AN INVESTIGATION OF COATED PAPER WET PICK USING SCANNING ELECTRON MICROSCOPY AND THE IGT PRINTABILITY TESTER

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Abstract: It is sometimes difficult to distinguish wet pick from wet repellency whether diagnosis takes place on press, on the printed sheet or on a laboratory test print. It is frequently taken for granted that during wet picking of coated paper on an offset press, the coating accumulates on the blanket and may even move against the flow, towards the plate and into the inking and dampening systems. Such an effect would make wet pick easy to detect, if it could be relied upon.

Evidence has been assembled that shows that wet pick can occur on single unit as well as multiple unit presses and, furthermore, with no observable accumulation of paper or ink debris on the blanket.

A reliable laboratory IGT test method was developed that can predict whether wet pick or wet repellency will occur during lithographic printing. A technique for analysis of the surface of a print by scanning electron microscopy (SEM) was developed that can determine whether pick or repellency occurred.

Cross sectioning followed by SEM microscopy revealed that the wet pick, encountered in this study, created a cavity no deeper than 2 microns below the surface. Each continuous zone of picking stretched from 5 microns up to 100 microns across. The cavities rarely reached down to the fibers in the base sheet, which were, on average, 15 microns below the paper surface. By examining wet pick in cross section, a possible mechanism by which wet pick occurs has been postulated.

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1 INTRODUCTION

Wet pick of coated paper has traditionally proven difficult to clearly identify on an offset press unless, for instance, a severe case resulted in "white" blankets, or the investigator took the trouble to analyze materials contaminating the press and was fortunate enough to find paper debris.

Wet repellency is usually seen as a trapping problem of last down colors where dampening solution on the paper surface prevents the transfer of ink. It has been known to occur on multiple unit web presses and on common impression sheetfed presses.

A definition and discussion of these terms can be found in the Appendix.

1.1 Scope of This Paper

This paper describes the investigation of an unfavorable interaction between fountain solution, ink and paper in the lithographic sheetfed printing process. SEM photomicrographs are presented showing the appearance of dry pick, wet repellency and wet pick. Using these images, two problems are successfully solved. Firstly the interaction is shown to be wet pick, secondly the use of IGT testing to predict wet pick is validated.

Through microscopy of the paper in cross section, the paper coating is examined for structural problems that may have led to a lack of resistance to wet pick.

1.2 Description of the Problem

This study began as a routine investigation of a problem that occurred during the single color sheetfed printing of label paper, which in this case was paper having a double coating on only one side. The complaint was about a light, grainy mottle, described initially as "grayness" of the solid black tones (see Figure 1). No unusual accumulation on the blankets was reported. When the flow of dampening solution was reduced, the grayness was reduced. All straight, trailing edges of solid images typically undergo roughening when wet pick is occurring, but in this case, these edges were all intact.

The only paper-related mechanism known to us that might have explained this observation was wet repellency. Up until this point, wet repellency had only been observed in multiple unit presses.

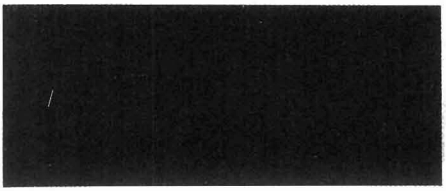


Fig 1a. Good print on control label paper, printed single color sheetfed offset.

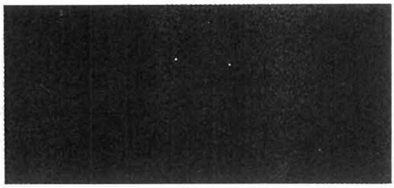


Fig 1b. Grainy mottle on complaint label paper, printed single color, sheetfed offset. This reproduction exaggerates the contrast of the actual defect.

A washed out appearance of lithographic prints is sometimes traced to the over emulsification of water in ink (Bassemir, 1989). Such a mechanism was eliminated here because this problem only occurred with specific lots of this grade of paper. It was clear that the problem was an anomaly that would require more than the usual analytical and test printing procedures to resolve.

1.3 Experimental Objectives:

(1) Determine the cause of the grainy mottle on the complaint paper.

(2) Examine the effect of the number of press units on the severity of wet pick and on piling.

(3) Develop and validate a laboratory test printing method capable of predicting wet pick and wet repellency.

(4) Develop an analytical microscopy procedure with which to examine prints and distinguish wet pick from wet repellency.

(5) With the benefit of cross sectioning followed by scanning electron microscopy, piece together the fundamental mechanism by which wet pick occurred on this complaint paper.

2 EXPERIMENTAL PROCEDURES

2.1 Summary of the Wet Repellency / Wet Pick Test Method and Interpretation Developed and Used During This Investigation

A description of the basic test method can be found in a paper dedicated entirely to the use of the IGT dampening attachment (Webster, 1989). Modifications made to the wet repellency/wet pick test are described here:

Equipment: Reprotest AIC2 IGT Printability Tester with Dampening unit, Ink Distribution System and IGT ink pipette. Densitometer.

Conditions:

Packing on sector:	4 sheets of standard IGT packing.
Speed:	Constant 0.8 m/s,
Delay:	Start with a delay setting of 0 s.

The nominal delay setting of 0.0 seconds is considered by Reprotest to actually be an interval of 0.07 seconds between application of moisture and ink. The nominal delay setting of 0.1 s , quoted in Figures 2b and 3b, is assumed to be 0.17 s.

Printing pressures:	625 N on both stations.
Dampening wheel:	Chromed A wheel

Materials:

Ink:	Medium tack (12 at 800 RPM) quickset cyan without driers, supplied by Sun Chemical, G.P.I. Division.
Fountain Solution Etch:	KSP 10 AS M3 supplied by Rosos.
Fountain solution conc.:	5 mL/170 mL in tap water. No additives.
Fountain solution volume:	5 mL of diluted solution.
Wipe size for dampening	2 inch by 3.75 inch wheel: roll into a 2 inch wide pad.

