BY MIKE WOOD

Gel color pickers—an exercise in futility?

THERE HAVE ALWAYS BEEN ISSUES with trying to match gel colors with color mixing luminaires. We've had the problem for years with dichroic, subtractive mixing lights, and, more recently, these problems have become even more important with the increasing availability of LED-based additive mixing luminaires. In earlier articles in this series I've talked about the metameric issues of trying to match colors formed from narrow-band emitters with those from a wide-band incandescent source and a piece of gel. As a recap, the problem is, even if you get colors to match on a white background, the different wavelength composition means that they will likely not look the same on a colored background of costumes, scenery, or skin tones.

Figure 1 shows a standard Macbeth color test chart when illuminated with four different flavors of white light. The lighting was adjusted for each light source so that the bottom left white squares were as visually similar as I could get them, and then the exposure was adjusted to try and get comparable images. Finally, I deliberately tweaked the brightness and contrast (but not the color) of the images in Photoshop to make the four whites look as identical as possible. This adjustment is slightly cheating, but it emphasizes real differences slightly and helps us see the problem more clearly. *(Note: These images will look different in this journal than they did in real life or on my computer monitor. They have been through at least four different color processes between reality and your eye: the camera RGB color sensor, Photoshop processing, magazine layout, and, finally, the CMYK printing process.)*

Figure 1 – Different whites

The chart was lit by four different sources; incandescent, cold white fluorescent, a mix of amber and blue LEDs balanced to a white, and, finally, a mix of red, green, and blue LEDs also balanced to white. I think the differences are very clear. Most striking is the chart lit with just amber and blue, where the white square and grey scale look pretty good, but just about everything else looks completely wrong. Only amber itself (second row, far left) and pale blue (third row, far right) escape unscathed, while anything with any green or red content is totally changed. The chart lit with RGB shows some lack of subtlety with over-emphasis of hue, and has a particularly hard time with the two skin tone colors (top row, first and second from left) where the pale skin tone is rendered as a pale pink and the dark skin tone is far too red. These are key colors for us in entertainment and, as such, are touchstones for the quality of the color rendering. Your audience may not know what color the costumes are, but they have years of experience with skin tones and know exactly what they are supposed to look like!

Let's assume for the moment that we have dealt with these issues and accept that, even if colors match on a white surface, they won't necessarily match on a colored one. Surely with that limitation, it's reasonable to expect a good match from a gel color

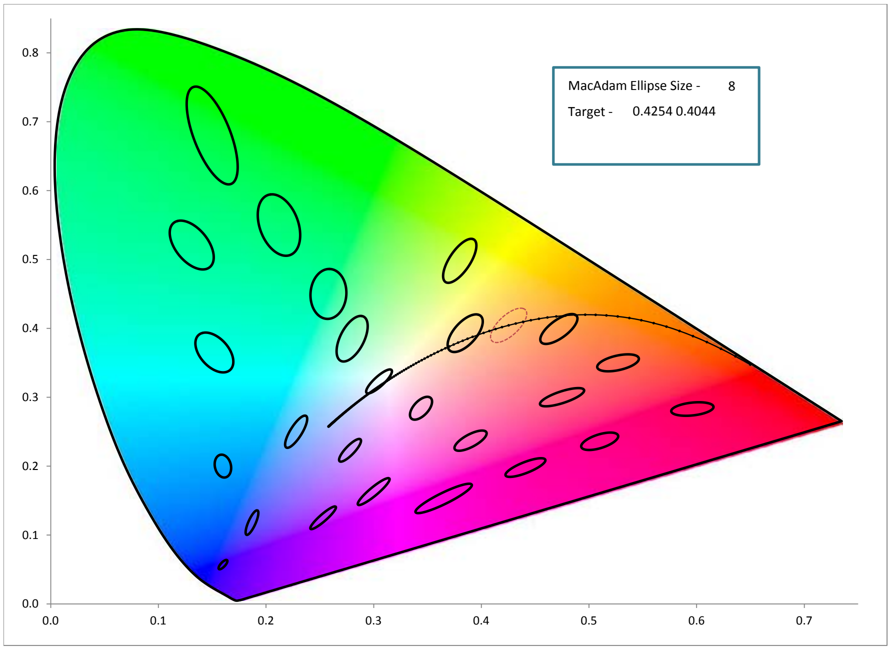

Figure 2 – Equal color differences

to a mixed LED source on a white surface, isn't it? Why should that be so hard? My console has a gel picker and I can select any gel I like, but I find the mixed colors never look quite right. Why is that, you might ask? Come on console manufacturers—get your act together!

