SPECIFICATIONS AND TOLERANCES FOR PUBLICATION PRESS PROOFING

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Abstract: This paper reviews the details of the 1993 SWOP press test, including the construction of the testform, the printing conditions and the analysis of the printed results. The densitometric and colorimetric data from the press test are compared to the proposed aim points and tolerances based on the analysis of a selected sets of SWOP Hi-Lo Color Reference patches. The SWOP press test results were very close to the aim points and well within the tolerances.

Introduction

CGATS SC4 is working on a standard that specifies the characteristics required for sheetfed printing of process color material to be used as proofs for web offset publications. When complete, this standard will be published as CGATS.6-1995 Graphic Technology - Specifications for Graphic Arts Printing - Type 1. This standard represents the first in a series of process control standards for printing.

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The numerical data contained in CGATS.6 was derived from the following three sources.

The 1993 SWOP® booklet[1] 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 patches 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 patches were analyzed by the CGATS SC4 committee. The mean values for the Hi-Lo patches are proposed in CGATS.6 as numerical aim points for solid density and color for the printed process colors. Tolerances for solid density and color were also derived from the Hi-Lo patches.

The analysis of the 1993 SWOP press test was done by CGATS SC4. 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.

1993 SWOP Press Test

SWOP, Inc. began the development of the SWOP Calibration Test Kit in 1992. One use of the Kit was to supply physical samples to the industry of press sheets printed to SWOP specifications. The Test Kit contained films of a testform designed by SWOP in conjunction with CGATS SC4 and the IT8 Standards Committees. Standard elements included in the testform could be analyzed to supply data for the CGATS SC4 work on process control and print specifications and the IT8 Committee work on print characterization.

The images used to create the printing form were from a set of digital test images that were part of a draft data set proposed for inclusion in ISO 12640[2]. These include 8 natural images (pictures identified as N1 through N8) and 10 synthetic images (test objects identified as S1 through S10). It should be noted that two of the natural images of the draft proposal have been withdrawn and replaced by other images. SCID images S7 through S10 provide a physical representation of the CMYK data

set defined in ANSI IT8.7/3[3]. On this printing form, images S7-S10 have been grouped to form a single page layout with the size of each patch being 6 mm square. In addition, SCID images S7 and S8, which represent the basic data set of IT8.7/3, were repeated with a patch size of 10 mm square to facilitate analysis using large aperture instruments. The GATF production control bar and the GATF/SWOP proofing bar were included on the gripper edge of the testform and the GATF production control bar was included on the tail edge of the testform.

In 1993, SWOP ran a press test to produce press sheets for the Calibration Test Kit and to help support the standards activtites. 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.

Third generation hard dot films of the SWOP Calibration Kit testform were used to image the printing plates. Original films of the GATF production control bar and the GATF/SWOP proofing bar were exposed directly to the plates. 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[4]. All tones on the testform 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 patches. 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[5]. Prior testing and modification of the ink rheological characteristics was used to insure that the dot gain was within the tolerances of the SWOP specifications.

Data Collection

Four portable spectrophotometers (two Gretag SPM 100s and two X-Rite 938s) were used to measure the spectral reflectance of the GATF/SWOP proofing bar and the IT8.7/3 target.

Prior to press sheet measurements, inter-instrument agreement was verified using selected 10 mm patches from the IT8.7/3 target. The results of this analysis, reported by McDowell and Taggi,[6] show a ΔE^* of less than 1 among average values of the four instruments. This indicated that the instruments themselves were in agreement and allowed the rest of the testform analysis to be considered valid.

Six press sheets were selected from the press run for evaluation. These press sheets were certified by SWOP, Inc. as conforming to SWOP specifications for press proofing. Three sheets were used for the Gretag measurements, and the other three 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

The GATF/SWOP proofing bar was read on each press sheet in the 20 inch wide area directly above the IT8.7/3 extended and basic targets. This area contained six repeats of solid, 75%, 50% and 25% patches in the color sequence (left to right): black, four-color, three-color, cyan, blue, magenta, red, yellow and green. In addition, two unprinted patch areas on the IT8.7/3 target were read to collect paper data on each press sheet. Templates were supplied to each lab to record the data in two files. One file contained the spectrophotometric data (at 10 nm intervals) for each patch read. The other file contained calculated colorimetric and densitometric values for each patch.

