Study of Pantone® basic colors in different Pantone® libraries

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Abstract – The Pantone Matching System® (PMS) color library is widely used in packaging, architecture, textile, and fashion industries. The Pantone® color libraries are available in Photoshop® Illustrator® and InDesign® software. Printed Pantone® books and inks are supplied by ink manufacturers, using the same Pantone® numbers. Color differences for some Pantone® numbers were studied for several stages of color reproduction. Large color differences and potential metamerism were observed and reported here.

Key words – Pantone, spot color printing, metamerism

Introduction

Pantone® Color Libraries are extensively used in packaging and product printing[1], and other color critical industries, such as textiles, plastics, architecture and interior design[2]. These libraries include the popular Pantone® Matching System (PMS) and the newer Goe system colors. They are available in both printed and digital forms[2]. The digital versions are supported by designer software, including Photoshop, Illustrator and InDesign.

In the printing industry, using spot color in package and product printing is common[1]. Spot colors are used to avoid variation caused by process colors. When a package is designed and a shade is selected on a computer, a Pantone® color library is usually used for spot color selection and the designer communicates shades by the associated Pantone number[3]. Usually one standard is sent to the color-matching lab. The standard might be a printed shade, a Pantone® number or even a piece of cloth. At some places, a recipe is calculated by trial and error based on the matcher's judgment or by computer colorant formulation software. Generally, acceptance of the shade is decided visually and QA/QC is carried out by using a spectrophotometer.

Pantone® numbers are used for color communication from designer to ink chemist, and from ink chemist to printer[4]. If any Pantone® shade is in a company's logo, then to maintain the house stile standard, the Pantone® number is used for communication. Photoshop® has Pantone® color library, and the same library is available as a printed Pantone® book and in the market, approved inks are available[5].

The current study is investigating color differences in Pantone® basic shades during the process of color reproduction. Photoshop® provides CIEL*a*b* values in $D_{50/2}$. The problem is that spectral details are not available to calculate metamerism index and color inconstancy index[3] in order to evaluate the consistency of these systems.

To calculate CIE XYZ[6] tristimulus values, the following equations are used:

$$X = K \int_{380}^{730} d\lambda \left(S(\lambda) R(\lambda) \bar{X}(\lambda) \right) \qquad 1a$$

$$Y = K \int_{380}^{730} d\lambda \left(S(\lambda) R(\lambda) \bar{Y}(\lambda) \right) \qquad 1b$$

$$Z = K \int_{380}^{730} d\lambda \left(S(\lambda) R(\lambda) \bar{Z}(\lambda) \right) \qquad 1c$$

where $S(\lambda)$ is the spectral emission of the illuminant, $R(\lambda)$ is the reflection spectrum of the measured color and $\bar{X}(\lambda)$, $\bar{Y}(\lambda)$ and $\bar{Z}(\lambda)$ are color matching functions.

Likewise, the CIELAB 1976 formulas are

$$L = 116f(Y/Y_n) - 16 \qquad 2a$$

$$a = 500[f(X/X_n) - f(Y/Y_n)] \qquad 2b$$

$$b = 200[f(Y/Y_n) - f(Z/Z_n)] \qquad 2c$$

where:

$f(Y/Y_n) = f(Y/Y_n)^{1/3}$ for $(Y/Y_n) > .008856$

$f(Y/Y_n) = 7.787(Y/Y_n) + 16/116$ for $(Y/Yn) \leq .008856$, etc.

CIE1976 color difference formula was used is this work.

$$\Delta E_{ab} = [(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2]^{0.5} \qquad 3$$

Color (In)constancy 3'[7] **–** Color constancy is nothing but perceiving the same color appearance after changing the light source. An example of this is our eye, accepting that a paper looks white under many light sources. Ideally, color constancy does not exist, because if we look carefully, paper looks white under different light sources, but those whites are not all the same. Therefore, we need to see how much color change there is after changing the light source and that is color constancy. Color constancy is very important for printed products, such as gravure laminates, because they are viewed under several illuminants. When colors and recipes are selected, the criterion of color constancy is not usually considered. The Color inconstancy index is very helpful for selecting ink recipes. Metamerism also has a close relation with color inconstancy. In metameric pairs, samples usually have different color inconstancy indices[3].

