The Science of Tuning Color on Toner-Based Copiers/Printers

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Keywords: color inconstancy, digital printers, electrophotographic printing, ICC profile, print quality

Abstract

This Technical Innovation paper is a summary of experience acquired while tuning many production printers and copiers installed at customer sites in-order to optimize color accuracy, consistency and image quality. The emphasis is on tuning device, profile and calibration properties, and does not simply present profile building or color validation techniques. The majority of this experience has been gained while tuning Ricoh printers and copiers, but concepts apply to other toner-based devices. Examples and processes are as used on EFI Fiery RIPS, but practices apply to other RIPs with minor change. This document identifies needed processes and components without full operational details; relevant vendor service documentation should be consulted.

Introduction

Tuning color and image quality optimization is a process that must begin at basic machine setup. A printer/copier must first be operating properly, in a consistent and repeatable manner before consistent and accurate color reproduction can be achieved, and maintained. A three step process is recommended:

A. Print engine setup

B. Densitometric tuning for conciseness

C. Colorimetric tuning for accuracy

Each of these steps is addressed in this document. Each must be performed and maintained to achieve optimized color and image quality.

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Print engine setup

The print engine must be installed and maintained to specification. Mechanical, electrostatic and paper handling properties need to be working to their intended purpose. Basic imaging artifacts need to be corrected.

1. Confirm that the machine has been properly installed, with all components level and aligned. Correct any media jamming, media creasing/folding etc. issues. A front-to-rear out of level condition of as little as a degree or so can cause the toner/developer mixture to migrate to the low side of the developer housing, creating density differences.

2. Perform any Preventative Maintenance (PM) needed indicated by specification or observation. Replace any imaging components (optical drum, cleaning blades, drum charging unit, developer, etc) that are nearing the end of their PM lifetime, or that are showing less than expected performance.

3. Examine printed output for banding more pronounced than is expected for the model of print engine. Consult relevant service bulletins for corrective action as needed.

4. Examine printed output for fine line streaking. These are streaks more narrow than would be attributable to laser shading segments. Fine-line streaking is normally attributable to issues with the imaging drum, charger, imaging drum cleaning blade, contamination on the laser shield glass, or contamination behind the doctor blade in the developer unit. Consult relevant service bulletins for corrective action as needed.

5. Examine printed output for lack of voids. Voids are small, randomly distributed light/white spots. Voids are usually the result of incomplete toner transfer at the PTR (Secondary transfer), and are usually related to use of heavier weight, uncoated media, or very low humidity. Voids will cause a reduction in d-max, and will cause problems in color conciseness and accuracy. Voids may frequently be improved by adjustment of the secondary/PTR transfer bias settings, found in the paper catalog entry or machine settings.

6. Select Productivity or Quality priority option in the engine. Selecting Quality will maximize IQ but reduce productivity by applying more frequent engine operation checks, possibly during jobs. The Productivity option usually limits engine checks to less frequent intervals between jobs.

Densotometric tuning for conciseness

“Densotometric conciseness” is defined as achieving an even and controlled (i.e., concise) toner deposition across the printed sheet achieving consistent density levels. Differences in density level across the sheet will translate into errors in achieving accurate calibration, as well as causing hue, density and chroma shifts. The transforms embodied in the Fiery calibration set, and in the Fiery ICC output profile can only correct for a single, static variation in density/hue/chroma for any given input value. The measurement process used for calibration and profile building can only measure the density and color at a single point on the printed page, or at best average two or more points. The resultant correction built into the calibration set and into the output profile can correct for only a single error. They cannot correct for differences across the page. The problem is compounded when trying to achieve matching color on two or more machines. In other words, color accuracy is directly tied to density consistency. For dry toner based engines, a density variation range of 1-3 delta L (<2 preferred) is realistic. The density consistency process, commonly referred to as linearization, can be effected on most machines by laser power adjustment in multiple segments across the primary image formation component (i.e, optical drum).

