HOW BIG IS A HALFTONE HOLE

Don Leister*

Abstract: The structure of silver halftone dots on photographic film has been studied using photomicrography, microdensitometry, and computer-aided plotting of density contours. Halftone dots are shown to have variable density as well as highly variable edge gradation or acutance. The density of the "hole" is therefore quite variable. Some of the typical halftone dots and holes illustrated were electronically generated on scanners; some were screened on scanners with lasers or broad-band light; others were conventionally screened by direct, indirect, or rapid-access systems. Further, differences between lith and high contrast, continuous-tone (rapid-access) processed dots are shown. Chemically etched halftone dots are studied, along with contact dots on positive and negative films. The conclusion is presented that the densities of dots and holes are important aspects of a halftone image and are often overlooked when considering the various photographic steps on the way to producing ink on paper.

Introduction

A large volume of work has already been published on this subject, dealing with the unique structure of a dot on film. This study deals not so much with the dot structure in itself but with a comparison of the structures of various kinds of halftone dots. Dots are arbitrarily distinguished from holes by considering the dot to have high optical density

---

*Eastman Kodak Company, 1983

and holes to have low density. Of particular interest too is the analysis of the structure with microscopic and densitometric methods. The combination of these techniques has allowed the study of halftone dots as presented in this report.

Experimental

The microdensitometry of the halftone dots is done on a Perkins Elmer microdensitometer, model PDS, using a four-micron aperture. Scanning an area of about six dots (60-lines per centimetre or 150-lines per inch) provides about 4×10^4 density values (200 by 200). This represents an area of dots and holes as shown in Figures 1 and 2. In this case, the solid black area represents all values above 4.0 density, and the white area represents values less than 0.15 density. The two shaded areas are values of 0.15 to 1.0 and 1.0 to 4.0 density. Two different kinds of halftone dots are shown here at two levels of dot size. The shapes of the dots are characteristically described. From this kind of a contour plot, it is clear that the density and size of the "hole" are not clearly defined any better than that of the "dot."

Another manipulation of the density values was made by averaging the gradient plots from the center of each hole to the center of each dot. This provides a plot of the dot and hole gradient and describes the dimension of the dot. Figure 3 shows this kind of plot. This can be considered as an average cross-section of a dot. The dot area values on the plot are mathematically defined by considering a checkerboard dot at the 50 percent level and gradually shifting to a symmetrical round dot at 90 percent and 10 percent values. On some of the gradient plots in this report, the densitometer values from commercial instruments are indicated. In these cases, the zero value of dot area is arbitrarily adjusted to some just-not-printable density value. Under these test conditions, it is noted that the dot is defined at a density of about one to two.

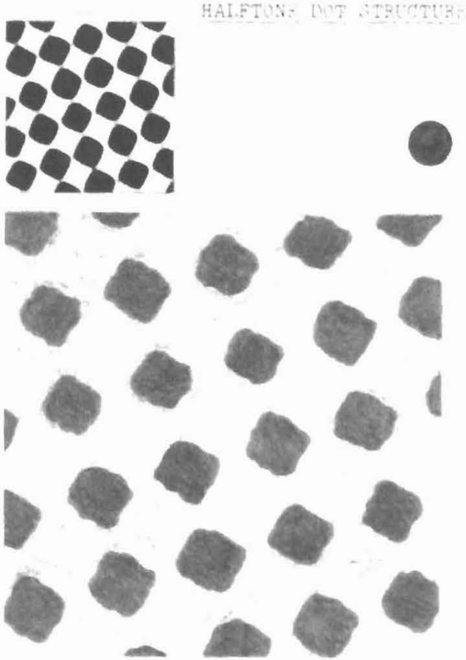


Figure 2. Kodalith MPII Scanner Film 2595
Crosfield Magnascan 510 Scanner
Kodalith MPII Developer

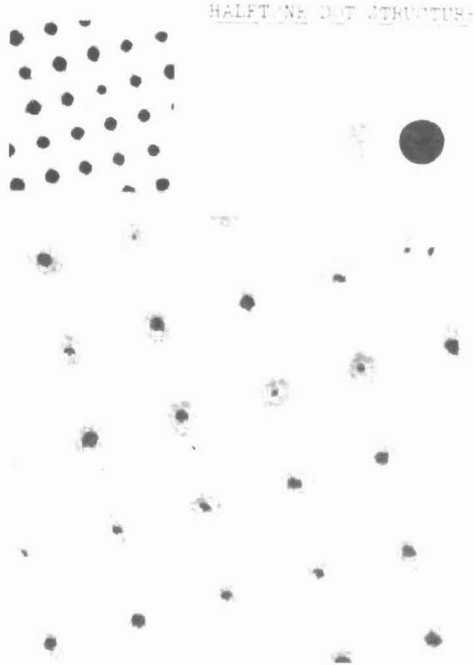


Figure 1. Kodalith MPII Scanner Film 2595
Crosfield Magnascan 510 Scanner
Kodalith MPII Developer

