A Comparison of Four Color Printing At One Angle and At Four Angles

James S. Rich, Jr.*

Abstract: Printing four colors: yellow, magenta, cyan and black at the same angle in offset lithography has exhibited characteristics that, in some cases, add flexibility and quality to the existing four color printing technology. This test involved a subject that was screened with six different screen rulings 100, 120, 133, 150, 175, and 200 lines per inch at one angle, 45 degrees, for yellow, magenta, cyan and black and at the conventional angles 45 degrees black, 75 degrees cyan, 90 degrees yellow and 105 degrees magenta. It was then printed on a 50 lb coated paper on a four color web press.

The results show: 1. The one angle system did not perform as consistently as the four angle system for tone reproduction, except at 120 lines per inch. 2. The coarse line screen rulings 100, 120, and 133 lines per inch at one angle exhibited more apparent sharpness than at four angles. 3. In the neutral areas of all the subjects at one angle, the interference pattern (the rosette) was eliminated, where as, the neutral areas of the subjects at four angles displayed an interference pattern.

Introduction

The technique of printing four colors at the same angle has been available for at least 30 years (Greenwood 1950). "Yet it has not been used extensively until recently in the newspaper field (Garbett 1980)." A primary factor appears to have been the lack of prepress and press controls. "As printing technology has become more sophisticated in the last 4 or 5 years, with tighter prepress and press controls, the use of one-angle printing has become more practical and popular (Garbett 1980)."

*National Geographic Society

The object of this study is to show the differences on coated paper between one-angle and four-angle printing. It is hypothesized that if one angle screening and printing with its advantages can be proved comparible to four angle printing by using the current advanced technology, a superior quality product can be achieved.

There have been limited investigations on one-angle printing (Greenwood 1951 and Yule 1967). "The results of these investigation indicate that it is possible to print at one-angle or in parallel, but an infinite moirè pattern will occur (Tollenar 1945)." "This is not a typical moirè pattern in which periodically alternating light and dark patches occur, but a change of color from sheet to sheet as the register changes (Pollack 1958 and Yule 1967)." No mention is made in these studies of the elimination of the rosette pattern (a symetrical dot system which is the least objectional type of moirè pattern) or the increased sharpness of the screened image. "Only Rich (1981) does this in his comparison of one-angle screens. Where he describes how one-angle printing appears to be sharper by resolving at a higher resolution than the actual line ruling that is 100 lpi at one angle appears to resolve at 120 lpi at 4 angles and 120 lpi one angle would appear to resolve at 133 lpi at 4 angles and so forth."

"In some cases, screening and printing at one angle adds quality and allows greater flexibility to the process of four color printing (Rich 1981)."

This study will show the differences between one angle printing and four angle printing in three distinct areas: 1. Tone reproduction. 2. Sharpness. 3. Elimination of the rosette pattern.

Methodology

"It is not necessary to use a special one-angle screen for screening and printing four colors at one angle. Any type of screen will work if the angle integrity, the maintenance of the screen at a consistent position, is upheld (Rich 1981)." Angle integrity can be achieved by the use of any conventional pin system. If angle integrity is not upheld, a moirè pattern will occur.

This test involved magenta positive screens from different manufacturers. The screens' rulings were 100 lines

per inch (lpi), 120 lpi, 133 lpi, 150 lpi, 175 lpi, and 200 lpi.

One set of continuous tone color separation negatives were used for the screening of each screen ruling at one angle and at four angles. The angle used for the one-angle screening was 45 degrees for all colors: yellow, magenta, cyan, and black. The angles used for the four-angle screening were 45 degrees for black, 75 degrees for cyan, 90 degrees for yellow, and 105 degrees for magenta. The tone reproduction characteristics were comparable for each screen; that is, the 100 lpi one angle and the 100 lpi four-angle color separations had equal dot sizes. But the dot sizes were not equal when comparing, for example, the 100 lpi one-angle screen to the 133 lpi one-angle screen, as shown in Appendix A.

After the screened positives were made, they were positioned so the one-angle screened copy printed along a top row and the four-angle screened copy was printed along a bottom row in a corresponding position to the one-angle copy of the same ruling, as shown in Figures 2a and 2b. They were then contacted into a one-piece film litho negative.

