Viewing Conditions, Colorimetric Measurements & Profile Making

A conundrum—How to make standards consistent and technically correct, as well as match industry practice.

BY DAVID MCDOWELL

I am sure everyone would agree that the standards that define colorimetric measurements, viewing conditions, and profile building must be consistent with each other. More important, we would all agree that they must be consistent with current practice and technically sound. However, as we begin the process of revising these standards we find that it is easier said than done.

In each of these areas, there seems to be a series of inconsistencies between what we do and what we say we should do. The real riddle is how do we reconcile them with each other, with industry practice, and also keep them technically sound.

Let's look at some of the issues, identify the conflicts, and try to identify the potential impact if we are unable to find compromise solutions. As you read this, keep the following three questions in mind:

- Do you have an opinion?
- What would you recommend?
- Does it impact you or do you care?

Background

The standards that define colorimetric measurements for the graphic arts are ISO 13655 and ANSI/CGATS.5. The viewing condition standard is ISO 3664. Both ISO documents are currently in review as part of the regular review process. In addition, the ICC profile specification, ISO 15076, is currently in DIS ballot. These standards form the core of color management and color data exchange.

When CGATS.5 and 13655 were first created in the mid 1990s, the use of colorimetric measurements was in its infancy in the graphic arts. In addition, the viewing condition standard had been an exclusive prerogative of the photographic standards community and had not been updated in 25 years. Industry practice was inconsistent. Therefore, getting workable documents published was the first priority.

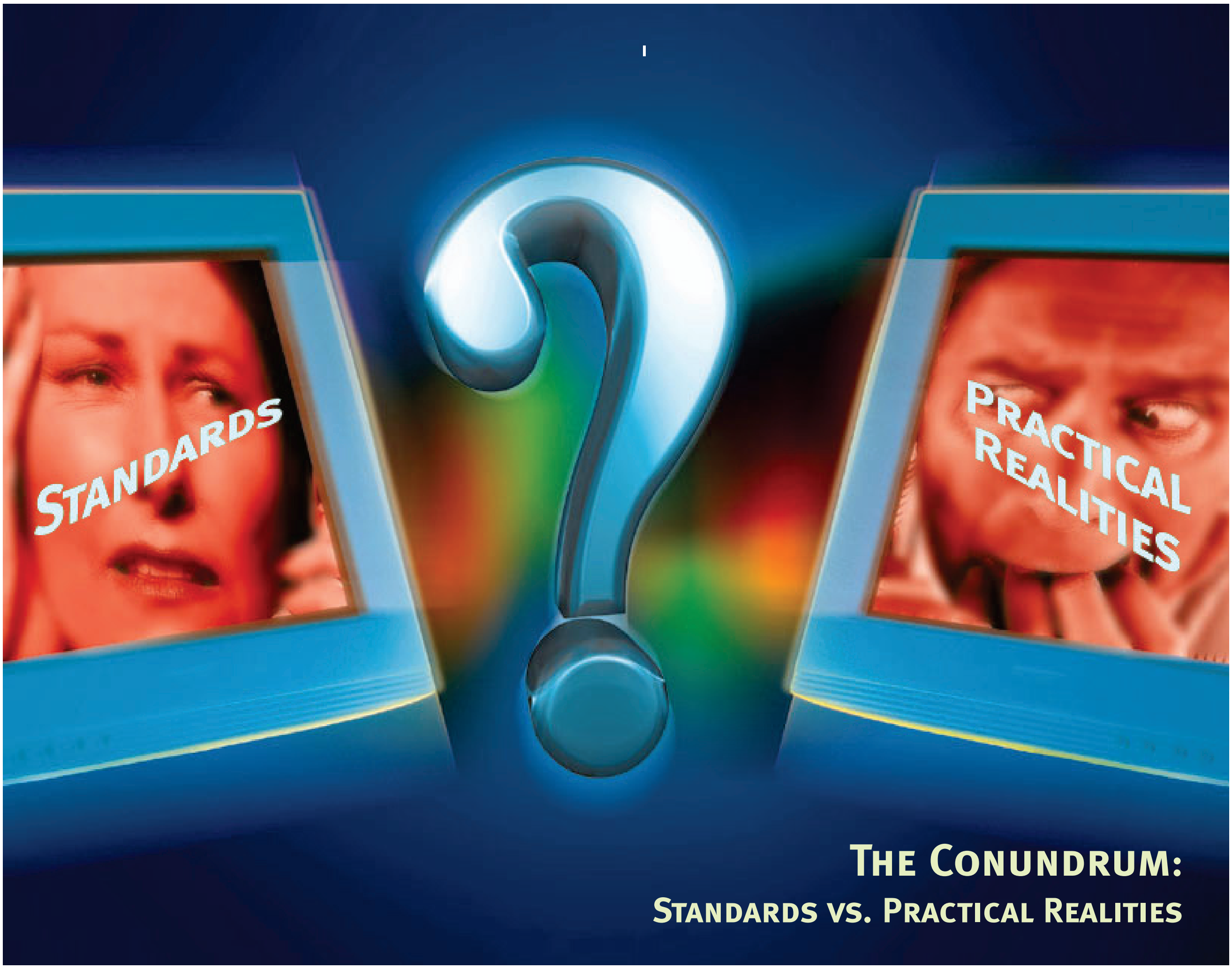
Today, we are far more sophisticated. Digital proofing and color management are being widely used, and we are learning some of the issues related to their use. Some of these issues are directly related to how we make measurements and how we view the printed/proofed products that are produced. The issue of proof-to-print comparison and the desire for metrologically-based certification of proofing systems are also a significant part of the puzzle.

