Measurements of Ink Film Thicknesses Printed by the Litho Process

by John MacPhee * and John Lind **

Abstract: A method for measuring printed ink film thickness on paper is described. Four conditions which must be satisfied to achieve acceptable precision in the results are identified and discussed. The validity and usefulness of the method are demonstrated with data obtained in more than forty five measurements, made over the past nine years. These consist of nine measurements on a newspaper press, five on a heatset web press, and over thirty on two different sheetfed presses. Data presented include numerous plots of print density versus ink film thickness and comparisons showing the extent to which the water used in the lithographic process affects print density and ink lay.

Introduction

A knowledge of the average thickness of the ink films on litho prints would be of immense help in gaining a better understanding of this particular printing process. For example, comparisons with prints obtained on a "dry" printability tester, using the same ink and paper,would provide indications of what effect, if any, the water used in lithography has on ink lay. Similarly a knowledge of the ink film thickness on litho test prints would make it possible to separate the effects of ink and paper on print variables such as density range and dot gain. The purpose of this paper is to satisfy the above need by describing a method, which has been used to collect reliable and useful information on average printed ink film thicknesses for various combinations of ink, paper, and press settings.

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The section immediately followed by this introduction describes the experimental procedure which must be used for each thickness measurement. This is followed by a section which discusses possible sources of error when using the method and which emphasizes the four conditions which must be satisfied to obtain accurate results. The third major section of this paper describes forty-seven measurements of ink film thickness, made by one of the writers (MacPhee) over the past nine years. This data is used to demonstrate the reliability of the method, to point up the differences between sheetfed and web lithographic printing, and to show the extent to which the water used in lithography affects the properties of solid prints. The last section lists the various conclusions which can be drawn from the results reported on here.

Experimental Procedure

The method, which is the subject of this paper, is relatively straightforward and was first used, in a rudimentary form, at least as early as 1968 (Anonymous, 1968). In summary, it involves printing a minimum of between 1,000 and 5,000 impressions of a form having an accurately known image area, which provides a measure of the total area of ink printed during the run. The weight of ink consumed during the press run is measured and used in conjunction with total area to calculate average ink film thickness in grams per square meter. The detailed procedure which has proved successful consists of eight steps as follows:

1. The press to be used is made ready using the ink and paper for which measurements are desired, and a test form having an image area that is accurately known. The makeready operation is continued until the target densities are achieved, insuring that density across the sheet is uniform to within plus/minus .05 density units. (This corresponds to an ink film thickness variation of about plus/minus 6% when printing on a #1 grade of coated paper.)

2. Following makeready, the press is shutdown, the run counter is reset to zero, and all of the ink in the ink fountain is removed - taking care not to open the fountain.

3. A known amount of ink is weighed and added to the fountain. The amount weighed out should be 10 - 20% more than needed for the run. (More information is given later on how to estimate the amount of ink needed.)

4. The press is then started up and sample prints are pulled at regular intervals and numbered. The sampling rate should be such that at least 10 and preferably 20 prints are saved for subsequent analysis.

5. When the prescribed number of impressions has been run, the press is shut down and the reading of the press counter, indicating the length of run, is recorded.

6. The ink remaining in the ink fountain is removed and weighed. This and the weighing prior to the run are then used to determine the amount of ink consumed.

7. Steadystate operation of the press during the run is checked by measuring and recording the average density of each sample sheet. These readings should then be analyzed to determine their mean value and standard deviation. A standard deviation of no more than .02 - .03 density units will provide an indication that the press was running in steadystate and therefore that the data obtained from the run is reliable.

8. Average printed ink film thickness for the given press run is calculated using the following formula:

$$\text{Ink Film Thickness } \{gms/m^2\} = \frac{[\text{Ink Consumed } \{gms\}]}{[\text{Image Area } \{m^2/\text{impression}] \times [\text{Length of Run } \{\text{Impressions}\}]}$$

Discussion of Accuracy

Although this procedure is quite simple and straightforward, there are a number potential sources of error which must be guarded against, if accurate results are to be achieved. A discussion of these is presented here in the form of four conditions which, experience has shown, must be satisfied to obtain reliable results.

Accurately Known Image Area. Although the essential nature of this need may seem obvious, the realization of this requirement can be difficult or impossible if care is not used in selecting the form. This is because it is difficult to accurately measure the area presented by type and halftones. This is true even if a plate scanner is used, since many plate scanners are unreliable when it comes to scanning type and small dots, i.e., screen areas of 10% or less. Thus it is recommended that the image area of the test form should be made up primarily of solids of simple geometry, i.e., having areas easily determined through manual measurements and calculations. However, some screens or test targets should be included to enable the pressman to gage water feedrate and dot gain.

Adequate Run Length. The number of impressions run during a single measurement must be large enough to insure that the amount of ink consumed is in turn large enough to be measured with precision. A number of factors must be taken into consideration in this regard. First, is the error due to varying amounts of ink being left in the fountain when it is emptied. The magnitude of this error can be determined, for the press and pressman to be used, by running half a dozen trials of adding and removing a known weight of ink to the fountain and weighing the amount each time. It has been the writers' experience that this error is never more than plus/minus one gram and is not the determining factor in selecting run length. A second possible source of error is the amount of ink stored on the rollers of the ink train; because any variation in this quantity would change the measured consumption by a like amount. Thus, the amount of ink consumed should be large relative to the amount stored on the rollers. Preferably, ink consumption should be at least ten times the roller storage level, but good results have been obtained where the ratio has been as low as six. In any case, it is this factor which determines minimum run length. The corresponding number of impressions will depend on ink coverage, but has been found to range from 1,000 impressions for forms with relatively heavy coverage (33%) to 5,000 impressions for forms with relatively light coverage (8%). In addition to reducing the minimum required run length, heavy coverages are preferred because they decrease the response time of the press (MacPhee, Kolesar, and Federgrun, 1985).

Minimal Filling of Ink Fountain. The third condition considered essential for precision is that the amount of ink loaded into the fountain, prior to the run, should not greatly exceed the amount of ink to be consumed. There are two reasons for this. First, this will improve weighing accuracy. Second, it reduces the potential error due to possible water logging of the ink remaining in the fountain at the end of the run. To satisfy this condition, one must of course be able to estimate ink consumption ahead of time. There are two ways to do this: by making a trial run, or by calculation, using an assumed ink film thickness. When using the second approach, the measured values, reported in the next section, can be used as a guide in selecting the assumed value for a given set of conditions.

