ANALYSIS OF INK FILM THICKNESS ON SCREENLESS LITHOGRAPHIC PLATES BY MICROSCOPY

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Abstract: Screenless lithography is used in applications requiring reproductions superior to those obtained with halftone processes. While this process has been in use for many years, its working mechanisms have only recently been investigated. Past studies have investigated many of the factors which contribute to the continuous tone effect of screenless printing, but none have determined if ink film thickness variation is a contributing factor.

Positive working lithographic plates were exposed to control scales, processed, inked, and allowed to dry. These plates were physically cross-sectioned and observed under a high magnification microscope to determine if variations in ink film thickness exist.

Results showed that variations did indeed exist. These variations contribute to the ability of screenless lithography to reproduce continuous tone originals.

INTRODUCTION

The screenless lithographic process is nothing new. It was used extensively prior to the invention of the halftone screen. Since its inception, screenless lithography has come to be known by a wide variety of names: grainless lithography, random dot printing, unscreened printing, continuous tone lithography, random grain printing, and even controlled scum. The most widely used designation is screenless lithography and this term, or simply screenless, will be used.

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Screenless lithography will be defined as the process of using positive working lithographic plates, without a screen pattern, for reproducing continuous tone originals.

Whether or not screenless is a continuous tone process has been a source of confusion for some time. This, of course, depends on how one defines continuous tone. For practical purposes, continuous tone is recorded information which the naked eye cannot resolve into discrete points. Continuous tone printing will be defined in this paper as the ability to print an ink film which varies in thickness between areas of different density and has a randomly distributed grain pattern. The purpose of this study is to determine if ink film thickness varies on screenless lithographic plates.

THEORY OF SCREENLESS LITHOGRAPHY

The development of diazo oxides such as o-quinon diazides, diazo phenols and their derivatives have enabled the production of modern screenless lithographic plates. These light sensitive compounds are positive working; they become **soluble** upon exposure to UV radiation.

A grained aluminum plate is coated evenly with a solvent based mixture containing a diazo oxide compound. When the coating has dried, it is exposed through a continuous tone positive film. Solubilization of the coating proceeds from the surface down towards the plate base, the depth being controlled by the amount of radiation transmitted through the positive film image. The exposed plate is processed in an alkaline solution which dissolves the exposed portions of the coating. Varying areas of ink receptivity are formed by the coating which remains in the "hill and valley" structure of the plate surface. This concept is readily illustrated by Pobboravsky and Pearson's (1967) model of inverted cones shown in Figure 1. As exposure increases the ink receptive area of the cones is reduced. Highlights, having received the most exposure, will print small areas while shadows, having little exposure, will retain more of the ink receptive coating and print larger areas.

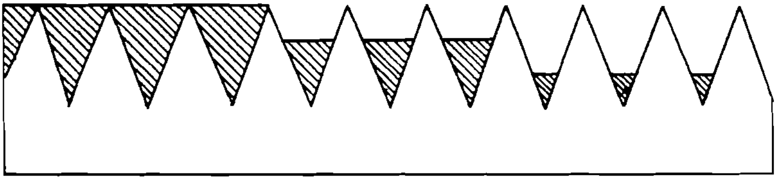

Figure 1. Processed Plate Model

The inverted cone model is only a representation of the image forming mechanism in screenless lithography. Actual plate topography is a randomly grained surface as shown in Figure 2.

Figure 2. Actual Plate Topography Model

Many studies have explored the variables which influence tone reproduction characteristics of screenless plates, but few have postulated the exact working mechanisms of such plates. Pobboravsky and Pearson (1967 p. 251) state: "Although screenless lithography is called a continuous tone process, the printed image is not a continuous film of ink, but is made up of randomly distributed spots of ink that vary in size and are irregularly shaped." They worked under the premise that "the lightness of a given tone seems to be due to the average area of a large number of ink spots that cover the paper." Other sources indicate that ink film thicknesses vary within the plate.

The fact that the grained plate surface both produces and markedly influences the ability to achieve the screenless effect is not challenged. The objective is to analyze screenless lithographic plates to determine if there actually is variability in ink film thicknesses which contributes to their ability to reproduce continuous tone originals.

METHODOLOGY

Introduction

A conventional reflection densitometer was not useful for measuring ink film thickness as it integrates substrate influences, scattering of light within the ink film, printed area, and a number of other factors which do not necessarily relate to changes in ink film thickness. A densitometer measures changes in reflection density caused by changes in actual ink film thickness, but these changes are not necessarily numerically proportional to changes in ink film thickness, as Yule (1967 pp. 205-216) points out.

Ink films were measured directly from plates. The splitting of an ink film between the plate and blanket of an offset press and subsequent splitting again between blanket and paper greatly reduces the film's thickness, making it more difficult to measure. This splitting could also induce variability. For these reasons, measurement directly from the plate was chosen.

