Tobias Associates, Inc.
50 Industrial Drive
Ivyland, PA 18974
215-322-1500

Dots...The Way We Print

Printers struggle to maintain consistent color quality throughout the press run in order to provide their customers with the best possible product. An important concern is in the control of the halftone reproduction of continuous tone photographic images. This is done by monitoring the effective dot area of halftones and the solid ink density. As a result, considerable effort has been spent on understanding and measuring dot area. This discussion attempts to encapsulate some of the often confusing aspects of dot area and dot gain.

Dot Size and Dot Area

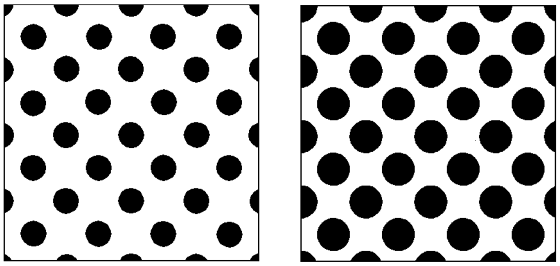
Understanding the importance of dot area begins with an understanding of the importance of dot size. A photographic image is printed onto paper in the offset process by converting it into a halftone dot pattern. The lighter portion of the image is printed as a pattern of small dots, while the darker portion is printed with larger dots in the same pattern. The most convenient way to measure dot size is in terms of dot area. The area of the dot may change from one stage of the production process to another. This change in dot area is called dot gain and is the difference between the original dot and the reproduced dot.

This gain is a fact of life in the reproduction of halftone images. As long as the dot gain is predictable and within reasonable bounds, the process can be adjusted to compensate. Therefore, to print a quality image, it is important to control and minimize dot gain to avoid reduction of image range, loss of detail and maintain color balance.

Physical Dot Gain

Physical dot gain (or loss) can occur at the various stages of the prepress and printing processes. At the prepress level, the exposure of the plate can introduce some change in dot size. Screen ruling also determines the magnitude of dot gain the process will exhibit. The finer the screen, the more sensitive it is to the effects of dot gain and the choice of screen ruling will be a compromise between keeping dot gain to an acceptable value and maintaining print detail. For example, due to the high physical dot gain exhibited by uncoated papers, such as newsprint, a coarse screen ruling is generally used.

On press, the primary cause of physical dot gain is the amount of ink feed and the consistency of the ink. In addition, the characteristics of the paper (or substrate), blanket pressures, water feed, press speed— all can influence the degree of dot gain experienced. Other factors that also may appear as dot gain are slurring, doubling and scumming. Although physical dot gain does occur at every percentage of dot screen, the maximum effect generally occurs at 50%. This is because the effective perimeter of the dot is largest at this percentage value, resulting in more of an area change for a given amount of movement of the boundary. The choice of paper stock quality has a great effect on physical dot gain. Lower grades of paper, such as newsprint and uncoated stocks, absorb the ink more than better quality papers, causing an



20% Dot Area (left), with 16% Dot Gain or 36% Dot Area (right).

increase, or spread, in dot size. Thicker ink films will also cause an increase in dot gain due to the mechanical squashing of the dot.

Murray-Davies Equation

Dot gain is generally measured with a densitometer. Readings are taken of the relative density, i.e. with white paper subtracted, of a solid and of the uniform tint to be measured. Dot area, often referred to as effective dot area (EDA), can be calculated using the Murray-Davies equation. Dot gain is the difference between the EDA of the printed halftone and the negative (or positive) dot area of the film used to make the printing plate. In printed work, such as an offset press sheet, it is important to take the density readings of the solid and tint as close to each other on the press sheet as is possible. If this is not done, the solid ink density would not necessarily represent the solid ink density of the dots comprising the tint. In photographic work, the solid image density is usually more constant and this constraint is not as important.

The Murray-Davies Equation

$$EDA = \frac{1 - 10^{-D_t}}{1 - 10^{-D_s}} \times 100$$

EDA = Effective dot area
D_t = Relative density of tint
D_s = Relative density of solid

The Murray-Davies equation determines the dot area assuming:

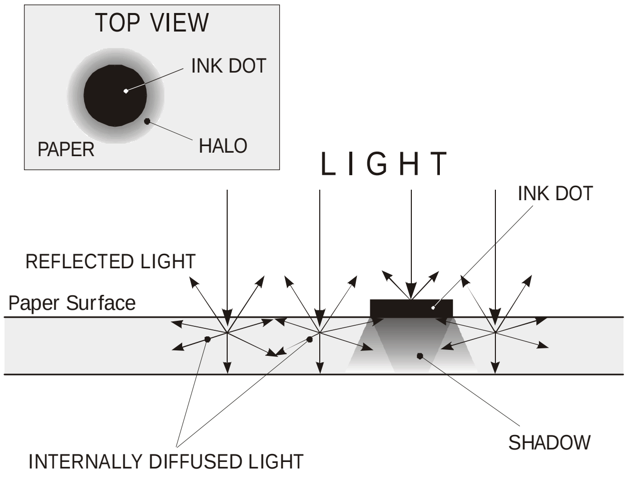
1.) The inked dot has the same reflectance as a solid,
2.) The white paper between the dots reflects the same amount of light as unprinted paper, and,
3.) The densities of the tints and solids are read as the differences from unprinted paper.