Density Gradient of Halftone Dot

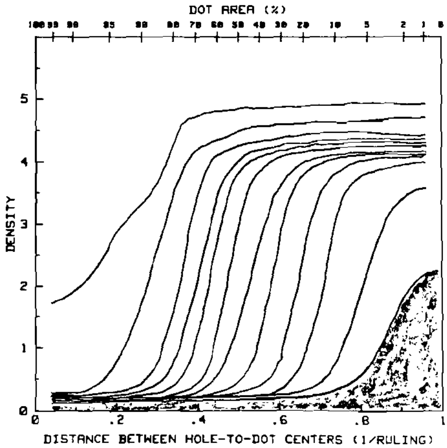
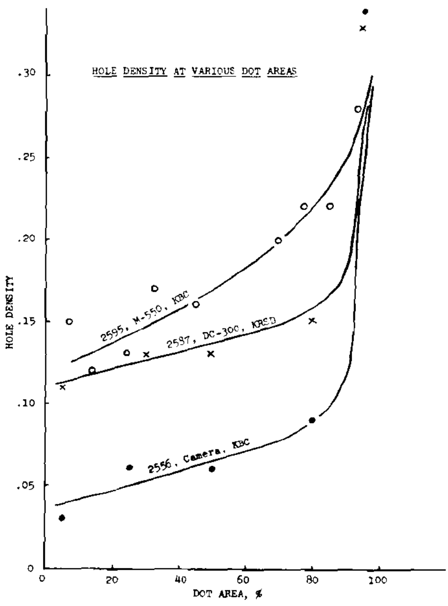


Figure 3. Kodalith MPII Scanner Film 2595
Crosfield Magnascan 550 Scanner
Kodalith Blender Concentrates

Figure 4.



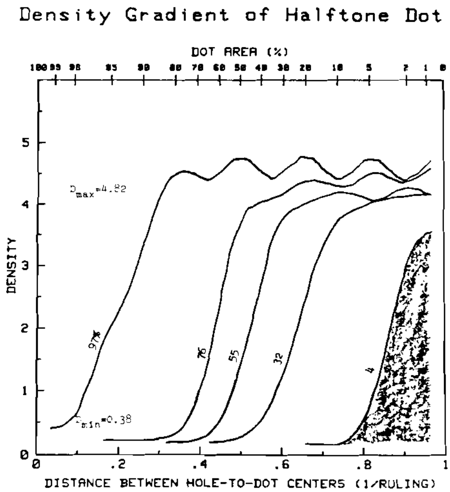
Results

A. Scanner Halftones

Figure 3 shows gradient plots for KODALITH MPII Scanner Film 2595 exposed on a Crosfield Magnascan 550 Scanner using a xenon light. The particular emphasis here is the density of the center of each dot. This varies from a value of two for the small dot to a value of five for the large dot. Also, the density of the hole increases as the percent dot area increases. Figure 4 plots the increasing density of the holes for this film and some other films to be considered later. This is a particularly significant effect because it contributes to a variable light transmission in photographic contacting. The tone scale or dot size changes significantly as the exposure changes. Dry dot etching, using exposure variations, is made possible because of this variation in hole density throughout the tone scale. Different types of film and developer systems have more or less hole density. First generation screen dots tend to have more variable hole density than found in contact or hard dots.

Figure 5 shows dots on KODAK ES Scanner Film 2587 exposed on the Hell DC-300 B/L Scanner using an argon-ion laser for electronic dot generation. The slope of the dot is slightly greater than that of the "soft dot" films, but the hole density is still increasing significantly (Figure 4). This is somewhat influenced by the developer. Figures 5 and 6 show a comparison between rapid access and lith-developed dots. The lith developers produce dots with higher gradation and lower hole density. A high-contrast, continuous-tone developer (KODAK Rapid Scanner Developer) produces higher hole density and a lower slope on the dot edge.

Figure 7 shows dots on KODAK ES Scanner Film 2587 having been exposed with argon-ion laser light on a Dainippon SG-808 Scanner using a fine pitch, electronic dot generation. These dots are very sharp, and the hole density is low.



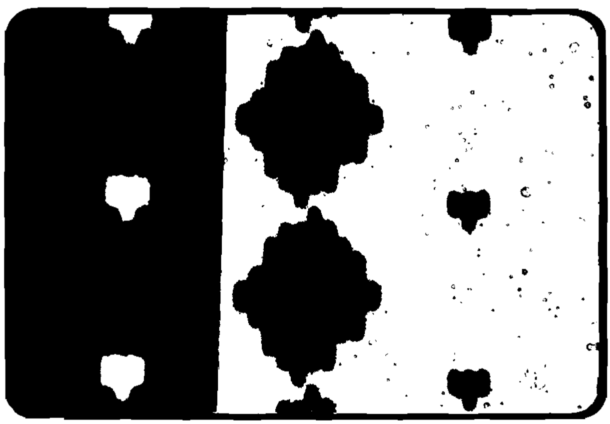
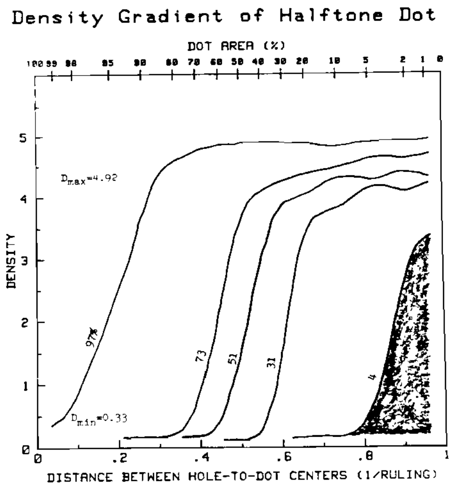


Figure 5. Kodak ES Scanner Film 2587
Hell Chromagraph DC-300 B/L Scanner
Kodak Rapid Scanner Developer



