A NEW GRAPHICAL FORMAT WHICH ILLUSTRATES THE DIFFERENT WAYS IN WHICH INK, WATER, PAPER, PLATES, AND BLANKETS CAN AFFECT THE TONE REPRODUCTION CHARACTERISTIC OF A GIVEN PRINTING PRESS UNIT.

by John MacPhee * and John Lind **

Abstract: In the work reported on in this paper, each printing unit on a press is treated as a stand-alone reproduction process in which the film from which its plate is made is considered as the original, and the corresponding print the reproduction. Within this context, a new format for a print characteristic curve is defined which displays all three of the print properties which govern the tone reproduction characteristics of a press unit; the density of the printed ink film, the size of the printed dots relative to the original, and the picture contrast. Picture contrast, not to be confused with print contrast, describes the rate of change of the density of the reproduction with respect to the density of the original, and is analogous to the property "gamma" used in photography. Sample data from single color printing tests on a sheetfed press are plotted to illustrate the diverse ways in which the tone reproduction characteristics of the test unit were affected by changes in ink feedrate, water feedrate, ink tack, fountain solution composition, paper grade, type of blanket, blanket packing, and type of plate.

INTRODUCTION

One of GATF's current research projects is aimed at quantifying the effect of paper grade on the characteristics of prints produced on coated paper. During the course of analyzing and studying test prints, a question arose as to what format(s) would be most suitable for evaluating and presenting the data obtained. This question in turn led to an offshoot of the project wherein the features of the known formats were cataloged and judgements made of their relative merits. In the course of this subproject a new (to the best of the authors' knowledge) method for graphing print density data was devised. The perceived merits of this new approach were tested by using it to chart the response of a printing press to various changes in the press adjustments and process parameters. Based on these trials, it was concluded that the best presentation is one which includes both the new density data format and the familiar dot gain format. Thus, the purpose of this paper is twofold: (1) to describe the authors' recommended charting system for print data and (2), to present

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practical examples which point up the insightfulness of this format.

The main body of this paper consists of three sections which contain, in turn, background information including a review of existing formats, a description of the new format, and a description of the tests run to obtain sample data, along with presentations of the test results in the recommended form.

BACKGROUND

Two very important objectives in printing are (1), to reproduce the desired form or scene in a way which is pleasing to the viewer, and (2), to achieve consistent reproductions from one impression to the next. In pursuit of the first of these objectives, the concept of fingerprinting a press has been in use for many, many years. As the name suggests, this concept involves measuring the reproduction characteristics of the printing units on a press and then using the resultant fingerprints or press characteristic curves to devise separation and screening techniques which, when used in production, will result in visually pleasing prints.

Although this concept is well known, there is no general agreement on what is the best format for presenting or plotting the data which describes the reproduction characteristics of a printing press unit. Thus, the discussion shall begin by addressing that issue.

Definition of Press Characteristic Curve

The Jones diagram (Jones, 1931), well known to photographers, was designed to illustrate how the various stages of the photographic process affect the tone reproduction of the overall process, where tone reproduction can be expressed as the relationship of the density gradations of the reproduction to those of the original. Yule and Clapper (1958) adapted the concept of such a diagram to the photomechanical printing process where the original subject is a picture or scene and the reproduction is the halftone print of that subject produced by the press.

Both the original Jones diagram and the modified one devised by Yule and Clapper consist of an interrelated series of characteristic curves, wherein each characteristic curve portrays how a given step or stage of the process affects the tone reproduction of the overall process. Thus each characteristic curve can be looked upon as defining the relationship between the tonal properties of the input and output of the process stage it defines. For example, if the printing process is viewed as consisting of the stages shown in Figure 1, then the characteristic curve of the press (printing unit) can be viewed as a plot of the function relating the tonal properties of the print produced

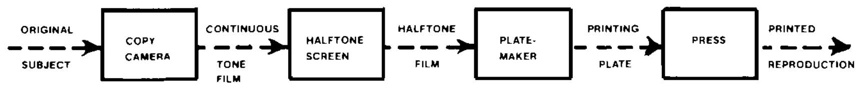

FIGURE 1 Block Diagram Representation of a Simple Photomechanical Printing Process. In this model, blocks represent stages in the process and dashed lines represent stage inputs and outputs.

by the press (i.e., the press output) to the tonal properties of the plate, which is the input to the press. However, because measurements of the film used to make the plate are more reliable, and easier to obtain, the common practice is to combine the platemaking stage with that of the press. Therefore, the characteristic curve of the press is defined here as a plot of a function relating the tonal properties of a print produced by the press to the tonal properties of the film used to make the corresponding press plate. With this definition in hand, the formats currently used for such curves can now be reviewed.

Formats Now In Use

The two formats most commonly used today are the dot-gain (or loss) curve, first used by Laseur, Haar, and DuPont (1959) and the density-dot-area curve, suggested as long ago as 1945 (Anonymous, 1945). Both curves use dot area on the film as the image input variable.

As shown in Figure 2, the dot gain curve is simply a plot of total dot gain on the print, relative to the film, versus dot area on the film. The widespread acceptance of this format is evidenced by the inclusion of recommended dot gain ranges in the suggested SWOP specifications (Anonymous, 1986). Although the curve is informative and does indeed represent a "fingerprint" of the press, it has been criticized as being deficient for several reasons. First is the objection that the dot gain curve is too narrow in scope in that it contains no information on an extremely important output image property, print density range. The importance of this will be realized if one stops to think of the difference in appearance given by the same image, printed

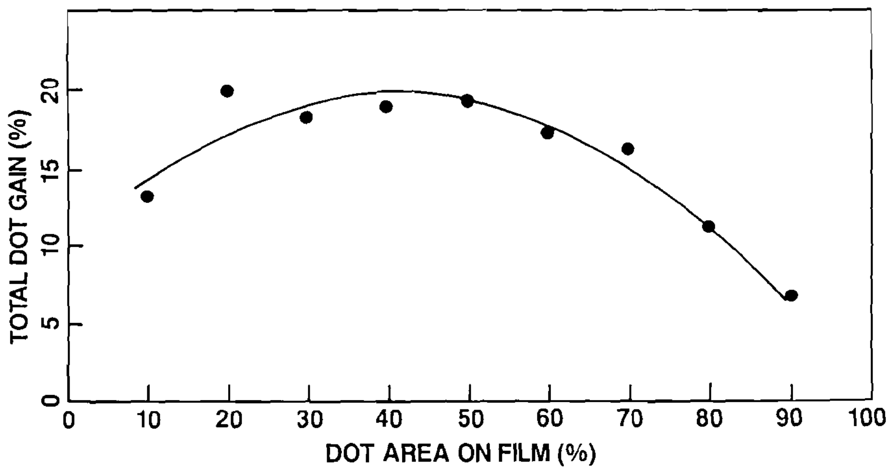

FIGURE 2 Existing Format used to Display Dot Gain Data. This type of plot is silent on density range and contrast information.

at two different ink film thicknesses with the same dot gains. A second, and perhaps more important, objection to the dot gain curve is that it contains no information on picture contrast, i.e., the relationship between the density of the input image and that of the output. (A more precise definition of contrast is given later on.) This of course stems from the fact that picture contrast depends on both dot size and ink film thickness or solid density.

