THE EFFECT OF UV FLEXO INK VISCOSITY, ANILOX CELL VOLUME, AND PRESS SPEED ON PRINT DENSITY AND DOT GAIN

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Key Words: UV, Ink, Viscosity, Flexo, Press

Abstract

Tests were conducted with a 10 inch Comco Captain press on a polyester substrate to determine the effect of UV ink viscosity, anilox cell volume and line count, and press speed, on print density and dot gain. Ink viscosity varied from 600 to 4,800 cps., press speed varied from 100 to 300 fpm, and cell volume from 1.5 to 8.0 BCM at 250, 400, and 700 lpi. Ink pigment concentration was constant, so that it was possible to make comparisons solely on the basis of ink viscosity.

In general, print density decreased with increased ink viscosity, particularly for viscosities greater than 2,000 cps. A significant decrease in print density occurred when press speed was increased from 100 to 300 fpm. The decrease in density with speed was less for the 700 line anilox than the 400 or 250 line anilox rolls. Without exception, dot gain decreased as cell volume increased. Also, for a 70 percent screen, dot gain decreased as ink viscosity was increased from 600 to 2,000 cps. For the same cell volume, dot gain was less for the 700 line anilox than the 400 line anilox roll.

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INTRODUCTION

Inks that dry (polymerize) by the action of photoinitiators and ultraviolet (UV) energy on reactive resins were developed more than twenty years ago. The initial attraction was the almost instantaneous drying of the inks when subjected to UV radiation and the fact that the inks did not dry on the press in the absence of radiation. This made it possible to leave an ink on the press overnight without having to clean rollers, plates, etc. In spite of these advantages, UV curable inks did not start to flourish until six years ago (1990) when the Clean Air Act amendments mandated strict limits on volatile organic compound (VOC) emissions from printing presses. Ultra violet inks contain no VOC's which makes them acceptable for the most stringent air quality regulations.

UV flexo inks are being used widely today for narrow web applications such as the printing of labels. The advantages cited are:

- No VOC's
- Improved Print Quality
- Improved Color Consistency
- Operator Friendly
- Better Adhesion
- Improved Rub and Chemical Resistance
- Less Clean-Up
- Less Waste

Although UV flexo inks are now widely used for narrow web printing, wide-web applications are in their infancy. One wide-web press is in operation today in the U.S. There is optimism that with continued development, wide-web applications will also grow.

Much has been published on the general characteristics of UV flexo printing. However, there is a lack of published information on actual UV flexo ink performance on press. Perhaps that is due to proprietary considerations for this relatively new technology. The FFTA (Foundation of (Flexographic Technical Association) conducted a comprehensive series of press tests which examined a large number of variables. This work was never published. Rather, the FFTA reported their results in a series of seminars that were given around the country.

Nataraj (1) reported the effect of ink viscosity and other variables on print density, and other print quality features. However, the pigment concentration of the three inks was not known, casting doubt on print density comparisons made on the basis of ink viscosity.

In this study, great care was taken to maintain the same pigment concentration for each of the five ink viscosities tested. This permitted comparisons to be made solely on the basis of viscosity.

EXPERIMENTAL

Ink. The five ink viscosities tested covered a range of 590 to 4,790 centipoise as measured with a Haake VT 500 viscometer at a shear rate of 897 sec^{-1}. The composition of the inks is shown in Table 1. For each ink, the phthalocyanine blue pigment base was maintained constant at 34.0 percent.

TABLE I

Composition and Viscosity of Test Inks

	(1)	(2)	(3)	(4)	(5)
Phthalo Blue Base	34.0	34.0	34.0	34.0	34.0
Ebecryl 450	-	-	20.0	25.0	45.0
Ebecryl 81	25.0	46.5	35.0	40.0	15.0
OTA -480	35.0	15.0	5.0	-	-
Igacure 369	4.0	4.0	4.0	4.0	4.0
ITX	1.0	1.0	1.0	1.0	1.0
Inhibitor	0.5	0.5	0.5	0.5	0.5
Haake vis., cps	590	982	2,148	2,951	4,790

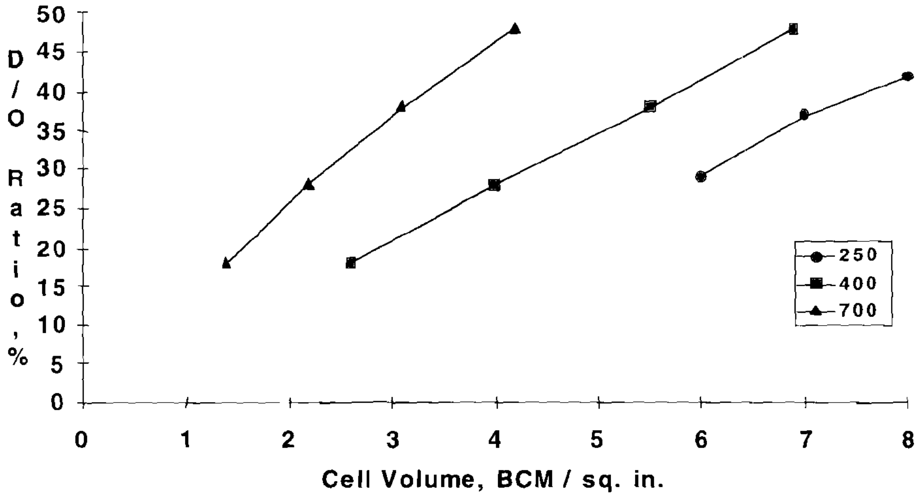
Press. A Comco Captain 10 inch web, 6 color in-line press capable of speeds up to 300 feet per minute was used. The second station was used for all tests, which eliminated station to station variables. An Epic photopolymer printing plate, 0.067 inches thick was used. The plate was mounted on a 3M 1115 (cushion back) stickyback. An ultraviolet lamp made by Fusion Systems having an energy output of 300 watts per inch was the UV energy source. A hardened steel reverse angle doctor blade was used.