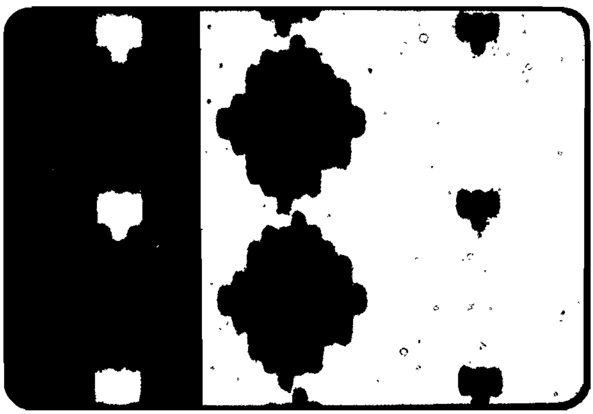
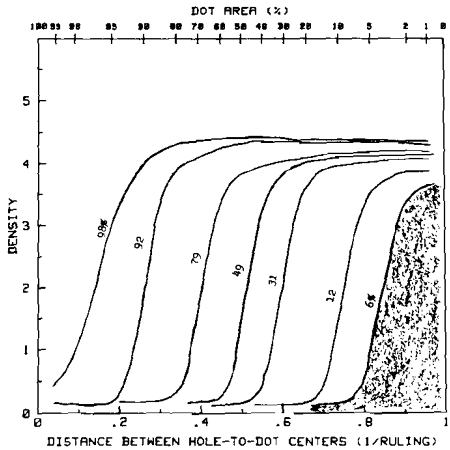


Figure 6. Kodak ES Scanner Developer
Hell Chromagraph DC-300 B/L Scanner
Kodalith MPII Developer

Density Gradient of Halftone Dot



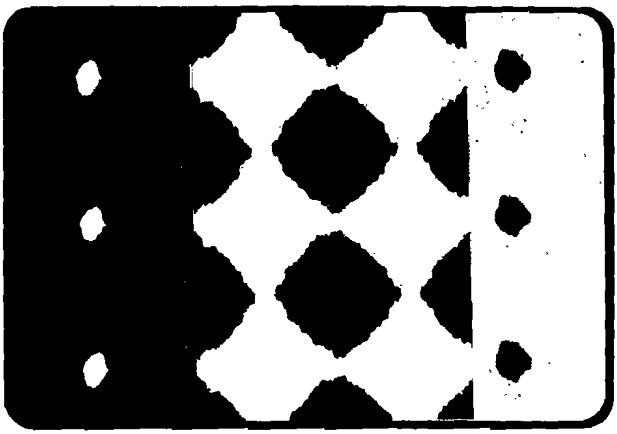


Figure 7. Kodak ES Scanner Film 2587
Dainippon SG-808 Scanner
Fuji HS-1 Developer

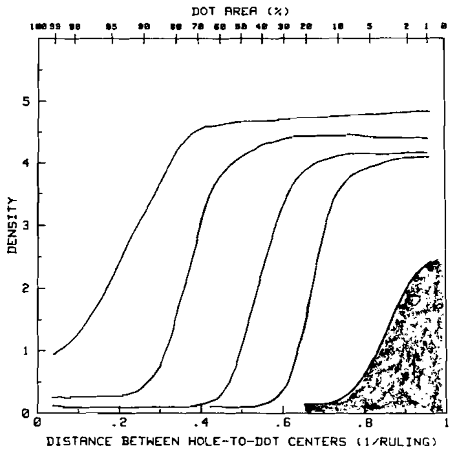
Figure 8 illustrates the dot contours for KODAK HN Scanner Film SO-553 from a Dainippon SG-606 Scanner using a helium-neon laser with conventional screening. The film shows fairly low-density 5 percent dots and rather veiled shadow dots or high-density holes. KODALITH GS Scanner Film SO-249 (Figure 9), exposed on a Magnascan 510 Scanner, has low-density or clean holes with high-density, smaller dots. KODALITH CS Scanner Film SO-161 on a Magnascan 550 Scanner (Figure 10) has very low-density 5 percent dots and low-slope, upper-scale dots. On a Magnascan 540 Scanner, an argon-laser screening scanner (Figure 11), the dots have higher-density, small dots and a sharper upper-scale dot with lower hole density.

B. Camera Halftones

Figures 12 through 15 represent the density gradient plots of the halftone silver dots in four films used for conventional first generation screening. Each of these examples feature different film, screen, and developer combinations.

With each of these halftone systems, there are some notable differences in the gradient plots that are not necessarily attributable only to the film. The entire photographic system of light-film-screen-developer must be considered. Figure 12, featuring KODALITH Ortho Film 2556, Type 3, shows a particularly sharp shoulder, fairly low, small dot density, and very clean low-density holes. KODALITH MPII Ortho Film 2577, used in the photographic scheme shown in Figure 13, has even cleaner holes at the 97 percent dot area. The shoulders are more rounded, and the dot density is higher. A rapid-access method using KODALINE Rapid Film 2586 (Figure 14) shows low-density, small dots with rather poor edge definition along with veiled, high-density holes. Probably the highest hole densities occur on the direct screened KODALITH MPII Pan Film 2554 in the area above 90 percent dot (Figure 15). Below the 90 percent dot area, the hole densities are at a more reasonable 0.2 level.