Figure 2a Layout of Subjects on Press Sheet

100 lpi	120 lpi	133 lpi
one angle	one angle	one angle
100 lpi	120 lpi	133 lpi
four angle	four angle	four angle

Figure 2b

150 lpi	175 lpi	200 lpi
one angle	one angle	one angle
150 lpi	175 lpi	200 lpi
four angle	four angle	four angle

This test was printed on 50 lb coated paper with process inks yellow, magenta, cyan, and black on negative plates mounted on a Goss Webb press. The press was adjusted for color and run at 500 feet per minute. From the accepted batch of press sheets, fifty-one sheets were pulled at random, analyzed and evaluated by comparative techniques. Three people judged these sheets for tone reproduction, and ten people judged them for sharpness and the elimination of the rosette pattern.

Tone Reproduction - This test does not attempt to evaluate quality standards because they vary from shop to shop. Its purpose is to show variability between the two techniques for printing four color process. In this evaluation of the color subjects, the criteria for variablility was very precise. Each standard subject was compared to

Figure 3a

TONE REPRODUCTION

ONE ANGLE RESPONSES 3 Judges

SAMPLE SIZE - 51 SHEETS

LPI	AVERAGED ACCEPTED	AVERAGED REJECTION	PERCENT OF REJECTIONS	STANDARD DEVIATION REJECTIONS
100	26.6	24.4	47.8	.57
120	48.0	3.0	5.8 *	1.73
133	29.0	22.0	41.3	3.6
150	36.6	14.3	28.0	8.5
175	22.0	29.0	56.8	7.5
200	24.3	27.7	54.3	11.9

*Comparable to four-angle rejection rate

the press sheets. Each judge was told to make his evaluation on the premise that if all the good press sheets were put in a pile, they would all look alike, and that any that did not would be rejected. When this was done, the results were ranked by acceptability and rejectability, and the percentage of rejected press sheets was tallied, as shown in Figure 3.

Figure 3b

TONE REPRODUCTION

FOUR ANGLE RESPONSES 3 Judges

SAMPLE SIZE - 51 SHEETS

LPI	AVERAGED ACCEPTED	AVERAGED REJECTION	PERCENT OF REJECTIONS	STANDARD DEVIATION REJECTIONS
100	47.6	3.3	6.4	2.8
120	48.3	2.6	5.1	3.8
133	48.0	3.0	5.8	2.6
150	46.6	4.3	8.4	7.5
175	46.6	4.3	8.4	3.7
200	46.6	2.3	4.5	4.04

Sharpness - This trait being a subjective judgement was evalutated by another comparison technique in which, for example, the 100 lpi at one angle was compared to the 120 lpi at four angles to see if the 100 lpi appeared equal to or sharper than that of the 120 lpi at four angles. Then the 120 lpi at one angle was compared to the 133 lpi at four angles and so forth through the 175 lpi at one angle compared to the 200 lpi at four angles. The results were ranked on a yes, one angle is sharper, or no, one angle is not sharper basis and then totaled as shown in Figure 4.

Figure 4

PERCENT OF YES RESPONSES WHEN COMPARING ONE ANGLE TO FOUR ANGLES FOR SHARPNESS 10 Judges

	LPI	LPI	LPI	LPI	LPI
Angles 1 to 4	100 to 120	120 to 133	133 to 150	150 to 175	175 to 200
Percent of yes responses	100	100	80	60	70

Elimination of the rosette pattern - This involved a visual determination made by comparing neutral areas (3 color); for example, a neutral area of the 100 lpi at one angle was compared to the same area of the 100 lpi at four angles. This was done for all screen rulings, and the results were ranked on a yes, there is a rosette or no, there is not a rosette and then totaled as shown in Figures 5 and 6.

Figure 5

PERCENT OF YES RESPONSES TO NO ROSETTE PATTERN IN THE ONE ANGLE PRINTING 10 Judges

LPI	100	120	133	150	175	200
Percent of yes responses	100	100	100	100	100	100

Figure 6

PERCENT OF YES RESPONSES TO A ROSETTE PATTERN IN THE FOUR ANGLE PRINTING 10 Judges

LPI	100	120	133	150	175	200
Percent of yes responses	100	100	100	90	80	0

RESULTS

The results of the investigation show a tendency for one-angle printing to be less consistent than four-angle printing. These results were based on the high percentage of rejectability in the one-angle printing when compared to the four-angle printing as shown in Figure 3. This high rejection rate was evident in all but one of the one-angle screen rulings. The rejection rate of the 120 lpi at one angle was comparable to that of the four-angle method.