Anilox rolls. The bcm and depth to opening ratio values of the three anilox rolls used in this study are shown in Figure 1. A bcm range of 1.5 to 8.0 and a d/o ratio of 18 to 48 percent are covered with the three rolls. Figure 1 shows graphically that as cell volume (bcm) increase, d/o ratio increases. The increase in d/o ratio with cell volume is counter-productive in that increased d/o ratio inhibits the flow of ink from the cell onto the substrate.

Substrate. The substrate used was Flexmark PM200W TC-249 made by the Flexcon Company. It is a 2 mil opaque white polyester film backed with adhesive on 3 mil release paper.

Figure 1

Anilox Cell Volumes, D/O Ratios



Test Image. The test image contained line counts of 85, 110. 133, and 150 lines per inch, with dot coverage of 1 to 100 percent. The same test pattern was repeated for the four bcm's for each anilox roll, permitting a direct comparison between bcm's. The test specimen also contained printed matter at small (4 point) to large (10 point) type.

Procedure. The press was brought to speed (100, 200 or 300 fpm), and signatures were flagged after one minute and two minutes of running time. The inks were tested in the order of increasing viscosity. Temperature of the ink in the fountain was measured periodically. It did not vary more than two degrees from 72° F throughout the run. The press was equipped with a corona surface treater which was used for the first few test runs, but was discontinued because of operational difficulties. There was no visible difference in the quality of print with and without surface treatment. The appearance of dust and lint was considered excessive in either case.

Measurement. All measurements were made with one densitometer (X-Rite 428) and by one operator. Each sample taken for measurement contained about 100 signatures. Measurements were made and recorded for seven consecutive signatures. The average, maximum, minimum, and standard deviation values were recorded.

All measurements were made with the 133 lpi screen. Density, 2% dot gain and 70 percent dot gain were recorded. A comparison of data taken for 1.5 and 3 minutes running times showed no significant difference, as shown in Table 2. Consequently, all data for subsequent test runs were taken at 2 minutes running time.

Table 2
Density and Dot Gain at 1.5 and 3.0 Minutes Run Time

Test No.	Time (Min)	Solid Dens.	70% D.G	2% D.G	BCM
1 *	1.5	1.81	24.0	21.6	5.5
1	3.0	1.84	24.0	21.6	5.5
5 * *	1.5	1.67	23.1	18.1	5.5
5	3.0	1.71	23.3	17.2	5.5

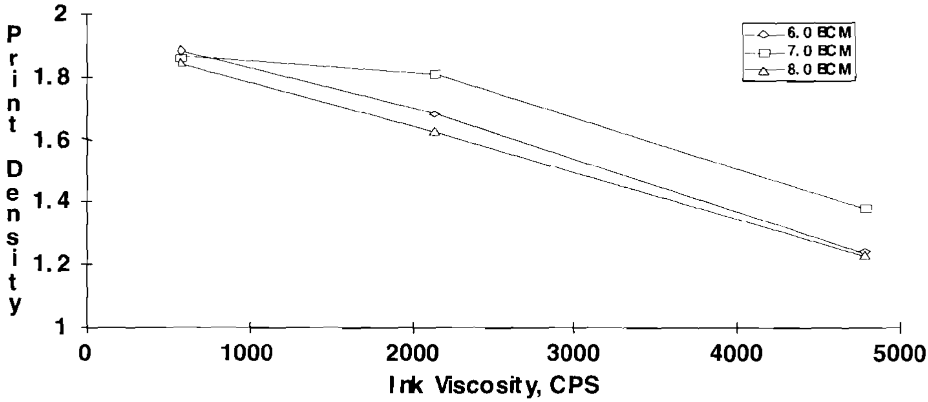
*590 cps; **2,148 cps

RESULTS

Density. The effect of ink viscosity on solid print density is shown in Figures 2 - 5 for the three anilox rolls. The press speed was constant at 100 fpm. Figure 2, the 250 line anilox, shows a slight decrease in density when viscosity was increased from 590 cps to 2,148 cps, and a decrease when viscosity is increased further to 4,790 cps. The 7.0 bcm cell volume had the highest density, with no significant difference between the 6.0 and 8.0 bcm cell volumes. In Figure 3, the same pattern is shown for the 400 line anilox, i.e. a decrease in print density with ink viscosity, particularly for viscosities greater than 2,148 cps. Densities for the four cell volumes are as expected, with no significant difference between the 5.5 and 6.9 bcm cell volumes.

Figure 2

Effect of Viscosity on Solid Print De
(100 FPM - 250 Line Anilox)



The density curves for the 700 line anilox show a much lower decrease with viscosity, with again a greater decrease occurring for viscosities in excess of 2,148 cps.

