TOWARD A COLORIMETRIC SPECIFICATION FOR GAA GROUP VI/SWOP PROOFING AND PRODUCTION – PHASE II

James R. Huntsman* and John Souter*

Participants, GAA Colorimetric Ink Certification
and Combined Proofing Task Forces

Abstract

The need to characterize inks in a colorimetric fashion instead of densitometrically is long overdue in the United States, Europe having done so decades ago. The relationship between density measurements from a densitometer and color measurements from a colorimeter or spectrophotometer would be akin to "the weather and Thursday afternoon". The fact that there is weather on Thursday afternoons is the only relationship.

The GAA task forces responsible for colorimetric certification of Group VI/SWOP proofing and production inks report their findings to-date and make recommendations which could become the basis of a colorimetric specification for production and press proofing inks and off-press proofing systems. However, the implications of these findings and the recommendations must first be presented to the industry for evaluation. Areas such as sample preparation, measurement geometry, gloss, reproducibility among different instruments, and the principles of colorimetry need to be addressed so that a final specification will be useful. Having a colorimetric specification will not preclude the use of densitometers in printing, but rather will better define their proper use.

*3M Co., Printing & Publishing Systems Div.
Bldg. 209-2S-14, St. Paul, Minnesota 55144-1000

Introduction

A number of years ago, the printing industry in Europe realized that densitometry was inadequate, if not counterproductive, for assuring conformity and reproducibility in the color of printing inks. After extensive investigations, a colorimetric specification for one set of offset inks was set forth for Europe as CEI 1367. (In West Germany it is known as DIN 16539, and in the United Kingdom it is BS 4666. For international purposes it will be referenced as ISO 2846.) The purpose was not to force everyone to use only that set of inks but rather to ensure color reproducibility through colorimetric quality control for anyone making or using that particular set of inks. Densitometry still continued to be used, but as a means of *monitoring* an already colorimetrically specified and colorimetrically qualified ink set.

It is, therefore, somewhat surprising that in the United States, there is still no specification or even an agreed-upon (*de facto*) procedure for *colorimetrically* characterizing printing inks. Lacking such a colorimetric characterization, it is an inevitable consequence that unacceptable color reproduction will sometimes occur. The industry's GAA Group VI/SWOP specification did bring some degree of ink conformity through the use of a physical reference set. However, the occurrence of mismatches between prepress and production press reproductions even when adhering to Group VI/SWOP, showed that an ink qualification method based on ink solid density is inadequate.

An obvious consequence of the lack of a colorimetric specification faced almost daily by both gravure and offset printers is having differently scanned separations in the same imposition. If the scanners have different filter sets and are set up to different printing gamuts, none of which match the gamut to be used, it would be lucky indeed if each reproduction on that flat matched its offpress proof. At least with a colorimetrically defined gamut, scanners could be set up to reasonably match the specification.

Investigations have shown what colorimetry predicts – namely, that densitometry simply does not have the capability for characterizing and ensuring color reproduction accurately and reproducibly within the tolerance demanded by printing customers today. But then, densitometry was not designed for that purpose.

While colorimetric characterization of inks will not alone ensure accurate color reproduction, it will greatly minimize one source of color reproduction's many problems.

The use of "SWOP" in Group VI/SWOP, and throughout this paper refers to SWOP *inks* and not the SWOP *organization*, unless otherwise stated.

Color Reproduction

There are three fundamental principles of color reproduction necessary for acceptable results.

1. Match the color gamut with the inks and paper.
2. Match the tone reproduction capability of the press.
3. Maintain gray balance throughout tone reproduction.

If all these principles are met in a non-metameric way, an accurate color reproduction will occur, and the importance of the paper in implementing these principles cannot be overemphasized. In practice, the gamut of the original will be compressed for printing, non-linear tone scales will be piece-wise linearly approximated by color scanners, and gray balance will not always be truly maintained throughout. If the relevant variables are well characterized and consistent, a good color reproduction can be made, even on presses at different locations. A pre-press proof, designed to simulate a well characterized printing process, can predict the result and is often used as the criterion of acceptance. However, if all these principles are not followed because of the lack of a proper specification for the inks, paper, or off-press proofs, or because of non-adherence to a proper specification, acceptable color reproduction will be at best a matter of luck even when it does occur.

Densitometry and Colorimetry

Since acceptable color reproduction is always a visual judgment, an instrumental approach must correlate with visual perception. Densitometry has evolved from early camera color separation techniques where the separation filters' transmission characteristics were based on the separation films' colorants' spectral response, and not the human visual response. This fact was known then, so that such use of densitometry was never intended to correlate to visual response. That is why it was properly called densitometry instead of colorimetry. Densitometry was sufficient for the color reproduction capability of the colorants and presses of those days, but it is not sufficient for color specification and qualification for today's, let alone tomorrow's, demanding color reproduction fidelity.

It is usually overlooked that the ANSI Status T responses (ANSI PH2.18-1984, § 4.4) were intended for use in making color *separations* as part of a *photographic* reproduction process, not for evaluating a *print* from a four color, halftone process. It, therefore, does not necessarily follow that ANSI Status T filter responses are appropriate for evaluating lithographic or gravure reproductions, since the color characteristics of ink pigments are not the same as the dyes used in photography. Similarly, ANSI Status M responses (§ 4.3) are for evaluating *photographic* print film.

A specific deficiency in simulating a visual response is the inability of densitometer "red" filters to also match the "blue" region of the dual peak response of the CIE $\bar{x}$ color matching function. Cyan ink analysis will therefore be seriously affected. While a scaled portion of the densitometer's blue filter response is sometimes added to its red filter response in an attempt to approximate $\bar{x}$, such an approach can be no better than the extent to which the densitometer's red and blue filter responses match the CIE $\bar{x}$ and $\bar{z}$ functions. Consequences of densitometer filter response not corresponding to visual response can become even more problematic when narrow band (*e.g.*, 20 nm) filters are used.

This paper is not intended as a primer on colorimetry and color reproduction for which there are numerous treatises, for example, those by Hunt[1,2] and Yule[3]. One purpose is to emphasize that since colorimetry is intended to correlate to visual perception and small color differences, its use is far more likely to accomplish precise and accurate color reproduction than densitometry. However, one cannot use colorimetry complacently, presuming that it is not without its own restrictions and limitations[4]. Perceptual appearance is so complex and circumstantially dependent that methodology must be carefully defined and adhered to in order to have valid and useful results. Despite a reasonable level of scientific sophistication, colorimetry can be misused, leading to erroneous results. The principal objective of the task force efforts was to decide upon a colorimetric methodology appropriate for the printing industry that can be practically implemented. Ultimately, the scanning, pre-press proofing, and printing processes would be brought into harmony.

GAA Group VI/SWOP Colorimetric Specification

The initial impetus for a colorimetric ink specification was to better ensure the matching of press proofs and off-press proofs. The first investigation[5] was a colorimetric comparison of proofing press inks as they related to one another and to the Group VI/SWOP reference ink set as it is currently produced and distributed. The obvious question arising from that investigation became "What is the comparison of proofing press inks, the reference inks, and *production* inks?". As in the previous study[5] GATF prepared ink samples with an IGT AC2 Printability Tester and controlled the ink thickness to SWOP mid-range density with a Cosar 61 densitometer. The colorimetric analysis reported herein was based on integrating sphere geometry, specular component excluded, from 380 nm to 700 nm in 10 nm intervals. The CIELAB system was used for data analysis. It was found that, surprisingly, the distribution of production inks (Figures 1–4) was less varied than for the proofing press inks. Common to both investigations, however, was the fact that the Borden reference inks were significantly away from the center of the inks' distributions. Although unfortunate, this discrepancy should not be too surprising when one considers that the Borden reference inks were established about 15 years ago, while production inks have clearly changed over that time.

The obvious implication is that if the reference inks do not colorimetrically represent the population of production inks, proofs based on the reference ink colors will not likely be good predictors of production press output. Thus, the task forces faced not only the problem of establishing a colorimetric specification, but also whether to develop a new set of reference inks which accurately represented present day production inks. Given that reference inks must represent production inks if they are to have any utility, and one wishes to adhere to the principles of color reproduction, there is really no choice but to change the reference inks, since the alternative would be for ink manufacturers to change their production inks to match a reference set of inks at best based on production inks no longer used.

From the distribution of the production inks in CIELAB a^*b^* diagrams, boundaries were graphically determined which would encompass nearly all the production inks. Within the "wedge" formed by these boundaries, a centerpoint ("+"), representing the proposed new reference ink, was estimated, and its CIELAB L^*, a^*, and b^* values determined. The a^*b^* diagrams for the Y, M, C, and K inks are given in Figures 1–4. The legend in each figure contains the CIELAB L^*, a^*, and b^* values for the proposed new reference ink. The tolerance for each value was determined from the boundary lines of the wedge. Ink samples are now being formulated which will conform to the proposed colorimetric values so that they can be evaluated. At this time, there is NOT a new official reference ink set or a colorimetric specification. These results are only the basis of the next step toward a possible colorimetric specification of a reference color set, which needs complete support from all affected parties (*i.e.*, off-press proofing and ink manufacturers, publishers, agencies, printers, and separators).

