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A comparison of the effects of viscous and immersion processing on small image sizes in originals and duplicates

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A COMPARISON OF THE EFFECTS OF
VISCOUS AND IMMERSION PROCESSING
ON SMALL IMAGE SIZES IN ORIGINALS AND DUPLICATES

by

James D. Fahnestock

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

December 1975

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Special thanks must be given to James Peters of Eastman Kodak Company who arranged all the viscous processing for this thesis.

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ABSTRACT

A test target with three two bar groups was designed around the DIN microfilm standards. It was produced photographically on a litho film. This target was used to discover the factors significant in determining small image sizes and spacings in a microfilm. A 16 mm film holder was designed and built to facilitate the microfilm imaging process. Second and third generation images were made using a liquid-gated contact printing prodedure. It was found that the optical image size on the film at the time of exposure, the image generation, and the optical image size and the density interaction were significant factors in determining small image sizes and separations.

INTRODUCTION

Brief Overview

The major variables affecting viscous processing are time of development and the temperature at which development occurs. The chemistry can be stored in airtight containers for extended periods of time with no noticeable change in its chemical properties. The chemistry is used once and discarded so replenishment is not a factor. The viscous chemistry can be very concentrated and used at high temperatures reducing the volume used and the development time considerably over immersion type processes.

Start up time on a viscous processor is short and the processor can be maintained in control for periods of inactivity with little difficulty. Viscous processing is very clean since once the chemistry is coated on the film there is no way dust or dirt can come in contact with the emulsion and there is no problem with sludge which is encountered in immersion type machine processing.

These things make viscous processing ideal for situations where cleanliness is essential, processing time must be short and periods of inactivity are regularly encountered such as in aerial reconnaissance photography or data storage systems.

The original film may be very important and therefore second and third generation duplicates of the original may be made for actual study. In all cases, if time is important viscous processes are suitable.

Theoretical Background:

Basic Theory

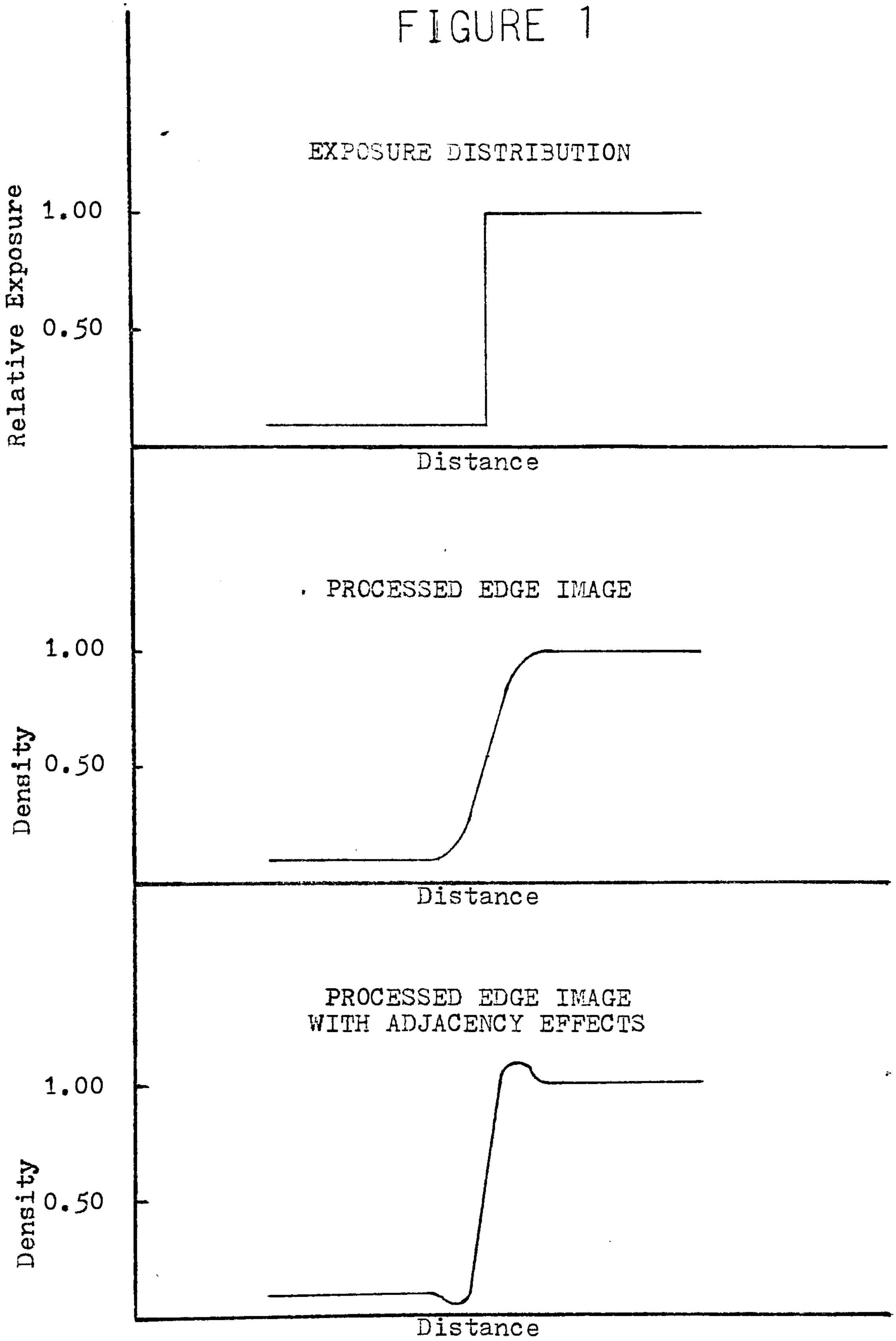
It has been reported that viscous processing yields sharper images than normal machine processing.[1] This reported increased image sharpness is based on the presence of edge or adjacency effects inherent in viscous processed images.

