Where are my CIELAB knobs? (Part 1)[1]

Back in the good old days, it was all about density. From the standpoint of the printer, density makes a lot of sense as a process control parameter. Density is a single number, and it relates directly to the only thing that can be easily controlled on press, the amount of pigment put down.

But those darn standards, such as the ISO 12647 series and FIRST 4.0, and ICC profiles – all they talk about is CIELAB. From the standpoint of the print buyer, this is a perfectly reasonable request. Running to a target density does not assure the proper color. A density measurement can't tell you whether there is an unwanted tint in the ink, say, a yellow ink spiked with a bit of cyan.

Going back to the printer again, running a job to a CIELAB target is something of a problem. There are no knobs for L*, a*, and b* on a press. What the press operator needs is a way to determine the optimal density, that density that will get him closest to the target CIELAB value.

This is part 1 of an article that describes the theoretical background of how to bridge this gap. Part 2 will talk about software that has been developed to deal with these issues.

First graph

At the very least, this darn CIELAB target makes the whole thing very complicated. The correspondence between pigment load and CIELAB values is not so straight-forward. For a black ink, more pigment means L* goes down, but a* and b* stay the same. For yellow ink, more pigment only decreases L* a small amount, but the b* value increases. For cyan ink, L* and b* both go down, but the a* value drops at small densities but then levels off, as shown in Figure 1. (*Are you taking notes? I'm a math guy, and I have to stop and think about this as I write it!*)

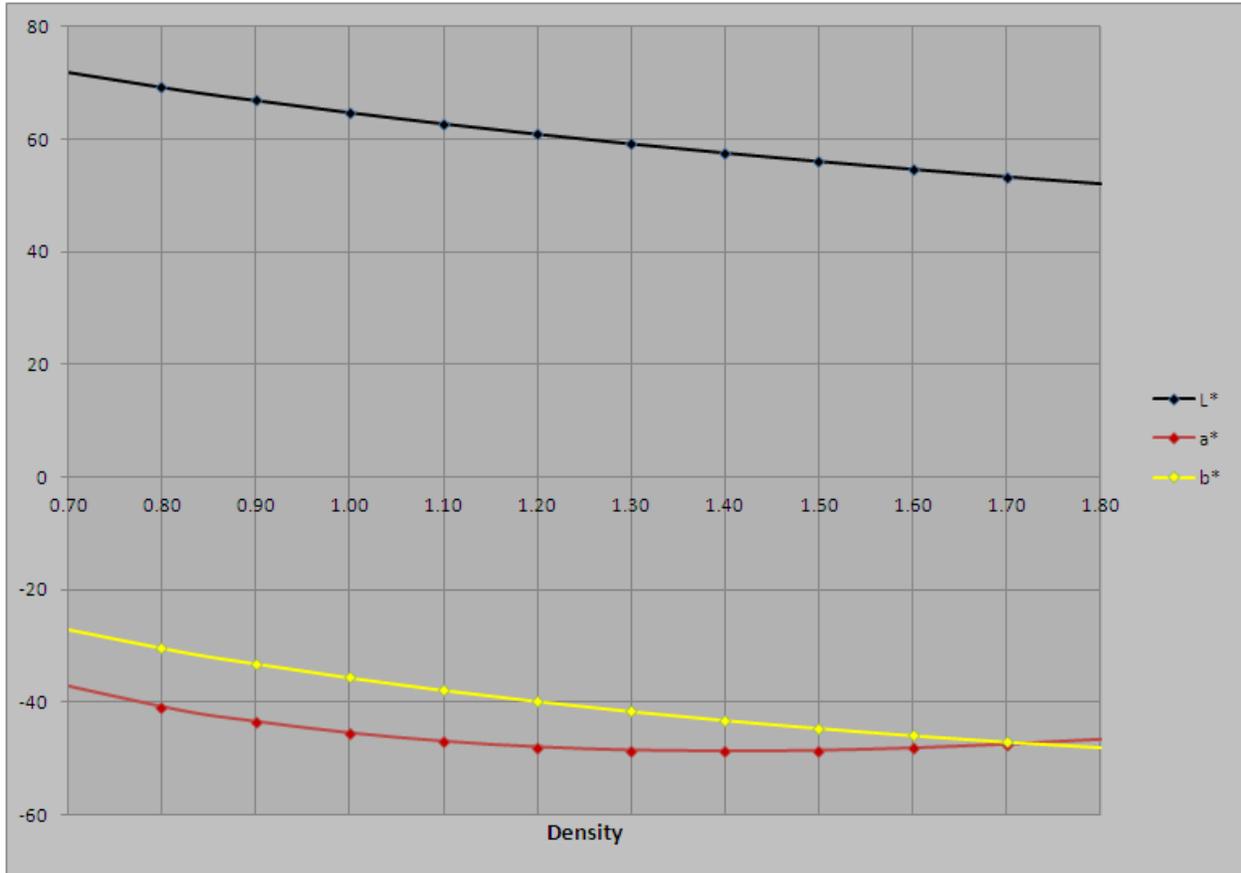[1] *This article appeared in FlexoGlobal eZine, Jan 21, 2013*

