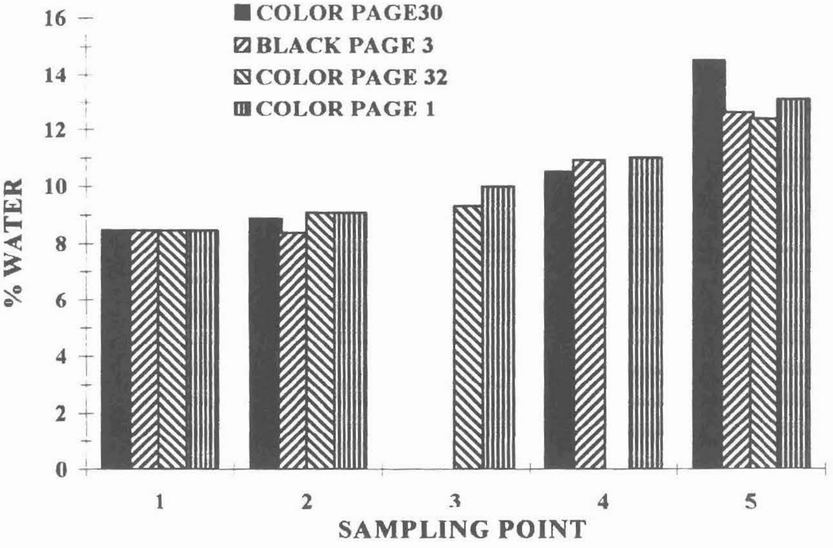

Figure 3. Newsprint moisture increases during four-color printing.

The effect of moisture increases in paper as it relates to registration problems was also examined during directory printing. The web width growth was determined using a laser measurement system and the % moisture was followed using the KJT-100 meter. The results are summarized in Table 1.

Paper Source	# of Rolls	Avg. Infeed % H_2O	M % H_2O	C % H_2O	Y % H_2O	K % H_2O	Web Width Growth
A	10	5.7	6.6	7.0	7.8	8.8	2.34 mm
B	6	6.1	6.9	7.4	8.1	8.8	2.23 mm
C	10	6.5	7.2	7.7	8.4	9.3	2.01 mm

Table 1. Increase in moisture during four-color printing and resulting web growth of three different directory papers.

Paper A showed the largest increase in moisture content (54%) while paper C had the smallest increase in moisture after four color printing (43%). Paper C had the highest in-coming moisture content *and* the smallest increase in web width growth, while paper A, which had the lowest in-coming moisture content, yielded the greatest increase in moisture (54%) *and* the largest web width growth. This result indicates that the in-coming paper moisture level determines the overall web width growth and the % increase of water uptake. Unfortunately, simultaneous monitoring of press registration was not possible at this time, and may be the subject of future work to clarify these results.

Monitoring Water On The Plate During Lithographic Printing

The dynamics of water distribution on the printing plate as the water settings are changed was followed using the KJT-100 Moisture Meter. Our in-house narrow web Didde ML-5 press was run at 400 fpm with either a Ryco spray bar or Molleten sponge providing the dampening. A conventional plate that was imaged as shown in Figure 4 was used, so that both water on the non-image areas of the plate and emulsified in the inked image areas could be followed.

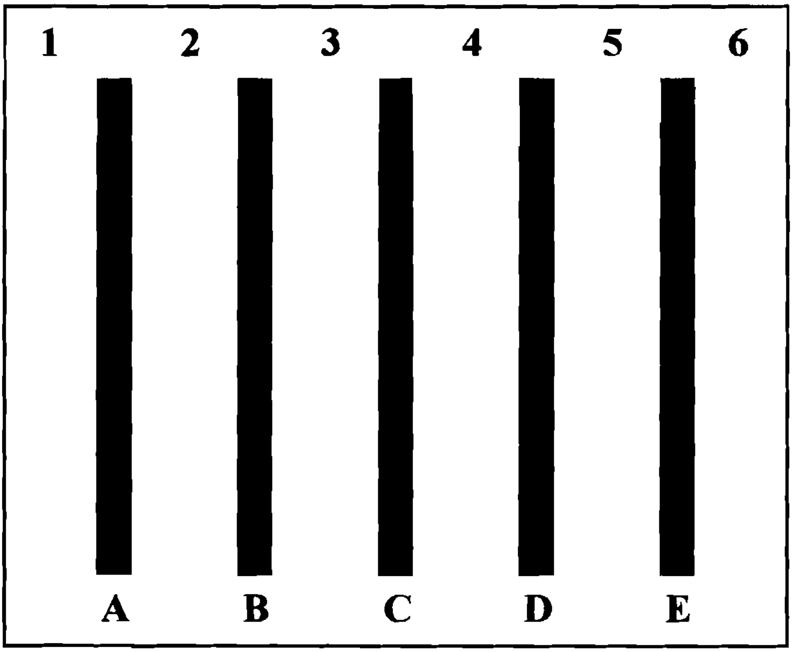

Figure 4. Plate image used to monitor water distribution during printing. The letters A-E and numbers 1-6 represent image and non-image areas, respectively.

