PRINT ANALYSIS AND COLORIMETRY OF NORTH AMERICAN COMMERCIAL PRINTING

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Abstract: The North American Commercial Print Survey was designed to examine methods used widely by commercial printers. The printing characteristics of a large number of press sheets submitted were analyzed using densitometry and colorimetry. Solid ink density, dot gain, and print contrast results showed a broad distribution for the commercial segment. A spectrophotometer was used to measure the ink color properties. A broad selection of process color ink hues was found. The survey results show there is little standardization in the commercial printing segment.

Introduction

As part of its long-standing commitment to the printing industry, the Du Pont Company routinely monitors new trends and advancements in commercial and publication printing. The past two decades have seen major changes in the industry, including widespread introduction of electronic prepress operations, standardization of publication printing, and significant new techniques in press analysis and control.

The results of the previous North American Print Survey (Muirhead, et al. 1985) helped support the development and introduction of SWOP standards for publication printing. The goal of this current survey is to measure the print characteristics of the commercial printing segment to determine what standards, if any, are used to govern the outcome of the commercial printing process. This paper, therefore, concentrates on two areas: the print analysis of solid ink density, dot gain and print contrast, and the colorimetric analysis of ink color properties.

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Measurement Techniques

All participants were provided with separation films of the "Commercial Printing Calibration Target", shown in Figure 1, from which they produced press sheets.

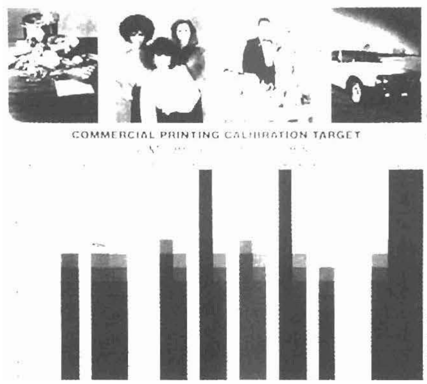

Figure 1: Commercial Printing Calibration Target

The form contains pictorial references, as well as elements used for mechanical color measurements. For additional information, a System Brunner Control Bar was included on each press sheet. All halftone measurements were based on a screen ruling of 150 lines per inch. At the conclusion of the test run, press sheets were returned to Du Pont for analysis.

A spectrophotometer was used to obtain colorimetric values for the process inks. Density and dot gain were measured on the Du Pont Print Manager using a narrow band densitometer, while hue error and trapping were measured with a wide band densitometer.

Each participant was asked to use his own proofing system to make an off-press proof as a color guide. The printers were instructed to make the press run using in-house standard procedures i.e., plate exposure, paper stock, ink, color rotation, and other materials and procedures. Ink density was to be run in balance and represent a good pictorial relationship to the proof.

No other specific printing conditions were given because the intent of the survey was to determine how printers operated in normal practice.

Participant Composite

All participants supplied technical information on their press conditions during the press run. Eighty percent of the participants were printers, while twenty percent were tradeshops doing some short-run printing. Tables 1 through 3 provide a participant composite.

PRESS TYPE	PERCENTAGE
Sheetfed - 4 unit	45
Sheetfed - 6 unit	36
Sheetfed - 5 unit	13
Web	5

Table 1: Participant Composite - Press Type

PRINTING STOCK	PERCENTAGE
80# Gloss, Coated	67
100# Gloss, Coated	13
70# Gloss, Coated	9
60# Gloss, Coated	4
A/O	7

Table 2: Participant Composite - Printing Stock

COLOR ROTATION	PERCENTAGE
K,C,M,Y	84
C,M,Y,K	7
Y,C,M,K	4
A/O	5

Table 3: Participant Composite - Color Rotation

Solid Ink Density

Table 4 shows the total density range and average for each printing color. The ink density range varied widely from the average. The lowest density run for yellow on a press sheet was 1.00, while the highest was 1.50. The density differences between low and high for magenta, cyan and black ran from 0.6 to 0.7 density.

	Yellow	Magenta	Cyan	Black
Average	1.23	1.42	1.35	1.68
Range	1.00-1.50	1.12-1.78	1.10-1.70	1.33-2.00

Density read on a narrow band densitometer

Table 4: Solid Density Summary
Average Density and Density Range

Figures 2 through 5 indicate the distribution of densities for each color and the frequency of occurrence in the sampling. The histogram for yellow, magenta and black each show a broad distribution across the full range of density values. The histogram for the cyan density distribution shows two clusters of density, one lower than the average and one higher than the average.

