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Test Targets 7.0: A Collaborative effort exploring the use of scientific methods for color imaging and process control

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Test Targets

An R.I.T School of Print Media Publication

7.0

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A collaborative effort exploring the use of scientific methods for color imaging and process control

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Introduction

Robert Chung

Test Targets was first created to use in my teaching six years ago and has been under my tutelage all these years. It is my pleasure to provide you with an overview of what *Test Targets* is all about.

Test Targets Serves RIT's Print Curriculum

Test Targets is a culmination of teaching and learning that reflects quality and analytic aspects of printing systems and their optimization. The creation of the *Test Targets* publication is a total experience that reflects the innovation, problem solving, and teamwork of the diverse team of faculty, staff, students, and professionals responsible for its contents and production.

Test Targets holds a unique position within the RIT community because it marks both the outcome of curriculum and collaboration as well as the starting point of new learning and research as it plays a role in the coursework and collaborative research to follow. The technical content of the publication is referenced regularly in undergraduate and graduate classes focused on print and production and image quality. The production of the annual publication is discussed as a case study in coursework focused on workflow and project planning.

The publication also serves as a connector between curricula and communities, both inside and outside of RIT. The RIT library, Wallace Memorial Library, preserves archived copies of the publication in its Digital Media Library for the general RIT population to access. Hardcopies of the publication are distributed directly to a growing number of scholars and professionals in the field. The increased access to *Test Targets* has fostered new dialogues and spurred conversations on topics of new learning, research, and opportunity.

Balancing Between Change and Tradition

With the presidential election coming up in 2008, we frequently hear candidates talking about 'change' vs. 'more of the same.' Given that change is essential, change itself does not always lead to better outcome. On the other hand, 'more of the same' or 'tradition' is not necessarily a bad thing. 'Change' or 'more of the same' also frequently surfaced when contemplating what to include in *Test Targets 7.0*. Let us take a quick look at what we have in this edition.

Test Targets 7.0 contains three broad sections: Articles, Gallery of Visual Interest (GVI), and Test Forms. Professor Wuhui Liu, a visiting scholar from Wuhan University, reported the color stability of an Epson inkjet printer. I wrote a paper on how to implement process color printing by colorimetry. Together, Professor Liu, Fred Hsu, and I wrote a paper on achieving color agreement using different color adjustment methods. Arvind Karthikeyan assessed the 30-inch Apple Cinema Display monitor against ISO 12646 standards as a softproofing device. Steve Suffoletto examined metrics for gray balance or neutrality determination in the pressroom.

Continuing on the notion of innovation and change, Franz Sigg describes how increasing local image contrast can enhance the quality of newsprint, which is a low or limited contrast printing system. In addition, he describes how to generate a custom test wedge in the form of an EPS file using a Microsoft Excel template that he has developed. The test wedge generator will be made available at the RIT URL for the Color Management Systems Lab: *http://www.rit.edu/~gravure/CMS2007/*.

The Gallery of Visual Interest, or GVI, has always been the most visual and talked about section of *Test Targets*. To be visually interesting requires that we seek new ideas and attempt new technologies that would make print media exciting. In this issue, we explored the synergy between graphic design and print with the idea of folded panels. The folded panel idea came to my attention when I visited Professor Tommie Nyström of Linköping University in Sweden. Produced by digital presses, the Folded panels not only provide extra 'real estate' for printed matter, but also support graphic design and communication in an interesting manner. In addition, this edition of GVI showcases different screening and gloss features available from the NexPress digital press. In short, we took an innovative approach in seeking changes while preserving the value of *Test Targets*.

We have kept the Test Forms section very much the same as in previous editions. After all, Test Forms is a collection of test elements with known properties. They are designed to analyze specific behaviors of imaging devices. For example, IT8.7/4 characterization target is a printer-profiling target. It is only useful when the target is used as originally defined.

Moving Towards a Stronger Team with Greater Industry Collaboration

School of Print Media (SPM) and Printing Applications Laboratory (PAL) are two administrative units at RIT. The former focuses on credit-bearing college education. The latter focuses on non-credit industry training and materials testing. The intellectual challenge of content creation and do-it-right-the-first-time challenge of print production have melded the two units and created a strong bond over the years for the production of *Test Targets*.

Looking ahead, it is desirable to form a joint group between SPM and PAL that meets regularly to steer the *Test Targets* direction, to attract students into the project, and to provide resources and support in its development and production. By having a stronger team, we can be more aggressive in setting agenda and in instilling a more rigorous peer review process. While industry assistance grows with every issue of *Test Targets,* such an organized approach would be a win-win situation for all entities involved, students, supporters, and *Test Targets*.

Acknowledgments

I appreciate very much the collaboration between student, faculty, and staff who have given their time and energy to conduct experiments, collect data, and document major findings as well as those who are diligently involved in the design and production of the publication. My kudos go to every author in the

publication. If *Test Targets 7.0* has a life, their contribution is the blood. I also want to thank Dr. Patricia Sorce, my chairperson, for her continuous encouragement and financial support of this project.

On the design side, a kudo goes to Drake Yang for his cover and other graphic design and a kudo goes to Matt Rees for his page layout design. On the editorial side, a special thank-you goes to Edline Chun for her final editing of all texts. On the production side, a big thank-you goes to Sri Hemanth Prakhya for his pagination and 'traffic' control. Sri and Sunchut Jongcharoensiri also assisted me with the layout in the GVI section. On the quality control side, I want to recognize Franz Sigg and Fred Hsu for their extraordinary efforts in making the digital-to-print production workflow accurate and complete.

The PAL staff, under the leadership of Bill Garno, gave birth to *Test Targets 7.0* with the cover printed by the Heidelberg sheet-fed press, body printed by Goss Sunday 2000 web offset, and GVI printed by Kodak NexPress. Barb Giordano coordinated the production schedule, including its binding and finishing by the Riverside Group. We documented each of the three printing conditions in the *Press Run Organizers*.

Dr. H.T. Tai of Eastman Kodak Company, a long-time friend of mine, supported us with not only the screening technologies in the production of the GVI, but also with valuable advice in the production of the panoramic images with gloss features. He is truly a godsend.

I always appreciate the support of many companies who donated materials or technologies that made the publication possible. Among them, Eric Johnson of NewPage Corporation provided paper; Jason Clark of Superior Printing Inks Corporation provided spot color inks; Kelly VandenBosch of X-Rite, Inc. provided us the iSis spectro-densitometer; Bob McCurdy of GTI Graphic Technology, Inc. provided the softproofing and hardcopy viewing station; Brian Rooney of Pantone, Inc. provided a complete set of the color swatch library; Elie Khoury of Alwan Color Expertise provided the link profiler; and Olaf Druemmer of Callas Software GmbH provided the color management plug-in in Adobe Acrobat.

In Closing

Test Targets 7.0 serves RIT's print curricular needs. *Test Targets 7.0* is a reflection of our collaboration between academe and industry. We would like to hear your comments regarding how we are doing. Please send your e-mail messages to Bob Chung at rycppr@rit.edu.

Implementing Process Color Printing by Colorimetry *

Robert Chung

Keywords

process color, colorimetry, densitometry, printing standards

Abstract

Standards-based printing is shifting from densitometry-based specifications to colorimetry-based specifications. Similar to switching rules in the middle of the game, this has caused confusions in pressrooms worldwide. This paper reviews how standards-based printing began, describes underlying reasons for shifting process control aims from densitometry to colorimetry, and addresses issues in implementing colorimetry in the pressroom. Analysis of ink drawdown samples and a sheet-fed lithographic press run were conducted to develop procedures that would allow pressmen to adopt colorimetry in the pressroom. In doing so, this paper also elaborates on how conformance to printing standards can be verified by colorimetry.

Introduction

Print media has been an effective mass communication media for centuries. Contents were printed and print quality was in the hands of the printer. As printing technology developed, process color printing became possible to render pictorial color images in the form of editorial contents and advertisements. Due to market conditions and technology advancements, print buyers and content creators started to demand color accuracy and consistency in printing.

Standards-based printing began evolving from craft to science. Specifications Web Offset Publication (SWOP) was the first printing standard developed in 1970s. Densitometric parameters, e.g., solid ink density and tonal value increase (TVI) were used to specify aim points and tolerances for process color printing. Portable densitometers were also developed in the 1970s to help pressmen implement color control in the pressroom. The process of adopting densitometers to aid pressmen in ink key settings and maintaining color consistency was a slow process. It took 15 years to transform the publication printing industry from eyeball-based color adjustment to instrument-based control because print-by-number involves not only capital investment, but also training and cultural change in the pressroom.

Printing technology mainly addresses the output side of the graphic arts industry. Print buyers need a total solution that encompasses content creation, prepress, printing, and distribution. Digital color management became a solution

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that addresses the integration of prepress and press to make color portable and predictable in the early 1990s. International Color Consortium (ICC) is the standardization body that specifies the file format for look-up tables that describe the relationship between the device color space and the device-independent color space. The metrology for device-independent color space is colorimetry.

The effectiveness of color management depends on color repeatability of the printing device. Device color repeatability begins from the color of the ink in the can. ISO 2846 specifies colors of process inks by colorimetry. It became evident that printing process control aims, such as ISO 12647, are shifted from densitometry to colorimetry. Therefore, the integration of prepress and press by means of color management is the main driver for implementing colorimetry in the pressroom.

Objectives

Densitometry has proven to be effective for process control in the pressroom. But density numbers do not correlate to colorimetric numbers directly. Thus, the issue at hand is how to apply colorimetry in the pressroom. There are four issues: (1) how to verify ink, (2) how to achieve press make-ready, (3) how to exercise process control, and (4) how to verify printing conformance by colorimetry.

Experimental

A pressman has to place the right amount of process color (CMYK) inks in register with one another on the substrate during the press make-ready. He also has to maintain the control of the press run so that all products printed conform to colorimetric requirements. This paper addresses that: (1) the correct inks are used, (2) the correct amount of ink is printed, (3) color control is maintained throughout the press run, and (4) color quality assurance is documented colorimetrically.

Verifying Ink

How does a pressman know he uses the correct process color inks to begin with? Process color inks are specified in ISO 2846-1 (ISO, 2006) and ISO 12647-2 (ISO, 2004). In this case, colorimetric values (L*/a*/b*) of CMYK solids are specified as K: 16/0/0; C: 54/-36/-49, M: 46/72/-5, and Y: 88/-6/90. Instead of sending inks to a laboratory, we verify the correctness of process inks by ink drawdown with a grind gauge block on a Little Joe proofer with inks supplied by Kohl & Madden. A single impression from the grind gauge block produces a range of ink film thicknesses. Color measurements were made at various ink film thicknesses. Color differences were calculated relative to the ISO specified aim points. ISO 12647-2 also specifies that deviation of CMYK solids should be less than 5 ΔE.

Conforming to Colorimetric Aims

We organized a press run with the following equipment, materials and procedures. From the input side, a customized test form was used for the press run. As shown in Figure 1, the test form can be used for calibration, press capability study and characterization.

The Creo Prinergy 3 CTP system was used to produce a set of linear plates at 170 lpi AM screening. A 6-color Heidelberg Speedmaster 74 sheet-fed offset press was used to print the test form on Sappi Lustro, Grade 1 coated paper, at the speed of 8,000 impressions per hour. The printing sequence for the 6-color press was blank-blank-K-C-M-Y-aqueous coating. Because of the use of aqueous coating, press sheets were delivered dry and color measurement can be done without delay. We measured color control bars, located at the perimeter of the test form, to set ink keys.

Figure 1: Test form printed in the first press run

In order to print by colorimetry, we used the IntelliTrax, a scanning spectro-densitometer from X-Rite, capable of measuring multiple color control patches width-wise in density and color. Any color measurement system capable of providing densitometric and colorimetric values must collect spectral data from the press sheets and compute density and color by formulation.

Solid ink densities of K: 1.69, C: 1.45, M: 1.52, Y: 1.00 were initially set using the X-Rite IntelliTrax scanning spectro-densitometer as the aim points (Figure 2). Press sheet densities were converted to CIELAB values in IntelliTrax and compared to ISO 12647-2 colorimetric aim points. Densities that correspond to the smallest ΔE for each of the CMYK keys were selected as the new aim points. In other words, pressmen are able to use familiar density for initial ink setting and ink key adjustments while conforming to colorimetric specifications.

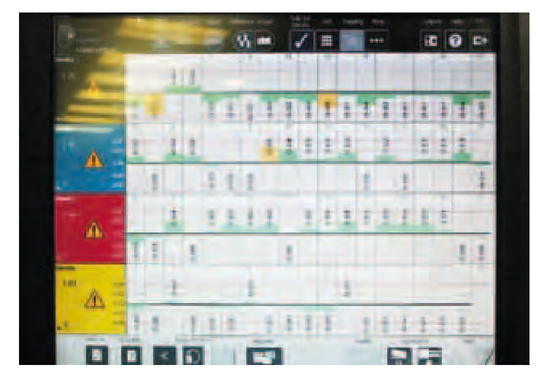

Figure 2: Spatial uniformity across the sheet as displayed by IntelliTrax

Controlling Color

When spectral reflectance data are collected, we can compute Status T (D_T) density per CGATS.4. We can compute spectral (D_{nm}) density at the wavelength having the maximum light absorption. As shown in Figure 3, the wavelength with the maximum absorption for cyan ink is at 630 nm; the wavelength of the magenta ink is at 570 nm; and the wavelength of the yellow ink is at 430 nm. We can also compute metric chroma (C*) from the spectral data per CGATS.5. The question we want to answer is, "Which metric provides the best signal for detecting process change or drift?"

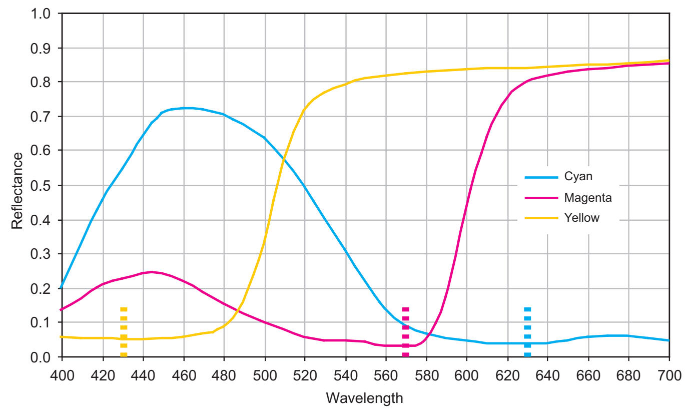

Figure 3: Spectral reflectance curves of process inks

In this study, we answer the above question by (1) selecting an ink film thickness (IFT) from the drawdown sample that matches the colorimetric aim point closest as the new reference, (2) calculating ΔD_T, ΔD_{nm}, and ΔC^* between the new reference and a range of ink film thickness of interest, and (3) studying the linearity and magnitude of change for each of the three metrics.

Assuring Process Quality

Printing specifications only provide aim points and tolerances. Press make-ready only provides evidence of initial conformance. Neither the specification nor the make-ready stipulates the spatial uniformity and the temporal consistency of the entire press run. In this study, we measure a pre-determined CMY chromatic gray patch over the width of the OK press sheet and press sheets sampled over time, respectively, to document the uniformity and the stability of the press run.

Results and Discussions

Below are results with discussions relative to major findings and experiences gained in ink verification, press make-ready, process control, and press run quality assurance based on colorimetric analyses.

Ink Verification

Figure 4 shows color difference as a function of relative ink film thickness. We collected multiple measurements from the drawdown sample plus trend lines in order to smooth out the noise. Notice that ΔE values at the ink film thickness at 5.5 relative IFT are less than the allotted tolerance of 5 ΔE for all three inks. This provides evidence of ink conformance.

Even though we did not know the exact ink film thickness, we know that the grind gauge block indicating the ink film at 5.5 µm has been split twice. The first ink split is between the ink in the gauge and the blanket; and the second ink split is between the ink on the blanket and the paper. Assuming that the ink split ratio is 45:55, the resulting ink film thickness is 5.5 x 0.45 x 0.45 or about one µm.

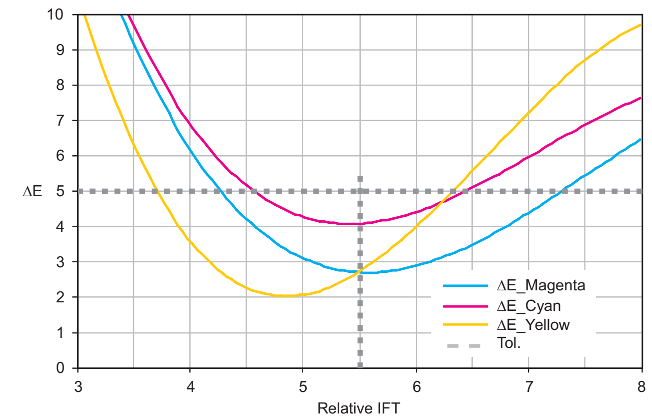

Figure 4: Color difference as a function of relative ink film thickness

Conformance to ink specification is the first step in implementing printing process control by colorimetry. Measuring ink drawdown samples with a spectrophotometer and the prescribed ink verification method in-house encourages us. We can extend the ink verification method to verifying spot color accuracy prior to the press run.

Colorimetric Conformance

Putting the correct amount of process inks quickly and accurately is the goal of press make-ready. ISO 12647-2 stipulates a window of 5ΔE for CMYK solid plus RGB overprints as the conformance rule. As shown in Table 1, all solid ink patches, except the (M + C) blue overprint, are in conformance. Achieving correct overprint color is a printability issue, e.g., adjusting ink sequence or ink tack. The tolerance of 5 ΔE on primary chromatic inks may be used strategically to encourage conformance of two-color overprint RGB colors.

Table 1: Colorimetric conformance of process color printing

ID	Location	K	C	M	Y	ΔEab
1	A1	0	100	0	0	1.8
2	A2	0	0	100	0	2.5
3	A3	0	0	0	100	4.1
4	A4	0	100	100	0	7.8
5	A5	0	100	0	100	2.1
6	A6	0	0	100	100	4.3
25	B12	100	0	0	0	3.1

In addition, current ISO 12647-2 also stipulates that tonal value increase (TVI) of each of the tonal ramps be conformed. TVI, traditionally defined densitometrically, has been redefined from using tristimulus values in ISO 12647-1 (ISO, 2004). We find the TVI aspect of the printing standard confusing, adding no value, and is difficult to implement.

Instead of using the seven solid ink patches and TVI as conformance criteria, we propose the use of metric chroma (C*) to calibrate tonal ramps of CMY via transfer curves. Figure 5 shows the magenta gradation in terms of C* between the initial press run and the ISO 12647-2. For the black printer, Darkness (100 – L*) can be used to calibrate the black ramp.

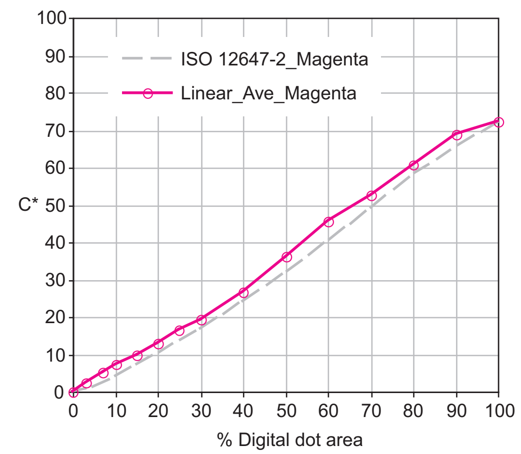

Figure 5: Magenta gradation in terms of C (left)*

To answer the question of colorimetric conformance, we compare a significantly larger number of color patches instead of the seven solid ink patches as specified in the current ISO 12647-2 standard. TVI should be eliminated from being a part of the standards. This is because TVI is a calibration issue, and not a conformance issue.

As an example, color differences of the IT8.7/3 basic data (182 patches) between the OK sheet and that from FOGRA39 where ISO 12647-2 aim points are compared. Figure 6 shows the CRF of ΔE between the two data sets. As a rule of thumb, process conformance threshold (the gray dotted line) is when the median ΔE is 3, the 90 percent tile ΔE is 6, and the maximum ΔE is 12 (Chung, 2001). In Figure 6, the median ΔE is at 4 that exceeds the conformance threshold.

This is where printing conformance just missed out; color image differences are visually noticeable if press sheet were compared with the standard press sheet.

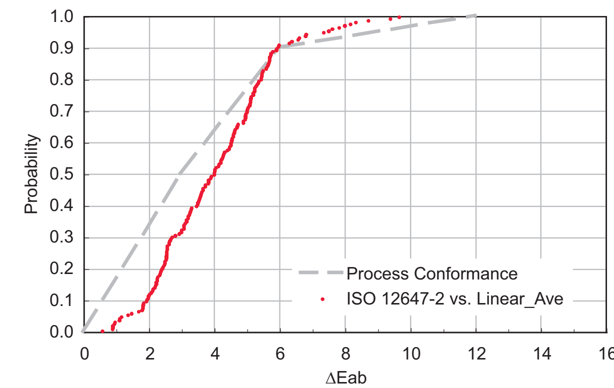

Figure 6: CRF of ΔE based on IT8.7/3 basic

Process Control Metrics

Regarding the choice of metric for printing process control, Figure 7 is graph of ΔD_T, ΔD_{630}, and ΔC* as a function of ΔIFT for cyan ink. Here, both status T and spectral density show linear responses to changes in cyan ink film thickness. On the other hand, metric chroma (C*) is only sensitive to changes in low cyan IFT region. Thus, status T density and the spectral density, computed from the reflectance at the wavelength of 630 nm, are the metrics of choice for cyan inking control.

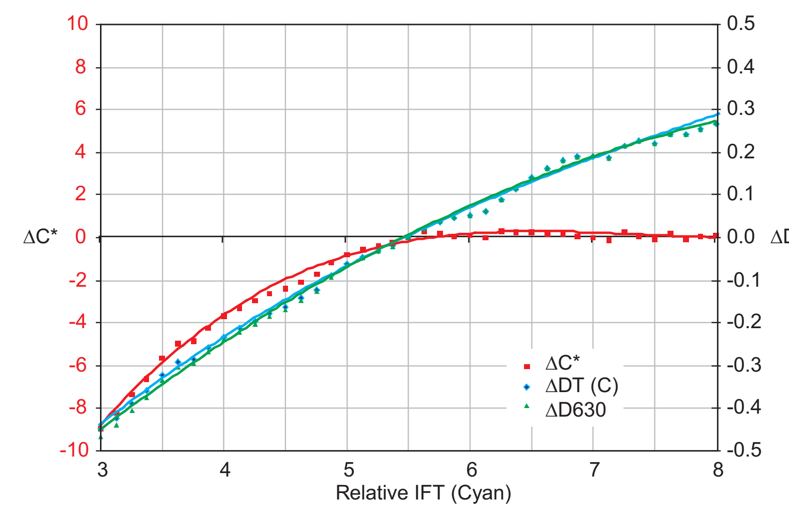

Figure 7: Three process control metrics in detecting changes in cyan ink film thickness

Figure 8 is graph of ΔD_T, ΔD_{570}, and ΔC* as a function of ΔIFT for magenta ink. Here, all three metrics are linear and behave similarly to changes in magenta ink film thickness. Thus, any one of the three metrics will be useful for magenta inking control.

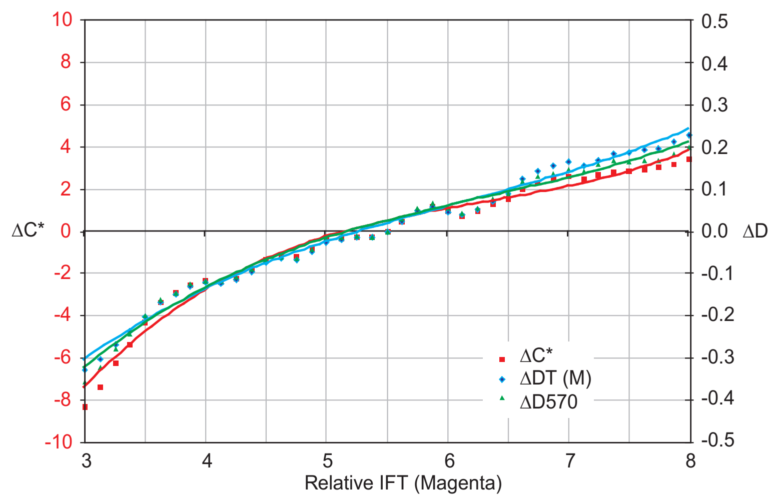

Figure 8: Three process control metrics in detecting changes in magenta ink film thickness

Figure 9 is graph of ΔD_T, ΔD_{430}, and ΔC* as a function of ΔIFT for yellow ink. Here, all three metrics are linear to changes in yellow ink film thickness. But, the slope of the spectral density of yellow ink is noticeably higher than that of the status T density. In addition, metric chroma has the largest change in yellow ink in comparison to the same range of ΔIFT in cyan and magenta inks. Thus, status T density is the least useful metric for controlling yellow inking.

