STUDIES OF INK-PAPER RELATIONSHIPS FOR INDIAN PRINTING PAPERS

A DISSERTATION

submitted in partial fulfilment of the requirements for the award of the degree

of

MASTER OF ENGINEERING

in

PULP AND PAPER TECHNOLOGY

By

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CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in the thesis entitled **"STUDIES OF INK-PAPER RELATIONSHIPS FOR INDIAN PRINTING PAPERS"**, in the partial fulfilment for the award of degree of Master of Engineering in Pulp & Paper Technology, submitted at Institute of Paper Technology (University of Roorkee) is an authentic record of my own work carried out during the period from August 1995 to March, 1996 under the supervision of Dr. S.P. Singh, Reader, Institute of Paper Technology, University of Roorkee, Saharanpur.

The matter embodied in this thesis has not been submitted by me for the award of any other degree.

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This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

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[K. JEEVAN KUMAR]

SYNOPSIS

Most of the paper produced is printed. Besides wiriting and printing papers, newsprints, packaging papers and boards are printed by one means or the other. Therefore the paper maker should know about the behaviour of paper under various printing conditions. Inspite of the extensive research work carried out in this area, the relationships between physical properties of paper as tested in a laboratory and its performance in a printing press are not very well established. Printability evaluation of papers, thus, generally involve actual printing of the paper. Ink-paper relationships involving ink transfer characteristics, print density and show through are critical aspects in the evaluation of printability.

Many authors have discussed various ink transfer parameters to study the printability of papers. The present work was intended to study these parameters in order to evaluate ink transfer, print density and show through for various grades of papers under a set of printing conditions.

Chapter 1 of this thesis deals with the introduction to the present work and available literature in this area. Chapter 2 deals with a brief description of various instruments and grades of papers used in the experimental work and the procedure for printing experiments. Eight grades of papers including three types of newsprints, two types of writing papers, MG White, Creamwove and Duplicating paper were examined in the present work. The results are discussed in Chapter 3 under three separate titles, namely, Ink transfer, Print density and Show through. Under each title, the effect of various ink transfer parameters is discussed. The conclusions drawn from these discussions are given in Chapter 4. Recommendations for future work are also given in this chapter. The experimental data have been tabulated in Appendix - I.

CONTENTS

LIST OF FIGURES AND TABLES

INTRODUCTION AND LITERATURE REVIEW

Almost ninety percent of the paper produced is printed by one means or the other. Although there are many types of printing methods in use, the phenomenon of transfer of ink to the paper during printing is the same for all types of printing. When paper surface comes in contact with the printing plate, the ink on the plate wets the paper surface, and some of the ink is absorbed (immobilized) by the pores of the paper. When the printing plate is separated from the paper, a fraction of the free ink that is available on plate transfers to the paper surface. The ink dries out either by oxidation, polymerization, evaporation or any combination of these mechanisms, thereby resulting in a printed image over the a paper. The quality of printed image depends upon the behavior of ink and paper at the nip of the printing press. Printing conditions like printing speed and printing load will also affect the quality of final print.

In order to produce good quality of paper suitable for printing, the paper maker should know the interactions between paper and ink that occur during printing. He should be familiar with the properties of printing inks, the characteristics of printing processes and the printing plate, the pressroom conditions in order to ensure that the paper is not rejected by printer when the fault lies with the choice of ink or in printing conditions and not with the paper.

Many authors have studied the phenomenon of transfer of ink to the paper in depth. Much of the work reported in the literature deals with the evaluation of ink transfer constants and their variation with changes in printing conditions and characteristics of ink and paper. Most important among them is the work of William C. Walker (1) on measurement of ink transfer form printing plate to paper during printing. He proposed an empirical equation relating amount of ink on printing forme, x, and amount of ink transferred to the paper, y, in terms of three parameters, namely, k, characteristic of printing smoothness of paper, b, the capacity of the paper surface to absorb or immobilize the ink applied, and the factor, f, of the non-immobilized ink that is transferred to the paper. The famous Fetsko Walker equation in its simplified form is given as

$$y = b + f(x - b)$$

The modified form of Fet sko Walker equation for lower values of x and y is given as

$$y = (1 - e^{-kx}) (b(1 - e^{-x/b}) (1-f) + fx),$$

The units of x, y, b are either in g/m^2 or microns. The units of k are m^2/g or reciprocal of microns.

Schaeffer et al (2) reported the increase of ink transfer from printing forme to the paper with increase in printing pressure, decrease in printing speed and decrease in ink viscosity. They carried out an extensive experimental work on slow and fast absorbing, coated and uncoated papers, with low and high viscosity inks over a wide range of printing conditions. They made a critical analysis of the variation of papers with variation in printing conditions. They also provided a good literature review on the earlier work done on the evaluation of transfer constants.

Tollenaar et. al. (3), in their work proposed a general expression for the variation in print density graph against the quantity of ink on the form, x. They proposed other characteristics of the paper, a density smoothness constant, m, which shows how quickely the saturation density ($D\infty$) can be obtained. The units of m are m^2/g. Saturation density is the value of print density approached by papers, when the quantity of ink on printing forme increases indefinitely. They suggested mathematical calculations to evaluate these constants. They discussed the effects of these constants in Halftone printing, and presented some practical examples of these constants with Machine coated papers.

In the present work, different grades of papers including newsprint, uncoated printing papers. have been printed with on IGT AIC 2-5 printability tester. The amount of ink on the printing disc has been varied over a wide range and vaious ink transfer parameters have been evaluated. The results have been discussed in the light of the available literature.

EXPERIMENTAL WORK

I. Description of Apparatus :

The following are the equipment used in the experimental work for the present study.

(i) IGT PRINTABILITY TESTER AIC 2-5

(ii) IGT INKING UNIT AE,

(iii) PRINTING DISCS, and

(iv) TECHNIBRITE MICRO TB-1C.

(i) IGT PRINTABILITY TESTER AIC 2-5 :

This tester manufactured by M/s Raportest B.V., The Netherlands can be considered as a mini, laboratory scale printing press (4). All parts of the printing press are in it. It consists of a impression cylinder (called sector), a printing forme (called printing disc) and a paper sample clamped to the sector. It is possible to adjust the thickness of ink layer, the printing force, the printing speed, the packing, similar to that of a real press. With this tester, it is possible to work with a constant speed between 0.2 and 5 m/sec, or with an increasing speed between 0.5 and 7 m/sec. In the constant speed mode there is a possibility to stop the sector after half of the rotation during a preset time interval of between 0.2 and 9.9 seconds. Intervals of more than 10 seconds can be realized by making two printing runs in succession. In the increasing speed mode the speed is increasing proportionally with the length of the print. The maximum print width can be 50 mm, resulting in a large printed area, which enables the visual judgment of evenness of print in a glance. For safety reasons there are two starting buttons that have to be pressed simultaneously to rotate the sector. In starting position the printing disc is an contact with the sector. At the end of the print, there is a provision for lifting the printing disc when the sector has made a revolution. There is an option of second printing disc, which is suitable for multi-colour printing and set-off tests.

(ii) IGT INKING UNIT AE :

This unit consists of two inking arrangements with common drive. This makes it possible to test two inks simultaneously. The dimensions of the cylinders are limited to rather narrow tolerances and the surface of an inking arrangement is large. Consequently when a known quantity of ink is applied to the unit, the film thickness is known accurately as the product of area and film thickness equals volume of ink. The inking arrangement features a combination of two anodized aluminum cylinders and an elastomeric top roller. The latter can be made of polyurethane, rubber or rubber resistant to ultra violet inks. The rear cylinders of the unit are driven by motor. The front cylinders are propelled through the top rollers. The front cylinders have an oscillating motion of a few centimeters in the order to distribute the ink evenly over the surface. To enhance the distribution there is an extra 30mm wide rubber covered distribution roller that travels back and forth over the rear cylinder. Further there are two hinged holders over each of the resilient top rollers, on which the printing discs are mounted and brought in contact with the top rollers to be inked.

(iii) PRINTING DISCS :

The tests are carred out using aluminum discs. The aluminum discs are anodized and are available in two types, milled and smooth edges, and in widths of 10, 20, 32 and 50 mm. Discs of 50 mm width have been used in present experiments. During tests, the printing discs are rotated by friction and in cases where thin ink is being used, slip between disc and sector may occur. To avoid this, discs with milled edges have been used instead of those with smooth edges.

(iv) TECHNIBRITE MICRO TB - 1C :

This instrument manufactured by M/s Technidyne corp., U.S.A. is specially intended for the measurement of diffuse refelctance of pulp, paper and related products including clay, pigments etc.(5). This instrument employs an integrating sphere optical system as defined by ISO standard 2469. The upper portion of the instrument referred to as optics console. The integrating sphere, lamps and all associated optical components are located in this housing. The lower portion of Micro TB-IC is referred to as the electronics console, which houses the microcomputer, power supplies and associated electronic components.

The optical system of Mirco TB-1C is based on a large integrating aluminum sphere of 150 mm diameter which is coated with a high reflectance Barium Sulphate paint. Two quartz tungsten halogen lamps and their respective projection lenses direct beams of light through holes on each side of the sphere wall. Infrared heat absorbing filters are located in each light beam to remove the heat energy before it can enter the sphere. The light beams entering the sphere from the external illuminators reflect off the white sphere lining. Multiple reflections from the sphere wall produce a highly diffuse illumination of the sample which covers a 34 mm diameter opening located in the bottom of the sphere. A spring loaded sample holder presses the sample aganist the flat bottom of the sphere. The light reflecting from the sample is viewed by the photocell through an objective lens which focuses the light on the photocell. An aperture is positinoed such that only a 30mm diameter circular area of the sample is viewed by the photocell. A selected filter is inserted into the light beam between the lens and the photocell. This filter is automatically adjusted by the microprocessor.