Sample Preparation:

Paper sample size:	2 inch by 13·75 inch in machine direction.

Procedure: First Inking: 200 µL (2 complete turns) are initially applied to the distribution system and allowed to distribute for 3 minutes. The print wheel is lowered and allowed to ink for 30 s. The wheel is cleaned without printing.

Fig 2a. IGT print with 0.07 s delay. Decreased density of lower third could be caused by wet repellency or wet pick due to fountain solution.

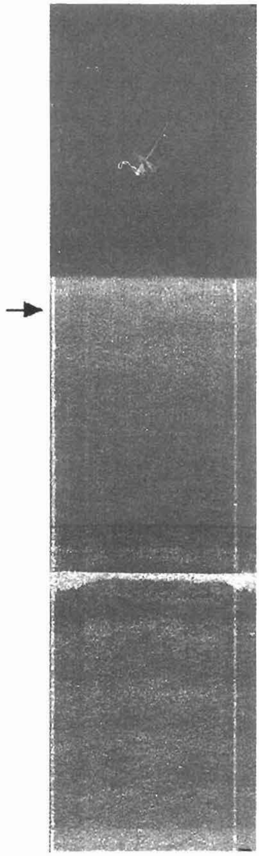


Fig 2b. Another strip of same sample. 0.1 s delay between dampening and printing. The worsened lower third strongly suggests wet pick.

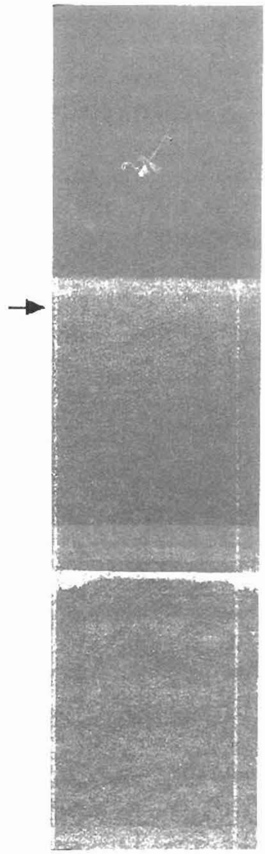


Fig 2c. This "offprint" confirms wet pick. It was run with ink remaining on wheel from test print. (Without fountain solution applied from dampening wheel)

Subsequent Prints: 20 μL (2 divisions) of ink are applied to the rubber distribution roller and allowed to distribute for 60 s. The print wheel is lowered and allowed to ink for 30 s.

Fig 3a. IGT print with 0.07 s delay. Decreased density of lower third could be caused by wet repellency or wet pick due to fountain solution.

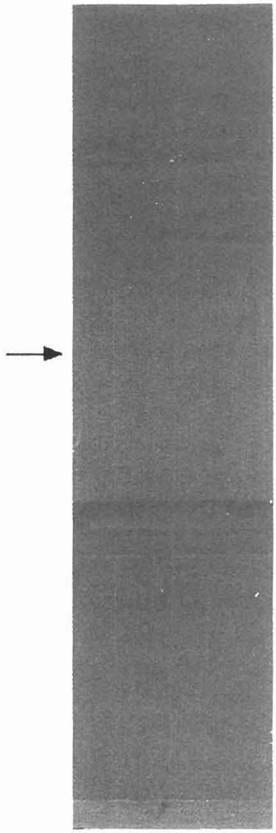


Fig 3b. Another strip of same sample. 0.1 s delay between dampening and printing. The improved lower third confirms wet repellency.

Principle of Operation: A 0.3 micron layer of fountain solution is first metered onto part of the paper via the dampening unit. After a preset delay, both the dry and moistened areas of the paper contact a moving inked wheel.

After each test printing, ink is continually replaced on the distribution rollers at an equal volume. The initial and replacement ink volumes were selected to yield a consistent cyan color density of 1.2 ± 0.05.

Interpretation of a Test Print

Ink trapping over the lower, dampened area is typically lighter in color and mottled due to either wet repellency or wet pick (Figure 2a). The middle third is wetted but there was no delay between wetting and printing, so it is ignored.

In order to narrow down the cause of the mottle to repellency or pick, the experiment is repeated with a longer delay between dampening and inking.

If the longer delay leads to worse transfer, then wet pick is indicated (Figure 2b). A print is made, onto standard paper, of ink and debris remaining on the wheel. If the lower third again looks light, wet pick has occurred, because the picked coating prevents transfer of ink from the wheel to the paper (Figure 2c).

If the longer delay leads to improved ink transfer, then wet repellency is indicated (Figure 3a and 3b).

Once the mechanism has been pinned down to pick or repellency, the result can be quantified by subtracting the density of the moistened bottom portion of the paper from the density of the dry top third (see Appendix).

2.2 Optical Microscopy

A stereo zoom microscope capable of magnifications up to 100 X was used to view picked areas of the complaint print. Comparisons of this image with examples of dry pick and wet repellency prepared in the lab were made.

2.3 Surface Topography Using Scanning Electron Microscopy

Equipment: The Amray 1810 scanning electron microscope was used for all of the surface topography images.

Conditions: The secondary electron mode was used, in which most of the detected signal originates very near the sample surface and thus provides topographic contrast. By trial and error, an accelerating potential of 20 keV was selected to render the highest subjective image quality. Magnifications adopted for this study were: 100 X, 1000 X and 5000 X.

Origin of Samples for Surface SEM Microscopy

(1) Three prints prepared in the lab exhibiting dry pick, wet pick and wet repellency, respectively.
(2) The original print of the complaint paper that exhibited the grainy mottle, printed on a Solnar single unit press.

