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Memorandum of Project MICHIGAN

THE LIMITING TRACE SPACING ON FILM RELATED TO EXPOSURE AND CONTRAST RATIO

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PREFACE

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Robert L. Hess
Technical Director
Project MICHIGAN

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THE LIMITING TRACE SPACING ON FILM RELATED TO EXPOSURE AND CONTRAST RATIO

ABSTRACT

Photographic film is one of the best materials known for storing maximum information in the smallest amount of medium. Data may be inserted in independent channels; it is therefore necessary to know the limiting channel spacing so that the uniqueness of each channel can be preserved.

This memorandum describes a procedure to determine the limiting channel spacing. The method consists of contact-printing on a test film the image from a mirror-surfaced, optically flat glass block. In the mirror surface, lines 42 μ wide are engraved with a variable spacing from 8.5 lines/mm to 62.5 lines/mm. The image is then scanned with a specular densitometer and the light transmission recorded. The scanning aperture is 5 μ.

From the recording, the contrast ratio at any resolution, i.e., the ratio of contrast at a given resolution to that at a low resolution (8.5 lines/mm) may be determined. This procedure is carried out with different amounts of exposure, all film being developed under constant conditions. A relationship is then expressed between light transmission through the image and the limiting resolution for a given contrast ratio (e.g., 0.707). Data for several commercially available films are given.

1
INTRODUCTION

Photographic film is one of the best materials known for maximum permanent storage of scientific information in the smallest amount of space. The data may be of several forms, but the maximum storage occurs when the variations of exposure are caused by either alternating cycles or pulses of light. The developed film may be considered as a high-resolution, three-dimensional representation in which the exposure corresponds to the third dimension.

The data may be inserted as a cathode-ray-tube trace in channels which may be of considerable width or only as wide as the limiting spacing so that the data, when recovered from storage by a flying-spot scanner, for example, have deteriorated by only a designated amount. The deterioration is a loss in contrast caused by the overlap of adjacent traces. This degradation is only a portion of the total degradation, the total being the sum of that caused by each component in the display system. This memorandum discusses the limiting film spacing as a function of contrast and describes a simple method for the experimental determination of this relationship. From this information the minimum channel spacing may be defined and a given contrast ratio maintained. This experimental method is also suitable for surveys of other photographic parameters.

2
DESCRIPTION OF THE METHOD

The experimental method consists of contact printing on the film under study the image from an optically flat glass block which has been mirror-coated and engraved. The film is then developed under controlled conditions. The resulting film image is then scanned with a specular densitometer, and the resulting light transmission is recorded with a Sanborn recorder. The recording shows the exposure, the total contrast, the film-base density, and the contrast at any particular resolution spacing.

This method of testing is applicable for survey studies where there are any number of variables, such as exposure and film-development parameters. In this work only the film exposures were varied.

2.1. THE IMAGE-FORMING BLOCK

The image-forming block is shown in Figure 1. The image formed by exposure through the block is also shown. Because the block was originally procured for a different purpose, the image follows a curve instead of a straight line.

The block is constructed of quality glass that has been ground optically flat and mirror-coated. In the mirror coat, a grating has been engraved in which the lines are 42 μ (23.8 lines/mm) wide with varying spacing between lines. Along the center of the grating (vertical straight portion) the widest distance between the lines is 118.2 μ (8.5 lines/mm), and the narrowest distance is 15.9 μ (62.8 lines/mm). The spacing between the lines and the corresponding lines per millimeter are shown in Figure 2.

The light transmission of this grating alone was measured on the densitometer using a very fine photomultiplier aperture (0.005 inch). This aperture corresponds approximately to a 5-μ aperture in the plane of the grating. It was found that the maximum transmission was uniform over the entire grating (85% + 2% of the incident light).

2.2. EXPOSURE AND PROCESSING

The film was positioned on a baseboard of a photographic enlarger and the block firmly pressed down on it with the grating toward the film. The enlarger lens iris was set at f/22, and the film was exposed for 0.2, 0.4, 0.6, and 0.8 second, one image at each exposure. Exposures were made using a Wratten 47 filter (blue light corresponding to P-11 phosphor) and a 5461-Å filter (green light). Neutral density filters were added in the light head of the enlarger to reduce the exposure intensity on the photographically faster films.

The films were then developed in a Houston-Feerless developing machine, in DK 76 developer at 69°F and at a machine speed of 6 fpm.

2.3. SCANNING THE IMAGE

The images were then scanned with the densitometer, using the 0.005-inch aperture previously mentioned, and the light transmissions recorded with a Sanborn recorder. Care was taken that the scanning speed did not cause electrical frequencies that exceeded the capabilities of the instruments used, and the densitometer linearity was checked against neutral-density filters. Sample recordings are shown in Figure 3. From these recordings, as previously mentioned, the parameter data can be determined.

2.4. DISCUSSION OF THE TEST METHOD

Before presenting and discussing test results, it may be well to discuss certain aspects of the test.

For years, optical resolution has been used to determine design criteria. Tests have been conducted with an alternating black-and-white line chart as a test target; as long as one black line is discernible from the next adjacent black line, the two are said to be resolved. It has been estimated (Reference 1) that the resulting contrast is approximately 2 to 3% of the original contrast in the line chart; 98% of the original contrast has been lost. Even if the lines are resolved, where the contrast is equivalent to the third dimension of data storage such a large loss can hardly be tolerated.

Recent optical theory is becoming patterned after electrical communication theory; the spatial frequency responses of film, lenses, and combinations of both have been determined from optical sine-wave patterns. A knife-edge exposure has also been used to obtain the spatial frequency response which is the Fourier transform (Reference 2) of the derivative (line-spread function) (Reference 3) of the edge function associated with such an exposure.

Besides frequency response, another widely used term in evaluating photographic results is "acutance." This is defined (Reference 4) as the mean-square gradient of the edge function divided by the density differences between two arbitrary points on the edge-function curve.