General Methodology

Four different brands of positive working lithographic plates were used: Enco P-30, Kodak P, Fuji FPD, and Howson-Algraphy Alympic Gold. All plates were exposed and processed by hand according to the manufacturer's recommendations. Kodak T-14 and T-21 control scales were used to produce areas of differing exposure. Their progressively stepped density ranges of 1.63 and 1.77, respectively, exceeds those found in continuous tone separations normally used for screenless work.

An offset lithographic duplicator was used for running tests prior to inking full size plates on a standard offset lithographic press. The press provided precise control and uniform inking. Initially, plates were inked with standard sheetfed inks and conventional fountain solutions. Plates were removed from the press and the ink was allowed to completely dry prior to preparation for the microscope.

Plate Preparation

A wide variety of methods was used for preparing the plates for the microscopes. Metallurgical studies of thin gauge plates are commonly done by first casting the sample in resin. A cast serves as a holding device during the subsequent polishing operations and helps eliminate edge deformation induced during the abrasive polishing of soft metals. Next, the cast is subjected to progressively finer grits of emery paper. This is followed by another progression of polishings with aqueous suspensions of silica particles on rotating, cloth covered wheels. Final polishing particle size is .06 microns, considerably smaller than the ink pigment particles being observed. This extremely fine polishing is necessary to eliminate distortion and deformation in the cross-sectioned plate surface caused during the initial cutting of the plate.

Difficulties with smearing and distortion of the soft aluminum plate material were encountered, particularly at the plate edges. Further problems were caused by the soft, flexible properties of the photopolymer and ink layers. Experimentation with the polishing technique minimized distortion and provided acceptable samples.

Another method common to sample preparation for metallurgical studies utilizes a silicon carbide abrasive cut-off wheel with a continuous flow of cutting fluid. The sample is cast in the same resin as before and cross-sectioned using the wheel. Subsequent polishing is not used. This method yielded samples with 80 percent of their area undistorted and suitable for viewing with a microscope. Because sample preparation time was substantially reduced, this method was used for preparing all subsequent samples.

Scanning Electron Microscopy

Initially the scanning electron microscope (SEM) was selected for measuring ink film thickness because of its ability to resolve extremely fine detail. An optical microscope has a limit of about 2000x before image quality becomes unsatisfactory. The SEM provided far greater magnifications.

Difficulties, however, were encountered when using the SEM. A phenomenon referred to as "charging", caused by the dielectric property of the epoxy material, degraded resolution to an unacceptable level. Attempts to eliminate the casting material using a temporary clamping device were unsuccessful, but charging was reduced with conductive epoxies. Insufficient contrast between the plate's light sensitive coating and the ink film did not allow accurate judgment of the ink film thickness with the SEM. This was due the similarities in electrical conductivity between the two materials and the fact that a standard SEM relies on differences in topography and conductivity to produce an image. Topographic differences were eliminated in the previously mentioned polishing operation. Without different conductivity between ink and photopolymer layers, image contrast was nonexistent. Attempts to find a conductive ink with the correct rheologicthe correct rheological properties were unsuccessful.

Due to aforementioned difficulties, use of the SEM was abandoned. An electron-probe microanalyzer probably would allow accurate analysis of plate samples. Diazo-oxides, inks, and aluminum are markedly different in elemental composition and would exhibit excellent contrast between layers. Electron-probe microanalysis was not readily available for use in this study and no experimental validity of this theory is provided.

Flourescent Microscopy

Initial experimentation with a conventional light microscope showed that contrast was also a problem with this instrument, even with inks complementary in color to the light sensitive coating. Many types of optical microscopy exist and research suggested ultraviolet (UV) microscopy might be suitable.

Three distinct advantages of the UV microscope over the SEM are elimination of charging problems, ease of sample mounting, and reduced time necessary for analyzing each sample. With the SEM, one must wait for vacuum chamber draw-down, instrument adjustment for optimum picture quality, and for the chamber to return to ambient pressure after viewing each sample.

Maximum interlayer contrast is obtained with the UV microscope by using an ink which fluoresces. Fluorscent inks suitable for line work and coarse halftone lithography are available, but inks suitable for screenless applications are those which perform well with extremely fine (300 line) halftone work.

Test plates were inked on a duplicator with an ink which fluoresced blue, allowed to dry, and then prepared for the UV microscope. Again, insufficient contrast between layers was encountered. The blue fluorescence of the ink was very similar in color to the visible portion of UV radiation reflected by the sample. Thus, the color contrast was inadequate for reliable interpretation of ink film thickness variability. Filtering out all visible light from the UV radiation source reduced its intensity to a level where fluorescence of the ink layer was no longer visible.

Although many inks are available which fluoresce in colors complementary to the blue-purple end of the visible spectrum, such as the Dayglo brand inks,press runs proved such inks unsuitable for screenless lithography. Plates which had five different control scale steps prior to inking would provide only one or two differently inked steps. Considerable manipulation of the ink-water balance proved these inks would simply not function properly with screenless lithographic plates. Even so, a plate prepared for the microscope showed the fluorescent properties of this type of ink would provide the contrast necessary for evaluation of ink film thickness.

