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Some Aspects of Printing Quality

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SOME ASPECTS OF PRINTING QUALITY

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ABSTRACT

The object of this experiment was to find the effect of various pressures upon the ink coverage and the visual appearance of the half-tone print. A specially designed plate with four evenly spaced elevations was used with a Vandercook proof press. Various grades of paper were used. Results showed: a variation in the range of ink coverage due to the grade of paper and the number of lines of the half-tone; within the area of good printing a small change in pressure caused a large change in ink coverage; the change in ink coverage varied from elevation to elevation; an excess of ink was used in this experiment; the optimum printing pressure might have fallen between elevations; and the nature and/or quality of the data gathered did not at this time lend itself to mathematical analysis.

HISTORICAL REVIEW

In order to retain the context of various articles, the same terminology that appears in the originals is used in this paper. It is recommended that for the purpose of this paper, the reader construe factors pertaining to press performance as those of printability and factors pertaining to the appearance of print as those of printing quality.

In 1934, Prior (1) made the observation that, "A large proportion of the paper manufactured is printed, but there is not a great deal of literature on the technical problem connected with the printing quality of paper." Larocque (2) blamed this lack of progress partially on the complexity of the printing operation and on the lack of suitable definition. This condition existed through 1942 and caused Weymouth (3) to lament that "Actually there are less than twenty articles in the literature which even touch upon printability and almost half of these are devoted to newsprint."

Since this time many definitions of printability and print quality have been offered by various authors. It is unfortunate that throughout the literature the terms of printability and print quality have been used interchangeably. The following are definitions of printability and printing quality by various authors: Larocque (4) states that printing quality is not the brightness and color of the paper nor whether the paper will run without breaking on the press, but rather whether a sheet will print to give a clean, crisp, attractive appearance--with smooth, solid blacks and half-tone illustrations, free from wire marking or other objectionable defects. Zettlemoyer, Fetsko and Walker (5) define printing quality as the aggregate effect of the various appearance characteristics of printed matter. Andella (6) describes printability as that quality in paper that lends itself well to faithful reproduction by possessing the necessary affinity to accept an ink from a printing plate and properly hold the full color tone values of the half-tone structure. Reed (7) states that, "print quality is defined as the general appeal or attractiveness of the printed reproduction to the viewer," and defines printability as "...the combined properties and condition of paper that affect its press performance." Kantrowitz (8) maintains that printability is not a single property of paper, but a property of condition, and cannot be entirely built into paper by the manufacturer. It results from a proper relationship of certain requirements of the printing process, the kind of ink and the paper used. Carlsson (9) attempts to give a definition of the term "printability of paper" showing that it comprises all the properties of the paper in the printing machine and the qualitative and quantitative printing result. Schaffert (10) proposes that printability be defined in terms of measurable quantities of the printed result, e.g., resolution, contrast and tone density.

In the attempt to measure print quality, research has been divided into two main areas. One group maintains that instrumental testing of paper is to be preferred (5) and that the printing quality of paper be inferred from the results of these tests. This has led many authors to attempt to attribute smoothness, (2, 12, 13, 7, 5, 14) compressibility, (13, 14) softness, (2) and ink receptivity (5, 14) as the main factors affecting printing quality. This has also led to various techniques of measuring the above printing quality factors. (15, 13, 16)

Other authors (4, 3, 5, 14) believe that the large number of variables makes it "difficult" to separate and understand each individually and to relate them to the process. They therefore maintain that measurement of the print is the criterion of printing quality. Zettlemoyer, Fetsko and Walker (5) state that the most important appearance properties in prints of solids and type matter are color, gloss, uniformity, sharpness of outline and print. Two main characteristics of half-tones which must be reproduced are their tone values and contrasts. Consideration must also be given to the matter of the exact shape of the individual dots. Edges may be irregular, or a squashing out of the ink may produce doughnut-shaped dots. The Lithographic Technical Foundation (17) and Yule (18) have published excellent treatises on the relationship between dot area, dot density and tone value. Dot area is obtained by the microscopic measurement of the actual fractional area occupied by the dots. The density of each dot and the tone value, or the integrated density of a group of dots, can be readily measured with a reflection meter. Voet (19) illustrates the characteristics of half-tone dot reproduction for the various printing processes in a series of photomicrographs. Bernstein (20) made an extensive study of dot formation. According to him, there are two main factors, namely sharpness of contours and the uniformity of ink coverage which determine the quality of the half-tone.