The method reported in this memorandum produces in each master exposure a series of identical knife-edge line exposures placed at varying distances from each other. Each line exposure, except for unavoidable light diffraction at the edges, is a true knife-edge exposure because no lenses are used. Any particular line exposure may be minutely examined to determine the edge function, acutance, and spatial frequency response. In addition, this method is designed to find the spacing at which the edge functions of successive line exposures overlap by only a specified amount. This specification may be labeled "contrast ratio," which is the ratio of two contrasts, one at a spacing where the edge functions do overlap and the other at a spacing where the edge functions do not overlap. The experimental determination of the contrast ratio is achieved by scanning the successive line exposures in each master exposure. At wide spacing, the amount of light recorded will vary from that transmitted through the base of the film to that transmitted through the exposed portions. As the line spacing decreases, the film in the spaces will be increasingly exposed because of edge overlap, and the resulting light transmission will decrease. The light transmitted through the intentionally exposed portions will decrease slightly, but will be substantially the same. Therefore the image will indicate the loss in contrast, and will indicate the maximum exposure that may be associated with a desired contrast ratio and spacing.

3
RESULTS

Samples of the following films were studied.

Ansco	Du Pont	Eastman Kodak	Ilford
Hyscan Ortho	Superior No. 1	Fine Grain Positive	FP3
Hyscan	Superior No. 2	Lina-Ortho	HPS
Telerecord	Superior No. 3	Microfile	
	824-B	Panatomic-X	
	834-B	Plus-X	
	931	SO 1209	
		Spectum Analysis No. 1	
		Tri-X	
		Tri-XAR	

A reconstruction of the Sanborn recording for Tri-X film when exposed to blue light (Wratten 47 filter) is shown in Figure 4. The ordinate is expressed as the fraction of incident light transmitted through the film, and the abscissa is the spacing between exposures. The four decending curves denote the transmission through the unexposed portions of the film at the four different exposures. The four bottom curves denote the transmission through the exposed portions of the film. From this figure, the spacing can be determined at which a desired contrast ratio can be achieved; the contrast at a spacing of 8.5 lines/mm is considered unity.

Figures 5 through 24 show the relationship between the specular density of the developed film and the spacing between line exposures while a contrast ratio of 0.707 and 0.500 is maintained. On the graphs, the dots indicate the 47 filter and the stars indicate the 5461 filter. The test curves show that, in the main, the results from the different films are quite similar. The results from some of the photographically slower, higher-resolving films are more favorable than the results from the photographically faster films; that is, a higher density signal can be more closely recorded on the slower film.

The method reported is not intended primarily to determine the film's frequency-response curve; however, the curve can be determined from the edge-function spread-function frequency-response relationships previously mentioned. That this relationship exists is borne out by the similarity between Figure 4 and the published frequency-response curves (Reference 5). These published curves of different photographic films, with the exception of those that are very slow photographically, show that the frequency responses for contrast ratios of 0.7 and 0.5 are very nearly the same, and that the large increase in resolving power is attained at low contrast ratios where, for the recording techniques mentioned in this memorandum, the increase is of no avail.

In Figures 25 (contrast ratio of 0.707) and 26 (contrast ratio of 0.5), the test data from Eastman Kodak Microfile, Panatomic-X, and Tri-X film have been shown, along with a design curve which is shown dotted. The one design curve is drawn because of the similarity of test results. The selection of an individual film to be used in a specific instrument depends on available light and lenses, and the amount of granular noise that can be tolerated. It should be emphasized that results from very high-resolving, extremely slow film, such as Eastman Kodak 649GH film, will not follow this design curve.

Recent comment on this work has been concerned with re-reflection of light reflected from film emulsion grains inasmuch as the test image is engraved in a mirrored surface.

Future work will be carried on with a test object in which lines have been engraved in a low-reflectance surface; however, it is felt that, because of the similarity of these results with other published results, the inaccuracies caused by the mirror surface are small.

REFERENCES

1. O. Schade, "Image Gradation, Graininess and Sharpness in Television and Motion Picture Systems," Part II, J. Soc. Motion Picture Television Engrs. March 1952, Vol. 58, p. 181.
2. R. L. Lamberts, "Relationship between the Sine-Wave Response and the Distribution of Energy in the Optical Image of a Line," J. Opt. Soc. Am., July 1958, Vol. 48, p. 490.
3. R. L. Lamberts, G. C. Higgins, and R. N. Wolfe, "Measurement and Analysis of the Distribution of Energy in Optical Images," J. Opt. Soc. Am., July 1958, Vol. 48, p. 487.
4. G. C. Higgins and F. H. Perrin, "The Evaluation of Optical Images," Phot. Sci. Eng., August 1958, Vol. 2, p. 66.
5. R. L. Lamberts, "Measurement of Sine-Wave Response of a Photographic Emulsion," J. Opt. Soc. Am., May 1959, Vol. 49, p. 425.