Density consistency, also called Linearization, can be achieved in several manners:

1. Factory tuning. It is expected that occasional re-tuning will be required during the life-span of the machine.

2. Laser power adjustment based upon visual inspection. Many engines provide an interface for such adjustment accessible to the service technician and optionally the user. Linearization based upon visual inspection usually yields sub-standard results.

3. Laser power adjustment based upon an instrumented approach. Density measurements are made across a test chart, corrective values computed and input into the engine.

To summarize, a printer/copier CANNOT be accurately color tuned unless it first has uniform density across the page.

As an example, Figure 1 displays density variation across the printed sheet prior to linearization for Magenta. The curve shows a reduction in density from left to right of 2.45 delta L.

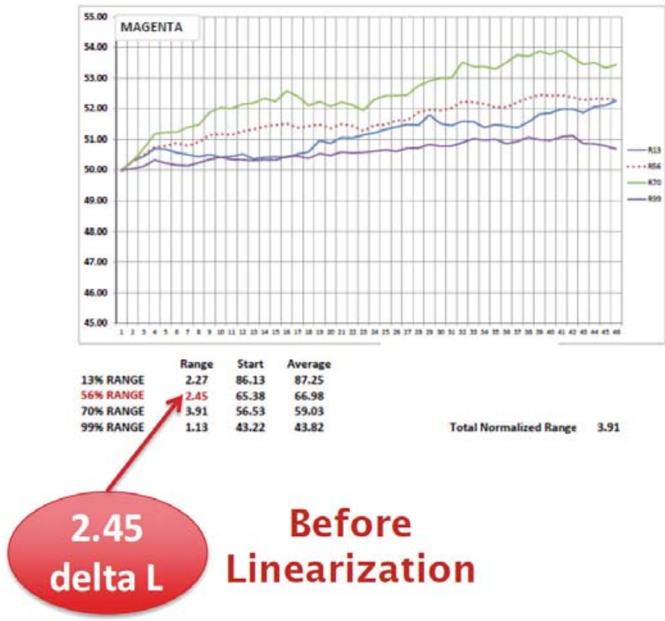

Figure 1

Figure 2 displays an improved density consistency post linearization for Magenta. Density consistency has been improved to .82 delta L. All toner colors need to be linearized individually.

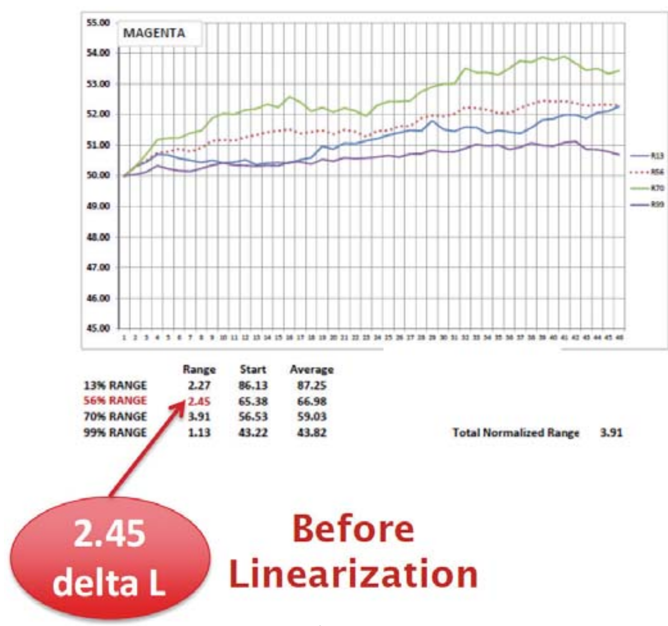

Figure 2

Colorimetric tuning for accuracy

Colorimetric tuning is the method to achieve accurate, repeatable color on a printer/copier, after the machine has been properly setup and has achieved consistency density across the page.
Colorimetric tuning is a component of a complete color workflow, all of which must be done accurately and correctly to achieve accurate color. Factors are:

1. Source color space
2. Media parameter setup
3. Source color space designation
4. Output color profile
5. Output calibration set

Each of these is covered in detail below.

