Process Control Characterization Data Color Management Profiles

What, When, & How They Are Related

by David McDowell, NPES/Eastman Kodak Company

I have recently noticed that in many printing related forums and discussions the topics of process control, color characterization, and color management profiles are often confused and intermixed. While these have a strong relationship to one another, each is unique. Let's look at these three topics to understand their role, how these roles have changed with the growing availability of color management and digital data, and see how they are related to one another and work best together.

Process Control

Process control of the printing process is still the cornerstone upon which quality and reproducibility depend. With color management and digital workflows, process control is even more critical than ever. That said, it is also the area that may see the greatest change and also offer the most opportunity for improvement.

Process control of color printing involves ongoing inspection and qualification of all raw materials—paper, ink, fountain solution, etc.—as well as the use of control steps to ensure that aim solid ink density, tone value increase, and trapping are achieved and maintained on the running press. For critical work, these steps are further refined by comparing the printed sheet to the supplied proof and achieving the best visual match possible. For practical reasons, today virtually all process control, once a job is on press, is based on density and data derived from density, i.e. solid ink density, tone value (apparent dot size), tone value increase, print contrast, etc.

Traditionally, when dots-on-film were the media through which we exchanged print ready "data," the only choice available was for everyone to match the color of the ink, the paper, the solid ink densities, and the tone value increase specified by industry associations such as SWOP (Specifications for Web Offset Publications). That often meant pushing the press to print outside of its optimal parameters. In actual practice the solids (and thus color gamut) are often compromised to get the "weight" of the image right (midtone gain) so the print will look more like the proof. The printer does not have (and may never have once on press) independent control of the midtowns and solids. In most cases the best match to the proof is influenced more by the midtone weight and color balance than by the color gamut, i.e. the solids.

Today, the digital workflow offers other options. Jobs are created electronically and plates are made directly from digital data. Even in those situations where film is used as the intermediate, full size films are also created from digital data. The individual shop creating the film or plates can introduce color management tools—often only single channel corrections are needed—to modify the incoming data to compensate for any differences in tone value increase, trapping, etc., between the local press and the industry aim. Too often, however, even when full color-management capability is available, at either film or platemaking, the printer does not take full advantage of this opportunity.

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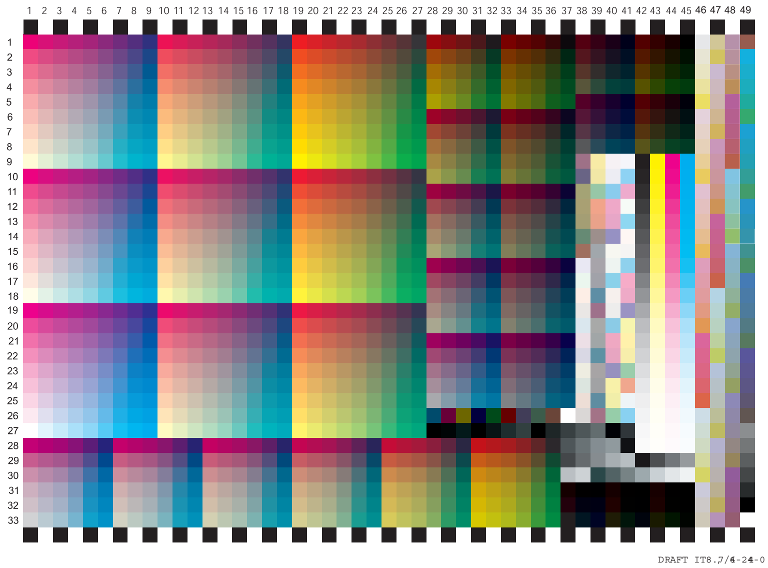
Ideally, the goal of the printer should be to determine the most stable operating point for the press—when the **color** of the solids and two-color solid overprints match the specified aims. Matching the solids and two-color solid overprints means the color gamut will be correct. However, although this operating point is a good place to operate the press, it may not match industry aims for the intermediate overprints that are affected by tone value increase, ink trapping, etc.

This requires that the printer do two additional things. First, a set of process control aims must be established for this local printing condition. Without local process control aims, even though the press is in a stable operating environment, it is not predictable or repeatable. Second, tools must be put in place to make the appropriate changes to incoming CMYK data so data that are used to make the film or plates will produce color that matches the color that would be produced using unmodified data and the industry aim printing conditions.