Adjacency effects depend on the diffusion of fresh developer from low to high density and exhausted developer from from high to low density areas.[2] Agitation minimizes the effect; therefore processes without agitation, such as viscous processes, increase this effect.

A common manifestation of adjacency effects is the case of an isolated edge (Figure 1).[3] Adjacency effects are most noticeable in edge images, but they affect images resulting from any form of exposure distribution.[4]

The photographic representation of objects is dependent on the functional relationship between the optical image boundries on the film at the time of exposure and the physical image boundries after processing which are due to the film developer combination. This functional relationship is different for different film developer combinations. This investigation is concerned with the width of images in a photographic film and how they are affected by two different processes.

FIGURE 1


EXPOSURE DISTRIBUTION
Relative Exposure
1.00
0.50
Distance
PROCESSED EDGE IMAGE
Density
1.00
0.50
Distance
PROCESSED EDGE IMAGE
WITH ADJACENCY EFFECTS
Density
1.00
0.50
Distance

Theoretical Background:

Experimental Design Considerations

Two processes are in use for processing small scale images such as microfilm and motion picture soundtracks. The first is immersion processing which is very common and widely used in machine processors produced by many manufactures. The basic processor is a series of tanks containing the necessary chemistry through which the film is moved by some type of transport.

The second is viscous processing which is seldom used and only a few processors using this method of processing have been produced. The basic processor consists of one or more chambers in which viscous chemistry is coated on the film and removed from the film while it is transported by means of rollers.

One processor of each type was used in this investigation. They were chosen for their production of similar characteristics in the film used and their easy accessibility.

EXPERIMENTAL PROCEDURE

Short Review and Objectives

The images measured in this experiment were bars and the spacing between them. The response variable of the experiment was the difference between the measured bar or space width and the width of the corresponding optical image on the film at the time of exposure.

Three two bar target groups with bar widths of 6, 12, and 24 micrometers (on the film) were used with spacings of 18, 36, and 72 micrometers respectively (on the film). Each of the bar-space-bar groups was imaged at two density levels (light bars on a dark background). The high density level was between 1.28 and 1.43 while the low density level was between 0.57 and 0.65. These are specular densities taken from the microdensitometer traces discussed later. The experiment was twice replicated so that a set of images consisting of the following were processed in each processor:

2 high density, large bars and spacing
2 low density, large bars and spacing
2 high density, medium bars and spacing
2 low density, medium bars and spacing
2 high density, small bars and spacing
2 low density, small bars and spacing

The processed images were then contact printed and processed in their respective processors forming second generation images. The second generation images were again printed and processed forming third generation images. The first and third generation images were used in the experiment resulting in the measurement of 64 line widths and 32 spacings. Using this type of experimental design, a statistical analysis of the data was conducted to fulfill the following objectives:

1. To test the hypothesis that a difference exists between the effects of viscous processing and conventional immersion processing on small image sizes and spacings.
2. To test the hypothesis that the generation of the duplicate has an effect on small image sizes and spacings.

3. To test the hypothesis that the overall density difference of an image has an effect on small image sizes and spacings.

4. To test the hypothesis that the optical image size (on the film) has an effect on small image sizes and spacings.

Target Design

The viscous processor used was designed for the processing of microfilm, and microfilm was used as the test film in this experiment. With this in mind, the test target was designed around the DIN standards for microfilm.

These standards specify that a microfilm system must be able to reproduce object line widths of 0.18 millimeters and object spacings of 0.50 millimeters. This is a line-space ratio of 0.18/0.50 or approximately 1:3. The 1:3 line-space ratio was used in the target.

Thirty times reduction is approximately the maximum used in most microfilm systems. Since the smallest object line width distinguishable must be 0.18 millimeters and the maximum reduction is 30X then the smallest image line width that must be distinguishable is 6.0 micrometers. The target was designed so that when it was imaged on the film at the proper reduction it would produce an image line width of approximately 6.0 micrometers.

A one micrometer slit aperture was to be used in the microdensitometer when tracing the images. The maximum length this slit might have was 120 micrometers; therefore the target was designed so that the smallest line image on the film had a length of 240 micrometers to promote ease in tracing and assure that the finite length of the lines had no affect on the density distribution near the center of the lines.

This experiment was designed to operate at two image sizes, but three image sizes were included in the target in case further investigation of the relationship between object size and image size in the two processes is desired. For a scale drawing of the target see Figure 2.

