Characterization of SWOP Printing

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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. Densitometric measurements of the GATF/SWOP proofing bar were used to relate the densities and dot gain achieved to the SWOP specifications. The IT8.7/3 color patches were then measured by several different labs using two types of portable spectrophotometers. These data were used to provide characterization of Type 1 printing. The details of the press test and the measurement procedure used are discussed along with a summary of 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 definition and characterization of the printing process 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.

The most significant printing standard in the United States is the press proofing portion of the current "Specifications Web Offset Publications"[3] or 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 References, prepared for SWOP by the International Prepress Association (IPA). Dot gain is provided as a numerical specification.

In 1992 ANSI CGATS (Committee for Graphic Arts Technologies Standards) 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,[7] 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. A companion document, ANSI/CGATS TR 001-1995 Graphic Technology Characterization Data for Type 1 Printing,[8] an ANSI Technical Report, provides color characterization data for this same printing condition.

SWOP Press Test

SWOP, Inc. began the development of the SWOP Calibration Test Kit in 1992. One use of the Kit was to supply to the industry physical samples of press sheets printed to SWOP specifications. The Test Kit contains duplicate films of the test form. This form was designed by SWOP in conjunction with CGATS SC4 and the IT8 Standard Committees. The images used were the draft data set proposed for inclusion as the SCID (Standard Color Image Data) Images of ISO 12640.[10] These include eight natural images (pretty pictures) and 10 synthetic images (test objects) which include the contents of the IT8.7/3[4] data set. The GATF production control bar and the GATF/SWOP proofing bar were included on the gripper edge of the test form and the GATF production control bar was included on the tail edge of the test form.

In the fall of 1993, SWOP ran a press test to produce press sheets for the Calibration Test Kit and to help support the standards activities. The goal of the SWOP press test was to produce press sheets as close as possible to the middle of the SWOP specifications for press proofing. 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.

The proofs were printed on 60-pound Champion Textweb paper, a SWOP specified proofing stock, using a Mitsubishi 40-inch sheet fed press. The printing sequence was KCMY using the standard SWOP/NAPIM reference process proofing inks. These inks conform to ISO 2846-1.[9] All halftones on the test form are 133 line screen, square dot configuration. During the press run, the process color densities were printed as close as possible to the mid-point of the SWOP Hi-Lo Color reference. Gray balance, as indicated on the GATF/SWOP proofing bar, was monitored and densities were adjusted to cause the printed balance to appear neutral when viewed under standard viewing conditions as specified in ANSI PH 2.30.[9] Prior testing and modification of the

ink rheological characteristics was used to ensure that the dot gain was within the tolerances of the SWOP specifications.

Printing Aim Data for SWOP Definition

CGATS.6[7] specifies the characteristics required for sheetfed printing of process color material to be used as proofs for web offset publications. The numerical data contained in that standard was derived from the following three sources.

The 1993 SWOP booklet[3] describes the film preparation requirements, paper and ink requirements, and numerical dot gain specifications for press proofing. The SWOP booklet also describes the use of the SWOP Hi-Lo Color References as physical references for print process control. Press proofing is controlled so that the process color densities fall within the Hi-Lo patch range while maintaining visual gray balance.

The densitometric and colorimetric values from sets of SWOP Hi-Lo Color References were analyzed by the CGATS SC4 committee. The mean values for the Hi-Lo Color References are used in CGATS.6 as numerical aim points for solid density and color for the printed process colors. Tolerances for solid density were taken from the SWOP specification and verified using the Hi-Lo Color References. Tolerances for color were derived from the Hi-Lo Color References.

A set of press sheets certified by SWOP were provided for CGATS evaluation. The GATF/SWOP proofing bar was analyzed densitometrically. Process colors and RGB overprint data were read. The results were compared to the SWOP specifications and the Hi-Lo aim points for density and color. All densitiometry and colorimetric measurements and calculations were made using the procedures specified in CGATS.4[5] and CGATS.5[6]. The press data fell very close to the aim density values and well within the proposed colorimetric tolerances. The committee therefore concluded that the IT8.7/3[4] target on the selected test forms was printed very close to the center of the SWOP specifications and could be used for the colorimetric characterization of the SWOP sheetfed press proofing process.

