CHARACTERIZATION OF SWOP PRINTING

David Q. McDowell *
Arthur J. Taggi **

Keywords: Color, Characterization, Printing, Proofing, Standards

Abstract: A cooperative effort was undertaken among several groups to characterize "Type 1" (i.e. SWOP) printing as part of the CGATS standards effort. Press sheets including the IT8.7/3 target were prepared to SWOP specifications. The IT8.7/3 color patches on a number of these sheets were measured by several different labs using two types of portable spectrophotometers. These data were used to provide characterization of Type 1 printing. The procedure used and some of the pitfalls discovered in this effort are described along with the results of the characterization.

Introduction

The introduction of electronics into the graphic arts, which began in the late 1970s and early 1980s, has allowed printing to become a much more open and distributed process. This has led to an increased dependence on more analytically-based processes including digital proofing, digital distribution of advertising, and direct-to-cylinder/direct-to-plate technologies. Such processes impose increasingly stringent requirements for consistency and predictability in the printing process. Many of the initial standards efforts in the graphic arts industry have been focused on these issues.

A key element required to allow the opening of the printing process and the digital distribution of data is adequate

* Professional & Printing Imaging, Eastman Kodak Company, Rochester, NY 14650
** DuPont Printing and Publishing, Boothwyn, PA 19061

characterization of the printing process(es) to be used. From a color perspective the characterization data of interest is the relationship between the input CMYK printing values and the color of the resulting image area. Such data is currently not publicly available.

ANSI CGATS (Committee for Graphic Arts Technologies Standards), working in conjunction with industry groups, is developing both standardization of printing conditions and characterization data for material printed in accordance with those conditions.

The most significant printing standard in the United States is the press proofing portion of the current "Specifications Web Offset Publications" (SWOP), which addresses the larger subject of the preparation and proofing of input material for reproduction by web offset and gravure publication printing. That specification has received wide acceptance and has provided the publication industry with consistent proofing of input materials. It provides for testing and certification of wet inks through GATF and specifies density and dot gain ranges for each of the process colors. The density range is defined by physical samples, called the SWOP Hi-Lo Color Reference Patches, prepared for SWOP by the International Prepress Association (IPA). Dot gain is provided as a numerical specification.

In 1992 CGATS undertook, at the invitation of SWOP, the task of creating a numerically-based standard to complement the current SWOP specification. ANSI CGATS.6 *Graphic technology — Specifications for graphic arts printing — Type 1* represents the culmination of that work and is the first of a series of CGATS standards that will define printing conditions important to the US printing and publishing industry.

In the fall of 1993 SWOP conducted a press test to provide printed samples as close to the middle of the SWOP specifications as was practical to achieve. This test was supported by CGATS with the intent that data from the test would be used in the development of the CGATS.6 standard and for the development of characterization data. Included on the press form were reproductions of the data set defined in IT8.7/3 *Graphic technology —Input data for characterization of 4-color process printing*. This data set includes 928 combinations of CMYK printing values, which encompass the full gamut of the printing process.

Long (1995) has described the details of that press test. The measurement of selected sheets from the test and the analysis of the results are described in this paper.

Printing Validation

Prior to preparing the plates to be used in the 1993 SWOP press test, the images of the IT8.7/3 target in the final films were evaluated and compared against the tabulated aim data of IT8.7/3 to insure imagesetter linearization and fidelity of the film duplication process. All film values were found to be within 1% dot value of the aims. These films were then used to prepare negative working printing plates to the manufacturer's recommendations.

The selection of sample sheets to be used in the CGATS analysis was made by SWOP, Inc. These sheets were selected to conform to the requirements of the SWOP specification and numbered and certified by SWOP. The sheets provided to the standards community for analysis are numbers 8, 9, 10, 12, 14, and 15. Unfortunately, the procedures used by SWOP did not preserve the sequence of printing of the sheets. These samples are believed to be very close together in the press run, but their numbering denotes their sequence of selection not the sequence of printing. This has the consequence of placing more weight on the assumption of the data analysis, detailed below, that the printing process changes slowly during a press run.

The aim density range, colorimetric aim values, and colorimetric tolerances (ΔE) of the single-color solids as defined in CGATS.6 are shown in Table 1. Also included are the average values obtained from the analysis of the printing control bars of the selected press sheets. The midtone dot gain aims and achieved values are shown in Table 2.

The density, colorimetry, and dot gain data of the process control elements provide assurance that the selected press sheets are representative of SWOP proofing as defined by the SWOP Specification and CGATS.6.