Consistent Print Density. The fourth and final necessary condition for reliable results is that the press must operate under steadystate conditions, as evidenced by a relatively constant print density throughout the run. Although details on how to ascertain if this requirement has been met are given in the procedure described earlier, the repetition here is to emphasize the fact that the measurement of ink film thickness in accordance with this method is totally dependent on the extent to which this condition is satisfied. A key factor in this regard is the design and condition of the press. Obviously, the press should be set up properly and run in - e.g., the test should not be run with a brand new blanket, but rather one that has "sunk". A modern dampening system on the press is also a must, to insure that steadystate is achieved rapidly, following start up.

MEASURED DATA

This method of measuring ink film thickness on litho prints was used by one of the writers (MacPhee) in 1982 to investigate whether improved ink laydown was produced by a Delta Dampener installed on a sheetfed press. Since then, the method has been used in ten additional tests of varying nature that are summarized in Table I. These tests were carried out on four different presses, having the characteristics listed in Table II. The data obtained is given in Table III, which lists a total of 47 separate measurements involving a wide range of inks and papers.

Before proceeding to discuss the implications of this data, a few notes about the listings in Tables I - III are in order. To begin with, the Roman numerals selected to designate the different press tests reflect the time sequence in which the tests were run. Similarly, the Arabic numbers generally indicate the time sequence of the runs within a given test; the exception being the Roman numeral IX and XI tests. Here the runs in Table III are not listed in time sequence, but rather in order of descending ink film thickness, for the various papers used. More will be said about this later on. It will also be noted that there are no paper densities recorded in Table III for tests I, II, and III; the reason being that these densities were not measured.

Because of the diversity in both time and location of the press tests, various balances were used to weight ink consumption, with some scales reading in pounds, others in ounces, and other in grams. All weight measurements were converted to grams, with the result that some of the weight recordings in Table III suggest greater precision in weighing than was actually achieved. The diversity in tests also

TABLE I SUMMARY OF PRESS TESTS IN WHICH DATA ON INK FILM THICKNESS WAS COLLECTED

Test Series	Date of Tests	Location	Primary Purpose of Tests
I	1/82	Commercial Sheetfed Printer	Investigate effect of Delta Dampener on ink laydown
II	9/84	GATF	Investigate fate of fountain solution
III	11/84	GATF	Investigate fate of fountain solution
IV	11/88	RIT	Measure performance of spray-type dampener
V	2/89	RIT	Measure performance of spray-type dampener
VI	11/89	Commercial Web Printer	Investigate effects of speed and ink film thickness on picking
VII	3/90	Commercial Sheetfed Printer	Investigate effect of fountain solution composition on dot gain
VIII	5/90	RIT	Investigate effect of water feedrate on ink mileage
IX	6/90	Commercial Sheetfed Printer	Measure effect of ink feedrate on dot gain
X	12/90	RIT	Investigate effect of paper on dot gain
XI	2/91	Commercial Sheetfed Printer	Investigate effect of paper on dot gain

TABLE II DATA ON PRESSES USED IN THE MEASUREMENTS

Test Series	Press Data		Inker Data	
	Type and Size in Inches	Manufacturer and Model	Roller Area (inches^2)	Ink Storage * (grams)
I, VII, IX, XI	Sheetfed 14 x 20	Heidelberg GTO	2000	6.5
II, III	Sheetfed 19 x 25	Miehle Favorite	4900	16
IV, V VIII, X	Single Width Newspaper 22 3/4 x 35	Rockwell Community	2500	16
VI	Heatset Web 21 3/4 x 38	Harris Graphics M1000B	5600	36

* Based on an average ink film thickness on the rollers of 5 gms/m^2 for the sheetfed presses and 10 gms/m^2 for the web presses.

resulted in non-uniformity in density readings, i.e., the same densitometer was not used throughout. A very important and helpful exception to this is the fact that the same (Status T) densitometer was used to measure the extensive magenta print densities recorded in Table III.

Some of the insights provided by this data, along with the testimony it provides in support of the reliability of the method are discussed in the following paragraphs.

Magenta Sheetfed Ink, Repetitive Tests. The Series VII tests consisted of five repetitive runs on the GTO press in which only fountain solution composition was varied. Although some variation (not reported here) in dot gain was observed, the consistency of the press ink settings and the repeatability of this procedure were evidenced by the fact that average solid print density for each run was within plus/minus .03 of the mean value of 1.44 and average measured ink film thickness on the prints for each run was within plus/minus .02 gms/m^2 of the mean value of 0.97 gms/m^2 for the five runs.

TABLE III SUMMARY OF INK CONSUMPTION MEASUREMENTS

Run ID #	Type of Press	Type of Paper	Ink		Printing Speed	Length of Run (imp)	Number of Samples Pulled	Solid Density		Density of Paper	Image Area/ Imp (inch^2)	Ink Con-sumed (gms)	Ink Film Thickness (gms/m^2)
			Type	Color				Mean with Paper	Std Dev				
I-1	Sheetfed	#1 Ctd	Sheetfed	Cyan	6,000 iph	1,000	20	1.31	.03	-	94	41.1	0.68
I-2	Sheetfed	#1 Ctd	Sheetfed	Cyan	6,000 iph	1,000	20	1.31	.02	-	94	41.1	0.68
II-1	Sheetfed	#1 Ctd	Sheetfed	Cyan	6,000 iph	5,122	10	1.35	.03	-	39.2	94.3	0.73
II-2	Sheetfed	#1 Ctd	Sheetfed	Cyan	6,000 iph	5,119	10	1.47	.02	-	138.7	424.1	0.93
III-1	Sheetfed	#1 Ctd	Sheetfed	Cyan	6,000 iph	5,145	10	1.33	.02	-	39.2	100.6	0.77
III-2	Sheetfed	#3 Unctd	Sheetfed	Cyan	6,000 iph	4,623	9	1.27	.02	-	39.2	136.2	1.17
III-3	Sheetfed	#1 Ctd	Sheetfed	Cyan	6,000 iph	5,105	10	1.31	.01	-	264	636.7	0.73
III-4	Sheetfed	#3 Unctd	Sheetfed	Cyan	6,000 iph	5,034	10	0.62	.01	-	138.7	112.6	0.25
IV-1	Newspaper	Newsprint	News Ink	Black	655 fpm	4,020	40	1.02	.02	0.24	153.9	439	1.10
IV-2	Newspaper	Newsprint	News Ink	Black	651 fpm	4,470	40	0.79	.02	0.24	153.9	269	0.61
IV-3	Newspaper	Newsprint	News Ink	Black	666 fpm	4,200	40	0.93	.02	0.24	153.9	425	1.02
IV-4	Newspaper	Newsprint	News Ink	Black	642 fpm	4,110	40	0.71	.04	0.23	153.9	241	0.59

