Using Printing Process Control Tools to Print to Dataset, A Case Study

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Abstract

Printing Standards Audit (PSA) is a printing certification scheme, developed by Rochester Institute of Technology (RIT), that certifies a printer's color reproduction workflow according to the U.S. standard, ANSI CGATS.21-1 — Printing from digital data across multiple technologies. In order to enable printers not only become certified but also improve their operational efficiency in the pressroom, RIT developed three printing process control tools, available as training materials in the future. The first tool, SCCA Calculator, is used to adjust the printing aims by calculating substrate-corrected dataset and deriving the substrate-corrected color aims (SCCA). The second tool, SID (solid ink density), is used for adjusting the inking of an offset press to match solid ink density aims quickly. The third tool, On-site, is used for assessing color accuracy and consistency of a production run. This article introduces how these tools, plus a commercial press calibration tool, Curve3, work. It describes why these tools are useful from a printer's perspective.

1.0 Introduction

The relationship between digital data and printed color is defined by the characterized reference printing condition (CRPC). The color of the printing substrate, used in actual printing conditions, often differs from the white point of the CRPC. ANSI CGATS.21-1 specifies the use of the tristimulus linear correction method to adjust the CRPC and use the substrate-corrected data as printing process control aims.

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To print by numbers, the pressman must know the printing aims. The first printing process control tool, SCCA Calculator, is used to compute substrate-corrected dataset and extract process control aims, including solids, single color tints, and grays, from the substrate-corrected dataset.

In order to print to substrate-corrected dataset, ISO/TS 10128 specifies three press calibration methods – TVI, gray balance, and device link. Regardless which method is used, a conventional output device, e.g., offset, is typically calibrated as follows:

a) Identify process control aims.
b) Print to solid ink conformance using linear plates.
c) Measure printed tonal ramps and calculate four 1-D curves to achieve TVI or gray balance conformity.
d) Print with the curved plates and verify printing conformance.

Calibrating an offset press requires that the printer adjusts the inking to match the colorimetric aims of the CMYK solid. The second printing process control tool, SID (Solid Ink Density), is used to determine the solid ink density that will produce the closest match to the colorimetric aims for the paper and ink being used.

Once the press is calibrated, it is the responsibility of the printer to maintain the color consistency in the production. The third printing process control tool, On-site, is used to analyze color measurement data and to display trends in color accuracy and production consistency over the course of the press run.

All three printing process control tools, in the form of Excel spreadsheets, use a Visual Basic macro to compute the color difference in terms of CIEDE2000 (ΔE_{00}). The computation is set to automatic. It is important that the Excel file be saved as .xls (not .xlsx) format in order to preserve the Visual Basic Macro.

Both process control tools, SID and On-site, require the use of a color control strip and associated color measurement devices as input. The color control strip is small in dimension (10 x 100 mm or 0.4 x 4 in) and can be included in the tail edge of a production job (Figure 1).

Figure 1. The RIT 10-patch target

To assess dataset conformance, a test form, including the IT8.7/4 test target (254 x 406 mm or 10 x 16 in), is necessary. This requires a special press run to print the test form. This no longer is a routine press run any more. Thus, dataset conformance is outside the scope of this article.

We need tolerance specifications to assess conformance to process control aims. The U.S. standard, CGATS.21, specifies that print buyers shall be responsible for communicating the tolerances to printers to indicate a satisfactory match between the printed job and the agreed upon characterization data.

2.0 Description of the Print Production Facilities

The minimum requirement to test the printing process control tools is a 4-color offset press. Preferably, the press is equipped with an off-line scanning spectrophotometer for controlling ink uniformity.

This case study, conducted by Wing King Tong Printing Ltd. (WKT), Hong Kong, was based on a production run of 5,000 impressions using the Heidelberg CD74 5-color sheet-fed offset press, Chenming Matte Premium (140 gsm) paper, FujiFilm CTP, and Sakata Ecopure soy inks. Figure 2 illustrates the print form, including the print job, the RIT color control target, and the D-Tone gray balance control strip, placed across six ink zones at the tail-edge of the substrate.

Figure 2. Print form including print job and color control bars

A Techkon scanning Spectro-Dens was used to control solid inking and its uniformity across all six ink zones during the press run (Figure 3).

Figure 3. Techkon scanning and hand-held Spectro-Dens

The print form was treated as a routine production job. There was no special press calibration introduced in the case study. An X-Rite i1 Pro2 spectrophotometer (M1) was used for press sheet measurement (Figure 4). Only color measurement data from the ink zone 2 was analyzed in this case.

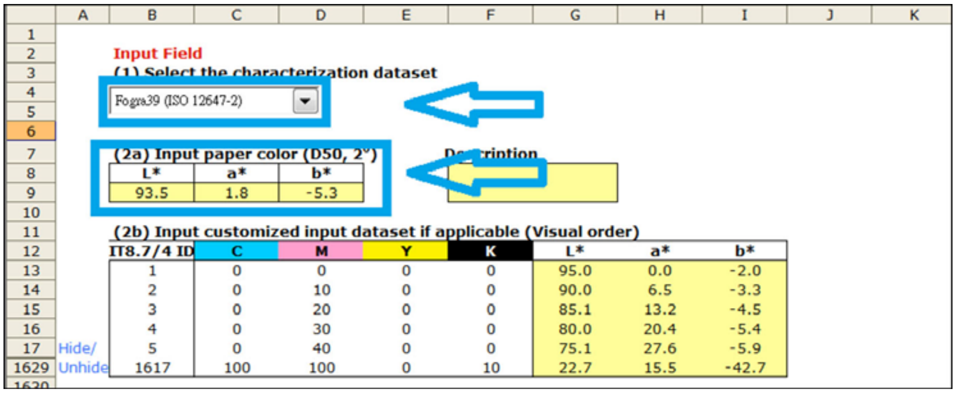
Figure 4. X-Rite i1 Pro2 spectrophotometer

3.0 The How and Why of Printing Process Control

For each color control tool, we first describe how to use the tool; then we assess why the tool is useful. In addition, we discuss how the tool may complement to other tools used in routine production, and how these tools may be used in hands-on learning and testing.

