Investigation on the Application of the Tristimulus Linear Correction and Colorimetric Density for Process Color Calibration

Dimitri Ploumidis*

Keywords: color, substrate, ISO 12647-2, neutrality, calibration

Abstract

The printing industry is in the process of refining its approach to press calibration towards colorimetric aims with the goal to provide a harmonized means to achieve and assess print conformance to a given standard. The latest, critical development is the focus on substrate corrected colorimetric aims (SCCA), allowing printers that use non-standard substrates to achieve such conformance.

The assessment of conformance, for the purposes of this paper, was based on the neutrality of the overprinted process colors (CMY triplet), as determined by the tristimulus linear correction method (ISO 13655). Then, the aims were converted from the CIEXYZ color space to colorimetric density, which was used to calibrate the response of the printer to these aims.

Through this experiment, conducted on a UV sheetfed offset press and printed on SBS substrate, it was shown that conforming neutrality for the CMY triplet can be achieved by means of the tristimulus linear correction and the colorimetric density conversion. Finally, the application of the tristimulus linear correction is discussed for solid process colors and their solid overprints.

---

* Pacific Southwest Container

Introduction

Print production is being greatly helped by the advancements in calibration methodologies that fulfill the need to reproduce and unambiguously communicate color. Print buyers are placing their trust in those printers, who demonstrate the ability to match a calibrated proof and maintain color conformity, and production efficiencies are being realized as waste and setup times are reduced.

Achieving color conformance to an industry wide standard or specification has been the main objective, with the main challenge being to accomplish this over different substrates. As the color of the substrate changes, so does appearance and color aims. Lacking targets that are harmonized over different substrates made the assessment of conformity qualitative, as the best match was being determined by comparing the reproduced color to the color of the characterization data set that best matched the white point of the paper. The latest focus of the printing industry's standardization bodies is to overcome these challenges by substrate corrected colorimetric aims (SCCA), which are established through the tristimulus linear correction method.

This paper uses the tristimulus linear correction method to calculate the near neutral SCCAs of the CMY triplet that would result in grey balance over a stock commonly used in packaging applications. The CMY triplet is then converted from CIEXYZ to colorimetric density aims. Likewise, the measured CMY triplet of the linear response of the printer was converted from CIEXYZ to colorimetric density, in an attempt to provide one-dimensional transfer curves for each color channel, match the reference CMY triplet, and calibrate the printer to grey balance. This method we term Substrate Corrected Neutrality Conversion (SCNC). Ultimately, the algorithms employed to provide the aims are used in calibrating the printer, closing the gap – if any - between the means and the ends.

Objectives

The goal of this paper is to determine whether the tristimulus linear correction method and colorimetric density conversion can be used both to calculate the substrate corrected colorimetric near neutral aims and achieve neutrality on a substrate that doesn't comply with the specifications outlined to the published standards. Compliance of grey reproduction is evaluated based on ANSI/CGATS TR016-2011: Graphic technology – Printing Tolerance and Conformity Assessment.

The second aim of this paper is to evaluate the effectiveness of the methodology compared to CGATS TR015-2011: Graphic technology — Methodology for Establishing Printing Aims Based on a Shared Near-neutral Gray-scale. The hypothesis is that the calibrated near neutral scales achieved through each approach have no significant color differences.

Literature review

The conversion that enabled the calculation of the SCCAs was brought in the forefront by a 2005 TAGA paper, Correcting Measured Colorimetric Data for Differences in Backing Material, published by McDowell, Chung, and Kong. The tristimulus linear correction method is based on the observation that the color of the measured samples over different backings is linearly scaled from the lightest to the darkest point, being approximately zero on the darkest point and reaching its largest difference on the lightest point. As discussed on that paper, if we know the difference between the backings, we can estimate the color of the measured samples on a different backing, or for our purposes a different substrate.

The formula used in this study is the simplified version of the original, as presented in Annex B of ISO/WD 12647-1, Graphic technology — Process control for the production of half-tone colour separations, proof and production prints — Part 1: Parameters and measurement methods (2009). Chung and Tian (2011) discuss the equation can also be used to calculate substrate corrected colorimetric aims for near neutrals.

$$Xt = Xr \times (1 + C) - Xmin \times C \qquad \textit{Eq. (1)}$$

with:

$$C = \frac{Xsr - Xst}{Xst - Xmin}$$

Xt is the target tristimulus value X of the specimen;

Xr is the tristimulus value X of the specimen over the reference substrate;

Xsr is the tristimulus value X of the reference substrate;

Xst is the tristimulus value X of the target substrate;

Xmin is the minimum tristimulus value X of the specimen over the reference substrate; the Xmin value can be assigned a value of 1, indicating that it is the darkest point (Chung, 2011b).

CIE Y and CIE Z are converted similarly.

Performing the tristimulus linear correction on a characterization data set like GRACOL2006 coated_1v2 provided the near-neutral aims for the given substrate. Then, neutrality was achieved by converting the CMY triplet throughout the 0-0-0 to 100-100-100 range to cyan, magenta, and yellow densities. This was accomplished by a 3x3 matrix transformation from CIEXYZ to RGB and then to colorimetric densities, as proposed by Viggiano and Wang (TAGA, 1991). We shall refer to this formula as LogRGB.

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 1.4391 & -0.2202 & -0.2027 \\ -0.7310 & 1.6386 & 0.0801 \\ -0.0064 & 0.0171 & 1.1995 \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} \qquad \textit{Eq. (2)}$$

The colorimetric density for each filter was measured by subtracting the white point of the paper from the sample measurement.

$$\begin{aligned} Dr &= Log(Rn) - Log(R) \\ Dg &= Log(Gn) - Log(G) \\ Db &= Log(Bn) - Log(B) \end{aligned} \qquad \textit{Eq. (3)}$$

It has to be noted that the Xr in the SCCAs calculation for the three-color overprints is different from the Xr of the calculation for the solids and two-color overprints. The preferred values for both would have been those of ISO 12647-2, but the standard does not specify near neutrals aims for any of the substrates. Therefore, for the near neutrals we chose to input the Xr of the near neutrals from the GRACOL2006 coated_1v2 characterization data set, and for the solids and overprints the Xr of the near neutrals from ISO 12647-2, under the PS1 and CD1 coordinates.