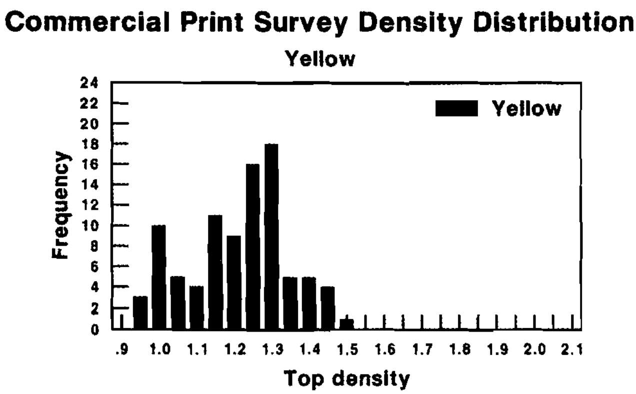

Figure 2: Yellow Solid Ink Denisty

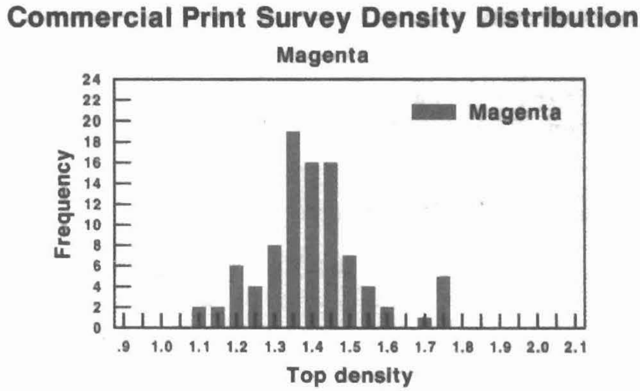

Figure 3: Magenta Solid Ink Denisty

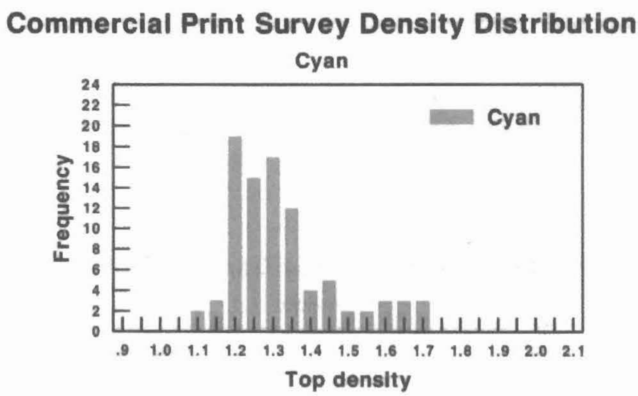

Figure 4: Cyan Solid Ink Denisty

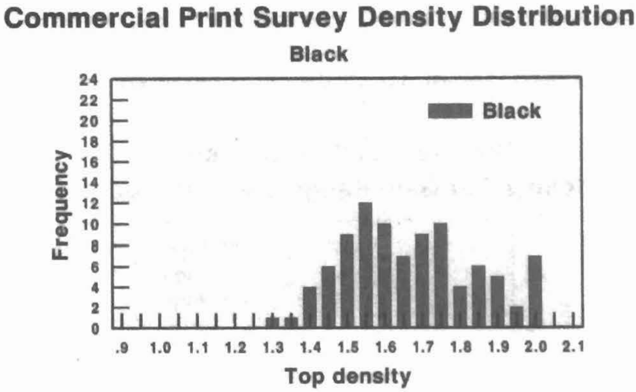

Figure 5: Black Solid Ink Denisty

The conclusion reached from the solid density results: there is a wide density range used to meet commercial printing needs. No single density standard would meet the requirements of this segment.

Dot Gain

The 25%, 50% and 75% halftone dot gain averages are shown in Figure 6. The average mid tone (50%) dot gains are: yellow - 18%, magenta - 20%, cyan - 20%, and black - 23%.

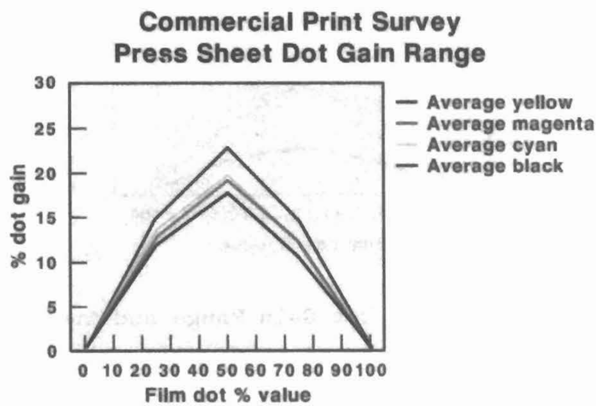

Figure 6: Average Dot Gain Curves For All Colors

The dot gain ranges and averages for yellow, magenta, cyan and black are shown in Figures 7 through 10.