Density Gradient of Halftone Dot



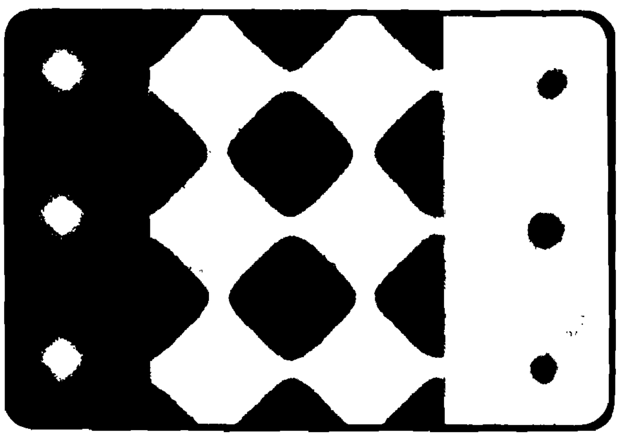
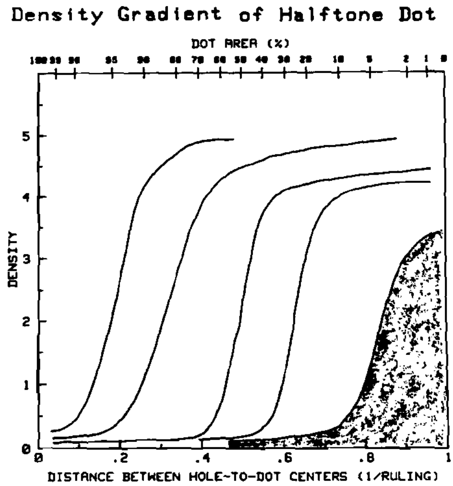


Figure 8. Kodak HN Laser Film SO-553
Dainippon SG-606 Scanner
Kodalith Blender Concentrates



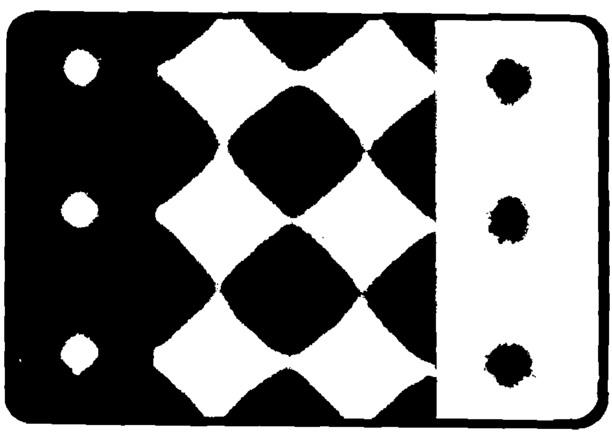


Figure 9. Kodalith GS Scanner Film SO-249
Crosfield Magnascan 510 Scanner
Kodalith Blender Concentrates

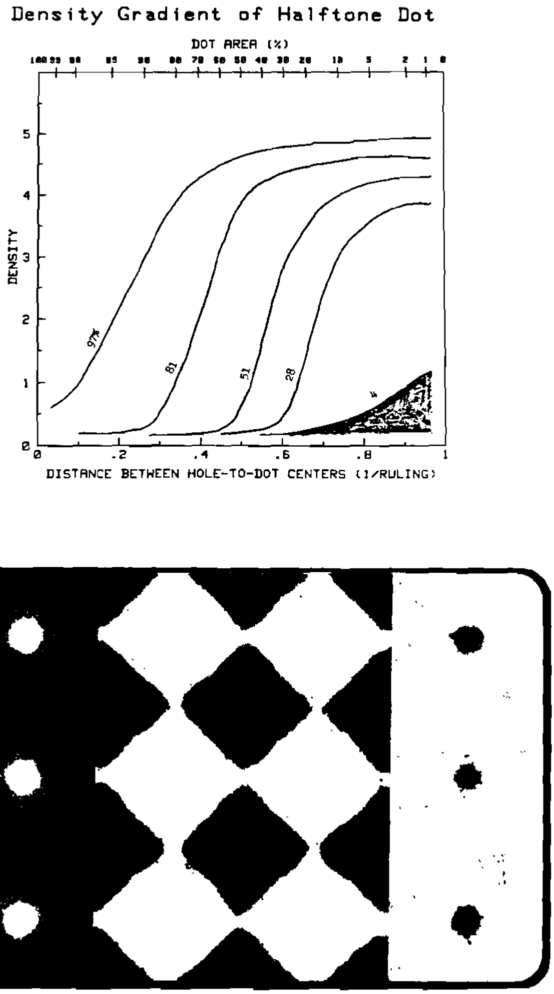
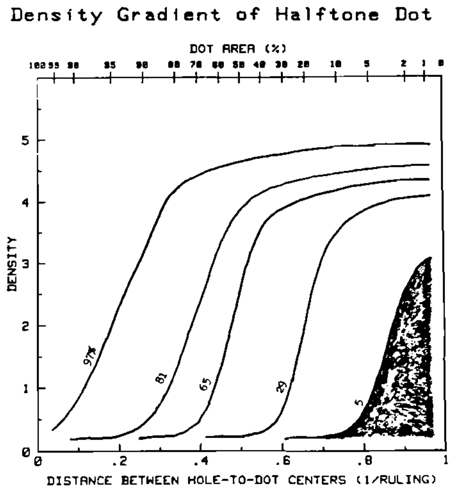


Figure 10. Kodak CS Scanner Film SO-161
Crosfield Magnascan 550 Scanner
Fuji HS-1 Developer



