THE ANALYSIS OF THE DOT GAIN PROBLEMS AND ITS EFFECT ON COLOUR REPRODUCTION

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Introduction The size of a dot in a final lithographic half tone print is usually increased from that produced at the graphic reproduction stage; this phenomenon is known as 'dot gain'. The effect occurs principally as a consequence of the pressure between the plate and blanket and also between the blanket and substrate. It can also occur at earlier stages of the process but it can effectively be eliminated in the pre-press processes.

Since these pressures are an essential feature of lithographic offset printing, some spreading of the ink dot as present on the plate will inevitably occur. The most important features are described below.

i. Inking Roller to the Plate (NIP): The dot gain phenomena, starts at the moment of contact between the inking roller and the lithoplate. Thus, during this transfer process, the size of the dot increases by about 2.5% depending on the ink film thickness.

ii. Plate/Blanket (NIP): The ink transferred to the plate, is further split at the nip area between plate and blanket, where it tends, due to the pressure, to cause again, an ink squash (2% - 5% increase).

iii. Blanket/Paper (NIP): The ink transfer mechanism which is achieved by the pressure at the nip (impression cylinder, blanket, paper and ink etc.) will lead to further ink squash. This in turn will lead to an increase on the ink coverage, which contributes to the dot growth. This phenomena takes place in any single printing unit, so that the above three points will occur in every unit in the printing chain.

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The dot gain phenomena is also quite noticeable in the overprint colours, when ready filtration of the liquid phase of the second ink becomes impossible. This is because the previously printed ink, especially when it is solid, tends to seal the surface of the substrate reducing the effects of capillary action. This causes the superimposed ink dot to spread onto the preceeding ink film. Therefore in the development of the colour correction methods for wet-on-wet printing, it is important to investigate the relationship between the colour of the single printing inks and their overprint in the form of superimposed halftone dot patterns and solids.

A close look at (Figure 1) shows clearly that ink trapping and ink transfer are not only affected by the material variables such as ink, paper etc. but also by the machine geometry and the press conditions.(1) With regard to the printed dot, either dot gain or other dot defects (slur and doubling) can occur. Both of these are well known as major problems in WOW offset lithography. The dot gain is influenced by:-

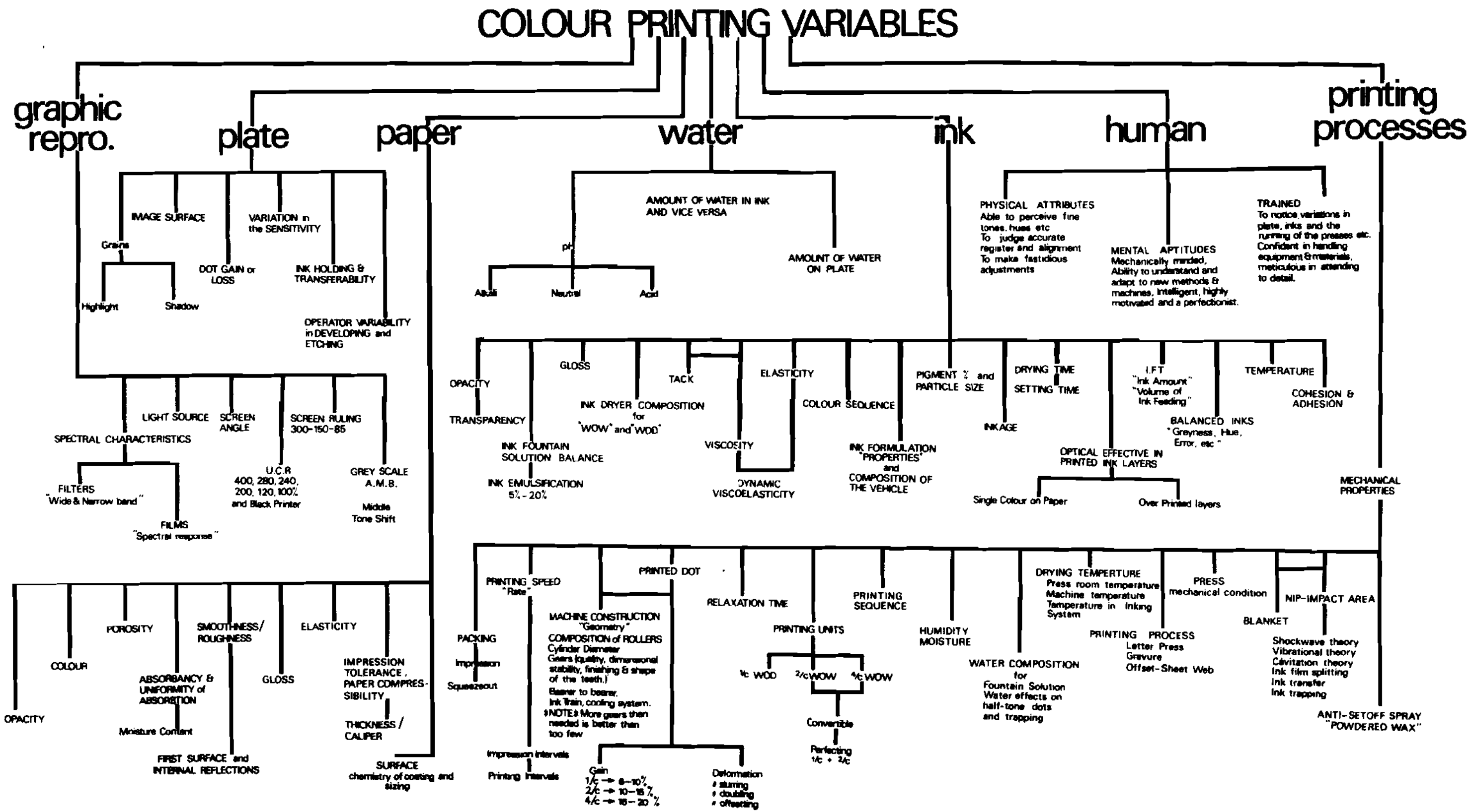
a. cylinder diameter
b. the number of gears, quality, dimension stability, finishing and shape of the teeth
c. bearer to bearer pressure
d. ink train
e. cooling system
f. type of bearing in housing

The dot gain phenomenon is at its worst in the middle tone areas towards the shadow areas, with percentage gains up to 15% - 20% being recorded.

