Predicting print mottle: a method of differentiating between three types of mottle

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ABSTRACT: There is considerable confusion in identifying the source of mottle when a coated paper shows print mottle on press. This paper presents a series of laboratory tests that, using paper and ink, gives an accurate understanding of why the mottle occurred. With this knowledge, short-term adjustments on the press and long-term adjustments in coating formulation and papermaking on the paper machine can be made to correct the type of mottle seen in the production print. Tests can monitor changes in the paper coating formulation and can incorporate various combinations of ink, paper, and fountain solution. These tests can then be used to predict when mottle will occur before going to press.

KEYWORDS: Ink absorption, ink lay, mottle, paper properties, print quality, test methods.

The term *mottle* is widely used throughout the printing trade and the paper industry to describe a nonuniform printed image. Sometimes mottle can be seen on white paper as nonuniform gloss, but the most elusive is the type of mottle that appears during printing as spots of varying density *(1)*. During the studies presented in this paper, three different types of print mottle were identified, and the ensuing information discusses new test methods that, when used together, can measure and predict when mottle will occur.

Three types of mottle will be defined. To help in identifying mottle on printed press sheets, each includes a description of what the color bars along the edge of a printed press sheet would look like in a typical four-color process job. **Figure 1** depicts good vs. mottled print.

A basic description of what occurs to the ink on paper in a four-color job is as follows. The first ink to be printed, usually called the first-down color, is printed from the blanket to the "dry" paper. The area where the ink is applied is called the "image" area. The "nonimage" areas contact the blanket too but are not receiving fresh ink. These areas do, however, receive a thin application of fresh fountain solution (a combination of water, acid, gum arabic, surfactant, and alcohols or replacements).

As the sheet goes into the second printing unit, the blanket contacts the entire sheet again. Ink can be printed to the sheet over wet ink from the first unit (called wet trapping), and it can also be applied to white paper that has been wetted by the fountain solution and is no longer dry. This process repeats as the sheet progresses through the press. There is continual interaction of ink and fountain solution with the surface of the paper, and it is these interactions that are measured using the test methods outlined in this study.

Backtrap mottle (BTM)

A condition called *backtrapping* occurs when the ink film on the paper loses its ability to transfer from the blankets to the printed paper as the sheet progresses through the multiple units of the press *(2)*. If the ink is too unstable or if there is great

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interaction between the ink and paper, the solvent/oil in the ink is lost too quickly, and the ink can no longer transfer. If the transfer of ink to the paper is nonuniform, the result is called backtrap mottle.

The most important characteristic of BTM is that it requires a combination of conditions to occur, and these are the four properties that are measured in the following studies: (a) multiple printing units, (b) fast-setting ink, (c) a fast-setting paper, and (d) nonuniform paper absorption. BTM is most often seen in the ink colors that are printed in the first few units on the press. Since the color cyan is dominant in most process color separations and because it is most often printed first or second, the mottle occurs in the cyan areas of the form (blue skies, for example).

Color bars on a four-color job: Sequence black (K) + cyan (C) + magenta (M) + yellow (Y)

The cyan ink will show mottle, but the magenta and yellow probably will not. In severe cases, the magenta may show some mottle. Also, if just the cyan is printed, there is no mottle. It is very important to understand why the first-down black ink does not always show BTM. Black ink is run on the press at an ink film thickness that is 1.5–2 times thicker than the three process colors of cyan, magenta, and yellow. A thicker film, together with the slower-setting nature of black ink formulations, typically prevents black inks from backtrapping.

Water interference mottle (WIM)

The unique characteristics of this type of print mottle are (a) that it requires only a single printing unit to occur and (b) any ink formulation can have WIM. For example, a single-color press printing only black can have severe mottle, and a multicolor job can have mottle in every ink color. Although WIM occurs throughout the job, it is most offensive in screen areas and halftone pictures. WIM dots have ragged edges, and WIM solids are broken and noncontinuous, leaving a mottled, washed-out look to the print. Measured densities are typically low *(3)*. See **Fig. 2.**

Water sensitivity mottle can be caused by a paper that cannot absorb fountain solution. If fountain solution is not absorbed, the ink cannot transfer: an uneven and mottled print appears. WIM can also be press related, e.g., feeding too much water onto the job, running an ink formulation that cannot pick up enough water, using an improperly mixed fountain solution, or running an excess of alcohol replacements. The experimental data reported in this study focus on paper-caused WIM.

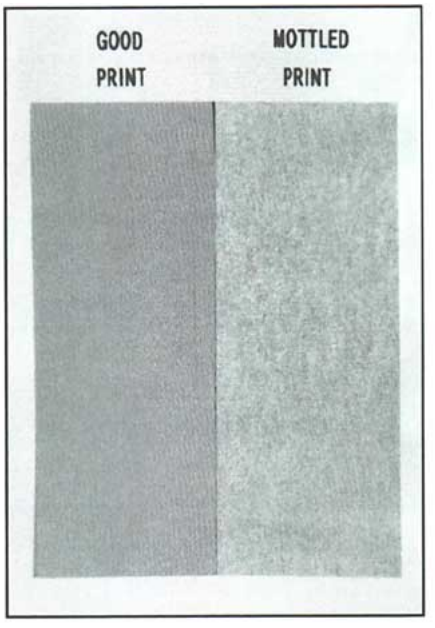
Color bars on a four-color job (K + C + M + Y)

In WIM Type 1, all the colors will show mottle, whether the printing units are run individually or all "on impression." In WIM Type 2, the last-down color will not print over white paper areas that have been "printed" with fountain solution from previous units. In this type of mottle, the first colors will be acceptable, and the last one or two colors will have severe mottle.

Wet ink trap mottle (WTM)

Another type of mottle that can be easily mistaken for BTM is that caused by inks that are out of proper tack sequence. (In multicolor printing, the first ink should be higher in tack than the next ink, and so on through the press.) If the inks are not in the proper tack sequence, and a high-tack ink is printed over a low-tack ink, the result will be a mottle that, like BTM, becomes worse as the number of printing units is increased. Solids, however, remain uniform and mottle free *(4, 5)*.

1. Good vs. mottled print



Color bars on a four-color job (K + C + M + Y)

This type of mottle is characterized by single-color solids that print acceptably, but the two- and three-color overprint patches show severe mottle.