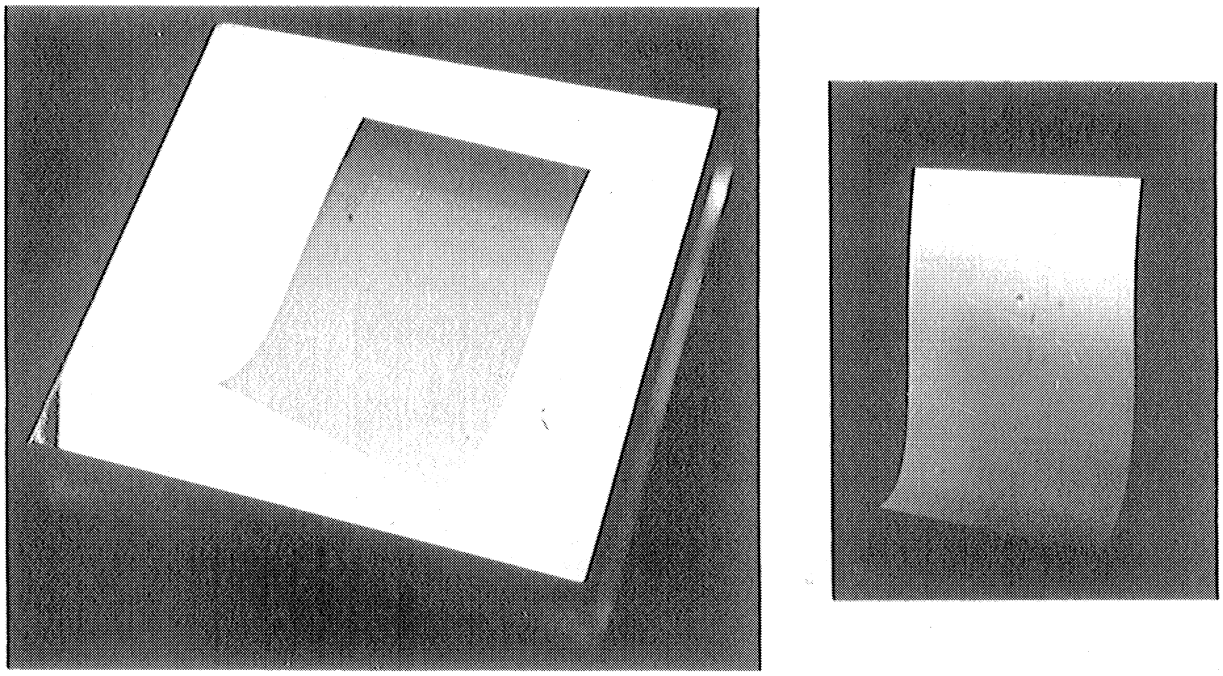

FIGURE 1. TEST BLOCK

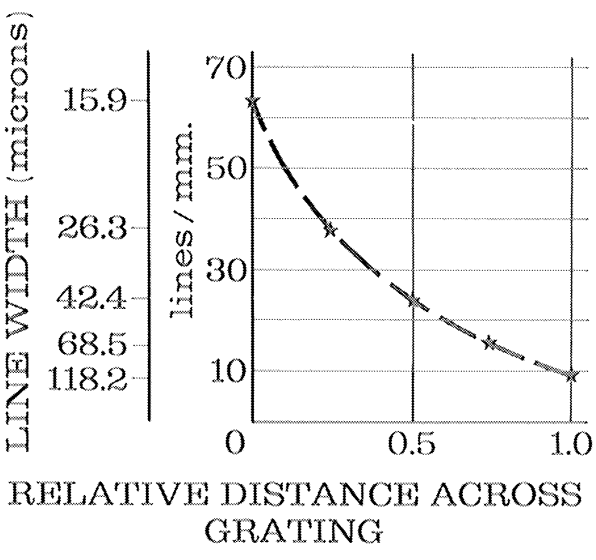

FIGURE 2. WIDTH OF UNEXPOSED PORTIONS ON FILM REPRODUCTIONS OF GRATING

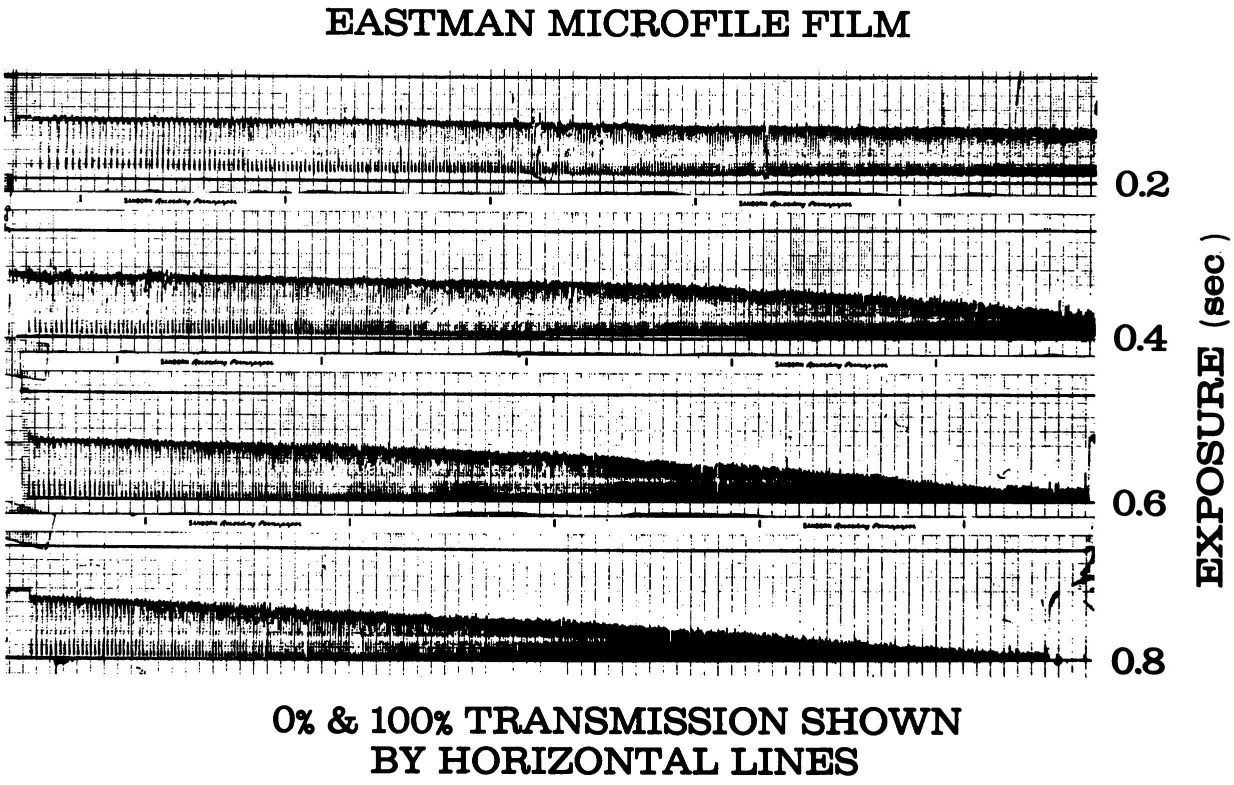

FIGURE 3. TRANSMISSION OF LIGHT THROUGH VARIABLE GRATING

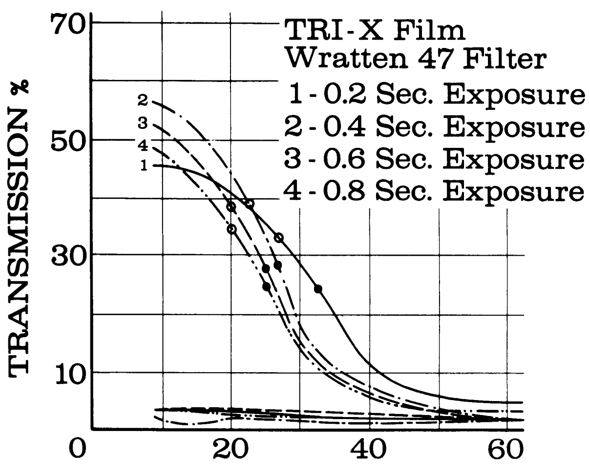

FIGURE 4. LIGHT TRANSMISSION THROUGH REFERENCE GRATING

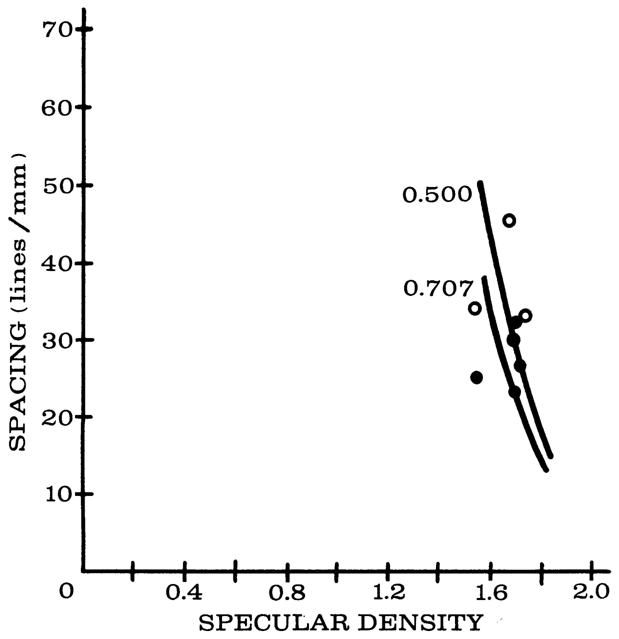

FIGURE 5. TEST CURVES, ANSCO HYSCAN ORTHO FILM