Colorimetric values reported were CIEXYZ and the associated L*, a*, b*, C* and h_{ab}. Density values computed were Status T (red, green, blue) and ISO Visual for all of the solid and tint patch readings. In addition, dot gain and print contrast values were calculated from readings of the 50% and 75% tint patches respectively on the GATF/SWOP proofing bar.

Densitometry and colorimetric measurements and calculations were made using the procedures specified in CGATS.4[7] and CGATS.5[8].

Results

The following tables and figures contain data which characterize the 1993 SWOP press test. These data were obtained from analysis of the SWOP certified press sheets numbered 8,9,10,12,14, and 15. CIELAB and Status T data reported are calculated from the average of 6 patches per sheet x 3 press sheets x 4 instruments for a total of 72 patch readings per value.

McDowell and Taggi (1995) have reported on the analysis of the IT8.7/3 target elements on the testform. A summary of the IT8./3 colorimetric data is reported in a separate ANSI Technical Report[9].

The mean and standard deviation for the process color densities from the press test are shown on the right side in Table 1. The aim points shown on the left side of Table 1 are measured from the mean value of a set of SWOP Hi-Lo color reference patches. A discussion of the Hi-Lo analysis is given later in this paper. The tolerances given for density are specified in the 1993 SWOP booklet. The mean densities from the press test are equivalent to the aim densities of the Hi-Lo patches.

The dot gain results for the press test analysis are shown on the right side of Table 2. The dot gain aim points and tolerances from the 1993 SWOP booklet are given on the left side. The dot gain from the press run was very close to aim and within the tolerances for SWOP specifications.

Table 1
CMYK Density Results (Status T)

	Density Aim Points		Press Test Results	
Color	Aim	Tolerance	Mean	Std. Dev.
Cyan	1.29	+/- 0.07	1.29	0.01
Magenta	1.40	+/- 0.07	1.40	0.02
Yellow	1.01	+/- 0.07	1.01	0.02
Black	1.59	+/- 0.07	1.58	0.02

Table 2
Dot Gain Results

	1993 SWOP Specifications			Press Test Results		
Color	Film Values (% Dot)	Aim	Tolerance	Film Values (% Dot)	Mean	Std.Dev.
Cyan				75	13	0.4
	50	20	+/- 3	50	18	0.6
				25	14	0.7
Magenta				75	12	0.4
	50	20	+/- 3	50	19	0.8
				25	15	1.0
Yellow				75	12	0.4
	50	18	+/- 3	50	17	0.6
				25	13	0.7
Black				75	13	0.5
	50	22	+/- 3	50	20	0.8
				25	17	1.0

Figure 1 shows a plot of the averaged dot gain data from the 1993 SWOP press test. The data readings were taken from the 10 mm spot size IT8.7/3 target. These curves illustrate dot gain profiles for the four process color ink halftone scales.

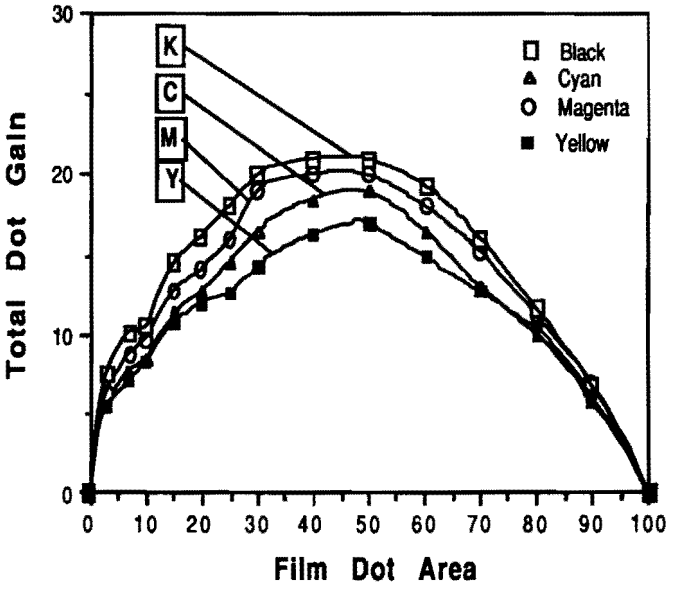

Figure 1: Dot Gain Characteristics.

