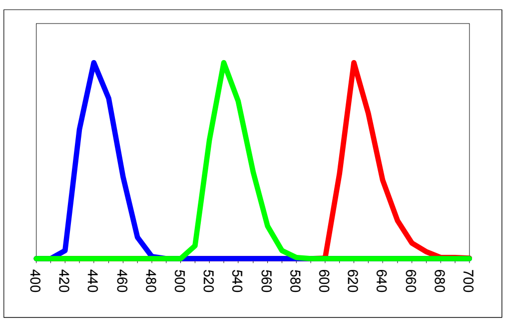
# Densitometry and Spectrophotometry

## Introduction

Color measurement has always been important in the graphics arts industry as a tool for improving color consistence, fidelity and quality. For many years, the densitometer has been the instrument that is usually found in the pressroom. Recently, another instrument, the spectrophotometer, has also made an appearance. Which one is better? What do they measure and what do the readings mean?

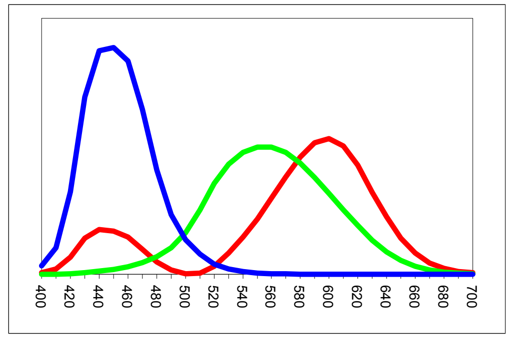
## The Instruments

Both the densitometer and the spectrophotometer have similarities. Both use 0/45 or 45/0 geometry for the optical system. In this the sample is




**Densitometer Response**

illuminated vertically and viewed at an angle of 45 degrees (or the reverse). This arrangement reduces specular, or glossy, reflections from the surface of the sample. Both essentially take a three-filter reading using a red, green and blue channel. In the case of a densitometer, these are physically three separate filters. In a spectrophotometer the instrument reads across the entire spectrum from deep red to violet. Certain parts of these readings are then combined to give three sets of readings equivalent to a red, green and blue channel.



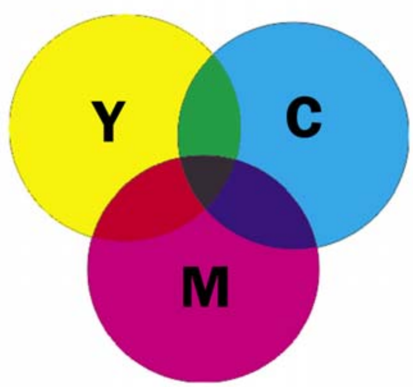

**Spectrophotometer Response**

The densitometer measures a sample and gives a density reading, for example the density of a Magenta sample might be 1.19. The spectrophotometer reading the same sample would give you a reading of L* 51.35, a* 69.91, b* -1.72. What do these numbers mean?

## How we print

First let's look at the sample that we are going to measure. In the graphics arts industry, offset lithography is one of the dominant printing methods and the densitometer has traditionally been used to control its process. To reproduce an image, the original is electronically scanned, using red, green and blue filters. The resulting images are then processed to give the four separations, cyan, magenta, yellow and black. The CMYK separated images are further processed to create a halftone image for each. In printing you can either put ink on the paper or not, there is no in between. So to represent the tonal range of the original image, the printed image is reproduced using halftone dots. Small dots correspond to light image areas, large dots to dark areas.

Nominally the solid ink density of the dots, large or small, is the same. From these halftone separations a printing plate is made for each process color, cyan, magenta, yellow and one for the black. Except for the black, these inks can be considered to be transparent.