Some types of conventional process yellow lithographic inks will fluoresce. Studies showed that their intensity of fluorescence was far below that of inks specifically formulated for fluorescent properties. Yellow inks by themselves were ruled inadequate.

Press tests of Dayglo ink modified with both conventional process yellow and/or fluorescent blue to improve its rheological characteristics were performed. A mixture, by volume, of 40 percent Dayglo and 60 percent fluorescent blue gave the best compromise of fluorescence and rheological properties. Fluroescent color of these inks varied with the type of UV source used. A UV source was necessary during press operation to accurately determine optimum inking of the plates.

After a test plate assured the success of this ink mixture under the microscope, all four manufacturers' plates were inked and prepared for viewing with the UV microscope. Samples of each plate type were analyzed and their ink film thicknesses recorded. Measurements were made with a reticle in the microscope's ocular that was calibrated with a standard stage micrometer. At least five readings from each step of the control scale were taken to provide a mean reading of the ink film. These readings were taken at 0.5 mm intervals.

RESULTS

Once a viable technique providing sufficient interlayer contrast was established, measurement of ink film thicknesses progressed smoothly. A greater number of Howson-Algraphy plates were analyzed due to their ability to reproduce a longer tone range. In all samples the ink film thickness became progressively thicker from high to low exposure areas. (See Figures 4-13.) Linear regression was used to obtain the best fitting straight line in Figures 6-13. This straight line gives an overall indication of plate contrast. Exponential curve fitting was necessary in Figures 4 and 5 because of the plates' non-linear nature.

A few plate samples (Howson-Algraphy Plate 2, for example) showed thicknesses which initially increased, decreased slightly for one step, and subsequently continued increasing. (See Tables 1-10.) This deviation is attributed to process variability. One factor which contributed to this was hand processing of the plates; it is universally recognized that uneven results can be generated by this procedure.

One of the most interesting phenomenon discovered was the variability of ink film thicknesses within each control scale step of uniform exposure. This appears to be caused by the differences in plate topography, and the consequential differences in the light sensitive coating thicknesses caused by the grain. The maximum standard deviation.of ink film thickness within any plate step was .69 microns, while the mean for the maximum standard deviations of all plates was .45 microns. The standard deviation of ink film thickness within the plates was 9.6 percent of the total thickness variation from highlights to shadows. (See Table 11.) Thus, while intra-step variation of thickness did occur, the degree of variation was not significant in comparison to total ink film thickness variation.

All plates showed low contrast (Δthichness/ΔLogE) in the highlight areas. The Fuji, Enco, and Kodak plates had markedly increased contrast in the shadow areas. Shadow contrast in the Howson-Algraphy plates was much lower than in the other plates. Observation of plate topography leads to the following explanation of contrast characteristics.

The method used to grain a plate, and the resulting plate topography, highly influence the relationship between exposure and corresponding ink film thickness. This concept can be understood by referring to the solubility plate model in Figure 3.

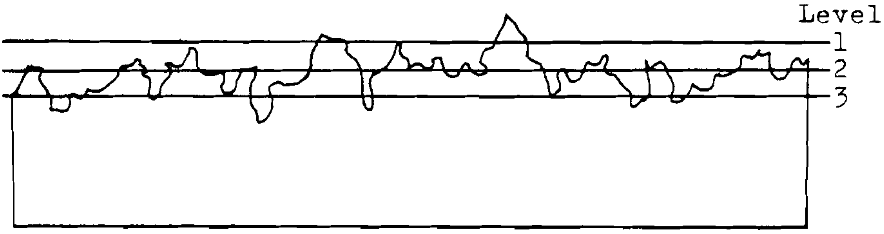

Figure 3. Solubility Plate Model

Solubilization to level I, representing a shadow area, would produce little change on this plate. Thus, in this plate, the shadow area would be low in contrast. An exposure to level 2 would produce a considerable change in printing areas and a sharp rise in contrast. As exposure increased and solubilization reached level 3, the proportion of light sensitive coating affected would be less and contrast would again be reduced. Thus, how the grain is formed - its depth, randomness, and shape, highly influences the contrast and tone reproduction characteristics of the resulting plate.

A factor which must be kept in mind when speaking of a plate's application to screenless lithograpy is the relationship between ink film thickness and exposure. Plates which produce a wide range of thickness, but in a narrow exposure range are of limited value. Tone compression would be extensive and the reproduction would not resemble the original.

Plates most suitable for screenless lithography yield the greatest differences in ink film thickness over a wide exposure range. Graphically, this is represented by a long straight line section of a gamma (slope) greater than zero. Although a tone reproduction study comparing printing density to density of the original would be necessary to determine the useful exposure range, exposures which do not produce a change in ink film thickness are not useful for tone reproduction purposes.