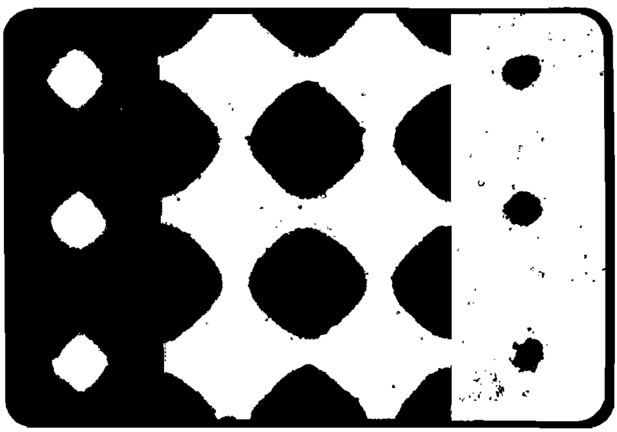
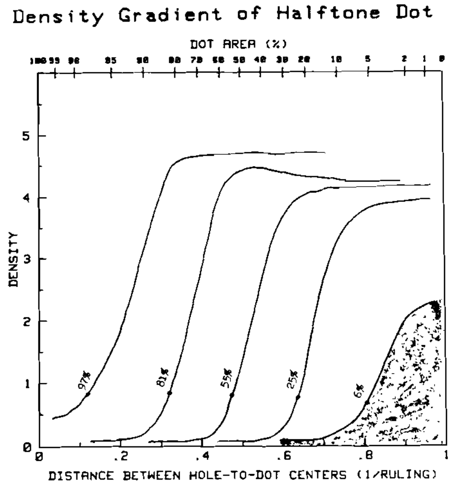


Figure 11. Kodak CS Scanner Film SO-161
Crosfield Magnascan 540 Scanner
Fuji HS-1 Developer



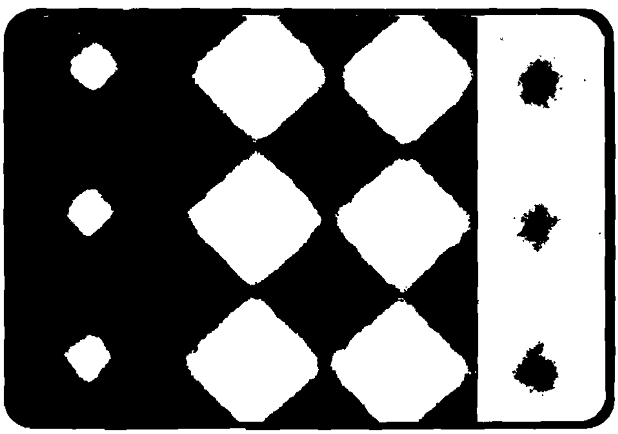
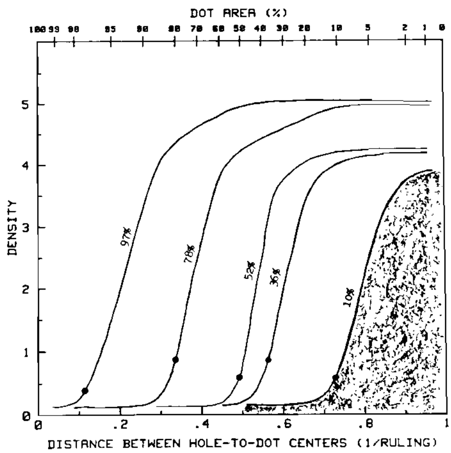


Figure 12. Kodalith Ortho Film Type 3 2556
Camera, Kodak Gray Contact Screen
Kodalith Blender Concentrates

Density Gradient of Halftone Dot



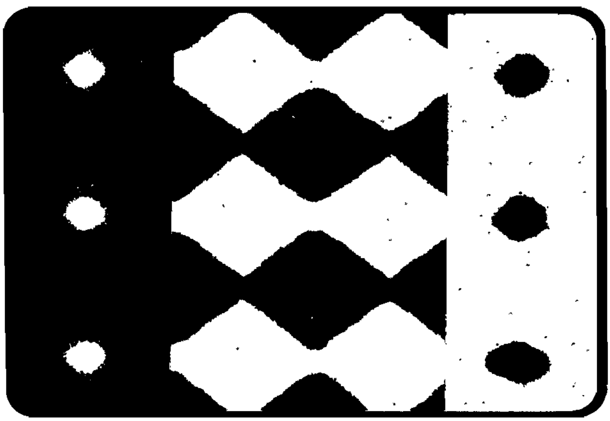
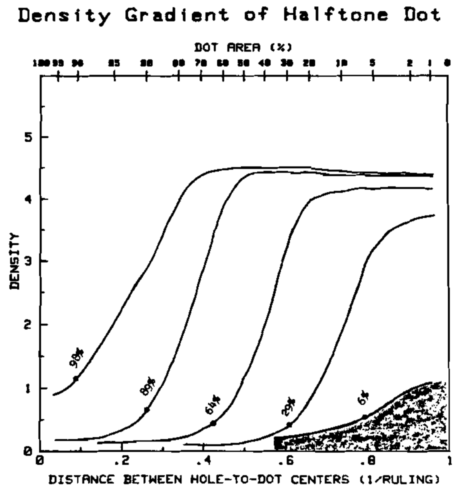


Figure 13. Kodalith MPII Ortho Film 2577
Camera, Kodak Mark MLR Contact Screen
Kodalith MPII Developer