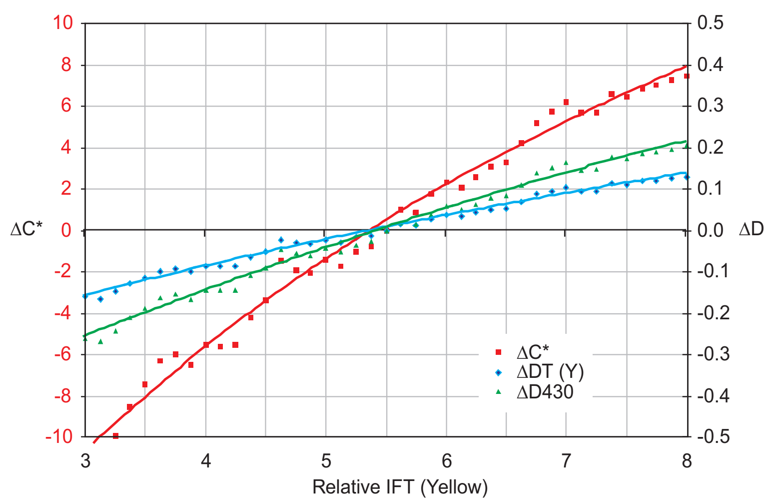

Figure 9: Three process control metrics in detecting changes in yellow ink film thickness

By judging from Figure 7 to 9, there is no single metric that demonstrates the best sensitivity and linearity over the ink film thickness of interest for all three chromatic process inks. If process control is implemented in a closed-loop environment, either spectral density or different metrics may be used without human intervention.

Printing Quality Assurance

Instead of assuming that inking is uniform across the sheet, we can investigate the spatial uniformity of the printing system. The spread of the data from its average can then be compared with the tolerance. In this case, we measured a chromatic gray bar plus a black tint across the sheet relative to its average (Figure 10). Notice that there is larger variation at either edge of the sheet. The data could have been removed from the analysis if this is the trim or non-image area of the sheet. While ISO 12647-2 specifies that variation of CMYK solids should be less than 4 ΔE, the spatial uniformity of the printing system, based on 3-color neutrals or black tints, is around 2 ΔE units.

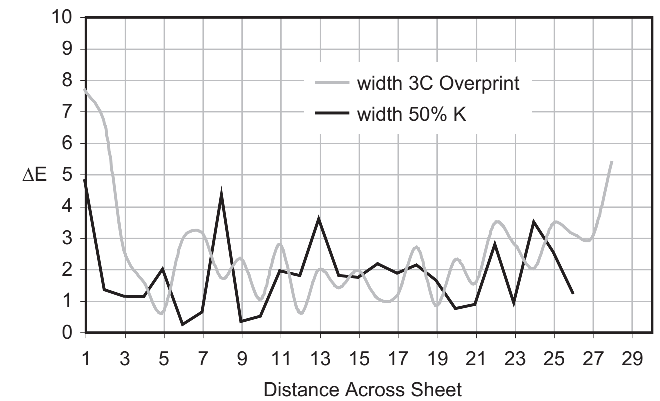

Figure 10: Spatial uniformity as assessed by 3-color gray and black tint

Instead of assuming that process does not drift after its make-ready, we investigate how to document the temporal consistency of the press run. Quality assurance of a press run begins with sampling and measuring multiple press sheets collected over time. We can depict the temporal consistency of a press run by depicting the colorimetric variation of a chromatic gray patch. If the chromatic gray is pre-determined, e.g., 75C, 63M, and 60Y, the spread of the data points in a*b* diagram as shown in Figure 11, may be off-centered. In this case, the tighter the spread is, the more consistent the printing process is.

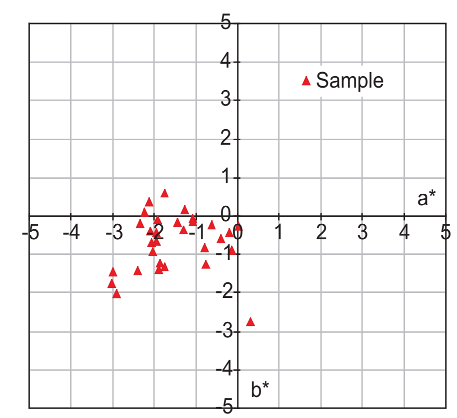

Figure 11. Temporal consistency of a chromatic gray patch

Conclusions

Density-based printing standards and using densitometry in the pressroom have facilitated color consistency since 1970s. As the demand for colorimetric accuracy and consistency in process color printing continues, it is inevitable that CIELAB-based printing standards will become the norm. Not only densitometers are replaced by spectral-based color measurement devices, all density-based specifications, including TVI, should be replaced by colorimetric parameters.

We explored the use of colorimetry for ink verification. Since density only specifies ink amount and not color, colorimetry is here to stay. We explored the use of colorimetry for achieving printing aims. Since printing aims are specified colorimetrically, colorimetry is essential for implementing standard-based printing. In addition, the knowledge of the prepress adjustment and the knowledge of the press control are essential to achieve closer printing conformance.

We explored three metrics (status T density, spectral density, and metric chroma) as process control parameters. We did not find a single metric suitable for monitoring all three chromatic process inks significantly better than other metrics. Finally, we looked at how a press run may be certified to assure its spatial uniformity and temporal consistency with the use of colorimetry. The results have been encouraging. More work and user feedback are necessary in order to make the transition from densitometry to colorimetry in the pressroom.

Acknowledgments

The author wishes to thank members of the Rochester Institute of Technology's Color Printing Outreach team and the Printing Applications Laboratory for their collaboration and implementation of the press run. He also wishes to express his sincere appreciation to Bill Birkett and David McDowell for their review of the paper.

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Challenges in the Implementation of a Softproofing System

Arvind Karthikeyan

Keywords

softproofing, calibration, standards, uniformity, colorimetry

Abstract

One of the latest advancements in the confluence of computers and the print industry is softproofing. Softproofing involves the use of calibrated and capable monitors to accurately display the proofs. Softproofing enables the display of the proofs on calibrated monitors at remote locations. This paper aims at providing the reader a better understanding of a softproofing system by reviewing *ISO 12646:2002 Graphic technology – Displays for colour proofing – Characteristics and viewing conditions* and testing the conformance of 30–inch Apple Cinema Display to such specifications. Performance issues such as spatial uniformity and the decay in the brightness levels of the Apple display are investigated. The article also provides a standard operating procedure (SOP) for using the softproofing set up to get the best possible results.

Introduction

Softproofing equipment is the latest addition to the state of the art facilities at the Color Measurement Lab, School of Print Media, Rochester Institute of Technology. The presence of this equipment has opened doors to further research and a better understanding of the softproofing industry. For all further research in this area, the devices have to be calibrated and the characteristics understood. The article will focus on the requirements for a softproofing system and the challenges in the implementation.

For any new technology to be implemented and studied, it should be compared with some form of standard. The standard will serve as a benchmark and help in the development of an operating procedure to get the best out of the system at hand. In the case of softproofing, the standard that is to be followed is *ISO 12646:2002 Graphic technology – Displays for colour proofing – Characteristics and viewing conditions*. The standard spells out the hardware requirements for the softproofing system and the calibration procedures that are to be followed.

Key points of ISO 12646

The following paragraphs summarize the contents of ISO 12646 standard. Various aspects spelled out by the standard such as requirements, calibration, color gamut, and inter-site calibration are explained.

Initial assumptions

ISO standards have been developed for a CRT (Cathode Ray Tube)- based system, which acts as the display medium utilized for softproofing. The CRT-based system is now replaced by the LCD (Liquid Crystal Display)- based system that is devoid of problems such as flicker and opto-electronic convergence (the convergence of the light from the components of a LCD system that transfers electrical signal into light). ISO 12646 specifies the minimum requirements for the display devices that are to be used in softproofing in terms of uniformity, convergence, refresh rate, size, and spatial resolution. The standard specifies that some of the requirements specified are subject to continuous improvement and hence this represents just the minimum requirements.

The standard also specifies that it does not include the specifications that define the conversion of the data from the digital file to display even in the best of display devices.

The standard begins by describing the scope of the standard and the areas where it could be employed. The definitions of all the terms that are employed in the standards are also given upfront. Terms such as uniformity, convergence, opto electronic transfer function, and refresh rate are defined in this section.

Requirements

ISO 12646 then describes the minimum requirements for a softproofing display. The resolution of the display device used should be more than 1280 x 1024 pixels. The minimum size of the display device (17″ diagonal) and the refresh rate (80 Hz) are also specified in this section.

The requirements for other parameters such as uniformity, geometric accuracy and convergence are also specified. These standards apply to a smaller extent to LCD. The specifications of the 30-inch Apple Cinema Display meet all the above requirements (www.apple.com/displays). The specification for the ambient illumination pertains to all types of monitor displays and is worth mentioning. The level of illumination in the surroundings should not be more than the 10% of the maximum illumination of the monitor. The standard also specifies that D50 lighting be used for the surrounding in the softproofing area.

The chromaticity and the luminance of the black and the white points of the display device are specified in the standard. The LCD-based system that is widely used now has only the brightness point that can be adjusted. The brightness specifies the luminance of the monitor, which can describe the display range of the monitor. The gamma of the monitor/LCD that describes the range of the display device is also specified in the standards.

The standard specifies the test methods that can be used to check for the requirements of the display device. For example, the standard provides a test chart model that can be used to check for the resolution of the display device. The chart can also be used to check for the uniformity of the monitor used. This uniformity problem exists in a LCD system and hence has to be paid attention to. The test method specifies that the uniformity of the display device is measured at 9 points in the display using a radiometer or an X-Rite Eye-One tristimulus colorimeter, of known specifications. The standard also specifies that the uniformity test is

performed for the display device when it displays white, gray, and black images. The uniformity of the display device, after proper calibration, gives an idea of the spatial variation in the displayed image across the monitor. For the sake of softproofing it is always advisable to have a very high uniformity.

Displaying a test chart with vertical and horizontal lines of 2-pixel width will help to check the geometric accuracy of the display device. If the display is accurate, the lines should appear continuous and straight. The lines displayed are checked for any abnormalities as it can indicate geometric irregularities. The luminescences of the white and black points are also tested for. The measurements are made using a radiometer or a tristimulus colorimeter at the centre of the screen. The white point has to be measured with the screen displaying the maximum digital value in each channel (255 in all the 3 channels) and the black point with no digital count in all the 3 channels.

It can be seen that the equipment for the softproofing system is available in most printing companies (with the exception of Eye-One Pro). The only investment in this case would be the monitors and the booths for viewing the samples.

Calibration

The calibration and characterization part of the standard states that the images in different formats must be converted to the format that the display system can show without problems. The conversion, if needed, should be effected using a color management system. The standard again states that most of the specifications that are given are not necessary for a LCD-based system, as it is comparatively more standard and devoid of most of the problems of the CRT-based systems.

The standard specifies that all the images that are displayed in the softproofing device should have a white border of 1 inch surrounding it on all sides. The standard again states the importance of using the proper ambient lighting in the viewing area. The standard also states that the image that is displayed in the softproofing device has to have the profile of the device it is simulating and the profile of the monitor applied to it.

Color gamut

The standard states that the gamut of the display device must fully cover/enclose the gamut of the device we are trying to simulate. The standard spells out the steps involved in determining the gamut of both the print sample and the monitor. After the gamut boundaries are marked approximately, the standard then describes the method of calculating the chromaticity coordinates, i.e., x and y, L*, C* and hue angle h. The standard also mentions that the chromaticity coordinates of the monitor display be calculated. The standard then describes the test where each hue angle colors are simulated in the monitor to see if the display of the monitor covers all those colors that are reproducible in the print medium. This is done because there are some colors in print that cannot be displayed in the monitor. The standard also hints that the display devices used for softproofing have to calibrated from time to time to account for changes that happen with the passage of time.

Inter-site calibration

When a softproofing system is set up, the customer should be able to look at the proofs and approve them from a remote location. The standard describes the kind of system that is required for this case: the devices used for softproofing must be calibrated and should be of comparable quality. The standard also recommends the use of ISO 12641 target (refer to Figures 1a, 1b, and 2) for the calibration of the display devices.

Figure 1a: Resolution target

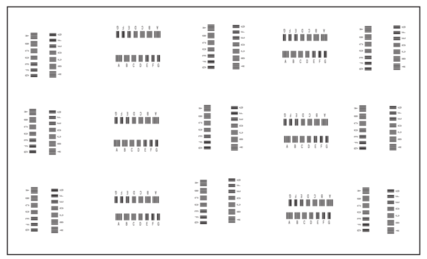

Figure 1b: Layout of resolution targets

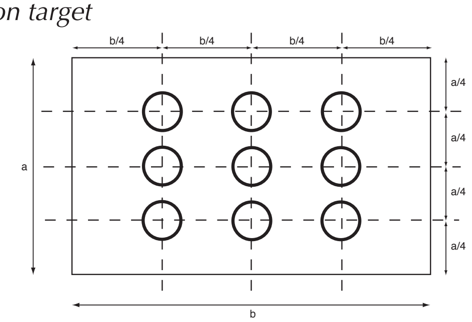

Figure 2: Positions for uniformity measurement

Figures 1 and 2 show the ISO 12646 prescribed test target to be used. The condition of the display device could also be checked by displaying a known value of color, using a spectrophotometer to measure it, and finding the deviation, if any. The monitor is in an acceptable working condition if the ΔE (1974) between the known value of color displayed and that, which is measured, is less than 2.

Challenges in softproofing

Challenges in implementation of softproofing involve studying the decay in the brightness of the monitor, in order to be able to predict when the monitor will neither display the right colors nor have spatial uniformity across the monitor. The parameters, the methodology, and the results are discussed below.

Luminance decay

It is documented in all the resources for softproofing that the luminance level of the monitor decays over a period of time and the operating range of the monitor should be kept below the maximum luminance of the monitor at any given point. To study the decay in the luminance of the 30-inch Apple Cinema Display monitor, calibration was performed over a period of time and the luminance level after each calibration procedure was noted. The calibration results were saved with the date of the calibration. It was found that the luminance level of the display decayed from 294 to 265-candela/ m^2 over a period of a month. The measurements and the calibration routine were performed every day for the first 2 weeks and after the luminance stabilized once every 3 days. The brightness of the display is designated in units of cd/m^2 (candela/meter^2). However the conversion tables indicate that the relation between lumens and candela/ meter2 is 1:1. The terms and the values are interchangeable.

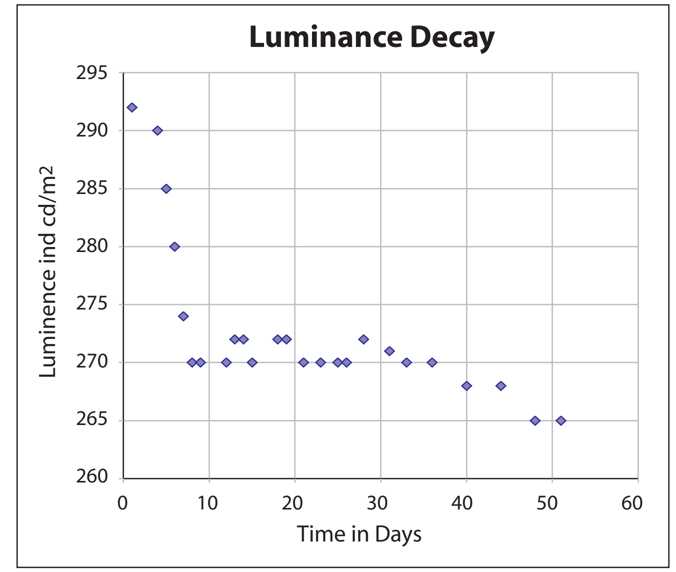

Figure 3: Luminance Decay of the 30-inch Apple Cinema Display

From the results reported in Figure 3, it is evident that the LCD display needs to be calibrated and checked for the brightness from time to time. It was observed that the LCD display deteriorated rapidly in the beginning and later stabilized at 265-270 cd/m^2. It is important to calibrate and check the luminance decay in the display until it stabilizes. Once this stable period is reached calibration could be performed once a week. In the case of remote softproofing, it is imperative that the lowest luminance of the displays in the proofing is used for as the operating value.

Spatial Uniformity

Spatial uniformity is one of the factors of major concern in the softproofing industry. We had qualms about the uniformity across the monitor. The changes across the Apple 30-inch monitor are not clearly visible when an image is displayed and hence it demands the design of a test target to check for the spatial uniformity. The best method to check for the uniformity of the display is to use a uniform color patch as a test target (of size equal to the size of the monitor) and display the same in remote director. The color that is chosen for this is a L50 color with the a and b values as 0. This color is made into a background file of the size of the display and is displayed.

Measurements of the luminance at various points in the display could be made with the use of the Eye-One Pro, a popular hand-held colorimeter form X-Rite (GretagMacbeth). The software that is used for the measurement of the luminance is Eye-One Share. The software allows for the measurement of the luminance and the color temperature of the ambient lighting and the display. The luminance was measured at 12 different points in the display and was tabulated. It was found that there was a great difference in the luminance of the display across the monitor. The experiment was repeated 5 times and the values measured were tabulated.

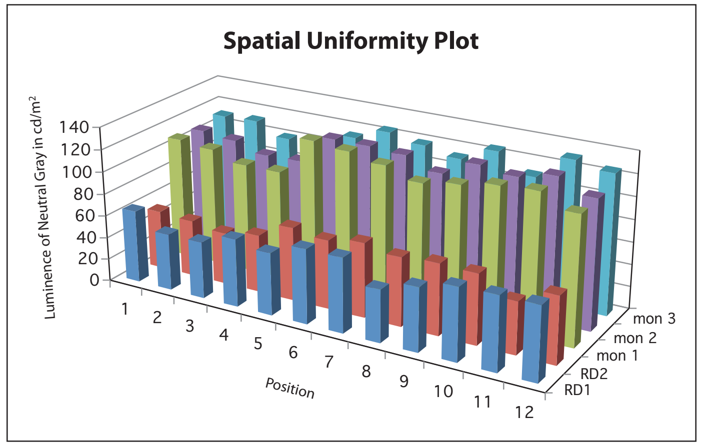

Figure 4: Spatial uniformity plotted (lumen vs. position)

The measurements, as shown in Figure 4, with the label RD indicate those that were measured inside the display of Remote Director, the remote softproofing software developed by ICS (Integrated Color Solutions). Remote Director alters the display property of the display and hence it is beneficial to study the behavior of the display when Remote Director is running. It is observed that the values of the measurements made inside Remote Director are less than the measurements made on the display, as Remote Director uses a different number system to represent the luminance. For the sake of measuring the spatial uniformity of the display a test form was designed to fit the screen of the display. The color that was filled in the test form was a neutral gray (L= 50 a=0 b=0)

The measurements were also made displaying the test using Adobe Photoshop and the plots labeled “mon” (used to represent the readings made on the LCD display) indicate them. It can be seen that the luminance measured across the display varies irrespective of using Remote Director or not. This indicates that there is a lack of spatial uniformity in the display device used.

From the tests that were performed on the Apple monitor, it is evident that there is a problem with spatial uniformity as far as the displays are concerned. The lack of spatial uniformity can pose a serious threat to the very concept of softproofing. Variation in color across the display can greatly disrupt the perception of color. There is no way to address this problem from the hardware (display) as such. There is software available that can be used to solve this problem of spatial non-uniformity. The software that is a part of Remote Director divides the screen into 64 or 128 subsections and calculated the intensity of the light coming from each of the subsections. The software then modulates the intensity across the display so that all positions only emit the lowest intensity, thereby ensuring uniform intensity across the Apple display (www.icscolor.com).

Color Gamut

Another area of concern in using a 30-inch Apple Cinema Display monitor for proofing is the gamut of colors the monitor can display. It is imperative to check the color gamut of the device to see if it encompasses a standard profile like that of ISO 12647-2. This verification requires the creation of a profile for the display.

The profile of the display is created using ProfileMaker 5.0, a popular profiling software from X-Rite, and is saved with the appropriate name. The profile is opened in ColorThink Pro version 3.0, a product of CHROMiX that helps in analyzing profiles, and is compared to that of GRACoL Profile (2006), based on ISO 12467-2, in the 3-D plot tool. Figure 5 and 6 are screen shots obtained when they were plotted.

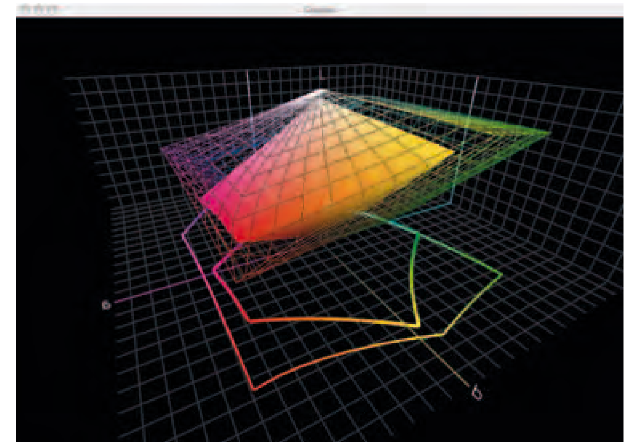

Figure 5: View 1 - Comparison of the color gamut of GRACoL and the display

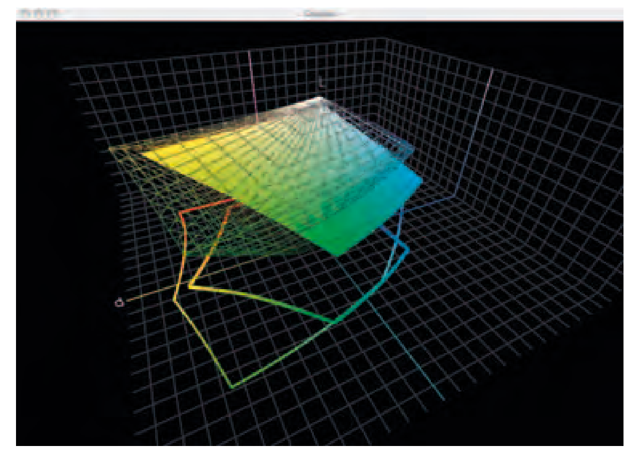

Figure 6: View 2 - Comparison of the color gamut of GRACoL and the display

The smooth shape represents the gamut of GRACoL (2006) profile whereas the wireframe represents the gamut of the Apple 30-inch display. It is evident from Figures 5 and 6 that the display is not capable of representing colors that occur near the green end of the spectrum. This is a problem with the display and hence proves to be a stumbling block in softproofing colors in that region.

Inferences and recommendations

The study of the decay in luminance indicates that the display is likely to deteriorate over a period of time. This implies that the display has to be calibrated from time to time to check for the luminance range and the luminance range of

Remote Director (if used) should be set accordingly. After the luminance of the display has stabilized, the reference luminance range where the system is to operate could be set. The monitor that was studied seemed to stabilize at around 265 cd/ m^2 and hence the max luminance of operation was fixed at 250 cd/ m^2.

The study of the spatial uniformity indicates variations in the luminance of the display. This is attributed to the display and cannot be eliminated at the hardware level. However the software developed by ICS will go a long way in addressing the problem of spatial uniformity.

The comparison of the gamut of the display and a reference printing condition such as GRACoL shows that there are a few colors in the gamut of GRACoL that the 30-inch Cinema Display cannot display, such as some cyans.

Another issue with the use of LCD displays for softproofing is the limitation in the viewing angle. The images displayed on the monitor start to look different when they are viewed at an angle more than 20 degrees from the centre of the screen.

Taking into consideration both the advantages and the disadvantages of the LCD display discussed above we can say that Apple's 30-inch Cinema Display could be used as a part of softproofing process if properly calibrated and monitored.

Acknowledgement

I would like to thank Prof. Bob Chung for having given me this opportunity to work on this relatively new technology in the Color Measurement Lab. This experience has been truly wonderful and I have learnt a lot through this. Thanks to Prof. Franz Sigg for being there for me always, helping me out with any and every issue. It has been a pleasure working with Prof. Sigg. Thanks to Mr. Mike Stern for it was he who introduced me to the world of softproofing. Thanks to Mr. Steve Suffoletto for taking interest in my article and reviewing it. Thanks to Prof. Edline Chun for making this article what it is today by means of revisions. Thanks to the technical support team at RIT for helping us with the installation of the softproofing system. Finally I would like to thank Sri Hemanth Prakhya, the production expediter of *Test Targets 7.0* and a close friend of mine, for being there all along and helping me at each and every stage.

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ISO 12647-2:2004 Graphic Technology – Process control for the production of half-tone colour, separations, proofs and production prints – Part 2: Offset lithographic processes.

Stability of an Inkjet Color Proofer

Wuhui Liu

Keywords

device stability, color consistency, CP, color variation

Abstract

A good color-proofing device depends on its stability and color management applied. If a color proofer is not stable, its ICC profile will not reflect its color characteristics over time. In this study, we tested the stability of an Epson Stylus Pro 4000 Inkjet printer by outputting 30 color samples over a period of three months. We analyzed the proofer stability in terms of density of solids, TVI of 50% tints, and metric chroma of a near-neutral color patch. We found that the stability of Epson Stylus Pro 4000 is acceptable as a color-proofing device using GRACoL tolerance as a guideline. Its color shift, although measurable, is not noticeable when serving as a color proof.

Introduction

Device stability refers to the ability of a device to produce the same outcome when using known input and consumables over a period of time. In color proofing, the stability of the proofer determines its color consistency within a production and from run to run.

Device accuracy, however, refers to the ability of the device to produce the desired outcome as dictated by an external aim point. In color proofing, the accuracy of a proofer depends on both how well it is calibrated and controlled such that the average of all outcomes agrees with the aim point.

Both device stability and accuracy are important in color proofing. This is because a color proof is a simulation of the press results before the job is printed.

When selecting a color proofing device, the device stability should be addressed before the device accuracy. This is because stability is an inherent characteristic of the device and accuracy can be addressed by calibration and the use of ICC profiles. This research focuses mainly on device stability. Thus, the objective of this research is to devise a method to test proofer stability and to assess the proofing performance.