3.1 Using the SCCA Calculator

The input of the SCCA Calculator includes (a) selecting a standard dataset, (b) specifying the printing paper color (Figure 5). In this instance, Fogra39 is selected as the dataset; and the printing paper, Chenming Matte Premium (140 gsm), has a white point of (93.5L*/1.8a*/-5.3b*).



Input Field

(1) Select the characterization dataset

Fogra39 (ISO 12647-2)

(2a) Input paper color (D50, 2°)

L*	a*	b*
93.5	1.8	-5.3

Description

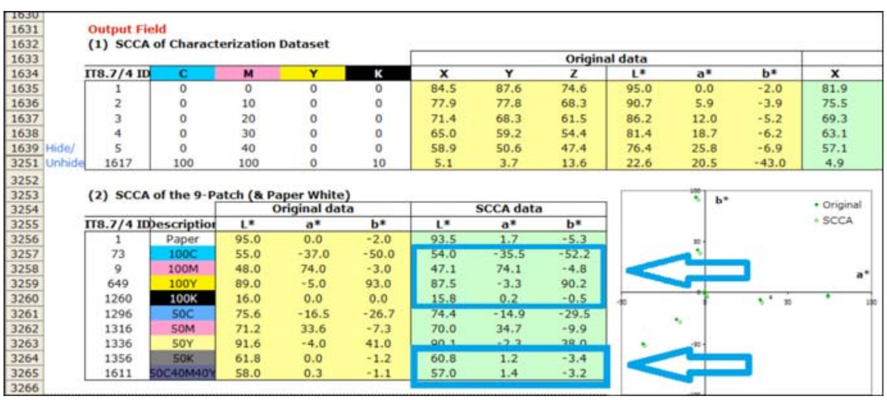
(2b) Input customized input dataset if applicable (Visual order)

IT8.7/4 ID	C	M	Y	K	L*	a*	b*
1	0	0	0	0	95.0	0.0	-2.0
2	0	10	0	0	90.0	6.5	-3.3
3	0	20	0	0	85.1	13.2	-4.5
4	0	30	0	0	80.0	20.4	-5.4
5	0	40	0	0	75.1	27.6	-5.9
1617	100	100	0	10	22.7	15.5	-42.7

Figure 5. Input section of the SCCA calculator

M1 measurement is used for color measurement because the paper contains OBA (Optical Brightening Agent). In addition, the 'unprinted' area of a printed sheet is measured as opposed to a virgin paper. This is because an aqueous varnish, applied in line with CMYK printing, can change the paper color slightly.

The output section (Figure 6) includes the substrate-corrected dataset (row 1,635-3,251) and process control aims (row 3,256-3,265), i.e., CMYK solids (top arrow), CMYK tints, 50K and 50C40M40Y patches (bottom arrow).



Output Field

(1) SCCA of Characterization Dataset

IT8.7/4 ID	C	M	Y	K	Original data X	Y	Z	L*	a*	b*	X
1	0	0	0	0	84.5	87.6	74.6	95.0	0.0	-2.0	81.9
2	0	10	0	0	77.9	77.8	68.3	90.7	5.9	-3.9	75.5
3	0	20	0	0	71.4	68.3	61.5	86.2	12.0	-5.2	69.3
4	0	30	0	0	65.0	59.2	54.4	81.4	18.7	-6.2	63.1
5	0	40	0	0	58.9	50.6	47.4	76.4	25.8	-6.9	57.1
1617	100	100	0	10	5.1	3.7	13.6	22.6	20.5	-43.0	4.9

(2) SCCA of the 9-Patch (& Paper White)

IT8.7/4 ID	Description	Original data L*	a*	b*	SCCA data L*	a*	b*
1	Paper	95.0	0.0	-2.0	93.5	1.7	-5.3
73	100C	55.0	-37.0	-50.0	54.0	-35.5	-52.2
9	100M	48.0	74.0	-3.0	47.1	74.1	-4.8
649	100Y	89.0	-5.0	93.0	87.5	-3.3	90.2
1260	100K	16.0	0.0	0.0	15.8	0.2	-0.5
1296	50C	75.6	-16.5	-26.7	74.4	-14.9	-29.5
1316	50M	71.2	33.6	-7.3	70.0	34.7	-9.9
1336	50Y	91.6	-4.0	41.0	90.1	-2.3	38.0
1356	50K	61.8	0.0	-1.2	60.8	1.2	-3.4
1611	50C40M40Y	58.0	0.3	-1.1	57.0	1.4	-3.2

Figure 6. Output section of the SCCA calculator

Because of the influence of the substrate, as shown in Figure 6, the original process control aims (yellow highlighted area) are affected. In this instance, the printing paper is less bright, but bluer, than the white point of the Fogra39 dataset, and colorimetric aims for both CMYK solids and neutrals are affected (green highlighted area).