Table 3 gives the range of values for print contrast from the 1993 SWOP booklet. This range is provided as a guideline in the SWOP booklet but not a specification. The press test results are shown on the right side of the Table. The magenta print contrast results are slightly lower than the suggested range.

Table 3
Print Contrast

	1993 SWOP Guidelines	Press Test Results	
Color	Range	Mean	Std. Dev.
Cyan	30-35	33	1
Magenta	30-35	24	1
Yellow	25-30	25	1
Black	35-40	25	1

Table 4 lists the mean colorimetric data for the press run and the variance in ΔE* calculated from 3 times the standard deviation. The process colors and two color overprint colors are listed. This data is compared to the colorimetric aim points calculated from the SWOP Hi-Lo patch analysis discussed later in this paper.

Table 4
Mean and Uncertainty of Press Test Process Color Data

Color		L*	a*	b*	ΔE* (3 sigma)
Cyan	Mean	55.7	-37.8	-40.4	
	Std. Dev.	0.2	0.4	0.4	2.5
Magenta	Mean	46.3	70.1	-2.2	
	Std. Dev.	0.3	0.4	0.6	2.3
Yellow	Mean	84.3	-5.8	84.5	
	Std. Dev.	0.2	0.3	0.9	2.9
Black	Mean	18.5	0.4	0.9	
	Std. Dev.	0.7	0.1	0.3	2.3
Red	Mean	46.1	64.3	43.4	
	Std. Dev.	0.3	0.4	0.7	2.6
Green	Mean	51.3	-61.5	28.7	
	Std. Dev.	0.3	1.1	1.1	4.8
Blue	Mean	24.7	20.2	-41.0	
	Std. Dev.	0.5	1.0	0.5	3.7

Figure 2 is a plot of the a*b* coordinates for a halftone scale of each of the primary and secondary colors produced during the SWOP press test. Figure 2 demonstrates how the hue and chroma change as the dot area increases across the tone scale from paper to the solid ink.

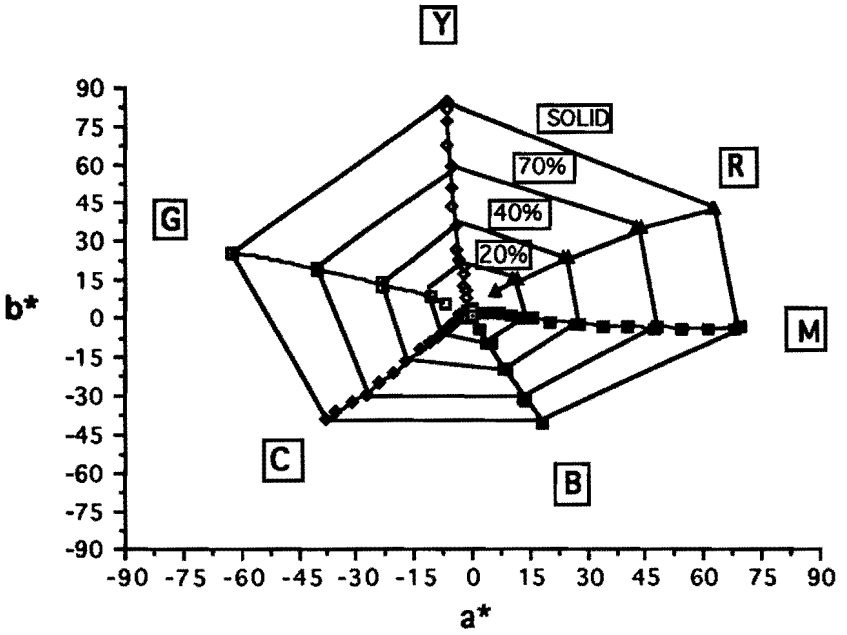

Figure 2: Colorimetric Data for Primary and Secondary Colors.