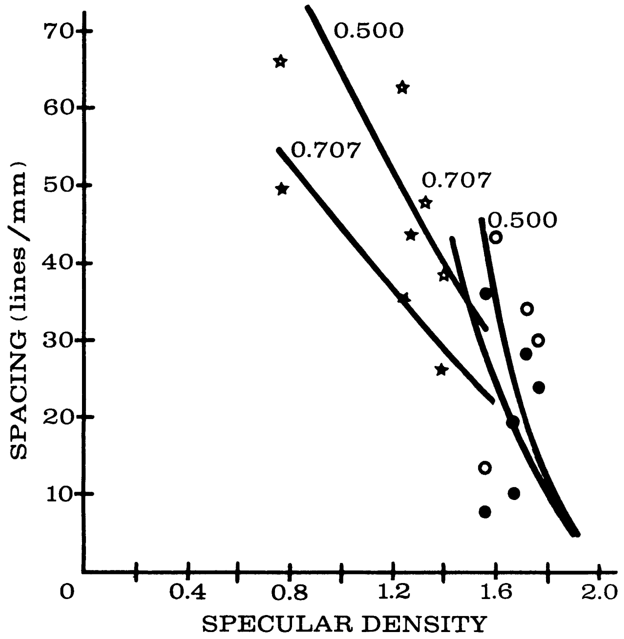

FIGURE 6. TEST CURVES, ANSCO HYSCAN FILM

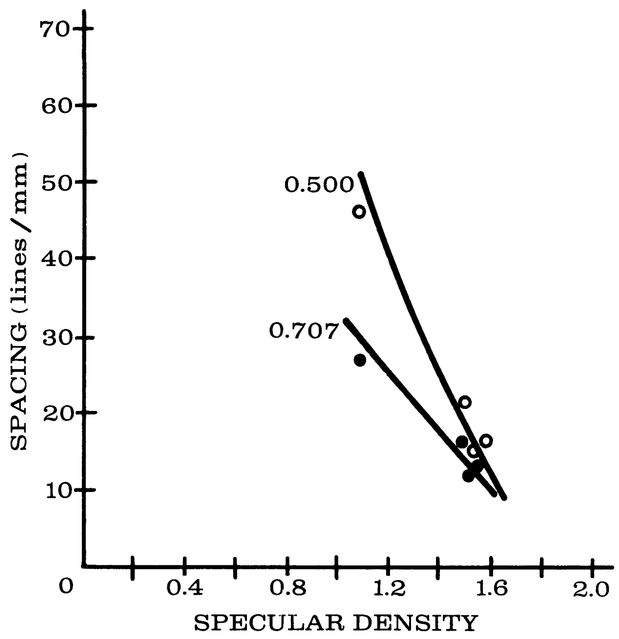

FIGURE 7. TEST CURVES, ANSCO TELERECORD FILM

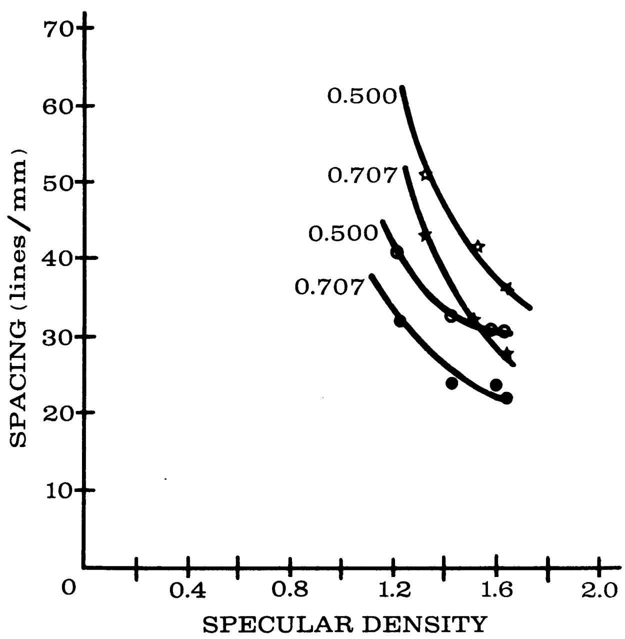

FIGURE 8. TEST CURVES, DU PONT SUPERIOR NO. 1 FILM

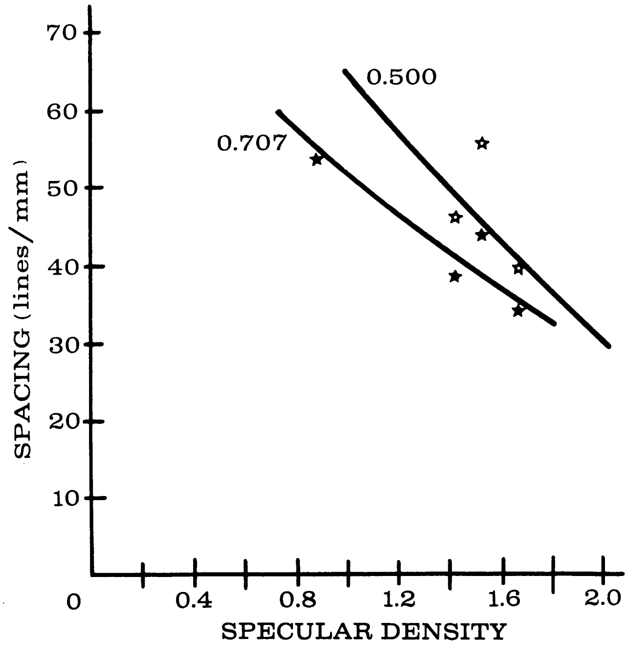

FIGURE 9. TEST CURVES, DU PONT SUPERIOR NO. 2 FILM

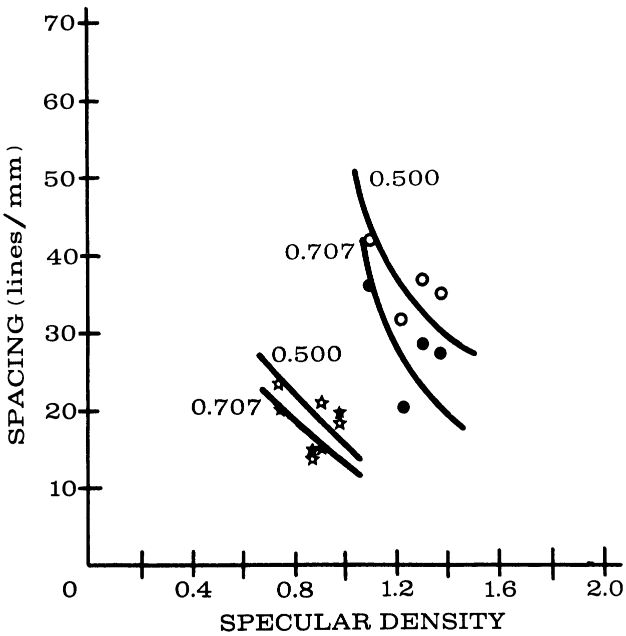

FIGURE 10. TEST CURVES, DU PONT SUPERIOR NO. 3 FILM

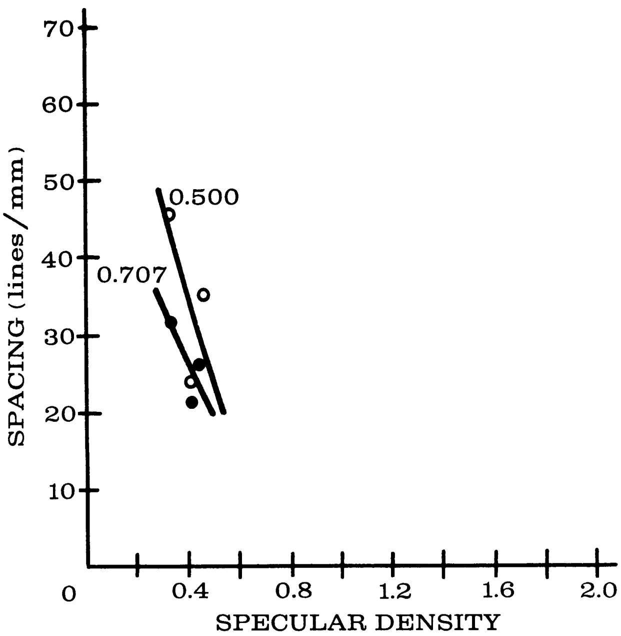

