A Colorimetric Test for Reflection CMYK Colorant Output

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Abstract: This paper discusses practical applications for use of IT8.7/3 test object and TR001. These applications include but are not limited to evaluation of analog and digital proofing systems, computer-to-plate systems, and press responses.

Proliferation of digital systems, multi site printing, and collateral printed material requires characterizing and mapping the color gamuts of various devices. The IT8.7/3 target is a well defined, readily available device that effectively samples primary, secondary, three color and four color overprints of a cmyk system. It is described in ISO 12642, is not a proprietary target, and as such is significant as a universal profiling test object.

ANSI CGATS Technical Report TR001 has provided a numerical colorimetric target for SWOP® printing and presented the challenge to define tolerances around this target. The fact that many in the printing industry have embraced the TR001 document as a de-facto standard suggests there is a need for well defined colorimetric targets including good metrics and tolerances. Delta E calculations to TR001 and rank order plots are useful techniques to evaluate variables in proofing, printing, and profiling.

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Background

ANSI CGATS Technical Report TR001-1995 has its history in SWOP Certified Press Run 1993. The 1993 SWOP press test provided press sheets that were as close to the center of the SWOP specifications for press proofing as possible. Care was taken to print to density, dot gain, and gray balance specifications using 60 pound Champion Textweb and SWOP/NAPIM proofing inks. These printing characteristics were monitored on GATF/SWOP color bars on the top and bottom of the press sheets.

The 1993 SWOP press test form included the images from ISO 12640 commonly called the SCID(standard colour image data) images which includes 8 natural images and 10 synthetic images. SCID images S7-S10 were grouped together to form a single page 8 x 10 layout of the cymk data set defined in ANSI Standard IT8.7/3-1993. This layout of 928 color patches is commonly referred to as the IT8.7/3 target or 'extended ink value data'. It is more recently defined in ISO 12642, Graphic technology--Prepress digital data exchange--Input data for characterization of 4-colour process printing. See Appendix A for layout diagram.

Press sheets were given to a CGATS.6 committee that was working on Type 1 printing standards. Two sets of three press sheets were sent to three testing sites each for measurement of the IT8.7/3 target. All data was collected, compiled, and a report issed with the colorimetric results of each patch. This report is identified as CGATS TR 001-1995 'Graphic Technology-Color Characterization Data for Type 1 Printing', a sample of which is in Appendix B. Imation Corporation was one of the original test sites that measured the IT8.7/3 target on three 1993 SWOP Certified Press Sheets using a Gretag SPM 100 and an XY table with black backing.

Experimental

The experimental work described in this section of the paper is in two parts. First, the measurement and analysis protocol details the test objects, instrumentation, configuration, measurement, calculations, and graphing techniques used. Second, case studies illustrating the use of IT8.7/3 and TR001 are presented.

Measurement and Analysis Protocol

Imation was one of the measurement sites for the initial TR001 data and where possible, the same equipment and measurement configuration was used for the work presented in this paper. All measurements were made with a Gretag SPM100 spectrophotometer on an Imation XY table to facilitate automated measurement on large press or proof sheets without cuttting the sample down to a small size. The configuration was D50 illumination, 2 degree, no polarization and black backing behind the sample unless otherwise noted. CIE L*a*b* values were extracted from the data and used for analysis.

Delta E was calculated using the formula below. In most cases the target data was the TR001 L*a*b* data although any data set could be used as the target or reference data.

$$\Delta E = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2} \quad (1)$$

or $$\Delta E = [(L_t^*-L_s^*)^2 + (a_t^*-a_s^*)^2 + (b_t^*-b_s^*)^2]^{1/2}$$

where,

t: target data

s: sample data

Data handling becomes an issue when each sample is described by 928 patches in the IT8.7/3 target times three metrics (Lab) for a total of 2784 data points. Automated systems for measuring samples and collecting data reduces errors but error checking is still necessary. Measuring the patches of the IT8 target in the same order as the TR001 data file reduces the need for sorting data for comparison purposes.

Analyzing 928 patches on multiple samples becomes problematic. Mike Rodriquez of R.R. Donnelley suggests the use of a CumSum% graphing procedure which we refer to as the Donnelley Initiative. It is a method of comparing two or more samples or systems to get a goodness value for a color match.