Literature Review

Variability exists everywhere. Some are common-caused and others are special-caused. Common-caused variations are inherent and we have to live with. But, special-caused variation might be removed. Common-caused variations can come from many sources, including materials, operations, and environments. In the case of a color proofer, material-related factors include paper, inks, inkjet head, etc. Operational factors include variation as a result of ink replacement and cleanliness of inkjet head. Environmental factors include ambient temperature, relative humidity, etc.

When assessing stability of a color proofer, the best we can do is to not include any special-caused variation. Measuring instrument stability can contribute significantly to the device stability, as can the condition (age) of the inkjet sample.

Chung and Shimamura (2001) studied repeatability of a scanning spectrophotometer color measuring instrument (Spectrolino SpectroScan). A Cumulative Relative Frequency (CRF) curve between two sets of measurements made from the same press sheet was generated. They found a ΔE of 0.19 at the 50 percentile, a ΔE of 0.40 at the 90 percentile, and a ΔE of 0.64 for all 182 color patches in the IT8.7/3 basic target.

Chan, Chung, and Cheung (2000) performed an output sample stability test. In their study, an IT8.7/3 basic target sample printed by EPSON SC300 was measured seven times in 24 hours. Delta E of the four process color ramps, paper, and an average (based on all 182 patches of IT8.7/3basic) were calculated based on the first measurement. They found that there was a sufficient delta E difference in the first two hours, and a minimal between two to eight hours.

Chung (2003) exhibited a method to test process variation and deviation of an offset press. CMYK solid ink density (SID) variation and deviation and dot gain variation and deviation were assessed to decide the best sheet that is closest to standard in his research. Vogl (2004) presented tests and evaluation methods to assess the temporal consistency of a digital printer. In his research, samples are printed at different times and solid ink density, tone value increase (TVI), and midtone spread were measured; the capability of the printing process were assessed by statistical measures of CP (Capability of a Process) index, CpK index, variation curve of CMYK solid density, and variation curve of 50% CMYK TVI.

Materials and Equipment

In this research, EPSON Stylus Pro 4000 (EP4K) was taken as a proofer example. It is run by ColorBurst RIP 4.01. Ultrachrome ink and EPSON Premium Semigloss Photo Paper were used in the experimental phase. IT8.7/3 basic target file was output to EP4K for testing samples that were used to reflect proofer characteristics. Spectrolino Spectroscan was used for measurement to collect data. In addition, GretagMacbeth ProfileMaker 5.0 and CHROMix ColorThink Pro 3.0 application software were applied in ICC profile creation and analysis. Three Excel workbooks were used to analyze the data: Spectro-D_Color.xls, Onsite.xls, and Output Compare.xls.

Experimental phase

In this document, we will first describe the procedures used to test for inkjet sample stability. This is followed by the procedures for conducting the measuring instrument repeatability. Finally, the procedures for conducting the color proofer stability is described.

Inkjet Sample Stability Study

In this study, a single sample IT8.7/3 basic target was output to the EPSON Stylus Pro 4000, and then it was measured immediately on the Spectrolino Spectroscan. One measurement cycle took 12 to 15 minutes. Five consecutive measurement sets were finished in about an hour on a single sample. The average ΔE of 182 patches between each measurement and the last measurement was calculated, and the outcome expressed as a curve.

Measuring Instrument Repeatability Study

A dry IT8.7/3 basic target sample, printed by the EPSON Stylus Pro 4000, was selected to be measured on the Spectrolino Spectroscan. It was measured twice in a single measurement session. The colorimetric data was analyzed to assess instrument repeatability.

Inkjet Color Proofer Stability Study

In our experiment, EP4K was taken as a proofer device. EP4K has eight color ink cartridges. We only enable CMYK to make it only a CMYK color proofer. There are many factors that affect inkjet proofer color stability. To investigate the color proofer's long-term stability, we printed many samples over an extended time period and measured their color values for our assessment, since the output can act as an integrated result of all factors.

Procedures:

1. Calibrate EP4K and create an environment in ColorBurst RIP. After many tests, we set its CMYK Bezier Curve as shown in Figure 1 and saved the environment as TT_RUN26.env (env26). The output samples were all printed under this environment.

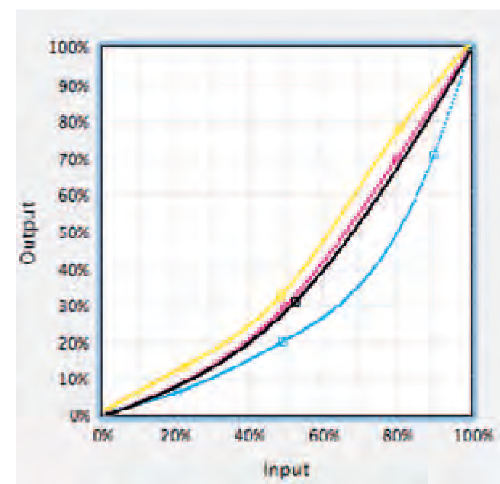

Figure1: Env26 settings

2. Print the IT8.7/3 basic test target to produce 30 samples over three months time. All print samples were printed with the same paper and inks and there was no manual cleaning of the inkjet head.

3. Measure the samples to obtain spectral data. The measurements were carried out after 1 hour of printing the sample to guarantee measurement on a dried sample. To get accurate measurement data, care was taken not to make the samples dirty or scratched when measuring.

4. Convert spectral data to CIELAB values and Status T densities for all 30 samples using Spectro-D_Color.xls.

5. Extract color data of C, M, Y, K solid, their 50% color, secondary color, and CMY color (see Table 1). We need those data in further evaluation.

Table 1: The data table of one sample

	Patch ID	Dv	Dr	Dg	Db	L*	a*	b*
Sample 1_0207	Zero	0.07	0.08	0.07	0.04	93.98	0.24	-4.24
Description:	100%_K	1.92	1.91	1.92	1.90	10.58	0.80	-0.59
	50%_K	0.51	0.50	0.53	0.56	61.97	2.09	4.24
Feb. 7, 2007	3 C_Neutral	0.61	0.57	0.56	0.63	56.93	-2.45	3.73
	7%_K	0.11	0.11	0.11	0.09	90.51	0.48	-3.03
	100%_C	0.73	1.42	0.39	0.14	56.63	-36.79	-54.28
	50%_C	0.29	0.42	0.17	0.07	79.50	-17.67	-24.63
	7%_C	0.09	0.10	0.07	0.05	92.81	-1.36	-6.04
Time:	100%_M	0.70	0.32	1.56	0.66	45.84	77.48	-17.19
	50%_M	0.33	0.15	0.49	0.22	71.41	39.52	-19.53
	7%_M	0.09	0.08	0.10	0.06	91.73	4.64	-5.78
Temp:	100%_Y	0.12	0.09	0.14	1.18	88.66	-7.39	102.97
	50%_Y	0.10	0.09	0.10	0.52	91.16	-9.94	54.10
	7%_Y	0.07	0.08	0.07	0.11	93.59	-2.19	5.32
Humid:	Green	0.86	1.50	0.51	1.23	47.89	-76.19	37.35
	Red	0.71	0.32	1.65	1.75	44.34	69.92	53.06
	Blue	1.64	1.58	1.65	0.71	18.48	37.07	-59.35

6. Import the data to the Onsite.xls tool for further analysis.

7. Calculate averages data based on all 30 samples.

8. Use the averages as references and perform data analysis on proofer stability.

Result and Findings

Information in this section follows the Experimental Phase with inkjet sample stability reported first, followed by measuring instrument repeatability, and color proofer stability.

Result of Inkjet Sample Stability Study

Figure 2 is the average ΔE between each of the five measurements taken within about an hour of printing, and the last measurement, plotted against time. We can see that ΔE reduces as time changes. The ΔE between the first measurement and the last measurement is 0.2, and the ΔE between the fourth measurement and the last measurement is near 0.1, which is such a small color difference that it makes us consider the ink has already dried at that time. It is not advisable to measure color data right after printing the sample; it is necessary to wait for the ink to dry. Therefore, when making measurements only after an hour of printing, it can be assumed that the influence of ink dry down does not affect the study on stability of inkjet color proofer.

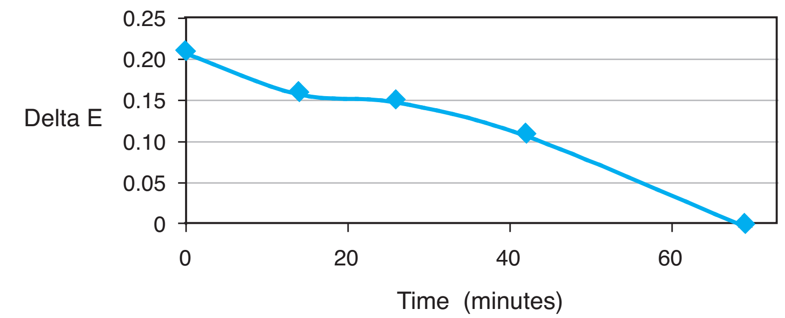

Figure 2: The average ΔE shift curve

Result of Measuring Instrument Repeatability Study

Color repeatability of the measuring instrument includes the instrument itself, positioning mechanism, and the uniformity of the sample. By comparing ΔE of each color pairs in IT8.7/3 basic, we found that the average ΔE is 0.09 and the maximum ΔE is 0.33. A CRF curve of two measurement sets is shown in Figure 3. It indicates that ΔE of 50% of the colors is less than 0.07, and ΔE of 90% of the colors is less 0.20. We also can find that color variation of the Spectrolino Spectroscan with EP4K is one-half of the color variation of the Spectrolino Spectroscan with Epson Stylus Pro 5000 in Chung and Shimamura's study (2001). Therefore, we can say the Spectrolino Spectroscan in our study has high repeatability.

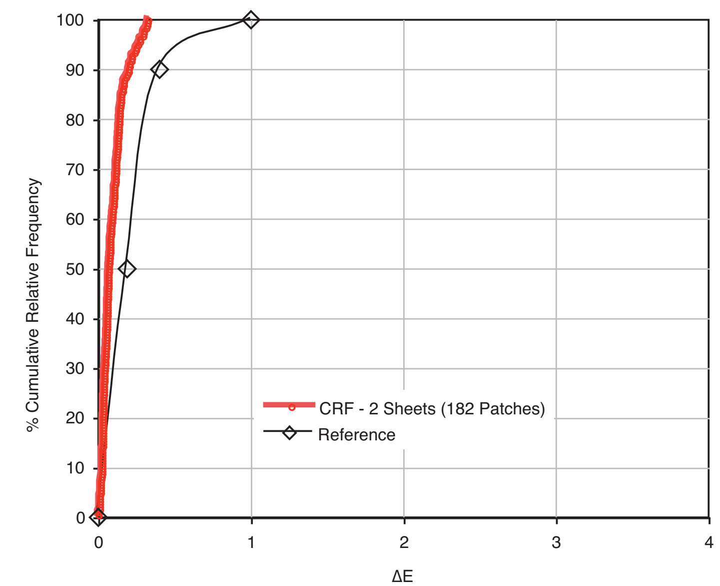

Figure 3: CRF of ΔE between two measurements

Results of Inkjet Color Proofer Stability Study

1.Density-based Analysis on Stability of Proofer in Terms of Standard Deviation and Time Chart

Figure 4 is a control chart of CMYK solid density values of 30 samples. The X-axis stands for samples taken over the period of 30 days, Y-axis stands for density difference between primary inks solid and reference density. Here average density of 30 samples is taken as reference density; tolerance of solid ink density (+/- 0.10) is used per GRACoL printing specifications. We can see that the CMYK density shifts are in tolerance, only the solid density of magenta is not stable.

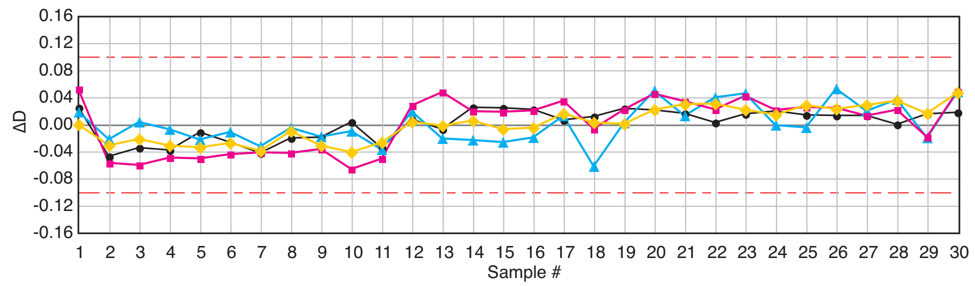

Figure 4: Variation of CMYK solid density

Figure 5 shows the variation of 50% CMYK TVI of 30 samples. Y-axis stands for TVI difference between samples TVI and reference. Average TVI is taken as a reference; tolerance of TVI (+/- 3%) is also used per GRACoL printing specifications. In the chart, we can see that there are big drifts in the first two samples; the variation of 50% Yellow and Cyan TVI is larger than the rest. If the large drift was the result of special causes, they were unknown.

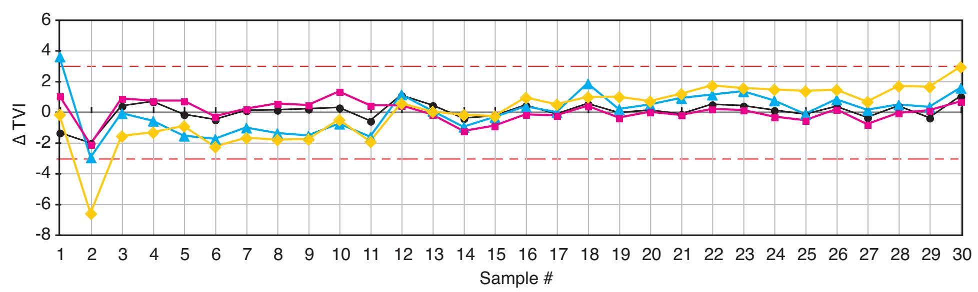

Figure 5: Variation of 50% CMYK TVI

2. Density-based Analysis on Stability of Proofer in Terms of Process Capability, CP

CP means the capability of a process to stay within specification limits. CP is the ratio of the variance of the process in relation to the tolerance specified for the process. The computing formula of CP is :

$$CP = \frac{\text{Tolerance}}{6s}$$

Here s stands for Standard Deviation. Tolerance is specified, usually from a standard. The meaning of tolerance and standard deviation is shown in Figure 6. In this project, we specify tolerance according to GRACoL specification. A CP of more than 1 indicates a process is capable. For this project, if CP is more than 1, it means EP4K is capable.

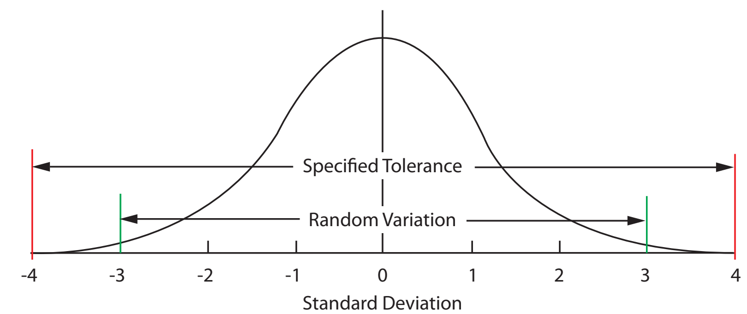

Figure 6: The meaning of tolerance, standard deviation

Table 2 is the CP value of CMYK solid density. In the table, CP of cyan, yellow, and black solid density is more than 1, indicating that their process variability is less than the tolerance. But the variability of solid density of magenta ink as shown in Figure 4, indicates that there was a shift in process average at Samples 11 and 12. Although the cause is not known, there must have been an assignable cause; the data seems to represent 2 populations, each one having a small variability. This explains why no data point for magenta in Figure 4 is outside the tolerance, and still CP is less than one.

Table 2: CP of CMYK solid density

SID	Dv (K)	Dr (C)	Dg (M)	Db (Y)
CP	1.46	1.15	0.85	1.32
comment	good	good	not good	good

Table 3 is the CP value of 50% CMYK TVI. We can see that CP of 50% Cyan and 50% Yellow TVI are less than 1, indicating those two are not stable.

Table 3: CP of 50% CMYK TVI

TVI (50%)	K	C	M	Y
CP	1.59	0.76	1.41	0.54
comment	good	bad	good	worst

3. Colorimetric-Based Analysis on Stability of Proofer

Because neutral color is more sensitive to color change, a near neutral color (60C 45M 45Y) is selected to assess EP4K stability. We calculated the chroma value of this color and observe the ΔC* deviation to analyze proofer stability. This is another way to assess proofer stability in term of colorimetry.

Figure 7 is the chart of ΔC distribution of this gray color compared to reference (average C*). We can see that this color is not very close to gray, and the Sample 2 and Sample 12 have noticeable fluctuations. We also can find ΔC* of a few samples exceeds 2, indicating the color is not neutral. The distribution of sample positions in a*b* plane is not around the aim point according to the plot in Figure 8. That means this color is not stable in this period.

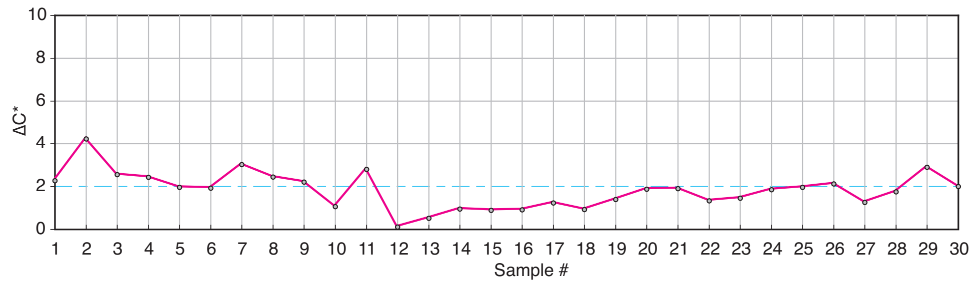

Figure 7: Variation of ΔC

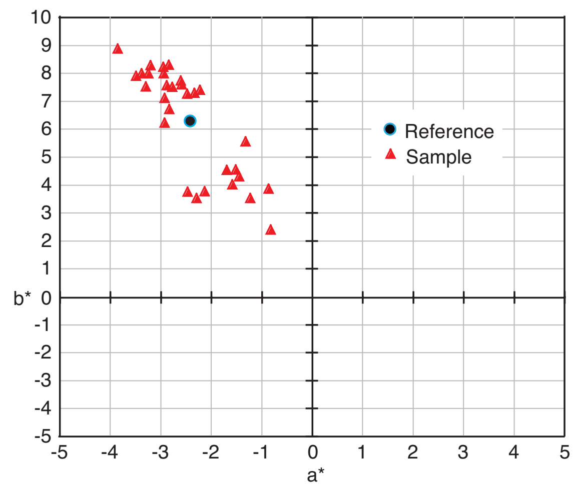

*Figure 8: The distribution of neutral color positions in a*b* plane*

Discussion

Figure 5 and Figure 7 indicate there are significant deviations in the first two samples. If we exclude the two samples for analysis, process capability is improved. The results are shown in Table 4 and Table 5. We can find CP of magenta density is near 1 and CP of cyan mid-tone TVI is more than 1, only CP of yellow mid-tone TVI magenta solid is less than 1. That indicates EP4K is nearly stable in the time that produced 28 samples.

Table 4: CP of CMYK solid density

SID	Dv (K)	Dr (C)	Dg (M)	Db (Y)
CP (30 sam)	1.63	1.17	0.91	1.36
CP (28 sam)	1.46	1.15	0.85	1.32

Table 5: CP of 50% CMYK TVI

TVI (50%)	K	C	M	Y
CP (30 sam)	1.59	0.76	1.41	0.54
CP (28 sam)	2.42	1.01	1.81	0.74

Further Research – Explore the impact of proofer consistency on color proofing

We know that color shifts existed for EP4K from the above analyses. How will these numerical shifts influence visual color appearance? This is what we should be concerned about. To clarify this question, a test has been done in our research with the following procedures.

1. Choose the biggest shift samples (the second sample) of IT8.7/3 basic to create an ICC profile.
2. Use average data of 30 samples of IT8.7/3 basic to create an ICC profile.
3. Assign two ICC profile to a legacy IT8.7/3 basic image.
4. In ColorThink, read LAB data of two images.
5. Input these two sets of LAB data into OutputCompare.xls to compare color difference between them.
6. Draw CRF Curve of color difference in OutputCompare.xls.

Figure 9 is the CRF curve. We can find that more than 90% ΔE of IT8.7/3 basic are less than 3. If two ICC profiles apply to an image, it is hard to observe color difference. Therefore, we can say that the color shift of EP4K will not affect its color proofing heavily.

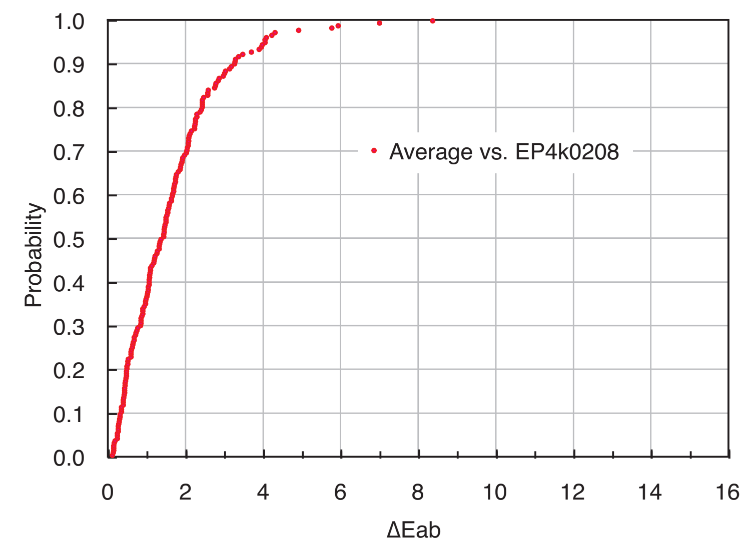

Figure 9: CRF curve

Conclusions

In this research, we studied proofer stability by sampling, measurement, and data analyses. Densitometric data and colorimetric data were used in our analyses. Since an output sample includes an integrated result of all inherent variation, we assessed the samples of a proofer in our study. By applying inkjet sample stability study, we knew that measurement can get stable color data after an hour after the sample was printed. By applying measuring instrument repeatability study, we found the variation of measuring instrument was very small. The following are our main findings in this research:

1. Using GRACoL tolerances as a guideline, the stability of the color proofer studied is considered acceptable with the exception of magenta solid ink density and yellow TVI. However, we would have hoped that a proofer is more stable than a press.
2. There is no noticeable color image difference between the sample with the largest deviation and its average according to ΔE CRF curve.
3. Currently, the industry knows how to certify a color proofer based on one-time evaluation of a single proof. This research demonstrates how one would certify routine performance of a color proofer.

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Achieving Color Agreement: Evaluating the Options*

Robert Chung, Fred Hsu, and Wuhui Liu

Keywords

printing, calibration, color matching, color management

Abstract

Color repeatability addresses conformance to standards and process control to ensure color consistency in process color printing. While repeatable color is a virtue, poor color agreement often exists among color printing devices. In this research, a number of image adjustment methods, from applying transfer curves to applying device link profiles, were examined to see if one method would achieve significantly better color agreement than any other methods. We found out that there is no single method that produces significantly better visual agreement when the color differences between the two printing systems are small. On the other hand, the device link achieves the best color agreement when the colorants of the two color printing devices are different.

Introduction

When sending the same CMYK file to different output devices, the hard copies often appear differently in color. This is because CMYK is device dependent. When print buyers demand color matching between different printing devices, they will not accept the above as an excuse. Thus, printers need a solution to reconcile the color difference between different color output devices. For repeatable printing devices, the reconciliation can be done by means of device calibration and color image adjustment.

Three Levels of Color Match

Before we delve into color matching solutions, let's take a look at the three levels of color matching expectations: spectral match, colorimetric match, and appearance match. Spectral match, being the most stringent of the three, relies on ink formulation and colorant mixing. The match does not depend on light source and is regularly applied to ink mixing and spot color printing. Colorimetric match relies on the principle of tristimulus integration, i.e., by integrating spectral energy of the light source, the spectral reflectance of the colorant, and the color matching functions of the human eye. The match may exist between dissimilar colorants.

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Colorimetric match is applicable to proof and press sheet match. Appearance match, being the least stringent of the three, relies on visual judgment of human observers that can be influenced by the viewing conditions and the color vision of the observers themselves. Appearance match is applicable to pictorial color image agreement, e.g., between proof and print, and is frequently exercised by graphic designers and print buyers.

Objectives

Given that color differences exist between CMYK devices and that color differences can be reconciled using image adjustment methods, this research raises a basic questions, i.e., "Does a particular adjustment method yield better color agreement than the rest of the methods, and why?" In this research, color agreement of different image adjustments is determined by visual examination in the form of paired comparison.

Experimental

This section first describes a situation whereby two printing devices belong to two different color reproduction workflows. The output of the first workflow is the press sheet that serves as the reference. The output of the second workflow is the proof that serves as the sample. Sample proofs need to match the press sheet closely by means of different image adjustment methods. This section then describes input materials and equipment used in the experiment. This is followed by various color image adjustment procedures.

Two Color Reproduction Workflows

To explore various options in achieving color agreement between two dissimilar color-printing devices, we consider the following two workflows: publishing and proofing. As shown in the top row of Figure 1, the publishing workflow involves the conversion of RGB images to the press CMYK space plus printing these images under calibrated press conditions. The press sheet ($CMYK_1$) represents the reference.