Colorimetric Considerations for a Specification

A second part of the investigation was to compare off-press proofs with press proofs because although off-press proofs are not made via the lithographic printing process, they have become the dominant criteria for press matching and customer acceptance. Even though they utilize a variety of technologies, they must still represent a reproduction within the press's capability. A dazzling proof unachievable on a press is a source of frustration and "discussion". Therefore, a colorimetric analysis of both press and off-press proofs was undertaken for comparison. In doing so, a number of methodology factors arose which can affect the analysis and therefore have to be resolved in order to have a useful specification. The task forces chose the following areas to be considered initially in defining a colorimetric specification. Others might be added in the future.

1. Paper substrate
2. Measuring geometry for reflectance values
3. Spectral range and interval for reflectance values
4. Sample backing

5. Illuminant
6. Standard Observer functions
7. Density target and range
8. Density filter sets and computation

Paper

The importance of the paper in color reproduction cannot be overemphasized. It can be considered a primary color comparable to Y, M, C, and K, or as a fifth color. Furthermore, a colorimetric specification of the paper is not sufficient to predict the results of the ink on the paper. Its absorption and refractive properties are just as significant as its colorimetric values since colorimetric values will not indicate its tone reproduction characteristics. There are also many other paper properties relevant to the process which are beyond the scope of this report. However, some paper must be chosen.

The paper should:

1. Conform to that used for printing the reference samples.
2. Be non-fluorescing.
3. Be free from mechanical wood pulp.
4. Be non-thermochromic.
5. Be light fast.

Measurement Geometry

With numerous, well-known restrictions, it is said that if the tristimulus values of two similar samples match, the samples will appear the same. An exception to this can occur if the samples' reflectance spectra were obtained with different measurement geometries. There are different, accepted measurement geometries, which deal with the angle of incidence and collection of light, either usually about 0° and 45° for "collimated" light. If the incident and/or collected light is diffuse, it is indicated by a *d*. The use of diffuse light negates the need of an angle for it. Diffuse collection is usually called integrated collection, and should be done with a properly baffled integrating sphere. Incident geometry is designated first, and collection geometry is second, separated by a /.

Typical geometries are 0°/*d* for near-normal (*ca.* ± 5°) incident collimated light and integrating sphere collection, and 0°/45° for near-normal (*ca.* ± 5°) incident collimated light and collection along an axis 45° from normal with a small solid angle about the axis. Similarly, others are *d*/45° and 45°/0°. Usually, 0°/45° is used to refer to both 0°/45° and 45°/0° geometries, but it is bad practice. The true geometry should be known and reported with measurement data. Densitometer geometry is typically 0°/45°. Collection is done by a few discrete sensors or by circumferential integration.

Reflectance values determined by an integrating sphere are usually considered true reflectance; whereas, in non-integration collection, the reflectance values are considered reflectance factors. It seems totally overlooked that the Murray-Davies equation used for dot area calculation from density was derived based on integration collection, while in practice densitometer measurements are seldom, if ever, done in integration collection geometry.

The gloss of the sample's surface will greatly affect measurement results. Since, in viewing color reproductions, one usually positions the reproduction so that gloss is not perceived, the measurement geometry should reasonably reflect this viewing condition. When 0°/*d* integrating sphere is used, the specular component should be excluded and not included. Otherwise, the colorimetric values will have higher lightnesses and lower chromas and purities than perceived. Even though a matte surface diffusely scatters, the first surface reflection is also scattered so that integration collection even with specular component excluded will result in lower chromas and higher lightnesses than in 0°/45° since the first surface reflection comprises the spectrum of the incident light. The specular component will be much greater in 45°/0° than in 0°/45° from Snell's Law, especially for glossy samples. Tolerances for a 45° incident angle are, therefore, usually stricter than for a 0° incident angle or a 45° collection angle. Although calibration can reduce the incident angle effect so that 45°/0° and 0°/45° are equivalent, the refractive index and surface gloss of the calibration standard should be very similar to that of the samples being measured.

Since viewing is similar to 45°/0° measurement geometry, it is the preferred geometry. However, viewing lights are not collimated sources but rather somewhat diffuse so that a *d*/0° measurement geometry might also be suitable. The eye collects light not as an integrating sphere but within a cone of a small solid angle. However, the solid angle is larger than that allowed for 45° collection (*ca.* ± 5°) so that the eye's collection is between these two geometries.

Colorimetric parameters from integrating sphere (specular component excluded) and 45°/0° geometries are given in Table I for samples of press and off-press proofs measured with Diano Match Scan II and Color Scan II/45 spectrophotometers, respectively, with a *ca.* 6 mm sample aperture. The scan range is 380 nm to 700 nm in 10 nm intervals in both cases. From Table I, there is a tendency for glossy surfaces to have a smaller ΔE^* than the matte surfaces. This tendency occurs for the yellow, magenta, and black inks, but seems reversed for cyan ink.

Spectral Range and Interval

The CIE recommends[6] a range from 380 nm to 780 nm in an interval not greater than 5 nm. For very critical color matching such values are appropriate. However, for graphic arts, such resolution is usually not necessary, and practical values would be 380 nm to 700 nm in 10 nm intervals, which are available on nearly all commercial color analysis spectrophotometers. An interval of 20 nm will pose a problem if certain narrow band densities (*e.g.*, DIN 16536) are calculated from spectra, since the peak values for these blue and green filters are not at a 20 nm value. In any case, the range and interval should always be reported.

Colorimetric parameters from 45°/0° geometry from a Macbeth MS 4045 spectrophotometer are given in Table II. The scan range is 400 nm to 700 nm in 20 nm intervals. The targets measured in Table II are not the same as those in Table I. However, the targets in Tables I and II were taken from the same sheet. Thus, differences could be due to nonuniformity of the colors throughout the sheet rather than range and interval. Normal inter-instrument differences are also a factor. Solid blacks were not measured.

Sample Backing

For translucent papers, some light can be expected to be returned from the backing material which holds the sample and pass through the sample. To reduce this effect, a sample backing of an achromatic material having a density not less than 1.5 should be used in accordance with ISO 5/4 - 1983. A Munsell sample of N 2/ is equivalent. The effect of sample backing for the integrating sphere geometry for Table I is given in Table III.

Illuminant

The illuminant used to calculate the tristimulus values should be colorimetrically equivalent to that used for viewing. Since ISO 3664 and ANSI PH2.30 (1985) specify an illuminant equivalent to CIE D50 for viewing color reproductions, D50 is chosen as the illuminant for both viewing and tristimulus value calculation. While CIE D65 is a popular illuminant, especially in Europe, it is not the chosen standard for viewing and can lead to metamerism differences relative to D50.

Standard Observer

The CIE has two Standard Observers, a 2° and a 10°. The angle represents the angle of subtense used in the color matching experiments which determined the Standard Observer color matching functions $\bar{x}$, $\bar{y}$, and $\bar{z}$, which are each subscripted with the relevant angle. The angle correlates to an area of the fovea stimulated during viewing by a *homogeneous* color field of a given size at a given viewing distance. The choice of the 2° or 10° functions should be determined by the size and distance of the homogeneous samples being compared. For ink samples of 1" diameter or less, the 2° functions would be appropriate. For judging or measuring pictorial areas where there are relatively large areas of homogeneous color (*e.g.*, sky, water, grass, carpet, painted walls, etc.), the 10° functions would be more appropriate. In either case, the areas being judged should be properly masked with a neutral color, since surround colors will affect visual judgments. Unless otherwise stated, CIE illuminant D50 and the 10° Standard Observer are used for all data herein.

Figures 5 and 6 show the colorimetric effect for the four combinations of 2° and 10° Standard Observer and D50 and D65 illuminants applied to the spectrum of the current SWOP magenta mid-density sample in Table I, Sample 1, measured I.S./W. It is emphasized that it is not necessarily valid to compare colorimetric parameters for different illuminants on the same plot, since doing so implies perfect viewer adaptation to each illuminant, which might not be true. The ΔE^*_{ab} values among these data are given in Table IV, and they are not all negligible.

Table IV

ΔE^*_{ab} Values Among the Data for SWOP Magenta Mid Density in Fig.5.