3.2 Usefulness of the SCCA Calculator

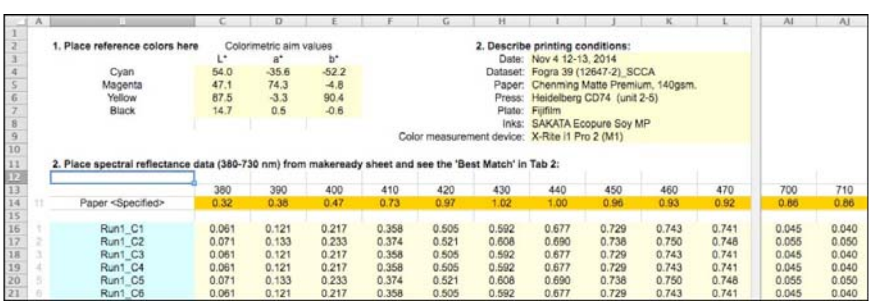
According to the U.S. standard, CGATS.21 (2013), substrate correction is a normative requirement in printing to characterization dataset. It is also a normative requirement in press calibration to gray balance according to the G7 Pass/Fail requirements (2012). This is because more and more brightened papers, varying in their OBA amounts, are used in printing. 'Printing by numbers' becomes more important and, at the same time, more challenging for printers unless substrate colors are accounted for when determining printing process control aims. Thus, the SCCA Calculator performs an important function that enables 'print by numbers' in the pressroom.

The original and substrate-corrected dataset (1,617 patches) are included in the SCCA Calculator. The substrate-corrected dataset can be used to derive substrate-corrected process control aims. It can also be used to profile the source color space in digital printing and in color proofing.

Other than the RIT SCCA Calculator, CGATS and IDEAlliance also published their versions of the calculator and offer them free of charge (see Section 8, Web Sites, for detail). Substrate correction has also been integrated into many commercial printing process control software packages.

3.3 Using the SID Tool

During the press make-ready stage, only a limited number of solid patches are measured. The input section of the SID tool, also highlighted in yellow, includes (a) substrate-corrected colorimetric aims of CMYK solids from the SCCA Calculator, (b) description of the printing conditions, (c) spectral reflectance data of the paper, and (d) spectral reflectance data of solid ink measurements (Figure 7). Spectral reflectance data of the paper and spectral reflectance data of solid ink come from measuring patches A~E of the RIT 10-patch color control bar (Figure 1).



1. Place reference colors here

	Colorimetric aim values L*	a*	b*
Cyan	54.0	-35.6	-52.2
Magenta	47.1	74.3	-4.8
Yellow	87.5	-3.3	90.4
Black	14.7	0.5	-0.6

2. Describe printing conditions:
Date: Nov 4 12-13, 2014
Dataset: Fogra 39 (12647-2)_SCCA
Paper: Chenming Matte Premium, 140gsm.
Press: Heidelberg CD74 (unit 2-5)
Plate: Fijifilm
Inks: SAKATA Ecopure Soy MP
Color measurement device: X-Rite i1 Pro 2 (M1)

2. Place spectral reflectance data (380-730 nm) from makeready sheet and see the 'Best Match' in Tab 2:

	380	390	400	410	420	430	440	450	460	470	700	710
Paper <Specified>	0.32	0.38	0.47	0.73	0.97	1.02	1.00	0.96	0.93	0.92	0.86	0.86
Run1_C1	0.061	0.121	0.217	0.358	0.505	0.592	0.677	0.729	0.743	0.741	0.045	0.040
Run1_C2	0.071	0.133	0.233	0.374	0.521	0.608	0.690	0.738	0.750	0.748	0.055	0.050
Run1_C3	0.061	0.121	0.217	0.358	0.505	0.592	0.677	0.729	0.743	0.741	0.045	0.040
Run1_C4	0.061	0.121	0.217	0.358	0.505	0.592	0.677	0.729	0.743	0.741	0.045	0.040
Run1_C5	0.071	0.133	0.233	0.374	0.521	0.608	0.690	0.738	0.750	0.748	0.055	0.050
Run1_C6	0.061	0.121	0.217	0.358	0.505	0.592	0.677	0.729	0.743	0.741	0.045	0.040

Figure 7. Input section of the SID tool

The output section of the SID tool shows (a) the selected ink color via a pull-down menu, (b) the colorimetric aim of the selected ink, (c) the solid density of the selected patch and ΔE_{00} in relation to its aim, and (d) the required best match density and the smallest ΔE_{00} the press can achieve (Figure 8).

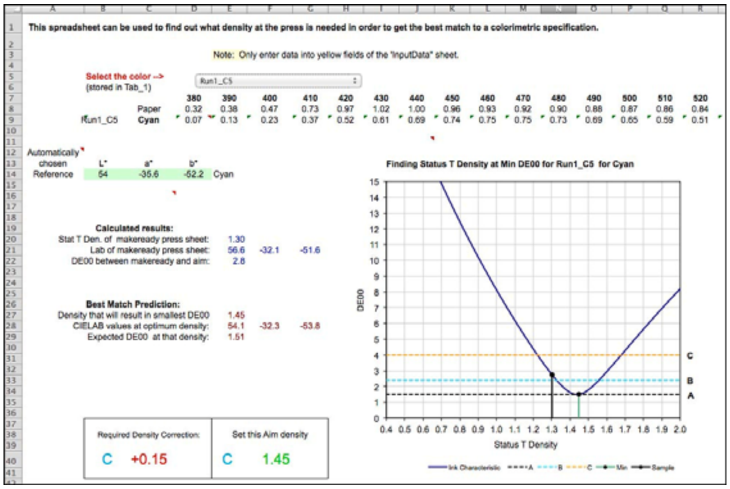


Figure 8. Determining the density for best solid color match

As shown in Figure 8, the x-axis of the graph is density (an indication of ink film thickness) and the y-axis is color difference (ΔE_{00}). The color difference increases when the ink film thickness is either too thin or too thick. The SID tool is designed to find the 'valley' of the V-shaped curve based on an arbitrary solid ink data. In this case, the sampled cyan ink density is low (1.30) and has a 2.8 ΔE_{00} from its printing aim. The solid ink should be raised to 1.45 density in order to achieve the best match (or 1.51 ΔE_{00}). CGATS TR016 (2012) tolerance levels (A, B, and C) are also included to aid in the solid ink conformity assessment.

