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Densitometrically measured effective dot area as a function of ink hue

Jeffrey Latzko

DENSITOMETRICALLY MEASURED EFFECTIVE DOT AREA AS A FUNCTION OF INK HUE

by

Jeffrey E. Latzko

A thesis submitted in partial fulfillment of the requirements for the degree of Bachelor of Science in the School of Photographic Arts and Sciences in the College of Graphic Arts and Photography of the Rochester Institute of Technology

April, 1982

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Accepted by ______________________
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ABSTRACT

Percentage dot gain on coated and uncoated papers has been determined to be different depending on the ink hue used for 150 line screens. Cyan, magenta, yellow, and black inks all showed different amounts of dot gain from the printing plate to the paper. Effective dot area on the paper versus dot area on the printing plate data are presented.

ACKNOWLEDGEMENTS

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A thank you is due to the Graphic Arts Research Center and its staff for their donation of press sheets used in this thesis and for their time and help. An individual vote of thanks goes to Mr. Dick McAllen, Mr. Irving Pobboravsky, and Mr. Milton Pearson whom each made contributions to this study.

Thanks is due to the CIA for their support. Their donation helped to the completion of this work.

A final thanks is due to the author's parents, Mr. & Mrs. Walter O. Latzko, whom provided support in all ways. They were always an inspiration when morale was lacking.

DEDICATION

This thesis is dedicated to

the whole Latzko family

who provided support and inspiration

not only during this thesis,

but throughout my whole scholastic career.

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INTRODUCTION

Effective dot area, or relative tone value, in the printing industry has been of question in recent years. Most questions arise from the way dot area is calculated using "large area" density measurements and what variables affect dot area calculations. It has been determined that tone reproduction depends on many parameters such as screen frequency, ink film thickness, and light scattering in paper.[1] To understand what affects tone value, one must understand what tone value is.

Tone value is a certain step of the light-dark scale and is measured by a percentage scale from 0% to 100%.[2] In halftone printing, 0% is paper white and 100% tone value is solid ink density.[2] For all steps between 0% and 100%, tone value is a percentage of the light absorbed relative to the quantity of light absorbed by the solids.[2] A problem that occurs in the halftone process from the halftone film to the printing plate and finally to the paper is dot gain or the increase in tone value from what is expected from the actual percent dot area on the film. For example, when a dot percentage of 50% at a point on the halftone positive gives a dot percentage of 65% on the print at the same point, the dot gain or increase in tone value is 15%.

Increase in tone value is partially due to variable ink film thickness.[2] The ink dot undergoes spreading (Fig. 1) from the printing plate to the paper. The rest of the gain is due to a phenomenon called "light capture". "Light capture" (Fig. 2) is a purely optical phenomenon which occurs only in the incident-light observation and "large area" densitometric measurement of halftone dots.[2]

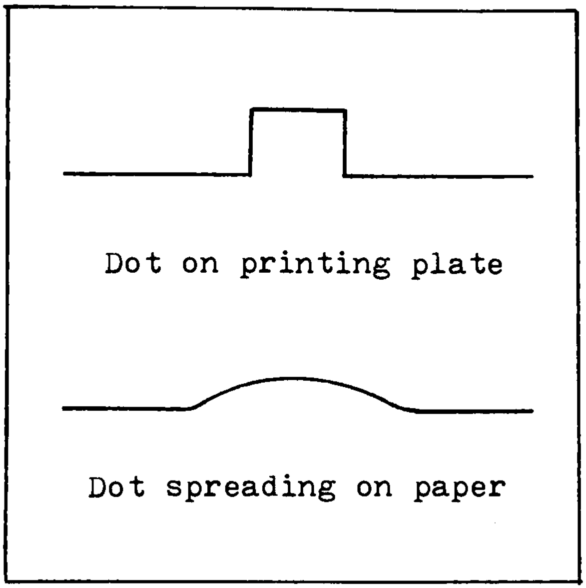


Fig 1. Dot spreading.

