Narrow-band *vs* Wide-band Densitometry
An Update

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Abstract: SPI narrow-band densitometry was introduced almost ten years ago. Since its introduction, it has been the subject of much controversy. It is the intent of this paper to review how and why SPI was developed, and whether or not the rationale for its development is still valid.

The original application for graphic arts densitometry was in the prepress area. Therefore the filters in the densitometer were the same ones typically used for color separation. This allowed the camera man to measure the tonal range of an original to obtain the proper exposures for each separation. These units eventually found their way into the pressroom because they were the only thing available at the time. Narrow-band SPI, was the first attempt to develop a densitometer specifically for the pressroom. It was intended to answer many of the problems which had been encountered with wide band units in this application, such as:

Poor inter-instrument agreement

Poor stability

Poor sensitivity to yellow ink.

The new responses indeed proved to successfully address these shortcomings, however the controversy has continued to the present day. Technology has obviously changed dramatically over the last ten years. Many of these developments, such as the increasing power of microprocessors have made themselves evident in densitometers. Many proponents of wide-band densitometry insist that these developments in technology in conjunction with improved industry standards have eliminated the benefits of narrow-band densitometers. This paper is intended to review the current state of densitometry and how it relates to the narrow-band; wide-band controversy.

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What is Narrow-band?

To begin with, it is important to understand what narrow-band means and how it was developed. Very generally, narrow-band simply means that the filter of the densitometer only allows a very limited number of wavelengths of light to pass through it. Wide-band means that a larger number of wavelengths of light are allowed to pass through the filter (see Figure 1). It can be easily seen that these terms, by themselves, are not very descriptive. There is certainly a lot more involved in the specification of the Macbeth SPI responses than the fact that they are narrow-band, yet the use of this term is one of the reasons for ongoing confusion over this issue.

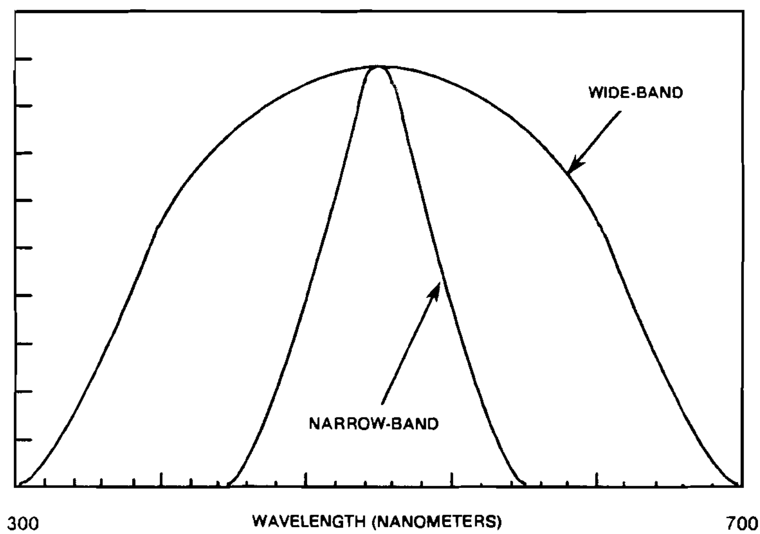

Figure 1. Comparison of Narrow-band and Wide-band Filter

SPI Development

In developing SPI densitometry it was first necessary to identify what the most important criteria for a pressroom densitometer should be. As stated before, these criteria were determined to be: sensitivity to ink film thickness, stability and inter-instrument agreement. Existing densitometers had to be analyzed to determine where they were deficient and how they might be improved. It was found that inter-instrument agreement was very poor; with units from the same manufacturer giving density readings that could be .20 density apart. Between manufacturers the differences seen were even larger. The major components that contributed to variability were: filters, detectors and light sources. The effect of filter variations are obvious and there are only two ways of minimizing this source of variability: sort wratten filters to find those that conform most closely to the specification, or use a different kind of filter. Because the bulk of the applications for wratten filters do not require the level of control that is necessary to get good inter-instrument agreement in densitometers, it was impractical to try to try to get the manufacturer to narrow their tolerances. However, these tolerances allow for a ±5% variation in transmittance at any wavelength. This can result in density variations of ±.05. Sorting filter material is very costly and still does not guarantee good quality because the filters are made in large batches. Each batch will have a different characteristic, but within the batch the characteristic is fairly similar. So if a sample from a batch is unacceptable it will be very difficult to find filters that did not come from that batch. The other difficulty with Wratten filters is that they fade and degrade with time. The green filters tend to be the least stable of the filters used in densitometers. If the filter only fades half of the allowable fade tolerance the effect on the density reading can be as large as .14. The best answer is to go to a different type of filter, such as glass, or glass interference. With colored glass filters it may be possible to get material made to specifications, but there will still be variability from batch to batch. With glass interference filters the nature of the filter gives the basic curve shape which, will always be the same. The variables are then reduced to the peak wavelength and the half band width. The peak wavelength is obvious and can be controlled within ±1 nanometer fairly easily. The half bandwidth bears a little description. Half band width is the total width of the filter transmittance band at a point which is fifty percent of the peak transmittance. Essentially this parameter defines the width of the response. However it is also necessary to specify the width of the filter at other points and the level of rejection of light outside the area of interest. With the interference filter all of this can be specified and controlled very precisely, much more so than with any other type of filter.