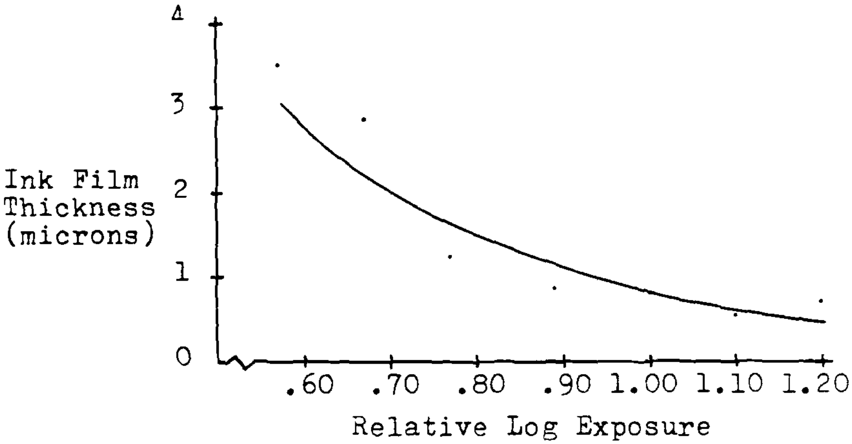

Figure 4. Ink Film Thickness vs. Relative Log Exposure for Fuji Plate 1

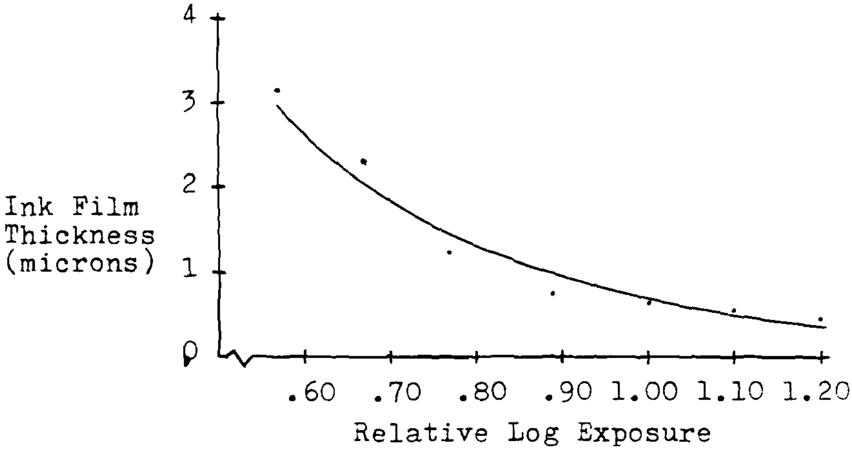

Figure 5. Ink Film Thickness vs. Relative Log Exposure for Fuji Plate 2

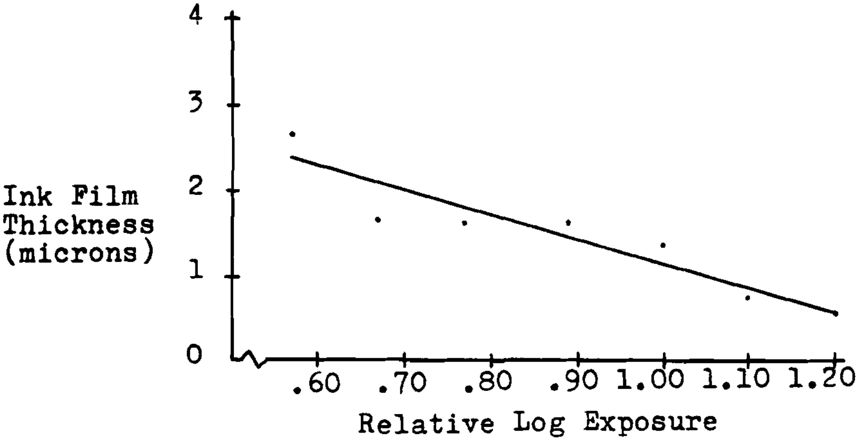

Figure 6. Ink Film Thickness vs. Relative Log Exposure for Kodak Plate I

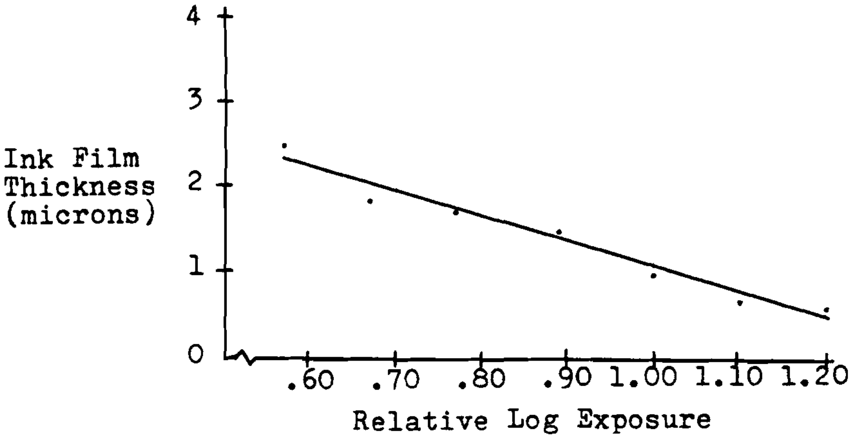