There are four steps to the CumSum graph procedure.

1. Calculate ΔE of sample versus target data
2. Sort ΔE data in descending order
3. Calculate rank order for number of data points
4. Graph sorted ΔE versus rank order

Use formula 1 to calculate ΔE for all the patches and then sort the ΔE's in descending order. Ascending order can also be used though interpretation of the graph would change. To calculate the rank order, first produce a column of row numbers from one to total number of patches. Then take each row number and divide by the total number of patches and multiply by one hundred(See formula 2). The new column of numbers represents the rank order of each of the sorted ΔE measurements. Then graph rank order against sorted ΔE. The data from an IT8.7/3 target is represented in Table 1.

Rank order is calculated as follows:

$$RO = (\text{row }\#/\text{total }\#\text{ of patches}) \times 100 \qquad (2)$$

ΔE	ΔE Sort	Row #	RO
2.39	7.19	1	0.11
1.39	7.06	2	0.22
3.19	6.88	3	0.32
3.99	6.38	4	0.43
1.32	6.38	5	0.54
.	.	.	.
.	.	.	.
2.66	2.62	462	49.78
1.90	2.61	463	49.89
1.57	2.61	464	50.00
1.52	2.61	465	50.11
.	.	.	.
.	.	.	.
2.23	0.39	926	99.78
1.67	0.37	927	99.89
1.94	0.05	928	100.00

Table 1: Representation of data for CumSum graph

Figure 1 is an example of the CumSum graph. How does one interpret this graph? If the sample data was an exact match to the target data the graph of ΔE would be the vertical axis at ΔE=0. The graph in Figure 1 represents three press sheets that do not perfectly match the target. Of 928 patches that were measured, fity percent of the patches are less(and fifty percent more) than 2.5 ΔE. Furthermore, ten percent of the patches are greater than 4 ΔE and ninety percent are less than 4 ΔE.

The curves in Figure 1 represent the match to TR001 of three SWOP Certified Press Sheets from 1996 SWOP Run 2. The press sheets are identified as #65, #113, and #115. The fact that the Run 2 press sheets are not perfectly matched to Run 1 (TR001) may have many reasons. The press run was in 1996 but these measurements were made in 1999. Although kept in dark storage, the paper and inks undoubtedly changed over time. This raises the issue of continuing to use it as a visual target without an expiration date to determine its useful life. It is also likely that Run 1 and Run 2 were different eventhough both were within the ANSI and ISO Type 1 Printing specifications.

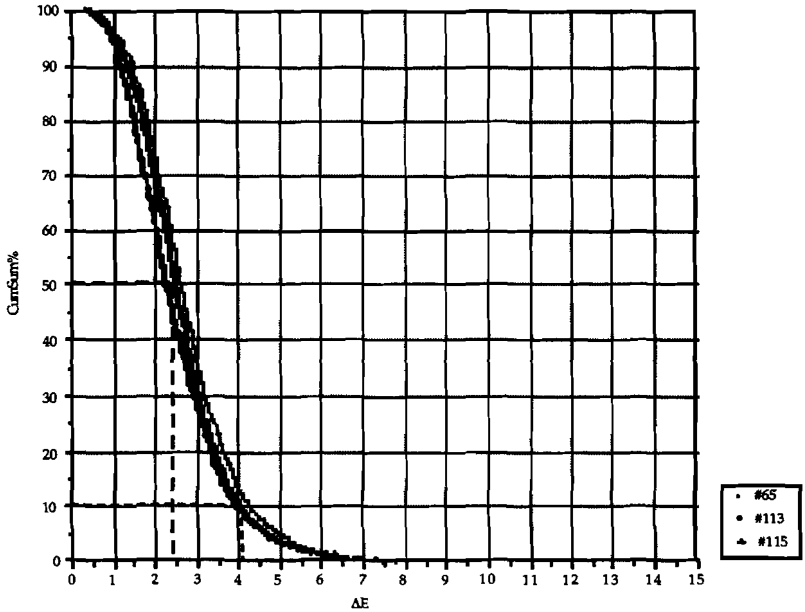

Figure 1: CumSum graph comparing 3 SWOP Certified Press Sheets to TR001

Care must be taken so two equivalent curves are not interpreted to mean visually matching samples. Two curves that lie nearly on top of each other do not indicate that the two samples are visually the same. DeltaE does not indicate the direction in color space that the sample varies from the target. Thus, one sample could have a green cast and one sample have a magenta cast yet still differ from the target by the same amount. The CumSum technique only gives an overall measure of conformance to a target.