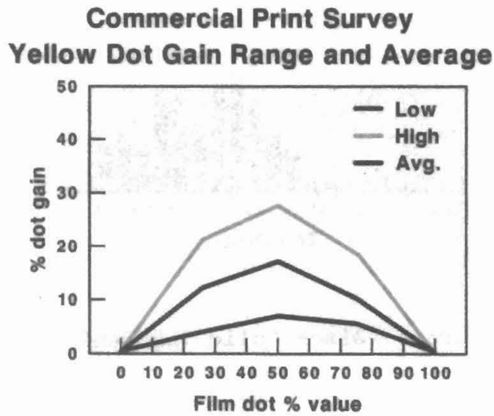

Figure 7: Yellow Dot Gain Range and Average

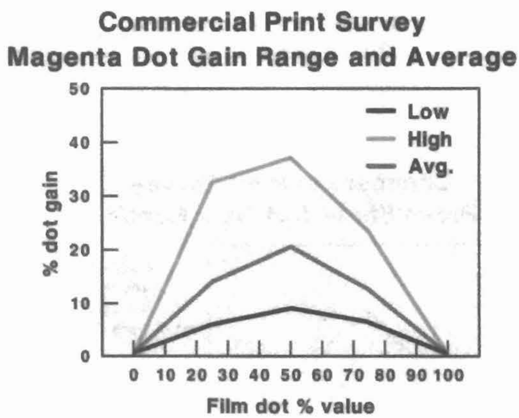

Figure 8: Magenta Dot Gain Range and Average

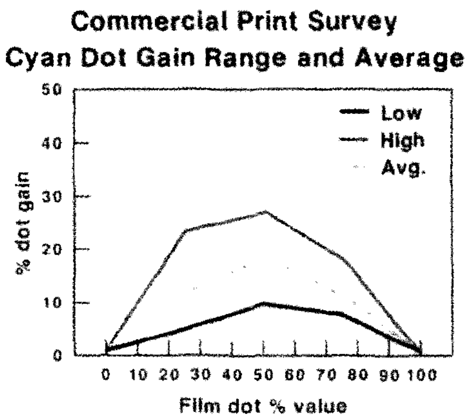

Figure 9: Cyan Dot Gain Range and Average

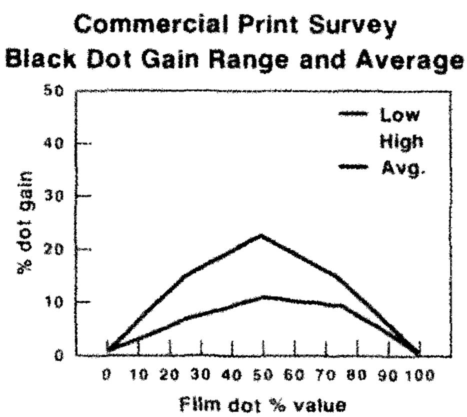

Figure 10: Black Dot Gain Range and Average

The conclusion reached from the dot gain results: the averages represent a definite downward trend from that of five years ago, but not as low as the industry generally expected.

Ink Color Properties

The reflectance values for the process ink colors from the survey were read on a spectrophotometer and converted to 1976 CIE L*a*b* system values. The colorimetric values expressed in this system have the unique advantage that they numerically express visually equal color differences when moving in color space and relate directly to how the color is seen by the observer.

An example of the usefulness of this numerical color system is shown in the evaluation of the process color inks in the print survey. Individual inks and groups of inks can be compared in hue to the whole process gamut. Using this approach, the number of visually significant hues in the process gamut can be determined.

Figure 11 is an overview of the color measurement results of process colors and overprints on the a*b* diagram which shows the relative "hue" location for the colors. Process yellows lie on the yellow-blue axis, while the red overprints lie in the first quadrant between yellow and red. Magentas lie on the a*, or red axis. Moving around the circle we see the location of the blue overprints, process cyans and green overprints.

Each of the gamuts for the process colors has been expanded for a close-up look.