Discussion

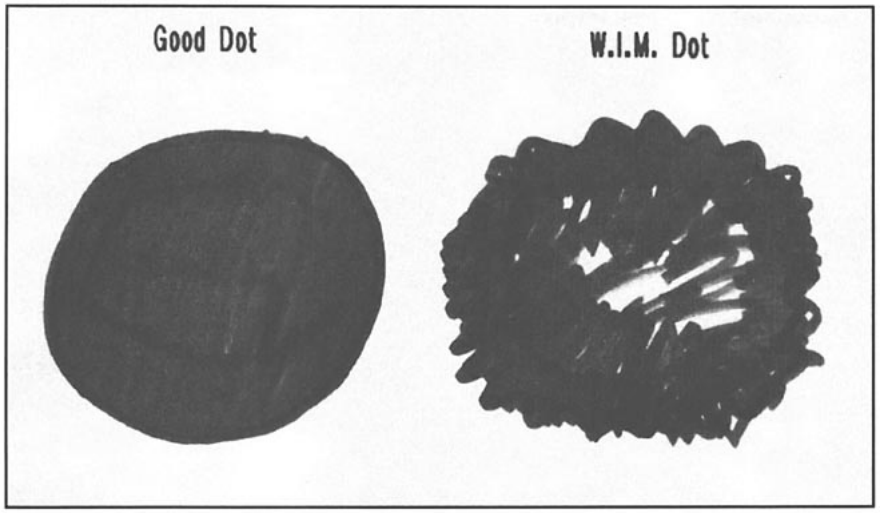
Experimental evidence described here has shown that, if coated paper is evaluated using a combination of three specific test procedures along with certain tests on the inks, the mottle in the printed job can be identified so corrective procedures can be taken.

Each type of mottle will be discussed using actual case studies in which the defect occurred on the press. In most cases, a competitive paper that printed successfully was also run. Where appropriate, the inks were tested, and these data are included with the paper test data.

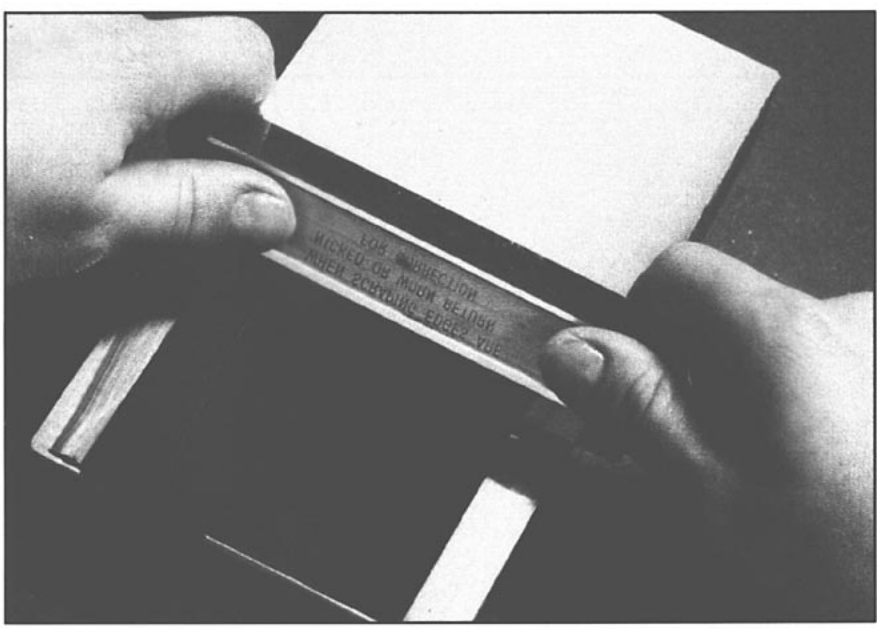
Test conditions

All tests conducted in this study were performed on a flatbed Vandercook proofing press, a printing machine that is a most reliable test instru-

2. Good dot vs. WIM dot



3. Drawdown printing block



ment. The press has a flat, adjustable bed and a motorized printing cylinder that is covered with an offset blanket. After ink is applied to the blanket, the cylinder moves forward on impression and over the paper sample. The cylinder can return to its start position, either "on" or "off" impression, depending upon the test requirements.

The printing speed and impression squeeze, or pressure, can easily be controlled. When set up with special equipment, this type of press allows us to control the two most important variables in testing ink and paper to ensure repeatable and reliable test results: ink film thickness and percent solvent content.

Ink film thickness

This study uses a constant ink film thickness to control the amount of ink being used. Density readings are not used, because density alone does not measure ink film thickness. Specially designed, precision-milled blocks are used to apply the ink to the blanket for printing. The thickness of all ink films was measured using the Interchemical Thickness Gage, made by BYK Gardner, Inc., Silver Spring, MD. See **Fig. 3**.

The block is machined between its shoulders to a constant depth and, when ink is drawn onto the block, the measured wet film thickness on the block is 0.2 mil. When the blanket cylinder is passed over the block to apply ink to the blanket, this film splits in half, applying 0.1 mil of wet ink to the blanket and leaving 0.1 mil on the block. During the first pass over the sample, the ink film splits in half, depositing 0.05 mil of wet ink on the paper sample. This is slightly thicker than that used on a single-ink film commercial job, which is approximately 0.035–0.045 mil *(6)*. See **Fig. 4**.

A film thickness of 0.05 mil, however, is significantly thinner than that applied on an inkometer for tack readings or that applied to the spindles of an IGT or Prüfbau. Each time a test is run, the same amount of ink is used, for a number of reasons:

- The ink film thickness must be controlled to assure repeatable test results.
- As shown in **Fig. 5**, as an ink film thickness is increased on paper, the energy to split that film of ink also increases, again requiring precise control of the film thickness for each test.
- Inks set, or change in tack, at different rates depending upon the amount of ink used, so it is imperative to run the same ink thickness on each test *(7)*.
- Weighing an ink film during testing is less reliable since, when measuring the weight of the spindle with ink (i.e., on an IGT or Prüfbau), the operator cannot determine what percentage of that weight is solvent. Again, repeatability is difficult at best.

