Further Study of ICC-based Digital Proofing

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Keywords: CMS, ICC, Digital, Proofing, Profiling

Abstract: This paper is a further study of ICC-based digital proofing performance with actual press runs conducted to test the color matching performance between the digital proof and the press sheet. Emphasis in the study has been placed on digital proofer qualification and minimization of press variability. In order to improve color match between digital proof and press sheet, we tested stability and color gamut of the digital proofer. In addition, we used a modified one-ink-zone profiling target and a modified one-ink-zone IT8.7/3 basic target as a means to minimize the influence of press variability. The average ΔE of the IT8.7/3 basic target between digital proof and press sheet was further reduced to 2.3. This study also provided us with physical samples for visual comparison between digital proofs and press sheets. It was observed that there were noticeable color differences between the ICC-based digital proof and the press sheet which can be summarized by the CRF (Cumulative Relative Frequency) curves for proofs and press sheets.

Introduction

In recent years, printing workflow has been changed from closed-loop color, one device to the other, to open-system color, many devices to many devices. In closed-loop color, the color reproduction characteristics of the output device are used to make scanner settings, "closing the loop" between input and output. The color reproduction characteristics are determined by test target analysis and settings are manually entered into

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the scanning or image-editing software. In open-system color, a device-independent color space, or profile connection space (PCS), is used as an intermediate step and color management software is used to derive and make color settings. Therefore, attention is being focused on Color Management System (CMS) for the new workflow. CMS attempts to make color adjustments automatically with the use of device profiles, a color management module (CMM), and an application programming interface (API) (refer to Figure 1).

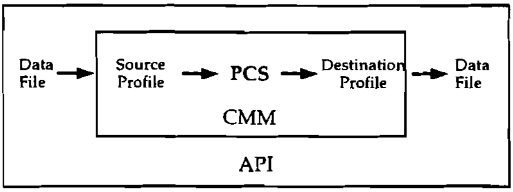


Figure 1. Color transformation of CMS

Numerous efforts were made to appraise ICC-based digital proofing performance. For instance, it was reported that ICC-based digital proofing did not perform better than a well-calibrated film-based proofing system (Chung and Komori, 1998). More recently, it was reported that digital proofing with CMS performed better than without CMS when press variability was eliminated. The elimination of press variability was possible by adopting the CGATS TR001 data as the printing condition (Chan, Chung, and Cheung, 2000).

In these previous studies, although ICC-based digital proofing performed well when press variability was eliminated, it is not clear that whether the ICC-based digital proofing works well in simulating an actual press sheet.

Therefore, the objective of this study was to investigate an improved methodology to obtain profiles that lead to a better match between digital proof and actual press sheet.

Experimental Approaches

In order to improve the color match between digital proof and press sheet, we tested the digital proofer qualification and CMM compatibility, using ANSI CGATS TR001 data set. Then, we built a press profile to perform CMS with the digital proofer. We especially focused on minimization of press variability for building the press profile using a modified one-ink-zone profiling target and a modified one-ink-zone IT8.7/3 basic target.

Limitation
This experiment was tested under the conditions listed in Appendix A.

Experimental Findings

Digital-proofer testing
Iris Realist FX was tested as a digital proofer. We made a material stability test, device consistency test, and measured the color gamut of the Iris Realist FX. From these digital proofer tests, we confirmed that Iris Realist was a very useful digital proofer for this study (refer to Appendix B).

CMM compatibility
CMM compatibility was tested by CMS performance of Iris Realist FX to ANSI CGATS TR001 data using two different CMMs, Kodak CMM and Imation CFM (Color Fidelity Module) to select a better CMM for this study. Imation CFM is able to preserve black in A to B to A (CMYK to L*a*b* to CMYK) conversion.

Although we found that Imation CFM worked better than Kodak CMM in this test, the difference was small, and there are another aspects about CMM that also need to be considered (refer to Appendix C).