SWOP Hi-Lo Color Reference Patch Analysis

The SWOP Hi-Lo Color Reference patches are used commercially as limits for the density range for printing to SWOP specifications for press proofing. They are also frequently used as the limits for the density range for production printing. The Hi-Lo patches are provided to the industry as a material reference.

The Hi-Lo patches are produced by offset printing solid stripes of the standard SWOP/NAPIM reference process proofing inks on standard SWOP paper. After inspection to insure that release specifications are met, patches are cut and mounted on a carrier/folder to produce a set of physical samples that represent the high and low density aims for each color. The Hi-Lo patches are usually released in batches on a three month basis and are marked with an expiration date.

Batches of SWOP Hi-Lo Color Reference patches in commercial use during the time period when the SWOP press test was run were chosen for analysis. These batches had expiration dates of 3/31/93, 9/30/93 and 6/30/94. Each batch included six sets of Hi-Lo patches. A total of 18 sets of Hi-Lo patches were analyzed.

All of the sets of patches were read with the same four spectrophoto-meters used in the evaluation of the 1993 SWOP press test as described previously. A total of 72 patches for each color were averaged to obtain mean Hi and Lo density values. These density values were used as limits in monitoring the press run. The Hi-Lo values were also used as the density limits to define the colorimetric aim values, shown in Table 7, for the printed process inks.

Templates were supplied to each lab to record the data in two files. One file contained the spectrophotometric data (380 nm to 730 nm). Another file contained the calculated colorimetric and densitometric values for each patch. The colorimetric values computed were CIEXYZ and the associated L^*, a^*, b^*, C^* and h_{ab}. Density values computed were Status T (red, green, blue) and ISO Visual.

Densitometry and colorimetric measurements and calculations were made using the procedures specified in CGATS.4 and CGATS.5.

Results

The Hi-Lo patch data reported in Table 5 is the mean and standard deviation for all 72 patch readings for each color.

The mid-point of the Hi-Lo patches define the aim values for density used in printing the 1993 SWOP press test. The mid-point value was calculated for each pair of Hi-Lo patches for each color. Table 6 shows the mean and standard deviation of these 4 populations (72 samples each) of mid-point values.

Table 5
Density and Colorimetric Data for Hi-Lo Patches

Color		Density Status T	L*	a*	b*	C*	h_{ab}
Cyan Hi	Mean	1.36	53.4	-37.1	-41.5	55.7	228.0
	Sigma	0.01	0.5	0.9	0.8	0.8	0.9
Cyan Lo	Mean	1.22	56.0	-36.6	-38.5	53.1	226.0
	Sigma	0.01	0.4	0.8	0.6	0.6	0.9
Mag. Hi	Mean	1.47	45.3	71.3	-0.1	71.2	360.0
	Sigma	0 .01	0.4	0.7	0.8	0.7	0.7
Mag. Lo	Mean	1.33	47.2	68.7	-2.9	68.8	358.0
	Sigma	0.01	0.3	0.7	0.6	0.7	0.5
Yel. Hi	Mean	1.07	84.4	-4.5	88.5	88.7	93.0
	Sigma	0.02	0.3	0.5	1.1	1.1	0.3
Yel. Lo	Mean	0.95	84.8	-5.7	80.9	81.1	94.0
	Sigma	0.02	0.3	0.5	1.2	1.2	0.4
Blk. Hi	Mean	1.66	16.4	0.3	0.4	0.5	-
	Sigma	0.02	0.4	0.2	0.2	0.2	-
Blk. Lo	Mean	1.52	20.1	0.5	0.9	1.0	-
	Sigma	0.02	0.5	0.2	0.2	0.2	-

Table 7 contains the proposed colorimetric aim values for process colors printed within the SWOP density range. The density ranges in Table 7 are the values taken from Table 5 from the analysis of the SWOP Hi-Lo Color Reference patches. The colorimetric aim values in Table 7 are the mean values from the analysis of the SWOP Hi-Lo patches shown in Table 6. The Discussion section of this paper addresses the derivation of the tolerances shown in Table 7.

