HANDHELD SPECTROPHOTOMETERS: THEIR USE IN PRINT PROPERTIES ANALYSIS

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ABSTRACT

Prior TAGA papers [1], [2], [3], [4], [5], [6], [7], [8] have considered the controversy between densitometry and chromaticity as a tool for graphic arts production use. These papers were mainly concerned with explaining the technique and practice of these two measuring means. Little has been published on the actual use of chromaticity in practical graphic arts work area applications. A paper by Engeldrum [9] the authors [10], and [11] detail the use of a colorimeter for some ink selection activities and compares the accuracy of a colorimetric device to a densitometer for this purpose.

A paper at the TAGA 1988 [12] Annual Meeting introduced a reduced cost "portable" spectrophotometer and its use in the in process control of the Gravure web printing process. Since then at least one additional portable spectrophotometer has appeared in the market place. It is the intent of this paper to compare these two devices and offer hands on examples of some of the areas which can lend themselves to spectrophotometric analysis.

INTRODUCTION

General

An understanding of the uses of a portable spectrophotometer requires us to understand light, color and the action of a spectrophotometer.

Radiation comes to us in the form of waves. The term wavelength is used to describe these waves. We cannot see all the available wavelengths. We only see a part of those waves with lengths from 380 to 750 nanometers. A nanometer is a measure of the wave. The integrated wavelengths over the visible range we perceive as white light. When we pass white light through a prism the different wavelengths spread out and we see color. When visible light falls on an object

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some of it is absorbed by the object and the rest is reflected to our eyes. The wavelengths are not colored, rather an interaction between our eyes and brain produces the sensation of color.

Spectrophotometry

A spectrophotometer measures the wavelengths that reflect off an object when it is illuminated by white light. It measures reflection wavelength-by-wavelength. Computer programs manipulate the values by factors that describe how the brain perceives color and also modifies those values to accommodate how one sees that color under different illumination.

Conventional spectrophotometers tend to be expensive bulky devices selling for at least $ 40,000, and occupying a footstep of 1.5' x 2.5' x 2.5' x. The sampling aperture of many such devices is about 10mm or larger. Although adapters could be used to allow samples of about 6 to 8mm diameter these samples have to be cut off a full signature and requires excessive handling time. The size and weight of these devices further limits their portability into press rooms and milling areas.

Two portable spectrophotometers are now available: the Gretag SPM 100 and the Minolta CM-1000. The Gretag device weighs slightly less than three pounds and occupies a space of 11" x 3.5" x 3.8". The Minolta measuring head weighs 2.2 pounds and occupies a footstep of 3.5" x 4.9" x 9.1". It should be pointed out that the Minolta requires a dedicated proprietary lap computer with printer and these use an additional space of 13.5" x 17.3" x 4.5" with a total weight of 25.3 pounds.

The control patches in a standard target like the GATF Compact Color Bars or similar test targets are 5mm square. The Gretag analyzes a 3mm diameter sample. The Minolta presently uses an 8mm aperture (11mm minimum sample size), but we are told other sizes will be available.

The illumination in the Gretag device is 0/45 as prescribed in the ANSI/ISO and ASTM specifications for densitometers and spectrophotometers. The Minolta uses diffuse/0 illumination, a slightly different geometry. Computer programs embedded into the Gretag allow output in both colorimetric values as well as several densitometric values: Status T, European (DIN), and interference 20 nm filtration (the Status I filtration). Therefore the Gretag device can be used for both densitometry and chromaticity measurements with only one sample measurement. A variety of illuminants are available in both machines, including daylight and tungsten. The Gretag device includes a D50 illuminant - the Minolta device does not, but has the capability of including other illuminants by computer programming.

A summary of the features of both devices is included in the following table.