"CMCCON02 formula"[8]**-** To calculate the color inconstancy index, the CMCCON02 formula was used. For calculation, CII degree of adaptation was considered equal to 1. Calculation steps are shown below.

Step 1) Calculate tristimulus values under source illuminant, CIE XYZ and L*a*b*c*h*.

Step 2) Use CAT02 formula and calculate CIE XYZ and L*a*b*c*h* values under destination illuminant.

Step 3) Calculate the color difference by CMC(2:2) color difference formula.

Experimental:

CIEL*a*b* values of Pantone® basic colors were taken from the Photoshop® Pantone® library. Measured values were taken from a new Pantone® book for Pantone® basic colors. In addition, ink drawdowns of Pantone® basic colors were received from Wikoff Color ink manufacturer, which were close to the standards of Pantone® basic color reproductions. Photoshop® provides CIEL*a*b* values at $D_{50/2}$ condition, so the $D_{50/2}$ illuminant/observer angle combination was selected for the experiment. By using reflectance data, CIEL*a*b* values were calculated for $D_{50/2}$, using equations 1 and 2. Color differences were calculated between different representations of the libraries.

Variables-

Instrument- x-Rite i1, Geometry – 45/0,

Filter – None, Software- ProfileMaker 5.0 MeasureTool,

Color Space-CIEL*a*b*, Apperture-3.4mm

UV component –on.

Color difference formula- CIE 1976

Results and Analysis

First, color differences between Photoshop values, Pantone book and ink drawdowns for particular shade were calculated (Figure 1).