The Parts Of The Riddle

Let's look at the various issues involved and see why it seems to be a riddle.

Backing: The question of which backing to use when making spectral reflectance measurements to compute densitometry and colorimetry has many answers depending on the application and perspective of those using the data. The densitometry standards all call for a black backing to minimize the impact of back-printing, to minimize variability due to translucency effects, and to avoid problems associated with local variations in opacity and backing uniformity. On the other hand, the color management world finds more consistent results between visual comparisons of proof and print when using profiles based on white or self backing. On top of that, everyone would prefer to be able to compute both density and colorimetry from the same set of spectral data and to not have to measure everything twice.

The existing viewing standard also specifies viewing over black to achieve consistency with the measuring



standard and minimize any effects of printing on the back side of the material being examined. However, a black backing is rarely used in practice.

The most significant effect of black backing on a slightly transparent substrate is to reduce the color gamut (including the dynamic range) compared to that achieved with white backing. This affects both viewing and measurement. Although it can be argued that this shouldn't affect the use of a profile in practice, the experience of many ICC members is that it is better to use a white backing for measurements used to create color management profiles.

An additional complicating factor is that proofs are often made on a substrate that is less transparent than the media used for the actual printing. If a proof and a print are being compared, the judgments made can differ depending on the backing used and the difference in transparency of the two materials.

Another option that is often proposed is to use self-backing. That is to back a sample with as many sheets of unprinted substrate as are necessary to ensure that there is no further change in measurement when more are added. This can prove difficult in practice, particularly on scanning instruments; and comparing data measured this way at different sites becomes problematic.

What should the backing standard be—black or white? Should the same backing be used for colorimetric measurements, densitometric measurements, and viewing?

Illumination: Another area that is beginning to receive attention is the spectral power distribution of the illumination used for both measurement and viewing. We usually identify illumination (and monitor white points) by its equivalent color temperature—D50, D65, etc. However, this only takes into account one characteristic of the illumination. The spectral power distribution of the illumination specifies the amount of energy at each wavelength, including energy outside of the visible portion of the spectrum. Two illuminants with the same color temperature can have significantly different spectral power distributions. The dyes and pigments used in proofing systems often do not match the spectral reflectance of the printing inks. Therefore, differences in the spectral power distribution of viewing illumination (even when it meets the color temperature criteria) will change the match of proof and print.

Even more critical is the use of brightened papers and/or fluorescent inks. Their effect is directly proportional to the amount of UV light present, and can be dramatic. The viewing standard defines the spectral power distribution of the reference D50 illuminant in both the visible and in the UV. It also has test criteria for how closely a viewing booth should match the specified spectral power distribution in both the visible and UV. Unfortunately, few systems match the UV criteria because it is difficult to produce illumination systems with the correct UV content.

In addition, the current viewing standard has two levels of illumination. One is relatively high and is recommended for comparing images (proof-to-print, etc.). The other is more nearly the level of room light illumination for evaluating the aesthetic appearance of a print all by itself.

The measurement standard says, "If the materials do not fluoresce, the spectral power distribution of the measurement source is not a concern and so no specification is given for the conformity of the spectral power distribution of the measurement source to the illuminant specified…"

It goes on to say that if the materials do fluoresce then the spectral power distribution of the measurement source should match D50. The illumination source in most spectrophometers is designed for efficiency, long life, stability, etc.—not to match D50. However, some do include a UV cutoff filter and/or a filter that provides some enhancement of the UV but not to the extent that it matches D50.

