Plate Control to Optimise Halftone Reproduction

by

L.E.Lawson, D.J.Hodgson and J.E.Cox

Howson-Algraphy Group, Vickers PLC.

Introduction

The increasing awareness of printer and customer alike concerning the large number of variables which arise during the reproduction process from original to final copy has led to demands for methods of standardisation to improve quality and consistency of the final printed products.

To date, considerable effort has been directed towards standardising plate production variables but optimum pictorial reproduction has not been adequately considered. The following seeks to do this when dealing with the plate-making department and its operations.

The importance of dot gain and dot control in halftone reproduction both on the plate and on the press is discussed. The practical use of various fixed plate imaging standards, based on microlines, is considered. Attention is drawn to the problems which can arise if standards are rigidly employed without due regard for the variables that can influence halftone reproduction during printing.

The Control of Dot Gain - On the Plate

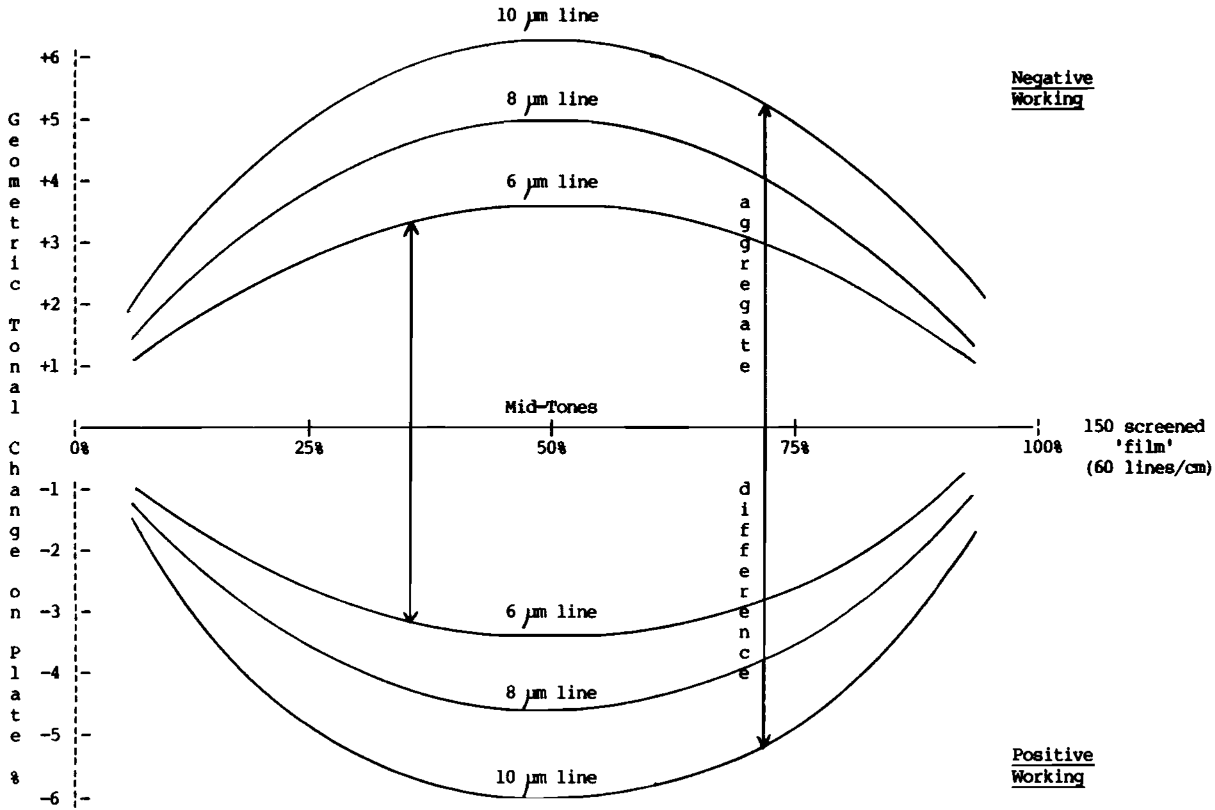
The main factor relating to reproduction which concerns both the plate-maker and the printer is the accurate control of dot size. Changes in dot size are inherent and unavoidable in both the plate-making and printing processes and, in order to achieve optimum results, it is necessary to exercise control at all stages.