These and other objections to the dot gain format have led many graphic arts specialists to use the so-called density-dot-area curve. In this format, print density is plotted versus dot area on film, as shown in Figure 3. This format overcomes the two objections to the dot gain curve, but in turn can be criticized for doing so at the expense of not providing information on dot gain. An additional objection is that the contrast information obtainable from such a plot is misleading and has no physical significance. For example, the curve in Figure 3 suggests that in a typical print there is significant tone expansion in the shadows, whereas in actuality there is significant compression, as will be shown later.

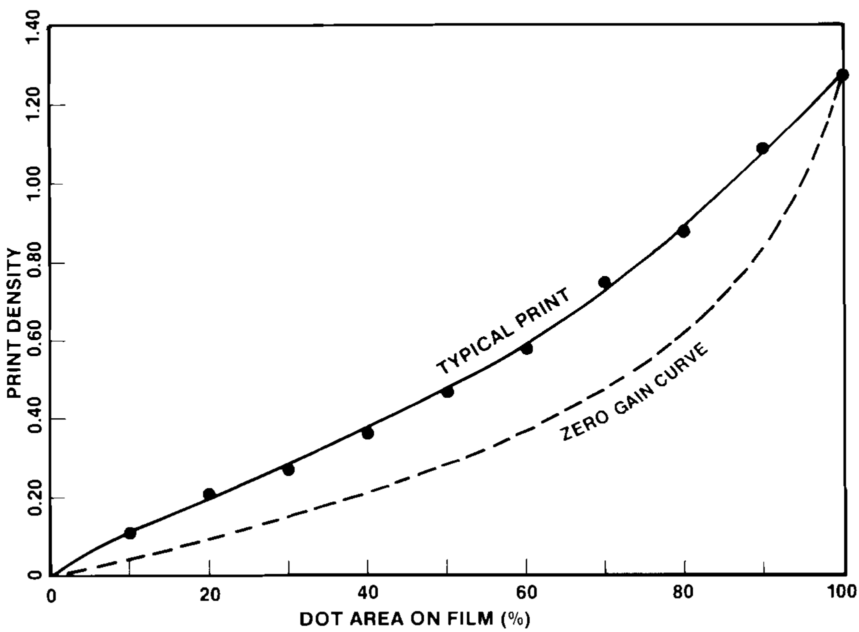

FIGURE 3 Existing Format Used to Display Density Data. Zero dot gain curve is plot of Murray Davies Equation based on measured solid density.

A third format in use is a variation of the density-dot-area curve which utilizes a nonlinear density scale, as shown in Figure 4. Known as a PC (printing characteristic) plot, this method of graphing was first described by Archer (Archer, 1978). Its distinguishing feature is the nonlinear density scale used for the ordinate. This nonlinear density scale was selected on the basis that it corresponds to a linear spacing of brightness scale and that such a brightness scale is "preferred • • • for its closer relationship to the way humans see complex fields".

Another advantage claimed for the PC plot is based on the discovery that when n=2.2 (in the Yule Nielsen Equation) the relationship between tint density and dot area is a straight line when plotted on this graph paper. That is, it has been suggested that a relative measure of dot gain can be obtained by observing the differences between the curve of measured densities on PC graph paper and the corresponding straight line. However, in those cases where an absolute measure of total dot gain is desired, a plot of the Murray

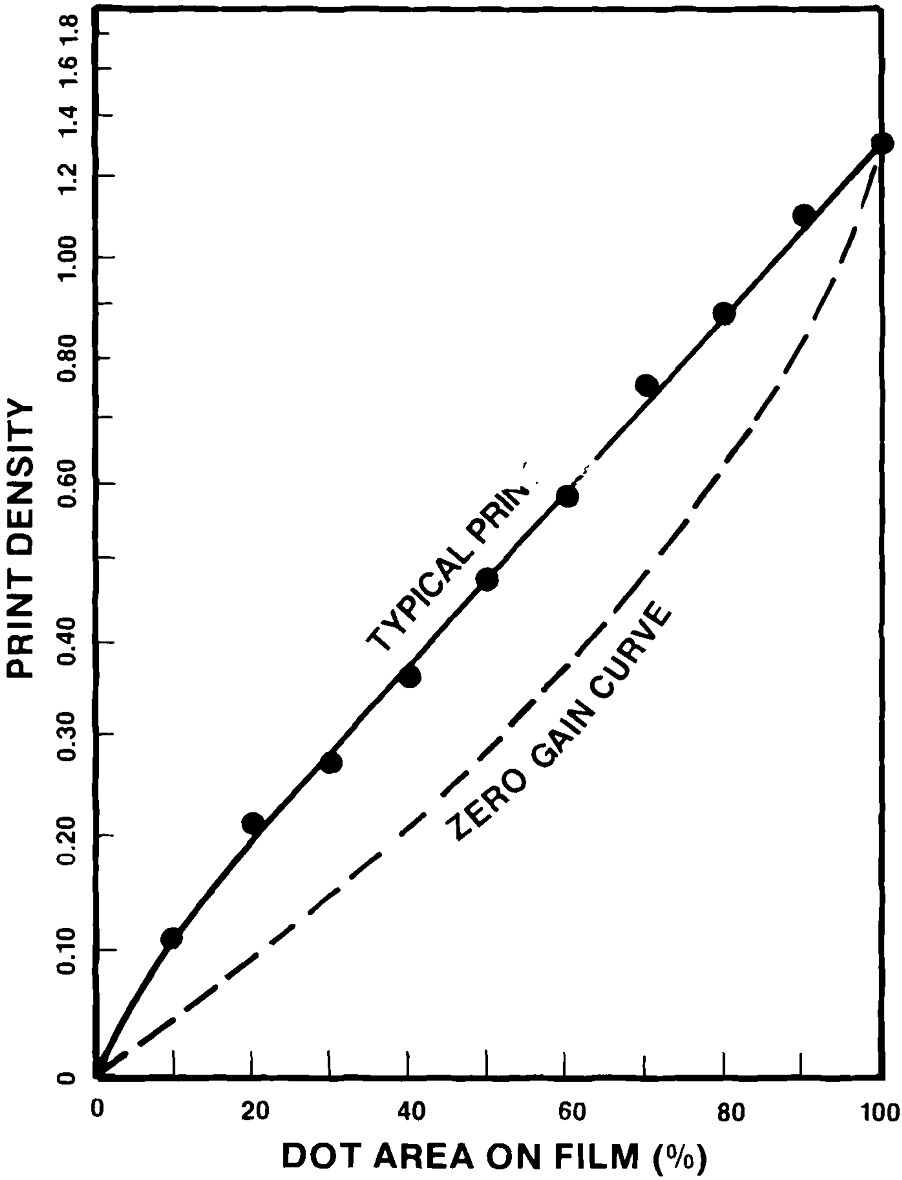

FIGURE 4 PC Format Used to Display Density Data. Zero dot gain curve is plot of Murray Davies Equation based on measured solid density.

Davies Equation must be used, and for this the values must be calculated since its plot is not a straight line. In the authors' view the major drawback of the PC plot is that like the linear plot in Figure 3, it does not accurately portray contrast information - since neither scale is linear with respect to density. An added disadvantage is that the user cannot construct the nonlinear scale himself, but must use paper supplied by RIT.

