

# Understanding Initial Color Consistency

## Introduction

Color point consistency is extremely important in presenting merchandise, artwork, and architectural features in an attractive, non-distracting way. It is particularly important when white light shines on a white wall, preventing the “fruit sherbet” effect of varying tints of pink, green, violet, and yellow in closely spaced spots and wall washers.

Color point consistency typically gets worse over time, so it is especially important that it starts out absolutely as precise and consistent as possible. This article touches on how color consistency is evaluated, and compares Xicato’s processes and standards to industry norms specifically with regard to initial color consistency.

## Evaluating Color Consistency

Color consistency is evaluated in terms of MacAdam ellipses, defined in the 1930s by David MacAdam and others to represent a region on a chromaticity diagram that contains all colors that are indistinguishable by the average human eye from the color at the center of the ellipse. In other words, 50% of people can just barely see as different the color at the center and colors at the edge of the ellipse.

This concept has been extended and standardized as Standard Deviation Color Matching (SDCM), with higher SDCM representing proportionately greater, more recognizable and more objectionable

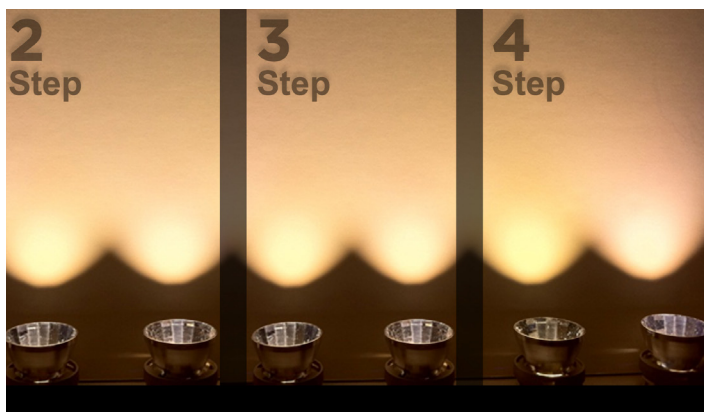


Figure 1: each incremental step in SDCM makes a bigger and bigger difference in color variation (illustrative: visibility of subtle variations i limited by camera color gamut)

differences in color. The threshold of “tolerable” varies between applications and between observers. Generally, the more highly trained the observer, the more discriminating and the less tolerant they become, as they begin to recognize color variations

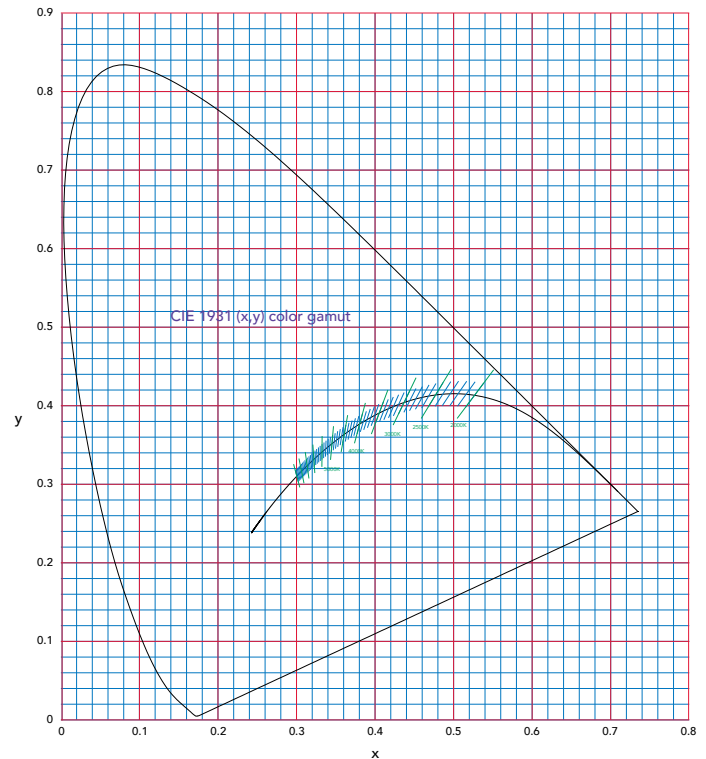


Figure 2: CIE 1931 (x, y) color space with the Black Body Locus (BBL) shown as a heavy black line. “Perfect” white light is exactly on the BBL. Major (green) and minor lines (blue) represent increments of 500 CCT and 100 CCT, respectively.

that, while perhaps not noticed by many observers, nevertheless have an impact on those observers in terms of comfort, productivity, and other functional attributes of the space.

So achieving color consistency is important. But how is it achieved? How does a lighting designer and end user ensure that their space at least starts out with clean, consistent white light?

## Color Consistency and Bin Size

Achieving initial color consistency is not as simple as it sounds. Targeting a color point with most LED manufacturing processes is a lot like targeting a bullseye with a shotgun... depending on the size of the target, some percentage of the LEDs hits the target, but the remainder is scattered outside the target and has to be discarded as scrap or sold at a steep discount to less discriminating buyers. It is therefore advantageous to the manufacturer to have a larger bin, to reduce scrap. However, a larger bin means more color variation in the delivered product. Lighting quality dictates that lighting specifiers, manufacturers, designers and end users insist on the smallest bin possible.