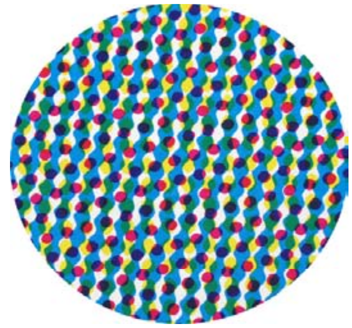

**Subtractive Color**

Based upon subtractive color theory, printing a combination of these inks allows a wide range of colors to be reproduced. Now when we

print from these plates the resulting image consists of a multitude of dots from large to small, in the four colors, cyan, magenta, yellow and black. Looking through a loupe at such an image, one might say "what a mess", yet surprisingly, when viewed at the correct distance, a rich colorful image can result.

**What do we measure**

Yes the image is a mess. It is impossible to separate the individual elements that create the image to be able to analyze



**Halftone Dots**

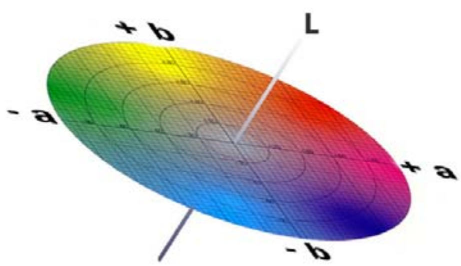
them. To overcome this a color bar, or control strip, is usually printed along with the image. A color bar will consist of a regular sequence of control targets. For example, there will be areas of solid ink, for each color, areas of known dot size, usually 40 or 50%, for each color, plus other similar items. Measuring this control strip with a densitometer will give density values for the solid ink areas. What is a density value? It is a measure of the amount of light that is reflected from the sample. Within certain limits the density values are proportional to the thickness of the ink layer. A density value is therefore a direct measurement of the amount of ink, higher densities mean more ink, lower densities less ink.

**Color Bar**

For proper color control the ink densities must be held at a constant value and the densitometer provides the tool for the job. Other functions of the densitometer measure the size of the dots in the control strip, this allows the dot gain of the process to be monitored. Dot gain is inevitable in the printing process, but it must be controlled and maintained at a constant value. Failure to do so will result in poor color consistency.

**What do these numbers mean**

So what does our spectrophotometer make of this?  Using our example from before, the densitometer reads a Magenta solid as 1.19, as we have seen, this is an indication of the ink film thickness. Perhaps from our previous experience we have found that printing process produces best results when we run the magenta at 1.30. This then tells us that we need to feed a little more magenta ink to meet our standard.




**Lab Color Space**

The spectrophotometer gives us a reading of:L* 51.35, a* 69.91, b* -1.72. What does this tell us? The L*, a*, b* measurements describe the color of the sample. This is done using what is called a “color space”. The “L” value indicates the lightness of the sample, the “a” value describes the horizontal axis showing how red or green the sample is, the “b” value describes the vertical axis showing how blue or yellow the sample is. “L” values range from 0 to 100 and the “a” and “b” values are between about –100 to +100.  Using the numbers from above you can plot the position of the sample in the color space. This provides a very precise definition of the color. By comparing two samples another value may be obtained that describes the color difference between the two, this is called Delta E.
While the spectrophotometer has given us a very accurate definition of the color, it has given us no information on how to control the color. The L*, a*, b* readings are derived from a complicated series of calculations based on the red, green and blue readings. These RGB readings are based on human vision, not on process ink colors as with the densitometer. The L value for lightness is essentially a green channel reading. This models the photopic, or cone, response of the human eye. We are most sensitive to green light and will perceive it to be brighter than an equivalently bright blue light.

**So what instrument do we use?**

The densitometer will give us accurate information on items affecting the printing process - solid ink densities and dot gain. It provides an essential tool for monitoring the process to produce consistent color reproduction.

The spectrophotometer precisely defines the color of a sample, and is useful in meeting specifications, for example, corporate colors or advertising specifications for a product color. This tells us that the color of the sample is correct but provides little information on controlling it. The consistency of color throughout a press run still requires the densitometer to maintain the stability of the printing process.