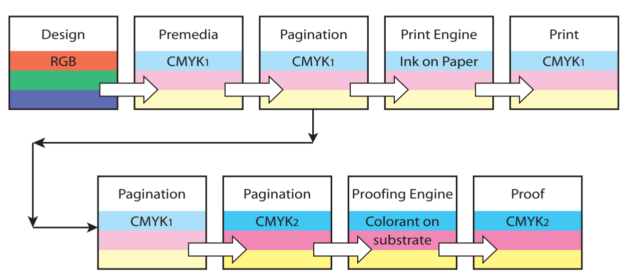

Figure 1: Two workflows involving two color printing devices

The color proofing workflow (bottom row of Figure 1) starts with the press CMYK as the input data. The adjustment of color image data from the press color space ($CMYK_1$) to the proofer color space ($CMYK_2$) is the objective of the study. Adjusted image data are then printed by the proofer under its calibrated conditions.

Materials and Equipment Used

The Heidelberg Speedmaster 74 sheet-fed offset press is the output device in the publishing workflow. The Kodak NexPress 2100 digital press is the output device in the proofing workflow. Figure 2 depicts the test form used in the initial phase of the experiment. Here, color control bars are used for press calibration and printing process control; IT8.7/3 (basic) color patches are used to analyze color differences between the two color printing devices and are used to reconcile the differences; and pictorial images are used for visual assessment of color agreement between proof and press sheet.

Figure 2: Test form for visual and quantitative analyses

Four Image Adjustment Methods

The first adjustment method is gradation adjustment. A transfer curve is derived between the reference gradation and the sample gradation. As shown in Figure 3-left, the procedure begins from (1) identifying an input value, e.g., 80% digital dot, and trace through the reference gradation to find out the magnitude of the output (1.0 density); and (2) finding the specific digital dot that produces the same magnitude in the sample device (85%). If we find enough data points, e.g., 80% vs. 85%, using the procedure and construct the transfer curve (Figure 3-right), we can reconcile the gradation difference channel by channel.

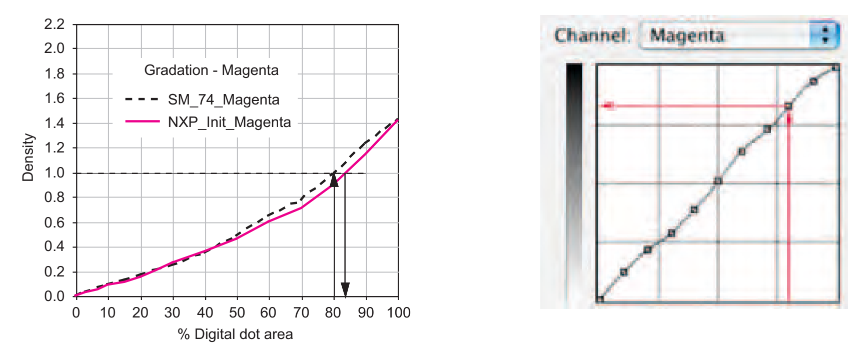

Figure 3: Using gradations (left) to derive a transfer curve (right)

Instead of using density as the gradation, transfer curves may be derived using metric chroma (C*) for chromatic inks and darkness (100 - L*) for black printer. Transfer curves are typically applied at the RIP stage prior to output. In this research, transfer curves are applied at the image editing stage (early device-binding) so that sample prints, prepared by different adjustments, can be printed in a single press run.

The second adjustment method is based on tone reproduction and gray balance (TrGb for short). This is accomplished by deriving three (CMY) transfer curves (Figure 4) that satisfy gray balance and, when added the adjusted black gradation by the first method, also satisfy the tone reproduction between the reference and the sample.

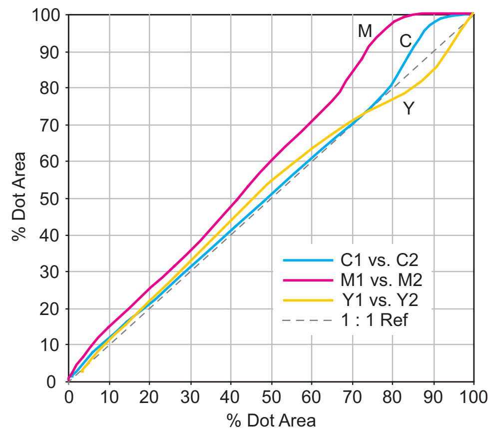

Figure 4: Using gray balance and tone reproduction to derive a transfer curve

To implement the TrGb method, we need to know the combination of CMY that would render a series of neutrals (also known as equivalent neutral dot area) for both the reference and the sample device. One way to obtain equivalent neutral dot area is to construct ICC profiles without the black channel; then use a color management API, such as ColorThink 3.0 Pro, to find out the equivalent neutral dot areas for both the reference and the sample device.

As shown in Table 1, the same neutrals are rendered by different CMY amounts between the offset reference and the NexPress. Here, the neutral is represented by Darkness (DK), i.e., (100 – L*). So, Figure 4 is the result of plotting the equivalent dot area of the reference (x-axis) against the equivalent dot area of the sample (y-axis) for each of the cyan, magenta, and yellow channel. As in the gradation adjustment method, these transfer curves may be applied at the image editing stage (early device-binding) or at the RIP (late device-binding) stage prior to output.

The third adjustment (A-B-A for short) method converts color image data from the press CMYK (A) space, via the profile connection (B) space, to the proofer (A) color space. We use the Adobe Photoshop as the color management API to specify the two ICC profiles and the absolute colorimetric rendering intent. Depending on workflow considerations, other API, e.g., PDF and RIP, may also be used prior to output.

Table 1: Equivalent neutral dot areas of two printing devices

DK	SM74			NexPress		
(100 - L*)	%DA C1	%DA M1	%DA Y1	%DA C2	%DA M2	%DA Y2
75	89.6	80.6	87.4	96.6	97.7	81.7
65	78.2	65.2	69.6	78.3	76.1	70.4
55	63	50.4	52.7	63.1	60.2	56.7
45	48.3	39.1	41.7	48.7	45.7	44.8
35	35	26.5	30.3	35.4	31	32.1
25	21.6	15.5	19.7	22.2	19.9	20.9
15	8.7	5.5	9.4	10.1	8.9	10.1
5	1.1	0.2	3.5	1.2	0.6	2.8
0	1.2	0.2	3.7	1	0.4	2.7

The fourth adjustment method converts color image data from the press CMYK space directly to the proofer space using a device link profile and the absolute colorimetric rendering intent. We use Alwan LinkProfiler to construct the device link profile by concatenating the source (offset press) profile and the destination (NexPress) profile together while preserving purity of all single ramps and two-color print solids. We use the Adobe Photoshop plug-in by Alwan to perform the device link conversion. Color conversion can also be applied to PDF files using Acrobat plug-in from Callas.

Results and Discussions

Results of the experiment are organized in the following three sections: (1) verification of adjustment methods, (2) color agreement testing by paired comparison, and (3) further color agreement testing using different colorants. Subsequent discussions are also included to reflect key findings in the research.

Verification of Adjustment Methods

Let's begin with the before-and-after comparison of to gradation adjustment method. Figure 5 shows the adjusted NexPress print (dotted line) and the initial print (solid line). The left-hand side of Figure 5 is the overall gradation, expressed as % digital dot area vs. density; and the right-hand side of Figure 5 shows the density differences relative to the offset reference (x-axis). There are two observations: (1) the gradation difference is quite small to begin with (something that we did not envision beforehand), and (2) the experimental error is very small, i.e., we implemented the gradation adjustment well.

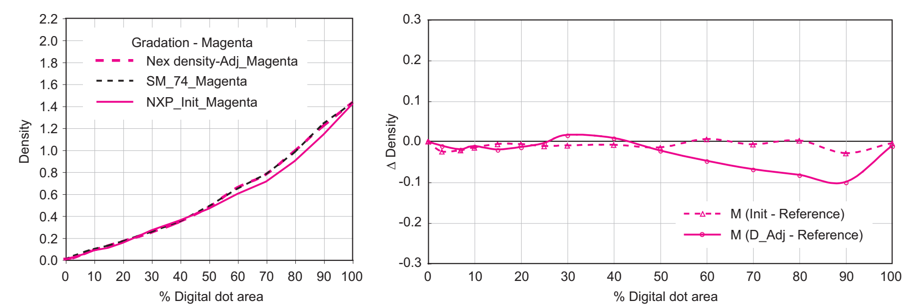

Figure 5: Verification of density-based gradation adjustment

The verification of the TrGb based adjustment is illustrated in Figure 6. Notice that the tone reproduction (solid line) between the initial print and the offset reference, as shown in Figure 6 (left), do not have a one-to-one relation. The adjusted tone reproduction becomes a straight-line at 45 degrees (dotted line).

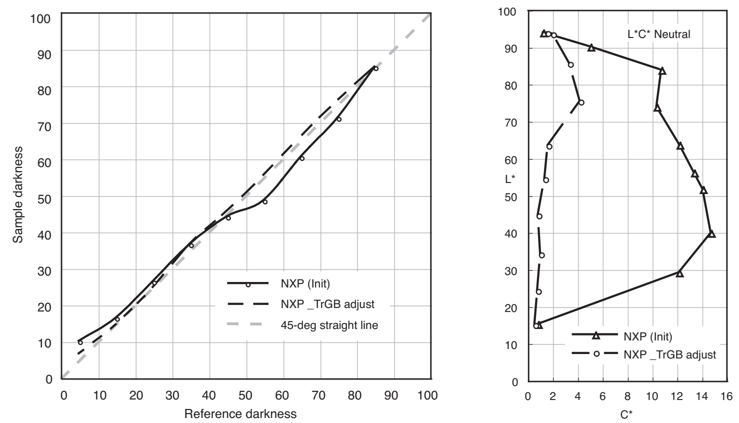

Figure 6: Verification of tone reproduction (left) and gray balance (right) based adjustment

Figure 6 (right) is the L*C* plot of chromatic neutrals indicating neutrality difference between the NexPress and the offset reference. Here, the NexPress, when printed with equivalent dot areas of the offset reference, has fair amount of colorcast (solid line). The result of the TrGb adjustment restores neutrality (dotted line) rather well.

Incidentally, the GRACoL Committee in the U.S. developed a Computer-to-Plate calibration technique, known as the G7 method (IDEAlliance, 2006). It requires the use of a specially designed gray balance target along with special-purpose software to derive the transfer curves relative to a few pre-defined reference conditions. The TrGb adjustment method, described in the paper, offers a generalized solution for any user-defined reference conditions.

The effect of the A-B-A method can be verified from color gamut of the initial state (solid line) and the adjusted state (dotted line) of the NexPress in comparison to the offset reference. As shown in Figure 7, (1) the color gamut of the NexPress is slightly larger than that of the offset reference; and (2) all corner points of the adjusted color gamut (dotted line), particularly the yellow solid and CMYRGB ramps, are closely aligned to that of the offset reference (gray line).

A potential drawback of the A-B-A method is that primary colorants, e.g., cyan only pixels, are mapped to pixels with multi-colorants. Consequently, a small amount of magenta or yellow is also printed where the cyan is by the destination device. This effect becomes pronounced when single back type becomes rich (CMYK) black that challenges the registration ability of the press and causes quality issues in clarity and readability of small types.

The effect of the device link adjustment method is evidenced in Figure 8. Notice how corners of the adjusted color gamut stay unchanged due to the constraints imposed when constructing the device link profile.

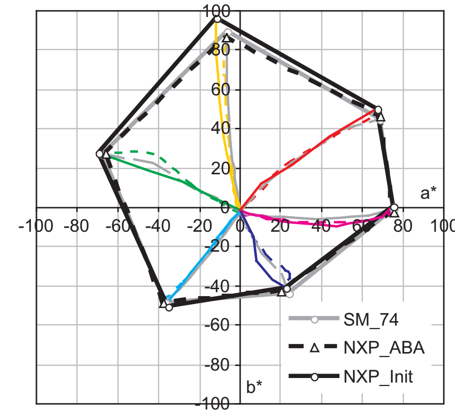

Figure 7: Verification of A-B-A adjustment

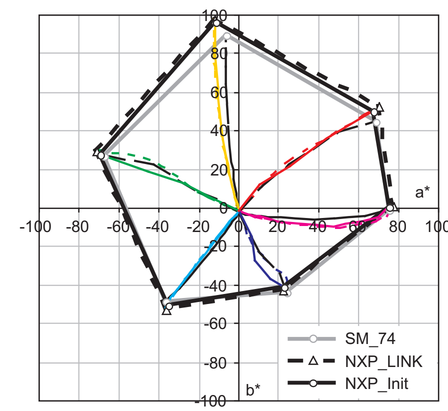

Figure 8: Verification of the device link adjustment

By preserving the purity of single solids and ramps, it overcomes the printability issues as discussed in the A-B-A method.

One may wonder what is the downside of using device link profile, particularly in the context of colorimetric accuracy. Our experiences have been none. This is because pixels in real life pictorial images do not have pixels with pure primary chromatic colors. Even though the device link profile trades colorimetric accuracy of the primary colorants for printability, colorimetric accuracy of pictorial images between the reference and the sample is preserved.

Color Agreement Testing by Paired Comparison

We conducted a paired comparison test using two pictorial subject matters, *Old Man* and *Gears* as shown in Figure 2. Each subject matter is prepared by five adjustment conditions: (A) initial or no adjustment, (B) gradation, (C) tone reproduction and gray balance, (D) color management, and (E) device link. Ten observers were asked to pick one from a pair of prints, under standard viewing conditions, which matches closer to the offset reference. The test was conducted one judge at a time (Figure 9).

Figure 9: A judge compares a pair of prints to a reference

By means of non-parametric statistical analysis (Rickmers, 1973), Table 2 shows that six out of ten judges are consistent in judging a given subject matter. Only four judges who are consistent in judging both subject matters. Due to similarity of the color gamut of the two devices, there is no real difference in the print samples. In fact, the initial print (A) was not ranked the last in both cases; and the longer one stares at the images, the less certain is about the visual difference between them. The only exception that a print has real difference is the *Old Man* print adjusted by the TrGb method. The TrGb method was ranked as the best match to the offset reference.

Table 2: Summary of color agreement by paired comparison

Scene	# of consistent judges	Ranking of adjustment methods from best to worst	Significant agreement among judges at 0.05 risk	Correlation coefficient (R)	Print that has real difference
Old man	6	CBDAE	Yes	0.5	C
Gears	6	BAECD	No	0.1	None

It became clear that color agreement between printing devices with similar colorants is lesser of an issue than color agreement between devices with different colorants. The reason is because there is not much color difference existed between the two devices to begin with. In addition, the magnitude of the process drift and run-to-run variability can easily reduce the effect of the adjustment.

Further Color Agreement Testing using Different Colorant Conditions

We conducted the experiment using different colorants between the reference and the sample device in order to further test the effect of image adjustment methods. In this case, we used the Heidelberg Speedmaster 74 sheetfed offset press as the reference device and the Epson 4000 inkjet printer as the sample device. Figure 10 illustrates the test from with the pictorial color images used to the color agreement assessment.

Figure 10: Test form for visual and quantitative analyses—Round Two

The ColorBurst 4.1 RIP controls the Epson 4000 inkjet printer by enabling all CMYK primary inks and disabling all light inks. Figure 11 illustrates the color gamut difference between the offset press and the Epson 4000 inkjet printer. Figure 11 suggests that the inkjet color gamut is significantly larger. In addition, the two magenta inks are very different with the printing ink being more reddish and the inkjet ink more bluish. In term, there are sufficient color differences in two-color overprints (red and green).

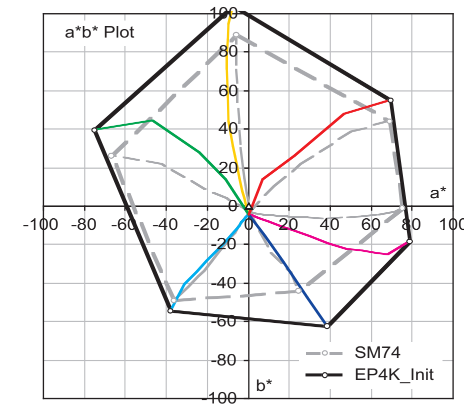

Figure 11: Color gamut comparison between offset press and the Epson 4000

Color Agreement Testing by Paired Comparison—Round Two

We conducted a paired comparison test using five pictorial subject matters prepared in five adjustment conditions: (A) density, (B) chroma and darkness, (C) tone reproduction and gray balance, (D) color management, and (E) device link. Ten observers were asked to pick one from a pair of prints, under standard viewing conditions, which matches closer to the offset reference. By means of non-parametric statistical analysis, the results are summarized in Table 3.

Table 3: Summary of color agreement by paired comparison

Scene	Number of consistent judges	Ranking of adjustment methods from best to worst	Significant agreement among judges at 0.05 risk	Correlation coefficient (R)	Print that has real difference
Camel	7	EDCAB	Yes	0.8	E and B
Pink Peony	8	EDCAB	Yes	0.7	E and B
Red Peony	6	EDCAB	Yes	0.9	E and B
Lotus	9	EDACB	Yes	0.8	E only
Pumpkin	7	DEACB	Yes	0.6	B only

To elaborate, six or more judges are consistent in judging a given subject matter. There is good agreement among these consistent judges. Due to large color differences between the two devices, there is real difference in the print samples prepared by the device link method (E) that produces the best match to the reference press sheet. The color-managed (D) print came as a close second. The print sample by tone reproduction and gray balance (C) falls in the middle of the color agreement ranking. The print sample prepared by the chroma adjustment method (B) produces the worst match to the reference press sheet.

Conclusions and Further Research

This research explored various image adjustment options in achieving color agreement between different color printing devices. When colorants are similar, the color difference between the reference and the initial sample print is small; no one color image adjustment method yields better color agreement than other methods. When the color difference between the reference and the initial print sample is large, the print sample adjusted by the device link method produces the best match to the reference. This is followed by the color management method.

To achieve color agreement between similar colorant conditions, e.g., from press run to press run, transfer curves derived from either the gradation adjustment or the tone reproduction and gray balance work well. To achieve color agreement between different colorant conditions, e.g., proof and print, device link method performs the best.

Several follow-up research projects are under way. We want to find out to what extent we can improve the color agreement further by means of profile editing. We want to predict visual assessment outcome by quantitative analysis with the use of a synthetic test image that is image content-based, as oppose to colorant-based, e.g., IT8.7/3 (basic) target. In addition, we want to explore the above research objectives by means of simulation, i.e., using soft proofing to replace hard copy, in order to eliminate process drifts and run-to-run color variations.

Acknowledgments

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IDEAlliance (2006). *Calibrating, Printing and Proofing to the G7 Method*, Version 5, June 2006, Alexander, VA: Author.

Increasing Local Image Contrast

Franz Sigg

Keywords:

global contrast, local contrast, unsharp masking, newsprint, Photoshop actions

Abstract

This report explains the notion of local image contrast, why it may be desirable to increase it, and shows how it can be implemented in Adobe Photoshop.

Statement of the problem

Contrast can be defined as the brightness ratio of two areas of an image. A natural outside scene on a sunny day can have an overall contrast of one to a million. A photographic transparency with a density range of 3.0 has a contrast of about one to a thousand, an offset print on coated paper with a density range of 2.0 has a contrast of one to one hundred, and an image printed on newsprint has a mere contrast of one to ten. This means that a reproduction, particularly on a low contrast system like newsprint or uncoated paper is relatively "flat" when compared to the original. We could favor, say the highlights, but only at the cost of even lower contrast in the shadows. So, the question is: is there a way that we could make a reproduction with perceptually higher contrast, in spite of the low overall contrast printing system we have to use?

How do painters do it?

Painters have an advantage over a camera: they look at the highlights and paint the contrast that they see. Then they look at the midtones and shadows and also paint the contrast that they see in those image areas. This way they can maintain local contrast even if the global contrast of their canvas is limited. Could we do something like this when printing?

What is local contrast?

Here is an example of a local effect on contrast:

Looking at Figure 1, it seems that the left side of a given step is darker than its right side. The steps are actually uniform, the apparent non-uniformity is strictly perceptual in our visual system. Figure 2 shows that this effect can be magnified by placing gradients along the step wedge. And Figure 3 shows that this effect is negated when the gradients are reversed.

Figure 1: Step wedge

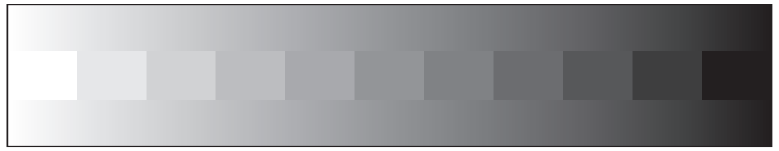

Figure 2: Step wedge with gradients in same direction

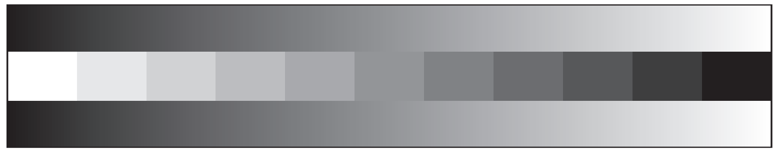

Figure 3: Step wedge with gradients in opposite direction

These effects take place in the eye-brain because of local influences. They help us see edges and therefore shapes. In case you do not believe that the steps are truly even, take two pieces of paper and mask off a single step.

There are other famous examples: Adelson's Checker-Shadow Illusion shown at *http://infohost.nmt.edu/~armiller/illusion/checkerboard.htm* and also at the web page of Arthur Shapiro at *http://www.shapirolab.net/* Also on this page, at the upper left item in the Contrast Isolation menu, Shapiro shows a remarkable example how, perceptually, contrast is more important than absolute lightness.

Measurement vs. perception

What is seen is not what is measured. Measurement is not affected by surround while perception is. Perception relates to *relative*, not absolute relationships. Perception has to do with *contrast* (tonal and color), with *differences* between various areas in the visual field, and these differences also include time differences. The eye-brain wants to see contrast and emphasizes edges because they contain information; uniform areas contain less information. Perception also has to do with memory. We know how "memory colors" such as sky, skin, grass should look like. Perception is a very complex phenomenon.

Measurement is important but, in the end, image quality must be judged by looking, not by measurement. Optimizing reproduction can only be done well by someone with an understanding of perception.

Increasing local contrast by using unsharp masking

It is possible to increase local contrast by using unsharp masking. Traditionally, unsharp masking is used to increase sharpness. Sharpness has to do with edge contrast, which is one aspect of nearby locality. By enlarging the range of unsharpness, we can increase local contrast instead of just sharpness. The degree and quality of unsharpness defines what is "local".

Figures 4a and 4b explains how unsharp masking can be used to increase local contrast. They illustrates what is meant by local and global contrast, and show how the mask does reduce global contrast (because it is negative), while at the same time, it does not reduce local contrast (because it is unsharp).

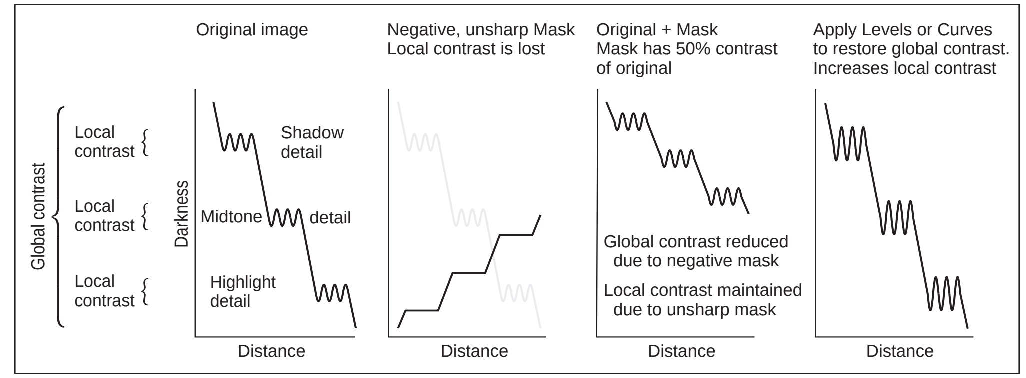

Figure 4a: Using unsharp masking to increase local contrast

Original | 65% Unsharp Mask | Original + Mask | Restored Global Contrast

Figure 4b: Using strong unsharp masking to increase local contrast for an image

Methodology of increasing local contrast in Adobe Photoshop

1. It is desirable to use as large an image as possible, and downsize the image after local contrast was increased. Make a duplicate of the image: *Image > Duplicate…* Edit the name by replacing " copy" with "_LC".
2. Increasing local contrast has to do with tone reproduction, not with color reproduction. Therefore, the duplicated image is first converted to Lab Color space: *Image: > Mode > Lab Color* and only the L* channel is activated: *Window > Channels > Lightness*. (At the end, the file can be converted back to the original color space.)
3. To make the unsharp mask: *Window > Channels*, (make sure only the Lightness channel is selected), click on the button with the arrow on the tab of the Channels window, a pull down menu opens, select *Duplicate Channel...* and name it *Mask*.

   Now this mask has to be made unsharp: *Filter > Blur > Smart Blur…* The big advantage of the Smart Blur tool is that, by setting the threshold, high contrast edges are not blurred which avoids "haloes" around edges. For each pixel, the *Radius* sets the distance which is searched for dissimilar pixels (spatial aspect of "local"). The threshold sets how dissimilar the pixels have to be in order not to be blurred (tone value aspect of "local"). The selected area is then blurred. Choose *Quality: High* and *Normal* mode, and set *Radius* to 5 and *Threshold* to 40. These two settings define what is meant by "local". All texture should be lost in areas where contrast finally should be increased, but not more than that. Figure 5 shows various amounts of smart blur.