Some of the variables e.g. printing substrates, IFT of single colour only, the press speed, could be standardised but others e.g. IFT for the overprint colours, are almost impossible to be controlled without generating data and compensating for the dot gain in the early stages of the process.

It has been said that the dot gain is no problem, others have said that it could be eliminated. As far as I am concerned it would be like trying to live without being born. That is to say, the dot gain is present at the birth of the process.

Thus, the aim of this dot gain investigation is not to prove the existance or how to eliminate it but to analyse



THE VARIABLES AFFECTING THE APPEARANCE OF THE PRINTED COLOUR REPRODUCTION

FIGURE (1)

the variables which influence its magnitude.

Therefore extensive work has been done on a production press in a commercial and practical environment away from laboratory simulation conditions so that the results give a true indication of what would happen in the printing industry.

The following variables have been investigated due to their direct effect on the gain problem.

a. different kinds of substrates
b. single colour IFT variations
c. the impression pressure in the Nip area
d. the effect of perfecting on gain

Two methods of measurements have been applied. One applied the conventional printability gauge with microscopic examination, the other, was a new application of image analysis equipment, known as the Quantimet 720. Additionally, the results have been compared with X-ray Fluorescence Spectroscopy (XRFS) analysis.[1-3]

1. THE APPLICATION OF THE PRINTABILITY GAUGE IN MEASURING DOT GAIN

i. Brief description of the Printability Gauge: The Printability Gauge consists of parallel lines arranged on sets. Each set contains two blocks of lines one at right angles to the other. All the lines are of the same width while the width of the white spaces are different (Figure 2)

ii. Platemaking Stage: Extreme care was necessary during the platemaking procedure to ensure that there was no dot gain on the printing plate. Extensive tests were undertaken varying the exposure time (a light integrating meter was used to compensate for light intensity fluctuations) and development time to achieve facsimile plate reproduction.

iii. Note on precision of measurements:

a. All measurements were made to a precision of ± 2.5 m. It is an easy matter to improve the precision to ± 1 m say, but there is little value in doing so since the edges of the printed lines are indistinct at this magnification so that an average edge position must be estimated.

b. The objective in this section is to show that useful quantitative dot gain information can be derived from this widely used gauge.

c. The use of the printability gauge proved to be a useful tool in measuring the image gain. The measurements were continued with the application of the MICRODENSITOMETER, to avoid the laborious measuring and also to improve the precision of the measurement. The application of the printability gauge is preferred rather than the conventional half tone pattern for the following reasons:-

i. for conversion it is better to use a test image that presents straight edges that can be lined up accurately with the slit. The bars of the printability gauge give such a suitable image.

ii. a halftone tint pattern has curved edges and at the magnification available, the slit height is in the same order of size as the diameter of the dot and therefore it is much more difficult to interpret the density changes and the size of the image.

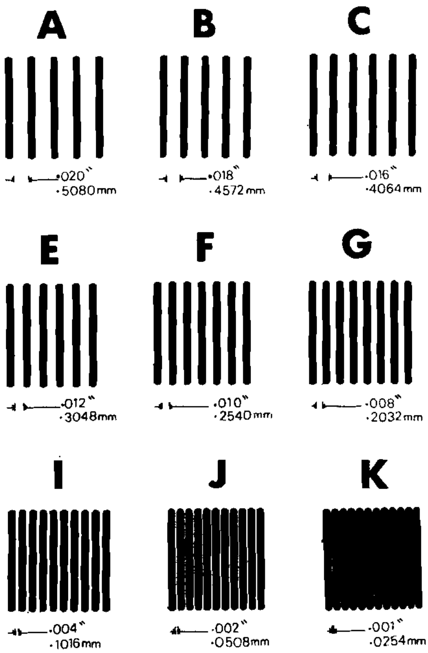


Figure (2)

The Printability Gauge

The width of the printing bars is ·010" (·254mm) from A to K

1.2 The Effects of the Substrate on the Dot Gain

Four different kinds of paper were printed with a constant (standard) IFT with printing speed of 5000 iph. The cyan printed as single colour first in the sequence.

The results are illustrated in (Figure 3) as follows:-

Mellotex High dot gain in Highlight which results in:-

a. shorter range of dot gain between Highlight and Shadow

b. constant gain in mid tone areas (C - G) which amounts to an average of dot growth of about 13.5%

c. The growth reaches its maximum in the early shadow area (H) and it prints completely solid at top shadow (J & K). This will have a considerable effect on any details in the shadow area as well as ink trapping.

Gambit and Nimrod behave similarly to each other with an average of 9% dot growth and printing solid in the shadow areas J-K where the spread was more noticeable than the highlight area (A-B-C).

Ambassador This is a coated paper and it gave lower dot gain with an average of 6%. It also produces sharp details due to less dot gain in the shadow area.

Conclusion The fraction of the free ink transfer to the paper depends on both the surface smoothness, oil absorbency and compressibility of the substrate.

It was found that when printing with standard ink film thickness the dot gain "growth" on rough paper such as Gambit and Nimrod was slightly more than that on smooth paper such as Ambassador with a difference of 2.5% dot gain.

1.3 The Effect of Single IFT Variation on Dot Gain %

In this investigation, only one kind of paper was used which was Ambassador Art and the ink volume varied between very thick, thick, standard and thin (controlled by measurement of final printed solid density i.e. 1.5, 1.4, 1.2, .90 respectively).