For the 6 color press trial (see Figure 8):
(3) Center of the 5th down and 1st down black image areas of the complaint paper run under controlled conditions in a 6 color sheetfed press trial.
(4) Edge of the 5th down black image area of complaint paper.
(5) Unprinted complaint paper .
(6) Edge of the 5th down black image area of paper that did not exhibit picking.
(7) Unprinted sample of paper that did not exhibit picking.

Sample Preparation: Samples for surface imaging by SEM were chosen from each paper sample taking care to select regions that had minimal surface abrasion and that had not been contaminated by fingerprints, etc. Samples were mounted on conductive metal stubs using silver paint around the perimeter. For high resolution SEM, a conductive layer of Au/Pd was coated onto the samples.

Test Printing Method Used to Prepare a Sample for the Known Dry Pick SEM Study

A Modified Vandercook press was used. A single strip was printed using multiple impressions of the same print. A delay of 5 seconds was imposed between each impression until pick occurred. The blanket was removed along with the print for SEM microscopy.

Test Printing Method Used to Prepare a Sample for the Known Wet Pick SEM Study

A sample of paper, known to have a low resistance to wet pick, was tested using the IGT test method already described. The area where wet pick was visible was removed for SEM evaluation.

Test Printing Method Used to Prepare a Sample for the Known Wet Repellency SEM Study

A sample of light weight coated paper, known to impart wet repellency, was tested on the IGT. The area where wet repellency had occurred was removed for SEM evaluation.

Press Trial Protocol for Six Color Sheetfed Test Printing of the Complaint and Comparison Papers

A six color Komori Lithrone 40 sheetfed press was used to evaluate the complaint and comparison paper. Figure 8 is a photograph of the 6 color sheetfed print form used to test coated paper in sheets measuring 24" by 30". The color sequence was black, cyan, magenta, yellow, black, cyan. The fifth down black and sixth down cyan were of the same tack as the respective first and second down inks. The control sample was chosen for its known resistance to wet picking, to carryover picking and to wet repellency. The press was made ready at a speed of 6,600 impressions per hour, using the control paper. The complaint paper was run directly behind the control without stopping or adjusting the press. After printing the complaint sample, the press was stopped for inspection of the blankets and plates.

2.4 Elemental Analysis of Surface Debris

Principle: During SEM analysis, the bombardment of atoms in the sample by electrons creates X - rays. The frequencies of these X - rays are dependent upon the element from which they have been generated.

Origin of Samples for Surface SEM Microscopy

The surface debris found on the complaint paper where picking occurred at the center of the 5th down black from the 6 color sheetfed press trial.

2.5 Cross Sectional Scanning Electron Microscopy

Equipment: Cambridge S-360 SEM, Balzers BG 800 Evaporator and Struers Abramin for metallographic polishing.

Conditions: Back scattered electron mode with 15 keV accelerating potential. Magnifications of 1000 X and 5000 X.

Materials for Sample Preparation: Dow epoxy resin DER-330 and hardener DEH-24 mixed 7.7:1. SiC papers down to 4000 grit, 3 and 1 micron diamond compounds and Struers OP-5 colloidal silica.

Principle: OsO_4 stained latex shows up in SEM images as cloudy, grayish white areas within the coating. When the latex is distributed homogeneously, it is difficult to identify individual areas of latex. When the latex is distributed heterogeneously, its presence is distinguished by its brighter appearance. After staining, the samples were impregnated with epoxy resin. The cured resin is organic and yields a very low energy signal, which appears as dark areas in the photomicrograph.

Sample Preparation: Samples are stained in OsO_4 vapors for 48 hours and mounted in epoxy resin prior to metallographic polishing. An epoxy mixture is added to the samples via vacuum impregnation, this practice provides improved impregnation of the paper fibers and the coating and also reduces air bubbles in the bulk epoxy, leading to a higher quality polished surface. The samples are then cured. This is followed by metallographic polishing, which consists of grinding with SiC papers down to 4000 grit followed by diamond then by colloidal silica compounds. Under ideal conditions, residual scratches and deformation will be reduced to less than 0.05 mm. The polished cross sections are mounted onto conductive metal mounting stubs using double stick tape and silver paint, then coated with a conductive coat of carbon using the Balzers Evaporator.

Origin of Samples for Cross-sectional SEM Microscopy

Fifth down black image area of the complaint paper from the press trial.

3 RESULTS AND DISCUSSION

3.1 IGT Test Printing

Unprinted samples of both the rejected complaint paper and accepted lots of the same grade were tested in the lab for their relative tendency to impart wet repellency or wet pick. The complaint sample exhibited severe wet pick. The acceptable sample exhibited mild wet repellency, which is a typical response of most grades of coated paper. Wet pick of the complaint paper was unexpected because experience had indicated that wet pick was unlikely to occur on a single unit press.

3.2 Optical Microscopy

A microscopic analysis was undertaken. Prior to this study, optical microscopy had already been tried as a tool to discriminate between wet pick and wet repellency. At 100 X, the limit for our stereo microscope, it had been difficult to distinguish clearly between small pits in the coating (pick) and the un-inked areas caused by wet repellency. Although small visual differences existed, both showed up as uneven, rounded white areas distributed across the ink film with poor depth resolution of the images. To observe the detail of one of these voids in the ink film would require magnifications in the vicinity of 1000 X, together with a clearly resolved image of the damage below the plane of the paper surface. The next step was to try Scanning Electron Microscopy.

3.3 Scanning Electron Microscopy

With no previous experience of examining wet pick or wet repellency under high magnification, it was necessary to accustom the eye of the observer to images of pick and ink refusal.

First, dry pick of a fast setting paper was induced to occur on the Vandercook press. Both the picked paper and a piece of the blanket were taken to the SEM, examined and photographed. An effort was made to find a void in the coating that corresponded exactly to the corresponding pick clinging to the blanket, see Figure 4.

As clay platelets are ripped from the coating, one would expect to see a jagged periphery, but note that the inked edges around the pick exhibit smooth contours at 950X (Figure 4b). The sharp edges only just become visible as the magnification reaches 2200X (Figure 4d).