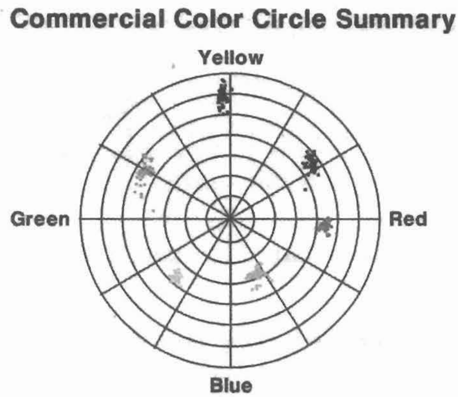

Figure 11: a*b* Diagram of Process Colors and Overprints in CIELAB Color Space

Figure 12 shows the survey results for the yellow process ink color gamut. Each circle is the colorimetric a*b* location for one ink. As you move up the b* axis, you move toward higher strength or greater density ink. Moving across the a* axis from left to right is moving from green to red shade hues of ink.

The IPA high-low ink reference patches for yellow SWOP inks were read on the spectrophotometer. The average value for the swatches was plotted on the a*b* diagram representing the hue location of the average SWOP ink. Hue line boundaries are drawn to include the SWOP ink and encompass all of the yellow inks with the same visual hue as the SWOP ink in color space. Any points outside the hue lines are visually different to the human eye and represent a different hue of ink. Therefore, any two plotted points farther apart than the distance identified by the hue lines would be distinctly different colors.

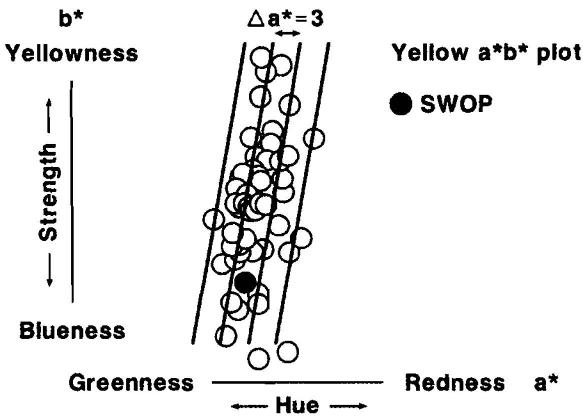

Figure 12: Yellow Process Ink Color Gamut

Hue lines are drawn to enclose three groupings of hues for yellow, which cover the majority of the colors in the yellow process color space. Inks on the left are green shade yellows and the group on the right are red shade yellows compared to the group in the center. Based on this survey, at least three hues of yellow ink are required to cover the yellow process gamut.

Figure 13 shows the color data for the magenta process inks. The magenta strength or density increases moving from left to right on the a* axis and hue changes on the b* axis. As you move from the bottom to top of the b* axis, you go from a rhodamine blue-shade magenta toward a rubine yellow-shade magenta hue. The SWOP color is plotted for reference, with the hue lines indicating the limits in color space satisfied by a given hue.

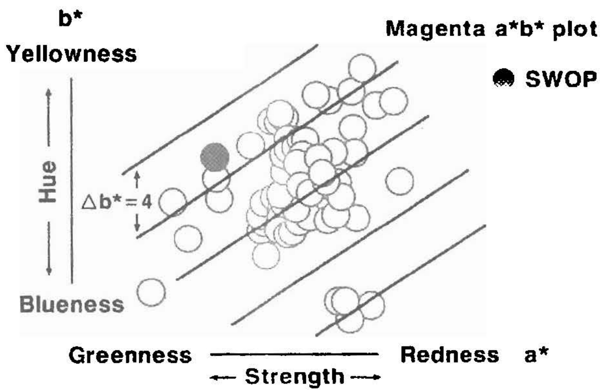

Figure 13: Magenta Process Ink Color Gamut

Hue lines are drawn to enclose the groups of magenta inks that are visually different. Note that there are several clusters of different hues and strengths in the survey, generally being higher in density and bluer hues than SWOP. Four hue sets are needed to cover the magenta color gamut from very yellow to very blue hues.

Figure 14 shows the cyan process ink color gamut. In this plot, strength or density runs on a 45-degree angle, becoming higher in strength toward the lower left corner of the plot. The cyan hues run from green shade to red shade from left to right across the plot. The SWOP point, enclosed by the visually significant hue lines, is shown for reference.

Three hue sets are required to cover the cyan hues used by printers in the survey. There are clusters of inks that are higher in density and redder in hue than SWOP.