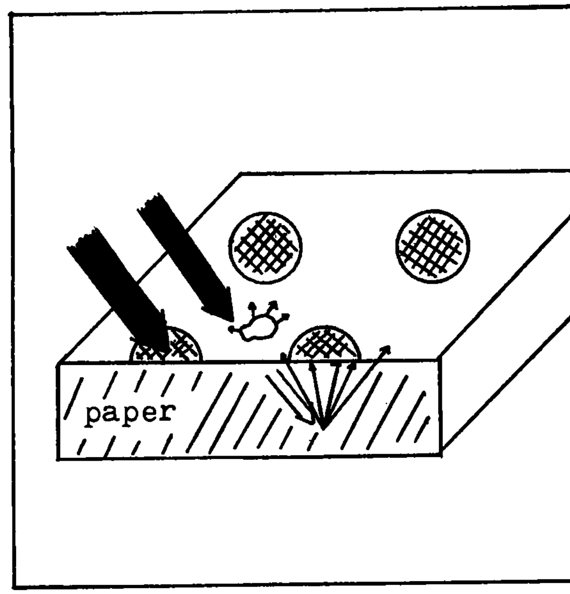


Fig 2. "Light capture".

The idea behind this phenomena is that some incident light hitting the paper between the dots is being trapped underneath the halftone dots. Therefore, less light reflects back making the tone value seem higher.

The method that is used for calculating dot area from "large area" density measurements in this study is the Yule-Nielsen equation[1]:

$$\%\text{Dot area} = \frac{1 - 10^{-D_t/n}}{1 - 10^{-D_s/n}} \times 100$$

where: D_t = Density* of the screened area

D_s = Density* of the solid area

n = constant for the light scattering properties of paper

$*D_{paper} = 0$

Dot area determination by planimetry or some other geometric method of the areas of enlarged dots has been used and discussed in many papers. On transmission density, they work, because the dots are sharp, and this sharpness can be reproduced well on enlargements. But, the methods are inexact on printed sheets because the dots have no sharply defined boundaries and also because of the uneveness of the ink layer on the dots.[5] Because of this, the Yule-Nielsen equation is used instead. There may be problems with this equation though, in that there is no exact standard for the n values used in it.

The interaction between printing inks and coated paper has been studied since 1942.[4] The effect of the paper is not of interest in this study, but measurements on coated and uncoated papers are separated into their respective groups.

To summarize, the objective of this study is to determine if there is a difference in the amount of dot gain between various ink hues. This correlation will inform a printer of the dot gain properties of various inks.

EXPERIMENTAL

A tone scale target of 150 line screen frequency obtained from the Graphic Arts Research Center at the Rochester Institute of Technology was used for all measurements. Block 5 of the Gray Balance Chart is the target that was chosen. It is a target that is produced by the Graphic Arts Research Center (GARC). The targets used were all printed on the MED Commercial 38 web press used by GARC for lithographic plate printing. Eleven targets were obtained on coated paper and five on uncoated paper. This proved sufficient because the measurements were close together and had a small standard deviation. The target itself is a 9-step tone scale with a solid. The only lines of interest were the cyan (C), magenta (M), yellow (Y), and the black (K) tone scales. The tone value numbers that were referred to were those across the top of the target that range from 7% to 84%. Each step of the tone scale was measured for "effective" percent dot area for the ink hues of interest.

The halftone negative for the Gray Balance Chart target was obtained from GARC so the dot areas could be checked to determine how close their correlation is to the dot area values printed on the target. The transmission densities were measured using a Macbeth TR927 densitometer located in GARC. The densities were converted to percent transmission using a conversion chart that was also obtained through GARC. The data for these measurements is located in Appendix I.

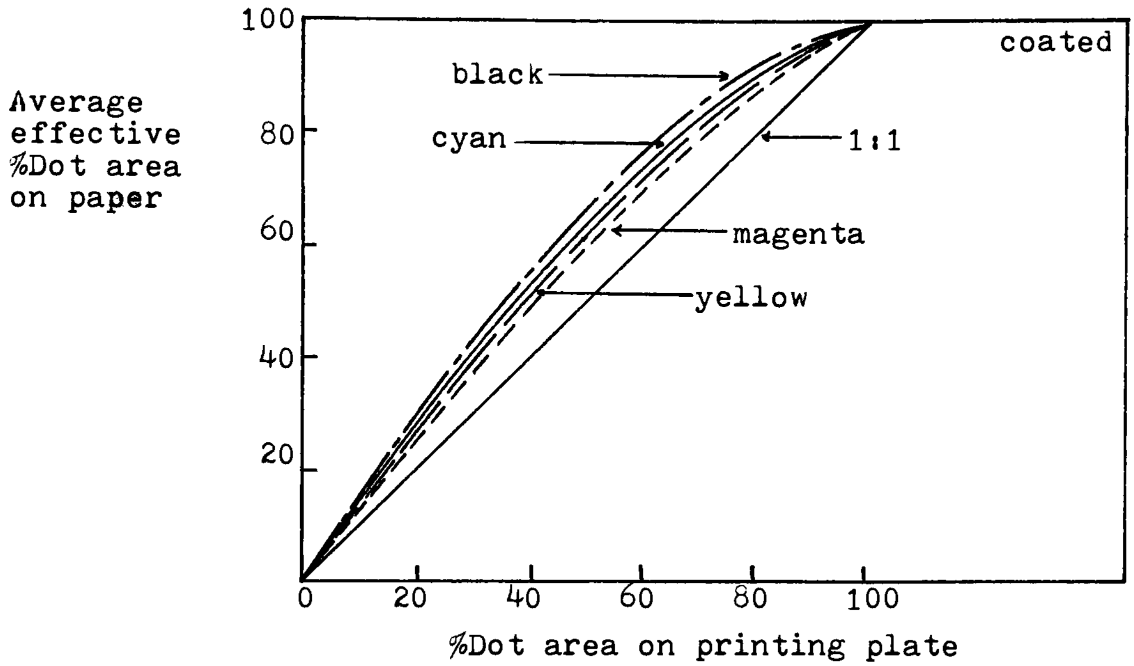
A Macbeth RD-918 reflection densitometer was used to measure all samples. Information and operating instructions for this instrument are located in Appendix II.