PROPOSED FORMAT

Strictly speaking, the proposed format is not new in principle because it simulates a plot of print density versus density of the original, the importance of which in printing was described many, many years ago (Dorst, 1950). However, it is thought to be new in concept because of the following:

a) It constitutes a tone reproduction curve of a printing unit in that it portrays the relationship of the density of the reproduction (the print) to the density of a hypothetical original, represented by a hypothetical positive photographic contact print, made from the negative plate film. (Thus, the slope of such a curve provides a direct measure of contrast.)

b) Only print density vs film dot area data is needed to plot the curve since the linear density scale of the hypothetical original is converted to a nonlinear dot area scale using the Murray Davies Equation.

Thus, the new format embodies the advantages of both types of existing formats and yet also provides relatively true contrast information. That is, the proposed format is designed to convey the following information:

(i) A measure of dot gain vs area
(ii) A measure of print density range
(iii) A measure of print contrast over the entire density range

Figure 5 is a plot of a typical test result, using the proposed format. The upper horizontal axis is marked off with a linear density scale of zero to 2.0, corresponding to the density range of the hypothetical original. The corresponding film dot area scale, marked off on the bottom horizontal axis, was calculated using the Murray Davies Equation, assuming a solid density of 2.0.

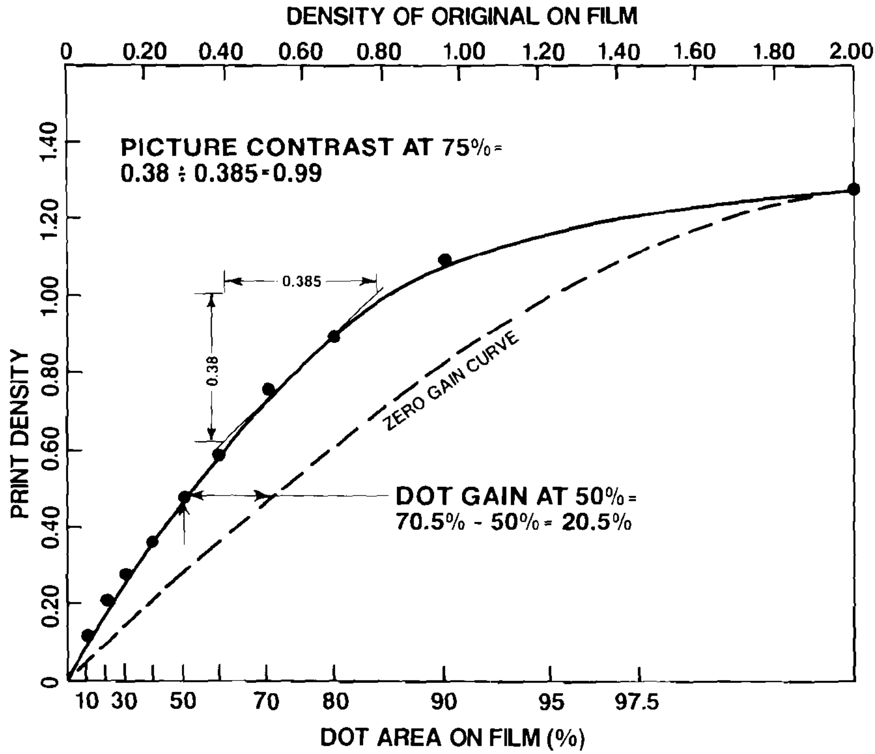

FIGURE 5 Proposed New Format. Upper curve is plot of same data set displayed in Figures 2, 3, and 4.

The manner in which the above three items of information on output image properties can be obtained from Figure 5 will now be described.

(i) Dot Gain. Dot gain at a given film dot area can be read directly as the difference in dot area between the actual print and the ideal or zero gain curve. As an example, the dot gain at 50 percent is shown in Figure 5 to be approximately 70.5 percent minus 50 percent, or 20.5 percent. (The gain obtained from the best fit curve of the same data, shown in Figure 2, is also 20.5 percent.)

(ii) Print Density Range. Print density range is read as the solid ink density (100 percent dot area density) i.e., 1.28 for the example shown in Figure 5.

(iii) Picture Contrast. Picture contrast is the slope of the curve obtained using the linear horizontal scale at the top. Thus, for example in Figure 5, picture contrast varies from 2.0 in the highlights to 1.4 in the midtones. At 75 percent, picture contrast decreases to 0.38 divided by 0.385, or 0.99, and lower beyond, illustrating the actual tone compression which exists in the shadows.

Before proceeding to review the sample data, the similarity between the format of Figure 5 and one of the tone reproduction curves used by Terada (1983) should be noted. In principle, the two graphs are identical,except that Terada's Figure 5 derives its dot gain scale from the transmission density of the halftone film, which in his case was a positive. In addition, the uses to which he put this type of format were entirely different from those set forth here.

TEST RUNS AND SAMPLE DATA

The perceived merits of the format shown in Figure 5 were tested by using it to show how variations in press adjustments and process parameters affect the tone reproduction characteristics of a typical sheetfed printing unit. The nine most common variables,listed in Table I, were investigated in printing tests, in which only one variable at a time was changed. (One additional variable, coating, was also investigated in the form of a varnish and a 0.002 inch thick bonded transparent overlay.)

TABLE I Press Adjustments and Process Parameters Which Can Be Varied to Affect a Change in Print Properties. Asterisks indicate changes made on the fly.

<u>Press Adjustments</u>	
Ink Feedrate *	Water Feedrate *
<u>Process Parameters</u>	
Printing Pressure *	Type of Paper *
Plate-Blanket Squeeze	Type of Plate
Type of Blanket	Fountain Solution Properties
Ink Properties	

The form that was printed consisted of solid and screened bars, across the sheet, with a total ink coverage of 42%. The form also included one or more test targets. In general, the procedure was to first obtain a book of sheets printed under the reference conditions listed in Table II. Following this, the variable under study was changed and a second

TABLE II Test Press Reference Parameters. Ink film thickness was measured on press using a procedure described previously (MacPhee, 1985).

Ink	
Color	Magenta
Tack	20.3 @ 1,200 rpm
Plastic Viscosity	290 poise
Paper	
Grade	No. 1 Coated
Basic Weight	100 pounds
Type of Blanket	Conventional
Plate/Blanket Squeeze	0.004 inches
Fountain Solution	
Type	Acid
Concentrations:	
Part 1 (gum & etch)	2.5 ounces/gallon
Part 2 (alcohol substitute)	3 ounces/gallon
Solid Density (to paper)	1.26 - 1.37
Ink Film Thickness	0.8 grams/meter^2

book of prints was collected. The effect of the change on print properties was gauged by comparing density measurements of the test target, which consisted of a solid patch plus nine halftone patches (150 line per inch ruling) ranging in dot area from 10 to 90 percent.

In the case of four of the variables listed in Table I; ink feedrate, water feedrate, type of paper, and printing pressure, the changes were made on the fly, i.e., without stopping the press. In the case of the remaining five, it was necessary to stop the press to make the change. When the press was restarted, the pressman was instructed to adjust ink and water so as to achieve the reference density. A total of five series of printing tests, identified by the letters O, G, B, C, and F, were run over the period from July 25, 1989 through March 15, 1990. (A sixth series, R, was run using cyan ink.) All of the tests were run on the same four color press in a commercial printing company. Series R, O, G, and B, were run on press unit number four while Series C and F were run on unit three. Plates were not saved; thus a new plate was made for each series, except for R, which was printed with the O Series plate. All of the density data reported here are referenced to the paper and were measured at GATF using the same (Status T) densitometer.