Diehm (21) describes a method of numerically evaluating printing quality, whereby he measures ink coverage and print fidelity. Diehm measures print fidelity in terms of presence of dots, uniformity of dot size and distortion of dot contour. He claims that, "Broken and distorted dots are almost as detrimental to print fidelity as are missing dots." and, "Only a few dots need to be absent before even the inexperienced eye can detect loss of fidelity in the print." He further states that a print has little if any commercial value when more than twenty-five percent of the dots are missing.

Eckhart and Burnett (22) combined the methods of (3), (23) and (21) to give a method of determining the printability of paperboard. The authors found that with this method the evaluation of a given board could be reproduced to within plus or minus three percent. They further claim that although the method is too time-consuming for routine mill control, it does provide the mill with a means of comparison of the printability of the current run with that of a standard or that of a previous run. It also furnishes information about variations in printability during a run which may not have been detected by routine mill physical tests. Eckhart and Burnett also state that only a limited correlation with physical tests has been observed, and that they have not found any single physical test or any group of physical tests which correlate with printability as determined by this test.

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EXPERIMENTAL DESIGN

In order to print samples of paper for evaluation the Vandercook No. 4 Proof Press and a specially designed half-tone plate were employed. The special plate showed half-tone areas consisting of ten, fifty and ninety percent etch in both 133 and 85 lines. These areas are present on the plate in four elevations, each differing by 0.003 inch. Also on the plate are two solid areas which correspond to the highest elevation.

The ink and papers were conditioned in the constant humidity room at 72^{o} F. and 50% relative humidity. The actual printing was also done under these conditions. The press was inked with 3 cc. of No. 2 H. T. black letter press ink. Six prints were made for each grade of paper. After each series of six prints the press was washed up. The following are the grades and code numbers of the paper used:

A-1 60# C1S Non varnish
A-3 70# C2S Imperial offset enamel
A-4 62# Letter press duplex super
A-5 60# EF
A-6 60# Egg shell
A-7 16# Bond
A-8 60# Offset
A-9 Newsprint
A-10 70# C2S Velour enamel

Ink coverage for each area on each grade of paper was evaluated by the following method: the brightness of the paper, the half-tone areas and the solid black areas were measured by the G. E. Brightness tester. Ink coverage was calculated for each half-tone area by use of the following formula: Ink coverage $= \frac{BP - BA}{BP - BS} \times 100$ where BP is the brightness of the paper, BA is the brightness of the half-tone area and BS is the brightness of the solid area.

The half-tone areas were also examined visually and evaluated as to appearance, presence and shape of dots.

PRESENTATION OF RESULTS

Tables I and II show the ink coverages of each half-tone area along with a description of the individual area. The values are listed according to the paper used.

Table III shows the differences in ink coverage between each elevation. Column A represents the ink coverage of the highest elevation minus the second highest elevation. Column B represents the second highest elevation minus the third highest. Column C is the difference between the third highest and the lowest. Column D represents the ink coverage of the highest level minus the ink coverage of the lowest, that is, the entire range of ink coverage.

Figures 1, 2, 3 and 4 are graphs of the ink coverage versus the plate elevation. Figures 1 and 2 are 10% and 50% etch, respectively, of the 133 line areas. Figures 3 and 4 are 10% and 50% etch, respectively, of the 85 line areas.

TABLE I

(133 Lines)

EVALUATION OF INK COVERAGE - (results in percent)