The SWOP aim and tolerance data from this analysis, as included in CGATS.6, are as follows:

Color	Absolute Density Status T	L*	a*	b*	Delta E Tolerance
Cyan	1.22-1.36	54.7	-36.9	-40.0	4
Magenta	1.33-1.47	46.2	70.0	-1.5	5
Yellow	0.94-1.08	84.6	-5.1	84.7	6 (a)
Black	1.52-1.66(b)	18.3	0.4	0.7	3
Red		46.1	64.3	43.4	8
Green		51.3	-61.5	28.7	7
Blue		24.7	20.2	-41.0	6
3-color		23.2	1.7	1.0	

Notes: a. Yellow is further constrained such that hue angle is restricted to 93.4 +/- 2.7
b. ISO Visual

The densitometric analysis of the press test as well as a discussion of the development of the colorimetric aims and tolerances of the solids is discussed in detail by Long in Reference 1.

The dot gain at an input dot size of 50% is specified by SWOP as follows:

Cyan	20 +/- 3
Magenta	20 +/- 3
Yellow	18 +/- 3
Black	22 +/- 3.

Colorimetric Characterization Data

As mentioned earlier, 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.[4] This data set includes 928 combinations of CMYK printing values, which encompass the full gamut of the printing process. Prior to preparing the plates to be used in the 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 ensure image setter 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 were 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.

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 because 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 ensure that all four instruments

were in agreement. The results of this analysis showed an average E* 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.

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 degree observer and the D50 illuminant.

To ensure that the data included no obvious measurement errors, several different analysis techniques were used. These are discussed in detail by McDowell and Taggi in Reference 2. Three measurements out of a total population of 11136 were eliminated as a result of this analysis.

The data from all instruments were then combined and analyzed. One approach used was 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 and laboratory). The delta E* value of each of the 12 measurements of a particular patch compared to the mean was then calculated. Of the 11133 individual measurements made (12 $\times$ 928 - three error points), only 89 showed delta E*>1.5. The mean delta E* was 0.56. These statistics indicate a low contribution of noise from either the measurement process or the sheet to sheet variation in the printing.

These averaged values of L*, a*, b*, X, Y, and Z for each patch are published in ANSI/CGATS TR001-1995.[8] In addition these colorimetric data along with the averaged spectral reflectance data for each patch are available as ASCII files on a floppy disk from the CGATS Secretariat.[11]

The committee believes that these data provide an accurate color characterization of this press test, which has been deemed by SWOP to be representative of SWOP sheet-fed press proofing.

It is hoped that all manufacturers of color separation systems, color management systems, and color proofing systems will use these data as the primary colorimetric reference for SWOP. This will help improve the consistency between data prepared in, or exchanged between, systems manufactured by different vendors. In addition, all applications that use this characterization data are urged to identify ANSI/CGATS TR 001-1995 as the characterization data source. This will more readily enable end users to validate the intended output for the color separations being prepared or exchanged.

End users are encouraged to request their suppliers to make available color data exchange profiles and separation aims based on these data.

References

1. J. W. Long, 1995."Specifications and tolerances for publication printing," *TAGA Proceedings*, 1995.
2. D. Q. McDowell and A. J. Taggi, 1995."Characterization of SWOP Printing," *TAGA Proceedings*, 1995.
3. SWOP, Specifications Web Offset Publications, 1993; SWOP Incorporated, 60 East 42nd Street, Suite 721, New York, NY 10165.
4. ANSI/IT8.7/3-1993, Graphic technology "Input data for characterization of 4-color process printing".
5. ANSI/CGATS.4-1993 Graphic technology "Graphic arts reflection density measurement - Terminology, equations, image elements and procedures".
6. ANSI/CGATS.5-1993, Graphic technology, "Spectral measurement and colorimetric computation for graphic arts images".
7. ANSI/CGATS.6-1995, Graphic technology "Specifications for graphic arts printing" Type 1.
8. ANSI/CGATS TR 001-1995 Graphic Technology Characterization Data for Type 1 Proofing/Printing; an ANSI Technical Report.
9. ANSI/PH2.30-1989 Graphic Arts and Photography - Color prints, Transparencies, and Photomechanical Reproductions—Viewing Conditions.
10. ISO/DIS 2846-1 Graphic technology "Specifications for colour and transparency of printing ink sets" Part 1: "Sheetfed and heatset web offset lithography printing".
11. ISO/DIS 12640, Graphic technology "Prepress digital data exchange" Standard colour image data (SCID). Note: The actual images used for the SWOP press form came from a working draft of SO/TC130/WG2, dated October 1992. This draft is not publicly available. The images contained in the presently available DIS have two images that differ from those in the draft. All other images are identical.
12. CGATS Secretariat, NPES The Association for Suppliers of Printing and Publishing Technologies, 1899 Preston White Drive, Reston, VA 22091-4367, Tel: 703-264-7200.

☆ This paper was previously published in *IS&T's 4th Technical Symposium on Prepress, Proofing & Printing,* p. 81 (1995).