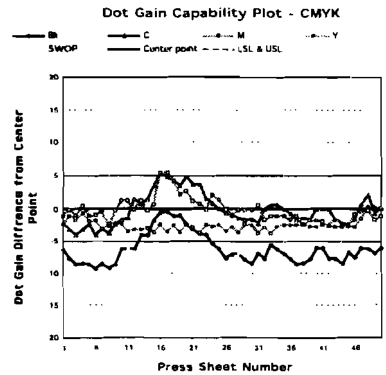
Conducting calibration & characterization press run
Press run
A Calibration and characterization press run was conducted using Harris M-1000B Web-Offset Press at Rochester Institute of Technology (refer to Appendix D). SWOP specification was used as aim points for this press run. A TOBIAS SDT scanning densitometer was used to check the solid ink density during the press run. Two kinds of sampling were done to collect the press samples:

a) Short-term sampling: approximately 400 sheets were collected at the press okay stage.
b) Long-term sampling: two consecutive sheets were collected every 30 seconds during the press run.

Actually, we conducted two calibration & characterization press runs. However, the first press run was rejected because the inking uniformity across the sheet was not good.

In this first press run, we compared solid ink densities of the different control patch positions of the press sheet to determine which control patch we should measure. The solid ink densities of the lead, center, and tail side of the press sheet were small. Therefore, we only used the one-ink-zone control patch located at the lead side of the sheet for measurements.

Doubling was observed for this press run. This is a printing defect. Figure 2 shows the doubling effect on dot gain during a test press run. Dot gain was calculated using the Murray-Davies formula. In this figure, the biggest doubling was observed in black and there was no doubling in yellow. Black was the first unit and yellow was the fourth unit of the press. So, it was considered that the paper infeed caused the doubling.



	Dv (K)	Dr (C)	Dg (M)	Db (Y)
Average	19.75	21.77	21.74	17.40
Max	25.63	27.40	27.44	20.20
Min	16.87	18.01	19.22	[illegible]
Range	[illegible]	9.40	8.22	4.00
s	2.36	2.43	1.88	[illegible]
CP	0.71	[illegible]	[illegible]	[illegible]
CPK	[illegible]	0.65	0.84	[illegible]

Figure 2. Doubling effect on dot gain during a test press run

Therefore, print samples had to be carefully checked for doubling when the 'best' sheet was selected.

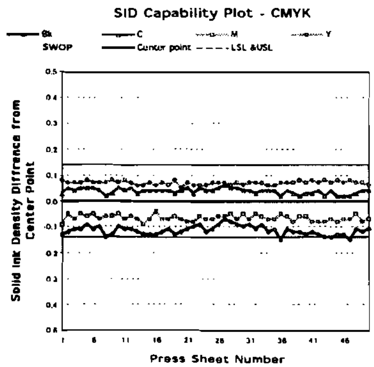
After these analyses, the calibration & characterization press run was conducted. During the press run, two kinds of sampling, short-term and long-term (64 sheets) were done to collect the press samples. Press okay was achieved at sample #36 in the long-term sampling set.

Press capability analysis

Figure 3 shows short-term capability of the press run.

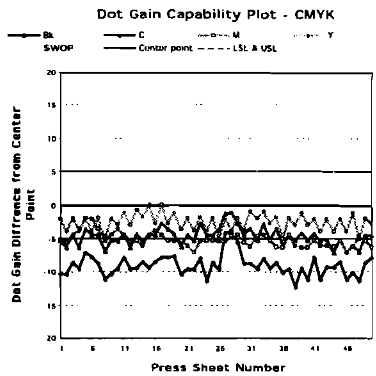
Doubling was also observed in this press run. In addition, up & down cycling of the dot gain was observed, especially for yellow. These differences were between 1% and 2%. It is assumed that they came from the double-size blanket cylinder of the press.

Although almost all solid ink densities were within the SWOP tolerance in these short-term samples, black was slightly lower than SWOP aim point. Besides, the dot gain of black was below the SWOP tolerance. Therefore, the best sheet for the press profiling was selected from the long-term samples.



Doubling #27, 28, 29, 50

	Dv (K)	Dr (C)	Dg (M)	Db (Y)
Average	1.47	1.33	1.33	1.08
Max	1.51	1.36	1.38	1.09
Min	1.43	1.31	1.31	1.06
Range	0.08	0.04	0.06	0.03
σ	0.02	0.01	0.01	0.01
CP	2.66	4.55	4.08	6.45
CPK	0.46	3.35	2.18	3.28