The approach of optimizing printing conditions of the press based on achieving the desired gamut and working at a stable operating condition with locally defined process control aims is still not widely understood or accepted. However, this is one of the few benefits to the printer (other than digital plate making) that is offered by digital data and color management. More about various ways to accomplish this later.

Color Characterization

In graphic arts printing, color characterization is simply the relationship between CMYK data and printed color. You might even think of it as colorimetric process control. Yes, we usually use many patches so the color characterization fully maps not only solids and solid overprints but also single color scales and a variety of overprints of tints at many levels. However, if a printer simply used his current process control patches and measured color instead of density that would be both a minimal color characterization and process control at the same time. Most important, building the relationship between CMYK and printed color is useless unless printing conditions can be consistently reproduced—i.e. process control is a must.



Draft IT8.7/4 CMYK Characterization Target, Visual Layout (1610 patches)

There are many different flavors of color characterization. Within an individual printing plant, presses are optimized and process aims are established for different printing substrates and job aims. In many plants, a color characterization of that press or group of presses is part of the setup process.

We also have industry groups—SWOP, GRACoL (General Requirements for Applications in Commercial Offset Lithography), SNAP (Specifications for Newsprint Advertising Production)—and major print buyers (for example in packaging for consumer product companies) who create color characterization data to be used as the reference aim for proofing and data exchange. (This type of color characterization data is sometimes called reference characterization data or a reference printing condition.) Such reference data should always be accompanied by a definition of the printing process aims used to achieve the data along with a clear definition of the ink and substrate used.

However, once established, such reference data can standalone. This is particularly true in the area of digital proofing. Here, non-halftone proofing devices use color management to provide an emulation of the printed piece that matches the reference color characterization data, even though the colorants and substrate may not be the same as those used for the final printing; and the device process control bears no relationship to the process control aims used to create the reference. Sounds a little like black magic.

Color Management Profiles

Color management profiles are relatively easy to define but difficult to create and understand. We will focus on CMYK output profiles and only touch on other types of profiles—they are another article all by themselves. We will also restrict our discussion to the color management model and profile definitions of the International Color Consortium (ICC) and documented in ICC.1, *Image technology color management—Architecture, profile format, and data structure.*

First, the definition: In its simplest form, a color management CMYK output profile is simply a mathematical model of the relationship between color and CMYK data. That mathematical model is expressed as a set of transforms. The ICC profile specification (ICC.1) defines allowable forms that these transforms may have, their encoding, the colorimetric details required in the characterization data, and the metadata that must be included with the transforms.

The "color" reference in a profile is the so called "profile connection space" or PCS. That is the color reference through which input and output data is "connected" in a color management system. However, in the colorimetric intent mode, color in the PCS is closely related to color on the printed sheet. And, in fact,it is the relationship between CMYK data and the color that is printed in a specific process—the color characterization data—that is used to begin the profile building process. However, in addition to modeling the relationship between printed color and CMYK input data, profiles also include the computations necessary for color separation; black printer generation (including UCR and GCR); perceptual and saturation intents; and gamut compression. All output profiles must contain transforms for all three intents—colorimetric, perceptual and saturation.

The software used to build profiles from color characterization data is largely proprietary. Modeling a particular printing process based on the discrete characterization data is a significant task that involves color science, three-dimensional scaling and smoothing of data, as well as elaborate multi-dimensional curve fitting. In addition, each company that provides profile building software uses different schemes for color separation, black printer generation, and gamut compression. Each has advantages and disadvantages—there is no single or best answer.

When used in the colorimetric mode, these transforms allow the printed color to be calculated for any set of CMYK data. (As an aside, all profiles based on the same characterization data should give the same answer when going from CMYK to color, regardless of profile software vendor.) That is the easy part. However, the more typical use of profiles (even in a colorimetric mode) is to calculate the CMYK data required to print a specific color within the color gamut of the printing condition associated with the profile. This requires that specific choices (or assumptions) are made before the black printer can be calculated because there is no unique solution.

Thus, although profiles are based on color characterization data, they are much more elaborate and contain color science input and capabilities provided by the company that created the profile building software. The bottom line is that many different profiles can be created from the same characterization data.