FIGURE 11. TEST CURVES, DU PONT 824-B FILM

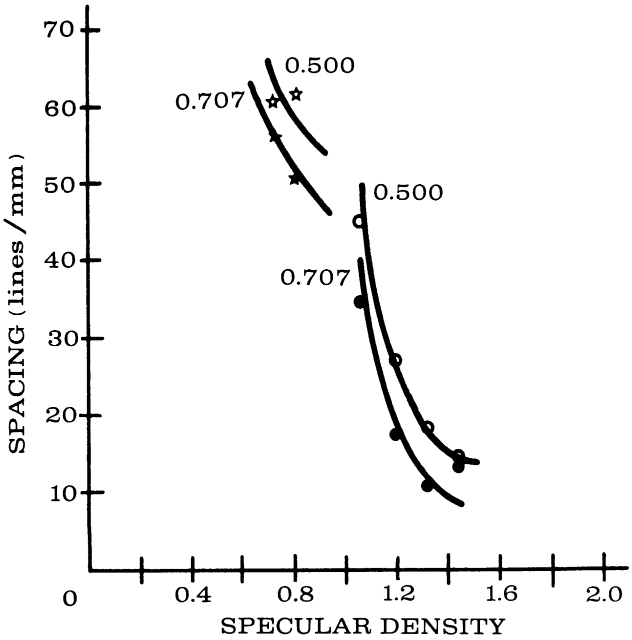

FIGURE 12. TEST CURVES, DU PONT 834-B FILM

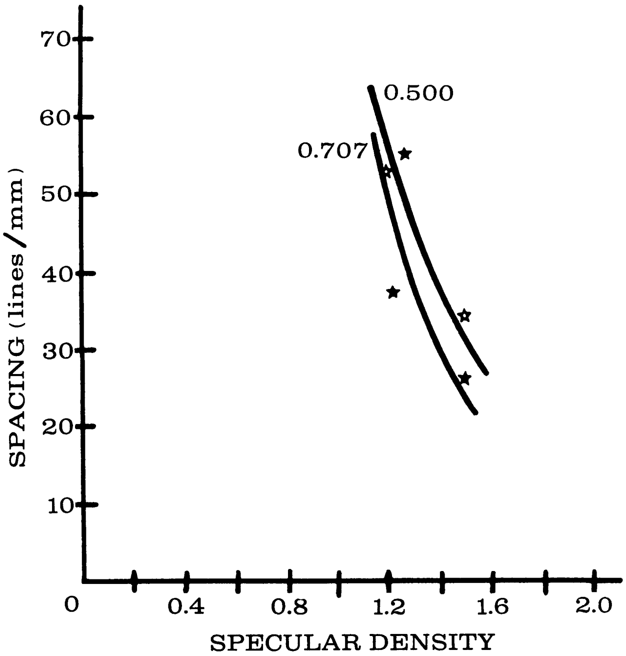

FIGURE 13. TEST CURVES, DU PONT 931 FILM

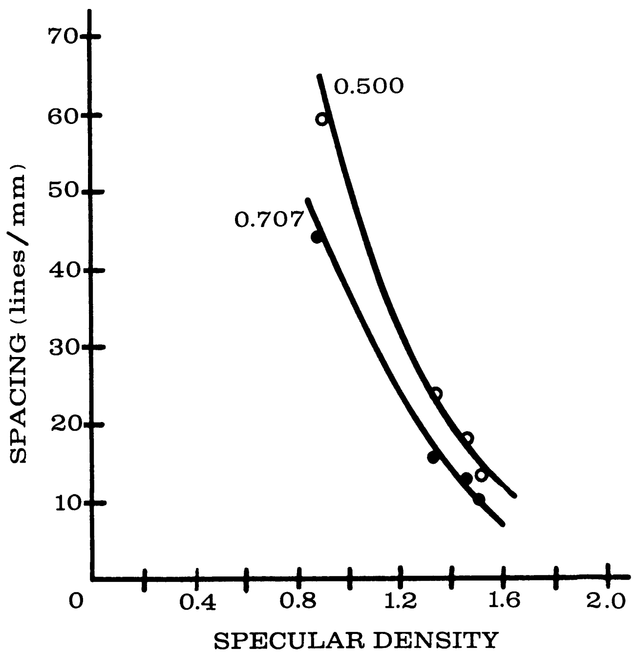

FIGURE 14. TEST CURVES, EASTMAN KODAK FINE GRAIN POSITIVE

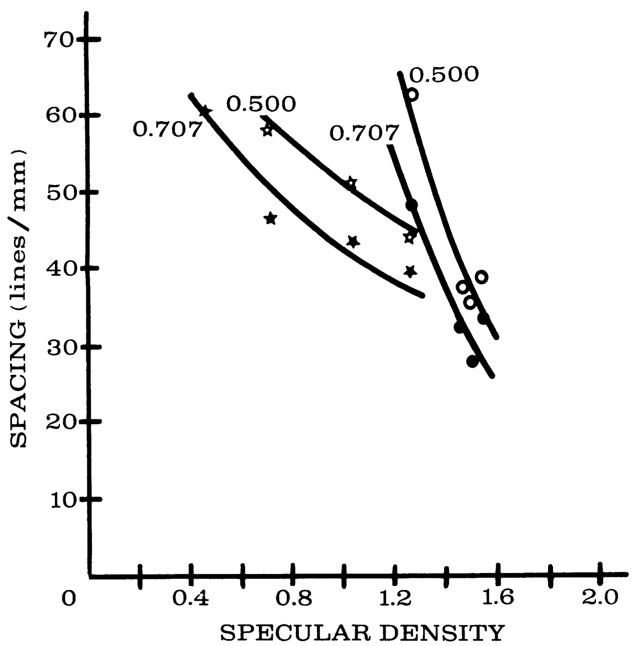

FIGURE 15. TEST CURVES, EASTMAN KODAK LINA-ORTHO

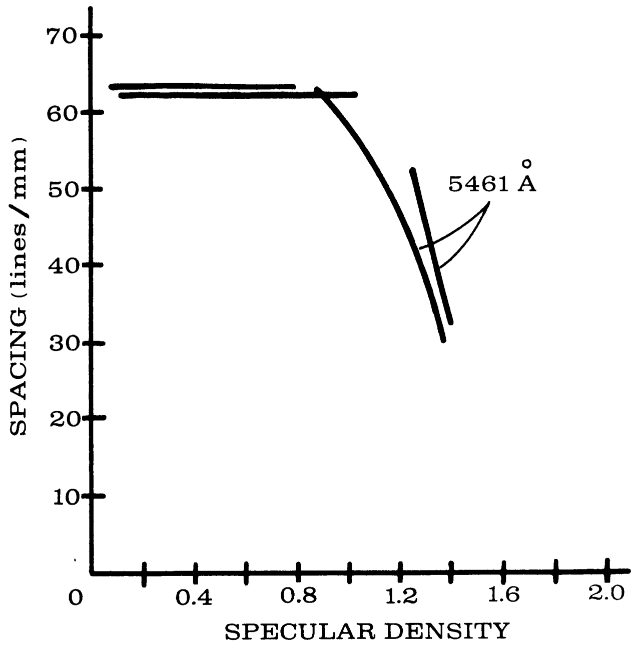