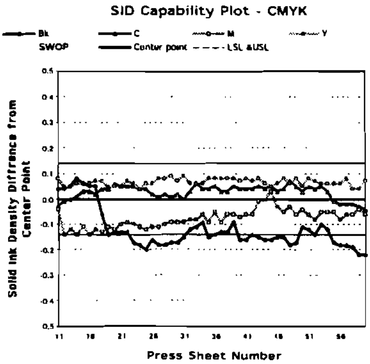


Doubling #27 28, 29, 50

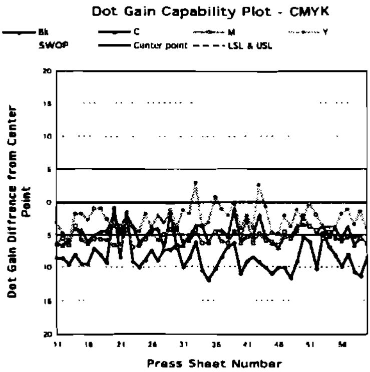
	Dv (K)	Dr (C)	Dg (M)	Db (Y)
Average	16.98	17.31	16.81	17.43
Max	21.85	20.87	20.06	20.01
Min	13.82	14.83	14.83	14.96
Range	8.03	6.05	5.23	5.06
σ	1.82	1.34	1.08	1.29
CP	1.03	1.24	1.55	1.20
CPK	-0.83	0.08	0.08	0.83

Figure 3. Short-term capability plot of the press run

Figure 4 shows long-term capability of the press run. Although 64 samples were collected from the press run as the long-term sample, the solid ink densities of the first ten samples and some of the last samples were not good. Therefore, the rest of 50 samples were used for analysis as long-term samples. In this figure, the solid ink density of cyan and yellow were capable, but black and magenta were not. Especially, black was lower than the SWOP specification. On the other hand, the dot gains were not stable and not capable. Although many kinds of reasons were considered about it, such as ink/water balance, clearly, the one reason of it was the doubling, which occurred at samples #20, 22, 33, 39, 43, and 51. They coincided with the peaks of Figure 4.



	Dv (K)	Dr (C)	Dg (M)	Db (Y)
Average	1.46	1.32	1.32	1.08
Max	1.66	1.38	1.43	1.10
Min	1.36	1.28	1.26	1.06
Range	0.30	0.11	0.17	0.05
σ	0.05	0.03	0.04	0.01
CP	0.80	1.78	1.28	3.58
CPK	0.08	1.43	0.57	1.89



	Dv (K)	Dr (C)	Dg (M)	Db (Y)
Average	17.45	17.20	16.58	17.57
Max	25.05	20.87	19.87	22.97
Min	14.02	14.92	15.11	14.22
Range	11.02	5.95	4.76	8.74
σ	2.21	1.48	1.05	1.77
CP	0.76	1.12	1.67	0.94
CPK	0.52	0.04	0.13	0.48

Figure 4. Long-term capability plot of the press run

Best sheet selection

We selected sample #50 in Figure 9 as the best sheet. The solid ink densities and dot gains of the best sheet are shown in Table 1.

	Solid ink density				Dot gain (%)			
	K	C	M	Y	K	C	M	Y
SWOP aim	1.59	1.29	1.40	1.01	26.0	22.0	22.0	20.0
Best sheet	1.47	1.32	1.36	1.06	20.6	18.6	19.9	17.4
Δ	-0.12	0.03	-0.04	0.05	-5.4	-3.4	-2.1	-2.6

Table 1. Solid ink density and dot gain of the best sheet

From SWOP specification, the tolerance of solid ink density is ±0.14 and the tolerance of dot gain is ±5% for production. Although only the black dot gain of sample #50 was slightly out of the tolerance, it was almost okay and the others were within the SWOP tolerance. Besides, since the dot gain differences are all on the low side, gray balance is maintained. Therefore, sample #50 was selected as the best sheet in this press run and this sample was used for the following analysis and for profiling.

Inking uniformity analysis

Inking across the best sheet is shown in Figure 5. Although there was a peak in the test press run, there was no peak in this best sheet. Therefore, it was considered that a better profile could be made from this press sheet.