Measurement of dot area on the plate is inaccurate when using densitometers. The physical size of the dots can be determined by using microscopic planimetry. This is consistent with the view expressed by Vonášek of VUP Czechoslovakia (ref.1) that changes in halftone size can only be followed reliably from geometric measurement. Microscopic planimetry is a research and not an industrial technique.

A number of indirect methods have been proposed for controlling the sizes of halftone dots during plate-making. The use of the familiar continuous tone step-wedge is a well-proven method of exposure control for both positive and negative plates. In recent years, other systems have been put forward which involve the use of microlines.

Proposals by Brunner, Fogra and Ugra, in effect, recommend that plates should be exposed and processed to hold rigid pre-determined microline values. Based on experimental evidence, the assumption is made that, if plates are imaged to these criteria, the tonal range of the halftone image reproduced on the plate will produce a satisfactory result when both proofing and printing. In other words, fixed plate-making criteria will adequately cater for press variables and yield optimum halftone reproduction.

Figure 1: Geometric Trends when Halftone Plate-Making



There is well-established practical evidence to support the use of microline plate control. Figure 1 shows the trends when negative and positive halftone images are printed down from film to plate according to microline criteria. The difference in behaviour between negative and positive-working plates concerning halftone dot size variations can be clearly seen. It is evident that the maximum variation in area occurs in the mid-tones and that the dot areas are dependent on the width of the finest microline reproduced.

Figure 2 shows the effect of exposure on positive plate images of the 50% mid-tone. It illustrates the experimental results obtained using an electronic planimeter and a high powered microscope and compares them with the results calculated in accordance with the mechanical/geometric border zone theory. As can be seen, the practical and theoretical results are in reasonable agreement. The border zone theory appears to be valid.

Figure 2: The Effect of Increasing Exposure on Dot Area
(50% Control Tone, Round Dots, 150 Screened, Positive Plate)

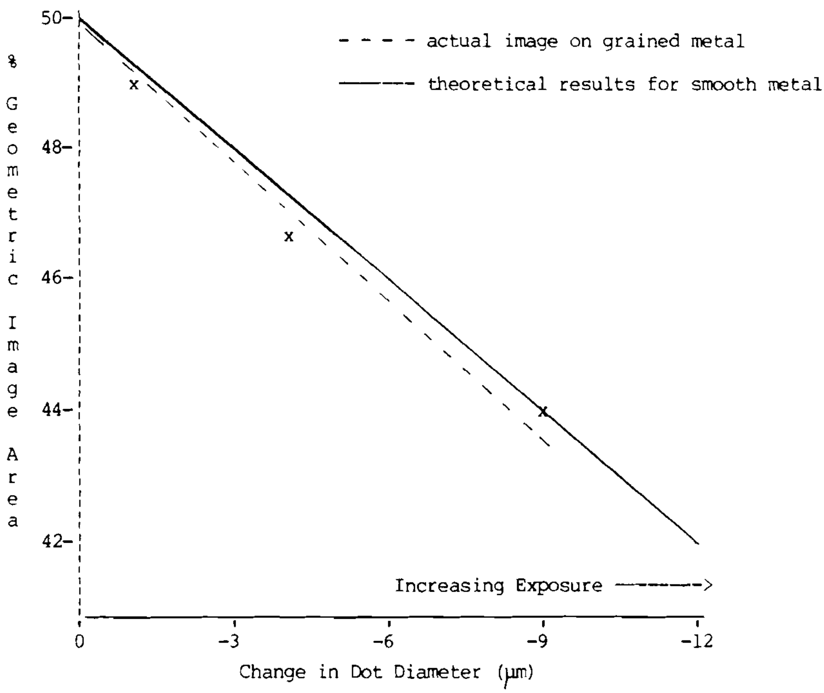
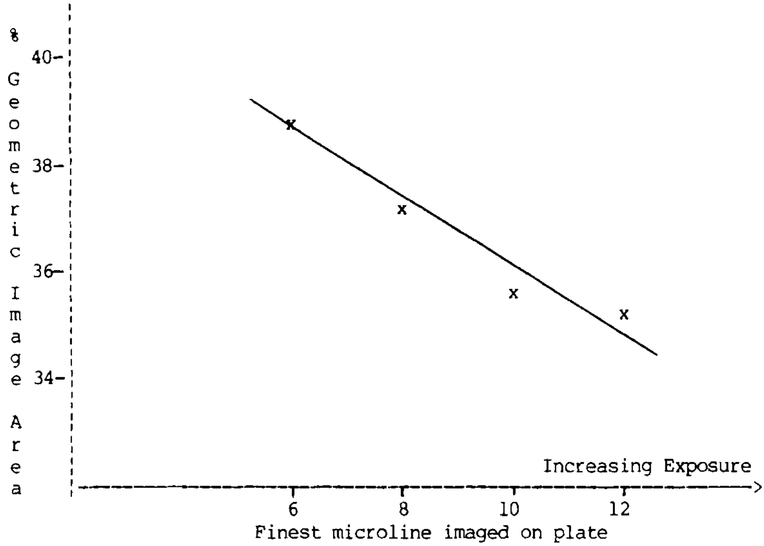