1. Source color space

Color files to be printed use a color space, even when not known by the customer. In general, the source color space is either RGB or CMYK. For most customers, RGB is preferred. RGB usually comes in one of two flavors: sRBG or AdobeRGB. The key difference is the size of the gamut, with sRGB having a smaller gamut than AdobeRGB. RGB is usually preferred since most sources (scanners and digital cameras) generate RGB, and most display screens use RGB as a native representation. Some customers use CMYK as a source color space, with many flavors possible; SWOP, GRACol, ISO, etc., each with multiple variants. The CMYK color spaces usually characterize the achievable gamut of a particular printing technology (ink and press type) on a certain class of media. Since EP digital printers use toner, they can usually only emulate rather than natively match the CMYK printing standards. The CMYK source space may also be used to emulate the lowest common denominator of two or more digital printers/copiers when matching output between the multiple printers/copiers. In any case, the source color space and variant must be known for optimum output color. A tag or profile is frequently placed into the source file to identify the color space being used. The tag may be directly read in the Fiery job parameters. If the source color space is not known or discernable, experimentation must be used to find the closest match.

Other parameters specified in the Source area of the Fiery job setup pertaining to color are:

Processing method : Almost always leave at the Full Output GCR default, allowing GCR parameters in the output ICC profile to specify black channel generation. Setting this parameter to Full Source GCR may cause color translation problems and should be avoided. Full Source GCR attempts to maintain the GCR specification found in the source ICC profile. The source profile may use a Total Area Coverage (TAC – Also known as the toner limit) higher than used by the applicable printer/copier. Most digital printer/copiers use 240%-320% as a toner limit, while industry standard (i.e., SWOP, GRACol) spaces may use TAC limits up to 330%. Since the source space TAC limit cannot be achieved, unknown translations may occur. It is better to use the GCR specification found in the output profile which can be tuned for the output device.

Rendering type : Usually set to Relative Colorimetric which assures maximum colorimetric accuracy of in-gamut colors. The default Fiery Presentation designation increases chroma of many in-gamut colors, rendering them inaccurate. Photographic (Perceptual) also changes many in-gamut colors, but may be useful if the shadows tend to block-up.

2. Media parameter setup

Fiery job parameters related to media setup and imaging style must be consistent for the customer's job, as well as for the related profile generation and calibration pages. Specific determining factors are;

Fuser temperature: Higher fuser temperature results in increases in gloss and density. The primary specification for fuser temperature is Paper Weight, with a lesser degree of control through paper type (Plain, Glossy, Matte). Fuser Nip (dwell) and direct Fuser Temperature setting in the paper catalog entry also have an effect on fuser temperature. Figure 3 shows density changes caused by fuser temperature on a Ricoh C901:

	CYAN	MAGENTA	YELLOW	BLACK
Low Temp	1.77	1.57	1.04	1.74
High Temp	1.96	1.66	1.08	1.96

Figure 3

Halftone Mode: Also known as screening type. Specifies whether line or dot screening is used, and in some products, the halftone resolution (lpi) and native resolution (600 or 1200).

Resolution: Effective pixel addressability, collected pixel size and gray tone possibilities. May be specified combined with Halftone Mode.

These job properties must be decided upon prior to any further color tuning, and used for all customer jobs, calibration sheets and profile targets for the applicable job/media setup. Of course, any given machine and customer may use one or more job/media setups with varying parameters.

Any adjustments determined in Print Engine Setup should be made by application engine mode and/or a paper catalog entry and used for all applicable prints.

3. Source color space designation

The color space and variant used to create the job must be designated in the Fiery job parameters. The easiest and most consistent way to do this is via the Use Embedded Profile When Present checkbox in the color setup tab which is only effective when the job contains an embedded tag/profile. This is usually the first item to check when printed colors are significantly different than expectations. For example, AdobeRGB jobs printed as sRGB appear flat, sRGB jobs printed as AdobeRGB appear too dense with high chroma, and flesh tones in GRACol/SWOP jobs printed as ISO appear rather sun burnt.