FIGURE 16. TEST CURVES, EASTMAN KODAK MICROFILE

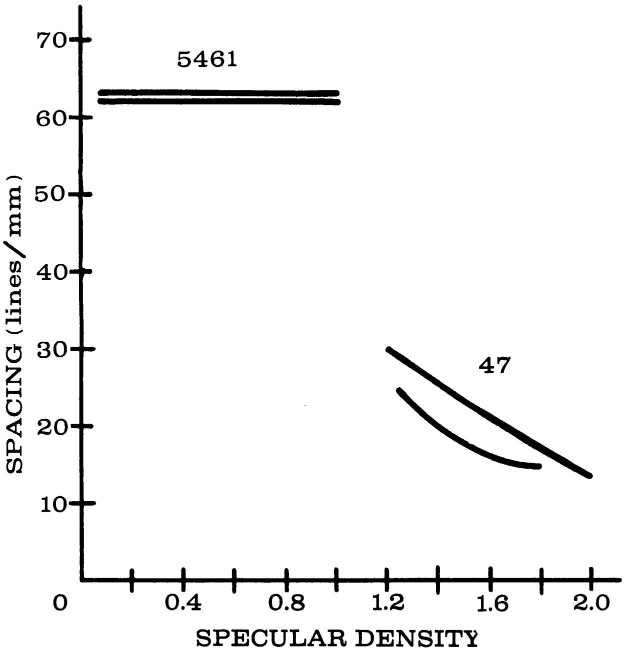

FIGURE 17. TEST CURVES, EASTMAN KODAK PANATOMIC-X

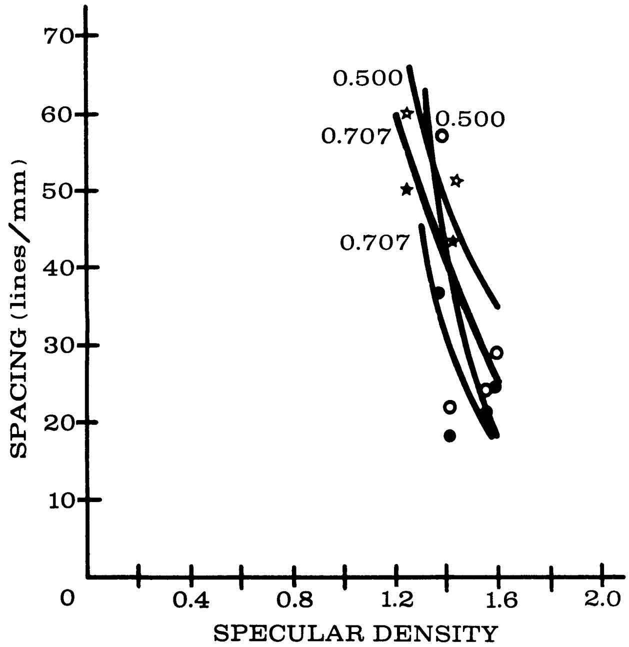

FIGURE 18. TEST CURVES, EASTMAN KODAK PLUS-X

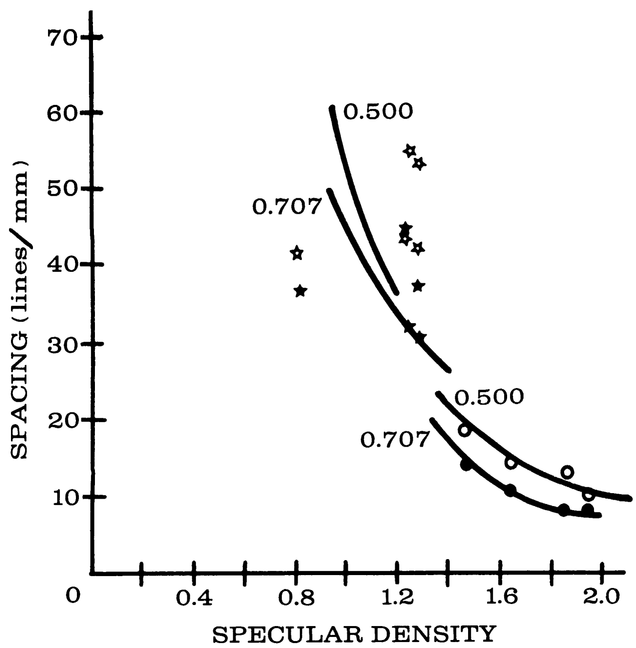

FIGURE 19. TEST CURVES, EASTMAN KODAK SO 1209

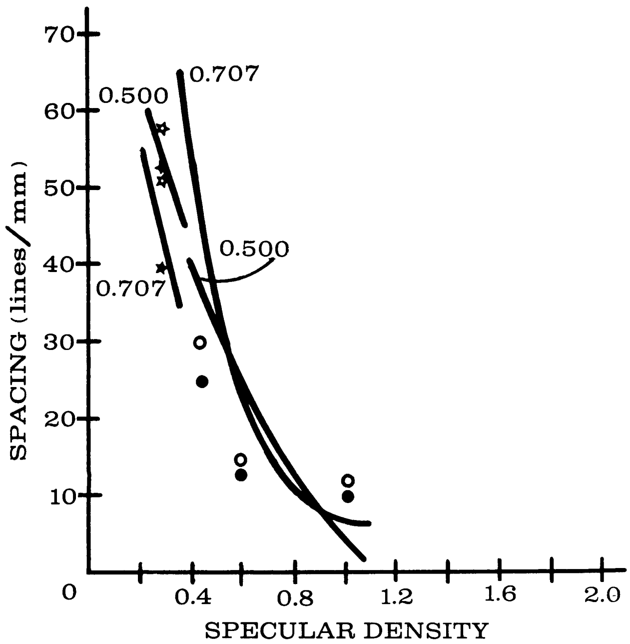

FIGURE 20. TEST CURVES, EASTMAN KODAK SPECTRUM ANALYSIS NO. 1

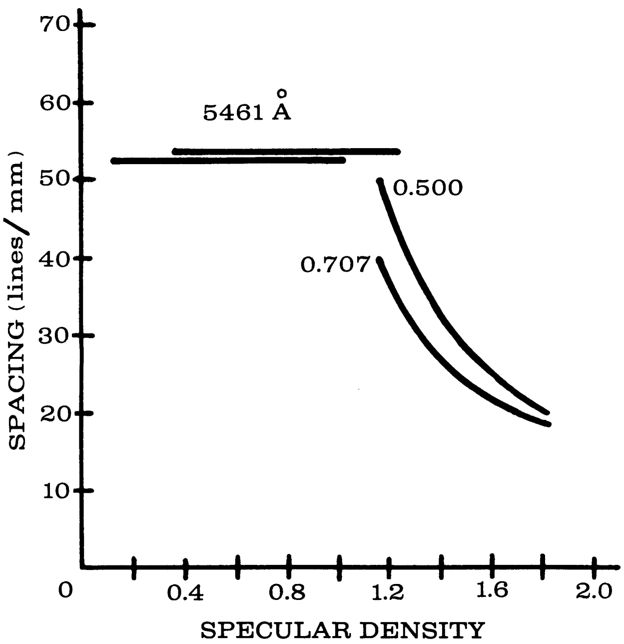

FIGURE 21. TEST CURVES, EASTMAN KODAK TRI-X