Figure 3 shows the actual changes to a 39% mid-tone which were recorded after exposing a typical positive-working plate to retain different microline values.

Figure 3: Relationship of Microline Imaging and Dot Area
(39% Control Tone, Round Dot, 150 Screened, Positive Plate)

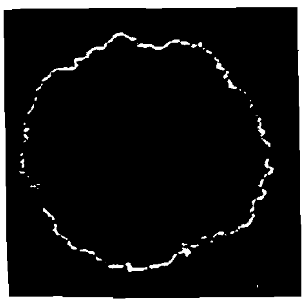


Figures 2 and 3 show that, when positive plate exposure is increased, dot diameter and hence dot area both decrease, the image becomes sharper. At the same time, the finest positive microline reproduced on the plate increases in width. The converse applies when imaging negative plates, the image becomes fuller. This is to be expected because the factors affecting the change in dot size are related to undercutting which occurs at the border zone around the circumference of the dot. There is, of course, a simple mathematical relationship between dot diameter, dot circumference and dot area when perfectly round dots are employed.

It follows, therefore, that, to accurately control tonal image and obtain optimum results, close attention must be paid to plate exposure.

The plate-dot perimeter illustrated in Figure 4 was obtained using the same equipment.

Figure 4:



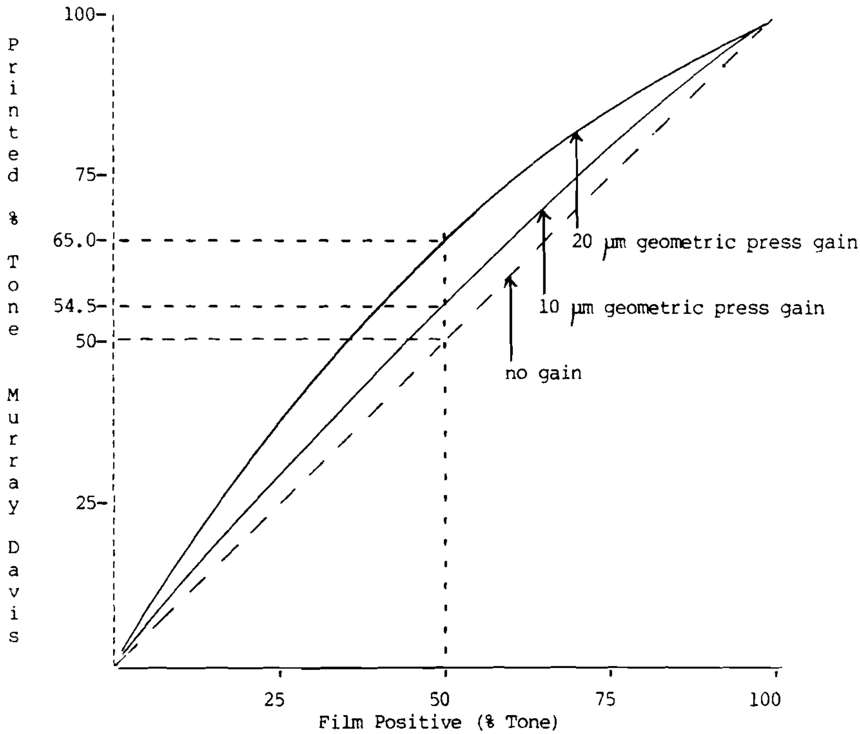
In practice, the use of microline plate control has proved reasonably useful when applied to positive plate imaging. From the above, it has been argued that the same criteria should prove of value for the control of negative plates. On this premise, Fogra, in 1984, extended the concept of microline control to negative plates.