This graph could also be produced by using a cumulative summation calculation available in spreadsheet and statistical programs. Essentially histogram bins are established and cumulative sums are calculated which can then be graphed.

Case Studies

This section of the paper will illustrate three cases where the IT8.7/3 target, TR001 data, and the CumSum graph was used to evaluate proofing systems, measurement protocols, and system variables.

Case 1

The printing industry today has many analog and digital proofing systems available that have been certified to meet ANSI and ISO Type 1 printing specifications for ink solid density, dot gain, ink colorimetric aimpoints and paper stock. Yet each of these proofing systems look different from each other. Since TR001 was issued as a technical report of Type 1 printing, people in the printing industry have begun using it as a numerical aimpoint eventhough there is no visual reference and no tolerances around the numbers. TR001 was not intended to be used as a standard but it fills the need for an aimpoint.

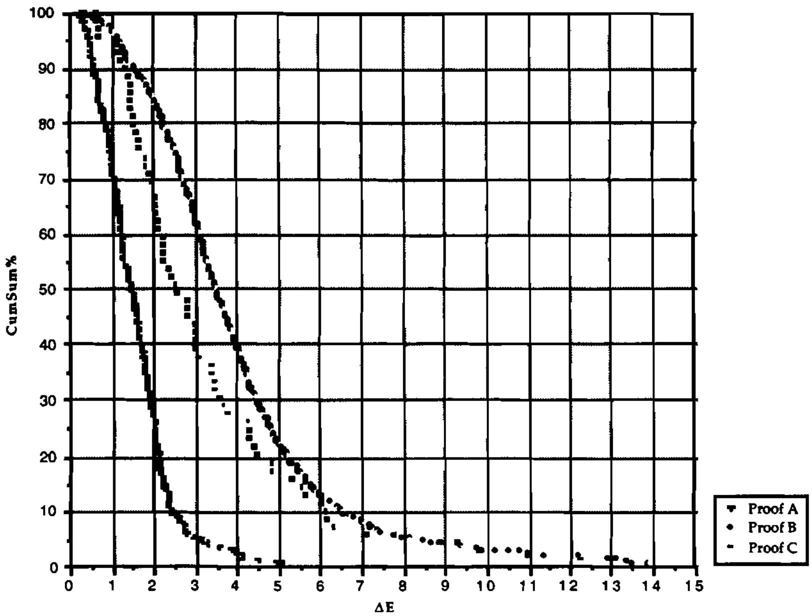

Figure 2. Digital proofing systems compared to TR001

Figure 2 is a CumSum graph of three digital proofing systems which are compared to TR001. All three meet density, dot gain, and ink color aimpoints for Type 1 printing. Yet as you can see, proof A is a better match to the aimpoint. It is interesting to look at both the 50% and the 10% levels when comparing proofing or reprographic systems.

Case 2
ANSI and ISO have standardized protocols for densitometric and spectrophotometric measurement. Included in the protocols are specifications for instrument, illuminant, degree observer, geometry, pol/no pol, and black backing/white backing. Often the tests for the effects of these variables are performed on solid ink patches or primary tints which may or may not exhibit the differences you would see in a real image.

In this case, the effects of black backing and white backing are evaluated using the CumSum technique. ANSI and ISO specify using a black backing behind the sample when using a densitometer or spectrophotometer so as to minimize the effect of back printing on thin paper stock. Black backing was utilized when measuring the press sheets included in the TR001 report. Thus, the TR001 numerical aimpoints are based on black backing. To use another backing could present an unfair advantage or unfair disadvantage in system comparisons.