	D50, 10°	D65, 2°	D65, 10°
D50, 2°	6.44	3.64	8.72
D50, 10°	0.	5.73	3.51
D65, 2°	0.	0.	6.48

Density Target and Range

The target solid density should be that of the reference sample which matches the colorimetric target. The range should conform to SWOP without allowing the printed ink to be outside the specification's colorimetric tolerances. The densitometer must always be calibrated in accordance with its manufacturer's instructions. Solid density values are not specified for any inks or paper and are to be considered as *relative* values for *comparison* between the reference inks and the inks used. Solid density values are to be used for process *monitoring* and control of a known ink and paper, and not as a means of color comparison.

Density Filter Sets and Computation

Filter sets, whether ANSI 2.18 Status A, M, and T, or DIN 16536, should be chosen on the basis of relevant applicability. The densitometer filters should measure at a wavelength complementary to the dominant wavelength of the inks for control of ink film thickness. Since a reflection densitometer is used to indicate ink film thickness and not measure color, filter sets which are affected by reflecting wavelengths will give density values lower than those sets not similarly affected. Since some "filters" are defined spectrally (*e.g.*, ANSI Status A, M, and T, DIN 16536, Wratten), densities can be calculated from the sample's reflectance spectrum. Whenever density values are reported, the instrument brand, model number, filter set, aperture size, and measurement geometry should be stated.

Table V gives ANSI Status T densities calculated from the spectra producing Table I's data and Status T densities determined by an X-Rite Model 418 densitometer which was calibrated to a GCA T–Ref card. The spectrally computed densities are from an author's (JRH) program and not from the instrument used. From Table V, it seems that there is good agreement between spectrally computed 45°/0° and densitometer (0°/45°) densities, except for yellows. The spectrally computed densities for integrating sphere reasonably agree with the other two when the sample is glossy. When the sample is matte, the integrating sphere densities are nearly always lower, again except for yellows, possibly because of integration of the first surface reflection due to yellow's opacity.

Large, bench-top spectrophotometers are not always convenient for real-time press evaluation, and "hand-held" spectrophotometers are now becoming available. Table VI gives the colorimetric data using a Gretag SPM100 hand-held spectrophotometer for the same samples as for Table I. The SPM100 utilizes 45°/0° geometry, has a scan range of 380 nm to 730 nm in 10 nm intervals, and uses a 3 mm sample aperture. Its density values are internally computed from the spectrum used to calculate colorimetric parameters. There are differences in the values obtained, which is to be expected, when different types of instruments are used, or even for different instruments of the "same" model. However, since the objective is the minimization of color *differences* and not the determination of accurate *absolute* numbers, the consistent use of good colorimetry methodology will accomplish that objective.

It is emphasized that the use of instrument brand and model names herein does not constitute a recommendation, nor even an inference, for these instruments or their manufacturers. Similarly, the absence of instrument brands or models herein is not a recommendation, nor even an inference, against such instrument brands or models. Instrument designation is given herein only for the sake of comparison of data and represents the instruments available to the investigators. Persons desiring to acquire instruments for the purposes described herein should contact representatives of the manufacturer of such instruments and determine the suitability of any instrument for the application intended.

Recommendations

The recommendations from the investigations to-date are relatively simple. First, a new set of Group VI/SWOP reference inks should be developed, which colorimetrically represents the production inks in use today. Second, a reference ink set should be used in conjunction with a consistent colorimetry methodology relevant to the color reproduction application. In the next phase, new possible reference inks will be evaluated in laboratory and press production testing regarding color, tone reproduction, and gray balance. In addition, visual discrimination studies will be used to determine realistic tolerances of acceptability.

Acknowledgements

The authors wish to make it known that much work by many persons and organizations have been involved in these investigations, and the results reported herein are only a part of the work done. Persons interested in the topics discussed herein or other topics should contact the task force chairman regarding availability of specific information.

GAA Group VI/SWOP Colorimetric Certification Task Force

John Souter – Chairman – 3M
Bill Sullivan* – SWOP Chairman – Southview Graphics
Vince Bellini* – General Printing Ink
Paul Borth* – International Pre-Press Association
Sam Colvin – 3M
Don Demarest – Young & Rubicam, Inc.
Joe Dooley – BASF Corp. – Inmont Div.
Dan Enright – General Printing Ink
Harvey George – Gravure Association of America
Joseph Gugliotta – BASF Corp. – Inmont Div.
Jim Huntsman – 3M
John Lind – Graphic Arts Technical Foundation

Chuck Rinehart – Eastman Kodak
Joel Rubin – Phototype Color Graphics
Bill Schaeffer* – Graphic Arts Technical Foundation
Ken Smith – E. I. DuPont DeNemours
Jim Tubay – R. R. Donnelley & Sons Co.
Gregory Tyszka – Gravure Association of America
Gustavo Vergara – Reader's Digest Association, Inc.
Paul Volpe – National Assoc. of Printing Ink Manufacturers

* = mailing list

GAA Group VI Combined Proofing Task Force

Chuck Rinehart – Chairman – Eastman Kodak

Bob Balzan – Krueger Ringier
Bill Cushman – Eastman Kodak
Don Demarest – Young & Rubicam, Inc.
Dan Enright – General Printing Ink
Dennis Garrison – Quad Graphics, Inc.
Jim Huntsman – 3M
Guenter Klaus – Meredith-Burda Graphics
Robert Oppenheimer – Gravure Association of America
Stan Pinover – Master Eagle
Joel Rubin – Phototype Color Graphics
Ken Smith – E. I. DuPont DeNemours
John Souter – 3M
Jim Tubay – R. R. Donnelley & Sons Co.
Gregory Tyszka – Gravure Association of America

Literature Cited

1. R. W. G. Hunt, *The Reproduction of Colour*, 4th Ed., Fountain Press, England, 1987.

2. R. W. G. Hunt, *Measuring Colour*, Halsted Press, 1987.

3. J. A. C. Yule, *Principles of Color Reproduction*, Wiley, 1967.

4. M. Pearson, "Image Reproduction Colorimetry", *Color Res. Appl.*, 11, 1, Spring 1986, pp.47–50.

5. "The Investigation of a Colorimetric Specification for GAA Group VI/S.W.O.P. Proofing Inks", GAA Task Force for Color Certification, TAGA 1988, pp.549–570.

6. *Colorimetry*, 2nd Ed., CIE Publication 15.2, 1986.

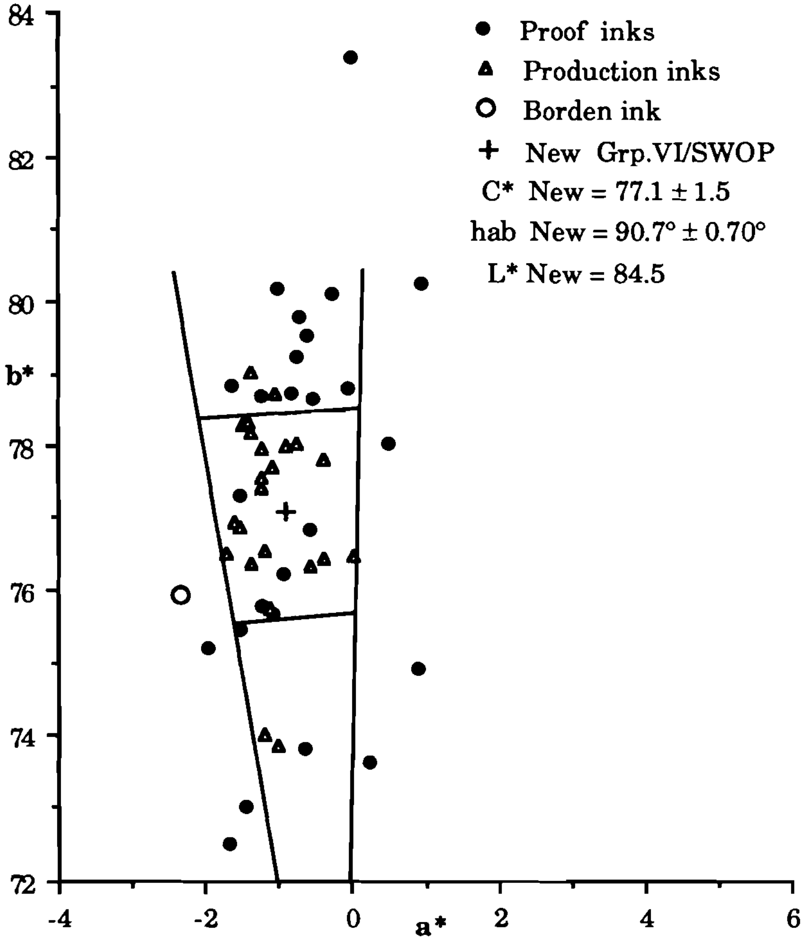

Figure 1. Distribution of proofing and production yellow inks.