Application of microline control to negative plates has led to a number of practical problems (ref.2). It is now evident that sole reliance on this plate-making criterion can be unreliable and lead to unacceptable run lengths on the press. Recognising these limitations, Fogra now recommend that microlines should always be used in conjunction with continuous tone step-wedges and that the plate should be exposed and processed in accordance with manufacturer's recommendations.

Printed Dot Gain

Printed dot gain relates to the overall change in dot size when halftones are transferred from film to print. This includes the changes that arise both during plate-making and press work.

Figure 5: Printed Tonal Reproduction Curves



On the basis of the border zone concept, Figure 5 predicts the printed tonal reproduction of round dots in respect of arbitrary but typical amounts of geometric press gain when working with '150' screened halftones. This again illustrates that the maximum change in dot area occurs in the mid-tones. From this, it can be seen that a 10 µm press gain increases the dot area of a 50% control tone to approximately 54.5%. Similarly, a press gain of 20 µm increases the dot area to approximately 65%.

It must be remembered that, in practice, the same degree of printed dot gain can be achieved by numerous permutations of dot change on both plate and press. This has been confirmed by many measurements of plates and printed copy.

Table 1 illustrates fifteen different combinations of photo-mechanical plate and mechanical press gain which can give rise to the same degree of dot gain between film and print - in this instance, using round dots.

Table 1: Typical Combinations of Photo-Mechanical Plate Change and Mechanical Press Gain

Film to Plate Image Change (µm on dot diameter)	Plate to Printed Impression/Press Gain (µm on dot diameter)	Aggregate Geometric Dot Gain (µm on dot diameter)
Negative Plates		
+ 5	+10	+15
+ 4	+11	+15
+ 3	+12	+15
+ 2	+13	+15
+ 1	+14	+15
Positive Plates		
- 1	+16	+15
- 2	+17	+15
- 3	+18	+15
- 4	+19	+15
- 5	+20	+15
- 6	+21	+15
- 7	+22	+15
- 8	+23	+15
- 9	+24	+15
-10	+25	+15

Listed under two relevant amounts of densitometrically-determined Murray-Davis dot gain (ie 15% and 30%) observable when printing on coated stock, the component effects of varying amounts of photo-mechanical plate change and mechanical press gain can be seen in Table 2. For instance, with a generous but realistic amount of 'film to print' Murray-Davis dot gain of 30%, a wide variation of actual geometric press gain could be occurring. The precise amount in a given situation would depend on the choice of plate, on the imaging from film to plate and the prevailing press gain.

Table 2: Typical Effects due to 'Plate Gain'

Photo-Mechanical Change[●] (50% mid-tone - 150 screened)	Typical 'Film' to Print (Murray-Davis) Printed Dot Gain 15%	30%
	caused by mechanical press gain*	caused by mechanical press gain*
Negative Plates		
+ 6	N/A	2
+ 4	N/A	4
Positive Plates		
- 4	2	12
- 6	4	14
- 8	6	16
-10	8	18

● dot diameter change (µm) film to plate
* dot diameter change (µm) plate to print

N/A It is not normally possible to achieve as little as 15% Murray-Davis dot gain on coated stock when working from negatives.

Note: Same geometric press gain can be occurring when widely different Murray-Davis dot gains prevail.

Commercial Test Results

The following shows the extent to which the choice of plate and its degree of exposure can influence printed dot gain. The results recorded in Table 3 were obtained from a series of tests carried out on two commercially available plates, one negative- and the other positive-working. Four plates of each type were selected at random. The work was carried out on four presses, including a modern flat bed proof press and a mint condition sheet fed four colour/four unit press. Three sets of standard four colour process inks were employed together with coated stock. Details of the press conditions are given in Table 3a.

Plate-making was controlled using the same 50% control film tint, step-wedges and scales throughout. The image format selected was typical of industrial practice, having a wide range of tonal values. The same exposure and processing equipment was used throughout the tests. Processing was in accordance with manufacturers' recommendations.

Press conditions were closely supervised and the printed densities were carefully controlled using a densitometer. To avoid complications arising from multi-unit blanket gain, measurements were taken of impressions that had been produced with only the appropriate single unit of the four colour press operating in each instance. The plate exposures were realistic in practical terms and, although sometimes slightly extreme, were less than some of the extremes known to occur in industry.