In the colorimetric mode they should all provide the same definition of the color associated with any set of CMYK data but may all differ in the identification of the CMYK data to be used to produce a specific color. More about the implications of that later.

Process Control Specifications vs. Reference Characterization Data

The relationship between industry process control specifications and reference characterization data are one of the more obvious areas of confusion. One of the key principals in establishing specifications is that parameters should not be "double dimensioned." If they are, there will inevitably be conflicts where one parameter is met and the other is not —which is correct?

Therefore, once an industry group decides to prepare a set of color characterization data as reference for a specific printing process, their process control aims must become secondary. Because these process control aims represent achievable printing conditions, they are the best aims to use for the printing test to create color characterization data. However, such color characterization printing tests will **not** exactly match the aim values of all of the process control parameters. In addition, there may be printing issues that impact the printed color that are not covered by the process control aims.

The industry group must decide if the color characterization data (and the print run that produced it) is realistic and representative of their printing goals. If it is, the color characterization data should become the primary reference. The process control aims are then background information for color characterization data and are useful for printers in preliminary setup and or checking. If both are retained as primary definitions, there will inevitably be conflicts and confusion.

SWOP is the best example of the widespread use of reference color characterization data. Some time ago, SWOP made the following statement with respect to remote proofing, "When color management is employed, the characterization data in ANSI/CGATS TR001 must be used as the aim point. ANSI/CGATS TR001 documents the colorimetric characterization of the CMYK to CIELAB relationship for print conditions that are used to reproduce SWOP Certified Press Proofs."

SWOP also made a comparable statement with respect to color management profiles—a very strong step into the future. However, SWOP has not clearly defined the relationship between process control aims and the color characterization data of TR001.

How Is Reference Characterization Data Used?

First, a little about color management systems. The basic way in which a color management system works is that it uses the transforms contained in profiles to change data from one data space to another. Usually one of these data spaces is the colorimetric data space called profile connection space or PCS. This is a data space in which everything is defined colorimetrically in CIELAB (or CIEXYZ). This is often referred to as a device independent space. The other data space can be any CMYK for which there is characterization data, one of the defined RGB spaces, a defined scanner data space that again must be characterized, etc. Profiles are tools the color management system uses, but profiles are based on characterization data—as the old saying goes, "You can't have one with out the other."

The way in which reference color characterization data are used is that when a trade association or standards committee publishes such data as a reference, that reference color characterization data become a tool that can be used several ways. First, because these data are publicly available, many profile builders will build (and sell) profiles based on these data. Individuals with appropriate profile building software can also build their own profiles based on these data. Second, desciptions of such reference data are usually posted on the ICC Characterization Registry, which is maintained by the International Color Colnsoritum (ICC) at www.color.org. For reference color charaterization data included in the registry, it is much easier to point to a particular printing condition/specification without actually including all of the data. In fact, the PDF/X family of standards requires that either a pointer to reference characterization data on the ICC website or an output profile be included in every PDF/X file to define intended printing conditions (in the Output-ConditionIdentifier key).

With color managed workflows, users process scanner data (with appropriate scanner profiles) and/or computer generated or edited color data (usually in profiled sRGB) through the combination of the input profile and an appropriate CMYK output profile to generate the CMYK data for the intended printing process. Typically, for initial generation of CMYK data, the perceptual intent is used to bring the color of the input data within the available color gamut of the intended printing condition. The control of gamut compression, black printer generation, etc., is through the choice of the parameter settings used to create the output profile selected for a particular job or part of a job. If the final page or job assembly is being done in CMYK, different output profiles (all based on the same reference color characterization data) can be used for different elements in the job. This is not true for so called color-managed or RGB work-flows—we will go into those work-flows in another article.

A Quick Overview

Process Control - Characterization Data
Color Management Profiles

Process control, either based on industry aims or local aims, is critical to maintaining repeatability and consistency in press operation.

Color characterization data tabulates the relationship between CMYK data and color for a specific set of inks, paper, and printing process control aims.

Reference color characterization data tabulates the relationship between CMYK data and color for the specific set of inks, paper, and printing process control aims associated with an industry specification or standard.

CMYK output profiles are a set of mathematical transforms that are based on color characterization data but also provide the gamut compression, color separation, and black printer generation functions necessary for the creation of CMYK data. These functions may have multiple settings and be based on various technologies. Many, equally valid, profiles may exist based on the same color characterization data. Different profiles, therefore, may/will specify different sets of CMYK data to produce the same color.