The results are illustrated in (Figure 4) as follows:-

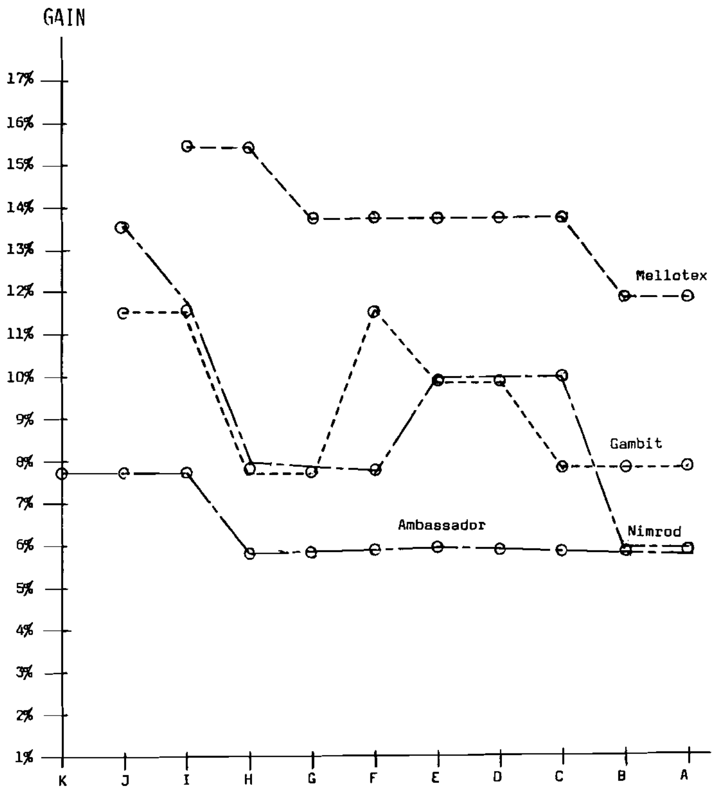


FIGURE (3)

THE EFFECT OF THE SUBSTRATE VARIATIONS ON THE DOT GAIN

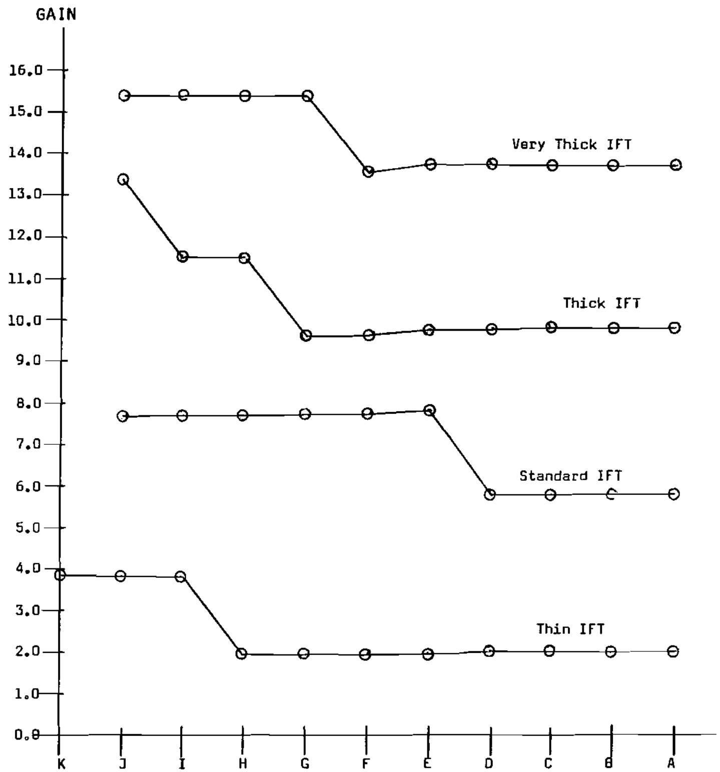


FIGURE (4)

THE EFFECT OF SINGLE IFT VARIATIONS ON DOT GAIN PERCENT

A. The dot gain increases as the IFT increases
B. With thin IFT dot gain average is 3%
C. With standard IFT dot gain average is 7%
D. With thick IFT dot gain average is 11%
E. With very thick IFT dot gain average is 14%

In all the above cases, the dot gain is less in the highlight area (A-D) than in the shadow area (H-K).

The above shows the relationship between the IFT and the dot growth % which could be compensated in advance at the Graphic Reproduction stage.

1.4 The Effect of the Impression Pressure on the Dot Gain %

As it is obvious that the effect of any increase of the pressure applied by the impression cylinder increases the dot size, it was felt that it might be useful to study the effect of reducing the pressure below the normal used.

Thus, the impression pressure was reduced by .050mm (The usual convention of expressing impression pressure in terms of distance of movement of impression cylinder has been employed).

The printing substrate used was Nimrod, printed with standard cyan IFT, with low pressure and then with normal pressure. Cyan was first in the sequence.

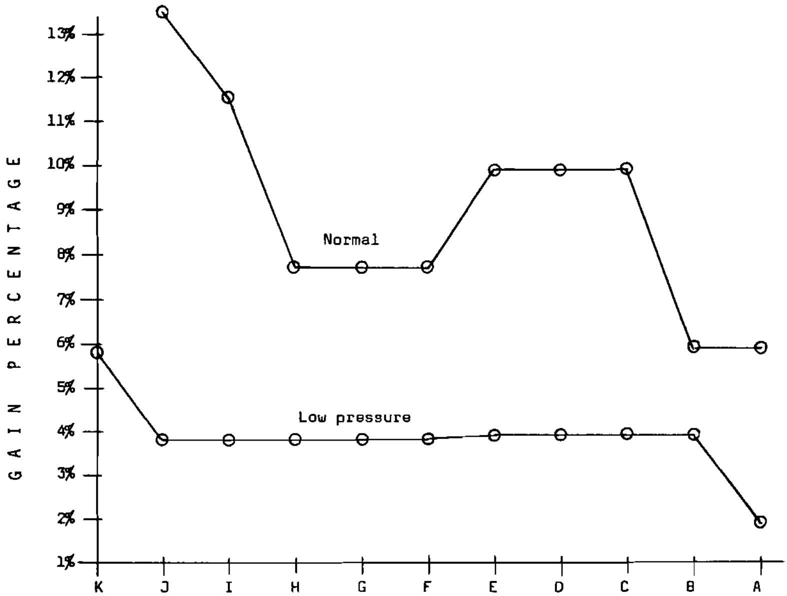
(Figure 5) shows the effect of both pressures, in normal and in the lower position, on the gain % when printing with standard IFT in single colour.