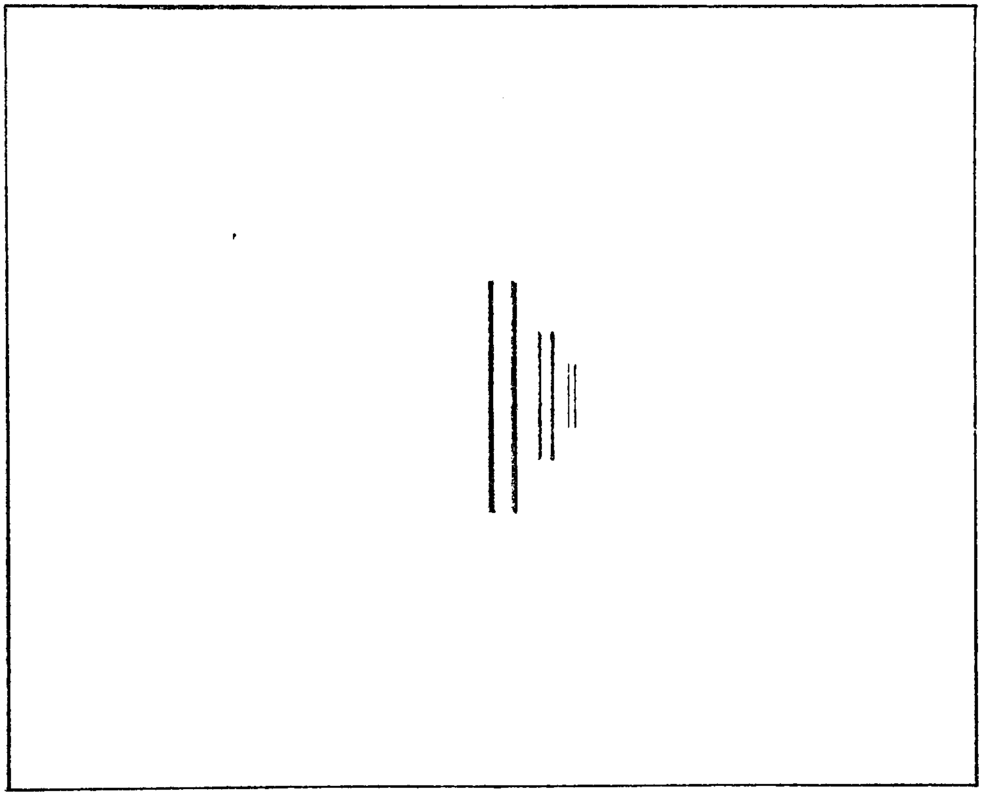
Target Production

A two bar line group with the desired 1:3 bar-space ratio was produced by masking off a piece of opal plexiglass forming white lines on a dark background. The lines' widths were 8.0 millimeters and their lengths 320 millimeters. This gives the total group, two lines and the space between them, dimensions of 40 millimeters by 320 millimeters.

This bar group was back lit by a light box located at 290 millimeters and was imaged on Dupont 710 Cronar Ortho S Litho COS-4 4X5 inch film, emulsion 1025 485. The lens used was an Ilex Wide Angle Acugon No. 153 with a focal length of 65 millimeters and maximum aperture of f/8. The shutter was a Copal-No. 0, and exposures were at f/11 for 32 seconds. Three exposures were made on one piece of film at 42X reduction, 21X reduction, and 10.5X reduction. The film was moved between the exposures to produce the desired spacing between the groupes. The film was processed in Eastman Kodak Kodalith A&B

FIGURE 2

TEST TARGET
Actual Size



developer for three minutes with a fifteen second stop, four minute fix, and ten minute wash. It was dried at 125 degrees Fahrenheit.

This target was imaged on the test film at 32X reduction to produce the desired image sizes.

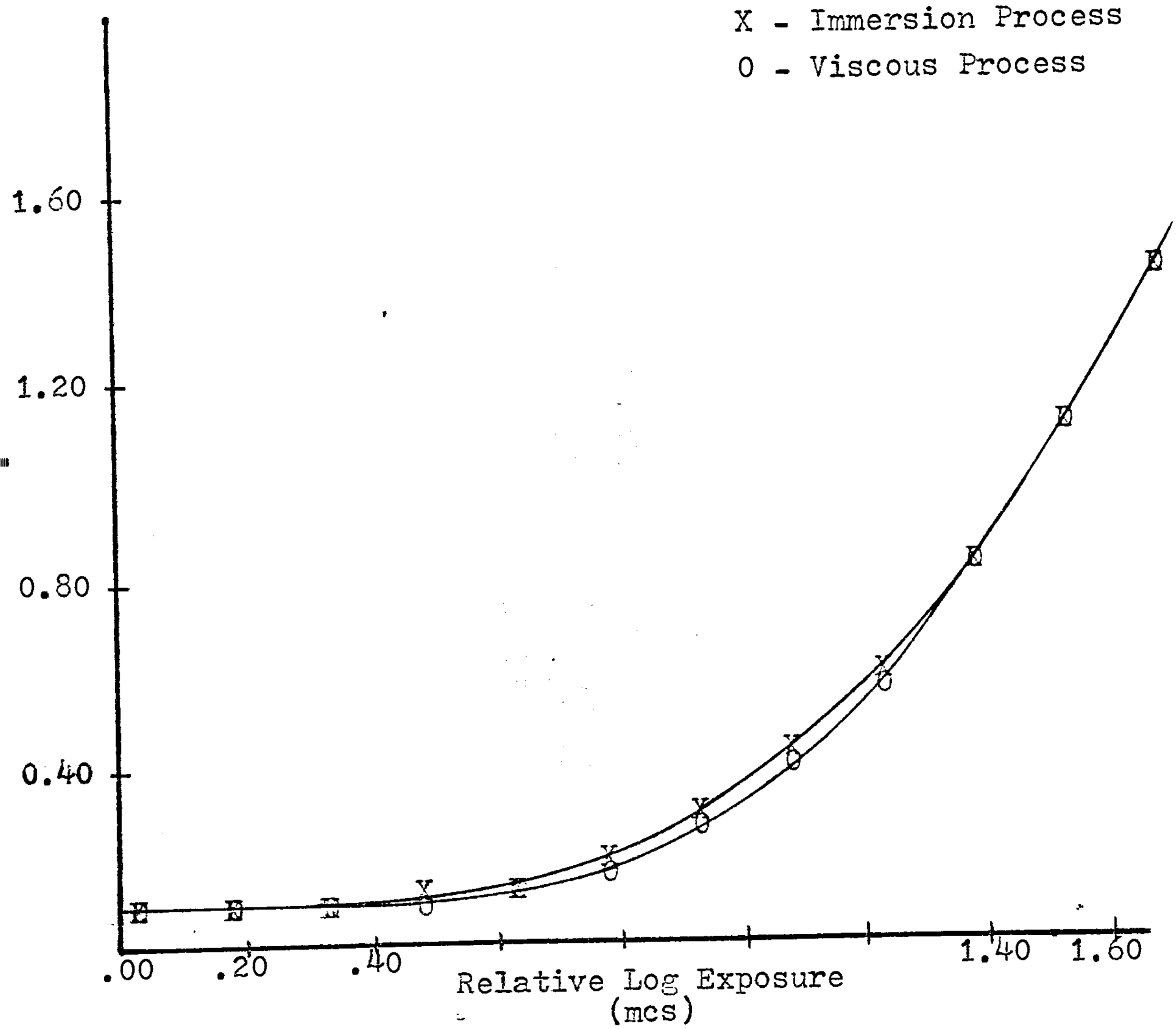
The Test Film

Recordak Fine Grain Print Film 7464 emulsion 035-32 254 was used throughout this experiment. It is a slow, medium contrast film with extremely fine grain and high resolving power. It is used mainly in the production of distribution prints with reversed polarity from camera microfilms or from Recordak Direct Duplicating Intermediate Film 5470/7470.[5]

Two processors were used in this experiment, one viscous and one immersion. The viscous processor was an Eastman Kodak Viscomat, Model 36 and the immersion processor was an Eastman Kodak Recordak Prostar Film Processor, Model DVR.

