RELIABLE REFLECTION DENSITY MEASUREMENT

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Abstract: The densitometer instrument is a mainstay of control of the process of producing printed materials from the time of initiation of the image to the final product. However, it is well known that the data obtained from various instruments cannot be interchanged or expected to be accurate in the sense that data from any given instrument is "correct." Those who use densitometry have routinely observed the caution that only one instrument is used for a given condition to obtain comparable density. This report is based on a study that has shown that the precaution of using a single instrument need not be observed if the basis of the data is spectrophotometric measurement calibrated in terms of absolute reflectance with density values calculated according to procedures described in appropriate ANSI standards. Further information is given on the various instrument calibration standards with the recommendation of a more reliable universal standard which can be used for calibrating densitometers of any manufacture.

Introduction

The reflection densitometer is the most important instrument that is used to make objective measurements of printed materials from their inception in prepress to the check of the uniformity of production. Although it is recognized that the property being measured is ink film thickness rather than color, per se, it is nonetheless an important determinative property. At any time in the Clemson laboratories there will be perhaps about a dozen desnitometers from several manufacturers available for student and faculty use. It is a well known precaution that data can be taken with only one densitometer if comparable and meaningful

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numbers are to be obtained. This is a necessary caution, despite careful calibration of each instrument according to the manufacturers recommendation.

Since there is great dependance upon density data in all studies that are done in conjunction with regular Graphics course work as well as special projects, it was necessary to find a method that could be considered reliable and easily used by students. This led to an investigation of a means to make absolute reflection measurements that conform to CIE procedures and then convert these to density using ANSI methods which have been descibed in CGATS.5 It has been pointed out by Hensel (Hensel, 1989) that Status T densities can be calculated form spectral data. It is now possible with some hand-held spectrophotometers calculate density in this way but it is important to have a general procedure which allows density to be derived from any proper spectral data.

"All densitometers are not created equal"

This an apt quotation from Vogelsong (Vogelsong, 1990) whose point is well taken and this is shown in Figure 1. Three densitometers were selected at random to measure a set of yellow, magenta, and cyan samples. The data were collected and plotted in the following figure.

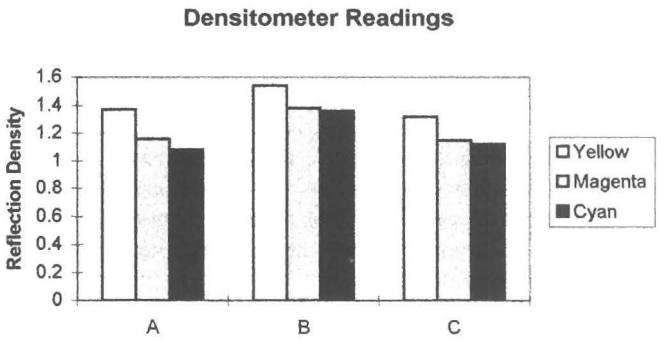

Figure 1. Density values obtained on three densitometers

The same set of samples was measured on three other instruments that are spectrophotometers which provide an added function of reporting density values that have been calculated internally. The data are presumably calculated from spectral data using Status T tables. The resulting are better than the filter densitometers as is shown in Figure 2. These are called spectrodensitometers.

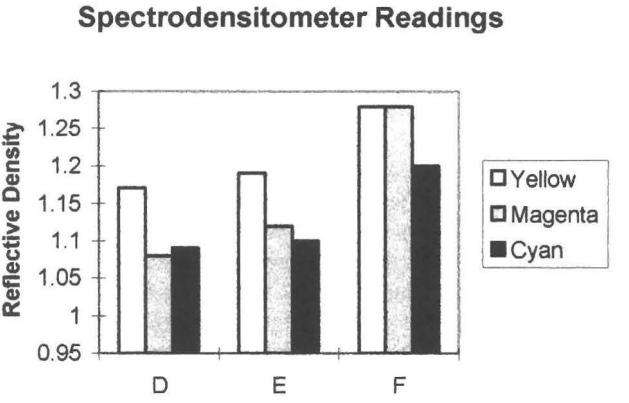

Figure 2. Density values obtained with three spectrodensitometers. Note the large change in scale values