Figure 1 – How the CIELAB values change with density (cyan version)

A slightly better graph

The rules for how CIELAB values change and the graph in Figure 1 are just not human-friendly ways to look at how to hit the target color. Figures 2a and 2b are a little more intuitive look at the same data portrayed in Figure 1. These are plots of the *ink trajectory* for cyan. Looking down at color space from above, the plots show the change in color of a cyan solid as the pigment gets richer. Note that color is three dimensional, and the "up and down" (L*) is not shown. L* goes down as the ink gets richer in color.
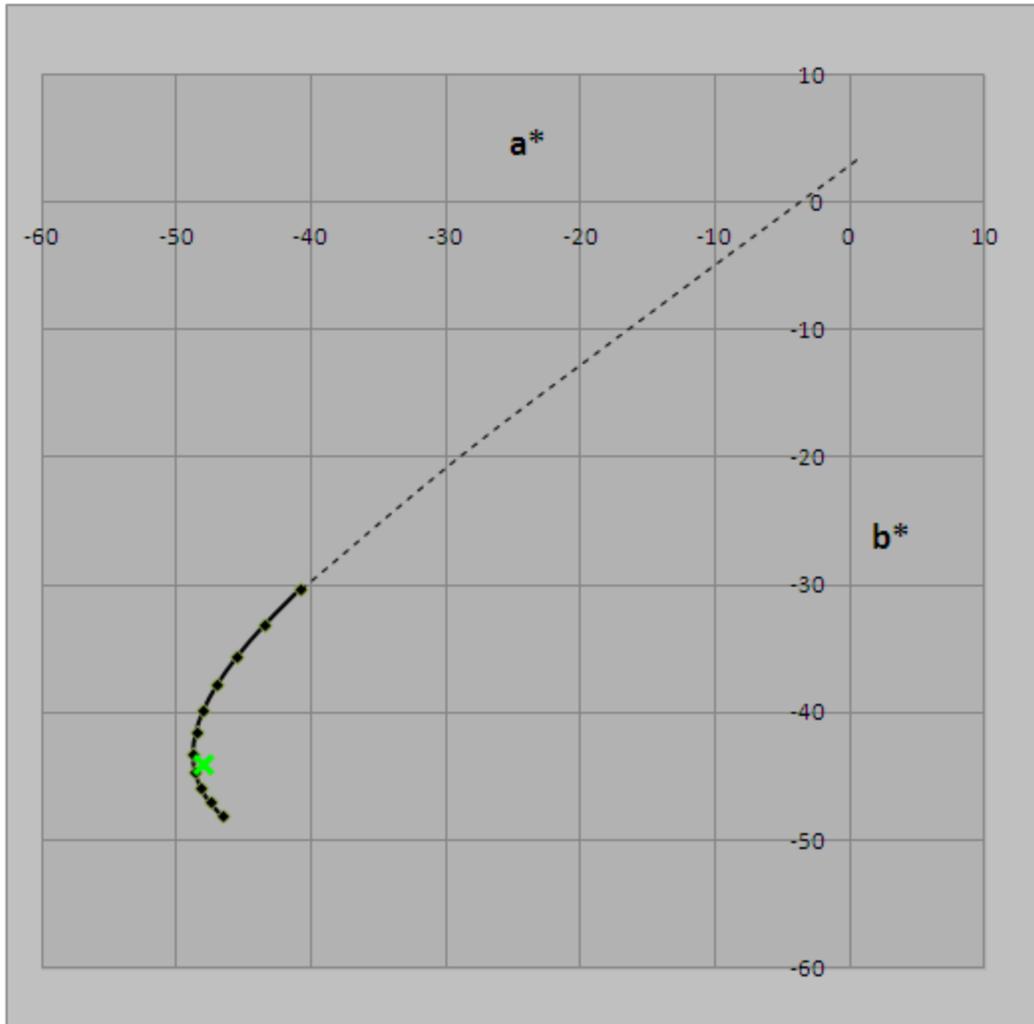
Figure 2a – a*b* plot of cyan ink from a density of 0.8D to 1.8D