The results of these tests are summarized in Table III and discussed later. After plotting this data on the proposed format, two observations were made:

(i) All of the responses could be categorized as one of the three types described in Table IV, wherein arrows are used to indicate increases and decreases in print properties.

(ii) The new format did not provide enough resolution in displaying dot gain. For this reason, the authors recommend that print data be displayed in a dual format: the proposed density dot area curve, shown in Figure 5, and the older dot gain curve, shown in Figure 2.

TABLE IV Categorization of Print Property Responses

Response Category	Dot Gain	Solid Density Range	Print Contrast: Highlight End	Print Contrast: Shadow End
Type 1	↑	No Change	↑	↓
Type 2	↑	↑	↑	↑
Type 3	↑	↓	↑	↓

TABLE III SUMMARY OF ALL PRESS RESPONSES STUDIED

ADJUSTMENT OR PARAMETER THAT WAS CHANGED	MAGNITUDE OR NATURE OF CHANGE	RESULTANT RESPONSE OF					
		Solid Density		Midtone Dot Gain (%)		Midtone Picture Contrast	
		Ref Value	Change	Ref Value	Change	Ref Value	Change
Ink Feedrate	Increased 60%	1.32	+0.24	16.0	+4.8	1.38	+0.27
Water Feedrate	Increased 45%	1.32	-0.07	16.0	+ .7	1.38	0.0
Printing Pressure	Increased .003 inches	1.28	-0.01	20.0	+1.3	1.24	0.0
Plate-Blanket Squeeze	Increased .002 inches	1.28	*	20.0	+2.3	1.24	-0.01
Type of Blanket	Conventional to Compressible	1.28	*	20.0	+1.5	1.24	0.0
Ink Properties	Decreased Tack 5.3 points	1.28	*	20.0	+4.8	1.24	+0.1
Paper Grade	Changed to No. 1 Uncoated	1.37	-0.44	15.7	+7.0	1.40	-0.35
Type of Plate	Negative to Positive	1.28	*	20.0	-8.5	1.24	0.0
Fountain Sol. Properties	Replaced Substitute with 20% IPA	1.22	*	20.5	-0.2	-	-
Fountain Sol. Properties	Change from Brand X to Y	1.33	*	20.6	+2.4	-	-
Coating	Added .002 inch Thick Overlay	1.26	+0.02	19.8	+11.3	1.25	+0.29
Coating	Applied Varnish On Press	1.30	zero	19.6	+1.6	1.25	0.0

* Interrupted test, density adjusted to same level after change was made.

To illustrate the recommended portrayal, sample plots of the variations which produced significant changes in press response are shown in Figures 6 through 11. The dot gain curves (and the gain data in Table III) were obtained from a special computer program (Hefferon, 1990) which generates the least squares best fit, of (measured) total dot areas, to a second order polynomial equation. Dot gains were then taken as the difference between best fit total and film dot areas.

DISCUSSION AND CONCLUSIONS

Reliability of Data

It is well know that the characteristics of prints produced on a properly functioning press unit are not constant, but instead exhibit small random variations about mean values. Bain assembled data from a variety of tests by others to demonstrate that solid density readings exhibit standard deviations in the range of 0.01 to 0.03 with most close to 0.01 (Bain, 1987). Based on their experience, both authors not only concur in this but would extend Bain's generalization to tint density as well, i.e., that the corresponding tint densities exhibit a like standard deviation of about 0.01. In the midtones, this converts to a standard deviation in dot area of about 1 percent. Further confidence that this is indeed the level of random variation in dot area was provided by the authors' observation that the standard deviation between the best fit and measured values of dot area for a given print were in most cases 1 percent or less. In addition, the variation between the best fit dot area values of randomly selected prints from a given test were 0.5 percent or less. As a result, the authors believe that best fit dot area data of theirs which differ by more than 2 percent (three times 0.5 or 1.5 percent rounded off) are statistically significant, provided the data sets are from the same series of tests.

The reason why data from different test series cannot be compared directly is because significant drift in the dot gain characteristics of reference prints (i.e., prints produced under the conditions listed in Table II and thus of the press unit) was observed. In other words, while dot gain was consistent over the short run (days) it varied over the long term (months). This is illustrated in Figure 12 which shows the best fit dot gain data for reference prints produced in five different series of tests. The data for test series O and G, run on consecutive days, conforms quite well while the three remaining series, run months apart, show large variations. Preliminary analyses

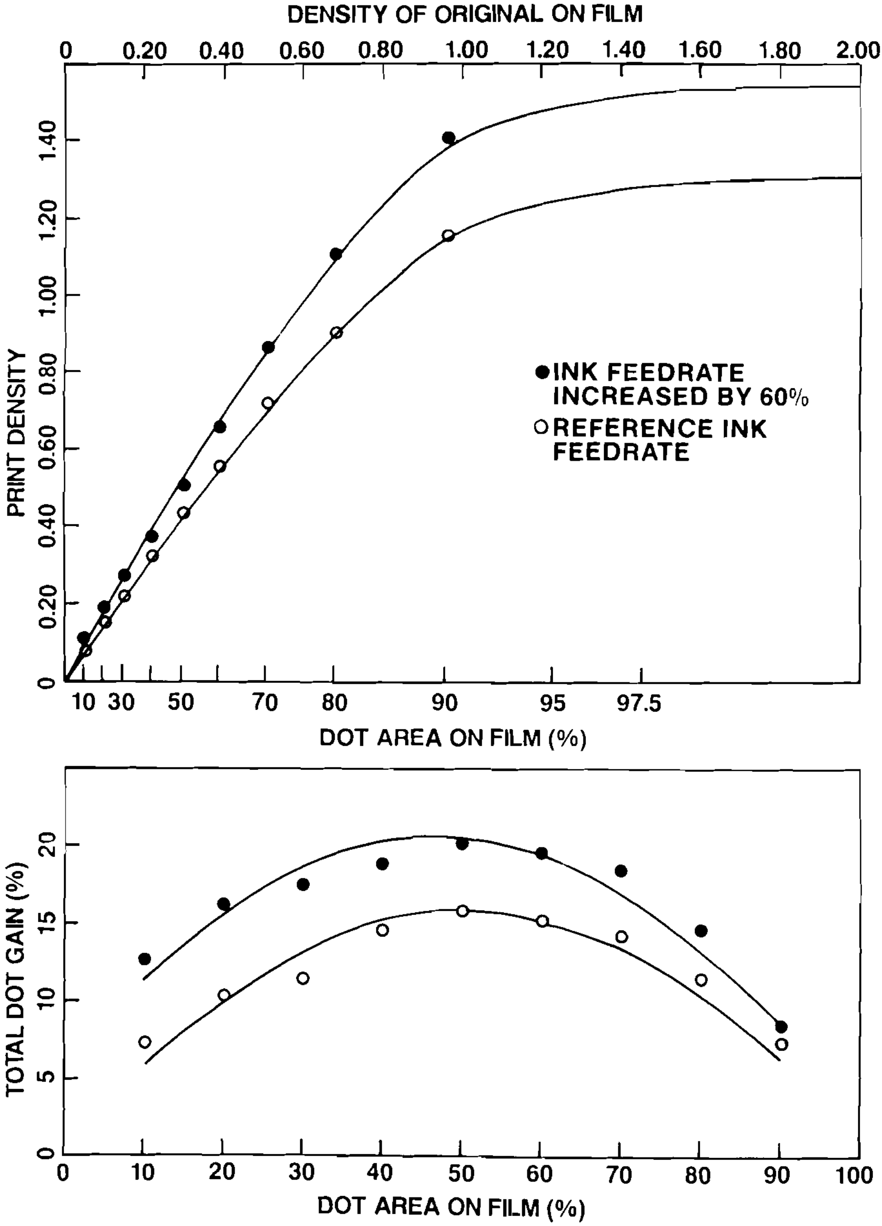

FIGURE 6 Effect of Increasing Ink Feedrate on Print Properties. Change was made on the fly by increasing ink ductor sweep setting from 17 to 27.