Each press sheet obtained that contained the target chosen, had it removed from it and measured for effective percent dot area in cyan, magenta, yellow, and black inks. The data for these measurements are located in Appendix III.

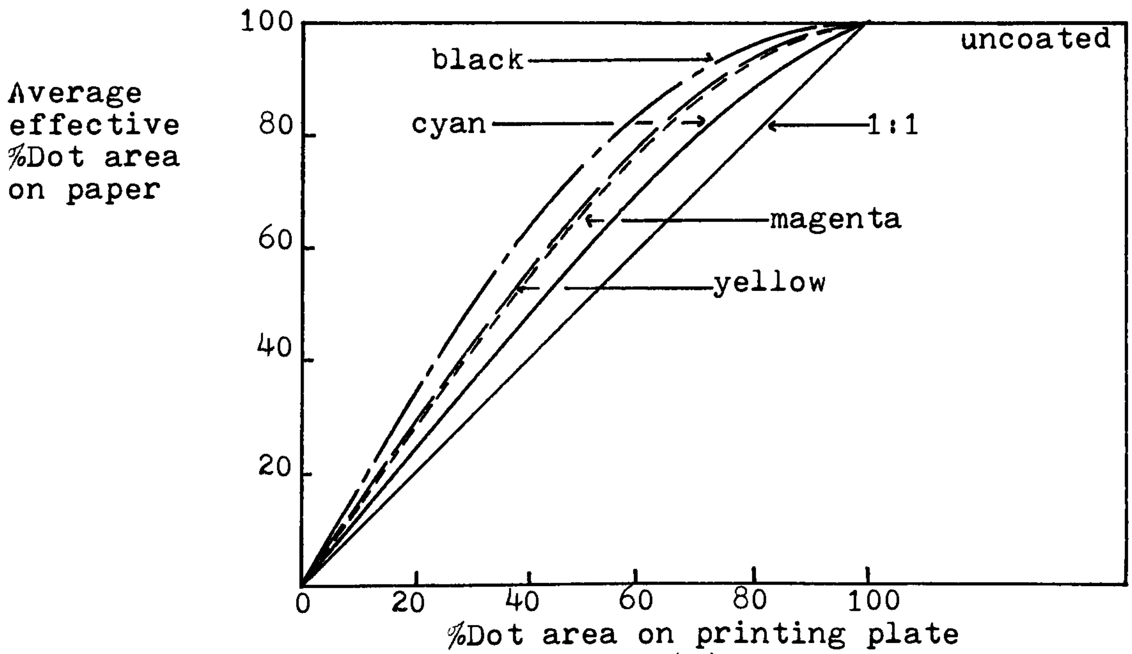
Once the data was documented, plots of average "effective" percent dot area on the paper versus percent dot area on the plate were generated. Two plots were generated; one for coated paper and one for uncoated paper. The plots are presented in the next section. After the plots were generated, the data was examined and a paired comparison statistical analysis was performed to obtain results and conclusions about dot gain between ink hues.

EXPERIMENTAL RESULTS AND DISCUSSION

The plots for cyan, magenta, yellow, and black inks are presented in Figure 3.



(a)



(b)

Figure 3. Average "effective" dot area on paper vs. dot area on printing plate for (a) coated paper and (b) uncoated paper.