This leaves the detector and light source as potential contributors to variability. Careful design of regulation circuits and the lamps themselves can control the color temperature to about ±200K. Although this is good, it still allows a shift which can effect the response of the instrument. The spectral output of a lamp at ±200K from 2850K is shown in Figure 2.

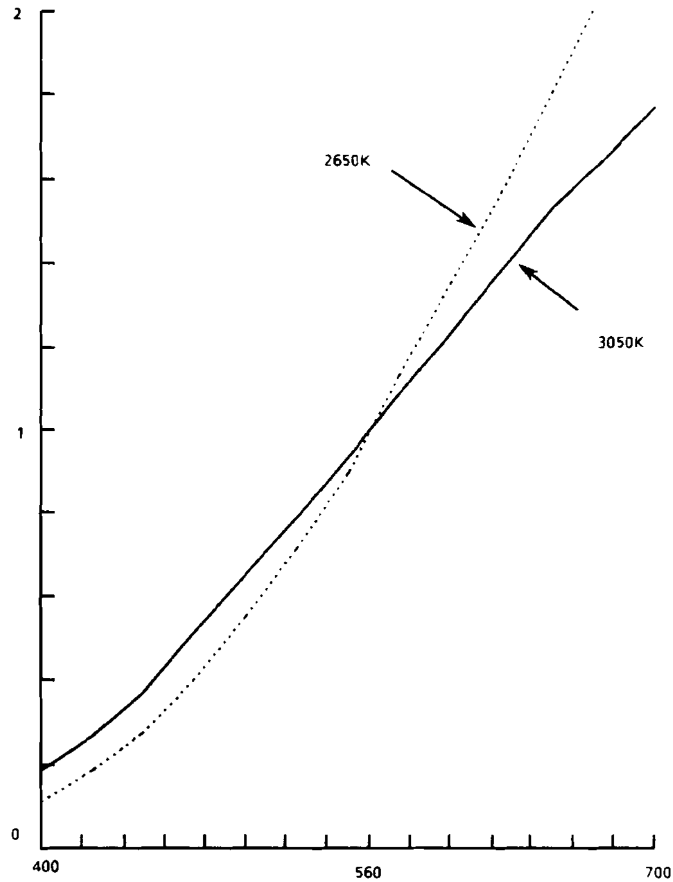

Figure 2. Spectral Output Variaation over 400K Color Temperature Range

The same is true of the detectors and the same type of broad shifts in spectral response occur. There is only one way to further minimize the effect of these shifts on the overall performance of the instrument, look at very narrow, discrete parts of the spectrum. By doing this, the broad spectral output variations of these components are reduced to only impacting the peak level of the response not the shape. Testing these theories against actual printing inks confirmed these conclusions. Table 1 (shown on the following page) shows the effect of

COMPONENT	VARIATION	BLUE FILTER		GREEN FILTER		RED FILTER	
		Wratten	Inter-ference	Wratten	Inter-ference	Wratten	Inter-ference
Light Source	± 200K	± .0107	± .0001	± .00015	± .0001	± .0002	± .00005
Color Filter	Wratten 13 Samples Interference: ± 2nm Shift ± 1nm Bandwidth	± .01225	± .0031	± .0449	± .0036	± .00095	± .00175
IR Cutoff Filter	± 10mm Thickness Variation	± .00025	± .00000	± .00065	± .00005	± .00035	± .00015
Detector	26 Samples 3 Sensors	± .0141	± .00015	± .00075	± .0002	± .0002	± .00005
TOTAL	All Components	± .0375	± .0035	± .048	± .004	± .001	± .002

Table 1. Maximum Variations in the Measurement of SWOP Ink Density as a Function of Variations in Spoectral Characteristics of Densitometer Components

the variation of individual components on the density reading of SWOP inks, for both a wide-band Status T instrument and a narrow-band (20nm half band width) filter. From these studies it was determined that the best filters would be glass interference filters with 20 nanometer half bandwidths. All that remained was to specify the peak wavelength of the filters.