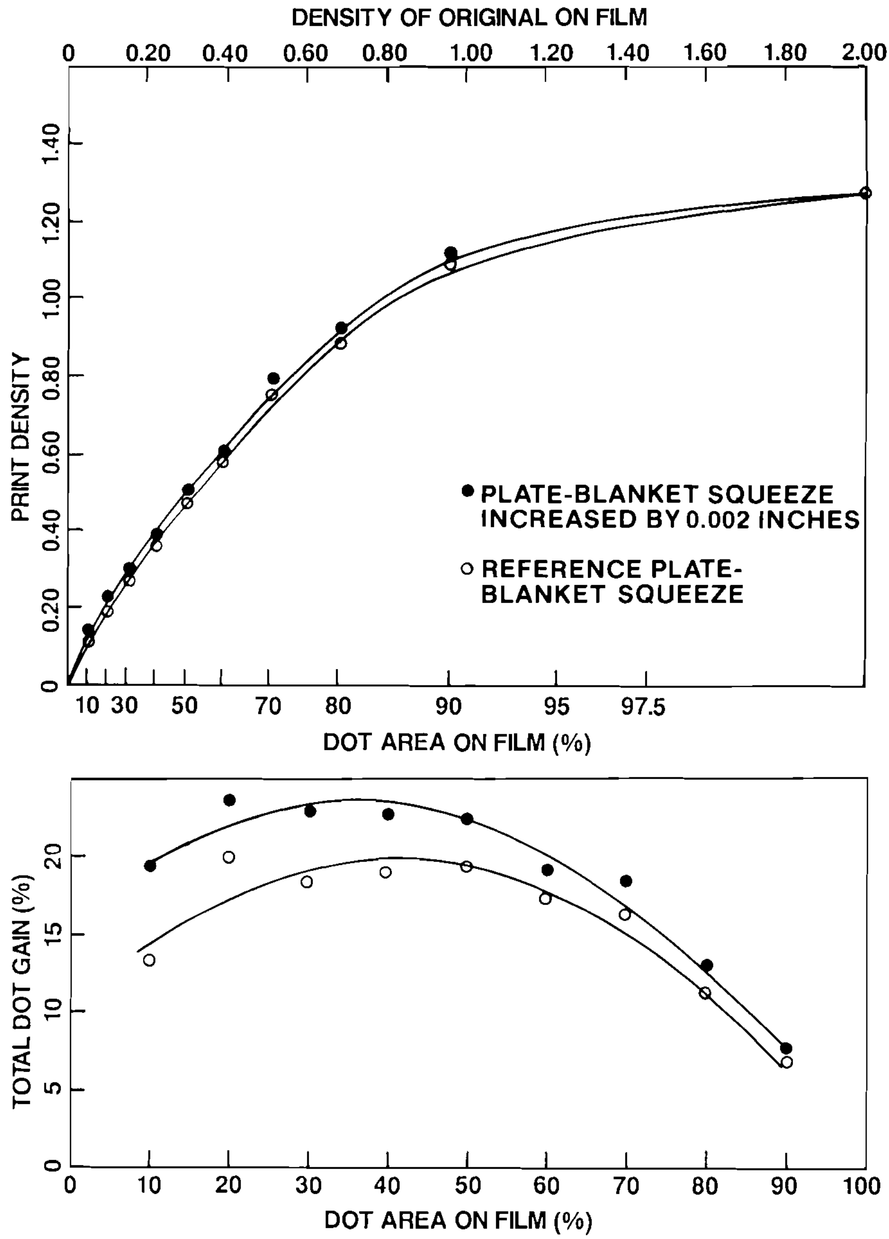

FIGURE 7 Effect of Plate-Blanket Squeeze on Print Properties. Change involved stopping press, increasing blanket packing, and reducing printing pressure by like amount.