Figure 7. Ink Film Thickness vs. Relative Log Exposure for Kodak Plate 2

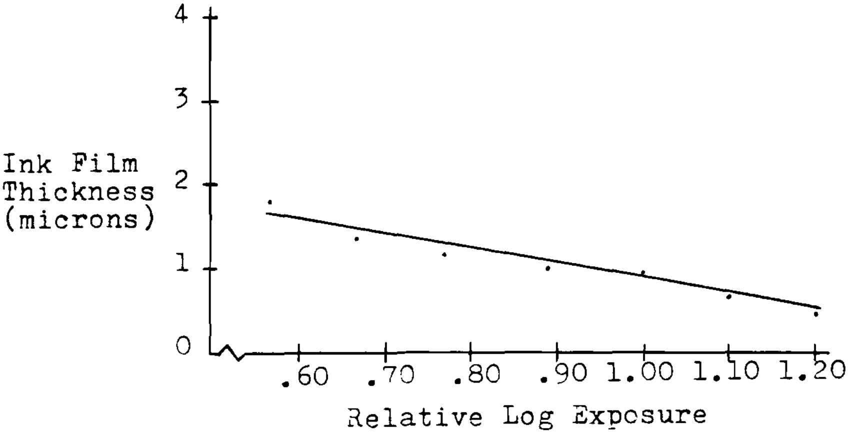

Figure 8. Ink Film Thickness vs. Relative Log Exposure for Enco Plate 1

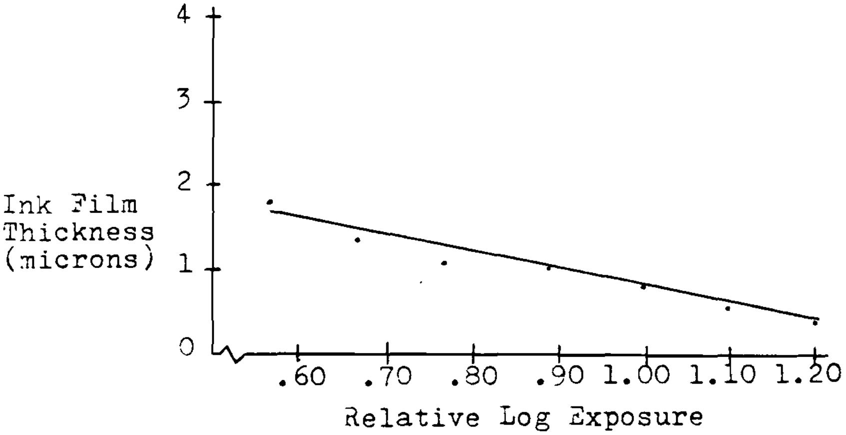

Figure 9. Ink Film Thickness vs. Relative Log Exposure for Enco Plate 2

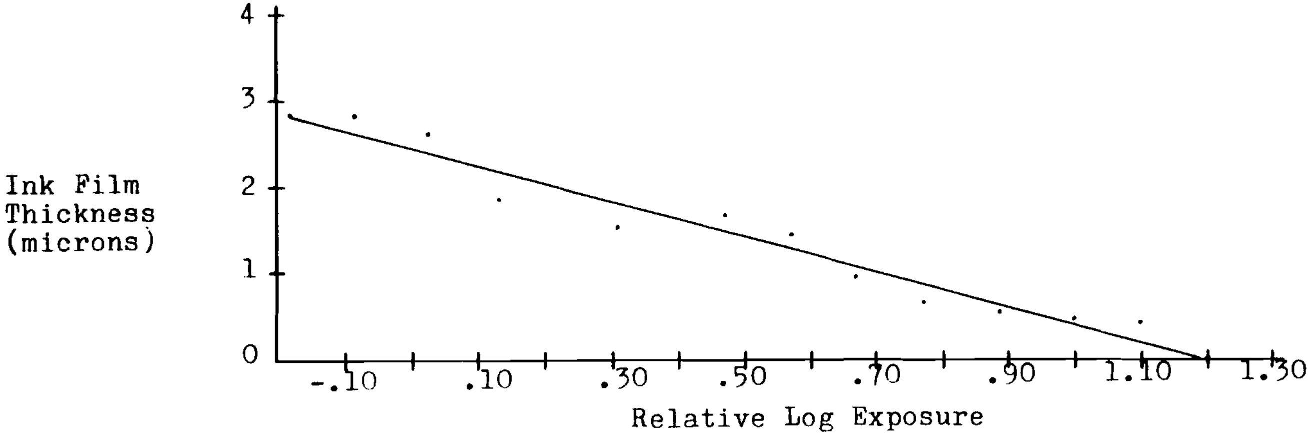

Figure 10. Ink Film Thickness vs. Relative Log Exposure for Howson-Algraphy Plates 1 & 5

