TECHGUIDE SERIES:

A Functional Comparison of Densitometers and Spectrophotometers

Understanding the differences of each color measurement instrument is an essential part of the decision making process

by Hapet Berberian

Spectro-Densitometers: Versatile Color Measurement Instruments for Printers

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Introduction

Through observations of typical proofing and press room operations, there would be general consensus that the use of color measurement instruments to measure and control the color reproduction quality of a press run is more reliable, accurate, and repeatable than the use of human subjective judgment. It's fair to say that humans can be trained to detect subtle shifts in the hue, luminance, or saturation of most color samples, if they have access to a proper light booth. An instrument has the advantage of being able to assess samples without a reliance on ambient illumination. Instruments are also not subject to fatigue and use standardized numeric metrics versus qualitative metrics. As a result, the majority of print facilities have one or more of these instruments on hand to assure quality.

It's important to remember that the quality of color reproduction on a press run is highly dependent on the ability of a press operator to maintain a target range of ink densities (the print control strip) along with gray balance for each of the process colors both during make ready calibration and during the actual press run. The instruments discussed here are critical for

- accurate and repeatable color measurement
- system calibration and characterization (generating ICC profiles)
- reliable proof to press match
- accurate and repeatable color reproduction on press

The ability to compare printed results with expected target values through color measurement standards is a benefit to both print buyer and print service provider. Color measurement and control with these devices will ensure that a given printed product will have consistent color reproduction

- from press to press
- from operator to operator
- from week to week, month to month, and year to year

This article describes the operational characteristics and functional comparisons of three important color measurement instruments used by the printing industry - **densitometers, spectrophotometers, and spectro-densitometers.**

Densitometers

Density is a measure of the absorbance of an ink at specific wavelengths of light. As an example, yellow ink has a maximum absorbance in the blue region, so its density is calculated using a filter with a blue response. For CMYK inks, the corresponding filters are red, green, blue and “visual”, which is slightly wider than the green filter. Beyond measuring specific wavelengths of light, the densitometer also transforms the reported result according to the following relationship:

$$\text{Density} = -\text{Log}_{10}\ (\text{Remission})$$

Remission is a measure of the reflected light, so 1.0 is perfectly reflective and 0.0 is a perfect absorber. Following the equation above, paper that has a remission of 0.85, would yield a density of 0.07 D. A saturated ink with a remission of 0.1 would yield a density of 1.0 D. Density is useful because it corresponds closely with relative ink film thickness of most printing inks. Most observers would agree that it is very difficult to see the difference between yellow ink at 0.8 D and 1.0D and yet they would have used 125% of the ink to arrive at the 1.0D result. As a result of those characteristics, the densitometer quickly eclipses the capabilities of even the best trained eye when used on the task of monitoring ink film thickness. Establishing correct masstone density is important as the separations are done based on an assumption of a specific ink film thickness.

Once density is measured, additional data can be calculated using standardized equations. Those metrics are:

- Apparent dot area
- Apparent trap
- Dot gain and print contrast
- Slur and doubling

While Density is useful for controlling the masstones, Dot area or Dot gain / contrast monitors the halftones. Those metrics monitor tone reproduction quality which varies due to press printing conditions. Trapping evaluates ink performance as it applied directly to a substrate, as would be the case in a masstone and as it is applied to wet ink, as would be the case in an overprint. Slur and Doubling can detect defects in imaging where dots are stretched in one dimension or repeated due to a phenomenon of contamination of the blanket from previous impression.

It's important to note that there is a significant difference between filter spectral characteristics used in various applications and locations for density measurements. The commercially available variety of accepted filter sets conforms to ANSI established standards.

- Status A and M standards are used in photographic applications.
- Status T standards represent wide band filters typically used in North America.
- Europeans use Status E filters.
- There is yet another set of narrow band filters referred to as Status I.

For calibration, color process control, and quantitative color communications it is critical that the Status response of the filter set be identified.

Spectrophotometers

The previous section has identified the fundamentals of print quality measurement as provided by a traditional three filter densitometer. It's fair to say that this technique, as useful and practical as it is for monitoring printing variables, does little to qualify the materials used during printing. To qualify the ink and paper, a spectrophotometer is more useful. The modern spectrophotometer for the press room and for ink and paper manufacturers is a cost effective, fast, and useful measurement instrument for capturing discreet spectrum amplitude values at typically 10 nm or 20 nm intervals. This instrument is typically used

- in the proofing area
- in the press room
- by paper and other substrate manufacturers
- by ink and colorant manufacturers

In the printing industry, a spectrophotometer is most often used to measure reflected light from a printed sample and compute light absorption as well as several other important parameters. As in the case of the densitometer, a stable white light source perpendicular to the printed sample is used for illumination. The main difference is that in the optical path the reflected light is separated by very narrow band filters into spectral samples spaced 10 nm to 20 nm apart. The resultant spectral reflectance curve is an excellent identifier of a color sample somewhat analogous to how fingerprints can be used to identify individuals. With such a spectral fingerprint, one can quickly see whether the magenta ink delivered to the press is formulated with rubine or rhodamine pigment, which although quite similar visually, would achieve dramatically different color across the resulting gamut. One of the most humanly intuitive metrics that can be computed from this spectral data is the Lightness (L*), Chroma (C*), and hue angle (h˚) of a color sample. This type of metric has its roots in early work done by Alfred Munsell and others that attempted to organize the color that they saw in nature.

- L* – the value of the sample relating to lightness or darkness without regard to color.
- C* – a measure of the saturation or intensity of a color.

- h˚ – the quality of color in terms of the primary colors red, yellow, green and blue.

Computing metrics that correlate to human perception is typically called colorimetry. So, in a sense most spectrophotometers also qualify as a spectrocolorimeters as they also can provide colorimetric data based on the measured spectral data.