DESCRIPTION OF FILTERS :

POSITON	EFFECTIVE WAVE-LENGTH	DESCRIPTION
B	457 nm	ISO Brightness.
X	595 nm	CIE Tristimulus red response, Illuminant C.
Y	557 nm	CIE Tristimulus green response, Illuminant C, also known as luminosity, luminance and newsprint brightness.
Z	455 nm	CIE Tristimulus blue response,Illuminant C.
IR	950 nm	Board brand filter for measuring reflectance in near Infra Red of the spectrum.

II. Material Used :

(i) Paper :

Three types of Newsprint, two grades of Writing Papers a Duplicating Paper, a Creamwove and a MG White paper have been used in the present experimental work. The physical and optical properties of these grades of papers are given in table 1.

(ii) Ink :

Black colour off-set ink suppplied by m/s United Ink and Varnish Company Limited, Bombay was used in the present experimental work.

(iii) Experimental Procedure :

Strips of standard sizes (23.8 cm x 5.6 cm) prepared for each grade of paper.

Table 1 : Physical and Optical Properties of Different Grade of Papers

Grade	Basis Weight	Smoothness (ml/min)	Porosity (ml/min)	Opacity (%)	R∞
Newsprint 1	48	172/237	710	94.10	52.33
Newsprint 2	48	240/335	530	93.85	56.66
Newsprint 3	48	185/282	520	90.87	57.61
Writing Paper 1	53	112/302	150	86.91	69.81
Writing Paper 2	58	107/260	180	89.50	66.52
MG White	42	182/345	240	83.90	66.53
Cream Wove	59	289/337	370	93.66	66.40
Duplicating Paper	60	754/1412	470	95.20	66.89

A printing load of 200 N and a printing speed of 1.2 m/sec were used for the present experimental work.

Two aluminium discs of same dimensions (0.01025 m^2 surface area) and approximately same weight were used as printing discs. An IGT inking unit AE was used to transfer the ink on to the printing discs. Inking time of 90 seconds used to transfer ink on the printing discs from inking unit.

The weights of uninked printing discs (a, gms), were taken for both the printing discs.

After 90 seconds of inking time on inking unit, the weight of inked discs (b,gms), were taken.

Printing was done with a single disc on the strip of paper, clamped to the sector of the IGT printability tester, at above mentioned printing conditions.

After printing, the weight of the printed disc (c, gms), was taken and the disc was cleaned with petrol to remove remaining ink on the printing disc.

The procedure repeated for second grade of paper.

After completion of first set of strips of all grades of papers, the entire procedure was repeated for another set of strips.

quantity of ink on printing disc = $x = (b-a)/A$ g/m^2

quantity of ink transferred to the paper = $y = (b-c)/A$ g/m^2

where, A is the area of printing, m^2.

The reflectance values for the both printed and unprinted papers for all grades of papers were taken with the help of Technibrite Micro TB-1C, manufactured by Technidyne Corporation, U.S.A.

The values of print density and show through are calculated by using following formulae :

Print density = $\log_{10}(R_\infty/R_{\infty p})$ on print side,

R_∞ = Reflectance of unprinted paper with a thick paper pad backing.

$R_{\infty p}$ = Reflectance of printed area of strip backed by a thick pad of same papers.

Show through = $\log_{10}(R_\infty/R_{\infty p})$ on reverse side of print,

$R_{\infty p}$ = Reflectance of printed area on reverse side of paper, with thick paper pad backing.

RESULTS AND DISCUSSIONS

I. Ink Transfer :

The values of y, the amount of ink transferred to the paper, were plotted against x, the amount of ink on the printing disk before printing, in fig. 1 for Newsprints 1,2 & 3 & Writing paper 1. Both x and y are expressed as gms of the per m^2 surface area. A similar plot is given fig. 2 for Writing paper 2, MG White, Cream wove, and Duplicating paper. It is seen from these figures that y is nearly a linear function of x for greater values of x (> 16 g/m^2). However the linear relationship does not hold good for lower values of x.

The behavior is in agreement with the Fetsko - Walker equation (1) which states that,