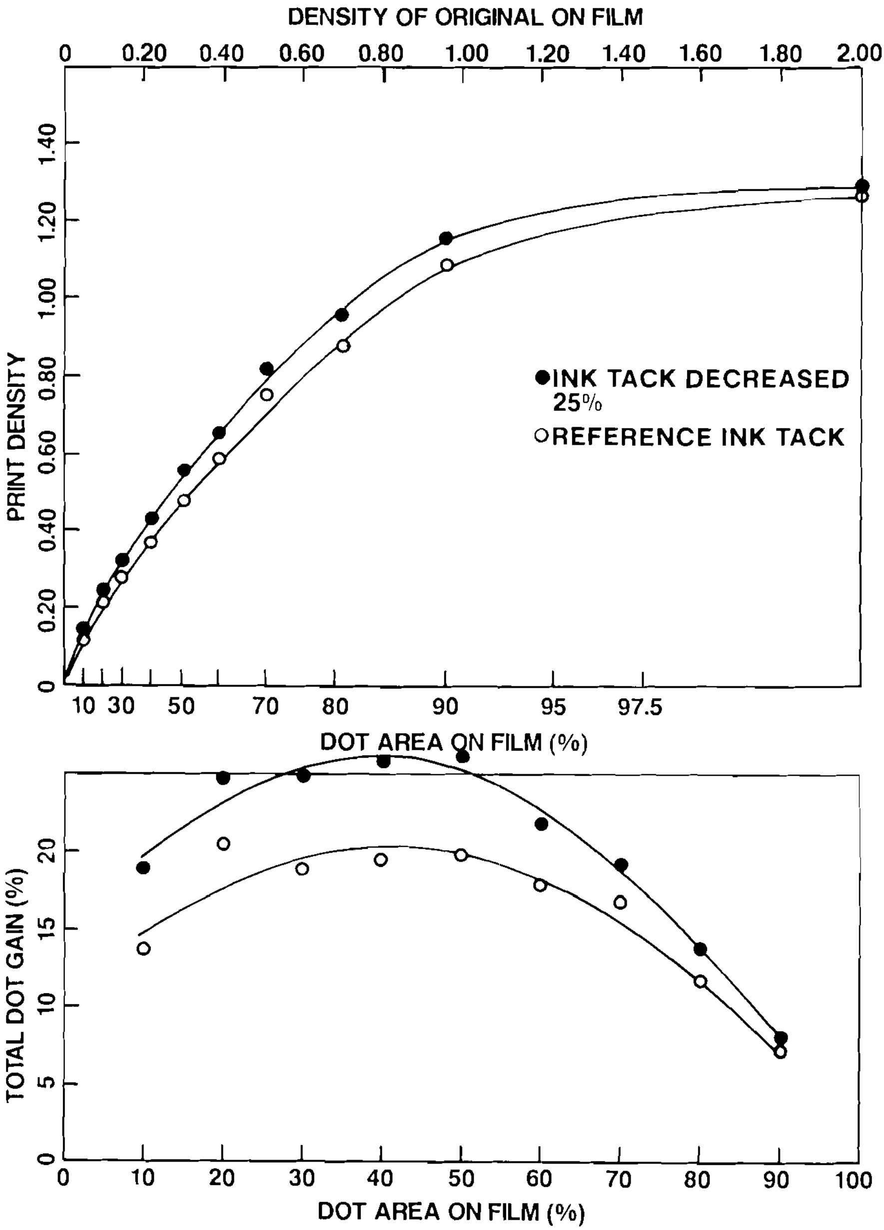

FIGURE 8 Effect of Ink Properties on Print. Tack was reduced from 20.3 to 15 by adding one ounce per pound of commercial reducer. Corresponding reduction in viscosity was from 290 to 195 poise and in yield from 3000 to 1500 dynes/cm^2. Press was stopped and washed up prior to changing ink.

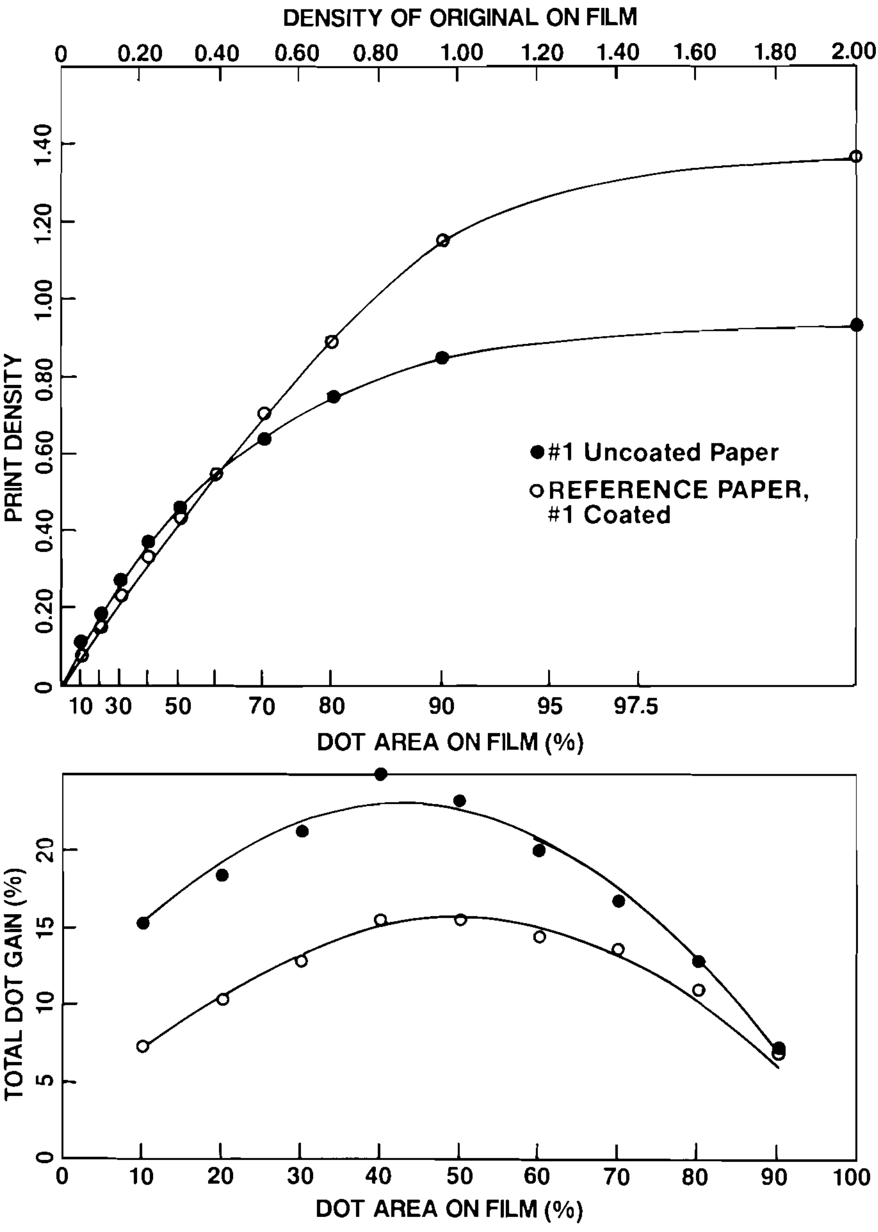

FIGURE 9 Effect of Paper Grade on Print Properties. Change was made on the fly with the objective of maintaining the same ink film thickness on print.