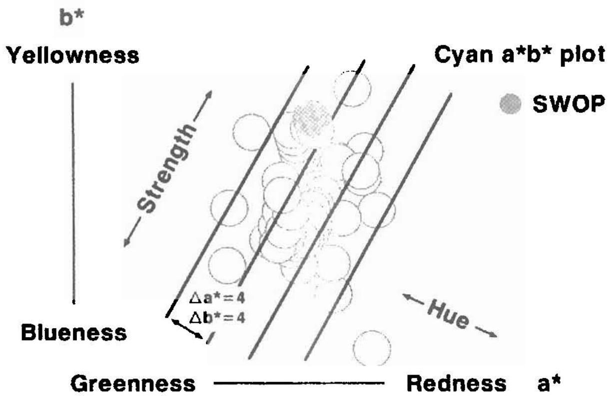

Figure 14: Cyan Process Ink Color Gamut

A study by colorimetry shows distinct hues of process colors are used to meet the commercial printer's needs. A standard process color set is not sufficient to satisfy the needs of this segment. While there are groupings of data points in each process color studied, there remains a diversity of "desired color" choices. It is further evident that SWOP colors are not sufficient to satisfy the color needs of the commercial printing segment. The trend depicted in the survey for each color versus SWOP shows a chromer yellow, a bluer magenta and a redder cyan, as well as higher strengths overall.

Print Contrast

Print contrast is a comparison measurement between the 75% halftone density and its respective solid. In general, lower contrast numbers mean less separation between the 3/4 tone and solid values. Conversely, higher numbers mean a greater separation between these two values. In reviewing the data in Table 5, good print contrast results should fall generally within the 40% to 50% value. While the contrast ranges in the survey are considerable, the average for the commercial segment agrees with the recommended range.

COLOR	PERCENTAGE	
	RANGE	AVERAGE
Yellow	21-47	37
Magenta	12-52	41
Cyan	24-57	39
Black	8-57	43

Table 5: Print Contrast Summary

Trapping

The trapping calculation is a percentage measurement of how well a wet ink has transferred to a previously printed ink, and is rotation sensitive. For the majority of participants (91%) the cyan-magenta-yellow color rotation was constant, and the following guidelines would apply when reviewing the data in Table 6.

If the trapping percentage in red is lower than the average, it would appear as a somewhat "colder" (-yellow) red and, if higher, as "warmer" (+yellow). For green a lower number indicates a bluer green (-yellow) and a higher number is a yellower green. For blue, a lower number indicates a "violet" blue (-magenta) and a higher number indicates "purple" blue (+magenta).

This trapping summary is not a classification of "good vs. bad" trap. It is merely indicative of the range in overprint colors being utilized by the commercial segment to satisfy very unique printing requirements.

COLOR	PERCENTAGE	
	RANGE	AVERAGE
Red	52.8- 79.3	70.5
Green	70.6-100.0	87.3
Blue	46.3- 94.6	72.3

Table 6: Trapping Summary

Hue Error

The measurement of ink hue error is designed to determine the amount of unwanted color being reflected by a particular ink, and is calculated by the following formula:

$$HE = \frac{M-L}{H-L}$$

Because many in the industry have, over the years, attempted to also use hue error as a means of defining and controlling color, those reference figures have been provided in Table 7.

In reviewing these figures, it should be pointed out that the higher the hue error number, the greater the amount of unwanted color being reflected. In the case of yellow, the higher the number, the greater the amount of blue being reflected; for magenta, the greater the amount of green; for cyan, the greater the amount of red.

COLOR	PERCENTAGE	
	RANGE	AVERAGE
Yellow	2.5-8.2	4.9
Magenta	35-48	42.7
Cyan	18-23	20.1

Table 7: Hue Error Summary

Summary

The results of this survey demonstrate a great deal of diversity in the way commercial printers meet their customers' needs.

Solid ink densities, as shown by the data, vary by as much as 50% from one printer to another. This diversity of density greatly influences the print contrast and color saturation of the final printed sheet. Dot gain averages for each color range from 18-25% within the survey. These averages are not as low as generally suggested but show a definite downward trend. Ink color properties data show several distinct hue lines within each process color gamut. No single set of process hues, therefore, would satisfy the commercial segment's ink color requirements.

Given the diversity found in the survey for top density, dot gain and ink color, it seems fair to infer that print buyers are asking for individualized treatment of their color printing, and that printers are providing this diversity to differentiate themselves in the marketplace.

Literature Cited:

Muirhead A. R., Burgstein M., and Fahr R. H., "North American Print Survey", TAGA Proceedings 1985 pp 585-601.