3.4 Usefulness of the SID Tool

Normally, finding the solid ink density, corresponding to the lowest ΔE_{00}, requires multiple measurements of the solid patches across the width of the press sheet. The SID tool works differently than the above-mentioned method. It only needs one solid ink measurement to determine the best match density. Thus, the use of a hand-held spectrophotometer is manageable in the press run. It does not matter if the initial solid ink density is high or low. By applying Beer's Law, the spreadsheet predicts the best match density corresponding to the lowest ΔE_{00} directly.

In order to get the full value of the SID tool, factors that affect solid ink must be accounted for. For example, density dry-back must be accounted for unless an aqueous varnish is applied in-line with the process color printing. In addition, the SID tool is equally applicable to printing spot color by numbers.

3.5 Using the Tonality and Gray Balance Adjustment Tool

After the first step in printing to the required color gamut, the second step in printing to the characterization dataset is to print to the required tonality (TVI) and gray balance. There are graph-based manual solutions and more automated software solutions. This article introduces a commercial software package, Curve3, available from HutchColor and CHROMiX, to generate 1-D adjustment curves. The 'curved' plates are then used to print to match the substrate-corrected color aims in the production run.

Figure 9 illustrates an example of gray balance and tonality of CMYK ramps based on the initial print with linear plates using Curve3 software. In this example, the CMY gray balance (lower left diagram) looks good because the converging nature of a* and b* trend lines as the gray ramp darkens. The tonal gradation in the midtone of the CMY or NPDC (upper left diagram) is higher than the CMY tone reproduction aim. The tonal gradation in the midtone of the black ramp or NPDC (upper right diagram) is slightly higher than the black tone reproduction aim.

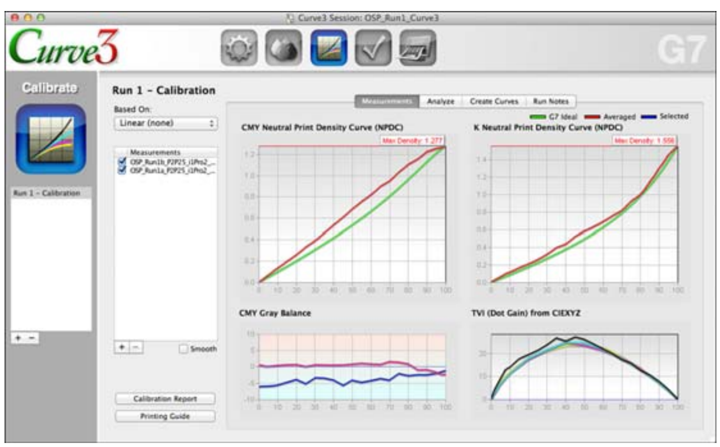


Figure 9. An example of G7 tonality or gray balance analysis in Curve3

Figure 10 illustrates specific dot area adjustments, in the form of 1-D (%dot in vs. %dot out) curve, in the curved plates to conform to the substrate-corrected midtone aims.

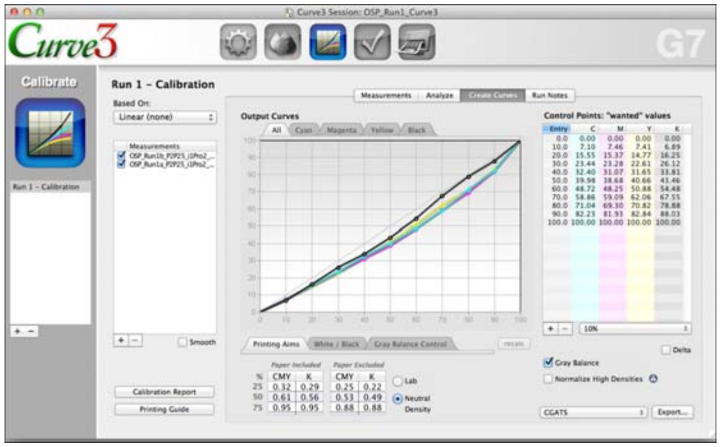


Figure 10. An example of 1-D curves for tonality or gray balance adjustment in Curve3

3.6 Usefulness of the Tonality and Gray Balance Adjustment Tool

CGATS.21-1 (2013) is a framework for specifying characterization data sets for all types of printing (offset, flexo, gravure, screen and digital). CGATS.21-2 (2013) specifies a series of inter-related datasets, i.e., CRPC-1~CRPC-7. The notion of "inter-related datasets" means that these datasets, having different white points and color gamut volumes, share the same tone reproduction and gray balance characteristics. If the color separation is prepared for the CRPC-6 printing condition, the same color separation, when printed, will conform to other CRPC printing conditions as well. Thus, the tonality and gray balance adjustment tool, such as Curve3, is useful in specifying the dot areas required in the 'curved' plates to conform to substrate-corrected calibration aims.