Sample No.	10% etch		50% etch		90% etch	
A-1	17.0	S	69.3	*	99.9	F
	15.8	S	68.5	MD	99.4	F
	11.3	*	66.7	DM	95.5	F-MD
	10.6	DM	56.2	DM	86.7	F-MD-DM
A-10	15.7	S	67.4	*-S	99.5	F
	14.7	S	67.4	MD	99.2	F
	10.7	*-MD	64.4	MD	95.0	F-MD-DM
	10.2	DM	51.3	MD-DM	81.1	F-MD-DM
A-3	15.6	S	66.5	S	99.1	F
	15.2	S	65.3	*	98.5	F
	10.9	*	63.8	DM	94.6	F-MD-DM
	10.8	DM	54.4	DM	85.2	F-MD-DM
A-4	11.9	S	55.4	*-MD	92.2	F
	11.4	*	55.2	MD	92.2	F
	7.8	MD	53.7	DM	79.2	MD-DM
	7.8	DM	43.2	DM	72.5	MD-DM
A-5	21.6	S	70.3	S	95.8	F-MD
	20.3	S	68.3	*-S	95.4	F-MD
	13.0	*-DM	62.7	MD-DM	92.7	F-MD-DM
	10.8	MD	52.2	DM	82.4	MD-DM
A-6	31.8	S	80.3	*-F	99.7	F-MD
	29.1	S	79.7	MD	99.5	F-MD
	20.8	*-MD	69.7	DM	95.8	F-MD-DM
	16.8	DM	60.2	DM	84.4	F-MD-DM
A-7	30.5	S	84.2	*-MD	98.4	F-MD
	29.6	S	81.8	MD	98.2	F-MD
	20.1	*-MD-DM	73.1	DM	96.6	F-MD-DM
	17.2	DM	61.5	DM	86.6	F-MD-DM
A-8	28.0	S	81.2	F-MD	99.0	F-MD
	25.8	S	78.9	*-MD	98.5	F-MD
	19.0	*-MD	73.3	MD-DM	96.0	F-MD-DM
	15.3	DM	60.9	DM	91.4	F-MD-DM
A-9	26.6	S	80.5	F-S-MD	99.2	F
	24.0	S	79.0	*-S-MD	98.4	F
	17.7	*-MD	71.7	MD-DM	95.0	F-MD-DM
	13.9	DM	61.7	DM	89.4	F-MD-DM

KEY:

* — Best Print
OK — Print Good, But Not Best
F — Filled In
S — Smudgy
MD — Misshaped Dots
DM — Dots Missing

TABLE II

(85 Lines)

EVALUATION OF INK COVERAGE - (results in percent)

Sample No.	10% etch		50% etch		90% etch	
A-1	13.7	S	71.2	*	99.9	F
	13.7	OK	67.8	MD	99.8	F
	11.2	*	65.6	DM	94.6	F-MD-DM
	10.7	OK	61.2	DM	76.4	MD-DM
A-10	13.1	S	68.4	*	99.7	F
	13.1	S	65.7	MD	99.2	F
	11.9	*	63.7	MD	92.8	MD-DM
	10.9	OK	59.7	MD-DM	75.5	MD-DM
A-3	13.1	S	68.1	*	99.3	F
	12.5	S	65.6	MD	98.4	F
	11.2	*	64.8	DM	90.0	MD-DM
	10.2	OK	58.8	DM	76.2	MD-DM
A-4	9.5	S	55.7	*	97.0	F
	10.6	OK	53.5	MD	96.4	F
	8.1	*	52.7	MD	89.6	MD-DM
	7.9	OK	48.3	MD-DM	77.8	MD-DM
A-5	18.1	S	69.1	*-S	96.6	F
	18.3	S	66.1	MD	94.6	F-MD
	13.9	*	63.1	MD	91.3	MD-DM
	13.5	OK	59.8	MD	85.7	MD-DM
A-6	26.0	S	76.1	*-S	98.4	F
	27.2	S	71.5	MD	97.9	F-MD
	22.3	S	67.1	MD	90.6	MD-DM
	14.8	*-MD	63.8	DM	79.0	MD-DM
A-7	28.2	S	82.0	*-MD	99.7	F
	28.2	S	78.2	MD	99.3	F-MD
	21.6	*-MD	74.0	DM	96.6	MD-DM
	20.4	MD	68.6	DM	84.1	MD-DM
A-8	25.2	S	78.5	*-S-MD	99.7	F
	27.5	S	76.7	MD	99.7	F-MD
	19.8	*	72.0	MD	97.5	MD-DM
	17.8	MD	69.1	MD	91.5	MD-DM
A-9	20.6	S	78.0	S	99.2	F
	22.6	S	74.2	*-MD	98.0	F-MD
	17.9	*	70.3	MD	97.6	MD-DM
	15.1	MD	67.5	MD	86.3	MD-DM

KEY:

* — Best Print
OK — Print Good, But Not Best
F — Filled In
S — Smudgy
MD — Misshaped Dots
DM — Dots Missing