Sharp | R 40 / T10 | R40 / T40 | R 5 / T80

Figure 5: Various degrees of blur, settings for: Radius / Threshold

4. Next the mask is made negative and added to the original Lightness channel. Go to: *Image > Calculations…* (see Figure 6.)

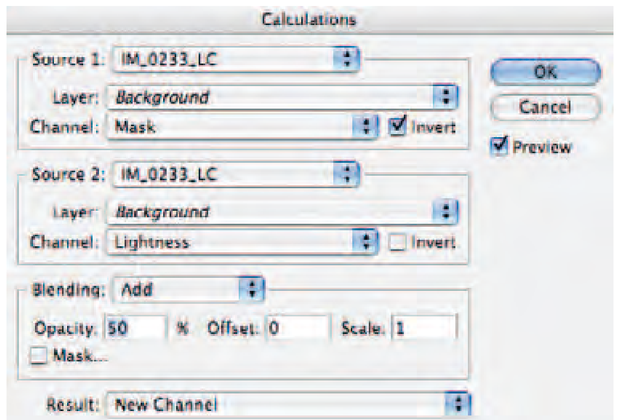

Figure 6: Image calculation settings

Source 1 should be the mask, and it should be inverted (made negative). *Source 2* is the Lightness channel, not inverted. *Blending* mode should be *Add*. The setting you may want to change in this dialog is *Opacity:* It sets the percentage of the contrast of the mask relative to the original. The higher the setting, the stronger will be the increase in local contrast. More than 60 may be too much, try 50 to start. After clicking OK, a new channel Alpha 1 is created which will become the new, enhanced Lightness channel.

5. Restoring channels: *Window > Channels*. The original Lightness channel and the mask channel are deleted by dragging them to the trash can symbol at the lower right of the Channels window. When the Lightness channel is deleted, the image mode is changed to Multichannel, and all channels become Alpha channels. To convert the image back to Lab mode, Alpha1 channel is dragged up and dropped as the topmost channel which is the position for the Lightness channel. Then, color mode is changed to: *Image > Mode > Lab Color*
6. Restoring global contrast: *Image > Adjustments > Levels …* Adjust the three pointers until the image regains the full contrast. The chosen settings have a large influence on final image quality. Set the dark pointer to almost the thin end of the shadow tail. This shadow tail contains the information for the darkest shadows and will be necessary if it is important to open up the shadows. The middle pointer (gray) is used to set the midtone darkness. This is where the decision is made where most of the detail should be, dark areas or light areas. The white pointer sets the white point of the image. Using an S-shaped curve on the lightness channel can be very effective in balancing highlights, midtones and shadows.
7. That's it, color mode can be changed back to what it originally was.
8. Sharpening could additionally be applied to further enhance the picture. Sharpening enhances the local contrast of edges. Other adjustments like curves, saturation, noise reduction, size may be necessary at this time.

Figures 7 and 8 on the following page demonstrate a result with strong local contrast enhancement. Sharpening was applied.

Application of local contrast enhancement

Local contrast enhancement can be used on "good" and "bad" images. The effect is most noticeable on images with larger areas of low contrast detail (large image). On images with lots of fine detail the effect is less visible (small images).

When an image is over- or underexposed, not all tone levels would profit from increasing local contrast. An overexposed image has flat highlights, and an underexposed image has flat shadows. However, the method shown enhances local contrast equally for all tone values. Therefore correcting poorly exposed images requires other tools before local contrast should be enhanced.

Changing tone reproduction may affect the saturation of colors. When applying curves on the final RGB image, saturation changes a lot. When applying curves to the Lightness channel of the Lab image, saturation is not affected.

Increasing local contrast for printing is particularly useful for low contrast printing systems such as newsprint. A Photoshop-based methodology was shown, but Photoshop has many other tools that affect contrast. Very effective in opening up shadows is the tool *Image > Adjustments > Shadow/Highlight…* .

The contrast that is seen on the monitor, or on a proof, or on a press sheet may be different. Large images need different settings than small images. An image with increased local contrast may look grainy when viewed at 100%. But at the actually used size, it is OK.

Acknowledgements

The basic theory and implementation was taught by Dr. Edward Granger. We have profited greatly from his knowledge and expertise.

Note

Additional information and a free download of an Adobe Photoshop Action for enhancing local contrast are at *http://www.rit.edu/~gravure/CMS2007/tools.html*

Figure 7: Original image (Courtesy: Lisbeth Scherrer)

Figure 8: Local contrast, Blur 5-40, Opacity 75 + sharpen + curves

Densitometric Gray Balance & Neutrality Determination

Steve Suffoletto

Keywords:

gray balance, neutrality, three-filter CMY density spread, C*

Abstract

This paper investigates the relationship between measurements of gray balance by densitometry and colorimetry. The research question is "Can three-filter CMY density spread be a useful predictor of gray balance?" If the correlation between Status T three-filter CMY density spread and CIE C* is strong enough, then density spread can be used to determine gray balance. It was found that absolute density is approximate but sufficient for determining gray. Better results are obtained when a known gray target is used as a reference and then the relative three-filter CMY density spread is measured. This technique can be used to find, monitor, and control gray balance if a colorimeter is either not available or its use is not understood.

Introduction

Gray balance is an important color reproduction parameter because it has a global effect on all colors in an image or on a press sheet. Any bias or drift away from gray balance also produces the same bias in all the other colors. This can cause adjacent colors on the color wheel or circle to change hue. For example, adding some yellow bias to magenta makes it appear redder. Likewise, complementary colors diagonally across from each other will become less saturated or grayer. A common term for this is dirty or muddy. For example, adding some yellow bias to blue (not cyan) makes it appear less saturated or grayer, not greener. See Figure 1.

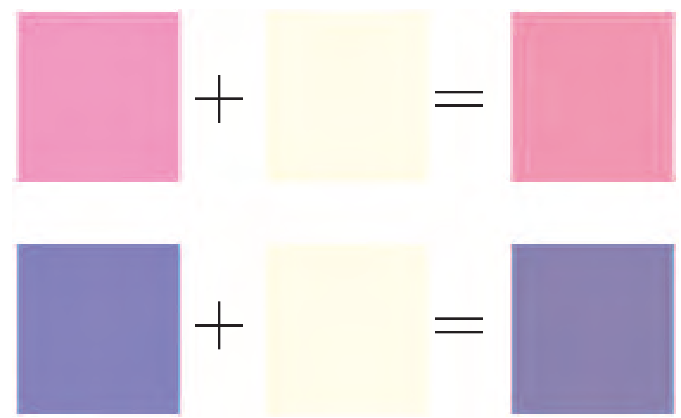

Figure 1: Magenta plus Yellow results in a hue shift toward Red. Blue plus Yellow results in a chroma loss adding Grayness.

Gray balance means grays appear neutral, without any predominant bias or cast. Photography and videography often call gray balance *color balance*, i.e., reproducing a gray scale in the scene as neutral as possible. In CIE Lab color space, neutral grays are located at the very center intersection where both a* and b* are zero (0). In the RGB color space, neutral gray occurs when there are equal and balanced amounts of red, green and blue light present, whether reflected from an opaque object, transmitted through a transparent object, or emitted from a light source. So, if R = G = B, then it is equal and balanced to neutral gray. For example, entering equal or balanced amounts of RGB into Adobe Photoshop's color picker always produces a neutral gray where a* and b* are zero (0). See Figure 2. RGB gray levels near 0 are black, near 255 are white and near 128 are middle gray. Thus, only the lightness or L* is changing.

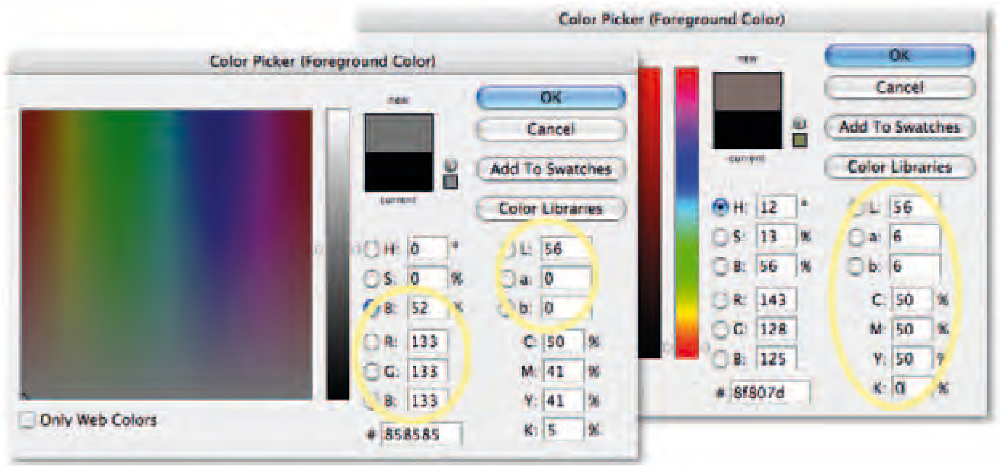

Figure 2: Equal RGB = Gray, but Equal CMY doesn't equal Gray

In CMYK color space that uses colorants that absorb RGB light, it is not equal or balanced CMY colorants we desire in order to achieve neutrality (50%C, 50%M, 50%Y) but rather their densities. But if we make the dot areas *un*equal (50%C, 40%M, 40%Y), we then make their densities equal. See Figure 2. The CMY dot areas are colorant input signals which modulate RGB light; the resulting CMY density is an output response. *D= -logR*. So what is true in RGB additive must also be true in CMY subtractive because of their complementary or opponent relationship.

The reason equal dot areas do not produce a gray is because the pigments used in the printing inks are not ideally pure and have some normal unwanted light absorption. Printers call this densitometric *hue error* and *grayness*. Since magenta has about 45% hue error toward yellow and cyan has about 25% hue error toward magenta, a 3-color gray of equal dot sizes (50%C, 50%M, and 50%Y) is contaminated with an orange, making it look warm brown. But, by reducing both the magenta and yellow dots from 50% to 40%, we can eliminate this warm colorcast. We could have also increased the amount of cyan from 50% to 60% but that would have also darkened the tone. In Figure 3, the outer surrounding background is always a 1/c-K screen tint of 50%. The center insets have different CMY dot areas.

Inset is too warm; C50, M50, Y50;	Inset is gray but too dark; C60, M50, Y50;	Inset matches C50, M40, Y40

Figure 3: Examples of different dot area gray balances

The theoretical or scientific definition of neutral, based on colorimetry, is when C* = 0, which means a* and b* are also zero. However, a more practical definition of neutral for technology implementation should take into account the effects of any visual references, such as the white paper (0% dot), the solid black ink (100% dot), or the 50% black screen tint which is halfway in the middle. At 50% dot, both the white paper and black ink are influencing the appearance. In the highlights, the paper has a larger influence. Likewise, in the shadows, the ink has a larger influence. So, any changes to the paper or ink, as well as the lighting or viewing conditions would change the appearance of neutral gray. There is a current trend for papers to be made bluer, with a larger -b* value. This increases their TAPPI brightness. Currently, an ISO type 1 paper (gloss coated) has Lab values of L* = 95, a* = 0, and b* = -2, when measured on a white backing material.

Certainly, gray balance is best measured using colorimetry, specifically with C* from CIE LCh. *Whenever possible, gray balance should be measured using Colorimetry C*.* Colorimetry is trichromatic due to the XYZ Tristimulus values. Tristimulus integration combines the effects of the light source, the object that modifies the light, and the human eye's visual response through red, green, and blue cones. Colorimetry is best because it strongly correlates with human vision since it uses the CIE Standard Observer (2-degree) and defines the light source with a standard illuminant (D50).

A densitometer is a trichromatic instrument that consists of three broad or wide band filters, Red, Green and Blue. In North America, Status T response is the norm. In normal process control practice, solid ink density (SID) is measured through the complementary filter to produce the highest density (signal). See Figure 4.

Ink Color	**Black**	**Cyan**	**Magenta**	**Yellow**
Filter Color	Calculated Average of RGB	Red	Green	Blue

Figure 4: Corresponding filter for ink color

However, by looking at three-filter CMY densities, (X-Rite "ALL" display mode) we can increase the limited information that only a single filter density provides (X-Rite "AUTO" display mode). Obviously, the trichromatic response of a three-filter densitometer is not the same as a colorimeter's standard observer. The technical term is *anomalous trichromat*.

C* is a more efficient metric than a* and b* because only a single value needs to be evaluated. Mathematically C* is the longest side of a right triangle, the hypotenuse. When C* is zero (0) the color is hueless, achromatic, and neutral gray. To evaluate neutrality in CIE Lab, both a* and b* must be examined and at zero to be neutral. Graphically, C* is a radius line of a certain length and shows magnitude but not direction. Hue angle (h') or a* and b* show direction. The shorter the length of the C* radius line, the more neutral. The shortest possible distance is zero, which is at the center intersection. The longer the C* radius line, the more colorful or saturated the color. Because C* is calculated from both a* and b*, it makes C* a two-dimensional measurement.

This paper's audience is focused at smaller-sized printers who may not have the necessary instrument technology and/or the understanding to properly practice colorimetry. A colorimeter costs about $4,000, twice the price of a densitometer at $2,000. A spectrophotometer is almost three times the price at $6,000. Many printers buy a spectrodensitometer but only use, know, and understand the simplest of functions, just density. Often, this is also the case for off-line scanners, not just hand-held instruments. Some printers may have a sophisticated X-Rite ATS or ITX scanner but only use it to measure density! So, this study has those printers in mind. Again, the research question is "Can densitometry be a suitable substitute for measuring gray balance?" With the recent introduction of GRACoL's "G7™" calibration and control method in 2006, there is a renewed interest in gray balance making this research topic timely and relevant. In the print media production workflow, prepress makes a color separation to establish gray balance then makes a proof to show that gray balance. Finally the pressroom prints to maintain and preserve the gray balance prepress established. Gray balance is an important aspect of work based on ISO, FOGRA, GRACoL and SWOP.

Objectives

Research was conducted to:

1. Determine if a Status T densitometer can be a useful predictor of neutrality to accurately measure gray balance.
2. Determine appropriate tolerance limits for densitometric gray balance.

Methodology & Experimental

To conduct the experiment, only a measuring device and a printed or proofed target are necessary. An X-Rite 528 spectrodensitometer was used to provide both densitometric (CMYK) and colorimetric (Lab) information. Spectral reflectance data is not required. The test target can be any typical gray balance finder target available from several sources or could be custom made. See Figure 5.

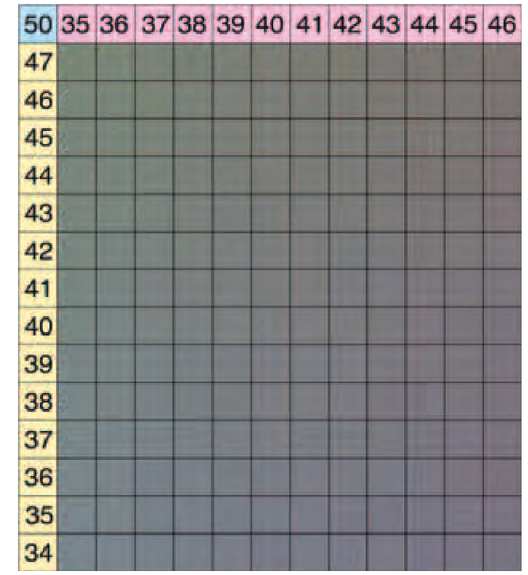

Figure 5: The actual gray balance finder target that was measured

The scope for this investigation is limited to just the 50% midtone portion of the tone reproduction scale and not the one-quarter (25%) or three-quarter (75%) tones. ISO 12647-2 states that mid-tone gray balance consists of 50%C, 40%M, 40%Y, and 0%K when at the correct solid ink density (SID) and tone value increase (TVI).

Measurements

All measurements were made to ANSI CGATS.4, CGATS.5, ISO 13655, and ISO 13656. The illuminant is D50, standard observer is 2-degree, 0/45 geometry, black backer, Status T filter response, dry densities, absolute with paper included, and non-polarizing.

Each patch was measured twice, once for Status T density then immediately again for CIE Lab color. Density was measured using All filters option with high precision so three decimal places was obtained.

Analysis

The measurement data was analyzed in Microsoft Excel and several graphs created. From Lab, C* was calculated. The formula for C* is simply $C^* = \sqrt{a^{*2} + b^{*2}}$. For each patch, three filter CMY density "gray spread" was calculated. Gray Spread = Max (Dr, Dg, Db) – Min (Dr, Dg, Db). For example, if C = 0.61, M = 0.60 and Y = 0.59, then the gray spread would be 0.02.

Results and Discussions

The first step was to determine which patches in the gray balance finder target were really gray using colorimetry. Of the 49 patches, 10 were identified as being "gray" using a C* tolerance <=2.0. See Figure 6. An a* and b* tolerance was not used since it produces a square shaped tolerance limit. Instead, C* produces a circular or round tolerance limit. Fitting the smaller area circle inside the larger area square produces four corners that the circle does not include. These corners represent unwanted false positive signals. At a tighter tolerance of C* <= 1.0, there were only 5 neutral patches. This was not used because such a tight tolerance is not practical in manufacturing.

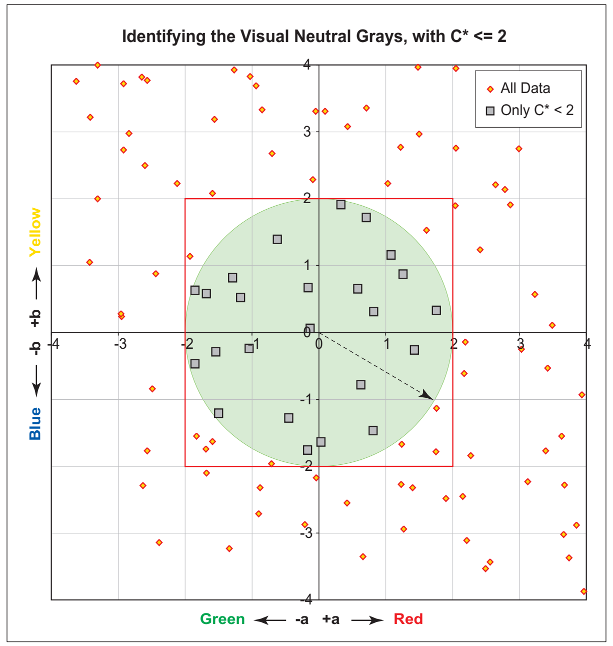

Figure 6: Identifying which patches are really neutral gray with C <= 2.0*

The next step was to evaluate the three-filter CMY density gray spread. The lower or smaller the gray spread, the more neutral gray the 3-color CMY patch should be. See Figure 7. There were 12 patches that had a gray spread of <= 0.02 density. Of these, 9 patches had good density agreement with the C* data. This is a 75% accuracy rate. A commonly quoted density spread for gray balance is =< 0.03. At this wider tolerance, now 20 patches are included. Unfortunately, this wider tolerance produces too many false positives and lowers the accuracy rate to just 50%.

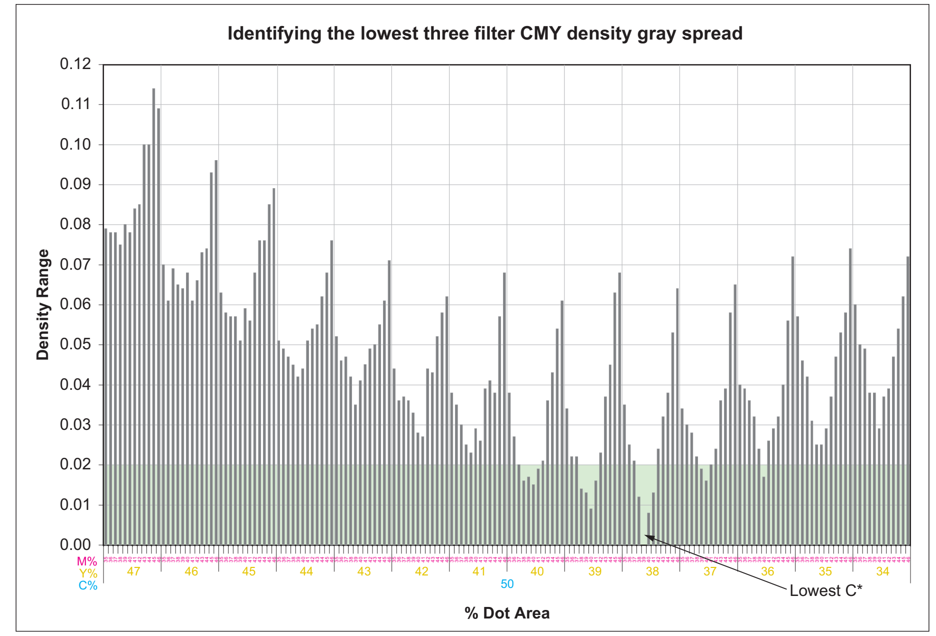

Figure 7: Identifying which patches have the lowest density spread

Finally, the correlation between C* and Gray Spread was compared and found to be good using a second order polynomial. See Figure 8. The correlation coefficient value (R^2) is 79% and considered acceptable for production use. If only the 10 patches where both C <= 2 and density Gray Spread <= 0.02 are used, then the correlation improves to 84%.

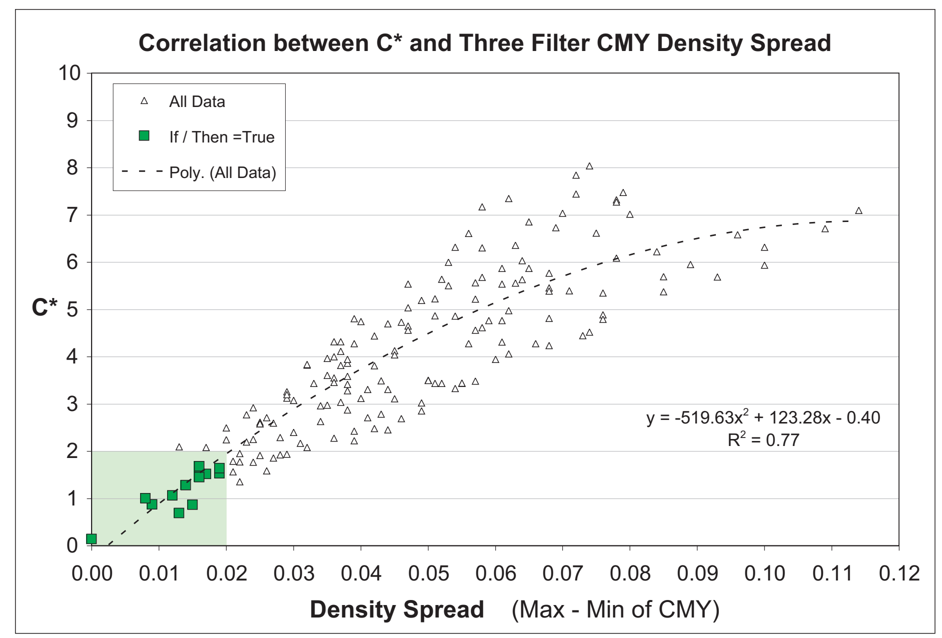

Figure 8: Graph showing correlation strength between C and Density Spread*

Conclusions

The following presented in questions-and-answers format summarizes this investigation.

Can a densitometer accurately measure gray balance? Yes.

For printers who do not have a measuring instrument capable of colorimetry or have operators who don't understand colorimetry, density spread is a somewhat effective (84% accurate) alternative method to C*. This method can easily be done with any hand-held densitometer that can display all four filters simultaneously. Having a software feature in the densitometer that automatically calculates the density spread would be of convenient value.

The advantage to this density method is that printers can use existing, older densitometers and do not need training on more sophisticated technology. An off-line scanner would obviously be much faster. X-Rite's IntelliTrax (ITX) scanner (software version 1.4.0.30) currently can display gray balance using CMY three-filter density spread.

What calibration, setup conditions, and procedures are necessary for this method?

The fundamental issue is densitometry uses Status T filtration and not colorimetry's D50 illuminant and 2-degree observer which imitates human color perception. Therefore, to compensate for this difference and improve accuracy, measurements are made relative to a known or targeted reference. The reference is stored into memory and can easily be automatically retrieved after measuring. The target stored as a reference can be an OK proof or OK press sheet. Usage this way is an effective process control technique. To find a known neutral gray of C* = 0 to be used as a reference, it must be obtained from previously verified samples measured with a colorimeter. Possible physical samples that have very low C* values may be Munsell N8 found on some color viewing booth table top or walls or Pantone Cool Gray 7.

What are appropriate tolerance limits for densitometric gray balance spread?

A three-filter CMY density gray spread of 0.02 or less (<=0.02) is an appropriate tolerance for determining gray balance with a densitometer. However, a significant portion of this tight tolerance is consumed by instrument repeatability error. Modern spectrodensitometers now have less instrument repeatability noise or error. With older instruments, it was +/- 0.01. Today it is better at only +/- 0.005 density, per the manufacture's technical specifications. So, the density spread tolerance of 0.02 compared to the instrument repeatability of +/- 0.005, represents about 25% measurement error. A Gage Repeatability and Reproducibility (GR&R) study recommends the measurement noise be less than 10% of the total tolerance range. However, to put this into practical perspective, current video camera plate readers are only accurate to 0.5% dot area. If the tolerance for CtP is +/- 1%, then the noise is also 25%! This amount of error does not seem to be much of a concern for many users.