The frequency setting of the water spray was held constant at 1/sec, while the water pulse width in milliseconds (ms) was periodically increased during printing. The water pulse width determines the amount of water that is delivered each time that the spray is engaged. The press was allowed to equilibrate for 30 seconds. The KJT100 was then focussed on non-image area 1 for 20 seconds before recording the absorbance at that location. Similarly the other non-image and image locations were recorded. The spray bar was aimed to spray directly onto the dampener form roller, just before the inking form roller, so there was only one roller to distribute the water before contact with the plate.

The KJT-100 was very sensitive to the mechanics of the water feed and the distribution on the press. We found that water was not equally distributed across the plate, with the center of the plate receiving a much greater amount of water per spray. The alignment of the spray bar produced a disproportionate amount of water in the center, due to overlapping of the spray pattern. Figures 5 and 6 relate the absorbance values acquired at each location of the plate as the water feed was increased from 8.5 to 14.0 ms. The KJT-100 values reported are averages that were collected beginning 60 seconds after a change in water setting was initiated. The absorbance values for the image areas of the plate are much higher than the non-image areas due to the emulsion of ink and water, resulting in an increased film thickness of the layer. Because of this, a direct comparison cannot be made between the absorbance values of the non-image and image areas. However, it is safe to say that the disproportionate values at position C, substantiated by the higher values detected in the non-image locations 3 and 4, indicate the distribution pattern of water on the plate.

To get a feel for the dynamic water distribution on the plate, the KJT100 was connected to a PC via an RS-232C cable and data was collected using software supplied by Kett. The water was set automatically on the press at a pulse width of 12.6 ms, and at a frequency of 1/sec. The Didde press was run at 400 feet/min. As the meter was scanned across the plate, there was again a higher amount of water in the center of the plate, due to the overlap of the spray bar. When the frequency of the water was doubled to 2/sec, the water in the center of the plate also increased, but was spread out more to neighboring areas of the plate. This occurred in both image and non-image areas, indicating that a limit to the amount of water/ink was being reached in the nip (Figure 7). The spray bar was then realigned by moving the unit farther back from the plate. This resulted in a more equal distribution in image areas B, C, and D, while, at the same time, non-image areas 3 and 4 continued to show a much higher water level than the rest of the non-imaged portions of the plate. When the water frequency was doubled to 2/sec, the water was equalized across most of the plate, with only the edges showing a deficiency. Again, similar maximum values were reached in the image and non-image regions, reinforcing the idea of a limiting amount of water through the nip.

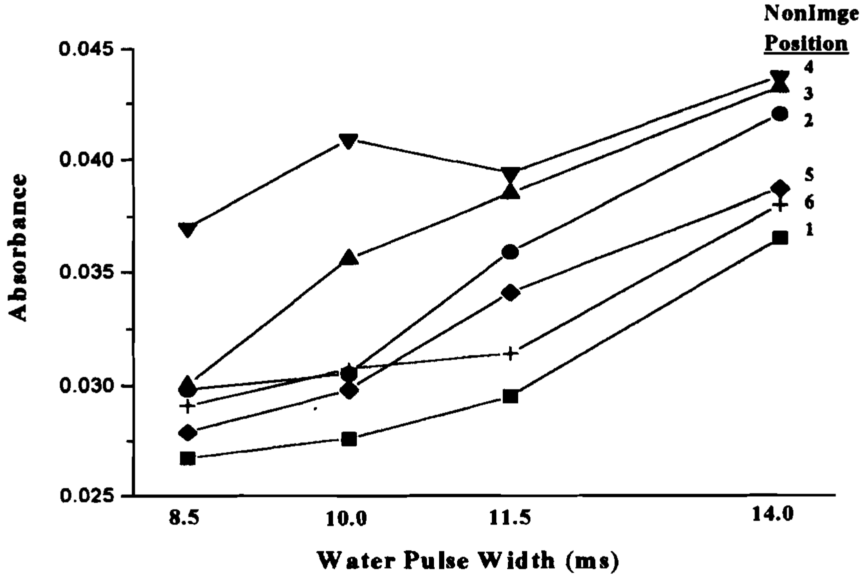

Figure 5. Change in water absorption on the non-image area as the water setting is increased (water pulse frequency held constant at 1).