3.7 Using the On-site Tool

For a production run of 5,000 impressions, twenty (20) samples are pulled at every 250-sheet interval, including the first pull or OK sheet, for production variation assessment. Before using the On-site tool, process control aims are known, press inking are adjusted, press sheets are sampled, and CIELAB measurements of the 10-patch target, patches A~J (Figure 1) measured.

The input section of the On-site tool (Figure 11) includes (a) substrate-corrected process control aims, (b) a description of the printing conditions, and (c) CIELAB values of sample measurements (only Sample 1~4 are shown). Note: The substrate-corrected process control aims should be the same as those from the SCCA Calculator (Figure 6).

Step 1: Paste printing aims from the SCCA Calculator below:

	Original data			SCCA data		
	L*	a*	b*	L*	a*	b*
Paper	93.5	1.7	-5.3	93.5	1.7	-5.3
100C	54.0	-35.5	-52.2	54.0	-35.5	-52.2
100M	47.1	74.1	-4.8	47.1	74.1	-4.8
100Y	87.5	-3.3	90.2	87.5	-3.3	90.2
100K	15.8	0.2	-0.5	15.8	0.2	-0.5
50C	74.4	-14.9	-29.5	74.4	-14.9	-29.5
50M	70.0	34.7	-9.9	70.0	34.7	-9.9
50Y	90.1	-2.3	38.0	90.1	-2.3	38.0
50K	60.8	1.2	-3.4	60.8	1.2	-3.4
504040	57.0	1.4	-3.2	57.0	1.4	-3.2

Step 2: Specify the printing conditions:

Date of press run:	4-Nov-14
Press:	Heidelberg CD74 (unit 2-5)
Paper:	Chenming Matte Premium, 140gsm.
Remarks:	WKT_RIT Test
	Fogra39_SCCA
	i1 Pro2
	M1

Step 3: Measure the RIT 10-patch control strip, copy and paste CIELAB measurements by samaple ID.

Sample ID	1			2			3			4		
	L*	a*	b*	L*	a*	b*	L*	a*	b*	L*	a*	b*
Paper	93.870	1.870	-4.990	93.980	1.920	-5.320	93.910	1.870	-4.970	93.930	1.930	-4.870
C100	55.240	-35.070	-50.020	53.700	-34.990	-51.490	53.590	-35.010	-51.160	54.920	-35.270	-50.160
M100	47.640	74.670	-3.860	47.410	74.990	-3.410	47.410	74.870	-3.590	47.230	74.930	-3.270
Y100	87.560	-3.990	92.390	87.820	-3.890	94.050	87.840	-4.000	94.340	87.530	-3.720	94.580
K100	16.770	-0.160	1.110	15.850	-0.190	0.930	16.860	-0.290	1.320	17.300	-0.140	1.180
C50	75.060	-20.800	-29.450	75.720	-19.640	-28.730	75.360	-20.280	-28.960	76.110	-19.610	-28.110
M50	69.310	40.880	-12.780	69.210	40.570	-12.510	69.640	39.890	-12.310	69.560	40.150	-12.270
Y50	91.010	-4.820	39.430	90.990	-4.870	41.840	90.860	-4.930	42.150	90.960	-5.020	42.980
K50	57.450	0.100	-1.610	57.470	0.180	-1.830	58.060	0.200	-1.740	58.780	0.250	-1.820
50/40/40	57.290	-0.230	-6.070	57.670	0.790	-3.730	57.930	-0.810	-3.680	58.020	0.720	-2.430

Figure 11. Input section of the On-site tool

The output section of the On-site tool is a series of trend lines. Note that all color differences (ΔE_{00}) are between the measurements and the process control aims. As a rule of thumb, when the trend line is low, the process can be described as accurate. When the trend line is flat, the process can be described as consistent. The opposite is also true.

Figure 12 illustrates trend lines of cyan, magenta, and yellow solids (top graph) and the trend line of black solid (bottom graph). CGATS TR016 (2012) tolerance levels are also included to aid in the conformity assessment. We can see that (a) magenta and yellow solids are consistent and accurate, i.e., trend lines are low and flat, (b) there is more variation in cyan solid during the first-half of the press run, and (c) the black solid is consistent and accurate, i.e. meeting Level A tolerance requirement.

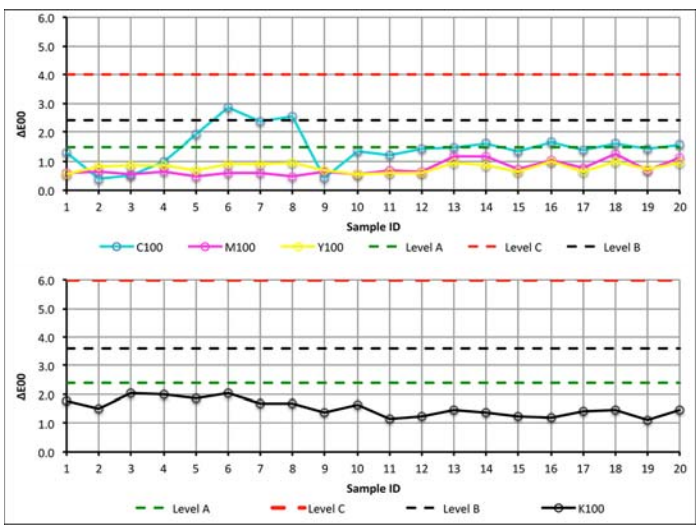


Figure 12. Output section of the On-site tool, solids

Figure 13 illustrates trend lines of CMYK midtone tints (top) and the trend line of the 3-color gray (bottom). We can see that (a) magenta and yellow midtone tints are accurate and consistent at Level C, (b) cyan and black midtone tints are not accurate (trend lines are too high), and (c) the trend line for the CMY triplet meets Level B tolerance.