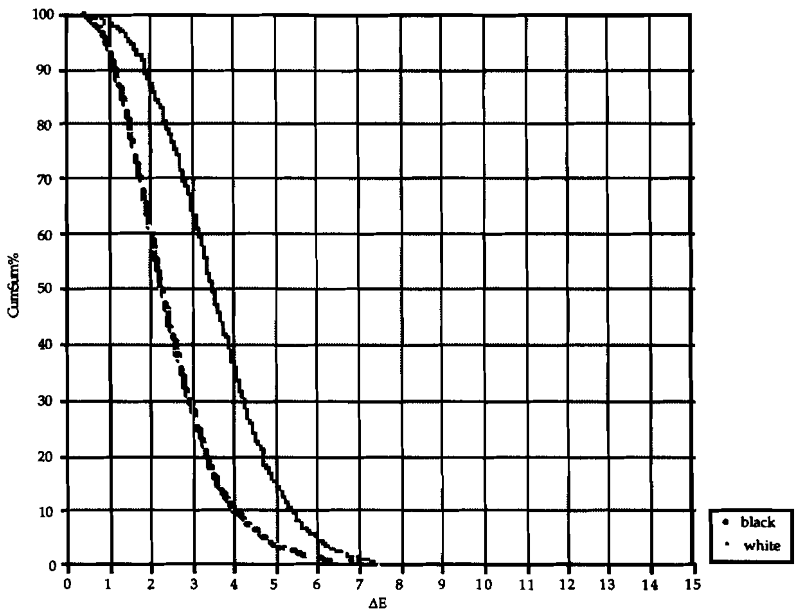

Figure 3. Effect of measuring over white and black backing

Figure 3 shows the difference in color match of 928 patches of IT8.7/3 to TR001. SWOP Certified Press Sheet #113 was measured with white backing and with black backing. As expected, the black backing came closer to the TR001 aimpoint than the white backing. This is an effective means to test the effects of measurement protocol because the cmyk color gamut is well sampled with primaries, 2, 3, and 4-color overprints.

Case 3

Each printing and proofing system produces images according to choices of many different variables. These variables include but are not limited to paper base, screen ruling, gloss/degloss, dot gain, and dot shape. Often the variables and their effects are ignored or minimized when comparisons between samples are made. The effect of paper base is presented in this example.

Three identical analog proofs were made and transferred to three different paper bases which were Champion Textweb, Imation Matchprint™ publication base, and Imation Matchprint™ commercial base. At the 50% level, ΔE changes from 2.5ΔE to 3.5ΔE to 4.5ΔE as the base changes. In this example the 10% level has a different trend than the 50% level which indicates the importance of monitoring more than one acceptance level.

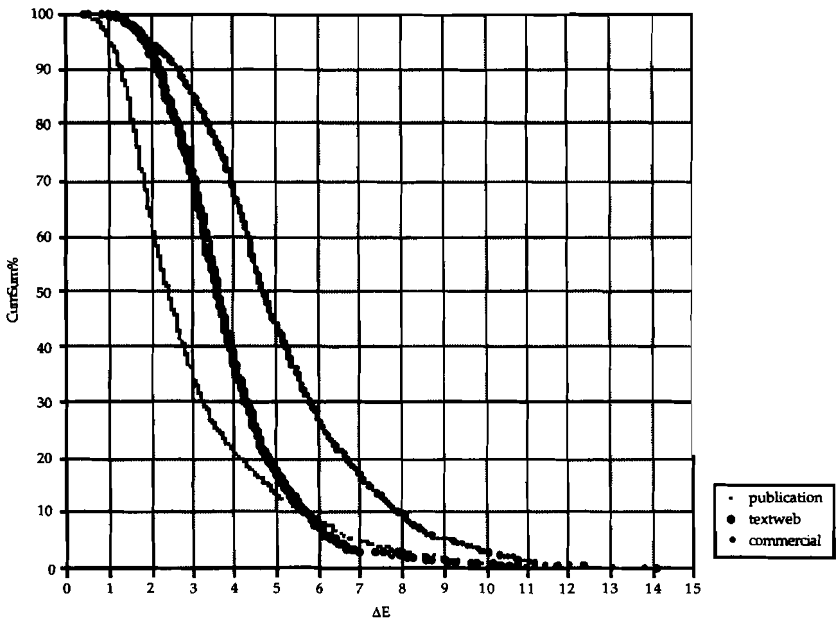

Figure 4. Effect of paper base on color match

Conclusions

The rank order or CumSum technique put forward by Donnelley is a very good tool to determine colorimetric matches to any aimpoint.