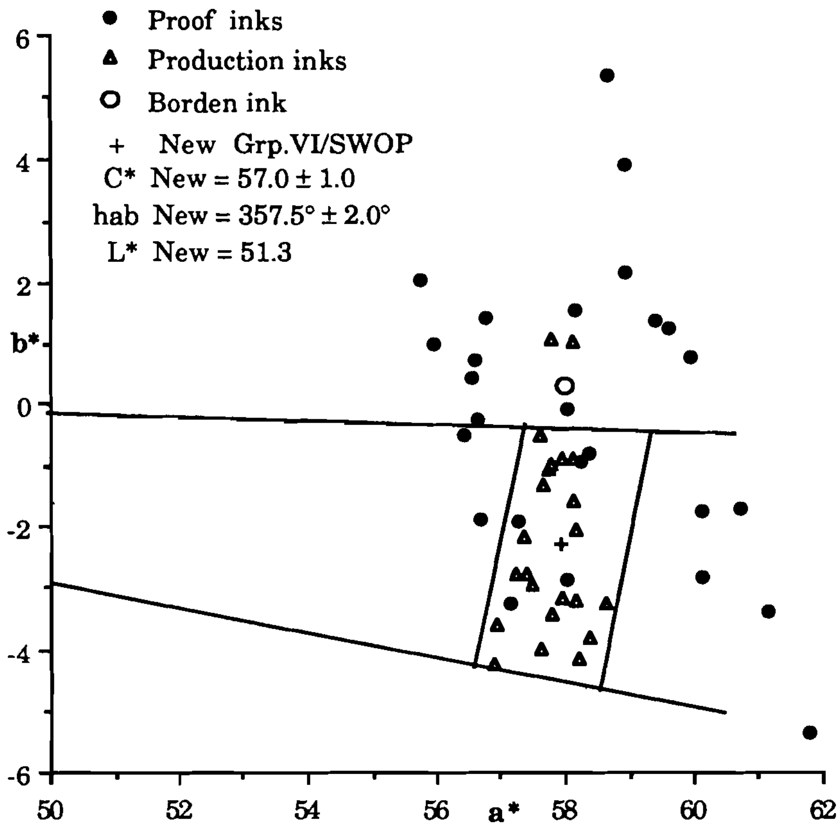

Figure 2. Distribution of proofing and production magenta inks.

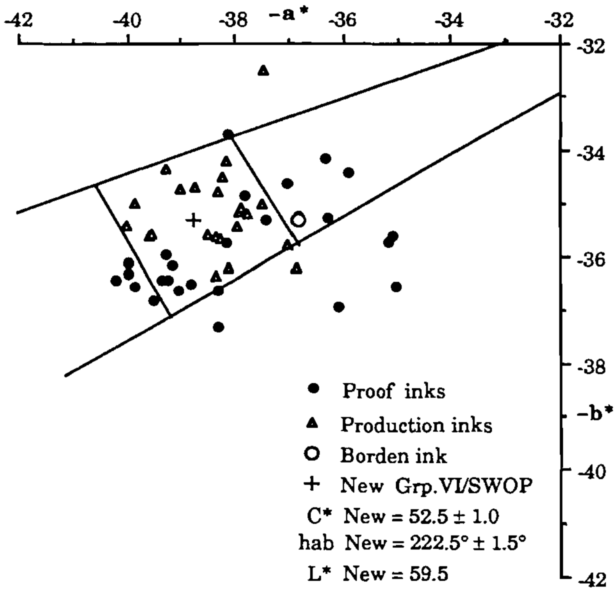

Figure 3. Distribution of proofing and production cyan inks.

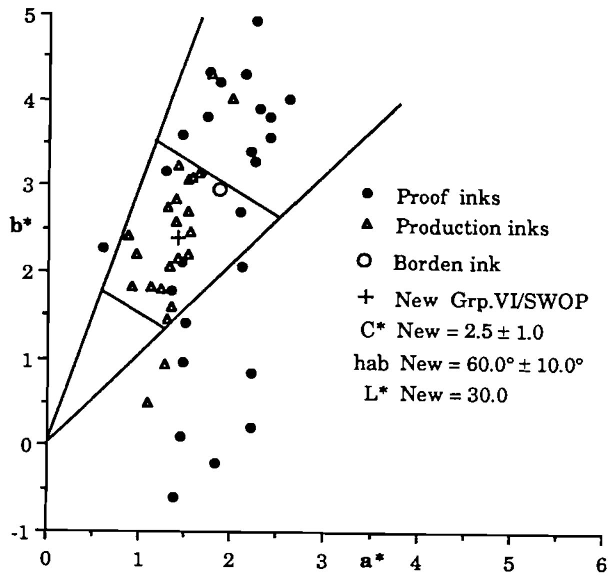

Figure 4. Distribution of proofing and production black inks.

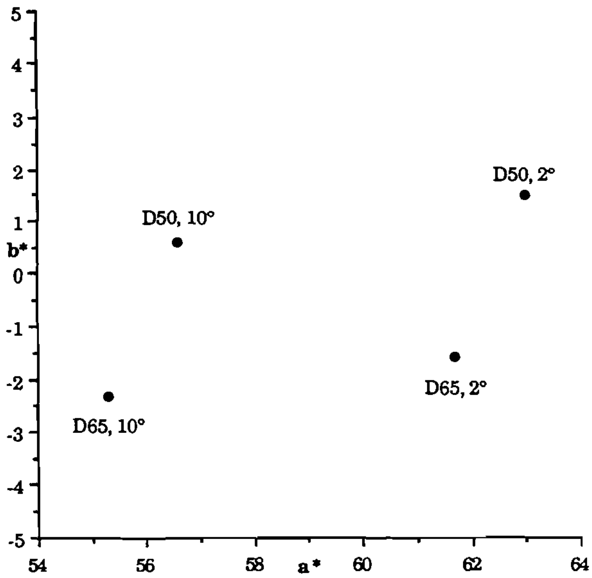

Figure 5. CIE a^*b^* distribution of SWOP magenta mid-density ink for combinations of D50 and D65 illuminants and 2° and 10° Standard Observers.

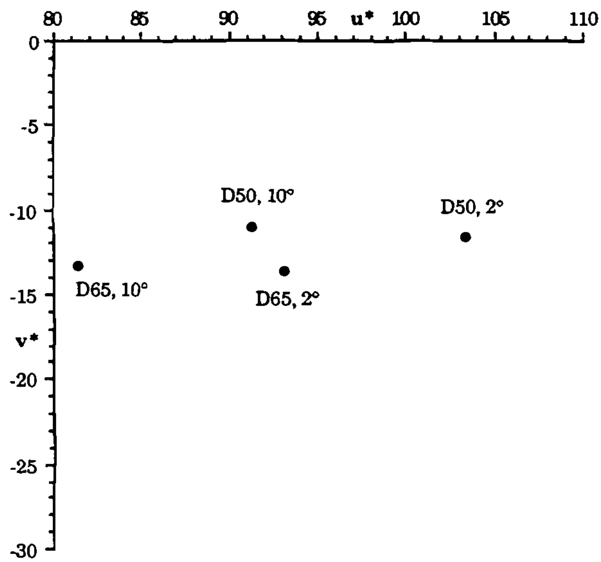

Figure 6. CIE u^*v^* distribution of SWOP magenta mid-density ink for combinations of D50 and D65 illuminants and 2° and 10° Standard Observers.

Table I

Comparison of Spectrophotometric Colorimetric Parameters from Integrating Sphere and 45°/0° Geometries, from 380 nm to 700 nm in 10 nm Intervals for Off-Press Proofs, Press Proofs and SWOP Press Proofs

		YELLOWS, I.S./W					YELLOWS, 45°/0°/K						
Spl.	T	L^*_{IS}	a^*_{IS}	b^*_{IS}	C^*_{IS}	h_{abIS}	$L^*_{45/0}$	$a^*_{45/0}$	$b^*_{45/0}$	$C^*_{45/0}$	$h_{ab45/0}$	ΔE^*	F
1	SM	84.06	-0.20	77.08	77.08	90.15	83.89	-2.31	84.44	84.47	91.57	7.66	M
2	SL	84.29	-1.02	72.44	72.45	90.81	83.78	-2.91	79.13	79.19	92.11	6.97	M
3	SH	84.00	0.25	79.82	79.82	89.82	83.14	-1.83	88.14	88.16	91.19	8.62	M
4	OP	84.60	-1.40	85.89	85.90	90.94	85.61	-3.39	84.68	84.75	92.29	2.54	G
5	OP	81.04	0.60	73.89	73.89	89.53	81.28	-1.66	76.74	76.75	91.24	3.65	M+
6	PP	83.35	-0.40	76.31	76.31	90.30	83.50	-2.62	82.82	82.86	91.81	6.88	M
7	OP	88.52	-0.48	85.21	85.21	90.32	90.42	-2.69	86.10	86.14	91.79	3.05	G
8	OP	Bad Sample; No Data Taken											
9	OP	85.32	-0.42	92.63	92.63	90.26	86.44	-2.66	89.87	89.91	91.70	3.73	G
10	OP	83.98	0.44	79.79	79.79	89.68	84.20	-1.67	82.33	82.35	91.16	3.31	M

Table I (cont.)