4. Output color profile

The combination of the ICC output profile and the calibration set adjust for the white point, imaging characteristics and d-max capability of the output media. For standard color, the output profile may have less effect on color than does the calibration set and other factors described previously. In most cases, the standard Fiery output profiles may be suitable for most customers on most media. After machine setup and linearization, the machine should be calibrated on the target media and test prints made using the applicable standard Fiery profile. Only if results appear unacceptable or sub-optimal should the time be spent to create custom output profiles.

If a custom output profile is necessary, it can be built using the EFI Color Profiler Suite or other profiling suite. Although detailed scientific tests have not been performed, the standard 928 patch target seems to provide suitable results on Ricoh printer/copiers. (Extended targets up to about 3000 patches have shown to improve gray scale linearity and accuracy in some cases). CPS Ver 4 supports the use of an iSisXL spectrophotometer to reduce the time and effort to read the test patch pages. Otherwise, an ES-1000 or ES-2000 can be used. Specific settings are:

Optimized: Creates custom calibration d-max calibration targets as read from the profile test patch page(s). This setting should generally be left ON, which is the default for Ricoh printer/copiers. Only the d-max end-point is read from the target. The intermediate curve is calculated using a general formula and does not follow any unique density variations in the printer/copier.

Black Generation: Specifies toner limit and GCR parameters. Specifying a black toner maximum of 95% instead of the default 100% will provide a smoother tone and gloss generation in the deep shadows. If designated at 95%, TAC reaches a 180-260% value in the shadows, while designating at 100% usually causes a TAC drop to about 130%. Using the 95% black specification prevents a gloss roll-off in the shadows on some media, while using the 100% black specification may reduce total toner usage. 95% is usually recommended for best image quality. A TAC (Toner Limit) value appropriate to the engine should be used. Very aggressive GCR settings may reduce banding and total toner usage dependent upon the colors found in the source job. Changes to other parameters may be used for specialized purposes.

5. Output calibration set

The calibration set contains a set of target d-max measurements. Each output profile is linked with a calibration set. One or more output profiles may be linked to each calibration set, but each output profile may be linked to only one calibration set. In practice, the density targets in the profile are combined with the measured density values in the calibration set to create a 2-D transform to adjust target densities to actual achieved densities.

As of Fiery System 9, each calibration set must be calibrated uniquely. Measurements from one calibration set are not normally transferable to another calibration set. This is a change from previous Fiery System versions where a single set of measurements could be applied to all calibration sets, whether appropriate or not.

For ease of operation, a single calibration set may be used for one or more media and output profiles. Output profiles containing similar target d-max values can share a single calibration set with minimal effect on output quality. Since each calibration set must be calibrated at regular intervals, sharing calibration sets may result in time/labor savings by customers. Of course, for ultimate quality, each output profile may be paired with a unique calibration set. Pairing each output profile with its own calibration set adds to the workflow complexity, and the complexity/accuracy tradeoff should be considered.

A frequent customer question is “How often should I calibrate?”. The answer is “It depends”. For color critical customers, calibrating at the start of each operating shift, or when a new calibration set is used within a shift is recommended. On a Ricoh C901, tests have shown that 7-10 printed pages are sufficient to result in steady-state densities within the page. Thus, users are recommended to print at least 7-10 non color-critical pages prior to calibrating a machine or performing other color critical operations. Users should test stability of their own hardware.

A further question is “How close is close enough”, or “how far is too far” when comparing target to measured density values. Once again, it depends upon customer expectations. A value of ±3% has been quoted, which is very difficult to achieve and maintain given the inherent variation and noise within toner based digital printers/copiers. A more appropriate value is likely somewhere in the ±5-10% range.

Figure 4 shows the effect on tonal range and accuracy when the target density is greater than the achieved density. Shadow blocking occurs in the input range from 91-100%, and the total tonal range is reduced to 1.57 from 1.84.