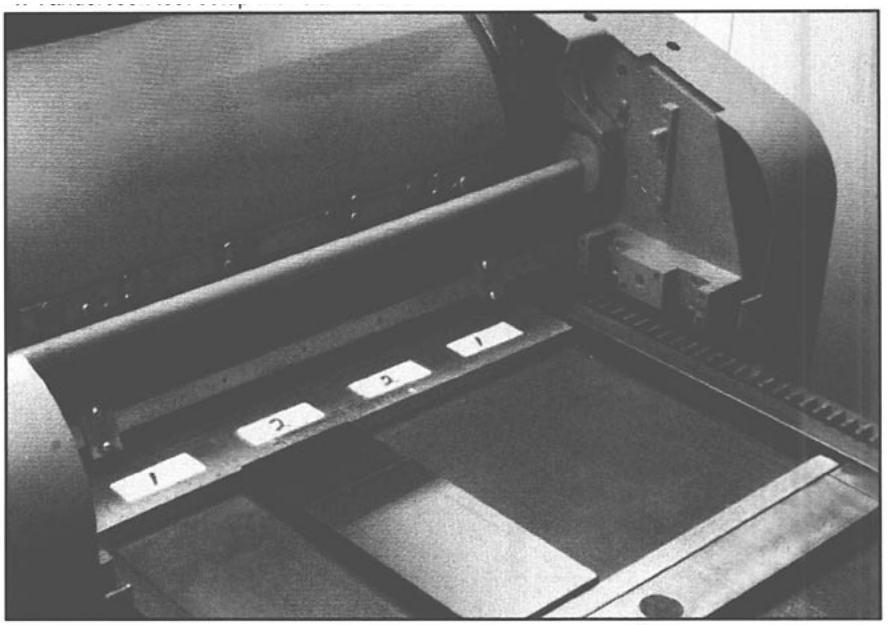
Percent solvent content

Controlling the thickness of the ink film is useless if precautions are not also taken to control the level of solvents or oils in the ink. When an offset ink is formulated, an initial mixture of pigment, resin, and oils (called a flush) is used. This flush is a highly viscous material, too high in tack to run through the press rollers. The ink manufacturer adjusts this flush to an acceptable tack level by diluting the ink using linseed, soya, and/or hydrocarbon oils. Different resins require different amounts of diluent, depending on their solubility properties. Then, during printing, as the solvents leave the ink film, the ink tack begins to return to its original viscous state. This is the "setting" function of an ink. Therefore, it is imperative during testing that the solvent content of the ink remain the same at the start of each test. On the press, these solvents will first evaporate with exposure to rapid air movement in the ink train and then by absorption into the printing blanket and the paper.

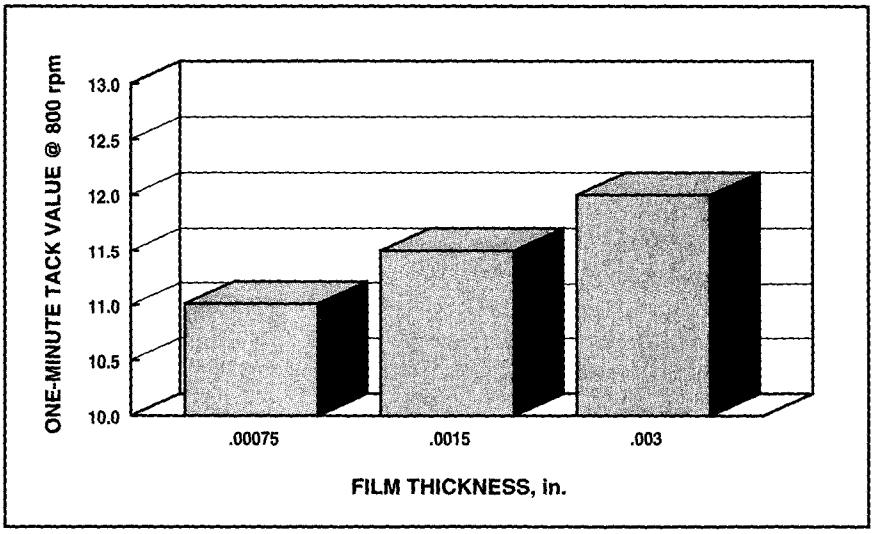
During testing, the solvent content of the ink is kept constant by taking the following precautions against evaporation and absorption:

- Evaporation normally does not occur, since these test methods do not use moving ink application rollers like the Prüfbau or IGT. The ink application blocks used in these studies are steel and nonabsorbent.
- Absorption is prevented into any material other than the paper sample being tested by using offset blankets that have a nonabsorbent surface.
- Since these test procedures are fast and efficient, the speed with which they can be run prevents solvent loss.

4. Vandercook test setup with blanket and block



5. Effect of ink film thickness on tack

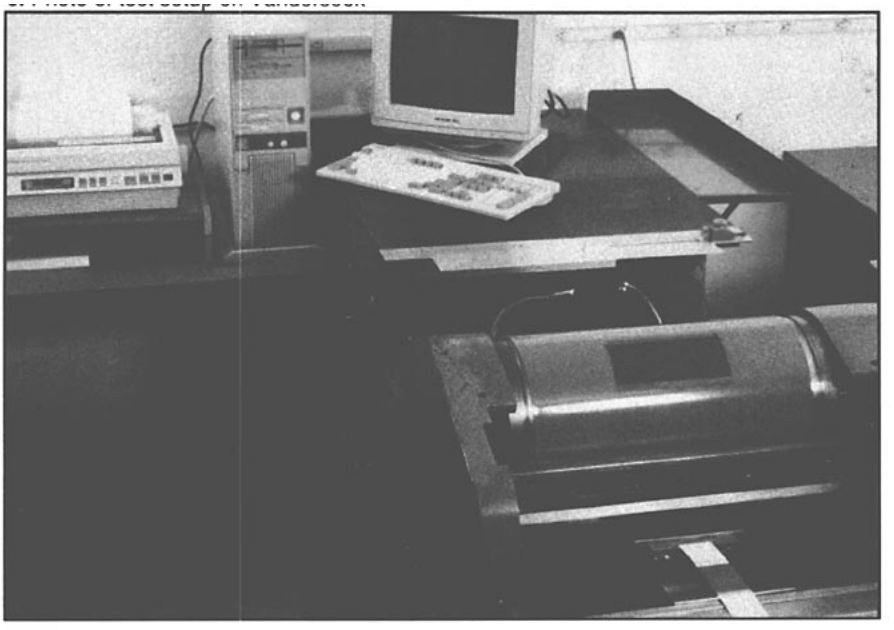


Test procedures used in this study

There are many variables that must be controlled when running tests with inks and papers. If these variables change, the test results will change *(8)*; we have already mentioned ink film thickness and percent solvent content. There is also a third variable, operator consistency, which has to be taken into consideration when evaluating lab-testing data. For example, machines like the Prüfbau and IGT use spindles to apply ink to the paper being tested. The ink is first applied to an ink roller distribution system, and after a given time, the spindles are placed in contact with the inking rollers. The spindle is then removed and used to print the paper sample.

During the time the ink is being distributed over the roller system, the solvent content of the ink changes. The degree of change is dependent on time, temperature, speed, film thickness, and the for-

6. Photo of test setup on Vandercook



mulation of the ink itself, making it difficult to reproduce a printed effect on a consistent basis.

We took a sheet-fed process cyan ink and applied it to the ink rollers on our inkometer *(9)*. The initial solvent content of the ink was 24%, but after just 1 min on the inkometer (90°F, 800 rpm), the solvent content was reduced to 22%. The same experiment, using a web process cyan ink, showed a decrease from 38% to 35% after 1 min at 1200 rpm. We concluded from this study that it is impossible to control solvent content in a test machine using ink-distributing rollers. The rate of change in ink solvent content during the test procedure depends on time, temperature, speed, ink film thickness, and ink formulation. In these studies, we have controlled these variables as follows:

- Time is consistent, because this method of testing is so easy and fast that the ink film remains on the blanket for short periods of time before the testing begins.
- Temperature is controlled by running the tests in a temperature-controlled lab. Since there are no moving ink application rollers and no friction to increase the temperature of the ink, the test equipment never generates a temperature change.
- The speed at which the test press runs is not fast enough to cause solvent evaporation in the ink on the blanket. This is evidenced by measurements of ink film splitting forces over time *(10)* (See "P&I test" below).
- Ink film thickness is controlled by the precision-milled blocks described above. In all tests, the amount of ink on the blanket at the start of the test is 0.1 mil.