Spl.	T	YELLOWS, I.S./W					YELLOWS, 45°/0°/K						
		L^*_{IS}	a^*_{IS}	b^*_{IS}	C^*_{abIS}	h_{abIS}	$L^*_{45/0}$	$a^*_{45/0}$	$b^*_{45/0}$	$C^*_{ab45/0}$	$h_{ab45/0}$	ΔE^*	F
11	OP	83.55	0.15	78.56	78.56	89.89	84.01	-1.88	80.74	80.76	91.34	3.01	M
12	OP	88.46	0.74	86.55	86.56	89.51	89.48	-1.65	87.67	87.69	91.08	2.83	G
13	PP	83.80	0.15	74.28	74.28	89.88	83.16	-2.16	80.94	80.97	91.46	6.98	M
14	OP	85.90	1.35	80.48	80.49	89.04	86.98	-0.72	86.43	86.44	90.48	6.39	M
15	OP	88.18	-0.02	88.19	88.19	90.01	89.90	-2.23	89.53	89.56	91.43	3.10	G
16	OP	81.55	6.04	76.18	76.42	85.47	83.55	4.08	78.25	78.36	87.02	3.48	G
17	OP	85.86	-0.44	89.43	89.43	90.28	87.64	-2.98	90.17	90.22	91.89	3.19	G
18	OP	84.30	1.83	78.42	78.44	88.66	83.09	-1.07	79.83	79.83	90.77	3.44	M
19	OP	81.52	0.82	74.98	74.98	89.38	81.43	-1.51	77.80	77.81	91.11	3.66	M
20	OP	85.26	-0.44	91.47	91.47	90.28	86.58	-2.60	90.07	90.10	91.65	2.89	G
21	OP	88.95	2.41	87.65	87.68	88.42	89.39	-0.40	93.59	93.59	90.24	6.59	M
22	OP	85.55	-0.92	92.07	92.07	90.57	86.95	-3.07	89.04	89.09	91.97	3.97	G
23	PP	83.20	-0.63	70.88	70.88	90.51	83.70	-2.68	77.45	77.50	91.98	6.90	M
24	PP	83.27	-0.59	72.26	72.26	90.97	84.28	-2.65	79.32	79.36	91.92	7.42	M

Table I (cont.)

Spl.	T	MAGENTAS, I.S./W					MAGENTAS, 45°/0°/K						
		L^*_{IS}	a^*_{IS}	b^*_{IS}	C^*_{abIS}	h_{abIS}	$L^*_{45/0}$	$a^*_{45/0}$	$b^*_{45/0}$	$C^*_{ab45/0}$	$h_{ab45/0}$	ΔE^*	F
1	SM	53.20	56.58	0.58	56.59	0.59	50.99	61.48	0.03	61.48	0.03	5.40	M
2	SL	54.03	55.55	-0.36	55.55	359.63	51.75	60.70	-1.07	60.71	358.99	5.68	M
3	SH	52.01	57.87	2.36	57.91	2.33	49.31	63.67	1.84	63.69	1.65	6.42	M
4	OP	47.26	58.26	4.25	58.42	4.17	48.99	60.75	5.62	61.01	5.28	3.33	G
5	OP	48.82	55.68	1.77	55.71	1.82	48.36	58.52	3.84	58.64	3.75	3.54	M+
6	PP	48.03	60.01	2.41	60.06	2.30	46.45	64.85	2.87	64.91	2.54	5.11	M
7	OP	51.46	62.90	2.07	62.94	1.89	53.71	65.52	3.35	65.61	2.93	3.68	G
8	OP	50.57	55.67	2.94	55.75	3.02	48.70	60.73	5.54	60.98	5.21	5.99	M
9	OP	47.10	60.99	3.95	61.11	3.70	48.94	62.76	5.25	62.98	4.78	2.87	G
10	OP	49.49	59.34	2.14	59.38	2.07	49.16	62.49	4.23	62.64	3.87	3.79	M
11	OP	48.98	59.87	2.46	59.93	2.35	48.75	62.91	4.72	63.09	4.29	3.80	M
12	OP	49.81	62.28	3.05	62.35	2.80	51.02	63.36	5.20	63.57	4.70	2.69	G
13	PP	51.08	56.71	-0.13	56.71	359.87	49.42	60.43	0.48	60.43	0.46	4.12	M
14	OP	51.22	55.07	1.58	55.10	1.65	50.47	60.67	4.42	60.83	4.17	6.32	M
15	OP	50.45	64.02	3.19	64.10	2.85	52.47	66.04	4.59	66.20	3.98	3.18	G

Table I (cont.)

Spl.	T	MAGENTAS, I.S./W					MAGENTAS, 45°/0°/K						
		L^*_{IS}	a^*_{IS}	b^*_{IS}	C^*_{abIS}	h_{abIS}	$L^*_{45/0}$	$a^*_{45/0}$	$b^*_{45/0}$	$C^*_{ab45/0}$	$h_{ab45/0}$	ΔE^*	F
16	OP	49.35	60.03	-4.26	60.18	355.94	51.37	62.40	-3.74	62.51	356.57	3.16	G
17	OP	47.13	63.56	3.54	63.66	3.18	49.20	65.51	4.99	65.70	4.36	3.19	G
18	OP	49.67	60.28	3.57	60.39	3.39	48.48	62.70	4.89	62.89	4.46	3.00	M
19	OP	48.89	55.51	2.47	55.57	2.55	48.25	58.31	4.56	58.49	4.47	3.55	M
20	OP	46.90	61.19	4.05	61.32	3.79	48.91	62.70	5.51	62.94	5.02	2.91	G
21	OP	49.70	58.43	1.13	58.44	1.11	49.34	62.69	4.38	62.84	4.00	5.37	M
22	OP	45.83	63.44	4.37	63.60	3.94	47.92	65.01	5.58	65.24	4.90	2.88	G
23	PP	51.47	54.06	-2.21	54.11	357.66	50.49	59.32	-0.11	59.32	359.90	5.75	M
24	PP	50.00	57.34	-1.34	57.36	358.66	49.26	62.23	0.67	62.23	0.61	5.34	M

Table I (cont.)

		CYANS, I.S./W					CYANS, 45°/0°/K						
Spl.	T	L^*_{IS}	a^*_{IS}	b^*_{IS}	C^*_{abIS}	h_{abIS}	$L^*_{45/0}$	$a^*_{45/0}$	$b^*_{45/0}$	$C^*_{ab45/0}$	$h_{ab45/0}$	ΔE^*	F
1	SM	59.26	-40.26	-33.51	52.38	219.77	56.67	-39.36	-38.34	54.95	224.25	5.55	M
2	SL	60.80	-39.25	-32.45	50.93	219.58	58.31	-38.91	-37.36	53.94	223.83	5.52	M
3	SH	59.02	-40.27	-34.16	52.81	220.31	56.25	-39.89	-39.34	56.02	224.61	5.89	M
4	OP	53.37	-37.50	-32.49	49.62	220.91	53.18	-34.30	-38.93	51.88	228.62	7.19	G
5	OP	55.65	-37.86	-33.28	50.40	221.32	52.96	-36.41	-37.91	52.56	226.16	5.55	M+
6	PP	61.67	-38.37	-31.86	50.03	219.55	59.05	-37.86	-36.22	52.40	223.73	5.11	M
7	OP	57.23	-43.32	-33.95	55.04	218.09	57.06	-39.29	-40.74	56.60	226.04	7.90	G
8	OP	56.89	-36.57	-37.21	52.17	225.50	54.42	-36.19	-42.28	55.66	229.44	5.65	M
9	OP	54.59	-40.37	-33.29	52.33	219.52	53.99	-36.49	-39.40	53.70	227.20	7.26	G
10	OP	57.43	-38.69	-36.04	52.87	222.97	55.44	-37.10	-40.60	55.00	227.58	5.22	M
11	OP	57.61	-38.40	-35.70	52.43	222.91	55.54	-36.51	-40.22	54.31	227.77	5.32	M
12	OP	58.84	-41.77	-40.38	58.10	224.04	57.93	-37.97	-45.49	59.25	230.15	6.43	G
13	PP	61.98	-37.70	-30.71	48.62	219.16	59.43	-37.69	-35.16	51.55	223.01	5.13	M
14	OP	57.62	-39.37	-32.42	51.00	219.47	55.02	-40.41	-37.48	55.12	222.85	5.78	M
15	OP	56.09	-44.25	-34.73	56.25	218.13	55.71	-39.78	-41.33	57.36	226.10	7.98	G

Table I (cont.)