Although any characterization data may be used to create these output profiles, when content data are being prepared for a specific application, such as SWOP publication printing, the profile should be based on the reference characterization data. This is true even when the actual proofing and/or printing is going to be done on devices that do not or cannot match the SWOP process control aims, e.g., inkjet proofers or gravure printing. When CMYK data is generated based on a particular reference color characterization data set, it can be safely combined with other data carrying the same characterization data tag. This becomes particularly important for publications that typically receive files from multiple sources. The pointer to a common set of reference color characterization data provides a first level assurance (but not a guarantee) that the data is all intended for the same printing condition.

However, as we suggested earlier, even though the printer is receiving input data based on the SWOP reference color characterization data, the printer may not be using the SWOP process control aims. The data must be transformed again to be suitable for the specific printing conditions of the press to be used.

How Are CMYK Data Modified?
Let's stick with SWOP as our example. SWOP, early on, recognized that offpress proofing systems (both analog and digital) often did not produce the best match to the appearance of material printed according to SWOP if they also tried to match SWOP process control aims. They introduced the concept of an Application Data Sheet that allows proofing system manufacturers to specify the unique process control aims for their system to best meet SWOP appearance, i.e., TR001. The way many proofing system manufacturers accom-

plished this was to create a color characterization data set for their system (under specific operating conditions) and compare it to TR001 and determine the necessary data transforms to make the two match.

In a similar fashion the publication gravure industry has said they support SWOP Specifications. Using color management principles and reference data such as TR001, the gravure printer can accomplish the necessary data manipulation to allow material printed by gravure to match the color appearance of offset printed material and SWOP proofs.

The "how" of this matching gets a little more complicated and requires us to delve into the relationship between color characterization data, profiles, printing processes, and color management a little deeper.

First, let's look at color management systems. The basic way in which a color management system works is that it uses the transforms contained in profiles to change data from one data space to another. Usually one of these data spaces is the colorimetric data space called profile connection space or PCS. This is a data space in which everything is defined colorimetrically in CIELAB (or CIEXYZ). This is often referred to as a device independent space. The other data space can be any CMYK for which there is characterization data, one of the defined RGB spaces, a defined scanner data space which again must be characterized, etc. To go from one CMYK to another CMYK a color management system will normally use the profile transforms to convert the first CMYK to PCS and then use the transforms of the profiles for the other data space to convert from PCS to the new CMYK. As long as both CMYK data spaces have the same outer gamut, everything is being done in a colorimetric mode so gamut compression is not involved and all we are doing is converting the overprint data that is internal to the outer gamut. When the outer color gamuts are not the same, then perceptual transforms must be used (a topic for a future article).

This should and does work to match color. But remember what we said earlier about profile design. Each manufacturer does UCG, GCR, separation and black generation differently; and even from the same manufacturer some of these variables are selectable choices in profile building. This means that typically the characteristics of the black printer including UCR, GCR, etc., are not preserved in a CMYK-to-CMYK color managed transform, and the setting of these parameters in the profile of the new CMYK data space are used regardless of the input data. For non-halftone proofing and printing systems the choices of black printer and separation technique are often not important and whatever settings are available are used.

However, for halftone systems, and those systems where consistency of the black printer is important, the color management system has another tool available. This tool is called a device link profile—that is to say a profile and transform set that goes directly from one CMYK data space to another CMYK data space (or really between any two device data spaces). Here, the transforms can be tuned (often by hand) so, for example, the relationship between the black printer and the three color channels can be maintained. These are more elaborate to create but once created can be used with many sets of data. For example, a single device link profile is all that is needed to provide SWOP emulation on a particular proofing system or gravure engraving system (as long as the receiving system was still operating with the same process control aims used to generate its color characterization data). Such device link profiles can even be tuned to tolerate color errors in single color areas (e.g., to preserve embedded text and line art) while correcting color in overprint areas.

Summary

Yes, these issues are complex and involved and require education and decision making on the part of everyone in the system. However, the potential benefits are large. The opportunity offered to the printer to be able to match color requirements of a job or industry specification without having to be tied to industry process control aims is something the industry needs to understand better and use to its advantage.

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