The LogRGB method was discussed by Seymour (2008), who after evaluating several formulae, concluded that this method provided the most reliable results with regards to converting from colorimetric to densitometric values.

The tolerances by which conformance will be evaluated in this study are those highlighted in ANSI/CGATS TR016-2011 and displayed in Table 1. For assessing the conformance of the near neutrals, we used the cumulative probability of color differences that was generated by the PSA survey and included in Annex A of TR016. The standard specifies that in order to achieve conformity under a given level, all the conditions need to be met. Since we didn't evaluate the entire data set in this study, we will refer to levels of conformance only descriptively.

Deviation tolerance (ΔE00)		Level A	Level B	Level C
95th percentile of all patches of ISO 12647-2		3	4	5
Solids	100C	1.5	2.4	4
	100M			
	100Y			
	100K	2.4	3.6	6
Solids	50C	1.5	2	2.5
	50M			
	50Y			
	50K			
Near Neutral	50C/40M/40Y	3	3.5	5

Table 1 – *Deviation metrics and tolerances*

The target CIELAB values of the solids were the CD1 coordinates of ISO 12647-2, with white backing and no adjustments for the substrate (Table 2). In this study the tristimulus linear correction was not used to target the solid aims. The focus was limited in an assessment of the capability of the methodology in achieving neutrality regardless of the solids, and there was no instrumentation that would allow efficient density corrections on-press. It can be argued that having closer conformance to the solid SCCAs would have a significant impact on neutrality as such a decision would have resulted in different ink film thicknesses.

ISO 12647-2 (WB)	L*	a*	b*
Paper	95.00	1.00	-4.00
Cyan	56.00	-36.00	-51.00
Magenta	48.00	75.00	-4.00
Yellow	89.00	-4.00	93.00
Black	18.00	0.00	0.00
Red	48.00	68.00	47.00
Green	50.00	-65.00	27.0
Blue	25.00	21.00	-46.00

Table 2 *– ISO 12647-2 PS1 and CD1 color coordinates*

During our evaluation, we will analyze the efficiency of the methodologies throughout the tonal value reproduction scale. Chung (2011a) expresses concerns about the ability of any methodology to achieve neutrality at the 100-100-100 overprint as it depends on factors that are not within the control of the calibration methodology. These not only do they affect the 100-100-100 overprint, but increasingly influence the near neutrals as L* decreases.

Methodology

The experiment was conducted on an 8-color UV press, using hybrid cyan, magenta, and yellow inks, and straight UV black ink, with aqueous coating. The chosen sequence was KCMY. The interdeck UV lights were placed after the black and the yellow. Prior to the experiment the press was prepared with new blankets and fresh dampening solution. The roller stripes to the plate and the packing were set at the manufacturer's specifications. The plates were linear at 175 lpi, verified within 1% of the nominal plate value. The paper used was SBS. The first, linear press run was targeting the CIELAB values of ISO 12647-2 for paper grade 1 below 3.00 ΔEab. Once these values were achieved 2,000 sheets were printed at the same density and 5 samples were gathered. The CIELAB values of the paper, the solids, the overprints, the CMY triplets at ¼-tones, ½-tones, ¾-tones, and the 100-100-100 patch were measured from the linear run. The values on Table 3 and thereafter were measured with an i1 device over white backing from the p2p target and were reported at D50/2.

MEASURED SOLIDS, OVERPRINTS, AND CMY TRIPLET			
C-M-Y-K	L*	a*	b*
0-0-0-0	94.61	-0.38	1.46
25-19-19-0	71.44	0.50	-1.48
50-40-40-0	53.17	0.38	-3.81
75-66-66-0	37.60	-1.41	-6.37
100-100-100-0	25.75	-3.12	-7.69
100-0-0-0	57.44	-38.40	-48.59
0-100-0-0	51.17	74.61	-4.05
0-0-100-0	89.43	-4.81	93.53
0-0-0-100	18.02	0.01	1.90
0-100-100-0	50.14	68.38	42.22
100-0-100-0	51.35	-65.11	23.17
100-100-0-0	27.80	14.86	-47.44

***Table 3** – CIELAB values of measured solids, overprints,*
and the CMY triplets from the linear run.

Then, the substrate corrected colorimetric aims were calculated. The solid and overprint values were derived by inputting the ISO/WD 12647-2 CD1 and PS1 coordinates in equation 1, and inputting the GRACOL2006_coated1v2 characterization data set in absolute colorimetric mode derived the near neutrals. The Xmin was at a value 1.00.

SUBSTRATE CORRECTED COLOR AIMS (SCCA) FOR SOLIDS, OVERPRINTS, AND NEAR-NEUTRALS			
C-M-Y-K	L*	a*	b*
0-0-0-0	94.61	-0.38	1.46
25-19-19-0	75.42	-0.31	1.37
50-40-40-0	57.28	-0.24	1.25
75-66-66-0	39.29	-0.17	1.08
100-100-100-0	22.90	-0.09	0.81
100-0-0-0	55.75	-36.60	-45.95
0-100-0-0	47.78	73.72	-0.97
0-0-100-0	88.63	-5.27	94.75
0-0-0-100	17.93	-0.24	0.83
0-100-100-0	47.78	66.77	47.86
100-0-100-0	49.78	-65.28	28.96
100-100-0-0	24.89	20.42	-42.71

***Table 4** – The substrate corrected color aims in CIELAB of the*
solids, overprints, and the CMY triplets

The measured samples where then converted to the RGB color space through the LogRGB formula and then to colorimetric densities (Table 5).