TABLE III

DIFFERENCES IN % INK COVERAGE BETWEEN ELEVATIONS

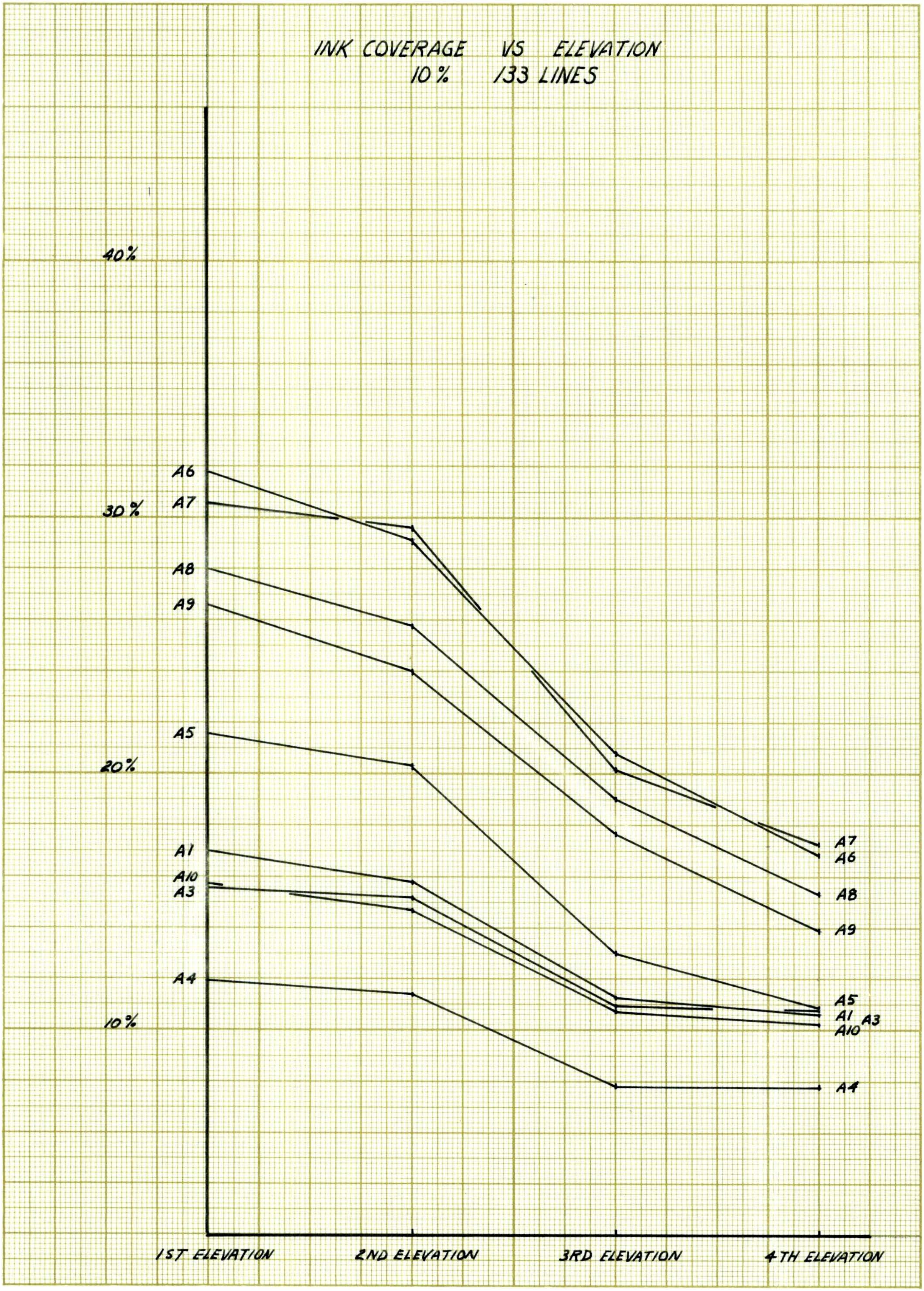
133 Lines

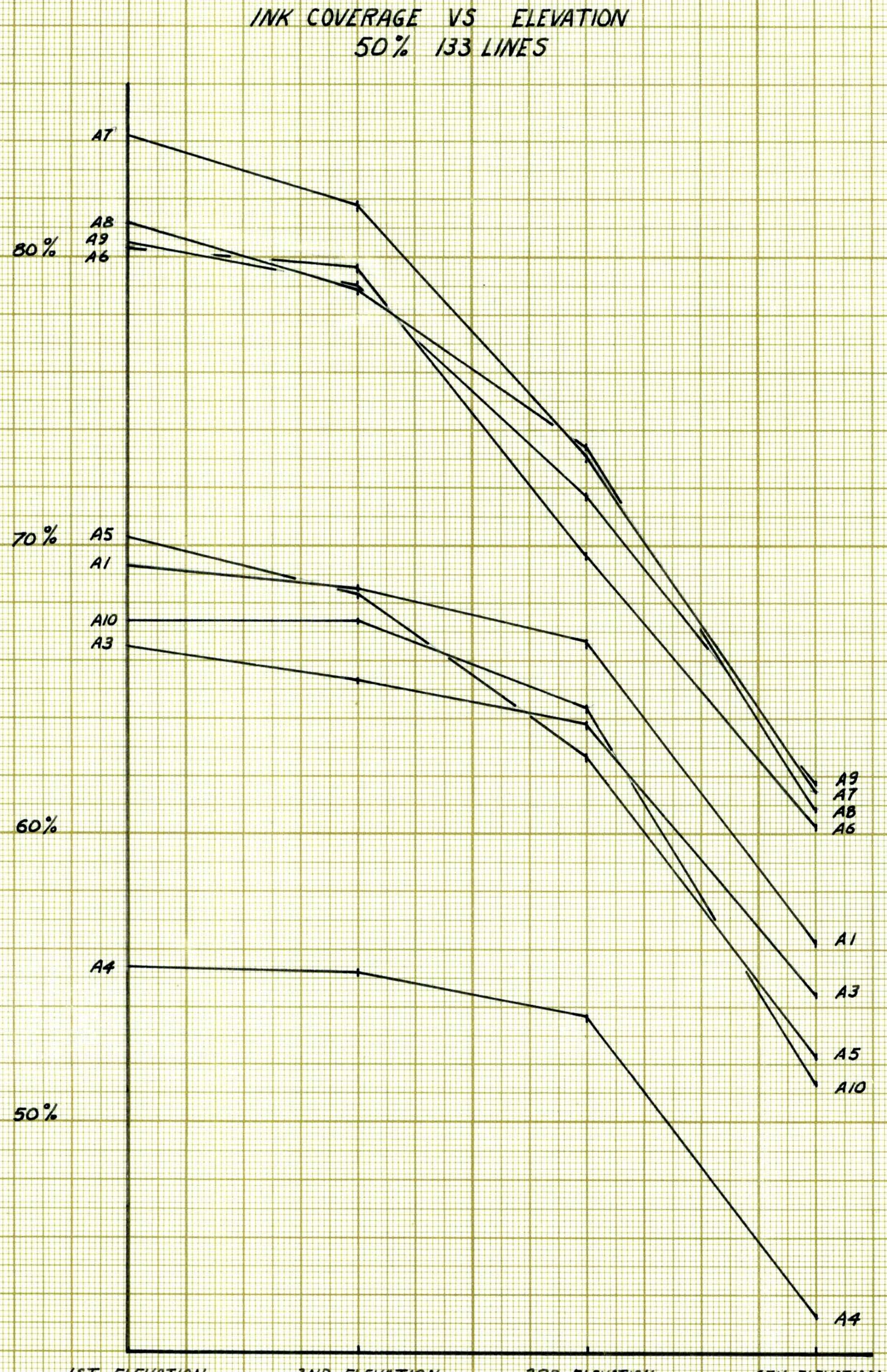
Sample No.	A	B	C	D
10%				
A1	1.2	4.5	0.7	6.4
A10	1.0	4.0	0.5	5.5
A3	0.4	4.3	0.1	4.8
A4	0.5	3.6	0.0	4.1
A5	1.3	7.3	2.2	10.8
A6	2.7	8.3	4.0	15.0
A7	0.9	9.5	2.9	13.3
A8	2.2	6.8	3.7	12.7
A9	2.6	6.3	3.8	12.7
50%				
A1	0.8	1.8	10.5	13.1
A10	0.0	3.0	13.1	16.1
A3	1.2	1.5	9.4	12.1
A4	0.2	1.5	10.5	12.2
A5	2.0	5.6	10.5	18.1
A6	0.6	10.0	9.5	20.1
A7	2.4	8.7	11.6	22.7
A8	2.3	5.6	12.4	20.3
A9	1.5	7.3	10.0	18.8
90%				
A1	0.5	3.9	8.8	13.2
A10	0.3	4.2	13.9	18.4
A3	0.6	3.9	9.4	13.9
A4	0.0	13.0	6.7	19.7
A5	0.4	2.7	10.3	13.4
A6	0.2	3.7	11.4	15.3
A7	0.2	1.6	10.0	11.8
A8	0.5	2.5	4.6	7.6
A9	0.8	3.4	5.6	9.8