The sharpness results showed that in the coarser screen ruling the one-angle system appeared to be sharper 100 percent of the time with the 100 lpi and 120 lpi, 80 percent of the time with the 133 lpi, 60 percent of the time with the 150 lpi, and 70 percent of the time with the 175 lpi.

In all the one-angle printing (100 lpi through 200 lpi) there was never a rosette pattern noted as shown in Figure 5.

In four-angle printing a rosette pattern was noted in the 100 lpi, 120 lpi, 133 lpi, 150 lpi, and 175 lpi.

A moirè pattern was not exhibited in the results of the one-angle printing. In four-angle printing, the 100 lpi, 120 lpi, and 150 lpi, had a moirè.

Discussion of Results

According to the tone reproduction quality standards, the one-angle system, except in the 120 lpi category, did not print as consistently as the four-angle system because of color shifts caused by dot-on-dot printing. The color

shifts occurred mostly in the 30 percent to 40 percent dot printing area, which is considered to be the weakest area for consistent tone reproduction in the one-angle printing system. The color shifts occur, especially in three-color areas, because of the relationship of different dot sizes and the method by which the dots are transferred to paper. Each dot can not be printed in exactly the same position as the dot before it. These color shifts were caused by a dot being off only half a dot in any color yellow, magenta, or cyan, whereas, in the four-angle printing these color shifts did not take place.

The 120 lpi subject at one angle was placed in the center of the sheet, where a minimum of paper fanout was taking place; this positioning appeared to aid in the consistent tone reproduction. But the 175 lpi subject was also in this position and did not reproduce consistently. So it appears that a combination of factors, i.e., the screen ruling (lpi) and the placement on a sheet where there is less paper fanout, makes one-angle printing comparable with four-angle printing at 120 lpi.

The two other areas studied, sharpness and the elimination of the rosette pattern, consistently add quality in the coarser line screen rulings 100 lpi, 120 lpi, and 133 lpi at one angle. Elimination of the rosette pattern with its apparent sharpness in the 150 lpi, 175 lpi, and 200 lpi at one angle, was not significant as in the coarser line screens.

The results of this investigation lead to the following conclusions: When using a highly selective comparison technique for tone reproduction, one-angle screening and printing is inferior, in this respect to the four-angle method. One-angle printing causes an increase in perceived color variations among individual sheets in a particular run. But because commercial acceptability of printed material allows a wide range of perceivable color variation, this drawback is negligible.

However, one-angle screening and printing has two distinct advantages over the four-angle method. It has greater flexibility because a single screen is used, and it results in a sharper image in coarse screen rulings. So, in return for sacrificing a degree of color consistency, the printer can obtain a print of over-all superior quality by using the more flexible one-angle method of screening and printing.

Selected Bibliography

Garbett, R.
1981. "Interview," Chemco Photo Products (Rockville, Maryland) March.

Greenwood, W. P.
1950. "The Color of Halftone Dot Patterns," TAGA Proceedings, pp. 61-66.

Pollack, F.
1958. "The Dependence of the Contrast of Moirè Patterns on the Colours of the Printing Inks," TAGA Proceedings, pp. 37-44.

Rich, J.
1981. "Direct Screen Sans A Continuous Tone Processor," Printing Impressions, October, p. 18.

Southworth, M. F.
1979. "Color Separation Techniques," (Graphic Arts Publishing Co., Livonia, N.Y.) 2nd Ed. p. 214.

Tollenar, D.
1945. "Moirè Interference Phenomena in Halftone Printing," Research and Engineering Council of the Graphic Arts Industry, Inc., pp. 3-9.

Wilson, W.
1982. "Interview," Capitol Printing Ink Co. (Washington, D.C.) January.

Yule, J.
1967. "Principles of color Reproduction," (John Wiley and Sons, Inc., New York, London, Sidney) pp. 328-345.