To ensure correct interpretation of the presence of cavities, the unprinted paper surface was photographed at the same magnification under identical conditions as the printed paper. Cavities seen in the printed surface could therefore be attributed to wet pick only if such cavities were not seen in the unprinted paper.

Before the complaint paper was examined, further "calibration of the eye" was performed by photographing known wet pick and known wet repellency generated during previous work. Lab confirmed wet repellency can be seen in Figure 5. Lab confirmed wet pick can be seen in Figure 6.

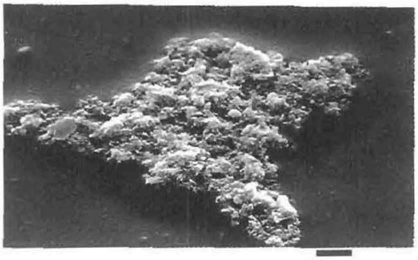


Fig 4a. Dry pick debris on Vandercook blanket. 10 μm at 950 X

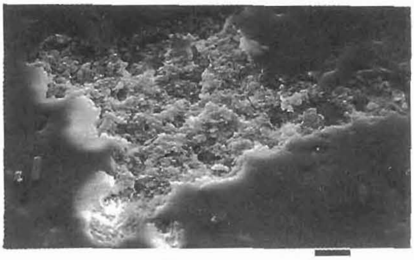


Fig 4b. Dry pick cavity in paper surface. 10 μm at 950 X

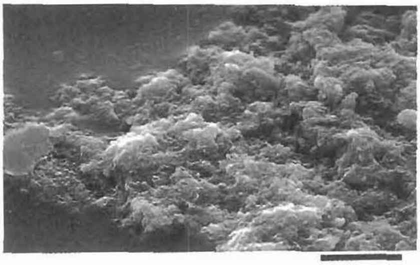


Fig 4c. As above, but at a higher magnification. 10 μm at 2200 X

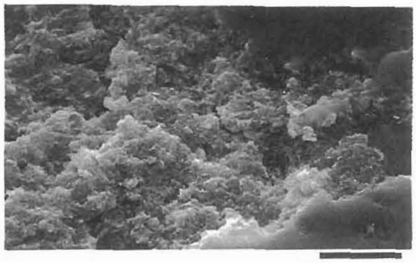


Fig 4d. As above, but at a higher magnification. 10 μm at 2200 X

In Figures 5a & 5b, The uninked areas arising from ink refusal due to wet repellency are seen to resemble the unprinted paper surface in Figures 5c and 5d. On the other hand, the picked areas in Figures 6a & 6b are severely pitted compared to the unprinted paper in Figures 6c & 6d.