Unfortunately, it still isn't that easy; there are still many variables standing between us and perfect color matching. Let's for a moment ignore the problems in consistency between different batches of dichroics and LEDs, and the difficulties of making two identical luminaires. We know from experience that even calibrated LED units seem to have this problem. If we move away from actual physical differences, then I believe one of the problems is that we have a heightened expectation when trying to perform color matching with these technologies, and we are less prepared to accept any errors. We always do color matching on a white surface if we can, as it's easier to see the differences, and we are often looking at the lights out of context. To get a perspective on the issue, let's take a look at what we might expect with gels and incandescent lamps—the situation we have accepted for years with few complaints.

> **"My console has a gel picker and I can select any gel I like, but I find the mixed colors never look quite right. Why is that?"**

Does a piece of gel in front of an incandescent light always look the same? No, it doesn't. First you have the lamp choice. Are you using a 3,200 K incandescent or a long-life incandescent which may have a color temperature 300 K lower? Are you running that incandescent lamp at exactly its rated voltage or do you have it on a dimmer? What kind of latitude do you afford a color as the lamp dims down from 100%?

I contend that the color differences we are seeing now with gel and traditional lights sources are huge—very often, the same or greater than the differences we see in matching color-mixing light sources. The reasons why we don't complain perhaps fall into a couple of main areas:

We are used to the color differences we see as a lamp changes color temperature or dims. We accept those changes as natural and expected, because we've been living with them for years. It's not that we don't see those differences; it's just that we ignore them most of the time.

The color changes from an incandescent lamp are nearly always along the red/blue axis of color. This is the direction that natural light changes color, the color change from a daylight blue sky to the warm glow of a red evening sky. The difference between daylight and candlelight, the transition from a warmly lit living room to a cool fluorescent lit kitchen. All transitions we are programmed to accept at a very deep level. Our brains recognize these changes and ignore them in order to keep our world at apparently constant colors.

Figure 2 shows a CIE color chart with plotted MacAdam ellipses. Each of the MacAdam ellipses represents an area in which the color difference from any point on that ellipse to the opposite point on the same ellipse appears the same to our eye. (*Note: For clarity, the actual ellipses shown in **Figure 2** are eight times larger than in reality*.) You can see that, close to the black body line where all true white sources lie, those ellipses tend to align with the major axes falling in the blue/amber-red direction. In particular, the red dotted ellipse is shown at the color point of an incandescent lamp and, at that point, it's clear that we have a much larger tolerance for changes in the red/blue direction than we do to anything in the magenta or green directions. This means that lamp color temperature changes have to be greater before they are visible than a change in the green/magenta direction.

Unfortunately, this isn't always the case when trying to match colors with a color-mixing luminaire; in those cases, a color error is just as likely to be along the green/magenta axis. Even more unfortunately, in addition to those differences being more noticeable, they are also much more objectionable to us. Even a small amount of green sticks out like a sore thumb.