Spl.	T	CYANS, I.S./W					CYANS, 45°/0°/K						
		L^*_{IS}	a^*_{IS}	b^*_{IS}	C^*_{abIS}	h_{abIS}	$L^*_{45/0}$	$a^*_{45/0}$	$b^*_{45/0}$	$C^*_{ab45/0}$	$h_{ab45/0}$	ΔE^*	F
16	OP	56.70	-39.03	-32.54	50.81	219.82	56.57	-35.34	-39.14	52.73	227.92	7.56	G
17	OP	55.08	-42.44	-30.89	52.49	216.04	54.60	-38.73	-37.38	53.83	223.98	7.49	G
18	OP	56.68	-37.98	-37.35	53.26	224.52	53.45	-35.67	-42.57	55.54	230.04	6.56	M
19	OP	55.98	-37.77	-32.37	49.74	220.60	53.63	-36.57	-37.17	52.15	225.47	5.48	M
20	OP	54.13	-40.65	-33.17	52.47	219.22	53.60	-36.92	-39.24	53.88	226.75	7.14	G
21	OP	59.83	-40.33	-37.78	55.27	223.13	57.71	-39.12	-42.70	57.91	227.51	5.49	M
22	OP	52.20	-41.02	-34.24	53.43	219.85	51.82	-35.97	-39.82	53.66	227.91	7.54	G
23	PP	54.32	-38.51	-36.48	53.05	223.44	51.98	-37.78	-41.53	56.15	227.71	5.61	M
24	PP	54.95	-39.18	-36.98	53.88	223.35	52.96	-38.16	-41.65	56.49	227.51	5.18	M

Table I (cont.)

Spl.	T	BLACKS, I.S./W L^*_{IS}	a^*_{IS}	b^*_{IS}	C^*_{abIS}	h_{abIS}	BLACKS, 45°/0°/K $L^*_{45/0}$	$a^*_{45/0}$	$b^*_{45/0}$	$C^*_{ab45/0}$	$h_{ab45/0}$	ΔE^*	F
1	SM	31.40	1.97	4.04	4.49	64.02	24.99	1.11	1.99	2.28	60.91	6.78	M
2	SL	35.17	1.77	4.04	4.41	66.34	27.65	1.10	2.38	2.62	65.22	7.73	M
3	SH	31.61	2.07	4.08	4.57	63.07	23.02	1.09	1.88	2.18	59.91	8.92	M
4	OP	23.32	0.38	1.11	1.17	71.02	22.73	1.04	-0.76	1.29	323.80	2.07	G
5	OP	20.44	0.65	0.59	0.88	42.46	16.63	0.90	1.00	1.35	48.07	3.84	M+
6	PP	27.74	1.82	3.22	3.70	60.56	18.71	0.94	0.74	1.19	37.96	9.41	M
7	OP	19.70	0.50	1.46	1.54	71.18	20.09	1.30	-1.69	2.13	307.71	3.27	G
8	OP	22.75	-0.04	0.84	0.84	92.58	16.11	0.55	0.73	0.92	53.16	6.67	M
9	OP	18.72	0.38	1.31	1.36	73.90	18.93	1.10	-1.19	1.62	312.65	2.61	G
10	OP	25.08	0.09	2.57	2.58	87.89	22.19	0.52	1.59	1.68	72.06	3.08	M
11	OP	26.70	0.09	2.63	2.64	88.11	23.45	0.54	1.74	1.82	72.71	3.40	M
12	OP	15.52	0.48	-0.18	0.51	339.51	14.77	0.61	0.97	1.14	57.56	1.38	G
13	PP	27.63	1.84	3.96	4.37	65.06	21.06	1.48	2.37	2.79	57.94	6.77	M
14	OP	25.96	-0.86	1.91	2.09	114.28	18.88	-1.27	0.31	1.31	166.12	7.27	M
15	OP	19.69	0.53	1.68	1.76	72.39	20.15	1.35	-1.60	2.10	310.20	3.41	G

Table I (cont.)

		BLACKS, I.S./W					BLACKS, 45°/0°/K						
Spl.	T	L^*_{IS}	a^*_{IS}	b^*_{IS}	C^*_{abIS}	h_{abIS}	$L^*_{45/0}$	$a^*_{45/0}$	$b^*_{45/0}$	$C^*_{ab45/0}$	$h_{ab45/0}$	ΔE^*	F
16	OP	21.63	0.48	1.59	1.66	73.37	22.06	1.21	-1.29	1.76	313.14	3.00	G
17	OP	20.14	0.52	1.50	1.59	70.85	20.62	1.27	-1.54	1.99	309.61	3.17	G
18	OP	25.34	0.23	2.17	2.18	83.92	20.73	0.69	1.35	1.52	63.03	4.70	M
19	OP	19.68	0.52	0.57	0.77	47.80	15.38	0.94	0.80	1.23	40.63	4.33	M
20	OP	18.64	0.42	1.36	1.42	72.93	18.57	1.10	-1.00	1.49	317.67	2.46	G
21	OP	22.03	-0.24	3.16	3.17	94.36	18.49	-0.66	3.14	3.21	101.82	3.56	M
22	OP	20.76	0.56	1.16	1.29	64.01	20.80	1.50	-2.54	2.95	300.56	3.82	G
23	PP	25.97	1.67	2.02	2.62	50.33	17.01	0.25	-0.34	0.42	305.76	9.37	M
24	PP	23.26	1.45	1.65	2.20	48.80	16.04	0.04	-0.41	0.42	275.09	7.64	M

T = Type: SM= SWOP Mid; SL = SWOP Low; SH = SWOP High; OP = Off-Press Proof; PP = Press Proof.

I.S./W = Integrating sphere, specular component excluded, white (ceramic) backing.
45°/0°/K = 45°/0°, matte black backing (Munsell N 2/).

Table II

Comparison of Spectrophometric Colorimetric Parameters from 45°/0° Geometry, 400 nm to 700 nm in 20 nm Intervals with White Backing for Off-Press Proofs, Press Proofs and SWOP Press Proofs

		YELLOWS, 45°/0°/W					MAGENTAS, 45°/0°/W				
Spl.	T	L*	a*	b*	C^*_{ab}	h_{ab}(°)	L*	a*	b*	C^*_{ab}	h_{ab}(°)
1	SM	83.1	0.7	86.7	86.7	90.	48.6	61.	0.1	61.	0.
2	SL	83.2	0.2	83.1	83.1	90.	49.3	60.3	-1.1	60.3	359.
3	SH	85.1	1.2	92.8	92.8	89.	47.3	62.6	2.4	62.6	2.
4	OP	84.8	-0.8	83.1	83.1	91.	47.7	58.7	0.7	58.7	1.
5	OP	80.4	1.7	79.4	79.4	89.	47.1	57.2	2.5	57.3	3.
6	PP	83.1	0.2	81.6	81.6	90.	46.5	60.9	-0.2	60.9	0.
7	OP	89.6	-0.5	84.9	84.9	90.	52.6	62.1	-3.	62.2	357.
8	OP	83.7	2.1	82.5	82.6	89.	47.4	59.3	3.7	59.4	4.
9	OP	86	0.3	88.5	88.6	90.	48.3	59.8	-1.	59.9	359.
10	OP	83.6	2.2	85.1	85.1	88.	47.5	61.	3.4	61.1	3.

Table II (cont.)

		YELLOWS, 45°/0°/W					MAGENTAS, 45°/0°/W				
Spl.	T	L*	a*	b*	C^*_{ab}	h_{ab}(°)	L*	a*	b*	C^*_{ab}	h_{ab}(°)
11	OP	82.9	2.	84.7	84.7	89.	47.0	61.1	3.6	61.2	3.
12	OP	87.5	2.	87.7	87.7	89.	50.1	61.5	2.9	61.6	3.
13	PP	82.5	0.8	83.6	83.6	89.	47.4	60.6	0.	60.6	0.
14	OP	84.5	2.1	87.4	87.4	89.	48.5	58.	2.9	58.1	3.
15	OP	88.8	-0.1	87.2	87.2	90.	51.4	62.7	-1.6	62.7	359.
16	OP		No	Sample				No	Sample		
17	OP		No	Sample				No	Sample		
18	OP	83.3	3.3	82.9	82.9	88.	47.7	61.5	4.6	61.7	4.
19	OP	80.2	1.7	79.	79.1	89.	46.5	57.1	3.4	57.2	3.
20	OP	86.5	0.4	89.5	89.5	90.	47.4	60.7	-0.1	60.7	0.
21	OP	88.2	3.4	94.9	95.	88.	48.2	60.3	2.4	60.4	4.
22	OP	85.6	-0.3	87.4	87.4	90.	46.3	62.6	-1.3	62.6	359.
23	PP	80.5	-0.3	76.3	76.3	90.	47.2	61.5	2.8	61.6	3.
24	PP		No	Sample				No	Sample		

Table II (cont.)