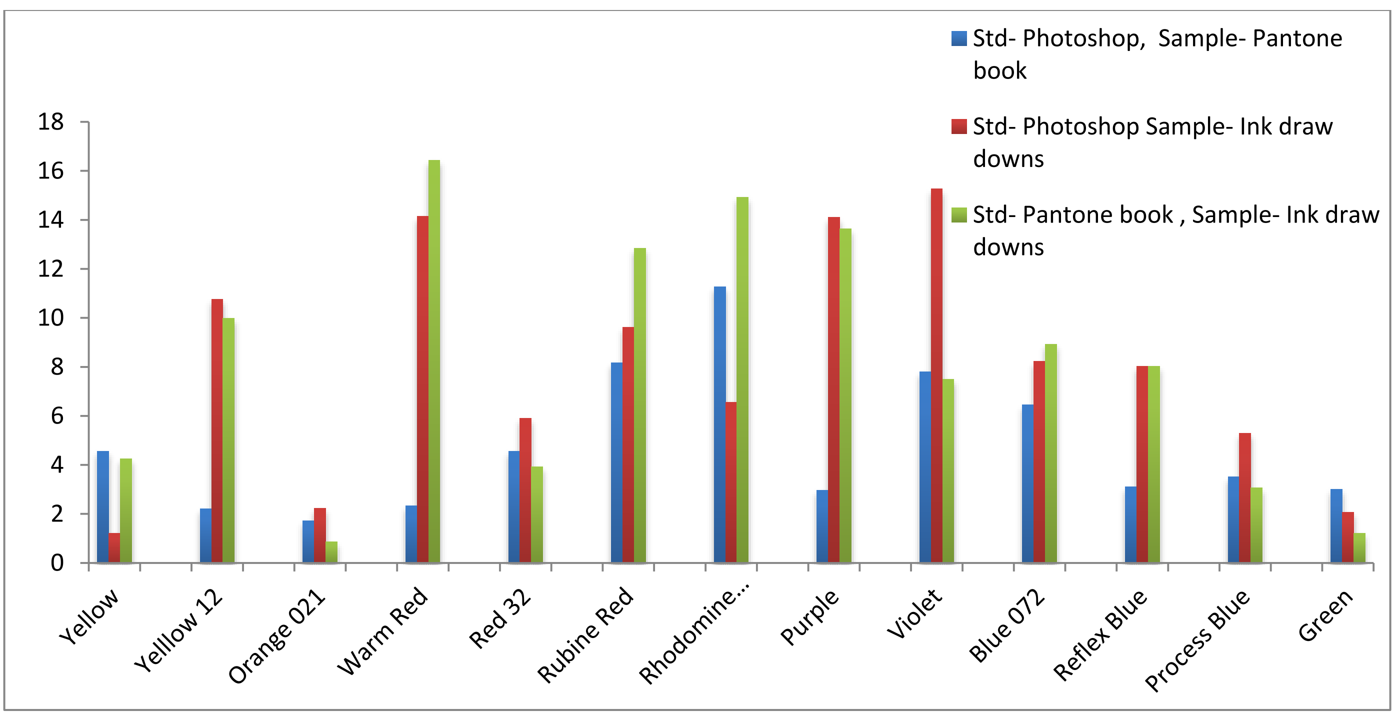

Figure 1 : Color difference in Pantone shades.

Table 1: CIEL*a*b* values and color difference.

	CIEL*a*b* values in different libraries			Color Differences		
Pantone Color	Photoshop® Library (1)	Printed Pantone® book (2)	Ink draw downs (3)	Sample 1 Sample 2	Sample 2 Sample 3	Sample 1 Sample-3
Yellow	89, -3, 112	89.12, -1.2, 107.81	88.13, -2.15, 111.83	4.56	4.25	1.22
Yellow 12	87, 4, 114	87.78, 2.05, 113.29	95.84, 4.42, 107.89	2.22	9.99	10.76
Orange 021	64, 62, 86	61.07, 64.75, 84.76	60.35, 64.31, 84.51	1.73	0.86	2.24
Warm Red	58, 70, 50	58.41, 69.95, 47.70	54.64, 72.65, 63.47	2.34	16.44	14.14
Red 32	54, 74, 46	54.57, 71.95, 41.97	52.57, 74.92, 40.34	4.56	3.92	5.9
Rubine Red	44, 77, 9	38.74, 70.79, 8.27	41.55, 78.45, 18.18	8.17	12.84	9.62
Rhodamine Red	52, 77,-16	43.84, 69.26, -15.36	49.50, 82.95, -17.17	11.27	14.93	6.56
Purple	48, 65, -42	50.06, 65.63, -44.03	41.75, 74.08, -50.78	2.96	13.64	14.1
Violet	24, 46, -66	19.51, 51.74, -68.79	15.31, 57.77, -70.33	7.8	7.5	15.26
Blue 072	20, 38, -78	15.62, 42.46, -76.41	16.48, 35.35, -71.05	6.45	8.93	8.22
Reflex Blue	19, 26,-68	16.98 27.93, -66.65	13.86, 32.16, -67.54	3.1	8.03	8.03
Process Blue	49, -33, -54	45.55, -33.61, -54.11	44.31, -31.55,-56.01	3.51	3.06	5.3
Green	58, -77, 2	59.28, -79.18, 3.63	59.34, -78.39, 2.72	3.01	1.2	2.07
Average color difference				4.74	8.11	7.96

Orange and green have lower color differences for all shades. Rhodamine and Rubine Red have very high color differences in between all libraries. The difference between Photoshop® libraries and ink draw downs in Yellow is acceptable. The average color difference between Photoshop® libraries and the Pantone® book is the least among color differences between different libraries. Large differences in lightness values account for much of the color difference, in many cases. In case of Yellow 12 the lightness difference between Photoshop® values and ink draw down is very high, so it shows a large color difference, but lightness difference between Photoshop® and printed Pantone book is less, which results in less color difference. Warm red and Green also show similar results. Warm red has the highest color difference between the printed Pantone® book and ink drawdowns.

The Metamerism index values are shown in Table 2.

Table 2: Metamerism index under different illuminant.