COLORIMETRIC DENSITIES OF MEASURED SAMPLES

C-M-Y-K	vC	vM	vY	vK
0-0-0-0	0.00	0.00	0.00	0.00
25-19-19-0	0.31	0.31	0.28	0.31
50-40-40-0	0.62	0.61	0.56	0.61
75-66-66-0	0.97	0.93	0.85	0.93
100-100-100-0	1.33	1.24	1.13	1.24
100-0-0-0	1.09	0.41	0.10	0.41
0-100-0-0	0.28	1.16	0.59	1.16
0-0-100-0	0.02	0.08	0.99	0.08
0-0-0-100	1.53	1.54	1.57	1.54
0-100-100-0	0.29	1.18	1.26	1.18
100-0-100-0	1.11	0.52	0.93	0.52
100-100-0-0	1.30	1.19	0.56	1.19

Table 5 – *Colorimetric densities of the measured samples for solids, overprints, and near neutrals*

Finally, the substrate corrected colorimetric aims were converted through the LogRGB formula to colorimetric densities. On this paper, we will focus only on the substrate corrected near neutral aims as displayed in Table 6.

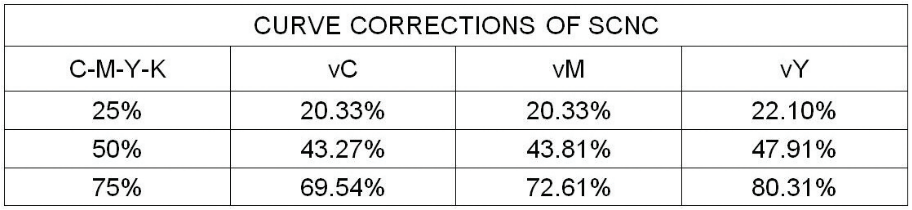
SUBSTRATE CORRECTED NEAR NEUTRAL AIMS

C-M-Y-K	vC	vM	vY	vK
0-0-0-0	0.00	0.00	0.00	0.00
25-19-19-0	0.25	0.25	0.25	0.25
50-40-40-0	0.54	0.54	0.54	0.54
75-66-66-0	0.90	0.90	0.91	0.90
100-100-100-0	1.30	1.30	1.31	1.30

Table 6 – *Substrate corrected aims for near neutrals*

The next step was to calculate the curve corrections that target neutrality; these were derived by a simple equation with one unknown as shown in Equation 4. The curve corrections are displayed in Table 7.

*Curve Correction % = (target dot area * tonal value at reference dot area) / reference dot area* ***Eq. (4)***

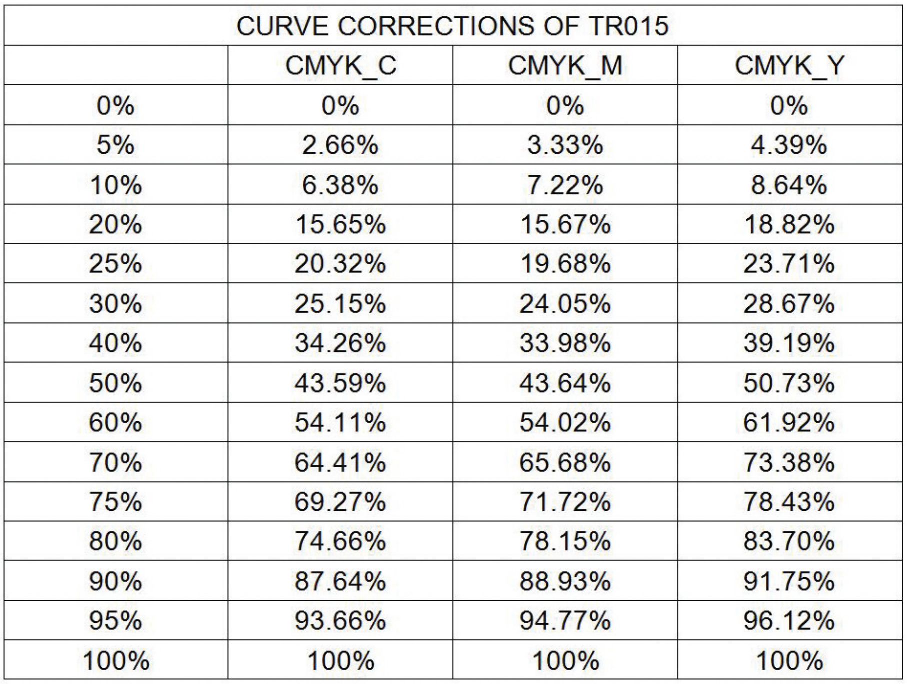


CURVE CORRECTIONS OF SCNC			
C-M-Y-K	vC	vM	vY
25%	20.33%	20.33%	22.10%
50%	43.27%	43.81%	47.91%
75%	69.54%	72.61%	80.31%

Table 7 *– Curve corrections through substrate corrected neutral conversion method (SCNC)*

The second set of curves was made using Curve2 software, configured with the 'G7' verify method and targeting the values for the Commercial (GRACoL2006 coated 1) characterization data set. The grey correction threshold was set at 60%, because neutrality in the shadow areas depends more on process stability. It is thus recommended to gradually decrease the impact of the correction after the midtone areas (Curve2 User Guide, 2009). Empirical knowledge also suggests that allowing for a correction above the 60% threshold might have an adverse effect on the tone value reproduction of usually the yellow color, as it could be disproportionately increased to compensate for the poor trap over cyan and magenta.