Appendix A

Dot Size for 100 lpi Negatives at One-Angle

	Density Step Number	YELLOW	MAGENTA	CYAN	BLACK
Shadow	16	0	0	0	17
Area	15	0	0	0	23
	14	2	2	2	36
	13	5	5	3	49
	12	10	10	7	60
	11	14	14	10	75
	10	20	20	14	88
	9	30	30	24	97
	8	43	42	34	100
Mid-Tone	7	51	56	44	
Area	6	64	72	56	
	5	81	86	74	
Highlight	4	94	100	89	
Area	3	100		98	
	2			100	
	1				

Dot Size for 100 lpi Negatives at Four-Angles

	Density Step Number	YELLOW	MAGENTA	CYAN	BLACK
Shadow	16	0	0	0	19
Area	15	0	0	0	22
	14	2	2	2	35
	13	5	5	4	48
	12	7	9	7	59
	11	14	15	10	75
	10	15	21	15	89
	9	30	30	26	97
	8	43	44	34	100
Mid-Tone	7	51	57	44	
Area	6	64	73	56	
	5	82	88	73	
Highlight	4	96	100	91	
Area	3	100		99	
	2			100	
	1				

Appendix A

Dot Size for 120 lpi Negatives at One-Angle

	Density Step Number	YELLOW	MAGENTA	CYAN	BLACK
Shadow	16	0	0	0	18
Area	15	0	0	0	21
	14	2	2	2	31
	13	4	3	2	51
	12	6	5	3	68
	11	10	9	6	86
	10	14	13	8	98
	9	18	18	12	100
	8	27	27	19	
Mid-Tone	7	39	38	27	
Area	6	55	54	41	
	5	72	71	59	
Highlight	4	88	86	78	
Area	3	100	99	95	
	2		100	100	
	1				

Dot Size for 120 lpi Negatives at Four-Angles

	Density Step Number	YELLOW	MAGENTA	CYAN	BLACK
Shadow	16	0	0	0	22
Area	15	0	0	0	25
	14	3	2	0	37
	13	4	4	2	58
	12	7	5	4	70
	11	9	9	5	88
	10	18	13	8	99
	9	23	19	11	100
	8	33	28	15	
Mid-Tone	7	45	40	23	
Area	6	59	54	32	
	5	75	71	47	
Highlight	4	89	85	64	
Area	3	100	98	82	
	2		100	97	
	1			100	

Appendix A

Dot Size for 133 lpi Negatives at One-Angle

	Density Step Number	YELLOW	MAGENTA	CYAN	BLACK
Shadow	16	3	2	0	25
Area	15	3	2	0	28
	14	4	3	1	40
	13	7	5	2	59
	12	9	8	4	70
	11	14	13	6	89
	10	19	18	10	99
	9	24	24	14	100
	8	33	33	22	
Mid-Tone	7	46	46	29	
Area	6	60	60	44	
	5	75	74	60	
Highlight	4	90	89	78	
Area	3	100	100	93	
	2			100	
	1				

Dot Size for 133 lpi Negatives at Four-Angles

	Density Step Number	YELLOW	MAGENTA	CYAN	BLACK
Shadow	16	3	3	0	20
Area	15	3	3	0	25
	14	4	4	2	36
	13	4	6	3	55
	12	10	8	5	70
	11	14	13	8	86
	10	18	17	11	97
	9	23	23	16	100
	8	33	33	23	
Mid-Tone	7	44	45	30	
Area	6	58	59	44	
	5	73	74	60	
Highlight	4	88	87	76	
Area	3	100	100	91	
	2			100	
	1				

Appendix A

Dot Size for 150 lpi Negatives at One-Angle

	Density Step Number	YELLOW	MAGENTA	CYAN	BLACK
Shadow	16	6	5	6	24
Area	15	6	5	6	28
	14	8	7	7	36
	13	11	9	8	51
	12	13	12	10	65
	11	17	16	13	79
	10	21	20	17	89
	9	25	24	20	96
	8	33	30	28	100
Mid-Tone	7	43	43	34	
Area	6	55	54	46	
	5	70	69	60	
Highlight	4	83	82	75	
Area	3	94	93	89	
	2	100	99	97	
	1		100	100	