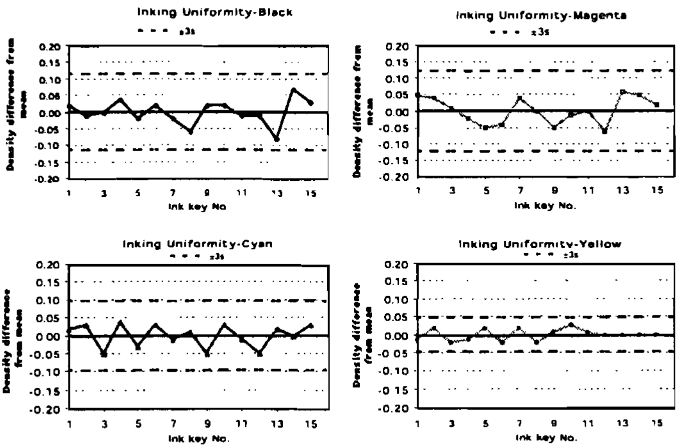


Figure 5. Inking uniformity of the best sheet

ICC-profiles preparation and CMS performance of digital proofing

ICC-profiles preparation

Since we already had a digital-proofer profile for Iris Realist FX, we used it. For the press profile, we built two press profiles from two kinds of Kodak ColorFlow profiling targets, normal layout and modified one-ink-key-zone layout, of the best sheet. These two press profiles were evaluated to select the more accurate one.

Profile evaluation

IT8.7/3 basic target was used in this test. Although A to B & B to A (CMYK to Lab & Lab to C'M'Y'K') conversion is normally performed in CMS, B to A & A to B (Lab to CMYK & CMYK to L'a'b') conversion was done for this profile evaluation using two press profiles. The accuracy of a profile could be verified by the delta E* between the original Lab data and the modified Lab data using tools, such as Dupont Color Scientist. The B to A LUT (look up table) of press and the A to B LUT of the digital proofer in ICC-based digital proofing are the ones that really matter.

We used ANSI CGATS TR001 Lab data as original data and got two modified ANSI CGATS TR001 Lab data. Delta E* values of all 182 patches of IT8.7/3 targets were calculated between the original Lab data and the modified Lab data. Then, more accurate press profile was selected in terms of delta E* values of all 182 patches of IT8.7/3 targets.

Figure 6 shows the profile evaluations of two press profiles.

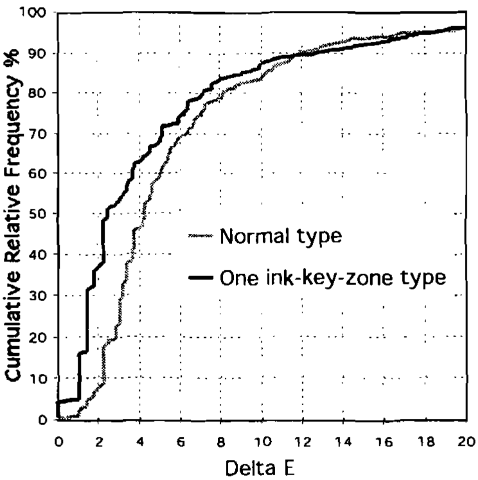


Figure 6. CRF Plot – Profile evaluations of two press profiles.

In this figure, there was a significant difference between a press profile from normal profiling target and a press profile from one-ink-zone profiling target at 50 percentile. The difference does have meaning for quantitative analysis. As a result, we selected the press profile from one-ink-zone profiling target as the press profile. From this result, it was verified that the one-ink-key-zone profiling target could reduce the press unevenness.

<u>CMS performance of the digital proofing</u>

In order to test CMS performances of the digital proofing to the press sheets, we made ICC-based proof. We applied ICC-profiles to IT8.7/3 basic target in Photoshop 5.0 API and Imation CFM. Source profile was press, Harris M-1000B web-offset press, and destination profile was digital proofer, Iris Realist FX. The better profile in profile evaluation was used as a press profile. The modified target was saved as TIFF file and printed out for the Iris Realist FX.

	Sample number	Average Delta E	Standard deviation
1	11	2.58	1.73
2	12	2.52	1 62
3	13	2.62	1.59
4	14	3.08	1 81
5	15	2.80	1.71
6	16	2.87	1.74
7	17	2.77	1.71
8	18	2.61	1.67
9	19	2.42	1.44
10	21	2.62	1.56
11	23	2.87	1.60
12	24	2.69	1 56
13	25	2.47	1.53
14	26	2.79	1.54
15	27	2.87	1.67
16	28	2.61	1 56
17	29	2.71	1.60
18	30	2.56	1.53
19	31	2.69	1.64
20	32	2.60	1.55
21	34	2.59	1.48
22	35	2 56	1.67
23	36	3.04	1.93
24	37	2.74	1.72
25	38	3.02	1.71
26	40	2 70	1.67
27	41	2.38	1.51
28	42	2.46	1.47
29	44	2.28	1.48
30	45	2.32	1.49
31	46	2 42	1 53
32	47	2.81	1.75
33	48	2.39	1.46
34	49	2.63	1.71
35	50	2.84	1.61
36	52	2 75	1.72
37	53	2.99	1.78
38	54	2.75	1.56
39	55	3.25	1.93
40	56	3.16	2.04
41	57	3.11	2.05
42	58	3.06	1.99
43	59	2.87	1.82
44	60	3.14	2.07
Maximum delta E		3.25	1.93
Minimum delta E		2.28	1.48
Average		2.73	1.67