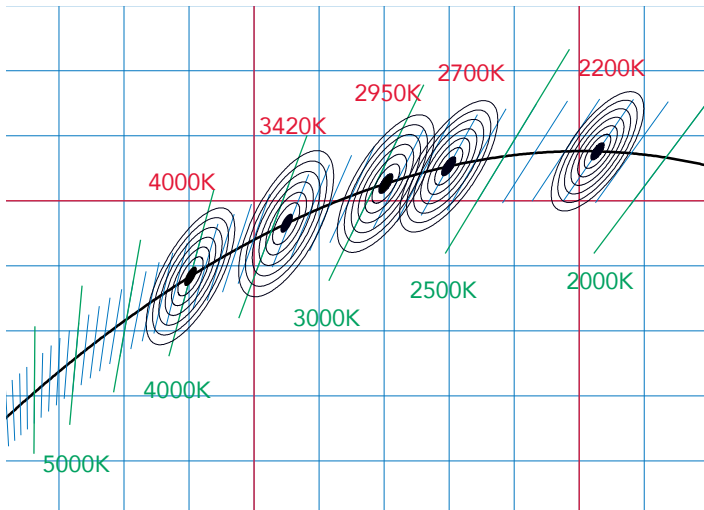


Figure 3: Typical CCT targets for white light. The black filled ellipses represent 1 SDCM from each target, and each successively larger, concentric ellipse represents one additional SDCM.

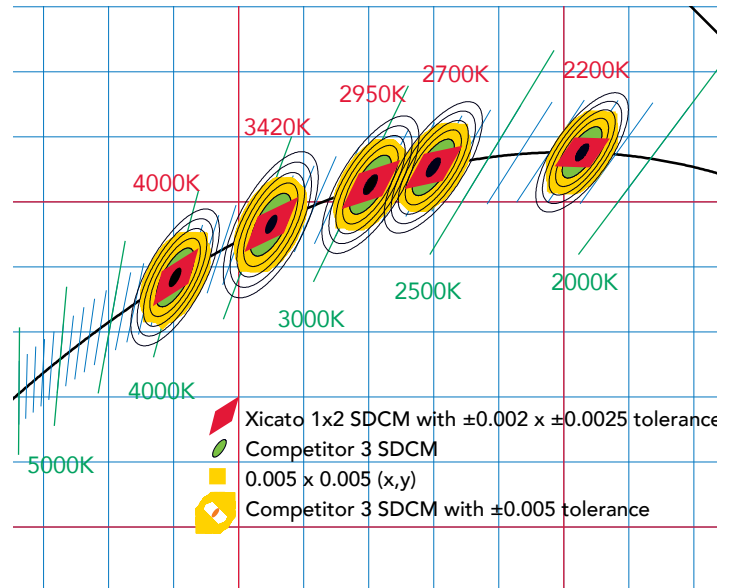


Figure 5: actual difference between the Xicato bin at 1x2 SDCM  $\pm 0.002$  and the competitors at 3 SDCM  $\pm 0.005$ .

## Color Consistency and Tester Tolerance

But that isn't the whole story. LED manufacturers determine which LEDs hit the target through testing, and high-quality manufacturers test every individual LED.

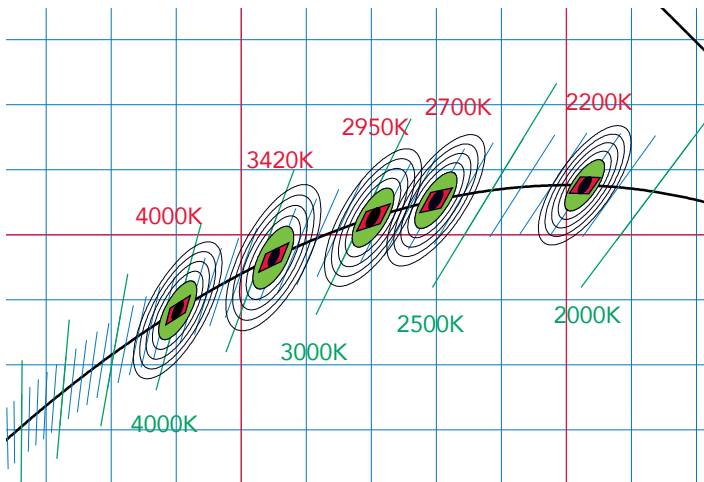


Figure 4: Xicato's nominal 1x2 SDCM bin size (red) vs the 3 SDCM nominal bin (green) that is the industry norm. Xicato's target is 1/3 the size, and particularly tight in controlling Duv, or distance from the BBL that affects tint.

But all testing is not created equal. Looking at most vendor datasheets, you can see that their testing tolerance is stated as  $\pm 0.005$  in both x and y axes. This means that their tester tolerance is larger than their bins! Exhibit 4 illustrates this.

## Conclusion

There are therefore two metrics that must concern lighting specifiers, designers, end users and luminaire manufacturers to ensure the initial color consistency of LEDs:

1. The size of the initial color target bin, as measured in SDCM. Smaller is better, especially in Duv, the direction perpendicular to the black body locus.
2. Tester accuracy: the accuracy with which the manufacturer is able to test which parts actually fall within their bin target.

For the record:

- Xicato's initial color target of 1x2 SDCM is 3 times smaller than the industry norm of 3 SDCM, and half as big as the "premium" standard of 2 SDCM. In particular, our standard demands closer tolerance of 0.001 Duv, which represents variation in tint, which is more objectionable than variations in color temperature (CCT).
- Xicato's proprietary testing methodology allows us to achieve a much tighter testing tolerance of 0.002 in Duv and 0.0025 in CCT – more than twice as accurate as the claimed  $\pm 0.005$  (x,y) accuracy that is the industry norm.

## Beyond Initial Color Consistency

Of course, you don't just want your lighting to start out with outstanding color consistency, but stay consistent for the life of your installation. Again, there are major differences between competing vendors when it comes to color lifetime. This will be the subject of another whitepaper entitled, "Understanding Color Consistency over Time."