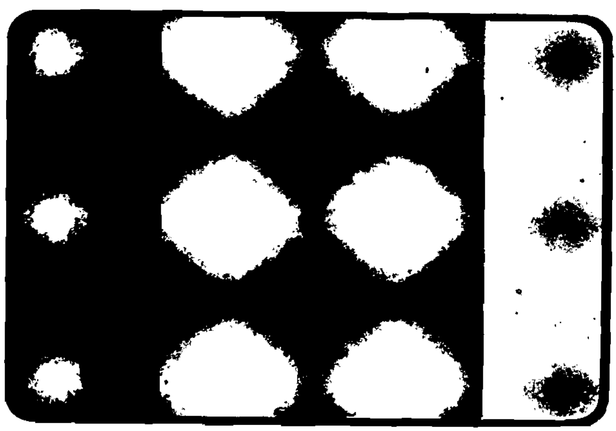


Figure 14. Kodaline Rapid Film 2586
Camera, Kodak RA Contact Screen
Kodak Rapid Scanner Developer

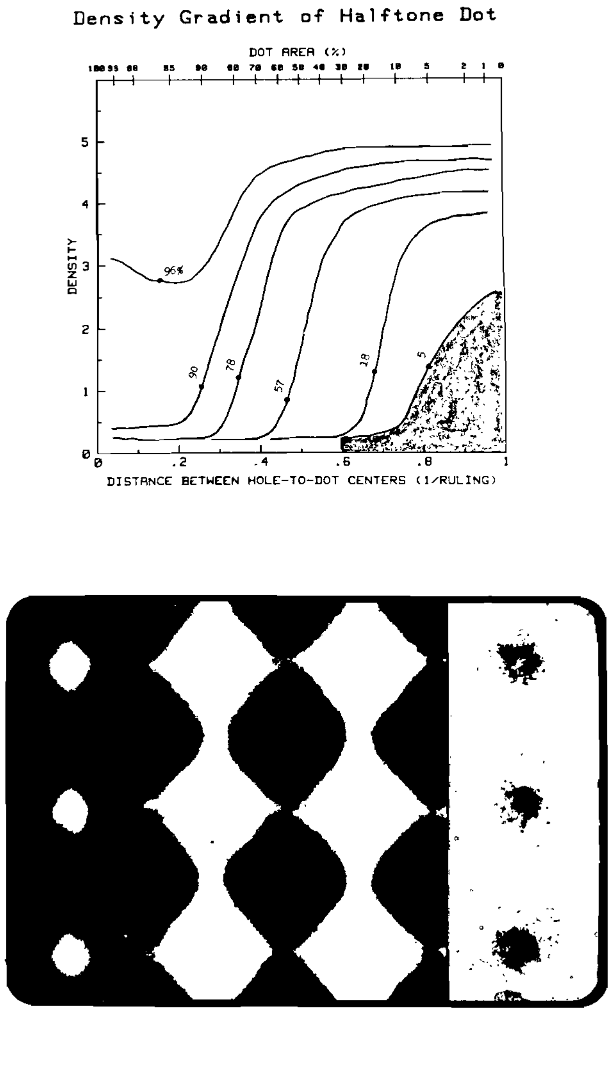


Figure 15. Kodalith MPII Pan Film 2554
Contact Direct Screen, Kodak Mark GMR
Kodalith MPII Developer

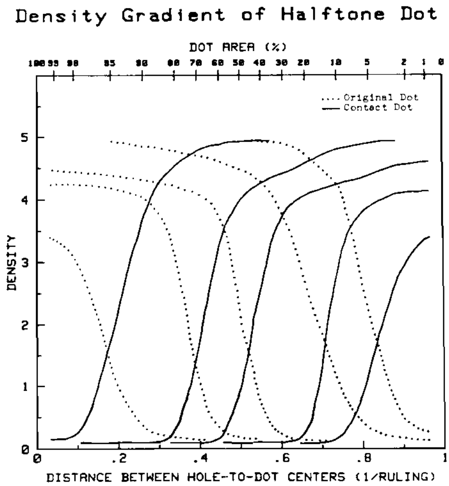
These density gradient plots show the dot area value as read on a Macbeth TD-904 densitometer. This is represented on each plot at a density level and the calculated dot area level. In most cases, it can be considered that the densitometer "averages" the gradient at about a density of one. The densitometer is zeroed in each case to some arbitrary density usually chosen as that at the "just-not-printable" dot (JNP). This is a reasonably practical method but obviously is subject to error, depending on the variable density of the hole (Figure 4) throughout the tone scale.

C. Contact Film Halftones

Having chosen a particularly sharp, first generation halftone film (KODAK GS Scanner Film SO-249), a contact was made on KODALINE Rapid Film 2586 using an optimum exposure condition. Figure 16 shows the density gradient plot of the contact negative, and the dotted lines show the inverted contours of the original. The symmetry of the plots suggests reasonably good dot-for-dot reproduction, and it is interesting that the complementary dot intersections occur at a density of about 1.5 value. This is close to where the densitometers "see" the dot.

For comparison of chemical processes, Figure 17 shows the result of the same film, KODALINE Rapid Film 2586, having been processed in KODAK Rapid Scanner Developer and KODALITH Blender Concentrates. The differences are relatively small, but the lith developer does produce slightly lower-density holes.