Table 1 - Press Test Density and Colorimetric Data

Color		Density (Status T)	L*	a*	b*	ΔE
Cyan	Aim	1.22-1.36	54.7	-36.9	-40.0	4
	Test	1.29	55.7	-37.8	-40.4	
Magenta	Aim	1.33-1.47	46.2	70.0	-1.5	4
	Test	1.40	46.3	70.1	-2.2	
Yellow	Aim	0.95-1.07	84.6	-5.1	84.7	6
	Test	1.01	84.3	-5.8	84.5	
Black	Aim	1.52-1.66	18.3	0.4	0.7	(a)
	Test	1.58	18.5	0.4	0.9	
Paper			88.7	-0.0	3.7	

(a) $\Delta L^* = 3$; Δa^*, $\Delta b^* = 2$

NOTE: The value shown for paper is for a representative sample of Champion Textweb paper that meets the SWOP specification.

Table 2 - Midtone Dot Gain (Based on Control Bar Evaluation)

Color	Aim	Measured
Cyan	20 ± 3	18
Magenta	20 ± 3	19
Yellow	18 ± 3	17
Black	22 ± 3	20

Design of Measurement Protocol

Discussions among the various standards groups involved resulted in an experimental design that made use of the two most common portable spectrophotometers in use in graphic arts applications. These are the Gretag SPM100 and the X-Rite 938. Two of each model instruments were used, at different labs. The entire IT8.7/3 target, as well as several process control elements on each of three sheets, was read by each site.

Two sets of sheets were used, one set for the Gretag measurements, another for the X-Rite measurements. Separate sets of sheets were used since we did not believe that a single set of sheets could survive the number of measurement cycles required without sustaining damage that would affect the readings. The following table indicates the labs, instruments and sheets read:

Instrument	Lab	Sheets
Gretag	Kodak	9,12,15
Gretag	3M	9,12,15
X-Rite	X-Rite	8,10,14
X-Rite	Kodak	8,10,14

Prior to measurements by the individual laboratories, inter-instrument agreement was checked using the following procedure. Selected patches from the IT8.7/3 basic data set on one press sheet were read five times with each instrument. These results were compared between instruments to insure that all four instruments were in agreement. The results of this analysis showed an average ΔE^* of less than 1 among the measurements made. This was used as an indication that the instruments themselves and the measurement procedures were in agreement.

The original experimental design called for the six sheets selected to be consecutive, so that effects of sheet-to-sheet variability could be expected to be negligible. Since the sheets chosen for each set were not consecutive from the press run, and because the printing process is not expected to show rapid sheet-to-sheet changes in ink density, we must assume that the sheets represent a uniform population. In any case, the design of the experiment precludes any statistical analysis, which addresses the sheet-to-sheet variability.

Measurement Procedure

All measurements were made in accordance with the procedures of ANSI/CGATS.5 That is to say the measurement geometry was 0/45 and a black backing was used behind the sample. In addition, calculation of the CIE tristimulus values, XYZ, and the subsequent CIELAB values used the weighting functions of CGATS.5, which are based on the 1931 CIE 2° observer and the D50 illuminant.

Data Reduction

The data were reorganized into a standard order (using the numerical patch identifiers established in IT8.7/3) and combined into single files for each instrument. The data remained tagged with the instrument type and laboratory throughout the analysis.

Each set was first analyzed by instrument used. The L*, a*, and b* values at each patch were averaged (6 measurements at each point) and the standard deviations calculated.

For the X-Rite data, the standard deviations were found to be very small. Only 14 of the 928 points showed a standard deviation >0.5 for any of L*, a*, or b*. Examination of these 14 points showed only one measurement (Patch 733, sheet 10, X-Rite measurement by X-Rite) which was distinctly different and was eliminated. *Only data that were obviously in error were eliminated in this way. If the data were not distinctly different, the differences were attributed to measurement variation, and the data point was retained.*

An alternate analysis, that of calculating the ΔE* values for each patch based on the average L*, a*, and b* values for each instrument type, also showed that the single datum noted above was the only one that we could be justified in removing.

A "T test" performed for each of L*, a*, and b* independently on the X-Rite data led to the conclusion that the measurements made with the two X-Rite instruments are statistically indistinguishable. The large number of patches precluded looking at each individually, but a spot check of the results indicates that less than 5% of the individual points are statistically different at >90% probability. Since the difference, even when statistically significant, is generally less than 0.5 units of L*, a*, or b*, this difference was judged to be unimportant. Thus the data from the two laboratories were combined.

Analysis of the standard deviations of L*, a*, and b* of the Gretag data, as well as the ΔE* values calculated from the mean of the data provided by each of the laboratories indicated that only two points (patch 918, sheet 15, and patch 925, sheet 12 , both as measured by Kodak) were anomalous. We could not justify removing any other points; all other errors in the data appear to be noise or experimental error.