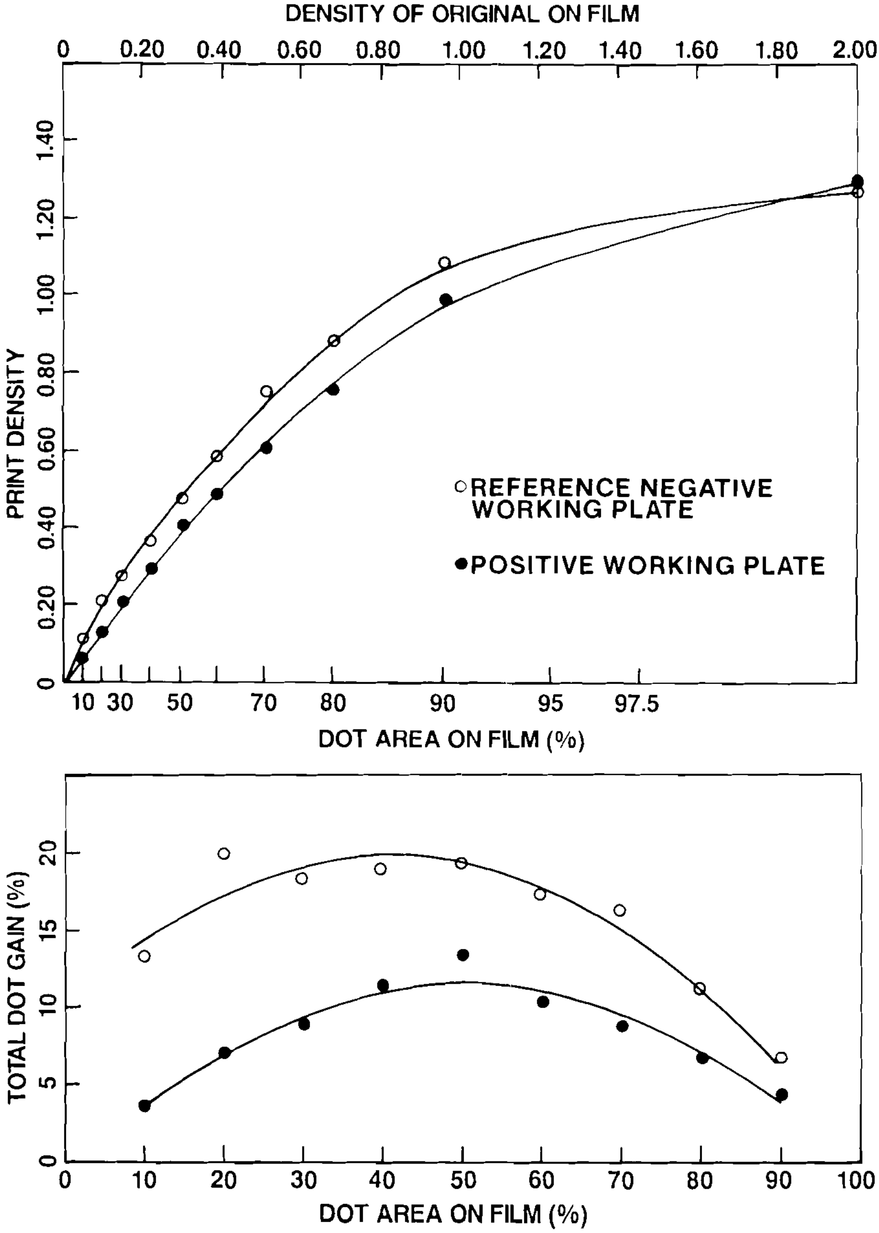

FIGURE 10 Effect of Using a Positive Plate in Place of a Negative Plate

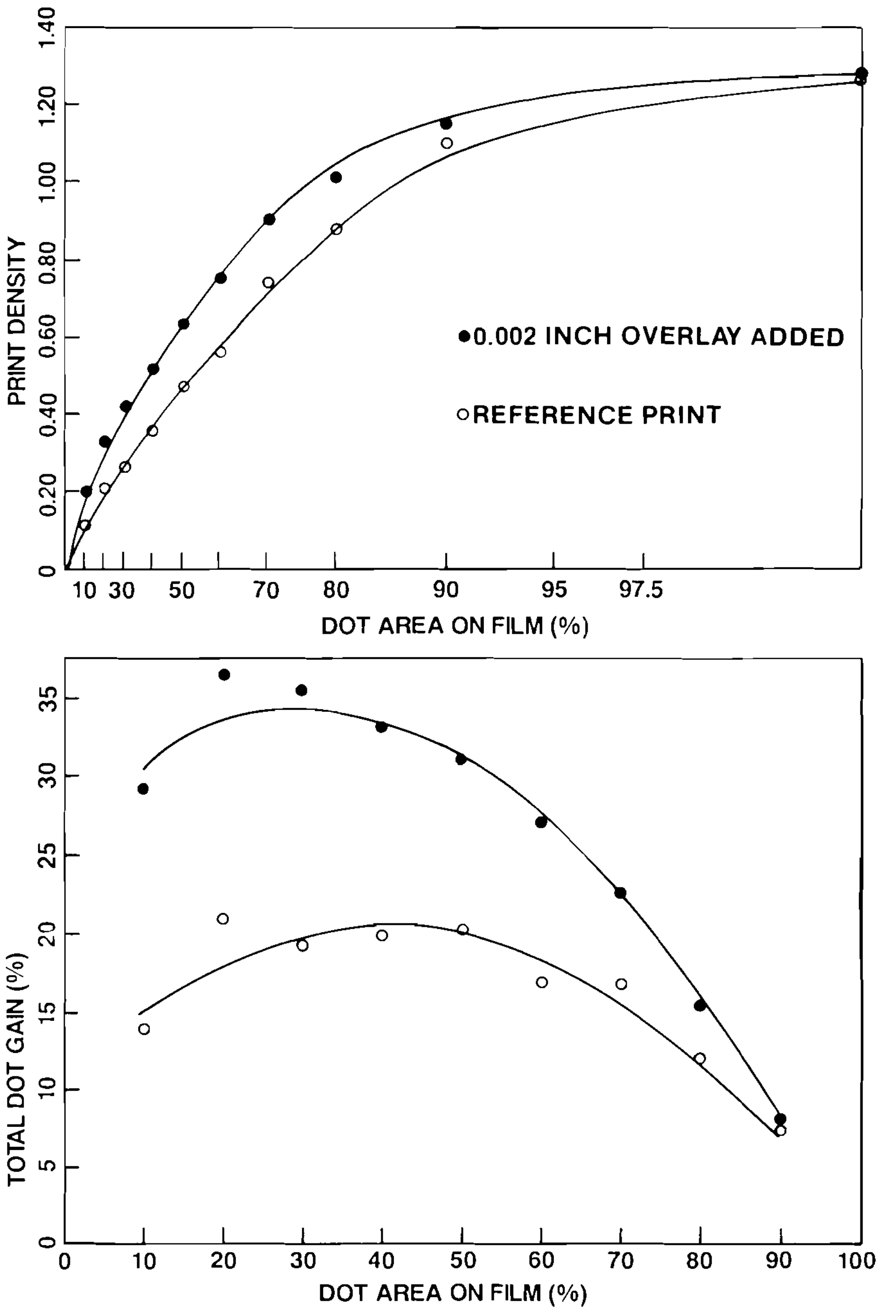

FIGURE 11 Change Produced on a Given Sheet by Adding a Bonded Transparent Overlay.

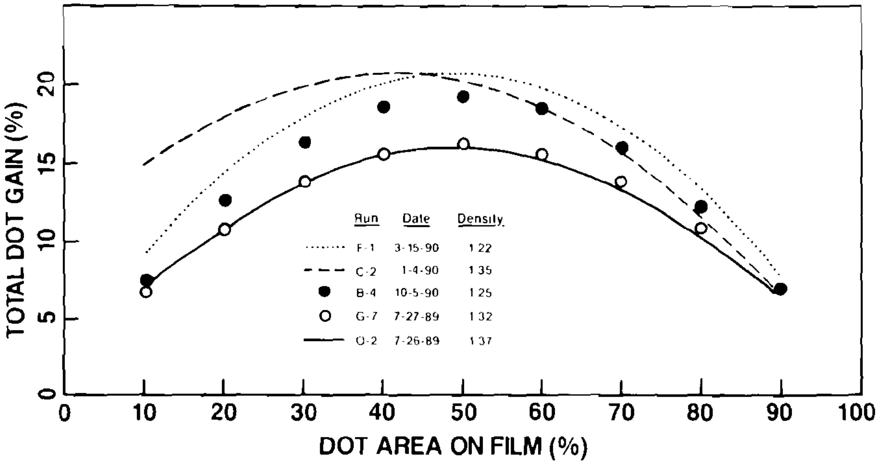

FIGURE 12 Best Fit Dot Gains of Reference Prints

of physical dot areas indicate that much of these deviations were produced in the platemaking operation, but more work must be done before any firm conclusions can be drawn in this regard.

In summary, then, the data from any given test series is regarded as very reliable and dot gain differences of more than 2 percent are considered to be real. However, comparisons between print data from different series cannot be made until the reasons for the long term drifts are fully understood.