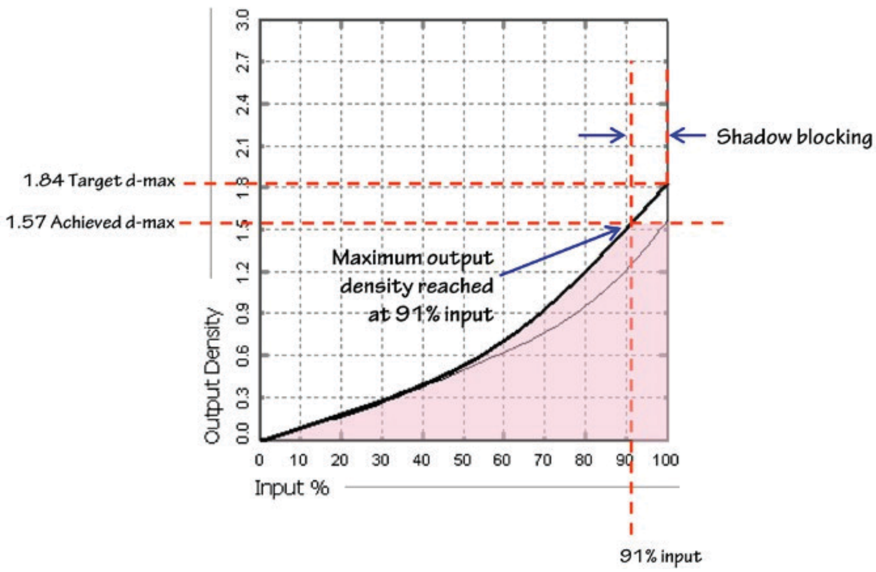

Figure 4

Figure 5 shows the effect on tonal range and accuracy when the target density is less than the achieved density. Solids are restricted to a partial 80% dot. The output range is compressed to a 1.1 density vs the 2.03 achieved density. Output dynamic range is compressed to 205 values (80/100*256=205) which may cause banding.

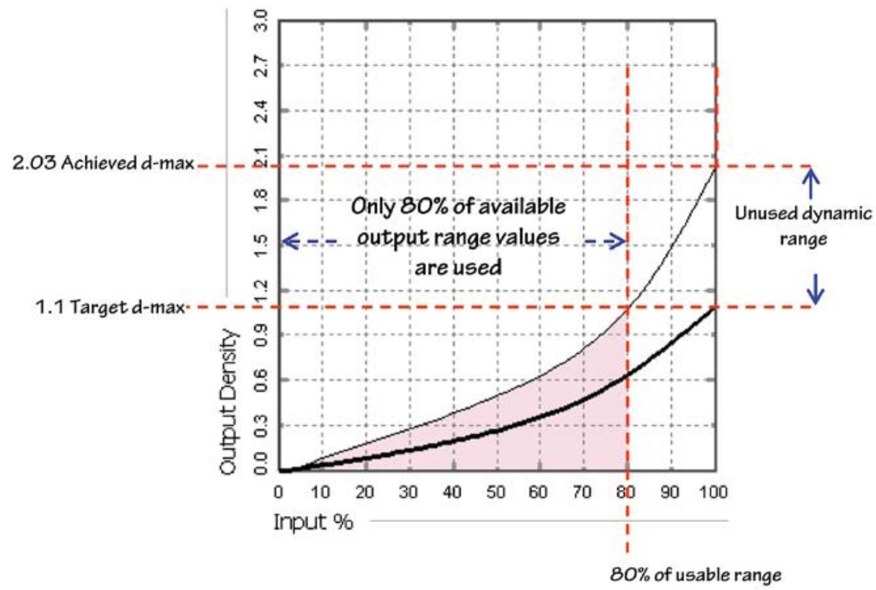

Figure 5

Output color tuning

Executing steps 1-5 usually results in meeting customer color expectations. What happens when color does not meet expectations? Most field practitioners will follow one or more of the following approaches after achieving standardized engine operation with the previous steps:

Spot Color: If color errors are observed solely in indexed/spot color, the Fiery Spot Color editor can frequently be used to adjust the colors of one or more specific erroneous colors. This approach is very effective when index colors are used. The edited spot colors can be stored as a pallet and applied to subsequent jobs.