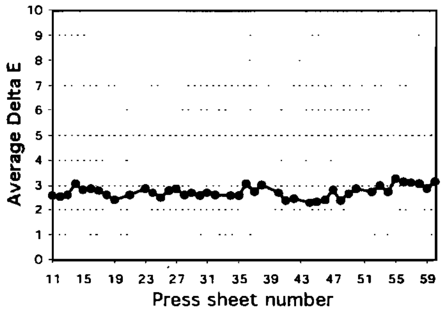


Figure 7. CMS performance of the ICC-based Iris Realist to the long-term samples in the calibration & characterization press run

The delta E* between ICC-based Iris Realist FX and the long-term samples in the calibration & characterization press run are shown in Figure 7. Since there were some doubling samples in the long-term samples, they were excluded from this analysis. So, ICC-based Iris Realist FX was compared with 44 long-term samples in the calibration & characterization press run.

From this figure, an average 2.73 delta E* of IT8.7/3 basic target between ICC-based Iris Realist and 44 long-term samples in the calibration & characterization press run was found (maximum delta E* was 3.25 and minimum delta E* was 2.28). It is usually said that a delta E* 3 is a criterion for a good match. For more detailed, color differences between Iris Realist and the best sheet are shown in CRF curves in Figure 8.

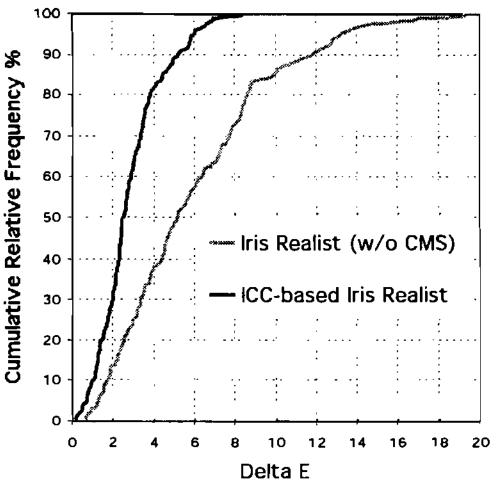


Figure 8. CRF Plot – CMS performance of the ICC-based Iris Realist FX

Figure 8 shows CMS works very well to perform the color matching between Iris Realist and the press sheet. However, upon visual assessment, there was noticeable color difference between them. This color difference is shown in Table 2.

	ΔE statistics			
	Average	50 percentile	90 percentile	Range
Iris Realist (w/o CMS)	6.01	5.15	11.89	19.31
Iris Realist (ICC)	2.84	2.47	5.24	9.01

Table 2. Delta E* statistics for Iris Realist and press sheet agreement

Summary

Digital proofer and CMS tools testing
Digital proofer and CMS tools testing were a prerequisite to analyze ICC-based digital proofing.

An improved methodology for building a press profile
It was found that single ink fountain key test targets are better for evaluation of CMS performance, because they are less subject to press variability.

CMS performance of digital proofing
An average 2.73 delta E* of IT8.7/3 basic target between ICC-based Iris Realist and 44 long-term samples in the calibration & characterization press run was found. It was clear that the ICC-based digital proofing works well in simulating the press sheet in actual production environment.

Other findings

Digital proofer testing
Iris Realist FX is a very stable digital proofer and has a larger gamut than that of CGATS TR001.

CMM compatibility
Imation CFM worked well in this CMYK to CMYK conversion.

Press runs

Process capability
Short-term samples, which are okay sheets, were stable, but not capable.

Inking uniformity
Although we tried to maximize inking uniformity, there were some peaks across the sheet. Therefore, it was very important to minimize this unevenness in the press sheet for press profiling.