Two strips of the microfilm were sensitometricly exposed with two exposures on each strip. For details on the sensitometric exposure see Appendix I. One strip was processed in each of the processors and the resulting densities were read. The two sets of densities for each process were averaged and the averages plotted. See Figure 3 for the resulting D log H curves. There is no significant difference in the D log H curves for the microfilm used when processed in the two processors.

FIGURE 3


X - Immersion Process
0 - Viscous Process
1.60
1.20
0.80
0.40
.00
.20
.40
1.40
1.60
Relative Log Exposure
(mcs)

First Generation Image Production

It was necessary to fabricate a 16 millimeter film holder to securely hold the film during the imaging process. It was made of double weight black mount board and mounted on a standard optical bench fixture. A film track was made by placing a double thickness of black tape on either side of the exposure aperture, and the film was advanced manually through the holder. See Figure 4.

The DIN microfilm standards specify that a black and white object, such as printed matter, should produce a background density of 1.10 in the microfilm. This experiment operated at two density levels; the one was 1.10 and the second was 0.40. The exposure necessary to produce these densities in the microfilm was calculated from the D log H curves for the microfilm.

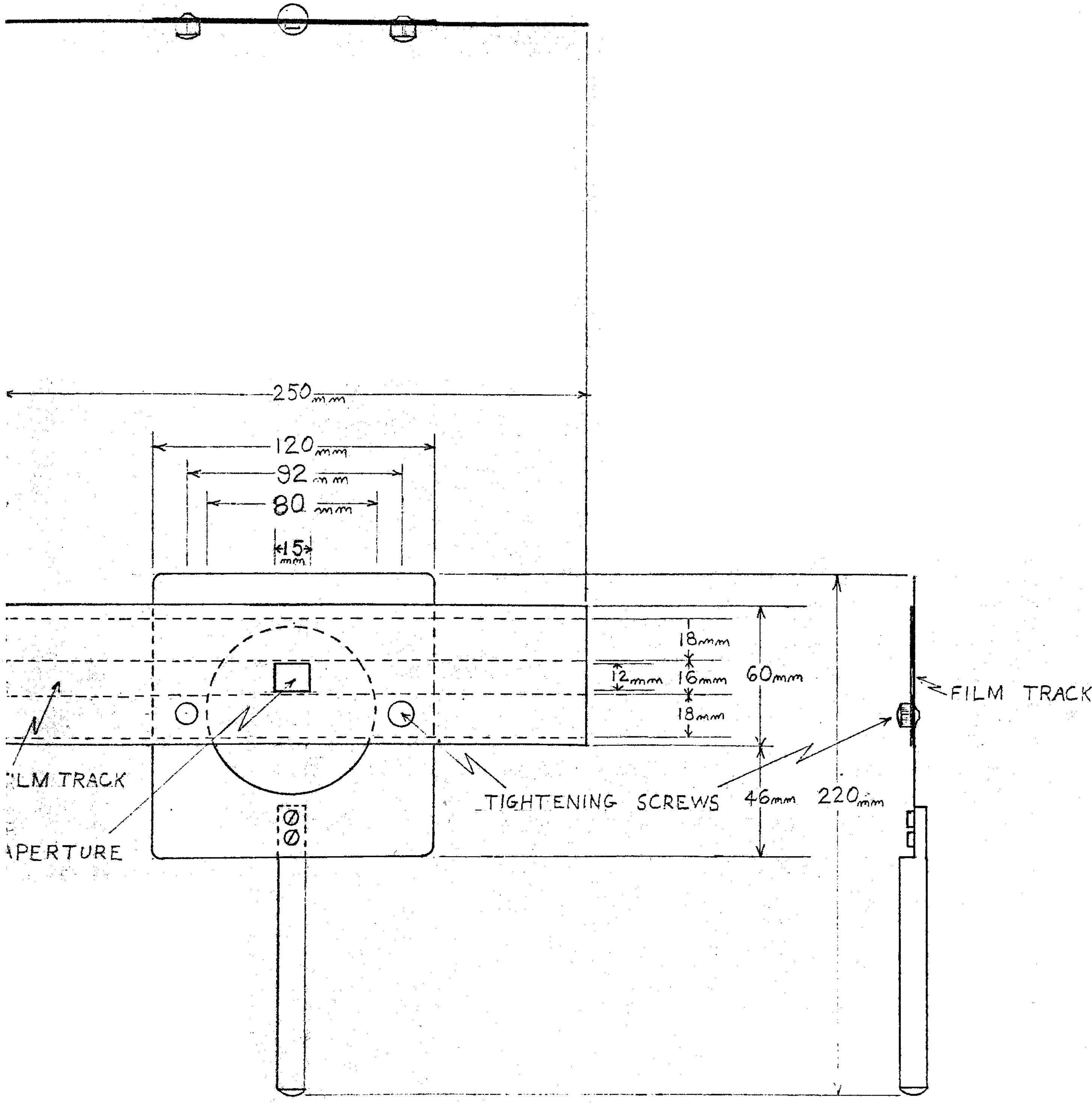
The test target was mounted on the surface of a light box. The target was imaged on the microfilm using a Schneider-Kreuznach 11 163 815 Symmar f/5.6 180 millimeter lens at 32X reduction. The microfilm was held by the film holder previously described.