Turning-the-knobs: The Fiery provides multiple methods of affecting the output color in a job. Some job parameters, such as the input color space, output color profile, calibration set, screening type, etc. will affect the output color, but usually in an uncontrolled fashion. Tuning color in this fashion is typically not recommended.

The color in a job can also be affected by use of the editing capabilities in the Fiery Image Viewer. The Image Viewer allows color to be edited in several ways; by curve or by specific point. When edited by curve, customer requests for "a bit more red" can be satisfied. The "specific point" capability can be used to adjust limited input colors. Selectively adjusting brightness, hue angle, saturation or black control is supported. The color adjustments made in the Image Viewer are made to a specific job, and can be saved in a form that can be applied to other jobs. The changes made in the Image Viewer can be effective for making quick changes, but lack colorimetric feedback for accurate control.

Simple output profile editing: A simple profile editor is available. This editor allows adjusting the d-max target of each toner color, and a multi-point control curve for the selected output profile. It allows editing of any of the four primary toner colors using Photoshop like curves. This capability is primarily useful for customers using CMYK input spaces, or familiar with CMYK editing. Once saved, all jobs specifying the adjusted output profile will be affected. The editing approach provides a rudimentary 2-D adjustment with limited colorimetric feedback.

Fiery CPS Profile Editor: The CPS Profile Editor provides several tools to edit the transforms contained within output profiles. Although the editor is rather complex and not well documented, it does contain rather concise methods to edit color transforms, and to provide visual and colorimetric data regarding the changes. It also provides support for using a spectrophotometer for measuring colors to be edited and verifying results. In operation, a profile and rendering intent are selected for editing, and a sample image chosen for sampling and verifying color changes. The resultant edited profile may be saved and applied to subsequent jobs, including being used as a component in a device link profile if desired.

Five editing tools are provided: Global Color, Hue Edit, Selective Color, Node Edit and Media Whitepoint. The sample print provides the capability of viewing before and after RGB and CMYK values. Some of the tools provide additional colorimetric feedback as indicated below.

- **Global Edit:** Supports global lightness, contrast and saturation changes to the profile, as well as Photoshop type curve controls on the individual CMYK channels. Similar to the Simple Output Editor.

- **Hue Edit:** Provides the capability to edit a source point/area, changing the original hue and relative saturation values to alternate values. The original value to be edited can be chosen by direct input, or by selection from the sample image using an eye dropper tool (typically more useful). A Range value supports specifying the broadness of the edit. For example, specifying a Range of 1 limits the changes to a single point in the profile, while higher values permits the changes to be made in a relative fashion over a larger volume of the profile. A Preview box allows changes to be visually observed on the demo file image. In practice, this tool seems to be rather slow in execution, especially when Ranges greater than 1 are chosen.

- **Selective Color:** Provides the capability to edit a source point/area, changing the original color value to a new value using several types of specification. The original value to be edited can be chosen by direct input, or by selection from the sample image using an eye dropper tool:

    a. **HLC:** Original and target values are chosen using hue, chroma and lightness. Indicators show the relative differences, and also limit the target values to those possible within the constraints of the output profile. The effect of the Range setting can be seen either as a preview of the changes in the sample image, or as contrasting color changes in the sample image. HLC supports very exact changes to transforms in the output profile. For example, multiple original points in the profile can be edited to the desired color using spectrophotometer readings to guide the process.

    b. **Coordinate Entry:** Original value is chosen using RGB or CMYK value, and the output value is chosen using CMYK.

    c. **Profile Cross Section:** Original value is chosen visually using a combination of identifying points in a 3D representation of the profile and sliders on a hue color indicator. Supplies a visual reference, showing the location and range of change in the 3D diagram. Supports editing of the hue angle only, and does not supply any numeric control over saturation and chroma.

    d. **Node Edit:** Original value is chosen in the source color space (usually RGB or CMYK, not LAB or other device independent space). Target is chosen in the output color space. Does not seem to be a Range control which limits the usefulness to edit very specific values.

    e. **Media Whitepoint:** Changes the white point designation in the output profile. Only affects the Absolute Colorimetric rendering type.