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Run ID #	Type of Press	Type of Paper	Ink		Printing Speed	Length of Run (imp)	Number of Samples Pulled	Solid Density		Density of Paper	Image Area/ Imp ($inch^2$)	Ink Con-sumed (gms)	Ink Film Thickness (gms/m^2)
			Type	Color				Mean with Paper	Std Dev				
V-1	Newspaper	Newsprint	News Ink	Black	695 fpm	4,730	40	1.17	.02	0.18	153.9	737	1.57
VI-1	Web	#5 Ctd	Heatset	Black	1,809 fpm	3,370	17	1.76	.03	0.13	281	1105	1.81
VI-2	Web	#5 Ctd	Heatset	Black	1,809 fpm	3,880	19	1.78	.03	0.13	281	1243	1.77
VI-3	Web	#5 Ctd	Heatset	Black	909 fpm	5,020	24	1.36	.02	0.13	281	912	1.00
VI-4	Web	#5 Ctd	Heatset	Black	1,210 fpm	5,030	24	1.34	.04	0.13	281	900	0.99
VI-5	Web	#5 Ctd	Heatset	Black	1,809 fpm	5,070	18	1.35	.07	0.13	281	968	1.05
VII-1	Sheetfed	#1 Ctd	Sheetfed	Magenta	5,500 iph	1,000	10	1.43	.02	.07	94	58.5	0.97
VII-2	Sheetfed	#1 Ctd	Sheetfed	Magenta	5,500 iph	1,000	10	1.42	.02	.07	94	58.5	0.97
VII-3	Sheetfed	#1 Ctd	Sheetfed	Magenta	5,500 iph	1,000	10	1.44	.03	.07	94	56.7	0.94
VII-4	Sheetfed	#1 Ctd	Sheetfed	Magenta	5,500 iph	1,000	10	1.42	.04	.07	94	58.5	0.97
VII-5	Sheetfed	#1 Ctd	Sheetfed	Magenta	5,500 iph	1,000	10	1.47	.06	.07	94	58.5	0.97
VIII-1	Newspaper	Newsprint	News Ink	Black	664 fpm	4,000	37	1.15	.02	0.20	153.9	723	1.82

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Run ID #	Type of Press	Type of Paper	Ink		Printing Speed	Length of Run (imp)	Number of Samples Pulled	Solid Density		Density of Paper	Image Area/ Imp (inch²)	Ink Con-sumed (gms)	Ink Film Thickness (gms/m²)
			Type	Color				Mean with Paper	Std Dev				
VIII-2	Newspaper	Newsprint	News Ink	Black	664 fpm	4,000	37	1.16	.01	0.20	153.9	794	2.00
IX-1	Sheetfed	#1 Ctd	Sheetfed	Magenta	6,000 iph	1,000	20	1.63	.02	.06	94	70.0	1.16
IX-2	Sheetfed	#1 Ctd	Sheetfed	Magenta	6,000 iph	1,000	20	1.48	.02	.06	94	60.2	.99
IX-3	Sheetfed	#1 Ctd	Sheetfed	Magenta	6,000 iph	1,000	2	1.34	.02	.07	94	50.1	.83
IX-4	Sheetfed	#1 Ctd	Sheetfed	Magenta	6,000 iph	1,000	20	1.30	.03	.06	94	47.9	.79
IX-5	Sheetfed	#1 Ctd	Sheetfed	Magenta	6,000 iph	1,000	20	1.16	.02	.06	94	39.4	.65
IX-6	Sheetfed	#3 Ctd	Sheetfed	Magenta	6,000 iph	1,000	20	1.64	.03	.15	94	70.4	1.16
IX-7	Sheetfed	#3 Ctd	Sheetfed	Magenta	6,000 iph	1,000	20	1.49	.03	.15	94	59.8	.99
IX-8	Sheetfed	#3 Ctd	Sheetfed	Magenta	6,000 iph	1,000	20	1.37	.02	.15	94	51.4	.85
IX-9	Sheetfed	#3 Ctd	Sheetfed	Magenta	6,000 iph	1,000	20	1.16	.02	.15	94	39.4	0.65
X-1	Newspaper	Newsprint	*	Magenta	664 fpm	4,000	19	0.84	.02	.22	223	345	0.60
X-2	Newspaper	Newsprint	*	Magenta	664 fpm	5,100	25	1.04	.07	.22	223	730	1.00

* Low Tack Sheetfed Ink

TABLE III SUMMARY OF INK CONSUMPTION MEASUREMENTS

Run ID #	Type of Press	Type of Paper	Ink		Printing Speed	Length of Run (imp)	Number of Samples Pulled	Solid Density		Density of Paper	Image Area/ Imp ($inch^2$)	Ink Con-sumed (gms)	Ink Film Thickness (gms/m^2)
			Type	Color				Mean with Paper	Std Dev				
XI-1	Sheetfed	Newsprint	*	Magenta	4,000 iph	1,000	20	0.94	.02	0.22	94.5	51.9	0.85
XI-2	Sheetfed	#1, Ctd	*	Magenta	4,000 iph	1,000	20	1.18	.02	0.07	94.5	50.7	0.83
XI-3a	Sheetfed	#1, Ctd	Sheetfed	Magenta	6,000 iph	1,000	20	1.57	.02	0.07	94.5	78.8	1.29
XI-3b	Sheetfed	#1, Ctd	**	Magenta	6,000 iph	1,000	20	1.60	.04	0.07	94.5	79.9	1.31
XI-4	Sheetfed	#1, Ctd	**	Magenta	6,000 iph	1,000	18	1.47	.02	0.07	94.5	71.2	1.17
XI-5	Sheetfed	#1, Ctd	Sheetfed	Magenta	6,000 iph	1,000	20	1.25	.02	0.07	94.5	48.8	0.80
XI-6	Sheetfed	#1, Ctd	Sheetfed	Magenta	6,000 iph	1,000	20	1.18	.01	0.07	94.5	44.8	0.74
XI-7	Sheetfed	#3, Unctd	**	Magenta	6,000 iph	1,000	20	0.98	.02	0.10	94.5	79.9	1.31
XI-8	Sheetfed	#3, Unctd	Sheetfed	Magenta	6,000 iph	1,000	20	0.98	.01	0.10	94.5	69.7	1.15
XI-9	Sheetfed	#3, Unctd	Sheetfed	Magenta	6,000 iph	1,000	20	0.85	.01	0.10	94.5	49.3	0.81
XI-10	Sheetfed	#3, Unctd	Sheetfed	Magenta	6,000 iph	1,000	20	0.82	.02	0.10	94.5	45.4	0.75