Test No. 1, Paper and Ink Stability Test (P&I test)

This instrumentation consists of a platform load cell, frame, amplifier, and personal computer, as shown in **Fig. 6**. The load cell in its frame is mounted to the test press bed; the paper to be tested is attached to the load cell. As the inked blanket prints the paper, the force required to release the printed sheet from the blanket is measured. Without replenishing the ink film, repeated prints are made and, each time, the release force is measured. This procedure simulates a paper printed with an ink in the first units of a press contacting subsequent blankets during multicolor printing. Because the ink film on the paper is not replenished, this test simulates the on-press process *(11)*.

Typical P&I test results, using a standard fast-setting ink, are displayed in **Fig. 7**. This graph compares a fast-setting coated paper (No. 1), a slow-setting coated paper (No. 2), and a nonabsorbent substrate (acetate) (No. 3). An ideal feature of this test is that any ink and paper combination can be used. We have tested blanket, paper, plastic, foil, board, films, acetates, and mylar samples as substrates, and have used various types of ink formulations: solvent-based, ultraviolet, EB, and waterless.

The following information can be derived from this test.

Characteristic No. 1: Setting rate. The average rate of force increase, or slope, is calculated. When a standard ink is used, this value defines the set rate of the paper. The higher the slope, the more absorbent the paper is to ink oil/solvent. In effect, this test places a value on the interaction of a particular ink with the paper's surface. When the paper is kept constant, inks can be tested as well. The set rate of various ink formulations can be measured on a standard paper or on any substrate in question *(12, 13)*.

$$\text{Slope} = (F_F - F_2)/[S \times (P - 1)] \qquad (1)$$

where

Slope = set rate of paper, g/cm/s

F_F = final force, g/cm

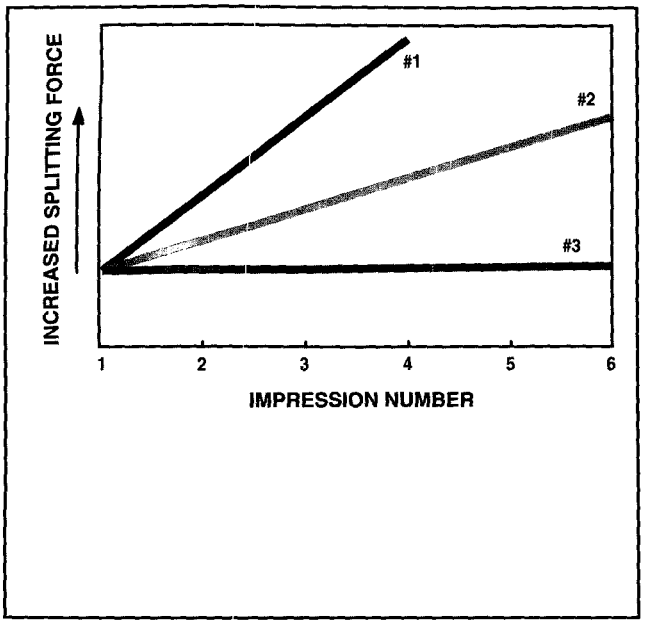
F_2 = force at second pass, g/cm

S = no. of seconds between passes, s

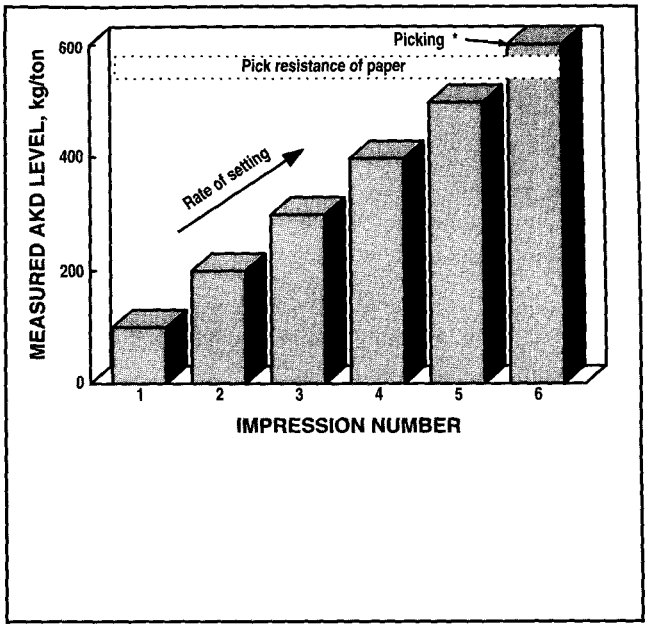
P = no. of passes run.

Characteristic No. 2: Dry pick strength. When the paper coating picks onto the blanket during the P&I test, testing is stopped, and the

7. Characteristic ink-setting curves



8. Measuring ink-setting time vs. coating pick resistance

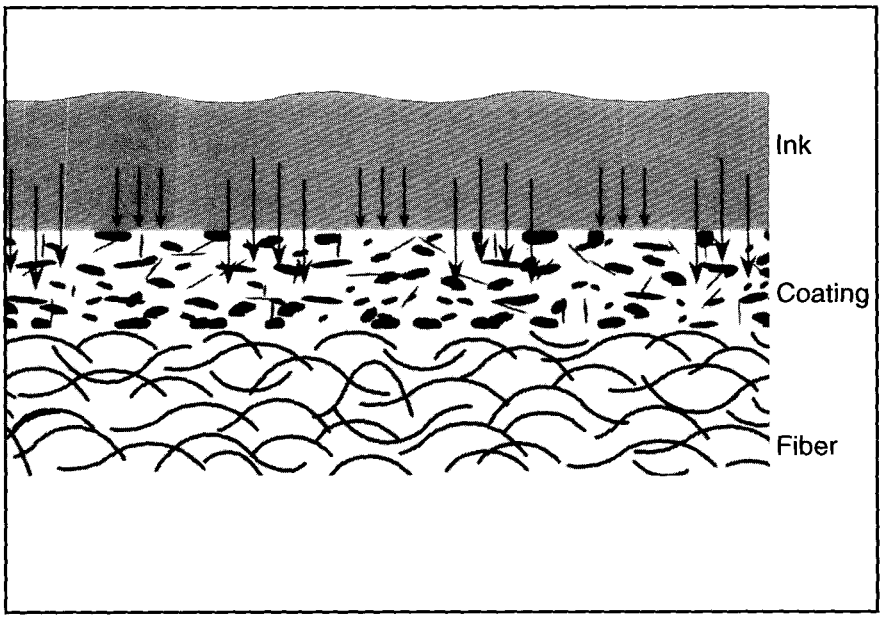


last force is recorded as the "force to fail" the sample. Refer to **Fig. 8.** This value is the dry pick resistance of the paper. [Note that the actual force needed to fail the paper falls between the last pass and the pass prior to it *(14-16).*] The most significant feature of this test is that it enables the papermaker to differentiate between a coating formulation that is failing because it is weak and one failing because it is fast setting. For example, adding more latex to a formulation decreases the slope value (set rate) but does not necessarily make the coating stronger.