Metamerism Index			
Std: Pantone book	Sample: Ink draw downs		
Color	D_{50}→A	D_{50}→D_{65}	D_{50}→F_2
Yellow	2.7	1.06	0.73
Yellow 12	1.86	0.43	0.76
Orange 021	0.85	0.33	0.79
Warm Red	1.47	0.68	1.61
Red 32	2.53	1.02	1.41
Rubine Red	1.39	0.59	1.67
Rhodamine Red	2.72	1.06	1.19
Purple	4.72	1.53	3.19
Violet	4.78	1.84	1.03
Blue 072	1.6	0.4	0.74
Reflex Blue	1.6	0.44	1.25
Process Blue	1.59	0.52	0.66
Green	0.44	0.18	0.3
Average	2.17	0.74	1.17

Table 2 shows significant metamerism in $D_{50} \rightarrow A$. The least metamerism is found in Green, which is 0.44. In $D_{50} \rightarrow F_2$ five colors shows metamerism index < 1. The least metamerism is found in $D_{50} \rightarrow D_{65}$. Rhodamine, Purple and Violet show large metamerism. The reason for high metamerism could be their dominant and complementary wavelength nature, because they lie on the purple line of the chromaticity diagram. For that, analysis of the spectral reflectance graph is necessary.

Spectral Reflectance Curves

Reflectance spectra are helpful for understanding match and behavior of color, irrespective of illuminant and observer. Thus, spectral reflectance curves of Pantone inks and Pantone book colors were plotted from 380 nm to 730nm (Fig.2-14).

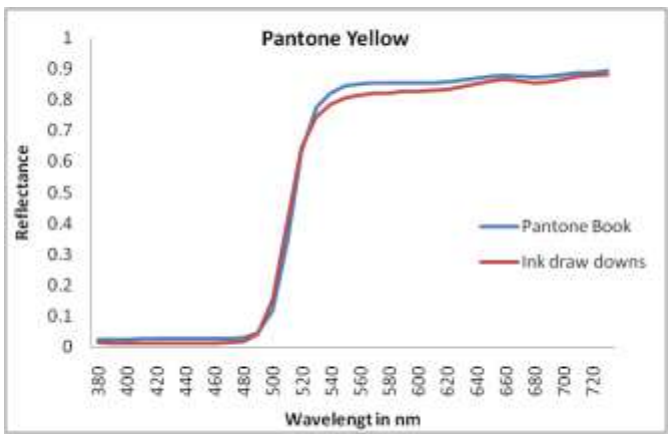

Figure 2: Reflectance graph of Pantone Yellow.

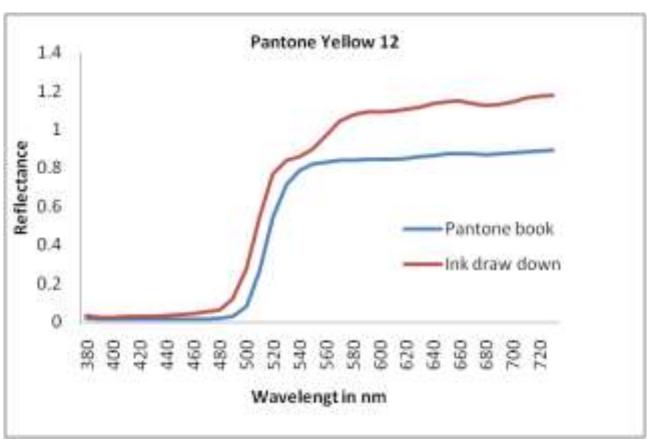

Figure 3: Reflectance graph of Pantone Yellow 012.

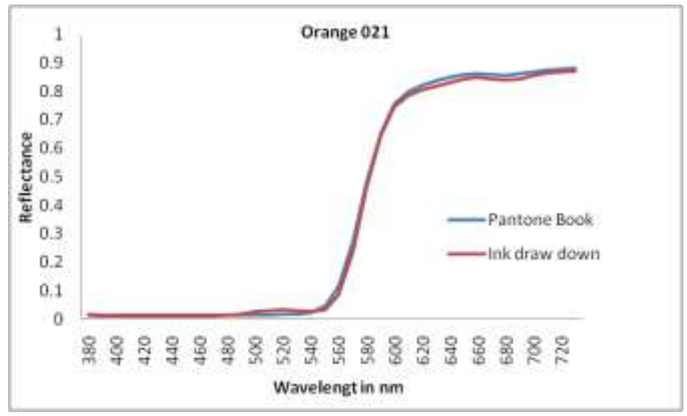

Figure 4: Reflectance graph of Pantone Orange 021.

