EFFECT OF INK WATER PICK-UP ON PRINTABILITY IN A HIGH SPEED LITHOGRAPHIC PRESS

NPIRI Task Force on Water Pick-Up*
(Presented by R.T. Peters)

Abstract

Tests were conducted on a high speed web lithographic press to determine the effect of ink water pick-up on print quality. Density, dot gain, gloss, trap and mottle were all measured. On an overall basis, the ink set having low water pick-up (LWPU) demonstrated excellent print quality and was easy to run. A high water pick-up (HWPU) set of inks had good print quality and was also easy to run. When the HWPU ink set was adjusted to LWPU with an additive, (AWPU) print quality deteriorated and runnability suffered.

Visual rating of prints using seven experienced panelists agreed with objective measurements of print quality. The LWPU ink set was rated best, the HWPU set was rated second best, and the AWPU ink was third. Results with the AWPU set confirm that the use of additives to decrease WPU to a given specification value has a detrimental effect on print quality.

Print quality for all inks deteriorated significantly when speed was decreased to 1,000 fpm.

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Water pick-up was significantly lower with fountain solution than distilled water in the Duke test (ASTM D4942). An in-depth study is planned using a wide variety of fountain solutions to learn more about this phenomenon.

Introduction

The purpose of this project was to investigate whether or not inks having high and low water pick-up print equally well, and to determine if additives that reduce water pick-up have an effect on print quality. Three sets of inks, four process colors each, were tested. These included a high water pick-up ink set (HWPU), a low water pick-up ink set (LWPU), and a set of adjusted water pick-up inks (AWPU). Printability tests at 1,500 and 1,000 fpm were conducted on a Harris M-1000 B web offset press at Rochester Institute of Technology. Density, dot gain, trap, gloss, and mottle were all measured using a specially designed test plate. A subjective evaluation of print quality using a panel of experts at RIT was also made. In addition, the operational water tolerance window for each ink was determined.

Test Inks

The LWPU ink is a commercial ink that is naturally low in water pick-up because of its formulation.

The HWPU ink is a commercial ink that normally tests high using distilled water in the Duke Test (ASTM D4942 A). However, when the fountain solution used at RIT was used with the HWPU ink set, water pick-up values were significantly lower. A surfactant was then added to increase WPU.

The adjusted water pick-up ink set (AWPU) was made by the addition of an additive to the HWPU ink set that reduced WPU.

Viscosity, yield stress, and tack for the test inks are shown in Appendix Table 1. Also shown in Appendix Table 1 are viscosity and yield stress results for the ink samples taken from the last form roller for each unit. Press sample viscosities agree fairly well with viscosities for unused ink. It was not possible to run tack for the press samples because the presence of water makes the test unreliable.

Water Pick-Up

Water pick-up values using the Duke Tester in ASTM Test Method A are shown in Figures 1 and 2.

Figure 1

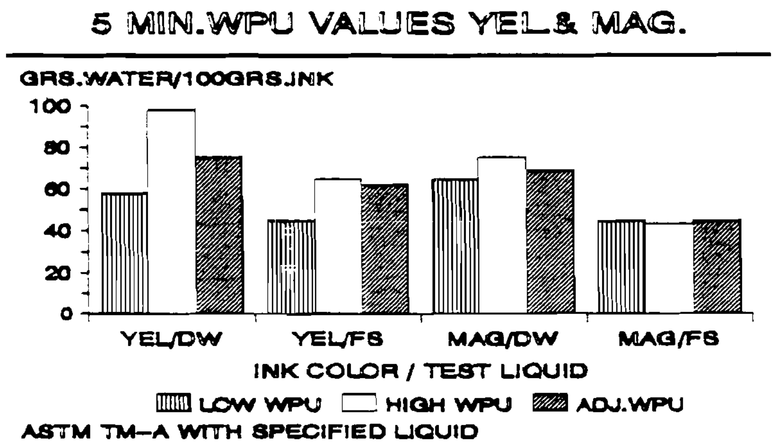
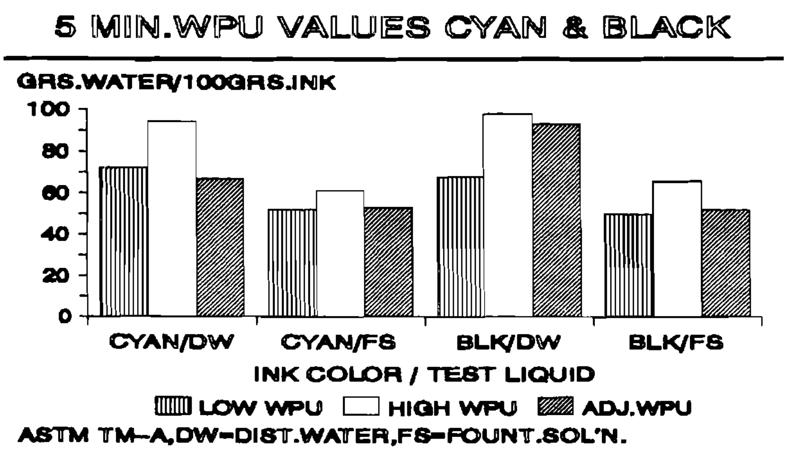


Figure 2



Initially, WPU tests were run using distilled water, which is commonly used by ink companies and printers for quality control and specification purposes. WPU values show a wide spread between the inks when distilled water was used. However, the Task Force decided to use the same fountain solution, Rosos KSP 500 AS M-4, in the Duke tests that was used on the press. When this was done, WPU values were significantly lower and there was less differentiation between the HWPU and LWPU inks. Several surfactants were tested to increase WPU and only one was found to be effective without unduly disturbing the rheology of the inks. The Task Force plans an in depth study to learn more about the difference in WPU between distilled water and a wide variety of fountain solutions.

WPU results using fountain solution and ASTM D4942 Test Method B (sequential addition of water to 10 minutes) are shown in Appendix Figures 1 through 4.

Sequential addition of water shows a good separation between the high and low water pick-up inks with the exception of magenta which demonstrated consistently low water pick-up for all inks.

The Press

The press used to conduct printability tests was the Harris M-1000 B heatset web offset press located at the Technical and Education Center at RIT. It is capable of speeds of 2,000 fpm and normally operates two shifts per day to test paper, ink, and other materials for the graphic arts industry. The press is equipped with a central fountain solution tank which is refrigerated and maintained at a temperature of 75°F. The dampening system is a Duo-Trol® continuous system which can be sensitive to ink feedback into the dampening system. The press is equipped with automatic register control and is operated from one main console. Blankets on the press are Reeves 2000 plus, compressible. The press is normally set up to deliver folded signatures as two eight page deliveries. In this test, printing was done only on the top side of the web.

Paper

The paper used was No. 5 magazine grade basis 36 pound, 25 x 38, 500 No. 5 coated, supplied by Boise Cascade. Four rolls, one ton each, were used during the test, all contiguous from the same manufacturing run.

Fountain Solution

The fountain solution used, Rosos KSP 500 AS M-4 without alcohol is recommended for the Harris Duo-Trol® system. It was used at 6-1/2 ounces per gallon of water and has a conductivity of 2450 micro Siemens when mixed with Rochester city water having a conductivity of 240 micro Siemens.

