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Color Considerations of LEDs

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No one in the lighting industry is debating that LEDs as a light source are unique, exciting, and here to stay. For the first time in decades we need a new vocabulary and knowledge base to properly apply this source in our work and for the benefit of customers. This is one of a series of overviews meant to build an understanding of LED technology and what the lighting design community needs to know to confidently discuss and successfully apply this electrifying technology.

The promise of LED lighting is tremendous. LED systems can be reliable, durable, long-lived, very efficient and incredibly flexible in how they deliver light to a space. The technology can also be cheap, inefficient and short-lived.

So the adage "you get what you pay for" still applies to LEDs, and this includes color quality. The color metrics below provide numbers and ranges to help compare and apply lamps effectively. Here we provide basic explanations of the most used color metrics and those color issues common to LEDs.

CCT, correlated color temperature, *describes the color of emitted light*

CCT describes the apparent color of the light being produced by a source, on a scale of warmer (yellowish) to cooler (bluish) color. Measured in degrees Kelvin (the basis for all temperature measurement), the incandescent lamp has a CCT of 2700K and a yellowish light, and fluorescents come in several standard CCTs such as 3000K (warmish white), 3500K (a neutral) and 4100K (cooler white), and higher. LEDs have not yet been standardized, and although industry pressure has led to a broader range of options, LED CCTs do not always parallel existing sources. Important to note is that CCT is a single number representing a complex color space, so two sources with the same CCT could look different.

Color temperatures of white light varying 2700K, 3000K, 3500K, and 4100K from left to right. Photo: Sacramento Municipal Utility District, as taken from *ALG Online*.

CRI, color rendering index, *tells generally how well a source will render colors*

The CRI value is on a scale of 0-100, which represents the average of how well eight sample colors appeared as compared to a reference source of the same CCT.

Because early white LEDs (remember they are blue LEDs) were introduced with mediocre color rendering, especially in the reds, a second set of colors is often discussed around LEDs that includes a deep red sample (R9) – so sometimes CRI for LEDs have two numbers: the first for its overall rendering (higher is better) plus an R9 value for red. Unlike the overall rating (good CRI for interiors would be in the 80s, and in the 90s is excellent) an R9 value above 0 is considered acceptable.

ABOUT ALG Connections

Through a series of abstracts and synopses, ALG Connections informs readers on timely topics such as research, conference reviews, industry trends and technology updates.

ALG Online is one of the design guides offered by New Buildings Institute (NBI) through its Advanced Buildings® suite of tools and resources.

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Issues with LEDs - Color consistency and shift

Color consistency is a measure of how similar in color appearance samples of a lamp/source tend to be, while color shift is the change in a lamp's correlated color temperature (CCT) over time, specifically defined at 40% of the lamp's rated life. There are ongoing challenges for LED color quality and color shift; DOE recently claimed these are enough to inhibit application growth.

Some variability comes from manufacturing processes and costs. Module quality often parallels color quality, so trade-offs made in production with regard to materials such as the chips themselves, phosphors, silicones and electronics can lead to performance and/or quality issues.

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Here are some general considerations that should be noted when considering the cost/color/efficacy balance of any light source:

- The CRI system is most accurate in the range of 80-100.
- Numerical comparisons of CRI are meaningless unless the sources involved have similar CCTs.
- Lamp color and especially CCT values in full-scale applications are modified by luminaire characteristics, room shape, room surface colors, reflectances, illumination level and the presence of daylight. The best design practice is to visually evaluate a lamp color together with the colors used in the application.
- The eye cannot typically see differences of 3-5 in CRI values.
- Side-by-side color comparisons using different lamps are useful, but human eyes adapt to color, so the final choice should be made after adaptation under the source or source combination proposed for the application.
- Lamp color is sometimes linked to vision, glare, productivity or health benefits.

For more information on LEDs and other lighting technologies and information, visit: Advanced Lighting Guidelines (ALGOnline.org).

Barb Hamilton is a lighting consultant for New Buildings Institute. Her experience includes lighting design, product sales and marketing and several educational functions. Barb supports NBI's involvement in commercial lighting including development of the Advanced Lighting Guidelines online resource (known as ALG Online) and working to move advanced lighting practices and products into the market.

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