Figure 3

Effect of Viscosity on Solid Print Density
(100 FPM - 400 Line Anilox)

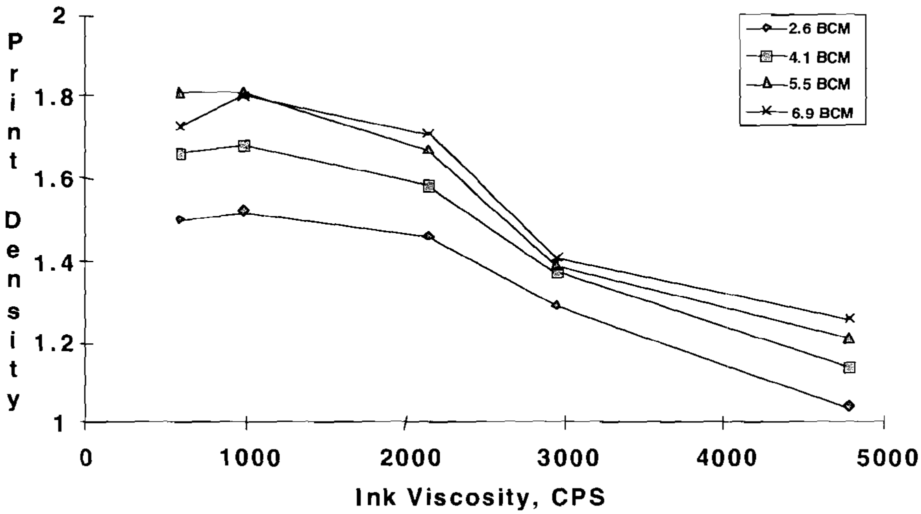


Figure 4

Effect of Viscosity on Solid Print Density
(100 FPM - 700 Line Anilox)

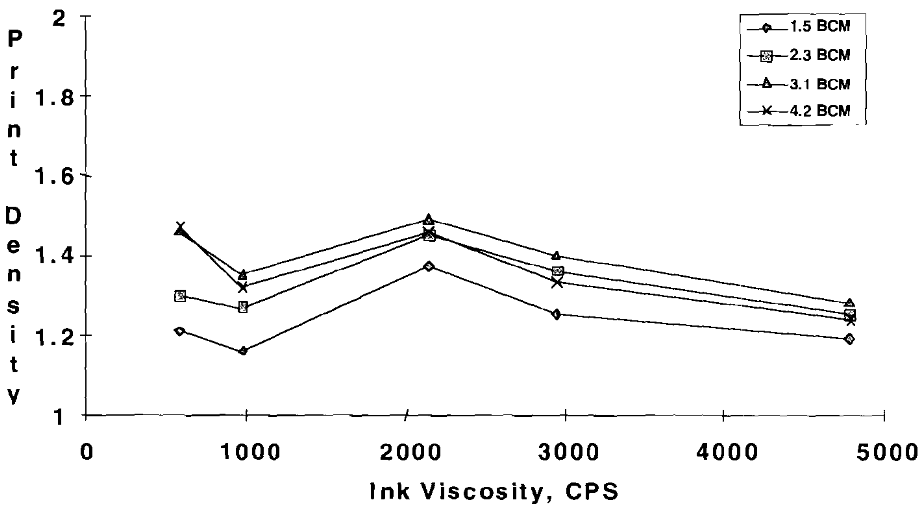


Figure 5

Effect of Viscosity on Print Density
(250, 400, & 700 Anilox Rolls)

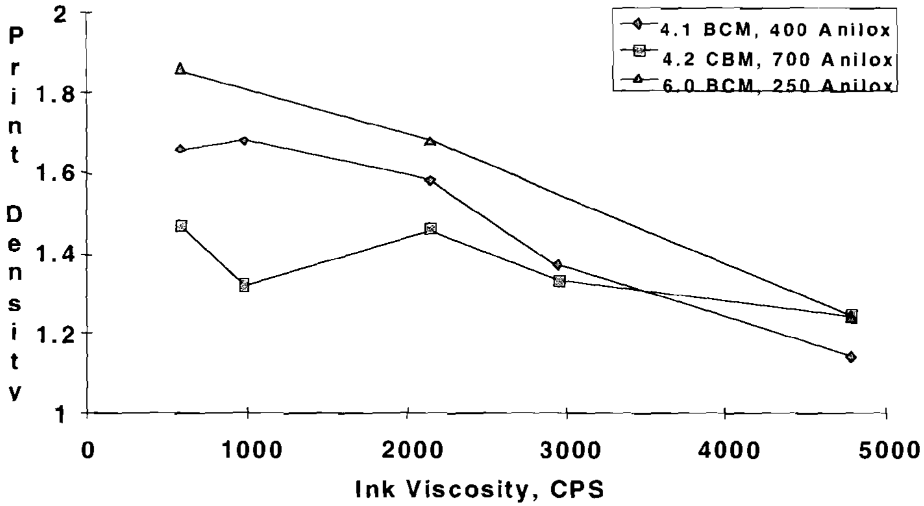
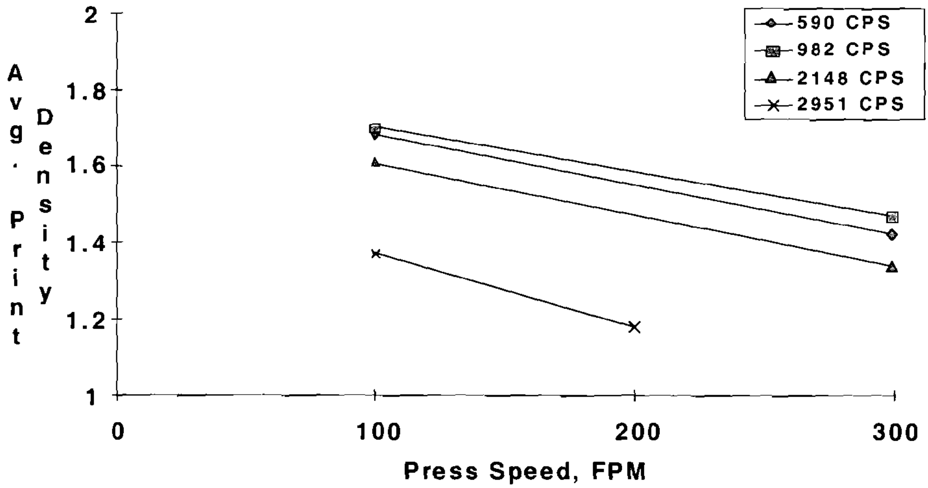