Through years of correlating these tests to on-press performance of inks and papers, there are several "ideal" values for the data obtained on the P&I test:

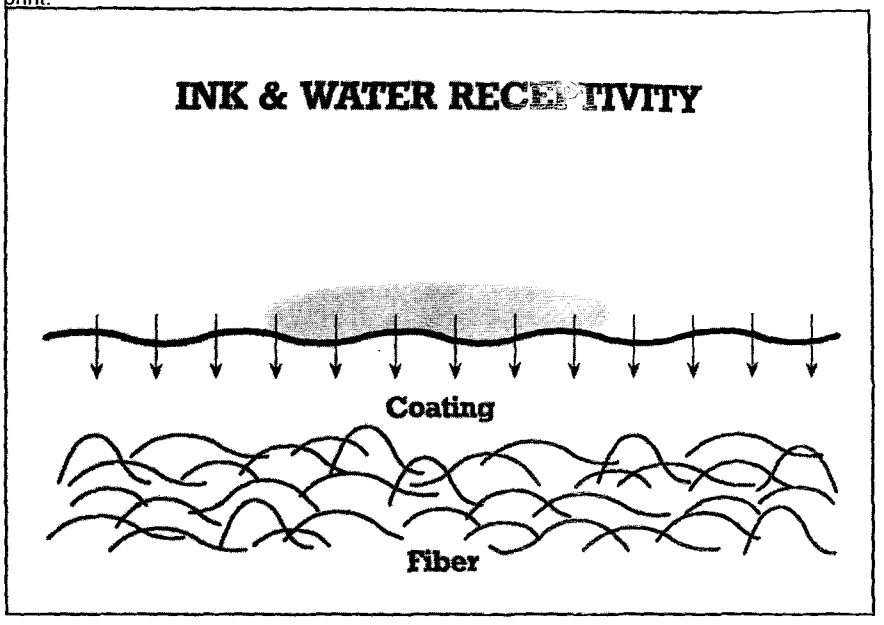
- Slope: A range of 4.0 to 10.0 g/cm/s is ideal. If the slopes fall below 4.0, offsetting can occur in sheet-fed printing, and blistering can occur in web printing. Also, low slopes generally indicate poor fountain solution absorption and WIM may result.
- Passes to fail: The minimum number of passes is four. Failure before the fourth pass will result in coating building up on the press.
- Force to fail: Sheet-fed papers normally fail at higher force values than web papers. Typical sheet-fed forces reach 600–900 g/cm before picking occurs on the blanket. Web papers usually fail at 400–600 g/cm.

9. Cross section showing nonuniform absorption

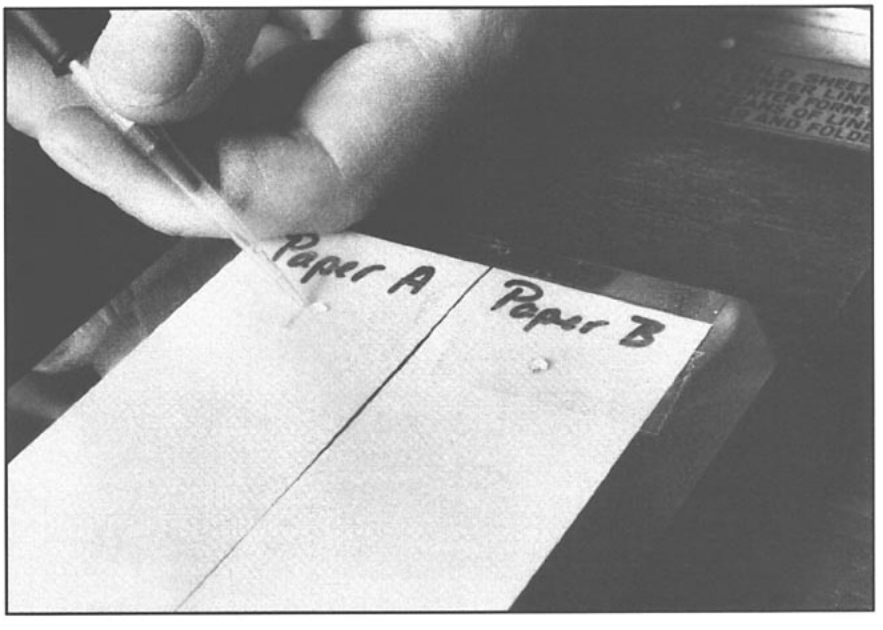


The setting rate *(17),* or slope, of the paper coating governs what happens to the printed ink film while the paper is in the printing press. Before one can identify what type of mottle is present, the setting rate must be quantified *(18).* If the paper coating is too open or fast, the mottle may be BTM. If the paper coating is too tight and slow, the mottle may be WIM or WTM.

10. Fountain solution (arrows) penetrates the coating in both the ink and nonink areas of the print.



11. Fountain solution drops being applied to test prints on Papers A (left) and B



Test No. 2, Mottle: the uniformity of ink absorption

This test is the only procedure in this series that has a subjective rating. However, mottle is subjectively judged on press, too. The level of nonuniformity is not important if taken by itself. The importance is that, if there is any nonuniformity, the set rate of the paper governs whether the mottle will show up on the press. Based on our testing, we have determined the following slope relationships:

- Paper slope > 10.0 + severe mottle = BTM
- Paper slope < 10.0 + severe mottle = NO BTM.

The mottle test used in this study is performed on the test press using two inks. The inks are intentionally printed in reverse-tack order, with the lower-tack ink printed first. A time delay between printing the first ink and applying the second ink allows the first-down ink to build tack on the paper's surface.

If the paper has differential tack build due to areas in the coating that are fast and other areas that are slow setting, the final print from this test will show mottle. This occurs because the first-down ink builds tack in selected areas and traps the second ink in those areas only. The color that results is different from other areas of the coating that cannot build tack, thus creating mottle. See **Fig. 9**.

In this test, two standard inks are used. In addition, the time delay between the application of the two inks is kept constant. This study is based on a delay of 7.0 seconds between ink applications. The prints are rated 1–5, with '1' having no mottle and '5' showing the worst mottle at the time delay of the test. [Note: In some cases, surface smoothness can affect trap, and this is considered in the subjective ratings, particularly in testing coated solid bleached sulfite (SBS) and recycled boards.]

Test No. 3, Water sensitivity

During the offset printing process using a fountain solution, the paper is exposed to water in two possible ways. First, the ink itself has fountain solution mixed into it as well as a thin film of fountain solution on its surface. Second, in multicolor printing, the nonimage area of the sheet is printed with a thin film of fountain solution in each unit. See **Fig. 10**. In both cases, if the coated paper cannot accept the fountain solution and absorb it quickly enough, the ink transfer will be incomplete. This type of ink rejection is always selective and always results in mottle on the press.

