Reproducing an image on a printing press is both an art and a science. Although many aspects of printing can be measured and dissected, the final printed result will always elicit a range of responses from a panel of viewers. One press variable that can have a large effect on print quality is dot gain.

Dot gain is the growth in size of a halftone dot. This may be a result of variation in the filmmaking or platemaking process, but more often than not it has to do with the interaction between plate, ink, and paper on press. Through all of this, dot gain can increase the size of a halftone dot by 30% or more. Dot gain is inevitable, but is not a problem as long as adjustments for it are built into your films.

Measuring halftone dot percent

Halftone dot percent (sometimes called halftone dot area) is a method for describing the relative size of the halftone dots in a screened tint or image. For example, halftone dots which cover 25% of the area in a tint or image are referred to as 25% halftone dots.

Figure 1 – The halftone dot percent of both examples shown here is about 25%. The example on the left has a much coarser screen ruling, and so its 25% halftone dot is larger than the 25% halftone dot on the right. However, in both cases 25% of the area is covered by black.

Halftone dot percent is measured with a densitometer (or a dot area meter). A densitometer doesn't measure dot percent, and strictly speaking it doesn't measure density either, instead it measures the amount of light that is either reflected from or transmitted through the surface of an object (or what may be called the 'substrate'[1]). Based on the amount of light that it receives, a densitometer can then calculate density or dot percent.

[1]Paper, film, plastic, in short, anything that you can print on is usually gathered under the generic term 'substrate'.

The aperture of the densitometer determines how large an area is measured. (Apertures are usually around 2 to 4 millimeters.) To measure accurately, this area must include an adequate number of halftone dots. It is important to note that the size of an individual halftone dot is not the key factor. What is important is the area covered by a group of halftone dots. (See Figure 1.)

Transmission and reflection

Dot percent measurements may be grouped in two categories:

• **Transmission** measurements which are usually made on black halftone dots on clear film. It's called transmission densitometry because the light from the densitometer is transmitted through the film.

• **Reflection** measurements, which may be made on a variety of materials including photographic paper, proofing material, or a press sheet. It's called reflection densitometry because the light from the densitometer is reflected from the substrate.

Theoretical values

Until a halftone dot is exposed on film, the halftone dot percent value that is assigned by a design, illustration, or scan manipulation program is purely theoretical. When a system is well-calibrated, the assigned dot percent value and the value that is measured on film will be identical. However, variations in halftone dot percent may occur due to poor calibration.

Apparent vs. physical

[2]There is no such problem with transmission densitometers. Although some light may not make it through the film, this is easily compensated for.

[3]The same was true if they converted density measurements using some of the commonly used density to dot percent conversion tables, which were based on the Murray-Davies equation.

[4]Warning: It's hard to judge anything but 50% checkerboards as having a 50% dot area.

Since densitometers can't measure the actual size of the halftone dot, they use formulas to do the next best thing, that is, calculate dot percent. Some of you may be familiar with the Murray-Davies or Yule-Nielsen equations. (See box to left.) These formulas allow densitometers to calculate dot percentage, but more specifically what they do is to allow densitometers to measure apparent and physical dot area.

Apparent dot area takes into account the visual effect that the substrate has on the halftone dot. Light from a reflection densitometer bounces off the substrate. Depending on the substrate that the light reflects off of, some of that light may be lost. Light may be absorbed by the paper, and some may reflect under printed areas and be lost. In any case, some of the light never makes it back to the analyzing head of the densitometer. This results in a dot percent reading that is larger than the actual size of the measured halftone dots.[2]

Apparent dot area tells you something about what the dot looks like to a human observer, and this gives you some clues about the interaction between the ink and the substrate, but it doesn't give you accurate information about the **physical dot area** (i.e., the size of the halftone dot, sometimes referred to as mechanical dot area). See Figure 2.

Most people don't care about the difference between apparent dot area and physical dot area. And in fact, if you are measuring halftone dot percent on film there is no need to worry about it at all. On film (i.e., transmission densitometer measurements), the two equations end up giving the same result. The problem arises when you try to measure halftone dot percent on a reflective substrate. Once that happens, there are significant differences between the results that the equations give.