By examining the plots in Figure 3, the black ink had the greatest amount of dot gain. The other inks are grouped a little closer together. To get a better correlation, the data which appears in Appendix III was divided into three blocks or regions. The three blocks are labeled highlights, midtones, and shadows. In Table 1, the average dot gain for each ink hue on coated and uncoated papers and in each region is presented.

HIGHLIGHTS (7%-27%)

Coated Paper Ink	Average %Dot Gain	Uncoated Paper Ink	Average %Dot Gain
Black	7.2	Black	13.5
Cyan	7.2	Cyan	3.7
Yellow	5.1	Yellow	9.6
Magenta	5.3	Magenta	7.9

MIDTONES (36%-53%)

Coated Paper Ink	Average %Dot Gain	Uncoated Paper Ink	Average %Dot Gain
Black	15.8	Black	25.5
Cyan	12.5	Cyan	8.3
Yellow	10.1	Yellow	14.0
Magenta	8.3	Magenta	13.3

SHADOWS (62%-84%)

Coated Paper Ink	Average %Dot Gain	Uncoated Paper Ink	Average %Dot Gain
Black	13.7	Black	18.8
Cyan	10.8	Cyan	8.9
Yellow	11.2	Yellow	14.6
Magenta	8.4	Magenta	14.5

Table 1. Average %Dot gains in the highlights, midtones, and shadows for cyan, magenta, yellow, and black inks on coated and uncoated paper.

The results of this table show that cyan, magenta, yellow, and black inks have different amounts of dot gain in the three tone regions. Overall, the largest amount of dot gain is in the midtone region. This spread or increase in tone value is most certainly due to the fact that there is more dot perimeter relative to the paper surrounding them. In the low tone regions, the dots are very small and have minute perimeters. In the high tone regions, dots are large and have already begun to run together as they approach a solid area. They, too, have a small perimeter in relation to the paper the ink surrounds. If the "light capture" theory holds true, the dots with the greatest perimeter will experience the greatest amount of "light capture" as there is more area for the light to be trapped beneath.

To further distinguish which ink hues have greater dot gain, a paired comparison statistical analysis was run. The results of this test are presented in Table 2.

COATED PAPER

HIGHLIGHTS

Comparisons	Greater than	Equal	Less than	S_p	Δx	Test	Conc.
Cyan-Magenta	18	5	10	2.0	1.9	5.8	C=M
Cyan-Yellow	26	0	7	2.2	2.1	5.3	C=Y
Cyan-Black	15	2	16	0.4	0.0	29.2	C=B
Magenta-Yellow	14	5	14	0.4	0.2	29.2	M=Y
Magenta-Black	3	7	23	2.0	1.9	5.8	M=B
Black-Yellow	19	9	5	2.2	2.1	5.3	B=Y

MIDTONES

Comparisons	Greater than	Equal	Less than	S_p	Δx	Test	Conc.
Cyan-Magenta	25	3	5	4.3	4.2	2.7	C>M
Cyan-Yellow	20	3	10	2.5	2.4	4.7	C=Y
Cyan-Black	8	4	21	3.4	3.3	3.4	C=B
Magenta-Yellow	10	1	22	2.1	1.8	5.5	M=Y
Magenta-Black	0	2	31	7.7	7.5	1.5	B>M
Black-Yellow	29	2	2	5.8	5.7	2.0	B>Y

SHADOWS

Comparisons	Greater than	Equal	Less than	S_p	Δx	Test	Conc.
Cyan-Magenta	25	3	5	2.6	2.4	4.5	C=M
Cyan-Yellow	11	3	19	0.7	0.4	16.7	C=Y
Cyan-Black	6	4	23	3.1	2.9	3.7	C=B
Magenta-Yellow	7	1	25	2.9	2.8	4.0	M=Y
Magenta-Black	0	1	32	5.6	5.3	2.1	B>M
Black-Yellow	19	5	9	3.0	2.5	3.9	B=Y

UNCOATED PAPER

HIGHLIGHTS

Comparisons	Greater than	Equal	Less than	S_p	Δx	Test	Conc.
Cyan-Magenta	0	3	12	4.4	4.2	1.9	M>C
Cyan-Yellow	0	0	15	6.0	5.9	1.4	Y>C
Cyan-Black	0	0	15	10.4	9.8	0.8	B>C
Magenta-Yellow	3	1	11	1.8	1.7	4.6	M=Y
Magenta-Black	0	1	14	6.0	5.6	1.4	B>M
Black-Yellow	12	1	2	4.7	3.9	1.8	B>Y