Today, there are many spectrophotometers available to industry that are specially adaptable to measurement of the small samples common to Graphic Arts. These are instruments are inexpensive and are portable allowing an instrument to be brought to portions of a large sample rather than requiring that it be cut out for presntation. Calculation of density values from spectrophotometric data is easily done with modern computer tools such as a spreadsheet; details of the procedure are given below. First, let us examine some data that was gathered using the same set of samples that were measured with the densitometers and spectrodensitometers which was shown above in Figures 1 and 2. In Figure 3, the scale of density has been further expanded which illustrates that the agreement among the density values derived from spectrophotometers is even better. Spectral data was even obtained from a sphere instrument (specular excluded) which differs in sample illumination from the 45, 0 geometry common to all other instruments used in this study.

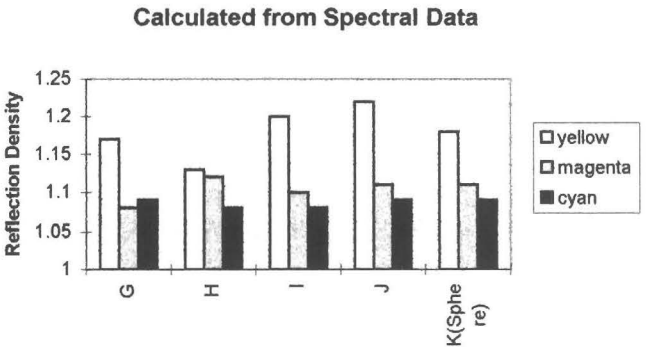

Figure 3. Reflection density (Status T) calculated from spectral data from five specrophotometers. Note the change in scale values from the previous figures.

Table I illustrates the range of density values obtained with the three methods of making measurements of the same set of samples.

	Yellow	Magenta	Cyan
Densitometer	0.17	0.13	0.18
Spectrodensitometer	0.11	0.11	0.11
Calculated from spectra	0.09	0.03	0.01

Maximum difference in density

Table I.

White Reference Standards

When the data shown in Table I are compared, it is apparent that the preferred method is to calculate density values from spectral data. However, although there is an improvement of density range with the spectrodensitometers as opposed to a filter densitometer, there seems to be a systematic difference between those data and the data from spectral calulation. Spectrodensitometers ostensibly use calculated spectral data, but the absolute level of density is apparent among those tested. One possible explanation is that the white reference for calibrating the instrument is not set to absolute reflectance. A convenient white reflection standards is Spectralon (Labsphere, Inc.) which has nearly Lambertian diffuse spectral properties; that is, the surface is almost uniform with

respect to angular reflection. Thus the optical geometry of the instrument is not critical because of angular dependance of the measurement.

The CIE (International Commision on Illumination) (CIE, 1982) specifies that the international standard for reflection measurement shall be in terms of absolute reflectance. Inasmuch as reflection densitometry is one of the forms of reflection measurement, it should conform to this standard. In order to obtain absolute reflectance data it is the practice to calibrate a spectrophotometer in terms of absolute reflectance with a white reference standard that has been measured by a national standards laboratory such as the National Institute of Standards and Technology in Washington (NIST) or National Physical Laboratory (NPL) in England. We show data on a white reference, Spectralon, which had been measured at the National Physical Laboratory with 45, 0 geometry. Standard data on Spectralon can be compared to measurements made with several of the spectrophotometers previously listed. The comparison is shown in Figure 4.