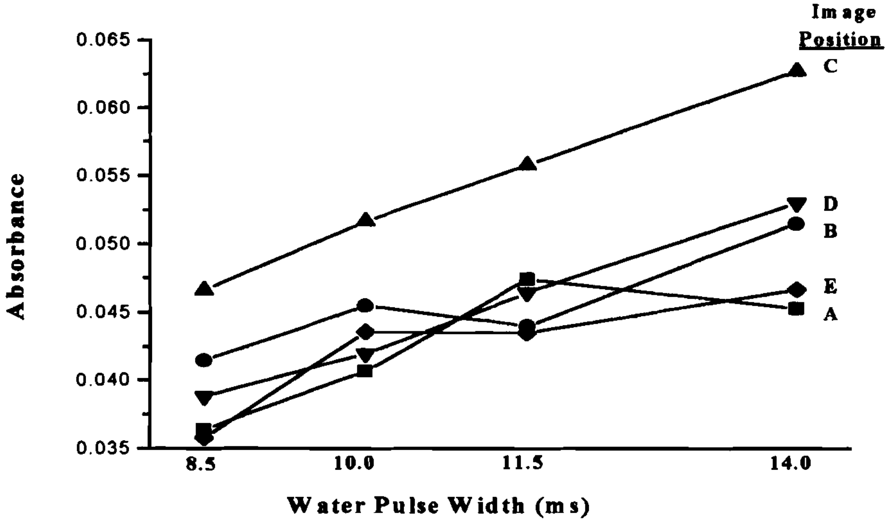

Figure 6. Change in water absorption on the image area as the water setting is increased (water pulse frequency held constant at 1).

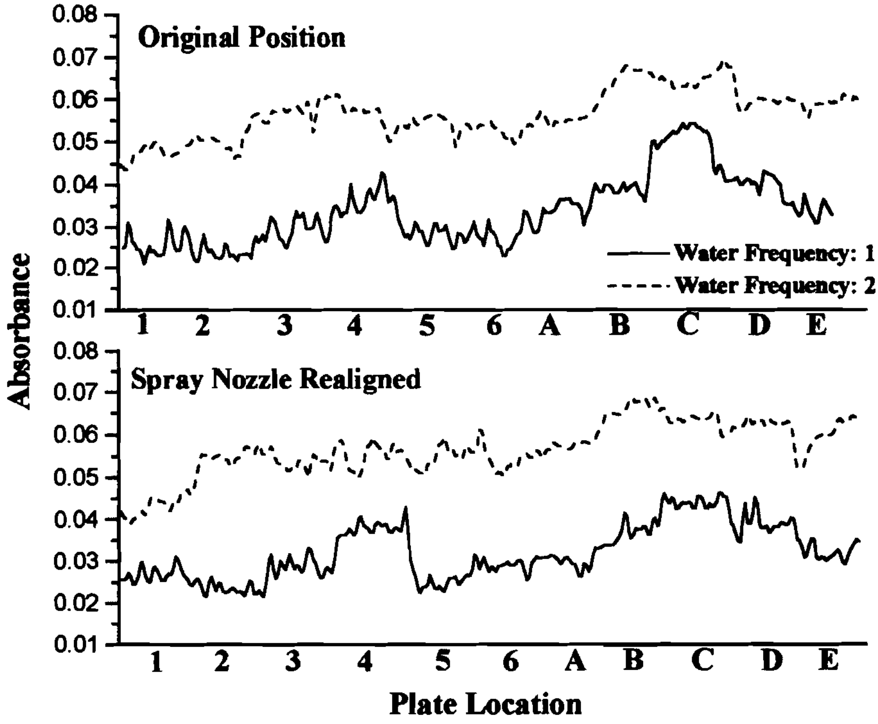

Figure 7. The influence of water frequency and spray bar position is evident in both image and non-image areas of the plate.

Image areas B and C were examined further as the KJT100 was set in place and the water evolution for each image stripe was monitored as the water pulse setting was increased, while water frequency remained at 1/sec. Figure 8 shows the steady increase in water absorbance as the water feed was increased without reaching a saturation point. Figure 9, illustrating image area C, shows that a limit to the maximum amount of water in the center of the plate is reached early on. Continued increases in the water pulse width are not reflected in the absorbance values.