Test Plate

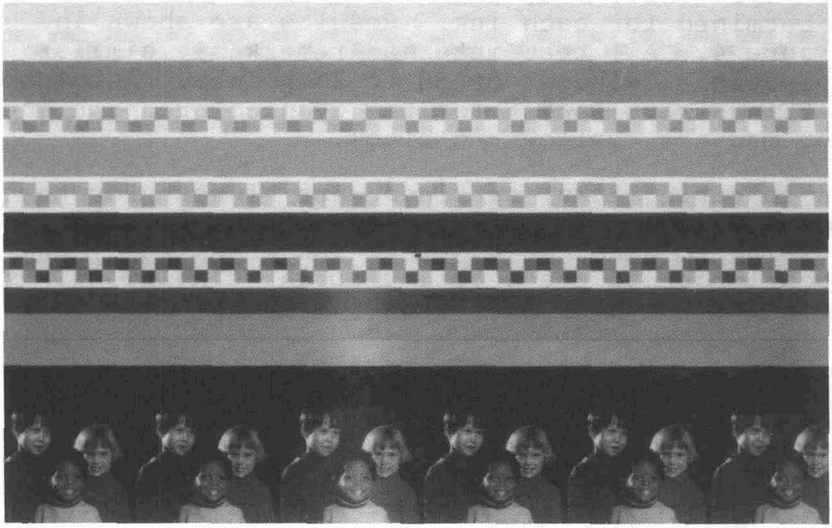
The test plate was an Enco EC (electrochemical etch) negative working plate which is used extensively by publication heatset printers. The plate was machine processed and extra plates for every unit were made. Each plate was exposed with a sensitivity guide to assure proper exposure and development. The image size of the plate was 22 inches by 35 inches.

Test Image

A picture of the test plate is shown below as Figure 3. The test plate was designed to contain one single pictorial with flesh tones and a dark red and dark purple in the same area. The four process colors and traps (red, green, and blue) for both solids and half tones were bars one inch square. Color bars were placed on the lead and tail ends of the sheets. Resolution targets were also spotted on the Plate.

Figure 3

Test Plate Design



Test Procedure

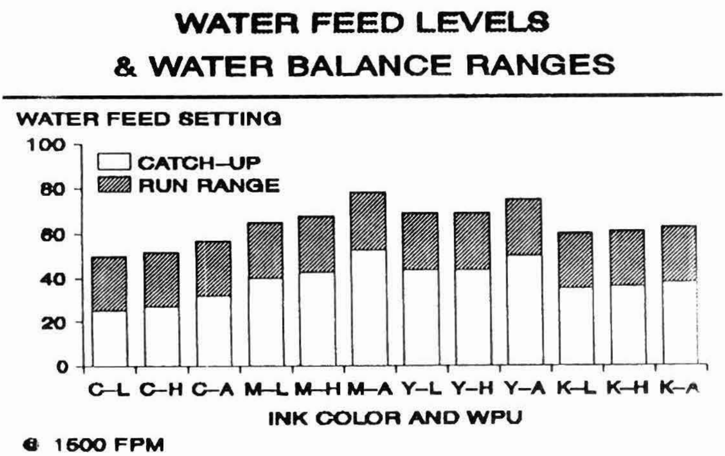
Samples for print quality measurements were taken at press speeds of 1,500 and 1,000 fpm. The same test sequence was used for each set of inks. The color sequence was black, cyan, magenta, yellow. The LWPU ink was run first, followed by the HWPU ink and the AWPU ink in that order. The press was made ready at a speed of 400 fpm. Speed was then increased to 1,500 fpm with ink and dampening solution settings optimized for print density. The settings were then kept constant and print samples taken every 1,000 impressions. Water tolerance limits were then determined by increasing fountain solution feed to wash-out, followed by decreasing feed to the scum point. Press settings were then returned to optimum conditions and speed decreased to 1,000 fpm with no change in press settings. Samples were taken at the 1,000 fpm speed after another 2,000 impressions were run. The press was then washed and the same sequence repeated for the next ink set.

Water Tolerance Limits

As explained above, water tolerance limits were determined for each ink. Results are shown in Figure 4. All test inks had remarkably similar operational windows of 25 to 26 points. Absolute settings were lowest for the cyan color and higher for magenta, yellow and black.

In comparing inks, settings were highest for the adjusted ink. It took a higher fountain solution setting to make the adjusted ink print well, and it took longer to reach optimum print conditions. The adjusted ink also misted on the press.

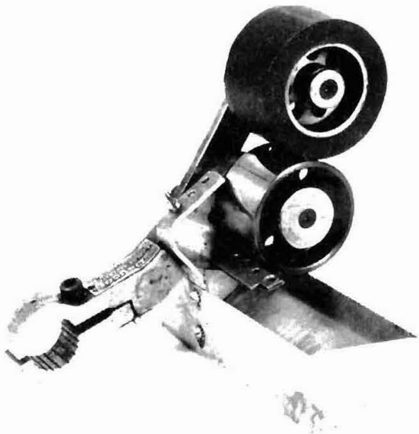
Figure 4



Press Ink Samples

RIT adopted a special apparatus to take ink samples from the press as it ran. This was an attempt to determine water content of the various inks at the plate nip. A photograph of the apparatus is shown as Figure 5.

Figure 5



Ink Sampling Device

The ink sampler was placed against the last form roller on the top of each unit. Although this was not the most desirable location, it was placed there because of practical considerations. Ink press samples were taken at press speeds of 1,500 fpm under equilibrium conditions. Samples were collected for approximately five minutes and placed in air-tight glass containers. Water content was determined the following day using a Brinkman Water Analyzer, which is a modified Karl Fisher apparatus. Viscosity and yield stress of stripped ink was measured immediately on site.

Water content results are shown in Table 1.

Table 1

Weight Percent Water - Ink Press Samples

Ink	Black	Yellow	Magenta	Cyan
LWPU	2.2	1.2	1.3	6.5
HWPU	1.0	1.2	1.4	5.0
AWPU	1.1	3.2	2.4	9.1

The results with the exception of cyan are all low, and much lower than expected. We believe this may have been due to the sampling procedure used. When the sample apparatus was lowered onto the form roller, it initially picked up surface water and emulsion present. However, as the run progressed with the sample apparatus in place, much of the equilibrium with respect to ink feeds and surface water pick-up may no longer exist. The sampling roll is splitting only a portion of the ink, and on the last form roll much of the surface water may have been emulsified or evaporated. Thus, the longer the sampling roll is left in continuous contact, the less representative the sample may be of the actual equilibrium condition. In hindsight, it may have been better to take a series of short-time samples rather than one long continuous sample.

We do not believe that much significance should be placed on the slight differences in water content shown for the various inks, since all values except cyan are unrealistically low. The Task Force has no explanation as to why the cyan inks retained more water. Also note that the cyan ink adjusted to low WPU with an additive contained more water than the high or low WPU inks.

TEST RESULTS

Density

Using a Cosar Autosmart Densitometer, signatures were evaluated for density at optimum, wash out and scum point water feed conditions. The densities reported in Table 2 below are the average for seven colors. Forty-one density readings for each color were taken over a 2 inch scan. It was found that average density did not change when more than 41 recordings were taken. Typical density traces for the LWPU black, yellow, magenta, and cyan colors are shown as Appendix Figures 5 through 8. Average densities for each color are reported in Table 2.

Table 2

Average Ink Density - All Colors 1,500 fpm

Water Feed	LWPU	HWPU	AWPU
Optimum	1.48	1.37	1.36
Low	1.42	1.33	1.44
High	1.37	1.29	1.38

Examining all the data at the three water feed conditions, there is a slightly higher density for the LWPU ink at optimum water feed. At low and high water feeds, the densities of the LWPU and AWPU are about the same with the HWPU slightly lower.

Average density data for all colors at 1,000 fpm and 1,500 fpm press speeds are shown in Table 3 below.