Global Color and Selective Color tools have been found to be most practical in use.

Color tuning case study

The customer has a long history of printing color coded labels containing bar codes for multiple industries. They have used equipment from multiple vendors to print their labels. They have a custom color pallet based upon the TruMatch system. The customer prints very detailed color sample books from which their customers select their colors. Each of these books contains over 2000 color patches from the TruMatch system. The customer had been printing on Ricoh C900s, having previously ported from another vendor's (Machine A) hardware. However, at the time of the port from Machine A to Ricoh, they continued to use the output profiles from the Machine A workflow and standardized upon the resultant colors. The history of these Machine A profiles is unknown. However, when used on a Ricoh C900, they produce significant (10-35 delta e (1976)) differences from the correct TruMatch colors. The customer has made these mismatched colors into a standard and wanted to maintain them on their recent upgrade to C901+ hardware. The objective with this customer was to match their in-house standard, rather than to match an industry standard.

TruMatch uses a primary patch page containing 50 color patches covering the entire gamut. Each of these patches is then used as a starting point for multiple variations. The primary target was to match the custom page showing the 50 samples as printed on the C900, on the new C901+ hardware.

As a first step, a basic workflow was established on the C901+ for the customer paper type. The Machine A output profile was installed and used to print a test page. Fiery "knobs" were turned to minimize color differences. Visual examination showed significant differences in many of the test patches. This approach while being simple was obviously not going to yield desired results, and also maintained an undesirable tie to old software.

We decided to perform a full machine workup and color tune, using the steps described previously in this document. The C901+ machines were examined for imaging defects/artifacts with several streaking/banding issues being corrected. Both machines were then linearized to a <2 delta level. A 928 patch target was printed with standardized parameters, read with an iSisXL, and an output profile generated with EFI CPS Ver 4. The profile was built using the Optimized setting to generate custom calibration targets. Since the customer uses internally developed label generation software, the source color space was somewhat suspect. Through investigation it was eventually identified as sRGB. After calibration using a custom calibration set, initial samples printed using sRGB and the custom profile showed significant differences in many of the 50 primary colors as judged visually.

Visual examination showed that global changes were not capable of achieving the desired color match to the 50 samples. Specific range editing was selected to edit the custom built output profile to match the customer master color book. The Fiery Selective Color Edit tool was used to edit the output profile to match the desired colors using the following sequence:

1. A visual comparison between the C901+ output and the master color book was used to select a mismatched patch to be adjusted.

2. An ES-1000 (XRITE i1) was used to measure the values and difference of the customer master color book vs. the current C901+ output. The Measure tool in X-RITE Profile Maker 5 was used, using LCh space. LAB could not be used since it is not supported in the EFI editing tools. Initial delta e (1976) values were typically in the 10-15 range, with some patches measuring as high as 35.

3. The source image of the 50 patch page was opened in the EFI Color Editor.

   The value of the target patch was read into the EFI editor using the eye-dropper tool. HLC was used as a close corollary to the LCh space as read in the Measure tool.

4. Edits to Hue, Lightness, and Chroma were made in the EFI editor based upon the values read from the master color sheet and from the sample file. Since the scales being used were not identical (HLC vs LCh), edits were made after adjusting for the scale differences.

5. The Range value was set using visual feedback from the demo page. If the Range value is set too small, the effect of the edit is constrained to a very small portion of the output profile and may not be effective. If the Range value is too large, the edit may affect too many adjoining patches, and also interfere with subsequent edits. A suitable compromise was found experimentally, typically falling between 4-7, with some cases as low as 1 and as high as 17.

6. The edited profile was written to the Fiery and a new test print made. The respective patches were measured. They would typically be found to be closer. If close enough (usually 1-2 delta e), another patch was chosen and the process repeated. If not close enough, the current patch would be iterated.

7. The process was repeated until there was an acceptable visual and colorimetric (measured) match for all 50 patches.

Approximately 98 iterations were used. The customer then printed the full TruMatch book, and compared it in several light sources to his master color book. Some differences were found in subordinate colors. On only one page were subordinate colors found to have sufficient differences to be significant.