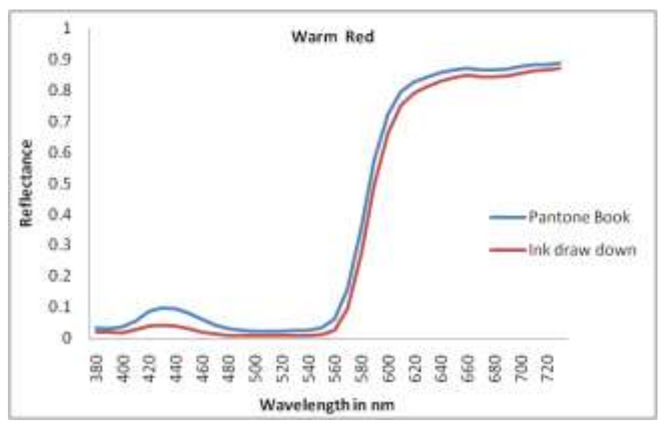

Figure 5: Reflectance graph of Pantone Warm Red.

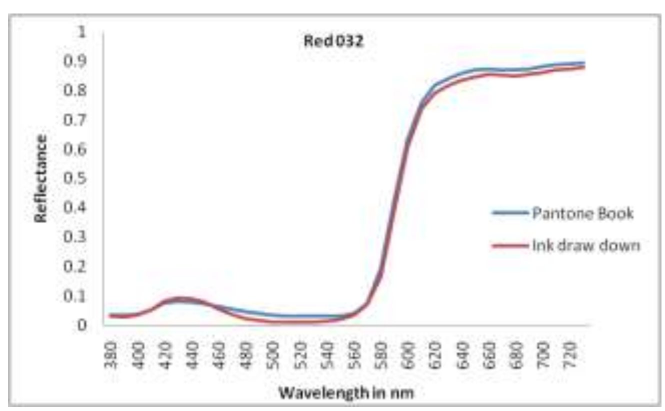

Figure 6: Reflectance graph of Pantone Red 032.

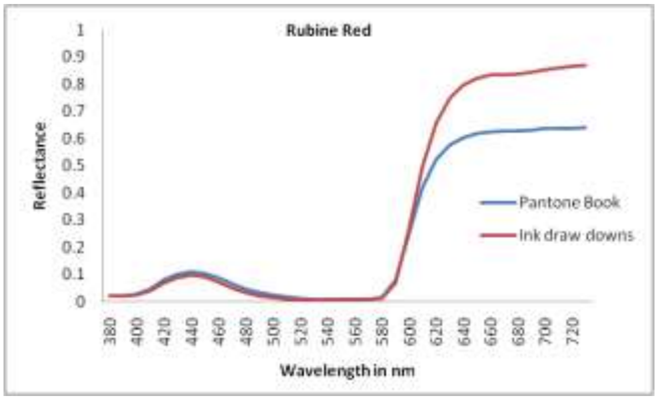

Figure 7: Reflectance graph of Rubine Red.