Since it is very difficult, if not impossible, to properly match the specified UV content of a D50 illuminant in a spectrophotometer, some have suggested that all colorimetric measurements should be made without any UV present at all to get better agreement between instruments. But that would imply that if viewing and measurement are expected to match, we should also block all UV in the viewing booth. If we block UV in viewing, the effect of paper brighteners goes away—but the client is paying for brightened paper and the customer (at least in some viewing environments) is seeing the effect of brightened paper. Why else would the client be paying a premium for it?

Others suggest that some UV, but not as much as D50 specifies, is a more manageable goal. But there are no real suggestions as to how much is enough. Bottom line is that if we are going to use brightened papers (and/or inks that fluoresce), the amount of UV present in both viewing equipment and measurement equipment must have some degree of consistency.

Is it important for the illumination for viewing and measurement to match? Is it important for viewing to show the effect of paper brighteners? How much UV should be present—match D50, some lesser amount, none? Should the spectral power distribution of the illumination used for subjective evaluation be the same as that used for proof-to-print comparison.

The Options

At this point we have too many questions and not enough information to make any choices. To reiterate:

- What should the backing standard be—black or white?
- Should the same backing be used for colorimetric measurements, densitometric measurements, and viewing?
- Is it important for the illumination for viewing and measurement to match?
- Is it important for viewing to show the effect of paper brighteners?
- How much UV should be present—match D50, some lesser amount, none?
- Should the spectral power distribution of the illumination used for subjective evaluation be the same as that used for proof-to-print comparison?
- Should both viewing intensity levels have the same UV content?

Before we answer these questions there are other factors that have an impact on our recommendations. Two of the most significant are the certification of proofing systems and instrument variability.

Certification Of Proofing Systems

One of the major issues in digital proofing is how to be sure that a proof is a reasonable predictor of the intended printing. This problem has always been around, it is just more visible as we depend more heavily on digital proofs made with a variety of technologies. Back in the days of press proofs, using the same ink and paper, matching the process control aims of density and dot gain was fairly reliable. However, today in most proofing systems we are not using the same substrate, we are not using traditional inks (or even ink at all), and the process parameters are completely different.

Most proofing uses color management tools to adjust image data to produce a reasonable match to a reference sheet printed using the same data. The final arbiter of a satisfactory match is a group of "experts" viewing pairs of proofs and prints for a variety of images. This process is used by an individual company buying a proofing system, by groups like SWOP and GRACoL in certifying the ability of a given system to match their specifications, and everything in between.

But that decision is time consuming, subjective, and image dependent as well as being heavily dependent on the spectral power distribution of the viewing equipment used. If a different brand of viewing equipment is used, potentially a different conclusion will be reached.

It would be ideal if we could use colorimetric measurements to move the decision making into a more objective realm. Unfortunately, even if we could make the right decisions for backing and illumination, we are left with another dilemma. We can only reliably predict that a visual comparison will match if the backing and illumination used for both measurement and viewing is exactly the same and if the data match exactly—a virtual impossibility. If data do not match exactly, we cannot make any real prediction.

All the work done by the CIE and others in developing color difference formulae has been based on detectability. What is important in comparing images is acceptability. Even more difficult is the fact that all of the work in detectability of color difference only applies to large patches of single colors—not to many colors in a complex image viewed all at once.

Some work has been started in the area of acceptable color difference in complex images, but it is progressing slowly. The difficulty is that the judgments of expert human observers must be correlated with colorimetric measurements of test targets, which, in turn, must be related to the images being compared.

It would appear that unless backing and illumination match in measurement and viewing, the use of metrology to predict proof-to-print matching will not be possible—even if we can learn how to correlate measurement and viewing under controlled conditions.

Further, if profiles are based on one set of measurement conditions, can they reasonably be used to color manage proof preparation when the viewing conditions do not match the measurement conditions?

Tristimulus Correction Method

The tristimulus correction method is based on the observation that when the deltas in X, Y, and Z between measurements made over two backing materials (i.e., black and white) are plotted vs. the X, Y, and Z values for measurements made over either material, the best fit result is approximately a straight line. At the lowest value of each tristimulus value, the delta between measurements made over the two backings is at or near zero. The maximum difference in measurement due to backing material characteristics is always at the maximum tristimulus value which equates to a measurement of the substrate (usually paper) alone, i.e., in an area containing no printing.

This implies that measurements over one backing can be used to estimate the measurements that would be made over another backing by simply adding (or subtracting) a correction factor in X, Y, and Z. This correction factor is simply a proportional amount of the difference between measurements of the substrate alone over the two backings where the proportion added is defined by the value of X (or Y, or Z) on the first substrate compared to the minimum value of X and the value of X for the substrate alone.