* Low Tack Sheetfed Ink
** Fast Dry Sheetfed Ink

Interestingly no difference in ink lay on the sheets could be detected either visually under high magnification or from reflectance measurements made with a spectrophotometer.

<u>Black News Ink, Effect of Excess Water</u>. This group of tests, consisting of Series IV, V, and VIII, were all carried out on the single width Community newspaper press at RIT printing with black news ink. This group of data shows two ways that increasing water feedrate significantly above the just scumming level can affect print density. Runs IV-1 and IV-3 were made with water feedrate at the just above scum level, the only difference being that in run IV-1 a continuous flow dampening system was used while in Run IV-3, a spray dampener was used. In the runs immediately following each of these, the only change was to drastically increase water feedrate, by a factor of 2.9 in Run IV-2 and by a factor of 1.9 in Run IV-4. Even though no change was made in the ink feed adjustments, printed ink film thickness and solid density decreased dramatically as shown by the plot of this data in Figure 1. This was in sharp contrast to a similar test, run on a sheetfed press (MacPhee and Lind, 1990) on coated paper, where density decreased very little (from 1.32 to 1.25) in response to increasing water feedrate by a factor of 1.45.

Runs VIII-1 and 2 were carried out over a year later to determine what effect, if any, excess water has on ink mileage. In Run VIII-1, the ink fountain keys were adjusted during makeready to achieve a target density of 0.95 with water at the just above scum level. In Run VIII-2, water feedrate was increased by a factor of 1.6 and the ink keys were readjusted to achieve the same target density. As shown by the data in Table III and Figure 1, 10% more ink was needed to produce the same solid density. On the basis of these two runs alone, one might suspect that this effect on ink usage is not real but instead was due to the inability of the pressman to precisely duplicate density on the second run. However, users of spray dampeners report lower ink consumption, and that is consistent with these findings, since the lateral control available on spray dampeners makes it possible to run water closer to the scum level across the entire width of the press. In other words, spray dampeners use less water than brush dampeners and as a result produce better ink mileage.

Two measurements of black news ink on newsprint made by others are also plotted in Figure 1, by ANPA (Anonymous, 1968) and by Ahrenkilde (1991). The ANPA measurement used the same basic procedure described here and involved a run of an entire roll of

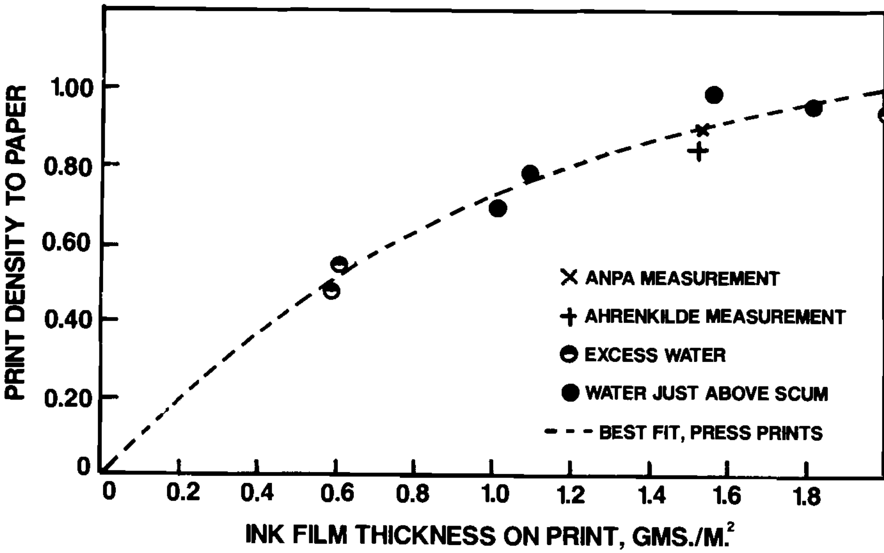

Figure 1 Black news ink on newsprint, community web press, Series IV, V, and VIII data.

paper, using the ANPA test form. Density was reported to be 0.9 but it was not specified whether this was to the paper. The best recollection of the former director of ANPA's Research Institute (Jaffe, 1991) however is that the measurement was to the paper, and that is how it has been plotted in Figure 1. Ink usage was reported as 4,653 pages per pound of ink. In order to convert this to a film thickness, it was necessary to determine the area of the image on the ANPA test form. This not only posed a problem but also pointed up the difficulty of estimating the image area of a form containing many half tones and/or much text. Three methods were used by the authors with the following results:

Calculation/estimate by author (MacPhee)	81.1 in.^{2}
Measurement by plate scanner	101 in.^{2}
Measurement by film scanner	
by production personnel	99.6 in.^{2}
by Ray Reinertson	98.4 in.^{2}

The point plotted in Figure 1 is based on the image area measurement by Reinertson because it is considered to be the most reliable and is in quite good agreement with the other two made with scanners. The large error in the estimate by one of the authors points up the necessity for using a test form consisting mainly of measurable solids.

In this regard, it is to be noted that the test form used in the Series IV, V, and VIII tests could not be calculated with any precision, and therefore was also measured by Ray Reinertson using a film scanner.

The measurement by Ahrenkilde involved running a form having a uniform 25% screen. Ink mileage was measured at 6,500 pages per pound of ink at a density (including paper) of 1.05.