Table 3

Average Ink Density at
1,000 and 1,500 fpm, Optimum Conditions

		Ink		
Press Speed		LWPU	HWPU	AWPU
1000 fpm	Avg. All Colors	1.37	1.37	1.48
1500 fpm	Avg. All Colors	1.48	1.37	1.36

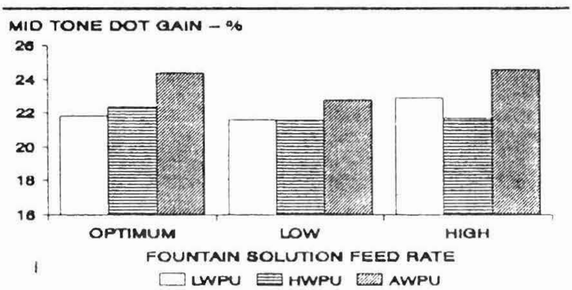
At 1,000 fpm and optimum feed conditions the AWPU ink set had slightly higher density than the other test inks. At 1,500 fpm the LWPU inks were slightly higher. There was no consistent pattern of increasing or decreasing density in reducing press speed from 1,500 to 1,000 fpm. The LWPU inks decreased in density, the AWPU inks increased and the HWPU set stayed about the same.

Dot Gain

Average dot gain data are presented in Figure 6 and 7 below. The dot gain data reported are averaged from eight readings taken for each color, which are then averaged for each set of test inks. At 1,500 fpm dot gain was significantly greater for the AWPU ink set at each fountain solution feed. The dot gain for the LWPU set was slightly lower than the HWPU ink set except at high fountain solution feed.

Figure 6

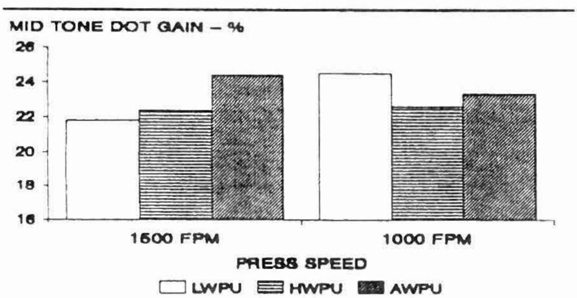
AVERAGE DOT GAIN
ALL COLORS – 1500 FPM



Dot gain data at 1,500 and 1,000 fpm are compared in Figure 7. Press speed did not have a consistent effect on dot gain. The LWPU set increased as speed decreased, the HWPU remained the same, and the AWPU inks decreased.

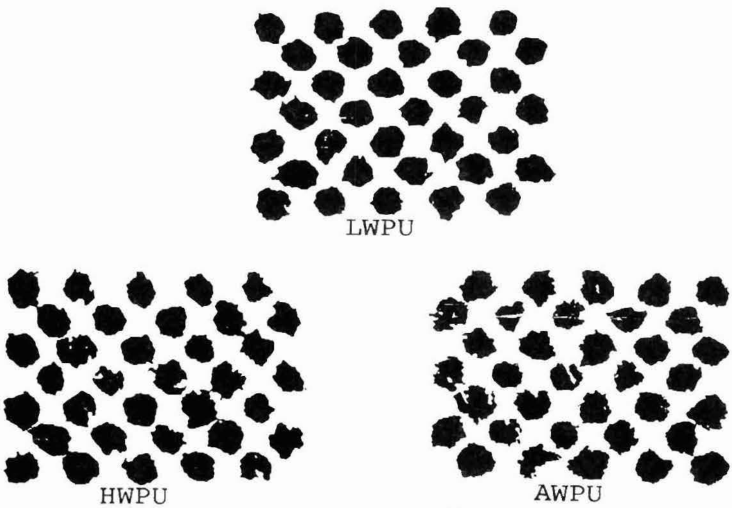
Figure 7

AVERAGE DOT GAIN ALL COLORS
EFFECT OF PRESS SPEED



A photomicrograph of dot structure at 1,500 fpm and optimum conditions is shown in Figure 8 below. Figure 8 shows clearly that dot structure for the AWPU ink is not as tight as the LWPU or the HWPU ink sets.

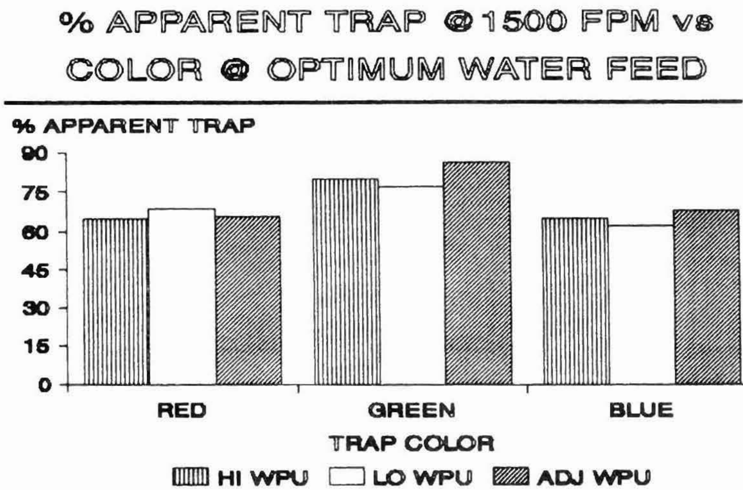
Figure 8



Trap

Apparent trap under optimum water feed conditions are shown in Figures 9 and 10.

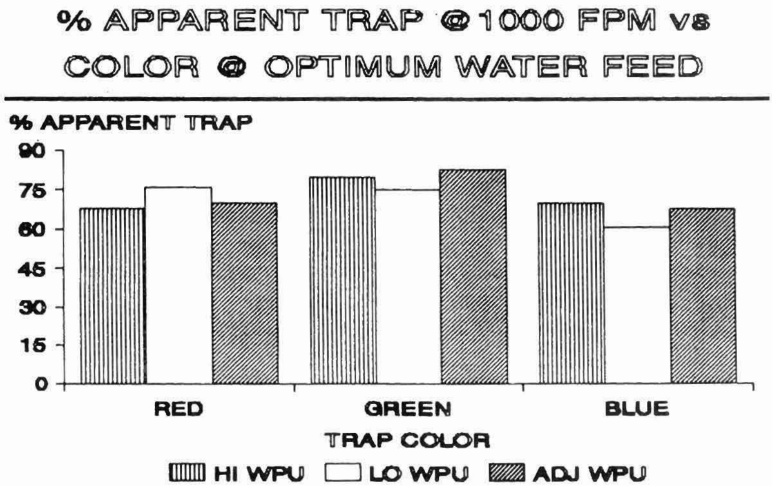
Figure 9



There are no consistent differences in trapping among the test inks under any of the water feed conditions.

Trapping at 1,000 and 1,500 fpm are compared in Figure 10. Percent trapping is about the same at 1,000 fpm and 1,500 fpm.