MIDTONES

Comparisons	Greater than	Equal	Less than	S_p	Δx	Test	Conc.
Cyan-Magenta	2	1	12	5.0	5.0	1.7	M>C
Cyan-Yellow	0	2	13	6.1	5.7	1.4	Y>C
Cyan-Black	0	0	15	17.2	17.2	0.5	B>C
Magenta-Yellow	3	1	11	1.8	0.7	4.6	M=Y
Magenta-Black	0	0	15	12.2	12.2	0.7	B>M
Black-Yellow	15	0	0	11.8	11.5	0.7	B>Y

SHADOWS

Comparisons	Greater than	Equal	Less than	S_p	Δx	Test	Conc.
Cyan-Magenta	2	1	12	5.6	5.6	1.5	M>C
Cyan-Yellow	1	1	13	5.8	5.7	1.4	Y>C
Cyan-Black	0	0	15	10.1	9.9	0.8	B>C
Magenta-Yellow	5	3	7	0.9	0.1	9.2	M=Y
Magenta-Black	2	0	13	5.0	4.3	1.7	B>M
Black-Yellow	14	1	0	4.6	4.2	1.8	B>Y

Table 2. Paired comparison statistical analysis results. S_p is pooled standard deviation, Δx is the difference between the average dot gains of the inks compared, and Test is the test statistic. Refer to Appendix IV.

The results of Table 2 clearly show there is a difference in the amounts of dot gain for each ink hue. There are some cases where there wasn't any difference. On coated paper, the inks all experienced the same dot gain in the highlights and in the shadows, except for the black and magenta comparison in the shadow region. There were three comparisons that also proved to be equal in the midtone region for coated paper. Whether there was significance between two inks was determined by testing to see if Δx was greater than the test statistic. If it was, the inks were different and the one with the greater amount of higher tone values was the ink with the greater amount of dot gain. One comparison that was very close was the cyan and black relationship on coated paper. The test statistic exceeded the Δx by only .1, and this is therefore questionable.

Uncoated paper was more obvious as all inks were different in their amount of dot gain. The exception was the magenta and yellow comparison, which proved to be an equal amount of gain for each. This equality ranged through the three tone regions, although in the highlights, there was only a .1 margin between the test statistic and the Δx.

The black ink showed higher dot gain in both cases for coated and uncoated papers. The probable reason for this is that the black ink is an opaque ink, while the others are transparent inks. This makes a difference in the "light capture" theory as any light trapped underneath an opaque dot will not come through it. Any light trapped underneath a transparent dot, though, might make its way back through the dot.

Further work in this area needs to be done with some better controls. It would be much better if all samples were made from one single printing plate using different inks. For this study, it was possible to acquire a plate, but not a qualified printer with a press. This study was just a feasibility study, and if it resulted that all inks experienced the same dot gain, then no further work need be done. But, it did result that there was a difference according to this study and that there were some close relationships between certain inks. It is suggested, therefore that a printing plate be acquired and samples run using different inks on the same press. More samples should be taken than was used in this study, and measured and documented for "effective" dot area.

CONCLUSION

It has been determined that percentage dot gain on coated and uncoated papers for 150 line screens is different, depending on the ink hue used. Black ink showed the greatest dot gain and is different from cyan, magenta, and yellow. These three showed similar dot gain. Further analysis should be done on magenta and yellow inks on uncoated paper and with cyan and black inks on coated paper.

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APPENDIX I

Dot areas on the halftone negative for Gray Balance Chart Block 5:

C	*7.24	17.38	27.54	35.48	44.67	53.70	61.66	74.13	83.18
M	7.07	17.78	27.54	35.48	42.66	52.48	61.66	74.13	83.18
Y	7.24	17.78	26.92	36.31	42.66	51.29	61.66	70.79	83.18
B	6.91	17.38	26.30	36.31	43.65	53.70	61.66	74.13	83.18
AVG.	7.12	17.58	27.08	35.90	43.41	52.79	61.66	73.30	83.18

*All values are %dot areas.

The accuracy of the TR927 densitometer is ± .02D units which converts to an average of ± 1.28 % transmission units. The above data proves that the numbers on the target are accurate.