Table 3: Related % dot gains according to choice of plate and plate exposure (50% control tone)

	Positive Plate		Negative Plate	
	* Clear 5	* Clear 2	* Solid 3	* Solid 6
Press Conditions 'A'				
Black	5%	16%	18%	24%
Yellow	5%	11%	18%	27%
Magenta	7%	18%	20%	28%
Cyan	16%	23%	28%	41%
Press Conditions 'B'				
Black	5%	15%	21%	26%
Yellow	11%	22%	24%	27%
Magenta	12%	22%	26%	31%
Cyan	20%	26%	31%	38%
Press Conditions 'C'				
Black	1%	10%	13%	18%
Yellow	-1%	6%	9%	15%
Magenta	0%	8%	15%	22%
Cyan	9%	16%	21%	31%
Press Conditions 'D'				
Black	15%	27%	27%	28%
Yellow	10%	19%	18%	25%
Magenta	15%	17%	21%	29%
Cyan	18%	27%	29%	37%
Average of all colours and press conditions	9.3%	17.6%	21.2%	28.0%

* Continuous tone scale with density increments of 0.15

Table 3a: Summary of Press Conditions Used in Table 3

	A	B	C	D
Press	FAG 104 Flat Bed Proofing	Komori Lithrone 26	FAG 104 Flat Bed Proofing	Heidelberg Kord
Blanket	Perfect Dot	Vulcan 714	Cow TR Compressible	Unknown
Inks BS4666	Coates Prism	Fishburn Syncroset	Shackle Edwards Autoset	
Paper	Trulux Gloss 115gsm		Arjomara Chromomat 100gsm	

Negative Plates

Reduction of plate exposure by 70% changed the step-wedge reading from 'solid 6' to a minimal 'solid 3'. This resulted, on average, for all colours, in a 7% reduction in Murray-Davis printed dot gain. The plates exposed to produce 'solid 3' were re-exposed after processing to improve durability on the press.

Positive Plates

Increasing exposure by 150% resulted in step-wedge readings rising from a very minimal 'clearing step 2' to a maximum 'clearing step 5' and the Fogra microline reading changing from 6 to 15 µm. On average, this produced a reduction of 9% in Murray-Davis printed dot gain.

Comparative Performance

As expected, the use of positive plates consistently produced less overall printed dot gain than negative plates, on average 11% less. This difference in dot gain was increased to as much as 19% by the controlled variation of positive plate-making by increasing exposure to clear step [illegible].

When exposure of the negative plates was minimised and the printed results compared with the results obtained from maximum exposure of positive plates, it was found that the positive plates still produced less printed dot gain, approximately 12%.

The results show that, on both negative and positive plates, printed dot gain can be adjusted by up to approximately 8% by controlling exposure. It must be remembered, however, that this practical example studies the percentage dot gain at the extremes of exposure and that, under normal circumstances, a latitude of ± 4% is unacceptable. A more reasonable latitude which coincides with the recommendations on the use of microlines, ie ± 2 µm, would be ± 1.8% on a 50% control tone.

In practical terms, on positive plates, this means that initially the manufacturer's exposure guidelines using a continuous tone step-wedge should be followed. This will ensure complete photolysis occurs and hence the plate will develop quickly and cleanly with no background problems caused by resin retention. Subsequent exposures can then be adjusted accordingly by using the microline technique to achieve the required or optimum amount of printed dot gain.

On negative plates, special precautions are necessary when using this technique to exploit the full reproduction latitude by varying exposures. Any reduction in exposure from the manufacturer's recommended continuous tone step-wedge reading would result in a deterioration in run length potential of the plate. Therefore, it is essential when using this technique on negative plates to restore the run length of the plate by post-exposure or post-baking.

Positive Plate Imaging Criteria

When plate-making using microline control strips, two factors need to be established in order to optimise the printed results:

1. The finest microline which must be reproduced on the plate.

2. The permitted latitude in the halftone image of the plate.

Fogra have stated that the rendering of the 50% mid-tone can be accepted as characterising the complete tonal image transfer from film to print as well as that from film to plate. This premise was also adopted by Brunner, GATF and SFM. However, Fogra, 3M and Gretag have recently used the 40% mid-tone. In practice, as can be seen in Table 4, the difference that arises when either of these mid-tones are used is usually negligible. In this presentation, we have used the 50% value.