This problem became particularly apparent to people who were trying to calibrate tints as output on imagesetter paper. If they had a reflection densitometer that read halftone dot percent, the measurements showed that the device was way out of calibration.[3] However, if they examined the 50% checkerboard of a round/square halftone dot (an area that they knew to be close to 50%[4]), this area actually read much higher perhaps 60% or 70%. If you go ahead and calibrate based on these values, then you are adjusting for the apparent dot size, not the physical dot size, and this, in short, is a mistake. Linotype-Hell supplied a density to dot percent conversion table that provides much better results for those who are calibrating to imagesetter paper. This article containing this table, *Calibrating on Imagesetter Paper* also supplies information on how to calculate conversion charts based on your own requirements.

Why use apparent dot area?

If apparent dot area is such a potential stumbling block, then why don't more densitometers calculate physical dot area with the Yule-Nielsen equation? For one thing, apparent dot area, as calculated by Murray-Davies, does give you more information about what the dot actually looks like on the target substrate. In addition, the Yule-Nielsen equation is a little more complicated than Murray-Davies. If densitometers used the Yule-Nielsen formula, then users would have to factor in an 'n' value for each of their substrates. This would make it much easier for errors in calculation to occur, and also make it much harder to compare measurements from a variety of substrates.

In general, dot gain experts recommend that you avoid using the Yule-Nielsen formula unless you have very specific requirements (as in the case of calibrating on imagesetter paper). In terms of measuring dot gain on press,
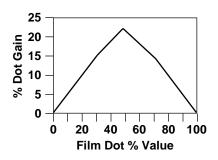

30%

Theoretical

Physical

Apparent

Figure 2 – Theoretical, physical and apparent halftone dot size.

it is much more convenient to measure apparent dot area. And although the value may not correspond to the physical size of the dot, it still provides a much more consistent means of comparing dot gain measurements.

Dot gain

Dot gain can be thought of in three ways: physical dot gain, optical dot gain, and total dot gain. **Physical dot gain** is the difference in the physical size of the halftone dot from the film to the printed sheet. This is solely a result of increases (or decreases) in the size of the halftone dot during the platemaking and printing process. **Optical dot gain** is the added dot gain that is due to the scattering of light in the substrate. **Total dot gain** includes both physical and optical dot gain. It includes the difference in the physical size of the halftone dot from the film to the printed sheet, plus the optical dot gain due to the scattering of light. This takes apparent dot area into account.

Figure 3 – Average dot gain values at a 150 line per inch screen ruling for the black printer/separation. (Source: DuPont North American Commercial Print Survey.)

In discussions of total dot gain, a 20% dot gain value means that a 50% halftone dot on film becomes a 70% halftone dot on the press sheet. The dot gain at other halftone dot percentages will be somewhat less. (See Figure 3.) One common misconception is that the dot gain value means that all halftone dots will increase in size by the same percent. This is not true, dot gain values refer only to an additive increase to the 50% halftone dot.

[5]The average value was approximately 23%.

Dot gain is usually highest around the 50% halftone dot because it occurs around the perimeter of the halftone dot. Larger dot sizes (up to 50%) have a larger perimeter, and therefore are more likely to grow in size. And while a 5% halftone dot may double in size, that still amounts only to a 5% increase. Beyond 50%, halftone dots have merged on at least two sides with their neighbors, and therefore the perimeter available for dot gain begins to decrease. DuPont's North American Commercial Print Survey, which tested the dot gain (and a number of other print characteristics) of a wide range of commercial printers, found dot gain values of up to 45% on the black printer![5]

Solid ink density, paper, and screen ruling all play a role in dot gain. Printers who try to increase the solid densities of their inks will find that they get corresponding increases in dot gain in the midtone areas. In addition, dot gain increases as screen ruling increases. Under the same printing conditions, dot gain might be 2% for a 65 lpi (line per inch) screen ruling, and 20% for a 200 lpi screen ruling. However, research has revealed that it is not so much the paper type as the amount of ink applied to the paper that plays a role in dot gain. It is more difficult to achieve high solid ink densities on poorer quality paper, and as a result, printers may be tempted to increase their ink settings to make up for it. Unfortunately, it is this increase in ink that causes an increase in dot gain, particularly in the midtone. And unless the midtone has been adjusted for dot gain, you can't increase the solid ink densities without paying the penalty in the midtone.