Figure 5 is a comparison of the three anilox rolls at approximately the same bcm values. Note that the bcm's for the 700 and 400 line anilox are 4.2 and 4.1, respectively, and the bcm for the 250 line anilox is 6.0, the lowest for that roll. For the 700 and 400 line anilox rolls, density is higher for the 400 anilox up to an ink viscosity of 2,148 cps. Densities are about the same for the 2,951 cps ink, and slightly higher with the 700 line anilox for the 4,790 cps. viscosity ink.

Figure 6

Effect of Speed and Viscosity on Print Density
(400 Line Anilox)



The effect of press speed on print density as a function of ink viscosity is shown in Figures 6 - 9. In all cases, density decreased with speed. These data are somewhat limited in that it was not possible to run the 2,951 cps ink faster than 200 feet per minute (fpm), without excessive ink slinging on the press. The 4,790 cps ink was limited to 100 fpm because of ink slinging. Nevertheless, there are sufficient data to show a significant decrease in density with speed which is more pronounced as ink viscosity increased.

Figure 7

Effect of Speed and Viscosity on Print Density
(700 Line Anilox)

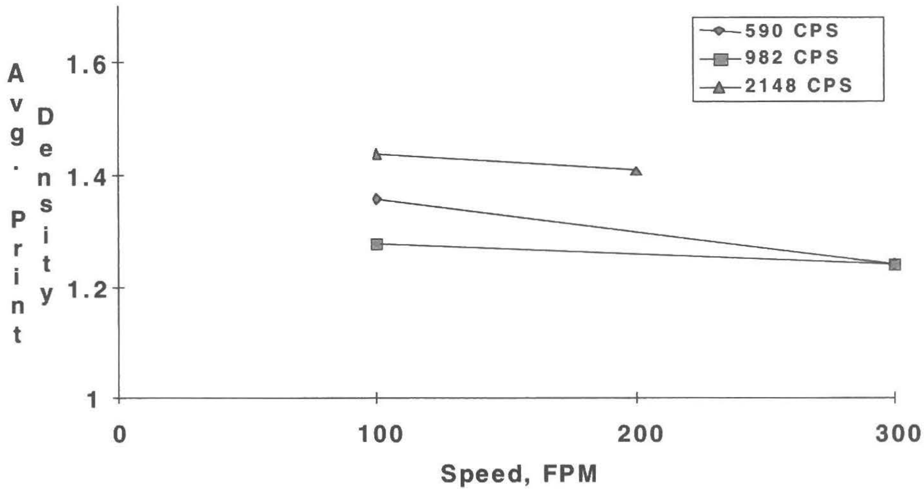
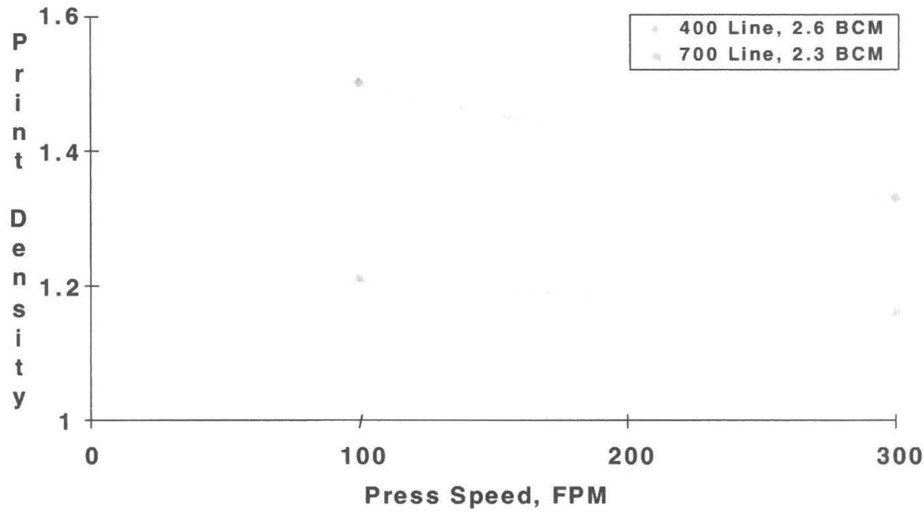