Both the measurements for the Curve2 software and for the tristimulus linear correction methodology were taken from p2p targets. For the SCNNA calibration methodology only the 25%, 50%, and 75% CMY triplets were used as control points, where the Curve2 application was set at 10% increments.



CURVE CORRECTIONS OF TR015			
	CMYK_C	CMYK_M	CMYK_Y
0%	0%	0%	0%
5%	2.66%	3.33%	4.39%
10%	6.38%	7.22%	8.64%
20%	15.65%	15.67%	18.82%
25%	20.32%	19.68%	23.71%
30%	25.15%	24.05%	28.67%
40%	34.26%	33.98%	39.19%
50%	43.59%	43.64%	50.73%
60%	54.11%	54.02%	61.92%
70%	64.41%	65.68%	73.38%
75%	69.27%	71.72%	78.43%
80%	74.66%	78.15%	83.70%
90%	87.64%	88.93%	91.75%
95%	93.66%	94.77%	96.12%
100%	100%	100%	100%

Table 8 *- Curve corrections of the TR015 methodology*

The difference in the curve corrections between the two methodologies was minimal, mainly in the amount of the yellow correction (Figure 1). The SCNC method is calling for less compensation for the yellow colorant up until the 65% area. After the 65% dot area, the impact of the compensation of Curve2 software gradually decreases and then the SCNC method suggests a higher tonal value.

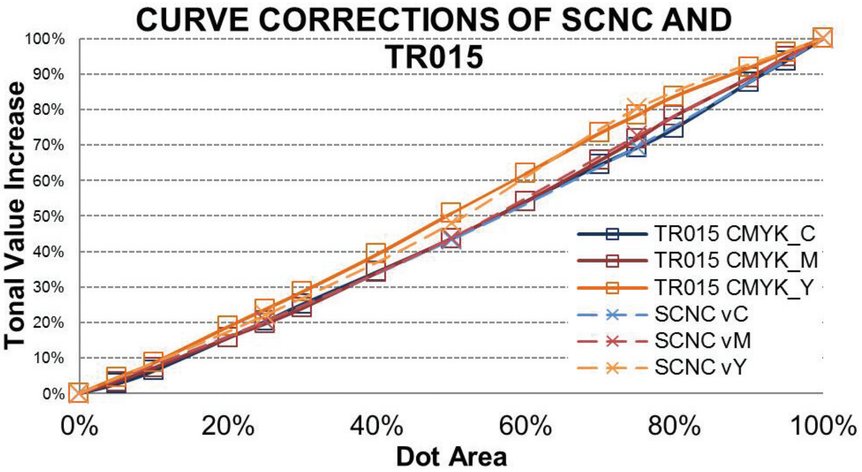


***Figure 1** – Curve corrections of TR015 and SCNC*

The second part of the experiment was then conducted. Using the target density values of the first press run, we put the first set of plates on the press and run 3,000 sheets, collecting 5 samples at the end of the process, verifying that the density was maintained at the same level. Subsequently, we switched to the second set of plates and run another 3,000 sheets at the same density before collecting 5 samples. The measurements of the samples were averages of the sheets.

Results & Discussion

The first part of the analysis examines the results of the conversion for the near neutrals and compares them against the substrate corrected colorimetric aims. The 50-40-40 midtone patch has a color difference of 2.13 ΔE00 (Table 9), which would conform to Level A conformance according to ANSI/CGATS TR016-2011, if we were to narrow the tolerance discussion only to near neutrals. The 65th percentile of the near neutrals has a color difference of 3.3 ΔE00.

	SCCA			Measured SCNC Calibrated Run			
	L*	a*	b*	L*	a*	b*	ΔE00
25-19-19	75.42	-0.31	1.37	75.93	0.37	1.39	1.07
50-40-40	57.28	-0.24	1.25	58.54	-0.26	-0.58	2.13
75-66-66	39.29	-0.17	1.08	39.83	-1.77	-4.83	5.84

***Table 9** – Color difference of near neutral measured patches to SCCA*

We can see in Figures 2 to 4 the deviation of L*, a*, and b* respectively, which are contained within 2.00 ΔE00 from 0% to 60% for all the coordinates, but exceed that threshold for b* after 60%.