Table 1
Features of Minolta CM-1000 and SPM 100

	GRETAG SPM 100	MINOLTA CM-1000
MEASURING HEAD		
SIZE	11" x 3.5" x 3.8"	3.5" x 4.9" x 9.1"
WEIGHT	3 lbs.	2.2 lbs.
DEDICATED COMPUTER		
SIZE	NA	13.5" x 17.3" x 4.5"
WEIGHT	NA	23.1 lbs.
MEASURING APERTURE	2.8 mm.	8 mm.
MINIMUM SAMPLE SIZE	3.5 mm.	11 mm.
COLORIMETRIC	Reflectance, Absorbance	Reflectance, Absorbance
GEOMETRY	0/45	diffuse/0 (spec included)
ILLUMINANT	D50, D65, A, C	D65, A, C, F2, F7, F11, user
OBSERVER	2°, 10°	2°, 10°
COLOR SPACES	Yxy, L*a*b*, L*C*H*, Luv.	Yxy, L*a*b*, L*C*H*, XYZ, Hunter Lab, Munsell
WAVELENGTH RANGE	380-730 nm.	400-700 nm.
DENSITOMETRIC	Status T, DIN, DIN NB, Status A	None

EXPERIMENTAL

For purposes of this paper, three practical uses of spectrophotometry will be illustrated. However, the most valuable use is for incoming raw material testing such as inks and papers.

Fluorescence

Some familiar colors like safety colors which are made with fluorescent pigments appear to glow or stand out under illumination. Fluorescent materials absorb the UV component of radiation which we cannot see and emit that energy at a different wavelength. Not all fluorescent colors show the extreme effect of these safety colors. Many inks, especially yellow inks, fluoresce [13]. The fluorescent effect of these yellow ink samples limits their usefulness in the reproduction of standard images. A densitometer or colorimeter can not indicate if an ink fluoresces. A spectrophotometer can perform that function.

Two yellow inks, both ink-on-paper, were compared by spectrophotometry. One was identified as a SWOP yellow patch, the other the yellow image used in the T-Ref.

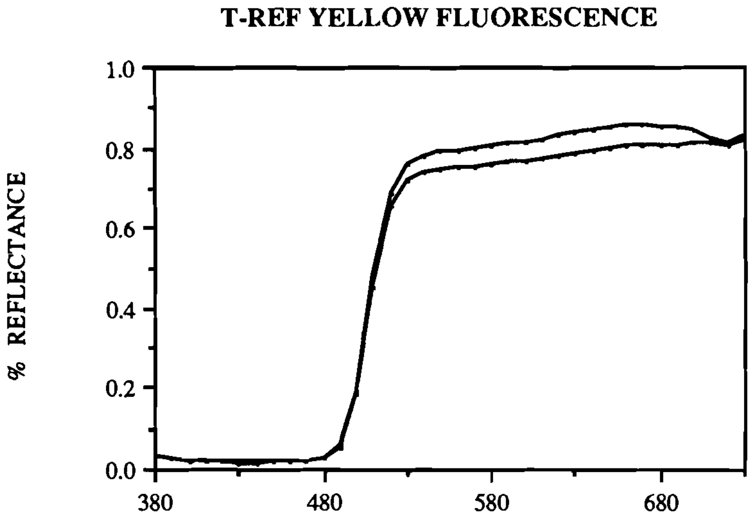

Figure 1

YELLOW SWOP FLUORESCENCE

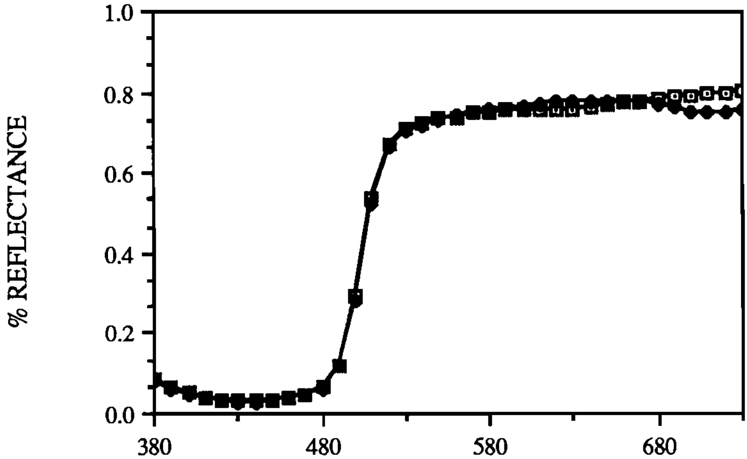

Figure 2

Such spectrophotometric tests included chromaticity analysis with and without UV component. As can be seen the yellow ink used in the T-Ref is fluorescent in nature unlike the SWOP physical standard. The following change (Table 2) in CIE L* a* b* values expressed in delta e units (equivalent to Just Noticeable Difference Values (JND)) indicate the degree of fluorescence exhibited for each sample.