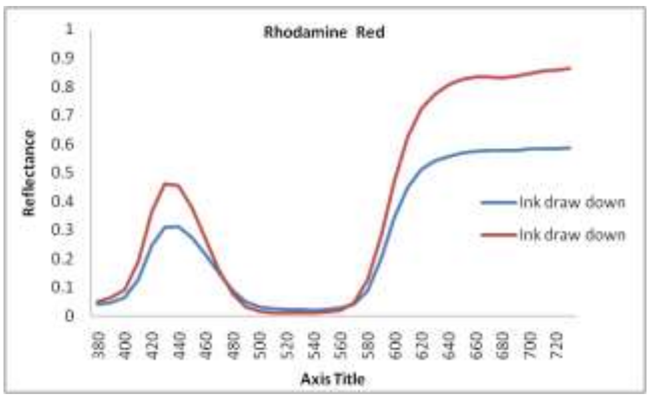

Figure 8: reflectance graph of Pantone Rhodamine Red

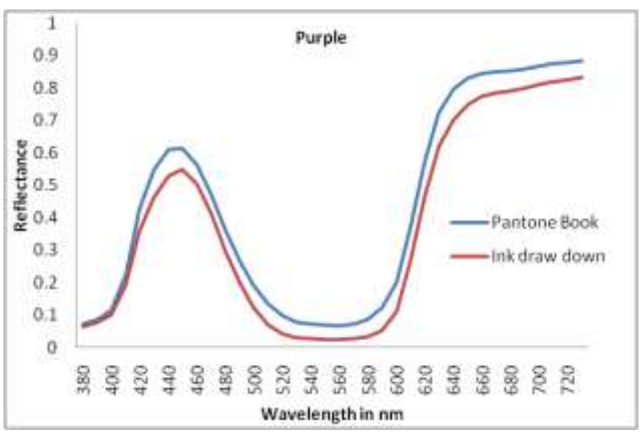

Figure 9: Reflectance graph of Pantone Purple.

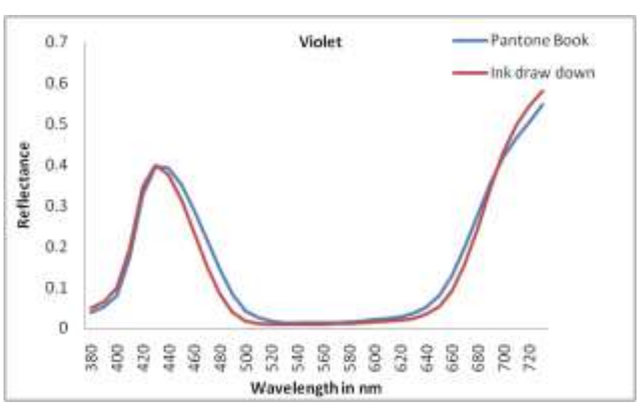

Figure 10: Reflectance graph of Pantone violet.

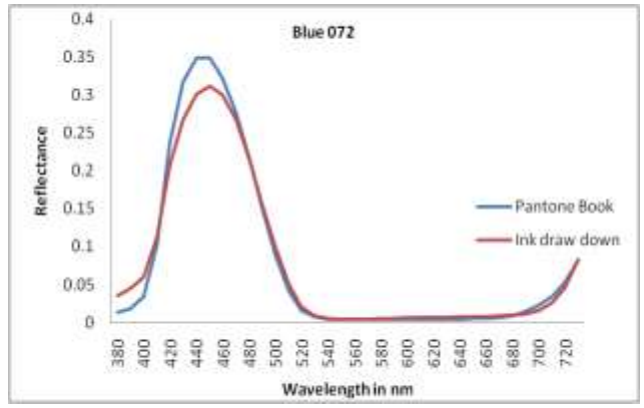

Figure 11: Reflectance graph of Pantone Blue 072.

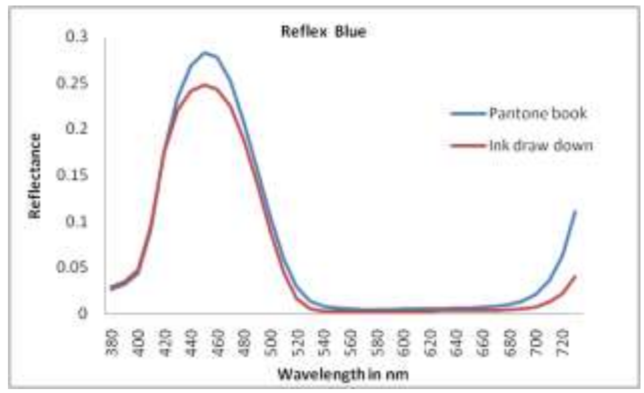

Figure 12: Reflectance graph of Pantone Reflex blue.