Using the test press, a 2.0-μL drop of fountain solution is applied to the paper by spreading it with the ink

film on the blanket. As the blanket cylinder passes over the sample and the ink is printed, the fountain solution is spread ahead of the ink and is forced into the paper. If the paper cannot absorb the water, the ink will not transfer, as shown in **Fig. 11.**

As the paper's ability to absorb fountain solution increases, the amount of ink transfer from the blanket to the paper increases. If the paper coating absorbs the fountain solution too quickly, the coating may wet pick and pick off onto the blanket. If the fountain solution cannot penetrate the paper's coating, the ink will remain on the blanket. Refer to **Fig. 12.**

A second print is then taken from the image remaining on the blanket. Both prints are used for a series of density readings to determine the amount of ink transfer, ink refusal, and wet pick, if any, on the blanket, as shown in **Fig. 13.** Density measurements are made on the printed sample and on the print from the blanket. Both prints are measured where the fountain solution was spread and on the inked area outside of the water spread area. These four areas are indicated as A through D in **Fig. 14.** These density readings are then entered into formulas to calculate ink refusal, ink transfer, and wet pick:

$$X = (B/A) \times 100 \quad (2)$$

$$Y = [(100D - XC)/100A] \times 100 \quad (3)$$

$$Z = 100 - X - Y \quad (4)$$

where

X = ink transfer, percent

Y = ink refusal, percent

Z = wet pick, percent

A = density of ink area of water sensitivity print

B = density of water strip area of water sensitivity print

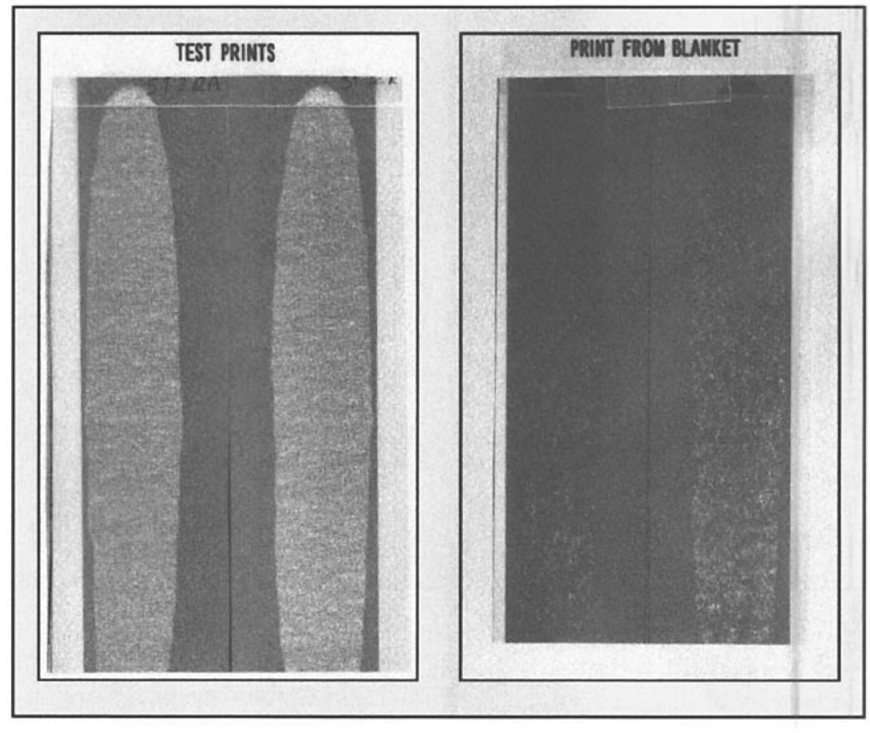
C = density of ink area of the print from the blanket

D = density of water strip area of the print from the blanket.

12. Blanket after the test, showing wet pick from Paper A (left) and ink refusal on Paper B (right)



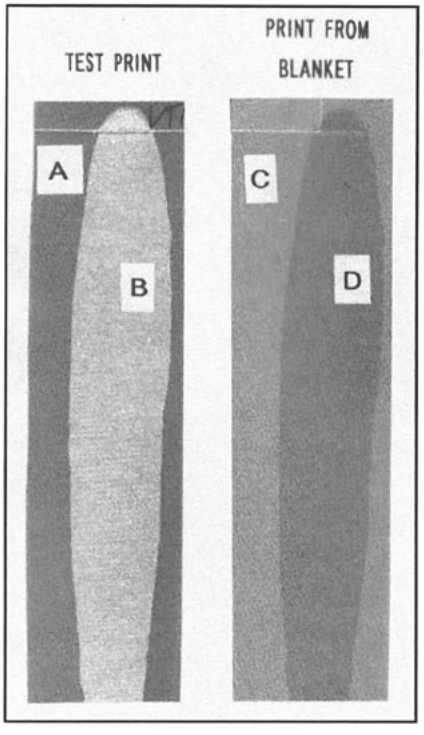
13. Test print and print from the blanket



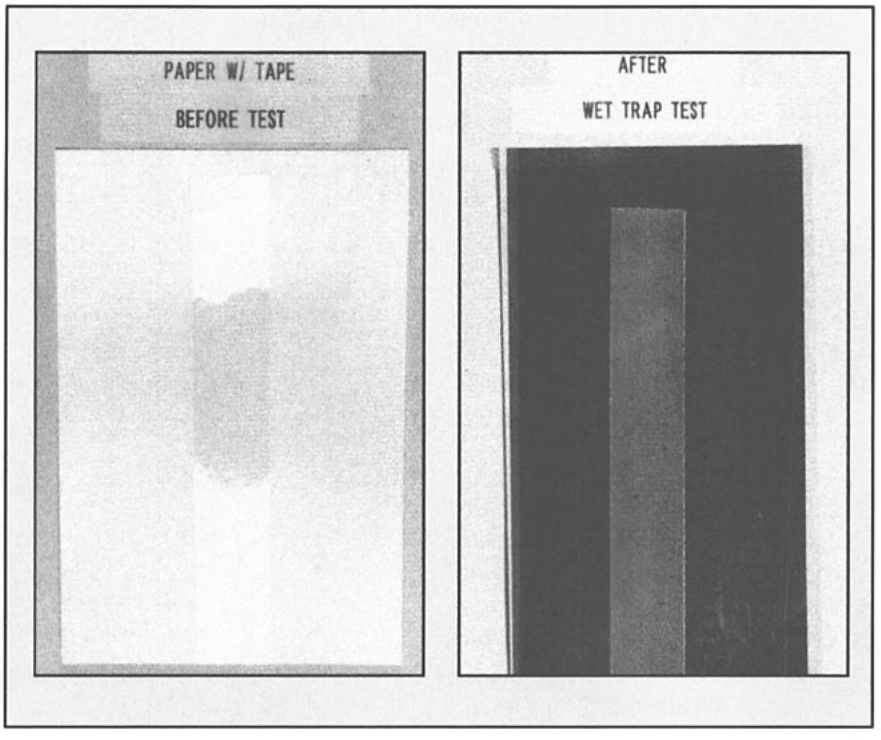
An average of five density readings is taken for each of these values. A 100% transfer indicates no print interference; a value less than 100% indicates some degree of interference. As the ink transfer drops below 50%, the likelihood of WIM increases significantly.