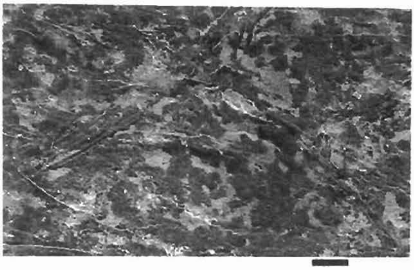


Fig 5a. Wet repellency on an IGT test print. | 100 μm at 100 X

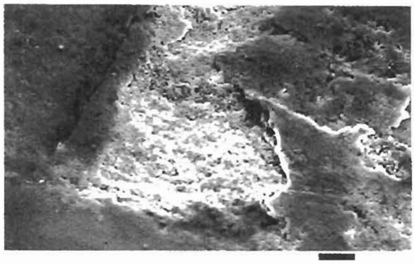


Fig 5b. IGT Wet repellency at a higher magnification. | 10 μm at 1000 X

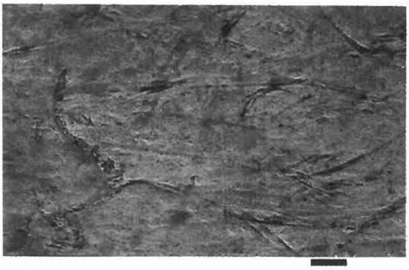


Fig 5c. Unprinted paper for the sample shown above. | 100 μm at 100 X

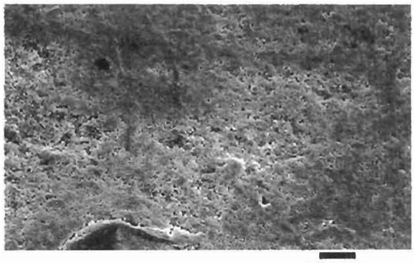


Fig 5d. Unprinted paper for the sample shown above. | 10 μm at 1000 X

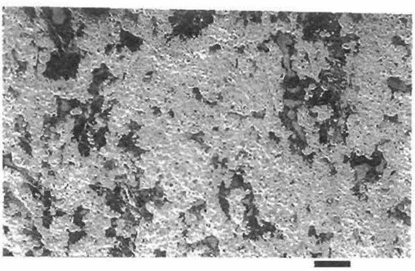


Fig 6a. Wet pick on an IGT test print. | 100 μm at 100 X

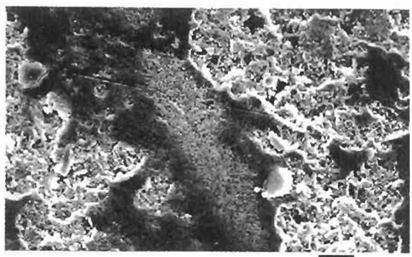


Fig 6b. IGT Wet pick at a higher magnification. | 10 μm at 1000 X

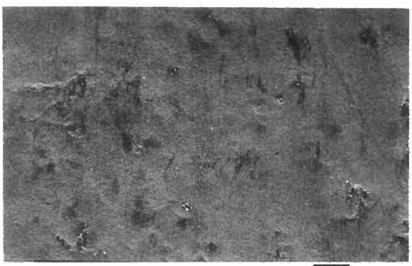


Fig 6c. Unprinted paper for the sample shown above. | 100 μm at 100 X

Fig 6d. Unprinted paper for the sample shown above. | 10 μm at 1000 X

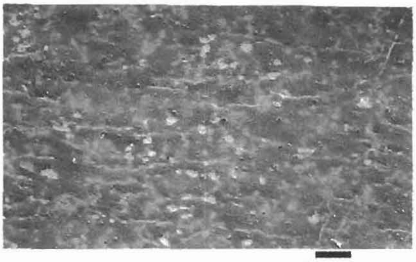


Fig 7a. Complaint sample showing grainy mottle. | 100 µm at 100 X

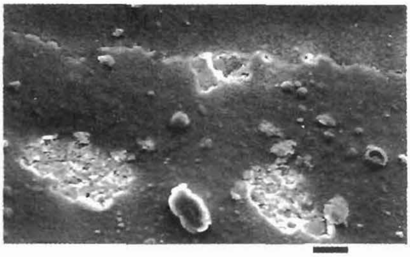


Fig 7b. Grainy sample at higher magnification. | 10 µm at 1000 X

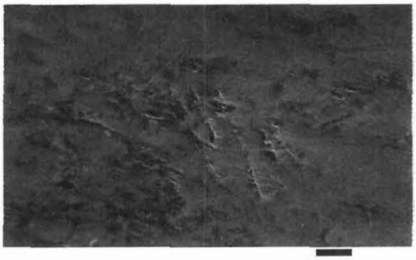


Fig 7c. Unprinted paper for the sample shown above. | 100 µm at 100 X

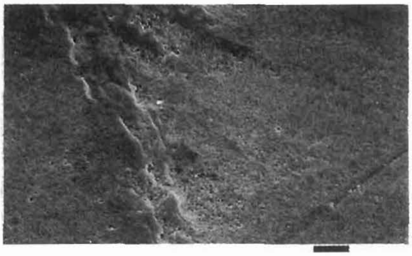


Fig 7d. Unprinted paper for the sample shown above. | 10 µm at 1000 X

3.4 Examination of the Complaint Paper

With greater confidence established to differentiate between wet pick and wet repellency, the complaint print was then examined. This sample, as mentioned in the introduction, had been printed in a single unit sheetfed offset press and had exhibited a fine grainy mottle. In Figure 7a, at 100X, areas of missing ink are visible but no cavities can be positively identified. In Figure 7b, cavities can be clearly seen.

The debris on the surface, seen in Figure 7b, was typical of views of the image area. Such material is not present on any unprinted surface. The same debris was seen in the following press trial samples.


The Dow Chemical Company
1st DOWN BLACK
5th DOWN 2nd BLACK
CYAN
MAGENTA
Fig. 8

3.5 Six Color Sheetfed Press Trial Followed by SEM Surface and Cross Sectional Microscopy

Prior to this six color trial, a four color, Heidelberg sheetfed commercial trial had been run. A grainy mottle was observed in the third down magenta, but was not considered to be wet pick because the blankets and plates did not exhibit any visual signs of build up. When the complaint paper was run on the Komori six unit press, the grainy mottle pattern appeared most severely in the later colors: at the fifth and sixth units. In the first down black the mottle was less severe. The degree of graininess of the later colors was worse on this 6 unit press than on the single unit Solnar or on any unit on the 4 color Heidelberg. After 2000 impressions, the blankets and plates were carefully examined for any sign of piling, especially in the areas corresponding to grainy areas of the print. There was no sign of any coating or unusual ink buildup; an attempt to scrape material off the blanket was abandoned because the layer of material lacked sufficient depth. For the same reason, tape pulls were not attempted.

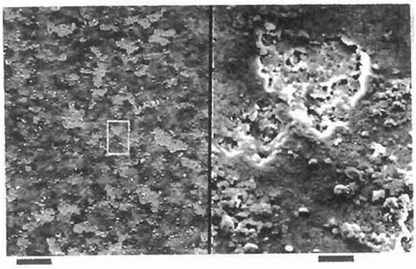
3.5.2 SEM Microscopy Evaluation of Six Color Prints

Samples of these mottled complaint papers were taken to the lab for analysis by scanning electron microscopy. Prints without picks, made on the printer's premium grade house paper during the same press trial, were also analyzed together with all corresponding unprinted paper.

Figure 9a indicates the severity of the pick that is causing the grainy mottle. Some of the picked areas stretch to at least 100 microns across. The small white rectangle in the 100 X region indicates the area selected for viewing at 1000 X. At 1000 X, pieces of debris can be seen scattered around the surface in the ink film. This may have originated from the clumps of coating pigment that were plucked out of the surface and "ground" by the action of the press down to approximately 10 micron fragments. This example, together with the evidence of Figure 7, suggests the presence of coating pigments in the printed ink film.

Figures 9c and 9d depict the undisturbed paper surface: approximately 1 micron wide clay pigment platelets laying parallel with the surface.

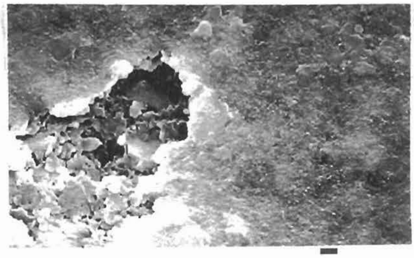
Pick could be easily seen at the trailing edge with the naked eye so a comparison with picking in the solid area at high magnification was undertaken. In Figure 10a, the cavities look more numerous and contiguous at this edge than they appear in the middle of solid areas.



100 µm
at 100 X

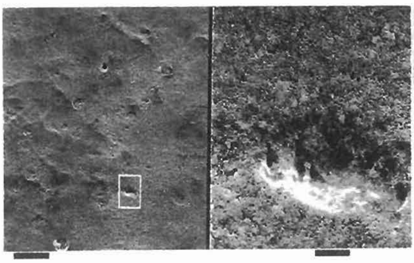
10 µm
at 1000 X

Fig 9a. Grainy mottle on 5th down black. 6 color, sheetfed press trial.