One notable feature of this graph is the hook at the end. When the ink reaches this hook, adding pigment will no longer increase the chroma (perceived saturation) of the ink. But adding pigment will change the hue. As you add pigment, the hue of the cyan ink turns toward blue. Anyone who has looked at a bucket of cyan ink has seen this change in hue.
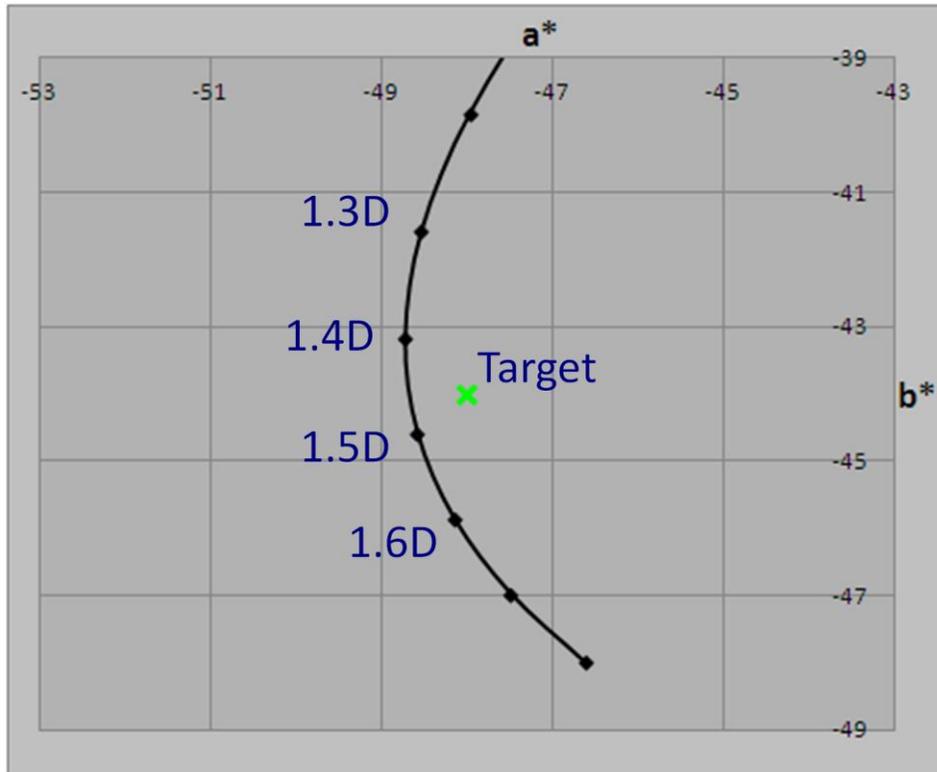
Figure 2b – Close-up of 2a, with the target and several density points indicated

Figure 2b illustrates how the ink trajectory can curve around any particular CIELAB target value. In this graph, the target is somewhat arbitrarily shown as a* of -48 and b* of -44. In this case, it is not possible to exactly hit the target color. Adjusting the pigment level is like missing an exit ramp on an interstate highway. You just watch your destination go by as you drive past.