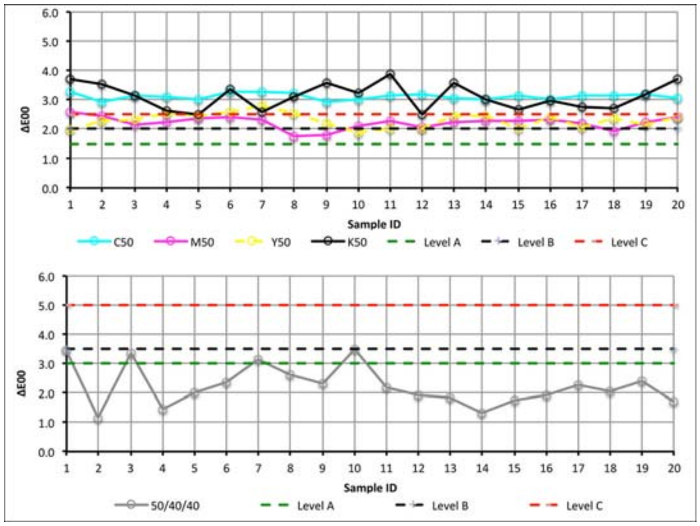


Figure 13. Output section of the On-site tool, midtone and the 3-color gray

3.8 Usefulness of the On-site Tool

As mentioned earlier, the test form in this case study was treated as an ordinary production job. The job was printed with the assumption that the press was in calibration. The fact that C50 and K50 trend lines show excessive color deviation, i.e., more than Level C tolerance, is an indication that the press was not in calibration. The remedy is to generate a new set of curved plates.

The On-site tool is limited to measuring only one ink zone to verify color conformity of 4 solids, 4 tints, and one 3-color neutral. In routine production, there are six or more ink zones and each ink zone should be controlled to yield the best match to substrate-corrected color aims. Thus, achieving accurate and uniform inking is best implemented using a closed-loop inking control system by the press side.

3.9 Using D-Tone color control bar

D-Tone is a color control system, developed by WKT, and used routinely for color control in its pressroom. As shown in Figure 14, the top portion of the D-Tone color bar contains 50K patches and the bottom portion of the D-Tone bar contains 50C/40M/40Y gray patches. By means of the interlocked design, the 50K patches and the 3-color gray patches, with their edges in contact, provide high visual sensitivity of gray balance between 50K and 3-color gray patches.

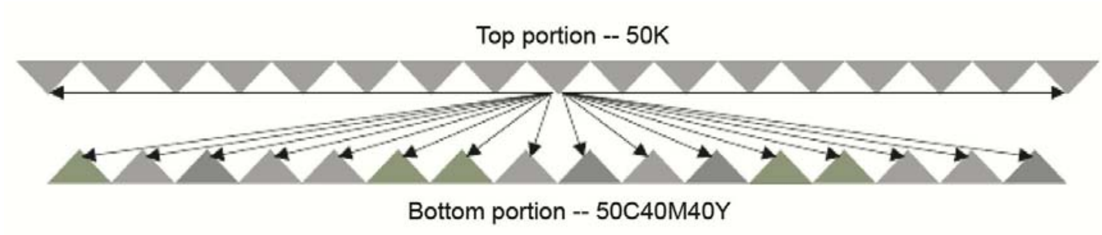


Figure 14. D-Tone gray balance control bar

During press make-ready, there are three steps to carry out the D-Tone color control. The first step is to control the black tint reproduction by controlling the solid ink density (100K) from the center of the print form and extend outward. Press operator should verify that the 50K patches conform to the substrate-corrected 50K aims (60.8 L* in this case). By utilizing the scanning spectrophotometer and the remote inking control system, the press operator makes sure that the black inking is evenly distributed across the printed sheet. The second step is to control the solid densities of cyan, magenta, and yellow inks and verify that the 50C40M40Y patches conform to the substrate-corrected 3-color neutral aims (57 L*/1.4 a*/-3.2 b* in this case). The third step is to examine the D-Tone color bar in the standard D50 viewing booth. The D-Tone color bar should look like a flat gray bar without the interlocking pattern.

During the production run, press operator can sample and examine the press sheets visually. If the D-Tone bar remains as a flat gray bar, there is no need to adjust the inking on press. If the bar is not flat, trouble-shooting is required (see section 4.2, In-depth Analysis of Production Variation). If the D-Tone bar is measured, it provides a record regarding inking accuracy and uniformity of a press run (Figure 15).

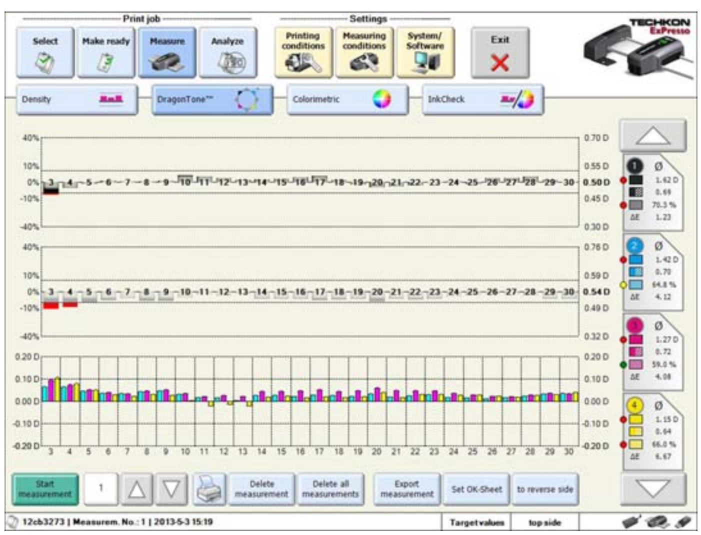


Figure 15. Inking uniformity according to D-Tone gray balance control bar

3.10 Usefulness of the D-Tone Color Control Bar

D-Tone color control system takes advantage of the metameric effect between a K50 patch and a 3-color CMY patch in process color printing. *Metamerism* means that spectral reflectance values of the K50 patch and the 3-color CMY patch are different, but their CIELAB values are the same. When CIELAB values of the patches are the same, they match each other visually under the standard lighting condition.