Figure 8

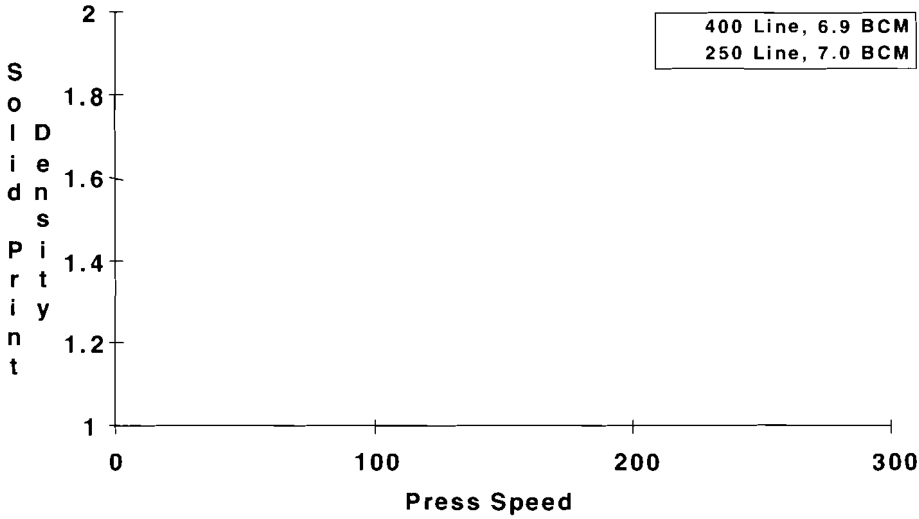
Effect of Press Speed on Density
400 & 700 Line Anilox Rolls
(590 CPS Ink)



Anilox line count also has an affect on density as speed increases. In Figure 8, the decrease in density with speed is not as great for the 700 line anilox than the 400 anilox at about the same cell volume. However, note that the overall density with the 700 line anilox is significantly lower. The same comparison is made in Figure 9 for the 250 and 400 line anilox rolls. Here again, the decrease in density with speed is not as great for the finer line (400 lpi) anilox, but the overall density is lower.

Figure 9

Effect of Press Speed on Density
400 & 250 Anilox Rolls
(590 CPS Ink)



<u>Dot Gain</u>. Dot gain data are presented in Figures 10-15. Figure 10 shows an increase in dot gain of about 1 percent for the 250 line anilox, 70 percent screen when viscosity is increased. Figure 11 shows a dip (decrease) in the dot gain curve at a viscosity of 2,148 cps for the 400 anilox which increases as ink viscosity is increased. Dot gain overall is lower for the higher cell volumes.

Dot gain data for the 700 line anilox roll (Figure 12) show no change with increase viscosity. However, dot gain decreased significantly as cell volume increased.

Dot gain for the 2 percent screen with the 250 line anilox (Figure 13) shows an increase with an ink viscosity of 2, 148 cps, which decreased as viscosity increased to 2,950 cps. Note the sharp decrease in dot gain as cell volume was increased from 6.0 to 8.0 bcm.

For the 400 line anilox, (Figure 14), dot gain decreased significantly when ink viscosity was increased from 590 to 980 cps. Dot gain continued to decrease as ink viscosity increased to 4,790 cps.

Figure 10

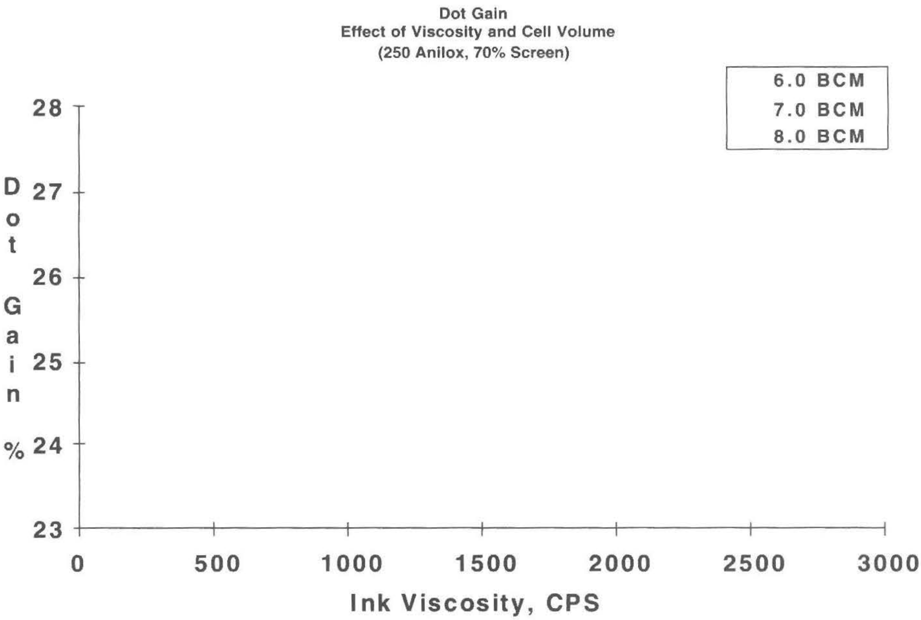
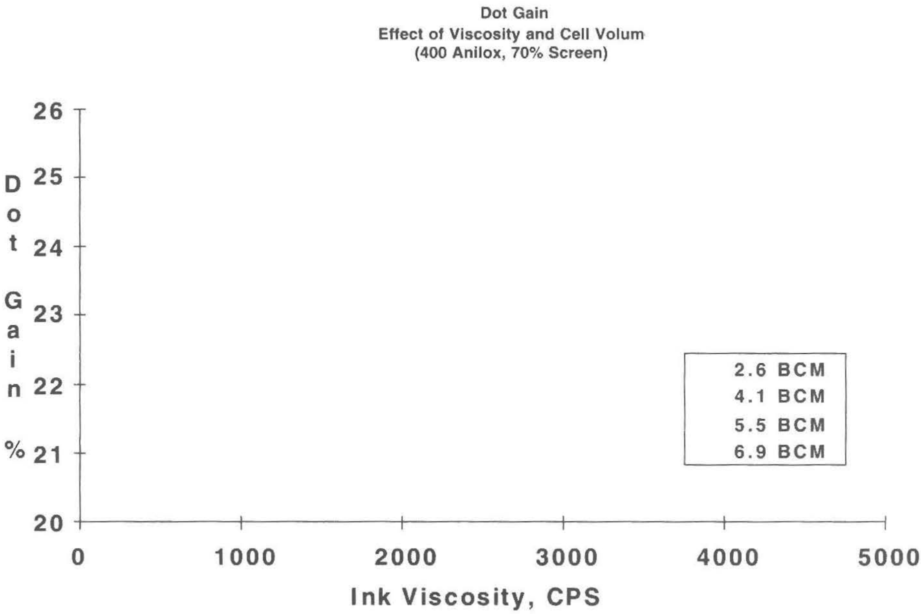