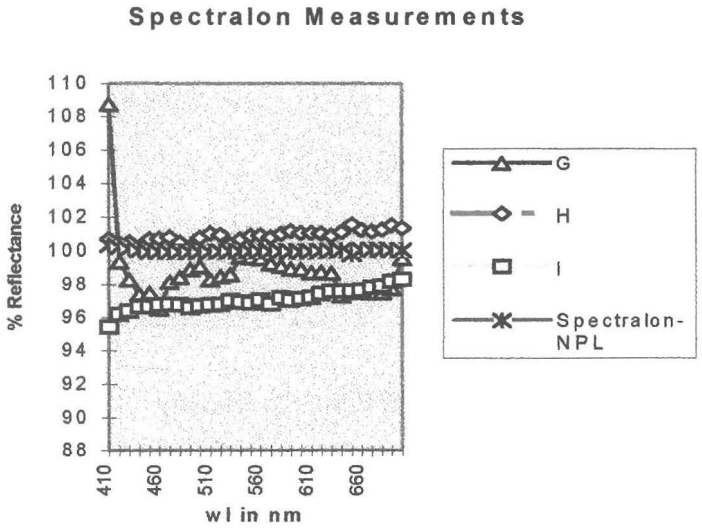

Figure 4. Spectralon measurements on several spectrophotometers compared to the National Physical Laboratory (NPL) data in absolute reflectance.

"Uncommon" Density Calibration

Each filter densitometer manufacturer supplies their own set of Reference standards with which you are supposed to calibrate the instrument. In addition, the Graphic Communications Association (GCA) sells a set of Status T reference targets that are called TRef which claim to be individually calibrated to known traceable standards.