The human eye's sensitivity to green remains a concern in manufacturing both

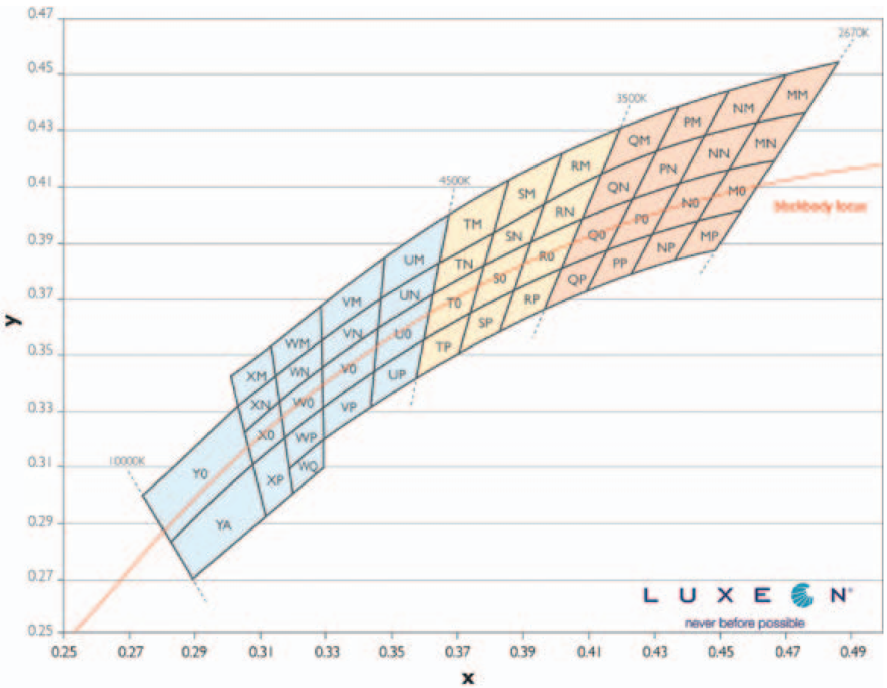

Figure 3 – White LED binning (Diagram courtesy Philips Lumileds)

high-intensity discharge lamps and LEDs. Tolerance in the manufacture of HID lamps means that the white point tends to straddle quite a large area of the color chart. To avoid having to throw too many green lamps away as unacceptable, the manufacturers don't actually aim at producing a white exactly on the black body line. Instead, they set their target white point slightly to the magenta side; we will accept a little pink in our white but never, ever green.

*With white LEDs, the problem is exacerbated by our quest for higher efficiency; as a generalization, the greener and cooler a white LED is, the more efficient it will be. The range of available ANSI bins for white LEDs shown in **Figure 3** illustrates this issue, with twice as many bins on the green side of the black body line than on the magenta side. Making these bins more evenly straddle the black body line, or shifting it down to favor the magenta, would result in an overall loss of efficiency and, in our current energy-saving climate, that isn't a good strategy for mass-market products. We may have fewer concerns in entertainment, but these bins are fixed by manufacturers selling to markets that are many times larger than all of us put together. Our voice is a small one.*

> **“ . . . we have a much larger tolerance for changes in the red/blue direction than we do to anything in the magenta or green directions. ”**

Back on topic: Even though the changes in color along the red/blue axis are, in general, less of a problem than other differences, they can still be very noticeable. These differences are particularly apparent in complex colors such as aquas, ambers, and lavenders, where a small change in the red/blue mix of the illuminant makes a significant difference in the way we perceive that color. **Figure 4** shows some examples.

This represents three gels in front of an incandescent lamp. The left patch in each case is the color when using a 3,200 K incandescent (common for short-life lamps), while the right patch is the same gel when using a 2,900 K (long-life) lamp. Nothing else has changed. Within the limits of the color printing process I think you will agree that these changes are not small. The aqua at the top shifts from a bluish aqua to a greenish one, while the lavender at the bottom moves from a pale magenta to a peach. Which is correct? Which one do you want? Which is the one you want your gel color picker to provide?

The problem gets even worse when you start to consider what actually happens in the real world. Your lamp may be rated for 115V or 230V operation, but what is actually reaching it? You have transformers and cables in the link that provide unknown voltage changes, not to forget the deliberate changes introduced by a dimmer. Dim those lamps down to 50% output, and the color changes even more! Do you want the gel picker to match that instead?