CYANS, 45°/0°/W

Spl.	T	L*	a*	b*	C^*_{ab}	h_{ab}(°)
1	SM	57.3	-43.1	-34.	54.9	218.
2	SL	57.6	-43.	-34.	54.8	218.
3	SH	55.8	-44.	-35.5	56.6	219.
4	OP	54.4	-38.	-34.3	51.2	222.
5	OP	54.1	-40.2	-33.9	52.6	220.
6	PP	57.7	-42.6	-34.2	54.6	219.
7	OP	57.5	-43.5	-38.3	57.9	221.
8	OP	55.2	-39.	-37.6	54.1	224.
9	OP	55.7	-40.6	-35.9	54.2	222.
10	OP	55.8	-40.9	-36.1	54.6	221.
11	OP	55.1	-41.2	-36.4	54.9	221.
12	OP	57.3	-42.1	-42.3	59.6	225.
13	PP	59.1	-41.5	-31.2	52.	217.
14	OP	54.5	-43.	-33.1	54.3	218.
15	OP	57.	-43.3	-37.7	57.4	221.
16	OP		No	Sample		
17	OP		No	Sample		
18	OP	54.4	-40.5	-37.	54.8	222.
19	OP	53.9	-39.7	-32.7	51.5	219.
20	OP	55.3	-40.3	-35.3	53.6	221.
21	OP	58.4	-42.5	-38.2	57.1	222.
22	OP	53.	-40.6	-37.3	55.1	223.
23	PP	54.2	-40.9	-34.4	53.4	220.
24	PP		No	Sample		

T = Type: SM= SWOP Mid; SL = SWOP Low; SH = SWOP High; OP = Off-Press Proof; PP = Press Proof.

45°/0°/W = 45°/0° measurement geometry, white backing. Blacks were not measured.

The samples measured here were from the same sheet as the samples in Table I but were not the same samples as used for Table I.

Table III

Effect of White (/W) vs. Black (/K) Sample Backing on Colorimetric Calculations

(a) Effect of Backing on the Paper Itself

Paper/backing	L*	a*	b*	C^*_{ab}	h_{ab}(°)	ΔE*
King James (cover)/W	93.13	0.16	3.57	3.57	87.37	0.88
King James (cover)/K	92.55	–0.06	2.94	2.94	91.12	0.
Becket Hi-White (cover)/W	96.71	–0.06	2.87	2.87	91.25	0.57
Becket Hi-White (cover)/K	96.32	–0.16	2.47	2.48	93.65	0.
Navajo Ultra White (cover)/W	96.80	–0.29	2.35	2.36	96.97	0.95
Navajo Ultra White (cover)/K	96.03	–0.28	1.80	1.83	98.72	0.
Reflections (offset)/W	94.30	–0.05	2.84	2.84	90.98	1.66
Reflections (offset)/K	93.13	–0.42	1.72	1.77	103.69	0.
Adproof (offset)/W	89.07	–0.28	4.52	4.53	93.54	3.06
Adproof (offset)/K	86.70	–0.70	2.63	2.72	104.80	0.
Textweb (offset)/W	88.47	–0.39	4.99	5.01	94.51	1.56
Textweb (offset)/K	87.53	–0.89	3.85	3.95	102.97	0.
White backing (ceramic)	91.98	–0.95	0.84	1.27	138.52	72.2
Black backing (Munsell N 2/)	19.79	0.00	–0.20	0.20	90.00	0.

Table III (cont.)

(b) Effect of Backing on Printed Gravure Inks

Color/backing	L*	a*	b*	C^*_{ab}	$h_{ab}(°)$	ΔE*
Yellow/W	81.89	5.60	81.68	81.87	86.08	5.01
Yellow/K	79.26	3.75	77.84	77.93	87.25	0.
Magenta/W	48.10	56.88	–1.86	56.91	358.13	3.80
Magenta/K	46.50	54.01	–3.77	54.14	356.00	0.
Cyan/W	50.09	–30.68	35.24	46.72	228.95	1.69
Cyan/K	49.15	–29.30	35.50	46.03	230.47	0.
Red/W	45.87	57.27	37.64	68.53	33.31	3.52
Red/K	44.38	54.65	35.83	65.35	33.25	0.
Green/W	41.98	–42.83	21.83	48.08	153.00	1.41
Green/K	41.18	–42.03	20.99	46.98	153.46	0.
Blue/W	25.59	4.87	31.38	31.76	278.82	0.37
Blue/K	25.32	5.02	31.17	31.57	279.15	0.

The above are Diano Match Scan II data, integrating sphere, specular component excluded, 380 nm to 700 nm in 10 nm intervals.
Paper samples used in (a) were from ca. 26"x40" sheets. ΔE*s are relative to the black backing samples.

TABLE V

Spectrally Calculated and Measured
ANSI Status T Densities of Samples in Table I

Spl.	F	$D_{Y,IS}$	$D_{Y,45/0}$	$D_{Y,418}$	$D_{M,IS}$	$D_{M,45/0}$	$D_{M,418}$	$D_{C,IS}$	$D_{C,45/0}$	$D_{C,418}$	$D_{K,IS}$	$D_{K,45/0}$	$D_{K,418}$
1	M	0.89	0.95	1.05	1.08	1.24	1.25	1.14	1.26	1.29	1.16	1.35	1.37
2	M	0.82	0.89	0.97	1.04	1.20	1.20	1.07	1.19	1.22	1.06	1.27	1.29
3	M	0.92	1.02	1.11	1.13	1.35	1.35	1.15	1.30	1.33	1.15	1.41	1.42
4	G	0.97	0.92	1.00	1.29	1.31	1.32	1.22	1.24	1.26	1.41	1.43	1.47
5	M+	0.92	0.93	1.01	1.27	1.39	1.41	1.20	1.31	1.31	1.51	1.65	1.69
6	M	0.89	0.93	1.04	1.28	1.48	1.51	1.04	1.14	1.14	1.26	1.57	1.59
7	G	0.89	0.84	0.90	1.24	1.24	1.25	1.23	1.23	1.25	1.53	1.52	1.55
8	M	.X	.X	.X	1.21	1.45	1.46	1.18	1.32	1.31	1.43	1.67	1.72
9	G	1.06	0.98	0.98	1.34	1.34	1.34	1.25	1.26	1.29	1.57	1.56	1.62
10	M	0.91	0.92	1.00	1.22	1.33	1.34	1.19	1.28	1.28	1.35	1.44	1.47
11	M	0.91	0.90	0.98	1.25	1.35	1.35	1.18	1.25	1.25	1.30	1.40	1.43
12	G	0.91	0.88	0.96	1.39	1.41	1.43	1.26	1.27	1.26	1.70	1.73	1.81
13	M	0.87	0.94	1.02	1.14	1.28	1.29	1.01	1.12	1.14	1.26	1.48	1.54
14	M	0.89	0.91	1.00	1.14	1.31	1.33	1.16	1.32	1.32	1.32	1.57	1.58
15	G	0.93	0.89	0.97	1.30	1.30	1.32	1.29	1.29	1.31	1.53	1.52	1.57
16	G	0.93	0.90	0.97	1.25	1.25	1.28	1.16	1.16	1.18	1.46	1.45	1.50
17	G	1.01	0.95	1.04	1.42	1.42	1.45	1.25	1.26	1.28	1.52	1.50	1.55
18	M	0.90	0.92	0.99	1.23	1.36	1.39	1.20	1.34	1.34	1.34	1.50	1.54

TABLE V (cont.)

Spl.	F	$D_{Y,IS}$	$D_{Y,45/0}$	$D_{Y,418}$	$D_{M,IS}$	$D_{M,45/0}$	$D_{M,418}$	$D_{C,IS}$	$D_{C,45/0}$	$D_{C,418}$	$D_{K,IS}$	$D_{K,45/0}$	$D_{K,418}$
19	M	0.93	0.94	1.01	1.27	1.40	1.41	1.18	1.28	1.27	1.53	1.70	1.75
20	G	1.04	0.97	1.05	1.36	1.34	1.36	1.27	1.28	1.29	1.57	1.58	1.63
21	M	0.95	0.99	1.05	1.22	1.36	1.36	1.16	1.25	1.25	1.45	1.58	1.61
22	G	1.03	0.94	1.03	1.47	1.45	1.49	1.35	1.32	1.39	1.49	1.50	1.52
23	M	0.83	0.88	0.96	1.09	1.22	1.22	1.28	1.42	1.45	1.32	1.64	1.65
24	M	0.85	0.89	0.89	1.18	1.32	1.38	1.29	1.40	1.45	1.41	1.68	1.66

$D_{*,IS}$, $D_{*,45/0}$ = Calculated Status T density based on spectral data 380 nm to 700 nm in 10 nm intervals:
IS = Integrating sphere, specular component excluded, white backing;
45/0 = 45°/0° geometry, matte black backing (Munsell N 2/).

