Color Rendering Index (CRI)

by
Dick Erdmann, GE Specification Engineer

Color Temperature vs. Color Rendering Index

All to often the terms Color Temperature and Color Rendering Index (CRI) get confused as to what they really mean.

Color Temperature of a light source is defined by its warmth or coolness and is expressed in degrees Kelvin. It comes from when a theoretical object called a "black body radiator" is heated, its color changes from black to red to yellow to white to blue. At the lower end of this scale the object is considered to be "warmer" in color while at the higher end its color is considered to be "cooler". At the warmer end of this scale a candle would be approximately 1,800 degrees K whilst at the higher end the North Sky is as high as 28,000 degrees K. In a more practical sense we generally consider colors of artificial light sources to be approximately be in the 2,000 to 10,000 degree K range.

Interestingly two different types of lamps can have the same color temperature but render colors quite differently. As an example of this the General Electric Co. SP and SPX fluorescent lamps have approximately the same color temperature as high wattage incandescent lamps but these fluorescent lamps have far less red energy in their spectrum. Thus red colors appear brighter when illuminated by incandescent then with fluorescent sources.

Color Rendering Index (CRI) is defined as being the measure of the degree of color shift of an object when illuminated by a light source as compared to when illuminated by a reference source of comparable Color Temperature.

This came about in the 1960s and 70s when a system was devised that mathematically compares how a light source shifts the location of eight specified pastel colors as defined by C.I.E. as compared to the same colors lit by a reference source of the same Color Temperature. The average differences are then subtracted from 100 to arrive at the CRI. Six additional colors are sometimes used for special purposes, but they are not used for calculating CRI. By definition if there is no change in appearance, the source in question is given a CRI of 100. Thus for small differences the CRI will be closer to 100 while larger differences will produce a lower number. When comparing Color Temperatures ranging from 2000K to 5000K the reference source is a Black Body Radiator and with Color Temperatures above that daylight is the agreed upon source.

Interestingly, both incandescent light sources and outdoor north sky daylight are both considered to have a CRI of 100 yet neither of these is really perfect. Incandescent is very weak in blue (try and sort out your darker blue and black socks under incandescent) and outdoor northern sky daylight at 7500K is weak in red. However, CRI in spite of its limitations is still useful in specifying the "quality" of color.

Originally, CRI was developed to compare continuous spectrum sources who's CRI was above 90 because below 90 it is possible to have two light sources with the same CRI, but which render color very differently. Technically, CRI's can only be compared for sources that have the same Color

Temperatures. However, as a general rule light sources with high (80-100) CRI's tend to make people and things look better than light sources with lower CRI's.

CRI and LED's

There is some research going on that is finding that white light produced by mixing red, green and blue LED's is preferred over halogen and incandescent light sources, even those with higher CRI values. In fact the CIE Technical Report 177:2007, *Color Rendering of White LED Light Sources*, states, "The conclusion of the Technical Committee is that the CIE CRI is generally not applicable to predict the color rendering rank order of a set of light sources when white LED light sources are involved in this set."

This recommendation comes from a survey of multiple academic studies that considered both phosphor coated white light LED's and red-green-blue LED clusters. Observers ranked the appearance of illuminated scenes using lamps with different CRIs and found that, in general, there is not a good correlation between the rankings and calculated CRI values. In many cases the RGB based LED's had CRI's in the 20s but still did a good job of rendering colors. One possible reason for this is that they typically tend to increase the perceived saturation (chroma) of most colors without producing hue shifts.

Recommendations for CRI and LEDs

The US Department of Energy recommends the following:

A long-term research and development process is underway to develop a revised color quality metric that would be applicable to all white light sources. In the meantime, CRI can be considered as one data point in evaluating white LED products and systems. It should not be used to make product selections in the absence of in-person and on-site evaluations.

1. *Identify the visual tasks to be performed under the light source. If color fidelity under different light sources is critically important (for example in a space where color or fabric comparisons are made under both daylight and electric lighting), CRI values may be a useful metric for rating LED products.*
2. *CRI may be compared only for light sources of equal CCT. This applies to all light sources, not only to LEDs. Also, differences in CRI values of less than five oints are not significant, e.g., light sources with 80 and 84 CRI are essentially the same.*
3. *If color appearance is more important than color fidelity, do not exclude white light LEDs solely on the basis of relatively low CRI values. Some LED products with CRIs as low as 25 still produce visually pleasing white light.*
4. *Evaluate LED systems in person and, if possible, on-site when color fidelity or color appearance are important issues.*

Conclusion

So why use CRI if it has so many drawbacks? For now it's the only internationally recognized color rendering system that provides some guidance. However, it should be noted that there is some work being done by the National Institute of Standards and Technology (NIST) to develop a Color Quality Scale to address some of the problems of the current CRI scaling system but as of yet this has not been generally adopted.

Sources:

GE Lighting website
http://www.gelighting.com/na/business lighting/education resources/learn about light/

US Department of Energy website
http://www1.eere.energy.gov/buildings/ssl/measurement.html

National Institute of Standards and Technology website
http://physics.nist.gov/Divisions/Div844/facilities/vision/color.html

Lighting Research Center website
http://www.lrc.rpi.edu/education/learning/terminology/cri.asp