A 9 exposure exposure series centered around the exposures calculated from the D log H curve and reciprocity law failure data for the film was made. The exposures were as follows:

Exposure	Time	f/	Exposure	Time	f/
1	1sec.	8	6	1sec.	19
2	1sec.	9.5	7	1sec.	22
3	1sec.	11	8	1sec.	27
4	1sec.	13.4	9	1sec.	32
5	1sec.	16			

FIGURE 4

16mm Film Holder



The film was immersion processed, and it was found that exposures 3 and 6 produced background densities closest to those desired.

The first generation immersion images were produced by making four exposures on a piece of microfilm, two at exposure level 3 and two at exposure level 6. these images were processed in the immersion processor.

Two exposure series like the series listed on page 11 were made on the microfilm. These images were viscous processed. Exposures 3 and 5 were found to have the background densities closest to those desired and were used as the first generation viscous images.

Duplicate Image Production

Considering the desired background density of 1.10, the base plus fog density of the first generation images of 0.05 to 0.06, and the reciprocity law failure data for the microfilm being used, an exposure was calculated for the printing process, 0.27 foot candles for 10 seconds.

A standard 8X10 inch contact printing frame was used to insure good contact between the two emulsions. All contact prints were made emulsion to emulsion. The light source was a Super Chromega Enlarger #166032 in the fully raised position and at the white light setting. The illuminance at the contact printing plane was measured using a Photovolt Corporation Meter #9085 Model 200A. The accuracy of this measurement was questionable since the meter was being operated at the low end of the lowest scale.

A test exposure was made using the first generation immersion processed images. This test film was processed in the immersion processor. On inspection of this test film, it was found that Newton's Rings were present. This caused variations in density in the image and had to be eliminated. p-Xylene was used as a liquid-gate and was placed between the glass in the contact print frame and the base of the processed film, and between the emulsion of the processed film and the emulsion of the film being exposed, (Figure 5). Liquid-gating eliminated the Newton's Rings and was used in all contact printing steps.

Using this method of contact printing, second generation images were printed and processed for both the viscous and immersion processes. From the second generation images, third generation images were produced for both processes in the same way.

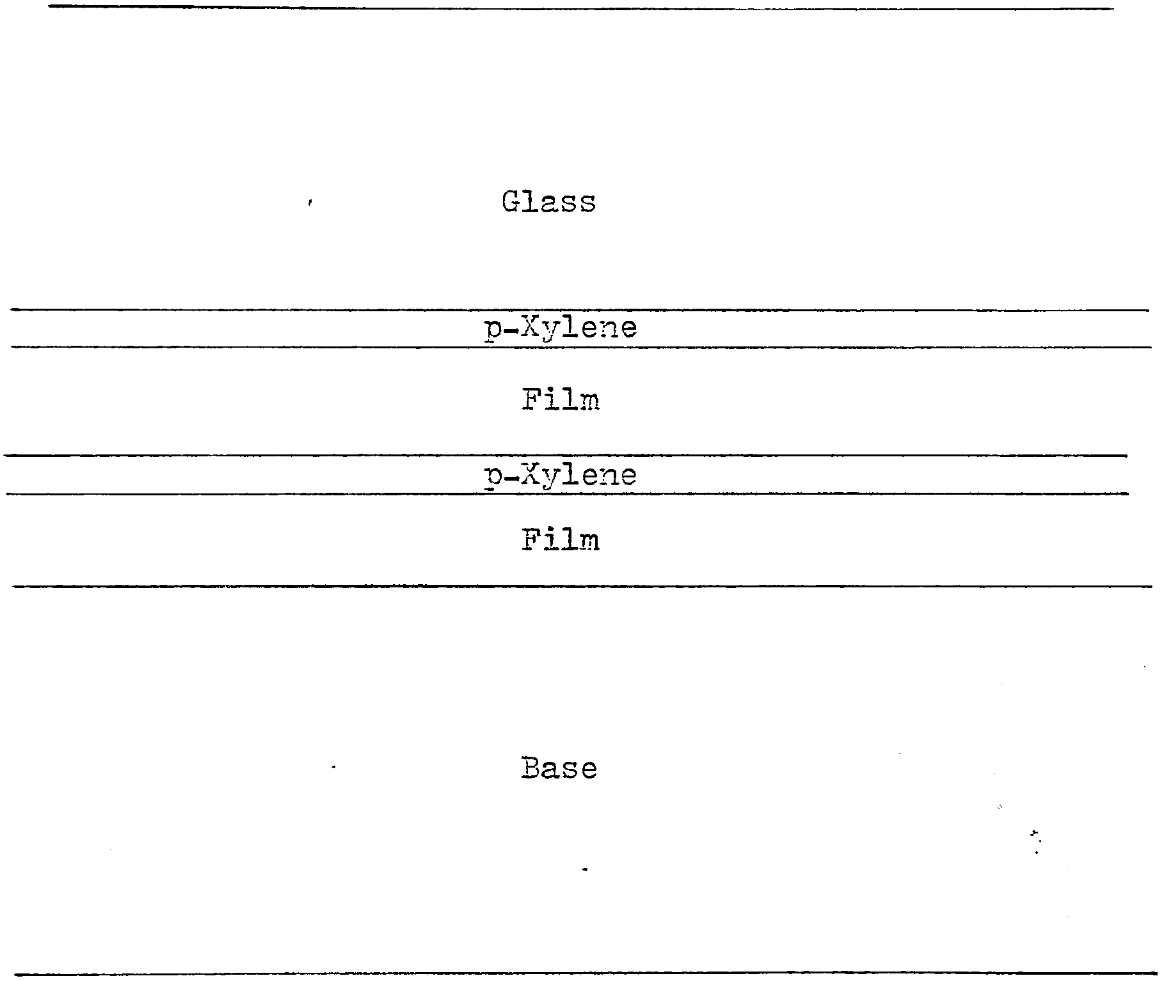
Image Width Determination

Microdensitometer traces were made of the images being evaluated. The microdensitometer used was a David W. Mann Company Automatic Digital Microdensitometer, A.D.M. Mk III. The optics were matched 20.5X objectives with .25 N.A. and an effective slit aperture of 1X80 micrometers. After the tracing, it was obvious that the third generation immersion processed images of the smallest line pair, 6 micrometer bars with 18 micrometer spacing, were not resolved. Due to this the anaylsis was completed using the largest line pair, 24 micrometer bars with 72 micrometer spacing, and the middle size

FIGURE 5

Cross Section of the Contact Print Frame

(Expanded)



pair, 12 micrometer bars with 36 micrometer spacing.