The small root mean square error (of 0.02) between the author's measurements in Figure 1 and the best fit Tollenaar (Tollenaar & Ernst, 1961) curve is remarkable considering that the measurements were made on three separate occasions (Series IV,V,and VIII) which spanned a period of over a year and a half. Because of this the good agreement may well be fortuitous but in any case there is nothing about the data to suggest that the test procedure is suspect.

Black Heatset Ink, Repetitive Tests. The five data points obtained in the Series VI tests provide several additional insights. First, the good agreement between the pair of measurements at high density and the good agreement between the three readings at the lower density further attest to the reliability of the test procedure. Second, the plot of the data in Figure 2 gives some indication that the density vs ink film thickness curve for a typical heatset ink is not all that different from a sheetfed ink printed on the same grade of paper. This is consistent with a similar observation made by one of the authors (Lind) about dry print data obtained on the IGT printability tester.

Magenta Sheetfed Ink, Effect of Dampening and Paper on Density vs Ink Film Thickness Curve.

Of all the measurements made, this group is the most extensive, consisting of the 22 data points obtained on four different paper grades in the Series IX, X, and XI runs. The same densitometer was used for measurements on all of the prints made. In addition, the same standard or "house" magenta ink was used for all press prints with two exceptions. In the first, a low tack ink having the same pigment concentration was formulated and used when printing on newsprint, so as to preclude picking. The second exception involved Runs XI - 3b, 4, and 7 which were made unwittingly using a new house ink which the printer had switched to during the interval between the series IX and XI runs. The usage of this new ink was inadvertent and therefore these three runs have not been included in the analysis which follows.

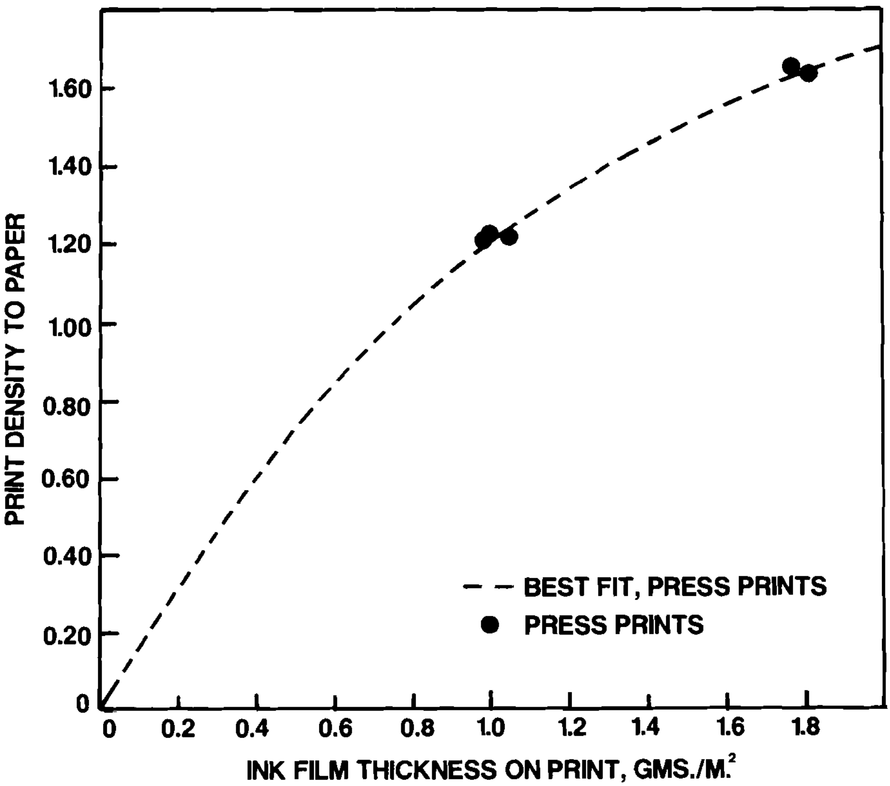

Figure 2 Black heatset ink on #5 coated paper, M1000B web press, Series VI data.

For each combination of paper grade and ink, data on density versus ink film thickness under dry conditions (i.e., without water) were also obtained from prints made on an IGT printability tester. Each such data set consisted of 15 - 20 measurements. It was found that these dry measurements could be fitted extremely well to Tollenaar's curve (Tollenaar and Ernst, 1961) using a least squares fitting technique. Figure 3 shows a plot of one such data set in which the r.m.s. error between the measured points and the curve was 0.01 density units. This small error was typical of all the dry data sets. In subsequent figures containing comparisons of wet vs dry data, the dry data is presented in the form of the best fit curve so as to avoid cluttering the graph with an excessive number of points.

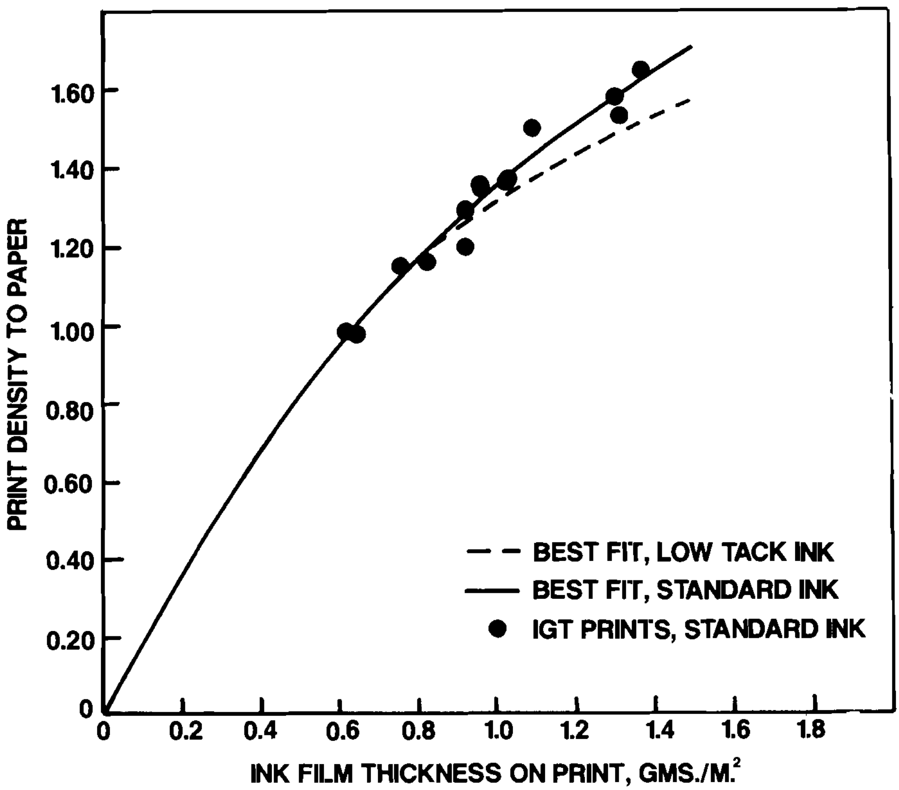

Figure 3 Plot of typical data set obtained on IGT Printability Tester, magenta sheetfed ink on #1 coated paper.