The lower pressure indicated an average gain of 3% - 4%. This gain was, in fact, somewhat higher than initially anticipated.

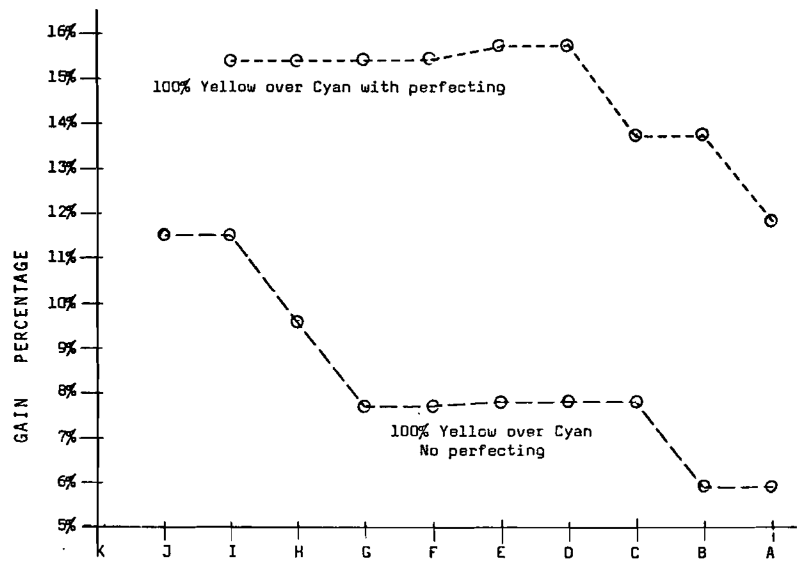
The reason for this was almost certainly the dot gain which had already occurred on the blanket as a consequence of the plate/blanket nip.

1.5 The Effect of Perfecting on Gain %

During recent years, the convertible multi-colour and perfecting machines have gained widespread use, for good economical reasons. The printing industry became used to the existance of convertible presses that permit the conversion of one unit or several units from straight printing to perfecting, where one or more colours will



FIGURE(5) THE EFFECT OF LOW PRESSURE ON DOT GAIN IN SINGLE COLOUR



FIGURE(6) THE EFFECT OF PERFECTING ON GAIN PERCENTAGE IN TWO COLOURS WOW print on the back side of the substrate simultaneously, with the other images on the front side of the printed sheet.

There are several factors that determine the suitability of a job for running on a convertible press such as, kind of paper, because certain types of light weight and coated stock may cause difficulties on a convertible press, type of printing forms, number of colours and distribution of images on the sheet.

The last three factors are governed by the amount of the area which is printed with solid inks as well as the IFT and the number of colours printed on the front side, all of which will influence the ink transfer and trapping of inks on the other side, especially where images are distributed to back up the already printed front side.

In the case of an overprint over a solid colour (Figure 6) the dot growth is found to be an average of 14% with perfecting while it is 8% on average without perfecting.

In addition, with the effect of perfecting on dot growth, it was found that the shadow area (K-J) was printing as solid with a greater mottle effect in spite of the IFT being standard.

2. THE APPLICATION OF THE QUANTIMET AS A NEW TECHNIQUE OF MEASURING DOT GAIN PHENOMENA

2.1 Abstract Photomicrographs, at approximately 200X magnification were made of the cyan screen tints printed with standard IFT over standard yellow IFT. Individual screen dots were then typically 8-20mm in diameter. The mean areas of these dots were measured using the Quantimet 720 image analysing system. The 720 is capable of performing three basic types of counting operation. The full feature counting type was found to be suitable for this work.

The application of this measuring technique proved to be effective in measuring the irregular shape of the final printed dot.

This system is equipped with an Epidiascope input peripheral and a Hewlett Packard 9830A control calculator.

The photomicrographs were placed on the Epidiascope and the dot features were automatically detected by the electronic system. Ten repeat measurements were made for each group of dots and the results were averaged to produce a mean area, in mm^2 on the photomicrograph print, for a single dot.

The true percentage dot areas were calculated and finally the dot gain was calculated.

2.2 Brief description of the Technique and Equipment

Area measurements of the dots were analysed by the Quantimet 720 Image Analyser [4] of the Research Division, Kodak Ltd., which is a system similar to that shown in (Figure 7).

The Quantimet consisted of a high resolution vidicon TV Scanner (specifically developed for image analysis) attached to an Epidiascope (Figure 8) input peripheral for processing colour and black and white photographs.

The area measurements of the detected features are displayed by the Quantimet in a digitised form on a cathode ray tube screen.

This screen contains 720 lines each of which is divided into 694 separate parts - giving a total of some 500000 light points or picture points.

The automatic setting of the density threshold allows the features and image details (i.e. black dots in positive form, of which area in negative form) particularly the printing mottle, to be selected for automatic detection and measurement.

2.3 Counting The Quantimet is permanently calibrated in picture points. It measures areas by counting the number of picture points in a field which fall within the detected feature boundaries. There are three modes of counting available, i.e. End Count, Topological count, and Full Feature counting. The latter mode has been used in this work.