> **Dot gain may occur during:**
> - Film contacting or duplication
> - Plate exposure
> - The press run
>
> Note: Solid ink density, paper, screen ruling and even the printing order of the colors can play a role in dot gain.

Dot gain and the midtone

Though many people pay close attention to the placement of the highlight and shadow dot of an image, the critical area regarding dot gain is the midtone. And while a thorough discussion of tone compression and tone reproduction is beyond the scope of this article, manipulating the tone reproduction curve at a midtone control point is a simplified way of adjusting an image for dot gain.[6]

[6]The Quality Control Scanner (Volume 9, Number 2) contains an article called *Control the Middletone for the Best Color Reproduction.* This article provides more insight on this topic. See list of references.

If you make adjustments to the midtone halftone dot, it gives you much more flexibility on press. Without that adjustment, any effort to increase solid ink density will darken the midtone unacceptably.

Prepress dot gain adjustments

Having said this, adjusting for dot gain during prepress can still be a difficult task. How do you adjust for dot gain unless you know something about the dot gain characteristics of the target press? And even if you do know the target press, how do you make adjustments when dot gain values may vary considerably from shift to shift or press operator to press operator.

So when should dot gain adjustments be done?[7] The answer to that depends on the object type: tint, synthetic artwork, or scan. With a tint, it is always handy to have a printed example of what the tints appear like on the target substrate. And while running a press test is only workable with large projects, obviously it provides much better accuracy than judging tints from a monitor. But even without a press test, you may have access to similar jobs that were run under comparable conditions. With tints, if you find that your tint appears darker than you want it, you can simply choose a lighter tint for the next job.

The question becomes a little more difficult with synthetic artwork.[8] If the artist has consistently chosen tint values that print too dark on press, you would be wise to have the artist reconsider those tint choices. But what if that isn't possible? What if you have no control over the creation of the synthetic artwork? Many desktop publishing applications, including Adobe Separator™ and Aldus PrePrint®, provide methods for adjusting dot gain. Some people have also tried to adjust for dot gain using a calibration program, but this goes beyond the primary purpose of calibration and must be monitored carefully to avoid overcompensation.

For scans, it is a question of adjusting the midtone, as described earlier. Both high-end and desktop publishing programs commonly include a menu option for paper stock, press gain, or dot gain. They may even allow users to adjust the transfer curves of each separation. In most cases, when proper adjustments have been made for gray balance, it is not necessary to assign varying levels of dot gain adjustment for each separation.

Linotype-Hell and dot gain

Using a Linotype-Hell DC 3000 ChromaGraph® system with NewColor 3000, the dot gain adjustment is handled by an automatic function called the Characteristic Curve of Printing. ColorPilot users will be familiar with the Press Correction and Print Process Calibration (PPC) functions which allow them to fingerprint their printing process. PPC is described in greater detail in the Linotype-Hell Technical information article entitled *Color Management.*

Conclusion

The critical role of dot gain adjustment reinforces the importance of good communication between the prepress operation and the printer. For more information on dot gain, please look to the following references:

- *The North American Commercial Print Survey (*1988), and *The North American Print Survey* (1983), DuPont Company, Wilmington, DE 19898

- *Introduction to Densitometry,* by Peter V. Brehm, Graphic Communications Association, 1730 North Lynn St., Arlington, VA, 22209. 1-703-519-8160.

The following titles are from the Graphic Arts Publishing Company (3100 Bronson Hill Road, Livonia, New York, 14487, 1-716-346-2776):

- The Quality Control Scanner, Vol. 2, Number 9, *Dot Gain,* and Vol. 9, Number 2, *Control the Middletone for the Best Color Reproduction.*

- *Quality and Productivity in the Graphic Arts,* Miles and Donna Southworth

- *Color Separation Techniques,* Miles Southworth

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