Figure 11



For the 700 line anilox (Figure 15), dot gain was relatively unaffected as ink viscosity increased for 1.5, 2.3, and 3.1 bcm cell volumes. In contrast there was a dramatic decrease in dot gain as cell volume was increased to 4.2 bcm. Dot gain also decreased with ink viscosity for the 4.2 bcm cell volume.

Figure 12

Dot Gain
Effect of Viscosity and Cell Volume
(700 Anilox, 70% Screen)

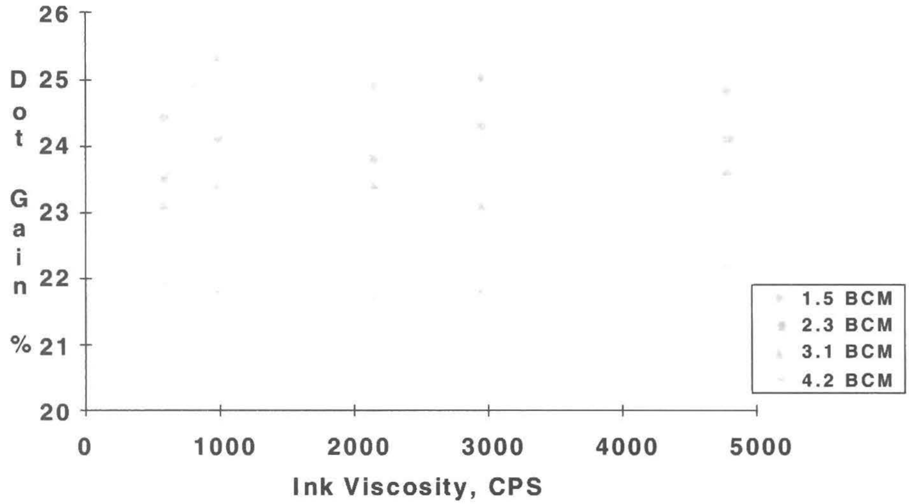


Figure 13

Dot Gain
Effect of Viscosity and Cell Volum
(250 Anilox, 2% Screen)

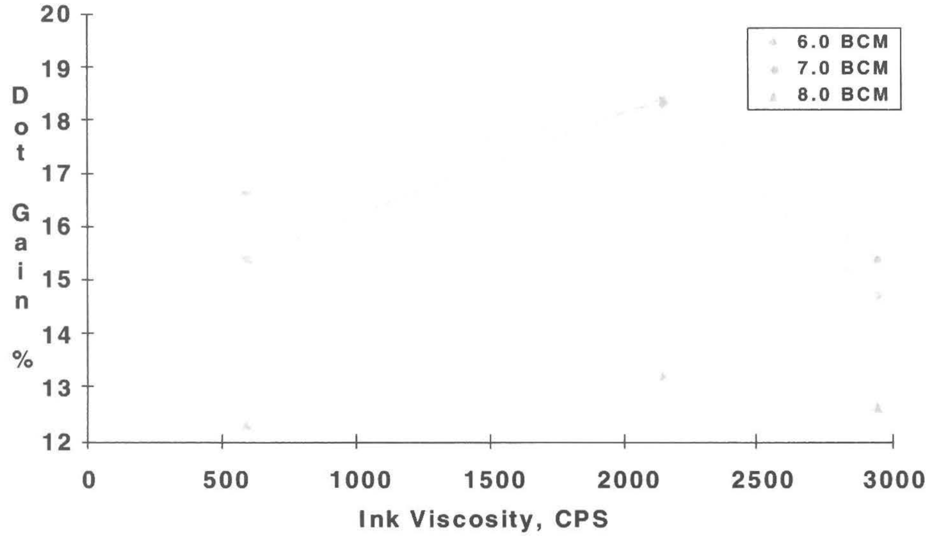


Figure 14

Dot Gain
Effect of Viscosity and Cell Volume
(400 Anilox, 2% Screen)