The ANSI CGATS IT8.7/3 test object is a standardized, readily available, compact target that samples the CMYK color gamut thoroughly. It is a useful test object for characterizing CMYK output devices and systems

The ANSI CGATS TR001 is a useful numeric aimpoint for evaluating the effect of measurement variables, proofing and printing conformance to Type 1 printing, and of system variables. Since this technical report has filled a void for a comprehensive numeric target it has taken on a life of its own. To be accepted as a standard it requires a couple items. It needs tolerances or windows of acceptability. Press conditions that represented the limits as well as the center of the SWOP specifications would be required to establish these tolerances. In addition, it would require a visual reference as the final test for most people is how it visually looks. Press Run 2 does not visually represent Press Run 1 numbers. For those in the industry who require it, a SWOP Certified press sheet may need to be supplied with its own spectrophotometric certification sheet. However, much needs to be learned about the aging characteristics of the papers and inks.

As we move toward more numeric targets, a renewed awareness of measurement protocol will be needed. When the capabilities of a proofing system approach 1.5ΔE at the 50% level on a CumSum graph, care must be taken to make fair comparisons.

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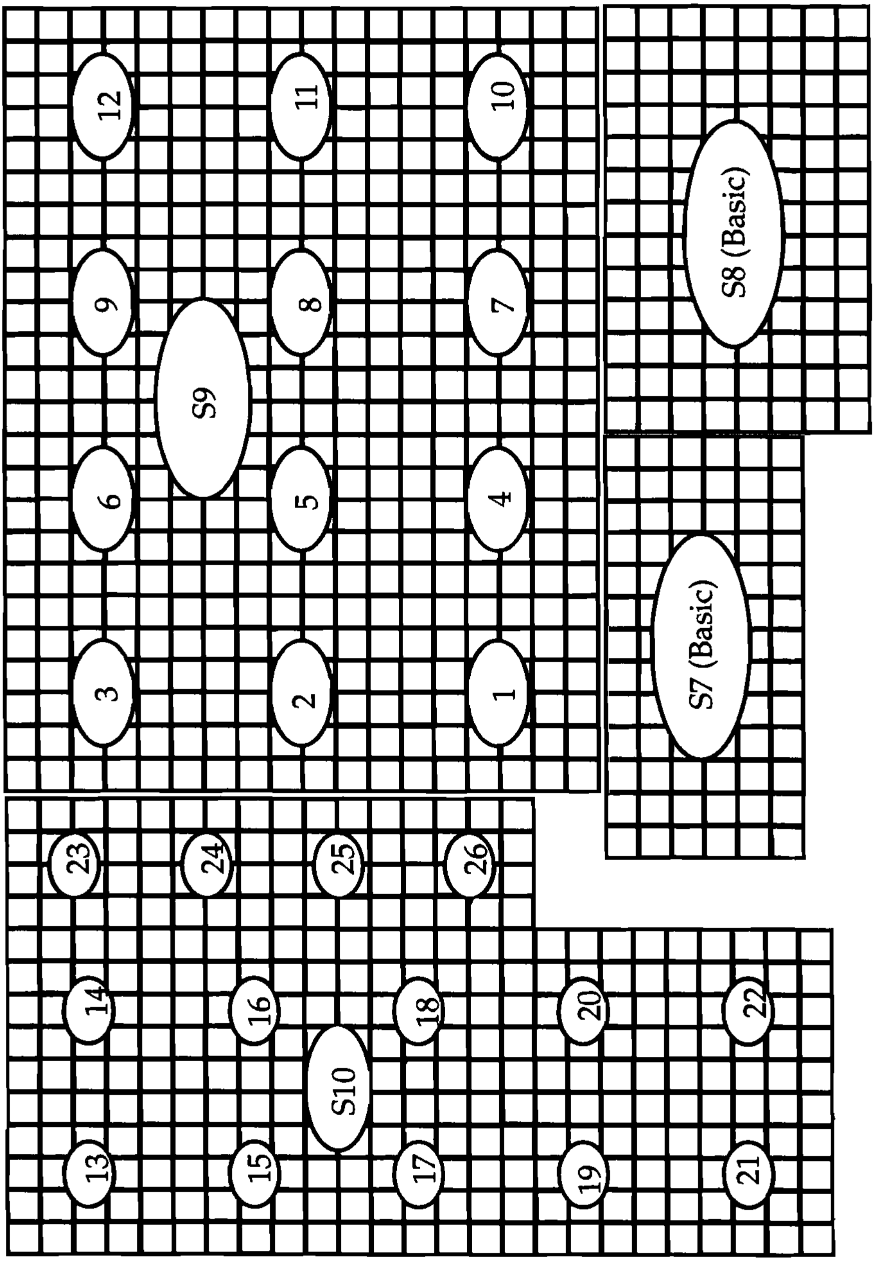
ANSI® CGATS.5-1993	Graphic technology-Spectral measurement and colorimetric computation for graphic arts images
ANSI® CGATS.6-1995	Graphic technology-Specifications for graphic arts printing - Type 1
ANSI® CGATS TR001-1995	Graphic technology - Color Characterization Data for Type 1 Printing
ANSI® IT8.7/3-1993	Graphic technology - Input data for characterization of 4-color process printing