Spectrodensitometers

As the name implies, a spectrodensitometer is a spectrophotometer that also provides computation of density and colorimetric values using standardized metrics. It applies spectral measurement techniques and computes ink film thickness and dot gain values normally provided by a densitometer; however, it is capable of calculating density values equivalent to any ANSI status filter set. This instrument is only limited by the color computation capabilities provided in its on-board computer. New functionality can be added easily by software upgrades.

Most manufacturers of these instruments provide both handheld units as well scanners for automatically scanning and recording a set of color samples printed in a rectangular array. High speed spectrodensitometers are also available for inline press applications for on-the-fly real time press monitoring and control. The important features and functions of these devices include

- A single measurement computes all four CMYK density values for each sample
- No mechanical moving parts
- Full G7 functionality for calibrating and maintaining printers based on the GRACoL G7™ specification
- Measurement modes include
    - Spectral density CMYK
    - CIELab, XYZ
    - L*a*b*
    - GRACoL G7™
    - CIE94, CIE2000, CIE99, CIEcmc, CIEuv
    - CIE L Chab, xyY, Luv, LCHuv, DIN Lab99
    - Status T and E densities
    - Dot area
    - Dot gain
    - Trapping
    - Whiteness, yellowness

Automated vs. Handheld Systems for Improved Performance in Prepress and Production

Fortunately, for the sake of productivity, handheld instruments have evolved into automated devices, which fall into the categories of scanning and inline spectrodensitometers. Automated measurement has dramatically increased the effectiveness of a press operator to provide consistent high quality color reproduction. It has also demonstrated a rapid return on investment for new measurement equipment purchases, typically within 12-18 months. The initial impact of these automated devices is that they have increased the number of samples that can be practically measured for calibration before a press run. They have also reduced the effort on the part of press operators so they can tend to other critical production tasks. They can also be given credit for avoiding measurement errors. The following is a description of two of the most important new developments in color measurement instrumentation.

Scanning Spectrodensitometer
The first is the scanning spectrodensitometer for higher productivity when compared to manual types. Scanning spectrodensitometers are able to capture not only density values but spectral data, dot gain, blur and slur factors, Delta E, and G7 calibration data for gray scale correction. Productivity is enhanced since scanning spectrodensitometers are able to measure 250 color swatches in 8 seconds.

Inline Spectrodensitometer
A second important development is the inline system, which provides closed loop color monitoring and control. Mounted inside the printing press, the in-line spectrodensitometer provides real-time spectral and density measurements as well as G7 calibration data with remarkable color accuracy. It improves precision by automatically calibrating color through a closed loop, on-the-fly correction system. This not only offers improved productivity but also eliminates errors associated with hand-held devices. The inline spectrodensitometer reduces press downtime because there is no need to interrupt the press to pull a sheet and monitor color. No interruptions translate into more efficient press runs.

Summary of the Advantages of a Spectrodensitometer

- Spectrodensitometers are typically more accurate and useful than the previous generation of densitometers. A traditional densitometer uses a stable white light source for illumination. Red, green, or blue filters in the light source optical path are needed to limit the color of the source that reaches the color target to measure C, M, Y, and K ink densities. Over time, these filters, which are sensitive to moisture and temperature, may degrade and produce incorrect measurement values. The filters are designed to measure the maximum absorbance region of process inks. Non-process ink densities, which are often used in spot colors, can be difficult to measure using the non-optimal filters. A spectral measurement is optimal. A spectrodensitometer uses 16 or more bandpass filters to divide the visual spectrum equally. These instruments produce a spectral fingerprint of the material measured. From the spectral data, all forms of color and density data can be accurately derived. The extra data allows a spectrophotometer to be a versatile tool that can control process and non-process inks.
- Spectrodensitometers can detect ink contamination during a press run; whereas, densitometers cannot. This common problem can be caused by many factors such

as unintentional deposition of too much of one color ink on paper. This can propagate through the press to another ink fountain. Since contamination impacts the high reflectance region of an ink and not the maximum absorbance region, a densitometer is blind to the phenomenon.

- The versatility of the spectrodensitometer allows it to provide other useful metrics such as CIELab values, which are based on the human visual response to hue, luminance, and saturation of a sample. These same capabilities allow for new control strategies such as those described in G7™ calibration specifications like SWOP, GRACoL, SNAP, and FIRST.
- Today’s spectrodensitometers are widely used for the G7™ calibration process. This process monitors two gray scale targets. One scale is the black ink target and the second is the CMY gray scale target. The objective is to accurately maintain near neutral colors. With such a process, the color fidelity of the printing process is greatly improved.
- The printing industry has been adopting the scanning spectrodensitometer because of its high productivity factor and fast make ready. A scanning spectrodensitometer has a high return on investment (ROI) potential. For example: the average make ready on a Heidelberg SM 74-6 press is about 25 minutes and in excess of 200 sheets of paper. With a scanning spectrodensitometer, the average make ready time reduces to less than 17 minutes and the press sheet waste is reduced to fewer than 125 sheets. This shorter period of make ready time gives the operator more press time for more jobs on the press and reduces paper waste by about 38% per job resulting in reduced overall costs for the job.

The trend in the industry is to print high quality jobs in shorter runs with minimal waste. This will require collective efforts from multiple hardware and software products to create and produce the print job. As from the color measurement side, the trend is small color patches to save on media with real-time color measurement feedback and closed loop color control to automatically correct color on-the-fly without operator intervention. It’s all about high productivity, high quality, and minimum waste. The spectrodensitometer is the most versatile instrument for press room color monitoring and control, and it has a return on investment history which makes it affordable and indispensable.