Table 2
Fluorescence of SWOP and T-Ref Inks

Sample	L*	a*	b*	ΔE
T-Ref (with UV)	87.97	-3.7	106.94	
T-Ref (w/o UV)	86.06	-4.15	104.74	3.0
SWOP (with UV)	86.16	-6.37	92.90	
SWOP (w/0 UV)	86.20	-5.14	94.56	2.1

<u>Paper and Ink Combinations</u>

Although we in the graphic arts talk about specifications that encompass 3 or 4 color printing and specific spot colors we fail to recognize the invisible fifth color. The fifth color is the paper itself. [14] There are SWOP specifications covering paper stock including chromatic specifications. A densitometer can not quantify the color of paper stock in those terms. The combinations of ink on paper are not only the attributes of the paper color and the ink color but also combinations of other factors including base surface reflections. An actual sample of the particular ink on paper serves as the best prediction of that combination [15].

Figure 3 depicts the spectrophotometric curves of 3 different paper stock. Figure 4 depicts the spectrophotometric curves of a single yellow process ink on three different paper stocks.

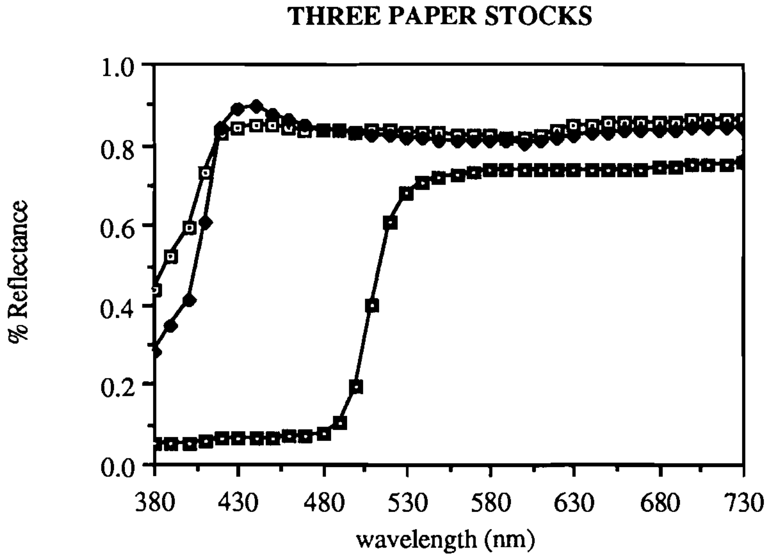

Figure 3

YELLOW ON THREE PAPERS

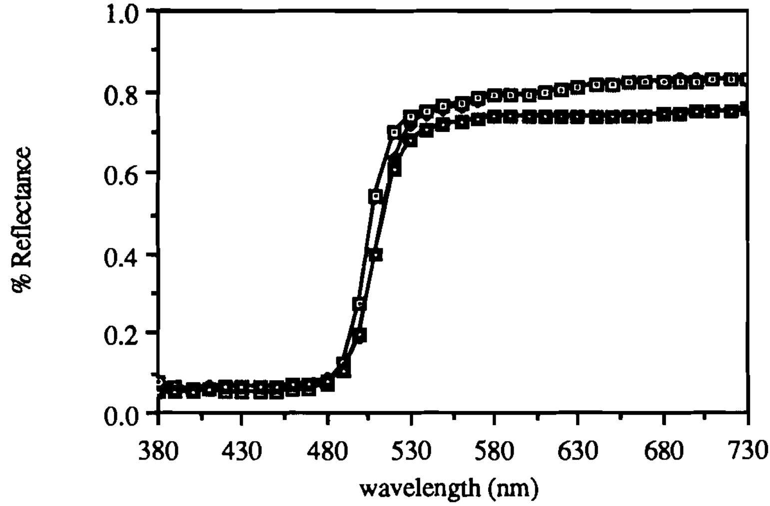

Figure 4

Table 3 details the CIE L*a*b* values obtained from those samples and their delta e values. Figure 5 graphically illustrates the visual changes in the ink colors as seen by a Standard Observer in CIE L*a*b* color space. The individual fifth colors have changed the color of the yellow ink. A spectrophotometric analysis can indicate the combinations of ink on paper for different yellow inks and therefore allow for better ink and paper raw materials control especially during stock replacement.