Coated papers must have the ability to quickly absorb the fountain solution in the offset printing process; otherwise, ink transfer will be incomplete. The mottle that results from the paper's inability to accept fountain solution (WIM) can look

14. Prints with Areas A-D, which will be measured for ink density



15. White paper with tape applied (left) and print after wet trap test (right)



similar to backtrap mottle (BTM) on the printed job. Because corrective measures for water receptivity problems are different from those for ink receptivity problems, it is imperative to know which type of surface reactivity is occurring on the press.

Test No. 4, Percent wet ink trapping

As previously discussed, in multicolor printing, the first ink is printed onto dry paper, and the subsequent inks are applied wet to the wet film already down. It is possible to measure how much ink can be printed over the previous wet ink by measuring the percent of wet trap. These measurements, taken using a densitometer, commonly use the color bars along the edge of the press sheets.

In four-color process work, the black ink is not used for trap calculations, which leaves the three process colors cyan, magenta, and yellow. These three inks combine in pairs to create the following colors:

- Cyan + Magenta = Blue
- Magenta + Yellow = Red
- Yellow + Cyan = Green.

Using the test press, we apply the two ink films being tested to separate locations on the blanket. A paper sample is taped to the impression block, and the blanket cylinder is moved forward to print the first color. The impression block is then moved into position where the blanket cylinder is reversed, printing the second color on top of the first, with a time delay of 2–3 seconds.

We use a fast-setting paper, 80-lb gloss-coated stock, with a strip of clear tape applied to the middle of the sheet, as shown in **Fig. 15**. The method of paper sample preparation enables us to measure the percent trap of the inks on a fast-setting substrate (the white paper) and on a nonabsorbent surface (the tape) at the same time. This is important, since we want the inks to trap well on various papers with different absorption rates. We then measure the percent trap on the paper and on the tape. The goal is not necessarily to obtain 100% trap, but rather to attain equal or nearly equal percent trap values on both absorbency areas. This assures us that the inks are in the proper tack sequence, are trapping on their own, and require little assistance from paper absorbency to trap well.

The percentage of wet trap is calculated by measuring the amount of ink that can be applied on top of another wet ink and comparing this measurement to the amount that can be applied to the white paper. If the same color density can be applied to each, the trap is 100%. It is possible to attain more than 100% trap, since the amount trapped onto white paper is based on a 50:50 ink split from the blanket. If more than 50% of the ink film on the blanket transfers to the wet ink film, the percent trap will be over 100%. This is, however, highly unusual.

Modern densitometers are programmed to calculate trap automatically once the operator has read certain areas on the color bars. In

our test, we must also make individual solid prints of each ink color. These single-color solids are then used to compare the wet trap density values of the two-color trap print. The calculation for percent trap is as follows:

$$T = [(D_{op} - D_1)/D_2] \times 100 \quad (5)$$

where

T = trap value, percent

D_{op} = density of two-color overprint

D_1 = density of first-down color

D_2 = density of second-down color

(Note: all densities are read using the filter for the top ink color.)

In order to measure wet trap, three areas must be read for each color. For example, if the percent of magenta trap over the cyan trap is needed, the following readings are taken using the densitometer as if it were reading magenta ink each time (i.e., filtering the light with a green filter):

- density of overprint area = 1.45
- density of magenta = 1.40
- density of cyan = 0.16.

The calculation showing the percent magenta trap over cyan trap is:

$$[(1.45 - 0.16)/1.40] \times 100 = 92\% \quad (6)$$

Case studies

The three case studies shown in the appendix represent actual printing complaints where the test methods described in this study were used to resolve these complaints, and to some extent, act as a guide for the printers, paper mills, and ink companies to make adjustments to their products. Grade and trade names have been intentionally omitted.

Literature cited

1. Plowman, N., *Graphic Arts Monthly* 63(1): 125(1991).
2. Van Gilder, R. and Purfeerst, R., *TAPPI 1991 Coating Conference Proceedings*, TAPPI PRESS, Atlanta, p. 461.
3. Plowman, N., *Graphic Arts Monthly* 63(3): 124(1991).
4. Plowman, N., *Graphic Arts Monthly* 61(12):102(1991).
5. Plowman, N., *Graphic Arts Monthly* 63(5): 122(1991).
6. Plowman, N., *Graphic Arts Monthly* 62(9): 197(1990).
7. Plowman, N., *Graphic Arts Monthly* 61(4): 126(1989).
8. Plowman, N., *Graphic Arts Monthly* 65(6): 103(1993).
9. Plowman, N., *Graphic Arts Monthly* 61(2): 110(1989).
10. Plowman, N., *Graphic Arts Monthly* 61(8): 133(1989).
11. Plowman, N., *Graphic Arts Monthly* 61(6): 114(1989).
12. Swan, A., *Paper & Board* 32(8):32(1973).
13. Swan, A., "The Problem of Ink Piling on Offset Litho Presses," ECC International, Inc., Atlanta, GA, March 30, 1990.
14. Van Gastel, L. A., *Reed Engineering* 27(3): 44(1974).
15. Strukhoff, R., *Professional Computing* 3(2):13(1986).
16. Concannon, P.W., and Wilson, *TAGA 1992 Conference Proceedings*, p. 282.
17. Plowman, N., *Graphic Arts Monthly* 64(9): 162(1992).
18. Plowman, N., *Graphic Arts Monthly* 65(1): 89(1993).

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Appendix

Case Study No. 1: Backtrap mottle

This problem, described in **Table I**, was reported when the printer had a severe mottle problem on the press using Paper A, but when Paper B was run, the mottle disappeared. Because of the evidence that the first colors had mottle but the last three did not, it was assumed that the problem was BTM.

Results. The problem with Paper A was BTM. This paper was nonuniform and its set rate was fast. Paper B was also nonuniform but was slow setting. Paper B was unable to set the ink fast enough to cause it to stop transferring. The results of the three tests on the two papers were as follows.