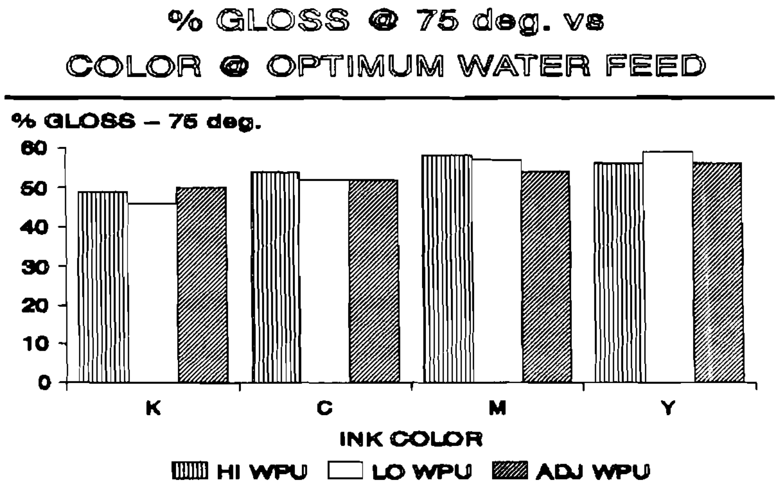
Figure 10



Gloss

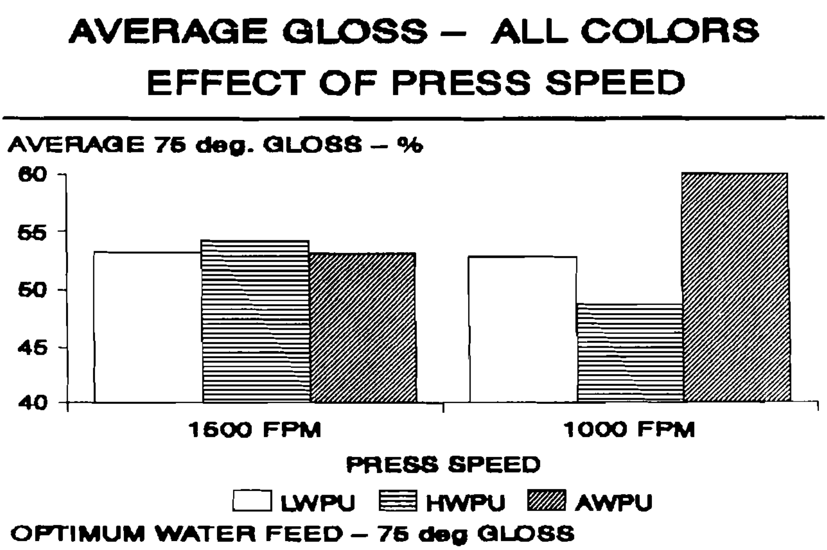
Gloss readings using a Hunter instrument with 75° optics are shown in Figures 11 and 12 below. Examination of the individual colors in Figure 11 shows no significant difference among the different inks.

Figure 11



A comparison of average gloss at 1,500 fpm and 1,000 fpm shows that the LWPU ink set did not change with speed, the HWPU set decreased, and the AWPU set increased significantly when speed was decreased to 1,000 fpm. Perhaps the lower shear forces at 1,000 fpm permitted the AWPU inks to set up better on the paper.

Figure 12



Mottle

Mottle for the purpose of this paper is defined as differences in density over a two inch scan. Solid prints of each color and the solid over prints were measured. Optical density and the standard deviation of the optical densities for three signatures for each color and water feed condition were also measured. The values were then averaged for each color and each condition. The standard deviation or variation in optical density is then an indication of mottle.

Standard deviation data are summarized in Figure 13. Data for the three test inks under three water feed conditions show a slightly lower deviation (less mottle) overall for the LWPU set of inks. The HWPU ink set showed higher mottle at low and high water feed conditions.

Figure 13

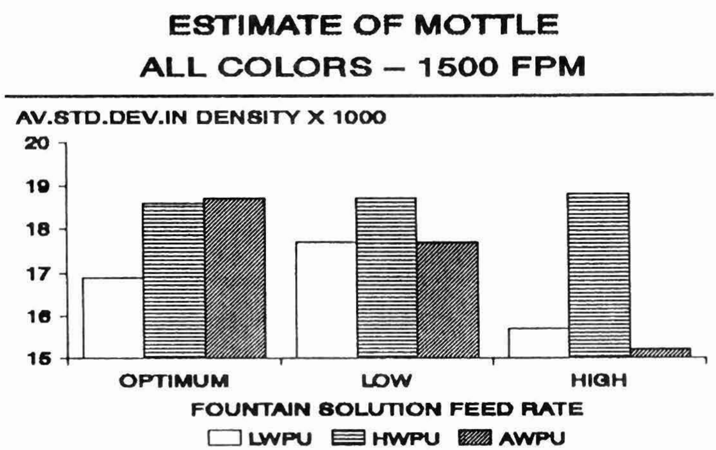


Table 4 summarizes mottle (average standard deviation in density) by color. These data are the average of all test inks under all conditions for a given color.

Table 4

Estimate of Mottle by Color

(Average Standard Deviation in Density, 1,500 fpm)

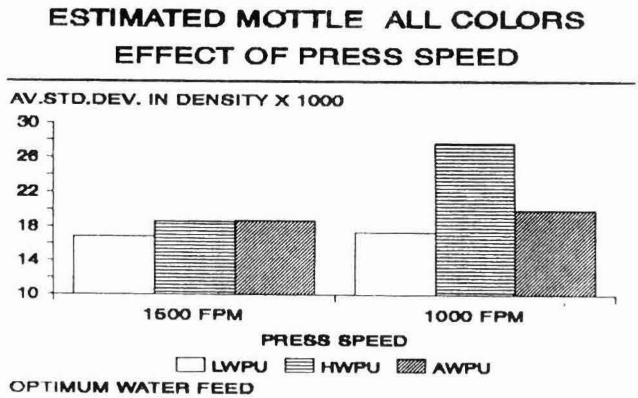
Color	Avg. Deviation(1)	Min.	Max.	Spread
K	0.0212	0.0259	0.0181	0.0078
C	0.0249	0.0367	0.0110	0.0256
M	0.0164	0.0204	0.0130	0.0074
Y	0.0114	0.0134	0.0086	0.0048
R	0.0167	0.0193	0.0125	0.0068
[illegible]	0.0132	0.0167	0.0094	0.007
	0.0178	0.0260	0.0131	0.012

) Average values for three inks, three water feed conditi

The data show that the greatest average deviation or mottle occurs with cyan, followed by black. The lowest variation in density or mottle occurs with yellow followed closely by magenta for the process colors. All three overprint colors show low average deviation in density. The greatest spread between maximum and minimum values is shown for cyan which also had the highest degree of mottle. In addition to having the lowest deviation in density, yellow also had the lowest spread between maximum and minimum values.

The effect of press speed on estimated mottle is shown in Figure 14. Average standard deviations are summarized for each set of inks under optimum water feed conditions. The data show little difference in estimated mottle at 1,000 and 1,500 fpm except for the HWPU set of inks which is higher at 1,000 fpm.

Figure 14



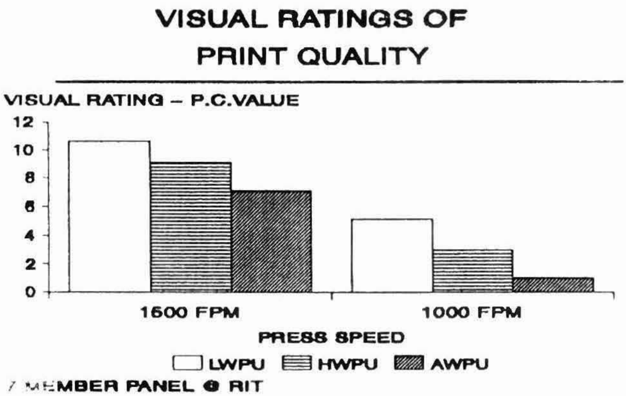
Visual Rating

A seven member panel of experienced graphic arts personnel at RIT visually evaluated the pictorial portion of the test print. Prints were selected randomly for the three sets of inks under optimum print conditions at 1,500 fpm and 1,000 fpm. The pair comparison technique was used to evaluate coded samples. The sample that was rated better received a PC (pair comparison value) of two, and the sample rated poorer received a PC value of zero. Samples rated equal received PC values of one each.

The M-1000 B press geometry is such that one turn of the blanket produces two consecutive prints and requires two turns of the plate cylinder. Both prints were used in the evaluation to avoid any question related to the configuration of the press. The picture selected for evaluation was the third image from the operators side of the press (third from the left looking at the print). It is also in line with the area that was used for quantitative measurements.

The response of the seven panelists is summarized in Appendix Table 3 and in Figure 15 below. Results agree well with objective measurements. At 1,500 fpm press speed, the LWPU ink set was rated better than the HWPU set which was better than the AWPU set. Visual rating results confirm that the use of additives to decrease the water pickup of ink has a detrimental effect on print quality.