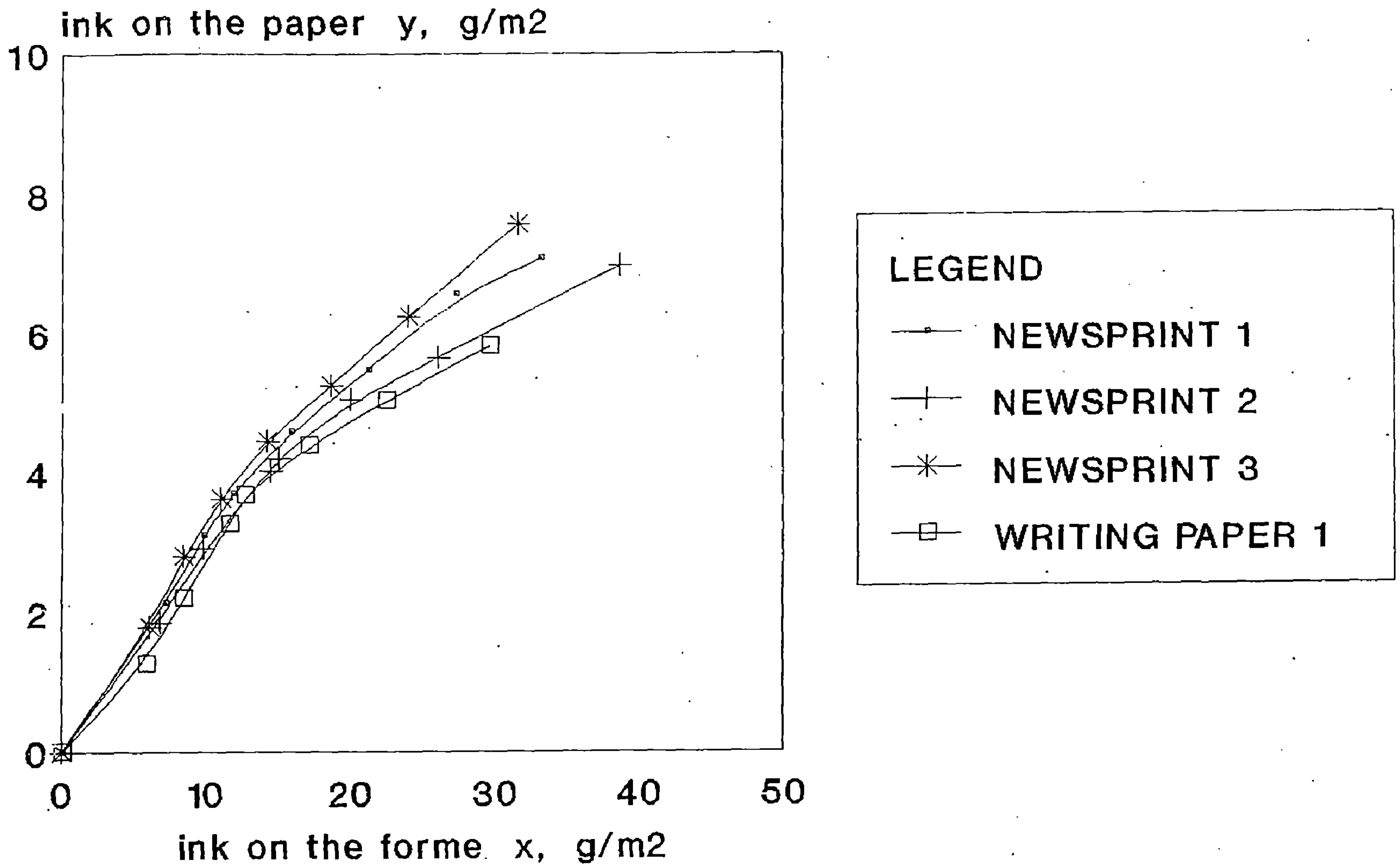
$$y = b + f(x - b) \qquad (1)$$

where,

b = quantity of ink immobilized by the paper, g/m^2,

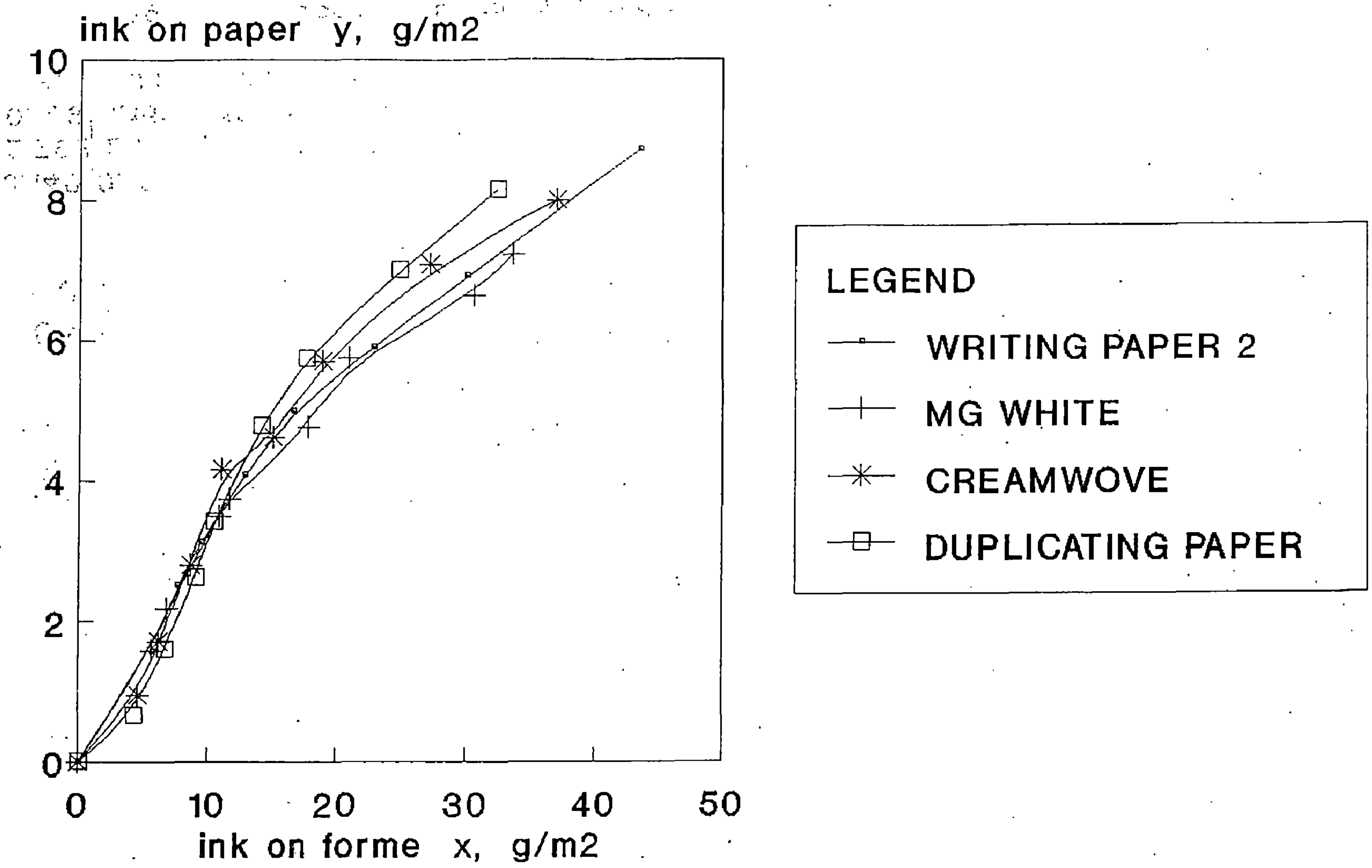
f = fraction of free ink transferred to the paper.

The x-y data (for $x > 16$ g/m^2) were fitted in the above Fetsko-Walker equation and the values of b and f were calculated for each grade of paper.



	NP1	NP2	NP3	WP1
f =	0.140	0.133	0.180	0.116
b =	2.792	2.769	2.317	2.830, g/m2
k =	0.169	0.150	0.184	0.131, m2/g

Fig 1. Relationship between x and y for Newsprints 1,2,3 & Writing Paper 1



	WP2	MGW	CW	DP
f =	0.134	0.160	0.154	0.162
b =	3.235	2.380	2.485	3.345, g/m2
K =	0.151	0.133	0.124	0.089, m2/g

Fig 2. Relationship between x and y for Writing Paper 2, MG White, Creamwove, and Duplicating Pape

These values are given in table 2. The fig. 3 presents different papers on a f vs b plot. The different grades of papers are scattered all over the region, on this plot, indicating that there may not be any definite relationship between the two ink transfer constants.

In Fetsko-Walker equation, it is assumed that the paper immobilizes a fixed amount of ink, b, and the remaining amount, x-b, gets divided between the paper and the printing disk. The factor, f, is dependent of the behaviour of two surfaces, the nature of ink, and the printing conditions used. But when a paper is printed with a small amount of ink on the printing disk, there may not be enough ink which the paper can immobilize. Moreover, due to roughness of paper surface the thin ink layer on the printing disk is not able to contact the entire surface of the paper. Fetsko - Walker suggested the following modification to their equation to take into account these effects.

$$y = (1-e^{-kx})[b(1-e^{-x/b})(1-f)+fx] \qquad (2)$$

The term $(1-e^{-kx})$ is the fraction of paper surface area contacted by the ink. It is zero when x is zero, and approaches 1.0 as the x value increases. The term $(1-e^{-x/b})$ is introduced to correct b, the amount of ink that can be immobilized by the paper surface. When x approaches zero, the term $(1-e^{-x/b})$ also approaches zero and for large values of x, the term $(1-e^{-x/b})$ approaches unity. Thus for medium to high quantities of ink, the equation is reduced to the simpler form of equation (1). The value of k,

Table 2 : Ink Transfer Constants for Different Papers. (Fetsko-Walker).

Grade	f	b (g/m^2)	k (m^2/g)
Newsprint 1	0.140	2.792	0.169
Newsprint 2	0.133	2.769	0.150
Newsprint 3	0.180	2.317	0.184
Writing Paper 1	0.116	2.830	0.131
Writing Paper 2	0.134	3.235	0.151
MG White	0.160	2.380	0.133
Cream Wove	0.154	2.485	0.124
Duplicating Paper	0.162	3.345	0.089

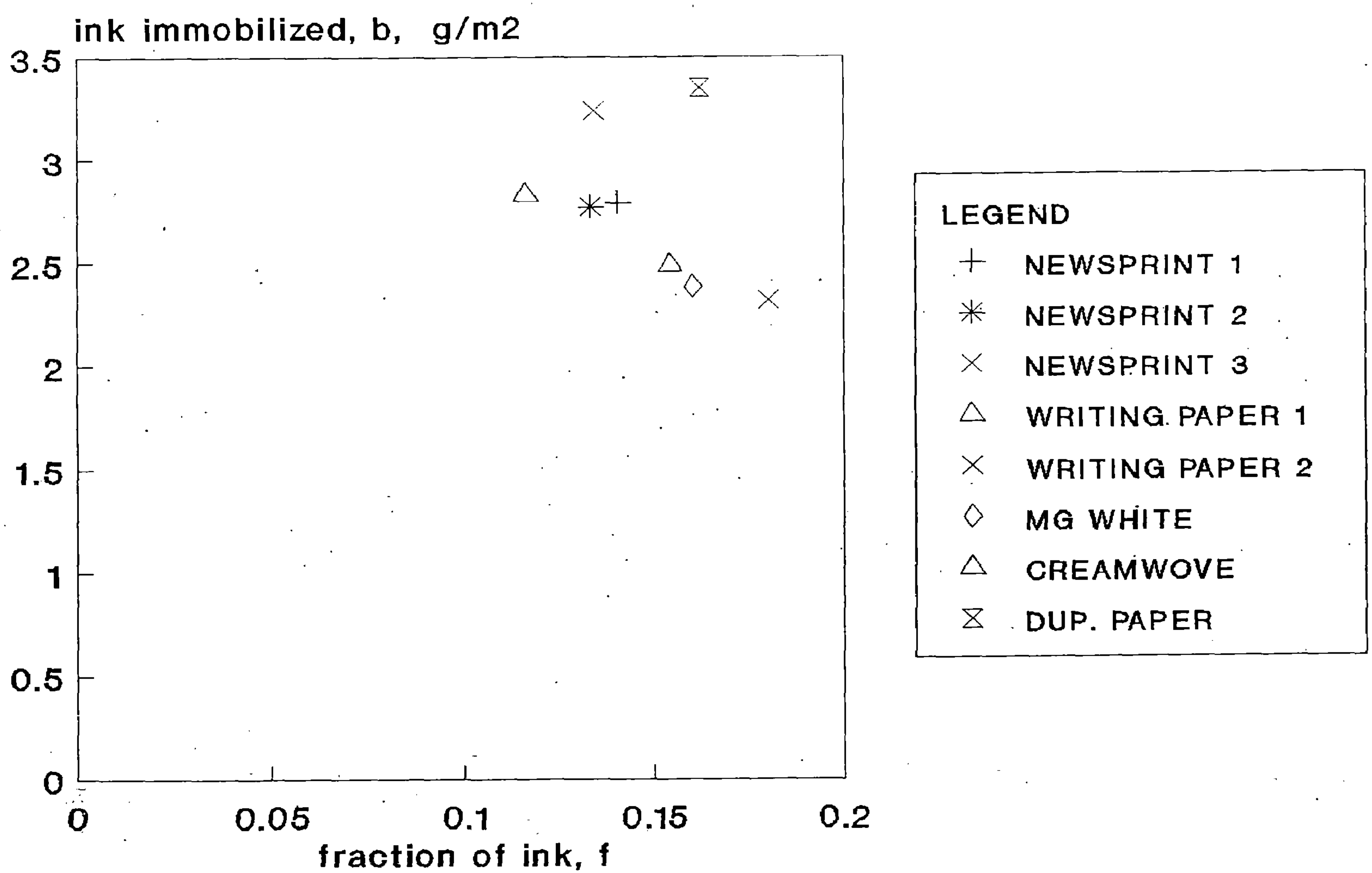


Fig 3. Relationship between ink transfer constants f and b, for different papers

the paper smoothness constant can be calculated by using the following formula, derived from the above equation (2).

$$k = (1/x) \ln \left[\frac{[b(1-e^{-x/b})(1-f)+fx]}{[b(1-e^{-x/b})(1-f)+fx]-y} \right] \qquad (3)$$

The values of k (m^2/g) for different grades of papers, calculated by using above formula, given in table 2.