Table 6
Mid-point Values for Hi-Lo Patches Density and Colorimetric Data

Color		Density Status T	L*	a*	b*	C*	h_{ab}
Cyan	Mean	1.29	54.7	-36.9	-40.0	54.4	227.3
Mid-point	Std. Dev.	0.01	0.4	0.8	0.7	0.7	0.9
Magenta	Mean	1.40	46.2	70.0	-1.5	70.0	358.8
Mid-point	Std. Dev.	0.01	0.3	0.7	0.7	0.7	0.5
Yellow	Mean	1.01	84.6	-5.1	84.7	84.9	93.4
Mid-point	Std. Dev.	0.02	0.3	0.5	1.0	1.0	0.3
Black	Mean	1.59	18.3	0.4	0.7	0.8	-
Mid-point	Std. Dev.	0.01	0.3	0.2	0.2	0.2	-

Table 7
Process Ink Set Density Range and Colorimetric Aims

Color	Absolute density range Status T	L*	a*	b*	C*	h_{ab}	ΔE*
Cyan	1.22-1.36	54.7	-36.9	-40.0	54.4	227.3	4
Magenta	1.33-1.47	46.2	70.0	-1.5	70.0	358.8	5
Yellow	0.94-1.08	84.6	-5.1	84.7	84.9	93.4	6[a)]
Black[b)]	1.52-1.66	18.3	0.4	0.7	0.8	-	3

a) Yellow is further constrained such that h_{ab} = 93.4 +/- 2.7
b) ISO Visual filter

Discussion

The average of the SWOP Hi and Lo patches were used to establish mid-point values. Table 5 tabulates the mean value of the combined data for the Hi and Lo patches and represents the best estimate of the mid-point or aim colorimetric values for SWOP printing. The Hi and Lo patches represent the allowable deviation from the mid-point value. Table 5 provides the mean values of the Hi and Lo patches as well as the related statistical uncertainty in the estimate.

Because the mid-point is derived from the Hi and Lo patches, one half the difference between these patches might be considered the maximum deviation from the mid-point value. However, this does not take into account the uncertainty of the mean value of the Hi and Lo patches. Accordingly, 2 times the standard deviation of uncertainty was added to the outer limit of the Hi and Lo values to increase the maximum expected difference in L^*, a^* and b^*. One half of each of these increased ranges was used as the allowable variation from the mid-point value. This data is shown in Table 8 along with the ΔE^* that corresponds to the combination of these limits.

Table 8
Colorimetric Range of SWOP Hi-Lo Patches

Color	ΔL^*	Δa^*	Δb^*	ΔE^*
Cyan	2.2	2.0	2.9	4.1
Magenta	1.7	2.7	2.8	4.2
Yellow	0.8	1.6	6.0	6.3
Black	2.8	0.5	0.7	3.0

The variation in cyan and magenta is relatively symmetrical in all three variables, therefore a simple ΔE^* tolerance will suffice for these colors. Note that the tolerance shown in Table 7 for the magenta has been increased to $\Delta E^* = 5$. This was done to bring this tolerance into conformance with the magenta tolerance limit given in ISO 2846-1.

The variation in yellow is predominately in the b^* direction. To reflect this characteristic, a tolerance is placed on h_{ab} value in addition to an overall ΔE^* tolerance. Data drawn from Table 4

indicates that if the same tolerencing used for L*, a* and b* were applied to h_{ab}, the values would be a nominal 93.5 with a tolerance of +/- 2.7. The variation in black, $\Delta E^* = 3$, is taken from Table 8.

A comparison of the colorimetric results from the analysis of the 1993 SWOP press test to the aims and tolerances shown in Table 7 is given in the following Figures.