Figure 15



Visual print quality is significantly poorer for all inks at 1,000 fpm which also agrees with objective measurements. The individual inks also line up in the same manner, with the AWPU set having an average PC rating of only one.

It is interesting to note from the data in Appendix Table 3 that consecutive prints (A and B in the table) had PC values that were almost identical, which attests to the validity of the ratings.

CONCLUSIONS

- On an overall print quality basis, objective measurements showed an advantage for the LWPU ink set over the HWPU ink set which in turn demonstrated better print quality than the AWPU set.

- The visual rating of randomly selected prints by seven experienced panelists agreed with the objective measurement of print quality.

- The use of an additive to decrease water pickup had a detrimental effect on print quality as well as runnability.

- The AWPU ink set required a higher water feed rate and it took pressmen considerably longer to adjust for optimum print conditions.

- Water pickup values using the Duke Tester were significantly higher in distilled water than fountain solution. An in-depth study is planned by the Task Force to investigate this phenomenon.

- Print quality deteriorated as speed was decreased from 1,500 fpm to 1,000 fpm.

- All inks had the same (25 points) water tolerance window.

- A new method to measure mottle has been introduced which uses the Cosar Autosmart Densitometer.

Acknowledgments

The Task Force wishes to acknowledge the professional job done by the RIT pressmen in running the test. Special thanks go to William Eisner and Chester Daniels who helped plan the press test and evaluate the data. Our thanks also to David Cohn and Ching Yih Chen who made measurements of print quality. Finally, thanks go to Graphic Fine Color who supplied the test inks, and Boise Cascade who contributed the paper.

Appendix Table 1

Ink Inspections

Ink	Unused Ink Tack(1)	Unused Ink Laray Visc.	Unused Ink Yield Stress(2)	Press Sample Laray Visc.	Press Sample Yield Stress(2)
LWPU					
Yellow	8.9	85	800	45	1249
Magenta	13.4	143	1100	126	3482
Cyan	12.4	124	700	126	3493
Black	12.5	152	1100	145	4000
HWPU					
Yellow	9.4	85	700	56	1538
Magenta	11.8	134	900	128	3527
Cyan	11.7	82	200	67	1842
Black	11.8	122	700	160	4417
AWPU					
Yellow	9.9	101	600	73	1999
Magenta	12.2	138	900	127	3506
Cyan	12.9	92	200	78	2152
Black	11.7	109	600	70	1929

(1) One minute at 1200 rpm
(2) Power Law Values

Appendix Table 2

Average Ink Density 1500 fpm

Inks	Color	SWPU	HWPU	AWPU
Optimum	Black	1.6665	1.5692	1.6012
	Cyan	1.5429	1.3598	1.3598
	Magenta	1.6197	1.4742	1.4646
	Yellow	1.1713	1.0744	1.0675
	Red	1.7201	1.5536	1.5283
	Green	1.1076	1.1217	1.0973
	Blue	1.5113	1.4113	1.4290
	Avg. All Colors	1.4777	1.3663	1.3640
Low Water Feed	Black	1.7151	1.4767	1.6939
	Cyan	1.5422	1.2977	1.4441
	Magenta	1.4529	1.4172	1.5888
	Yellow	1.1810	1.0767	1.1220
	Red	1.6129	1.5182	1.6105
	Green	1.1029	1.1194	1.1589
	Blue	1.3298	1.3998	1.4894
	Avg. All Colors	1.4195	1.3294	1.4439
High Water Feed	Black	1.6283	1.3967	1.6427
	Cyan	1.3845	1.1673	1.2289
	Magenta	1.4205	1.4189	1.4944
	Yellow	1.1282	1.0449	1.0799
	Red	1.6109	1.5002	1.5678
	Green	1.0826	1.0741	1.1282
	Blue	1.3126	1.4257	1.5165
	Avg. All Colors	1.3668	1.2897	1.3798

Appendix Table 3

Summary of PC Values for Print Quality

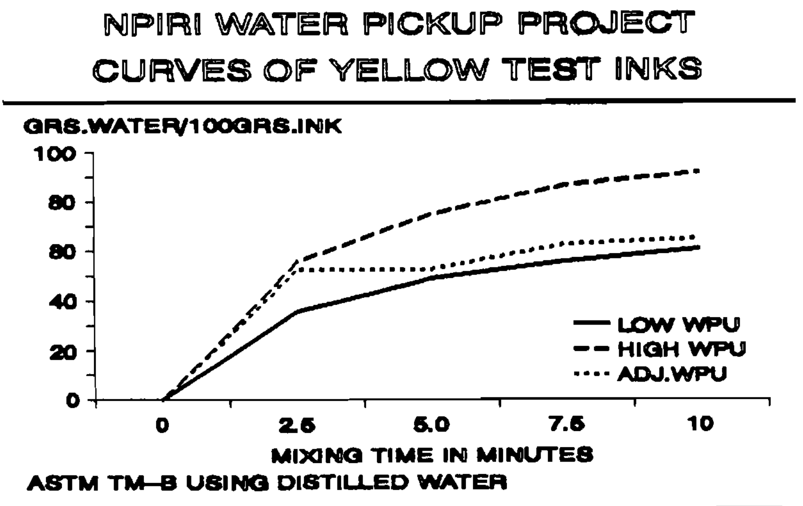
Prints from Blanket Section A

Code	Identification	Observer 1	2	3	4	5	6	7	Mean	Rank
1	HWPU-1500 fpm	9	9	9	9	9	9	9	9	2
2	AWPU-1000 fpm	1	1	1	1	1	1	1	1	6
3	LWPU-1000 fpm	5	5	5	5	5	5	5	5	4
4	HWPU-1000 fpm	3	3	3	3	3	3	3	3	5
5	AWPU-1500 fpm	7	7	9	7	7	7	7	7.29	3
6	LWPU-1500 fpm	11	11	9	11	11	11	11	10.71	1