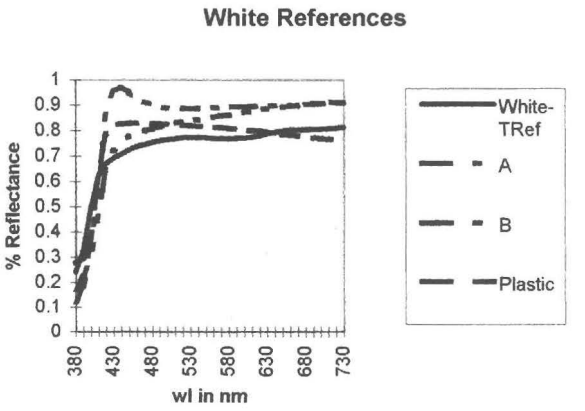

Figure 4. Comparison of several white refernce standards

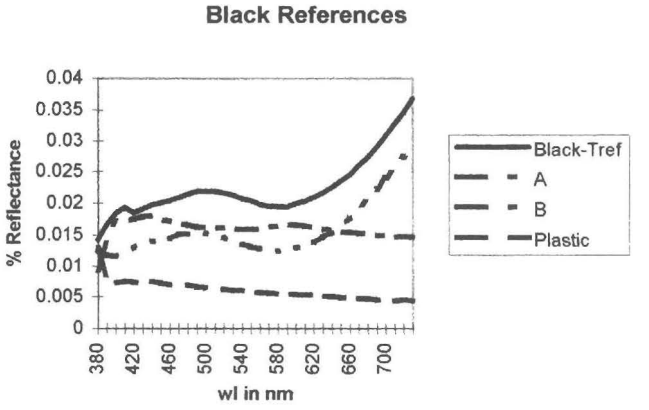

Figure 5. Comparison of several black reference standards

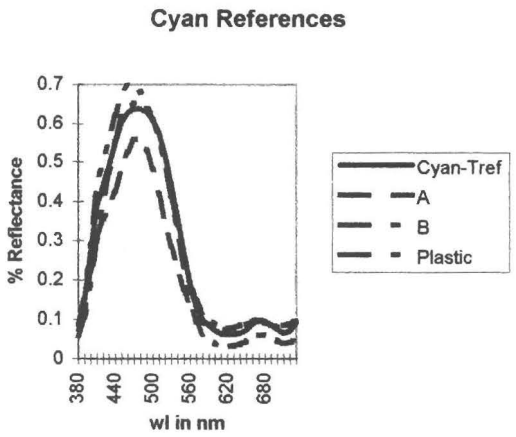

Figure 6. Comparison of several cyan reference standards

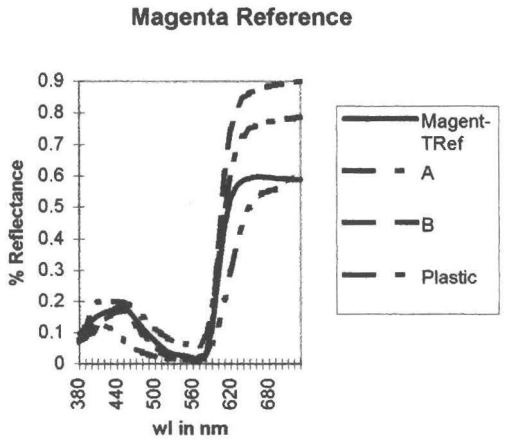

Figure 7. Comparison of several magenta reference standards

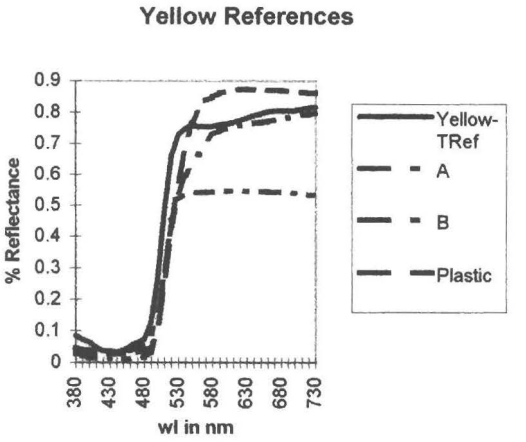

Figure 8. Comparison of several yellow reference standards

The spectral reflectance curves shown in Figures 4 to 8, illustrate the lack of commonality among those densitometer references shown. This is undoubtably a source of discrepancy in readings obtained on various instruments. One of the difficulties is that most reference standards are made from printing inks with the assumption that they should be typical of the material being measured. But this argument has little validity since there are many different sets of ink used in the Graphic Arts industry. Besides most typical process inks have relatively short lives when exposed to light and it is recommended by densitometer manufacturers that the reference set be replaced at least once a year.

Our recommendation is that one universal standard be used for all densitometer calibration. A set that we put together is made from pigments that have been incorporated into acrylic plastic. The spectral curves marked "plastic" are of the new set, shown for comparison in Figures 4 through 8 . These are made from some durable pigments that are known to be unchanged for at least 10 years. Furthermore, the plastic set can be carefully washed to renew the surface in case they become dirty which makes it unnecessary to replace them frequently.

Computation Methods

Modern computers give us the means to do sophisticated calculation with great ease. We use the Microsoft Excel spreadsheet to do density calculation from spectral data . Since most spectrophotometers have the facility to put data directly into Excel, Status T weighting functions from CGATS.5 need to be

installed in a data sheet so they can be accessed. The Excel function, MMULT, is used to do the computation of density.

There are two caveats to the calculation of density using the instructions given in CGATS.5. According to section 5.3:

$$D_R = -\log_{10}[(\Sigma\Pi(\lambda)R(\lambda))/\Sigma\Pi(\lambda)]$$

where

Σ is the summation over the wavelength range

$\Pi(\lambda)$ is the spectral product at wavelength λ for the appropriate density response;

$R(\lambda)$ is the reflectance value (range 0 to 1) at wavelength λ

Unfortunately, reflectance values are most frequently given in percent which gives incorrect values

The other caveat is that Table H-4 is given as $\log_{10}$ spectral products. First the antilog must be taken of these tabular values before they can be used in the above equation. Although they are given in the table as Π_T products, they are also used for reflectance calculation. It would be much better to list the table as it is to be used; that is, in its exponentiated form and normalize it to 1.0

Acknowledgement.

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References

CIE (Commisiion Internationale de l'Eclairage)
1982. Colorimetry. 2nd Edition

Hensel, Roy E.
1989. "Modified Colorimetric Methods for the Graphic Arts" TAGA Proceedings 1989, pp 54-66

Labsphere, Inc. P.O. Box 70, North Sutton, NH

Vogelsong, W.F.
1990. "Capability Studies of Densitometers and Densitometry", TAGA Proceedings 1990, pp.1-10