The yellow a*b* plot in Figure 3 shows the tolerances $\Delta E^* = 6$ and Δh_{ab}+/-2.7. The Hi, Aim and Lo colorimetric values from the Hi-Lo evaluation are plotted. The 2 sigma variation from the Hi and Lo is shown in the Figure. The SWOP press run data is also plotted in Figure 3 along with the mean value for the data. All of the press data falls very close to the aim density value and well within the proposed colorimetric tolerances.

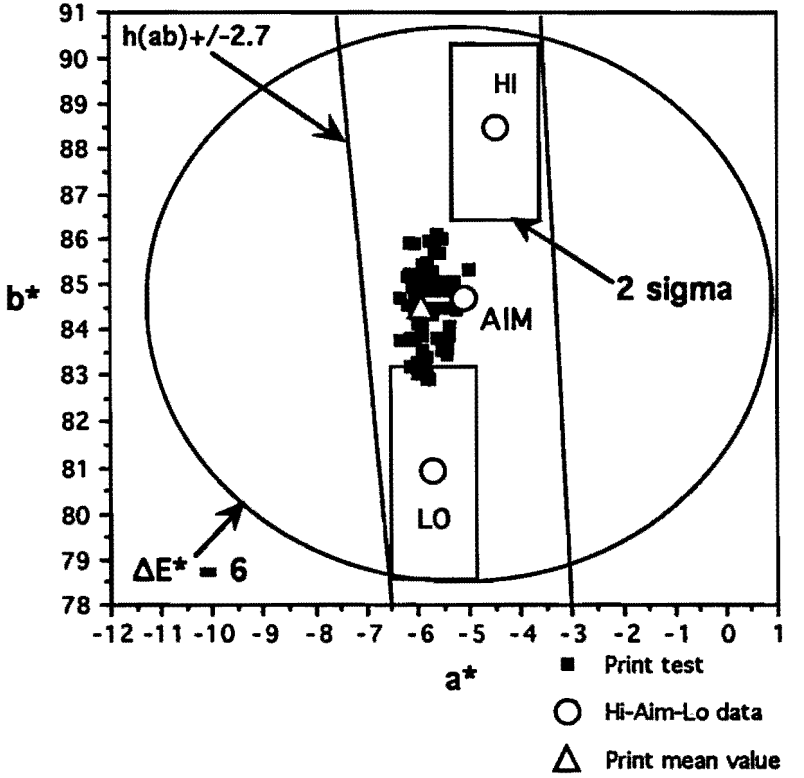

Figure 3: Yellow a*b* Plot with Hi, Aim and Lo Points and Press Data.

The magenta a*b* plot in Figure 4 shows the tolerance $\Delta E^* = 5$. The Hi, Aim and Lo colorimetric values from the Hi-Lo evaluation are plotted. The 2 sigma variation of the Hi and Lo is shown in the Figure. The SWOP press run data is also plotted and the mean density value is shown.

The press data falls very close to the aim density value and well within the proposed colorimetric tolerances.