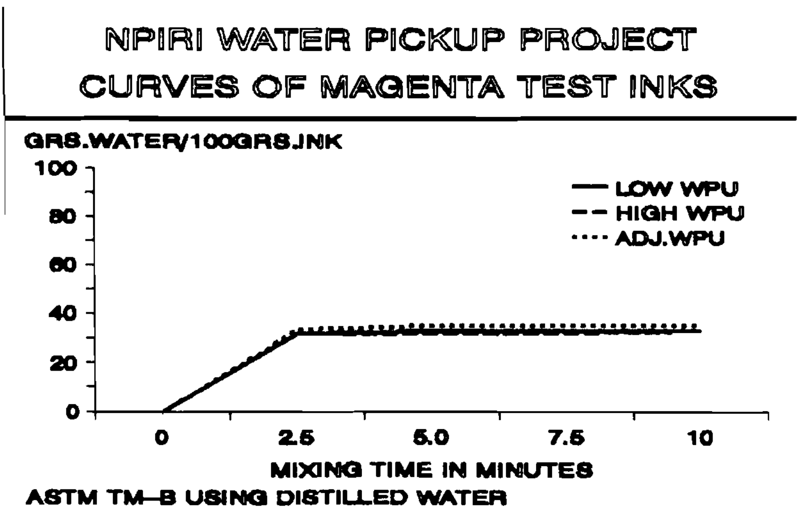
Prints from Blanket Section B

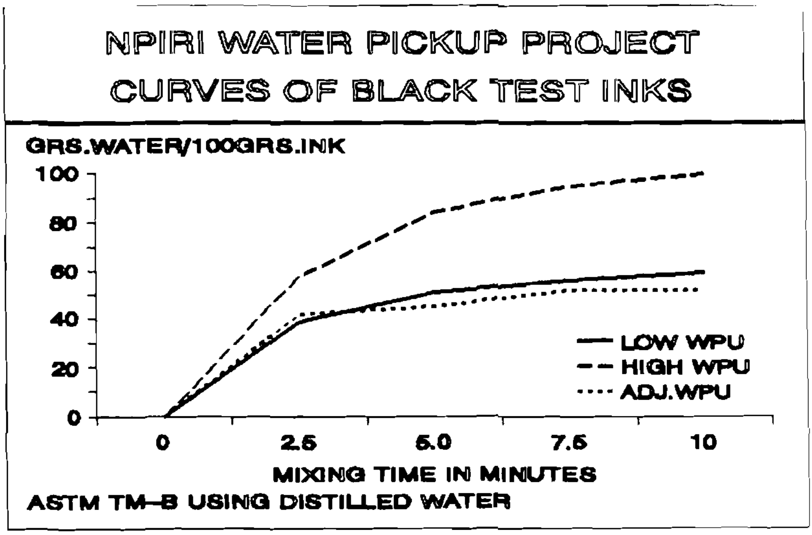
Code	Identification	Observer 1	2	3	4	5	6	7	Mean	Rank
1	HWPU-1500 fpm	9	11	9	9	9	9	9	9.29	2
2	HWPU-1000 fpm	3	3	3	3	3	3	3	3	5
3	AWPU-1000 fpm	1	1	1	1	1	1	1	1	6
4	LWPU-1500 fpm	11	9	9	11	11	11	11	10.43	1
5	AWPU-1500 fpm	5	7	9	7	7	7	7	7	3
6	LWPU-1000 fpm	7	5	5	5	5	5	5	5.29	4

Rank	Section A	Section B	Grand Mean	Standard Dev.
1	LWPU-1500fpm	LWPU-1500fpm	10.57	0.85
2	HWPU-1500fpm	HWPU-1500fpm	9.14	0.53
3	AWPU-1500fpm	AWPU-1500fpm	7.14	0.95
4	LWPU-1000fpm	LWPU-1000fpm	5.14	0.53
5	HWPU-1000fpm	HWPU-1000fpm	3.00	----
6	AWPU-1000fpm	AWPU-1000fpm	1.00	----

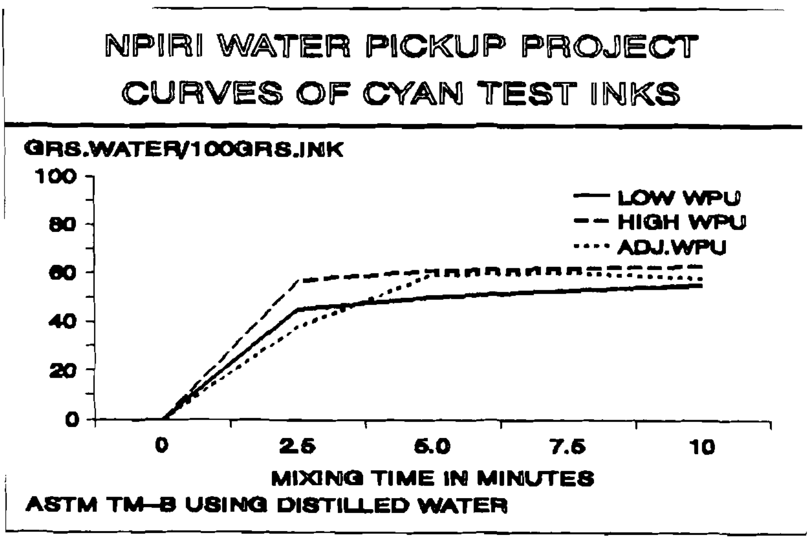


Appendix Figure 2





Appendix Figure 4



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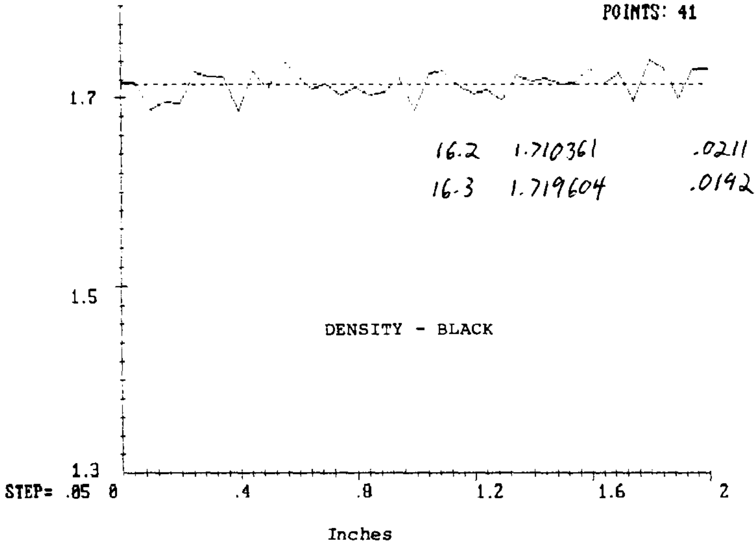
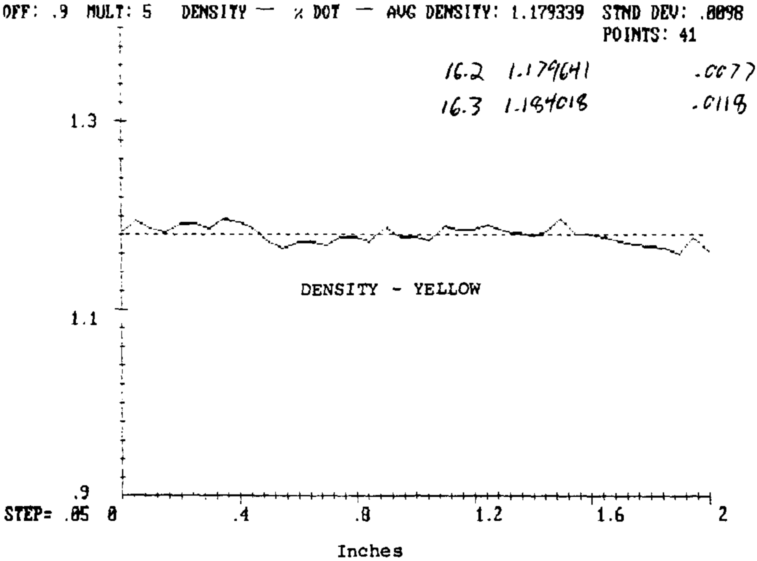
OFF: 1.3 MULT: 5 DENSITY — % DOT — AVG DENSITY: 1.715295 STND DEV: .0149
POINTS: 41



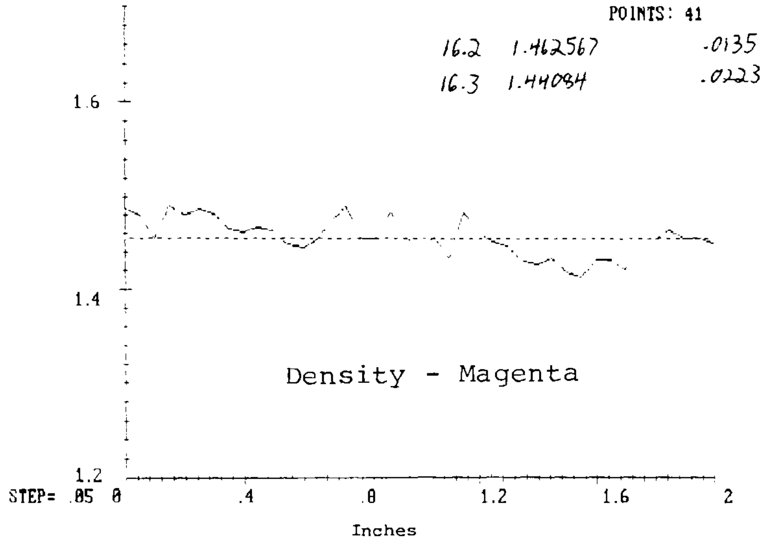
Appendix Figure 5

TONE SCANNING: FILTER(Y) 12-13-1989 11:43:26 LOW 16.1 YELLOW
OFF: .9 MULT: 5 DENSITY — % DOT — AVG DENSITY: 1.179339 STND DEV: .0098
POINTS: 41