The availability of wet and dry prints, made using the same ink and paper, presented an opportunity to investigate the effect of water on ink lay. As in the case of using different fountain solutions, no difference in ink lay on wet vs dry prints could be detected either visually under high magnification or from reflectance measurements made with a spectrophotometer.

All of the data to be discussed here is contained in four figures; one for each grade of paper used. These four graphs have much in common and therefore will be described and discussed as a group. Because of this the reader is advised to carefully review Figures 4, 5, 6, and 7 before proceeding further.

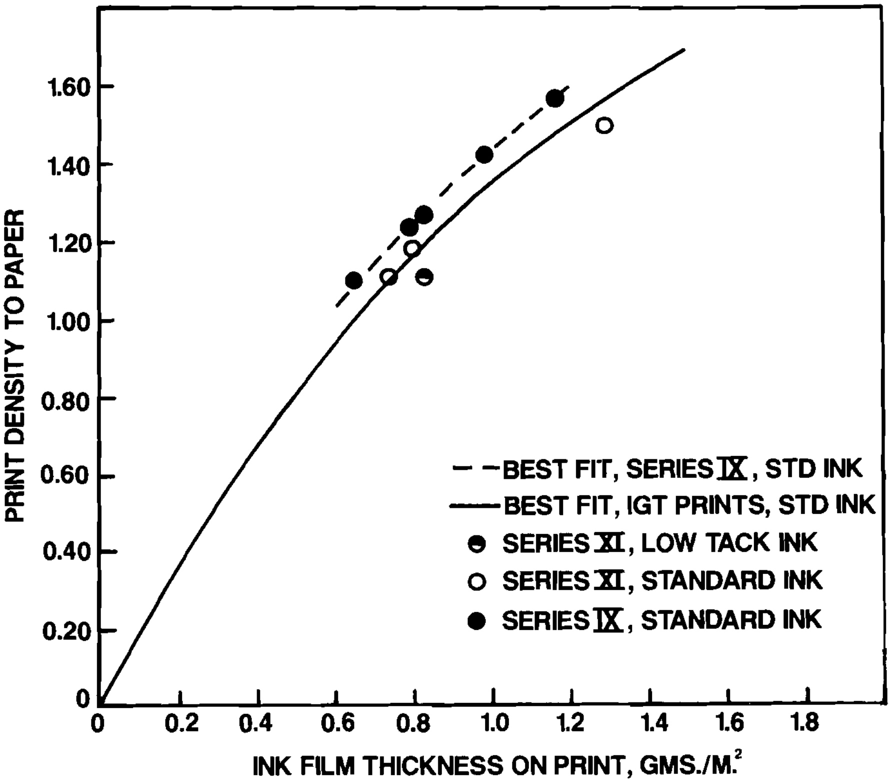

Figure 4 Magenta sheetfed ink on #1 coated paper, GTO sheetfed press, Series IX and XI data.

Taken as a group, these four figures exhibit two features which stand out. The first is that two of the graphs, Figure 5 containing the #3 coated paper data and Figure 7 containing the newsprint data, show excellent agreement between the wet and dry print plots. This agreement is especially impressive in the case of newsprint because the wet data was derived from prints obtained on two different presses. The second feature is that the other two graphs, Figure 4 containing the #1 coated paper data and Figure 6 containing the #3 uncoated paper data, show evidence of just the opposite, a discernible offset between the wet and dry plots. The authors believe that these offsets are the result of some yet unexplained systematic error and therefore are to be looked upon as an anomaly, rather than as an indicator of some significant phenomenon.

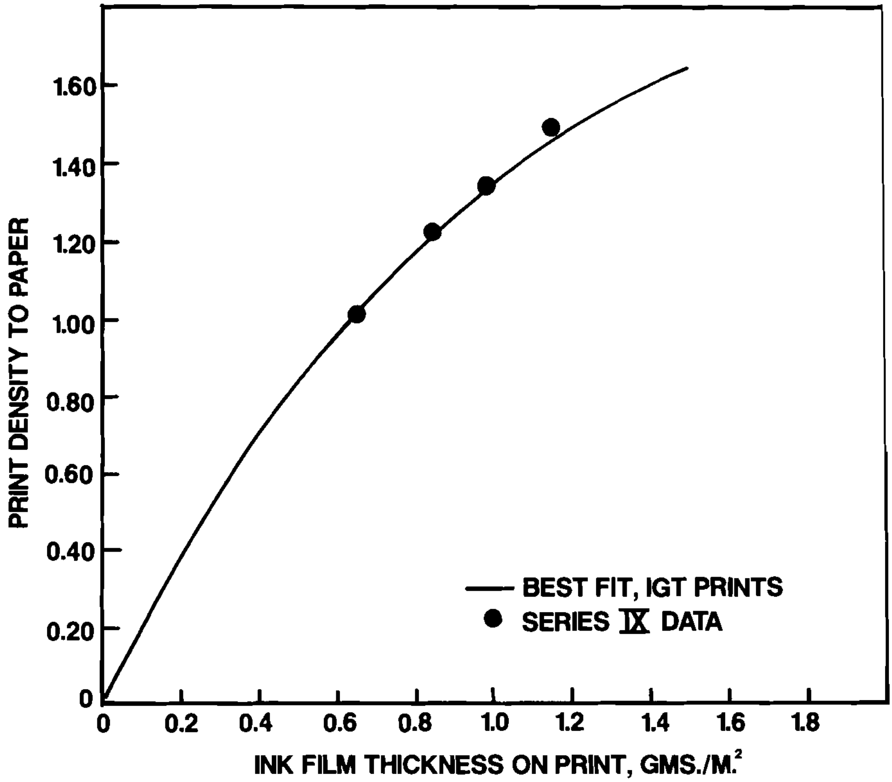

Figure 5 Magenta sheetfed ink on #3 coated paper, GTO sheetfed press, Series IX data.