Printing defects
There were some printing defects that affect CMS performance. Doubling and up & down cycles of dot gain were observed in the press run. Therefore, it is very important to check printing defects to select the best sheet.

CRF curve
CRF curves are a very useful tool to show the color difference between images. They are much more descriptive of a process than calculation of an average of delta E*s.

Acknowledgments

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Appendix A
Test Conditions

1) Operation System:
    Mac OS 8.6
2) CMS:
    System based CMS: ColorSync 3.0
    Profiling Software: Kodak ColorFlow Profile Editor 2.0
    Color Matching Module (CMM): Imation CFM
    API: Photoshop 5.0.2
    Page Layout Software: QuarkXPress™ 4.0
3) Measurement Instrument:
    Gretag MacBeth SpectroLino/SpectroScan
4) Proofer:
    Iris Realist FX
    Paper: Iris Pro Media Glossy
    Test targets: IT8.7/3 basic target (Normal type, One-ink- zone layout type)
    Printer Driver: Brisque 3.0
5) Press Run:
    Press: Harris M-1000B web-offset press
    CTP: CREO Trendsetter
    Plate: KPG (12 mil), thermal sensitive
    Fountain Solution: MXEH IIS Emerald Premium
    Blanket: Day 9500
    Ink: SUN CHEMICAL Standard heatset
    Paper: Champion Influence 35"/60lb
    Test targets: T8.7/3 basic target (Normal type, One-ink-zone layout type), Kodak ColorFlow CMYK_MediumTarget (Normal type, One-ink-zone layout type), RIT color control bar 1997, Doubling grid, One-ink-zone control patches, SCID images

Appendix B
Digital-proofer testing

Methodology

Stability test

Material stability test

An IT8.7/3 basic target was printed out via QuarkXPress 4.0 for Iris Realist FX and was measured nine times: right after printed, 30 minutes, one, two, three, four, six, eight, and twenty-four hours after printed. Delta E* of four process colors (cyan, magenta, yellow, and black), paper, and an average of all 182 patches of IT8.7/3 were calculated relative to the first measurement data.

Device consistency test

Thirty IT8.7/3 basic targets were printed on Iris Realist FX during a month. All targets were measured two hours after printed. The average value of L*, a*, b* of each color patch of the thirty samples was used as a reference.

Color gamut

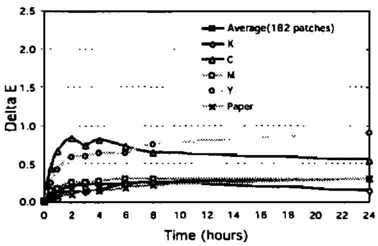
An IT8.7/3 basic target was printed out for Iris Realist FX to analyze the color gamut. The color gamut was compared to SWOPreference, CGATS TR001 data.

Result

Stability test

Figure B-1 shows material stability of Iris Realist FX within 24 hours. It shows that there was a delta E difference in the first two hours and a minimal change between two and 24 hours. This suggested that between two to 24 hours are best time for taking measurements.

Figure B-2 shows device consistency of Iris Realist FX within a month. It shows that device consistency of Iris Realist FX within a month is approximate 0.45 ΔE. As a result, Iris Realist FX was confirmed as a very stable digital proofer.



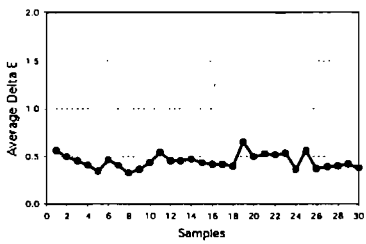


Figure B-1. Material stability (24 hours) Figure B-2. Device consistency (a month)

Color gamut

Figure B-3 shows the color gamut of Iris Realist FX. This figure shows that Iris Realist FX has a larger gamut than the SWOP reference, ANSI CGATS TR001 data.

From these digital proofer tests, we confirmed that Iris Realist was a very useful digital proofer for this study.