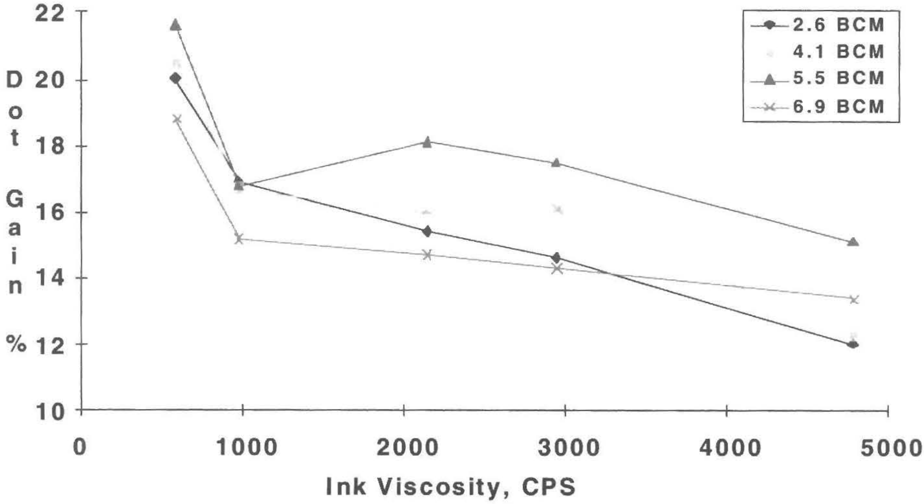
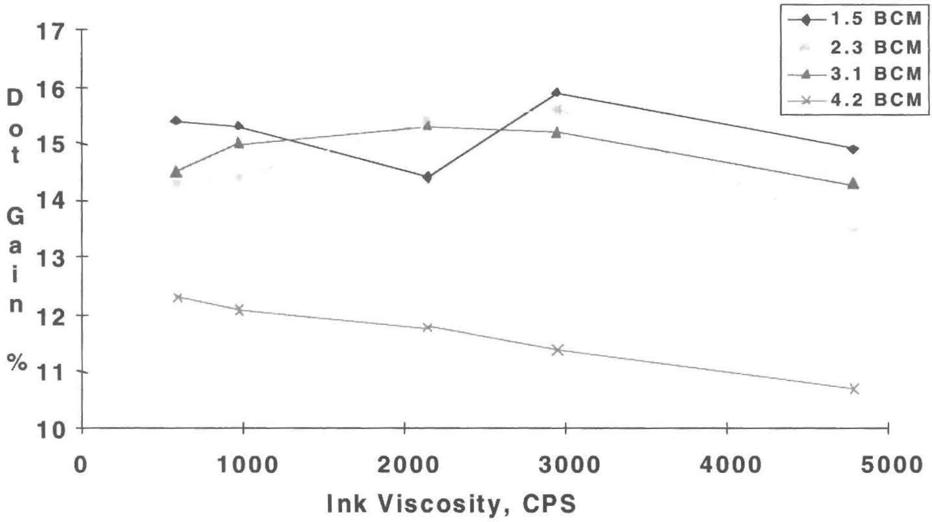


Figure 15

Dot Gain
Effect of Viscosity and Cell Volume
(700 Anilox, 2% Screen)



Press Speed. The effect of press speed on 70 percent dot gain is shown in Table 3.

Table 3
Effect of Press Speed on 70% Dot Gain
(590 cps Ink)

Anilox lpi	BCM	Speed, FPM	Dot Gain %
250	6.0	100	26.1
250	6.0	300	27.5
400	4.0	100	25.3
400	4.0	300	24.8
700	4.2	100	21.1
700	4.2	300	21.1

For the conditions studied, press speed had a negligible effect on dot gain.

DISCUSSION OF RESULTS

Density. Solid print density decreased with increased ink viscosity for each anilox roll that was more pronounced for viscosities greater than 2,148 cps. For a given viscosity, print density decreased with increased anilox line count. However, the rate of decrease in density was less with increased ink viscosity as anilox line count increased. It has been postulated that the high line count (700) anilox may be acting as a roll-coater with the high viscosity inks.

Without exception, density decreased with increased press speed for each ink viscosity and for each anilox. The decrease was most pronounced with the 250 anilox and least with the 700 anilox. Although centrifugal force (which would increase the expulsion of the ink from the anilox cells) is greater at the higher press speeds, residence time between the anilox and substrate is decreased. Residence time is evidently more important than centrifugal force in the transfer of ink from anilox cells.

Dot Gain. It was not possible to generalize on the effect that ink viscosity and anilox cell line count had on dot gain. Test results were not consistent. For the 250 anilox roll, 70 percent dot gain increased with increased ink viscosity, but decreased with increased cell volume (Figure 10). The 400 line anilox showed anomalous behavior (Figure 11) in that 70 percent dot gain decreased as ink viscosity increased to 2,148 cps, but then increased as viscosity was increased to 4,790 cps. This behavior is unexplained at this time but is considered to be valid (see discussion on normal variation). For the 700 line screen, there was no change in dot gain as ink viscosity was increased from 590 to 4,790 cps. However, for a given viscosity, dot gain increased markedly as cell volume was increased from 1.5 to 4.2 bcm.