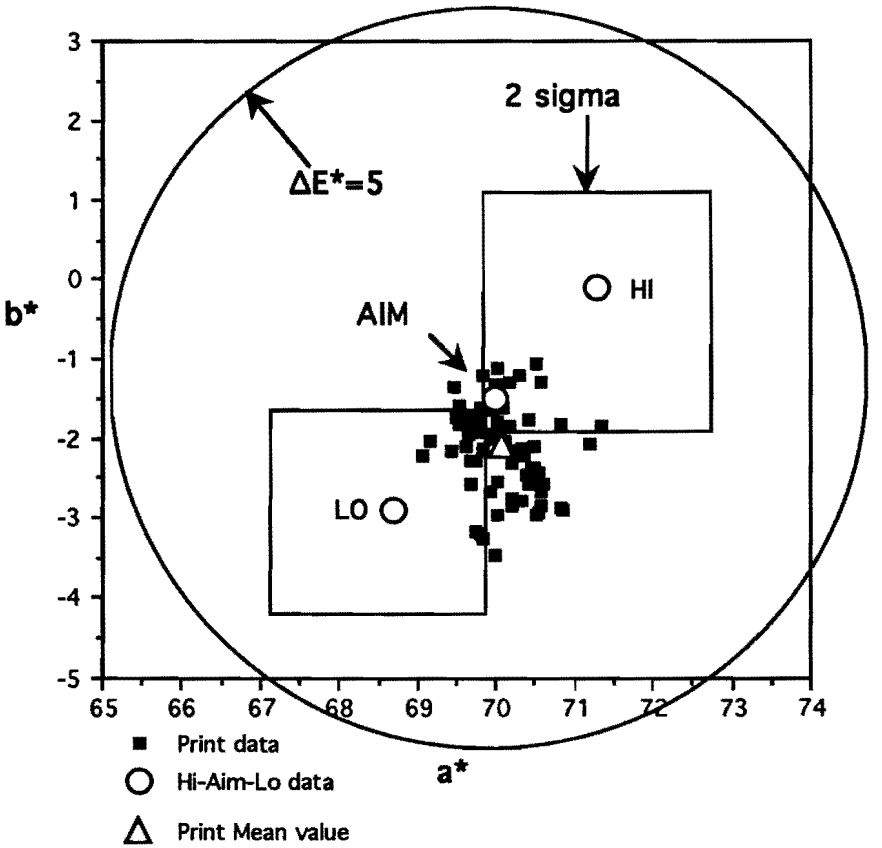

Figure 4: Magenta a*b* Plot with Hi, Aim and Lo Points and Press Data.

The cyan a*b* plot in Figure 5 shows the tolerances $\Delta E^* = 4$. The Hi, Aim and Lo colorimetric values from the Hi-Lo evaluation are plotted. The 2 sigma variation from the Hi and Lo is shown in the

Figure. The SWOP press run data is also plotted and mean density value is shown.

The press data falls very close to the aim density value and well within the proposed colorimetric tolerances.

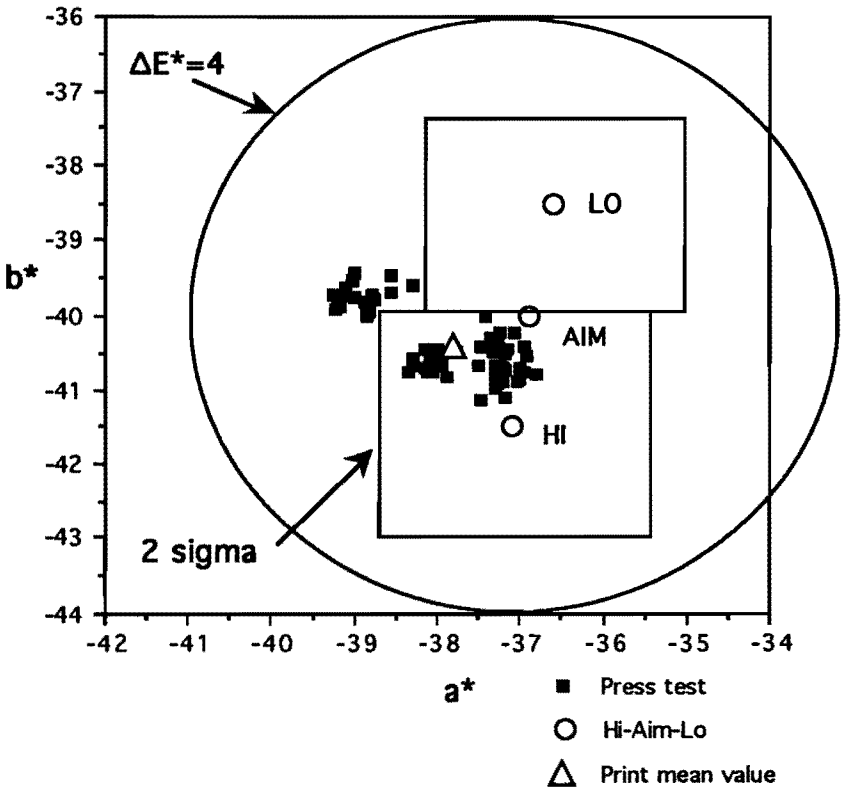

Figure 5: Cyan a*b* Plot with Hi, Aim and Lo Points and Press Data.