The irregular shape of the printed dot area is almost impossible to describe or to measure. A determination of dot area by planimetry or some other geometric method of the area of enlarged dots have been found in many papers [5-14] but the methods are inexact because the dots have no sharply defined outline or boundary and because of the unevenness of the ink layer on the dots. Thus a mathematical method

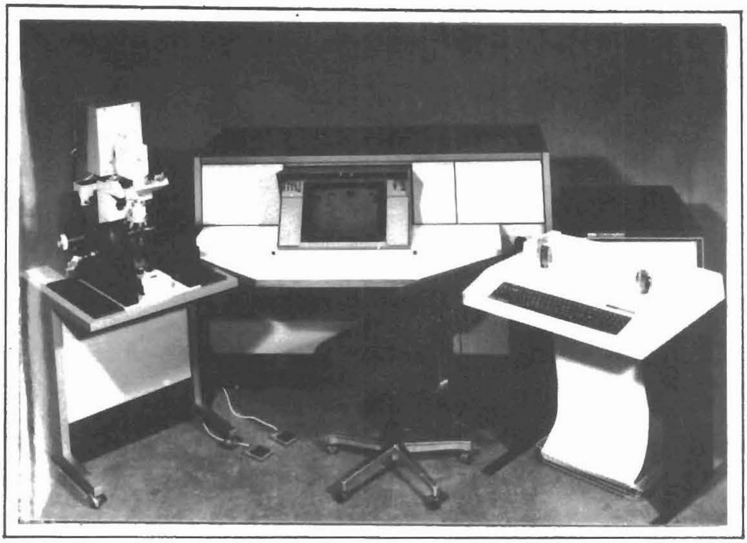
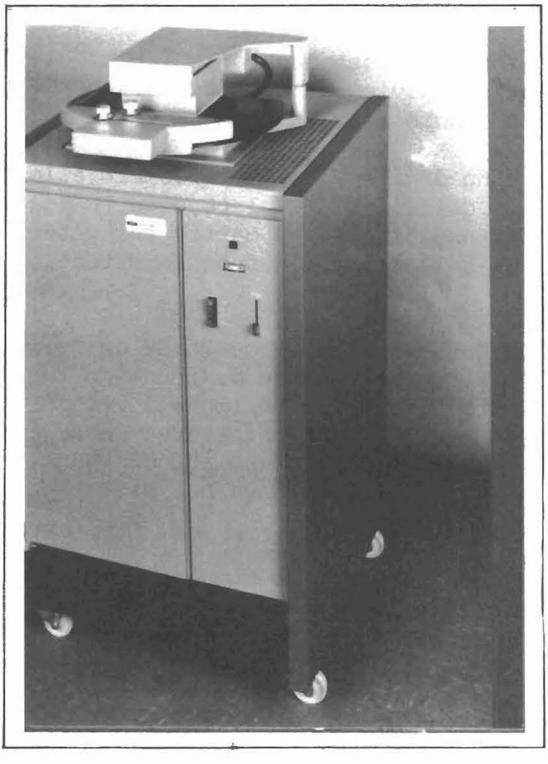


FIGURE (7) QUANTIMET 720 General view of standard system



EPIDIASCOPE
replaces
Microscope
in above system

FIGURE (8)

of calculating the area is equally not possible. The Quantimet is capable of measuring irregular shapes in both the inked and non-printed white paper areas, providing an average mean area in mm^2 which can be converted to a true dot % area.

The above counting results can normally be displayed on the display screen, or fed to external peripherals such as a desk-top calculator.

2.4 Interpreting the data The picture points data represent the average area of the data, in mm^2 as they appear on the 182.7 magnified photomicrographs.

These data were calculated to the true original dot percentage size, in order to be related to the printed cyan screen dots where the original screen was 150 line per inch (60 Lp cm.) in the following example.

A. The mean area of the original dots =

$$\frac{\text{Black area on print}}{\text{The magnification squared}}$$

B. % true dot area =

$$\frac{\text{mean area } (mm^2) \times (\text{screen ruling (lines per inch)})^2 \times 100}{(25.4)^2}$$

2.5 Discussion of Results

a. Figure 9 shows the dot gain with the single colour indicating that there was a 3.2% gain in the Highlight area and as can be seen this increased to a 7.7% gain in the shadow area.

This demonstrates the range of dot gain increase which was due to the effect of the second unit nip area since the cyan was here printed second in the sequence.

This work confirms the existence of the dot gain phenomena in the highlight area. This conclusion agrees with the results of both the printability gauge and XRFS analysis. However, it is interesting to note that these new findings are in opposition to the work of Cook at PIRA [15] and Yule [14]. These measuring techniques also indicated that the dot gain appeared higher in the mid shadow (60% dot) than the highlight area.

b. Figure 10 shows that the dot gain increases to the

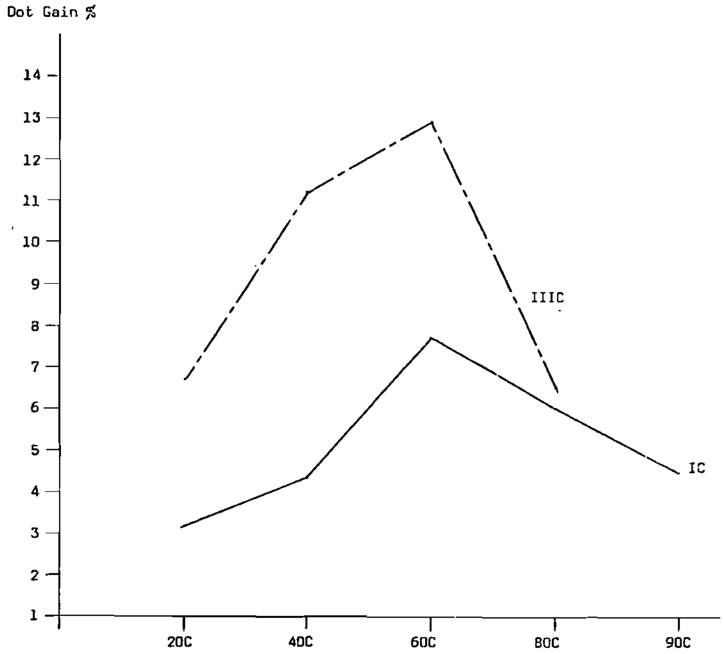


FIGURE 9 . DOT GAIN MEASUREMENT

Cyan printed 40% Yellow (IIIC)