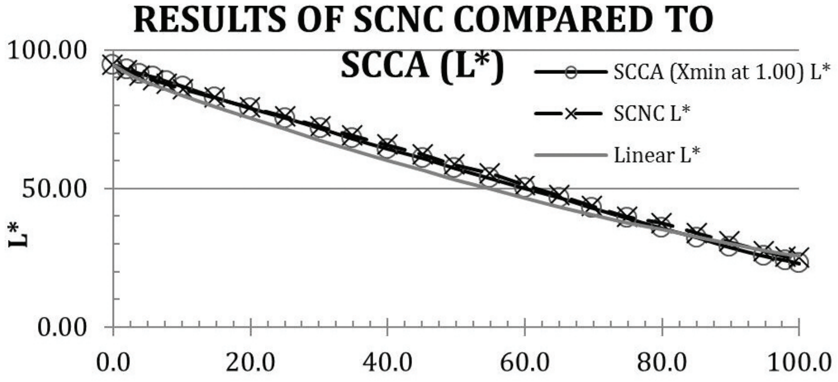


Figure 2 – L analysis of substrate corrected near neutral aim conversion*

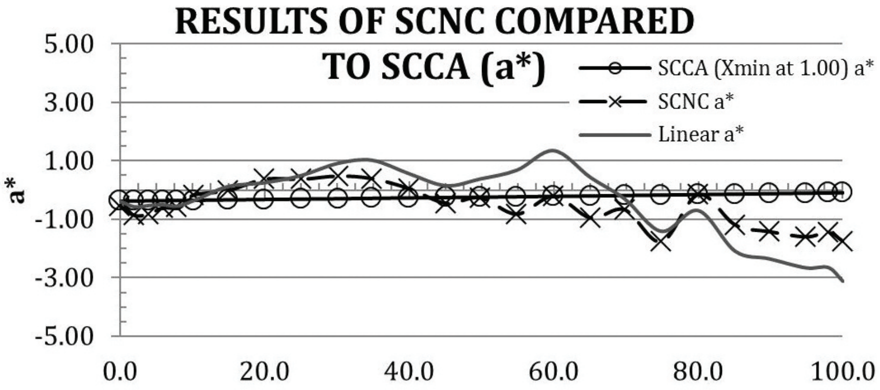


Figure 3 – a analysis of substrate corrected near neutral aim conversion*

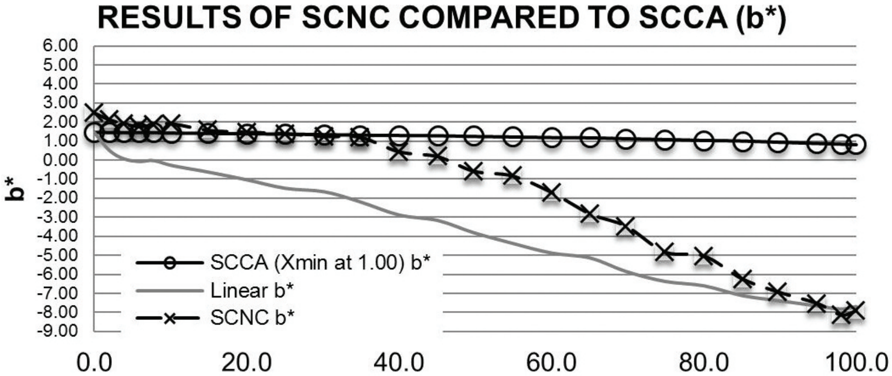


Figure 4 – b analysis of substrate corrected near neutral aim conversion*

It is noteworthy that the methodology fails to correct neutrality beyond the 60% dot area. This is due to the rendering of the yellow channel, as seen in b* (Figure 4). The substrate corrected near neutral aim for the yellow filter of the CMY triplet is 1.31 (Table 6) and the actual measurement of the linear run was 1.13 (table 5) for the 100-100-100 region, 0.54 and 0.56 for the midtone, and 0.91 and 0.85 for the 75-69-69 respectively; We can see the impact of the trap of the yellow in the gradual loss of yellow density above the 50-40-40 dot area.

At this point, we need to discuss the conformance of the solids and the fact that we were targeting the values of ISO 12647-2. The b* of the yellow SCCA is 94.75 and of ISO 12647-2 CD1 is 93.00. The measured b* of the yellow from the linear run was 93.53. Since we were targeting the values of ISO 12647-2 CD1 we didn't attempt to run the yellow at a higher ink film thickness. It is doubtful that increasing the yellow ink film to 94.75 b* would reduce the 0.17 density points difference that lies in the yellow filter of the 100-100-100 overprint. Most likely, it would have resulted in non-conforming yellow, as the color difference was only 0.63 ΔE00.

Furthermore, the color conformance of the solids to the color aims for the SBS substrate is displayed in Table 10. It is only the magenta that doesn't fit into the Level A tolerance specified at TR016 and this is because the process didn't target the appropriate ink film thickness during the experiment: running the ink heavier would have resulted in a lower L* and higher a*, bringing the color within tighter conformance. Likewise, the conformance of the blue overprint is likely to have been within tolerances if the magenta had run heavier; this is however a process dependent assumption. We couldn't estimate the color conformance of the 50% patches to ISO 12647-2, since there are no relevant CIE X, Y or Z values to be input on the tristimulus linear correction.

	SCCA			Measured SCNC Calibrated Run			ΔE00
	L*	a*	b*	L*	a*	b*	
Cyan	55.75	-36.60	-45.95	57.02	-38.61	-48.24	1.44
Magenta	47.78	73.72	-0.97	50.71	74.66	-2.86	3.02
Yellow	88.63	-5.27	94.75	89.42	-4.85	93.01	0.63
Black	17.93	-0.24	0.83	17.12	-0.07	1.55	0.92
Red	47.78	66.77	47.86	49.77	68.54	42.12	3.59
Green	49.78	-65.28	28.96	51.14	-64.93	22.73	2.83
Blue	24.89	20.42	-42.71	26.83	15.58	-47.13	5.52

Table 10 - *Color difference of measured solid and overprint patches to SCCA*

The second part of the study examines how the SCNC method compares to the TR015 method. In Figure 5 we can see that both provide similar results, with small differences with regards to each other and to neutrality.