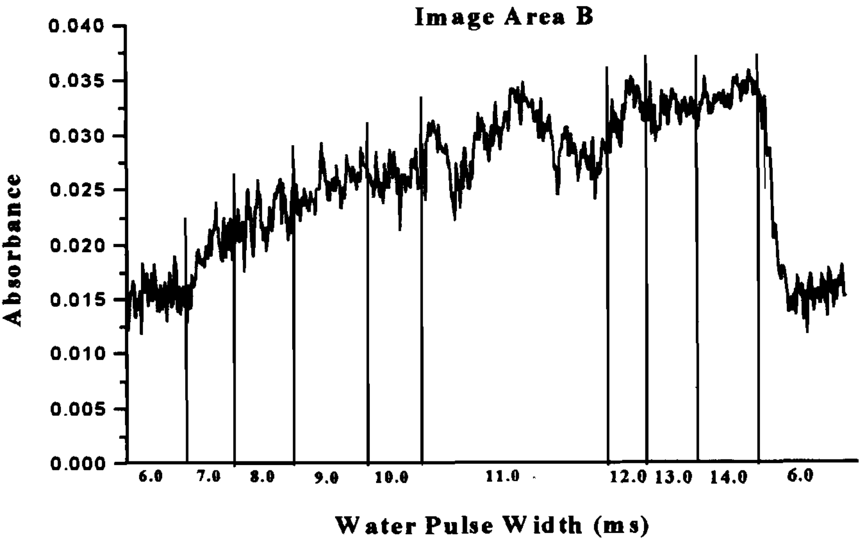

Figure 8. Change in water level in image area B as the water pulse is increased. Water frequency is constant at 1/sec.

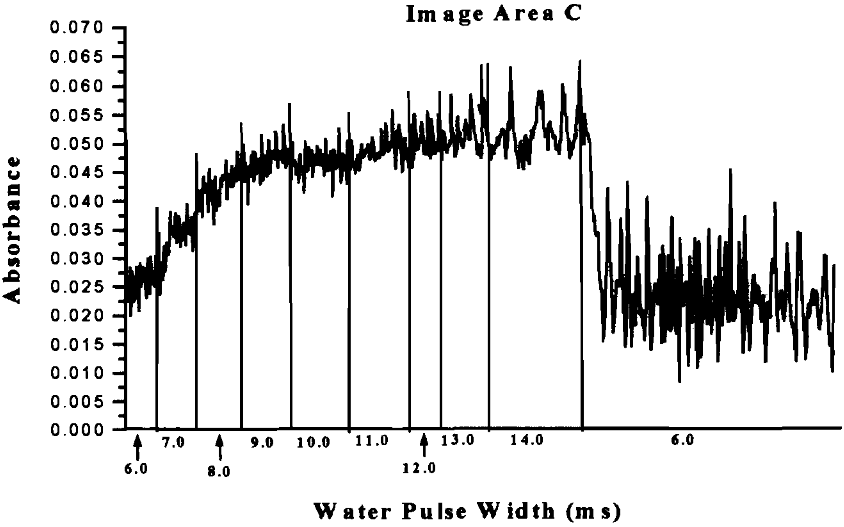

Figure 9. Change in water level in image area C as the water pulse is increased. Water frequency is constant at 1/sec.

A Molleten sponge dampener then replaced the spray bar dampening system. As seen in Figure 10, the water level across the plate was much more uniform, even as the water setting was increased. The mechanical oscillation of the Molleten dampener can also be seen in the data.