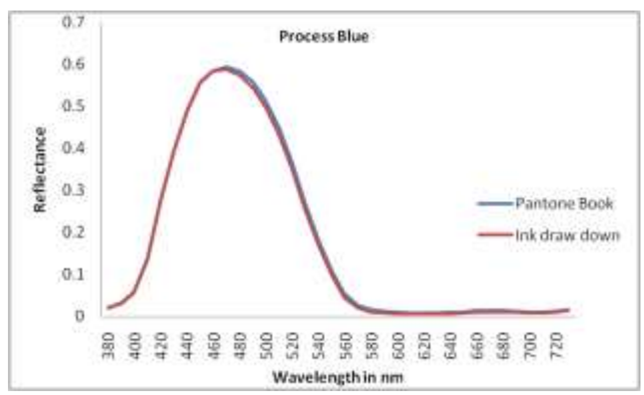

Figure 13: Reflectance graph of Pantone Process Blue.

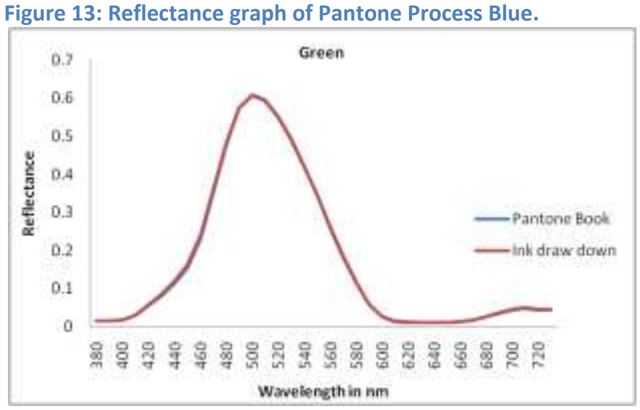

Figure 14: Reflectance graph of Pantone Green.

Figures 2-14 show that only Green is a nearly perfect spectral match and no metamerism under incandescent or fluorescent light. In the Orange and Process blue spectra, the sample graph follows the nature of the standard spectrum. The reflectance spectra of standard and sample cross each other in Red 032, Rubine Red, Violet, Rhodamine Red, and Blue 072 colors.

CII- As metameric ink has different inconstancy index, so color inconstancy index of Pantone basic colors from the Pantone book and ink draw downs were calculated and compared. Reflectance graphs of ink drawdowns and printed Pantone book have the same nature and considerable difference in CII was not found. The CII values are summarized in Figure 15.