The values of f and b are dependent on the ink receptivity and absorptivity of the paper. A higher value of b indicates that the paper can be printed more easily, and a higher value of f indicates that more ink can be transferred to the paper. The constant k, a paper smoothness parameter, describes how smoother the paper would be under printing load. It is often called as printing smoothness parameter of the paper. The greater the value of k the greater will be the printing smoothness of paper. Although the smoothness of the free surface of the paper is different from printing smoothness, there would be some kind of correlation existing between value of k and smoothness of the paper surface as it is evident from fig. 4. The grade of paper with maximum Bendtsen roughness (Duplicating Paper), also has the least value of k. But the grading of papers based on the printing smoothness does not necessarily match with the grading based on Bendsten roughness. The printing smoothness measured for the paper under dynamic printing pressure and expressed as k, differs from the smoothness of the

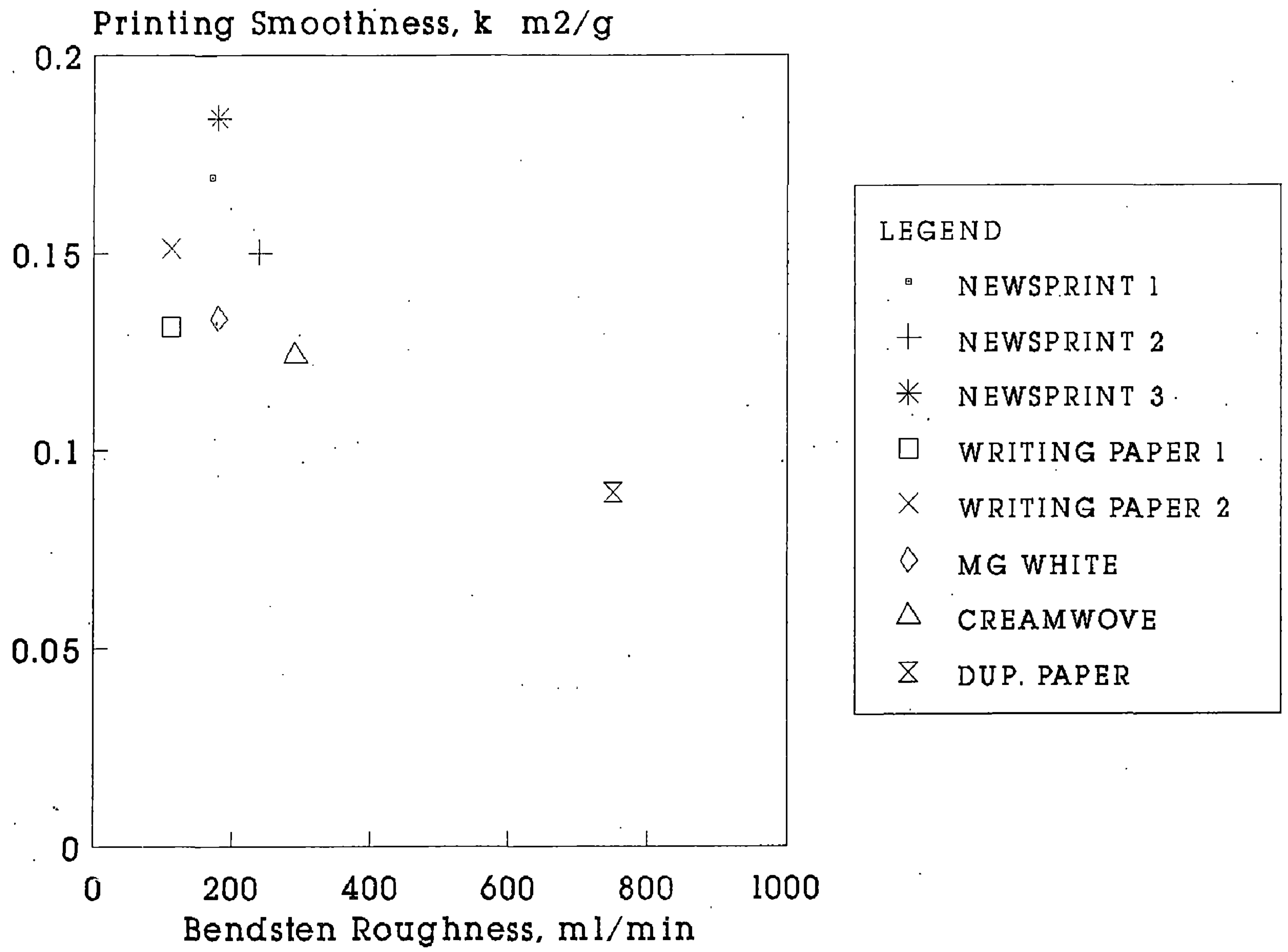


Fig 4 Relationship between Bendsten Roughness and Printing Smoothness k, for different papers

free surface of the paper, as measured by Bendtsen tester, in the following respects:

(a) The paper is a resilient material. Its surface when loaded becomes smooth. This property of paper is called as surface compresibility. While determining printing smoothness, the surface compresibility of paper is also taken into account.

(b) A liquid film (ink) is compressed between the paper surface and printing disc which can flow and cover the portions of paper surface which have not necessarily made contanct with the printing disc.

As mentioned earlier, the term $(1-e^{-kx})$ represents the fraction of paper surface which comes in contact with the ink during printing. This value of k indicates how quickly complete contact can be obtained between ink and paper. The higher the printing smoothness, the better the contact.

II. Print Density :

Print Density is defined as the contrast of the printed area with respect to unprinted area. It can be calculated by using the following formula,

$$\text{Print Density} = \log_{10} (R_\infty / R_{\infty p}), \text{ on print side.}$$

where,

R_∞ = Reflectance of unprinted paper backed with thick paper pad

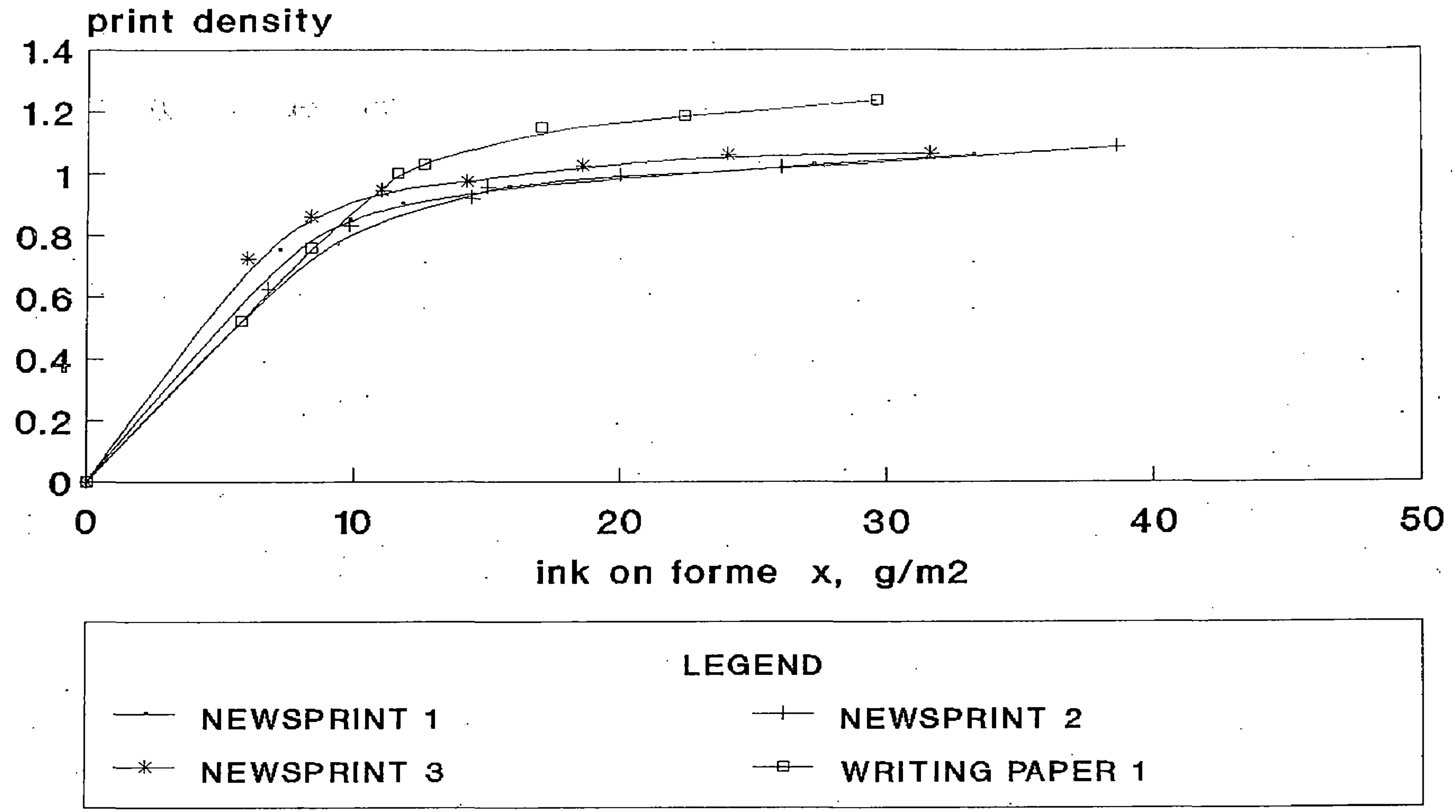
$R_{\infty p}$ = Reflectance of printed paper backed with thick unprinted paper pad.

Fig. 5 shows the graphs of print density against x, for Newsprint 1,2 & 3 and Writing paper 1 and fig. 6 shows the similar graphs for Writing paper 2, Creamwove, MG White and Duplicating paper.

It is observed from these plots that the print density values for all the newsprints were in one range and for printing papers, in another range. The print density of newsprints was in general lower than the print density of other grades. One reason for this is that the Y-values (R_∞) for newsprints was lower than other grades of papers.