But it's not the end of the road. The goal on press is not to actually reach the target color – just to come close enough. From the looks of Figure 2b, it would appear that the closest match occurs at a density of just below 1.5D. It would appear that the press operator just has to hold to a density around 1.48D to assure that the target color is met as close as possible.

That closest match – the point on the ink trajectory that is closest to the target color – is called the *perifarbe*. The prefix of this word is shared with the words perigee and perihelion, meaning the closest approach of a satellite to the Earth or the Sun, respectively. "Farbe" is the German word for color.

But before everyone goes out and jots 1.48D in their notebooks, I need to add two more things. The first is that the perifarbe density depends on all the variables in the process. Any change in the ink formulation or substrate will potentially result in the perifarbe moving. The perifarbe density should be determined whenever something changes, and ideally is calibrated on every run.

There is a little difficulty, though. Figure 2b is only part of the story. It neglects how L* is changing with respect to density. Figure 2c shows a different perspective, looking at color space

from the side, rather than down from the top. In this plot it looks like the perifarbe density is somewhere around 1.39D.
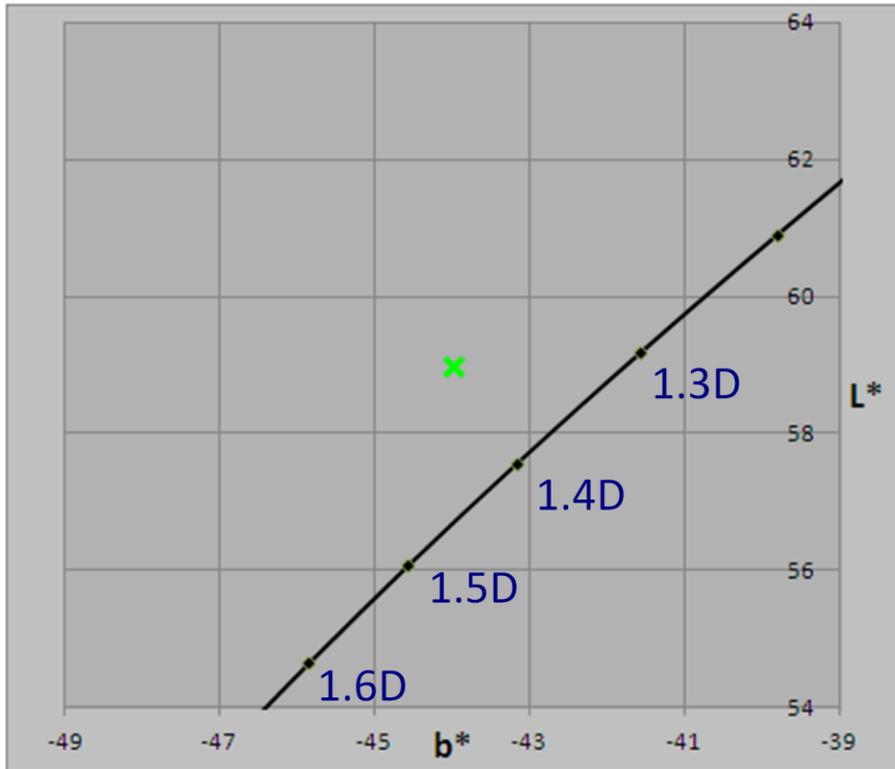