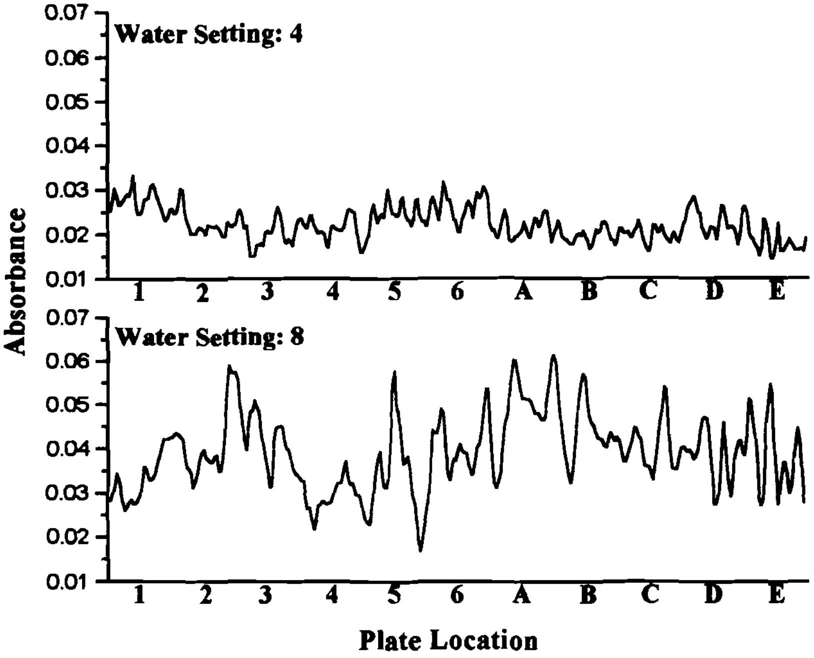

Figure 10. The uniformity of water distribution across the plate is more uniform with a Molleten dampener. An increase in the water setting is reflected in the absorbance values and highlights the mechanical oscillation of the dampener.

The KJT100 meter was sensitive to the press mechanics of water delivery to the plate. The overlap effect of the spray bar was easily detected, while the uniformity of a Molleten sponge dampener was also quite evident. When water levels on press are changed during a press run, it can be very educational to follow both the time lags for the increase/decrease to take effect and the changes in water distribution at the plate. We have done some work to follow the change in print density as water settings are manipulated on press. The absorbance of the image areas on the web was collected immediately after printing. Density values of each image stripe were taken from the 500th copy to allow for press equilibration at each water setting. There were no clear correlations between density values and water absorbances, although some trends were noted. Further work in this area is continuing, to clarify the impact of water changes on press to print density values and water absorbance in the paper.

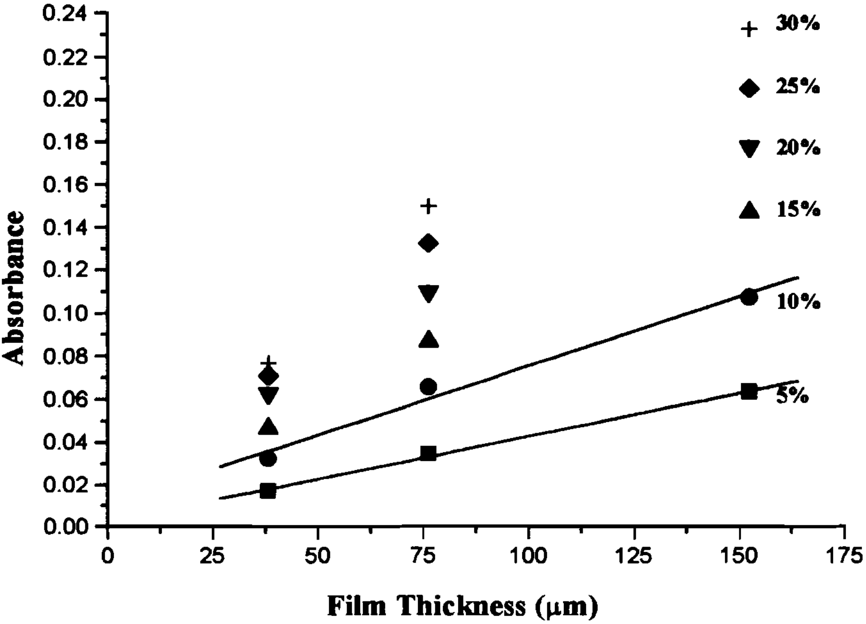

Figure 11. Emulsified ink films on plate image area. A linear fit was applied to the 5 and 10% film data.

An attempt was made to calibrate the amount of water that was in an ink film to evaluate water absorbance as a function of film thickness. Emulsions of ink and water were made containing 5% water, up to 30%. The emulsified inks were drawn down over an imaged plate using a bar applicator to form films of 38.1, 76.2, and 152.4 micrometers thick. Figure 11 demonstrates the linearity of the emulsified films for the low water % and the curvature for inks of 15% and greater emulsification. The data from the press would indicate, via extrapolation, that the water content on the plate image surface is much higher than previously imagined. An independent measurement of the film thickness on press is needed to deconvolute the relationship of ink film thickness and water content on press. This approach, using a non-contact measuring device on press, offers a distinct advantage over previous attempts employing physical sampling of ink off the press, as noted by Nieminen (1992).

Summary

The KJT-100 moisture analyzer offers a convenient means to follow water content during lithographic printing. It is sensitive enough to follow a variety of dynamic changes within paper, ink on the roller train, and ink/water on the printing plate. Some of the potential applications of the KJT-100 Moisture Meter to lithographic printing includes:

(1) the relationship of paper moisture to print quality and registration problems;
(2) the mechanics of water delivery on press;
(3) response changes in volume and equilibrium time as water feed changes are made on press (which can then be related to ink transfer and water balance).

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