The variation in a* and b* in the black press data is very small with most of the variance in the L* value. Figure 6 is a plot of the L* vs. C* to provide a more graphic example of the press run results vs. the HI-Lo aims and tolerances. The black L*C* plot in Figure 6 shows the tolerance ΔE* = 3. The Hi, Aim and Lo colorimetric values from the Hi-Lo evaluation are plotted. The 2 sigma variation of the Hi and Lo is shown in the Figure. The SWOP

press run data is also plotted and the mean density value is shown.

The press data falls very close to the aim density value and well within the proposed colorimetric tolerances.

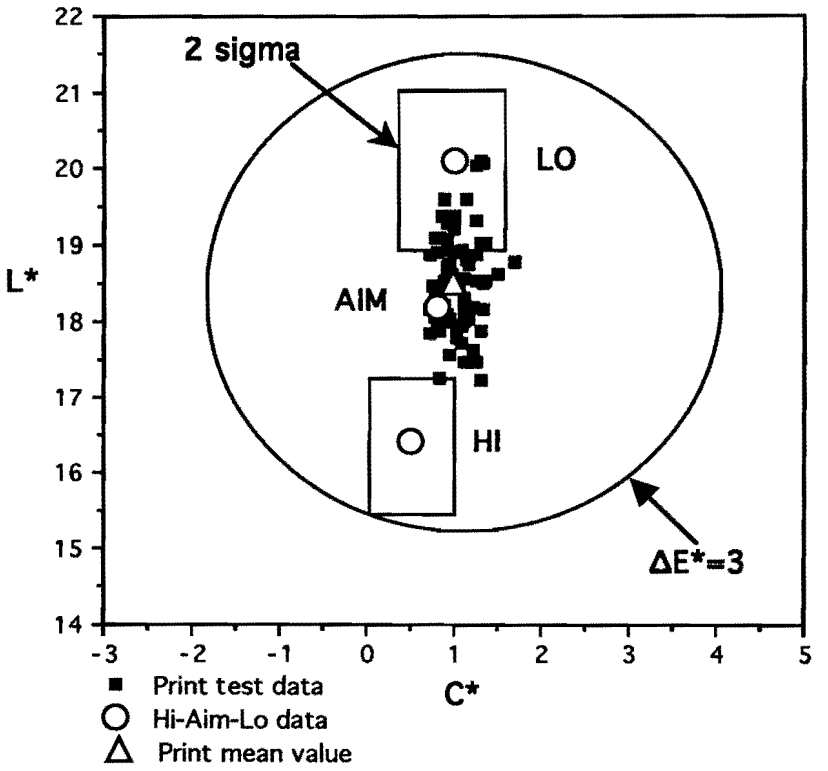

Figure 6: Black L*C* Plot with Hi, Aim and Lo Points Press Data.

Conclusions

The analysis of the 1993 SWOP press test compared the data to the proposed aim points and tolerances for sheetfed press proofing. The press test fell very close to the center of the aim points for density, dot gain, print contrast and colorimetric values.

The print and colorimetric data from the analysis of the press test and SWOP Hi-Lo patches will be used to complete the CGATS.6 standard on print specifications for sheetfed press proofing.

The IT8.7/3 target on the testform was printed very close to the center of SWOP specifications and can be used for the print characterization of the SWOP sheetfed press proofing process.

Acknowledgments

Many individuals participated in the development of the print testform, producing the pressrun and analyzing the data reported in this paper. I would like to acknowledge those who have contributed through the following organizations:

- SWOP, Inc. and the SWOP Print Test Kit Committee
- CGATS SC4 - Process Control
- CGATS SC8 - Color Data Definition (previously IT8 SC4)

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