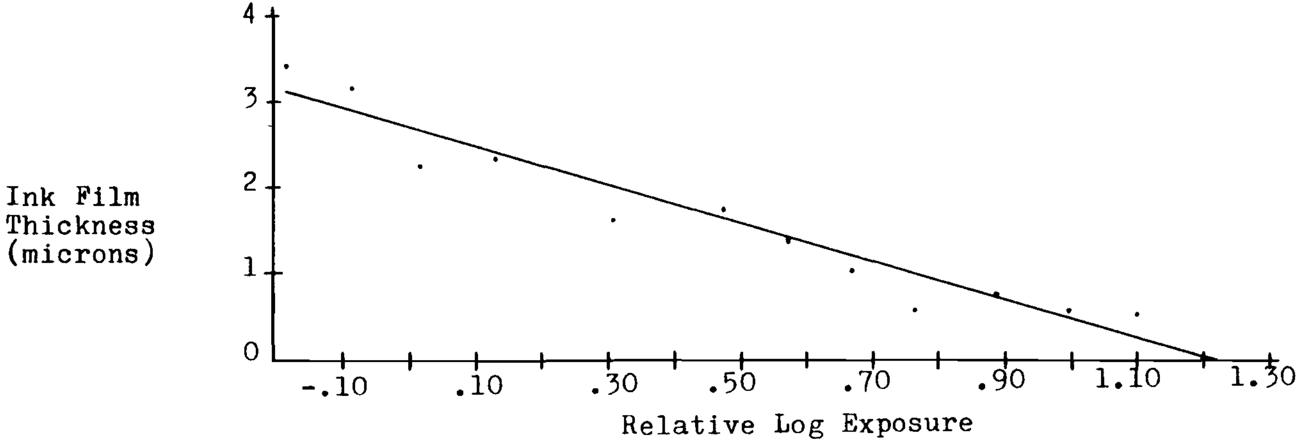

Figure 11. Ink Film Thickness vs. Relative Log Exposure for Howson-Algraphy Plates 2 & 6

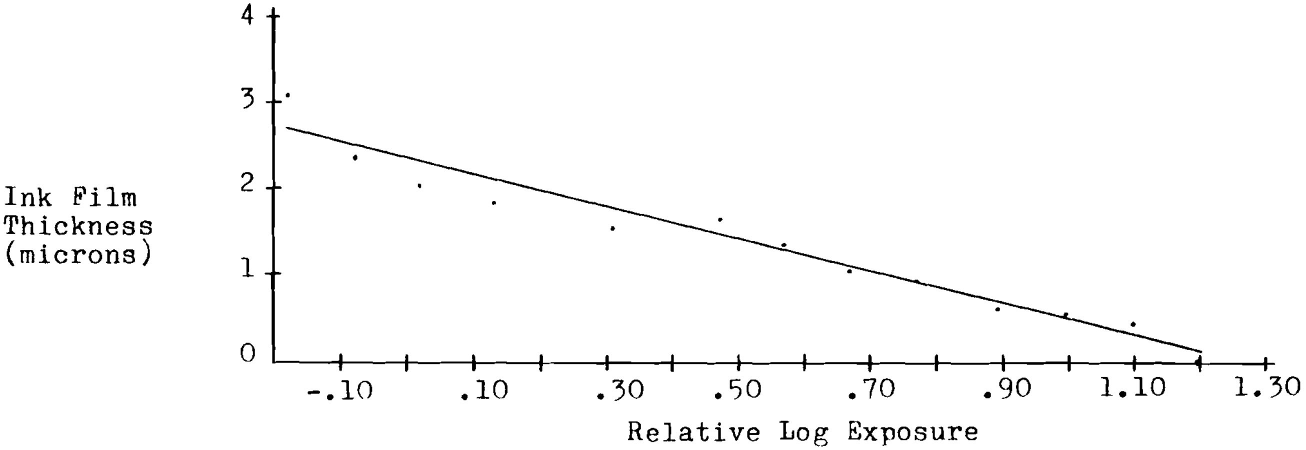

Figure 12. Ink Film Thickness vs. Relative Log Exposure for Howson-Algraphy Plates 3 & 7