Appendix A. Diagram of IT8.7/3 Extended Color Set



Appendix B. Sample of Characterization Data from TR001

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IT8.7/3
ORIGINATOR "ANSI CGATS"
DESCRIPTOR "Color Characterization Data, Type 1 Printing - Colorimetric Data"
CREATED "March 27, 1995"
# This file is provided in support of ANSI/CGATS TR001-1995 which is titled
# ANSI/CGATS TR 001-1995 "Graphic Technology - Color Characterization
# Data for Type 1 Printing".
# These data represent the average of 12 sets of measurements as described in
# ANSI/CGATS TR001 noted above.
INSTRUMENTATION "See ANSI/CGATS TR001"
MEASUREMENT_SOURCE "See ANSI/CGATS TR001"
PRINT_CONDITIONS "See ANSI/CGATS TR001"
ILLUMINANT "D50"
OBSERVER "CIE 2 degree"
NUMBER_OF_FIELDS 12
KEYWORD "SAMPLE_LOC" # Patch location in printing form, see ANSI IT8.7/3
BEGIN_DATA_FORMAT
SAMPLE_ID SAMPLE_LOC CMYK_C CMYK_M CMYK_Y CMYK_K LAB_L
LAB_A LAB_B
XYZ_X XYZ_Y XYZ_Z
END_DATA_FORMAT
NUMBER_OF_SETS 928
BEGIN_DATA
```

# ID#	Loc	Input Dot Value									
# NUM		C	M	Y	K	L*	a*	b*	X	Y	Z
1	0A01	100	0	0	0	56.02	-37.58	-40.01	15.67	23.93	45.64
2	0A02	0	100	0	0	47.16	68.06	-3.95	30.40	16.14	14.82
3	0A03	0	0	100	0	84.26	-5.79	84.33	59.79	64.57	7.16
4	0A04	100	100	0	0	26.57	17.60	-41.24	6.27	4.94	15.54
5	0A05	100	0	100	0	51.46	-61.59	26.08	9.29	19.67	7.58
6	0A06	0	100	100	0	46.94	62.21	41.81	28.62	15.98	3.06
7	0A07	100	100	100	0	24.84	-1.30	-0.51	4.12	4.36	3.68
8	0A08	70	70	0	0	40.62	12.83	-31.30	13.07	11.63	22.10
9	0A09	70	0	70	0	60.03	-39.96	18.66	18.38	28.16	14.66
10	0A10	0	70	70	0	56.79	43.06	34.90	35.05	24.71	7.67
11	0A11	40	40	0	0	57.63	8.39	-19.69	26.67	25.57	32.53