Figure 2c – Close-up of 2a, viewed in the b*/L* plane

The perifarbe graph

This failure in Figures 2a, 2b, and 2c leads us to a third diagram that allows one to determine the perifarbe, shown in Figure 3. The black line in this plot shows the color error (ΔE distance from the target CIELAB target) at each density. From this, it can be seen that the perifarbe density is a bit lower than either of the views in Figure 2 would have led us to believe. The true perifarbe is at 1.38D.
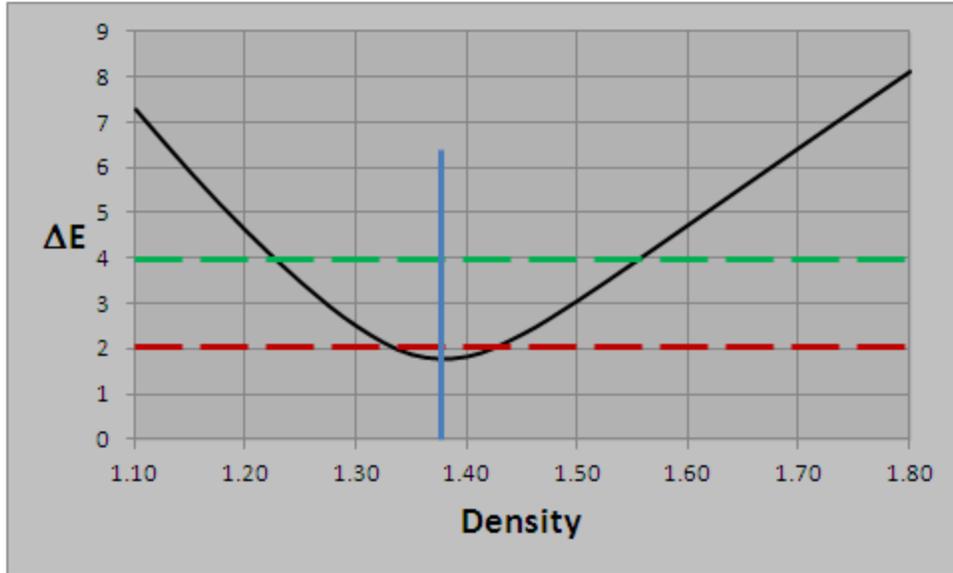
Figure 3 – Plot of distance to target CIELAB value

Figure 3 also gives us an idea of how hard it will be to keep this job in tolerance. If the customer requires that the color be within 4 ΔE (as shown by the dashed green line), then a fairly wide range of density will bring the color into tolerance. Anywhere from 1.23D to 1.55D would be acceptable. If, on the other hand, the tolerance is 2 ΔE (as shown by the red dashed line), the acceptable density range is from 1.34D to 1.41D, and even at its best, the color will be borderline acceptable.

Summary

In this first part, I have discussed the difficulties posed by having target CIELAB values. Through a series of different types of graphs, I have described from a theoretical standpoint what is possible. Along the way, I have introduced the phrase "ink trajectory", which is the collection of CIELAB values that you can get with a given ink through adjustment of the pigmentation level. The idea of a perifarbe has been introduced, which is the point along the ink trajectory that comes closest to a target CIELAB value.

In the next part, I will take a look at various pieces of software that are available to simplify the color tweaking process on press.

Where are my CIELAB knobs? (Part 2)

In the first part of this article, I looked at the problem faced by printers when trying to control a press to CIELAB tolerances. I explained, through a series of graphs, how the problem could be solved. The approach, however, was theoretical. This second part of the article takes a look at practical solutions in the form of software that can be used at press side to help tune the press to the optimum CIELAB value.

How can I use this on press?

All these fancy graphs from the first part are helpful to get an understanding of what is going on, but the most important two pieces of information needed are the perifarbe density (what density gets me closest to the target CIELAB), and the perifarbe ΔE (how close can I get). Between these two numbers, the press crew can decide whether to a) leave well enough alone, b) adjust the pigment levels at press side either up or down, and by how much, or c) send the ink back to the kitchen for re-formulation.

Several options are available to make use of this analysis. While it may be possible to hire a competent applied mathematician to run a slide rule at press side, there are other possibilities that are perhaps more cost effective.