Further Research

In the future, additional testing should also be done in the 25% highlights and 75% shadows. Also, the gray balance test target varies the magenta and yellow for a fixed 50% cyan value. Additional +/- 5% cyan values, from 45-55%, should also be evaluated. An alternative measurement method would have been to measure spectral data and use Excel to calculate Status T density and CIE Lab, LCh.

Acknowledgements

Thank you to Rochester Institute of Technology (R.I.T.) and the Printing Applications Laboratory (PAL) for their support and use of color measurement instruments.
A special thank you to Professor Bob Chung and Franz Sigg of RIT's School of Print Media (SPM) for their support, multiple peer reviews, suggestions, and assistance.

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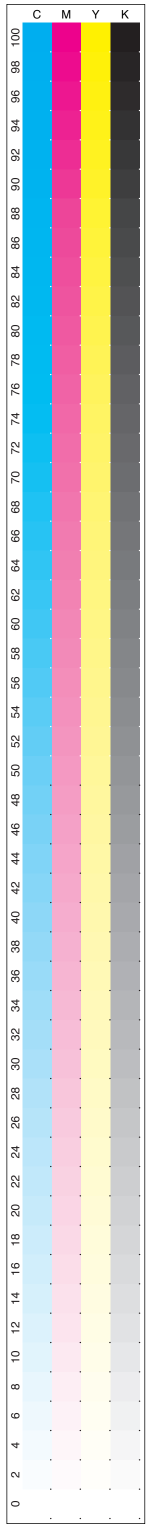
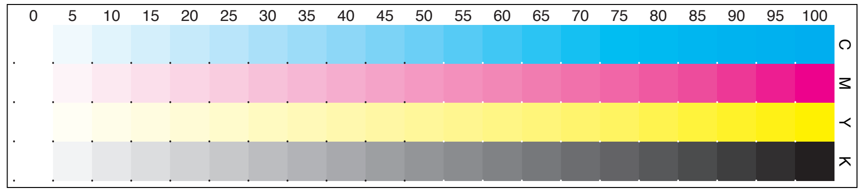
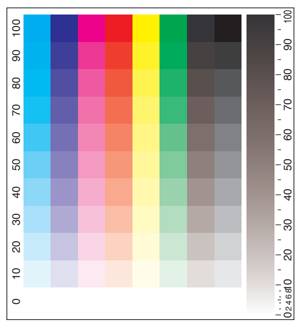
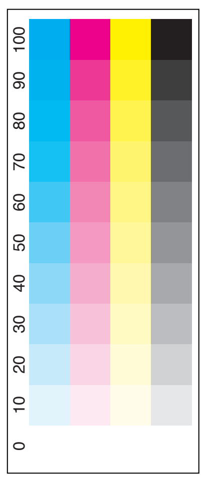


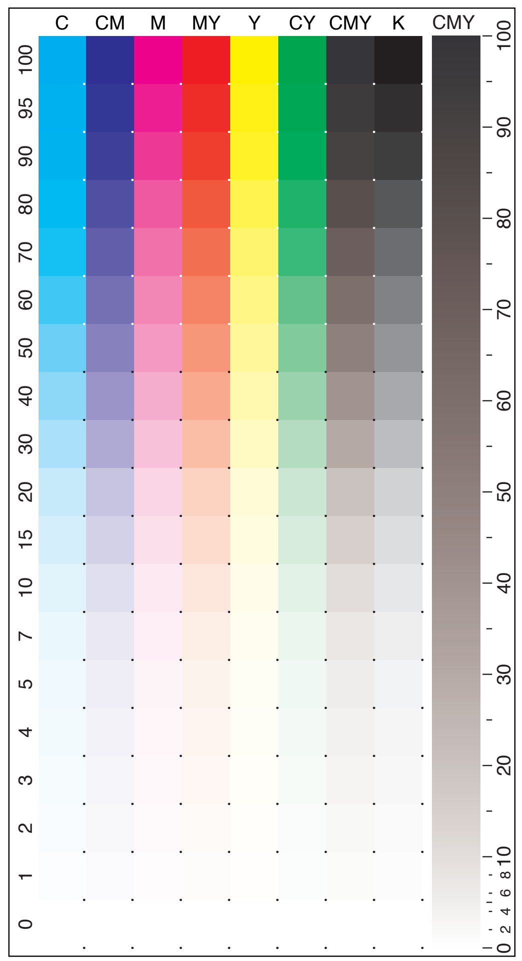


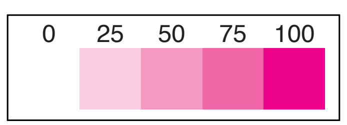
Variations on Test Wedges

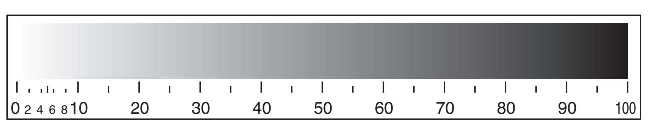
The sample wedges on this page show some of the possible variations. There are different color labels, corner dots, gradients, and different colors and sizes. Since the content of this book is printed CMYK only, no spot colors are shown.











Automated Test Wedge Generator

Franz Sigg

Keywords:

step wedges, gradients, gray scales

Abstract

Step wedges and gradients are basic tools used for production control, testing, and research. This article describes an automatic test wedge generator that permits custom designing of these tools.

Introduction

When doing testing, research or production control, special test wedges are needed, but often we use generic scales because that is all we have and to make a customized version is not a trivial matter. Often we have specific needs for the number of steps and the dot areas on these steps; the size of the patches; the number of colors, overprints and possibly spot colors; and the inclusion of an additional gradient.

Test Wedge Generator

To facilitate production of these tools for research at RIT, PostScript code was developed where the necessary modules can be customized by setting parameters in the header of the EPS file.

This helped a lot, but was still a little cumbersome to use because, for instance, to calculate the BoundingBox in the EPS file is not that simple. Therefore, a Microsoft Excel spreadsheet was developed that lets the user define the aspects of the desired scale and then, with the use of a Visual Basic macro, the parameters in the EPS file are automatically set, and an indication is given where the test wedge file is saved.

This EPS file can be used in an Adobe InDesign page as part of a test form or it can be converted to PDF using Adobe Distiller. And, if necessary, it can even be fine tuned in Adobe Illustrator. The file is a legacy CMYK file and should not be color managed.

Note that in Illustrator, spot color patches are shown white. However, when clicking on a step, the correct color designation is actually there; just the preview feature does not work right. The same file opened in InDesign shows the correct preview. Acrobat also does not show the spot colors, but, when using *Advanced > Output Preview*, the spot colors are named, and the dot areas are indicated when the cursor is placed on a given step.

There is a free download of this Test Wedge Generator tool from *http://www.rit.edu/~gravure/CMS2007/tools.html*

How is a Gradient Made?

A gradient shows very smooth transitions from 0 to 100% tone values. In a digital system, the smallest difference between two tone values is one bit. This means that for an 8 bit system, there are 2^8 or 256 gray levels. Therefore, a gradient is nothing other than a step wedge, where the steps have one bit tone value difference between them.

PostScript can be in vector or bitmap mode. Normally, gradients are programmed as bitmaps. But they could also be many small steps in vector mode. The code generated by the *Test Wedge Generator tool* uses vector code for the step wedges and a bitmap for the gradient. This version of the tool can only make one gradient. If several gradients of different colors are needed, the following ‘trick’ can be used to make multi-color gradients:

Make a 256-step wedge where each step increment is 0.39215686 percent dot area (i.e.,100% divided by 255 increments). If you make the step size 4 mm wide, this makes a step wedge that is more than 40 inches long. That is OK, because the generated EPS file can be edited in Adobe Illustrator for various aspects such as rescaling (possibly non-uniform), text addition / removal, etc. Go to *Object > Transform > Scale...* in the *Non-Uniform* scaling option, change the size to 10% in the horizontal direction and to 100% (or more) in the vertical direction. Keep the *Scale Strokes and Effects* option *un*checked.

Now the wedge becomes a manageable size, but all labels are unreadable. To correct this, press *command+A* on the keyboard to select all the objects; and restore character width (*Horizontal Scale*) to 100% in the *Type > Character* window. Delete the labels for the step wedge (there are too many), only keep the ones for the gradient. What you now have is a vector version of the gradients. Notice that there is no visual difference between the step wedge and gradient in Figure 1.

Gradients can, of course, also be made in Adobe Photoshop. The difference is, that the ones generated by the *Test Wedge Generator tool* are linear and calibrated; therefore more useful as a test target. When the EPS file is opened in Photoshop, it will show a flat histogram; while a gradient natively-made in Photoshop shows a curved histogram.

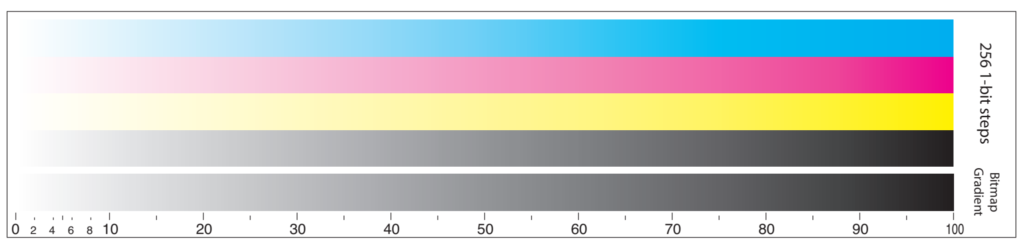
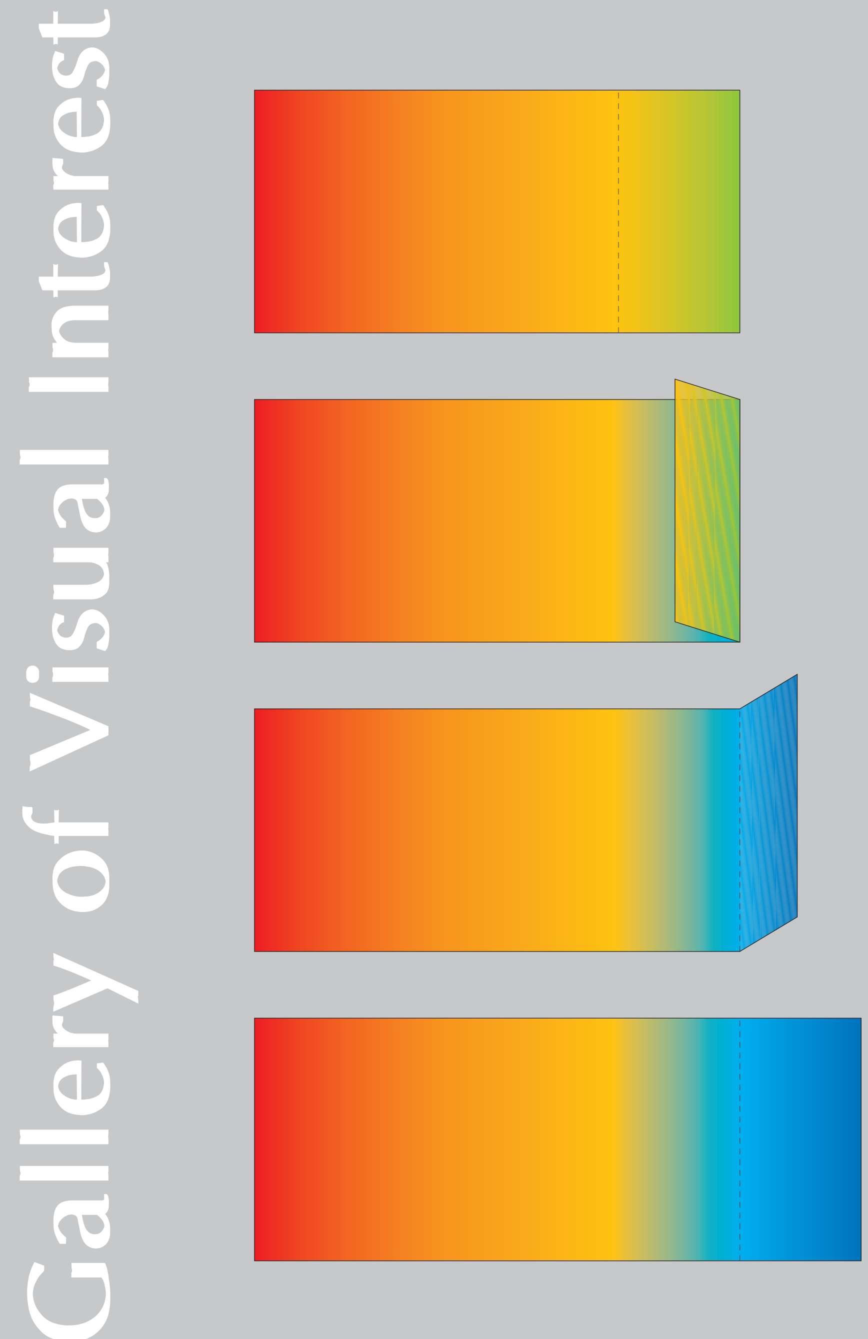


Figure 1: Edited version of 256-step wedge and a bitmap gradient



Folded Panel in Design and Print Media Applications

Robert Chung

What is a Folded Panel?

A folded panel is a page with an extra fold in a publication. What is obvious about a folded panel is that it has more area when the panel is unfolded. What is interesting about a folded panel seen below, is that it can showcase two different visual effects: (1) the scene is surprisingly changed when the panel is flipped open, and (2) the scene is extended when the panel is flipped. In either case, carefully designed folded panels provoke visual interest and lively discussion.

An example of a folded panel (courtesy of Linköping University)

Folded Panel as a Design Element to Reflect Changing Scene

The first visual effect, changing scene, results from carefully capturing two different scenes with an identical "common" portion in the unfolded portion of the page. Elements in the scene and its stability are carefully chosen to reflect an intended message or purpose. Adobe Photoshop is often used to help blend the two scenes together according to design.

Examples of "changing scene" are from students in Professor Tommie Nyström's class in Linköping University (*http://www.lith.liu.se/en/*), Sweden. These students, including Pauline Säll, Robbin Ingvarsson, Johan Andreasson, and Tomas Nilsson, majors in Graphic Design & Communication at Linköping University. I was pleasantly surprised by the innovative use of print media in communication design when I visited Professor Nyström in June of 2007.

The example on p. 65 on the right shows how a dorm room initially looks in a reading or quiet mood and changes to a chat or party mood with the flip of the panel. There are many technical requirements that are required to realize the visual effect. Aside from lighting, exposure, and tripod required in photography, the cut edge of the folded panel has to align seamlessly with the previous page.

Courtesy of Linköping University

unfold

Folded Panel in Design and Print Media Applications

Robert Chung

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Courtesy of Linköping University

fold

This means that imposition has to be exact; front-and-back registration has to be exact; tone and color at the crossover has to match. In addition, cutting at the bleed edge and folding to make the page slightly less than 8.5" wide have to be exact.

The other example of "changing scene" on p. 67 shows the effect of a street scene changing from 'with traffic' to 'pedestrian-only' with a flip of the panel. The street scene in the photograph looks natural. In other words, no model was hired and people are constantly moving in the street. This can challenge the common portion of two similar, but not identical, images. It is difficult to tell where one image ends and the other begin. Just by looking at the image with and without the folded panel, I sensed the difference in air quality and friendliness of the street almost instantly.

Due to space constraint, we were not able to include more "changing scenes" with folded panel in the publication. I want to thank Professor Nyström and his students for sharing their class assignments with us. I personally believe that the project has equal significance for design and print media students alike.

Folded Panel as a Design Element to Reflect Unchanging Scene

Extending the folded panel concept from 'changing scene' to 'unchanging scene' started out as an idea. You may wonder why this could be of interest. Below is an explanation.

I made a connection between metamerism and 'unchanging scene.' The term *metamerism* means two colors that match each, but having different colorants. Thus, why not have two scenes matching each other, but with something different in each? We can make the difference between the page and its folded panel very subtle or obvious. For example, the difference between two screenings can be subtle; but the difference between two gloss conditions can be obvious. Indeed, this is more of a printing technology issue than a design issue. For ease of testing, we decided to use a digital press to carry out the experiment.

By taking the above idea to action, the first example of a folded panel with an unchanging scene on p. 68 and 69 is a panoramic view of downtown Rochester, viewed from the Ford Street (courtesy of Frank Cost). Professor Cost took a series of overlapping photographs with a digital camera on a leveled tripod. The overlapped area is at a constant angle so that the images can be digitally stitched together. There are two interesting effects to look at. You may wish to interrupt reading this article temporarily and examine the panoramic reproduction.

First, the panoramic image is long to begin with; it is further lengthened when the panel is unfolded. Second, different screening technologies are applied to the image. FM screening was applied to the left-hand-side page where the Hyatt Hotel is clearly seen; Classic AM screening was applied to the right-hand-side page where the pyramidal-shaped top identifies the Bausch & Lomb Building; and finally, line screening was applied to the folded panel.

The second example of a folded panel with an unchanging scene is on p. 70 and 71, a panoramic view of the Gannett Building that houses the School of Print Media on RIT's campus. I took the digital photo on a tripod equipped

Courtesy of Linköping University

unfold

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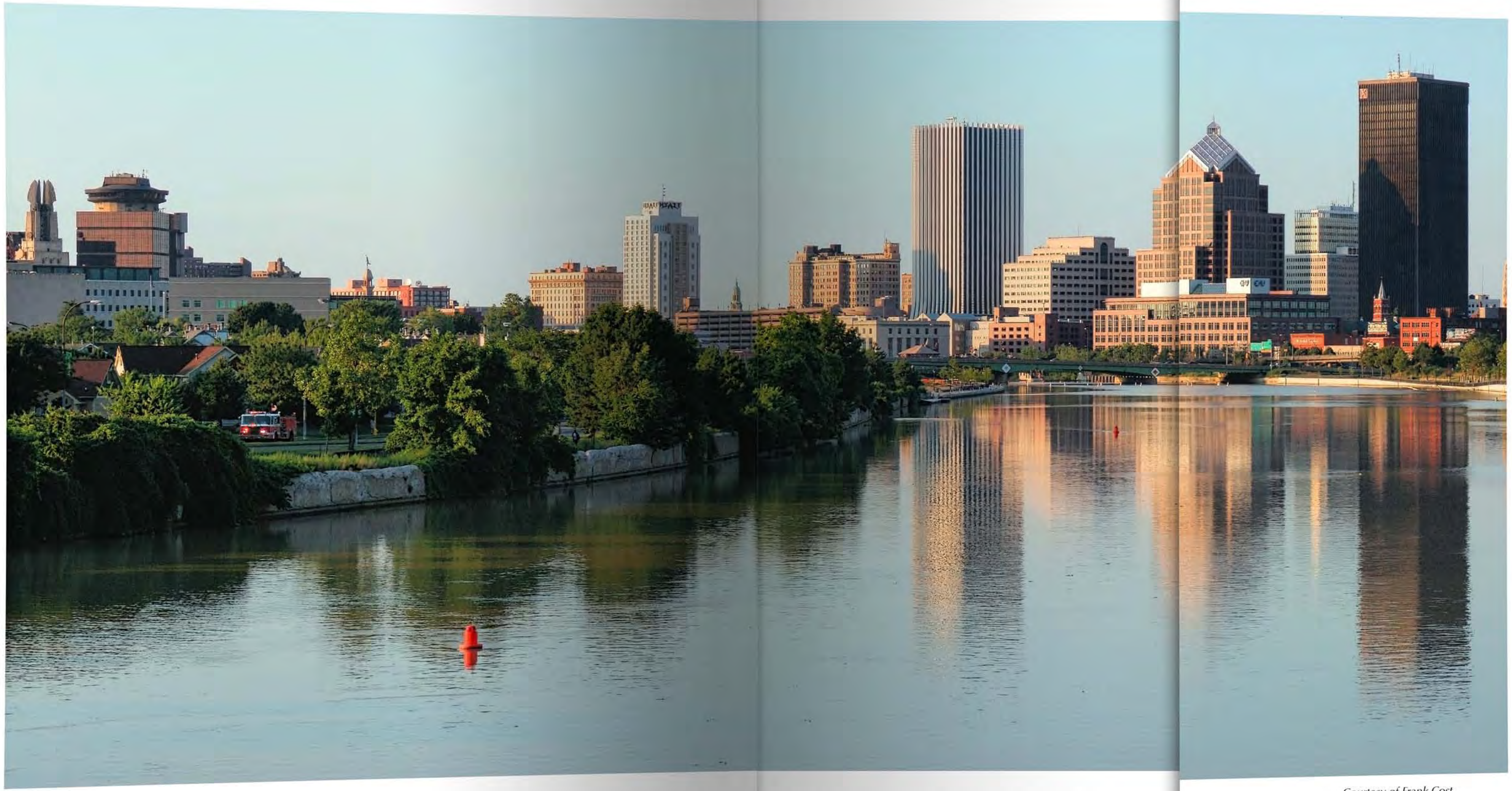
Courtesy of Linköping University

fold



Courtesy of Frank Cost

unfold

Courtesy of Frank Cost

fold

Courtesy of Robert Chung

unfold

Courtesy of Robert Chung

fold

with a pano head in the same manner as Professor Cost did in the morning of a spring season. Red brick building, red brick pathway, and crab apple trees were accentuated by the blue sky and green grass nicely. There are also a couple of interesting effects to look at.

You may see the effect of gloss in this panoramic reproduction on p. 70. A text-based gloss used with the message "RIT Gannett Building, Home of School of Print Media" is detectable on the left-hand-side page; line screening without gloss was used on the right-hand-side page. This is to bring contrast between it and the folded panel, which is printed in full gloss. In addition, notice the two lines running on top and bottom of the panoramic image. Are they just one-point rules? No. Are the two lines identical? No. What are they? They are micro texts, RIP-based micro fonts available, from NexPress.

Conclusion

Examples of "changing scene" from students in Professor Tommie Nyström's class at Linköping University in Sweden are enlightening. I'm beginning to think about giving a similar assignment to my students at RIT. What kind of image will they come up with? An advertising promotion for a stretched limo? A stretched laptop computer with a wider screen?

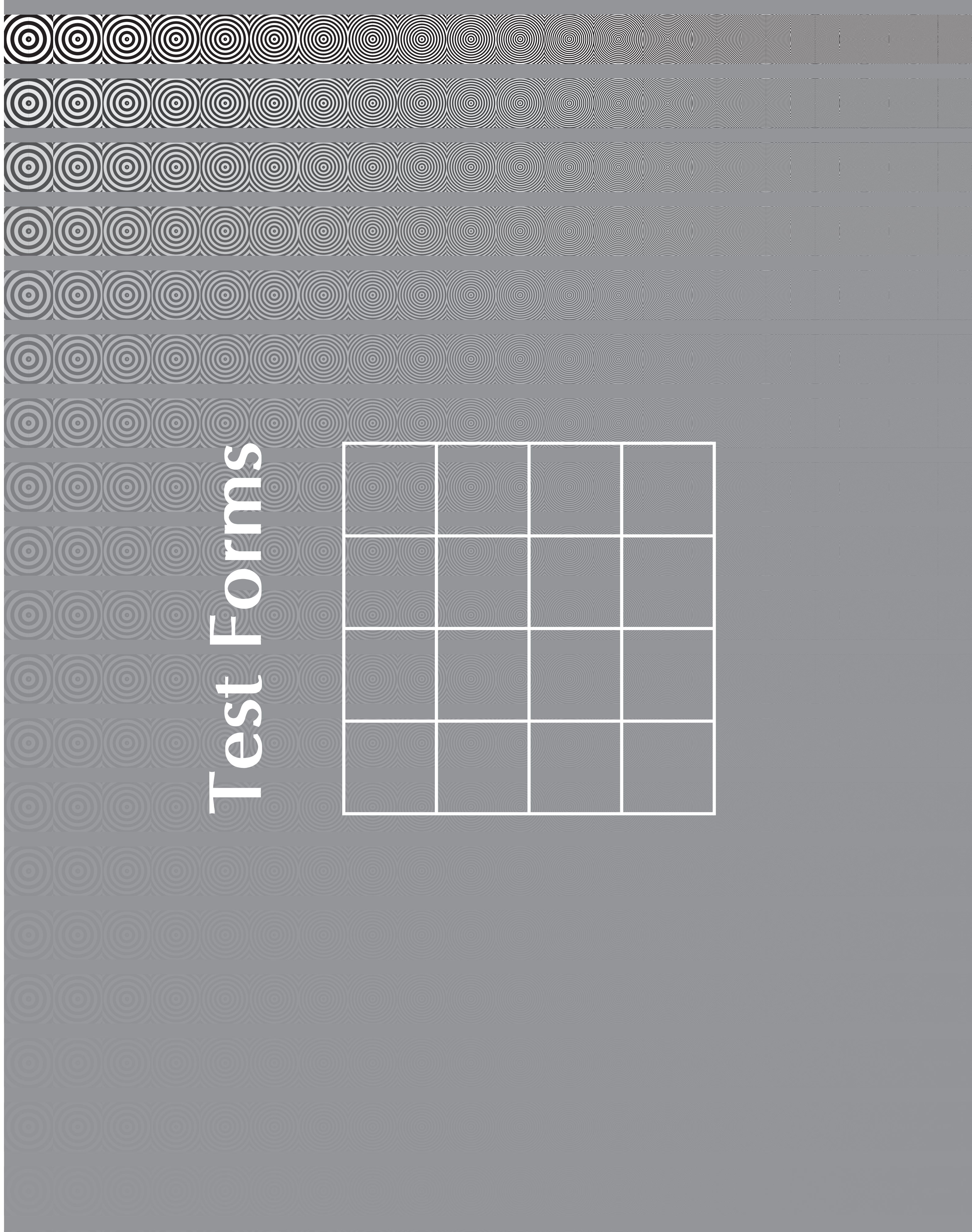
Executing the 'unchanging scene' with folded panel is more of a technology challenge than design-oriented solution. The use of a panoramic scene is desirable because of the added width. The page-to-panel match depends on cutting and folding accuracy. It also depends on color match at the crossover. Thus, the degree of success depends on planning, testing, and execution. For *Test Targets 7.0*, we took aim at pushing the technology to its limits. In the end, we will find out what worked well, what can be done better if given more time and resources, and what to avoid at all costs.