There is no guarantee that the K50 patch and the 3-color CMY patch match each other. In fact, the substrate-corrected process control aims indicate that there is an appreciable L* difference between the K50 patch and the 3-color CMY patch. The remedy is to adjust the black dot area of the K50 patch. As shown in Figure 6, the K50 patch is lighter (60.8 L*) than the 3-color CMY patch (57.0 L*). By increasing the dot area of the K50 patch in the D-Tone gray bar, it will overcome the mismatch.

D-Tone color control system requires a robust standard operating procedure, including ink qualification, gray balance calibration, standard viewing booth, etc. Once the press is calibrated and the dot area of the nominal ‘K50’ patch adjusted, the visual inspection between the interlocking 50K patch and 3-color CMY patches will provide a quick clue of both spatial uniformity and temporal consistency of a press run. Figure 16 illustrates visual inspection of press sheets with a loupe in a standard compliant viewing booth, including an enlarged view of the interlocking 50K patch and 3-color CMY patches.

Figure 16. Visual inspection of the press sheet

4.0 Discussions

4.1 Using Printing Process Control Tools

Printing aims, whether substrate corrected or not, should be clearly identified and communicated between print buyers and printers. The SCCA Calculator provides substrate-corrected colorimetric aims based on a selected dataset and the CIELAB value of a printing paper. The SID tool accepts substrate-corrected colorimetric aims, spectral reflectance data of the paper and arbitrary solid process ink as input to compute the best match density and the minimum color difference for the ink. Thus, both SCCA tool and SID tool are essential for pressmen to determine and adjust solid ink densities during press make-ready quickly and accurately. In addition to the three process control tools, developed by RIT, we are pleased to introduce Curve3 software, which enables the press calibration according tonality and gray balance or G7 methodology.

4.2 In-depth Analysis of Production Variation

CGATS.21-1 (2013) defines production variation as the color difference between sample measurements and substrate-corrected color aims. CGATS TR016 (2012) further specifies the production variation as the 95 percentile of the ΔE_{00} distribution between individual measurements and SCCA. Column 2 of Table 1 shows the combined variation in terms of a single metric, i.e., 95%tile ΔE_{00} between individual measurements and SCCA. In this instance, the 95%tile ΔE_{00} is based on the production variation of 20 samples from ink zone 2.

Table 1. Different metrics to describe production variation

Patch	ΔE_{00} (95%tile) between individual measurements and SCCA	ΔE_{00} between the average od all measurements and SCCA (accuracy)	Average ΔE_{00} between individual measurements and the average (consistency)
C100	2.57	1.38	0.57
M100	1.20	0.66	0.38
Y100	0.98	0.73	0.32
K100	2.03	1.35	0.74
C50	3.27	3.05	0.51
M50	2.46	2.19	0.30
Y50	2.55	2.23	0.51
K50	3.72	3.09	0.49
C50M40Y40	3.44	1.57	1.51

The combined production variation can be further divided into the accuracy of the run and the consistency of the run. Column 3 of Table 1 describes the *accuracy* of the run in terms of ΔE_{00} between the average of all measurements and SCCA. Column 4 of Table 1 describes the *consistency* of the run in terms of the ΔE_{00} between individual measurements and the average of all measurements.

For each of the 8 metrics (4 CMYK solids and 4 CMYK tints), Figure 17 illustrates the distinction between (a) the combined variation, i.e., ΔE_{00} between individual measurements and substrate-corrected aims (dotted line) and (b) the variation due to consistency, i.e., ΔE_{00} between individual measurements and their average (solid line). The 'offset' between these two trend lines is the variation due to accuracy.

Figure 17. Time plots of production variation of CMYK solids and tints (zone 2)

Color variation of the 3-color CMY patch is larger than any single color (Figure 18). This is because gray reproduction is influenced by the stability of all three chromatic inks.

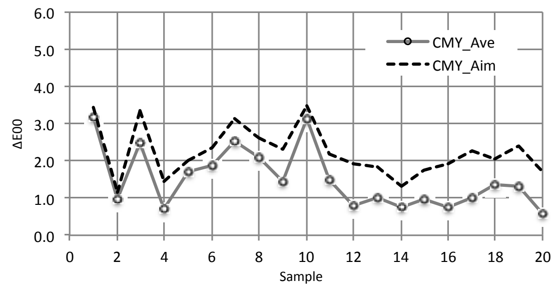


Figure 18. Time plots of production variation of CMY gray (zone 2)

For trouble-shooting, the visual mismatch of the D-Tone bar is a quick indication that something has gone wrong, but without specific causes. The On-site tool offers many clues. For example, if ΔE_{00} of the solids are too large, inking should be adjusted. If the ΔE_{00} of the best match density is too large, ink contamination is possible. If ΔE_{00} of the solid is small, but the ΔE_{00} of the tint is too large, TVI or dot gain has changed and a new CTP curves should be considered.