This leads to a correction equation for X as follows:

$$X(n)_2 = X(n)_1 + (X(s)_2 - X(s)_1) * \frac{(X(n)_1 - X_{MIN})}{(X(s)_1 - X_{MIN})}$$

where

$X(n)_1$ = **Measured value of X for sample n over backing 1**

$X(n)_2$ = **Predicted value of X for sample n over backing 2**

$X(s)_1$ = **Measured value of X of the substrate over backing 1**

$X(s)_2$ = **Measured value of X of the substrate over backing 2**

X_{MIN} = **Minimum value of X which generally corresponds to a 4-color solid, which is patch ID 24**

The corrections for Y and Z are performed in the same way. These new X, Y, and Z values are used to compute new CIELAB values.

Instrument Variability

Even though the measurement standards specify a reasonable number of constraints on the geometry and design of spectrophotometers, variations between the design of different instruments (even from the same manufacturer) introduce differences in results. We have all heard the comment, "If you want consistency between measurements you need to use the same brand and model for all measurements."

In a world of open data exchange that simply doesn't work. Both ISO 13655 and CGATS.5 include annexes that provide some guidance on ways to improve inter-instrument agreement. CGATS has a procedure in place that is used when reference characterization data (such as TR 001) is being prepared that identifies the differences between instruments/labs (and makes sure they are reasonable) but does not correct the data to a common reference.

Some industries that depend heavily on color measurements have established reference laboratories and reference instruments to which individual labs and equipment can be correlated. That has not happened in the graphic arts and it is not clear who would be either willing or able to take on such a task.

Do we need some sort of reference measurement laboratory to standardize measurement instruments used for profile building and proof-to-print comparisons?

Mean Plus, An Instrument Correction Program

Mean Plus is a software program that corrects spectrophotometric errors so that two or more instruments will read color nearly identically. It corrects instrumental spectrophotometric errors that are systematic. This includes instruments manufactured by different manufacturers and instruments manufactured by the same manufacturer. The program works on six different modalities, including bi-directional geometries, that is, 45°/0°; hemispherical, either d/0° or d/8° geometries; or multi-angle geometries. Multi-angle geometries are used to characterize and assess gonioapparent inks and coatings. It is not necessary that both instruments be of the same geometry. For more information contact: Jack Ladson; Color Science Consultancy; 1000 Plowshare Road; Yardley, Pennsylvania 19067; phone 215-369-5005; jack.ladson@verizon.net

Some Small Pinpoints Of Light

A couple of small steps that can help have recently come to light. At the recent CGATS and ICC meeting a technique was discussed that partially corrects colorimetric data for differences in backing material. This is not a perfect correction but may be adequate for some profile building applications. (See sidebar *Tristimulus Correction* on previous page.)

The other is a commercial product, which I recently learned about, that is available to help in the area of inter-instrument agreement. (See sidebar *Mean Plus* above.) This is the first commercial offering that I am aware of that provides specific assistance in this area.

One Recommendation

A recent ICC white paper recommended that colorimetric measurements for profile building be done with white backing with an instrument in which the UV has been excluded. It also recommends that polarization filters not be used in measurement and that multiple readings be averaged to minimize effects of instrument and printing variability. No other groups that I am aware of have suggested a position.

What Do We Do?

Some possibilities that were discussed at the recent TC130 meeting include (but are no means limited to):

a) Three conditions for viewing:

1) D50 with D50 UV, Black backing, 2000 lux (Ideal or reference condition);
2) D50 without UV, White backing, 2000 lux (Proof-to-print comparison);
3) D50 with D50 UV, White backing, 500 lux (Perceptual viewing).

b) Comparable measurement conditions are:

1) D50 with D50 UV, Black backing (Ideal or reference condition);
2) D50 without UV, White backing (Profile building and proof-to-print comparison);
3) D50 with D50 UV, White backing (Perceptual viewing).

It is not clear that these make complete sense. However, they represent one possibility. Once these are settled we still have the issues of using metrology to validate the match of proof and print, a reference measurement base for graphic arts to allow multiple instrument correlation to a common reference, better conversion between measurement conditions, etc.

The Challenge

Do these suggestions answer the questions of:

- What should the backing standard be—black or white?
- Should the same backing be used for colorimetric measurements, densitometric measurements, and viewing?
- Is it important for the illumination for viewing and measurement to match?
- Is it important for viewing to show the effect of paper brighteners?
- How much UV should be present—match D50, some lesser amount, none?
- Should the spectral power distribution of the illumination used for subjective evaluation be the same as that used for proof-to-print comparison?
- Should both viewing intensity levels have the same UV content?

Do you have an opinion? What would you recommend? Do you care?

I welcome any thoughts or suggestions. I cannot promise anything except that any input I receive will be collated and passed on to the standards committees involved. Send comments to mcdowell@npes.org and use "Conundrum" as the subject.