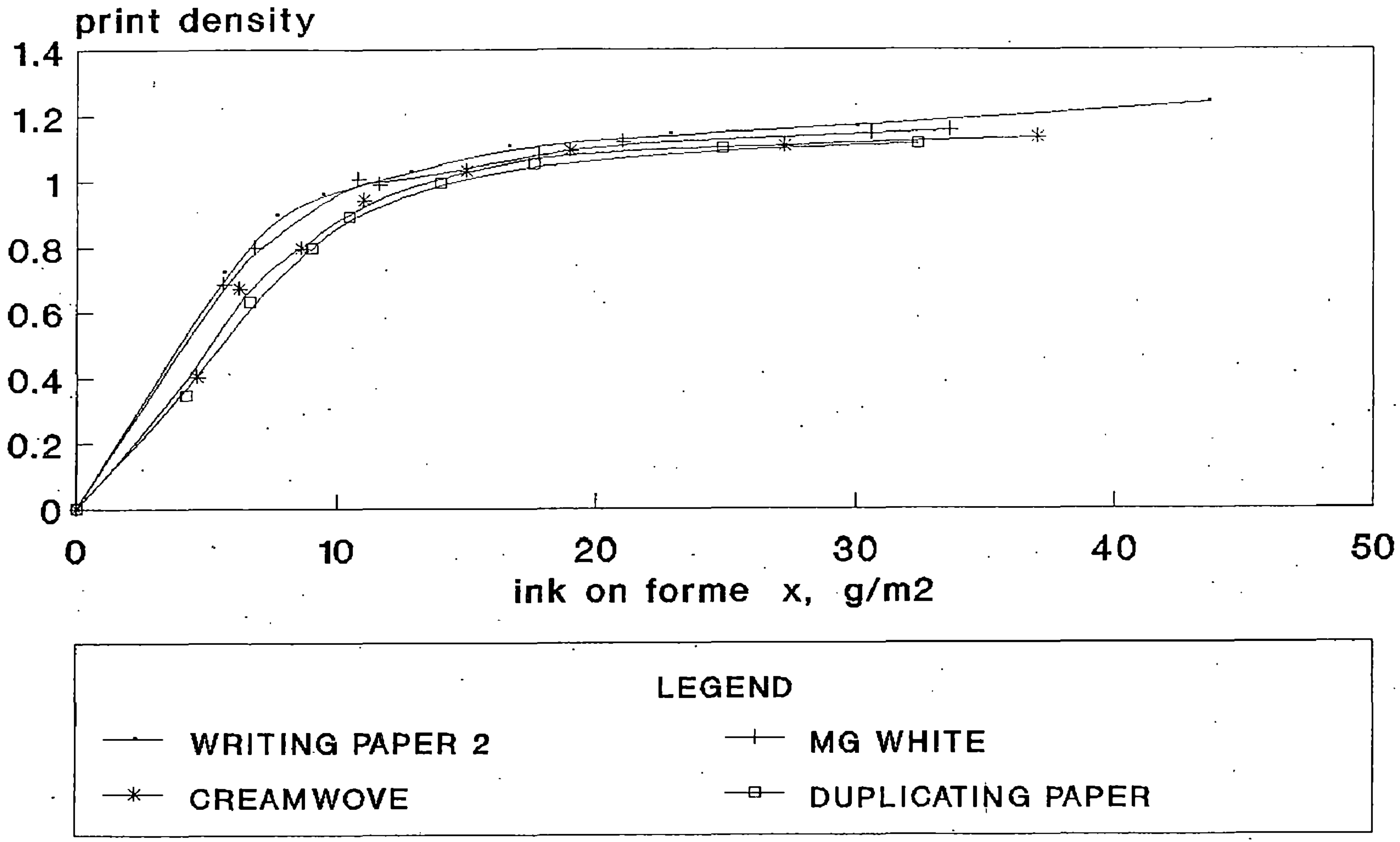
The print density increases as the value of x is increased, and after a certain value of x , the curve flattens, i.e. the rate of increase in print density is not as much as the increase in the value of x. The point on the graph, where the variation in slope of the plot is high gives the minimum possible value of x in order to obtain good print density. We may call this value of x as critical amount of ink, and expressed as x_c.

Table 3 shows the values of critical amount of ink x_c, and corresponding print density and show through values for different grades of papers. It appears from the table that this critical value of x was around 10 g/m^2 for all grades of papers. The print density values corresponding to x_c are slightly lower than the saturation density values. Fig. 7 & 8 shows the different grades of printed papers at this value of x.



Sat.den. = 1.10 | 1.10 | 1.15 | 1.30
NP1 | NP2 | NP3 | WP1

Fig 5. Relationship between x & Print Density for NP 1,2,3 & WP1



Sat.den. =	1.30	1.20	1.16	1.14
	WP2	MGW	CW	DP

Fig No.6 Relationship between x & Print Density for WP2, MGW CW & DP.

Table 3 : Print Density and Show Through at x Critical, for Different Grade of Papers.

Grade	$x_{crt.}$	Print Density	Total Show Through	Show through due to ink penetration
Newsprint 1	10.0	0.95	0.064	0.0375
Newsprint 2	10.6	0.94	0.055	0.0274
Newsprint 3	10.0	1.04	0.080	0.0384
Writing Paper 1	10.8	1.15	0.110	0.0490
Writing Paper 2	10.0	1.12	0.096	0.0478
MG White	10.4	1.11	0.156	0.0797
Cream Wove	10.8	1.10	0.064	0.0355
Duplicating Paper	11.2	1.09	0.048	0.0266

It was checked whether the experimental data satisfied the print density equation suggested by Tollenaar et.al., (3):

$$D = D_\infty(1-e^{-mx})$$

Here D_∞ is the saturation print density, i.e., the density approached when the quantity of ink increased indefinitely, and m is the density smoothness constant, which shows how quickly the saturation density can be obtained. It was attempted to calculate the values of the constants D_∞ and m following the approach suggested by Tollenaar et.al. using only two data points on the D vs x curve. The calculation procedure is briefly given below :

As the Tollenaar equation consists of two constants, two independent equations are necessary to evaluate their values.. These two equations can be obtained at $x = x_1$ and $x = 2x_1$, with D_1 and D_2 as their corresponding print densities:

$$D_1 = D_\infty(1-e^{-mx_1}), \text{ and}$$

$$D_2 = D_\infty(1-e^{-2mx_1})$$

Rearranging the above equation, we get

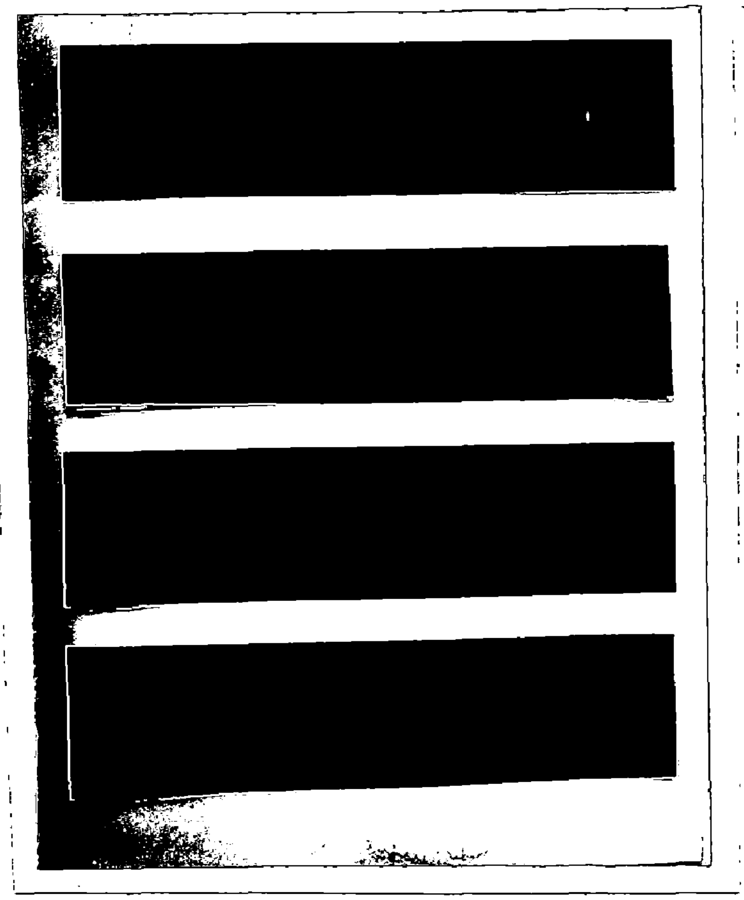


Fig No. 7 The appearance of printed strips at x critical for NP 1,2,3 and WP 1.

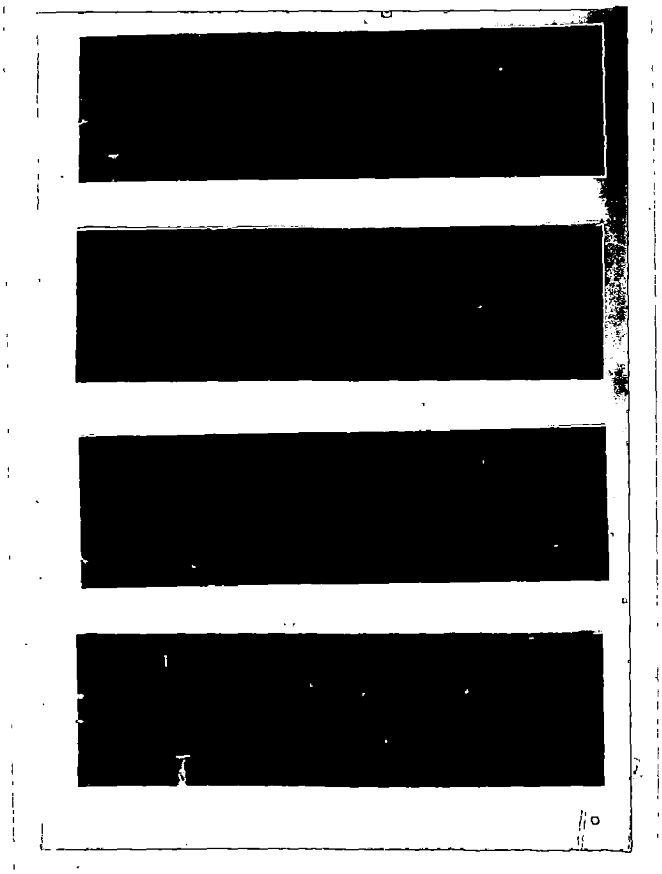


Fig No. 8 The appearance of printed strips at x critical for WP 2, MGW, CW and DP.

$$m = (-1/x_1)\log_e[(D_2/D_1) - 1]$$

$$D\infty = \frac{D_1}{(1 - e^{-mx_1})} = \frac{D_2}{(1 - e^{-2mx_1})}$$

When the values of m and D∞ were calculated at two different sets of data, quite large differences in m and D∞ were observed. This indicates that the experimental data do not very well fit into the Tollenaar equation. However, in a simpler approach, D∞ value was obtained from the graph and the value of m was then determined by plotting [- ln (1 - D/D∞)] vs x graph. m is given by the slope of straight line fitted into these data. The values of m and D∞ for different grades of papers are given in table 4. The graph of [- ln (1 - D/D∞)] vs x for Newsprint 2 was shown in fig. 9.