Table 3

	Ink and Paper Combinations			ΔE vs.	
Sample	L*	a*	b*	#1	#2
Ink & Paper 1	87.62	-4.78	90.03		
Ink & Paper 2	86.73	-1.14	86.67	5.0	
Ink & Paper 3	84.70	-3.03	84.00	6.9	3.9

L*a*b*
Ink and Paper Combinations

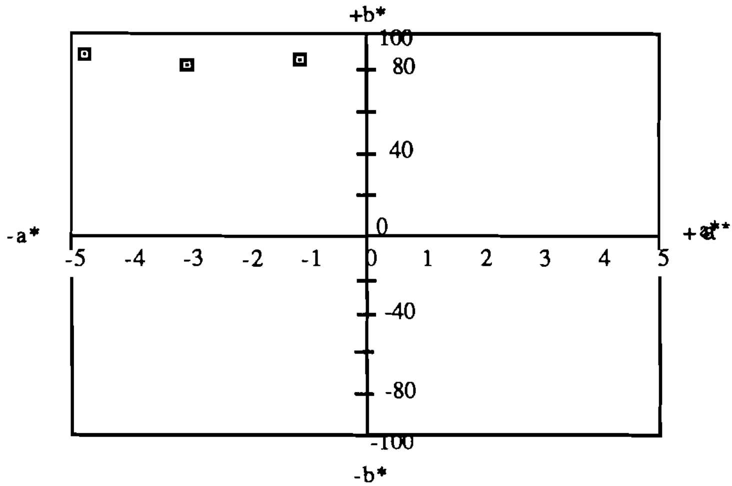

Figure 5

<u>Metamerism</u>

Metamerism is the term given to the property of color pairs that look alike under one light source but appear different under a different illumination.

In practical applications one ink may be a candidate for replacing another ink. Both inks match under D50 illumination. The D50 illumination is prescribed for viewing image color during the press proofing Ok and used for printing QC. The final replacement color incorporated in an image is combined into a publication. Which of us has D50 in our rec or living rooms? That publication is viewed at home under tungsten illumination. The customers of the product imaged with the metameric ink see them differently than what the proof Ok depicted. The replacement ink is a metameric match to the original ink. Such color differences may cause a condition where the product is less desirable than what was expected by the advertiser.

A spectrophotometer can depict such metameric difficulties. Macbeth Corporation makes available a graphic demonstration of Metamerism Test Kit #3. It includes a set of four cyan inks that are metameric colors. Under various illuminants, different combinations of the four inks appear to match. Ink #2 will be detailed first. Figure 6 indicates that ink #2 will appear the same under A, C, and D50 illumination. The curves lie on top of each other. However under D65 illumination the ink appears quite different. Table 4 details the L*, a*, b*, and ΔE values for ink #2 comparing D50 and D65.