Some spectrophotometers come equipped with a feature that can predict these two important numbers. The TECHKON SpectroDens is one example. In the screen shot shown in Figure 4, a black patch is found to be over 6 ΔE from the target. It recommends increasing the black density by 0.24D, and predicts that the color error will drop to 0.8 ΔE.
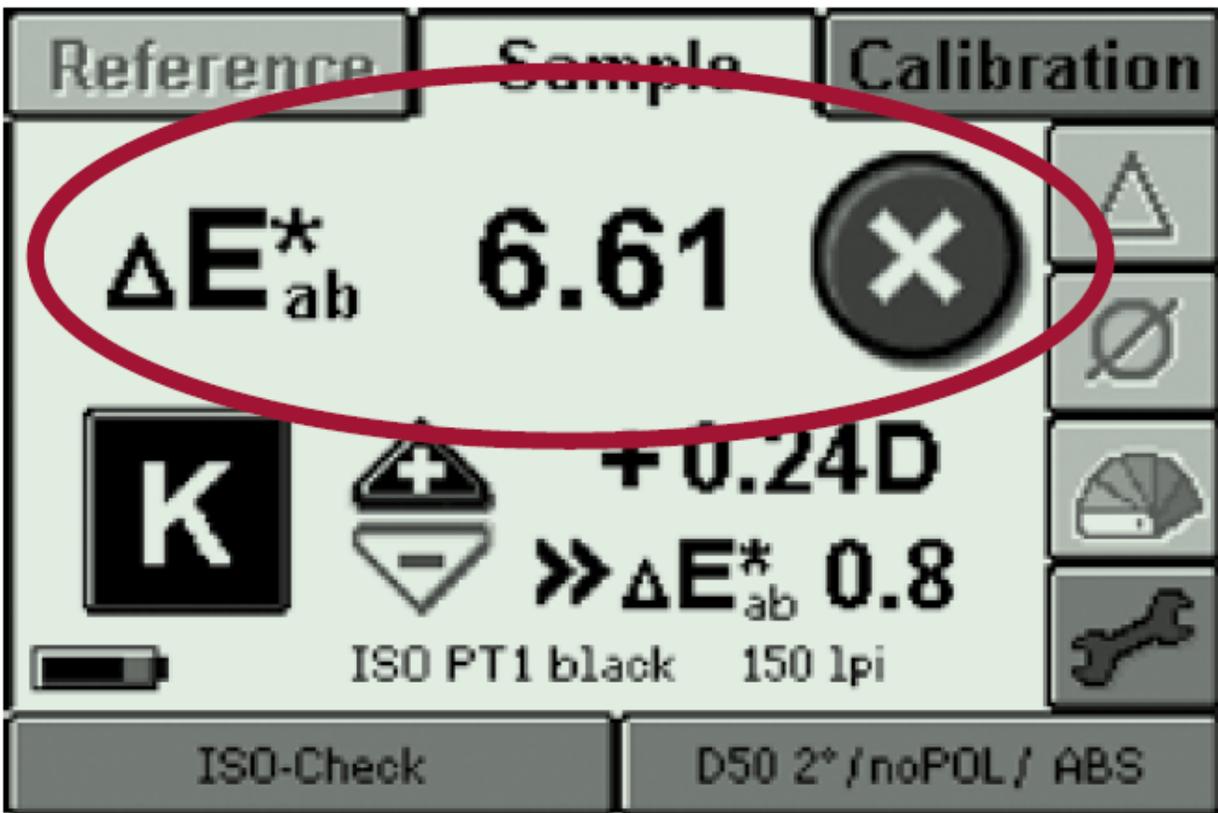