Fig. 10 shows the graph between printing smoothness of paper (k) and the density smoothness (m) of the print for different grades of papers. There appears to be a linear relation between k and m. This may indicate that the two constants represent the same characteristic of the paper. Higher the value of k, better the density smoothness of the print.

III. Show Through :

Show through is a defect in print which means that the printied image is visible through the paper when seen from the reverse side. It

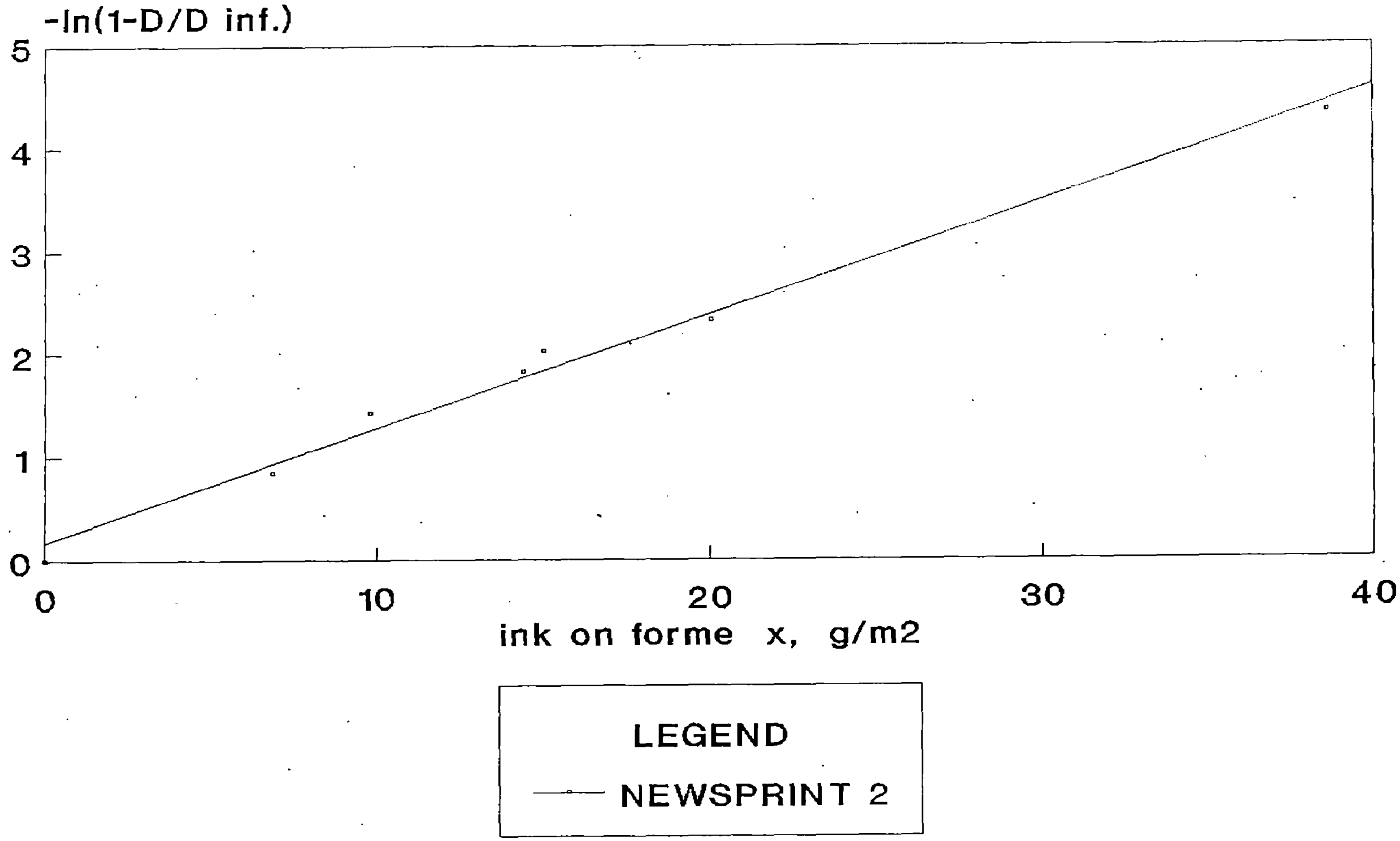


Fig No.9 Relationship between -ln(1-D/D inf.) and x.

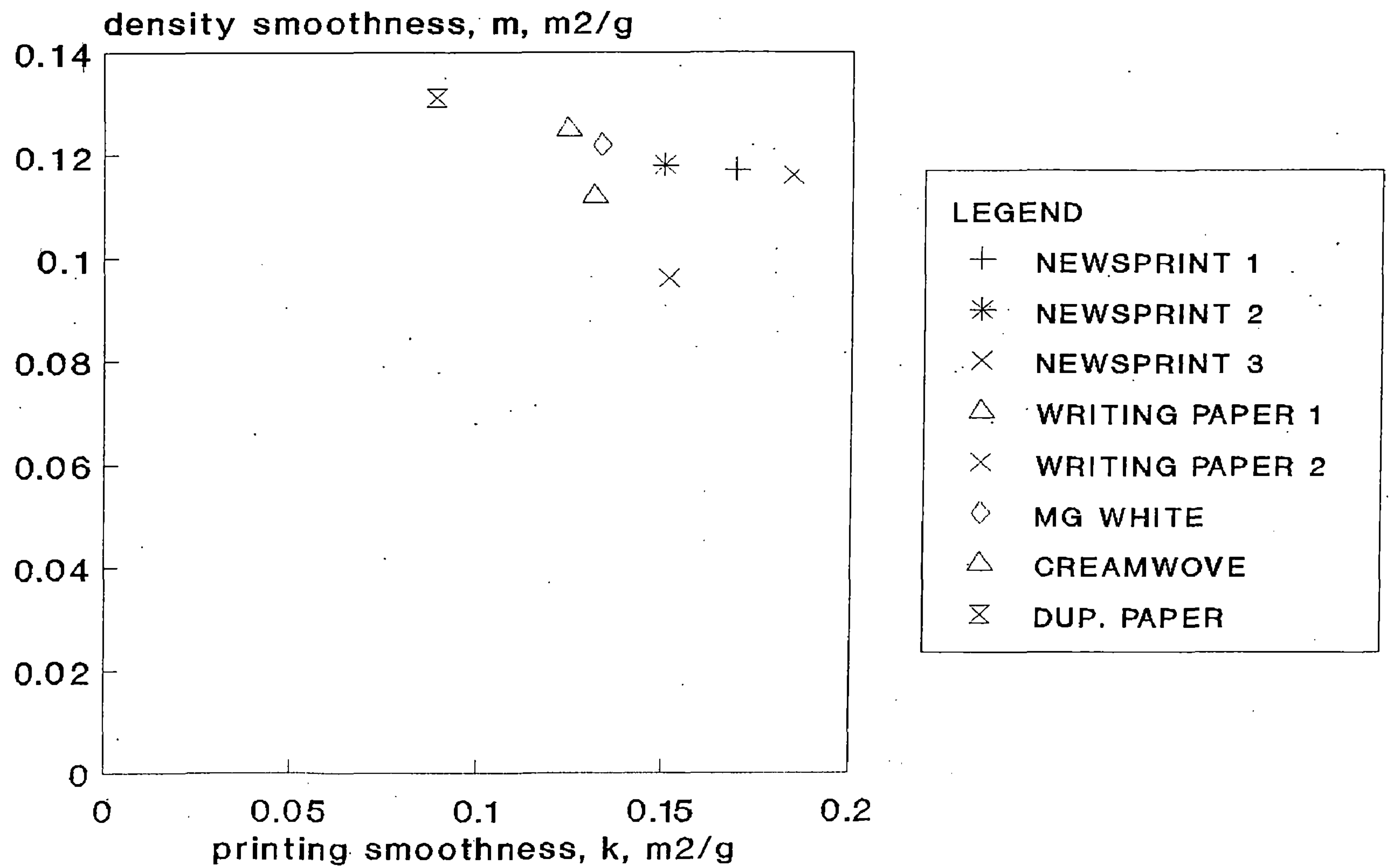


Fig No 10 Relationship between k and m for different grades of papers.