Paper and ink stability test:

- Paper A Side 1 slope = 11.5 g/cm/s
- Paper A Side 2 slope = 10.0 g/cm/s
- Paper B Side 1 slope = 7.5 g/cm/s
- Paper B Side 2 slope = 8.8 g/cm/s

Mottle test:

- Paper A Side 1 rating = 5
- Paper A Side 2 rating = 5
- Paper B Side 1 rating = 5
- Paper B Side 2 rating = 5

Water sensitivity test:

- Paper A Side 1 = 85% transfer
- Paper A Side 2 = 87% transfer
- Paper B Side 1 = 95% transfer
- Paper B Side 2 = 96% transfer

Analysis. The problem is BTM for the following reasons:

- Paper A has a high slope (fast setting), which causes BTM if the sheet is nonuniform.
- Paper A is nonuniform, having a severe mottle rating of 5.
- Paper A has good water receptivity and ink transfer values.
- Although Paper B is also nonuniform, it did not have mottle on the press because its slope was low (slow setting).

Case Study No. 2: Water interference mottle

This problem, shown in **Table II**, was reported as a mottle complaint on Board A. The printer had severe mottle throughout the job, in every color. Since all the colors have the mottle pattern, this must be a water-related mottle problem.

Results. Board A caused WIM because it was so tight it could not absorb the fountain solution on the press; therefore, the ink could not transfer. Tests performed on the two boards showed why Board B worked so well.

Paper and ink stability test:

- Board A slope = 2.5 g/cm/s
- Board B slope = 8.5 g/cm/s

Mottle test:

- Board A rating = 4
- Board B rating = 3

Water sensitivity test:

- Board A Side 1 = 8% transfer
- Board B Side 1 = 87% transfer

Analysis. The mottle problem on Board A is WIM because:

- Paper A is too slow (ink setting) to cause BTM.
- A slope of 2.5 g/cm/s confirms that this board is extremely tight and nonabsorbent to both ink solvents and water solutions.
- When fountain solution is used, the percent ink transfer of Board A is too low. This stock is not capable of absorbing enough fountain solution to allow the ink to transfer properly.
- The water interference area on the test strips are nonuniform. This is a subjective determination.
- The mottle test shows Board A is not uniform in its surface absorption. This pattern will influence the ink and fountain solution transfer, resulting in mottle on the press.

Case Study No. 3: Wet ink trap mottle

This problem, described in **Table III**, was reported on a form where there were many blue skies in the artwork. The single-color solids along the color bars were printing uniformly and smoothly, but the overprint areas, particularly in the skies where magenta was trapping over the cyan, was mottled. By running another paper, the printer was able to minimize the mottle, and the job was accepted by the customer.

Since the mottle appeared only in the overprint areas, the inks were checked for their tack, stability, and wet-trapping capabilities. Mottle that appears in the areas where two or more colors are trapping is usually the result of running inks that are out of tack sequence (i.e., applying the highest-tack ink first followed by inks of decreasing tack values). Another possible cause of WTM could be the use of uni-tack inks. These are fast setting inks formulated at equal tack values; they depend upon the set rate of the paper to build tack between printing units. Sometimes these inks are formulated at varying pigment strength levels as well, where the strongest ink with the thinnest film is run first. Different levels of trap can be expected on papers that have various slope values.

In this case, the inks were run on the paper and ink stability test on three substrates: acetate, Paper A, and Paper B. As mentioned earlier, this test measures the splitting forces of an ink at a film thickness close to what is run on the press. The forces generated are quite accurate in determining how inks trap onto one another in multicolor printing. Furthermore, the P&I test allows any ink and paper combination to be run. A constant ink film was used for each test, and the testing was performed as follows.

Testing. Papers A and B were first tested using our standard ink to classify their setting rate:

- Paper A slope = 3.0 g/cm/s
- Paper B slope = 8.9 g/cm/s.

Both papers were then tested with the process inks that were run on the job. This second test confirmed Paper A was slower in its setting rate with these inks as well. A comparison of the slope values is as follows:

- Black: Paper A = 2.5 g/cm/s
- Black: Paper B = 5.0 g/cm/s
- Cyan: Paper A = 3.2 g/cm/s
- Cyan: Paper B = 7.8 g/cm/s
- Magenta: Paper A = 4.6 g/cm/s
- Magenta: Paper B = 8.9 g/cm/s
- Yellow: Paper A = 3.4 g/cm/s
- Yellow: Paper B = 5.0 g/cm/s.

Results. Following the first test, Paper A was slower to set the ink. If the inks are out of tack sequence, or if the inks are unitack, Paper A cannot build tack between units to the extent of Paper B. Therefore, Paper A will always have lower percent trap

(continued next page)

values. Paper B can build tack more quickly between the printing units. Although the results with Paper B may be improved, the percent trap of the colors will not be high enough to eliminate WTM.

The second-test slope values prove that Paper B is more absorbent and is more likely to increase the tack of each ink before it reaches the next printing unit. Therefore, Paper B will create a higher percent wet ink trapping and less mottle.

I. Case Study No. 1 - Backtrap mottle: 80-lb web gloss text paper; Paper A-Bad, Paper B-Good.

Press	*Ink sequence*	*Mottle in?*
Six-color web	K + PMS aqua	Black - Yes
		PMS aqua - Yes
		Cyan - Yes
		Magenta - No
		Yellow - No
		PMS tan - No
		Y/C trap - Yes
		Y/M trap - No
Offset	C + M + Y + PMS tan	M/C trap - Yes

II. Case Study No. 2 - Water interference mottle: 24 pt SBS C1S board; Board A-Bad, Board B-Good.

Press	*Ink sequence*	*Mottle in?*
Four-color, sheet-fed	K + C + M + Y	Black - Yes
		Cyan - Yes
		Magenta - Yes
		Yellow - Yes
		M/C trap - Yes
		Y/C trap - Yes
		Y/M trap - Yes

III. Case Study No. 3 - Wet ink trap mottle: 100-lb gloss text paper; Paper A-Bad, Paper B-Good.

Press	*Ink sequence*	*Mottle in?*
Four-color, sheet-fed	K + C + M + Y	Black - No
		Cyan - No
		Magenta - No
		Yellow - No
		M/C trap - Yes
		Y/C trap - No
		Y/M trap - No

Summary

There are several types of mottle that can appear on a printed job. Nonuniform printed density can be caused by at least three different mottle conditions: backtrap, water interference, and wet trap mottle. Tests can be run on papers and inks to predict what type of, and when, mottle will occur on the press. A series of at least three tests must be run.

The first test, the P&I stability test, measures the ink-setting rate of the paper. This test can also determine the set rate of the inks being run and their relative printing tack values.

A second test measures the ability of the paper to accept fountain solution. It is important to control both the amount of water used and the printing impression squeeze (pressure) on the samples as they are tested. This test yields values for percent ink transfer, percent ink refusal (due to water interference), and percent of print interference due to wet coating pick. A final test measures the paper's uniformity of absorption to the oils in ink. This test, a subjective evaluation of the mottle in the print, is based on a reverse ink trap sequence. (Mottle on the press is rated subjectively as well.)

By measuring the absorption rate of both ink oil and fountain solution into the paper's coated surface, conclusions can be drawn about why a particular type of mottle occurred. These tests can be further used to monitor production changes in the paper coating and the effect these changes will have on overall print quality.