The criteria used in selecting the peak wavelengths was to maximize both inter-instrument agreement and sensitivity on standard process printing inks. The following list of inks were used in this part of the study:

SWOP
Hartmann Europe
Hartmann DIN Offset
Capico Offset
Gravure, GTA Group 1
Gravure, GTA Group 5
American Research and Chemical,Flat
American Research and Chemical, Glossy

BSI
Japan-GS4 Magenta
Japan-RS4 Magenta
Japan-ZS4 Magenta
Japan-GS4 Cyan
Japan-ZS2 Yellow
Japan-RS2 Yellow

The narrow-band peak wavelengths were then varied and at each peak the tolerances for each of the components of the densitometer explored to determine the reproducibility that could be expected for each center wavelength for each ink. This resulted in a series of curves. The minimum points of the curves show the best center wavelength to minimize reproducibility error. Using this technique the following wavelengths were chosen:

Blue	432nm
Green	536nm
Red	624nm

So what has happened over the last ten years? First of all a number of organizations around the world have evaluated the narrow-band approach. These organizations include: *Magazine Association of Canada, Deutches Institut für Normung a.V*, (DIN), and what was then the *Gravure Technical Association*, Both MAC and GTA conducted tests with their members that illustrated the superior performance of the SPI responses. MAC then went on to adopt SPI narrow-band as the recommended response for pressroom densitometry. DIN the German equivalent of ANSI has adopted a standard for densitometry which includes narrow-band. However, standards alone are not sufficient to overcome the controversy. It is important that the state of densitometry today be evaluated in order to understand the importance of narrow-band ten years after it's introduction.

Quality of Densitometer Components

Surprisingly, there has been little change in the quality of the components used in densitometers over the last ten years. This is not referring to the microprocessors, but to those components that contribute to spectral variability: wratten filters, no improvement, detectors, no improvement in spectral response stability, light sources, no improvement in stability. This is not to say that densitometry is no better than it was in 1979. There have been improvements in industry standards.

ANSI Standards

ANSI has adopted a standard for prepress densitometry: Status T. This has definitely narrowed the variability between manufacturers to some extent. But note that this is only a standard for prepress densitometry. There is still not a standard for pressroom densitometry. ANSI is currently beginning work on a pressroom standard.

Physical Standards

A number of things have happened in the way of physical standards. SWOP standards continue to be an important contributor to industry consistency for the publications industry, particularly with the high low standards. However, instances have occurred where the hi-lo standards do not completely solve the problem. These instances occur when the spectral characteristic of the ink being printed, or the proof being tested does not closely match the spectral reflectance of the SWOP standards. Figure 3 illustrates a particular case in which the sample yellow has a bump in the blue region which causes it to fall outside the standard only within a certain wavelength range. Under these conditions any number of things may happen. It is possible for the densitometer to indicate that the sample is between the high and the low, but for the sample to look visually outside the tolerance. It is also possible for one densitometer to indicate that the sample is within standard and another one to indicate that it is out of standard. Because of this condition, it is important that the inks that are being used to be a good spectral match to the SWOP inks in order to prevent this type of problem. This type of spectral mismatch would also cause potentially visible differences in overprints from inks that appear to match the standards when printed alone.

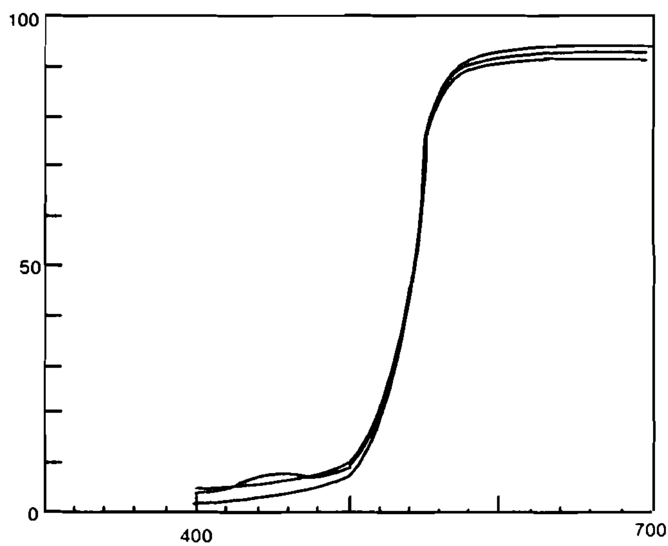

Figure 3. Example of Reflectance Curve for a Sample which Does Not Match the Curve for a Hi-Lo Standard