There are several reasons for this opinion. First, there is no basis for thinking that water would have no effect in the case of the one pair of papers but have a significant effect in the case of the other pair, especially since each pair is made up of a coated and an uncoated grade. Second, the press tests provided convincing evidence that equal film thicknesses produced higher densities on the #1 coated stock compared to the #3 coated stock (as chronicled by the data in Table IV) whereas the dry print data indicated that equal film thicknesses produced equal densities on #1 and #3 coated stock. Because the former is in agreement with numerous other press tests (Lind and MacPhee, 1990), the conformity of the ink or paper used to obtain the dry print data in Figure 4 is judged suspect, and by extrapolation, so too are the materials used to obtain the dry print

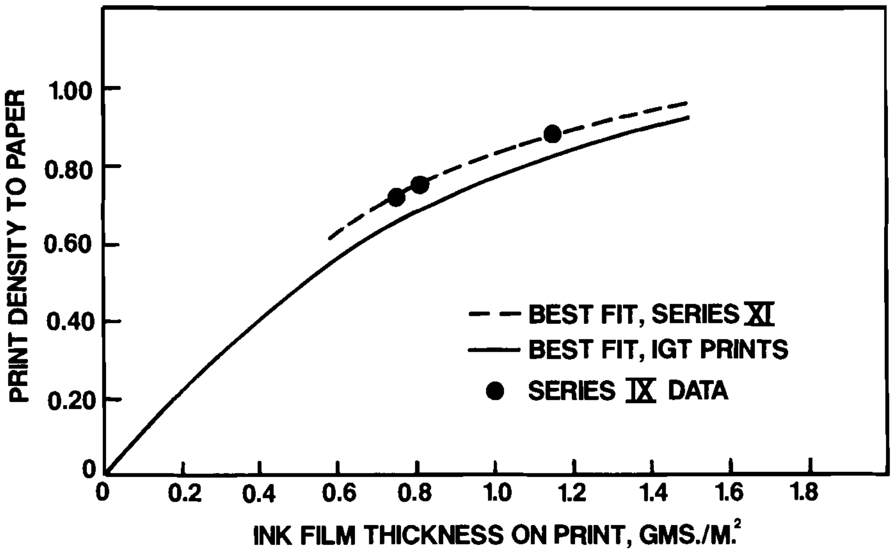

Figure 6 Magenta sheetfed ink on #3 uncoated paper, GTO Sheetfed press, Series XI data.

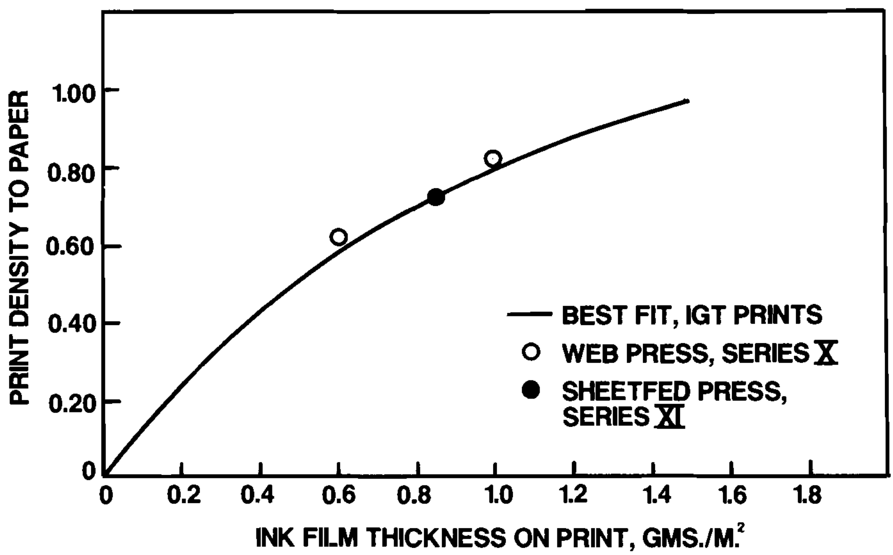

Figure 7 Low tack magenta sheetfed ink on newsprint, community web press and GTO sheetfed press, Series X and XI data.

Table IV Listing of three pairs of Series IX tests in the sequence in which they were run. Data demonstrates that for a given press setting, equal amounts of ink were transferred to the two different grades of paper and that the resulting equal ink film thicknesses produced lower print densities on the #3 coated paper.

Ink Ductor Sweep Setting	Run Number	Paper Grade	Ink Usage (gms)	Average Print Density
26	IX-1	#1 Ctd	70.0	1.57
	IX-6	#3 Ctd	70.4	1.49
21	IX-2	#1 Ctd	60.2	1.42
	IX-7	#3 Ctd	59.8	1.34
14	IX-4	#1 Ctd	39.4	1.10
	IX-9	#3 Ctd	39.4	1.01

data in Figure 6. Thus one very important conclusion drawn from this group of data by the authors is that normal dampening has no significant effect on the density produced by a given printed ink film thickness. A second conclusion is that at a given set of press settings the amount of ink transferred to the paper is independent of paper grade or properties - as evidenced by the data in Table IV and similar pairings of #1 coated sheets with #3 uncoated and with newsprint sheets in the Series XI tests. In addition, the data in Table IV and the good behavior of all the data in this group constitutes further testimony to the reliability of this procedure.

Cyan Sheetfed Ink

The last group of data to be presented and discussed is from the Series I, II, and III tests run with cyan ink and is plotted in Figure 8.