Using KODALITH MPII High Speed Duplicating Film 2564, the same halftone as used above was duplicated. Figure 18 shows the gradient plot of the original and the dupe. This comparison describes the typical problem encountered in making a perfect dupe. The particular light exposure was chosen to compromise both highlight and shadow. The hole density of the dupe at the 98 percent dot area could have been reduced with more exposure. However, the small dot and the



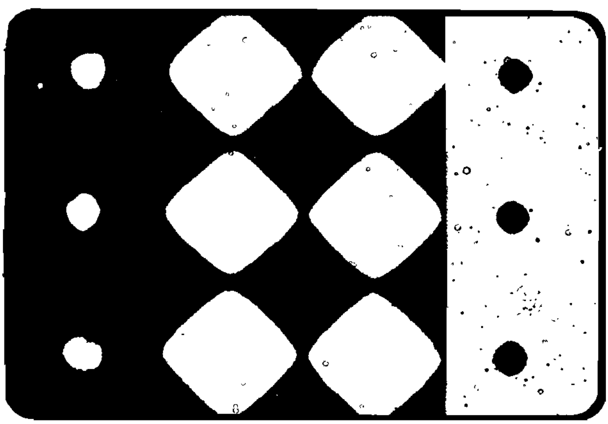


Figure 16. Kodaline Rapid Film 2586
E-to-E Contact From Soft Dots
Kodalith Blender Concentrates

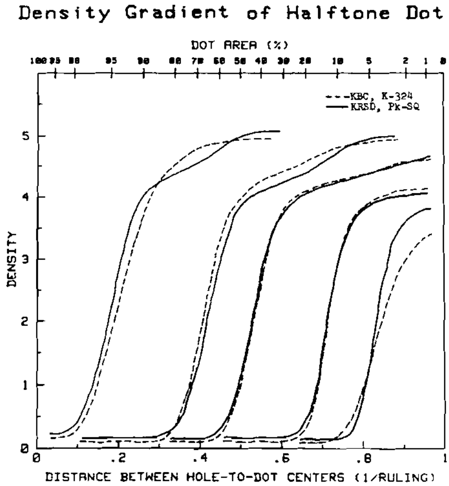


Figure 17. Kodaline Rapid Film 2586
E-to-E Contact, RA vs Lith
Pako SQ with KRSD vs K-324 With KBC

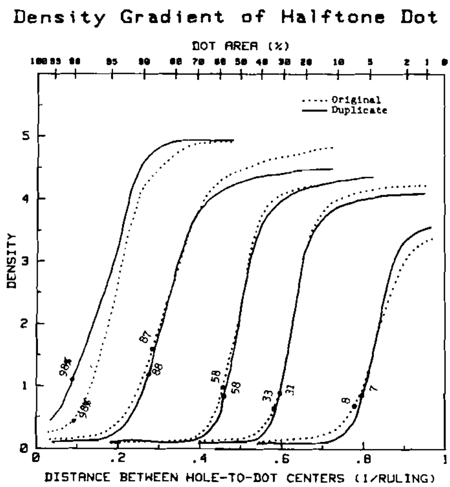


Figure 18. Kodalith MPII High Speed Duplicating Film 2564
E-to-E Contact From Soft Dots
Kodalith MPII Developer

midtone dots have been already slightly overexposed and reduced in density. The hole areas are well cleaned out, and more exposure would reduce the dot area. The exposure used gave a reasonable compromise. It might be noted in Figure 18 that the densitometer read both of the high end dots at 98 percent even though the hole densities are different. Again, this error comes from the use of a single JNP value for the entire scale of each film. The gradient plot shows that the hole densities are different, and very likely, the next photographic step (platemaking or proofing) would show a comparable difference.

D. Chemically Etched Halftones

Beginning with scanner halftone dots as described in Figure 19, a Senelith Etch solution was used to reduce the dot sizes as shown in Figures 20, 21, and 22. This level of dot reduction at 150-second etch time is about as far as would be practical. In Figures 20, 21, and 22, only three dot levels were chosen to show the reduction of silver density at the maximum etch time. In each case, the contact duplicate of the original and etched halftone is profiled. The densitometric dot values are listed as follows:

Percent Dot Values on Film

Dupe		Original Dot		Etched Dot		Dupe
99%	←	98%	→	65%	→	73%
83%	←	83%	→	31%	→	37%
52%	←	52%	→	5%	→	7%

These plots demonstrate how thin a dot can be etched and successfully duplicated.

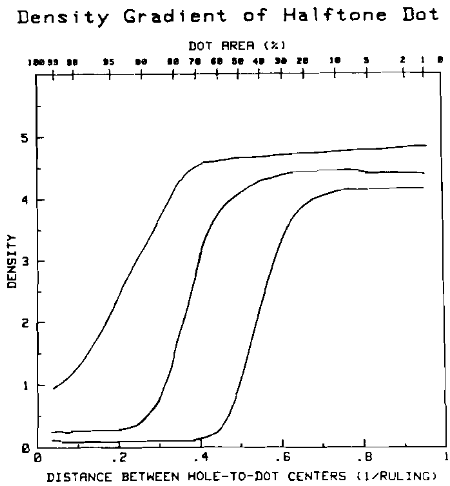


Figure 19. Kodak HN Laser Film SO-553
Dainippon SG-606 Scanner
Kodalith Blender Concentrates

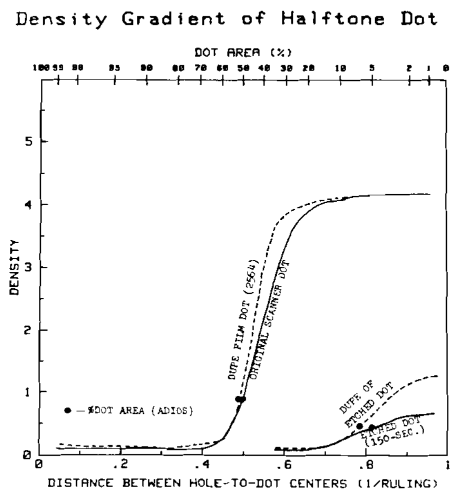


Figure 20. Kodak HN Scanner Film SO-553
Dainippon SG-606 Scanner
Senelith Etch, 1:3 Dilution