When working to the middle of the Brunner positive microline recommendation, ie 10 µm, Table 4 shows that the 50% tone will be reproduced on the plate as approximately 43% when imaging round dots. The data in this Table is comparative having been rounded to the nearest half percent to accord with practical limitations. The trend is obvious. Dot size decreases significantly as the width of the finest microline imaged increases.

Such data enable decisions to be made regarding the choice of microline and hence exposure when positive working but, before selecting a particular microline criterion, it is first necessary to consider the **image** latitude that can be permitted in the halftone printing areas, as distinct from the latitude in the microline renderings.

Table 4: Relationship of Microlines and Dot Reproduction

Microline Width Criteria (finest positive line imaged on the plate)	Round Dots		Square Dots		Elliptical Dots	
	* (40%)	* (50%)	* (40%)	* (50%)	* (40%)	* (50%)
6 µm	36.5	46	36.5	45.5	36.5	47
8 µm	35	44.5	35	43.5	35	45
10 µm	33	43	33.5	42.5	34	43.5
12 µm	32	40	32	41	33.5	42

* Control

Plate Image Latitude

Recommendations on imaging latitude vary. For example, the positive method offered by Brunner adopts a narrow and virtually fixed criterion which permits a ± 1 μm plate image latitude. This compares with Fogra whose original recommendations meant that, with commercial high resolution (6μm) positive plates, the 8 μm lines should be held with a permitted latitude of ± 2 μm. Recently, the adoption of a wider image latitude of ± 3 μm was considered. This was found to be more practical by Lawson and Watkinson (ref.3) and Dolezalak (ref.4) also referred to its use.

Table 5: Brunner Microline Target (10 μm)

Percent Dot Area on Positive	Microline and % Halftone Image Latitude			
	9 - 11 μm (ie ± 1 μm)		8 - 12 μm (ie ± 2 μm)	7 - 13 μm (ie ± 3 μm)
5%	3%	± 0.2%	± 0.4%	± 0.6%
7%	5%	± 0.25%	± 0.5%	± 0.75%
10%	7%	± 0.3%	± 0.6%	± 0.9%
20%	16%	± 0.5%	± 1%	± 1.5%
40%	33%	± 0.75%	± 1.5%	± 2.25%
50%	43%	± 0.9%	± 1.8%	± 2.7%

Table 6: Fogra Microline Target (8 μm - for high resolution plates)

Percent Dot Area on Positive	Microline and % Halftone Image Latitude			
	7 - 9 μm (ie ± 1 μm)		6 - 10 μm (ie ± 2 μm)	5 - 11 μm (ie ± 3 μm)
5%	3.5%	± 0.2%	± 0.4%	± 0.6%
7%	5%	± 0.25%	± 0.5%	± 0.75%
10%	7.5%	± 0.3%	± 0.6%	± 0.9%
20%	17%	± 0.5%	± 1%	± 1.5%
40%	35%	± 0.75%	± 1.5%	± 2.25%
50%	44.5%	± 0.9%	± 1.8%	± 2.7%

A ± 1 μm alteration in microline rendering equates with a ± 0.9% change in dot area of the 50% control tone. Larger imaging latitudes when working with microlines, typically ± 2 and ± 3 μm, produce increases in dot area of ± 1.8% and ± 2.7% respectively. Tables 5 and 6 show how different extents of microline image latitude will affect dot areas when positive plates are imaged to 10 and 8 μm width target criteria, respectively. These Tables show that significantly different percentage areas will occur depending on which microline criterion is adopted.

The influence of the general "process variables" when plate-making have been referred to elsewhere (ref.3). It was suggested that a ± 3 µm image latitude is required to adequately accommodate the variables found in commercial circumstances. This recommendation was principally based on the fact that it can be difficult to obtain sufficiently even illumination during exposure, particularly when working with large formats.

When aiming to optimise the final printed products, it is essential that one also considers whether the monochrome and multicolour renderings will be acceptable. This càn be answered by ascertaining the typical effects that various degrees of image latitude will have:

a) on the printed tone reproduction and

b) on the printed 'grey balance'.

Printed Tone Reproduction

This relates to black and white monochrome and also where black is employed in the traditional manner in colour work to augment the dark colours. Approximate printed tone densities can be derived from appropriate Yule-Nielsen data which relates densitometric measurements to the physical size of dots. In this way, the data given in Table 7 was calculated from data previously given in Table 5.