APPENDIX II

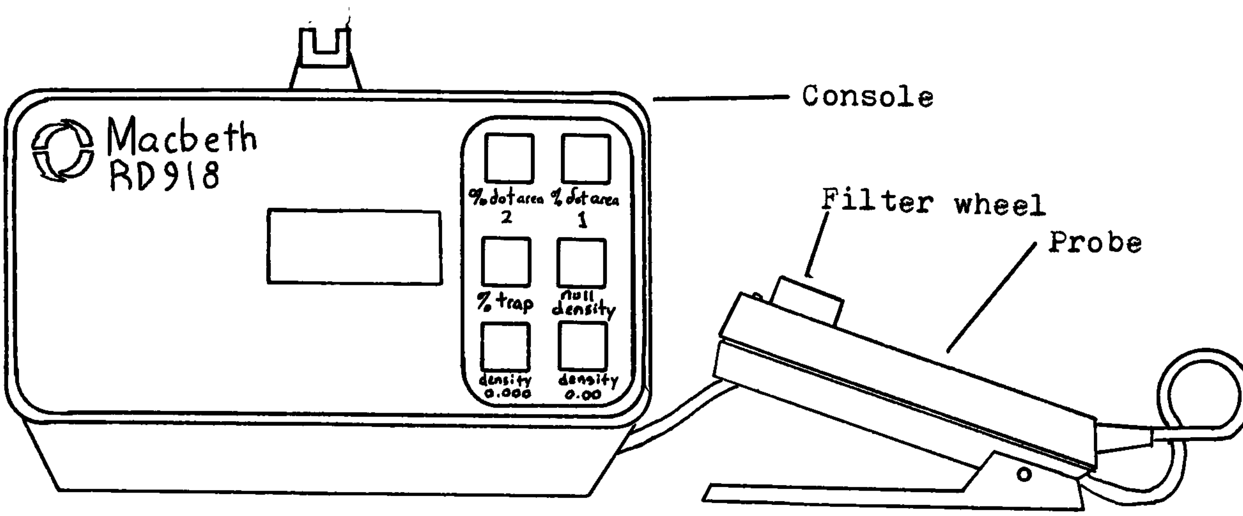

Figure 4. Diagram of Macbeth RD-918 densitometer.

The Macbeth RD-918 reflection densitometer was used for all targets. The densitometer has two modes for %dot area and two density modes. Both dot area modes use the Yule-Nielsen equation. In the dot area mode 1, the Yule-Nielsen equation is used with an n value of 1.65. In the dot area mode 2, any n value can be entered. In this study, dot area mode 1 was used with an n value of 1.65 for measuring on coated paper, and dot area mode 2 was used with n = 2.70 for measuring on uncoated paper. These n values are those recommended by the manufacturer.

To calibrate the instrument, a two step ceramic check plaque is used. First the filter wheel is turned to the visual position. Next, the zero is calibrated to the white step on the plaque, whose value is listed on the back of the plaque. This is done with the zero pot on the back of the console. Once the zero is set, the black high density step is read with the probe. This is calibrated by adjusting the calibration pot on the back of the console until the display reads the calibration value on the back of the plaque. The plaque used in this study had a zero of .06 and a calibration value of 1.80.

To measure a sample for %dot area, the following steps must be done:

(1) Turn filter wheel to position for ink hue to be measured.

(2) Place probe on paper white and calibrate it to 0% by pressing button on side of probe once.

(3) Place probe on solid ink area of ink to be measured and calibrate it to 100% by pressing the button on the side of the probe twice.

(4) Place probe on any halftone tint, corresponding to the ink hue calibrated for, on the target and a dot percentage will appear in the display.

(5) To measure on another target or another ink hue, repeat the above steps.

"Effective" dot area was measured, "effective" meaning relative to the dot area on the plate, for all the targets collected. These measurements are listed in Appendix III.

The accuracy of the instrument is ± .02D units and its repeatability is ± .01D. These are the values specified by the manufacturer. These values were confirmed during the study. A question arose about the background used to measure samples upon. All samples were measured on a white background. It was mentioned by Mr. Irving Pobboravsky of GARC that a black background might be better for measuring double printed material because the black background would negate the effect of the material printed on the opposite side. Because all the measuring had been completed by this time, a test was done to see the effect of the background and also to check the repeatability. The results follow:

REPEATABILITY AND BACKGROUND TEST DATA

		WHITE					BLACK				
CYAN	7)	20	20	20	22	21	18	18	18	18	18*
	17)	37	37	37	38	38	35	35	35	35	35
	27)	49	49	49	49	49	47	47	47	47	47
	36)	58	58	58	59	59	57	57	57	57	57
	44)	65	65	65	66	66	64	64	64	64	64
	53)	74	74	74	74	74	73	73	73	73	73
	62)	84	84	83	84	84	83	83	83	83	83
	73)	91	91	91	91	91	91	91	91	91	91
	84)	96	96	96	96	96	96	96	96	96	96
MAGENTA	7)	12	12	12	12	12	10	10	10	10	10
	17)	21	21	21	21	21	19	19	20	19	19
	27)	31	31	31	31	31	29	29	30	30	29
	36)	39	39	39	39	39	37	37	38	38	38
	44)	47	47	48	47	47	46	46	46	46	46
	53)	56	56	56	56	56	55	55	55	55	55
	62)	67	67	67	67	67	67	66	66	66	67
	73)	79	79	79	79	79	79	78	79	79	79
	84)	88	88	88	88	88	88	88	88	88	88
YELLOW	7)	8	8	8	8	7	8	8	7	7	7
	17)	19	19	19	19	19	17	18	18	18	18
	27)	29	29	29	29	29	28	28	28	28	28
	36)	39	39	39	39	39	39	39	38	38	38
	44)	50	50	50	50	50	49	49	49	49	49
	53)	60	60	60	59	60	59	59	59	59	59
	62)	72	72	72	72	72	72	72	72	72	72
	73)	81	81	81	81	81	81	81	81	81	81
	84)	92	92	92	92	92	92	92	92	92	92
BLACK	7)	10	10	11	11	11	9	9	9	9	9
	17)	20	21	21	21	21	19	19	19	19	19
	27)	29	29	29	29	29	28	28	28	28	28
	36)	38	38	39	39	38	37	37	37	37	37
	44)	49	49	50	50	50	48	48	48	48	48
	53)	60	60	60	60	60	59	59	59	59	59
	62)	69	69	69	69	69	69	68	68	68	68
	73)	81	81	81	81	81	80	80	80	80	80
	84)	89	89	89	89	89	88	88	88	88	88

*ALL NUMBERS ARE %DOT AREAS.

All samples were measured five times on each background. The measurements weren't consecutive, although they were measured on the same day. The densitometer was turned off periodically and the filter wheel was turned frequently between measurements.

APPENDIX III

TEST TARGET MEASUREMENT DATA

COATED PAPER:

		SAMPLE #												
		1	2	3	4	5	6	7	8	9	10	11	AVG.	AVERAGE %DOT GAIN
Cyan	7)	11	8	14	12	6	14	15	16	13	6	14	11.7	4.7
	17)	23	23	27	24	19	25	29	30	25	19	26	24.5	7.5
	27)	33	40	38	36	30	36	42	42	35	31	37	36.4	9.4
	36)	42	55	49	46	41	45	53	54	46	42	47	47.3	11.3
	44)	50	68	59	56	52	54	62	62	55	53	58	57.2	13.2
	53)	57	77	67	64	64	61	69	70	65	65	68	66.1	13.1
	62)	66	84	76	72	75	70	77	77	75	76	75	74.8	12.8
	73)	76	90	86	81	88	79	85	85	83	88	85	84.2	11.2
	84)	86	94	93	91	95	89	93	94	92	96	93	92.4	8.4
Magenta	7)	11	11	12	11	7	11	12	11	9	8	14	10.6	3.6
	17)	24	25	26	20	20	21	26	24	17	21	26	22.7	5.7
	27)	35	36	38	30	31	32	38	36	26	32	37	35.7	6.7
	36)	45	46	50	39	41	41	50	48	36	42	48	44.2	8.2
	44)	52	56	58	48	50	51	58	56	44	53	57	53.0	9.0
	53)	60	63	64	54	60	57	64	63	57	62	65	60.8	7.8
	62)	70	75	74	65	73	68	74	72	63	74	75	71.2	9.2
	73)	81	87	81	78	84	80	82	82	79	85	85	82.2	9.2
	84)	89	96	90	88	93	88	91	91	87	93	93	90.8	6.8
Yellow	7)	9	7	12	8	8	8	14	14	9	8	13	10.0	3.0
	17)	21	21	26	20	22	19	28	28	20	22	24	22.8	5.8
	27)	32	33	39	29	33	28	40	39	29	33	34	33.5	6.5
	36)	42	45	51	41	43	40	51	51	39	45	43	44.6	8.6
	44)	50	53	62	50	54	51	61	60	49	57	53	54.5	10.5
	53)	59	61	72	60	67	59	69	68	58	70	62	64.1	11.1
	62)	68	74	81	72	80	72	77	76	70	82	72	74.9	12.9
	73)	77	83	89	82	91	83	84	83	81	90	81	84.0	11.0
	84)	88	96	96	93	97	93	93	92	91	97	94	93.6	9.6
Black	7)	13	13	14	10	7	11	14	13	9	8	13	11.4	4.4
	17)	27	29	29	20	21	22	28	27	23	22	27	25.0	8.0
	27)	37	43	41	28	34	32	40	39	33	34	37	36.2	9.2
	36)	50	57	56	39	49	42	53	52	48	48	51	49.5	13.5
	44)	60	67	67	50	62	51	63	62	60	60	62	60.4	16.4
	53)	70	77	78	59	73	60	72	71	69	72	75	70.5	17.5
	62)	77	84	88	68	80	72	78	77	76	79	86	78.6	16.6
	73)	87	91	95	80	89	83	87	86	86	88	93	87.7	14.7
	84)	94	96	98	89	94	91	93	93	93	94	97	93.8	9.8