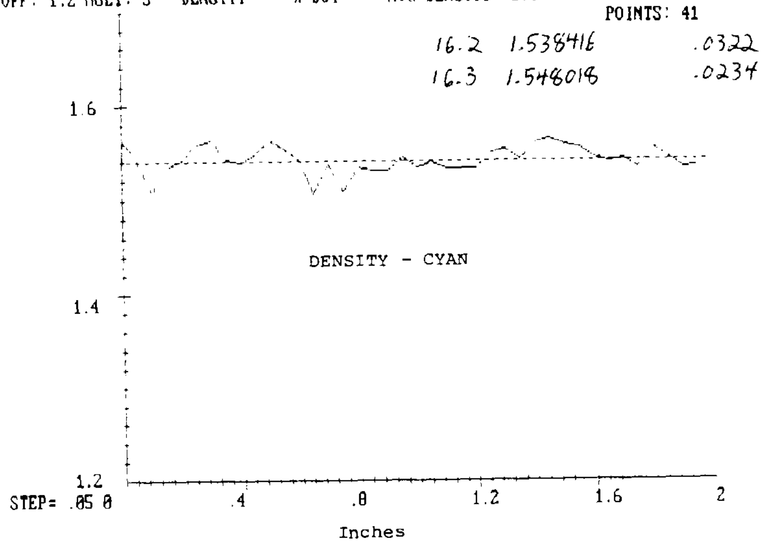
Appendix Figure 5

TONE SCANNING: FILTER(M) 12-13-1989 11:41:47 LOW 16.1 MAGENTA
OFF: 1.2 MULT: 5 DENSITY — % DOT — AVG DENSITY: 1.455438 STND DEV: .0208
POINTS: 41



Appendix Figure 7

TONE SCANNING: FILTER(C) 12-13-1989 11:38:23 LOW 16.1 CYAN
OFF: 1.2 MULT: 5 DENSITY — % DOT — AVG DENSITY: 1.540129 STND DEV: .0151
POINTS: 41



Appendix Figure 8

Ink-Water Emulsified State in Offset Printing

Toru Iwaki*, Kazuhiko Sato*, and Toyoo Nimoda*

Abstract: In offset printing, print quality depends on balance of the feeding amount of ink and fountain solution. It is well-known that ink/fountain solution on printing press co-exist in the form of W/O emulsion. In this report, the surface of ink films and water-droplet formation on them have been investigated by the observation through emulsion visualization apparatus developed in our research center. It was made clear that the surface of any ink film on a roller is not flat during rolling and that surface water-droplets appear on the emulsified ink film at a certain water content, which greatly effects the properties of emulsified ink.

The IPA-substituted reagent has been selected by examining the emulsifying characteristics on the ink tester and printing machine among several kinds of surfactant solutions in orderto come to close to the aqueous IPA solution as a standard solution, which exhibits the metastable emulsified state. Further, the role of fountain solution in image production on plates by emulsified ink film has been discussed.

1. Introduction

Offset printing is a printing system utilizing repellence of ink and water. Ink is mixed with dampening water on a group of ink rollers to be emulsified ink and is transferred from one roller to another until printed on a paper. Offset printing has a variety of print quality problems (ghost, greasing, poor inking, insufficient gradation reproducibility) resulting from emulsification.

When an emulsified ink film is transferred between rollers under high speed revolutions (roller speeds = 2 ～ 10 m/s), various changes such as adhesion or filamentation of ink films, ink/water emulsification, leveling and water vapor evaporation due to the nature of roller surface and physical properties of ink because of intermittent extended shearing (rate of shear ≒ $10^{3\,1}$/s) at the nip of rollers.

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To a chieve a high print quality in printing process what should we control from the view point of ink and water.

(1) In inking unit, emulsified ink must transfer from ink pan to plate through rollers, showing stable and uniform flow.

(2) On the plate emulsified ink must adhene to the image area uniformly and exactly according to the plate image. Further, the image-formed ink on the plate must be transtered to blanket and on the paper uniformly and stably.

(3) Emulsified ink on the paper must be subject to leveling and drying by the structural relaxation. These subject are considerd to be remarkably associated with the emulsion state of the ink and its rheological properties.

To prove such phenomena, we had previously developed the ink film thickness and water content meter (1) which can be use don a machine for continuous measurements. A newly developed emulsion visualization apparatus (2) has proved uneven film shape, existence of surface water-droplets and inner water.

In this study, we have also made an emulsion evaluation tester on an experimental basis for mixing ink/water on a plate surface. Emulsifying characteristics such as the rate of emulsification, equilibrium water content, and the distribution of W/O emulsion droplets as well as ink/water replacing velocity onthe plate have been investigated and the IPA characteristics as a fountain solution have been verified incomparison with demineralized water and additive solution. Also made clear was the role of a fountain solution in offset printing.(3,4) Based on these results, it has become possible to lead to development of substitute additives by establishing the selection criteria for IPA-substitute reagents and narrowing down its type.

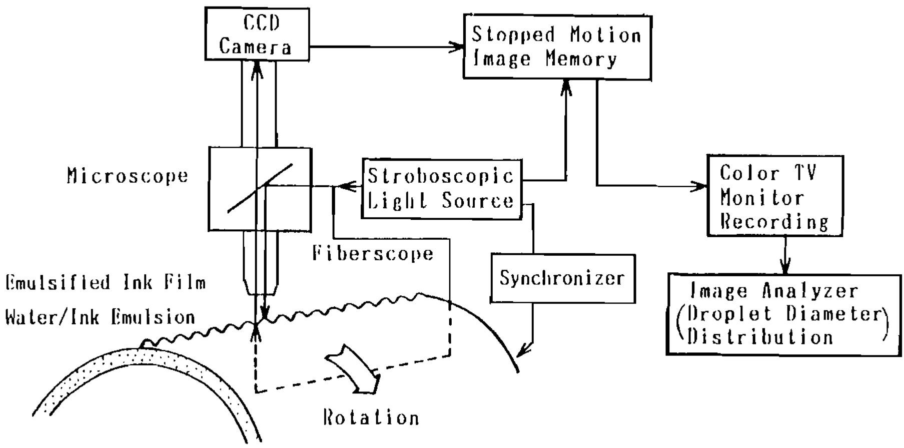

Fig. 1 Schematic diagram of emulsion visualization test apparatus

2. Emulsified ink condition on rollers

An observation method for distribution of water droplets in emulsified ink on roller has recently been developed and an attempt is being conducted to obtain the characteristics of emulsified ink from the distributing condition.(5,6,7) We,Mitsubishi, have also developed an emulsion visualization apparatus for investigation of ink film condition, water mixing behavior and emulsifying condition and studied effects on ink transfer and gloss of emulsified ink.

2.1 Emulsion visualization apparatus

Fig. 1 shows the schematic diagram of the visualization appratus. In combination with a microscope, stroboscopic light source (half breadth 0.5 ～4 μs) CCD camera, image memory and picture processor, permeable and reflected images of ink films on the roller surface under rotation (roller speed ≒ 3m/s) were observed and analyzed. The resolution is 0.2 μm.