$D_{*,418}$ = Density from X-Rite Model 418, calibrated to T–Ref; * = respective color (Y, M, C, K)

F = surface finish: M = matte or deglossed; G = glossy; M+ = >M, but <G.

Table VI

Spectrophotometric Colorimetric Parameters and Status T Density from 45°/0° Geometry, 380 nm to 730 nm in 10 nm Intervals for Off-Press Proof, Press Proof and SWOP Press Proof Samples in Table I

		YELLOWS/K						MAGENTAS/K					
Spl.	T	L*	a*	b*	C^*_{ab}	$h_{ab}(°)$	D_T	L*	a*	b*	C^*_{ab}	$h_{ab}(°)$	D_T
1	SM	82.11	0.40	87.31	87.31	89.74	1.07	48.47	58.95	-3.83	59.07	356.29	1.24
2	SL	81.93	-0.52	82.17	82.17	90.36	1.00	49.08	58.33	-4.97	58.54	355.13	1.21
3	SH	81.57	0.85	90.42	90.42	89.46	1.13	46.61	61.49	-2.64	61.55	357.54	1.36
4	OP	84.01	-0.93	84.92	84.93	90.63	1.00	46.45	60.08	-2.23	60.12	357.87	1.33
5	OP	79.74	0.59	78.71	78.71	89.57	1.02	45.71	57.55	-1.09	57.56	358.92	1.42
6	PP	81.71	-0.04	90.02	86.31	90.02	1.05	43.43	62.15	-1.84	62.18	358.31	1.49
7	OP	89.14	0.00	86.01	86.01	90.00	0.90	51.02	64.68	-5.22	64.89	355.39	1.25
8	OP	Bad Sample						46.26	60.74	0.65	60.74	0.62	1.48
9	OP	84.99	0.06	89.68	89.68	89.96	1.06	46.23	62.25	-3.41	62.34	356.86	1.37
10	OP	82.46	0.83	85.31	85.31	89.44	1.02	46.55	60.32	-0.02	60.32	359.98	1.34

Table VI (cont.)

		YELLOWS/K						MAGENTAS/K					
Spl.	T	L*	a*	b*	C^*_{ab}	$h_{ab}(^\circ)$	D_T	L*	a*	b*	C^*_{ab}	$h_{ab}(^\circ)$	D_T
11	OP	82.31	0.59	83.58	83.58	89.60	1.00	46.21	61.03	0.52	61.03	0.49	1.36
12	OP	87.88	1.20	90.48	90.49	89.24	0.99	48.39	63.38	0.06	63.38	0.06	1.45
13	PP	81.38	0.34	82.95	82.95	89.76	1.04	46.94	58.60	-3.60	58.71	356.48	1.29
14	OP	84.91	2.35	89.84	89.88	88.50	1.03	47.77	59.40	0.33	59.40	0.32	1.33
15	OP	88.58	0.57	90.40	90.40	89.64	0.97	49.84	65.57	-4.18	65.70	356.35	1.32
16	OP	81.92	6.27	77.71	77.97	85.39	0.96	48.81	61.62	-11.64	62.71	349.30	1.27
17	OP	86.15	0.17	90.48	90.48	89.89	1.04	46.45	65.25	-3.87	65.37	356.60	1.45
18	OP	81.18	1.36	82.16	82.17	89.05	1.02	45.63	61.07	0.61	61.08	0.57	1.39
19	OP	79.79	0.84	79.91	79.91	89.40	1.04	45.63	57.88	0.04	57.88	0.04	1.43
20	OP	84.77	0.03	88.37	88.37	89.98	1.04	46.19	61.78	-3.01	61.85	357.21	1.36
21	OP	87.77	3.06	94.53	94.58	88.14	1.04	46.92	61.11	-0.70	61.11	359.35	1.36
22	OP	85.41	-0.38	89.03	89.03	90.25	1.03	45.09	64.80	-3.48	64.89	356.93	1.50
23	PP	82.52	-0.13	79.84	79.84	90.09	0.96	48.61	56.91	-4.41	57.08	355.57	1.19
24	PP	82.10	0.13	81.86	81.86	89.91	1.00	46.43	60.59	-2.89	60.66	357.27	1.34

Table VI (cont.)

Spl.	T	CYANS/K						BLACKS/K					
		L^*	a^*	b^*	C^*_{ab}	$h_{ab}(^\circ)$	D_T	L^*	a^*	b^*	C^*_{ab}	$h_{ab}(^\circ)$	D_T
1	SM	57.46	-43.28	-32.77	54.29	217.13	1.27	24.14	0.68	2.67	2.75	75.62	1.38
2	SL	58.82	-42.68	-32.14	53.43	216.98	1.21	27.06	0.72	2.94	3.03	76.22	1.29
3	SH	57.00	-44.10	-34.06	55.71	217.68	1.32	22.36	0.74	2.19	2.31	71.36	1.44
4	OP	54.27	-38.68	-35.72	52.65	222.72	1.26	21.78	1.37	-2.83	3.15	295.72	1.46
5	OP	54.21	-41.21	-33.61	53.18	219.20	1.34	15.73	0.35	1.16	1.21	73.34	1.69
6	PP	59.78	-41.49	-31.77	52.25	217.44	1.16	17.76	0.60	1.16	1.31	62.78	1.60
7	OP	58.61	-43.69	-37.70	57.71	220.79	1.24	19.84	1.87	-4.82	5.17	291.16	1.53
8	OP	55.72	-40.88	-38.04	55.84	222.93	1.34	14.87	0.13	0.81	0.82	80.85	1.72
9	OP	55.37	-40.95	-36.51	54.86	221.73	1.28	17.47	1.64	-4.14	4.45	291.66	1.62
10	OP	56.13	-42.09	-35.36	54.97	220.03	1.31	20.91	-0.34	2.22	2.25	98.73	1.49
11	OP	56.42	-41.74	-35.40	54.74	220.30	1.30	21.88	-0.36	2.31	2.34	98.80	1.46
12	OP	59.19	-43.22	-41.11	59.64	223.57	1.30	12.75	0.16	1.31	1.32	82.99	1.81
13	PP	60.32	-41.49	-30.46	51.47	216.29	1.13	19.91	1.00	2.70	2.88	69.66	1.52
14	OP	56.07	-44.91	-32.45	55.41	215.85	1.34	18.06	-1.74	0.88	1.95	153.11	1.60
15	OP	57.39	-44.51	-38.05	58.56	220.52	1.30	19.22	1.94	-4.80	5.18	292.07	1.56

Table VI (cont.)

		CYANS/K						BLACKS/K					
Spl.	T	L*	a*	b*	C^*_{ab}	$h_{ab}(°)$	D_T	L*	a*	b*	C^*_{ab}	hab(°)	D_T
16	OP	57.93	-39.11	-36.39	53.42	222.94	1.17	21.01	1.76	-4.22	4.58	292.59	1.49
17	OP	56.06	-42.91	-34.30	54.93	218.64	1.27	19.57	1.91	-4.69	5.07	292.14	1.54
18	OP	54.41	-40.76	-37.41	55.32	222.54	1.37	19.57	-0.04	2.10	2.10	91.22	1.54
19	OP	54.66	-41.14	-32.57	52.47	218.37	1.31	14.61	0.55	0.71	0.90	52.22	1.73
20	OP	55.15	-40.83	-35.49	54.10	221.00	1.27	17.18	1.68	-3.71	4.07	294.34	1.63
21	OP	58.93	-43.91	-38.09	58.13	220.94	1.28	17.45	-1.21	3.32	3.54	110.03	1.62
22	OP	53.28	-41.32	-37.73	55.95	222.40	1.37	20.28	2.30	-6.33	6.74	289.99	1.52
23	PP	52.94	-42.81	-36.28	56.12	220.28	1.45	16.74	0.08	0.40	0.40	77.98	1.65
24	PP	53.89	-43.44	-36.27	56.59	219.86	1.43	14.23	-0.43	-0.10	0.44	193.43	1.76

T = Type: SM= SWOP Mid; SL = SWOP Low; SH = SWOP High; OP = Off-Press Proof; PP = Press Proof.

D_T = ANSI Status T density appropriate for that color.

All samples read over matte black backing (Munsell N 2/).