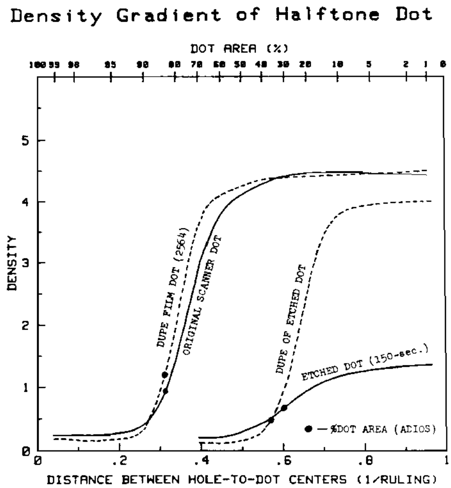


Figure 21. Kodak HN Scanner Film SO-553
Dainippon SG-606 Scanner
Senelith Etch, 1:3 Dilution

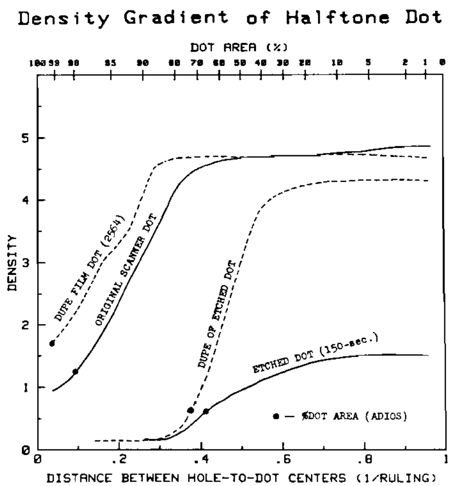


Figure 22. Kodak HN Scanner Film SO-553
Dainippon SG-606 Scanner
Senelith Etch, 1:3 Dilution

Discussion

The collection of data presented in this report serves primarily to characterize some of the various kinds of halftones on photographic film. In addition, it has been shown that the hole density is an often overlooked aspect of tone reproduction. No one ever speaks of "hole quality;" it is always "dot quality." Both the dot and the hole have variable density, and the exact dimension where one ends and the other begins is arbitrary. This work is intended to shed some light on this aspect. The procedures of photographic contact reproduction and dot etching are very much dependent on the dimension of the density gradient. A densitometer is a very valuable tool to measure the silver density distribution as percent dot or hole coverage, but this is only an indirect measure of dot area. It should be considered a quality control value. If the structure of the dot is different for various films, the interpretation of the densitometer values should change.

Although this study does not deal with proofing methods or platemaking, the same effects should be considered for any photosensitive material used in the reproduction method. If the density of the halftone hole varies, the amount of light reaching the photosensitive material will vary, and the dot size will vary. In most cases, this variation is empirically compensated without knowledge of the reason. For quality reproductions, this is all part of the logic behind the scheme of starting at the press and working back to the darkroom or scanner. With consistent feedback and consistent recording of densitometric dot values, along with judicious changes in values, high-quality reproduction can be achieved.

Conclusion

Because of the variable density of halftone dots and holes in photographic film images, it is very difficult to accurately judge the final printed dot size that will result from a first generation halftone. With the same consideration, a densitometer provides only a very repeatable measure of light transmission and an empiracle expression of dot area coverage. Of prime concern is the light response characteristic of the photographic material used in the various procedures of generating the final halftone image.

Acknowledgment

The author is thankful to John Hamilton for computer programming, to Ted Doerner and Debbie Smith for densitometry, to Jim Delabarto for photomicrographics, and to Dave Scheible for graphics.

KODAK, KODALITH, MPII, ESTAR and KODALINE are trademarks.

Bibliography

W. Schneider, Spatial Pulse Modulation for Coherent Optical Densitometry, CSIR, Pretoria, South Africa, Opt. Acta (GB), Vol. 21, No. 7, July 1974.

H. Kato, J. W. Goodman, Nonlinear Transformations and Logarithmic Filtering in Coherent Optical Systems, Fuji Photo Film Co., Ltd., Nishiazabu, Minato-Ku, Tokyo, Japan, Opt. Commun. (Netherlands), Vol. 8, No. 4, August 1973.

C. Mora, W. Markocki, Study of the Properties of Lith Photosensitive Layers in the Reproduction of Screen Dots, Inst. Org. Phys. Chem., Wroclaw Polytech., Wroclaw, Pol., Sb. Prednasek-Symp. Fotochem., Fototyz. Ved. Fotogr., Fotogr. Acad. Mezinar. Vcasti, 9, 1980.

P. Oittineu, H. Saarelma, Density Formation of Halftone Dots, Finnish Pulp and Paper Res. Inst., Helsinki, Finland, TAPPI, Vol. 65, No. 1, 1982.

R. J. Byer, Facile Image Evaluation of High Resolution Films, E. I. du Pont Co., Inc., Rochester, NY, J. Appl. Photogr. Eng., Vol. 3, No. 2, 61-6, 1977.

J. P. Allebach, B. Liv, Analysis of Halftone Dot Profile and Aliasing in the Discrete Binary Representation of Images, Dept. of Elec. Eng., Princeton Univ., J. Opt. Soc. Am., Vol. 67, No. 9, 1977.