Dot Size for 150 lpi Negatives at Four-Angles

	Density Step Number	YELLOW	MAGENTA	CYAN	BLACK
Shadow	16	7	5	7	26
Area	15	7	5	7	30
	14	9	6	8	40
	13	13	8	9	56
	12	14	11	11	70
	11	17	15	14	82
	10	22	19	18	91
	9	26	24	21	97
	8	34	32	28	100
Mid-Tone	7	45	42	35	
Area	6	59	55	47	
	5	74	70	63	
Highlight	4	87	82	78	
Area	3	98	94	91	
	2	100	100	99	
	1			100	

Appendix A

Dot Size for 175 lpi Negatives at One-Angle

	Density Step Number	YELLOW	MAGENTA	CYAN	BLACK
Shadow	16	3	3	2	27
Area	15	3	3	2	32
	14	5	5	3	45
	13	8	7	4	62
	12	10	10	6	74
	11	14	14	9	87
	10	19	20	13	99
	9	24	25	17	100
	8	34	37	26	
Mid-Tone	7	46	48	34	
Area	6	60	62	48	
	5	73	74	63	
Highlight	4	85	87	76	
Area	3	99	100	93	
	2	100		100	
	1				

Dot Size for 175 lpi Negatives at Four-Angles

	Density Step Number	YELLOW	MAGENTA	CYAN	BLACK
Shadow	16	3	3	2	24
Area	15	4	3	2	28
	14	5	4	3	42
	13	8	6	4	59
	12	11	9	6	71
	11	16	13	9	85
	10	21	17	13	99
	9	26	26	17	100
	8	37	34	25	
Mid-Tone	7	49	46	34	
Area	6	62	60	48	
	5	74	72	64	
Highlight	4	88	84	77	
Area	3	100	100	94	
	2			100	
	1				

Appendix A

Dot Size for 200 lpi Negatives at One-Angle

	Density Step Number	YELLOW	MAGENTA	CYAN	BLACK
Shadow	16	6	5	4	28
Area	15	6	5	4	32
	14	8	7	5	41
	13	11	10	6	59
	12	14	13	9	72
	11	18	19	13	84
	10	24	23	16	94
	9	28	28	20	99
	8	36	36	27	100
Mid-Tone	7	46	47	32	
Area	6	61	60	40	
	5	73	71	54	
Highlight	4	88	85	67	
Area	3	98	96	81	
	2	100	100	90	
	1			96	

Dot Size for 200 lpi Negatives at Four-Angles

	Density Step Number	YELLOW	MAGENTA	CYAN	BLACK
Shadow	16	6	2	5	26
Area	15	6	2	5	29
	14	8	6	6	38
	13	11	8	7	54
	12	14	11	9	66
	11	18	16	12	80
	10	24	22	16	92
	9	27	26	20	98
	8	35	35	26	100
Mid-Tone	7	44	44	32	
Area	6	59	58	40	
	5	71	70	53	
Highlight	4	85	83	66	
Area	3	97	94	80	
	2	100	99	92	
	1		100	98	

Appendix B

Density of Continuous Tone Negatives

	Density Step Number	YELLOW	MAGENTA	CYAN	BLACK
Shadow Area	16	.19	.16	.14	.66
	15	.20	.18	.15	.71
	14	.26	.23	.18	.84
	13	.35	.30	.23	1.02
	12	.41	.38	.29	1.12
	11	.50	.48	.37	1.29
	10	.60	.58	.46	1.42
	9	.67	.67	.54	1.53
	8	.80	.80	.68	1.68
	7	.91	.90	.79	1.80
	6	1.03	1.02	.92	1.92
	5	1.16	1.15	1.06	2.07
Highlight Area	4	1.31	1.29	1.20	2.20
	3	1.46	1.44	1.38	2.34
	2	1.57	1.56	1.49	2.45
	1	1.62	1.64	1.61	2.51

Appendix C

INK ROTATION

FIRST - CYAN

SECOND - MAGENTA

THIRD - YELLOW

FOURTH - BLACK

SAMPLE SIZE = 6	PERCENT OF TRAPPING	STANDARD DEVIATION
MAGENTA OVER CYAN	70.0 percent	3.22
YELLOW OVER MAGENTA	63.5 percent	3.39
CYAN OVER YELLOW	78.0 percent	4.70

TRAPPING EQUATION:

$$\frac{\text{Density overprint} - \text{Density first color}}{\text{Density second color}} \times 100 = \text{Percent Trapping}$$