The images were light bars on a dark background. The .005 slope standard used in accutance determination was used to determine the line-space boundries. See Figure 6.

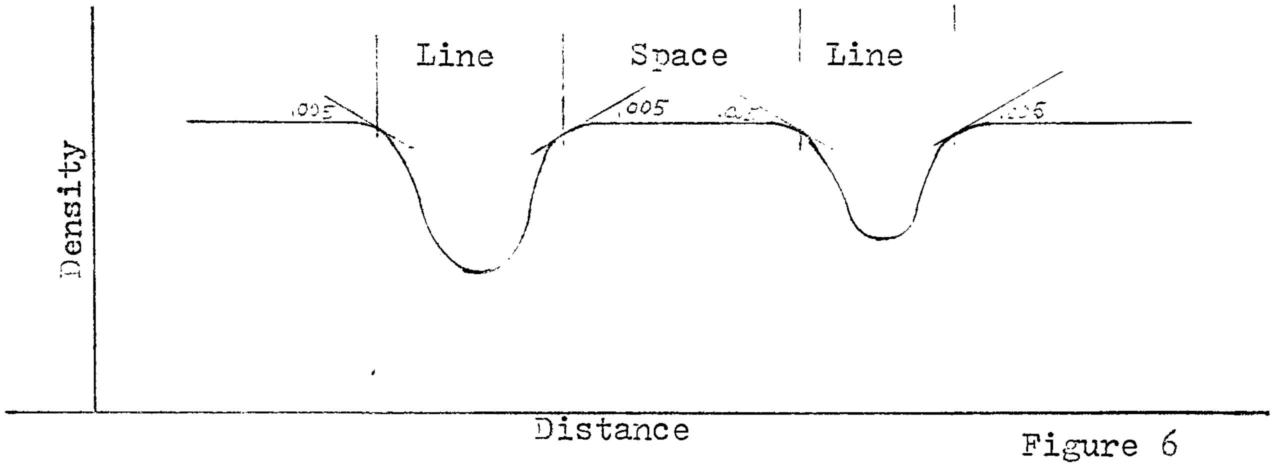


Figure 6

RESULTS

Statistical Analysis

This project was designed as a four factor, fully crossed experiment with four replicates using the line width differences and a four factor, fully crossed, and twice replicated experiment using the space width differences. The analysis was carried out using the Yates Method and the final assemblage of data is given in Appendix II. The response variable- the difference between the optical bar or space image width on the film at the time of exposure and the bar or space image width determined by microdensitometry of the processed image - was determined by subtracting the measured value from the known value.

The ANOVA tables resulting from the statistical analysis are as follows:

Space Width Differences

Source	Sum of Squares	Variance	Mean Square	F Ratio	F (.05) Table
Process (P)	69.03	1	69.03	3.46	4.49-NS
Density (D)	28.13	1	28.13	1.41	4.49-NS
Width (W)	1540.13	1	1540.13	77.12	4.49-S
Generation (G)	136.13	1	136.13	6.82	4.49-S
P X D	11.28	1	11.28	.56	4.49-NS
P X W	.78	1	.78	.04	4.49-NS
D X W	21.13	1	21.13	1.06	4.49-NS
P X G	19.53	1	19.53	.98	4.49-NS
D X G	210.13	1	210.13	10.52	4.49-S
W X G	36.13	1	36.13	1.81	4.49-NS
P X D X W	9.03	1	9.03	.45	4.49-NS
P X D X G	9.03	1	9.03	.45	4.49-NS
P X W X G	1.53	1	1.53	.08	4.49-NS
D X W X G	36.13	1	36.13	1.81	4.49-NS
P X D X W X G	7.03	1	7.03	.35	4.49-NS
Error	319.50	16	19.97		

Line Width Differences

P	49.00	3	16.33	.49	3.16-NS
D	182.25	3	60.75	1.83	3.16-NS
W	784.00	3	261.33	7.86	3.16-S
G	841.00	3	280.33	8.43	3.16-S
P X D	1.56	3	.52	.02	3.16-NS
P X W	5.06	3	1.69	.05	3.16-NS
D X W	45.56	3	15.19	.46	3.16-NS
P X G	126.56	3	42.19	1.27	3.16-NS
D X G	588.06	3	196.02	5.90	3.16-S
W X G	.06	3	.02	.00	3.16-NS
P X W X D	1.00	3	.33	.01	3.16-NS
P X D X G	56.25	3	18.75	.56	3.16-NS
P X W X G	.25	3	.08	.00	3.16-NS
D X W X G	.25	3	.08	.00	3.16-NS
P X D X W X G	1.56	3	.52	.02	3.16-NS
Error	598.50	18	33.25		

Statistical Results

The statistical analysis has indicated the following results for both the line width and the spacing width differences:

1. There is no significant difference between the effects of viscous processing and conventional immersion processing on small image sizes and spacings.
2. There is a significant difference in the effect of different generations (1st, 2nd, 3rd ...) on small image sizes and spacings.
3. There is no significant difference in the effect of different overall density differences on small image sizes and spacings.
4. There is a significant difference in the effect of different optical image sizes (on the film) on small image sizes and spacings.
5. There is a significant difference in the effect of the optical image size (on the film) and density interaction on small image sizes and spacings.