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	SAMPLE # 1	2	3	4	5	AVG.	AVERAGE %DOT GAIN
Cyan	7)15	9	7	7	7	9.0	2.0
	17)26	20	18	21	19	20.8	3.8
	27)40	30	30	32	30	32.4	5.4
	36)51	40	41	42	40	42.8	6.8
	44)61	50	51	52	51	53.0	9.0
	53)67	59	62	62	61	62.2	9.2
	62)80	70	74	71	70	73.0	11.0
	73)87	80	82	85	80	82.8	9.8
	84)88	91	90	90	91	90.0	6.0
Magenta	7)18	9	9	10	9	11.0	4.0
	17)32	20	25	26	26	25.8	8.8
	27)47	30	37	38	37	37.8	10.8
	36)57	40	46	50	47	48.0	12.0
	44)69	49	58	60	58	58.8	14.8
	53)76	56	67	66	66	66.2	13.2
	62)85	67	80	80	79	78.2	16.2
	73)92	80	91	90	91	88.8	15.8
	84)97	90	99	95	97	95.6	11.6
Yellow	7)17	10	13	14	12	13.2	6.2
	17)31	22	29	32	26	28.0	11.0
	27)41	31	38	45	38	38.6	11.6
	36)51	42	52	56	52	50.6	14.6
	44)61	51	64	63	58	59.4	15.4
	53)71	61	73	73	67	69.0	12.0
	62)78	72	83	86	79	79.6	17.6
	73)87	82	91	91	89	88.0	15.0
	84)97	93	98	97	92	95.4	11.4
Black	7)18	13	11	13	12	13.4	6.4
	17)40	28	30	34	31	32.6	15.6
	27)50	40	45	48	44	45.4	18.4
	36)65	54	59	63	58	59.8	23.8
	44)76	64	69	73	68	70.0	26.0
	53)88	73	79	81	78	79.8	26.8
	62)87	78	87	89	87	85.6	23.6
	73)94	89	93	96	93	93.0	20.0
	84)98	94	98	98	96	96.8	12.8

APPENDIX IV

STATISTICAL ANALYSIS

$$\Delta x = \text{Avg. \%dot area}_{\text{ink a}} - \text{Avg. \%dot area}_{\text{ink b}}$$

$$S_p = \sqrt{\frac{\text{deg. of freedom}(S_1^2 + S_2^2 + S_3^2 + \ldots)}{\text{D.O.F.}_1 + \text{D.O.F.}_2 + \ldots}}$$

$$\text{Test statistic} = \frac{t_{v,.05} \times \sqrt{n}}{S_p}$$

If Δx is greater than the test statistic, then there is significance.

VITA

Mr. Latzko was born in Goshen, NY, a small town that is approximately 70 miles north of New York City. He grew up on a small lake called Tomahawk Lake which is located in Blooming Grove, NY. He attended Washingtonville Senior High School in Washingtonville, NY where he majored in math and science and was a member of the National Honor Society. He graduated with honors and was in the top ten percent of his class and also won a New York State Regents Scholarship. Upon graduation, he went to Orange County Community College in Middletown, NY where he majored in math and science. After two years there, he transferred into the Photographic Science and Instrumentation program at the Rochester Institute of Technology. He has also worked a summer as a test engineer at Macbeth Division of Kollmorgen Corporation in Newburgh, NY. This is where the background experience for this thesis was obtained. After graduation from RIT, Mr. Latzko will be accepting a position at Teletype Corporation in Skokie, Illinois as a VLSI (Very Large Scale Integration) engineer in their Research and Development area.