Figure 4 – The TECHKon SpectroDens

A similar feature, called "BestMatch", is available for X-Rite's SpectroEye. The display is shown in Figure 5. In this example, a sea-foam green patch is measured to have a density of 1.76. The color difference from the target is almost 7 ΔE, so it recommends reducing the density by 0.31. If this were to be done, it predicts a color error of 0.14 ΔE. One more number is worth noting is the "%-26". This is a suggested change in concentration.
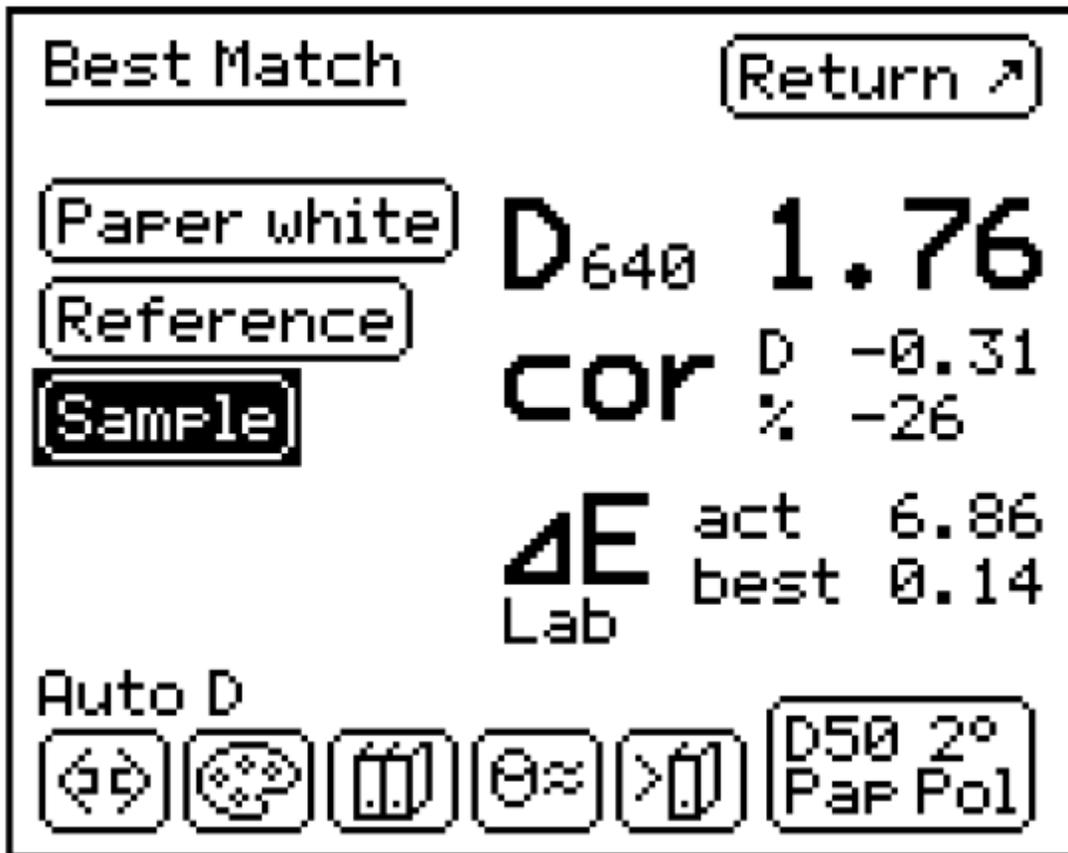
Figure 5 – X-Rite "BestMatch" feature on the SpectroEye

SpotOn! Flexo software allows this analysis to happen with several brands of spectrophotometers. In addition to being able to generate a variety of reports, Figure 6 shows a screen shot where SpotOn! is recommending running this orange ink to a yellow density of 1.37D. It predicts that the color error at this point would be 1.41D. This software can take advantage of having a computer screen (rather than the tiny screen on a handheld spectro) to provide additional information. The plot at the right of Figure 6 shows the current and predicted color against the acceptable tolerance ellipses.

Figure 6 – Screen shot from SpotOn! Flexo

QuadTech offers software to simplify the process of matching inks on a flexo press. QuadTech has collaborated with other industry leaders to provide a solution that connects all the pieces together. QuadTech's SpectralCam will measure color on press as it is being printed. This is a boon to roll-to-roll operations where measurements were previously only available at the end of a roll, or by tearing a section out of the web.

Measurements from SpectralCam are then sent to X-Rite's InkFormulation software. This software goes beyond determination of the ink trajectory for the current ink. This software can determine the best match that can be made with the current inventory of ink. The X-Rite ink formulation software will then pass the ink recipe along to Huber Group, which controls the actual mixing of ink.

Summary

The evolution from density control to CIELAB targets is painful, but necessary. This article has described theoretically, how to make the transition, and then provided practical examples of software that can ease the blow.