In conclusion, folded panels offer plenty of creativity, visual interest, and lively discussion. Print media mixed with design is fun, isn't it?

Acknowledgments

Unfolding the mystery of the folded panel in design and print media applications has proven to be an exciting and rewarding journey. Many people gave their time and energy to make the piece a reality. I wish to thank Professor Tommie Nyström and his students for giving us permission to reprint their work on changing scenes with folded panel. I want to thank Professor Frank Cost for his beautiful panoramic scene of downtown Rochester. I want to thank my lab assistants, Sunchut Jongcharoensiri and Sri Hemanth Prakhya for constructing the layout and numerous revisions. I want to thank Fred Daubert of the Riverside Bindery Group for suggesting how to bind the GVI section with the rest of the publication. Last, but not the least, I want to thank Dr. H. T. Tai of Kodak for advising us on screening and glossing options that are available from NexPress. Without their enthusiasm and support, I could not have written this piece.

Pages 65 - 72 of the Gallery of Visual Interest were printed on a NexPress digital press, for it is impractical to produce the folded panels with selective gloss and watermark effects on a web press.



Device Characterization Target

IT8.7/3 Basic Data Set from ISO 12640 SCID

Press Goss Sunday 2000 Web
Paper New Page Sterling Ultra gloss
Web Gloss 100#

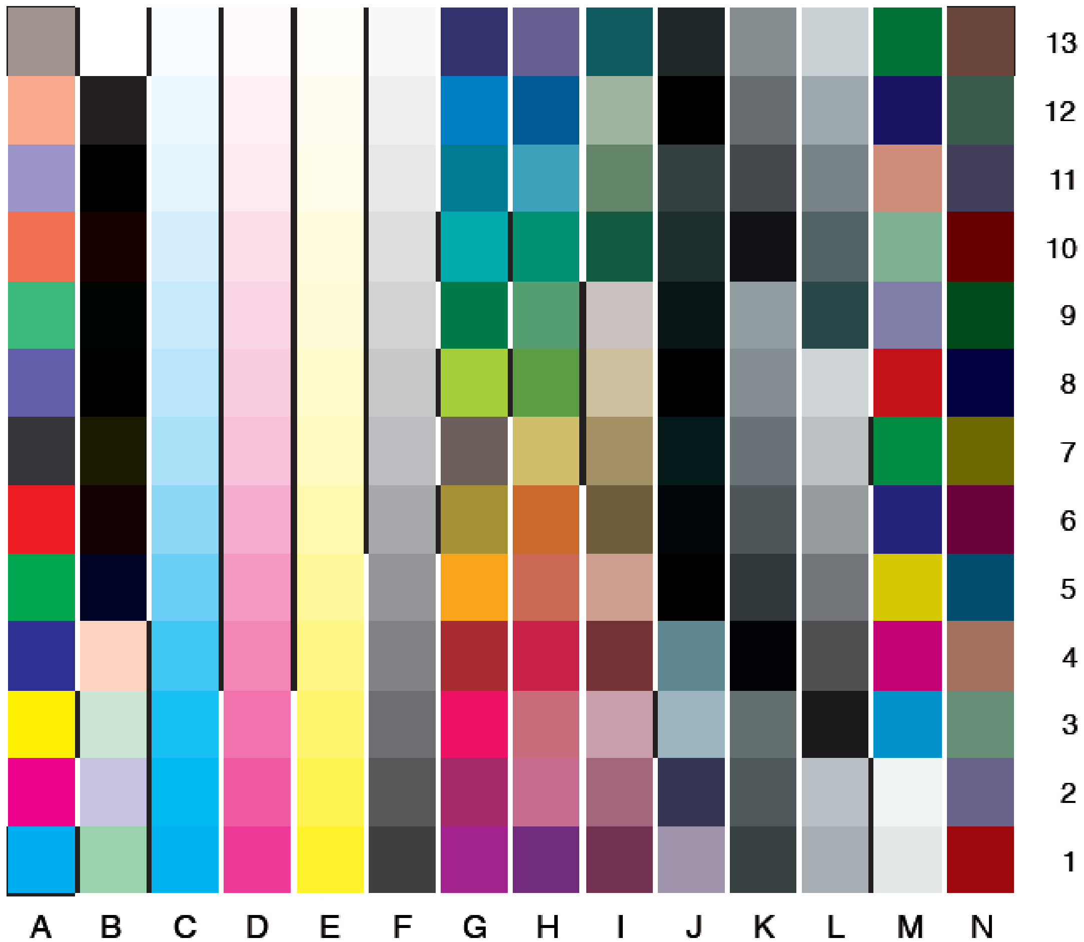
RIP Information:
Acrobat Distiller 8.1.0

600 spi, 42.3 μ/spot
PS Version: 3016.102
PS Language Level: 3

Premedia InDesign CS3
Notes Legacy CMYK
Prepress Prinergy

TR4V03U.EPS

DG4CE11U.EPS



IT8_Basic_iO.TIF

P4BAR03U.EPS

GCRBAR3U.EPS

Pictorial Reference Images

ISO 12640 Standard Color Image Data

Press Goss Sunday 2000 Web
Paper New Page Sterling Ultra gloss
Web Gloss 100#

RIP Information:
Acrobat Distiller 8.1.0

600 spi, 42.3 μ/spot
PS Version: 3016.102
PS Language Level: 3

Premedia InDesign CS3
Notes Legacy CMYK
Prepress Prinergy

TR4V03U.EPS

ISO 12640 N7A.tif

ISO 12640 N4A.tif

P4BAR03U.EPS

TR4V03U.EPS

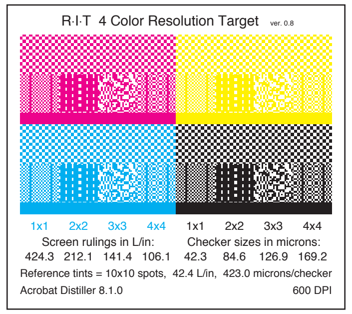
GCRBAR3U.EPS

Synthetic Targets

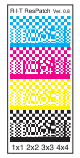
Targets for Resolution, Register, Dot Gain and Gray Balance

Press	Goss Sunday 2000 Web	**Premedia**	InDesign CS3
Paper	New Page Sterling Ultra gloss	**Notes**	Legacy CMYK
	Web Gloss 100#	**Prepress**	Prinergy

RIP Information:
Acrobat Distiller 8.1.0
600 spi, 42.3 µ/spot
PS Version: 3016.102
PS Language Level: 3

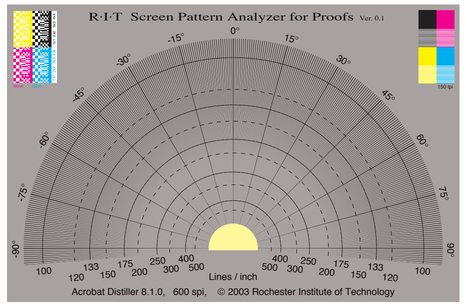


4Res08U.EPS

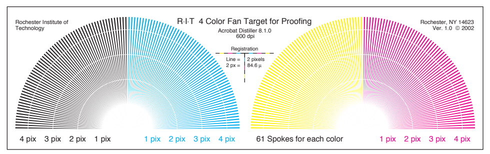


4VREP08U.EPS

Not all targets are shown at original size.

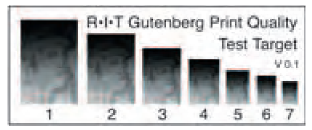


ScrPat2U.eps Documents screen angles and ruling for proofs

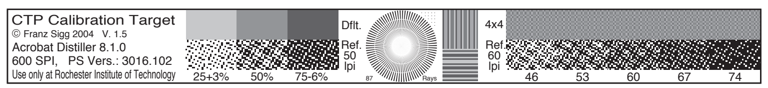


FANP10U.EPS

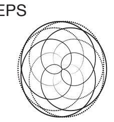
GutenbergPQ01.tif Evaluation of overall print quality

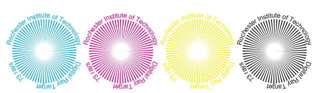


nLISS02F_ill.EPS

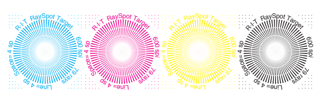


CTPEX15.EPS Customizable target plate making

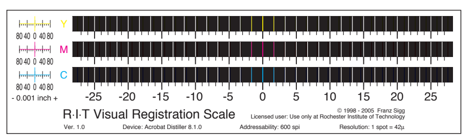




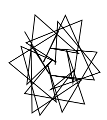
RA73T_U.EPS, There is also a version with 37 rays



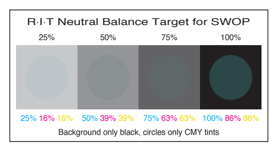
RAYSPT2U.EPS, Adjustable Ray Target. Rays in terms of spots. Can be used to check printing and focus of laser imager.



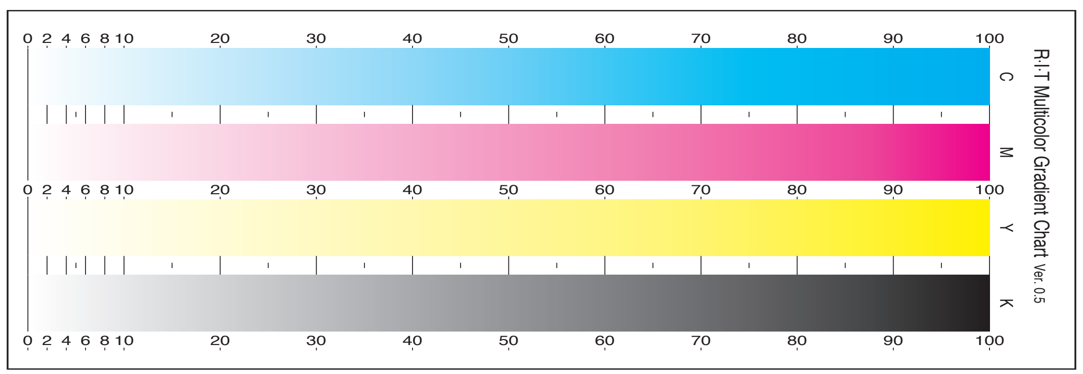
VREGH10inU.EPS Comes in inch / metric and horizontal / vertical versions



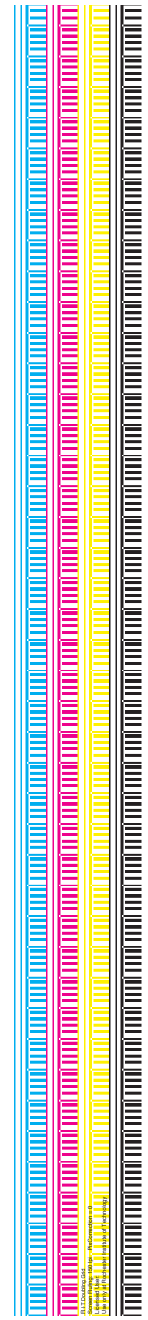
LISS02Ymac.EPS



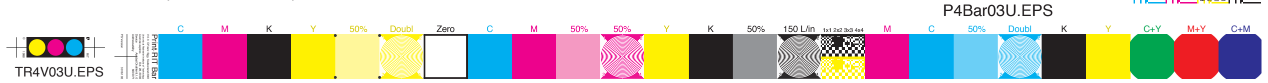
SWGR04U.EPS



GRAD05U.EPS Overprint colors and Spot colors can be added



P4Bar03U.EPS



TR4V03U.EPS

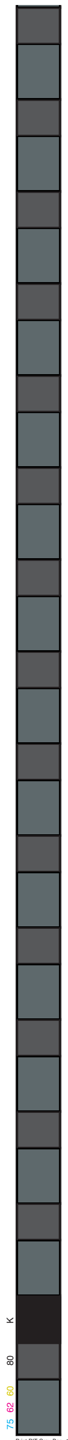
GCRBar4U.eps

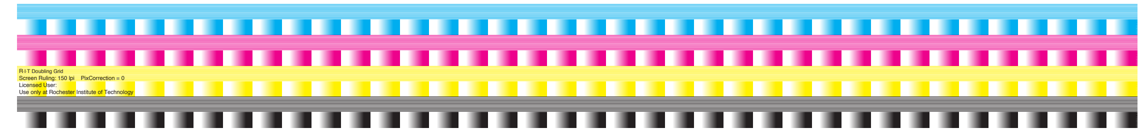
Total Area Coverage Chart (TAC)

For Total Area Coverage Determination of a CMYK Output

Press	Goss Sunday 2000 Web	**Premedia**	InDesign CS3
Paper	New Page Sterling Ultra gloss	**Notes**	Legacy CMYK
	Web Gloss 100#	**Prepress**	Prinergy

RIP Information:
Acrobat Distiller 8.1.0
600 spi, 42.3 µ/spot
PS Version: 3016.102
PS Language Level: 3





DG4CE11U.EPS

TAC Chart v 1.3 RIT, 2003	45 C 36 M 36 Y	58 C 47 M 47 Y	70 C 58 M 58 Y	82 C 70 M 70 Y	95 C 84 M 84 Y	100 C 88 M 88 Y
A1 paper	B 117	C 152	D 186	E 222	F 263	G 276
2 50 K	167	202	236	272	313	326
3 60 K	177	212	246	282	323	336
4 70 K	187	222	256	292	333	346
5 80 K	197	232	266	302	343	356
6 90 K	207	242	276	312	353	366
7 100 K	217	252	286	322	363	376

TAC_CMYK(v1.3).tif

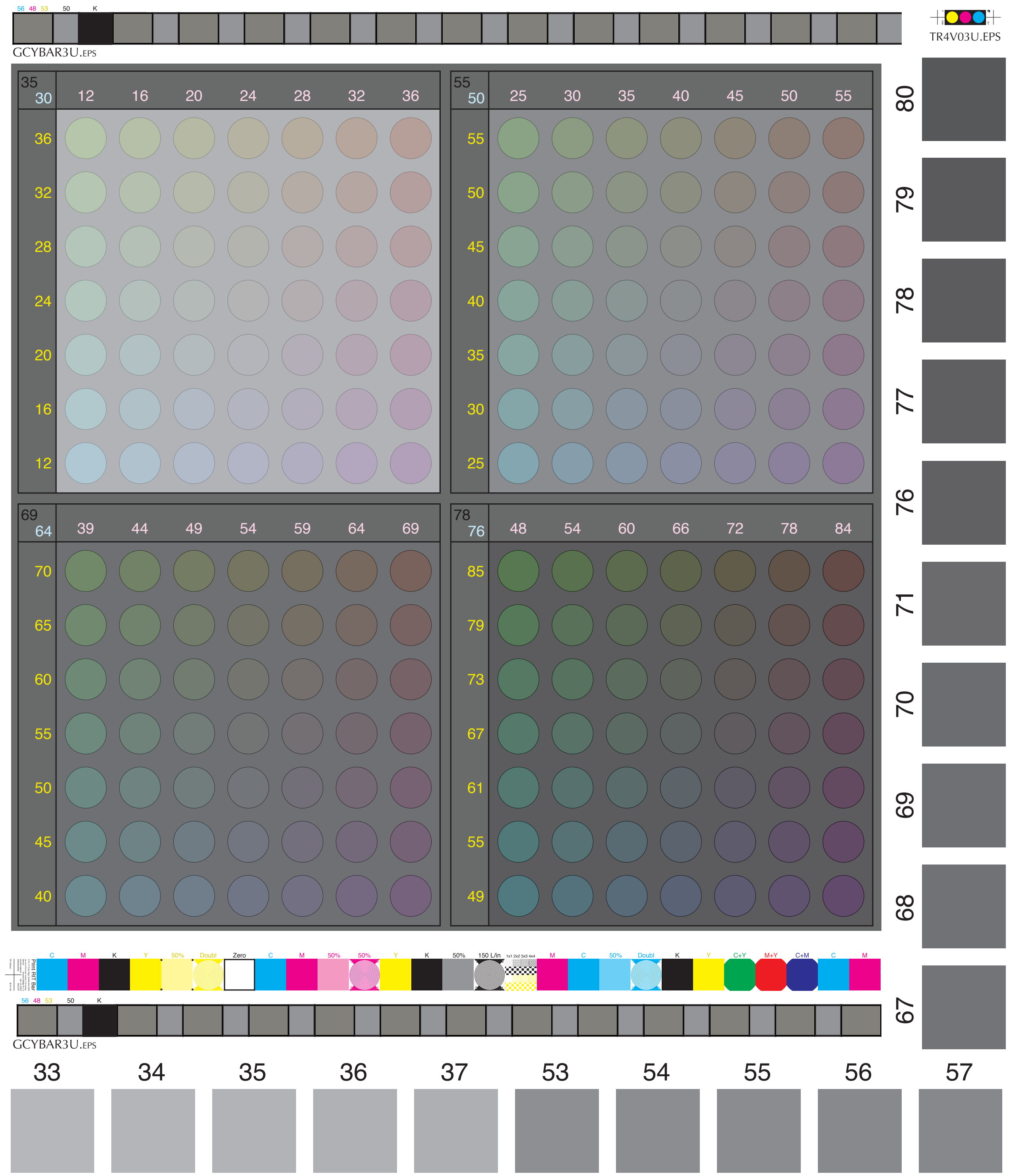
GCRBAR3U.EPS

RIT Gray Balance Chart

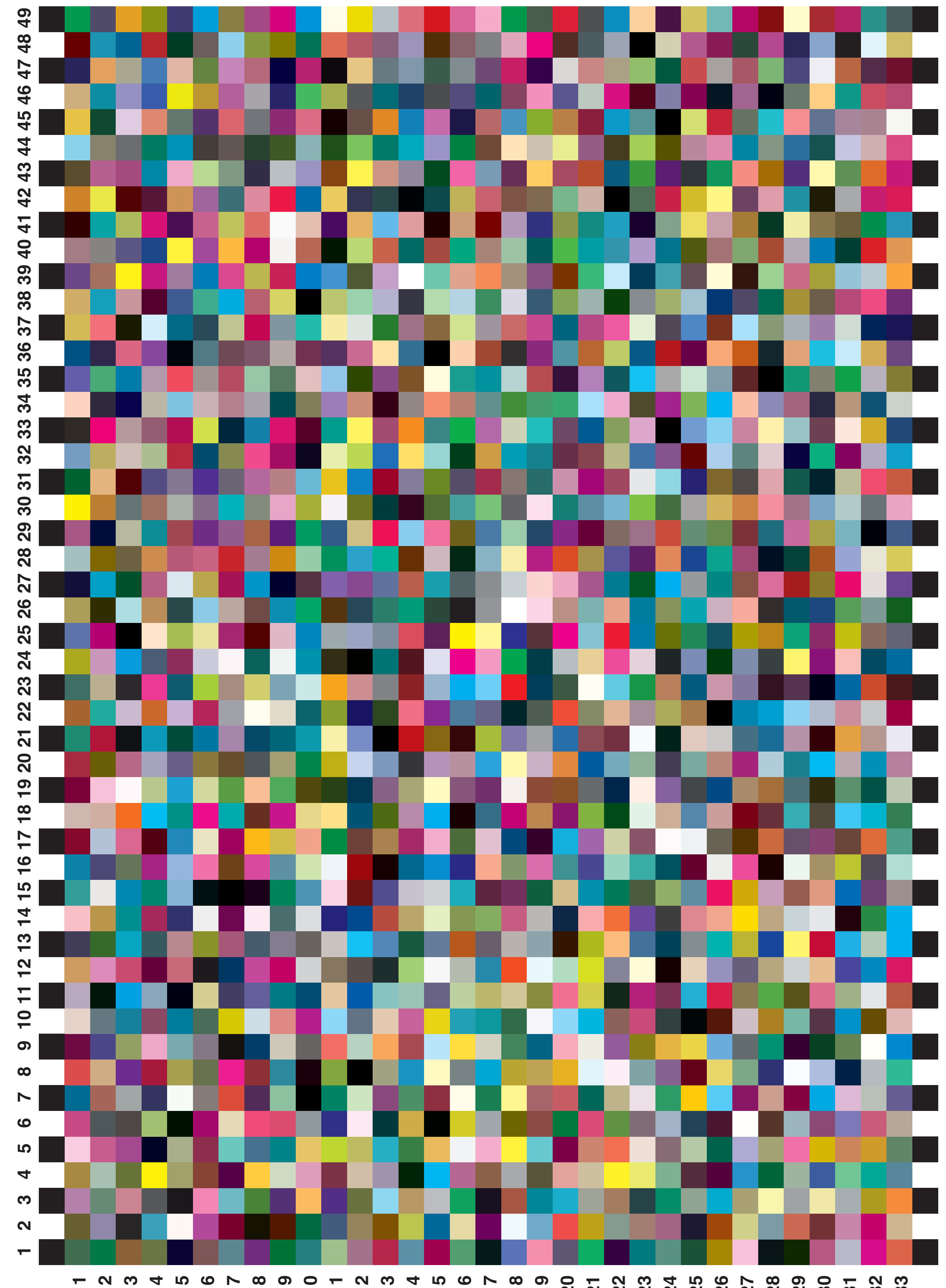
Press	Goss Sunday 2000 Web	**Premedia**	InDesign CS3
Paper	New Page Sterling Ultra gloss	**Notes**	Legacy CMYK
	Web Gloss 100#	**Prepress**	Prinergy

RIP Information:
Acrobat Distiller 8.1.0

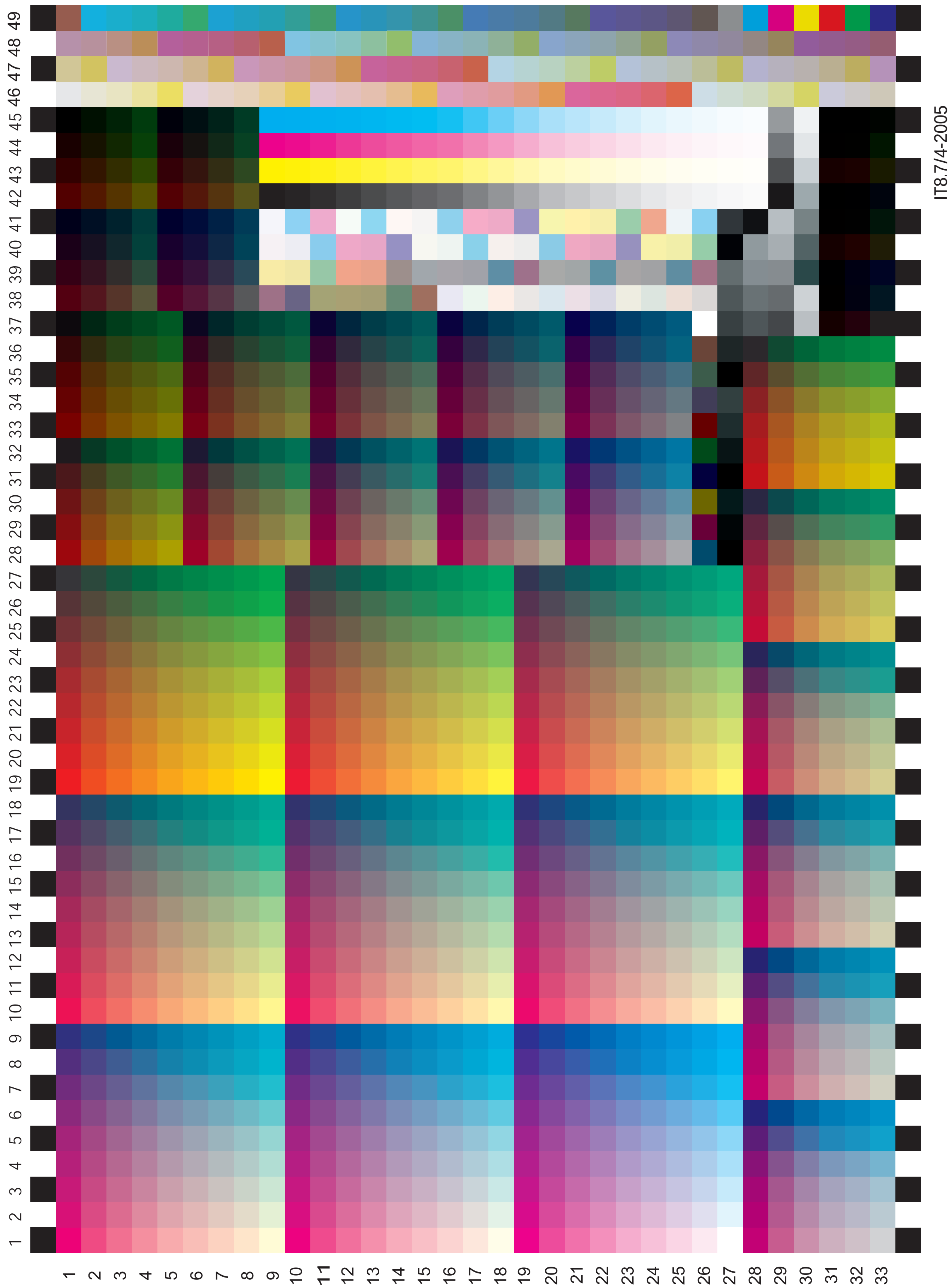
600 spi, 42.3 μ/spot
PS Version: 3016.102
PS Language Level: 3



