

Energy Efficiency & Renewable Energy

Chromaticity Adrift: Understanding LED Color Stability

Lightfair

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Michael Royer, PNNL



MacAdam Ellipses

- Experimentally-derived indicators of human color vision tolerances at various chromaticities
- Based on the observations of one highly-trained observer in a very specific scenario/apparatus; results cannot be translated to every installation
- Sometimes referred to as SDCM (standard deviation of color matching)
- Can be reported in multiples (e.g., 3step ellipse)
- Do not convey the direction of shift/difference





<mark>Δu'v'</mark>

- Δu'v' is the Euclidian distance between two sets of chromaticity coordinates in the CIE 1976 UCS chromaticity diagram.
- As with MacAdam Ellipses, Δu'v' does not convey the direction of a shift
- Δu'v' does not convey whether or not a difference is noticeable



What metrics are used to describe color shift/color stability?



Δu'v' and MacAdam Ellipses

- MacAdam ellipses are approximately circles in the 1976 (u', v') chromaticity diagram
- A 1-step ellipse is approximately equal to a Δu'v' of 0.001
- ANSI definitions of white light allow for fairly large tolerances (~14-step difference from edge to edge)



The million dollar question... It depends.

Viewer Field of View Surface Characteristics **Proximity Time**

In MacAdam's experimental setup, a just noticeable difference was determined to be three times the standard deviation of color matching (or a 3-step ellipse) for a given observer. However, a 1-step ellipse is often called a *MacAdam unit of color difference*.















GATEWAY Smithsonian LED PAR38 c. 2011



• Bare Lamp

• Bare Lamp with Secondary Optics Removed



NEW LAMP 4600 lux @ 1.26m

5750 HOUR LAMP 5000 lux @ 1.26m 6600 HOUR LAMP 4600 lux @ 1.26m

Image Courtesy of Scott Rosenfeld, Smithsonian American Art Museum



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http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/2013_gateway_color-maintenance.pdf





CALIPER Series 20 LED PAR38 c. 2012





CALIPER Series 20 LED PAR38 c. 2012





CALIPER Retail 3 LED A19 c. 2013





CALiPER Retail 3 LED A19 c. 2013





CALIPER Retail 3 LED A19 c. 2013





U.S. Border LED Area Lighting c. 2014













- LED Packages
- Lamp and Luminaire Materials (Optics)
- Driver
- Application considerations

• HEAT!





- Determine if color shift is a concern, and to what degree.
 - Will early failures be a financial concern?
 - Is mitigation possible?
- Seek data (LM-80, LM-84 are only current relevant standards)
- Look for products with a warranty (there are few)
 - Understand what monitoring/measurement is necessary