Cyan printed over paper only (IC)

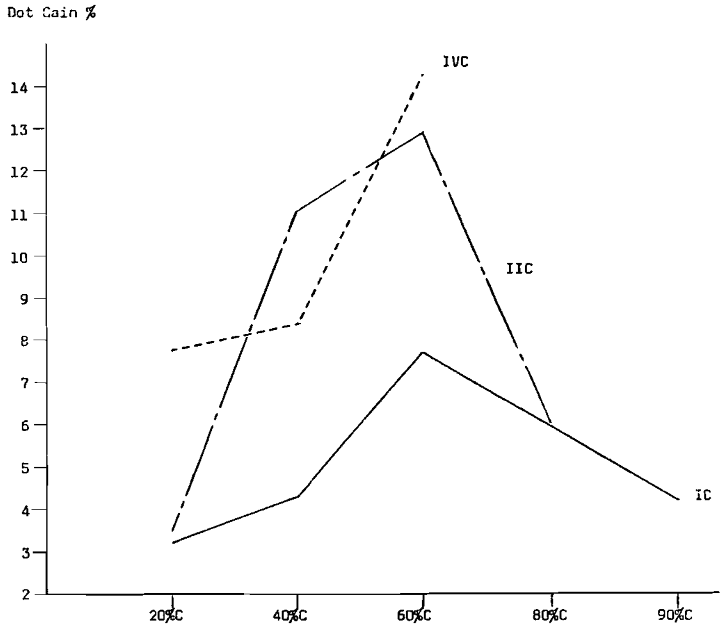


FIGURE 10 THE EFFECT OF THE UNDER COLOUR VARIATIONS ON THE DOT GAIN PHENOMENA

Cyan over 60Y (IVC)

Cyan over 20Y (IIC)

Cyan over paper only (IC)

mid shadow area which is 60% but in the heavy shadow area, that is 80%, 90%, 100%, this dot gain percentage is shown to be reducing. This is due to the undertrapping and printing mottle effect in the overprinting colour.

c. Figure 11 shows the behaviour of the 80% dot when printed over a variety of under colour tint values. The 80% dot showed an average increase of 6.5% when it was printed as a single colour and over 20% and 40% yellows. (i.e. mid tone yellow areas).

This indicated better trapping over highlight dots. However, this increase in the highlight area shows changes to an average decrease of 5.5% in the 80%, 90%, and 100% (shadow yellow area).

d. Figure 12 illustrates the effect of the 20% white reverse dot inside the printed 80% dot.

As the 80% dot printed over 60%, 80% and 90% , it was found that the 20% white reverse dot in the photograph was getting bigger i.e. instead of 20% white it was printing as 26% white. This, in fact, was due to the undertrapping of the original 80% cyan dot, which had been printed as 74% as shown in (Figure 12).

Therefore in (Figure 12) the top part indicates that there is no dot gain as well as the filling-in phenomena which usually occurs but the undertrapping and the pin holes and the ink mottle compensates for both dot gain occurrence and filling-in.

When the 80% dot is printed over paper alone, as well as light half tone tints, it prints as 86% as shown in (Figure 11). This means that 20% white reverse dot has been decreased (shrinkage) in size to 16%.

The possibility of measuring these white reverse dots on paper was only possible by the use of the Quantimet.

3. COMPARISON OF INK TRANSFER AND DOT GAIN MEASUREMENTS

a. The visual appearance of a print depends on the reflection and absorption of light in the presence of ink film(s) on the substrate. In general, the more ink present the greater the amount of absorption, however, the same amount of ink spread over a large area of the substrate will also result in greater absorption of light. Comparison of the XRFS and the dot gain measurements under the same

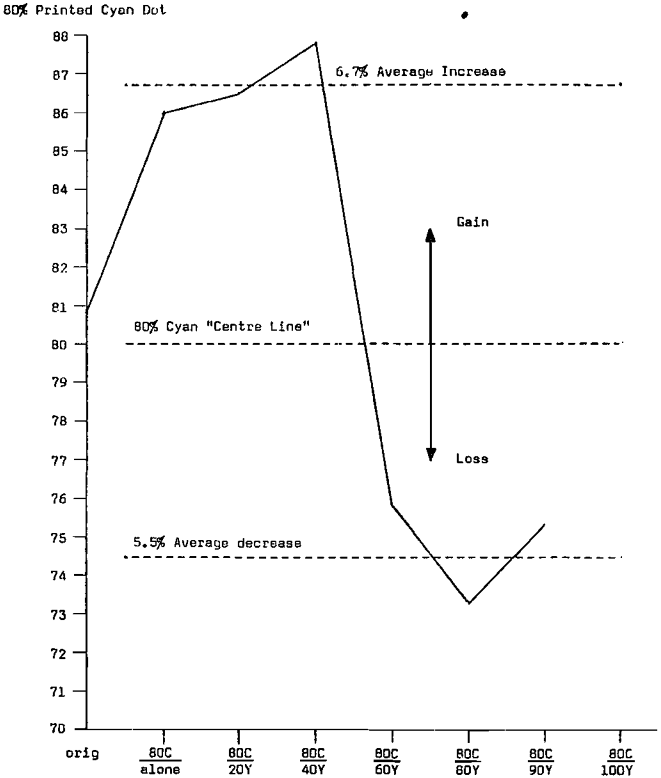


FIGURE 11 THE INTERESTING BEHAVIOUR OF THE DOT GAIN ON THE EFFECT OF THE UNDER COLOUR ON THE 80% DOT "SHADOW"