1 µm
at 5000 X

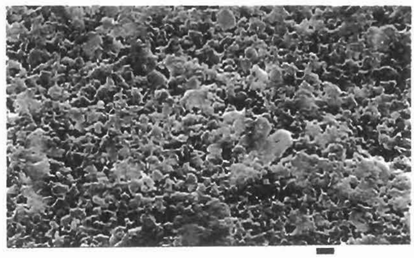
Fig 9b. Grainy mottle on 5th down black at a higher magnification.



100 µm
at 100 X

10 µm
at 1000 X

Fig 9c. Unprinted paper for the sample shown above.

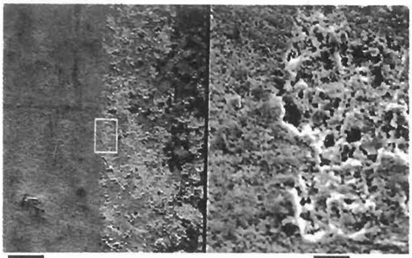


1 µm
at 5000 X

Fig 9d. Unprinted paper for the sample shown above.

The right half of Figure 10a, at 1000X, plainly shows the margin between uninked paper on the left and the picked area on the right. Although the margin is less clear at 5000 X , the disruption of the coating to the right of the margin is easier to see.

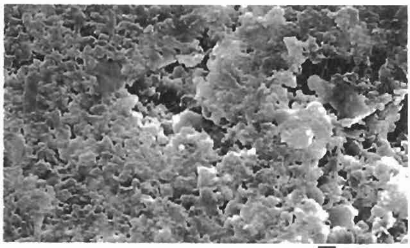
Areas of the print representing the first down black were examined under the same magnification. Comparison of Figure 11a with Figure 9a shows a much lower degree of erosion due to picking in the first down black than in the fifth down. This parallels the degree of damage seen by the unaided eye. The amount of debris partially embedded in the ink film is also lower on this first down black area, suggesting that the quantity of debris is proportional to the quantity of picking.



100 µm
at 100 X

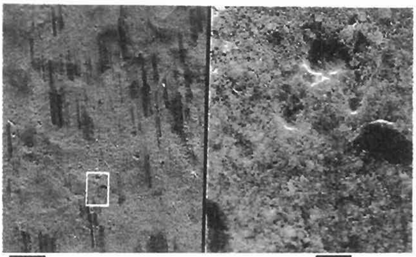
10 µm
at 1000 X

Fig 10a. Edge pick on 5th down black. 6 color, sheetfed press.



1 µm
at 5000 X

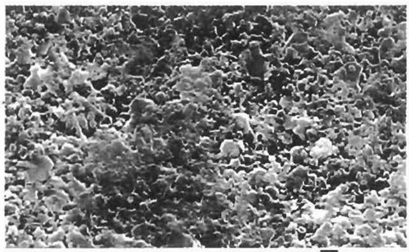
Fig 10b. Edge pick on 5th down black at a higher magnification.



100 µm
at 100 X

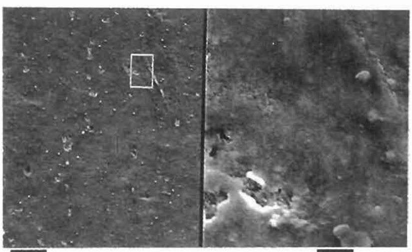
10 µm
at 1000 X

Fig 10c. Unprinted paper for the sample shown above.



1 µm
at 5000 X

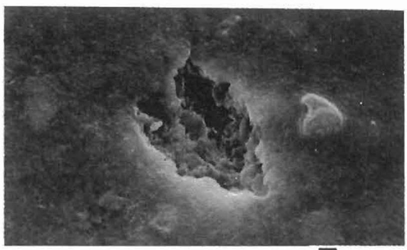
Fig 10d. Unprinted paper for the sample shown above.



100 µm
at 100 X

10 µm
at 1000 X

Fig 11a. 1st down black, for comparison to Fig 9a (on same print).



1 µm
at 5000 X

Fig 11b. 1st down black at a higher magnification.(Compare to Fig 9 b).

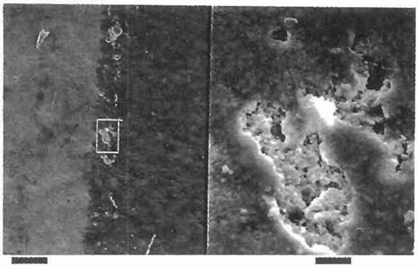


Fig 12a. Edge pick on 5th down black, sheet trial. Not visible to the naked eye.

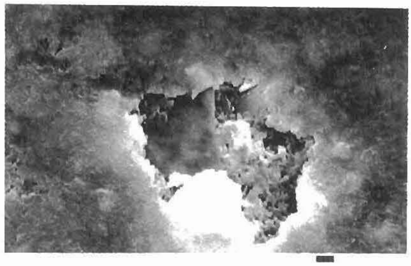


Fig 12b. "Invisible" edge pick on 5th down black at a higher magnification.

The printer's premium grade house paper was examined next . This stock had been used to set up and make ready the press for at least thirty sheetfed press trials on the same press with the same inks and fountain solution. No printed defects on this make ready stock were encountered. In order to see how much, if any, disturbance of the coating might have taken place, the print was examined under high magnification.

The only picking that could be found, under high magnification, was on the edge of the fifth down black. This is shown in Figure 12 at the same three magnifications used for the complaint paper.