DISCUSSION OF RESULTS

The statistical analysis of the experiment clearly shows that small image sizes and spacings are dependent on the generation of the image being measured. See Figure 7. This is to be expected since the measurement technique used measures the image widths near their bases. The film and printing process spread functions are applied to the images with the production of each generation causing significant changes in the image widths near their bases.

The optical image size on the film at the time of exposure is a factor affecting small image sizes and spacings. See Figure 7. As the image width approaches the width of the spread function of the system the modulation of the resultant image is reduced. When this occurs through several generations it is obvious that the image width will be affected. However, with larger images, the modulation will not decrease as rapidly. The major cause of modulation decrease in this case is flair and the effect on image size is different.

Density had no significant effect on small image sizes and spacings at the alpha=0.05 level. The lack of the effect of density on small image sizes and spacings was also seen in, "The Influence of the Technologist, Image Size, and Image Density on the Visual Measurement of the Size of Microimages," by Walter F. Shafer (see bibliography). In that thesis it is stated that this is not consistent with theoretical predictions. As in that research, this experiment was not sensitive enough to detect the difference, if the difference does exist as theorized. Density can not be ignored, because the density and generation interaction terms are significant. See Figure 8.

The general trends in Figures 7 and 8 show that bar width differences and spacing width differences are inversely related with

FIGURE 7

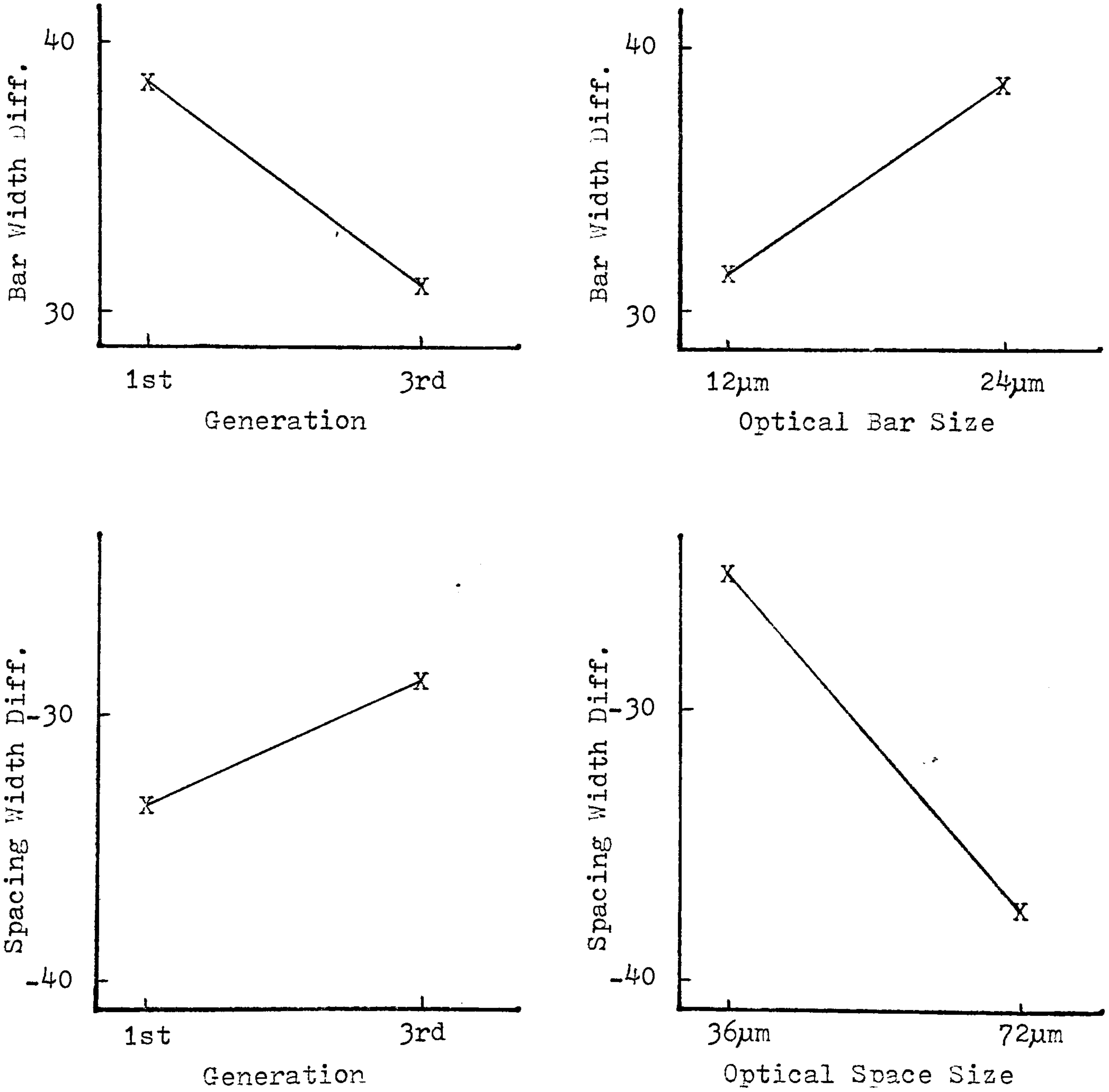
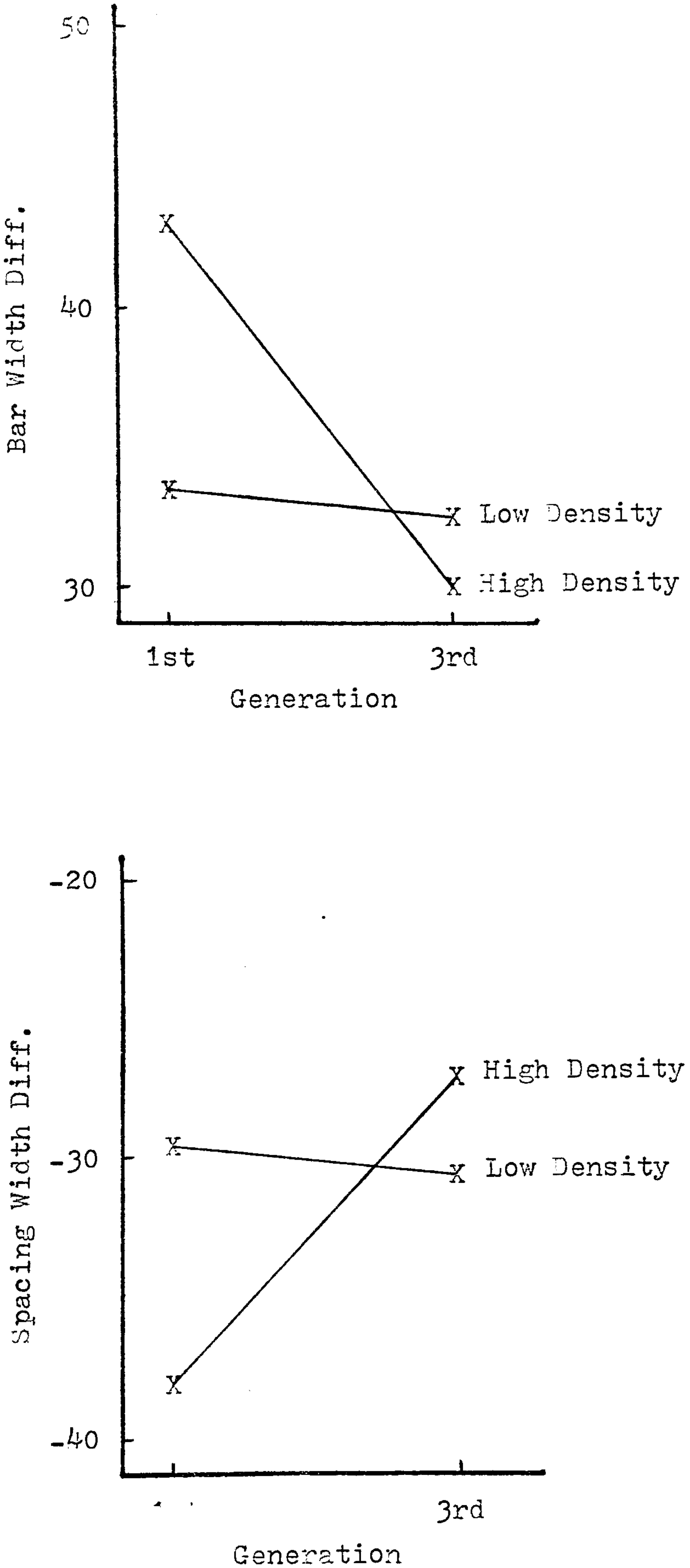