Understanding the limitations of the first two assumptions provide a means for describing why the Murray-Davies dot area departs from the physical area of the dots.

Optical Dot Gain

There are special cases where the internal light scattering properties in the paper will significantly affect the readings of a densitometer. This is especially true when working with photographic material, newsprint, some coated stocks, and any material that exhibits substantial internal light diffusing characteristics. It is safe to say that almost any white base will exhibit this property.

Unprinted paper appears white because of the perceived combination of the light reflected from the surface, and the light diffused into and reflected from the substrate. A dot, printed on paper, acts as a mask and affects the reflection of light from the printed sheet primarily in two ways. First, the dot prevents light from entering the substrate of the paper and thereby prevents the diffusion, or scattering, of that light into areas adjacent to the dot. Second, the converse of this occurs and the light scattered by the white paper adjacent to a dot decreases the effective density of the areas inside the boundary of the dot, in opposition to the effect of the shadow halo in the white areas.



Light scattering in paper creates "halo" effect.

The white paper in the area next to the dots, then, has a lower apparent reflectivity than unprinted paper, resulting in a darker “halo” surrounding the dot. Since the dot area calculation is based upon the reflectivity of the unprinted white paper, the halo causes the dot area to be reported as a higher value than would be expected.

Optical dot gain is affected by the dot size, screen ruling, and the paper characteristics. It is useful to keep in mind a few aspects of dot area measurement. The densitometer, when it measures dot gain, produces the ***absolute*** difference in dot area. For example, a 1% dot that prints as a 2% dot would show a gain of 1%; relatively the 1% dot has increased in size by 100%! And an 85% dot can increase in its area by only 15% as a maximum, to equal a 100% dot. Resin-coated photographic papers or a press print on an “opaque” white plastic base because of the great translucency of the base, will exhibit substantial optical dot gain.

Physical Dot Gain and Yule-Nielsen

When the actual dot size, or physical dot area, needs to be determined, the Yule-Nielsen Equation attempts to compensate for the light scattering effects of the paper. This modifies the Murray-Davies Equation for dot area calculation by introducing the “n” factor. This factor is chosen to give an approximate correlation between the measured dot and the physical dot size and must be determined for each of the various types of work that you will be doing. Its value depends on the combination of paper, ink and screen ruling that is used. Typical values for “n” will range from 1.0 (no correction, or equivalent to Murray-Davies) to as high as 4.0.

The Yule-Nielsen Equiation

$$EDA = \frac{1 - 10^{-D_t}}{1 - 10^{-D_s}} \times 100$$

EDA = Effective dot area
D_t = Relative density of tint
D_s = Relative density of solid
n = Correction factor

The testing of the different materials, however, is a long process that yields minimal advantage. For this reason, a value for “n” of 1.7 is sometimes recommended as a convenient general value for most situations [Pearson, Milton, ”n” Value for General Conditions, TAGA Proceedings, 1980, pp. 415-425].

Murray-Davies vs. Yule-Nielsen

Which equation should a user work with, Murray-Davies or Yule-Nielsen? Each represents a compromise that depends upon the application. A printed tint, for example, can be said to have a certain dot gain compared to the original film. The measurement generally is made at 40% to 50% tint value. To maintain good color balance in process work, it is desirable that the dot gains of magenta, yellow, and cyan inks be similar. The Murray-Davies equation is useful in monitoring this balance because the visual effect follows the optical dot gain and meaningful comparisons can be made between presses, inks, and press conditions.

On the other hand, when a desired photographic dot area is to be retained, for example, on resin coated paper, the Yule-Nielsen equation will allow the “n” factor to give a dot area reading that will correspond better to the dot area as seen by the camera. One should keep in mind that the Yule-Nielsen equation gives the correct dot area at only one area value but may depart substantially from the true values at other portions of the tonal scale.

The Yule-Nielsen equation does not guarantee that, for example, a dot measured as an “n” corrected 50% will reproduce as a 50% on a camera negative. Among other factors, the camera exposure will have a critical effect on the area of the reproduced dot with optical gain operating to some extent.

The IQ Series Densitometers

The Tobias IQ Series is the most innovative and advanced family of densitometers available today. The IQ 150 and IQ 200 provide the user with the best of both worlds, allowing the user to switch quickly between the Murray-Davies and Yule-Nielsen equations by simply pressing the clearly labeled soft key. When the Yule-Nielsen calculation is selected, the IQ Densitometers will automatically recalculate and display the dot area with each new value of the "n" factor. The intelligent IQ 150 provides a step-by-step guide through the measurement of density, density difference, dot area and dot gain. The powerful IQ 200 adds contrast, trap, hue error and grayness. Whether checking OK sheets or measur-ng original art for halftone exposure predictions, the IQ 150 and IQ 200 are the ultimate in densitometry.