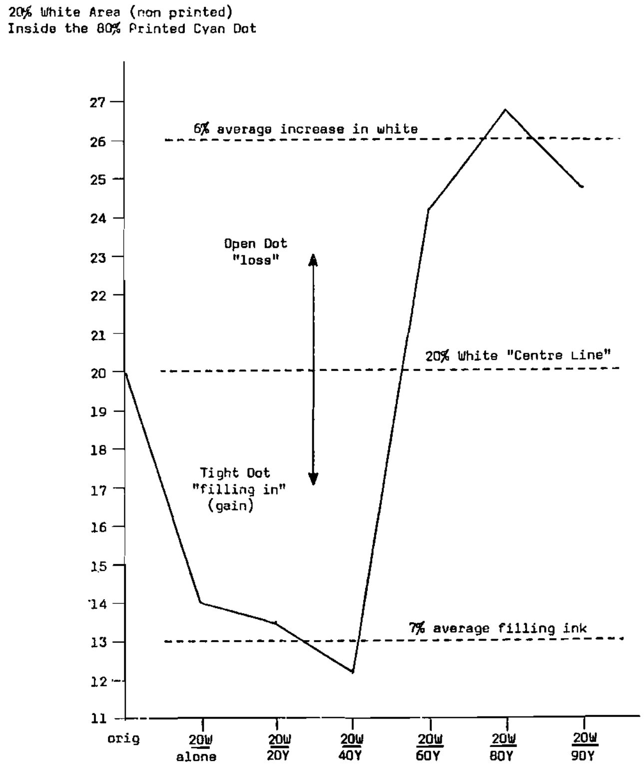


FIGURE 12 THE STUDY OF THE NON PRINTED DOTS IN THE SHADOW AREA (80%) IN RELATION TO THE DOT GAIN AND THE UNDER COLOUR

20W = 20% White non printed area inside the 80% printed cyan dot printing conditions allows us to make deductions about what actually happens during normal print runs (see Figure 13).

b. In (Figure 14) printed dot areas and % transfer of ink have been plotted against dot areas on the plate. In this case a single ink on paper has been considered. It will be noticed that the XRFS results follow closely the ideal straight line indicating that trapping is excellent. However, the Quantimet and Printability gauge results show that substantial dot gain occurs particularly in the mid tone to shadow region.

c. This implies that situation (b) in (Figure 13) is occurring i.e. the 'correct' amount of ink is being transferred but that is being spread over a large area. (Figure 15) is an example of overprinting one ink on a previously printed ink, (60% tint in this case). The XRFS results follow the ideal in the highlight region but shows increasing undertrapping in the mid to shadow region. The Quantimet results show also dot gain increasing from the highlight to mid tone region and dot loss in the shadow region. This implies that situation (B) Figure 13 applies in the highlight areas as above and situation (A) for a small region around 80% dot area. Elsewhere case (C) applies. Thus the dot gain is compensated to some extent in the mid tone region by trapping loss but there will be lack of density in the shadow region primarily due to poor trapping.

d. In general, therefore the final shape of the tone curve produced in wet-on-wet printing can be attributed to dot gain, which is the dominant factor in the mid tone region, and poor trapping which is the dominant factor in the shadow region (Figure 16). The difference in the case of printing on paper alone, which approximates to wet-on-dry printing, and wet-on-wet printing means that the printing sequence is of prime importance in compensating for defects at the graphic reproduction stage. Furthermore the shadow regions will always be the most difficult area to compensate, necessitating some sort of compromise, as suggested in a previous paper. [16]

4. Further Work

Screenless litho, and e.g. printing from a chrome on copper bimetal plate involves printing from a recessed image area, though the bimetal case probably involves a smaller and certainly more uniform recess depth. In the screenless case, it would be expected that the peaks of the plate grain