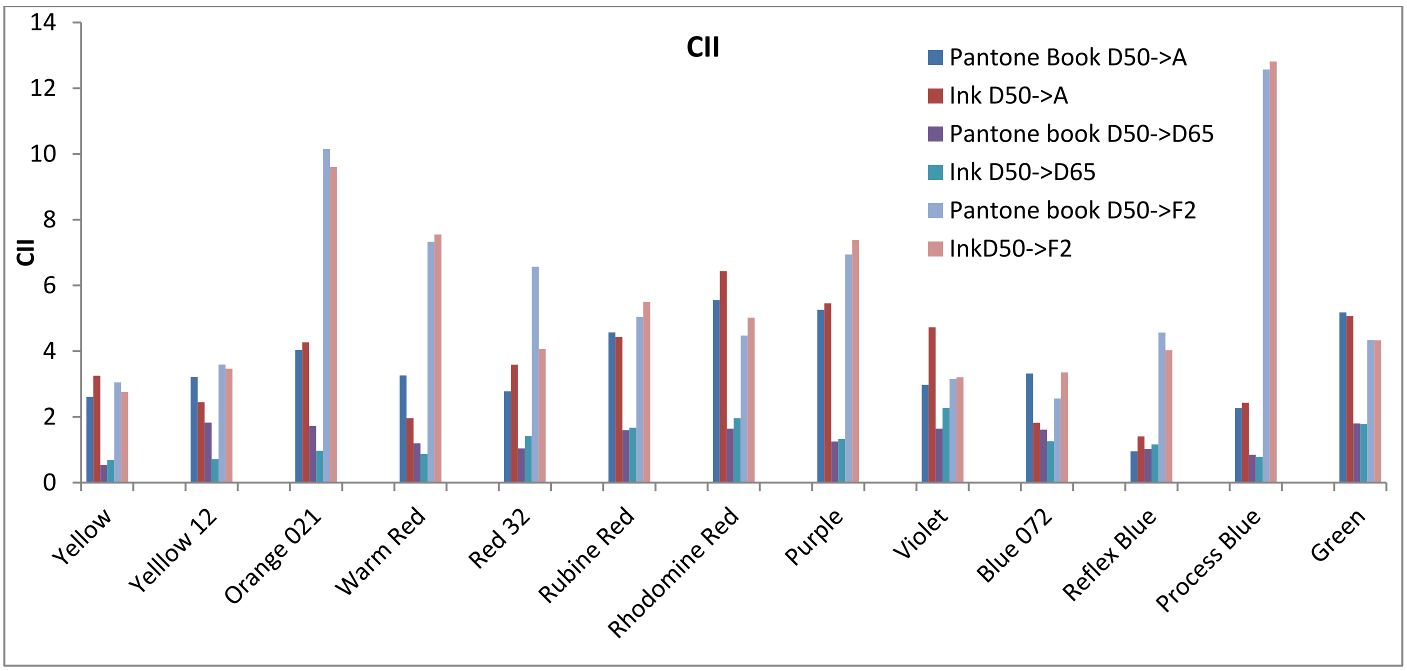

Figure 15: Comparison of CII of Pantone basic colors of different libraries

Table 3: Color inconstancy index calculated from Pantone book and ink draw downs for D50 to D65, F2 and A

CII- Pantone book and Ink draw downs								
	$D_{50}\rightarrow A$			$D_{50}\rightarrow D_{65}$			$D_{50}\rightarrow F_2$	
Color	Pantone book	Ink		Pantone book	Ink		Pantone book	Ink
Yellow	2.6115	3.2509		0.5372	0.6853		3.0509	2.7607
Yellow 12	3.2142	2.4493		1.828	0.7146		3.5926	3.4676
Orange 021	4.0371	4.2712		1.7241	0.9683		10.1465	9.6046
Warm Red	3.2641	1.9606		1.1984	0.8735		7.3254	7.5476
Red 32	2.782	3.5879		1.0445	1.4182		6.5666	4.0654
Rubine Red	4.5696	4.431		1.5974	1.6716		5.043	5.4964
Rhodamine Red	5.5557	6.4358		1.6425	1.9609		4.476	5.0187
Purple	5.2554	5.4548		1.2514	1.3319		6.9405	7.3824
Violet	2.9762	4.7277		1.6426	2.2765		3.1555	3.2096
Blue 072	3.32	1.822		1.6102	1.263		2.5635	3.3526
Reflex Blue	0.9576	1.4058		1.0255	1.1648		4.5671	4.031
Process Blue	2.2703	2.4315		0.8467	0.7786		12.5666	12.8132
Green	5.1805	5.0699		1.8014	1.783		4.3355	4.3334

When the nature of the reflectance graphs of the standard and sample is similar, then if the color difference is more and if the pair is metameric, then also there will be no significant difference in color inconstancy indices. The data show that when there is a large difference between Pantone libraries in Photoshop, Printed Pantone book and ink draw downs, there is no match in spectral graphs except green and Process Blue colors. This leads to slight metamerism in these pairs as well. The color inconstancy indices of the investigated colors in the printed Pantone book and ink library are similar because difference is negligible considering the high values of inconstancy indices.

Conclusion: Large unacceptable color differences, large Metamerism indices and reflectance graphs of the same color between different color libraries show no consistency in shade between libraries for color communication by using specified number or name. Thus, it is not reliable to communicate shades by Pantone® number for the Pantone® basic colors.

Acknowledgement

The authors are grateful for generous support from *Wikoff Color Corporation* and to the Omnova Solutions Foundation for partial financial support of this work.

Note

Photoshop® is registered trademark of *Adobe systems Incorporated.*

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