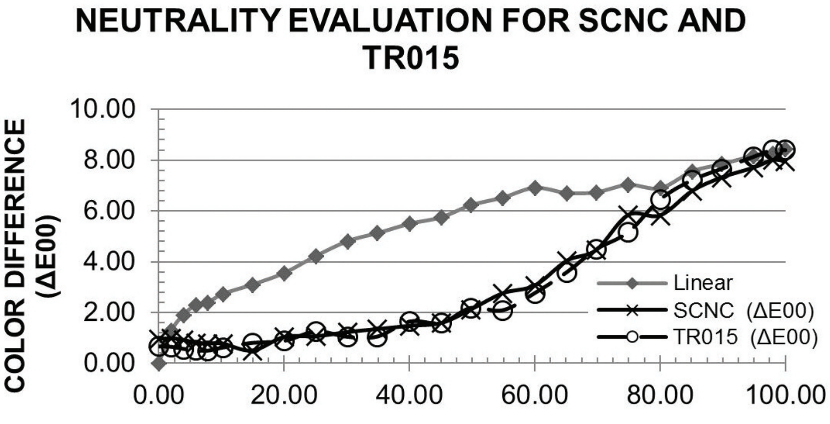


***Figure 5** – Color difference between SCNC and TR015*

It is notable that both methodologies fail to provide a neutral match above the 60% dot area. This confirms Chung's concern (2011a) about the non-convergence of the CMY solids. Performing the tonal value corrections above the 60% dot area had a limited effect in terms of correcting for grey balance. We can hypothesize that the impact of ink trap is stronger than that of dot area or of the calibration methodology. A possible solution would have been to try different chemistries that would provide better trap of the last down color, different ink transparency, use of grey component replacement, or curing of the cyan and the magenta with interdeck UV lights. The later solution was not attempted because it is not typically used in production, as the use of interdeck UV lights could result in inefficiencies (partially cured ink pilling on the impression cylinder or blankets) and higher energy consumption.

To further discuss this topic, we can analyse the impact of each correction on the midtone spread (Table 10). Both methodologies provide conforming results throughout the tonal reproduction scale, with a tolerance of 5%. This indicates that the relationship of tonal values and grey balance is not strong, as we fail to achieve grey balance above the 60% area, but yet the midtone spread is conforming.

Midtone spread (%)													
	0	5	10	20	30	40	50	60	70	80	90	95	100
SCNC	0.00	0.27	0.69	2.34	2.67	2.39	2.98	3.61	2.49	2.15	1.36	0.65	0.00
TR015	0.00	1.35	1.66	1.50	0.63	1.31	1.65	2.46	2.30	3.52	1.37	0.87	0.00

***Table 11** – The midtone spread between PC1 and the tonal values of the two methodologies*

The last part of the analysis is to determine whether the differences are statistically different. In order to test this hypothesis we performed two tests: a t-test and a CRF analysis.

At 95% confidence level and under the assumption that the populations are normally distributed, we assumed that there is no difference between the means of SCNC and TR015. To test our hypothesis, we performed the one tailed t-test for equal variances. We found that the test statistic was 0.486, which is greater than 0.05, and therefore we can conclude that there is no difference between the populations. It has to be noted that since color differences are not normally distributed, sigma statistics like the t-test shouldn't be used. In this case however, taking into account that the behaviour of the color differences is similar for both populations, we allowed ourselves the use of the t-test.

Likewise, the CRF test showed no difference between the cumulative relative frequency distribution of the color difference among the neutral reproduction scale between the two methodologies, which was below 2.00 ΔE00.

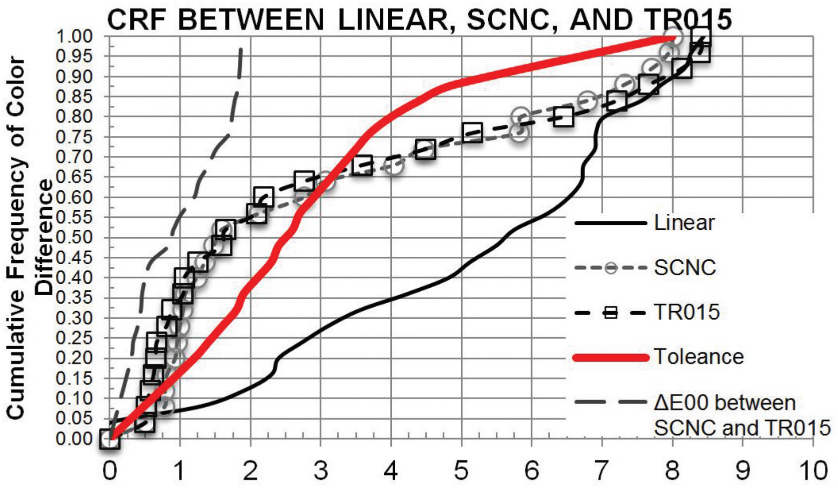


Figure 6 – Cumulative relative frequency of color difference between linear, SCNC, and TR015 press runs

Finally, Table 11 displays the color difference between the two methodologies at the 65th, 85th, and 95th percentile, where we can see that they are practically identical, without a difference more than 0.40 ΔE00 throughout the entire reproduction scale of the near neutrals.

	LINEAR	SCNC	TR015
65th percentile	6.7	3.3	3.0
85th percentile	7.6	6.9	7.3
95th percentile	8.2	7.9	8.3

***Table 12** – Color differences of the two methodologies for the 65th, 85th, and 95th percentiles.*

Conclusions

We can conclude that the SCNC method is able to achieve neutrality for the CMY triplet. This means that the substrate corrected color aims derived through the tristimulus linear correction method and used for assessment of color conformance can be used to calibrate a process towards neutrality, when converted through the LogRGB formula to colorimetric densities. Conformance for the neutral highlights and neutral midtones can also be considered to comply with ANSI/CGATS TR016, with a color difference of 1.07 ΔE00 and 2.13 ΔE00 at the 25-19-19 and 50-40-40 patches respectively.

It is displayed that there is no significant difference between the results of TR015 and SCNC.

Another important finding was that both methodologies fail to provide grey balance conformance to the SCCA targets after the 60% dot area. This indicates that the inability to achieve grey balance for the shadow region is not so much a result of the methodology that was used; rather, it is mostly a factor of the process.