2.2 Observation result of emulsified ink films

The generative form of emulsified ink by means of dampening water on the roller was observed with a transparent roller of acrylic resin (Fig.2). Raw ink films are not uniform and they present irregular surfaces (melon pattern) having

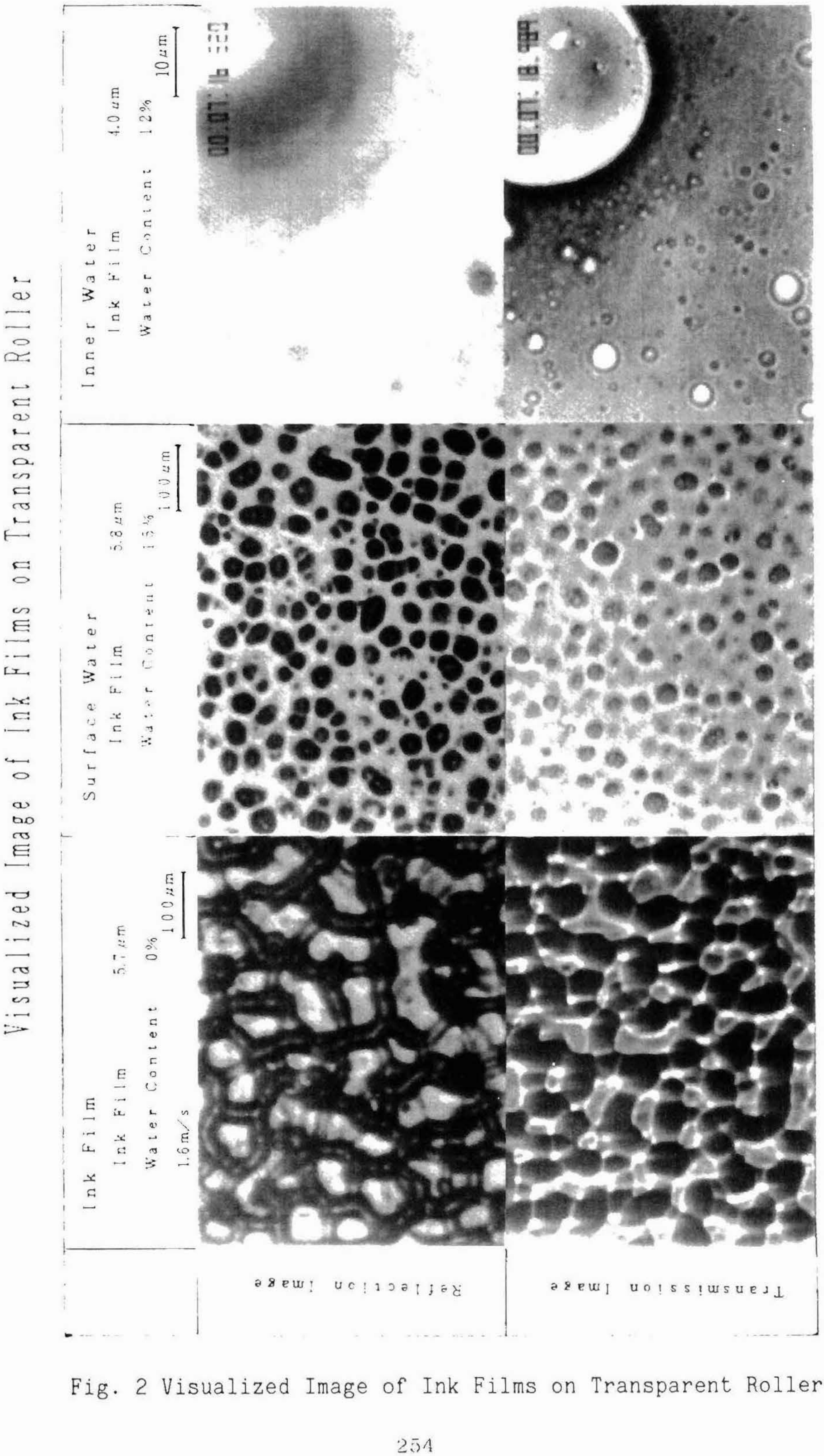

Fig. 2 Visualized Image of Ink Films on Transparent Roller

network structure like the pericarp of a melon. This configuration is resulted from the filamention of ink at an nip exit between rollers. As emulsification progresses by mixing with water, the network pattern is sphitted to fine pieces. When water droplets begin to appear on the surface, the network structure disappears. When the emulsifying limit is reached,ink surface is covered with droplets alone. From the fact that these droplets are quickly evaporated and that fine droplets existin the ink films, they are verified to be surface waterdroplets. The cross-section of ink films of different emulsification degree is assumed as in Fig. 2 by comparison of a permeable image with a reflected image. The network pitch P of melon pattern is represented in the following equation by dimensional analysis:

$$\frac{P}{t} = A\left[\frac{t}{R}\right]^{\chi}\left[\frac{tv\rho}{\mu}\right]^{y}\left[\frac{tv^2\rho}{\gamma}\right]^{z} \cdots\cdots\cdots\cdots (1)$$

Where, t, A, R, v, μ , ρ and γ represent film thickness, constant, roller diameter, peripheral speed, viscosity, density and surface tension respectively. The third term of right-side shows Reynold's number, and the fourth term shows Weber's number. Coefficients χ , y and z become χ ,z > 0, y < 0, and the network pitch decreases with the lowering of viscosity and decrease of speed and film thickness. The unevenness of ink films on the plate surface of a machine is very fine.

With the progress of emulsification, surface water droplets exist at the network pitch, when the water content isindependent of ink film thickness, but varies according to the type of ink. Offset ink is liable to cause surface water droplets. This is considered to be caused by small compatibility of resin in the ink with water. The tack of sheet ink suddenly decreases as surface water droplets appear.It is also considered that from the generative form of surface water droplets, emulsified water has a part in separation of emulsified ink films.

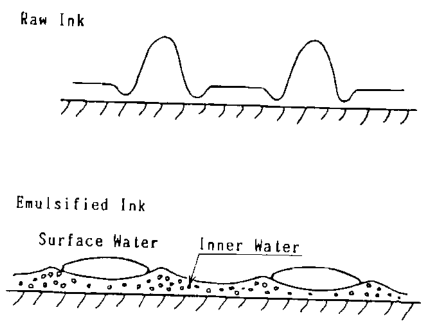

Fig.3 Cross-section of ink films (Assumed picture)

The droplet-size distribution of surface water observed by the emulsion visualization apparatus was obtained by means of image analysis and part of the result is shown in Fig. 8. When surface water begins to appear, the droplet size start sfrom 0.3~100μm. As for maximum emulsification rate, sheet ink has the widest distribution. When ion-exchanged water is used as dampening water, the droplet size increases.

Inner water can be distinguished by comparison of a permeableimage wiht a reflected one. The droplet diameter ranges from 0.3 μm to slveral micrmeters according to the film thicness. When inner water is saturated, excess water forms as surface water. The amount of inner water also depends on ink species and water species.

3. Evaluation of emulsifying characteristics

3.1 Emulsion evaluation tester

The emulsion evaluation tester fabricated for study of emulsifying behavior by mixing ink/water on the plate consists of a plate cylinder, dampening unit, ink mixing rollers anda transparent roller. This is a testing device for emulsion visualization on the roller although no printingis made. The ink film thickness and water content in emulsified ink by uptake of water were measured by the film thickness and water content measurement instrument installed on the oscillating roller (copper roller). The distribution of water droplets in emulsified ink was measured on the plate and the transparent roller above the ink form roller bymeans of the emulsion visualization appara tus. The feeding methods of fountain solution are a plate dampening method (AD method) to feed water on the plate by the dampening system and an emulsion feeding method (Diamatic G type dampening method) to feed water to the inking system, namely to the nip between the ink form roller and the copper roller.

3.2 Emulsion evaluation method on the roller

The rate of emulsification of thin film ink, equilibrium water content (emulsifying limit) and distribution of water droplets in W/O emulsion type emulsified ink can be investigated as follows:

3.2.1 The rate of emulsification

Water is supplied at a given velocity to the ink film adjustedby the inking system on the copper roller for