Figure 5 shows just how far apart these colors are when plotted on a color chart. This is just one example for Rosco 69, Brilliant Blue. Although well into the blue region with a 3,200 K lamp, it's moving very much towards the green when down to 2,900 K. *(Note: This is no reflection in any*

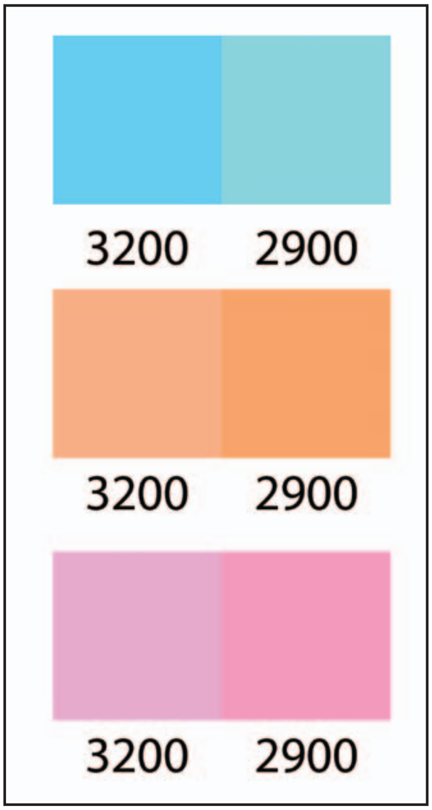

Figure 4 – Color shift

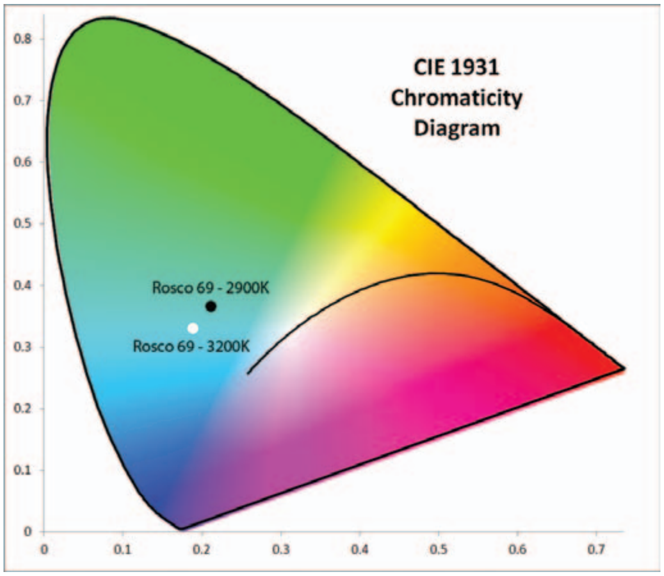

Figure 5 – Rosco 69 at 2,900 K and 3,200 K

way on Rosco. All gels, from any manufacturer, will show this same shift; it's the lamp that's changing, not the gel. I just used Rosco as the data it publishes on its web site makes it easy to do the math.)

I'm not trying to be an apologist for control desks and gel pickers, but I do want to point out the futility of relying on them, or expecting them to be accurate. When the target they are aiming at varies so widely, how can the desk know which variant of that color you actually want? Do you want to match the color coming from a brand-new short-life lamp, in a luminaire with clean optics that's right next to the dimmer room and is running at a full 115 V? Or do you want the color that's dribbling out of that old luminaire front-of-house with a low color temperature, long-life lamp, a cable run that means it only ever sees 105 V, and lenses that haven't been cleaned in five years? Yes, I'm exaggerating a little, but even if we can agree on that, then the color will only match on a white surface. Should the gel picker get us in the right ballpark? Yes. Should it get us an exact match? No, it never can, no matter what the sales literature says or what you would wish. ■

Mike Wood runs Mike Wood Consulting LLC, which provides consulting support to companies within the entertainment industry on product design, technology strategy, R&D, standards, and Intellectual Property. A 30-year veteran of the entertainment technology industry, Mike is the current chair of the PLASA Governing Body and Treasurer of PLASA North American Regional Board. Mike can be reached at mike@mikewoodconsulting.com.