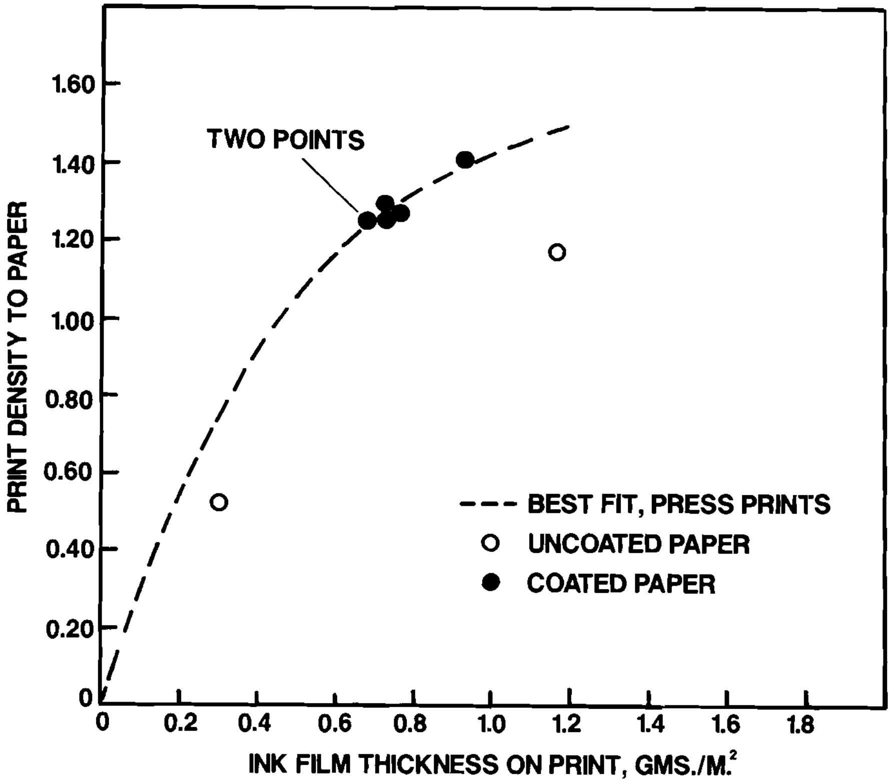

Figure 8 Cyan sheetfed ink on #1 coated and #3 uncoated paper, two different sheetfed presses, Series I, II, and III data. Paper density assumed to be 0.06 for the coated and 0.10 for the uncoated grade.

The good agreement between the five data points clustered around an ink film thickness of 0.7 gms/m^2 provides yet another piece of evidence in support of the reliability of this procedure.

Conclusions

Based on the consistency and good behavior of the numerous measurements reported here, the authors have concluded that a high level of confidence can be placed in this procedure for measuring printed ink film thickness - provided of course that the four conditions set forth in the description are satisfied. Beyond this general conclusion, the data provide significant new insight into the lithographic process through the disclosure of the following behavior:

1. Printed ink film thicknesses are typically about 1.0 gms/m^2 for sheetfed inks on coated paper and somewhat greater for both news inks on newsprint and heatset inks (wet) on coated paper. The figure of 1.0 gms/m^2 is consistent with an earlier measurement made with an electron microscope (MacPhee, 1979).

2. Over the above range of film thicknesses, Equation (1), described by Tollenaar (Tollenaar and Ernst, 1961) can be fitted with very small error to the curve of solid density versus printed ink film thickness.

$$D = D_{\infty} (1 - E^{-mt}) \qquad (1)$$

where D = solid density
t = ink film thickness
D_{∞},m = constants

3. Under normal printing conditions, i.e., with water feedrate at or just above the scumming level, the water used in lithography has no appreciable effect on solid density versus ink film thickness, nor on ink lay as measured by a reflectance spectrophotometer.

4. At a given set of press settings, printed ink film thickness is independent of the paper fed through the press.

5. Paper has a significant effect on the curve of solid density versus printed ink film thickness as shown in Figure 9.

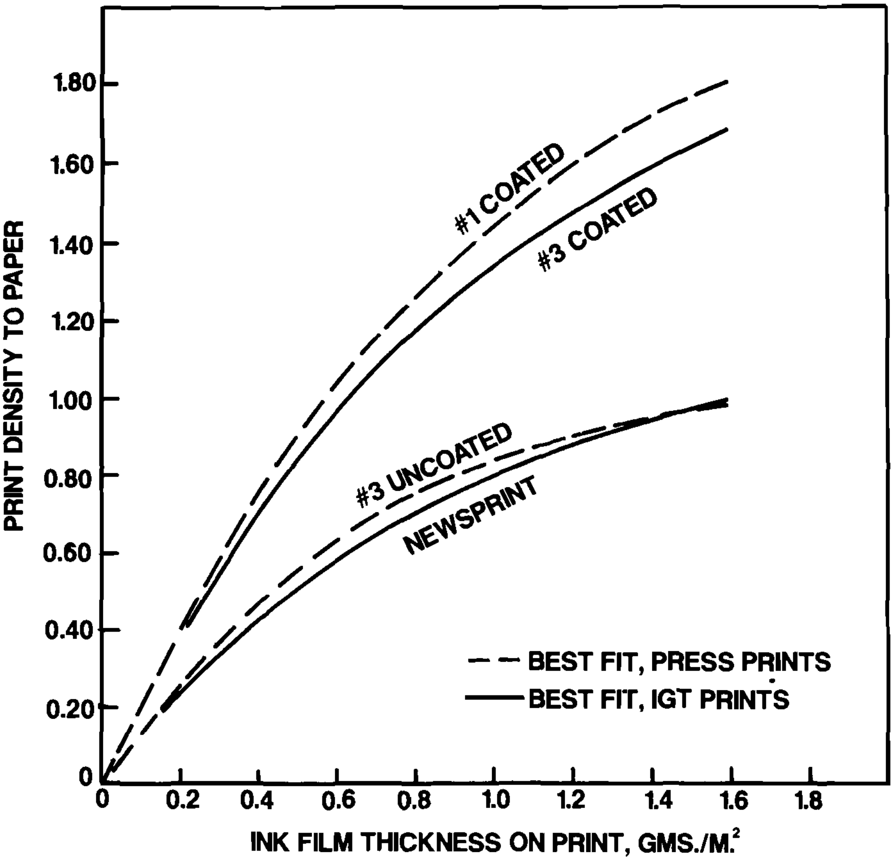

Figure 9 Sheetfed magenta ink

Figure 9 Effect of paper grade on print density versus ink film thickness curve, sheetfed magenta ink, GTO sheetfed press. Newsprint curve obtained with low tack ink.

6. An excess water feedrate has a large effect in newspaper printing. For a given set of ink control settings, solid print density will be reduced drastically by feeding excess water. If the ink controls are then adjusted to restore print density, the net effect will be an increase in the ink film thickness needed to achieve the given density. Thus excess water reduces ink mileage in newspaper printing.

Acknowledgements

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