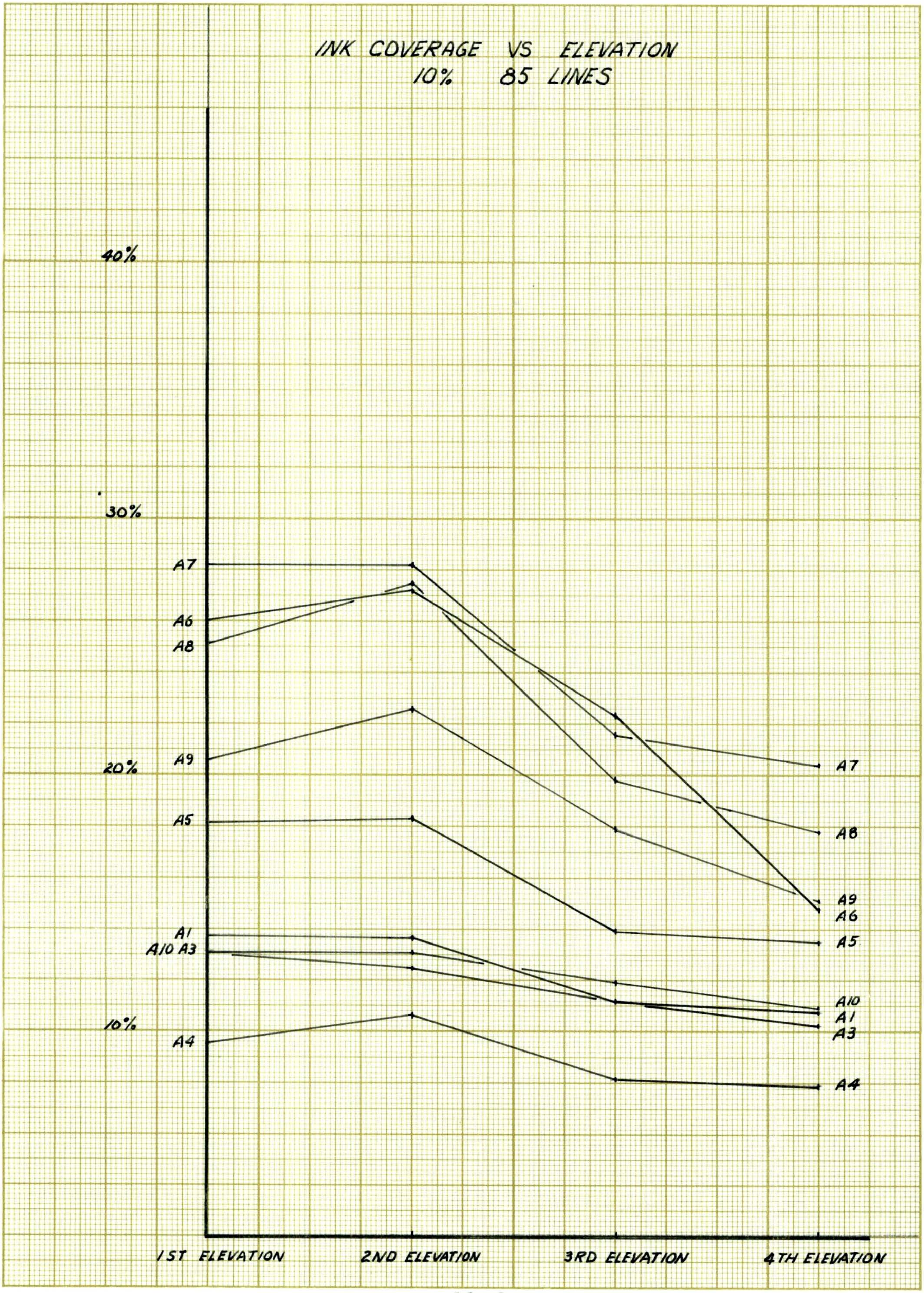
85 Lines

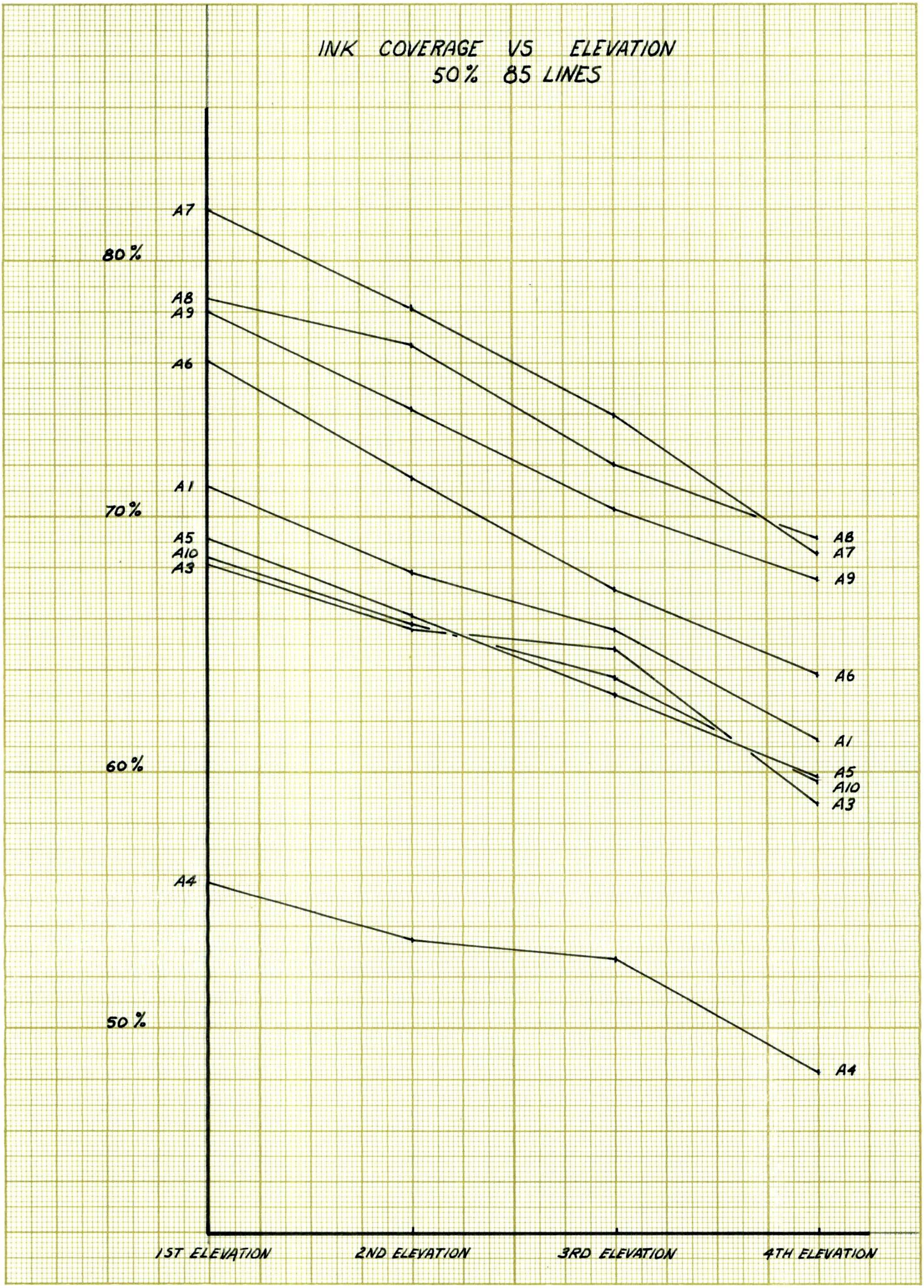
Sample No.	A	B	C	D
10%				
A1	0.0	2.5	0.5	3.0
A10	0.0	1.2	1.0	2.2
A3	-0.6	1.3	1.0	2.9
A4	+1.1	2.5	0.2	1.6
A5	+0.2	4.4	0.4	4.6
A6	+1.2	4.9	7.5	11.2
A7	0.0	6.6	1.2	7.8
A8	+2.3	7.7	2.0	7.4
A9	+2.0	4.7	2.8	5.5
50%				
A1	3.4	2.2	4.4	10.0
A10	2.7	2.0	4.0	8.7
A3	2.5	0.8	6.0	9.3
A4	2.2	0.8	4.4	7.4
A5	3.0	3.0	3.3	9.3
A6	4.6	4.4	3.3	12.3
A7	3.8	4.2	5.4	13.4
A8	1.8	4.7	2.9	9.4
A9	3.8	3.9	2.8	10.5
90%				
A1	0.1	5.2	18.2	23.5
A10	0.5	6.4	17.3	24.2
A3	0.9	8.4	13.8	23.1
A4	0.6	6.8	11.8	19.2
A5	2.0	3.3	5.6	10.9
A6	0.5	7.3	11.6	19.4
A7	0.4	2.7	12.5	15.6
A8	0.0	2.2	6.0	8.2
A9	1.2	0.4	11.3	12.9