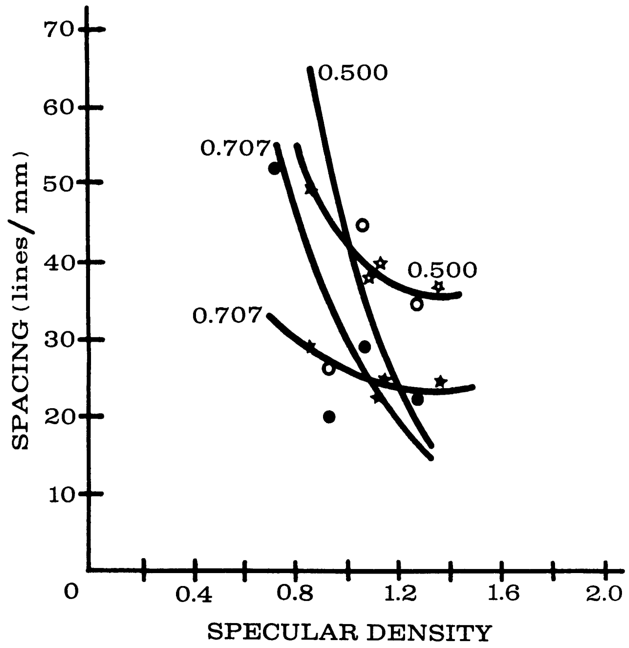

FIGURE 22. TEST CURVES, EASTMAN KODAK TRI-XAR

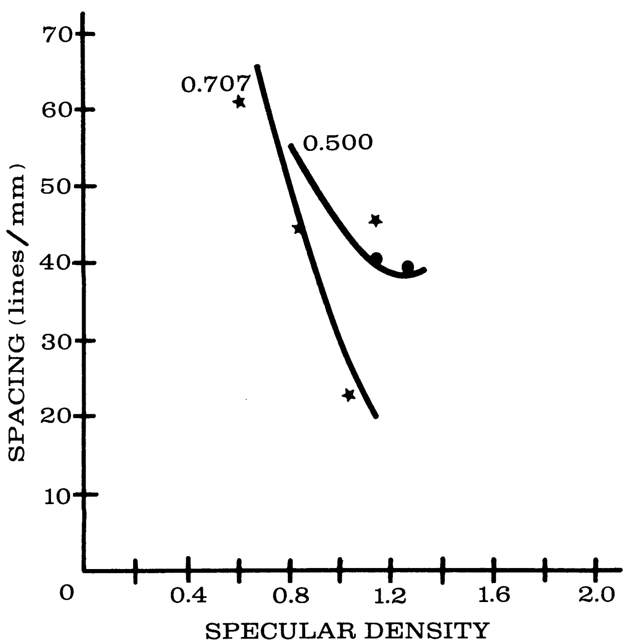

FIGURE 23. TEST CURVES ILFORD FP3

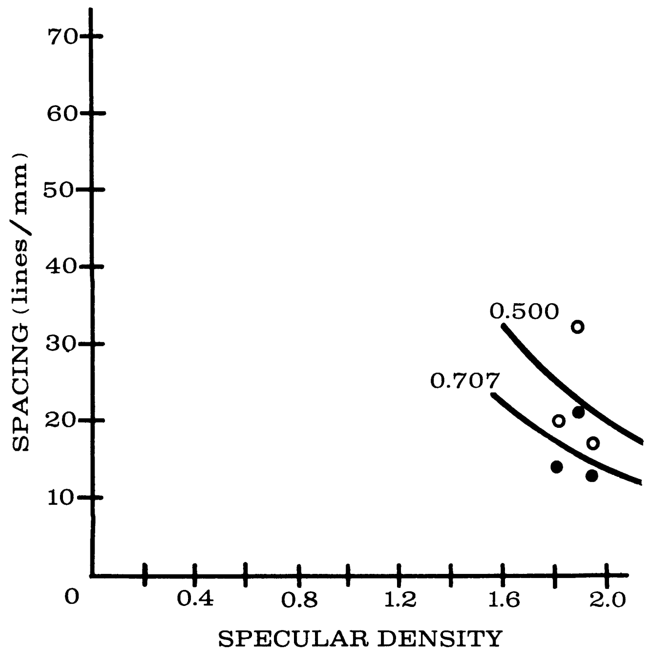

FIGURE 24. TEST CURVES, ILFORD HPS

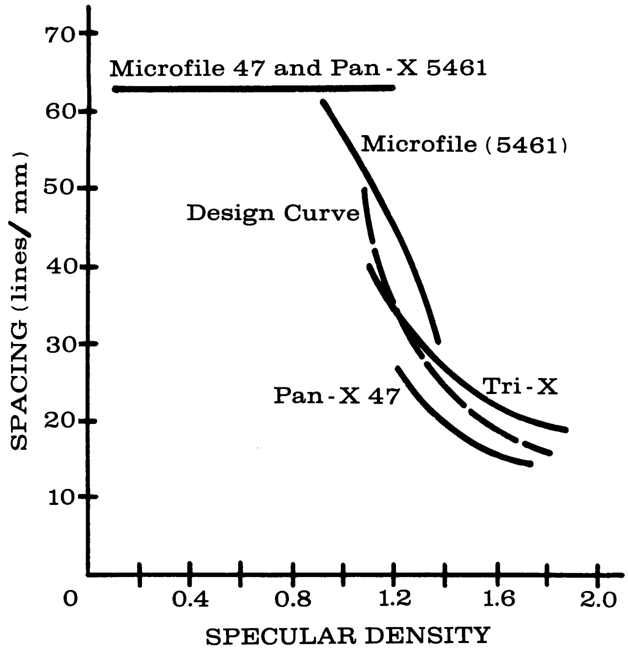

FIGURE 25. RESOLUTION VS. EXPOSURE TO MAINTAIN A CONTRAST RATIO OF 0.707

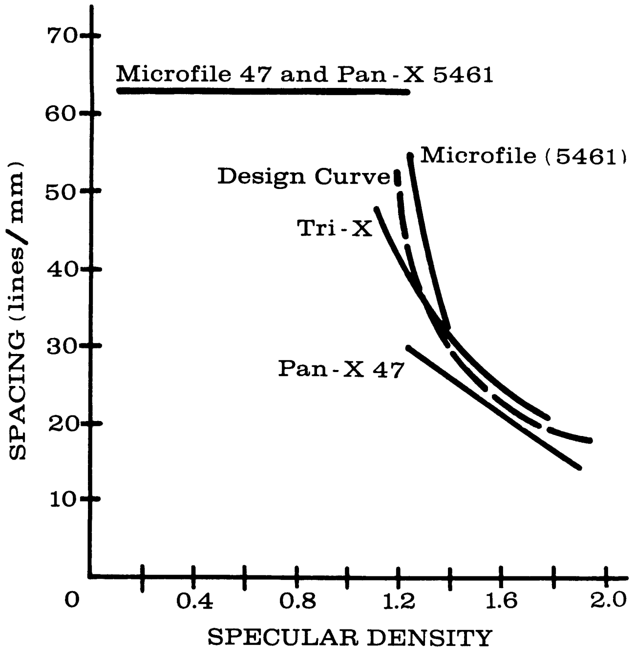

FIGURE 26. RESOLUTION VS. EXPOSURE TO MAINTAIN A CONTRAST RATIO OF 0.500

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Willow Run Laboratories, U. of Michigan, Ann Arbor
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(Memo. no. 2900-84-R)
(Contract DA-36-039 SC-78801) Unclassified report

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1. Photographic film – Test results

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II. Henry, E., and Harrison, M.
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