3.5.3 Cross Sectional SEM Study of Areas of Six Color Print That Show Evidence of Wet Picking on the Surface

This is an average, cross sectional view through an area that has undergone wet pick. Cells of the base sheet fibers appear as large, dark, flattened ovals below the brighter toned coating. In some cases these fibers were seen extending almost to the surface of the coating (in other words, the fibers were only just covered). The base and top coat can be differentiated thus: the base coat has a coarser grained, more porous structure than the top coat. The darkest areas represent air voids. In Figure 13a, observe the white boundary at the interface between the two layers indicating the presence of a high concentration of latex. The possible causes are briefly discussed in Section 3.8.

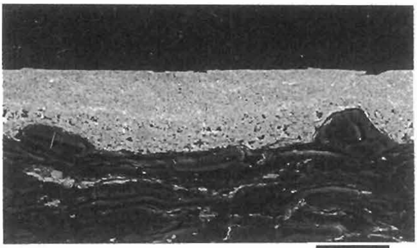


Fig 13a. Cross section of coating with wet pick. This corresponds to the area of Fig 9a at 1000 X

20 µm at 1000 X

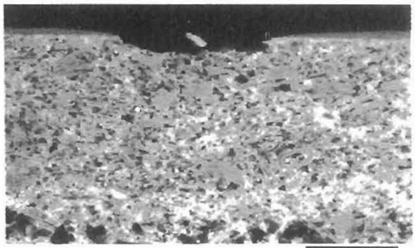


Fig 13b. Cross section of wet pick at higher magnification. This corresponds to the area of Fig 9b at 5000 X

5 µm at 5000 X

The damage at the coating surface is so shallow that it is hard to see at 1000 X. At 5000 X the depth of this cavity is about 1 micron and is typical of the cavities seen in this sample. The deepest cavity seen was 2 microns deep.

3.5.4 Analysis of the Debris Embedded in the Ink Film Around Cavities of the Picked Press Trial Sample

Qualitative interpretation of the X-ray spectra for the surface fragments showed the following composition. Aluminum, calcium and silicon were strongly detected. Titanium and magnesium were weakly detected.

The detection of aluminum, calcium and silicon is consistent with the presence of Kaolin and calcium carbonate that are often present as paper coating pigments.

3.6 Discussion of Carryover Picking and Wet Picking in Terms of Their Occurrence During Multiple Unit, Sheetfed Printing

This discussion of image area pick is separated into two categories: carryover picking and wet picking. Non image area piling certainly occurs but is not considered here. The two mechanisms are first summarized and then discussed in greater depth.

Carryover Picking vs Wet Picking Summarized

For carryover picking, the weakest link is within the coating because the ink's cohesion builds until it is higher than the coating's cohesion, which has remained the same.

For wet picking, the weakest link is again within the coating: not because ink tack is higher but because the coating cohesion has been decreased.

Image Area, Carryover Dry Picking (Carryover Piling)

Pick is usually observed during sheetfed press trials on the first and second down colors as trailing-edge pick (tail pick). The position at which they have picked and sometimes piled on the blanket has typically been on the last three printing units (4, 5 and 6). Such carryover picking has been attributed to the increase in tack of ink on the paper as the ink's low viscosity oils rapidly abandon the resins and pigment and soak into the porous paper coating. By the time the paper has reached the subsequent blankets, the tack has built to such a degree that the weakest link in the chain of forces is the cohesion within the coating; therefore, the split occurs within the coating rather than within the ink film. Initially the coating fragments are clinging to the ink on the blanket, not to the blanket itself. Such a situation cannot be assumed to guarantee a permanent build up every time there is picking. The specific circumstances that lead to the permanent accumulation of debris, known as piling, are not well understood.

This phenomenon is discussed, along with other paper-related printing problems, in a problem solving bulletin published by the S. D. Warren Company entitled "Specks in Printing" (Warren, 1988). Cohesion and adhesion across interfaces in terms of a chain of forces is discussed by J. F. Padday (1969).

Image Area Wet Picking

The mechanism by which wet pick can occur in the last units of a multiple unit press could be explained as follows:

(1) Each impression at the non image areas of the early units deposits a film of fountain solution to a thickness of about 0.3 microns per blanket.

(2) At 10,000 impressions per hour, roughly 1.0 second elapses while the sheet travels between each unit. There is (intuitively) plenty of time for this solution of low surface tension to be absorbed into the porous coating. This makes room for more solution to be applied on subsequent units, which in turn further raises the moisture level.

(3) Paper coatings are designed to temporarily accept water: the presence of the binder maintains the coating's strength. Areas of coating that are starved of binder would have a greater affinity for water than would well-bound coating. Fast uptake of water would be expected to the point where a "white mud" is formed on the coating surface.

(4) Upon being brought into contact with the inked blanket at, say the fifth unit, coating would adhere to the ink. Then, rather than the ink splitting as normally required, the coating is split.

(5) Leaving the nip, the coating is clinging to the ink rather than directly to the blanket. The fate of this softened coating within the press is not known, except to say that in the case studied, coating debris is seen embedded in the printed film.

For the complaint paper, the observation that no piling occurred suggests that the rate at which the coating fragments are picked out of the paper is equal to the rate at which the fragments are carried away.

3.7 Single Unit Wet Picking

From the evidence described herein, the complaint that prompted this study was shown to be a problem of wet pick on a single unit press. Is it possible that the ink and water mixture can cause spontaneous wet pick within the short time that the substrate is in a single nip?

Iwaki, Sato and Nimoda (1990) showed that micron sized droplets of water exist on the surface of ink on the plate. If we assume that droplets also exist on the surface of ink that lays on the blanket, then a hypothetical scenario can be developed.

First the water droplet is offered to the paper. The short elapsed time may not be sufficient for wetting to occur. Next the water is squeezed into the tiny pores of the coating just ahead of the ink. The movement of liquid into a porous substrate under the application of a force is known variously as plug flow, hydraulic impression or hydrodynamic impression. Because the water has been pushed down into the paper away from the surface, the ink is able to attach itself to the coating. The water has spontaneously weakened the surface pigments so, upon leaving the nip, the split occurs within the moistened unbound coating.