Table 4
MacBeth Metamerism Ink # 2

Illuminant	L*	a*	b*	ΔE
D50	49.18	-7.30	-40.01	
D65	52.11	-0.50	-40.15	7.4

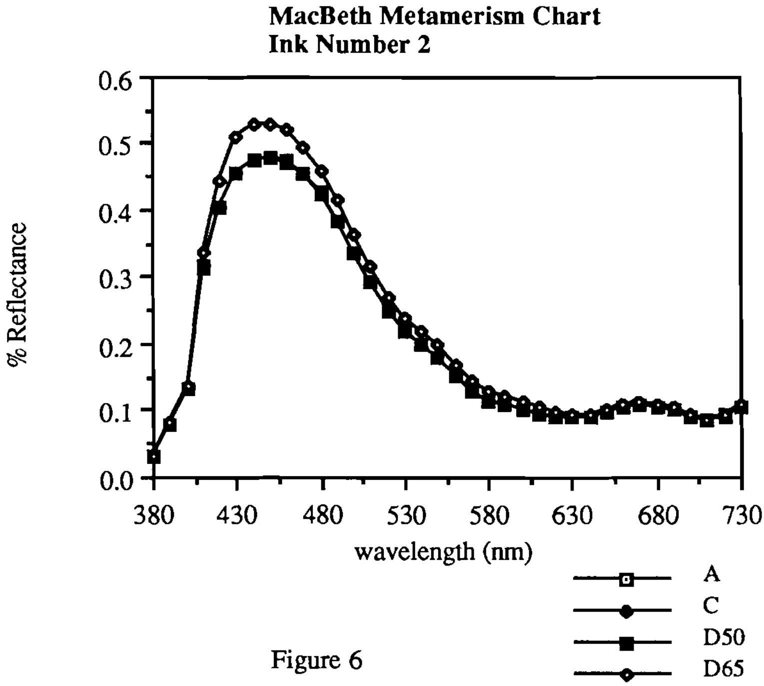

Figure 6

The first three inks of the MacBeth Chart are depicted by spectral curves in Figures 7(Illuminant C) and 8(Illuminant D65). The shape of the curves and the relationship between the curves change dependent on illuminant. In Figure 7 the spectral curves of Inks 2 and 3 are nearly identical and in practice appear identical in tungsten light. Yet in Figure 8(D65) Ink #2 has changed significantly. In daylight conditions Inks 2 and 3 would not appear the same.

Macbeth Metamerism Test Kit #3
Illuminant C

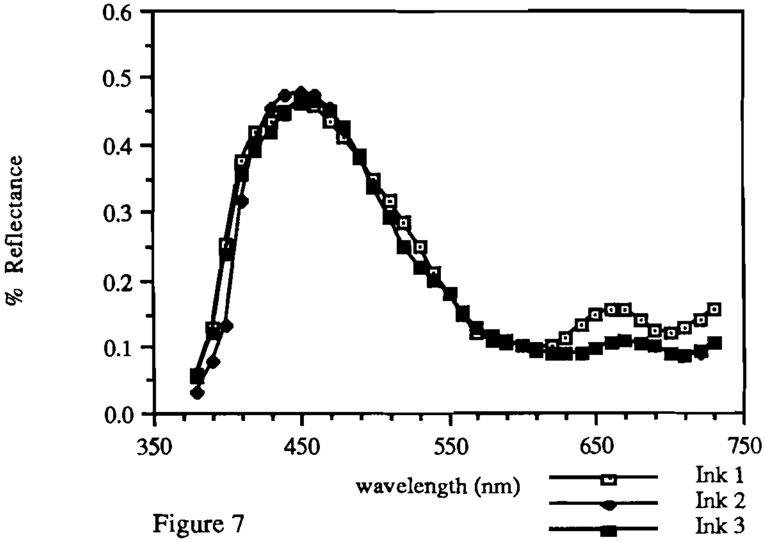

Figure 7

Macbeth Metamerism Test Kit #3
Illuminant D65

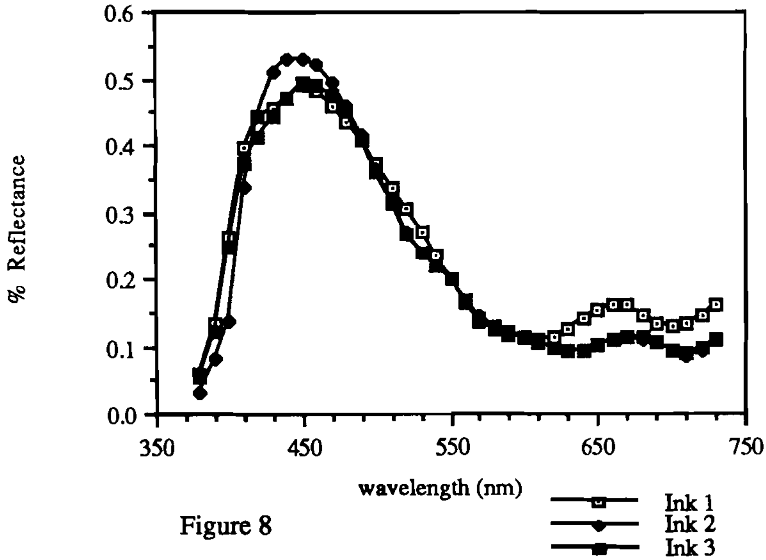

Figure 8

CONCLUSION

A printer is a manufacturer of color images, as much as GM makes cars or 3M makes tape. Manufacturers need to know and check the quality of the raw materials used in making their products. Some of the raw materials used by the printer are his inks and papers.

A portable spectrophotometer which can be brought into specific work areas like QC, milling, and press areas to measure the compact control patches used as routine printing control images can insure quality from RM selection and trouble shooting. Specific examples such of ink and paper properties such as florescence, metamerism, as well as ink paper interactions and paper selection have been detailed. Those are only a few uses of portable spectrophotometers.

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