The standard deviations of the six measurements of each patch as measured by the Gretag instruments were found to be considerably larger than those of the X-Rite measurements. A T test showed that the data from both labs again came from the same distribution, although in this case about 10% of the points showed a statistically significant difference at >90% probability. Since the maximum difference is less than 1 unit of L*, a*, or b*, this was judged to be unimportant. Thus the data from the two laboratories were combined.

The data from all sets and all instruments were then combined and analyzed. A T test of the hypothesis that the data from the two different instrument types belonged to the same distribution was conducted. Spot checking of the results showed that a large number of points were significantly different at the >90% probability level. This shows that the data from the two different instruments actually represent two different populations. Strictly speaking, the data should not be combined and treated as a single data set.

In order to investigate the practical significance of this observation, the value of ΔE* for each of the patches between the two data sets (by instrument) were calculated. Of these 928 values, 117 were found to have $\Delta E^* \geq 1.0$, with the following general statistics:

Max ΔE*	1.81
Min ΔE*	0.07
Average ΔE*	0.67

It is interesting to note that if we look only at the data for the basic set of patches, as defined in IT8.7/3, similar statistics are obtained:

Max ΔE^*	1.78
Min ΔE^*	0.08
Average ΔE^*	0.59

This would appear to show that the basic data set is a fair representation of the results that are obtained with the full data set. Statistical analysis to test this hypothesis has not been performed.

The relatively small ΔE^* values between the sets of data indicate that although they represent different data populations, the actual difference may be small enough for practical purposes to combine the data sets. This is especially true given the variable nature of printing. Another way to look at this is to assume that the actual value of L*, a*, and b* for a particular patch is the average of all 12 measurements made (i.e. equally weighting the results from each instrument). We can then calculate the ΔE^* value of each of the 12 measurements of a particular patch from the mean, "assumed" to be the actual value. Of the 11133 individual measurements made (12 x 928 - 3 error points), 89 showed $\Delta E^* \geq 1.5$. Figure 1 shows the histogram of these data.

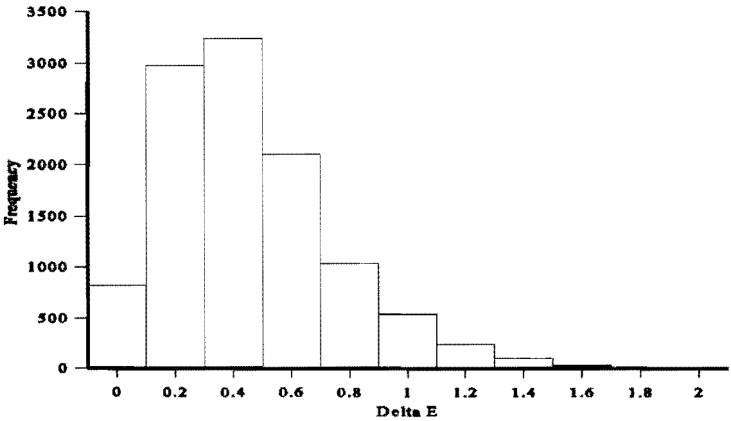

Figure 1 Histogram of Delta E values

Averaging the 12 ΔE^* measurements for each of the patches and calculating the standard deviations resulted in only 5 points with ΔE^* >1.0. The two largest ΔE^* values were 1.55 and 1.43. The difference from the assumed actual value (the average of all data for each patch) represents a single value that indicates the accuracy of the data. The small differences are for all practical purposes small enough that they can be ignored.

Colorimetric Data

All of the data (with the exception of the three points found to be in error) were combined into a single data set. The mean values of L*, a*, b*, X, Y, and Z for each patch were calculated and are reported in an ANSI/CGATS Technical report to be issued in mid 1995.

Digital Data

The colorimetric data and the averaged spectral reflectance data for each patch are available as ASCII files on floppy disk from NPES the Association for Suppliers of Printing and Publishing Technologies, 1899 Preston White Drive, Reston, VA 22091-4367, Tel: 703-264-7200.

Literature Cited

Long, J. W.
1995. "Specifications and tolerances for publication printing," TAGA Proceedings , 1995

Specifications and Standards

ANSI/CGATS.5-1993, Graphic technology — Spectral measurement and colorimetric computation for graphic arts images.

ANSI/CGATS.6-1995, Graphic technology — Specifications for graphic arts printing — Type 1.

ANSI/IT8.7/3-1993, Graphic technology - Input data for characterization of 4-color process printing.

SWOP, Specifications Web Offset Publications, 1993; SWOP Incorporated, 60 East 42nd Street, Suite 721, New York, NY, 10165.