Such single unit wet picking is very rarely reported, but this does not mean it happens rarely. Without blanket build it could be wrongly diagnosed.

3.8 The Contribution of Binder Migration to Wet Pick

The movement of synthetic and natural binders (adhesives) is known to occur during the drying of a paper coating. The resulting localized depletion of binder can render the coating susceptible to wet pick.

The application and drying of a paper coating must be considered in order to gain an understanding of the resulting coating structure. The label paper being studied was coated with water-based dispersions of clay mixed with a styrene butadiene latex binder. This was done in two stages, the base coat was applied and dried followed similarly by the top coat.

Careful examination of the image (Figure 13a) reveals thin whitish bands of stained latex approximately parallel with the surface that represent zones of relatively high binder concentration. The two most intense bands are at the margin between the base and top coat and at the top surface. Discontinuous zones are distributed roughly parallel with the surface throughout the topcoat. Of the two most prominent layers, the lower layer is the thickest at roughly 2 microns compared with the surface layer at less than a micron. These zones do not consist purely of binder: they contain pigments but exhibit a relatively high concentration of binder.

This falls in line with current knowledge on the subject of binder migration during drying. Immediately after application of the coating, the immobilization phase starts to occur. There is rapid drainage of water and binder through the pigment layer towards the substrate. This is followed by evaporation of water in the heated dryers, which pulls more water and binder towards the surface. On its way out of the coating, the water has carried the binder with it, then deposited the binder along the interfaces through which it has left the top coat.

The migration of binder to create binder rich zones, would be balanced by depletion of binder in other portions of the coating. During the printing process these depleted zones would be expected to exhibit high porosity and low resistance towards the softening effects of fountain solution. The geometry of the picks seen in Figure 13 suggests that there was a zone or layer of binder depletion 1 or 2 microns below the surface.

4 CONCLUSIONS

(1) When examining an offset print, it is often difficult to visually distinguish between wet pick and wet repellency.

(2) Wet pick in the image area can occur without any visual evidence of accumulation on the press blanket.

(3) Wet pick can occur on single unit presses, but the same paper would exhibit wet pick to a greater extent on a multiple unit press.

(4) A reliable laboratory IGT test method was developed that can predict whether wet pick or wet repellency will occur during lithographic printing.

(5) Careful evaluation of the print with SEM microscopy is the best way to distinguish between wet pick and wet repellency.

(6) An uneven distribution of binder in the paper coating may lead to the presence of zones of unbound coating pigment. These unbound zones are susceptible to the softening effect of absorbed fountain solution and the high tack forces of the attached ink.

(7) Image area picking is not necessarily followed by piling on the press blanket and plate. Fragments of coating may be continuously carried away from the nip, embedded in the ink, at a rate equal to the formation of the fragments.

5 ACKNOWLEDGMENTS

For conversations that have helped to clarify many points:
Don Schultz and the craftsmen at McKay Press, Midland, Michigan.

For assistance in ink and printing related matters: Bob Bassemir and John Priesmeyer of Sun Chemical .

At Dow Chemical: Barb Miller, metallography; Frank Wang and Shirley Vanderveer, SEM; the laboratory support staff who really did the work and all those people who contributed valuable advice and comments. Special thanks to Garth Williamson of Dow for help in understanding some of the complicated problems of paper coating technology.

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7 APPENDIX

Definition and Discussion of Terms: The word "pick" typically refers to removal of coating or paper fibers in either the image or non-image areas of the printing nip.

"Wet pick" is defined here as the removal of paper coating or fibers, in the image area, that has been weakened by the transfer of fountain solution (F.S.) from non-image areas of previous blankets or by F.S. that is carried to the paper by the ink.

"Dry pick" can be thought of as pick that would have occurred even without the weakening effects of F.S. The term, dry pick, is used throughout the paper industry even though paste ink is always found on the press blanket together with fountain solution.

"Wet repellency" is defined here as ink refusal by wet paper. This phenomenon can be better understood by considering the fate of dampening solution on a multiple unit press. The paper continually accumulates moisture transferred by blankets in the non-image area at an estimated thickness of 0.3 micrometers on the paper (Juhola et al, 1985). Although the evidence is circumstantial, the surface of the paper is thought to either absorb the F.S. into micropores, or retain the F.S. on the surface. If retained on the paper surface, the F.S. can then interfere with ink transfer on subsequent units, the color looking washed out and exhibiting a grainy mottle. Ink refusal from a dampened, hydrophilic surface is more rigorously described as splitting within the F.S. layer that lies between the ink and the paper surfaces. A thorough description of this type of splitting mechanism is given by John MacPhee in his analysis of the lithographic printing process (MacPhee, 1979). It is also referred to as water interference, fountain solution interference, fountain solution sensitivity, and wet trap. Water interference and wet trap are used in other areas of printing science, so "wet repellency," being less ambiguous, is preferred by the authors and is the term used by Reprotest in the IGT test method (IGT, 1985). The word repellence (or repellance) is sometimes used: it cannot be found in an English dictionary.

IGT Test Method Evolution: Prior to this project, an IGT test method had been successfully developed to predict wet repellency on all grades of web and sheet paper. The method outlined in Section 2.1 contains modifications that allow wet pick to be seen while maintaining predictability of wet repellency.

Numerical Evaluation of an IGT Test Print: One Test Determination is the mean of four density readings from the top of the test strip minus the mean of four density readings from the bottom of the same strip. One Test Result is the mean of three test determinations reported along with the standard deviation. Replication should be randomized. Wet pick was not quantified for this paper because the primary objective was to identify the mechanism. For wet repellency, TAPPI repeatability has been determined as 0.05 density units, which is equivalent to 18% of a typical test print having a density of 1.2 density units in the dry printing area.