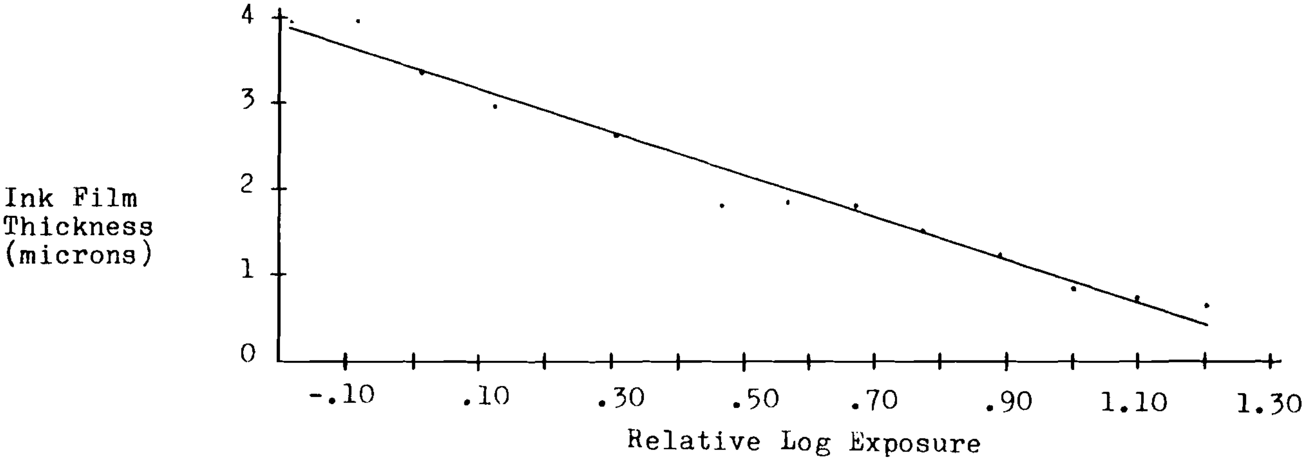

Figure 13. Ink Film Thickness vs. Relative Log Exposure for Howson-Algraphy Plates 4 & 8

TABLE 1

Fuji Plate 1

Rel. Log E	Step	Mean	S.D.	Var.
1.20	1	.70	.16	.03
1.10	2	.63	.13	.02
1.00	3	.81	.13	.02
.89	4	.87	0	0
.77	5	1.22	.13	.02
.67	6	2.90	.35	.17
.57	7	3.54	.38	.20

TABLE 2

Fuji Plate 2

Rel. Log E	Step	Mean	S.D.	Var.
1.20	1	.41	.16	.03
1.10	2	.58	0	0
1.00	3	.63	.13	.02
.89	4	.75	.16	.03
.77	5	1.22	.13	.02
.67	6	2.32	.46	.29
.57	7	3.13	.24	.08

TABLE 3

Kodak Plate 1

Rel. Log E	Step	Mean	S.D.	Var.
1.20	1	.58	.20	.06
1.10	2	.75	.16	.03
1.00	3	1.39	.38	.20
.89	4	1.62	.16	.03
.77	5	1.62	.33	.15
.67	6	1.68	.13	.02
.57	7	2.67	.24	.08

(All measurements are in microns.)

TABLE 4

Kodak Plate 2

Rel. Log E	Step	Mean	S.D.	Var.
1.20	1	.58	0	0
1.10	2	.64	.13	.02
1.00	3	.99	.16	.03
.89	4	1.45	.20	.06
.77	5	1.68	.24	.08
.67	6	1.80	.13	.02
.57	7	2.49	.20	.06

TABLE 5

Enco Plate 1

Rel. Log E	Step	Mean	S.D.	Var.
1.20	1	.46	.16	.03
1.10	2	.64	.13	.02
1.00	3	.93	.13	.02
.89	4	.99	.16	.03
.77	5	1.16	.20	.06
.67	6	1.39	.13	.02
.57	7	1.80	.24	.08

TABLE 6

Enco Plate 2

Rel. Log E	Step	Mean	S.D.	Var.
1.20	1	.41	.16	.03
1.10	2	.58	.20	.06
1.00	3	.81	.24	.08
.89	4	1.04	.16	.03
.77	5	1.10	.38	.20
.67	6	1.39	.24	.08
.57	7	1.80	.42	.14

(All measurements are in microns.)

TABLE 7

Howson-Algraphy Plate 1

Rel. Log E	Step	Mean	S.D.	Var.
1.20	1	0	0	0
1.10	2	.41	.15	.03
1.00	3	.46	.16	.03
.89	4	.52	.14	.03
.77	5	.63	.14	.03
.67	6	.93	.20	.06
.57	7	1.44	.48	.33
.47	8	1.68	.28	.12
.31	9	1.51	.22	.07
.13	10	1.86	.50	.37
.02	11	2.61	.29	.12
-.08	12	2.84	.32	.16
-.18	13	2.84	.31	.14

TABLE 8

Howson-Algraphy Plate 2

Rel. Log E	Step	Mean	S.D.	Var.
1.20	1	0	0	0
1.10	2	.52	.20	.06
1.00	3	.58	.17	.04
.89	4	.75	.23	.08
.77	5	.58	.24	.08
.67	6	1.04	.28	.12
.57	7	1.37	.24	.08
.47	8	1.74	.20	.06
.31	9	1.62	.16	.03
.13	10	1.32	.20	.06
.02	11	2.26	.32	.14
-.08	12	3.19	.29	.12
-.18	13	3.42	.69	.66

(All measurements are in microns.)