Two percent dot gain results were erratic. This was due in part to the variability of the data as evidenced by the high standard deviation for seven measurements (Appendix Table 1). Significance notwithstanding, the one constant which agrees with 70 percent dot gain results is that 2 percent dot gain decreased with increased cell volume for each anilox. The increase in dot gain for the 250 line anilox (Figure 13) with the intermediate viscosity (2,148 cps) and the subsequent decrease at 2,950 cps is unexplained.

For the 400 line anilox, 2 percent dot gain (Figure 14) behaved differently than 70 percent dot gain (Figure 11). For the 2 percent screen, there was a significant decrease when ink viscosity was increased to 986 cps, which gradually decreased as viscosity was increased further.

Dot gain for the 2 percent screen with the 700 line anilox (Figure 15) was similar to 70 percent screen results (Figure 12) in that dot gain was unaffected by ink viscosity. However, there was one exception with the 2 percent screen for the 4.2 bcm cell volume which was significantly lower, and decreased with increased viscosity.

Variance. As mentioned previously in Experimental Procedure, density and dot gain measurements were made and recorded for seven consecutive signatures, with the average and standard deviation also reported. Representative average and standard deviation values for solid print density, 70 percent dot gain and 2 percent dot gain are shown in Appendix Table 1. Solid print density had standard deviations that ranged from 0.01 to 0.1 for density values that ranged from 1.19 to 1.86. In making comparisons, significant differences can be determined by adding or subtracting standard deviations from the values being compared. For example, in comparing the density for Test 17 with the 250 line anilox at 6.0 bcm (590 cps ink) with the density for Test 19 (same anilox same cell volume, but 2,148 cps ink) the average densities are 1.86 and 1.68, respectively. Subtracting the standard deviation (SD) of 0.04 from 1.86, and adding the SD to the 1.68 value yields denisties of 1.82 and 1.72, respectively, a significant difference.

The same analysis can be used to make comparisons for 70 percent and 2 percent dot gain values. However, it is readily apparent that there was considerably more variation for 2 percent dot gain where standard deviations varied from 0 to 35 percent of the dot gain value.

CONCLUSIONS

1. Solid print density increased with decreased ink viscosity and decreased press speed.

2. Solid print density increased with decreased anilox roll line count.

3. Solid print density increased with increased anilox cell volume.

4. Dot gain decreased with increased anilox line count and cell volume.

5. When ink viscosity was decreased, 70 percent dot gain decreased with the 250 line anilox, was variable with the 400 line anilox, and was unchanged with the 700 line anilox.

6. When ink viscosity was decreased, 2 percent dot gain was variable with the 250 line anilox, decreased with the 400 line anilox, and was unchanged with the 700 line anilox.

7. Press speed had a negligible effect on dot gain.

ACKNOWLEDGEMENT

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Literature Cited

(1) Nataraj, Chiranth, and Crouch, Page. 1995
"Optimize UV Flexo Inks", Flexo, August, pp. 82-90

APPENDIX TABLE 1
DENSITY, DOT GAIN, AND STANDARD DEVIATION
(ALL DATA AT 100 FPM PRESS SPEED)

Dot Gain/Std. Dev.

Test No.	Viscosity	BCM	Ds/Std Dv	70%	2%
250 Anilox					
17	590	6.0	1.86/0.04	26.1/0.3	16.6/5.8
17	590	8.0	1.84/0.04	24.0/0.5	12.3/1.1
19	2148	6.0	1.68/0.04	26.6/0.3	18.3/1.0
19	2148	8.0	1.81/0.04	24.7/0.7	13.2/0
20	4790	6.0	1.24/0.02	27.1/0.5	14.7/2.4
20	4790	8.0	1.38/0.04	25.2/0.5	12.6/2.0
400 Anilox					
1	590	2.6	1.5/0.02	25.4/0.3	20.0/2.1
1	590	6.9	1.73/0.09	23.6/0.8	18.8/1.3
3	982	2.6	1.52/0.03	24.4/0.6	16.9/1.5
3	982	6.9	1.80/0.1	23.9/0.6	15.2/1.1
5	2148	2.6	1.46/0.04	23.4/0.4	1.46/0.04
5	2148	6.9	1.71/0.06	22.6/0.7	1.71/0.06
7	2951	2.6	1.29/0.03	24.3/0.7	14.6/1.0
7	2951	6.9	1.41/0.04	23.4/0.9	14.3/1.5
8	4790	2.6	1.04/0.02	25.2/1.0	12.0/1.1
8	4790	6.9	1.26/0.02	24.1/0.4	13.4/1.0
700 Anilox					
9	590	1.5	1.21/0.01	24.4/0.6	15.4/2.0
9	590	3.9	1.47/0.03	21.9/0.7	12.3/1.0
13	2148	1.5	1.37/0.02	24.9/0.4	14.4/1.1
13	2148	3.9	1.46/0.02	21.7/0.6	11.8/0.8
15	2951	1.5	1.25/0.02	25.0/0.3	15.9/1.4
15	2951	3.9	1.33/0.01	21.8/0.7	11.4/2.3
16	4790	1.5	1.19/0.02	24.8/0.8	14.9/1.6
16	4790	3.9	1.24/0.03	22.7/0.9	10.7/1.2