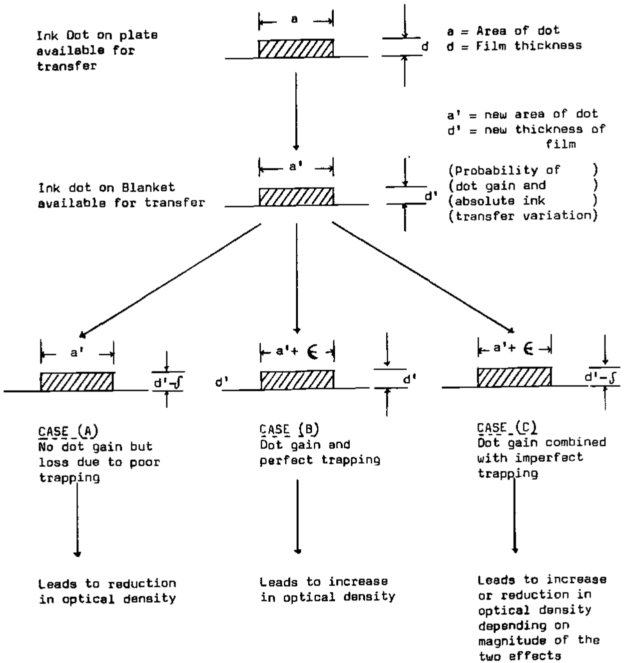


FIGURE 13

DIAGRAM ILLUSTRATING SITUATIONS WHICH MAY OCCUR DURING TRANSFER FROM BLANKET TO SUBSTRATE

ʃ = reduction in ink film thickness

∈ = increase in dot area

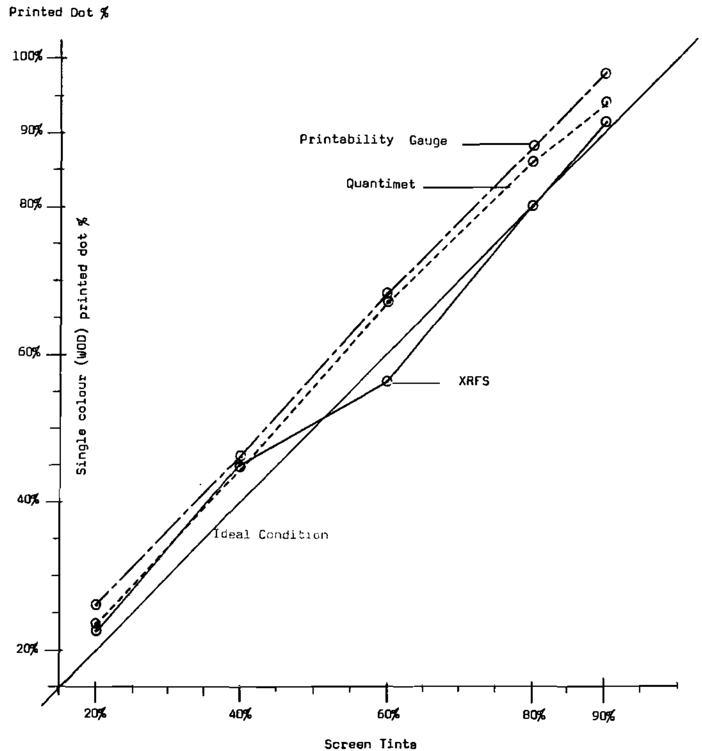


FIGURE 14

A COMPARISON BETWEEN XRFS, QUANTIMET AND PRINTABILITY GAUGE FOR DOT GAIN MEASUREMENT (WOD)

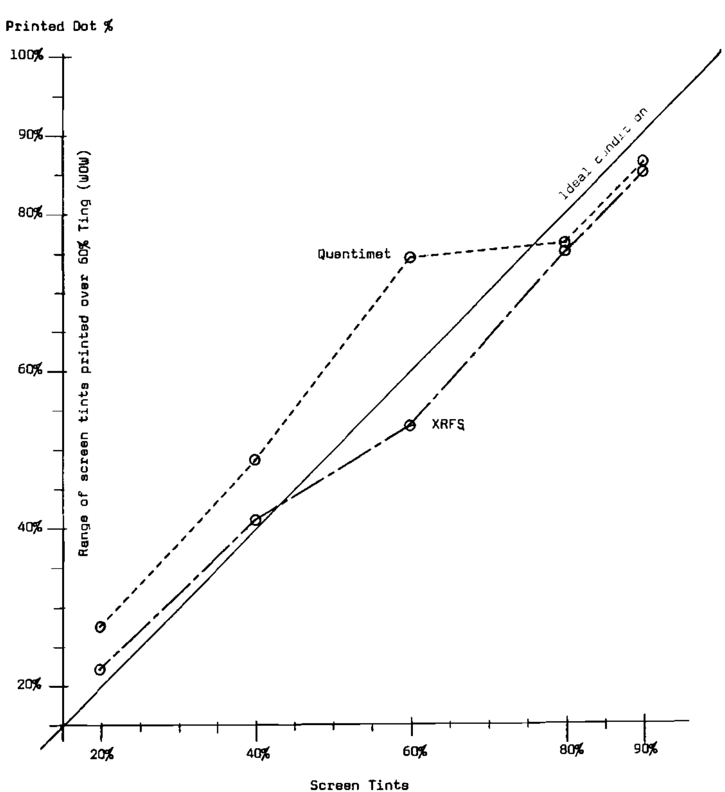


FIGURE 15

A COMPARISON BETWEEN XRFS AND QUANTIMET FOR DOT GAIN AND INK TRAPPING MEASUREMENT (WOW)

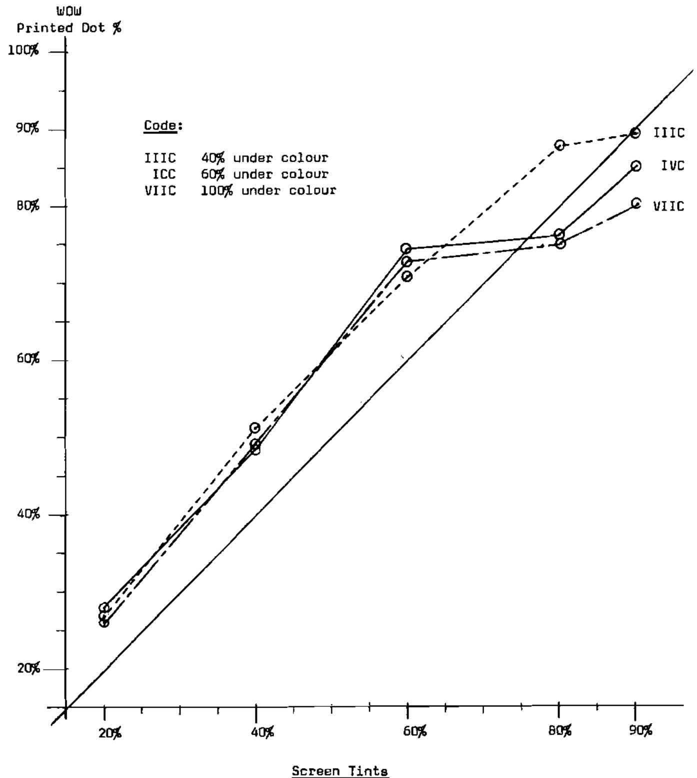


FIGURE 16

QUANTIMET ANALYSIS FOR DOT GAIN AND LOSS "IMPERFECT TRAPPING" DEPENDING ON THE UNDER COLOURS structure, i.e. the non-printing areas, would support the substrate during the impression period, and then reduce the pressure build up in the ink in the nip area. This, of course, particularly applies to a highlight area, and to a reduced extent, to a shadow area. In the case of a solid printing area no such support will take place. As a result of this support of the substrate, one may expect that the shadow areas would show a similar % 'dot gain' to that shown with a normal surface coates plate, but in the highlight areas the 'dot gain' would be reduced since the degree of support of the substrate would be greater. Investigation into such a possibility would seem desirable in the event of screenless litho being even further developed.

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