Table 7: Overall Density Variations of Black Tones

	Printed Density Variation (Yule-Nielsen)		
Control Tone	± 1 µm latitude	± 2 µm latitude	± 3 µm latitude
5%	0.06	0.12	0.18
7%	.04	.09	.13
10%	.04	.08	.11
20%	.03	.05	.08
40%	.02	.04	.06
50%	.01	.04	.05

From examination of Table 5, it can be seen that, when a 50% halftone is imaged to a ± 2 µm image latitude, this results in a variation in dot area of 1.8%. From Table 7, it can be seen that this equates to a Yule-Nielsen tonal variation of density 0.04.

Working on the basis that a density variation significantly greater than 0.1 is not acceptable, it can be seen that adoption of a ± 3 µm image latitude would result in excessive tonal error. The microline latitude of ± 2 µm is more acceptable. It is also important to note that when the control tone is around 40 or 50%, the printed density variations are very small and very difficult to measure.

In the light of this information, the use of the ± 3 µm latitude should be reconsidered.

Printed Grey Balance - Conventional Chromatic Reproduction

The recommendations published by DuPont (ref.5) concerning the effect of percentage image latitude on process grey balance and hence process colour reproduction in general are worthy of reference. These state that, when 50% tones are used to produce tertiary colours that are virtually grey, the print is only acceptable when the cyan and magenta deviate by ± 2% or less. This important conclusion is supported by a report from Rochester Institute of Technology (ref.6) who, with their TRAND work, showed that, when 50% cyan was printed as a component colour, a variation of ± 2.5% in the magenta produced a variation in the three colour grey combination which was only just acceptable. They also showed that, when the same amount of variation was allowed in both magenta and yellow, the result was not acceptable.

It follows, therefore, that the maximum microline latitude allowable on colour plates should not exceed ± 2 µm - see Tables 5 and 6. Any deviation in imaging which results in as much as ± 4% variation in the halftone image, as is sometimes proposed, is not acceptable.

Printed Grey Balance - Achromatic Reproduction

Complete 'under colour removal' requires that the grey content of the coloured original as well as that of the grey scale is reproduced by the black printer. Therefore, not only should the colour plates be correctly exposed as for normal reproduction but, additionally, it is even more important that the black plate be correctly exposed. Accordingly, the preceeding reference to printed tone reproduction is relevant and the data in Table 7 is applicable. The overall density variation in respect of the 5% tone when the plate is imaged to a microline latitude of ± 2 µm is given as 0.12. This again suggests that the maximum imaging latitude should not exceed ± 2 µm.

Conclusions

1. The inherent properties of positive and negative plates dictate that, on image transfer from film to plate, positive plates show dot sharpening and negative plates show dot gain and that this is influenced and controlled by exposure.

2. This change is more dramatic in the mid-tone areas, particularly 40 - 60% dots.

3. A direct relationship between dot diameter, dot circumference and dot area has been established which confirms the border zone theory.

4. This has been extended to establish the relationship between dot area and microline reproduction.

5. The latitude on exposure for positive and negative plates relative to the percentage dot gain is approximately the same. However, the worst example of positive plate dot reproduction (ie minimum exposure) is still superior to the best example for negative plates (also minimum exposure).

   It must also be remembered that, when exploiting the latitude of negative plates by minimising the exposure, it is essential that a post-exposing or post-baking treatment is carried out to restore the run length.

6. The halftone image latitude preferred for positive plates is ± 2 µm. This takes into account the problems of achieving suitable printed densities and tone reproduction and grey balance where a ± 3 µm latitude would be considered unacceptable. It also considers the light coverage and consistency, particularly on large format plates where the exposure variation would make a ± 1 µm latitude impractical.

Therefore, although standardisation of halftone printing is very desirable and the current proposals are useful, there is no guarantee that optimum printed results will be achieved. It is our opinion that, to achieve optimum printed results, plates must be chosen (ie negative or positive) and exposed to take account of the prevailing conditions on the individual presses. It, therefore, follows that to choose and image plates to comply with a virtually fixed National or International plate specification will not necessarily lead to optimum printed results unless some flexibility is permitted in their everyday application.

Essentially, the plate control guides and the microline control strips for positive plates should be used as quality control **guidelines** to achieve consistency and optimum reproduction in individual working circumstances rather than applied as a mandatory reference standard.

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