Caution on Generalizing the Results

One example should be sufficient warning to the reader not to draw any general conclusions from the test results here, for example, that dot gain is always unaffected by a certain variable. The tests run to compare Brand Y fountain solution to Brand X (neither of which was the reference brand) were prompted by the experience of another printer. His observation, confirmed by the authors, was that prints produced with Brand Y had a midtone dot gain that was larger, by 9.4 percent, than prints produced with Brand X. However, when tested by the authors under the reference conditions described here, the corresponding difference was only 2.4 percent, as recorded in Table III. This startlingly different finding could be attributed to differences in one of the other variables such as the ink, but in any case it shows that these results cannot be extrapolated to other conditions.

Relative Sensitivity of Press Response to Variables Investigated

Within the limits of these tests, the following adjustments and parameters had little or no statistically significant effect on print properties: water feedrate, printing pressure, type of blanket, isopropyl alcohol vs the reference substitute, and on-press varnish coating. Those adjustments and parameters which did have an effect were, in order of the magnitude of the effect: the .002 inch thick transparent overlay, type of plate, paper grade, ink feedrate, ink properties, one brand of fountain solution (Y), and plate-blanket squeeze.

Comparison of Results with Observations of Others

The results obtained in this program were not always consistent with the findings of others, as discussed in the following paragraphs.

1. Effect of Water Feedrate. The effects of increasing water feedrate were similar to those observed by one of the authors (MacPhee) in unpublished tests run on a heatset web offset press at a speed of 1,200 feet per minute. However, tests run on a web offset newspaper press produced different results in that both solid ink density and dot gain decreased significantly when water feedrate was increased. This difference may be due to the difference in rheological properties of the two inks.

2. Effect of Ink Feedrate. The connection between increased ink feedrate and increased dot gain observed here is consistent with earlier on-press tests at RIT (Pobboravsky, Pearson, and Daniels, 1989) and the lore of press operators.

3. Effect of Printing Pressure. The negligible effect of printing pressure on dot gain is consistent with both the above referenced RIT tests and the finding of an investigation of sheetfed printing (Takahashi, Fujita, and Sakata, 1986-7) that mechanical dot gain only occurs during transfer from plate to blanket.

4. Effect of Plate-Blanket Squeeze. This study showed that this variable does indeed affect dot gain and thus is consistent with the above referenced study of sheetfed printing and the recommendations of FOGRA (Anonymous, 1984). The RIT results differed in finding no correlation.

5. Effect of Type of Blanket. The negligible effect of blanket type on dot gain found here is not consistent with the report by many

pressmen that higher dot gains result when printing with one type or the other, and the above referenced FOGRA report.

6. Effect of Ink Properties. The results reports here are in agreement with the recommendations of the above referenced FOGRA report.

7. Effect of Fountain Solution. Perhaps the most surprising result was that print properties were no better when using isopropyl alcohol in place of the reference substitute. This flies in the face of the long accepted maxim that alcohol improves print quality, i.e., that nothing is as good as alcohol.

8. Variability of Reference Performance. The long term variability in the print properties of the reference prints is not surprising in view of the variability observed in a survey of North American Printing (Long and Browne, 1988). However, it will be a surprise if, as suspected, the variability occurred primarily in the platemaking process - because the current industry view is that the properties of modern plates are extremely consistent.

Recommendations on Format

Based on their experience with its use, the authors came to the opinion that the proposed format, illustrated in Figure 5, is most insightful when comparing print properties wherein dot gain and solid density range vary in opposite directions, that is Type 3 in Table IV, and as exemplified in Figure 9. For Type 1 differences (no change in density range) the dot gain format, shown in Figure 2, is often adequate. However, for a complete portrayal of print characteristics, the dual format, used in Figures 6 - 11 is recommended.

Need to Rely on Mean Values

One lesson, constantly relearned during the course of this project, is that comparisons of single measurements of dot gain can be extremely misleading. Valid conclusions can only be drawn from comparisons of mean values of data sets comprising statistically large populations. This requirement can be satisfied either by using the best fit curves of a large population of different measurements from a single sheet, or from a large population of similar measurements from different sheets, run under the same conditions.

Observations on Method of Evaluation

The results of measuring the effect of a 0.002 inch thick transparent film on dot gain are pertinent to one method which has been used to evaluate "n" in the Yule-Nielsen Equation. In this method, "n" is evaluated by comparing transmission and reflectance density measurements of halftones imprinted on transparent films. The above results for thick versus thin (on-press varnish) films suggest that for such evaluations to be valid, extremely thin films must be used.

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The names of the commercial printer and the various material suppliers involved in the program purposely have not been disclosed, in order to shield them from controversy. Nevertheless, their help and cooperation is gratefully acknowledged.

REFERENCES

Anonymous
1945 "Dot Area, Dot Density and Tone Value", Technical Bulletin No. 5, (Lithographic Technical Foundation, NY) Third Printing, 1960, pp 19

Anonymous
1984 "BVD/FOGRA Standardization of Offset Printing", FOGRA Report Nr 30, (Duntsche Forschungsgesellschaft fur Druck-und Reproduktionstechnik, Munich), Revised Edition, 1984, pp 15

Anonymous
1986 "Recommended Specifications Web Offset Publications", (American Association of Advertising Agencies, American Business Press, Magazine Publishers Association, NY) May, 1986, pp 12

Archer, H.B.
1978 "A Miniature Test Form for Press Evaluation", 1978 TAGA Proceedings, pp 116-133

Bain, L.J.
1987 "Optical Density and Process Control", (Graphic Systems Division, Rockwell International, Chicago), August, 1987, pp 3

Dorst, P.W.
1950 "Reproduction of Tones by Offset Lithography", Technical Paper #702, (Lithographic Technical Foundation, NY), Second Printing, June 1960, pp 22-27

Hefferon, G.J.
1990 "Dot Area Analysis Program", Unpublished Internal Report, (Baldwin Technology Corporation, Stamford), February 8, 1990, 11 pp, plus appendices

Jones, L.A.
1931 "On the Theory of Tone Reproduction, With a Graphic Method for the Solution of Problems", Journal of the Society of Motion Picture Engineers, (White Plains), Vol. 16, May, 1931, pp 568-599

Long, J.W.; and Browne, R.W.
1988 "Print Analysis and Colorimetry of North American Commercial Printing", 1988 TAGA Proceedings, pp 654-668

Laseur, G.M.W.; ter Haar, H.; and DuPont, W.M.
1959 "Tone Reproduction in Halftone Engraving:, 1959 TAGA Proceedings, pp 109-120

MacPhee, J.
1985 "Further Insight Into the Lithographic Process - With Special Emphasis on Where the Water Goes", 1985 TAGA Proceedings, pp 269-297

Pobboravsky, I.; Pearson, M.; and Daniels, C.
1989 "Application of a Dynamic Measurement Technique for the Investigation of the Causes of Dot Gain in Web Offset Lithography", 1989 TAGA Proceedings, pp 481-495

Takahashi, Y.; Fujita, H.; and Sakata, T.
1986-7 "Ink Transfer and Dot Gain Mechanisms in Offset Printing Process", Graphic Arts Japan, (Japan Federation of Printing Industries, Tokyo), Vol. 28, pp 22-33

Terada, K.
1983 "Halftone Dot and Optical Density in Offset Printing" (Kohan, Co., Ltd., Tokyo), 44 pp

Yule, J.A.C.; and Clapper, F.R.
1958 "Basic Considerations in Reflection Copy Color Reproduction", 1958 TAGA Proceedings, pp 163-174