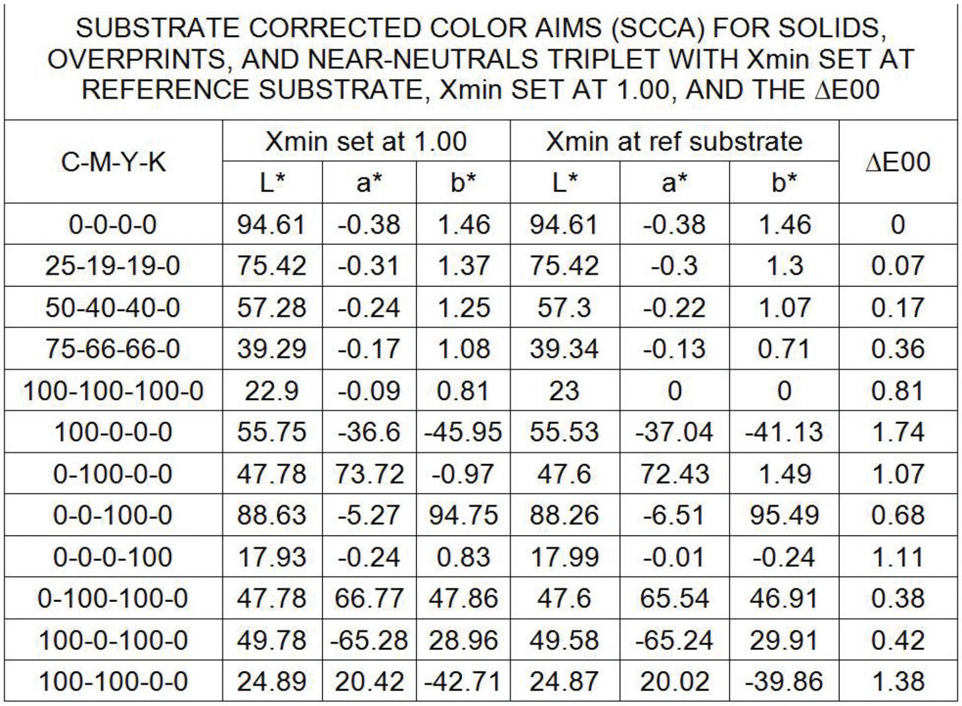
Further Study

The area where further study would be suggested would be the same area that presented a limitation to this study. We will continue to examine the relationship of the paper to color targets, but also include the solid and overprint aims along with neutrality. Secondarily, we would like to explore the implications of the choice of Xmin, a discussion that starts at Appendix A. Finally we would like to include the black colorant.

Acknowledgements

I would like to thank my colleagues at Pacific Southwest Container for providing the press time and helping me in conducting this experiment. I would also like to thank John Seymour and Professor Bob Chung for reviewing the paper as well as providing the necessary discussions and references for understanding the state of the industry as it pertains to neutrality and substrate corrected color aims.

APPENDIX A – The Effect of Xmin on SCCAs



SUBSTRATE CORRECTED COLOR AIMS (SCCA) FOR SOLIDS, OVERPRINTS, AND NEAR-NEUTRALS TRIPLET WITH Xmin SET AT REFERENCE SUBSTRATE, Xmin SET AT 1.00, AND THE ΔE00

C-M-Y-K	Xmin set at 1.00			Xmin at ref substrate			ΔE00
	L*	a*	b*	L*	a*	b*	
0-0-0-0	94.61	-0.38	1.46	94.61	-0.38	1.46	0
25-19-19-0	75.42	-0.31	1.37	75.42	-0.3	1.3	0.07
50-40-40-0	57.28	-0.24	1.25	57.3	-0.22	1.07	0.17
75-66-66-0	39.29	-0.17	1.08	39.34	-0.13	0.71	0.36
100-100-100-0	22.9	-0.09	0.81	23	0	0	0.81
100-0-0-0	55.75	-36.6	-45.95	55.53	-37.04	-41.13	1.74
0-100-0-0	47.78	73.72	-0.97	47.6	72.43	1.49	1.07
0-0-100-0	88.63	-5.27	94.75	88.26	-6.51	95.49	0.68
0-0-0-100	17.93	-0.24	0.83	17.99	-0.01	-0.24	1.11
0-100-100-0	47.78	66.77	47.86	47.6	65.54	46.91	0.38
100-0-100-0	49.78	-65.28	28.96	49.58	-65.24	29.91	0.42
100-100-0-0	24.89	20.42	-42.71	24.87	20.02	-39.86	1.38

Table 13 – *The substrate corrected color aims in CIELAB of the solids, overprints, and the CMY triplets, setting at the Xmin at the value of the reference substrate and the Xmin value of 1.00, and their respective color difference.*

In Appendix A, we can see that the choice of the darkest point in the tristimulus liner correction formula has an impact on the color of the solids. If we use the value of ISO 12647-2 CD1 as the reference substrate we are allowing the 100-100-100-0 CMY triplet to have a hue, since the perfectly neutral CIELAB doesn't correct for chromaticity. Most importantly, the solid aims will be more chromatic, since the amount of correction is less. However, when we use Xmin of 1.00 to calculate the SCCA CIELAB values of the CMY triplets, we see that the aims are yellower.

Using the Xmin of the reference substrate would result in lower yellow density at the solids, but more yellow throughout the tonal reproduction scale of the CMY triplet. It could be speculated, that if we were to perform another round of curve corrections in order to improve the neutrality, either application would have called for the addition of yellow in the midtones, quartertones and three-quartertones or a higher solid yellow target: this might indicate that the use of the reference substrate at the Xmin value could provide better results than Xmin set at 1.00.

Two additional observations are that the impact of Xmin as it relates to color difference is not as much in the yellow solid (1.74 ΔE00), but in the yellow component of the cyan solid (0.68 ΔE00), and that a choice of Xmin lighter than the darkest point results in a miscalculation of the darkest areas. It would be thus preferable and perhaps the focus of a new study, to include the black colorant on the darkest overprint.

Figure 7 better displays the effect of the choice of the Xmin value as well as the relationship between the solid and overprint targets and measurements.