TABLE 9

Howson-Algraphy Plate 3

Rel. Log E	Step	Mean	S.D.	Var.
1.20	1	0	0	0
1.10	2	.46	.16	.03
1.00	3	.58	.14	.03
.89	4	.63	.14	.03
.77	5	.93	.20	.06
.67	6	1.16	.28	.12
.57	7	1.36	.48	.33
.47	8	1.65	.33	.16
.31	9	1.57	.16	.03
.13	10	1.86	.26	.09
.02	11	2.03	.35	.17
-.08	12	2.38	.24	.08
-.18	13	3.07	.33	.15

TABLE 10

Howson-Algraphy Plate 4

Rel. Log E	Step	Mean	S.D.	Var.
1.20	1	.63	.14	.03
1.10	2	.75	.16	.03
1.00	3	.81	.14	.03
.89	4	1.22	.17	.06
.77	5	1.51	.46	.32
.67	6	1.80	.40	.24
.57	7	1.85	.67	.82
.47	8	1.80	.13	.02
.31	9	2.61	.35	.17
.13	10	2.96	.24	.08
.02	11	3.36	.33	.15
-.08	12	3.94	.33	.15
-.18	13	3.94	.33	.15

(All measurements are in microns.)

TABLE II

Statistical Significance of Intra-Plate Deviation (all data in microns)

Plate	ΔThickness	Max S.D.	% of ΔT	S.D.	% of ΔT
Enco	1.34	.24	18	.16	12
Enco	1.39	.42	30	.26	19
Fuji 1	2.84	.38	13	.16	5
Fuji 2	2.72	.46	17	.18	6
Kodak 1	2.09	.38	18	.23	11
Kodak 2	1.91	.24	13	.15	7
H.A. 1	2.43	.50	21	.25	10
H.A. 2	2.90	.69	24	.25	9
H.A. 3	2.61	.48	18	.24	9
H.A. 4	3.31	.67	20	.30	9

Legend

ΔThickness = Total difference in ink film thickness from thinnest areas to thickest areas

Max. S.D. = Maximum standard deviation of any scale step

S.D. = Mean value of the standard deviations

% of ΔT = Percent of thickness which the standard deviation represents

CONCLUSION

Variations in ink film thickness on screenless lithographic plates were shown to exist both in areas of uniform exposure and in areas of differing exposure. The variations between areas of differing exposure were for more significant than those within uniformly exposed areas, and contribute significantly to the superior tone reproduction characteristics of these plates.

Screenless lithography is capable of better gray scale reproduction compared to halftone lithography because it prints both varying areas of ink and varying thickness of ink. The concept is similar to that of variable depth/ variale area gravure.

With the knowledge that ink film thickness variation occurs in the process, the screenless lithographic printer may better understand the process and choose methods/materials which are compativle with the desired optimum results.

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APPENDIX A

MATERIALS

- Kodak control scales T-14 and T-21
- Lithkemko sea mist fountain solution
- Inks

Ronico - Conventional Black
Process Yellow
Invisible Blue EX 235
Magnetic Iron Oxide Pigment (53%) A4177

Dayglo - Arc Yellow (R1-16)

- Plates

Enco P-30 (Azoplate, Somerville, NJ)
Kodak Polymatic P (Eastman Kodak Company, Rochester, NY)
Fuji Positive FPD (Imported by Roberts & Porter, Inc., Des Plaines, IL)
Howson-Algraphy Alympic Gold processed with special screenless chemistry (Howson-Algraphy, Carlstadt, NJ)

- Presses

Itek 11-15 Duplicator
Heidelberg Cord Offset 18 x 24¼

- Buehler Cutter 10-1030 AB with silicon carbide discs

Bausch & Lomb table-top stereoscopic
Bausch & Lomb optical bench microscope
Leitz Wetzlar with L-2 Lamp (UV) and HBO Mercury Vapor Lamp
International Scientific Instruments ISI-40 (SEM)

APPENDIX B

CURVE FITTING

Figures 3 & 4 - Exponential Curve Fitting

Equation: $y = ae^{bx}$

	a	b	r^2*
Figure 3	14.46	-2.80	.85
Figure 4	17.02	-3.20	.95

Figures 5-12 - Linear Regresion Curve Fitting

Equation: $y = a_1 + a_0$

	a	b	r^2*
Figure 5	3.94	-2.79	.87
Figure 6	3.97	-2.93	.96
Figure 7	2.76	-1.92	.96
Figure 8	2.82	-2.03	.96
Figure 9	2.45	-2.06	.96
Figure 10	2.68	-2.24	.94
Figure 11	2.32	-1.81	.95
Figure 12	3.41	-2.50	.98

*r^2 is the coefficient of determination and indicates the equation fits the experimental data: the closer to 1 it is, the better the fit.