A relatively new development in physical standards are the T-Ref™ standards. These standards will help users identify when their densitometer is no longer meeting the Status T specifications. There is one potential problem with the T-Ref™ standards. These standards are printed cyan, magenta, yellow, and black patches with Status T density values assigned to them. A properly calibrated densitometer can measure these patches and should give the same density values as the assigned values. However, most densitometers today calibrate on a similar set of color patches which are shipped with the unit. If the spectral reflectance of the calibration standard patches closely match the T-Ref™ patches the calibration procedure will electrically correct the densitometer to give the proper reading on the T-Ref™ even if the spectral response of the unit is totally wrong. The question then becomes: Is this important, as long as the unit reads the standard properly? This type of electrical correction is acceptable as long as all the inks that are to be measured have the same spectral response as the T-Ref™ and the calibration patch. However, if inks are measured which have different spectral response, the unit will not necessarily agree with Status T standards. This is one of the downfalls of modern microprocessor based densitometers, it is very easy to do electrical calibration correction for spectral differences, however, this does not make the unit read correctly on anything but the calibration standard. This problem becomes even more evident when an instrument with an incorrect spectral response is calibrated to Status T references and then is used to measure hue error and grayness. Because the ink is being measured through all three filters the electrical correction will be of no value.

The bottom line is that there has definitely been improvement in the quality and consistency of densitometers over the last ten years but not major improvements in the consistency of spectral responses.

There are a number of things which should be clarified at this point regarding other attempts to improve inter-instrument agreement and stability. First of all, at the beginning of this paper narrow-band and wide-band were defined. This served to highlight that "narrow-band" is not an adequate qualifier of either a densitometer's response or its filter. The response needs to be qualified by peak and half bandwidth and the filter must be identified by type.

Narrow-band responses can be made from wratten filters, however, the stability of these filters then comes into play to degrade the response, as well as the accuracy with which the original filters were made. Even sealing these filters between glass does not stop their degradation, but only slows it, and protective seals never last long in an industrial environment.

SPI Disadvantages

There are some disadvantages to narrow-band SPI. These include the following. Narrow-band is not recommended for measuring ***hue error*** and ***grayness***. There is a good reason for this. Hue error and grayness were originally devised for use by the prepress department to allow them to measure an ink to see how they must adjust their masking for color separation to compensate for unwanted absorption in the ink. To do this, the densitometer must have the same response as the camera, or scanner (Status T). Today many people use this technique to control the color of the ink and to measure contamination. This can be done, however, the densitometer is not a colorimeter, therefore it is very possible that measurements of hue error will not correlate with what can be seen visually. Figure 4 is a graph of a range of colors plotted in color space that all have the same hue

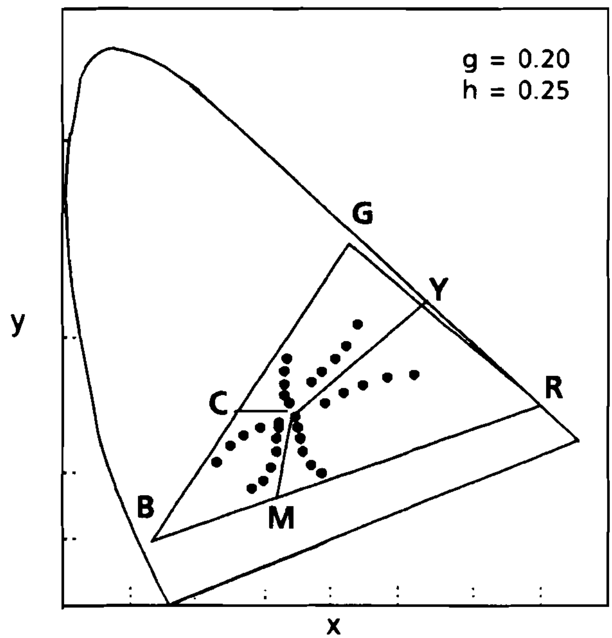

Figure 4. 36 Different Colors, All Having a Hue Errpor of 0.25 and a Grayness of 0.2 Plotted on the CIE Chromaticity Diagram

error and grayness, but will look *completely* different. Also if there are any spectral differences between densitometers these will be accentuated in the hue error calculation, because the ink is being measured with filters that are not usually used for this purpose. If, however, measurement of hue error and grayness is used carefully, it will probably give some degree of control. It is important only to remember the possible shortcomings in order to avoid the traps. There is one other disadvantage to narrow-band densitometers. There are some non-process colors which are not as easily controlled with narrow-band as with wide-band densitometers. These tend to be pastel colors with small absorption peaks in the blue-green or yellow region of the spectrum. The response peaks of the SPI densitometer may miss these absorption peaks resulting in low density readings and less sensitivity to these inks.

Conclusion

As can be seen from the previous discussion the state of densitometry has advanced over the past 10 years. However, there are still valid reasons for choosing SPI type responses for pressroom densitometry. Most organizations which have actually run tests have come to this same conclusion. It is now incumbent on the industry organizations to conduct tests for their particular industry segments to verify the benefit, or lack there of for their clients. It is alarming that so few organizations, which take strong stands on the narrow-band wide-band issue have conducted scientific studies to support their positions.

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