This was likely the result of setting the Range factor too small for the affected colors. Five additional iterations were used on the subordinate colors to improve significant colors to be acceptable to the customer.

Both C901+ machines were setup to use the edited output profile for printing to the customer's two primary papers: a 24lb Bond and a 100 lb Index. Generating trial calibration measurements showed both results from both media to be sufficiently close so as to use the same calibration set. The measured calibration values were similar but not exact on the two papers. Custom calibration sets may have been needed to improve shadow detail if full pictorial data was being printed. Since this customer only prints “spot” colors on labels, the convenience of using a single calibration set was considered appropriate. (The spot color editor could not be used since the colors being printed are designated as RGB in the source files and not as indexed/named color).The customer printed his full sample books on both media on both machines and found the results to be satisfactory.

This example demonstrates the use of the Fiery RIP and Profile Editor tools, used in conjunction with a Ricoh C901+ to emulate another printer (very non- standard colors). Emulating standard colors can use the same setup and tools but would be easier. It also shows that proper machine and workflow setup can color match multiple machines to an acceptable level. Although Ricoh and EFI product were used, a similar process should apply to comparable hardware from other vendors.

Related properties

Color varies dependent upon the media type and other properties of the digital printer/copier. Color also varies across the page, page to page, and over time. This section describes some of the properties related to color constancy, and, in some cases, what can be done about it. Limitations of the digital, toner-based process are discussed as an aid to setting realistic customer expectations.

Media type: The thickness (weight) and smoothness of the sheet have a major effect on the achievable density, and on the tonal smoothness and constancy. Optimal image quality is achieved when the toner can be transferred to the sheet uniformly, and fused to an even gloss level. This is best achieved with a very smooth sheet of at least 120 gsm (80 Text) weight. Non-smooth media can result in voids as addressed earlier.

Media white point: Changes in the white point of the media can affect image color. Since toner sits on top of the paper and is not directly affected by the color of the paper, the white point of the paper primarily affects the relative color of the highlights and lighter tones. For paper of similar white points (within 2-3 delta e), achievable density usually has a larger effect on color than white point.

Toner colorants: Toner colors do not typically match ISO 12647 colorant values as specified for offset press inks. Color values must be transformed to accommodate the differences in colorant value. This transform is accomplished in the output profile which is thus mandatory in most toner-based printer/copiers.

Toner particle size: The average dry toner particle size is about 5 um (microns). By comparison, the toner particle size used in offset printing ink or inkjet ink is about 0.1-0.5 um, about 10-50 times smaller than a toner particle. The relatively large particle size in a toner based device results in a lower level of control of density, and thus color than in an inkjet printer. The large toner particle size also contributes to less smoothness in gradients and other gradual tonal changes than can be achieved in offset or inkjet printing. Organic toners (wax based) are usually more uniform in size than pulverized toner (as used in older printers), giving an advantage in maintaining uniform density/color to organic toners.

Humidity and temperature: These two factors have a significant effect on many of the imaging and toner transfer processes in the printer/copier. Humidity and temperature are sampled automatically by the hardware, with compensating adjustments made with no user intervention. However, very low humidity environments, as found in the American Southwest and inside heated buildings in the winter, can have a detrimental effect on maintaining concise and complete toner transfer. A relative humidity surrounding the printer/copier of about 15% or less may causes issues, lowering achieved density and increasing tonal inconsistency. The only fully satisfactory solution is to raise the humidity.

Banding and streaking: All toner based digital devices have a certain degree of banding and streaking. Their presence is a matter of degree. Inkjet and some offset printers have less banding and streaking than toner based devices. Banding and streaking are most evident as color/density shifts in constant tone areas, and in areas with very gradual tone differences. Customer expectations need to be effectively managed in this area.

Display monitor calibration/characterization: Workstation display colors can be used for soft proofing purposes, but only if the display is color managed and has been calibrated/characterized. Customers color errors on the printer/copier based upon visual comparison with workstation displays need to be schooled in proper techniques of display color management and soft proofing.