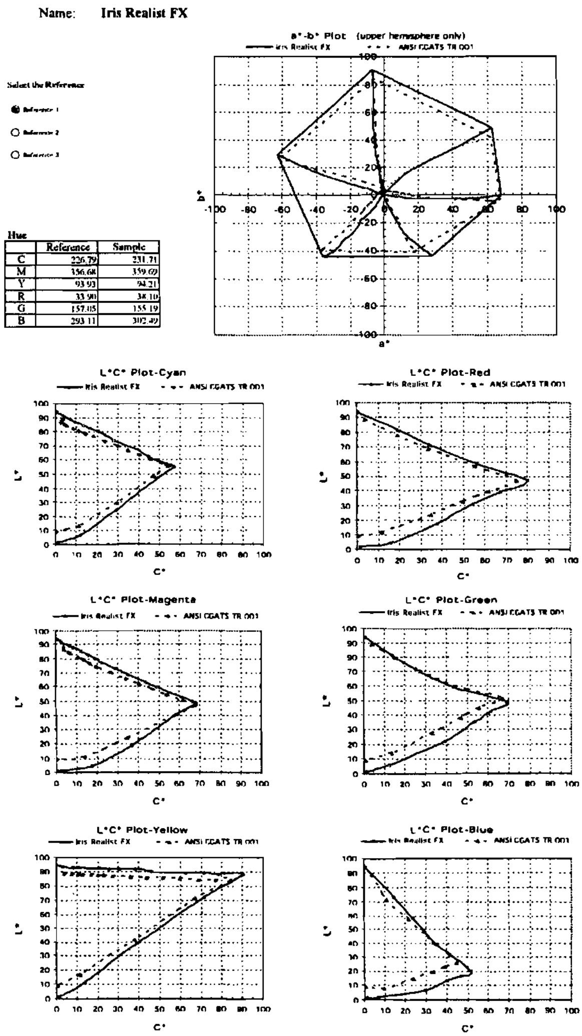


Figure B-3. Color gamut of Iris Realist FX

Appendix C
CMM Compatibility

Methodology
IT8.7/3 basic targets were modified by applying profiles in Photoshop 5.0 API using two CMMs, Kodak CMM and Imation CFM. Source profile was SWOPICC profile (provided by Eastman Kodak): destination profile was Iris Realist FX. The modified IT8.7/3 basic targets were printed out for Iris Realist FX to analyze the CMS performance.

Result
The result is shown in Table C-1 and Figure C-1. Table C-1 shows a very small difference between Kodak CMM and Imation CFM. However, Figure C-1 shows that even though there is only a small difference at the 50 percentile between them, the difference at 90 percentile is significant. This is an example how a CRF plot gives more meaningful information than just a single number like the average of the delta E*s. This figure also shows there is a dramatic improvement due to the use of color management.

As a result, we selected Imation CFM for this study. Imation CFM was able to preserve black in Ato B to A(CMYK to L*a*b* to CMYK) conversion.

	with CMS		without CMS
	Kodak CMM	Imation CFM	
Average Delta E*	3.25	2.51	5.88

Table C-1. CMS performance of Iris Realist FX to ANSI CGATS TR001 using different CMMs

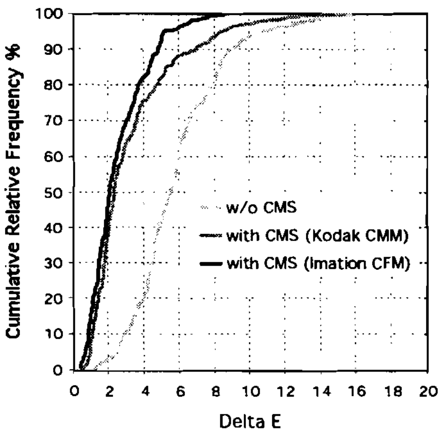


Figure C-1. CRF Plot - CMS performance of Iris Realist FX to ANSI CGATS TR001 using different CMMs

Appendix D

Preparations for the press run

A 24.25" x 38" size test form was created using QuarkXpress 4.0, Photoshop 5.0, and Illustrator 8.0 for the press run. A25% four-color gray was printed on the backside. Both IT8.7/3 basic target and Kodak ColorFlow profiling target were placed two ways, normal layout and one-ink-key-zone layout, to analyze the effect of profiling-target orientation in the press layout for building the press profile. In addition to the RIT Control Bar 1997, specially designed one-ink-key-zone control patches were placed in each ink zone. The plates were made by CREO Trendsetter, using a transfer curve with a 4% mid-tone dot gain, and the screen ruling was 133 lines/inch. Before printing, plates were verified by measuring the 50% dot areas and the screen angles of four colors, cyan, magenta, yellow, and black.

Layout of the press run