A — Elevation 1 minus Elevation 2
B — Elevation 2 minus Elevation 3
C — Elevation 3 minus Elevation 4
D — Elevation 1 minus Elevation 4


INK COVERAGE VS ELEVATION
10% 133 LINES
40%
30%
20%
10%
A6
A7
A8
A9
A5
A1
A10
A3
A4
1ST ELEVATION
2ND ELEVATION
3RD ELEVATION
4TH ELEVATION


INK COVERAGE VS ELEVATION
50% 133 LINES
A7
A8
A9
A6
80%
70%
A5
A1
A10
A3
60%
A4
50%
A9
A7
A8
A6
A1
A3
A5
A10
A4
1ST ELEVATION
2ND ELEVATION
3RD ELEVATION
4TH ELEVATION


INK COVERAGE VS ELEVATION
10% 85 LINES
40%
30%
20%
10%
A7
A6
A8
A9
A5
A1
A10 A3
A4
A7
A8
A9
A6
A5
A10
A1
A3
A4
1ST ELEVATION
2ND ELEVATION
3RD ELEVATION
4TH ELEVATION


INK COVERAGE VS ELEVATION
50% 85 LINES
A7
80%
A8
A9
A6
A1
70%
A5
A10
A3
60%
A4
50%
A8
A7
A9
A6
A1
A5
A10
A3
A4
1ST ELEVATION
2ND ELEVATION
3RD ELEVATION
4TH ELEVATION

DISCUSSION

Upon investigation of the data in Table III a tendency of the ink coverage range to vary was noticed. This tendency expressed itself in Column D. Smooth papers appear to have a smaller range, that is, a smaller change in ink coverage than rough papers. This behavior would suggest that paper with the smallest range would have the better printing quality.

Figures 1 through 4 show the effect of the number of lines on the ink coverages. The range of ink coverage in the 133 line areas is decidedly greater than in the 85 line areas. This would indicate that printing pressures in the 133 line areas would be more critical than in the others.

Due to the very poor printing results in the 90% etch areas, it was decided to graph the ink coverages in the 10% and 50% etch areas only. These graphs show the influence of the variation in pressure caused by the different elevations of the printing plate upon the ink doverage. The graphs indicate that within the area of good printing a proportionally smaller change in pressure will cause a greater change in ink coverage than in the poor areas of printing. This is shown best in the graphs of the 10% etch areas (Figures 1 and 3). The tendency is also evident in the graphs of the 50% etch areas (Figures 2 and 4).

Table III Columns A, B, and C show along with Figures 1 through 4 that the change in ink coverage varies from elevation to elevation.

The differences between the actual ink coverages of the different tone areas and the expected coverages were in most cases considerable. These differences along with the extensive filling in of the 90% etch areas would suggest that an excess of ink was used in the printing process. It is believed that if less ink had been used, the ink coverages would more closely have approached the theoretical.

Tables I and II show that in all cases the best print fell within the range of the plate. This was a criterion of the printing process. The tables also show that optimum pressure for best print quality could have fallen between the elevations; some of the tones chosen as "best print" have defects.

From the nature and/or quantity of the data gathered, a mathematical analysis of this print process is not possible at this time.

SUMMARY

Under the conditions of this experiment the following conclusions can be made:

The range in ink coverage varied due to the paper used and the number of lines of the half-tone print.

Within the area of good printing a small change in pressure caused a large change in ink coverage.

The change in ink coverage varied from elevation to elevation.

An excess of ink was used in the printing process.

The optimum pressure for printing might have fallen between the elevations.

At this time the nature and quantity of data does not lend itself to mathematical analysis.

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