4.3 Improving Printing Conformance through Testing

APTEC conducted tests by using gray balance, device link and substrate-correction to improve printing conformity due to the influence in paper color. The test was conducted on coated paper, wood-free paper, and CCNB paper.

The first press run was conducted with linear plates. The test form was printed to colorimetric aims (Figure 19). CTP output curves were created. The second press run was conducted with the curved plates. Before color conversion, paper white was measured and SCCA calculator tool was used to re-calculate IT8.7/4 targeted dataset. Then the color was converted by using Oris PressMatcher // Web. Finally, the third press run was conducted and IT8.7/4 dataset was verified to CGATS TR016 tolerance. The findings showed that substrate correction improves printing conformance.

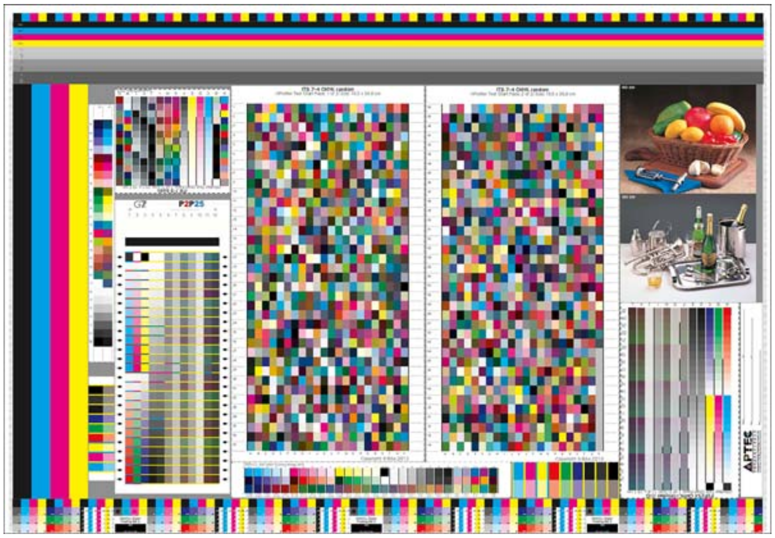


Figure 19. Test form used by APTEC

4.4 Integrating Process Control Tools in Routine Production

Like WKT, many printers rely on the use of Original Equipment Manufacturer (OEM) equipment to address print buyers' color printing requirements, e.g., substrate color and printing aims for their jobs. When substrate correction is specified, the SCCA Calculator is useful in finding the relationship between the various substrates and specified dataset.

WKT relies on the use of D-Tone and the Techkon Spectro-Dens to enable pressmen to monitor color printing. If the SID tool is integrated in the production software, it will be easier for the pressmen to achieve press make-ready without additional manual work. If the On-site tool is also integrated in the production software, it will give further clues as to what might have changed in the production when there is a visual mismatch in the D-Tone gray bar.

5.0 Conclusions

In the broadest sense, printing process control is about making data-driven decision to identify the vital few variables in pressroom operations, calibrating the process with the right tools, and use automation to meet print buyer's expectation. Printing process control tools, discussed in this case study, can enable printers to print by numbers, thus, improve their operational efficiency in the pressroom. We plan to include these tools as training materials to support a printing process control seminar in the future.

6.0 Acknowledgments

Printing to dataset conformance is not a new concept for the U.S. printing industry. But printing to a family of datasets, based on common pre-defined criteria, is a new standardization initiative, spearheaded by the U.S. As a result, it became the U.S. printing standard, ANSI CGATS.21-1 and ANSI CGATS.21-2, in 2013. The balloting process in the ISO track, however, took much longer. On March 9, 2015, ISO/TC130 Committee finally announced that the equivalent documents, ISO 15339-1 and ISO 15339-2, have been approved for publication as Publicly Available Specifications (PAS). Mr. David McDowell is the editor of the documents. We appreciate his tireless efforts in developing the groundbreaking work and in reviewing the manuscript.

This case study is collaboration among a printing company, a printing association, and an educational organization. We wish to express our gratitude to the following organizations: Wing King Tong Printing Ltd. for providing the printing facilities; Techkon for providing the Spectro-Dens in the press test; APTEC for providing the technical support; CHROMiX and HutchColor for providing Curve3 software; SpotOn! Press, Alwan Color Expertise, and Bodoni Systems for providing valuable advice on their process control tools; and RIT School of Media Sciences for supporting its faculty member to transform classroom teaching into practical solutions in the pressroom. Without their generous supports, this case study could not have been completed.

7.0 References

CGATS.21-1 (2013) Graphic technology — Printing from digital data across multiple technologies — Part 1: Principles

CGATS TR016 (2012) Graphic technology — Printing Tolerance and Conformity Assessment

G7 Pass/Fail (2012) Pass/Fail Requirements — G7 Master, G7 Process Control Master Qualification Programs

ISO/TS 10128 (2009) Graphic technology — Methods of adjustment of the colour reproduction of a printing system to match a set of characterization data

8.0 Web sites

APTEC: www.aptec.hkprinters.org

CHROMiX: www.chromix.com

D-Tone: www.d-tone.org

HutchColor: www.hutchcolor.com

RIT PSA: http://printlab.rit.edu/services/psa/

SCCA calculator (CGATS):

http://www.npes.org/programs/standardsworkroom/toolsbestpractices.aspx

SCCA calculator (IDEAlliance):

http://www.idealliance.org/downloads/substrate-relative-calculator-gracol-2013-swop-2013

TECHKON GmbH: www.techkon.com

Wing King Tong Printing Ltd: ww.wkt.cc