Table 4 : Ink Transfer Constants for Different Papers. (Tollenaar)

Grade	D_∞	m (m^2/g)
Newsprint 1	1.10	0.117
Newsprint 2	1.10	0.118
Newsprint 3	1.15	0.116
Writing Paper 1	1.30	0.112
Writing Paper 2	1.30	0.096
MG White	1.20	0.122
Cream Wove	1.16	0.125
Duplicating Paper	1.14	0.131

may be defined quantitatively as the contrast between the printed areas as seen from the reverse side, and the unprinted paper. It can be calculated by using the following formula,

$$\text{Show through} = \log_{10}(R\infty,r/R\infty p,r)$$

where,

$R\infty,r$ = Reflectance of reverse side of plain paper backed with a thick pad

$R\infty p,r$ = Reflectance of reversed side of printed portion backed with thick pad of unprinted paper.

Fig. 11 and 12 show the graphs of show through against x for different grades of papers. The show through increases as the amount of ink on printing disc, x, is increased. Different grades of paper have different show through values. The values of show through at x_c, critical amount of ink on printing disc, may be a characteristic property of paper. The values of show through corresponding to x_c are given in table 3. The show through of print may be assumed to be contributed by the following factors :

(a) the lack of opacity of the paper (show through),

(b) the depth of penetration of ink into the paper (print through),

(c) the separation of ink pigment and vehicle (strike through).

If we substract from the total show through, the contribution due to lack of opacity, a value of show through can be obtained which depends on

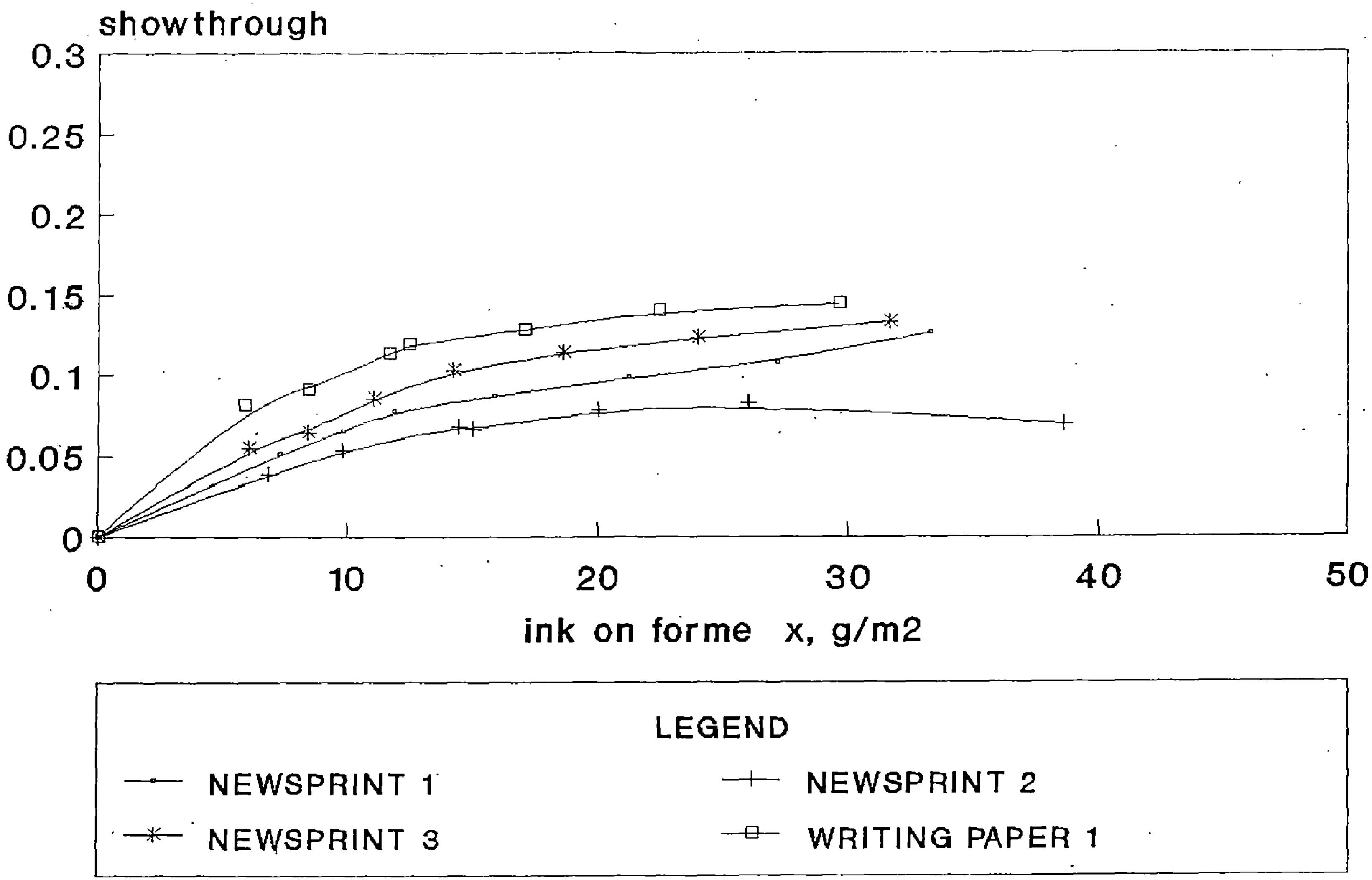


Fig. No.11 Relationship between x and show through for NP 1.2,3 & WP 1.

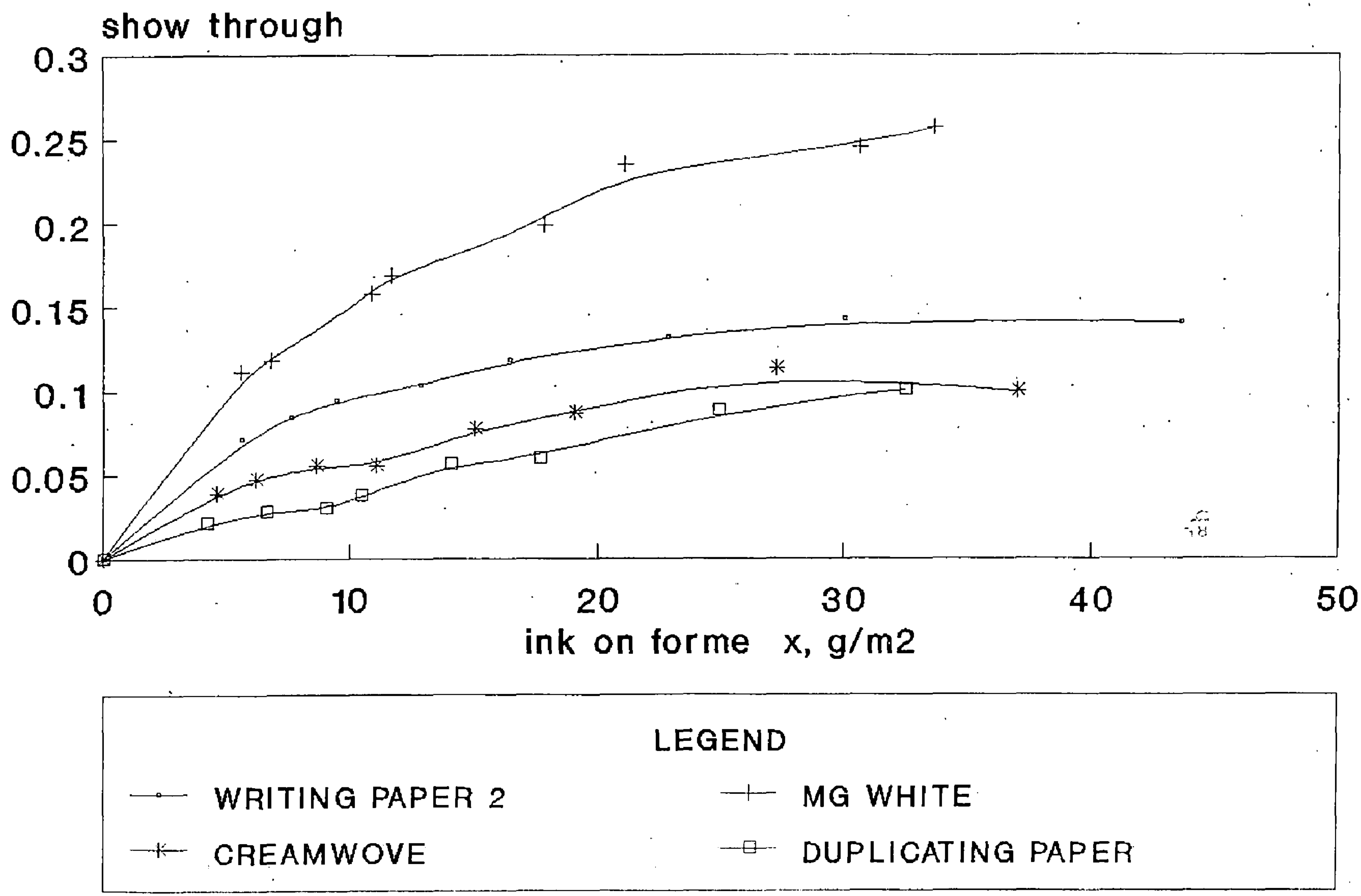


Fig No 12 Relationship between x and show through for WP 2, MGW, CW & DP.

the ink paper interaction under the given printing conditions. Such values can be calculated using the following formula :

Show through (due to ink penetration & vehicle separation)

$$= \log\left(\frac{R\infty,r}{R\infty p,r}\right) - \log\left(\frac{R\infty}{R_o}\right)$$

CHAPTER - 4

CONCLUSIONS

(1) The linear relationship between the quantity of ink on the printing forme, x, and the amount of ink transferred to the paper, y holds good only for higher values of x (> 16 g/m^2). There is a deviation from this linear relation at lower values of x.

(2) There may not be any direct relationship between the amount of ink immobilized by the paper, b, and the fraction of free ink transferred to the paper, f.