IT8.7/4-2005 Random



IT8.7/4-2005 Visual



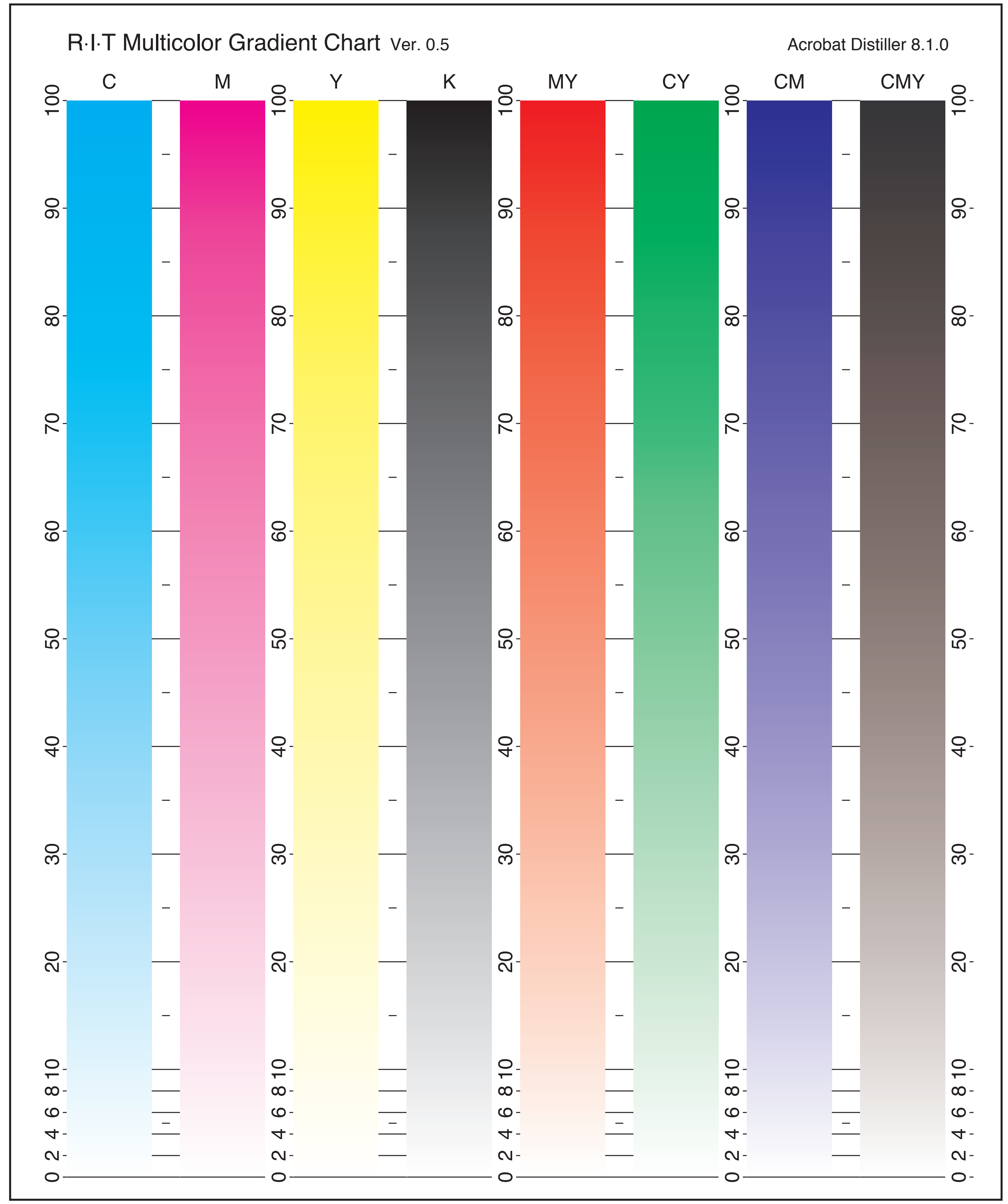
RIT Multicolor Gradient Chart

Press Goss Sunday 2000 Web
Paper New Page Sterling Ultra gloss
Web Gloss 100#

RIP Information:
Acrobat Distiller 8.1.0

600 spi, 42.3 µ/spot
PS Version: 3016.102
PS Language Level: 3

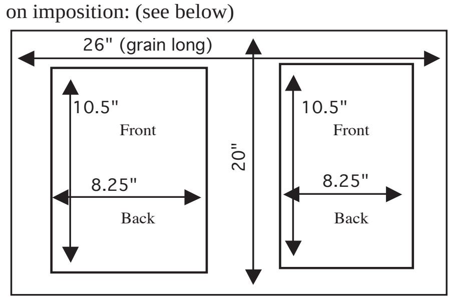
Premedia InDesign CS3
Notes Legacy CMYK
Prepress Prinergy



Press Run Organizer - Heidelberg SM 74

Project description:	**Test Targets 7.0 Cover**	Printing description: (1) Prepare publication cover using Illustrator CS3 and distill as PDF/X1a file; (2) prepare CtP using Creo Prinergy; (3) print to specifications (3 spot colors + black) using Heidelberg SM 74; (4) ship 2,000 for bindery. (1000 sheets - 2 up)
Press date:	Tue., Oct. 30, 2007	
Project leader(s):	Bob Chung, Franz Sigg, & Sri Prakhya	Product description: Cover printed by three spot colors plus black; five 16-page signatures of text printed by Goss Sunday 2000; 8 pages with folded panels, printed on NexPress; Binding: die score and PUR adhesive; trimmed to final size 8.25" x 10.5" - total 92 pages; Final quantity: 1,500
Telephone No:	475-6806 (CMS Lab)	
Today's date/time:	10/25/07	
Prepared by:	Bob, Fred White and Barb Giordano	

Job Specifications		Production Notes / Quality Assurance
PREPRESS		Notes on digital workflow:
Contents:	2-up: Front & back cover + type on spine	Paginated as reader's spread in Illustrator CS3; PDF/X-1a using Prinergy PPD and JobOptions as single page; Impose in Preps according to the imposition layout; Make sure 1/8" bleed is included in pagination; spine 7/32"
Color control bar:	Solids	
PROOF		Note on imposition: (see below)
Manufacturer:		
Brand:		
Proofing guide:		
RIP/PLATE	Creo Prinergy 3; 150 lpi AM	
Manufacturer:	CREO VLF 2400 dpi	
Brand:	KPG(12mil); thermal Gold	
Plate exposure guide:	Rex28.eps, Kexp34.eps	
PRESS		
Manufacturer:	Heidelberg sheetfed offset press	
Brand:	Heidelberg 6-color SM 74	
Size (max):	20'x29' (max)	
FOUNTAIN SOL'N		Notes on server: smb://cias-files.rit.edu/courses; then push to PAL server
Manufacturer:	Printer Services	
Brand:	Prisco 2451 + Alkaless 3000	Notes on RIP and screening:
pH/Conductivity:	pH 4.0 buffered; Conduct. 2100	RIP: Creo Normalizer JTP; PS Version: 3011.104
BLANKET		
Manufacturer:	Day International 3000	
Brand:	Patriot	
Packing:	0.006" over bearer (all units)	
INK	Pantone 7466 C, 1788 C, 361 C (5.0 Lbs each) are supplied, Black	
Manufacturer:	Superior Ink	Production schedules:
Brand:		Cover press run by SM74: Wed., Oct. 31, 2007
Temp./Tack:		Body by Goss 2000: Tue., Oct. 30, 2007
PAPER		GVI by Nexpress: Oct. 22 - 24, 2007
Brand:	NewPage Sterling Ultra	Bindery by Riverside: Thur., Nov. 1, 2007
Basis weigh / Size:	100# gloss cover, 20x26, grain long	Finished book delivery: Fri., Nov. 9, 2007
Quantity:	3,000 (incl. 2,000 for makeready)	Distribution: Paper donor 200
PRINTING	Reference:	RIT/PAL 200
Ink-down sequence:	3 spot colors + Black + aqueous (overall)	RIT/Sloan 200
*Solid ink density: **(±0.10)**	K: n/a	RIT/SPM 900



Approximate Lab values:

	L*	a*	b*
1788 C	53.29	71.36	46.24
7466 C	57.58	-52.94	-25.05
361 C	59.88	-50.68	47.59

Tolerance ΔE of 4 or less (D50 2º observer)

Dot gain: **(-3%/+6%) K: n/a

SAMPLING & REPORTING: Per Franz Sigg's input

Press Run Organizer - GOSS Sunday 2000

Project description:	**Test Targets 7.0 Body**	Printing description: (1) Prepare publication text using InDesign CS2; (2) prepare CtP with 175 lpi AM screening by Creo Prinergy; (3) print to specifications using Goss Sunday 2000 as indicated; (4) ship 2,000 signatures for bindery.
Press date:	Mon., Oct. 29, 2007	
Project leader(s):	Robert Chung, Franz Sigg, & Sri Prakhya	Product description: Cover printed by three spot colors plus black; five 16-page signatures of text printed by Goss Sunday 2000; 8 pages with folded panels, printed on NexPress; Binding: die score and PUR adhesive; trimmed to final size 8.25" x 10.5" - total 92 pages; Final quantity: 1,500
Telephone No:	475-2722	
Today's date/time:	10/25/07	

Job Specifications	
PREPRESS	Print on both sides
Signature contents:	Five 16-page signatures
Image resolution:	300 ppi
Color control bar:	RIT Color Control Bar plus 100 %
	Take-up bars for CMY; none for Black
ICC PROFILE	GRACol ICC profile
PROOF	
Manufacturer:	
Brand:	
Proofing guide:	
RIP/PLATE	Creo Prinergy 3; 175 lpi AM
Manufacturer:	CREO VLF 2400 dpi
Brand:	KPG(12mil); thermal Gold
Plate exposure guide:	Rex28.eps, Kexp34.eps
PRESS	
Manufacturer:	GOSS Web Press
Brand:	Sunday 2000
Size (max):	22.75" x 57"
FOUNTAIN SOL'N	
Manufacturer:	Anchor
Brand:	#20365 Prolmage 3000 HP
pH/Conductivity:	pH 4.0 buffered; Conduct. 2500 - 2600
BLANKET	
Manufacturer:	Day International Sleeve
Brand:	
Packing:	
INK	Process color
Manufacturer:	Flint Ink
Note:	
Temp./Tack:	
PAPER	
Brand:	NewPage Sterling Ultra Web Gloss
Basis weigh / Size:	gloss 100# text, 35" wide roll
Quantity:	
PRINTING	Reference: GRACoL --
Ink-down sequence:	Black, Cyan, Magenta, and Yellow
SID (wet): (±0.10)	K: 1.65 M: 1.40 C: 1.30 Y: 1.00
Dot gain: (-3%/+3%)	K: 24 M: 22 C: 22 Y: 20
Note:	

Imposition and Signature Alignment of the Hybrid Digital/Offset Workflow

TT7 Imposition 10/13/07 version 1_fs
5 Signatures @ 8x2 pages GOSS 2000; PDF/X-3 workflow
4 Sheets @ 4x2 pages Next Press; PDF/X3 workflow

NexPress Signatures	Web Signatures	Physical Pg #	Pagination	Right Left	Front / Back of Press sheet	Category	
	Sig. 1	1		R	F	Front matter	Title
		2		L	B	Front matter	Copyright
		3	i	R	B	Front matter	Table of Contents
		4	ii	L	F	Front matter	Intro and achnowledgments
		5	iii	R	F	Front matter	Intro and achnowledgments
		6	iv	L	B	Front matter	Intro and achnowledgments
		7	7	R	B	Robert Chung	Colorimetry
		8	8	L	F		
		9	9	R	F		
		10	10	L	B		
		11	11	R	B		
		12	12	L	F		
		13	13	R	F		
		14	14	L	B		
		15	15	R	B		
		16	16	L	F		
	Sig. 2	17	17	R	F	Arvind	Softproofing
		18	18	L	B		
		19	19	R	B		
		20	20	L	F		
		21	21	R	F		
		22	22	L	B		
		23	23	R	B		
		24	24	L	F		
		25	25	R	F	Wu Hui Liu	Inkjet Stability
		26	26	L	B		
		27	27	R	B		
		28	28	L	F		
		29	29	R	F		
		30	30	L	B		
		31	31	R	B		
		32	32	L	F		
	Sig. 3	33	33	R	F		
		34	34	L	B		
		35	35	R	B	Chung, Liu, Fred	
		36	36	L	F		
		37	37	R	F		
		38	38	L	B		
		39	39	R	B		
		40	40	L	F		
		41	41	R	F		
		42	42	L	B		
		43	43	R	B		
		44	44	L	F		
		45	45	R	F	Franz Sigg	Local Image Contrast
		46	46	L	B		
		47	47	R	B		
		48	48	L	F		
	Sig. 4	49	49	R	F		
		50	50	L	B		
		51	51	R	B	Steve Suffoletto	Densitometric Gray Balance
		52	52	L	F		
		53	53	R	F		
		54	54	L	B		
		55	55	R	B		
		56	56	L	F		
		57	57	R	F		
		58	58	L	B		
		59	59	R	B		
		60	60	L	F	Franz Sigg	Wedge Generator
		61	61	R	F		
		62	62	L	B		
		63	63	R	B	Gallery	Title
		64	64	L	F	Gallery	Folded Panel in Design …
NexPress		65	65	R		Gallery	
		66	66	L		Gallery	
		67	67	R		Gallery	
		68	68	L		Gallery	
		69	69	R		Gallery	
		70	70	L		Gallery	
		71	71	R		Gallery	
		72	72	L		Gallery	
	Sig. 5	73	73	R	F	TestPages	Title
		74	74	L	B	TestPages	IT8 Basic
		75	75	R	B	TestPages	SCID
		76	76	L	F	TestPages	Synthetic
		77	77	R	F	TestPages	TAC
		78	78	L	B	TestPages	GyBal
		79	79	R	B	TestPages	IT8/4 Ran CMYK
		80	80	L	F	TestPages	IT8/4 Vis
		81	81	R	F	TestPages	???
		82	82	L	B	BackMatter	PressRunOrg
		83	83	R	B	BackMatter	PressRunOrg
		84	84	L	F	BackMatter	PressRunOrg
		85	85	R	F	BackMatter	TestTargets Team
		86	86	L	B	BackMatter	TestTargets Team
		87	87	R	B	BackMatter	TestTargets Team
		88	88	L	F	BackMatter	Paper Press Info

SAMPLING & REPORTING: Per Franz's Input

Press Run Organizer - Kodak NexPress

Project description:	**Test Targets 7.0 GVI NexPress**
Press date:	Tue., Oct. 22 & 25, 2007
Proof date:	Fri., Oct. 19, 2007
Project coordinators:	Bob Chung & Franz Sigg
	475-2722 (o)
Today's date:	10/25/07

Objectives: (1) Content preparation for Test Targets 7.0
(2) Test visual elements on Pages with folded panels

Notes: File location: CMS server

Job Specifications

TEST FORM	Number of pages: 8
Descriptions:	Each sheet is one page with folded panel duplex
Image resolution:	
PAGE LAYOUT	
Software:	PDF or InDesign CS3 - Interchangeable Exchange Document
Dimension:	12" x 18"
Color control bar:	
COMMUNICATION	
File Submission Protocol:	CD or Flash Drive
File Creation Procedure:	TT7 PDF SOP
Hard copy Proof:	Yes
DFE	
RIP manufacturer:	NexPress NexStation
Brand:	Kodak
Screening:	AM (Classic/Line)
	FM

PRESS	PAL	Kodak
Manufacturer:	Kodak	Kodak
Brand:	NexPress 2100	NexPress
Number of colors:	4	5 + Gloss
Colorant sequence:	KYMC	KYMC + clear

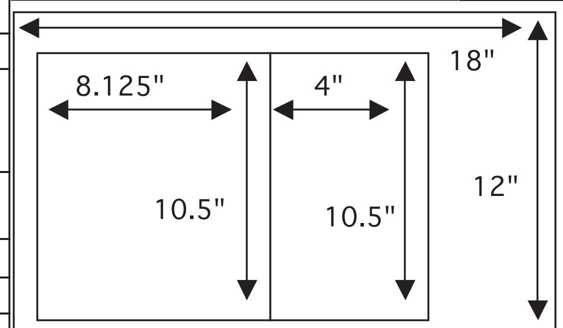
PAPER	
Brand:	NewPage Sterling Ultra
Basis weight:	gloss 100# text 18" x 12"
Grain direction:	Grain short

PRINTING	Reference:	NXP Calibration
Solid ink density:	C: 1.59	M: 1.59
(± 0.10)	Y: 1.04	K: 1.57
Dot gain:	C: 21%	M: 16%
(± 3%)	Y: 18%	K: 17%

SAMPLING	1) Short-term: None
	2) Long-term: None

Production Data

Sunday 2000	P1 AM	
	P2 AM	
NexPress PAL	P3 AM Classic	} Sheet 1
	P4 AM Classic	
	P5 AM Classic	} Sheet 2
	P6 FM	
NexPress Kodak	P7 AM Classic	} Sheet 1
	P8 AM Line + text gloss	
	P9 AM Line	} Sheet 2
	P10 AM Line + full gloss	



The Test Targets 7.0 Team

Authors

Robert Chung, *Gravure Research Professor*

Robert Chung is a professor in the School of Print Media, Rochester Institute of Technology. Bob teaches technical courses in process control and color management and has published over fifty technical papers. Bob was named the RIT Gravure Research Professor in 2004. He is the recipient of the 2007 Educator of the Year Award from the Electronic Document Systems Foundation (EDSF); the 2007 Fedrick D. Kagy Life Achievement Award from the International Graphic Arts Education Association (IGAEA); the 2006 Michael H. Bruno Award from the Technical Association of the Graphic Arts (TAGA); and the 1991 Education Award of Excellence from the Graphic Arts Technical Foundation (GATF). He can be reached at: rycppr@rit.edu

Franz Sigg, *Senior Research Associate*

Franz Sigg is a teacher, researcher, and thesis adviser to students at the School of Print Media at Rochester Institute of Technology. He holds a Master of Science degree in Printing Technology from RIT. He has spent much of his professional career developing, testing, and producing both analog and digital test targets for the graphic arts industry. Currently, he is involved in designing and programming PostScript targets for digital imaging systems. Recently Franz developed specialized test targets and test forms to help optimize and calibrate CTP systems, particularly for newsprint. Franz was the 1998 TAGA Honors Award recipient. He can be reached at: fxsppr@rit.edu.

Wuhui Liu, *Associate Professor*

Wuhui Liu is an associate professor at school of Printing and Packaging, Wuhan University where he teaches courses relating to printing color science, prepress, and printing materials. His research focuses on color management and quality control. He received his B.A. in printing science from Wuhan Technical University of Surveying and Mapping, China in 1988, M.S. in mapping Science from the same university in 1995, and Ph.D. in publishing science from Wuhan University in 2006. He has published over 30 technical papers and six books about graphic arts. He is a visiting scholar in RIT's School of Printing Media in 2007. He can be reached at: wuhui_liu@163.com

Steve Suffoletto, *Senior Training Specialist*

Steve Suffoletto is a Senior Training Specialist for RIT's Printing Application Laboratory since 1997. He trains and consults in a variety of subjects for public seminars at RIT and custom programs at the customer's site in the United States and Canada as well as Mexico, Barbados, Australia, France, England, Belgium, Trinidad, and Guatemala. Steve attended RIT and received his degree in 1981 from the School of Printing Management and Sciences. Steve has over 31 years of diversified industry experience and worked 10 years in production and quality management for sheetfed commercial, cosmetic folding carton packaging, and paperback book printers. Steve is a frequent speaker at tradeshows and conference across the country, especially Graph Expo in Chicago.

Fred Hsu, *Color Specialist*

Fred works for RIT's Printing Applications Laboratory as a Color Specialist. Upon receiving a Master of Arts in Graphic Communications from New York University in 2002, he started a second Master's degree from RIT's Printing Technology Program. Fred is involved in research related to process control and color management. He has extensive experience in coding macros that enable Excel spreadsheets to perform calculations and graphics for color analysis and process control applicatins. Fred can be reached at: cyhter@rit.edu.

Arvind Karthikeyan, *Graduate Student*

Arvind Karthikeyan is a graduate student from the School of Print Media, RIT, specializing in color and imaging sciences. His areas of interest include inkjet proofing, softproofing and color management. Arvind has earned a Bachelor of Engineering in Printing Technology from Anna University, Chennai India. His paper on 'Nanolithography' was published in the 2007 RIT TAGA Student Chapter journal, *Homage*. He has been working as a lab assistant under Prof. Chung in the Color Measurement Lab since Winter 2006. He can be reached at: ask1357@rit.edu

Editing, Premedia, and Design

Edline M. Chun, ***Adjunct Faculty***

Edline Chun has been a member of the Adjunct Faculty of the School of Print Media since 1993. She coordinated technical publications for the Instruments Group of Bausch & Lomb, Inc. during its divestiture period and later supervised technical publications for the Analytical Products Division of Milton Roy Company. She freelances as an editor-writer and can be reached at emcppr@rit.edu.

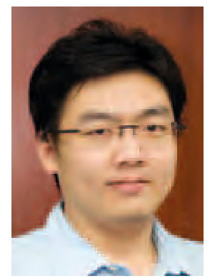
Michael Riordan, ***Assistant Professor***

Michael Riordan is an Assistant Professor at RIT's School of Print Media where he teaches coursework relating to color, premedia, and print production workflows. Through his research at RIT, he has specialized in streamlining workflow practices and works closely with publishers, print service providers, and creative agencies to help assess and optimize their production environments. Michael holds a Master of Science in Graphic Arts Systems from the Rochester Institute of Technology. He can be reached at: mprppr@rit.edu.

Sri Hemanth Prakhya, ***Graduate Student***

Sri Hemanth Prakhya is a graduate student of the MS in Print Media program at the School of Print Media, RIT. A PLGA Scholarship and GEF Resource Center Scholarship winner for the academic year 2007-08, he is about to complete his thesis on spot colors. His research projects have been extensively based in PDF & PDF/X workflows. He is also the production expediter for the *Test Targets 7.0* publication. Prakhya holds a degree in Bachelor of Technology in Mechanical – Production Engineering from Jawaharlal Nehru Technological University, Hyderabad, India. He had worked as a graphic designer for 5 years extensively in print applications; this experience led him to pursue higher studies in the field of printing. He can be reached at sreehemanth@gmail.com

Sunchut Jongcharoensiri, ***Graduate Student***



Sunchut Jongcharoensiri is a graduate student in the School of Multidisciplinary Studies at the Rochester Institute of Technology, since September 2006. His major concentration is printing technology, while business management is his minor concentration. Sunchut has worked at Pongsilp Plastic Co., Ltd., a flexible packaging manufacturer in Bangkok, Thailand, for two years. He was responsible for non-paper gravure printing such as hygienic LLDPE packages for sanitary products, PVC shrink sleeve labels, and OPP pouches. Sunchut completed his Bachelor of Engineering Degree in 2002 at King Mongkut's University of Technology Thonburi, School of Production Engineering, in Bangkok, Thailand. He can be reached at sunchut@gmail.com

Drake Yang, ***Graduate Student***

Drake Yang is a graduate student of the MFA in Computer Graphics Design program at RIT. He is also a web designer for Gravure Research at RIT and responsible for graphic design and new website of Gravure program, Color Management Systems, and Test Targets. Currently; he is involved in research related to interactive multimedia especially in Flash game design and user interface. Drake can be reached at: www.drakeyang.com

Matthew Rees, ***Graduate Student***

Matthew Rees has a Bachelor's degree in graphic design from RIT and is currently pursuing a Master's in Print Media also from RIT. His thesis research includes quantifying the variation of color within digital printing presses, as they exist in the field. Matthew is an Account Executive for Consolidated Graphics and works out of Tucker Printers, an award winning offset and digital plant based in Rochester, NY.

Print Production

This is the Print Production Team at the Printing Applications Laboratory at RIT, which has worked on *Test Targets 7.0*.

From Left to Right:

Fred Hsu Color Specialist
Barbara Giordano Operations Manager
Dan Gramlich Sheetfed Press Technologist
Neil Nowatchik Web Press Technologist
Dick Gillespie Web Press Technologist
Ed Pask Lead Web Press Technologist
Amanda Rice Student, School of Print Media
Bill Garno Director, Printing Applications Laboratory
Christina Stoll Student, School of Print Media
Fred White Manager, Press Operations
Jeremy Vanslette Manager, Digital Lab
Josh Messing Pressroom Assistant
John Dettmer Digital Systems Technologist

Cover printed at RIT's Printing Applications Laboratory on the Heidelberg Speedmaster 74 Sheetfed Press on NewPage Sterling Ultra Gloss 100# Cover, using spot color inks made by Superior Ink Co., Inc.

Body printed at RIT's Printing Applications Laboratory on Goss Sunday 2000 Web Press on NewPage Sterling Ultra Web Gloss 100# Text using Flint inks.

Pages 59 to 62 printed at RIT's Printing Applications Laboratory on the NexPress Digital 2100 Press on NewPage Sterling Ultra Gloss 100# Text.

Pages 63 to 66 printed at Kodak Digital Printing Solutions, Graphic Communications Group on a NexPress Digital 2500 Press on NewPage Sterling Ultra Gloss 100# Text.

Books bound by The Riverside Group, Rochester, NY.

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