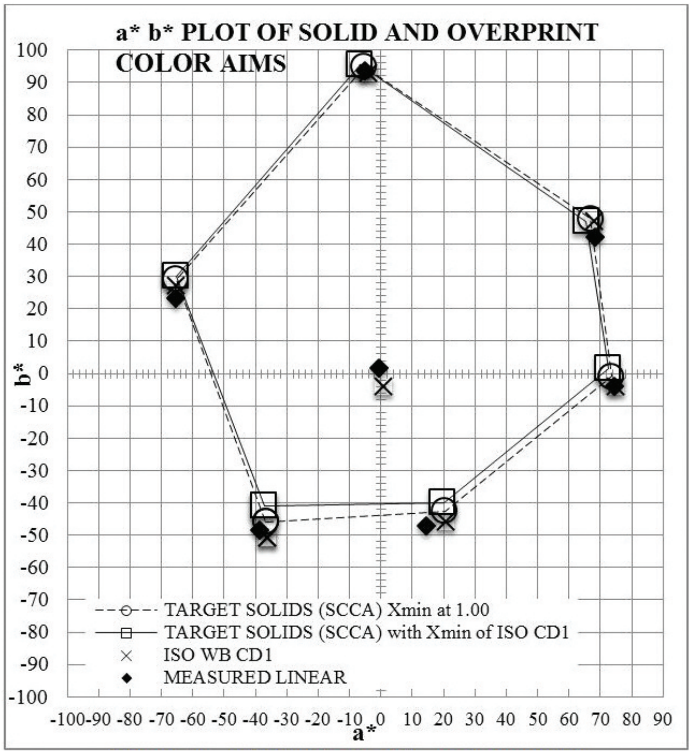


***Figure 7** – a* b* plot of solids and overprint*

Finally, Figure 8 displays the impact of the choice of Xmin for the near neutral targets. We can see that in this case we have the opposite impact: an Xmin value of 1.00 calls for minimally yellower near neutrals. This is a limitation of the study, where we chose the GRACOL2006 coated 1v2 data set as reference white point that has a* and b* values of 0 and -2 respectively, where the calculation of the solids was made with the ISO 12647-2 PS1 reference white point that has a* and b* values of 1 and -4.

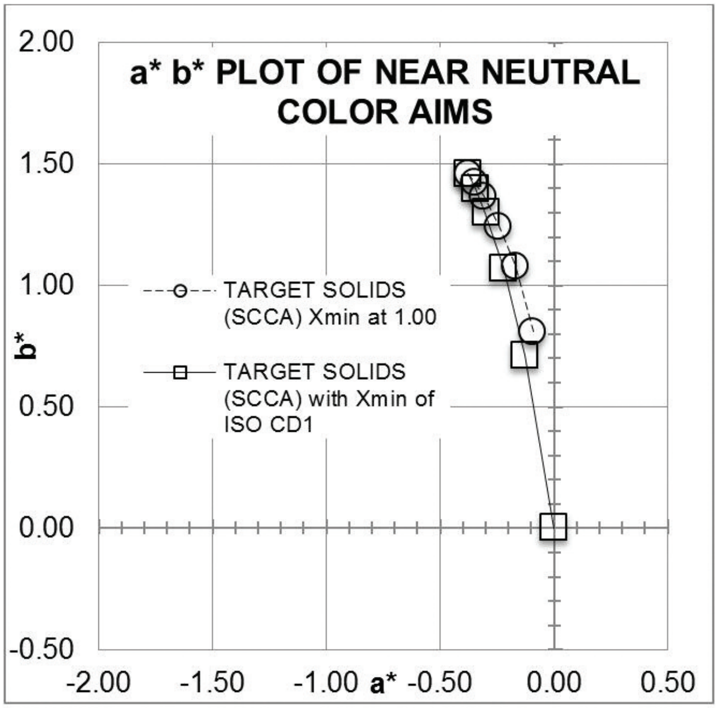


***Figure 8** – a*b* plot of substrate color corrected near neutral targets*

Literature Cited

ANSI CGATS/TR015-2011
2011 ANSI CGATS/TR 015 "Graphic technology — Methodology for Establishing Printing Aims Based on Shared
Neutral Greyscale Appearance", CGATS / SC3 N 1190, 2011

ANSI CGATS/TR016-2011
2011 ANSI CGATS/TR 016 "Graphic technology — Printing
Tolerance and Conformity Assessment", CGATS / SC3 N 1191, 2011

Chung, Robert and Quanhui Tian
2011 "Substrate Correction in ISO 12647-2", 2011 TAGA Proceedings

Chung, Robert
2011a "Assessing Print Conformance Based on ISO 12647-2", January 2, 2011 Draft
2011b "Grey Reproduction: Why And How", January 24, 2011 (v_1e) Draft

Curve2 User Guide
2009 "Curve2 User Guide", Document Version 1.02, Software Version 2.0 November 2009 Copyright © HutchColor, LLC and CHROMiX Inc.

ISO
2009 ISO/WD 12647-1 “Graphic technology — Process control for the production of half-tone colour separations, proof and production prints — Part 1: Parameters and measurement methods”, ISO TC 130/SC /WG 3 N 1023, 2009

2010 ISO/WD 12647-2:2010 “Graphic technology – Process control for the production of half-tone colour separations, proof and production prints – Part 2: Offset lithographic processes”, ISO TC 130/SC /WG 3 N 1026, 2010

McDowell, David Q., Robert Chung, and Lingjun Kong
2005 “Correcting Measured Colorimetric Data for Differences in Backing Material”, 2005 TAGA Proceedings, p. 302-308

Seymour, John
2008 “Building a Bridge from Dense City to Colorimetropolis”, 2008 TAGA Proceedings

Viggiano, J A Stephen and C Jeffrey Wang
1991 “A Suggested Method for Computing Colorimetric Densities”, 1991 TAGA Proceedings, p 196 - 215