(3) Increase in Bendsten Roughness of the paper decreases the printing smoothness (k) of the paper. But the grading of papers based on printing smoothness may not necessarily correlates with the grading of papers based on Bendsten Roughness.

(4) The print density for newsprints was lower than the remaining grades of papers. One reason for this may be, due to the lower y-value of newsprints.

(5) x_c, is a characteristic property of paper. This indicates the minimum possible value of quantity of ink required on printing disc in order to obtain good print. The values of x_c for different grades have been calculated and reported.

(6) The printing smoothness of paper, k, obtained from ink transfer data, and the density smoothness, m, obtained from print density data are closely related. They appear to be representing the same characteristic of the paper.

RECOMMENDATIONS

(1) The present work was undertaken to understand and evaluate the printing properties of different grades of papers made in India. It is recommended that more varieties of papers, especially coated papers, boards, super calendered magazine papers be included in such a study.

(2) The information about the raw material, pulping and bleaching process and paper making process conditions must also be known for the paper grades to be tested so that relationship between printability of paper and pulping and paper making processes can be studied.

(3) Commercial grade offset ink was used in the present study. It is recommended that various other types of inks such as low viscosity fluid inks, tacky inks be included in such a study.

(4) Only one set of printing force and speed, was used in present work to evaluate printing constants of different papers. Variation in these constants with respect to variation in printing conditions can also be a work for future study.

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APPENDIX - I

Table 1 : Physical and Optical Properties of Different Grade of Papers

Grade	Basis Weight	Smoothness (ml/min)	Porosity (ml/min)	Opacity (%)	R∞
Newsprint 1	48	172/237	710	94.10	52.33
Newsprint 2	48	240/335	530	93.85	56.66
Newsprint 3	48	185/282	520	90.87	57.61
Writing Paper 1	53	112/302	150	86.91	69.81
Writing Paper 2	58	107/260	180	89.50	66.52
MG White	42	182/345	240	83.90	66.53
Cream Wove	59	289/337	370	93.66	66.40
Duplicating Paper	60	754/1412	470	95.20	66.89

EXPERIMENTAL DATA :

Printing Speed = 1.2 m/sec.

Printing Force = 200 N

Area Printed, $A = 0.205 \times 0.05 = 0.01025\ m^2$

(1) NEWSPRINT - 1 :

Sample No.	Wt. of uninked disc (a, gm)	Wt. of inked disc (b, gm)	Wt. of disc after Printing (c, gm)	x =(b-a)/A g/m^2	y =(b-c)/A g/m^2	R_p (Avg.)	$R_{p,r}$ (Avg.)
1	197.9719	198.3120	198.2397	33.18	7.05	4.56	39.20
2	197.9772	198.2554	198.1884	27.14	6.53	4.90	40.83
3	197.9767	198.1940	198.1381	21.20	5.45	5.33	41.73
4	197.9760	198.1380	198.0911	15.80	4.57	5.76	42.90
5	197.9766	198.0985	198.0607	11.89	3.68	6.56	43.76
6	197.9765	198.0763	198.0447	9.73	3.08	7.40	45.10
7	197.9763	198.0491	198.0273	7.10	2.12	9.26	46.56

(2) NEWSPRINT - 2 :

Sample No.	Wt. of uninked disc (a, gm)	Wt. of inked disc (b, gm)	Wt. of disc after Printing (c, gm)	x =(b-a)/A g/m^2	y =(b-c)/A g/m^2	R_p (Avg.)	$R_{p,r}$ (Avg.)
1	198.8241	199.2188	199.1475	38.50	6.95	4.66	48.06
2	198.8294	199.0963	199.0386	26.03	5.62	5.46	46.70
3	198.8293	199.0335	198.9819	19.92	5.03	5.76	47.13
4	198.8269	198.9806	198.9376	14.99	4.19	6.30	48.43
5	198.8274	198.9746	198.9335	14.36	4.00	6.80	48.26
6	198.8285	198.9280	198.8982	9.70	2.90	8.33	49.90
7	198.8280	198.8974	198.8784	6.77	1.85	13.40	51.66

(3) NEWSPRINT - 3 :

Sample No.	Wt. of uninked disc (a, gm)	Wt. of inked disc (b, gm)	Wt. of disc after Printing (c, gm)	x =(b-a)/A g/m^2	y =(b-c)/A g/m^2	R_p (Avg.)	$R_{p,r}$ (Avg.)
1	197.9745	198.2989	198.2215	31.64	7.55	4.96	42.26
2	197.9771	198.2236	198.1597	24.04	6.23	5.03	43.30
3	197.9713	198.1621	198.1084	18.61	5.23	5.46	44.20
4	197.9769	198.1227	198.0771	14.20	4.44	6.13	45.36
5	197.9774.	198.0908	198.0538	11.06	3.60	6.56	47.20
6	197.9767	198.0631	198.0346	8.43	2.78	7.92	49.53
7	197.9766	198.0389	198.0206	6.07	1.78	10.93	50.63

(4) WRITING PAPER - 1 :

Sample No.	Wt. of uninked disc (a, gm)	Wt. of inked disc (b, gm)	Wt. of disc after Printing (c, gm)	x =(b-a)/A g/m^2	y =(b-c)/A g/m^2	R_p (Avg.)	$R_{p,r}$ (Avg.)
1	198.8287	199.1311	199.0717	29.50	5.79	4.08	49.94
2	198.8295	199.0598	199.0083	22.46	5.02	4.54	50.52
3	198.8287	199.0031	198.9583	17.01	4.37	4.98	51.88
4	198.8272	198.9554	198.9178	12.50	3.66	6.52	52.88
5	198.8288	198.9477	198.9144	11.60	3.24	6.69	53.62
6	198.8277	198.9128	198.8903	8.30	2.19	12.14	56.44
7	198.8284	198.8880	198.8752	5.81	1.24	21.04	57.78

(5) WRITING PAPER - 2 :

Sample No.	Wt. of uninked disc (a, gm)	Wt. of inked disc (b, gm)	Wt. of disc after Printing (c, gm)	x =(b-a)/A g/m^2	y =(b-c)/A g/m^2	R_p (Avg.)	$R_{p,r}$ (Avg.)
1	197.9797	198.4263	198.3369	43.57	8.72	3.76	48.82
2	197.9844	198.2925	198.2215	30.05	6.92	4.48	48.64
3	197.9829.	198.2164	198.1559	22.78	5.90	4.70	49.82
4	197.9815	198.1514	198.1002	16.57	4.99	5.14	51.42
5	197.9825	198.1141	198.0722	12.84	4.08	6.16	53.28
6	197.9804	198.0777	198.0458	9.49	3.11	7.20	54.42
7	198.8299	198.9084	198.8826	7.65	2.51	8.30	55.68
8	198.8295	198.8859	198.8699	5.50	1.56	12.36	57.38

(6) MG WHITE :

Sample No.	Wt. of uninked disc (a, gm)	Wt. of inked disc (b, gm)	Wt. of disc after Printing (c, gm)	x =(b-a)/A g/m^2	y =(b-c)/A g/m^2	R_p (Avg.)	$R_{p,r}$ (Avg.)
1	198.8281	199.1717	199.0976	33.52	7.23	4.58	36.24
2	198.8294	199.1427	199.0745	30.56	6.65	4.70	37.30
3	198.8319	199.0462	198.9872	20.90	5.75	4.96	38.20
4	198.8390	199.0125	198.9638	17.71	4.75	5.44	41.50
5	198.8325	198.9519	198.9136	11.64	3.73	6.70	44.48
6	198.8327	198.9435	198.9077	10.80	3.49	6.44	45.46
7	197.9815	198.0522	198.0298	6.89	2.18	10.40	49.94
8	197.9794	198.0363	198.0201	5.55	1.58	13.46	50.78

(7) CREAMWOVE :

Sample No.	Wt. of uninked disc (a, gm)	Wt. of inked disc (b, gm)	Wt. of disc after Printing (c, gm)	x =(b-a)/A g/m^2	y =(b-c)/A g/m^2	R_p (Avg.)	$R_{p,r}$ (Avg.)
1	197.9813	198.3604	198.2784	36.98	8.00	4.86	52.82
2	197.9833	198.2627	198.1900	27.25	7.09	5.18	51.16
3	197.9808	198.1747	198.1161	18.91	5.71	5.34	54.38
4	197.9814	198.1356	198.0883	15.04	4.61	6.18	55.64
5	197.9818	198.0942	198.0576	10.96	4.15	7.56	58.82
6	198.8307	198.9196	198.8909	8.67	2.80	10.60	58.50
7	198.8301	198.8937	198.8761	6.20	1.71	14.12	59.60
8	198.8307	198.8782	198.8684	4.63	0.95	26.34	60.68

(8) DUPLICATING PAPER :

Sample No.	Wt. of uninked disc (a, gm)	Wt. of inked disc (b, gm)	Wt. of disc after Printing (c, gm)	x =(b-a)/A g/m^2	y =(b-c)/A g/m^2	R_p (Avg.)	$R_{p,r}$ (Avg.)
1	198.8296	199.1618	199.0782	32.40	8.15	5.18	52.64
2	198.8328	199.0873	199.0154	24.83	7.01	5.36	54.12
3	198.8313	199.0123	198.9534	17.65	5.74	6.00	57.88
4	198.8300	198.9739	198.9250	14.04	4.77	6.84	58.30
5	198.8314	198.9370	198.9022	10.30	3.40	8.64	60.92
6	197.9820	198.0745	198.0475	9.02	2.63	10.82	61.98
7	197.9798	198.0477	198.0313	6.62	1.60	15.78	62.20
8	198.8299	198.8737	198.8670	4.27	0.65	30.58	63.24