Bar Width Diff.
40
30
1st
3rd
Generation
Bar Width Diff.
40
30
12µm
24µm
Optical Bar Size
Spacing Width Diff.
-30
-40
1st
3rd
Generation
Spacing Width Diff.
-30
-40
36µm
72µm
Optical Space Size

FIGURE 8


50
40
30
Bar Width Diff.
Low Density
High Density
1st
3rd
Generation
-20
-30
-40
Spacing Width Diff.
High Density
Low Density
3rd
Generation

respect to any one significant variable or interaction. This is expected since the image spacing widths and bar widths are inversely related.

The type of processing, viscous or immersion, had no significant effect on small image sizes and spacings. The only way this can be explained is if the experiment was not sensitive enough to detect the difference or the difference did not exist. There may not have been as much of an effect on the images due to viscous processing as expected because of the short development time (6.5 seconds).

CONCLUSIONS

The evaluation of the data and results produced the following conclusions:

1. The optical image size (on the film at the time of exposure), the generation of the image, and the interaction between image density and generation are significant factors in the determination of small image sizes and spacings.

2. The same factors and interaction were significant for both the line width data and the spacing width data which reinforces the results of either experiment separately.

3. The nature of the functions of the significant factors (listed in 1 above) and the response variables

(small bar and spacing width differences) can not be determined in this experiment since all the variables were treated at only two levels.

FOOTNOTES

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APPENDIX I

Sensitometric Data

All sensitometric exposures made in this experiment were made using an Eastman Kodak Model 101 Sensitometer with R.I.T. number 91935. The exposure at the step wedge assembly was 1700mc for .2 seconds. The step wedge densities are listed below with their corresponding log exposures.

Step	Density	log Exposure
1	3.10	$\bar{1}.44$
2	2.93	$\bar{1}.61$
3	2.76	$\bar{1}.78$
4	2.61	$\bar{1}.93$
5	2.47	0.07
6	2.33	0.21
7	2.18	0.36
8	2.04	0.50
9	1.88	0.66
10	1.74	0.80
11	1.60	0.94
12	1.46	1.08
13	1.30	1.24
14	1.15	1.39
15	1.00	1.54
16	0.85	1.69
17	0.70	1.84
18	0.54	2.00
19	0.38	2.16
20	0.22	2.31
21	0.06	2.47

APPENDIX II

Spacing Width Differences

		Viscous		Immersion	
		Generation		Generation	
		1st	3rd	1st	3rd
Low Density	36 µm	-23	-28	-24	-18
		-25	-26	-21	-27
	72 µm	-38	-35	-34	-39
		-34	-39	-36	-33
High Density	36 µm	-30	-25	-28	-15
		-31	-22	-30	-24
	72 µm	-43	-45	-42	-31
		-51	-30	-49	-25

Bar Width Differences

		Viscous		Immersion	
		Generation		Generation	
		1st	3rd	1st	3rd
Low Density	12 µm	30	30	31	26
		30	35	26	27
		31	33	32	33
		35	29	33	26
	24 µm	38	36	36	35
		36	33	34	32
		38	40	37	40
		36	36	36	29
High Density	12 µm	38	35	46	19
		37	28	37	18
		37	27	41	22
		39	25	36	29
	24 µm	45	40	51	35
		48	43	43	33
		43	33	55	29
		45	32	49	29